IEc

Phase II Hanford Natural Resource Damage Assessment Ecological Data Gap Report

Final | 10 January 2012

prepared for:

Hanford Natural Resource Trustee Council
Under U.S. Department of Energy Contract #DE-DT0001642

prepared by:

Industrial Economics, Incorporated

2067 Massachusetts Avenue

Cambridge, MA 02140

TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

As	Arsenic
ABCASH	Automated Bar Coding of All Samples at Hanford
Ba	Barium
Bo	Boron
Ca	Calcium
Cd	Cadmium
CFR	Code of Federal Regulations
COEC	Contaminant of ecological concern
COPEC	Contaminant of potential ecological concern
CRC	Columbia River Component
Cr	Chromium
CrVI	Hexavalent chromium
Cs	Cesium
Cu	Copper
DOE	U.S. Department of Energy
DSR	Data Summary Report
EMC	Ecological Monitoring and Compliance Project
ERDF	Environmental Restoration Disposal Facility
ERS	Environmental Release Summary
FS	Feasibility Study
GIS	Geographic information system
GiSdT	Guided Interactive Statistical Decision Tools
HAMMER	Hazardous Materials Management & Emergency Response
Hg	Mercury
HEIS	Hanford Environmental Information Systems
HGIS	Hanford Geographic Information System
HLAN	Hanford Local Access Network
HNRTC	Hanford Natural Resource Trustee Council

HWIS	Hanford Well Information System
I	Iodine
Mg	Magnesium
Mn	Manganese
MSA	Mission Support Alliance
NRDA	Natural resource damage assessment
NRDWL	Nonradioactive Dangerous Waste Landfill
OU	Operable Unit
PCBs	Polychlorinated biphenyls
Pb	Lead
PNNL	Pacific Northwest National Laboratory
Pu	Plutonium
QMAP	Hanford Map Mortal
RCBRA	River Corridor Baseline Risk Assessment
RI	Remedial Investigation
SESP	Surface Environmental Surveillance Project
Sb	Antimony
Se	Selenium
Sr	Strontium
Tc	Technetium
TEDF	Treated Effluent Disposal Facility
TPH	Total petroleum hydrocarbons
U	Uranium
USGS	U.S. Geological Survey
WCH	Washington Closure Hanford
WDFW	Washington Department of Fish and Wildlife
WIDS	Waste Information Data System
WTP	Hanford Tank Waste Treatment and Immobilization Plant
Zn	Zinc

EXECUTIVE SUMMARY

INTRODUCTION

The Hanford Natural Resource Trustee Council (HNRTC) is pursuing a natural resource damage assessment (NRDA) of the Hanford Site and proximal region. The HNRTC has directed the development of this data gaps report, one objective of which is to describe the nature and extent of information of potential use in natural resource injury determination and quantification.

The report also serves to highlight apparent data gaps, based on a preliminary review of a large volume of environmental data potentially relevant to NRD issues at the site. Given the amount of data available, the geographic scale of the site, and issues identified in this report, data gaps assessment and prioritization will be an ongoing, iterative process. Nevertheless, this document is an important step forward.

This report focuses particularly on the suite of contaminants—referenced in this report as "target analytes"—for which the HNRTC requested profiles to be developed. It also includes contaminants identified as contaminants of ecological concern (COEC) in the River Corridor Baseline Risk Assessment (DOE 2011b) and contaminants identified as contaminants of potential ecological concern (COPEC) in the Columbia River Component Screening-Level Ecological Risk Assessment (DOE 2011a). For biota, this report focuses on species for which the HNRTC previously requested profiles to be developed ("target species"). Recognizing Trustee interest in a broader spectrum of data, it also provides a more limited analysis of data availability for other species and contaminants.

This report is organized primarily by natural resource category (i.e., soils, surface water and pore water, sediments, biota, and groundwater), as set forth in the U.S. Department of Interior's NRDA regulations at 43 CFR Part 11.

The major focus of this report includes data types commonly relied upon in a NRDA. These include:

- Contaminant concentrations in environmental media and biota;
- GIS layers describing site features (e.g., habitat types, natural features, operational areas, physical structures, roads, groundwater plumes);
- Ecotoxicity information on the target analytes;
- Toxicity studies using site media;
- Natural history information on the target species; and
- Site-specific field studies of biota health.

This report focuses on the largest identified assemblages of information. For example, several programs have undertaken substantial efforts to identify and compile collections of contaminant concentration data, and the resulting databases form the basis of the data gap evaluation on this topic.

CONTAMINANT DATABASES

This report identifies seven partially overlapping databases that contain information on concentrations in site media and biotic tissues. Five of these databases are evaluated in more detail (see Exhibit 1-2), while the remaining two databases (Exhibit 1-3) are not evaluated due to overlap with the other databases and/or inaccessibility. However, based on conversations with the database managers, we believe that the reviewed databases comprise the large majority of available information on contaminant concentrations at and around the Hanford Site.[1]

The Hanford Environmental Information Systems (HEIS) database contains the largest numbers of samples of soils, surface water, biota, and groundwater, while other databases contain larger numbers of sediment and pore water samples. HEIS continues to be developed, and we understand that it is DOE's intention for HEIS to serve as the eventual repository for virtually all site sampling efforts, past and ongoing. A substantial effort has been underway within this past year to add more data to HEIS; as this effort progresses, it may become increasingly less necessary to rely on other compilations of contaminant information.

One key issue identified through this review is that geographic coordinate information is missing from a large number of records entered into HEIS. In many cases, this is likely due to the unavailability of GPS technology at the time the samples were taken. This gap is particularly acute for biota, sediment, and surface water samples.[2] Qualitative location information is available for many of these samples; however, estimating coordinates (e.g. for purposes of mapping) would likely require a substantial level of effort.

In addition to HEIS, this report evaluates: (a) the Columbia River Component historic database, (b) the Columbia River Component Data Summary Report for the Remedial Investigation of Hanford Site Releases to the Columbia River (WCH 2011), (c) the River Corridor Baseline Risk Assessment GiSdT database, and (d) extracts from the Near-Field Monitoring Program's collection effort, reported through the Environmental Release Summary (ERS). These databases jointly contain many measurements of contaminants in biotic and abiotic media. Measurements are available for all target analytes in many media, as well as for many additional contaminants.

---

[1] It is beyond the scope of this document to attempt to combine these databases or to formulate specific recommendations for doing so.

[2] There may be some samples for which coordinate information is available in spreadsheets from other sources, such as Lynn Bisping at PNNL (Bill Webber, CH2M HILL Plateau Remediation Company, personal communication).

CATEGORY OVERVIEWS

SOILS

This database review identified between 38,060 and 48,532 soil samples.[3] The largest two databases are HEIS (38,060 samples) and GiSdT (8,399 samples). Across all examined databases, sample depth is not specified for roughly 80 percent of available samples (mostly HEIS and GiSdT samples); however, sample depth could potentially be determined using the sampling method or sampling project for a limited number of samples. For instance, Surface Environmental Surveillance Project (SESP) and Near-Field samples have a documented sampling protocol that specifies sample depths[4] (three percent of samples are identified as either "SESPMNT" or "SESPSEPC"[5] in the "OWNER_ID" field). In addition, the sampling method is identified for approximately seven percent of HEIS soil samples. In addition, sample type in the CRC database can be used to estimate depth[6]. The GiSdT database does not include a sampling method field.

Appendix A includes summary maps showing soil sampling locations for which latitude and longitude data are available. As shown, soil samples tend to be concentrated near operational facilities and buildings. The databases also contain information on soil samples from a number of offsite locations scattered throughout Washington State.

With respect to temporal distribution, very few pre-1981 samples are available in the databases; however, results from samples taken prior to 1981 have been summarized in numerous environmental reports,[7] some of which are listed in Appendix B. More than 8,000 samples were collected during the 1981-2000 period, and 30,000 or more after 2000.

Soil samples have been tested for more than 1,000 analytes. Of the target analytes, the most commonly reported are generally Cs-137[8] and uranium, although other target analytes are also frequently measured. For example, HEIS includes over 11,000 sample measurements for Cs-137, Cr, U, and Hg. The target analytes associated with the fewest records are carbon tetrachloride and I-129, although each of these has still been measured in over 1,000 samples. Of the COEC/COPECs, most were frequently measured in all databases, except TPH-diesel, for which there are fewer than 50 measurements in the

[3] The smaller number reflects the number of samples in the largest database evaluated. The larger number reflects the sum of the sample numbers across all databases. There is an unquantified degree of overlap among the various databases.

[4] For example, for the Surface Environmental Surveillance Project and for Near-Field soil samples, sampling method includes compositing five one-inch deep cores. If otherwise, a different depth is noted in the database comments field (Ted Poston, PNNL, personal communication; Hanf et al. 2007, PNNL-16744).

[5] SESPMNT refers to SESP Maintenance and SESPSPEC refers to SESP Special Analysis.

[6] 98% of CRC samples are indicated as "grab" samples in the sample type field, and all grab samples are surface samples.

[7] Site environmental report appendices include sampling results dating back to 1959. HEIS was populated from 1970/1971 forward (Ted Poston, PNNL, personal communication).

[8] Cs-137 is analyzed by gamma spectroscopy, and during analysis, other gamma emitters may also be reported. It may be that some of these measurements appear in individual data reports but were not entered into HEIS (Ted Poston, PNNL, personal communication).

DSR database. HEIS contains over 10,000 measurements of arsenic, antimony, barium, cadmium, copper, lead, manganese, selenium, and zinc in soils.

SURFACE WATER AND PORE WATER

This database review identified between 21,314 and 31,854 surface water samples. The largest two databases are HEIS (21,314 samples) and CRC Historic (6,418 samples). Sample depth is not specified for the majority of available samples, and geographic coordinates are missing for about 90 percent of the samples in HEIS but are available for samples in other databases. Information on water hardness is frequently absent, although in general, hardness data may be available from other sources, such as United States Geological Survey sampling.

Appendix A includes maps showing the surface water sampling locations for which coordinates are available. As shown, sampling locations are scattered throughout the Hanford Reach, with a particular concentration associated with the 100 and 300 Areas. Most samples are on the right-hand bank (facing downstream), but some are available in more midchannel or left-hand bank areas. Samples have also been taken from upstream and downstream parts of the Columbia, from a few onsite areas not in the Columbia River, and from other rivers.

With respect to temporal distribution, HEIS is the only database to contain pre-1981 samples, and approximately one-third of samples are associated with this timeframe. Multiple thousands of samples are also available from the more recent time periods.

Surface water samples have been tested for more than 500 analytes. Of the target analytes, the most commonly analyzed are generally tritium, Cs-137, Sr-90, Cr, and uranium (234, 235, and 238, isotopes in particular), although other target analytes are also frequently measured. For example, HEIS includes over 1,000 samples for Hg and Tc-99. Target analytes associated with the fewest records are carbon tetrachloride, I-129, and PCBs.[9] No target analyte is lacking records entirely. All databases have some measurements of the COECs/COPECs, although relatively few measurements are available for TPH-diesel and dieldrin.

Our database review identified between 404 and 1,087 pore water samples. The largest database is the 2011 DSR database (404 samples), the next largest is HEIS (355), and the remaining each contain between 100 and 200 samples. Nearly all pore water samples are from the post-2000 period, and nearly all have geographic coordinates. Appendix A includes maps of pore water sampling locations. As shown, sampling locations are scattered throughout the Hanford Reach, with a particular concentration associated with the 100 and 300 Areas. Most samples are on the right-hand bank (facing downstream), but some are available in more offshore or left-hand bank areas. Few samples are available from locations identified as reference locations or outside operational areas.

[9] PNNL may have additional PCB data not present in HEIS (Ted Poston, PNNL, personal communication).

Pore water samples have been tested for more than 180 analytes. Of the target analytes, Cr, CrVI, Hg, U, tritium, PCBs, Cs-137, and Sr-90 are the most commonly analyzed (≥60 samples for most databases). No pore water samples were analyzed for I-129 or plutonium, and few (≤20) samples were analyzed for carbon tetrachloride or Tc-99. With the exception of dieldrin in the DSR database, each database contains between 15 and 112 measurements of each COEC/COPEC.

SEDIMENTS

This database review identified between 2,476 and 5,207 sediment samples. The largest two databases are the CRC Historic (2,476 samples) and 2011 DSR databases (1,203 samples). Sample depth is not specified for roughly 70 percent of CRC Historic samples, 90 percent of HEIS samples, and all GiSdT samples; however, the 2011 DSR database includes depth information for most samples. As with many of the other media samples, sample depth could potentially be estimated using information from other fields, such as the sample method field or owner ID field. For instance, 75 percent of HEIS sediment samples are identified as from SESP, and the depth of these samples could potentially be estimated by reviewing the SESP sampling protocol. In addition, all of the GiSdT samples have an associated source, such as PNNL or RCBRA, and these sources may have sampling protocol and metadata that could be used to estimate sample depth.

Coordinates are available for nearly all sediment samples in all databases with the exception of HEIS, for which coordinate information is lacking for about two-thirds of samples. Appendix A includes summary maps showing sediment sampling locations for which latitude and longitude data are available. Most sediment sampling locations are from the Hanford Reach, including islands within the river. Samples are found at slightly higher densities near the operational areas, but there are sediment samples throughout the river as well as numerous offsite locations, including upstream, downstream, and tributary sites.

The CRC Historic database is the only one to include pre-1981 data (587 samples). In excess of 1,000 samples are available in each of the subsequent timeframes analyzed (1981-2000 and post-2000).

Sediment samples have been tested for more than 500 analytes. Cs-137 is the most frequently measured target analyte across all databases, while Cr, Hg, Sr-90, Pu-238, Pu-239/240, and U-234, 235 and 238 were also commonly analyzed. I-129, Tc-99, and tritium are associated with the fewest numbers of records. In addition, each of the COEC/COPECs have been measured hundreds of times.

BIOTA

The evaluated databases contain contaminant information for between 16,237 and 34,263 distinct samples, representing over 150 types of biota and over 1,000 analytes. The largest databases are HEIS (16,237 samples), CRC Historic (10,166 samples), and GiSdT (6,607 samples).

Significant data gaps appertain to time period and geographic distribution. Few samples (<=10 percent) in target biota were from years prior to 1981. In HEIS, approximately 80 percent of samples lack coordinates, whereas nearly all samples in the other databases contain coordinates. In HEIS, other information is provided to identify a general location onsite, but estimating coordinates for these records (e.g., to allow for GIS depiction) would likely require a substantial effort.[10]

For those onsite samples where coordinate information is available, the sculpin, mussel, and sturgeon sampling locations appear to be relatively evenly distributed within the Hanford Reach. The geographic distribution for other target species is more limited. Of note, not all samples reflect on-site locations: for example, the CRC Historic database in particular contained sample locations from offsite locations, including all the lamprey locations, and a number of the sturgeon and salmon records. Sampling locations in that database include upstream and downstream sites as well as sites on other waterways.

We also note that for most of the target species/target analyte combinations that have served as a focus of this report, relatively few measurements are available. Within the target species, the most commonly analyzed target analytes include Cs-137, Cr, Sr-90, and U. Carbon tetrachloride, tritium, and I-129 were virtually never analyzed in the target species. Hexavalent chromium was also infrequently sampled. Among the COECs/COPECs, dieldrin was also infrequently sampled. Barium and boron were less frequently analyzed among target species than other COECs/COPECs.

Of the target species, the highest numbers of samples tended to be available in terrestrial mammals (cottontail rabbit, black-tailed jackrabbit) and certain fish (sculpin, sturgeon, salmon). Far fewer samples were typically available for lamprey, bulrush, caddisfly, mussels, frogs, and great blue herons (no samples). Beyond the target species, we note that there appear to be relatively few measurements for wild terrestrial birds (with the possible exceptions of pheasant and quail).

One observation suggests that, despite the large numbers of records in these databases, not all site-specific information on contaminant concentrations in Hanford biota has yet been incorporated into these databases. For example, Fitzner and Gray (1991) reviews several studies on herons published between 1978 and 1988 that report contaminant information in great blue heron rejecta, young, and eggs. Tiller et al. (2005) also provides information on metal concentrations in Hanford Reach great blue heron livers and excrement, yet none of the reviewed databases contain contaminant measurements associated with this species. It is not known whether the database developers intentionally omitted these data (e.g., due to issues of database scope/purpose or data quality).

---

[10] At least for the Surface Environmental Surveillance Project, there have been efforts to establish generalized coordinates for sampling regions (Ted Poston, PNNL, personal communication).

Ecotoxicity

Another significant data gap relates to the availability of information on the sensitivity of target species to target contaminants. The species/contaminant combination for which the most information is available is Chinook salmon/chromium, for which a moderate amount of information exists. For all other combinations, the amount of data was determined to be low or very low.

The River Corridor Baseline Risk Assessment (DOE 2011b) presents the results of site-specific toxicity tests with site media. These tests include soil toxicity evaluations (Sandberg's bluegrass, nematodes), sediment toxicity (pak choi, and the amphipod *Hyalella azteca*), and pore water (the daphnid *Ceriodaphnia dubia* and the frog *Xenopus laevis*). The results of these efforts provide information that may be valuable in the context of a NRDA; however, preliminary review of the approach and results suggests that they may have important limitations associated with their use. For example, soil samples used in toxicity testing are limited to sites that have already been remediated, whereas the HNRTC may also be interested in understanding the likely extent of toxicity of waste site soils prior to remediation for purposes of estimating interim losses. Altogether, we recommend additional review of these results, as described in "Coordination with Future Response Activities" below.

Community Assessments

The River Corridor Baseline Risk Assessment (DOE 2011b) also reports on efforts to gather community-level information on aquatic and terrestrial communities. Sampling efforts focused on: benthos including mussels (through rock basket deployment), the upland and riparian plant community, and the small mammal community. Preliminary review has identified important limitations in at least some of these efforts. For example, the plant community comparisons are limited in utility not only because of the previously-mentioned focus on remediated areas but also because site selection was intentionally biased towards sites with an established vegetative community (to ensure an adequate sample collection for contaminant analysis purposes). In addition, as recognized by DOE (2011b), the availability of only a single campaign's worth of data collection for the small mammal community significantly limits its usability.

Overall, we recommend additional review of all the RCBRA's community assessment results, as described in "Coordination with Future Response Activities" below.

Some additional information on site communities is available through Pacific Northwest National Laboratory's (PNNL) efforts. PNNL has been compiling species location information in its "Characterization" database for some years, in support of cleanup investigations. For purposes of natural resource damage assessment, this information may be useful in identifying likely locations for animals in the event that future field studies on these species are pursued, but it is not likely to be useful for direct injury determination purposes as the program has not been designed to definitively identify species absence, or to quantify population-level metrics such as abundance.

Histopathology

Some site-specific histopathology has been collected in recent years. DOE (2011b) discusses results of sampling in 2006 and 2007 for mussels, sculpin, juvenile suckers, and Asian clams. In addition, WCH (2011) reports histology information associated with several tissues from 30 Hanford white sturgeon. PNNL may be in possession of additional histopathology records, but we have not identified any reports describing the sampling approach or results.

Additional Field Investigations

Additional site-specific field research on potential contaminant-related effects include: a pilot study on bullfrog and Woodhouse's toad malformations (Poston et al. 2006), multiple years of research on Canada goose reproduction (Fitzner et al. 1991), an evaluation of adult male mule deer reproductive health (Tiller et al. 1997), an evaluation of great blue heron reproduction (Tiller et al. 2005), and a Chinook salmon spawning habitat selection study (Geist 2000). DOE (2011b) evaluated reproduction in cliff swallows, eastern kingbirds, and western kingbirds, but the authors note that predation was sufficiently high as to render interpretation impossible.

GROUNDWATER

This database review identified between 339 and 242,714 groundwater samples, representing measurements of all the target analytes and over 800 analytes altogether. For groundwater, HEIS is by far the largest database, with 239,945 samples. GiSdT is the second largest, with 2,430 samples. The CRC Historic database includes only 339 groundwater samples.

An important data gap appertains to the vertical extent of contamination in groundwater. Characterization of the vertical extent of contamination is necessary to estimate volumes of injured groundwater. There is a lack of samples from deep wells: the majority of groundwater monitoring wells on the Hanford Site are completed near the water table, representing the top of the unconfined aquifer. Recently, a few deeper wells have been installed, and associated sampling from these wells has provided information about the vertical extent of some plumes (DOE 2011c). However, this type of data has been collected for a limited number of plumes, and only since 2009. Consequently, the vertical extent of the plumes – and hence, plume volumes – does not appear to have been well characterized. Fewer than 5 percent of groundwater samples have associated depth information within the databases. That said, sample depth for DOE groundwater samples collected after a well has been drilled could potentially be estimated from the open interval of the well, which is not captured in the sample table view. Sample depth information could potentially be obtained from other HEIS-related databases or the Hanford Wells database through the Environmental Dashboard Application, and the pump depth or screen interval would provide an indication of the depth of the sample.

Although plume volumes and changes in volumes over time are not well characterized, plume areas are better understood. DOE has characterized these using visual interpolation methods and other relevant knowledge of source areas, hydrogeology, and chemical characteristics (see maps in Appendix A). Re-creating these maps by one or more independent groundwater geologists would provide an alternate interpretation of the current nature and extent of plumes and could help characterize the potential uncertainty in, or accuracy of, the plume maps. The HNRTC has contracted the U.S. Geological Survey to evaluate plume maps, areas, and volumes. Appendix A includes summary maps showing groundwater sampling locations for which latitude and longitude data are available. Samples are concentrated around the 100 and 200 Areas; however, groundwater samples are also distributed across the site and along the Columbia River.

The most commonly analyzed target analytes in groundwater include Cr, tritium, and Cs-137. However, HEIS contains over 15,000 samples that test for carbon tetrachloride, CrVI, Hg, Sr-90, Tc-99, antimony, As, Ba, Cd, Cu, Pb, Mn, Se, and Zn. Target analytes associated with the fewest records (less than 1,000 samples in HEIS) were Pu, Pu-239 and 241, U-233/234 and 236, and TPH-diesel.

A number of groundwater computer models have been applied at the Hanford Site to examine and simulate groundwater flow patterns, water budgets, aquifer responses to stresses, migration of plumes, and the performance of groundwater remediation systems. Currently, the most commonly used models at Hanford include STOMP and MODFLOW. The models and computer codes being employed by DOE are widely used and accepted in the technical community as appropriate for the intended applications. However, there are many assumptions and uncertainties associated with model inputs, and an independent review of Hanford groundwater models would help to determine the appropriateness of assumptions and input values.

COORDINATION WITH FUTURE RESPONSE ACTIVITIES

DOE has recently released two ecological risk assessment documents: the River Corridor Baseline Risk Assessment (DOE 2011b) and the Columbia River Component Screening-Level Ecological Risk Assessment (DOE 2011a). Review of these documents suggests several potential avenues for Trustee evaluation of the material and associated coordination with DOE.

The first step would be for the Trustees to carefully review these ecological risk assessment reports, either with internal staff or more formally through an external review process. For NRDA purposes, key components to focus on would include the laboratory toxicity testing as well as the field investigations of impacts.

An evaluation of the laboratory experiments should include: an evaluation of the study design, test acceptability, test relevance, methodological uncertainties, the adequacy of spatial coverage, statistical methods, and interpretation of results. Similarly, an evaluation of the field studies should include but not necessarily be limited to: an evaluation of the study design including the adequacy of spatial coverage, reference site selection, endpoint selection, endpoint measurement, statistical methods, and interpretation of results. We note that an HNRTC evaluation of these documents need not be limited to these topics; however, these issues are particularly relevant to natural resource damage assessment injury determination and quantification. To the extent that the Trustees determine that any of these components may have limitations, the HNRTC can work cooperatively with DOE to determine a path forward for addressing them.

We propose that the HNRTC undertake this type of detailed review not as a pro forma matter but because our preliminary review suggests that there may be some more substantive issues that would arise out of such an effort. For instance, in sediment toxicity testing using *H. azteca*, the positive control samples should achieve over 90 percent survival (Ingersoll et al. 2008); however, Figure 6-35 in DOE (2011b) indicates that at least some reference site samples did not meet this criterion. From the information presented, it is not immediately clear whether a true positive control (completely clean) sample was included in the testing. If not, it is unclear whether the less-than-ideal results at some reference site sediments might reflect contamination in those areas or problems with the test conditions.

In another example, DOE (2011b)'s statistical analyses tend to broadly group and compares "waste sites" with reference sites. Particularly given that the study sites represent different contaminant exposure regimes (e.g., due to proximity to different groundwater contaminant plumes), combining such samples into a single group for purposes of comparison with reference sites may effectively obscure real differences (if present).

Furthermore, to evaluate the issue of causality, DOE (2011b) conducts multiple linear regressions to explore potential relationships between contaminant concentrations and measured endpoints. Given the range of potentially influential factors (i.e., the presence of multiple contaminants as well as other environmental influences), multivariate methods may be a more appropriate choice to identify the extent to which contaminants or other factors may have influenced study results.

The above are examples of issues identified during our preliminary review of the recently-released ecological risk assessment documents. We emphasize that a more thorough review of these issues may or may not result in recommendations for additional work, which could potentially include repeating or expanding some studies, and/or re-analysis of existing data. That said, we emphasize that undertaking any such further activities may or may not produce different conclusions.

ADDITIONAL NEXT STEPS

The HNRTC is in the process of developing an injury assessment plan. This report represents an additional step on the road towards development of that document. Data gaps identified in this report may represent opportunities for further information-gathering to be included as part of the overall assessment plan. That said, it is acknowledged that the HNRTC may or may not determine that a potential gap warrants further data generation/acquisition efforts.

It is also acknowledged that the identification of data gaps is an iterative process. This report begins the process by providing a general characterization of the types of information that are readily available, and which may be relied upon during the course of a NRDA. In many cases, this first-level review of data is sufficient to identify areas where relatively little or no information exists. However, even if some information is present, whether it is likely to be sufficient (and whether a "gap" remains), is a much more complex issue. The answer to the general issue of data sufficiency depends on: (a) the more specific nature of the question being posed, and (b) the acceptable degree of uncertainty in the answer. As the HNRTC initiates particular injury assessment activities, it will be necessary to ask more refined sets of questions about injury to particular natural resources, and in light of these questions, revisit the identified data sources, review available information in light of specific study objectives and data quality requirements, and more specifically determine the extent to which gaps may remain.

In light of the information, we offer the following general observations/suggestions for specific next steps to better understand, prioritize, and begin to address potential data gaps.

1. The HNRTC should consider working with DOE to understand the process and timing of data information entry into HEIS. As the HNRTC's data management system is developed and begins to be populated, HEIS will likely become the major "go to" source for chemistry data. However, for the foreseeable future, it will be important to consider other data sources and to develop methods to identify potential overlapping data.
2. The HNRTC should consider working with DOE to determine if sample location, sample depth and potentially other attributes can be established for the relatively large number of samples lacking such information.
3. As noted previously, the HNRTC should closely review the recently-released River Corridor Baseline Risk Assessment (DOE 2011b) and the Columbia River Component screening level risk assessment (DOE 2011a) from an NRD perspective. We suggest in particular that the Trustees undertake a review of the field-based biological research and the laboratory toxicity testing, considering issues including but not limited to study design (including sampling strategy), evaluation of test acceptability, assessment of test relevance, methodological uncertainties, and the of adequacy of spatial coverage. Further statistical analysis of the studies' results may be warranted. We suggest that the HNRTC work closely with DOE and its contractors to ensure that any such re-evaluations are conducted, the better to inform both remedial decision-making as well as Trustee decision-making, as to the need for additional related work.
4. We suggest that the HNRTC work with PNNL to establish arrangements that will facilitate access of the HNRTC to data for which PNNL is the custodian.
5. HNRTC review and discussion of sample location maps would help determine the extent to which no or few samples are available from habitats/areas of particular concern.
6. Undertaking a PED (preliminary estimate of damages) would provide a vehicle for developing initial estimates of potential injuries based on comparisons of concentration data to appropriate potential injury thresholds (i.e., contaminant concentration thresholds above which impacts to ecological receptors are likely to occur). We note that particularly in the case of radionuclides, screening and injury threshold evaluations will require preliminary dose-rate based (i.e., in

rad/day) criteria of no harm/harm to different receptors, and either accept existing—or develop *de novo*—concentration guidelines that correspond to radionuclide concentrations in site media expected to result in the selected dose rate-based criteria.

Exhibit ES-1 sets forth DOI's NRDA injury determination requirements. As indicated in this diagram, laboratory and site-specific field studies can play a role in injury determination, along with review of information available in the literature.[11] IEc's natural resource review reports provide a variety of suggestions of potential *de novo* laboratory and field-based studies as well as analyses of existing information intended to address these questions for various natural resources. These study suggestions, summarized in Exhibit ES-2, are based in part on the data gaps identified in this document. More detail on the specifics and rationale for each is presented in the natural resource review reports.

[11] We recognize that in a cooperative assessment, parties may choose to rely on existing information rather than pursuing new studies, and also that adhering to DOI's NRDA guidelines is not mandatory.

EXHIBIT ES-1 DOI'S NRDA INJURY DETERMINATION REQUIREMENTS (43 CFR PART 11)

Definition	Requirements		Potential Means to Address
"death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions… or physical deformation" (11.62(f)(1)(i)))	The biological response must be: "often the result of exposure to oil or the hazardous substance… must be a commonly documented response…" (11.62(f)(2)(i)))	**Repeatability/ coherence**	Literature
	"Exposure to oil or hazardous substances is known to cause this biological response in in controlled experiments…" (11.62(f)(2)(iii)))	**Lab effects (causality)**	Literature / de novo lab study
	"Exposure to oil or hazardous substances is known to cause this biological response in free-ranging organisms… documentation must include the correlation of the degree of the biological response to the observed exposure concentration…" (11.62(f)(2)(ii))). "Biological responses that have been documented only in controlled experimental conditions are insufficient to establish correlation with exposure occurring in a natural ecosystem" (11.62(f)(2)(iii).	**Effects <u>can</u> occur in field**	Literature
"Exceed action or tolerance levels established under section 402 of the Food, Drug and Cosmetic Act… in edible portions" 11.62(f)(1)(ii)	"The biological response measurement is practical to perform and produces scientifically valid results… must be adequately documented in scientific literature, must produce reproducible and verifiable results, and must have well defined and accepted statistical criteria for interpreting as well as rejecting results…" (11.62(f)(2)(iv)))	**Effects are scientifically measurable/valid**	Literature
"Exceed levels for which an appropriate State health agency has issued directives to limit or ban consumption" 11.62(f)(1)(iii)	"injury determination must be based upon the establishment of a statistically significant difference in the biological response between samples from populations in the assessment area and in the control area" (11.62(f)(3)))	**Effects <u>are</u> occurring in the field**	Site-specific field study

EXHIBIT ES-2 PRELIMINARILY PROPOSED STUDIES

AQUATIC NATURAL RESOURCES	TERRESTRIAL NATURAL RESOURCES	GROUNDWATER
Evaluations of existing information		
Surface water – Comparisons with water quality standards	Identification of remediation-related impacts at Hanford	Validation of Hanford groundwater contaminant plumes and calculation of plume volume
Whole sediment chemistry - Comparisons to thresholds for adverse effects on sediment-dwelling biota	Comparisons of soil contaminant concentrations with adverse impact thresholds	Verifying validity and limit of Hanford groundwater modeling
Whole sediment toxicity - Documentation/compilation of Hanford-specific study results	Soil toxicity - Documentation/compilation of Hanford-specific study results	Verifying ability and limitation of current models to characterize contamination in the vadose zone
Invertebrate tissue chemistry – Comparison to thresholds for adverse effects to invertebrates and/or invertebrate consumers	Avian and wildlife impacts – Comparison of tissue and prey tissue contaminant concentrations to adverse impact thresholds	Gather, organize, and relate information on groundwater wells to sampling data
Fish tissue chemistry – Comparison to thresholds for adverse effects to fish and/or piscivorous wildlife	Develop GIS maps and summary data tables showing contaminant levels by time period, media, and location	White paper on the baseline services that would be provided by groundwater at Hanford, and the extent to which these services are affected by the presence of contamination
Develop GIS maps and summary data tables showing contaminant levels by time period, media, and location		
Primary data collection studies		
Pacific lamprey sediment toxicity method development	Native plant toxicity testing	Synoptic sampling of selected river corridor wells
Pacific lamprey toxicity testing	Assessment of plant community health	Characterization of groundwater upwellings in Columbia River
Benthic community survey	Nematode toxicity testing	Geology of Columbia River bed
Benthic macroinvertebrate toxicity testing	Great Basin pocket mouse population assessment	Vertical distribution of contaminant plumes
Chinook salmon – Avoidance studies	Great Basin pocket mouse: Carbon tetrachloride and histopathology	
Chinook salmon – Spawning habitat identification	Evaluation of exposure in Hanford Site avian species	
M. falcata habitat preliminary characterization		
Mussel *in situ* toxicity testing		
Mussel toxicity testing		
White sturgeon toxicity testing		
Sculpin toxicity testing		
Sculpin *in situ* evaluation		
Source: IEc natural resource review reports.		

CHAPTER 1 | INTRODUCTION

The Hanford Natural Resource Trustee Council (HNRTC) is pursuing a natural resource damage assessment (NRDA) of the Hanford Site and proximal region. The HNRTC has directed the development of this data gaps report, one objective of which is to describe the nature and extent of information of potential use in natural resource injury determination and quantification. The report also serves to highlight apparent data gaps, which the HNRTC may choose to address during the course of assessment activities.

This report is organized primarily by natural resource category, as set forth in the U.S. Department of Interior's NRDA regulations (43 CFR Part 11). Overall, this report focuses particularly on the species and contaminants for which the HNRTC previously requested profiles to be developed. These species and contaminants are referred to as "target species" and "target analytes" throughout this report. This report also addresses contaminants identified as contaminants of ecological concern (COEC) identified in the River Corridor Baseline Risk Assessment (DOE 2011b) and those identified as contaminants of potential ecological concern (COPEC) in the Columbia River Component Screening-Level Ecological Risk Assessment (DOE 2011a) (see Exhibit 1-1). This report provides a more limited analysis of data availability for other contaminants and species.

It is important to recognize that the identification of data gaps is an iterative process. This report begins the process by providing a general characterization of the types of information that are readily available, and which may be relied upon during the course of a NRDA. In many cases, this first-level review of data is sufficient to identify areas where relatively little or no information exists—e.g., by contaminant, natural resource, time period, and/or geographic area. The current report highlights many of these gaps.

It is also important to recognize that even if some information is present, whether it is likely to be sufficient (and whether a "gap" remains), is a much more complex issue. The answer to the general issue of data sufficiency depends on: (a) the more specific nature of the question being posed, and (b) the acceptable degree of uncertainty in the answer. Broadly speaking, information that may be sufficient in quantity or quality for preliminary screening purposes may not be adequate to address other, more particular questions. To give a more concrete example, data may be adequate to provide a general understanding of overall contaminant concentrations in a particular geographic area, but may or may not be adequate to determine with certainty that there are no unfound "hot spots" within that area. If the identification of hot spots is a goal, mathematical methods are available to design sampling schemes that will identify these given: (a) the minimum size of the hot spot that must be detected, (b), its anticipated shape, (c) the size of the larger area to be evaluated, and (d) the desired level of probability of identifying all hot spots of this size or larger (Gilbert 1987). Before determining whether available data are adequate to rule out the possibility of hot spots in an area, it would be necessary not only to understand the data and sampling strategies that have been used to date but also to choose values for (a) through (d), as well as select a contamination level that would constitute a hot spot.

EXHIBIT 1-1 TARGET SPECIES AND ANALYTES

SPECIES OR SPECIES GROUP COMMON NAME	CONTAMINANT
Black-tailed jackrabbit Bullfrog Bulrush Caddisfly Chinook salmon Great blue heron Lamprey Mountain cottontail Pacific treefrog Sculpin Western pearlshell White sturgeon	Antimony[b] Arsenic[b] Barium[b] Boron[b] Cadmium[b] Carbon tetrachloride[a] Cesium-137[a] Chromium (including hexavalent chromium)[a,b,c] Copper[b] Dieldrin[b] Iodine-129[a] Lead[b] Manganese[b] Mercury[a,b] PCBs[a] Plutonium[a] Selenium[c] Strontium-90[a] Technetium-99[a] TPH-diesel[b] Tritium[a] Uranium[a,b] Zinc[b]

Notes:

a. Ecotoxicological profile developed by IEc based on HNRTC request.
b. COEC as identified in DOE (2011b).
c. COPEC as identified in DOE (2011a).

As the HNRTC initiates particular injury assessment activities, it will be necessary to revisit the identified data sources, review available information in light of specific study objectives and data quality requirements, and more specifically determine the extent to which gaps may remain.

Finally, it is acknowledged that the identification of a potential data gap imposes no obligation on the HNRTC: the HNRTC may or may not determine that a potential gap warrants further data generation/acquisition efforts. The process for prioritizing data gaps and/or identifying studies to fill them is beyond the scope of this document.

DATA TYPES

The Hanford Site has a lengthy history, and over the years, a tremendous amount of information has been developed to meet the data needs for past site operations as well as past and ongoing site remediation efforts. The major focus of this report includes many data types commonly relied upon in a NRDA. These include:

- Contaminant concentrations in environmental media and biota;
- GIS layers describing site features (e.g., habitat types, natural features, operational areas, physical structures, roads, groundwater plumes);
- Ecotoxicity information on the target analytes;
- Toxicity studies using site media;
- Natural history information on the target species; and
- Site-specific field studies of biota health.

This report focuses on the largest identified assemblages of information. For example, several programs have undertaken substantial efforts to identify and compile collections of contaminant concentration data, and the resulting databases form the basis of the data gap evaluation on this topic.

CONTAMINANT CONCENTRATION DATABASES

OVERVIEW

Exhibits 1-2 and 1-3 list the databases of contaminant data we have identified. Where available, brief descriptive information is provided about the purpose of the database and known limitations. The database purpose and limitation information is based on personal communications with those responsible for managing the database in question as well as the cited documents.

It is important to note that there is some degree of overlap in the information contained in these various databases. Exhibit 1-4 depicts these overlaps in Venn diagram form.

It is also important to note that these databases have been compiled and managed by different organizations for different purposes, and many are still being developed or supplemented. Management of some databases has changed over time, and database managers have noted that there has been no concerted effort to definitively identify areas of overlap among the various datasets. The depiction presented in Exhibit 1-4 represents our current understanding of the relationship between these databases and is based on discussions with the managers responsible for each. In many cases, however, even these managers expressed uncertainty as to the degree of overlap among various databases. Consequently, the implied relationships in Exhibit 1-4 should not be considered definitive.

EXHIBIT 1-2 CONTAMINANT CONCENTRATION DATABASES EVALUATED

DATABASE	SAMPLED MEDIA	POINT OF CONTACT	NOTES
Hanford Environmental Information System (HEIS)	Groundwater, soil, sediment, biota, air, and surface water; external radiation.	William D. Webber CH2MHiLL Plateau Remediation Company (509) 376-4744 William_D_Webber@rl.gov	HEIS is designed primarily to store regularly collected environmental monitoring data and is continually updated. For example, HEIS is the repository for datasets including the Surface Environmental Surveillance Project (SESP). There is an ongoing effort to enter concentration data from many projects at Hanford into HEIS. For example, a huge number of records from Washington Closure Hanford (WCH) have been added into HEIS since February 2011. It is expected that at some point, contaminant data in GiSdT, the CRC Historical Database, and the information from the 2011 *Data Summary Report for the Remedial Investigation of Hanford Site Releases to the Columbia River* (WCH 2011) will be in HEIS. However, the data compilation effort is not complete, and at the time of this report, contaminant information in these other databases is not necessarily fully incorporated into HEIS. In addition, HEIS does not contain some information in the possession of individual contractors who have worked at the site (W. Webber, personal communication, 29 June 2011). Furthermore, because a primary purpose of HEIS is storing monitoring data, it may not contain some datasets of interest for purposes of NRDA.
River Corridor Baseline Risk Assessment (RCBRA GiSdT)	Soil, sediment, surface water, groundwater, biota, dosimetry.	Duane Jacques WCH Mission Completion 509-372-9644 idjacque@wch-rcc.com	The GiSdT database contains a wide range of new and historic data that support the River Corridor Baseline Risk Assessment. The data come from a variety of sources including HEIS and the Near-Field environmental monitoring program (ABCASH/ERS databases) (DOE 2010, main text and Appendix C-1). Data from other risk assessment activities have also been incorporated into the database, including the 100-B/C Pilot Project risk assessment, and the 100-NR-2 shoreline evaluation (DOE 2007). It is the intent that all contaminant data collected as part of this effort are, or will be, stored in HEIS. In addition to contaminant data, GiSdT also includes other data types. For more information about this database, see DOE (2010b), Appendix C.

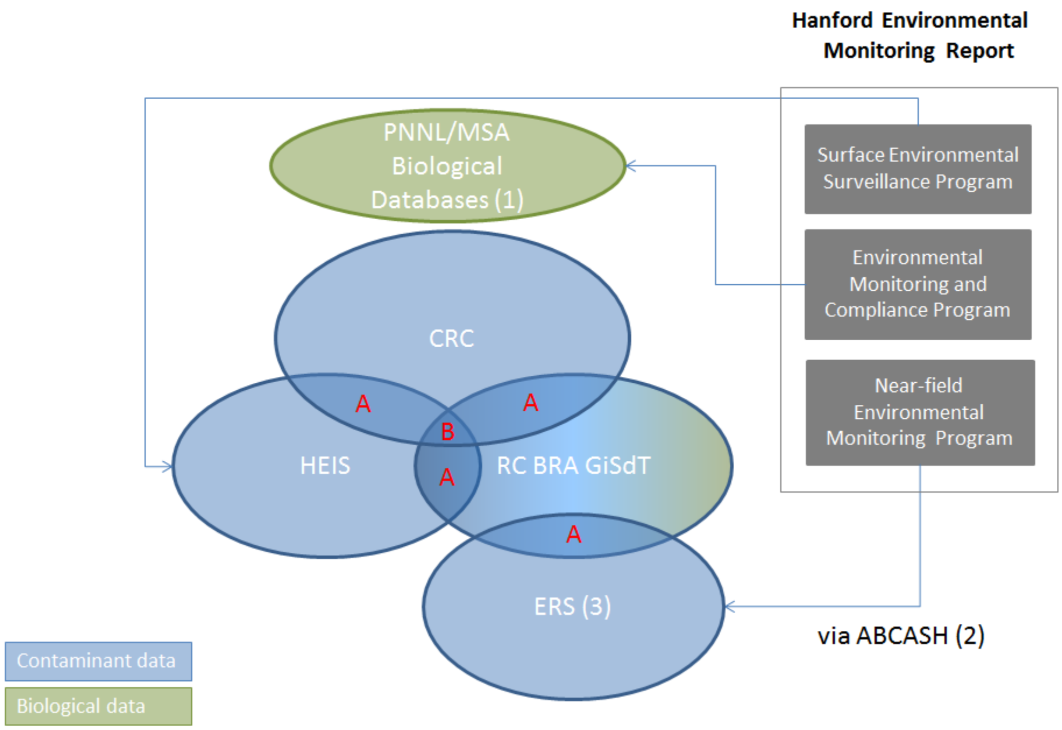
DATABASE	SAMPLED MEDIA	POINT OF CONTACT	NOTES
Columbia River Component (CRC) Historic Database, dated 06022008	Sediment, soil, surface water, pore water, groundwater, biota, aquifer tube, and effluent.	Larry C. Hulstrom Washington Closure Hanford (509)-372-9107 (office) (509)-392-9488 (cell) lchulstr@wch-rcc.com	This represents the original data compilation effort for the CRC. WCH (2006b) describes the process used to compile, classify, and manage the data. WCH (2006a) describes the activities that were undertaken to evaluate the data collected in the compilation effort and to assist in defining the extent of Hanford Site-related contamination. The data compiled into the first version of the CRC Database was used to identify potential data gaps in the spatial, temporal, and chemical composition of the existing data set. WCH (2007) presents the results. Because HEIS was one of the sources utilized to create this database, there is partial overlap between these databases. Based on personal communication with the database managers, there is also at least partial overlap with data contained in the RCBRA GiSdT database. In addition, the entirety of this database is contained within the complete CRC database managed by Woodward & Curran (see Exhibit 1-3).
Columbia River Component - Appendix O in the *Data Summary Report for the Remedial Investigation of Hanford Site Releases to the Columbia River* (WCH 2011)	Surface water, pore water, sediment, island soils, fish, and supplemental information (e.g., aquifer tube results).	Larry C. Hulstrom Washington Closure Hanford (509)-372-9107 (office) (509)-392-9488 (cell) lchulstr@wch-rcc.com	This database contains recently-collected information resulting from studies undertaken to address data gaps identified in WCH (2007). The full CRC database, housed at Woodard & Curran, also contains this information.

DATABASE	SAMPLED MEDIA	POINT OF CONTACT	NOTES
Near-Field Monitoring Program Data via the Environmental Release Summary (ERS)	Air, soil, vegetation, standing water, and effluent.	Craig Perkins Mission Support Alliance (509) 376-2049 Craig_J_Perkins@RL.gov	The reporting system's purpose is to calculate and report releases of radionuclides in airborne and liquid effluents to the environment and radionuclides present in the environment. It also calculates the cumulative decayed inventory of radionuclides in past discharges of liquid effluents to waste sites (DOE 2009). Direct access to this database is not available; however, IEc was provided with extracts in Excel from ERS representing contaminant concentrations in site soils and vegetation from PNNL's Near-Field monitoring program.

EXHIBIT 1-3 CONTAMINANT CONCENTRATION DATABASES NOT EVALUATED

DATABASE	POINT OF CONTACT	NOTES	OVERLAP WITH OTHER DATABASES
Automated Bar Coding of All Samples at Hanford (ABCASH)	Not identified	This database contains, in part, information on contaminant concentrations in air, soil, and vegetation, as well as dosimetry. It is the initial repository for the data collected as part of DOE's Near-Field environmental monitoring program. That program focuses on locations near facilities that have the potential to discharge or have discharged, stored, or disposed of radioactive or hazardous materials (Perkins et al. 2010).	Environmental data from the Near-Field monitoring program stored in ABCASH is transferred into the Environmental Release Summary Database (ERS).
Columbia River Component (CRC) - complete database	Larry C. Hulstrom Washington Closure Hanford (509)-372-9107 (office) (509)-392-9488 (cell) lchulstr@wch-rcc.com	Managed by Woodard & Curren for WCH. IEc does not have access to this database.	This database includes information from the June 2008 CRC Historic Database as well as the results from the 2011 *Report for the Remedial Investigation of Hanford Site Releases to the Columbia River* (WCH-398), and other information. It also includes information in HEIS as well as a limited amount of data from other sources, such as the U.S. Army Corps of Engineers and the U.S. Environmental Protection Agency, which may not be in other Hanford databases.

EXHIBIT 1-4 RELATIONSHIPS AMONG EVALUATED HANFORD DATABASES



Notes:

1. PNNL has referred to these databases as their "Characterization" and "Animal Health" databases. We have received these as a suite of Access files with various names (see Exhibit 1-5). As of mid-year 2011, management of these databases was transferred from PNNL to Mission Support Alliance.
2. Components of the Near-Field data are entered into ABCASH, which houses a wide and varied scope of data for Hanford.
3. The Near-Field data that are entered into ABCASH, in addition to the dosimeter data that are not, are all entered into ERS.

Key:

A. Confirmed overlap, based on personal communications with database managers and/or description of data sources used in database development.

B. Potential overlap, not definitively confirmed.

EVALUATION OF AVAILABLE METADATA

The appropriateness and potential usefulness to the NRDA of data will depend on the HNRTC's confidence in the processes by which the data were collected, analyzed, and quality controlled and validated. In addition to identifying and describing the contents of key sources of data, we review each of the key data sources to identify the extent to which information on the data's generation (i.e., "metadata") are readily available, and identify potential additional sources of information on this subject.

The types of metadata that may be of interest for NRDA purposes include but are not necessarily limited to:

- Collection information;
  - Who collected the sample?
  - By what method was the sample collected?
  - For what purpose was the sample collected?
- Analysis information;
  - What laboratory analyzed the sample?
  - What was the detection limit?
- Quality control and validation information; and
  - Did anyone reviewing the sample identify issues of concern?
  - What protocols were used for quality control and validation?
- Ownership information.
  - Who authorized or funded collection and analysis of the sample?
  - Who is responsible for the record or data point in question?

Our intent is not to conduct an exhaustive review of the metadata available for each data source or sample but rather to provide an overview of the metadata immediately available within the data source itself or through other documentation.

As the NRDA moves from the planning to the assessment phase, a more detailed review of the data, including identification of critical metadata which may be missing from a sample, may be conducted according to the process outlined in the Data Management Plan. At this time, contact with the program responsible for collecting and analyzing these data may help to fill in those gaps.[12] The contacts listed for each individual data source should be considered invaluable resources for information on each data source. It should be noted, however, that the extent to which these individuals are available and funded to support the NRDA differs from person to person.

[12] For example, staff associated with the Surface Environmental Surveillance Project provided information useful in estimating soil sample depths not available within HEIS.

Hanford Geographic Information System (HEIS)

The HEIS database is comprised of dozens of tables with many fields that provide information related to the collection, analysis, and parties responsible for each data point. To identify fields within the HEIS database that may contain relevant metadata we reviewed in detail the fields contained in the media-specific views of HEIS data, as well as the following key documents provided by Bill Webber of MSA:

- Media View Data Dictionaries;
  - Biota (Webber 2010a)
  - Miscellaneous Materials (Webber 2010b)
  - Soil (Webber 2010c)
  - Soil Gas (Webber 2010d)
  - Surface Water (Webber 2010e)
- Key Tables Data Dictionaries;
  - HEIS_SAMPSITE.pdf
  - HEIS_SAMPLE.pdf
  - HEIS_RESULT.pdf

Because the media-specific views and key tables do not represent the complete extent of data available in HEIS, we also conducted a cursory review of the HEIS Detailed Design Specifications (BHI 2002) to further identify potentially useful fields. Exhibit 1-5 lists and defines fields in HEIS which contain potentially useful metadata for NRDA purposes.

EXHIBIT 1-5 SELECTED METADATA FIELDS FROM HEIS

FIELD[1]	DEFINITION
Collection Information	
PROJECT_LEAD	Name of project leader of sampling effort.
COLL_MTHD	Surface water collection method used by PNNL SESP.
COLLECTION_PURPOSE	Code that identifies the primary reason a sample was collected.
Analysis Information	
LAB_NAME	Name of the lab performing the analysis.
LAB_CODE	Unique code for laboratory that performed the analysis.
METHOD_NAME	A code identifying the method used to analyze the sample for the specified constituent.
MIN_DETECTABLE_ACTIVITY	Sample-dependent estimate, typically dependent on the measured instrument background and sample yield, reported in the same units as result value for current analyte.
REQUIRED_DETECTION_LIMIT	Minimum level of detection required by the laboratory contract.

FIELD[1]	DEFINITION
STD_REQUIRED_DETECTION_LIMIT	Detection limit standardized to units stored in STD_ANAL_UNITS_RPTD
REPORTING_LIMIT	Lowest concentration of an analyte reported by the lab, corrected for the particular analysis conditions used with the sample. Typically the value reported for non-detected results.
LAB_COMMENT_CD	A lab-dependent comment code pertaining to the analysis for the constituent identified by the CON_ID of the record.
QA QC Information	
REVIEW_QUALIFIER	Set of codes indicating the quality of the record has been questioned by the in-lab reviewer.
RESULT_COMMENT	Comments on the result record as added by data reviewers.
VALIDATION_QUALIFIER	Set of codes indicating the quality of the record has been questioned by the validator.
Contact Information	
ANAL_SPONSOR [2]	The person, organization, or project that provided funding for the collection and analysis of the sample.
PROGRAM[3]	Field not defined in available data dictionaries. Sample valid field values include "AEA" (Atomic Energy Act) and "DOH" (Washington State Department of Health).
PROJECT_SOURCE[3]	Field not defined in available data dictionaries. Sample valid field values include "S&T" (Science and Technology) and "SGRP" (Soil and Groundwater Remediation Project).
OWNER_ID	HEIS computer project account that owns the record. Equates to the Hanford contractor or project that is responsible for the entry and maintenance of record.

Source:
Definitions acquired from HEIS Detailed Design Specifications document (provided by Bill Webber, MSA) unless otherwise noted.

Notes
1. The Media View data dictionaries, Key Tables data dictionaries, as well as the "Valid Codes" table provide definitions for all codes used in the fields described in this table.
2. This field was identified in the key table "SAMPLE" data dictionary, but was not included in the media-specific views provided to IEc.
3. This field is contained in the table "Valid Codes" but is not defined in any of the provided data dictionaries.

It is important to note that information for each individual record may not be complete. Furthermore, because HEIS contains records of samples collected and analyzed by multiple contractors for various purposes over a substantial timeframe, there is no single workplan or document that captures detailed metadata for the entire dataset.

River Corridor Baseline Risk Assessment Database (RCBRA / GiSdt)

The data contained within the GiSdT database were compiled or newly collected to support the River Corridor Baseline Risk Assessment. Newly-collected information was obtained using detailed and well-documented collection, analysis and quality control protocols, while historical data were reviewed to determine their usability for the risk assessment process.

Table C1.4-1 Description of Key Data Fields in Appendix C to the River Corridor Baseline Risk Assessment, Volume II: Human Health Risk Assessment, DOE/RL-2007-21, Draft C (USDOE 2010b) provides descriptions of fields in this database. Exhibit 1-6 lists fields of potential use in this NRDA.

EXHIBIT 1-6 SELECTED METADATA FIELDS FROM THE GISDT DATABASE

FIELD	DEFINITION
Collection information	
Sample_data_source_type	Describes the originator of the sample.
Analysis Information	
Analytical_method	Identifies analytic method used (where available).
Detect_status	Detect status derived from other qualifiers.
Gisdt_std_mda	Minimum detectable activity in standardized units.
QA QC Information	
Gisdt_usable	Indicates data meets minimum usability criteria.
Gisdt_not_usable_code	Indicates whether or not data meets minimum usability criteria.
Gisdt_not_usable_reason	Indicates usability code for data coded “not usable.”
Lab_qualifier	Lab-assigned qualifier.
Review_qualifier	Reports review qualifier (if available).
Validation_qualifier	Reports validation qualifier (if available).
Contact Information	
Gisdt_owner_id	Indicates contractor providing data.
Data_source_type	Indicates RCBRA, CVP_RSVP, PNNL, NR-2, BC_PILOT, etc.
Source: River Corridor Baseline Risk Assessment, Volume II: Human Health Risk Assessment, DOE/RL-2007-21, Draft C. Appendix C.	

In addition to the information in the database itself, a number of documents identify the methodologies and protocols used to collect, analyze and validate newly collected data, and document the review of historical data. These key documents include but are not necessarily limited to:

- River Corridor Baseline Risk Assessment, Volume II: Human Health Risk Assessment, DOE/RL-2007-21, Draft C. Appendices B and C (DOE 2010b);
- Sampling and Analysis Plan for the 100 Area and 300 Area Component of the RCBRA (SAP) and its appendices (DOE 2006);

- Sampling and Analysis Instructions for the 100 Area and 300 Area Component of the RBCRA Project (WCH 2006d).
- Data Quality Objectives Summary Report for the 100 Area and 300 Area Component of the RCBRA (BHI 2005);
- 100-NR-2 Study Area Ecological Risk Assessment Sampling and Analysis Plan (DOE 2005);
- Screening Assessment and Requirements for a Comprehensive Assessment: Columbia River Comprehensive Impact Assessment (DOE 1997);
- 100-B/C Area Ecological Risk Assessment Sampling and Analysis Plan (SAP) (DOE 2003); and
- 100-B/C Area Ecological Risk Assessment Data Quality Objectives (BHI 2003).
- Inter-Areas Component of the River Corridor Baseline Risk Assessment Sampling Summary (WCH 2008).

Columbia River Component (CRC) Historic Database

The Columbia River Component Historic Database represents a significant effort undertaken by Washington Closure Hanford to collect, review, and analyze the usability of 1,540 existing sources of data for the Columbia River Component Risk Assessment. The Existing Source Information Summary Report Compilation/Evaluation Effort: December 2004-September 2005 (WCH 2006b) describes the process by which this effort was conducted in detail. As reported in that document, the metadata for each individual data source were carefully reviewed to determine the known quality of the data, allowing the reviewers to identify the appropriate uses for each set in the context of the Risk Assessment. Data reviews and subsequent assignment to one of four data quality categories was based on the following criteria:

- Traceability;
- Comparability;
- Sample integrity;
- Measurement bias; and
- Sample bias.

As part of this review, each data source was evaluated to determine if it met key criteria related to each of these categories. The table "BIBLIOGRAPHY" includes the details of the review of each data source, including an evaluation of the adequacy of documentation for each source relative to the following topics:

- Availability of chain of custody;
- Evidence of chain of custody;
- Methods;
- Preservation;

- Holding time;
- Data qualifier;
- Method blanks;
- Matrix, spikes, and duplicates;
- Replicates;
- Surrogates;
- Lab control samples; and
- Lab qualifiers.

In addition to providing detailed bibliographic and documentation evaluation information on the data sources, the CRC database contains the individual sample and results records from these data sources. Other tables include details on the sample collection. The following documents provide documentation on the fields contained within the CRC database:

- CRC_database_component data entities updatedWC_06022008.doc; and
- CRC Application User Guide updatedWC_06022008.xls

Exhibit 1-7 lists fields that may be of particular interest for NRDA purposes.

EXHIBIT 1-7 SELECTED METADATA FIELDS FROM THE CRC HISTORIC DATABASE

FIELD	DEFINITION
Collection Information	
SOURCE_TITLE	The document title is the source from which the data is extracted. It may identify a published document or a data extraction from a database.
SAMP_TYPE	The field describes how the sample location is identified. There are three options to choose from: discrete, grab or composite. Discrete is a sample extraction taken from a specific point that has an (X,Y) coordinate, and typically have depth associated with it. Grab samples are similar to discrete, but do not have interval depths since they are taken from the surface. Composite is an extraction of several samples taken at different points within a general area that is identified by a centroid.
Analysis Information	
LAB_CODE	The laboratory code is the unique code for the laboratory performing the analysis.
COUNTING_ERROR	An error value is measured by counting disintegrations of radioactive analytes and is reported in the same units as

FIELD	DEFINITION
	the result value for the current analyte. Typically the counts are modeled with a Poisson distribution, where count variability is directly related to the number of counts. This error services as a lower bound for the uncertainty of the measurement.
DILUT_FACTOR	The dilution factor is a value representing the amount the sample was diluted by to determine the amount of the analyte in the Sample.
MIN_DETECTABLE_ACTIVITY	Minimum detectable activity is assumed to be a sample-dependent estimate, typically dependent on the measured instrument background and sample yield, reported in the same units as the result value for the current analyte. Generally, the MDA depends on the actual aliquot, count time, yield, efficiency, decay correction, and some measurement of the background. The background might be from associated instrument blanks, reagent blanks, baseline information for the sample, or some combination of these.
REQUIRED_DETECTION_LIMIT	Detection limit.
REPORTING_LIMIT	The limit required to report a value.
QA QC Information	
LAB_QUALIFIER	The lab qualifier is a laboratory-generated character string containing codes in combinations that qualify the associated result. Different forms have different permitted combinations of valid qualifiers; however, B and U are mutually exclusive qualifiers on all forms.
REVIEW_QUALIFIER	The review qualifier field uses the same qualifiers as the other qualifier fields. The list of valid qualifiers is provided with the Lab Qualifier entry. More than one qualifier may be combined together, however, some qualifiers are mutually exclusive and cannot be used together.
TOTAL_ANAL_ERROR	This field is a combination of counting error plus a laboratory-specific estimate dependent on the chosen analysis methods, representing sample-specific error (at 2 sigma) that could possibly be introduced into the sample while at the analytical laboratory, reported in the same units as the result value for the current analyte. For handling of gamma scan reporting, refer to “Reporting Results for Undetected Analytes”.
Contact Information	
SOURCE_TITLE	The document title is the source from which the data is extracted. It may identify a published document or a

FIELD	DEFINITION
	data extraction from a database.
AUTHOR	The author is the name of the person who created the document to be entered.
ORGANIZATION	The organization is the group, organization or individual that is the owner of the document.
Source: Columbia River Component Database Application User Guide.	

To the extent that additional information is required, the database documents in detail the original source of each data point, which may facilitate the identification of contacts to which these questions might be addressed.

Additional details on the CRC Historic Database are available in the following documents:

- Columbia River Component Data Evaluation Summary Report (WCH 2006a); and
- Existing Source Information Summary Report Compilation/Evaluation Effort: December 2004 to September 2005. Columbia River Component of the River Corridor Baseline Risk Assessment (WCH 2006b).

Data Summary Report Database (DSR)

The records contained in the Data Summary Report database represent results of samples collected and analyzed between 1/12/2008 and 7/2/2010 as part of the Remedial Investigation of Hanford Site Releases to the Columbia River. As with HEIS, the Data Summary Report Results database includes a number of fields that provide potentially useful metadata. The User Guide (WCH 2011-Appendix O) describes these fields, as summarized in Exhibit 1-8.

EXHIBIT 1-8 SELECTED METADATA FIELDS FROM THE DATA SUMMARY REPORT RESULTS DATABASE

FIELD	DEFINITION
Analysis Information	
LAB_CODE	Unique identifier for lab performing the analysis.
METHOD	Analytic method.
MDA	Minimum Detectable Activity.
REQUIRED_DETECTION_LIMIT	If required detection limit is specified, it is stored here.
REPORTING_LIMIT	Reporting limit.
REPORTING_LIMIT_TYPE	Type of reporting limit (e.g., MDL, RDL, PQL, EQL)
DETECTION_STATUS	Non-detects are identified in this field.
QA QC Information	
LAB_QUALIFIER	Lab qualifier assigned at lab.
VALIDATION_QUALIFIER	Validation qualifier assigned by validator.
REVIEW_QUALIFIER	Review qualifier may be set by persons reviewing the data.
Source: Data Results User Guide Supporting the Data Summary Report for the Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington (WCH-398).	

Although the DSR database does not include specifics on the collection, quality control, and ownership of the data, this information is generally available in documents developed by Washington Closure Hanford to support collection of these data, including:

- Remedial Investigation Work Plan for Hanford Site Releases to the Columbia River (DOE 2008), which includes the Sampling and Analysis Instruction for the Remedial Investigation of Hanford Site Releases to the Columbia River document as an Appendix; and

- Data Quality Assessment Report for the Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington (WCH 2010).

Near-Fields

Waste Sampling and Characterization Facility for the Effluent and Environmental Monitoring Program (aka, the Near-Fields Program) samples and data are collected and analyzed systematically, on an annual basis, according to a detailed Statement of Work (SOW) that is produced annually by Mission Support Alliance (MSA). Because these data represent original data collections conducted by one program under a standardized set of protocols, the standards applied to their collection and analysis, as well as quality control procedures that were employed, are much more uniform than those of data sources representing compilations of disparate programs.

The annual SOW (e.g., Rokkan 2011) issued by MSA includes a variety of detailed information helpful in understanding how these data were generated, from sample collection procedures to requirements for data publication. Information contained within the SOW that may be of interest to Near-Fields data users include:

- Sampling and analysis requirements;
- Laboratory procedures;
- Quality control; and
- Detailed inventory of location, numbers, and frequency of samples to be taken.

BIOLOGICAL DATA

OVERVIEW OF ECOLOGICAL MONITORING AND COMPLIANCE PROJECT - PACIFIC NORTHWEST NATIONAL LABORATORY DATABASES

From the mid-1990s until mid-2011, PNNL ran the Ecological Monitoring and Compliance Project (EMC). The EMC "conducts surveys and collects data to monitor the status and condition of biological resources on the Hanford Site. Information is used to identify sensitive habitats and species and assure compliance with legal and regulatory requirements for natural resources and environmental monitoring."[13] The work "involves collecting and analyzing the appropriate ecological data to assess potential impacts and detect population trends for key species. The work includes collection of population-level information for presence and abundance of biota for key habitat types, and collection and analysis of community and population-level data over longer time periods to detect changes in population sizes and condition."[14] Specific efforts include:

- Rare plant monitoring,
- Vegetation surveys,
- Fish and wildlife surveys,
- Long-term monitoring plots, and
- Ongoing historical surveys of several bird and fish species.

Data collected through the EMC are summarized in the annual Hanford Site Environmental Reports and in PNNL additional reports. For instance, a summary of some of this information is available in Downs et al. (2004), the objective of which is "to provide summaries of the characterization information and available spatial data on the biological resources and ecological receptors found in the upland, riparian, aquatic, and island habitats on the Hanford Site." Appendix A to this document is an Excel file that contains "a summary of the spatial data available for biota on Hanford. Appendix A is organized in tables for upland, riparian, island and aquatic biota, and plant species from the permanent monitoring plots on the Hanford Site." PNNL has also provided data electronically in the series of databases listed in Exhibit 1-9.

---

[13] http://www.pnl.gov/ecomon/default.asp, viewed 9 May 2011. As of the date of this report, however, the EMC work has now been transferred to Mission Support Alliance (MSA), including its subcontractor, Environmental Assessment Services (http://www.easbio.com/projects/). Information about the EMC has been removed from PNNL's website, and MSA does not appear to have yet provided comparable information online.

[14] http://www.pnl.gov/ecomon/monitoring_characterization.asp, viewed 9 May 2011.

PNNL also ran the Surface Environmental Surveillance Project (SESP)[15], which "is a multimedia [sitewide far-field and offsite] environmental monitoring effort conducted to assess onsite and offsite human health exposures to radionuclides and chemicals and to evaluate the impact of Hanford Site operations on the environment" (DOE 2008). Media sampled include air, surface water, river sediments, drinking water, agricultural products, fish, and wildlife. Bisping (2010) describes the 2010 sampling and general targeted sampling frequency by media. Data gathered under SESP are input into HEIS (Downs et al. 2004).

Evaluation of Available Metadata

Data provided by PNNL consisted of eight individual Microsoft Access databases, with varying degrees of associated metadata. In 2011, PNNL undertook an effort to compile succinct data dictionaries and study descriptions for long-term survey efforts (i.e., "Ecometa" documents) for each of these sources in preparation for the transition of the Ecological Monitoring Program to Mission Support Alliance. It should be noted that because of the transition of this program away from PNNL, the institutional knowledge associated with these data may not fully rest with the individuals currently acting as curators of these data.

Each database provided by PNNL consists of data from one or both of two types of studies. Some records are related to samples collected and analyzed through regular surveys that were conducted over a period of years on the Hanford site. Other records were generated through individual data collection efforts which have been undertaken by numerous organizations over time, including for Master's or PhD work, or other academic or non-academic research.

[15] We have also seen this called the Surface Environmental Surveillance Program.

EXHIBIT 1-9 PNNL ECOLOGICAL COMPLIANCE AND MONITORING DATABASES

DATA FILE[1]	KEY DATA TYPES[2]	ASSOCIATED STUDY EFFORTS[2]
Animals.mdb	Elk, deer, and herpetofauna counts, amphibian call responders, amphibian habitat characteristics, amphibian malformation presence by species and pool, amphibian occurrence, small mammal and other biota pitfall/trap captures.	• Amphibian survey (2003-2008) • The Nature Conservancy herpetofauna survey (1995-1998) • Mule deer survey (1994-2010) • Rocky Mountain elk survey (1983-2002) • The Nature Conservancy data for small mammals
Aquatic_Community .mdb	Clam counts and histology, salmon and steelhead redd counts by area and date; salmon strandings; substrate mapping.	• Washington State Department of Fish and Wildlife salmon stranding surveys (1999-2002) • Salmon (1948-2010) and steelhead (2007-2009) redd surveys • Benthic data collected in conjunction with Hanford Site monitoring for radionuclides and heavy metals (2001-2003)
AvianSurveys.mdb	Bird counts, nest locations, burrowing owl nest status (active/inactive), Canada goose egg hatching, eagle roosting observations, sage sparrow observations and habitat.	• Wintering bald eagles (1961-2000) • Canada goose nesting (1957-2001) • Raptor nesting (1975-2008) • Roadside bird surveys (1988-2009) • Burrowing owl surveys (2006-2008) • Riparian walking surveys (1991-2001) • HSI sage sparrow study (2003-2005)

DATA FILE[1]	KEY DATA TYPES[2]	ASSOCIATED STUDY EFFORTS[2]
HanfordBirds.mdb	Species present at site including (qualitative) abundance, residence/breeding status, state/federal T&E status, migratory status; bird counts; vegetative habitat types. [There is some overlap with AvianSurveys.mdb, including Rattlesnake and Snively Springs surveys, and Hanford Townsite Birds. Where there is overlap, AvianSurveys.mdb has the most recent and complete records.]	Please see Note 3. • TNC-Breeding Bird Surveys (1994-1995) • ECAP Winter Bird Surveys (1997-2002) • Riparian Breeding Birds (2003) • EcoMon 300 Area riverine winter birds • Hanford Reach Winter Birds • Riparian Migrant Birds (1995-1996) • BRMaP Birds (1996-2000) • ECAP 200E/W Breeding Birds (1999-2000) • Cowbird Parasitism • Hanford BBS Roadside Surveys (1988-2003) • Hanford Townsite Street Trees (1995-2001) • Hanford Townsite River Trees (1995-2001) • BRMaP Birds 2005 (2005) • Sage Sparrow HSI Validation (2005) • Duberstein master's thesis data (1995-1996) • Snively and Rattlesnake Spring surveys (1995-2001) • The Nature Conservancy (1994-1995)
Insects.mdb	Counts of beetle species trapped (alive/dead, market/not); butterfly/moth counts; caddisfly species captured; counts of other insects.	• PNNL beetle survey (1964-1995) • PNNL butterfly and moth data (1959-1992) • Strenge and Newell caddisfly data (1998-2004) • The Nature Conservancy insects (1994-1995) • Strenge moth data (1993-2009) • Rogers insects (1972-1983) • Zack (1996-2000)
SampleAnalysis.mdb	Histology results for clams, crayfish, fish, and frogs. Includes sex, weight, body measurements, reproductive status, and general body condition. Associated contaminant data are provided in HEIS.	• Listed "purposes" in tblSamplePurpose include: 100BC-Char., 100-NR-2, BC, BRMaP, EMC, HSL, Mesocosm, Routine, SESP.
Summaries.mdb	Links to other databases and the ECOMON webpage, and is the primary source of species names and T&E status. It provides a current list of species names and keeps a list of synonyms.	Not applicable.

DATA FILE[1]	KEY DATA TYPES[2]	ASSOCIATED STUDY EFFORTS[2]
Vegetation.mdb	Plant lists, cover and/or density estimates	• Plots established to study the effects of aerial herbicide application on native plant communities • Plots to evaluate fire recovery • BRMaP - Biological Resource Monitoring Plan • 1994-1995 collection by The Nature Conservancy • Habitat suitability index study for sage sparrow
Appendix_A-113004_no_insects.xls (Downs et al. 2004)	Species location information: plant/animal species name, count, location information, last date recorded, pre- and post-2000 fire vegetation type.	• Data compiled from the SESP and EMC databases.

Notes:

1. All these files are part of PNNL's "Characterization" database with the exception of SampleAnalysis.mdb, which is their "Health" database.
2. The presented information is based on the associated database dictionaries, dated March 2011, as well as the databases themselves. Data collected by these surveys varies with the type and purpose of the survey.
3. Based primarily on information found in tblStudies in the database. The database dictionary indicates that this list is not up to date but is current as of 2005. Date ranges reflect years for which data is presently available in the database. Some studies may be ongoing. If no date is provided, the database does not appear to contain records for the listed study. Additional studies are included in this list based on information from the database dictionary.
4. PNNL has not attempted to pull these data into GIS (Janelle Downs, personal communication).

In the case of long-term survey data, PNNL has provided a series of "Ecometa" documents that contain a brief summary of the survey effort and a data dictionary defining the associated fields that appear within PNNL's databases. The types of information contained within these documents which are of utility from a metadata perspective include:

- Abstract (generally including the purpose for which the surveys were being conducted);
- Sampling description (e.g., frequency and length of survey events);
- Detailed methodology of sampling events; and
- Study owner and other associated contacts.

The level of detail provided in the Ecometa documents varies substantially from study to study. Exhibits 1-10 through 1-17 provide a short description of the focus of each database and indicate the associated Ecometa file describing the methodologies, where available.

EXHIBIT 1-10 ANIMALS.MDB CONTENTS AND ECOMETA FILE AVAILABILITY

CONTENTS	ECOMETA FILE
Amphibian surveys (2003-2008)	Herpetofauna 2003 and 2004.doc, Herpetofauna 2005 Malformation and Call Study.doc, Herpetofauna 2006 Call Surveys.doc, Herpetofauna 2007 Tracking Study.doc, Herpetofauna 2008 Night Call Surveys.doc, Herpetofauna 2008 Tracking Study.doc
Herpetofauna surveys (1995-1998)	None (collected by TNC)
Small mammal surveys (1992-2005)	None (collected by TNC)
Mule deer surveys (1994-2010)	Deer Surveys 1994-2010
Rocky Mountain elk surveys (1983-2002)	Rocky Mountain Elk Surveys 1983-2002
Source: Animals_database dictionary_3-25-11.doc, provided by PNNL.	

EXHIBIT 1-11 AQUATIC_COMMUNITY.MDB CONTENTS AND ECOMETA FILE AVAILABILITY

CONTENTS[1]	ECOMETA FILE
Salmon and steelhead redd surveys	Salmon_Steelhead Redd Count Survey.doc
Benthic community surveys (2001-2004)[2]	Benthic Community Sampling and Analysis.doc
WDFW salmon stranding	None (collected by WDFW)
Substrate mapping	None

Source: AquaticCommunity_database dictionary.doc, provided by PNNL.

Notes:

1. PNNL provides an Ecometa file "Hanford Reach Benthic Macroinvertebrate Sampling.doc" which contains information on a long-term macroinvertebrate survey. The table reported to contain the results does not appear in any of the provided databases.
2. Data dictionary indicates no Ecometa file available, but one was provided.

EXHIBIT 1-12 AVIANSURVEYS.MDB CONTENTS AND ECOMETA FILE AVAILABILITY

CONTENTS	ECOMETA FILE
Wintering bald eagles (1961-2000)	Bald Eagles-Winter Counts 1961-2009.doc
Bald eagle nest and roost monitoring (1999)[1]	Bald Eagle Nest and Roost Monitoring.doc
Canada goose nesting (1957-2001)	Canada Goose Nest Monitoring.doc
Raptor nesting (1975-2008)	Raptor Nest Surveys 1973-2008.doc
Roadside bird surveys (1988-2009)	Roadside surveys of shrub-steppe birds.doc
Burrowing owl surveys (2006-2008)	Burrowing Owl Population Ecology and Nest Habitat.doc
Riparian walking surveys (1991-2001)	Riparian Bird Surveys-Rattlesnake Springs.doc, Riparian Bird Surveys-Snively Springs.doc
Habitat Suitability Index sage sparrow study (2003-2005)	Sage Sparrow HSI Study 2003-2005.doc
Bird Surveys – Hanford Town Site (1995-2005)[2]	Bird Surveys-Hanford Town Site.doc

Source: AvianSurveys_database dictionary.doc, provided by PNNL.

Notes:

1. Survey not long-term, and not listed in Data Dictionary, but Ecometa file provided.
2. Survey not listed in Data Dictionary, but Ecometa file provided.

EXHIBIT 1-13 HANFORDBIRDS.MDB CONTENTS AND ECOMETA FILE AVAILABILITY

CONTENTS	ECOMETA FILE
Records of surveys involving birds inhabiting the Hanford Site.	No

Source: HanfordBirds_database dictionary.doc, provided by PNNL.

EXHIBIT 1-14 INSECTS.MDB CONTENTS AND ECOMETA FILE AVAILABILITY

CONTENTS	ECOMETA FILE
Records of surveys for terrestrial insects	None (data collected by PNNL and TNC)
Beetles (1964-1995)[1]	Beetles.doc
Source: Insects_database dictionary_3-24-2011.doc, provided by PNNL. Note: Survey not listed in Data Dictionary, but Ecometa file provided.	

EXHIBIT 1-15 SAMPLEANALYSIS.MDB CONTENTS AND ECOMETA FILE AVAILABILITY

CONTENTS	ECOMETA FILE
Information regarding the health and condition of fish and wildlife that are collected.	None
Source: SampleAnalysis_DatabaseProcedures2011.doc, provided by PNNL.	

EXHIBIT 1-16 SUMMARIES.MDB CONTENTS AND ECOMETA FILE AVAILABILITY

CONTENTS	ECOMETA FILE
Primary source of species names and Threatened & Endangered status; links to other databases.	NA (does not contain data records)
Source: Summaries_database dictionary.doc, provided by PNNL.	

EXHIBIT 1-17 VEGETATION.MDB CONTENTS AND ECOMETA FILE AVAILABILITY

CONTENTS	ECOMETA FILE
Plant lists and cover and/or density estimates for long-term monitoring plots (BRMaP)	None (information available in the BRMaP)
Plant lists and cover and/or density estimates for plots established to study the effects of aerial herbicide applications on native plant communities	Herbicide_Vegetation_Sampling_in_2008_and_2009.doc
Plant lists and cover and/or density estimates for plots to evaluate fire recovery	Fire Recovery 2008, 2009, and 2010.doc
TNC 1994 and 1995 vegetation surveys	No (collected by TNC)
Vegetation data collected for the sage sparrow HIS survey (also contained in AvianSurveys.mdb)	Sage Sparrow HSI Study 2003-2005.doc
Source: Vegetation_database dictionary.doc, provided by PNNL.	

To assess the extent to which useful metadata are contained within the individual databases for both long-term and stand-alone data collection events, we reviewed the provided Data Dictionaries, as well as the contents of the databases themselves. Because each study is captured in one or more study-specific tables with a unique set of fields, we do not provide an exhaustive list of available metadata housed within these databases. However, the types of metadata that appear to be generally available for all study efforts include:

- Survey date and time;
- Observer name;
- Survey methodology (e.g., transect, pitfall or trip, grid/plot, etc.); and
- Weather conditions/cloud cover.

It should be noted that although all fields within each table within a database appear to be identified in the provided Data Dictionaries, definitions are not provided for all fields. It also appears that code may not be available for all codes used within the fields. Finally, the extent to which the identified information is filled out within a table varies.

ADDITIONAL DATABASES WITH BIOLOGICAL INFORMATION

The RCBRA (GiSdT) database includes not only contaminant measurements but also toxicity testing results using site media for several species. DOE (2011b) presents these results in more detail, as described in Chapter 5.

HANFORD GIS DATA LAYERS

We searched for collections of existing Hanford GIS data layers of potential utility in the context of a NRDA and identified a number of sources of geospatial information for the Hanford Site and surrounding area. Key repositories of this information include the Hanford Geographic Information System (HGIS) and spatial data files developed by PNNL as part of its environmental surveillance work and for other purposes.[16]

HANFORD GEOGRAPHIC INFORMATION SYSTEM (HEIS)

The Hanford Geographic Information System (HGIS) stores spatial data to support Hanford Site cleanup (DOE 2009). HGIS data are viewable through the QMAP online mapping tool, which is accessed through HLAN. The online mapping tool allows users to view extensive data, primarily related to wells and groundwater sampling. A subset of data are available for download through the QMAP interface including administrative boundaries, hydrography, topography, utilities, waste sites, plant and animal species, land use, geology, facilities/buildings, land cover, transportation, soils, and wells (*ibid.*). These data are listed in Exhibit 1-18.

The spatial data layers available for download through QMAP do not represent the complete extent of spatial data viewable through the online mapping tool or available in

[16] We understand that as of mid-2011, responsibility for maintenance of these files has changed from PNNL to Mission Support Alliance.

HGIS. Since development of the Data Gaps report began, we have been pursuing additional information on available GIS data. Although initial conversations with the designated contact indicated that an inventory and access to the data were forthcoming, all subsequent attempts to retrieve this information have been unsuccessful. With DOE's assistance we will continue to pursue access to these data, but that information is currently unavailable.

EXHIBIT 1-18 SPATIAL DATA LAYERS DOWNLOADED FROM QMAP VIA HLAN

TITLE	LAYER NAME	SHORT DESCRIPTION
Fence lines	imgfen	Depicts all fences on the Hanford Site.
Wells	imwelwel	Depicts shafts dug or drilled into the earth (i.e., wells and borings). Wells and borings are classified based on their general construction characteristics, which correlate with the purpose for which they were drilled and/or constructed (e.g., characterizing soil conditions, extracting soil gas, extracting water, etc.).
District area boundary	bdjurdsv	Depicts the boundaries of the operational areas on the Hanford Site.
Richland political boundary	bdjurpln	Boundary of the city of Richland.
Existing buildings	bggenexs	Existing structures that were created, by man, for occupation, storage, or to facilitate an activity.
Federal property interest site	cdfedint	Depicts interests held by outside agencies or enterprises for land under the control of the Federal government.
Agency owned area	cdfedown	Depicts property owned or being used by the Federal government not related to the Department of Defense.
Air emissions source	ehairasp	Identifies the locations of air emissions sources.
Air monitoring station	ehchamst	Depicts the location of air monitoring units.
WIDS Sites	ehsit	Depicts point, line and polygon features of mapped waste sites at Hanford.

TITLE	LAYER NAME	SHORT DESCRIPTION
WIDS Polygon Features	ehsitirp	Depicts the polygon features of mapped waste sites at Hanford.
WIDS Lines Features	ehsitpip	Depicts the line features of mapped waste sites at Hanford.
WIDS Point Features	ehsitpir	Depicts the point features of the mapped waste sites at Hanford.
Pipeline Point Features	ehsitppt	Depicts the process piping pipelines on the Hanford Site. Two types of points will be included, points that represent spot elevations along the pipeline and inline objects such as valves, reducers and tees.
Pipeline Line Features	ehsitpsg	Line file depicting the process piping pipelines on the Hanford Site.
Surface water course area	hysurcrs	Depicts a flowing course of water including rivers, streams, canals, etc.
Surface water body areas	hysurcrs	Depicts standing bodies of water that can be natural or man-made including lakes, ponds, pools, etc.
Island topography	lftopisl	Depicts areas of land completely surrounded by the waters of an ocean, sea, lake, or stream.
Sidewalks	trpedwlk	Depicts a paved or concrete pad used as a pedestrian walkway.
Railway	trrrdrcl	Depicts the center of a railway as measured from the outside edge of the rails.
Curbs	trvehcrb	Depicts the rim of concrete or joined stones that forms the edge of the roadway and beginning of a sidewalk, if present, or a dividing barrier.
Roadway	trvehrcl	Depicts the center of roadways as measured from the edge of the roadway.

In addition to the layers readily available for download from the QMAP interface, we requested and received all years of available groundwater plumes for 13 unique contaminants in point, contour, and polygon formats from Bill Webber, MSA. The contaminants represented in these data include:

- Carbon-14
- Cyanide
- Chromium
- Carbon tetrachloride
- Fluorine
- Iodine-129
- Nitrate
- Sulfate
- Strontium-90
- Technetium-99
- Trichloroethylene
- Tritium
- Uranium

Appendix A contains maps of groundwater plumes for target analytes.

PACIFIC NORTHWEST NATIONAL LABORATORY SPATIAL DATA

PNNL has gathered and maintained spatial information, and has maintained these files as part of the Environmental Monitoring and Compliance program. Downs et al. (2004) describes these data layers in general terms, and Janelle Downs (PNNL) provided IEc with the GIS files listed in Exhibit 1-19 below.

Downs et al. (2004) notes the existence of aquatic spatial habitat layers for the Columbia River adjacent to the Hanford Site, which we are in the process of acquiring. Our initial communication with Andre Coleman of the PNNL Hydrology Technical Group, indicates that this division of PNNL may have extensive geospatial information of potential use in the NRDA. Although initial discussions indicated that these data were forthcoming, all subsequent attempts to connect with the contact to retrieve this information have been unsuccessful. Consequently, a complete inventory of this information was not available as this report was being finalized.

MISSION SUPPORT ALLIANCE (MSA) SPATIAL DATA

MSA has been developing its own inventory of available GIS data (Doug Fenske, MSA, personal communication). This compilation was also not available at the time of finalization of this report.

EXHIBIT 1-19 SPATIAL DATA LAYERS PROVIDED BY PNNL

LAYER NAME	SHORT DESCRIPTION
2010_RarePlant_Points	Rare plants (points), occurrence and extent of rare taxa
2010_RarePlant_Polys	Rare plants (shapefile), occurrence and extent of rare taxa
all_known_salmon_spawn	Salmon redds in the Hanford Reach, 2000-2001, 2005, 2006
bridroutes031302	Breeding bird survey routes
brmap_plots	Long-term monitoring plots
elemocc95	High quality rare habitat locations as determined by Washington State Natural Heritage Program, 1995
elemocc97	High quality rare habitat locations as determined by Washington State Natural Heritage Program, 1997
FiresDATE (multiple)	Polygons representing most of the large areas burned by wildfires on the Hanford Site from 1974-2009
grouse	Sage grouse sightings, 1999-2003
HanBuowSites06_09	Hanford Site owl burrow locations, 2006-2009
Hanford_cover_2010	Vegetation land cover polygon based on dominant/subdominant species
HanfordEagleZones	Bald eagle roost and possible nest locations along the Hanford Reach; also, protection zone for wintering eagles.
riparian_2004_final	Riparian vegetation mapping shapefile
surve_route2002	Mule deer survey routes

WASHINGTON DEPARTMENT OF FISH AND WILDLIFE SPATIAL DATA

The Washington Department of Fish and Wildlife (WDFW) provided a number of statewide layers of interest including data related to fish distribution in Washington lakes and rivers, and locations of priority habitats and species, as shown in Exhibit 1-20 below.

EXHIBIT 1-20 SPATIAL DATA LAYERS PROVIDED BY WDFW

TITLE	LAYER NAME	SHORT DESCRIPTION
ecoregion_analysis_pts	Columbia Plateau Ecoregional Assessment Database	Contains documented point observations for numerous indicator wildlife species from multiple organizational sources. The database contains data from 1987 to the present.
fish_distribution	Fish Distribution of Washington State at the 1:24,000 scale: Washington Lakes and Rivers Information System (WLRIS)	Contains data on the life history and the documented presence, and also presumed or potential presence, of salmon and significant game species. Data exists from year 2003 to 2007, and is mapped at a 1:24,000 scale.
phs	Priority Habitat and Species	Contains polygons empirically mapped by biologists that identify occurrences of priority habitat and species. Priority habitats are those with unique or significant value to numerous fish and wildlife species. Priority species are those requiring special efforts to ensure their perpetuation due to low numbers, sensitivity to habitat alteration, or are of commercial, recreational, or tribal importance.
regap_pts		Metadata are not complete, and the content of this layer is currently unclear.
wsdm_poly	Observations of state and federally-listed wildlife species (polygons)	Contains documented polygon observations for state and federal listed wildlife species including those designated as endangered, threatened, sensitive, candidate, and monitor. Observations occur from 1881 to the present.
wsdm_pts	Observations of state and federally-listed wildlife species (points)	Contains documented point observations for state and federal listed wildlife species including those designated as endangered, threatened, sensitive, candidate, and monitor. Observations occur from 1881 to the present.
NAIP	National Agriculture Inventory Program Aerial Photography	Year 2009 National Agriculture Inventory Program (NAIP), 1 meter, both color-infrared and color, digital georeferenced aerial photo mosaic. Additionally, year 2006 photo mosaic exists at 18 inch resolution.[a]

Notes:

a. Since these data were provided by WDFW, 2011 1- meter resolution NAIP data have become available for the Hanford region.

POTENTIAL FUTURE DATA SOURCES

Much information of relevance to NRDA is typically generated and/or summarized during the ecological risk assessment process, and data gaps may be identified as well. The River Corridor Baseline Risk Assessment (DOE 2011b) and the Columbia River Component screening-level risk assessment (DOE 2011a) have both been recently released and contain information likely to be of use in a NRDA. To the extent that these documents may be revised in the future, those revisions may also contain useful information.

Exhibit 1-21 summarizes the currently anticipated dates by which additional risk assessment reports are expected.

EXHIBIT 1-21 ESTIMATED RISK ASSESSMENT DUE DATES BY HANFORD SITE AREA

AREA	RISK ASSESSMENT DUE DATE
Central Plateau Inner Area	
200 East	6/30/2014
200 West	6/30/2013
Central Plateau Outer Area	4/30/2012

CHAPTER 2 | SOILS

This chapter provides a summary of data types most commonly relied upon for purposes of determining injury to soil resources. Soils are a geological resource and are considered to be injured when any of a number of different injury definitions are met (43 CFR 11.62(e)(1) through (e)(11)). Broadly speaking, these definitions of injury include having a sufficient concentration of hazardous substances to meet characteristics identified under section 3001 of the Solid Waste Disposal Act, 42 U.S.C. 6921, possessing a certain pH or salinity values impeding soil microbial respiration, exhibiting phytotoxicity, causing toxicity to soil invertebrates, or more broadly, being sufficiently contaminated to cause injury to other natural resources.

The chapter begins by characterizing available information on exposure of soils to contaminants, as indicated through measurements of contaminant concentrations in soils. Measurements of exposure are relevant as components in establishing injury as noted above and in establishing a complete pathway (as described in 43 CFR 11.63) from releases to receptors. Soil measurements also provide information relevant to ascertaining the likely causality of potential injuries.

This chapter concludes with a summary of the presented information, highlighting areas where information appears to be limited or absent.

EXPOSURE TO CONTAMINANTS

We assembled available information to identify data on the exposure of soil to contamination. Available sources of information include the following:

- Hanford Environmental Information System (HEIS);
- The River Corridor Baseline Risk Assessment database (RCBRA / GiSdT);
- The 2011 Releases to the Columbia River Remedial Investigation Data Summary Report (DSR) database;
- The Columbia River Component (CRC) Historic database;
- Environmental Release Summary (ERS) database.

Because of the challenges associated with the partial overlap of information among various databases, we evaluated information within each database separately, as described below. Maps of all soil sampling locations are provided in Appendix A.

HANFORD ENVIRONMENTAL INFORMATION SYSTEM (HEIS)

Data Exploration

Evaluation of data from HEIS focused on the media-specific soil view available from HEIS, which consists primarily of a combination of fields from the HEIS "sample" and "result" tables. This view was downloaded from HEIS and provided to IEc by Bill Webber on June 30, 2011. Because HEIS is frequently updated, later downloads may include additional information.

The downloaded soil data included 1,483,035 records, comprising 41,854 unique sample numbers. We define a unique sample as a discrete unit of sampled soil, based on the "SAMP_NUM" field in HEIS.

Data Excluded from Analysis

We excluded from analysis all records for which the "SAMP_ITEM" field had the value "QC_SAMPLE", and samples identified as laboratory replicates (i.e., those having a value of "R", "S", or "B" in the "LAB_QC_TYPE" field). The "FIELD_QC_TYPE" field contained no information, so data was not excluded on the basis of field replicates. We also excluded all sediment records, identified with a value of "SEDIMENT" in the "SAMP_ITEM" field.[17] These records are analyzed in Chapter 4 (Sediments).

For purposes of tabulating numbers of records, data were not excluded based on laboratory, validation, or review qualifiers.

Unique instances of a sample being analyzed for a particular analyte are primarily identifiable as combinations of the sample number ("SAMP_NUM") field and the contaminant field ("STD_CON_ID") . We identified a few exceptions to this rule. For instance, Aroclors, carbon tetrachloride, chromium, mercury, plutonium, strontium-90, technetium-99, and uranium were sometimes tested using two different analytical methods, each of which represents a unique record. In addition, certain contaminants including carbon tetrachloride and plutonium-239 were measured using different dilution factors. For purposes of summarizing counts of total records and numbers of samples analyzed for a particular analyte, the record associated with the first reported method for the relevant sample/contaminant combination was retained.

After selecting and grouping data as described above, the resulting list of records is reduced from 1,483,035 to 1,309,489, comprising 38,060 samples. These samples were collected during 26,432 unique sampling trips.[18]

Data Analysis

HEIS contains samples from several sample types, as listed in the "SAMP_FROM"[19] field, including pond, sub-surface, surface, and trench samples. Samples are also

---

[17] The remaining "SAMP_ITEM" fields are described in Exhibit 2-1.

[18] A sampling trip is defined as a unique sample date and time ("SAMP_DATE_TIME" for a unique sample site ID ("SAMP_SITE_ID").

[19] The "SAMP_FROM" field is primarily used to designate the type of biota sample, and therefore may often be blank for other media.

categorized into sixteen subtypes, as listed in the "SAMP_ITEM" field. A number of samples do not have a type listed. Exhibit 2-1 lists the number of samples associated with each type ("SAMP_FROM" and "SAMP_ITEM"). All pond samples were sediment samples, and therefore, were previously excluded from this analysis.

EXHIBIT 2-1 COUNT OF HEIS SOIL SAMPLES BY SAMPLE TYPE[20] AND ITEM

SAMPLE ITEM	SAMPLE TYPE					
	BLANK	SEPTIC	SURFACE	SUB_SURFACE	TRENCH	TOTAL
BLANK	32,422	1	715	570	11	33,719
BIOTIC CRUST			14			14
COARSE SAND			2	4		6
FINE SAND				7		7
GEO_SAMPLE	2		48	2,103		2,153
MEDIUM SAND				6		6
MINERAL SOIL			4			4
ORGANIC SOIL			4			4
ROOTING ZONE			81			81
SILT_CLAY				10		10
SITE_BKGD_JUDGE			28	10		38
SITE_BKGD_REF	12		45	125		182
SOIL/SAND/DUST	1		5	6	9	21
SURF_SOIL			1,377	431		1,808
VERY FINE SAND				7		7
TOTAL NO. SAMPLES	**32,437**	**1**	**2,323**	**3,279**	**20**	**38,060**
TOTAL NO. SAMPLING TRIPS*	**22,562**	**1**	**1,756**	**2,099**	**14**	**26,432**

Note: The "SAMP_ITEM" field included "SEDIMENT" and "QC_SAMPLES" also, which were excluded from analysis.
* Sampling trip refers to all samples collected from the same point in space and time, and is determined by grouping records using "SAMP_SITE_ID" and "SAMP_DATE_TIME" fields. The "TOTAL NO. SAMPLES" row refers to unique samples as units of soil, as defined using the "SAMP_NUM" field. Multiple sample numbers can be associated with the same sampling trip.

[20] Identified by the "SAMP_FROM" field.

A few samples are also identified as composite samples in the COMPOSITE_FLAG field. Approximately 40 percent of the samples do not contain any information in this field; 50 percent are not composites identified with a "N", and the remaining 10 percent are identified as composites with a "Y" in the "COMPOSITE_FLAG" field.

Of the samples with information in the "SAMP_FROM" field (5,623 samples), 58 percent are identified as sub-surface samples and 41 percent are surface samples. Most of the surface samples with information on depth (45 percent) were taken between zero and six inches. The remaining samples either have no information in the sample interval bottom depth field ("STD_SAMP_INTV_BOT") or have bottom depths ranging between six and 216 inches. Samples identified as sub-surface samples have bottom depths ranging from zero to approximately 532 feet deep.[21] However, the majority of sub-surface samples were taken at depths greater than three feet (81 percent). Exhibit 2-2 lists the numbers of total and surface samples taken at each bottom depth. We note that the "OWNER_ID" field contains information on the owner or contractor responsible for the sample, and sampling protocol or methodology information associated with the program or owner may be used to estimate sample depth. Few samples (approximately three percent) are identified as from the SESP, 60 percent from "RIVERCOR", 18 percent from "CENTPLAT", 16 percent from "HEISPROD", and the remaining three percent from "PNLWELL", "FHAS", "PNLGW", and "TFVADZNP".

EXHIBIT 2-2 NUMBER OF HEIS SURFACE SOIL SAMPLES BY DEPTH TO BOTTOM OF SAMPLE

DEPTH TO BOTTOM OF SAMPLE (m)	DEPTH RANGE IN INCHES	NO. TOTAL SAMPLES	NO. SURFACE SAMPLES	NO. SURFACE SAMPLES/ TOTAL SURFACE SAMPLES (%)
Blank	Blank	20,081	1,270	54.7
0	0	44	30	1.3
>0 - 0.0254	>0 - 1	993	886	38.1
>0.0254 - 0.1524	>1 - 6	667	41	1.8
>0.1524 - 0.6096	>6 - 24	1,639	57	2.4
>0.6096 - 0.9144	>24 - 36	212	6	0.3
>0.9144 - 1.829	>36 - 72	483	12	0.5
>1.829	>72	13,941	21	0.9
	TOTAL	**38,060**	**2,323**	**100**

[21] It is unclear how samples were classified as surface versus sub-surface since both types of samples were taken at depths of zero.

We also explored the data as a function of samples testing for one or more of the target analytes (a total of 33,857 samples). Exhibit 2-3 presents the numbers of samples analyzed by soil type for each target analyte and Exhibit 2-4 presents the number of samples analyzed by soil type for COECs/COPECs. Note that each sample was taken from only one specific soil type but is likely to have been analyzed for multiple analytes.

EXHIBIT 2-3 COUNT OF HEIS SOIL SAMPLES BY TARGET ANALYTE AND SOIL TYPE[22]

TARGET ANALYTE	SOIL TYPE					
	BLANK	SEPTIC	SUB-SURFACE	SURFACE	TRENCH	TOTAL
Carbon tetrachloride	3,148		1,888	102	2	5,140
Cs-137	15,966		1,359	1,562	18	18,905
Cr	15,578	1	2,173	718	14	18,484
CrVI	13,703		93	365	11	14,172
I-129	649		331	52	1	1,033
Hg	9,299	1	2,062	909	14	12,285
PCBs*	4,922	1	1,511	419	1	6,854
Pu			46	46		92
Pu -238	5,121		842	1,315	12	7,290
Pu -239/240	5,062		694	1,317	12	7,085
Sr-90	171		1,273	1,202		2,646
Tc-99	2,547		730	169	2	3,448
Tritium	3,340		236	19	2	3,597
U	3,685		408	903		4,996
U-233/234	4,136		373	367	3	4,879
U-234	1,022		481	441	10	1,954
U-235	8,939		1,149	999	17	11,104
U-238	9,295		1,153	1,010	17	11,475
TOTAL NO. SAMPLES	**32,437**	**1**	**2,323**	**3,279**	**20**	**38,060**

*Samples tested for Aroclors, PCB congeners, or a mixture of both.

[22] Identified by the "SAMP_FROM" field.

EXHIBIT 2-4 COUNT OF HEIS SOIL SAMPLES BY COEC/COPEC[23] AND SOIL TYPE

TARGET ANALYTE	SOIL TYPE					
	BLANK	SEPTIC	SUB-SURFACE	SURFACE	TRENCH	TOTAL
Sb	7,977		2,082	674	3	10,736
As	14,344	1	2,057	714	5	17,121
Ba	13,828	1	2,133	705	5	16,672
B	6,865		70	424	2	7,361
Cd	13,949	1	2,169	706	5	16,830
Cu	7,934		2,102	668	3	10,707
Dieldrin	1,975		1,378	418		3,771
Pb	15,370	1	2,168	725	14	18,278
Mn	7,726		2,102	688	3	10,519
Se	13,569		2,082	704	5	16,360
TPH-diesel						0
Zn	7,770		2,102	678	3	10,553
TOTAL NO. SAMPLES	**32,437**	**1**	**2,323**	**3,279**	**20**	**38,060**

We explored the data as a function of sample site type (“SAMP_SITE_TYPE”) for all samples testing for target analytes (Exhibit 2-5). The majority of samples are identified as from a “sampling site” in the “SAMP_SITE_TYPE”) field.

[23] The depicted analytes represent COECs from the River Corridor Baseline Risk Assessment (DOE 2011b) and COPECs from the Columbia River Component Screening-Level Ecological Risk Assessment (DOE 2011a). Counts for COECs/COPECs previously presented in Exhibit 2-3 are not repeated here.

EXHIBIT 2-5 COUNT OF HEIS SOIL SAMPLES BY TARGET ANALYTE AND SAMPLE SITE TYPE

TARGET ANALYTE	SAMPLE SITE TYPE											
	AQUIFER TUBE	BORING	GROUNDING WELL	GW WELL	INSTRUMENT BORING	INVALID WELL OR BORING[1]	PROPOSED WELL OR BORING	SAMPLING SITE	SOIL TUBE	UNCLASSIFIED WELL OR BORING	VADOSE WELL	TOTAL NO. SAMPLES
Carbon tetrachloride		635		852	7	5	8	2,360	432	284	557	5,140
Cs-137		914	10	1,238	20	5	17	16,015	29	334	323	18,905
Cr		3,230	10	3,959	40	5	108	10,095	79	351	607	18,484
CrVI		2,829	10	2,733	6	5	108	8,372		101	8	14,172
I-129		432	--	318	40		8	88		88	59	1,033
Hg		876	10	926	40	2	12	9,411	79	334	595	12,285
PCBs[2]		351		434	7	2		5,340		241	479	6,854
Pu								92				92
Pu -238		713	10	422	8	5	7	5,597	29	215	284	7,290
Pu -239/240		652	10	429	8	5	7	5,561	29	234	150	7,085
Sr-90		224		346	34			1,560		189	293	2,646
Tc-99[3]	1	880		940	40	2	8	1,052		189	335	3,448
Tritium		616		626	7	2	16	2,161		86	83	3,597
U		350	10	1,339	7		7	2,937		111	235	4,996
U-233/234		443		430	7	2		3,737		187	73	4,879
U-234		274		48	1			1,530		36	65	1,954
U-235		817		896	8	5		8,869	29	316	164	11,104
U-238	1	876		1,208	41	5		8,791	29	315	209	11,475
TOTAL NO. SAMPLES	**1**	**4,892**	**10**	**6,224**	**136**	**5**	**151**	**24,736**	**439**	**515**	**949**	**38,060**

1. Invalid well or boring refers to an invalid sampling site to which historical data has been associated.
2. Samples testing for Aroclors, PCB congeners, or a mixture.
3. In addition to the depicted samples, there are two samples listed as a "cancelled well or boring" samples, one of which was tested for Tc-99.

Not all of the data summarized above may be suitable for use in the natural resource damage assessment. Many records lack key information. For instance, of the 1,309,489 retained records, 97,380 are null in the "STD_VALUE_RPTD" field.

Of the 38,060 unique samples, 7,443 samples (20 percent) from 1,613 sampling sites (based on "SAMP_SITE_ID") lack geographic coordinate information. Bill Weber of CH2MHiLL Plateau Remediation Company, database point of contact for HEIS, provided some context for the absence of coordinate information for many soil and other sample types. He notes that prior to the early 2000s and the development and proliferation of GPS technology, it was exorbitantly expensive to get coordinate information for a site; consequently, such measurements were not generally made. More recent samples may lack coordinate information if they were collected as part of a repetitive sampling program. In these cases, the relevant site location file may have been established prior to the existence of GPS. Newer collections will tend to reference that file, since the sites are pre-established and repeated. If this file has not been updated with coordinates, that information will not be available in HEIS (personal communication, June 29, 2011).

Of the samples identified as "SURFACE", approximately 41 percent lack coordinates, as do 17 percent of the identified "SUB_SURFACE" samples. Although general locational information is typically provided, (e.g., in the "SAMP_SITE_NAME", "SAMP_SITE_DESC" and other descriptive text fields), the absence of easting and northing in the database at a minimum makes mapping the precise locations of the data points a substantially more complicated and time-consuming exercise. Mr. Weber further confirms that the sample site description fields are generally not normalized, such that it could be difficult to match these entries with a particular location: no "look up" table is readily available (personal communication, June 29, 2011).

Exhibit 2-6 lists the numbers of samples by sample type and date, and for which specific coordinate information is available. For those samples without coordinates, Exhibit 2-7 indicates the number of samples for which there is general location information provided in other locational fields. As shown in this exhibit, all samples without coordinates have information in the "SAMP_SITE_ID" field; however, this is a unique, computer generated, numeric identifier for the sampling site, and alone, does not provide a description of the sample location. The "SAMP_SITE_NAME" often contains more descriptive information, and most (98 percent) of the samples without coordinates contain information in the "SAMP_SITE_NAME" field (Exhibit 2-7).

EXHIBIT 2-6 NUMBER OF HEIS SOIL SAMPLES BY TYPE AND TIMEFRAME

SAMPLE TYPE	TOTAL NO. SAMPLES	TOTAL NO. SAMPLES WITH COORDINATES	NO DATE	BEFORE 1981	1981 - 2000	AFTER 2000
SEPTIC	**1**				1	
SUB-SURFACE	**3,279**	2,720	4	63	2,639	573
SURFACE	**2,323**	1,371		235	890	1,198
TRENCH	**20**	19			11	9
BLANK	**32,437**	26,507			4,666	27,771
TOTAL	**38,060**	**30,617**	**4**	**298**	**8,207**	**29,551**
Samples date from 1971 to 2011.						

EXHIBIT 2-7 NUMBER OF HEIS SOIL SAMPLES WITH DESCRIPTIVE LOCATION INFORMATION

FIELD	NO. SAMPLES WITH INFORMATION
SAMP_SITE_ID	7,433
SAMP_SITE_NAME	7,413
SAMP_SITE_DESC	4,099
SAMP_LOCATION	2,940
SITE_CODE	1,711
None of the above	0
TOTAL NO. SAMPLES WITHOUT COORDINATES	**7,443**

Geographic Distribution

The 38,060 unique samples are from 17,036 distinct sampling sites (based on "SAMP_SITE_ID"). We analyzed the geographic location of soil samples further as a function of their proximity to the Columbia River and to operational areas as shown in Exhibit 2-8 and the maps in Appendix A.

Many samples (approximately 39 percent or 11,977 of 30,617 samples with coordinates) are within 500 meters of the on-site portion of the Columbia River. The majority of samples (approximately 91 percent or 27,802 samples) are found within 500 meters of the main operational areas and facilities (several of which are also found within 500 meters of the on-site portion of the Columbia River) (Exhibit 2-8). HEIS also contains information on soil samples from a number of offsite locations scattered throughout south-central Washington.

EXHIBIT 2-8 COUNT OF HEIS SOIL SAMPLES WITHIN 500 METERS OF HANFORD OPERATIONAL AREAS

OPERATIONAL AREA	NO. SAMPLES	PERCENT OF TOTAL*
100 Areas	20,212	66%
200 Areas	3,737	12%
300 Area	2,448	8%
400 Area	33	0.1%
All other operational areas	146	0.4%
TOTAL	**26,576**	**87%**
*Percent calculated out of total number of samples with coordinates, 30,617.		

RIVER CORRIDOR BASELINE RISK ASSESSMENT DATABASE (RCBRA / GiSdT)

Data Exploration

Evaluation of data from this source focused on all usable soil samples (i.e., data with a "Y" in the "gisdt_usable" field) as downloaded from the RCBRA data management website (http://rcbra.neptuneinc.org/rcbra/home/index.xml) on May 11, 2011. The downloaded data included 128,990 records, including 8,406 unique sample numbers.

Data Excluded from Analysis

We excluded from analysis all samples with an "N" in the "gisdt_usable" field as well as samples identified as laboratory replicates (i.e., those having a value of R in the "lab_qc_type" field). For purposes of tabulating numbers of records, data were not excluded based on laboratory, validation, or review qualifiers.

Although this table does not contain a primary key, unique records can often be identified as a combination of the sample ID and contaminant ID fields ("sample_id" and "gisdt_std_con_id"). However, we identified exceptions to this rule for uranium-233/234, thallium, and arsenic, which were measured using two analytical methods, each of which represents a unique record in the table. Other samples measured nitrogen in nitrate more than once per sample ID, where one record had a review qualifier of "Z". For purposes of summarizing counts of samples, the record associated with the first reported result for the relevant sample/contaminant combination was retained.

After selecting data as described above, the resulting list of records is reduced from 128,990 to 128,937, comprising 8,399 unique samples. These samples were collected during 1,916 unique sampling trips.[24]

[24] For purposes of this analysis, we define a sampling trip as a unique sample date ("samp_date") and sample location ("gisdt_sample_site_name"). There are 2,048 samples lacking a date; however, we count these as 128 separate sampling trips, since they are from 128 separate sample sites.

Data Analysis

As shown in Exhibit 2-9, this database contains samples from three environments ("gisdt_environment") (nearshore, upland, and riparian), although most soil samples are "upland". Some of the data are also described as "deep" or "shallow" in the "gisdt_sample_depth" field. The majority of samples do not contain any depth information, and all samples identified as deep or shallow are associated with the "waste_site" category (categories are discussed further below). The four samples identified as "nearshore" were taken from the same location, the White Bluffs Slough.

EXHIBIT 2-9 COUNT OF ALL GiSdT SOIL SAMPLES BY ENVIRONMENT AND DEPTH

ENVIRONMENT	TOTAL NO. SAMPLES	NO. BLANK IN DEPTH FIELD	NO. SHALLOW SAMPLES	NO. DEEP SAMPLES
Nearshore	4	4		
Riparian	341	341		
Upland	8,055*	6,248	1,331	476
TOTAL	**8,400**	**6,593**	**1,331**	**476**

*The remaining upland samples did not have information in the "gisdt_sample_depth" field.

The database also includes a variety of sample types ("gisdt_sample_type" field) including discrete, discrete-RP, focused, *MULTI INCREMENT®*[25] sampling (MIS), MIS-phyto, and statistical.

Samples are also assigned into a category ("gisdt_category"). The categories generally reflect the source of the data. For instance, samples from "BC PILOT" included data compiled for the 100-B/C Pilot Risk Assessment, samples from "NR 2" are from the 100-NR-2 Shoreline Assessment project, and those identified as "PNNL" are samples from historic and current source documents, projects, and databases maintained by the Pacific Northwest National Laboratories. Descriptions of the remaining categories can be found in Appendix C-1 (Database Contents and Structure) of volume 2, draft C of the River Corridor Baseline Risk Assessment (DOE/RL-2007-21).

The numbers of samples in each sample type and category are shown in Exhibit 2-10.

[25] *MULTI INCREMENT®* sampling is a comprehensive sampling approach used to represent a specific population or decision unit. It involves pooling several individual increments and is intended to provide a more reliable estimate of the average concentration in an area.

EXHIBIT 2-10 NUMBER OF ALL GiSdT SOIL SAMPLES BY CATEGORY AND SAMPLE TYPE

CATEGORY	SAMPLE TYPE						
	DISCRETE	DISCRETE-RP	FOCUSED	MIS	MIS-PHYTO	STATIS-TICAL	TOTAL
Area Background	542						542
BC Pilot	47						47
Near-Facility	2,607						2,607
Non-Waste Site	37						37
Operational	113	16		108			237
Reference				54			54
Reference Backfill				30			30
Reference Native Soil				30	3		33
Reference BC	21						21
Ref CP Backfill	4						4
Ref CP Native Soil	3						3
Ref CPOFF	6						6
Ref NR2	14						14
Ref PNNL	615						615
Regional	388						388
Statewide	1,769						1,769
Waste Site	18		535			1,273	1,825
Waste Site Backfill	20			60	2		82
Waste Site Native Soil	20			60	5		85
Total	**6,224**	**16**	**535**	**342**	**10**	**1,273**	**8,400**

We examined data availability by category and target analyte, and by category and COEC/COPEC. Exhibits 2-11 and 2-12 present the results.

EXHIBIT 2-11 COUNT OF GiSdT SOIL SAMPLES BY CATEGORY AND TARGET ANALYTE

CATEGORY	TARGET ANALYTE															TOTAL NO. SAMPLES
	C-tet	Cs-137	Cr	CrVI	Hg	PCBs*	Pu-238	Pu-239/240	Pu-241	Sr-90	Tc-99	Tritium	U-233/234	U-235	U-238	
Area Background	3	55	153		151	3	--	44		28			92	76	92	**542**
BC Pilot		20	20		12		16	16		20	12					**47**
Near-Facility		417					641	484		541			396	467	407	**2,607**
Non-Waste Site		12					20	16		22						**37**
Operational		141	130	96	130	111	17	17		151	41		129	129	129	**237**
Reference		40	40	40	40	40	10	10		40			40	40	40	**54**
Reference Backfill		25	25	25	25	25	25	25		25			25	25	25	**30**
Reference Native Soil		25	28	25	28	25	25	25		25			25	25	25	**33**
Reference BC		7	7		5		7	7		8	2					**21**
Reference CP Backfill		1	1		1	1	3	3		1				1		**4**
Reference CP Native Soil				1			2	2		1						**3**
Reference CPOFF		2					4	3		4						**6**
Reference NR2			6		6	2				6	6					**14**
Reference PNNL		427	183		66		407	407		426			364	431	364	**615**
Regional			30		30											**388**
Statewide			138		138											**1,769**
Waste Site	45	1,430	843	1,176	759	546	849	761	32	844	97	118	512	1,330	519	**1,825**
Waste Site Backfill		60	66	64	66	64	64	63		59			60	59	60	**82**
Waste Site Native Soil		62	62	57	62	57	57	57		62			57	57	57	**85**
TOTAL	**48**	**2,724**	**1,732**	**1,484**	**1,519**	**874**	**2,147**	**1,940**	**32**	**2,263**	**158**	**118**	**1,700**	**2,640**	**1,718**	**8,400**

EXHIBIT 2-12 COUNT OF GiSdT SOIL SAMPLES BY CATEGORY AND COEC/COPEC[26]

CATEGORY	TARGET ANALYTE											TOTAL NO. SAMPLES
	Sb	As	Ba	B	Cd	Cu	Dieldrin	Pb	Mn	Se	Zn	
Area Background	78	150	153		150	153	3	153	153	125	153	**542**
BC Pilot	20	20	20	20	20	20		20	20	20	20	**47**
Near-Facility												**2,607**
Non-Waste Site												**37**
Operational	125	130	130	98	130	107	98	130	130	130	130	**237**
Reference	40	40	40	40	40	40	40	40	40	40	40	**54**
Reference Backfill	25	25	25	25	25	25	25	25	25	25	25	**30**
Reference Native Soil	28	28	28	28	28	28	25	28	28	28	28	**33**
Reference BC	7	7	7	7	7	7		7	7	7	7	**21**
Reference CP Backfill	1	1	1	1	1	1	1	1		1	1	4
Reference CP Native Soil												**3**
Reference CPOFF												**6**
Reference NR2	6	6	6		6			6	6	6	6	**14**
Reference PNNL	183	183	174	162	183	183		183	183	183	183	**615**
Regional		28			30	30		30	30	30	30	**388**
Statewide		116			137	138		138	138	138	138	**1,769**
Waste Site	119	469	337	79	290	120	95	857	133	229	133	**1,825**
Waste Site Backfill	66	66	66	66	66	66	64	66	58	66	66	**82**
Waste Site Native Soil	62	62	62	62	62	62	56	62	62	62	62	**85**
TOTAL NO. SAMPLES	**760**	**1,331**	**1,049**	**588**	**1,175**	**980**	**407**	**1,746**	**1,013**	**1,090**	**1,022**	**8,400**

[26] The depicted analytes represent COECs from the River Corridor Baseline Risk Assessment (DOE 2011b) and COPECs from the Columbia River Component Screening-Level Ecological Risk Assessment (DOE 2011a). Counts for COECs/COPECs previously presented in Exhibit 2-10 are not repeated here.

We explored the data as a function of category and timeframe. The results are presented in Exhibit 2-13.

EXHIBIT 2-13 NUMBER OF GiSdT SOIL SAMPLES BY TIMEFRAME AND CATEGORY

CATEGORY	TOTAL NO. SAMPLES	TOTAL NO. SAMPLES WITH COORDINATES	NO DATE	1981 - 2000	AFTER 2000
Area Background	**542**	332		542	
BC Pilot	**47**	47			47
Near-Facility	**2,607**	2,607		362	2,245
Non-Waste Site	**37**	37			37
Operational	**237**	237		24	213
Reference	**54**	54			54
Reference Backfill	**30**	30			30
Reference Native Soil	**33**	33			33
Reference BC	**21**	21	5		16
Reference CP Backfill	**4**	4			4
Reference CP Native Soil	**3**	3			3
Reference CPOFF	**6**	6			6
Reference NR2	**14**	14			14
Reference PNNL	**615**	615		181	434
Regional	**388**	386	388		0
Statewide	**1,769**	1,745	1,769		0
Waste Site	**1,826**	1,825		830	996
Waste Site Backfill	**82**	82			82
Waste Site Native Soil	**85**	85			85
TOTAL	**8,400**	**8,163**	**2,162**	**1,939**	**4,299**
There are no sample records before 1981.					

Of note, all records have a value in the "std_value_rptd" field. However, as shown in Exhibit 2-14, 237 samples (~3 percent) lack geographic coordinate information. General locational information is sometimes provided in the "gisdt_sample_site_name" field or "gisdt_sample_area" field. For the 237 samples without coordinate information, 79 percent (188 samples) have information in the "gisdt_sample_site_name" field, which contains a text description of the location. The remaining samples without coordinates do not have any associated general locational information, as shown in Exhibit 2-14. In addition, depending on the analysis of interest, some samples may need to be excluded based on other criteria, such as category or sample type. For instance, reference samples (identified in the "category" field) may need to be analyzed separately.

EXHIBIT 2-14 NUMBER OF GiSdT SOIL SAMPLES WITH DESCRIPTIVE LOCATION INFORMATION

FIELD	NO. SAMPLES WITH INFORMATION
Gisdt_sample_area	**0**
Gisdt_sample_site_name	188
None of the above	49
TOTAL NO. SAMPLES WITHOUT COORDINATES	**237**

Geographic Distribution

The 8,400 unique samples are from 782 distinct sampling sites (based on "samp_site_name"). Approximately 18 percent of samples (1,462 of the 8,165 samples with coordinates) are within 500 meters of the on-site portion of the Columbia River. About half of the samples (4,197) are found within 500 meters of the main operational areas and facilities (Exhibit 2-15).

EXHIBIT 2-15 COUNT OF GiSdT SOIL SAMPLES WITHIN 500 METERS OF HANFORD OPERATIONAL AREAS

OPERATIONAL AREA	NO. SAMPLES	PERCENT OF TOTAL*
100 Areas	1,810	22%
200 Areas	2,156	26%
300 Area	217	3%
400 Area	14	<0.2%
All other operational areas	39	0.5%
TOTAL	**4,236**	**52%**
*Percent calculated out of total number of samples with coordinates, 8,165.		

2011 RELEASES TO THE COLUMBIA RIVER RI DATA SUMMARY REPORT (DSR) DATABASE

Data Exploration

The original table in this database includes 223,465 records spanning multiple media. Overall, there are 10,340 soil records (identified as having "SO" value in the "media" field). These samples were collected during 88 unique sampling trips.[27]

Data Excluded from Analysis

No data were excluded. The dataset already excludes duplicates, replicates, and blanks (Appendix O Data Summary Report – Data Users Guide.xls). For purposes of tabulating numbers of records, data were not excluded based on laboratory, review, or validation qualifiers.

This table does not contain a primary key; however, unique entries are primarily identifiable as combinations of the sample number ("samp_num") field and the contaminant field ("con_id") . However, we identified two exceptions; uranium-235 and uranium-238 were measured using more than one analytical method. For purposes of summarizing counts of samples, the record associated with the first reported analysis method for the relevant sample/contaminant combination was retained. Consequently, the primary key consists of the "samp_num", "con_id", and "method" fields.

After removing these records, 10,182 records remain, representing 97 unique samples.

Data Analysis

This database does not contain samples of different soil types (the "samp_from" field is blank for all records). However, samples are identified as collected within three different river mile ranges, as shown in Exhibit 2-16. The majority of samples (95 of 97) are also listed as from an "Island" under the "river_location" field; the remaining two samples contain the value "Right" in the river location field. The 2011 Data Summary Report for the Remedial Investigation of Hanford Site Releases to the Columbia River (WCH-398) states that island soil samples were collected from Island 3, Locke Island, White Bluffs, Homestead Island, Wooded Island, Johnson Island, Gull Island, and an unnamed island in Wanapum Pool. All samples were collected from the riparian zone. A few samples are also identified as "upriver" in the areas of other contributing influences ("oci") field; however, the majority of samples (86 of 97) do not contain any information in this field.

We explored the data as a function of sample depth. All samples either had no information about the sampling interval (14.4 percent) or had a value of zero in the "sample_depth_top" and "sample_depth_bottom" fields (85.6 percent), indicating a surface sample.

[27] For purposes of this analysis, we define a sampling trip as a unique combination of geographic coordinates ("x_coord" and "y_coord"), indicating sample location, and sample date and time ("samp_date_time").

EXHIBIT 2-16 COUNT OF DSR SOIL SAMPLES BY RIVER MILE RANGE

RIVER MILE RANGE	NO. SAMPLES
100 Area	31
300 Area	55
Upriver	11
TOTAL NO. SAMPLES	**97**

We also explored the data as a function of analytes. Exhibits 2-17 and 2-18 show the numbers of samples tested for each target analyte, or for identified COECs/COPECs.

All records have sample coordinates, a date (all samples were collected in 2009), and a result value. However, some data are qualified, and the Trustees may wish to reject data with specific qualifiers, or for other reasons.

EXHIBIT 2-17 COUNT OF DSR SOIL SAMPLES BY TARGET ANALYTE

TARGET ANALYTE	NO. SAMPLES
Cs-137	80
Cr	87
CrVI	77
Hg	87
Pu-238	79
Pu-239/240	79
Sr-90	79
Tc-99	79
Tritium	79
PCBs*	46
U	87
U-233/234	79
U-235	80
U-238	80
TOTAL NO. SAMPLES	**97**
*Samples testing for Aroclors, PCB congeners, or a mixture.	

EXHIBIT 2-18 COUNT OF DSR SOIL SAMPLES BY COEC/COPEC[28]

TARGET ANALYTE	NO. SAMPLES
Sb	87
As	87
Ba	87
B	87
Cd	87
Cu	87
Dieldrin	38
Pb	87
Mn	87
Se	87
TPH-diesel	28
Zn	87
TOTAL NO. SAMPLES	**97**

Geographic Distribution

The 97 unique samples were collected from 86 sampling sites (as defined by a unique combination of "x_coord" and "y_coord" fields). All of the samples are found within islands in the Columbia River (75 of 97 samples are within the on-site portion of the Columbia River). Unlike samples from HEIS and GiSdT, few samples from the DSR database are near Hanford operational facilities. A few samples (14) are within 500 meters of the 300 Area.

COLUMBIA RIVER COMPONENT (CRC) HISTORIC DATABASE

Data Exploration

This database contains a "RESULT_DATA" table and a "SAMPLE_DATA" table. The original result table includes 306,931 records spanning multiple media. Overall, there are 41,456 soil records, comprising 686 unique samples (identified as having "SO" value in the media field in the "SAMPLE_DATA" table.

The "RESULT_DATA" table in this database includes several fields in which values are reported: "VALUE_RPTD", "STD_VALUE_RPTD", and "WC_STD_VALUE_RPTD". The "VALUE_RPTD" field references the value in the particular units used when the sample was taken, and "STD_VALUE_RPTD" represents all values in a standard unit, whereas "WC_STD_VALUE__RPTD" represents instances when a conversion (e.g. to

[28] The depicted analytes represent COECs from the River Corridor Baseline Risk Assessment (DOE 2011b) and COPECs from the Columbia River Component Screening-Level Ecological Risk Assessment (DOE 2011a). Counts for COECs/COPECs previously presented in Exhibit 2-17 are not repeated here.

reflect percent moisture values) was performed (Larry Hulstrom, WCH, personal communication, November, 2011). Of note, a small proportion of records (about 0.15 percent) lack an entry in any of these fields. About 2.5 percent of the records have an entry in "WC_STD_VALUE_RPTD" field but not the others: all these records represent values for "total" contaminants of some sort –e.g., total PCBs, total furans, etc. Consequently, we expect that for these analytes, the stated values represent a calculation by Woodard & Curren ("WC"), a contractor involved in the development of the database, rather than the being present in the original source documents. Approximately 40 percent of the records include entries in "VALUE_RPTD" and "WC_STD_VALUE_RPTD" but not "STD_VALUE_RPTD". Spot-checking indicates that the "WC_VALUE_RPTD" figures are those of the "VALUE_RPTD" field, sometimes changed to reflect a different measurement unit. The remaining 56 percent of records include values in all three results fields.

Data Excluded from Analysis

This table does not contain a primary key; however, unique entries are primarily identifiable as combinations of the sample number ("samp_num") field and the contaminant field ("con_id"). However, we identified exceptions in which the same contaminant was measured at different laboratories and using more than one analytical method. For purposes of summarizing counts of records, the record associated with the first reported method for the relevant sample/contaminant combination was retained. Consequently, the primary key consists of the "SAMP_NUM", "CON_ID", and "METHOD_NAME" fields.

Records with an "S" in the "GiSdT_lab_qc_type" field, indicating a split sample, were also excluded. We also excluded records with "SEDIMENT" in the "SAMP_ITEM" field. For purposes of tabulating numbers of records, data were not excluded based on laboratory, review, or validation qualifiers.

After excluding data as described, the number of records was reduced to 40,713 and 612 samples collected from 243 unique sampling sites.[29]

Data Analysis

The soil records from this database do not contain any information in the "SAMP_FROM" or "SAMP_ITEM" fields (fields describing sample type detail). However, the majority of samples (98 percent or 601 samples) are identified as a "Grab" sample in the "SAMP_TYPE" field.

We also explored the depth of soil samples. Depth descriptions are listed in the "GiSdT_rcbra_sample_depth" field, the "sample_depth_to" and "sample_depth_from" fields, and the "WC_sample_depth_to" and "WC_sample_depth_from" fields. Many

[29] For purposes of this analysis, a sampling trip is defined as a unique combination of sample date ("SAMP_DATE") and sample location ("STD_EW_COORD" and "STD_NS_COORD"). One sample lacked coordinates, and it was assumed to be taken on a separate sampling trip. Using "SAMP_SITE" to define a sample location results in 213 sampling trips (202 samples lack a "SAMP_SITE" and these were assumed to be from 74 sampling trips since they were taken on 74 separate dates).

samples (213) do not contain information in any of these fields. One sample is listed as "shallow" and 276 samples as "surface" in the "GiSdT_rcbra_sample_depth" field. However, 98 percent of samples are grab samples (identified in the "SAMP_TYPE" field), and all grab samples are surface samples. Exhibit 2-19 shows the numbers of samples by depth in the sample "WC_sample_depth_to" and "WC_sample_depth_from" fields. After combining information from all of the depth fields, approximately 65 percent of the samples were taken within the top 12 inches, and the remaining 34 percent do not have associated depth information.

EXHIBIT 2-19 COUNT OF CRC SOIL SAMPLES BY SAMPLE DEPTH

SAMPLE DEPTH TO (INCHES)	NO. SAMPLES
0	6
0.4	12
1	98
2	6
Blank	490*
TOTAL	**612**
*277 of the blank samples are identified as "shallow" or "surface" in the "GiSdT_rcbra_sample_depth" field.	

All of the samples were collected from either upland (65 percent) or riparian (35 percent) areas (identified in the "GiSdT_environment" field). Exhibit 2-20 shows numbers of samples by environment and category.

EXHIBIT 2-20 COUNT OF CRC SOIL SAMPLES BY ENVIRONMENT AND CATEGORY

GISDT ENVIRONMENT	GISDT CATEGORY				
	BLANK	OPERATIONAL	REFERENCE	WASTE SITE	TOTAL
Blank	335				335
Riparian		62	35		97
Upland		78	60	42	180
TOTAL	**335**	**140**	**95**	**42**	**612**

Exhibit 2-21 presents the number of samples by "gisdt_category" and target analyte, while Exhibit 2-22 shows similar information for COECs/COPECs. Exhibit 2-23 shows the numbers of samples by timeframe.

All of the samples have a date, ranging from 1971 to 2006. One sample is missing coordinate information (Exhibit 2-17), but this sample was designated as a "RCBRA reference" sample in the "SAMP_AREA" field. Two records lack a value in the "WC_STD_VALUE_RPTD" field (although 1,350 records lack a value in the "VALUE_RPTD" field). Records are also qualified with laboratory and review qualifiers, and the Trustees may wish to reject data based on specific qualifiers, or for other reasons.

EXHIBIT 2-21 COUNT OF CRC SOIL SAMPLES BY TARGET ANALYTE AND CATEGORY

TARGET ANALYTE	GISDT CATEGORY				
	BLANK	OPERATIONAL	REFERENCE	WASTE SITE	TOTAL
Cs-137	207	117	75	35	434
Cr	45	115	80	35	275
CrVI		115	80	35	230
Hg	55	115	75	35	280
PCBs*		115	75	35	225
Pu	12				12
Pu-238	166	65	60	35	326
Pu-239/240	166	65	60	35	326
Sr-90	206	115	75	35	431
Tc-99	4				4
U	97	115	80	35	327
U-234	101	115	75	35	326
U-235	131	115	75	35	356
U-236	4				4
U-238	130	115	75	35	355
TOTAL	**335**	**140**	**95**	**42**	**612**

There are no soil samples testing for carbon tetrachloride, I-129, or tritium.
*Samples tested for Aroclors.

EXHIBIT 2-22 COUNT OF CRC SOIL SAMPLES BY COEC/COPEC[30] AND CATEGORY

TARGET ANALYTE	GISDT CATEGORY				
	BLANK	OPERATIONAL	REFERENCE	WASTE SITE	TOTAL
Sb	44	115	80	35	274
As	39	115	80	35	269
Ba	27	115	80	35	257
B		115	80	35	230
Cd	60	115	80	35	290
Cu	61	115	80	35	291
Dieldrin		115	75	34	224
Pb	55	115	80	35	285
Mn	27	115	80	35	257
Se	39	115	80	35	269
Zn	60	115	80	35	290
TOTAL NO. SAMPLES	**335**	**140**	**95**	**42**	**612**

EXHIBIT 2-23 NUMBER OF CRC SOIL SAMPLES BY TIMEFRAME

TIMEFRAME	TOTAL NO. SAMPLES	TOTAL NO. SAMPLES WITH COORDINATES
Before 1981	36	36
1981-2000	204	204
After 2000	372	371
TOTAL	**612**	**611**

Geographic Distribution

The 612 unique samples were collected from 120 sampling sites (defined as a unique combination of geographic coordinates using the "STD_EW_COORD" and "STD_NS_COORD" fields). Approximately half of the samples (311 of 612 samples with coordinates) are within 500 meters of the on-site portion of the Columbia River. Approximately 24 percent of samples (143 samples) are found within 500 meters from the main operational areas and facilities (Exhibit 2-24). This database also contains information on samples from numerous offsite locations scattered around Washington State.

30 The depicted analytes represent COECs from the River Corridor Baseline Risk Assessment (DOE 2011b) and COPECs from the Columbia River Component Screening-Level Ecological Risk Assessment (DOE 2011a). Counts for COECs/COPECs previously presented in Exhibit 2-21 are not repeated here.

EXHIBIT 2-24 COUNT OF CRC SOIL SAMPLES WITHIN 500 METERS OF HANFORD OPERATIONAL AREAS

OPERATIONAL AREA	NO. SAMPLES	PERCENT OF TOTAL*
100 Areas	109	18%
200 Areas		0%
300 Area	34	6%
400 Area		0%
All other operational areas	6	0.9%
TOTAL	**149**	**24%**

*Percent calculated out of total number of samples with coordinates, 616.

ENVIRONMENTAL RELEASE SUMMARY (ERS) DATABASE

Data Exploration

Exploration of data from this source focused on soil samples from the Near-Field Program database, received in an Excel sheet on June 2, 2011. This dataset contains 23,897 soil records, comprising 1,393 unique samples. Unique entries are identifiable as combinations of the sample number ("Sample#") and contaminant ("isotope") fields . The sample dates for these records range from May 1995 to February 2011.

Data Excluded from Analysis

Replicate records, identified in the audit report for this database, were excluded from analysis, reducing the number of records from 23,897 to 22,008. These records encompass 1,283 samples collected across 1,245 sampling trips.[31]

Data Analysis

No soil type or media detail information is provided in this database. However, all samples are surface samples, taken within one-half inch of the surface. All samples were also custom sifted, coarse screened, and large pebbles were removed.

Soil samples were analyzed for a number of different isotopes. Exhibit 2-25 shows the number of samples tested for each isotope by timeframe.

[31] A sampling trip is defined as a unique combination of sample date ("Sample Date") and sample location (unique geographic coordinates). The 59 samples lacking coordinates were assumed to be from 27 separate sampling trips, since they were taken on 27 separate dates.

EXHIBIT 2-25 COUNT OF ERS SOIL SAMPLES BY ISOTOPE AND TIMEFRAME

ISOTOPE	TOTAL NO. SAMPLES	NO. SAMPLES WITH COORDINATES	1981 - 2000	AFTER 2000
Am-241	8	4	1	7
Cs-134	1,266	1,213	457	809
Cs-137	1,280	1,222	465	815
Ce-144	1,121	1,083	311	810
Co-60	1,280	1,222	465	815
Eu-152	1,126	1,088	311	815
Eu-154	1,280	1,222	465	815
Eu-155	1,280	1,222	465	815
H-3	2	2	1	1
K-40	27	17	20	7
Pu-238	1,280	1,222	465	815
Pu-239/240	1,280	1,222	465	815
Ra-226	6	1	6	0
Ru-103	1,121	1,083	311	810
Ru-106	1,126	1,088	311	815
Sb-125	1,126	1,088	311	815
Sn-113	1,121	1,083	311	810
Sr-90	1,279	1,221	464	815
Th-228	8	8		8
Th-230	8	8		8
Th-232	8	8		8
U-234	1,279	1,221	465	814
U-235	1,277	1,219	465	812
U-238	1,280	1,222	465	815
Zn-65	1,121	1,083	311	810
TOTAL NO. SAMPLES	**1,283**	**1,224**	**506**	**886**
There are no samples pre 1981.				

Not all of the ERS data may be suitable for use in the natural resource damage assessment: for example, a number of samples lack key information: 59 of the 1,283 samples (~5 percent) lack geographic coordinates (Exhibit 2-25). Without more information on the site locations, these records cannot be mapped.

Geographic Distribution

The 1,283 unique samples were collected from at least 150 sampling sites, or unique geographic coordinates.[32] Approximately 10 percent of the ERS soil sampling locations are within 500 meters of the on-site portion of the Columbia River. In addition, the majority (82 percent) of sampling locations are within 500 meters of Hanford operational areas.

CONCLUSIONS

Exhibit 2-26 provides an overview of the main data gaps and sample characteristics within each database. As indicated, tens of thousands of soil samples have been collected across the Hanford Site, with the majority concentrated on or near operational areas. HEIS is the dominant repository for soil contaminant information, although it does not contain all records for all samples ever taken at Hanford. For instance, HEIS contains only the final verification samples from WCH, and does not contain the in-process WCH soil samples.

Approximately 20 percent of the HEIS soil samples lack coordinates, and depth information is missing for the majority (~80 percent or more) of these. Depth information is also lacking for most samples in other databases. Relatively few pre-1981 samples are available, with only HEIS and the CRC Historic database containing any data (0.8 percent and 6 percent of samples in those databases, respectively).

Soil samples have been tested for over 1,000 analytes. Of the target analytes, the most commonly analyzed are generally cesium-137, uranium, and chromium, although other target analytes are also frequently measured. For example, HEIS includes over 10,000 sample measurements for cesium-137, chromium, hexavalent chromium, and mercury. Of the target analytes, those associated with the fewest records are carbon tetrachloride and iodine-129, although each of these has still been measured in over 1,000 samples in HEIS. Of the COEC/COPECs, TPH-diesel and dieldrin were least frequently measured, whereas the other COEC/COPECs were measured in thousands of samples.

SUGGESTED FUTURE STUDIES

The above analyses suggest that a number of studies could support an injury assessment of Hanford soils. These include but are not necessarily limited to:

- Developing GIS maps and summary data tables showing contaminant levels by time period and location. Such maps and tables will provide a platform for discussing/exploring potential assumptions that might be agreed to by stakeholders to address gaps (and further refine primary data collection activities where agreement cannot be reached).
- Comparing contaminant levels in existing soil samples to soil quality values. In such a study, soil contaminant concentrations on Site would be compared against pertinent impact thresholds to determine whether, from 1981 through the present, the definition of injury has been met.

[32] There are 59 samples without coordinates, and therefore we are unable to determine the number of sampling sites from which these were collected.

- Assessing the toxicity of soils to site biota or representative test organisms, in laboratory and/or field studies. (This topic is discussed in Chapter 5.)

For additional background and detail on these suggested future studies, please refer to the *Terrestrial Resource Review Report* (Industrial Economics, Inc., November 9, 2011).

EXHIBIT 2-26 SUMMARY OF SOIL DATA GAPS WITHIN EACH DATABASE

DATABASE	NO. SOIL SAMPLES	DEPTH DISTRIBUTION	SAMPLE TYPES	GEOGRAPHIC DISTRIBUTION	TEMPORAL DISTRIBUTION	SAMPLES PER ANALYTE
HEIS	41,854	Most samples do not contain any information in depth fields. Of those characterized as surface or sub-surface samples (~16%), 62% are sub-surface samples ranging from 0 to 532 feet deep; 38% are surface samples ranging from 0 to 216 inches, with most occurring between 0 and 1 inch.	Majority of samples do not have sample type information. Those that do include: sub-surface (10%), surface (6%), trench (.05%), and septic (1 sample). Media detail includes: coarse, fine, geological, medium, mineral, silt, very fine, and reference.	~20% lack coordinates. Samples from the 100, 200 & 1100 areas, wells & borings, McNary dam area, Yakima barricade and other locations, concentrated near operational facilities and buildings. Few samples off Hanford Site.	**<1981**: 298 (0.8%) **1981-2000**: 8,207 (21%) **>2000**: 29,551 (78%) 4 (0.01%) lack a date	**No samples**: TPH-diesel **Least (<3,000)**: I-129, Sr-90, Pu, U-234 **More** (~3,000-7,500): Tc-99, tritium, carbon tetrachloride, U, U-233/234, Pu-238, Pu-239/240, B, dieldrin, PCBs **Most** (>10,000): Cs-137, Cr, CrVI, Hg, U-235, U-238, As, Sb, Ba, Cd, Cu, Pb, Mn, Se, Zn
RCBRA / GiSdT	8,400	Majority of samples (78%) do not contain depth information; approximately 16% are shallow samples and 6% are deep samples. All are upland samples.	Discrete, discrete-rp, focused, MIS, MIS-phyto, and statistical sample types. Most (96%) of samples are upland samples, remaining are nearshore or riparian.	~3% lack coordinates. Sampling locations are concentrated near operational facilities and buildings. Also contains samples from areas off Hanford Site.	**<1981**: 0% **1981-2000**: 1,939 (23%) **>2000**: 4,299 (51%) 26% lack a date	**No samples**: I-129, TPH-diesel **Few** (**<200**): Carbon tetrachloride, tritium, Tc-99, Pu-241 **More (>200-2,500):** Cr, CrVI, Hg, PCBs, Pu-238, Pu-239/240, Sr-90, U-233/234, U-238, Sb, As, Ba, B, Cd, Cu, dieldrin, Pb, Mn, Se, Zn **Most (>2500):** Cs-137, U-235

DATABASE	NO. SOIL SAMPLES	DEPTH DISTRIBUTION	SAMPLE TYPES	GEOGRAPHIC DISTRIBUTION	TEMPORAL DISTRIBUTION	SAMPLES PER ANALYTE
2011 DSR	97	Most samples (83 samples or ~86%) are surface samples, the rest do not contain depth information.	All island samples, except two 'right' samples. All also riparian samples.	All samples have coordinates. Samples from the 100, 300, and upriver sections of Columbia River from islands in the Columbia River. Few samples off Hanford Site.	**<1981**: 0% **1981-2000**: 0 **>2000**: 97% All samples from 2009.	**No samples**: Carbon tetrachloride, I-129 **Few (<50):** PCBs, TPH-diesel, dieldrin **Most (~80-90):** Cs-137, Cr, CrVI, Hg, Pu, Sr-90, Tc-99, tritium, U-233/234, U-235, U-238, Sb, As, Ba, b, Cd, Cu, Pb, Mn, Se, Zn
CRC Historic	686	Most samples (65%) are surficial (<12 inches to bottom of sample). Remaining samples do not contain sample depth information.	Operational, reference, and waste-site samples from riparian and upland areas. 98% of samples are grab samples.	Virtually all have coordinates. Majority of samples are along the Columbia River, concentrated near 100 Areas and 300 Area. Few samples off Hanford Site.	**<1981**: 36 (6%) **1981-2000**: 204 (33%) **>2000**: 377 (61%)	**No samples**: Carbon tetrachloride, I-129, tritium, TPH-diesel **Few (<20):** Tc-99, U-236, Pu **More** (200-400): Cr, CrVI, Hg, PCBs, Pu-238, Pu-239/240, U, U-234, U-238, Sb, As, Ba, B, Cd, Cu, dieldrin, Pb, Mn, Se, Zn **Most (>400)**: Cs-137, Sr-90, U-235
ERS	1,393	All samples are surficial, taken within one-half inch of the surface.	No sample detail is provided.	~5% lack coordinates. Samples are concentrated near operational facilities and buildings, particularly the 100, 200, and 300 Areas. Few samples off Hanford Site.	**<1981**: 0 **1981-2000**: 506 (36%) **>2000**: 886 (64%)	**No samples:** Carbon tetrachloride, Cr, CrVI, I-129, Hg, PCBs, tritium, Tc-99, dieldrin, As, Ba, B, Cd, Cu, Pb, Mn, Se, TPH-diesel **Most** (~1,000-1,300): Cs-137, Pu-238, Pu-239/240, Sr-90, U-234, U-235, U-238, Zn-65, Sb-125

This page intentionally left blank.

CHAPTER 3 | SURFACE WATER AND PORE WATER

This chapter provides a summary of data types most commonly relied upon in a NRDA for purposes of determining injury to surface water resources (excluding sediments, which are addressed in Chapter 4).

This chapter characterizes available information on the exposure of surface and pore waters to contaminants, as indicated through measurements of contaminant concentrations in water samples. Measurements of exposure are relevant in establishing a complete pathway (as described in 43 CFR 11.63) from releases to receptors. This information is also relevant in determining injury to surface waters in accordance with DOI's NRDA regulations. In particular, surface water resources are injured when concentrations of hazardous substances exceed certain drinking water or other water quality criteria, as set forth in 43 CFR 11.62(b)(i) through (iii), or when concentrations and duration in surface waters are sufficient to have injured other natural resources (43 CFR 11.62(b)(v)).

This chapter concludes with a summary of the presented information, highlighting areas where information appears to be limited or absent.

EXPOSURE TO CONTAMINANTS

We assembled available information to identify data on the exposure of surface water to contamination. Available sources of information include the following:

- Hanford Environmental Information System (HEIS);
- The River Corridor Baseline Risk Assessment database (RCBRA / GiSdT);
- The 2011 Releases to the Columbia River Remedial Investigation Data Summary Report (DSR) database;
- The Columbia River Component (CRC) Historic database.

Because of the challenges associated with the partial overlap of information among various databases, we evaluated information within each database separately, as described below. Appendix A provides maps of sampling locations.

For each database, we provide information on pore water samples. Pore water samples are included in this chapter because they are part of the surface water resource and because some databases group surface and pore samples together for some data classifications (e.g., classify both with "SW" as the media type, and more specifically distinguish between surface and pore waters in other fields).

HANFORD ENVIRONMENTAL INFORMATION SYSTEM (HEIS)

Data Exploration

Evaluation of data from HEIS focused on the surface water view, downloaded from HEIS on June 30, 2011. Because HEIS is frequently updated, later downloads may include additional information.

The downloaded surface water data (all samples identified as "SW" in the "MEDIA" field) included 218,988 records, comprising 21,780 unique sample numbers. Unique entries are primarily identifiable as combinations of the sample number ("SAMP_NUM") field and the contaminant field ("STD_CON_ID") . We identified a few exceptions to this rule. For instance, of the contaminants of concern, uranium was sometimes tested using two different analytical methods, each of which represents a unique record. In addition, carbon tetrachloride was measured using different dilution factors. For purposes of summarizing counts of samples, the record associated with the minimum measured value for the relevant sample/contaminant combination was retained. For samples with duplicate records for two separate dilution factors, duplicates were excluded by selecting the first of the two testing methods, identified in the field "METHOD_NAME".

Data Excluded from Analysis

We excluded records for which the "SAMP_FROM" field had the value "QC_SAMPLE", as well as those identified as laboratory replicates (i.e., those having a value of "R", "S", or "B" in the "LAB_QC_TYPE" field), and records that do not have analytical results recorded in the "STD_VALUE_RPTD" field. For purposes of tabulating numbers of records, data were not excluded based on laboratory, validation, or review qualifiers.

After selecting data as described above, there are 199,531 records remaining, comprising 21,314 unique samples. These samples were collected during 14,500 unique sampling trips.[33]

Data Analysis

The HEIS surface water view contains data on both surface water and pore water. It also contains data on a number of sample types that may not directly represent natural resources. According to HEIS documentation (the Sample Table description), the media code "SW" includes the following:

- Samples collected from rivers, ponds, puddles, riverbank seeps and springs, and streams.

[33] A sampling trip is defined as a unique sample date and time ("SAMP_DATE_TIME") for a unique sample site ID ("SAMP_SITE_ID"). HEIS defines "SAMP_SITE_ID" as "A unique, system generated number that is assigned to a sampling site. All samples that are not collected from wells should have a SAMP_SITE_ID value" (*Hanford Environmental Information System – Detailed Design Specification*, BHI-01639, May 2002).

- Samples collected at shallow depths (<1 meter) below the always-submerged riverbed.
- Standing water on pads, floors, roofs, etc.
- Water samples collected from water mains.

Exhibit 3-1 below shows the number of samples taken by sample source type, as indicated in the "SAMP_FROM" field in HEIS.

EXHIBIT 3-1 COUNT OF SAMPLES BY WATER SOURCE TYPE IN HEIS

WATER SOURCE TYPE	NO. SAMPLES	PERCENT
CATTLE DRINKING WATER	28	0.1%
DISCHARGE PIPE	1	0.0
DRINKING	1,111	5.2
DRIVE POINT	148	0.7
FACILITY	7	0.0
GROUNDWATER	22	0.1
IRRIGATION	178	0.8
LAKE	8	0.0
POND	124	0.6
PORE	194	0.9
RAW WATER INTAKE	10	0.0
RIVER	13,605	63.8
RIVERBED TUBE	13	0.1
SANITARY	2,501	11.7
SEA	1	0.0
SEEP	1,591	7.5
SURFACE	1,772	8.3
TOTAL NO. SAMPLES	**21,314**	**100%**

Note: "DRIVE POINT" and "RIVERBED TUBE" samples are pore water samples (written communication, Ted Poston, October 21, 2011). According to HEIS documentation (Sample Table description, Version: October 7, 2007), riverbed tubes are "engineered structures that provide access to the interface between groundwater and river water at the always-submerged riverbed. Well IDs are assigned to these tubes. Depending on the depth of the sampling port, the sampled may be classified as surface water ("SW") or groundwater ("GW"), depending on whether it is less than or greater than ~3 feet bgs [below ground surface], although this subdivision is considered to be fairly loose. Assignment of the media code is at the discretion of the sampling project manager, following consultation with the HEIS data management staff, who will advise with regard to consistent treatment for storage of analytical results."

We explored surface water data for distribution of sample depth. Depth information is only provided for surface, river, and a small number of drive point samples (Exhibit 3-2).

EXHIBIT 3-2 COUNT OF WATER SAMPLES BY WATER DEPTH IN HEIS

WATER DEPTH	NO. SAMPLES			
	SURFACE	RIVER	DRIVE POINT	TOTAL
0 to 2 m	32	128	14	**174**
2 to 8 m	28	74	0	**102**
8 to 16 m	0	12	0	**12**
16 to 30 m	3	9	0	**12**
[BLANK]	1,709	13,382	134	**15,225**
TOTAL NO. SAMPLES	**1,772**	**13,605**	**148**	**15,525**

Note: Water source types not shown do not contain depth data. Depth for Drive Point samples represents depth to the river bottom (personal communication, Ted Poston, October 21, 2011).

We also investigated available information on the target analytes and on identified COECs/COPECs. Exhibits 3-3 and 3-4 below present the results.

EXHIBIT 3-3 COUNT OF SAMPLES BY TARGET ANALYTE AND WATER SOURCE TYPE IN HEIS

TARGET ANALYTE	NO. OF SAMPLES																	
	CATTLE DRINKING WATER	DISCHARGE PIPE	DRINKING	DRIVE POINT	FACILITY	GROUND-WATER	IRRIGATION	LAKE	POND	PORE	RAW WATER INTAKE	RIVER	RIVERBED TUBE	SANITARY	SEA	SEEP	SURFACE	TOTAL
Carbon tetrachloride			4						17			331				94	36	**482**
Cr				51			19	8	8	61		1,499				661	203	**2,510**
CrVI							1			71		64	3	63		21	118	**341**
Cs-137			488	29		9	116	8	53		9	3,293		626	1	374	561	**5,567**
Hg				9			19	8	3	61		521				197	203	**1,021**
I-129			13									343		22		62		**440**
PCBs (Aroclors)										60		35					73	**168**
PCBs (Congeners)												5					3	**8**
Pu												34					1	**35**
Pu-238			4					8				618				9	65	**704**
Pu-239																	1	**1**
Pu-239/240			4					8				619				10	65	**706**
Sr-90			597	10		8	114				2	2,790		123	1	355	392	**4,392**
Tc-99			47	18			9		3	2		697		7		193	92	**1,068**
Tritium	28		701	34		22	107		84	60	9	3,097		226	1	463	367	**5,199**
U		1	12	66	3		19	8		61		426		20		77	190	**883**
U-233/234							1	8		60		45				17	123	**254**
U-234			55	38			96		3			2,461		79		178	56	**2,966**
U-235			55	38			97	8	3	60		2,506		79		195	181	**3,222**
U-236												1				2		**3**
U-238			55	38			97	8	3	60		2,506		79		196	181	**3,223**
TOTAL NO. SAMPLES	**28**	**1**	**1,111**	**148**	**7**	**22**	**178**	**8**	**124**	**194**	**10**	**13,60**	**13**	**2,501**	**1**	**1,591**	**1,772**	**21,314**

EXHIBIT 3-4 COUNT OF SAMPLES BY WATER SOURCE TYPE AND COEC/COPEC[34] IN HEIS

TARGET ANALYTE	NO. OF SAMPLES																	
	CATTLE DRINKING WATER	DISCHARGE PIPE	DRINKING	DRIVE POINT	FACILITY	GROUND-WATER	IRRIGATION	LAKE	POND	PORE	RAW WATER INTAKE	RIVER	RIVERBED TUBE	SANITARY	SEA	SEEP	SURFACE	TOTAL
Sb				19			19	8	8	61		1,467				644	203	2,429
As				28			19	8	5	61		1,411				347	202	2,081
Ba				51			1	8	8	61		449				376	201	1,155
B				14			1	8		61		90				7	182	363
Cd				51			19	8	8	61		1,490				644	203	2,484
Cu				13			19	8	8	61		1,528				647	200	2,484
Dieldrin							1			60		35					76	172
Pb				28			19	8		61		1,432				357	202	2,107
Mn				37			1	4	8	61		448				376	201	1,136
Se				42			19	8		61		1,413				351	202	2,096
TPH – diesel range				2			1			60		30					64	157
Zn				37			19	8	8	61		1,579				662	203	2,577
TOTAL NO. SAMPLES	**28**	**1**	**1,111**	**148**	**7**	**22**	**178**	**8**	**124**	**194**	**10**	**13,605**	**13**	**2,501**	**1**	**1,591**	**1,772**	**21,314**

[34] The depicted analytes represent COECs from the River Corridor Baseline Risk Assessment (DOE 2011b) and COPECs from the Columbia River Component Screening-Level Ecological Risk Assessment (DOE 2011a). Counts for COECs/COPECs previously presented in Exhibit 3-4 are not repeated here.

We also explored the availability of data to assess water hardness, as the toxicity of many metals is a function of hardness. Hardness is assessed based on the concentration of calcium (Ca) and magnesium (Mg) in mg/L; therefore, we tabulate the number of records testing for "Hardness" as well as those that record measures of Ca and Mg in the sample. Samples with analytical results for measures of hardness appear in Exhibit 3-5 below.[35]

EXHIBIT 3-5 NUMBER OF HEIS WATER SAMPLES PROVIDING HARDNESS DATA

WATER SOURCE TYPE	HARDNESS	CALCIUM	MAGNESIUM
DRIVE POINT		33	33
FACILITY		4	
IRRIGATION	1	1	1
LAKE		8	8
POND		8	8
PORE	57	61	61
RAW WATER INTAKE		1	
RIVER	46	452	424
SEEP		364	364
SURFACE	66	198	198
TOTAL NO. SAMPLES	**170**	**1,130**	**1,097**
Note: Water source types not shown to not contain hardness			

We also investigated the number of samples taken as a function of water source type ("SAMP_FROM") and timeframe, shown in Exhibit 3-6. Dates range from 1970 through 2011.

EXHIBIT 3-6 NUMBER OF SAMPLES IN HEIS BY WATER SOURCE TYPE AND TIMEFRAME

WATER SOURCE TYPE	TOTAL NO. SAMPLES	BEFORE 1981	1981 - 2000	AFTER 2000
CATTLE DRINKING WATER	28		28	
DISCHARGE PIPE	1		1	
DRINKING	1,111	82	609	420
DRIVE POINT	148			148
FACILITY	7		4	3
GROUNDWATER	22		22	
IRRIGATION	178		48	130
LAKE	8			8

[35] Of note, USGS collects water hardness data for the Columbia River: http://waterdata.usgs.gov/nwis.

WATER SOURCE TYPE	TOTAL NO. SAMPLES	BEFORE 1981	1981 - 2000	AFTER 2000
POND	124		13	111
PORE	194			194
RAW WATER INTAKE	10		10	
RIVER	13,605	3,668	4,985	4,952
RIVERBED TUBE	13		3	10
SANITARY	2,501	2,066	435	
SEA	1	1		
SEEP	1,591	81	527	983
SURFACE	1,772	854	334	584
TOTAL NO. SAMPLES	**21,314**	**6,752**	**7,019**	**7,543**

Exhibit 3-7 lists the number of sampling sites represented for each type of sample and the number of samples for which coordinate information is not available.

EXHIBIT 3-7 SAMPLE LOCATION INFORMATION BY WATER SOURCE TYPE

WATER SOURCE TYPE	SAMPLING TRIPS	NO. OF SAMPLING SITES	NO. OF SAMPLING SITES WITHOUT GEOGRAPHIC COORDINATES (NO. SAMPLES)
CATTLE DRINKING WATER	28	6	6 (28)
DISCHARGE PIPE	1	1	1 (1)
DRINKING	1,041	20	13 (783)
DRIVE POINT	79	31	31 (148)
FACILITY	7	6	2 (3)
GROUNDWATER	16	16	13 (19)
IRRIGATION	116	6	5 (175)
LAKE	8	2	2 (8)
POND	88	3	2 (111)
PORE	75	49	0 (0)
RAW WATER INTAKE	10	2	0 (0)
RIVER	8,324	262	198 (12,663)
RIVERBED TUBE	13	12	4 (5)
SANITARY	2,489	23	23 (2,501)
SEA	1	1	1 (1)
SEEP	696	112	43 (1,102)
SURFACE	1,550	409	35 (1,184)
TOTAL	**14,500**	**864**	**343 (18,732)**
Note: The sum of values within a column does not equal the presented totals because multiple sample types can be associated with a single sampling trip or location.			

Geographic Distribution

The 21,314 unique samples are from 864 distinct sampling sites. These samples were collected during 14,500 sampling trips, of which 343 sites (representing 18,732 samples), do not have geographic coordinates. A sample site can have more than one water source type collected at a single location (e.g., a seep and river sample); therefore, the totals in Exhibit 3-7 are greater than the total number of unique sampling sites.

Samples with coordinate information are concentrated around the 100 Areas and the 300 Area, with a relatively smaller number of locations distributed along the Columbia River between these two areas. Additionally, there are a few surface water sample locations upstream and downstream of the Hanford Site, and two pore water sample locations are located upstream of the Hanford Site, although none are downstream. Appendix A includes maps of sampling locations.

Not all of the data summarized above may be suitable for use in the natural resource damage assessment. Many records lack key information: as noted previously, approximately 88 percent of samples lack geographic coordinates. Although general location information is provided for all samples, (e.g., in the "SAMP_SITE_NAME", "SAMP_SITE_DESC" fields), the absence of easting and northing in the database at a minimum makes mapping the precise locations of the data points a more complicated and time-consuming exercise.[36]

RIVER CORRIDOR BASELINE RISK ASSESSMENT DATABASE (RCBRA / GiSdT)

Data Exploration

Evaluation of data from this source focused on a data query for all usable water matrix samples (i.e., data with a "y" in the "gisdt-usable" field) downloaded from the RCBRA data management website (http://rcbra.neptuneinc.org/rcbra/home/index.xml) on July 20, 2011. The download included 52,461 records. Similar to the HEIS database, this table does not contain a primary key. Unique records can be identified as a combination of the sample ID and contaminant ID fields ("sample_id" and "gisdt_std_con_id").

Data Excluded from Analysis

We did not exclude any data from analysis. All records were blank in both the "lab_qc_type" field and the "field_qc_type" field. For purposes of tabulating numbers of records, data were not excluded based on laboratory, validation, or review qualifiers.

Data Analysis

The GiSdT database contains data on both surface water and pore water. It also contains data on a number of other sample types. Exhibit 3-8 below shows the number of samples

[36] Though not available for this analysis, DOE has indicated that this effort may have been undertaken and additional information may be available in other parts of the HEIS database, or from PNNL.

taken by type, as indicated in the "gisdt_media" field. Exhibit 3-9 shows the number of sampling trips and sampling sites from which the samples were collected.[37]

EXHIBIT 3-8 NUMBER OF SAMPLES IN GISDT BY MEDIA TYPE

MEDIA TYPE	NO. SAMPLES	PERCENT
AQUIFER TUBE	29	0.8%
DRINKING WATER	60	1.7
DRIVE POINT	10	0.3
IRRIGATION WATER	3	0.1
PORE WATER	195	5.5
SEEP	288	8.1
SHALLOW AT	22	0.6
SURFACE WATER	2,935	82.9
TOTAL NO. SAMPLES	**3,542**	**100%**

EXHIBIT 3-9 SAMPLING TRIPS AND SAMPLE SITES IN GISDT BY MEDIA TYPE

MEDIA TYPE	NO. SAMPLING TRIPS (SAMPLE LOCATION)
AQUIFER TUBE	9 (5)
DRINKING WATER	58 (4)
DRIVE POINT	2 (2)
IRRIGATION WATER	1 (1)
PORE WATER	61 (48)
SEEP	125 (28)
SHALLOW AT	9 (8)
SURFACE WATER	772 (159)
TOTAL	**964 (177)**

Note: The sum of values within a column does not equal the presented totals because multiple sample types can be associated with a single sampling trip or location.
The 177 named sampling sites consist of 574 unique geographic coordinate locations. A single river mile, called a sample location (e.g., "300 Area HRM 43.1" has 43 distinct

All samples in this database are identified as from the nearshore environment and are classified as discrete samples.

[37] For the purposes of this analysis, we define a sampling trip as a unique sample date ("samp_date") and sample location ("gisdt_sample_site_type") combination. There are 18 samples lacking a sample date; however, we count these as three separate sampling trips, since they are from three separate sample sites.

Exhibit 3-10 shows the number of samples associated with each sample category by media type ("gisdt_media_type" field) (e.g., site described as "operational", "waste site", or "reference" in "category" field). As shown, the majority of samples are from operational areas, with a smaller number of samples from reference areas. Exhibit 3-11 displays the number of samples, arranged by specified operational area and media type.

We next analyzed the subset of records that represent measurements of the target analytes. Exhibits 3-12 and 3-13 show the number of samples tested for each target analyte and each COEC/COPEC, by media type.

EXHIBIT 3-10 NUMBER OF SAMPLES IN GISDT BY MEDIA TYPE AND SAMPLE CATEGORY

SAMPLE CATEGORY	NO. OF SAMPLES								
	AQUIFER TUBE	DRINKING WATER	DRIVE POINT	IRRIGATION WATER	PORE WATER	SEEP	SHALLOW AT	SURFACE WATER	TOTAL
BC Pilot						53		52	**105**
Operational	29	35	10	3	163	231	20	2,059	**2,550**
Reference					32			30	**62**
Reference BC								12	**12**
Reference NR2						4	2	11	**17**
Reference PNNL		25						771	**796**
TOTAL NO. SAMPLES	**29**	**60**	**10**	**3**	**195**	**288**	**22**	**2,935**	**3,542**

EXHIBIT 3-11 NUMBER OF SAMPLES IN GISDT BY MEDIA TYPE AND OPERATIONAL AREA

OPERATIONAL AREA	NO. OF SAMPLES								
	AQUIFER TUBE	DRINKING WATER	DRIVE POINT	IRRIGATION WATER	PORE WATER	SEEP	SHALLOW AT	SURFACE WATER	TOTAL
[BLANK]								2	**2**
300 Area	19		10		53	57		740	**879**
100 B/C		11			6	53		101	**171**
100 D/H	8	10			34	58		135	**245**
100-IU-2/100-IU-6					9	75		1,173	**1,257**
100-K		25			25	26		45	**121**
100-N		14			46	15	20	273	**368**
Outside Operational	2			3	22	4	2	466	**499**
TOTAL NO. SAMPLES	**29**	**60**	**10**	**3**	**195**	**288**	**22**	**2,935**	**3,542**

EXHIBIT 3-12 COUNT OF SAMPLES IN GISDT BY MEDIA TYPE AND TARGET ANALYTE

TARGET ANALYTE	NO. OF SAMPLES								
	AQUIFER TUBE	DRINKING WATER	DRIVE POINT	IRRIGATION WATER	PORE WATER	SEEP	SHALLOW AT	SURFACE WATER	TOTAL
Carbon Tetrachloride						33		84	**117**
Cs-137			10	1	60	124		474	**669**
Cr	15			1	61	45	10	883	**1,015**
CrVI	1			1	71	8		54	**135**
Hg				1	61	18	9	345	**434**
I-129						33		43	**76**
PCBs (Aroclors)				1	60			53	**114**
Pu-238						8		70	**78**
Pu-239/240						8		70	**78**
Sr-90		40		1	61	102	10	825	**1,039**
Tc-99			8		2	86	10	198	**304**
Tritium	4	39	10	1	60	129		1,075	**1,318**
U (Inorganic)	15			1	61	12	10	107	**206**
U (radionuclide)								113	**113**
U-233/234			10	1	60	86		814	**971**
U-235			10	1	60	85		814	**970**
U-236						2		7	**9**
U-238			10	1	60	86		815	**972**
Calculated Total U			10	1	60	85		787	**943**
TOTAL NO. SAMPLES	**29**	**60**	**10**	**3**	**195**	**288**	**22**	**2,935**	**3,542**

EXHIBIT 3-13 COUNT OF SAMPLES BY MEDIA TYPE AND COEC/COPEC[38] IN GISDT

TARGET ANALYTE	NO. OF SAMPLES								
	AQUIFER TUBE	DRINKING WATER	DRIVE POINT	IRRIGATION WATER	PORE WATER	SEEP	SHALLOW AT	SURFACE WATER	TOTAL
Sb				1	61	31	10	865	968
As	1			1	61	25	10	820	918
Ba	15			1	61	36	10	236	359
B	14			1	61			52	128
Cd	15			1	61	32	10	867	986
Cu				1	61	34		880	976
Dieldrin				1	60			52	113
Pb	1			1	61	25	10	825	923
Mn	1			1	61	36	10	254	363
Se	15			1	61	29	10	823	939
TPH - diesel range				1	60		2	52	115
Zn	1			1	61	46	10	914	1,033
TOTAL NO. SAMPLES	**29**	**60**	**10**	**3**	**195**	**288**	**22**	**2,935**	**3,542**

[38] The depicted analytes represent COECs from the River Corridor Baseline Risk Assessment (DOE 2011b) and COPECs from the Columbia River Component Screening-Level Ecological Risk Assessment (DOE 2011a). Counts for COECs/COPECs previously presented in Exhibit 3-12 are not repeated here.

In addition to these analytes, we also explored the availability of data to assess water hardness. Hardness is assessed based on the concentration of Ca and Mg in mg/L; therefore, we tabulate the number of records testing for "hardness" as well as those that record measures of Ca and Mg in the sample. Samples with analytical results for measures of hardness appear in Exhibit 3-14 below.[39]

EXHIBIT 3-14 NUMBER OF GISDT WATER SAMPLES PROVIDING HARDNESS DATA

MEDIA TYPE	HARDNESS	CALCIUM	MAGNESIUM
AQUIFER TUBE		15	15
IRRIGATION WATER	1	1	1
PORE WATER	57	61	61
SEEP		24	24
SURFACE WATER	1	193	193
TOTAL NO. SAMPLES	**59**	**294**	**294**
Note: Media types not shown do not contain hardness data.			

We also investigated the number of samples taken as a function of timeframe, as shown in Exhibit 3-15. There were no water samples collected before 1990 or after 2007, and the majority of water samples were collected after 2000.

EXHIBIT 3-15 NUMBER OF SAMPLES IN GISDT BY TIMEFRAME AND MEDIA TYPE

SAMPLE TYPE	TOTAL NO. SAMPLES	[BLANK]	BEFORE 1981	1981 - 2000	AFTER 2000
AQUIFER TUBE	29			4	25
DRINKING WATER	60			10	50
DRIVE POINT	10				10
IRRIGATION WATER	3				3
PORE WATER	195				195
SEEP	288			130	158
SHALLOW AT	22				22
SURFACE WATER	2,935	18		697	2,220
TOTAL NO. SAMPLES	**3,542**	**18**	**0**	**841**	**2,683**

For the most part, the water sample data contained in the GiSdT database is complete. All but two samples have geographic coordinates, and these records contain location information in the "gisdt_sample_site_name" field. Eighteen of the surface water samples do not have a date. In addition, some data are qualified with laboratory, review,

[39] As noted previously, USGS collects water hardness data for the Columbia River: see http://waterdata.usgs.gov/nwis.

and validation qualifiers, and the Trustees may wish to exclude data based on certain qualifiers or other considerations.

Geographic Distribution

As shown in Exhibit 3-10, the majority of surface and pore water samples are located near operational areas with a smaller portion (approximately one-quarter) from areas identified as reference locations. Exhibit 3-11 provides a more detailed break-down of sample locations by operational area, and Appendix A includes maps of sampling locations.

2011 RELEASES TO THE COLUMBIA RIVER REMEDIAL INVESTIGATION DATA SUMMARY REPORT (DSR) DATABASE

Data Exploration

The original table in this database includes 223,465 records spanning multiple media. This table does not contain a primary key; however, unique entries are primarily identifiable as combinations of the sample number ("samp_num") field and the contaminant field ("con_id"). Of note, uranium-235 and uranium-238 were measured using more than one analytical method on the same sample. For purposes of summarizing counts of samples, the record associated with the minimum measured value for the relevant sample/contaminant combination was retained. Consequently, the primary key consists of the "samp_num", "con_id", and "method" fields.

Overall, the DSR database contains 17,797 surface water records and 3,667 pore water records (identified as having either "SW" or "PW" in the media field, respectively) representing 579 surface water samples and 404 pore water samples. Among these are 353 surface water sampling trips from 346 sample locations, and 284 pore water sampling trips from 282 sample locations.[40]

Data Excluded from Analysis

The number of surface water records is reduced to 17, 577 when records testing with separate analytical methods are excluded. No pore water records are excluded for this reason. The dataset already excludes duplicates, replicates, and blanks (Appendix O Data Summary Report – Data Users Guide.xls), and all records are blank in the "lab_qc_type" and "field_qc_type" fields. For purposes of tabulating numbers of records, data were not excluded based on laboratory, review, or validation qualifiers.

[40] A sampling trip is defined as a unique combination of geographic coordinates ("x_coord" and "y_coord"), indicating sample location, and "samp_date_time". Sample sites are defined as unique "x_coord", "y_coord" combinations.

Data Analysis

Of the 579 surface water samples, 140 have "river" as the water source type, and 439 have "surface" as a water source type, as indicated in the "SAMP_FROM" field. Pore water samples have no further classification.

We then evaluated the availability of information on the target analytes and on COEC/COPECs, and the results are presented in Exhibits 3-16 and 3-17. None of the samples in the DSR database were tested for hardness, Ca, or Mg concentrations.[41]

EXHIBIT 3-16 COUNT OF SAMPLES BY TARGET ANALYTE IN DSR DATABASE

TARGET ANALYTE	NO. SAMPLES	
	SURFACE WATER	PORE WATER
Carbon Tetrachloride	60	20
Cs-137	110	
Cr	220	95
CrVI	105	190
Hg	220	92
PCBs (congeners and Aroclors)	61	
Pu-238	110	
Pu-239/240	110	
Sr-90	97	65
Tc-99	66	3
Tritium	68	75
U	220	137
U-233/234	110	
U-235	110	
U-238	110	
TOTAL NO. SAMPLES	**579**	**404**

[41] As noted previously, USGS collects water hardness data for the Columbia River, stored at http://waterdata.usgs.gov/nwis.

EXHIBIT 3-17 COUNT OF SAMPLES BY COEC/COPEC[42] IN DSR DATABASE

TARGET ANALYTE	NO. SAMPLES	
	SURFACE WATER	PORE WATER
Sb	220	95
As	220	95
Ba	220	95
B	220	95
Cd	220	95
Cu	220	95
Dieldrin	57	
Pb	220	95
Mn	220	95
Se	220	95
TPH - diesel range	42	15
Zn	220	95
TOTAL NO. SAMPLES	**579**	**404**

Among the surface water samples, information about water type is provided in the "media_detail" field. Entries in this field include "Surface Water, Deep" (9 samples), and "SW GW Upwelling" (252 samples), as well as general "Surface Water "(182 samples). No media detail information is provided for 136 samples. All deep surface water samples were collected directly above the sediment-water interface. Groundwater upwelling samples are from a sampling effort of known groundwater upwelling sites (WCH 2011).

We also explored the surface water data as a function of water depth. As shown in Exhibit 3-18 below, all deep surface water samples are taken at a water depth of greater than 30 feet. The majority of samples with no entry in the "media_detail" field were collected at water depths of less than 8 feet. Pore water records did not record a water depth.

[42] The depicted analytes represent COECs from the River Corridor Baseline Risk Assessment (DOE 2011b) and COPECs from the Columbia River Component Screening-Level Ecological Risk Assessment (DOE 2011a). Counts for COECs/COPECs previously presented in Exhibit 3-16 are not repeated here.

EXHIBIT 3-18 COUNT OF SURFACE WATER SAMPLES BY WATER DEPTH AND MEDIA DETAIL IN DSR DATABASE

WATER DEPTH[1]	NO. OF SAMPLES				
	[BLANK]	SURFACE WATER	DEEP SURFACE WATER	GROUNDWATER UPWELLING	TOTAL
Blank	6			230[2]	**236**
0 to 2 ft.	84	15		22	**121**
2 to 8 ft.	37	59			**96**
8 to 16 ft.	3	38			**41**
16 to 30 ft.	3	40			**43**
30 to 125 ft.	3	30	9		**42**
TOTAL	**136**	**182**	**9**	**252**	**579**

Notes:

1. Depth units are not provided for all records, but where provided, are in feet. In addition, the “Data Users Guide” for the DSR database indicates that all depths are in feet.
2. Although depth data is not explicitly provided for the majority of groundwater upwelling samples in the database, sample collection documentation indicates that all groundwater upwelling samples were taken from one foot above the river bottom (Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington: Collection of Surface Water, Pore Water, and Sediment Samples for Characterization of Groundwater Upwelling, WCH-380, Nov. 2010).

The DSR database describes the location of samples by specifying a river mile range in which the sample was collected. As with other databases, samples are concentrated around the operational areas, with a smaller portion of samples up and downstream of the Hanford Site for surface water only. Exhibit 3-19 shows the number of water records by river mile range. Upriver refers to a portion of the Columbia River upstream from the Hanford Site, northwest of the 100 Area, and Lake Wallula refers to an area downstream from the Hanford Site, southeast of the 300 Area. Appendix A includes maps of sampling locations.

General descriptive locations for reference samples (e.g., samples collected to measure “other contributing influences”, recorded in the “oci” field) are also provided in the database. Ninety-four surface water samples were taken to measure other contributing influences. Of these, 18 are from major tributaries, 39 are from upriver locations, and 37 are from wasteway or irrigation return sources. There are no identified pore water reference samples.

EXHIBIT 3-19 COUNT OF WATER SAMPLES BY RIVER MILE RANGE IN DSR DATABASE

RIVER MILE RANGE	NO. OF SAMPLES	
	SURFACE WATER	PORE WATER
Upriver Sub-Area (RM 388 to 440)	39	0
100 Area Sub-Area (RM 366 to 387)	314	287
300 Area Sub-Area (RM 340 to 365)	148	117
Lake Wallula Sub-Area (RM 292 to 339)	78	0
TOTAL NO. SAMPLES	**579**	**404**

All DSR water data collection events occurred between 2008 and 2010. All records have sample coordinates, a date, and a result value. Some data are qualified, and the Trustees may wish to reject data with specific qualifiers, or for other reasons.

COLUMBIA RIVER COMPONENT (CRC) HISTORIC DATABASE

Data Exploration

This database contains a "RESULT_DATA" table and a "SAMPLE_DATA" table. The original result table includes 306,931 records spanning multiple media. This table does not contain a primary key; however, unique entries are primarily identifiable as combinations of the sample number ("samp_num") field and the contaminant field ("con_id") . However, we identified exceptions in which the same contaminant was measured at different labs and using more than one analytical method. For purposes of summarizing sample counts, the record associated with the first method is used. Consequently, the primary key consists of the "SAMP_NUM", "con_id", and "method" fields.

Overall, there are 71,925 surface water records, comprising 6,418 unique samples, and 7,763 pore water records, comprising 123 unique samples, identified as having "SW" and "PW" value in the "MEDIA" field in the "SAMPLE_DATA" table, respectively.

Virtually all records include coordinate information: among surface water samples, only one sample in "SAMPLE_DATA" lacks an entry and no pore water samples lack this information. Some, but not all, surface water samples are categorized by "SAMP_FROM" (e.g., seep, irrigation, river, etc.). Similarly, some, but not all, surface water samples are categorized by "SAMP_AREA" (e.g., Columbia River, Yakima River, Esquatzel Canal, etc.), "River_Area" (100-B/C, 100-D, Hanford Townsite, upstream, etc.), and "SAMP_TYPE" (e.g., composite, discrete, raw grab, unfiltered, etc.).

Data Excluded from Analysis

In the surface water samples, we excluded duplicate records by retaining the record associated with the first-listed "METHOD_NAME" and "LAB_CODE" for each sample/contaminant combination.[43] We excluded any samples identified as a duplicate in the "DUP" field or with an "R" or "S" entry in the "GiSdT_lab_qc_type" field, indicating a replicate or split sample. We also exclude records for which there is no lab result value reported (indicated by no value in the "WC_STD_VALUE_RPTD" field).

After excluding data as described, the number of surface water records was reduced to 70,474 consisting of 6,400 samples from 2,392 sampling trips across 708 sample sites. The number of pore water records was reduced to 7,412 consisting of 120 samples collected during 37 sampling trips across 37 sites.[44]

For purposes of tabulating numbers of records, data were not excluded based on laboratory, review, or validation qualifiers. However, future users of this data may wish to consider excluding information based on these qualifiers.

Data Analysis

We reviewed the sample distribution across the study area, as reflected in the "River_Area" field for surface water samples, and in the "SAMP_AREA" field for pore water samples. Exhibits 3-20 and 3-21 present the results.

[43] Some samples were measured for the same contaminant by different labs and using different methods. "LAB_CODE" and "METHOD_NAME" are part of the primary key for the "RESULT_DATA" table.

[44] A sampling trip is defined as a unique combination of sample date ("SAMP_DATE") and a pair of geographic coordinates. Multiple samples at the same location at different times on the same date are considered one trip. Two samples do not have geographic coordinates; in counting sample sites, we assume these samples are not from unique sites.

EXHIBIT 3-20 COUNT OF CRC SURFACE WATER SAMPLES BY RIVER AREA

RIVER AREA	NO. OF SAMPLES
100-B/C Area	194
100-D Area	120
100-F Area	279
100-H Area	181
100-K Area	165
100-N Area	479
300 Area	2,232
Hanford Townsite	801
Lake Wallula	30
Upstream	742
[BLANK]	1,177
TOTAL NO. SAMPLES	**6,400**

EXHIBIT 3-21 COUNT OF CRC PORE WATER SAMPLES BY SAMPLE AREA

SAMPLE AREA	NO. OF SAMPLES
100-D	21
100-K Area	12
100-N Area	30
300 Area	40
RCBRA REFERENCE	17
TOTAL NO. SAMPLES	**120**

We examined the availability of measurements for the target analytes and COEC/COPECs. Exhibits 3-22 and 3-23 present the results for surface water, and Exhibits 3-24 and 3-25 for pore water.

Exhibit 3-26 shows sample availability by water source and timeframe. Overall, within this database, surface water dates range from 1997 to 2006. All pore water samples were collected in 2006.

EXHIBIT 3-22 COUNT OF CRC SURFACE WATER SAMPLES BY TARGET ANALYTE AND WATER SAMPLE TYPE

TARGET ANALYTE	[BLANK]	DRINKING	IRRIGATION	NA	RIVER	SEEP	SURFACE	TOTAL
Carbon tetrachloride	128				41	13		**182**
Cs-137	752		18	37	142	57		**1,006**
Cr	1,226			37	308	123	3	**1,697**
CrVI	29			39		5	4	**77**
I-129	66				16	5		**87**
Hg	494			37	123	43	2	**699**
Pu-238	83				48	1		**132**
Pu-239/240	83				48	1		**132**
Sr-90	870	42	18	37	368	45	2	**1,382**
Tc-99	250				78	19		**347**
Total PCBs*	48			39				**87**
Tritium	1,283	41	18	37	368	74	3	**1,824**
U	259			37		4	2	**302**
U-233/234	29							**29**
U-234	833		18	37	365	36		**1,289**
U-235	888		18	37	365	36		**1,344**
U-236	7							**7**
U-238	867		18	37	365	36		**1,323**
Calculated Total U				37				**37**
TOTAL NO. SAMPLES	**4,559**	**62**	**24**	**78**	**1,342**	**320**	**15**	**6,400**

*Aroclor information is available for some samples. Congener information is not available.

EXHIBIT 3-23 COUNT OF SURFACE WATER SAMPLES BY WATER SOURCE TYPE AND COEC/COPEC[45] IN CRC

TARGET ANALYTE	[BLANK]	DRINKING	IRRIGATION	NA	RIVER	SEEP	SURFACE	TOTAL
Sb	1,202			37	308	123	3	1,673
As	1,190			37	308	86	2	1,623
Ba	193			37		37	1	268
B	47			37				84
Cd	1,199			37	308	123	3	1,670
Cu	1,239			37	308	123	3	1,710
Dieldrin	144			37				181
Pb	1,141			37	308	86		1,572
Mn	194			37		37	1	269
Se	1,125			37	308	86	2	1,558
TPH - diesel range	29			37				66
Zn	1,239			37	308	123	3	1,710
TOTAL NO. SAMPLES	**4,559**	**62**	**24**	**78**	**1,342**	**320**	**15**	**6,400**

[45] The depicted analytes represent COECs from the River Corridor Baseline Risk Assessment (DOE 2011b) and COPECs from the Columbia River Component Screening-Level Ecological Risk Assessment (DOE 2011a). Counts for COECs/COPECs previously presented in Exhibit 3-22 are not repeated here.

EXHIBIT 3-24 COUNT OF CRC PORE WATER SAMPLES BY TARGET ANALYTE

TARGET ANALYTE	NO. OF SAMPLES
Cs-137	39
Cr	39
CrVI	41
Hg	39
Sr-90	39
Total PCBs*	39
Tritium	39
U	39
U-234	39
U-235	39
U-238	39
Calculated Total Uranium	39
TOTAL NO. SAMPLES	**120**

*Aroclor information is available for some samples. Congener information is not available.

EXHIBIT 3-25 COUNT OF CRC PORE WATER SAMPLES BY COEC/COPEC[46]

TARGET ANALYTE	NO. OF SAMPLES
Sb	39
Sb-125	39
As	39
Ba	39
B	39
Cd	39
Cu	39
Dieldrin	39
Pb	39
Mn	39
Se	39
TPH – diesel range	39
Zn	39
TOTAL NO. SAMPLES	**120**

[46] The depicted analytes represent COECs from the River Corridor Baseline Risk Assessment (DOE 2011b) and COPECs from the Columbia River Component Screening-Level Ecological Risk Assessment (DOE 2011a). Counts for COECs/COPECs previously presented in Exhibit 3-24 are not repeated here.

EXHIBIT 3-26 NUMBER OF CRC SURFACE WATER SAMPLES BY TIMEFRAME

WATER SOURCE TYPE	BEFORE 1981	1981-2000	AFTER 2000	TOTAL
[Blank]		1,534	3,025	**4,559**
DRINKING		22	40	**62**
IRRIGATION			24	**24**
NA			78	**78**
RIVER			1,342	**1,342**
SEEP			320	**320**
SURFACE			15	**15**
TOTAL NO. SAMPLES	**0**	**1,556**	**4,844**	**6,400**

Fewer than 100 surface water samples have associated depth information. Similarly, fewer than 100 surface water samples have an explicit "hardness" value, and about 250 samples have measurements of calcium and/or magnesium. Hardness is an important property of surface water samples, inasmuch as the toxicity of many metals is influenced by water hardness.[47]

All pore water data come from a single source, the 100/300 Area RCBRA. No pore water samples have depth information in the database; however, the RCBRA report (DOE 2011b) indicates that all pore water samples were collected from horizontal sampling tubes placed 10 to 15 cm (4 to 6 in.) below the riverbed. Thirty-seven samples have an explicit "hardness" value, while 39 samples have calcium and/or magnesium measurements.

Of note, not all of the data summarized above may be suitable for use in the natural resource damage assessment. For example, records are qualified with laboratory and review qualifiers, and the Trustees may wish to reject data based on specific qualifiers or for other reasons.

Geographic Distribution

As shown in Exhibit 3-20, approximately one-third of the surface water samples are associated with the 300 Area, and approximately one-fifth are associated with the 100 Areas. Another fifth of the surface water samples are not assigned to a specific river area, and the remainder are largely comprised of Hanford Townsite area samples (about 13 percent) and upstream samples (~12 percent). Forty-six surface water sampling locations are located outside the Hanford Site.

Among pore water samples, as shown in Exhibit 3-21, approximately half of samples are associated with the 100 Areas, and one-third are associated with the 300 Area. The

[47] As noted previously, USGS collects water hardness data for the Columbia River, stored at http://waterdata.usgs.gov/nwis.

remaining samples (~15 percent) are categorized as reference samples. No pore water sampling locations are located outside the Hanford Site.

Appendix A shows surface water and pore water sampling locations.

CONCLUSIONS

SURFACE WATER

Exhibit 3-27 provides an overview of the main surface water sample characteristics and data gaps within each database. As indicated, tens of thousands of surface water samples have been collected, and HEIS is by far the largest repository for these records. Surface water samples are often categorized by the source of the sample, including natural sources such as river or pond as well as human-use sources such as drinking and irrigation.

As shown in Appendix A, most surface water sampling locations are concentrated around Hanford facilities and operational areas, although upstream and downstream samples are also available. Somewhat fewer records are associated with the pre-1981 timeframe. Only HEIS contains any samples before 1981 (~32 percent of HEIS samples). Information on sampling data and hardness are is limited.

Surface water samples have been tested for more than 500 analytes. The databases—particularly HEIS—contain a relatively large number of surface water records for most target analytes and COEC/COPECs. Of the target analytes, tritium, cesium-137, strontium-90, chromium, and uranium (-234, -235, -238, in particular) are generally the most commonly analyzed, although other target analytes are also frequently measured. For example, HEIS includes over 1,000 samples for mercury and technitium-99. Carbon tetrachloride, iodine-129, and PCBs have are associated with the fewest records. No target analyte is lacking records entirely. Of the COEC/COPECs, all databases have samples measured for each contaminant. The most frequently measured contaminants are zinc and cadmium. Data are available for TPH-diesel and dieldrin; however, these analytes have been much less frequently sampled.

PORE WATER

Exhibit 3-28 provides an overview of the main pore water sample characteristics and data gaps within each database. Compared to other media, there are few pore water records. As shown in Appendix A, most pore water sampling locations are concentrated around Hanford facilities and operational areas, and all were collected after 2000. The DSR database contains records for the largest number of pore water samples (~ 400); HEIS and GiSdT appear to include very similar (possibly identical) sets of samples (~200), while noting that the "drive point" and "riverbed tube" samples in HEIS are also considered to be pore water samples.

Pore water samples have been tested for over 180 analytes. Of the target analytes, chromium, hexavalent chromium, mercury, uranium, tritium, PCBs, cesium-137, and strontium-90 are the most commonly analyzed (≥60 samples). No pore water samples were analyzed for iodine-129 or plutonium, and few (≤20) samples were analyzed for carbon tetrachloride or technetium-99.

Of the COEC/COPECs, each database has samples for all contaminants, with the exception of dieldrin in DSR. The number of samples ranges from 15 to 112 depending on the analyte and database.

SUGGESTED FUTURE STUDIES

The above analyses suggest that a number of studies could support an injury assessment of Hanford surface and pore waters. These include but are not necessarily limited to:

- Developing GIS maps and summary data tables showing contaminant levels by time period and location. Such maps and tables will provide a platform for discussing/exploring potential assumptions that might be agreed to by stakeholders to address gaps (and further refine primary data collection activities where agreement cannot be reached).
- Comparing contaminant levels in existing surface water samples to water quality standards, including all years from 1981 to the present. If exceedances are present (and if other pertinent criteria are met), an injury consistent with DOI's NRDA regulations may be determined.
- Assessing the toxicity of surface and/or pore waters to site biota or representative test organisms, in laboratory and/or field studies. (This topic is discussed in Chapter 5.)

For additional background and detail on these suggested future studies, please refer to the *Aquatic Resource Review Report* (Industrial Economics, Inc., November 9, 2011).

EXHIBIT 3-27 SUMMARY OF SURFACE WATER DATA GAPS WITHIN EACH DATABASE

DATABASE	NO. SAMPLES	DEPTH DISTRIBUTION	TESTING FOR HARDNESS	SAMPLE TYPES	GEOGRAPHIC DISTRIBUTION	TEMPORAL DISTRIBUTION	SAMPLES PER TARGET ANALYTE	SAMPLES PER COEC/COPECS
HEIS	21,314 (194 of which are Pore Water, 148 Drive Point, and 13 Riverbed Tube)	Majority do not have depth data. For those that do, Surface and River samples are distributed from 0 to 30 meters, with the majority measured at less than 8 meters.	Some River and Surface water samples have hardness data, while larger numbers of these types, in addition to Seep, have Ca and Mg data. Overall, 1 to 5% of samples measure hardness.	River (63.8% of samples), Surface (8.3%), Seep (7.5%), and multiple others, some of which are considered pore water samples (e.g., Pore, Drive Point, and Riverbed Tube)	Samples from 14,500 sampling trips, and 864 sampling sites. Approximately 12% of samples have coordinates. All samples have some type of location information.	Evenly distributed across years for all data, though only River, Seep, Surface, and Drinking have some in each period. **<1981**: 32% **1981-2000**: 33% **>2000**: 35%	**No samples**: None **Few (35 or fewer)**: PCBs (congeners), Pu, Pu-239, U-236 **Most**: Cs-137 (5,567), tritium (5,199) **All other target analytes**: 254-4,392 samples	**No samples**: None **Few (200 or fewer)**: Dieldrin, TPH - diesel range **Most**: Zn (2,577), Cd and Cu (2,484 each) **All other COEC/COPECs**: 363-2,429 samples
GiSdT	3,542 (195 of which are Pore Water, 10 additional are Drive Point)	No depth data provided.	Ca and Mg concentrations for ~7%; lacking measures for hardness.	82.8% "Surface Water", though differentiates 7 other types, e.g., Seep, Drive Point, Aquifer Tube, etc.	Samples from 946 unique sampling trips, and 177 sampling sites. Virtually all samples have coordinates. About 60% near 100 Areas, 25% near 300 Area, and 14% outside the Operational Areas.	Samples were collected between 1990 and 2007. **<1981**: 0% **1981-2000**: 24% **>2000**: 75% <1% lack a date.	**No samples**: None **Few (80 or fewer)**: I-129, Pu-238, Pu-239/240, U-236 **Most**: Cr (1,015), Sr-90 (1,039), tritium (1,318) **All other target analytes**: 113-972 samples	**No samples**: None **Few (fewer than 130)**: B, Dieldrin, TPH - diesel range **Most**: Zn (1,033), Cd (986) **All other COEC/COPECs**: 113-976 samples
2011 DSR	579 (140 River, 439 Surface)	All but 6 samples have depth information; 61% of samples are from 0 to 2 ft.	None available.	Surface water samples further categorized as Deep Surface Water (less than 2%) or GW upwelling (44%), 55% classified as "Surface Water" or not categorized.	Samples from 357 unique sampling trips, and 60 sample sites. All records have coordinates. 54% near 100 Areas, 26% near 300 Area, 7% from areas upriver, and 13% downstream.	All samples were collected between 2008 and 2010.	**No samples**: I-129 **Few (100 or fewer)**: carbon tetrachloride, PCBs, Sr-90, Tc-99, Tritium **Most (220 each)**: Cr, Hg, U **All other target analytes:** 110 each	**No samples**: None **Few (fewer than 60)**: Dieldrin, TPH-diesel **All other COEC/COPECs**: Sb, As, Ba, B, Cd, Cu, Pb, Mn, Se, Zn (220 each)

DATABASE	NO. SAMPLES	DEPTH DISTRIBUTION	TESTING FOR HARDNESS	SAMPLE TYPES	GEOGRAPHIC DISTRIBUTION	TEMPORAL DISTRIBUTION	SAMPLES PER TARGET ANALYTE	SAMPLES PER COEC/COPECS
CRC Historic	6,418	Fewer than 100 samples have depth information.	Less than 5% of samples (320 unique samples with data); Fewer than 100 samples have calculated hardness, and an additional 240 have Ca and Mg concentrations.	About one-third of samples are classified as River, Surface, Seep, Drinking, Irrigation, or NA.	Samples from 3,095 unique sampling trips. Virtually all samples have coordinates. 35% near 300 Areas, 22% near 100 Areas, 12.5% taken in Hanford Town Site, 12% upstream, the remainder from other areas of the Columbia, and other rivers.	Samples were collected between 1997 and 2006. **<1981:** 0% **1981-2000:** 24% **>2000:** 76%	**No samples:** None **Few (40 or fewer):** U-233/234, U-236 **Most (1,006-1,824):** Cs, Cr, Sr-90, tritium, U-234, U-235, U-238 **All other target analytes:** 69-699 samples	**No samples:** None **Few (100 or fewer):** B, TPH - diesel range **Most:** Zn and Cu (1,710 each), Sb (1,673), Cd (1,670) **All other COEC/COPECs:** 181-1,623 samples

EXHIBIT 3-28 SUMMARY OF PORE WATER DATA GAPS WITHIN EACH DATABASE

DATABASE	NO. SAMPLES	TESTING FOR HARDNESS	SAMPLE TYPES	GEOGRAPHIC DISTRIBUTION	TEMPORAL DISTRIBUTION	SAMPLES PER TARGET ANALYTE	SAMPLES PER COEC/COPECS
HEIS	194 (plus an additional 148 Drive Point samples, and 13 Riverbed Tube samples)	About one-third of all pore water samples have either hardness or Ca and Mg concentrations reported.	Pore samples aggregated into "SW" media type	Pore Water samples are from 49 sites, over 75 sampling trips. Drive Point samples are from 79 trips to 31 sites (none of which have geographic coordinates). Riverbed tube samples are from 13 trips to 12 sites, one-quarter of which do not have coordinates. Samples for which location information is available are generally concentrated around the 100 and 300 Areas.	All post-2000, with the exception of three riverbed tube samples (from the 1981-2000 period)	**No samples:** Carbon tetrachloride, I-129, Pu **Few (10 or fewer):** Tc-99 (2), Sr-90 (10) **Most (60-71):** CrVI, Cr, Hg, tritium, U, PCBs **All other target analytes:** 18 to 51 samples	**No samples:** None **Few (30 or fewer):** None **Most:** Cd and Ba (112 each) **All other COEC/COPECs:** 60-103 samples
RCBRA / GiSdT	195 (an additional 10 samples are classified as Drive Point samples)	About one-third of all pore water samples have either hardness or Ca and Mg concentrations reported.	Pore water samples aggregated into "SW" media type	Samples are from 61 sampling trips to 48 sample sites. The Drive Point samples represent two separate sampling trips, and two sample sites. 58% are from around the 100 Areas, 31% are from the 300 Area, and 11% are from outside operational areas.	All post-2000	**No samples:** Carbon tetrachloride, I-129, Pu, U-236 **Few (10 or fewer):** Tc-99 (2) **Most (60-70):** PCBs, U, Cs-137, Cr, Hg, Sr-90, tritium	**No samples:** None **Few (10 or fewer):** None **Most (60-71):** All remaining
2011 DSR	404	None available	Pore	Samples are from 294 sampling trips, and 33 sample sites. 71% around 100 Areas, 29% around 300 Area, none upriver, or downstream.	All post-2000	**No samples:** Cs-137, I-129, Pu, PCBs **Few (20 or fewer):** Carbon tetrachloride (20), Tc-99 (3) **Most (60 or more):** CrVI (190), U (137), Cr (95), Hg (92), Sr-90 (65)	**No samples:** Dieldrin **Few:** TPH - diesel range (15 samples) **All other COEC/COPECs:** 95 samples

DATABASE	NO. SAMPLES	TESTING FOR HARDNESS	SAMPLE TYPES	GEOGRAPHIC DISTRIBUTION	TEMPORAL DISTRIBUTION	SAMPLES PER TARGET ANALYTE	SAMPLES PER COEC/COPECS
CRC Historic	120	About one-third of all pore water samples have either hardness or Ca and Mg concentrations reported	Pore; All further classified as “Nearshore” and “Grab”	Samples are from 37 sampling trips, and 37 sample sites. 53% around 100 Areas, 33% around 300 Area, 14% are reference samples.	All post-2000	**No samples:** Carbon tetrachloride, I-129, Pu, Tc-99 **All remaining:** 39-41 samples	**No samples:** None **All other COEC/COPECs:** 39 each

CHAPTER 4 | SEDIMENTS

This chapter provides a summary of data types most commonly relied upon in a NRDA for purposes of determining injury to sediments. Sediments are considered to be part of the surface water resource (43 CFR 11.14(pp)) and are considered to be injured when either:

- "Concentrations of substances on bed, bank, or shoreline sediments [are] sufficient to cause the sediment to exhibit characteristics identified under or listed pursuant to section 3001 of the Solid Waste Disposal Act, 42 U.S.C. 6921" (43 CFR 11.62(b)(iv), or
- "Concentrations and duration of substances sufficient to have caused injury as defined in paragraphs (c), (d), (e), or (f) of this section to ground water, air, geologic, or biological resources, when exposed to surface water, suspended sediments, or bed, bank, or shoreline sediments" (43 CFR 11.62(b)(v)).

The chapter characterizes available information on exposure of sediments to contaminants, as indicated through measurements of contaminant concentrations in sediments. Measurements of exposure are relevant in establishing injury as defined above and in establishing a complete pathway (as described in 43 CFR 11.63) from releases to receptors. Sediment measurements also provide information relevant to ascertaining the likely causality of potential injuries.

This chapter concludes with a summary of the presented information, highlighting areas where information appears to be limited or absent.

EXPOSURE TO CONTAMINANTS

We assembled available information to identify data on the concentrations of contaminants in Hanford area sediments. Available sources of information include the following:

- Hanford Environmental Information System (HEIS);
- River Corridor Baseline Risk Assessment database (RCBRA / GiSdT);
- The 2011 Releases to the Columbia River Remedial Investigation Data Summary Report (DSR) database; and,
- The Columbia River Component (CRC) Historic database.

Because of the challenges associated with the partial overlap of information among various databases, we evaluated information within each database separately, as described below. Appendix A provides maps of sediment sampling locations.

HANFORD ENVIRONMENTAL INFORMATION SYSTEM (HEIS)

Data Exploration

Evaluation of sediment data from HEIS focused on all records from the soil view identified as "SEDIMENT" in the "SAMP_ITEM" field. Because HEIS is frequently updated, later downloads may include additional information.

The downloaded sediment data contains 24,784 records, comprising 1,238 unique sample numbers. This report defines a unique sample as a discrete unit of sampled sediment, based on the "SAMP_NUM" field in HEIS.

Data Excluded from Analysis

We excluded from analysis all records identified as laboratory replicates (i.e., those having a value of "R", "S", or "B" in the "LAB_QC_TYPE" field). QC samples did not have to be excluded as these were already excluded when selecting for only those samples identified as "SEDIMENT" in the "SAMP_ITEM" field ("SAMP_ITEM" field is where samples are identified as a "QC_SAMPLE"). We also exclude from the analysis any samples identified as field quality control samples in the "FIELD_QC_TYPE" field.[48] For purposes of tabulating numbers of records, data were not excluded based on laboratory, validation, or review qualifiers.

As with the most data in HEIS, unique instances of a sample being analyzed for a particular contaminant are primarily identifiable as combinations of the sample number ("SAMP_NUM") field and the contaminant field ("STD_CON_ID"). We identified a few exceptions to this rule for americium-241, thorium-228, thorium-232, and uranium-234, 235, and 238. Many samples had measurements for these contaminants using two different analytical methods, each of which represents a unique record. For purposes of counting samples, the record associated with the first reported analysis method for the relevant sample/contaminant combination was retained.

After selecting data as described above, the resulting list of records is reduced from 24,784 to 23,237, comprising 1,130 unique samples. These samples were collected during 803 sampling trips, as described in Exhibit 4-1.

Data Analysis

HEIS contains sediment samples from three sample types, as listed in the "SAMP_FROM"[49] field. Exhibit 4-1 lists the number of samples associated with each type. Based on their geographic location, the "sub-surface" and "surface" samples all appear to be riverine samples taken from the Columbia River or associated tributaries. The "POND" samples do not have coordinates, but are described as taken from "FFTF Pond" and "West Lake".

[48] As of June 30, 2011, the sediment data in HEIS did not contain any such samples.
[49] The "SAMP_FROM" field is primarily used to designate the type of biota sample, and therefore may often be blank for other media.

EXHIBIT 4-1 COUNT OF HEIS SEDIMENT SAMPLE NUMBERS BY TYPE[50]

SAMPLE TYPE	NO. SAMPLES	NO. SAMPLING TRIPS*
POND	30	30
SUB_SURFACE	870	645
SURFACE	230	128
TOTAL NO. SAMPLES	**1,130**	**803**

*Sampling trip refers to the number of unique combinations of space and time and is determined by grouping records using "SAMP_SITE_ID" and "SAMP_DATE_TIME" fields. The TOTAL NO. SAMPLES row refers to unique samples as units of soil, and are defined using the "SAMP_NUM" field. Multiple sample numbers can be associated with the same sampling trip.

The majority of samples (987 of 1,130) do not contain any information in the sample depth fields ("STD_SAMP_INTV_TOP" and "STD_SAMP_INTV_BOT"). Larry Hulstrom from WCH confirmed that samples without a bottom depth can be assumed to be surface samples with a depth of zero feet (personal communication, November, 2011). However, 755 of the samples without a bottom depth (and without a top depth) are listed as sub-surface samples. Most of the surface samples (202 of 230) do not have a bottom depth; one surface sample has a bottom depth specified as zero, and 27 surface samples have a bottom depth of 0.10 m (approximately 4 inches). Exhibit 4-2 lists the numbers of samples taken at each bottom depth. We note that it may be possible to infer sample depth information using information in other fields, such as the "OWNER_ID" field, which identifies the Hanford contractor that owns the sample record. For instance, 75 percent of the samples without a sample depth are identified as SESP samples in the "OWNER_ID" field (561 as "SESPMNT" and 177 as "SESPSPEC") and depth can be estimated using the SESP sampling methodology documented in the SESP procedures manual (PNNL-16744).

We also examined data availability by "SAMP_FROM" and target analyte (Exhibit 4-3) and by COEC/COPEC (Exhibit 4-4).

[50] As indicated in "SAMP_FROM" field.

EXHIBIT 4-2 NUMBER OF HEIS SEDIMENT SAMPLES BY DEPTH TO BOTTOM OF SAMPLE

DEPTH TO BOTTOM OF SAMPLE (m)	POND	SUBSURFACE	SURFACE	TOTAL NO. SAMPLES	% OF TOTAL
Blank	30	755	202	987	87
0			1	1	<0.1
>0 - 1		102	27	129	11
>1 - 2		2		2	0.2
>2 - 3		3		3	0.3
>3 - 4		4		4	0.4
>4*		**4**		**4**	**0.4**
TOTAL	**30**	**870**	**230**	**1,130**	**100**

***** Two subsurface samples have depths of 4.572 m, while the remaining two have depths of 22.25 m and 26.82 m.

EXHIBIT 4-3 COUNT OF HEIS SEDIMENT SAMPLES BY TARGET ANALYTE AND TYPE

TARGET ANALYTE	SAMPLE TYPE			
	POND	SUB-SURFACE	SURFACE	TOTAL
Cs-137	29	414	85	528
Cr		233	97	330
CrVI		18	69	87
Hg		189	71	260
PCBs*		36	57	93
Pu-238		286	2	288
Pu-239/240		286	2	288
Sr-90	29	403	28	460
Tc-99	28	13	11	52
Tritium		10		10
U		24	69	93
U-233/234			57	57
U-234	29	292	0	321
U-235	29	407	60	496
U-238	29	407	57	493
TOTAL NO. SAMPLES	**30**	**870**	**230**	**1,130**

*Samples tested for Aroclors.

EXHIBIT 4-4 COUNT OF HEIS SEDIMENT SAMPLES BY COEC/COPEC[51] AND TYPE

TARGET ANALYTE	SAMPLE TYPE			
	POND	SUB-SURFACE	SURFACE	TOTAL
Sb		222	97	319
As		133	71	204
Ba		114	97	211
B			69	69
Cd		277	97	374
Cu		265	97	362
Dieldrin		39	57	96
Pb		200	71	271
Mn		120	97	217
Se		115	71	186
Zn		267	97	364
TOTAL NO. SAMPLES	**30**	**870**	**230**	**1,130**

We also investigated the number of samples taken as a function of sample type and timeframe. Exhibit 4-5 presents the results.

EXHIBIT 4-5 NUMBER OF HEIS SEDIMENT SAMPLES BY TYPE AND TIMEFRAME

SAMPLE TYPE	TOTAL NO. SAMPLES	NO. SAMPLES WITH COORDINATES	BEFORE 1981	1981 - 2000	AFTER 2000
POND	**30**		0	1	29
SUB_SURFACE	**870**	150	0	375	495
SURFACE	**230**	230	0	28	202
TOTAL	**1,130**	**380**	**0**	**404**	**726**
Samples date from 1988 to 2010.					

Not all of the data summarized above may be suitable for use in the natural resource damage assessment. Of the 1,130 unique sample numbers, 750 (66 percent) lack geographic coordinates. However, general locational information is provided for all samples lacking geographic coordinates in the "SAMP_SITE_NAME" and "SAMP_SITE_ID" fields. Additional locational information for some samples can also

[51] The depicted analytes represent COECs from the River Corridor Baseline Risk Assessment (DOE 2011b) and COPECs from the Columbia River Component Screening-Level Ecological Risk Assessment (DOE 2011a). Counts for COECs/COPECs previously presented in Exhibit 4-3 are not repeated here.

be found in other fields. Exhibit 4-6 provides the number of samples for which there is general location information, but no coordinates, for each of the locational fields.

EXHIBIT 4-6 NUMBER OF HEIS SEDIMENT SAMPLES WITH DESCRIPTIVE LOCATION INFORMATION

FIELD	NO. SAMPLES WITH INFORMATION
SAMP_SITE_NAME	750
SAMP_SITE_ID	750
SAMP_SITE_DESC	371
SAMP_LOCATION	114
SITE_CODE	0
None of the above	0
TOTAL NO. SAMPLES WITHOUT COORDINATES	**750**

Some data are qualified with laboratory, review, and validation qualifiers, and the Trustees may wish to exclude data based on certain qualifiers or other considerations. In addition, approximately three percent of the records lack a value in the "STD_VALUE_RPTD" field.

Geographic Distribution

The 1,130 unique samples were collected from 203 distinct sampling sites (based on "SAMP_SITE_ID"). HEIS sediment sample locations are concentrated near the 100 Areas and the 300 Area. A few samples were also taken upstream of the Hanford Site. Appendix A contains maps of sampling locations.

RIVER CORRIDOR BASELINE RISK ASSESSMENT DATABASE (RCBRA / GiSdT)

Data Exploration

Evaluation of data from this source focused on the sediment table as downloaded from the RCBRA data management website (http://rcbra.neptuneinc.org/rcbra/home/index.xml) on May 11, 2011. The downloaded data included 16,432 records, comprising 598 unique sample numbers. Unique records can be identified as a combination of the sample ID and contaminant ID fields ("sample_id" and "gisdt_std_con_id").

Data Excluded from Analysis

We did not exclude any data from analysis. None of the samples were identified as laboratory replicates (i.e., those having a value of "R" in the "lab_qc_type" field, all records were null in the "lab_qc_type field," and no duplicate records were identified. For purposes of tabulating numbers of records, data were not excluded based on laboratory, validation, or review qualifiers.

Data Analysis

This database contains only discrete, nearshore environment samples from a number of categories. We examined data availability by sediment category ("category" field), as shown in Exhibit 4-7.

EXHIBIT 4-7 COUNT OF GISDT SEDIMENT SAMPLES BY CATEGORY

CATEGORY	NO. SAMPLES
BC_PILOT	4
OPERATIONAL	534
REFERENCE	45
REFERENCE_BC	2
REFERENCE_NR2	5
REFERENCE_PNNL	8
TOTAL	598
TOTAL NO. SAMPLING TRIPS[52]	255

We also examined data availability by target analyte. Altogether, 398 samples were tested for one or more target analytes. Exhibit 4-8 presents the number of samples by category and target analyte, while Exhibit 4-9 presents the number of samples by category and COEC/COPEC..

No samples contained information in the sample depth field; consequently, we were unable to characterize the data based on depth. However, all samples are associated with a source type in the "data_source_type" and "sample_data_source_type" fields. These sources may contain metadata or other information appertaining to sampling methods and sample depths. Many of the samples (55 percent) are from "PNNL", 41 percent from "RCBRA", three percent from "NR2", and the remaining one percent from "BC_PILOT".

We also explored the data as a function of category and timeframe (Exhibit 4-10).

[52] For purposes of this analysis, we define a sampling trip as a unique sample date and time ("samp_date_time") and sample location ("gisdt_sample_site_name"). The 260 samples lacking a date are assumed to represent 93 distinct sampling trips as they occurred across 93 separate sample sites.

EXHIBIT 4-8 COUNT OF GISDT SEDIMENT SAMPLES BY TARGET ANALYTE AND CATEGORY

TARGET ANALYTE	SEDIMENT CATEGORY						
	BC_PILOT	OPERATIONAL	REFERENCE	REF. BC	REF. NR2	REF. PNNL	TOTAL NO. SAMPLES
Cs-137	2	263	10	1		6	282
Cr	2	136	12	1	3	2	156
CrVI		55	10				65
Hg	2	108	12	1	1	1	125
PCBs*		50	10		1		61
Pu-238	2	124		1		5	132
Pu-239		1					1
Pu-239/240	2	129		1		5	137
Sr-90	2	233	10	1	1	6	253
Tc-99	2	10		1	1	1	15
Tritium		2					2
U-233/234		199	10			6	215
U-235		227	10			1	238
U-236		6					6
U-238		204	10			6	220
Total No. Samples	**4**	**534**	**45**	**2**	**5**	**8**	**598**

No samples were tested for carbon tetrachloride or I-129.
*Samples tested for Aroclors, PCB congeners, or both.

EXHIBIT 4-9 COUNT OF GISDT SEDIMENT SAMPLES BY COEC/COPEC[53] AND CATEGORY

TARGET ANALYTE	SEDIMENT CATEGORY						
	BC_PILOT	OPERATIONAL	REFERENCE	REF. BC	REF. NR2	REF. PNNL	TOTAL NO. SAMPLES
Sb	2	115	12	1	3	1	134
As	2	109	12	1	3	1	128
Ba	2	122	12	1	3	1	141
B		57	12				69
Cd	2	125	12	1	3	2	145
Cu	2	132	12	1		2	149
Dieldrin		47	10				57
Pb	2	112	12	1	3	1	131
Mn	2	122	12	1	3	1	141
Se	2	108	12	1	3	1	127
TPH-diesel		47	10				57
Zn	2	125	12	1	3	2	145
TOTAL NO. SAMPLES	**4**	**534**	**45**	**2**	**5**	**8**	**598**

EXHIBIT 4-10 NUMBER OF GISDT SEDIMENT SAMPLES BY CATEGORY AND TIMEFRAME

SEDIMENT CATEGORY	TOTAL NO. SAMPLES	NO. SAMPLES WITH COORDINATES	NO DATE	BEFORE 1981	1981 - 2000	AFTER 2000
BC_Pilot	**4**	4	4			
Operational	**534**	532	235		92	207
Reference	**45**	45	11			34
Reference BC	**2**	2	2			
Reference NR2	**5**	5	1			4
Reference PNNL	**8**	8	7		1	
TOTAL	**598**	**596**	**260**	**0**	**93**	**245**

[53] The depicted analytes represent COECs from the River Corridor Baseline Risk Assessment (DOE 2011b) and COPECs from the Columbia River Component Screening-Level Ecological Risk Assessment (DOE 2011a). Counts for COECs/COPECs previously presented in Exhibit 4-8 are not repeated here.

Not all of the data summarized above may be suitable for use in the natural resource damage assessment. All samples do have a value in the result field ("gisdt_std_value_rptd"), but two samples lack geographic coordinate information (Exhibit 4-7); these samples are described as from "RCBRA U3" and 'RCBRA U4" respectively in the "gisdt_sample_site_name" field. Many (260 of 598) samples lack a date. In addition, the Trustees may wish to exclude data on the basis of laboratory, review, or validation qualifiers, or for other reasons.

Geographic Distribution

The 598 unique samples were collected from 115 sampling sites (as defined by "samp_site_name"). GiSdT sediment sampling locations are well distributed along the onsite portion of the Columbia River, with samples concentrated near the 100 Areas and the 300 Area. Sediment samples were also taken upstream of the Hanford Site.

2011 RELEASES TO THE COLUMBIA RIVER REMEDIAL INVESTIGATION DATA SUMMARY REPORT (DSR) DATABASE

Data Exploration

The original table in this database includes 223,465 records spanning multiple media. Overall, there are 71,785 sediment records (identified as having "SD" value in the "media" field), representing 1,203 unique samples.

Data Excluded from Analysis

Unique entries are primarily identifiable as combinations of the sample number ("samp_num") field and the contaminant field ("con_id") . However, we identified two exceptions; uranium-235 and uranium-238 were measured using more than one analytical method. For purposes of summarizing counts of samples, the record associated with the minimum measured value for the relevant sample/contaminant combination was retained. Consequently, the primary key consists of the "samp_num, con_id" and "method" fields.

Data were not excluded on any other basis. The dataset already excludes duplicates, replicates, and blanks (Appendix O Data Summary Report – Data Users Guide.xls). For purposes of tabulating numbers of records, data were not excluded based on laboratory, review, or validation qualifiers.

After excluding data as discussed, the total number of records is reduced from 71,785 to 70,761, representing 1,203 samples collected during 482 sampling trips.[54]

Data Analysis

Sediment samples types are further categorized in the "media_detail" field. There are six different categories in media detail including deep cores, shallow cores, sediment groundwater upwellings, shallow sediment samples, deep sediment samples, and shoreline sediment samples. Deep cores were completed at water depths of up to 27 m

[54] For the purposes of this analysis, we define a sampling trip as a unique combination of geographic coordinates ("x_coord" and "y_coord"), indicating sample location, and sample date and time ("samp_date_time").

(90 ft) with thick (> 10 ft) sediment sequences, and shallow cores were completed in sediment sequences less than three meters thick. Shallow sediments were collected from water depths of less than 1.8 m (6 ft) and from the upper 10 centimeters (4 in) of sediment. Deep sediment samples were collected in water depths greater than 1.8 m (6 ft.) and from the upper 10 cm (4 in) of sediment. The numbers of samples in each media detail category are shown in Exhibit 4-11. All of the samples without a media detail, except perhaps one, should have been assigned to the "SD GW Upwelling" media detail category (Larry Hulstrom, WCH, personal communication).

EXHIBIT 4-11 COUNT OF DSR SEDIMENT SAMPLES BY MEDIA DETAIL

SEDIMENT MEDIA DETAIL	NO. SAMPLES
Blank	115
Core, Deep	77
Core, Shallow	142
SD GW Upwelling	8
Sediment, Deep	12
Sediment, Shallow	442
Sediment, Shoreline	407
TOTAL	**1,203**

The majority of samples (74 percent) are surface samples with a zero in the sample depth fields. However, a few samples (12 percent) lack information in the "sample_depth_bottom" and "sample_depth_top" fields, and the remaining 168 samples have bottom depths ranging from one to 11 feet deep (Exhibit 4-12). The samples without a sample depth are surface samples taken during the Phase III groundwater upwelling studies, and were all collected at depths less than one foot[55] (Larry Hulstrom, WCH, personal communication).

[55] These samples were collected with either a Ponar sampler or a split spoon core sampler as described in WCH-380 and WCH-2386 (Larry Hulstrom, WCH, personal communication).

EXHIBIT 4-12 COUNT OF DSR SEDIMENT SAMPLES BY TARGET ANALYTE AND DEPTH TO BOTTOM OF SAMPLE

DEPTH TO BOTTOM OF SAMPLE (FT)	NO. SAMPLES
Blank	145
0	890
1	40
2	36
3	17
4	23
>4 - 11	52
TOTAL	**1,203**

We also explored target contaminant and COEC/COPEC measurements as a function of media detail (Exhibits 4-13 and 4-14).

EXHIBIT 4-13 COUNT OF DSR SEDIMENT SAMPLES BY TARGET ANALYTE AND MEDIA DETAIL

TARGET ANALYTE	MEDIA DETAIL							
	BLANK	CORE, DEEP	CORE, SHALLOW	SD GW UPWELLING	SD DEEP	SD SHALLOW	SD SHORE-LINE	TOTAL
Carbon tetrachloride	8	3	14		1	101	112	239
Cs-137	41	45	64	4	4	157	198	513
Cr	41	45	64	4	4	189	198	545
CrVI	42	32	64	4	4	186	180	512
Hg	41	45	64	4	4	189	198	545
Pu-238	41	45	64	4	4	157	198	513
Pu-239/240	41	45	64	4	4	157	198	513
Sr-90	31	45	64	3	4	157	198	502
Tc-99	4	45	64		4	157	198	472
Tritium	4			1				5
PCBs*		3	10		1	144	139	297
U	41	45	64	4	4	189	198	545
U-233/234	41	45	64	4	4	157	198	513
U-235	41	45	64	4	4	157	198	513
U-238	41	45	64	4	4	157	198	513
TOTAL NO. SAMPLES	**115**	**77**	**142**	**8**	**12**	**442**	**407**	**1,203**

*Samples tested for Aroclors, PCB congeners, or both.

EXHIBIT 4-14 COUNT OF DSR SEDIMENT SAMPLES BY COEC/COPEC[56] AND MEDIA DETAIL

TARGET ANALYTE	MEDIA DETAIL							
	BLANK	CORE, DEEP	CORE, SHALLOW	SD GW UPWELLING	SD DEEP	SD SHALLOW	SD SHORE-LINE	TOTAL
Sb	41	45	64	4	4	189	198	545
As	41	45	64	4	4	189	198	545
Ba	41	45	64	4	4	189	198	545
B	41	45	64	4	4	189	198	545
Cd	70	45	78	4	8	226	215	646
Cu	70	45	78	4	8	226	215	646
Dieldrin		3	9		1	129	120	262
Pb	70	45	78	4	8	226	215	646
Mn	41	45	64	4	4	189	198	545
Se	41	45	64	4	4	189	198	545
TPH-diesel			2		1	88	96	187
Zn	70	45	78	4	8	226	215	646
TOTAL NO. SAMPLES	**115**	**77**	**142**	**8**	**12**	**442**	**407**	**1,203**

One of the objectives of the Data Summary Report for the Remedial Investigation of Hanford Site Releases to the Columbia River is to compare background contaminant concentrations to site concentrations to determine if Hanford Reach contaminant concentrations are consistent with concentrations observed in reference areas or areas of other contributing influences (OCIs). We explored the data as a function of the different OCI categories, as shown in Exhibit 4-15. According to Larry Hulstrom (WCH, personal communication), the 1,015 samples without information in the "oci" field are samples from the study area that was the focus of the particular investigation.

[56] The depicted analytes represent COECs from the River Corridor Baseline Risk Assessment (DOE 2011b) and COPECs from the Columbia River Component Screening-Level Ecological Risk Assessment (DOE 2011a). Counts for COECs/COPECs previously presented in Exhibit 4-13 are not repeated here.

EXHIBIT 4-15 COUNT OF DSR SEDIMENT SAMPLES BY OCI DESCRIPTION

OCI	TOTAL NO. OF SAMPLES	NO. SAMPLES TESTING FOR TARGET ANALYTES
Blank	1,015	486
Major Tributary	81	40
Upriver	73	47
Wasteway Irrigation Return	34	17
TOTAL	**1,203**	**590**

All records have sample coordinates, a date (ranging from December 2008 to February 2010), and a result value. Some data are qualified, and the Trustees may wish to reject data with specific qualifiers or for other reasons.

Geographic Distribution

The 1,203 unique samples were collected from 457 unique sampling sites (defined as a unique combination of “x_coord” and “y_coord”). DSR sediment sampling locations are well distributed along the Columbia River on the Hanford Site, with a higher density of samples near the 100 Areas and the 300 Area. There are also a number of samples from offsite locations.

COLUMBIA RIVER COMPONENT (CRC) HISTORIC DATABASE

Data Exploration

This database contains a “RESULT_DATA” table and a “SAMPLE_DATA” table. The original result table includes 306,931 records spanning multiple media. Overall, there are 51,180 sediment records, comprising 2,489 unique samples (identified as having “SD” value in the media field in the “SAMPLE_DATA” table).

Data Excluded from Analysis

We combined information from the results and sample tables. Unique entries in the resulting table are primarily identifiable as combinations of the sample number (“samp_num”) field and the contaminant field (“con_id”). However, we identified exceptions in which the same contaminant was measured at different labs and using more than one analytical method. For purposes of counting records, we retained the record associated with the first method for the relevant sample/contaminant combination.

We excluded all records identified as a duplicate in the “DUP” field and replicates identified with an “R” in the “gisdt_lab_qc_type” field. For purposes of tabulating numbers of records, data were not excluded based on laboratory, review, or validation qualifiers. However, future users of this data may wish to consider excluding information based on these qualifiers.

After excluding data as described, the number of records was reduced from 51,180 to 50,232, comprising 2,476 samples. These samples were collected during 1,590 sampling trips.[57]

Data Analysis

Sample type is often identified in the "SAMP_TYPE" and "SAMP_FROM" fields. As noted previously, "SAMP_FROM" is primarily used to designate some physical part of a biota sample, and therefore is often blank for other media. The numbers of records per sample type and sample from are shown in Exhibit 4-16. Most samples did not contain any information in the "GiSdT_environment" field or the "GiSdT_site_type" field, except for 73 samples identified as from the nearshore environment and aquatic site type. Samples were taken from a number of sample sites including the 100 Area, 300 Area spring, above Bonneville, John Day, McNary, Priest River, and Dalles dams, and the White Bluffs slough. Most samples did not contain information in the "GiSdT_category" field, but 58 samples were identified as "operational" and 15 samples as "reference".

EXHIBIT 4-16 COUNT OF CRC SEDIMENT SAMPLES BY TYPE AND SAMPLE FROM

SAMPLE TYPE	SAMPLE FROM			
	BLANK OR N/A	POND	SUB-SURFACE	TOTAL NO. SAMPLES
Blank	145	8	171	324
Composite	19			19
Core	510			510
Grab	1,623			1,623
TOTAL	**2,297**	**8**	**171**	**2,476**

We also explored the data as a function of depth. Depth information is available in the "sample_depth_to" and "sample_depth_from" fields, "WC_SAMP_DEPTH_TO" and "WC_SAMP_DEPTH_FROM" fields, as well as the "gisdt_rcbra_sample_depth" field. Seventy-three samples are identified as "sub_surface" in the "gisdt_rcbra_sample_depth field", and the remaining samples do not contain any information in this field. Many samples (69 percent) do not contain information in the "sample_depth_to" and "sample_depth_from" fields, and a few samples (41) only contain sample depth to information. Samples range from 0 to around 50 feet deep. Exhibit 4-17 shows the numbers of samples in each "WC_SAMPLE_DEPTH_TO" range.

---

[57] For purposes of this analysis, a sampling trip is defined as a unique sample date ("SAMP_DATE") and sample location (unique combination of "STD_EW_COORD" and "STD_NS_COORD"). There are 16 samples lacking coordinates; those taken on different dates were counted as separate sampling trips, and those samples lacking coordinates and a date were assumed to be taken on the same sampling trip. Using "SAMP_SITE" to define a sample location results in 1,354 sampling trips (47 samples lack a "SAMP_SITE" and these were assumed to be from 16 sampling trips since they were taken on 16 separate dates).

EXHIBIT 4-17 COUNT OF CRC SEDIMENT SAMPLES BY DAMPLE DEPTH TO

SAMPLE DEPTH TO (INCHES)	NO. OF SAMPLES
Blank	1,743*
0	88
>0-1	59
>1-6	202
>6-12	112
>12-24	121
>24-60	80
>60 – 1,056	71
TOTAL	**2,476**
*32 of these samples contained depth information but no units.	

We also examined data availability by target analyte. The total number of samples that test for one or more target analyte is 2,091. Exhibit 4-18 presents the results of the number of samples testing for each target analyte. Exhibit 4-19 presents the results of the number of samples testing for COPCs/COPECs.

EXHIBIT 4-18 COUNT OF CRC SEDIMENT SAMPLES BY TARGET ANALYTE

TARGET ANALYTE	NO. OF SAMPLES
Carbon tetrachloride	7
Cs-137	1,291
Cr	616
CrVI	22
Hg	672
PCBs*	310
Pu-238	493
Pu-239	1
Pu-239/240	505
Sr-90	559
Tc-99	24
Tritium	11
U	292
U-233/234	60
U-234	383
U-235	506
U-236	3
U-238	559
TOTAL NO. OF SAMPLES	**2,476**
*Samples tested for Aroclors, PCB congeners, or both.	

EXHIBIT 4-19 COUNT OF CRC SEDIMENT SAMPLES BY COEC/COPEC[58]

TARGET ANALYTE	NO. OF SAMPLES
Sb	461
As	583
Ba	272
B	58
Cd	756
Cu	765
Dieldrin	248
Pb	739
Mn	234
Se	414
TPH-diesel	56
Zn	755
TOTAL NO. SAMPLES	**2,476**

We also explored the data as a function of time frame and availability of coordinate information (Exhibit 4-20).

EXHIBIT 4-20 NUMBER OF CRC SEDIMENT SAMPLES BY TIMEFRAME

TIMEFRAME	TOTAL NO. SAMPLES	NO. SAMPLES WITH COORDINATES
No Date	9	0
Before 1981	587	587
1981-2000	1,102	1,095
After 2000	778	778
TOTAL	**2,476**	**2,460**

Not all of the data summarized above may be suitable for use in the natural resource damage assessment. For instance, out of the 50,531 retained records, 74 records lack a value in the "WC_STD_VALUE_RPTD" field (1,897 are null in the "VALUE_RPTD" field). Also, 16 samples lack geographic coordinate information, making these more difficult to map (Exhibit 4-20), although ten of the 16 samples lacking geographic coordinates contain information in the "SAMP_AREA" field indicating these samples were collected from either the "Columbia River" (1 sample), or areas referred to as "B2", "B3", 'D1", "D2", "D3", or "D4". The remaining samples do not have any associated locational information.

---

58 The depicted analytes represent COECs from the River Corridor Baseline Risk Assessment (DOE 2011b) and COPECs from the Columbia River Component Screening-Level Ecological Risk Assessment (DOE 2011a). Counts for COECs/COPECs previously presented in Exhibit 4-18 are not repeated here.

Geographic Distribution

The 2,476 unique samples were collected from 756 sampling sites (defined as a unique combination of geographic coordinates using the "STD_EW_COORD" and "STD_NS_COORD" fields). CRC Historic sediment sampling locations are distributed along the Columbia River on the Hanford Site, and particularly concentrated near the 100 Areas and the 300 Area. In addition, there are 364 sediment sample locations located outside of the Hanford Site. Samples extend far upstream and all the way to the Pacific Ocean downstream.

CONCLUSIONS

Exhibit 4-21 provides an overview of the main sample characteristics and data gaps within each database. As indicated, over 2,000 sediment samples have been collected, and the CRC Historic database is the largest repository for Hanford sediments at present.

As shown in Appendix A, most sediment sampling locations occur within the Hanford Reach, including islands within the river. Sample locations are somewhat concentrated around the operational areas, but there are sediment sampling locations throughout the Reach. Data are also available for a number of offsite sampling locations, including upstream, downstream, and tributary sites. The majority of samples lack depth information, and in HEIS, about two-thirds of the samples lack coordinate information. The CRC Historic database is the only identified database containing pre-1981 records (24 percent of samples in that database).

Sediment samples have been tested for more than 500 analytes. Of the target analytes, cesium-137 was generally the most frequently measured (over 1,000 samples). No samples were tested for iodine-129, and tritium has been infrequently measured. Tritium is primarily measured in water as it does not generally adsorb to sediments, and the few sediment samples of tritium were taken in pore spaces (Larry Hulstrom, WCH, personal communication November, 2011). Other target analytes, and all of the COEC/COPECs, were measured in tens to hundreds of samples depending on the database.

SUGGESTED FUTURE STUDIES

The above analyses suggest that several studies could support an injury assessment of Hanford sediments. These include (but are not necessarily limited to):

- Developing GIS maps and summary data tables showing contaminant levels by time period and location. Such maps and tables will provide a platform for discussing/exploring potential assumptions that might be agreed to by stakeholders to address gaps (and further refine primary data collection activities where agreement cannot be reached).
- Comparing contaminant levels in existing sediment samples to various sediment quality values. In such a study, sediment contaminant concentrations on Site would be compared against pertinent impact thresholds suggestive of the potential for adverse effects to benthic organisms or higher trophic level organisms to determine whether, from 1981 through the present, the definition of injury has been met.

- Assessing the toxicity of sediments to site biota or representative test organisms, in laboratory and/or field studies. (This topic is discussed in Chapter 5.)

For additional background and detail on these suggested future studies, please refer to the *Aquatic Resource Review Report* (Industrial Economics, Inc., November 9, 2011).

EXHIBIT 4-21 SUMMARY OF SEDIMENT DATA GAPS WITHIN EACH DATABASE

DATABASE	NO. SAMPLES	DEPTH DISTRIBUTION	SAMPLE TYPES	GEOGRAPHIC DISTRIBUTION	TEMPORAL DISTRIBUTION	SAMPLES PER ANALYTE
HEIS	1,238	Most samples (~90%) lack depth information. Of those with depth information, most are sub-surface samples (77%) ranging from 6 to over 72 inches deep, and only 20% are surficial samples ranging from 0 to 6 inches deep.	Sub-surface (77%), surface (20%), and pond (3%) samples.	About two-thirds of samples lack coordinates. Of those with coordinates, most are concentrated around the 100 and 300 Areas, but there are also samples along the Columbia River between these areas.	**<1981**: 0 **1981-2000**: 404 (36%) **>2000**: 726 (64%)	**No samples**: Carbon tetrachloride, I-129, TPH-diesel **Few (<25)**: Tritium **More (~50-500)**: Cr, CrVI, Hg, PCBs, Pu-238, Pu-239/240, Sr-90, Tc-99, U, U-233/234, U-235, U-238, Sb, As, Ba, B, Cd, Cu, dieldrin, Pb, Mn, Se, Zn **Most (>500)**: Cs-137
RCBRA / GiSdT	598	No depth information provided.	All discrete, nearshore samples.	Virtually all samples have coordinates. Samples are distributed throughout the Columbia River onsite.	**<1981**: 0 **1981-2000**: 231 (58%) **>2000**: 367 (42%)	**No samples**: Carbon tetrachloride, I-129 **Few (<25)**: Tritium, Tc-99, Pu-239, U-236 **More (~50-250):** PCBs, Cr, CrVI, Hg, Sr-90, Pu, U-233/234, U-238, Sb, As, Ba, B, Cd, Cu, dieldrin, Pb, Mn, Se, Zn, TPH-diesel **Most (>250)**: Cs-137 , U-235

DATABASE	NO. SAMPLES	DEPTH DISTRIBUTION	SAMPLE TYPES	GEOGRAPHIC DISTRIBUTION	TEMPORAL DISTRIBUTION	SAMPLES PER ANALYTE
2011 DSR	1,203	Most samples are surficial (74%), 14% are sub-surface samples ranging from one to 11 feet deep, and 12% lack depth information.	Media detail includes: core deep, core shallow, sd gw upwelling, sediment deep, sediment shallow, & sediment shoreline (~9% of samples lack media detail). River locations include: dam, island, left, right, slough, & tributary.	All samples have coordinates. Samples are distributed throughout the Columbia River onsite.	**<1981**: 0 **1981-2000**: 0 **>2000**: 1,203 (100%) All samples from 2008- 2010.	**No samples**: I-129 **Few (<25)**: Tritium **More** (>100-500): PCBs, carbon tetrachloride, Cs-137,Tc-99, TPH-diesel, dieldrin **Most (>500)**: Cs-137, Cr, CrVI, Hg, Pu-238, Pu-239/240, Sr-90, U, U-233/234, U-235, U-238, Sb, As, Ba, B, Cd, Cu, Pb, Mn, Se, Zn
CRC Historic	2,489	Most samples do not contain depth information (69%), 14% are sub-surface, and 18% are surficial samples.	93% of samples are blank or NA in samp_from field, 7% are sub-surface, and 0.3% are pond samples. 66% of samples are identified as grab, 21% core, 0.7% composite, and 13% blank in samp_type field (all samples with samp_type info are also blank or NA in samp_from field). 58 operational samples & 15 reference samples.	Nearly all (~99%) of samples have coordinates. Samples are distributed throughout the Columbia River onsite.	**<1981**: 587 (24%) **1981-2000**: 1,105 (44%) **>2000**: 778 (31%) 9 samples lack a date.	**No samples**: I-129 **Few (<65)**: B, carbon tetrachloride, CrVI, Tc-99, tritium, Pu-239, U-233/234, U-236, TPH-diesel **More (>200-800):** PCBs, Cr, Hg, Pu-238, Pu-239/240, Sr-90, U, U-234, U-235, U-238, Sb, As, Ba, Cd, Cu, dieldrin, Pb, Mn, Se, Zn **Most (>1,200)**: Cs-137

This page intentionally left blank.

CHAPTER 5 | BIOTA

This chapter provides a summary of data types most commonly relied upon in a NRDA for purposes of determining injury to biotic resources. The chapter begins by characterizing available information on the exposure of biota to contaminants, as indicated through measurements of contaminant concentrations in biotic tissues. Measurements of exposure are relevant both in establishing a complete pathway (as described in 43 CFR 11.63) from releases to receptors, and also because tissue measurements are frequently used as a basis for predicting the extent to which adverse effects may be occurring (e.g., in the context of a PED). Contaminant measurements also provide information relevant to ascertaining the likely causality of any documented injuries.

Subsequent sections in this chapter summarize the availability of natural history information for target species, the availability of information characterizing the sensitivity of target species to target contaminants, site-specific information including toxicity testing with site media, and site-specific field data, particularly data describing measures of species or community health. These types of information are relevant in determining injury in accordance with DOI's NRDA regulations (e.g., 43 CFR 11.62(f)(1)[59] and 11.62(f)(3)[60]).

This chapter concludes with a summary of the presented information, highlighting areas where information appears to be limited or absent.

EXPOSURE TO CONTAMINANTS

We assembled available information to identify data on the exposure of the target species to the target contaminants. Available sources of information include the following databases:

- Hanford Environmental Information System (HEIS);
- The River Corridor Baseline Risk Assessment database (RCBRA / GiSdT);
- The Columbia River Component (CRC) Historic database;

[59] This section states that an injury has occurred if the concentration of the hazardous substance is sufficient to "Cause the biological resource or its offspring to have undergone at least one of the following adverse changes in viability: death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions in reproduction), or physical deformities."

[60] This section states that "injury determination must be based upon the establishment of a statistically significant difference in the biological response between samples from populations in the assessment area and in the control area." Field-based measures of impact are therefore a critical component of injury determination.

- The 2011 Releases to the Columbia River Remedial Investigation Data Summary Report Database (DSR); and
- The Environmental Release Summary (ERS) database.

Because of the challenges associated with the partial overlap of information among the various databases, we evaluated information within each database separately, as described below. Appendix A provides maps of all biota sampling locations.

HANFORD ENVIRONMENTAL INFORMATION SYSTEM (HEIS)

Data Exploration

Evaluation of data from this source focused on those presented in the biota view (Webber 2010a), downloaded from HEIS on June 30, 2011. Because HEIS is frequently updated, later downloads of this view may include additional information.

The downloaded view included 275,526 records, comprising 16,237 unique sample numbers. This view does not contain a primary key; however, unique entries are primarily identifiable as combinations of the sample number ("SAMP_NUM") field and the contaminant field ("STD_CON_ID" or "STD_CON_LONG_NAME"). We identified two general exceptions to this rule, however: for algae samples, results are frequently presented in two measurement units (µg/L and µg/kg), each of which represents a unique record in the view. In addition, for certain contaminants including uranium, U-235, and U-238, samples were measured using more than one analytical method. For purposes of summarizing counts of samples, the record associated with the minimum measured value for the relevant sample/contaminant combination was retained.

Data Excluded from Analysis

We excluded from analysis all records for which the "SAMP_FROM" field had the value "QC_SAMPLE". We also excluded samples identified as laboratory replicates (i.e., those having a value of "R", "S", or "B" in the "LAB_QC_TYPE" field). This view did not contain any explicitly identified field replicates: all entries in the "FIELD_QC_TYPE" field were blank. We also excluded records that had no entry in the "STD_VALUE_RPTD" field (about 4.5 percent of all downloaded records). For purposes of tabulating numbers of records, data were not excluded based on laboratory QA/QC qualifiers.

After selecting data as described above, the resulting list of records is reduced from 275,526 to 260,491, representing 15,941 unique samples. [61]

[61] Multiple sample numbers can apply to a volume of material collected from a single sampling event (i.e., a single point in space and time) (Bill Webber, CH2M HILL Plateau Remediation Company, personal communication). Different samples (as indicated by possessing different "SAMPLE_ID" values) were sometimes subject to analysis for different analytes. Overall, of the 15,941 screened samples, roughly 54% are associated with a unique location ("SAMP_SITE_ID") and date/time.

EXHIBIT 5-1 COUNT OF SAMPLE NUMBERS BY BIOTIC TYPE IN HEIS

BIOTA	NO. SAMPLES	BIOTA	NO. SAMPLES
COW	3,454	POTATO	145
WHITEFISH	980	ASPARAGUS	140
PERENNIAL VEGETATION	692	GREAT BASIN POCKET MOUSE	119
CORBICULA	620	QUAIL	118
MULE DEER	551	CURRENT YRS GROWTH	112
BASS	498	ELK	109
CARP	492	CHERRIES	102
MALLARD	466	CLAMS	100
CANADA GOOSE	404	LIZARD	96
COTTONTAIL RABBIT	388	MILFOIL	96
PHEASANT	372	MICE	92
LEAFY VEGETABLES	344	DEER MOUSE	88
TEAL, GREEN WINGED	310	MULBERRY	73
STURGEON	299	CRAYFISH	73
CHICKEN	284	ALGAE	62
ALFALFA	280	TERRESTRIAL	61
JACK RABBIT	280	RUSSIAN THISTLE	60
WINE	278	GOOSE-LESSER CANADIAN	54
REED CANARY GRASS	270	TOMATO	52
SUCKER	269	INVERTEBRATE	50
MOUSE	265	HOUSE MOUSE	43
SCULPIN	245	OYSTERS	42
WHITE MULBERRY	198	WILLOW	41
APPLES	191	CHEATGRASS	40
MISC VEGETATION	172	ALLIUM	31
WHEAT	170		

Data Analysis

HEIS contains samples from 144 types of biota, as listed in the "SAMP_FROM" field. Exhibit 5-1 lists the number of samples associated with each type. For the sake of brevity, only those biota types with at least 30 samples are included in this exhibit. Biota types are listed exactly as they appear in HEIS.

We focused further analyses on the subset of records that represented measurements in the target species. Of the 12 target species, seven appear in HEIS. HEIS also includes two biota categories—FROG and MUSSEL—that are the closest available match to the target species of bullfrog, Pacific treefrog, and pearlshell mussel.[62]

As can be seen in Exhibit 5-2, by far the most frequently sampled target species in HEIS are the sculpin, sturgeon, jack rabbit, and cottontail rabbit with approximately 250-400 samples each.[63] Other target species have been sampled 20 or fewer times—in several cases, five or fewer times.

As shown in Exhibits 5-2 and 5-3, for most of the target analytes, at least one measurement has been made in six or seven of the target biota. Plutonium, however, has only been sampled in the cottontail rabbit and jack rabbit; tritium has been sampled once in a sculpin, and PCBs have been sampled only in mussels and sculpin. In addition, of the target species, boron and dieldrin have been sampled only in mussels, sculpin, and sturgeon.[64]

Overall, HEIS contains data for 460 distinct analytes in biota. If one groups all individual PCB congener measurements and Aroclors under the broader umbrella of "PCBs", this number decreases to 243. (This figure includes different radionuclides individually—e.g., thorium, thorium-228, -230, -232, and 234 count as five analytes). Of these 243 analytes, 164 have been analyzed in at least one of the target species. Exhibit 5-4 illustrates the number of different analytes measured in at least one sample of a given biotic type. In the target biota, the ten most frequently measured analytes in decreasing order are: potassium-40, strontium-90, cesium-137, cobalt-60, zinc-65, cadmium, chromium, lead, nickel, and selenium.

[62] These species do not appear in Exhibit 5-1 because there are fewer than 30 samples of each type; however, they are included in subsequent exhibits.
[63] These values represent the number of distinct physical samples in the database. The number of organisms sampled may be smaller to the extent that samples of different tissues were taken from the same organism.
[64] There may be additional PCB data collected by PNNL as part of the BC Pilot study report, which was not entered into HEIS (Ted Poston, PNNL, personal communication).

EXHIBIT 5-2 COUNT OF SAMPLES BY TARGET SPECIES AND PROFILED TARGET ANALYTE IN HEIS

TARGET BIOTA	TOTAL NO. SAMPLES (any analyte)	Cs-137	Cr / CrVI	Hg	PCBs*	Pu	Pu-238	Pu-239/240	Sr-90	Tc-99	Tritium	U	U-233/264	U-235	U-238
BULRUSH	**3**	3	3 / 0	3					3	3		3			
CADDISFLY	**20**	2	13 / 0	13					6	4		9			
COTTONTAIL RABBIT	**388**	163	24 / 0	13		9	77	77	148			29			
FROG	**4**		4 / 0	4								4			
JACK RABBIT	**280**	104				20	57	57	104						
MUSSEL	**18**		9 / 0	9	9					1		9	9	9	9
SALMON	**5**	5							1						
SCULPIN	**245**	12	174 / 0	168	42				41	39		169	36	36	36
STURGEON	**299**	3	126 / 66	138	93		126	126	2	126	126	126	126	126	126
No. Target Biota Types Sampled	**9**	**7**	**6**	**6**	**3**	**2**	**3**	**3**	**7**	**5**	**1**	**7**	**3**	**3**	**3**

*Some samples are Aroclor-based and some provide congener-specific information. Sculpin were sampled using both types of measurements. For each species, the highest number of samples, whether Aroclor- or congener-based, is presented.

EXHIBIT 5-3 COUNT OF SAMPLES BY TARGET SPECIES AND COEC/COPEC[65] IN HEIS

TARGET BIOTA	TOTAL NO. SAMPLES (any analyte)	Sb	As	Ba	Bo	Cd	Cu	Dieldrin	Pb	Mn	Se	TPH-Diesel	Zn
BULRUSH	**3**	3	3	3		3	3		3	3	3	3	3
CADDISFLY	**20**	13	13	9		13	13		13	9	13	13	13
COTTONTAIL RABBIT	**388**	24	24	8		24	24		24	24	24	24	24
FROG	**4**	4	4			4	4		4	4	4	4	4
MUSSEL	**18**	9	9	9	9	9	9	8	9	9	9	9	9
SCULPIN	**245**	171	171	169	108	174	165	35	174	169	174	171	171
STURGEON	**299**	126	126	126	126	126	126	126	126	126	126	126	126
No. Target Biota Types Sampled	**7**	**7**	**7**	**6**	**3**	**7**	**7**	**3**	**7**	**7**	**7**	**7**	**7**

[65] The depicted analytes represent COECs from the River Corridor Baseline Risk Assessment (DOE 2011b) and COPECs from the Columbia River Component Screening-Level Ecological Risk Assessment (DOE 2011a). Counts for COECs/COPECs previously presented in Exhibit 5-2 are not repeated here.

EXHIBIT 5-4 COUNT OF ANALYTES MEASURED IN TARGET BIOTA FROM HEIS

TARGET BIOTA	COUNT OF ANALYTES*
BULRUSH	49
CADDISFLY	30
COTTONTAIL RABBIT	38
FROG	17
JACK RABBIT	21
MUSSEL	146
SALMON	14
SCULPIN	146
STURGEON	56
*PCBs are considered to be a single analyte for purposes of this table.	

Different tissues were collected from different biota. Exhibit 5-5 lists, for the targeted species, the tissue types for which contaminant information is available in HEIS.

EXHIBIT 5-5 TISSUE TYPES COLLECTED IN HEIS BIOTA DATA

TARGET BIOTA	TISSUE TYPES
BULRUSH	Stems/leaves (3)
CADDISFLY	Whole (20)
COTTONTAIL RABBIT	Muscle (145), liver (106), bone (137)
FROG	Whole (4)
JACK RABBIT	Muscle (105), liver (77), bone (98)
MUSSEL	Multiple shell (9), multiple soft tissue (9)
SALMON	Muscle (5)
SCULPIN	Whole (18), multiple whole organism (66), liver composite (35), kidney composite (35), individual liver (57), carcass (34)
STURGEON	Carcass (95), fillet (95), kidney (30), liver (57), muscle (4), viscera (18)
Numbers in parentheses refer to counts of unique sample numbers.	

We also investigated the number of samples taken as a function of species and timeframe. Exhibit 5-6 presents the results.

EXHIBIT 5-6 NUMBER OF BIOTA SAMPLES IN HEIS BY ORGANISM TYPE AND TIMEFRAME

TARGET BIOTA	TOTAL NO. SAMPLES*	TOTAL NO. SAMPLES WITH COORDINATES	NO. SAMPLING LOCATIONS	<1981	1981-2000	>2000
BULRUSH	**3**	3	3		3	
CADDISFLY	**20**				4	16
COTTONTAIL RABBIT	**388**	8	1	47	243	98
FROG	**4**					4
JACK RABBIT	**280**			70	210	
MUSSEL	**18**	18	9			18
SALMON	**5**			3	2	
SCULPIN	**245**	139	30		7	238
STURGEON	**299**	295	30	4		295
No. Target Biota Types Sampled	**9**	**5**	**5**	**4**	**6**	**6**
*Because more than one tissue may have been sampled from a given organism, the number of organisms (or composites) sampled may be lower than the number of samples shown in this table.						

Of note, not all of the data summarized above may be suitable for use in the natural resource damage assessment. Many records lack key information. For example, of the 15,941 screened unique sample numbers, 12,403 (79 percent) lack geographic coordinate information. A number of other fields are available, some of which do provide general locational information. For instance, the screened samples reflect 333 "SAMP_SITE_ID" values, and all samples include an entry in this field. Of these 333 "SAMP_SITE_ID" values, all but ten have a descriptive information in the "SAMP_SITE_NAME" field: example entries here include "100 AREA FIRE STAT", "100 D AREA-RIVER", "100 B/CAREA OUTFL1", "EVA HALL FARM", "FFTF CP 62", "CONTROL BASKET 3", and "NORTHEAST". It may be possible, particularly in coordination with the identified record owner—i.e., the Hanford contractor that owns the sample record and is responsible for the sample and its attributes[66]—to obtain more information on interpreting entries in locational descriptive fields, and estimating coordinates.

It is noted that in some cases even where coordinates are included in HEIS, they may have been estimated: the COORD_SOURCE field (not included in the views provided to IEc) lists "the source of the coordinates for a sampling site."[67] Acceptable entries in this field are restricted to: "ESTIMATED, ""GPS", "HGIS", "MATH_TRANS", "MEASURED", and "SURVEYED". We also note that for mobile biota, the

[66] See HEIS documentation appertaining to the "SAMPLE" table, version 11/15/2007.
[67] See HEIS documentation appertaining to the "SAMPLING_SITE" table, version 5/18/2001.

capture coordinates represent a snapshot in time of the specific area used by the organism. Depending on the species, its habitat requirements, and life history, it may make use of smaller or larger area in the vicinity of its point of capture.

Exhibit 5-6 lists the numbers of samples by biota type for which specific coordinate information is presently available. In addition, of the 269,873 retained records, 9,382 (3.5 percent) have no entry in the result field ("STD_VALUE_RPTD"). Finally, some data are qualified, and the Trustees may wish to reject data with specific qualifiers, or for other reasons.

Geographic Distribution

We evaluated the distribution of sampling locations for which latitude and longitude information is available. Sculpin, sturgeon, and mussel sampling locations are relatively evenly distributed throughout the Hanford Reach. The distribution of locations for other target species is more limited. Appendix A contains maps of biota sample locations.

RIVER CORRIDOR BASELINE RISK ASSESSMENT DATABASE (RCBRA / GiSdT)

Contaminant Data Exploration

Evaluation of data from this source focused on the biota table as downloaded from the RCBRA data management website (http://rcbra.neptuneinc.org/rcbra/home/index.xml). The downloaded data included 98,071 records, comprising 6,607 unique sample numbers. Individual sample IDs represent unique tissue samples. The table's primary key can be based on the sample ID and contaminant ID fields ("sample_id" and "gisdt_std_con_id"). Appendix C-1 in DOE (2010b) describes the development of this database.

Contaminant Data Excluded from Analysis

Laboratory duplicates, identified as those samples with an "R" entry in "lab_qc_type" field, were excluded. There were no apparent field QA/QC samples, inasmuch as all entries in the "field_qc_type" column were blank.[68] For purposes of tabulating numbers of records, data were not excluded based on laboratory, validation, or review qualifiers.

Data Analysis

This database contains samples from 61 types of biota, as listed in the "gisdt_biota_media_type" field. Exhibit 5-7 lists the number of samples associated with each type. For the sake of brevity, only those biota types with at least 10 samples are included in this exhibit.

We focused further analyses on the subset of records that represented measurements in the target species. In some cases, the species was not specified but a more general class of organism was (e.g., FROG or MUSSEL), and we included those records in our analysis. Exhibit 5-8 presents the results. As can be seen, the target species with the greatest number of samples are the sculpin (282), and juvenile salmon (164). There are 36 cottontail rabbit samples; other target biota have fewer than 25 samples.

---

[68] This type of sample is most applicable to environmental media samples (e.g., sediments, soils, water).

Exhibits 5-8 and 5-9 also shows the number of samples in target species analyzed for target analytes. Antimony, arsenic, cadmium, cesium-137, chromium, copper, lead, manganese, mercury, selenium, TPH-diesel, strontium-90, uranium, and zinc have been measured in five or more of the target species. No target species were analyzed for hexavalent chromium, carbon tetrachloride, iodine-129, or tritium. Other target analytes were measured in two to three target species.

EXHIBIT 5-7 COUNT OF SAMPLE NUMBERS BY BIOTIC TYPE IN THE RCBRA DATABASE

BIOTA	NO. SAMPLES	BIOTA	NO. SAMPLES
TERRESTRIAL VEGETATION	2,702	RUSSIAN THISTLE	46
CLAM	758	SHRUB DOM	45
SCULPIN	282	JUV SUCKER	38
WHITEFISH	250	PERIPHYTON	38
CARP	246	COTTONTAIL RABBIT	36
MOUSE	242	MULE DEER	36
BASS	204	HOUSE MOUSE	34
JUV SALMON	164	AQUATIC MACROINVERTEBRATE	28
TERRESTRIAL INVERTEBRATE	152	CHEATGRASS	27
SUCKER	140	STEELHEAD	23
PERENNIAL VEGETATION	119	CLIFF SWALLOW JUV	22
LIZARD	94	GREAT BASIN POCKET MOUSE	22
CRAYFISH	91	MUSSEL	22
DEER MOUSE	87	EASTERN KINGBIRD JUV	19
REED CANARYGRASS	87	CADDISFLIES	16
PHEASANT	81	ELK	15
MULBERRY	73	SALMON	14
MILFOIL	70	TREE DOM	11
CANADA GOOSE	67	WESTERN KINGBIRD JUV	11
GRASS DOM	56	GRAY RABBITBRUSH	10
QUAIL	47		

EXHIBIT 5-8 COUNT OF SAMPLES BY TARGET SPECIES AND PROFILED TARGET ANALYTES IN THE RCBRA DATABASE

TARGET BIOTA	TOTAL NO. SAMPLES (any analyte)	Cs-137	Cr*	Hg	Pu-238	Pu-239/240	Sr-90	Tc-99	PCBs**	U (inorganic)	U-233/234	U-235	U-238	Calc. Total U
CADDISFLIES	16	2	9	9			6	4		9				
COTTONTAIL RABBIT	36	11	8	2	6	6	11			8				
FROG	4		4	4						4				
JUV SALMON	164		164							164				
MUSSEL	22	9	12	9			19	2	0 / 9	9	9	9	9	9
SALMON	14	7					7							
SCULPIN	282	46	186	180			69	34	18 / 73	193	35	37	35	35
STURGEON	7	7			6		7							
No. Target Biota Types Sampled	**8**	**6**	**6**	**5**	**2**	**1**	**6**	**3**	**2**	**6**	**2**	**2**	**2**	**2**

* These measurements are for "chromium"; this database does not contain measurements of hexavalent chromium specifically in biota.

** This database contains multiple different contaminant IDs for PCBs, including individual congeners, Aroclors, and "total PCBs." The first value represents the number of samples for which a listed "total PCBs" value is available, and the second lists the number of samples for which at least one PCB congener or Aroclor measurement is available.

EXHIBIT 5-9 COUNT OF SAMPLES BY TARGET SPECIES AND COEC/COPEC[69] IN THE RCBRA DATABASE

TARGET BIOTA	TOTAL NO. SAMPLES (any analyte)	Sb	As	Ba	Bo	Cd	Cu	Dieldrin	Pb	Mn	Se	TPH-Diesel	Zn
CADDISFLIES	16	7	7	9		9	7		9	9	9	7	7
COTTONTAIL RABBIT	36	8	8			8	8		8	8	8	8	8
FROG	4	4	4			4	4		4	4	4	4	4
JUV SALMON	164	30	30			30	30		30	30	30	30	30
MUSSEL	22	12	12	9	9	12	12	8	12	9	12	12	12
SCULPIN	282	176	176	169	108	186	170	35	186	181	186	176	176
No. Target Biota Types Sampled	**6**	**6**	**6**	**3**	**2**	**6**	**6**	**2**	**6**	**6**	**6**	**6**	**6**

[69] The depicted analytes represent COECs from the River Corridor Baseline Risk Assessment (DOE 2011b) and COPECs from the Columbia River Component Screening-Level Ecological Risk Assessment (DOE 2011a). Counts for COECs/COPECs previously presented in Exhibit 5-8 are not repeated here.

Different tissues were collected from different biota. Exhibit 5-10 lists, for the targeted species, the tissue types for which contaminant information is available in the RCBRA database.

EXHIBIT 5-10 TISSUE TYPES COLLECTED IN THE RCBRA DATABASE

BIOTA	TISSUE TYPES
CADDISFLIES	Whole organism (16)
COTTONTAIL RABBIT	Bones (11), liver (14), muscle (11)
FROG	Whole organism (4)
JUV SALMON	Whole organism (164)
MUSSEL	Multiple shell (9), multiple soft (9), shells (1), soft (3)
SALMON	Fillet (14)
SCULPIN	Bone (11), carcass (22), composite (1), kidney (1), liver (70), multiple kidney (35), multiple liver (35), multiple whole (66), offal (8), whole organism (33)
STURGEON	Not specified (7)
Numbers in parentheses refer to numbers of samples.	

We also investigated the number of samples taken as a function of species and timeframe. Exhibit 5-11 presents the results. Not surprisingly, given the purposes for which this database was assembled, the large majority of the data appertain to the most recent time period.

EXHIBIT 5-11 NUMBER OF BIOTA SAMPLES IN THE RCBRA GISDT DATABASE BY ORGANISM TYPE AND TIMEFRAME

BIOTA	TOTAL NO. SAMPLES	No Date	1981-2000	>2000
CADDISFLIES	16			16
COTTONTAIL RABBIT	36		2	34
FROG	4			4
JUV SALMON	164			164
MUSSEL	22			22
SALMON	14		14	
SCULPIN	282	2	5	275
STURGEON	7		7	
No. Target Biota Types Sampled	**8**	**1**	**4**	**6**
Note: No data are available for years before 1981.				

Of note, not all of the data summarized above may be suitable for use in the natural resource damage assessment. Some data are qualified, and the Trustees may wish to reject data with specific qualifiers. All records, however, do have sample coordinates.

Geographic Distribution

Sculpin and mussel sampling locations are distributed throughout the Hanford Reach. The distribution of sampling locations for other target species is more limited. For example, salmon collection locations are adjacent to the 100K, 100D, and 100H Areas, as well as one general area approximately three miles north of the 300 Area. Cottontail rabbits were sampled near 100N, 200E, the 300 Area, and offsite at a location north of the Yakima River. Caddisflies were sampled at 100BC and a more upstream location. The sturgeon samples are from a single location. Appendix A contains maps of biota sampling locations.

COLUMBIA RIVER COMPONENT (CRC) HISTORIC DATABASE

Data Exploration

This database contains a “RESULT_DATA” table and a “SAMPLE_DATA” table. Sample-specific information is contained in the “SAMPLE_DATA” table, which has 22,695 records, of which 10,166 are for biota (identified as having “BI” in the media field). All tables in this database include primary keys, as documented in the data table file named “CRC_database_component data entities updatedWC_06022008.doc”. In the “SAMPLE_DATA” table, the primary key consists of the source title, publication date, and sample number fields. Listed biota sample types include discrete samples, composites, and grabs. The “RESULT_DATA” table includes 306,931 records spanning multiple media. Overall, there are 120,042 biota records associated with the 10,166 biota samples.

It is worth noting that there appears to be some duplication of data within this database (e.g. “SAMP_NUM” entries B1B376 and B19W88). In particular, these “SAMP_NUM” values appear more than once in the “SAMPLE_DATA” table but are associated with different source documents. For example, one record may be associated with an annual site environmental report, while another is associated with a different source. We suspect these entries represent the same sample, given the identical sampling dates and analytical results, even though the sample location coordinates are not always identical. We have assumed that these are indeed the same samples and have eliminated the apparent duplication in presenting the count data in this report.

Data Excluded from Analysis

Samples identified as duplicates (identified as having “DUP” in the “DUP” field) were excluded. We excluded any samples with a value other than null or NA in the “GiSdT_lab_qc_type” and “GiSdT_field_qc_type” fields. We also exclude records for which there is no lab result value reported (indicated by no value in the “WC_STD_VALUE_RPTD” field).

Algae samples were also excluded from consideration, because a number of samples (likely the same samples also present in HEIS) were analyzed for the same contaminant by different labs using different measurement units, and this "duplication" made query construction significantly more complex.

For purposes of tabulating numbers of records, data were not excluded based on laboratory, review, or validation qualifiers. QA/QC samples, if present, were not clearly identifiable.

Data Analysis

This database includes information on samples from 153 biota types, as listed in the "SAMP_FROM" field. Of note, not all entries have corresponding values in the "RESULT_DATA" table. Exhibit 5-12 lists the number of samples associated with each biota type. For the sake of brevity, only those biota types with at least 30 samples are included in this exhibit. Biota types are listed exactly as they appear in the database.

We focused further analyses on the subset of records that represented measurements in the target species. Of the 12 target species, six appear in the CRC historic database. . This database also includes several biota categories—FROG, MUSSEL, and Mussels—that are the closest available match to the target species of bullfrog, Pacific treefrog, and pearlshell mussel. All samples from these target species have geographic coordinates. (Of note, a small number of other biota samples in this database lack coordinates.)

EXHIBIT 5-12 COUNT OF SAMPLE NUMBERS WITH RESULTS BY BIOTIC TYPE IN THE CRC HISTORICAL DATABASE

BIOTA	NO. SAMPLES	BIOTA	NO. SAMPLES
Whitefish	806	CLAM	72
Carp	400	Milfoil	69
Waterfowl-Mallard	343	Vegetation	69
Bass	314	Crayfish	66
Canada goose	313	Sturgeon	63
Perennial Vegetation	312	Largescale sucker	62
Reed Canary Grass	234	Chinook salmon	61
SCULPIN	205	Steelhead	59
White Mulberry	198	Salmon	57
Asiatic Clam	198	TERRESTRIAL INVERTEBRATE	54
Sucker	180	Willow	51
Juvenile Chinook Salmon	164	Lesser Canada goose	51
CORBICULA	138	MULE DEER	44
Mulberry	131	Oyster	42
Fish	125	QUAIL	38
Waterfowl-Green-winged Teal	117	COTTONTAIL RABBIT	38
MOUSE	94	Mountain whitefish	36
MISC VEGETATION	92	Northern squawfish	34

Exhibits 5-13 and 5-14 show the number of samples in target species analyzed for target analytes. Antimony, arsenic, cadmium, cesium-137, chromium, copper, lead, manganese, mercury, selenium, TPH-diesel, uranium, and zinc have been measured in seven or more of the target species. No target species were analyzed for hexavalent chromium, carbon tetrachloride, iodine-129, or tritium.

EXHIBIT 5-13 COUNT OF SAMPLES BY TARGET SPECIES AND PROFILED TARGET ANALYTE IN THE CRC HISTORIC DATABASE

TARGET BIOTA	TOTAL NO. SAMPLES (any analyte)	Cs-137	Cr*	Hg	PCBs**	Pu-238	Pu-239/240	Sr-90	Tc-99	U	U-233/234	U-234	U-235	U-238
Caddisfly	21	4	14	10				6		4				
Chinook salmon	61	8	53	53	53									
COTTONTAIL RABBIT	38	10	12	2		6	6	10		12				
FROG	4		4	4						4				
Juvenile Chinook Salmon	164		16							164				
MUSSEL	18	9	9	9	9				1	9	9		9	9
Mussels	1				1									
Pacific lamprey	12		12	12	12									
SCULPIN	205	46	164	158	39			60	34	159	10	25	35	35
Sturgeon	63	62				42	42	58		1		1		1
White sturgeon	25		24	24	24									
No. Target Biota Types Sampled	**8**	**8**	**8**	**8**	**5**	**2**	**2**	**4**	**2**	**7**	**2**	**2**	**2**	**3**

* No target biota were specifically analyzed for hexavalent chromium.

** Measured as Aroclors. For some samples, congener information is also available.

EXHIBIT 5-14 COUNT OF SAMPLES BY TARGET SPECIES AND COEC/COPEC[70] IN THE CRC HISTORIC DATABASE

TARGET BIOTA	TOTAL NO. SAMPLES (any analyte)	Sb	As	Ba	Bo	Cd	Cu	Dieldrin	Pb	Mn	Se	TPH-Diesel	Zn
Caddisfly	21	8	10	6	2	14	14		14	9	10	14	8
Chinook salmon	61	53	53	53		53	53		53	53	53	53	53
COTTONTAIL RABBIT	38	12	12			12	12		12	12	12	12	12
FROG	4	4	4			4	4		4	4	4	4	4
Juvenile Chinook Salmon	164	30	30			30	30		30	30	30	30	30
MUSSEL	18	9	9	9	9	9	9	8	9	9	9	9	9
Mussels	1							1					
Pacific lamprey	12	12	12	12		12	12		12	12	12	12	12
SCULPIN	205	161	161	159	101	164	161	35	164	159	164	161	161
White sturgeon	25	24	24	24		24	24		24	24	24	24	24
No. Target Biota Types Sampled	**8**	**8**	**8**	**6**	**3**	**8**	**8**	**2**	**8**	**8**	**8**	**8**	**8**

[70] The depicted analytes represent COECs from the River Corridor Baseline Risk Assessment (DOE 2011b) and COPECs from the Columbia River Component Screening-Level Ecological Risk Assessment (DOE 2011a). Counts for COECs/COPECs previously presented in Exhibit 5-13 are not repeated here.

Different tissues were collected from different biota. Exhibit 5-15 lists, for the collected species, the tissue types for which contaminant information is available in the CRC Historic database.

EXHIBIT 5-15 TISSUE TYPES COLLECTED IN THE CRC HISTORIC DATABASE

BIOTA	NUMBER OF SAMPLES BY TISSUE TYPE
Caddisfly	Whole (21)
Chinook salmon	Eggs/ovum (4), fillet (8), fillet, skin on (25), whole body (24)
Cottontail rabbit	Bones (10), liver (18), muscle (10)
Frog	Whole (4)
Juvenile Chinook salmon	Whole (164)
Mussel	Multiple shell (10), multiple soft tissue (8), NA (1)
Pacific lamprey	Fillet, skin on (3), whole body (9)
Sculpin	Carcass (18), kidney (34), liver (86), multiple whole (14), whole body (27)
White sturgeon	Fillet (6), NA (57), fillet, skin off (17), whole body (8)
Numbers in parentheses refer to counts of unique sample numbers.	

We also investigated the number of samples taken as a function of species and timeframe. Exhibit 5-16 presents the results.

Of note, not all of the data summarized above may be suitable for use in the natural resource damage assessment. Some data are qualified, and the Trustees may wish to reject data with specific qualifiers. All records of target species, however, do have sample coordinates. Overall, only 35 of the 10,166 biota records in "SAMPLE_TABLE" lack geographic coordinates. Although no site descriptive information is found in the "SAMP_AREA", "GenArea", "River_Area", or "GiSdT_site_type" fields, the "SAMP_SITE" field is populated with general descriptive information (e.g., "200 Areas").

EXHIBIT 5-16 NUMBER OF BIOTA SAMPLES IN THE CRC HISTORIC DATABASE BY ORGANISM TYPE AND TIMEFRAME

BIOTA	TOTAL NO. SAMPLES	<1981	1981-2000	>2000
Caddisfly	21	0	13	8
Chinook salmon	61	0	61	0
Cottontail Rabbit	38*	0	0	34
FROG	4	0	0	4
Juvenile Chinook Salmon	164	0	0	164
MUSSEL	18	0	0	18
Mussels	1	0	1	0
Pacific lamprey	12	0	12	0
Sculpin	205	0	7	198
Sturgeon	63	4	59	0
White sturgeon	25	0	25	0
No. Target Biota Types Sampled	**8**	**1**	**6**	**6**
* Four of these samples lack date information.				

Geographic Distribution

A number of sampling locations in this database are outside of the Hanford Site, including many of the sturgeon and salmon locations, all the Pacific lamprey locations, and some sampling locations for other species (cottontail rabbit, caddisfly, sculpin).

Of the onsite locations, those for sculpin and mussels are relatively evenly distributed throughout the Hanford Reach, while locations for other groups are limited to specific areas. Appendix A contains maps of biota sampling locations.

2011 RELEASES TO THE COLUMBIA RIVER RI DATA SUMMARY REPORT (DSR) DATABASE

Data Exploration

The original table in this database includes 223,465 records spanning multiple media. This table does not contain a primary key; however, unique entries are primarily identifiable as combinations of the sample number (“samp_num”) field and the contaminant field (“con_id”). However, as was the case in HEIS, certain contaminants were measured using more than one analytical method. For purposes of summarizing counts of samples, the record associated with the minimum measured value for the relevant sample/contaminant combination was retained. Consequently, the primary key consists of the “samp_num”, “con_id”, and “method” fields.

Overall, there are 1,014 biota samples (identified as having "BI" value in the media field) in this database, and these represent 134 fish composites. Composites were subsampled, with different samples being subject to different sets of chemical analyses. A spot-check comparisons of sturgeon data in this database with those in HEIS suggested that this information may now have been incorporated into HEIS.

Data Excluded from Analysis

No data were excluded. The dataset already excludes duplicates, replicates, and blanks (Appendix O Data Summary Report – Data Users Guide.xls). For purposes of tabulating numbers of records, data were not excluded based on laboratory, review, or validation qualifiers.

Data Analysis

This database contains samples from six fish species, as listed in the "samp_from" field. Composites are identified in the "designation" field. We focused further analyses on the subset of records that represented measurements for the target analytes. Only one of the six fish species is a target species for purposes of this report; however, because the number of species is small in this database, data are presented for all six (Exhibits 5-17 and 5-18). No samples were analyzed for carbon tetrachloride, iodine-129, or tritium. Otherwise, virtually all samples were analyzed for all target analytes.

Different tissues were collected from different biota. Exhibit 5-19 lists, for the collected species, the tissue types for which contaminant information is available in the DSR database. All these samples were collected between 2009 and 2010.

Not all of the data summarized above may be suitable for use in the natural resource damage assessment. Some data are qualified, and the Trustees may wish to reject data with specific qualifiers. All records, however, do have sample coordinates.

EXHIBIT 5-17 COUNT OF FISH COMPOSITES BY TARGET SPECIES AND PROFILED TARGET ANALYTE IN THE DSR DATABASE

SPECIES	TOTAL NO. COMPOSISTES	Cs-137	Cr / CrVI	Hg	Pu-238	Pu-239/240	Sr-90	Tc-99	Total PCBs*	U	U-233/234	U-235	U-238
BASS	20	20	20 / 0	20	20	20	20	20	20	20	20	20	20
CARP	20	20	20 / 0	20	20	20	20	20	19	20	20	20	20
STURGEON	30	30	30 / 30	30	30	30	30	30	30	30	30	30	30
SUCKER	20	20	20 / 0	20	20	20	20	20	20	20	20	20	20
WALLEYE	23	23	23 / 0	23	23	23	23	23	23	23	23	23	23
WHITEFISH	21	21	21 / 0	21	21	21	21	21	21	21	21	21	21

* Congener data are also available for these samples.

EXHIBIT 5-18 COUNT OF SAMPLES BY TARGET SPECIES AND COEC/COPEC[71] IN THE DSR RESULTS DATABASE

TARGET BIOTA	TOTAL NO. SAMPLES (any analyte)	Sb	As	Ba	Bo	Cd	Cu	Dieldrin	Pb	Mn	Se	TPH-Diesel	Zn
BASS	20	20	20	20	20	20	20	20	20	20	20	20	20
CARP	20	20	20	20	20	20	20	20	20	20	20	20	20
STURGEON	30	30	30	30	30	30	30	30	30	30	30	30	30
SUCKER	20	20	20	20	20	20	20	20	20	20	20	20	20
WALLEYE	23	23	23	23	23	23	23	23	23	23	23	23	23
WHITEFISH	21	21	21	21	21	21	21	21	21	21	21	21	21
No. Target Biota Types Sampled	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**6**

[71] The depicted analytes represent COECs from the River Corridor Baseline Risk Assessment (DOE 2011b) and COPECs from the Columbia River Component Screening-Level Ecological Risk Assessment (DOE 2011a). Counts for COECs/COPECs previously presented in Exhibit 5-17 are not repeated here.

EXHIBIT 5-19 TISSUE TYPES COLLECTED IN THE DSR DATABASE

BIOTA	TISSUE TYPES
BASS	Carcass (20), fillet (20), liver/kidney (20)
CARP	Carp (19), fillet (19), kidney (19), liver (19)
STURGEON	Carcass (30), fillet (30), kidney (30), liver (30), viscera (6)
SUCKER	Carcass (20), fillet (20), liver/kidney (20)
WALLEYE	Carcass (23), fillet (23), liver/kidney (22)
WHITEFISH	Carcass (21), fillet (21), liver/kidney (21)
Numbers in parentheses refer to counts of composites in which the tissue was sampled. Note that multiple samples were taken from a tissue composite and subject to different chemical analyses.	

Geographic Distribution

Sturgeon sampling locations include locations upstream and downstream of the Hanford Reach as well as a number of locations within the Hanford reach, from the 100K area downstream to a location slightly north of the 300 Area. Appendix A contains maps of biota sampling locations.

ENVIRONMENTAL RELEASE SUMMARY (ERS) DATABASE

This database stores data from the Near-Fields environmental monitoring program. Although IEc does not have access to ERS in its entirety, we requested and were provided with Excel-based extracts that reflect the results of vegetative sampling. Replicate samples (indicated in the "File Title" field of the audit report for this database) were excluded from this analysis.

Nearly all of the 1,119 samples are rabbit brush or sage brush; about five percent of samples are Indian rye grass. The tissue type for all samples is new growth leaf cuttings. Over 97 percent of the samples have geographic coordinates. Of note, a number of the results are associated with a laboratory qualifier (U) indicating that the analyte was not detected. Detection limits are not provided in the database; however, the laboratory's statement of work includes minimum detectable concentration criteria by analyte. Exhibit 5-20 shows the number of vegetative samples analyzed by radioisotope and time period.

EXHIBIT 5-20 COUNT OF VEGETATIVE SAMPLES BY RADIOISOTOPE AND TIME PERIOD IN THE ERS DATABASE

RADIOISOTOPE	<1981	1981-2000	>2000	TOTAL
Ce-144	0	280	621	901
Co-60	0	434	621	1,055
Cs-134	0	423	621	1,044
Cs-137	0	434	621	1,055
Eu-152	0	280	621	901
Eu-154	0	434	621	1,055
Eu-155	0	433	621	1,054
K-40	0	73	2	75
Pu-238	0	433	621	1,054
Pu-239/240	0	432	621	1,053
Ru-103	0	280	621	901
Ru-106	0	280	621	901
Sb-125	0	280	621	901
Sn-113	0	280	621	901
Sr-90	0	434	621	1,055
U-234	0	434	621	1,055
U-235	0	432	621	1,053
U-238	0	434	621	1,055
Zn-65t	0	280	621	901

TARGET SPECIES AT HANFORD

IEc developed a series of twelve profiles on target species selected by the HNRTC. These profiles included information on the species' life history and status at Hanford as well as a summary of available site-specific studies on the species, among other information. Exhibit 5-21 provides a thumbnail summary of this information, intended to highlight general areas where relatively more or less information is available. The profiles themselves may be consulted for further specifics.

EXHIBIT 5-21 SUMMARY OF NATURAL HISTORY INFORMATION AVAILABILITY FOR TARGET SPECIES[72]

SPECIES / SPECIES GROUP	SITE USE PATTERNS	ONSITE ABUNDANCE	REPRODUCTION & LIFE HISTORY	DIET / PREDATION	HUMAN USE	HANFORD-SPECIFIC HEALTH STUDIES
Black-tailed jackrabbit	Low[1]	Low[1]	High	High	Moderate	Low
Bullfrog	Low	Moderate	High	Moderate	Moderate	None
Bulrush	Low	Moderate	Moderate	N/A	High	None
Caddisfly	Low	Low	Moderate	Moderate	Low	Low
Chinook salmon	High	High	High	High	High	Moderate
Great blue heron	High	Moderate	High	Moderate	Low	Low
Mountain cottontail	Low	Low	Moderate	High	Moderate	Low
Pacific lamprey	Low	Moderate	Low	Moderate	High	Low
Pacific treefrog	Low	Low[2]	High	Moderate	Low	None
Sculpin	Low	Low	Mod - High	Moderate	Low	Low
Western pearlshell	Low	See Note[3]	High	Moderate	High	Low
White sturgeon	Moderate	Moderate	High	Moderate	High	Low

Key: see Exhibit 5-22

Notes:

1. An Ecology Group study had been planned for spring 2011 that would potentially provide specific site use data; however, the results were not available as of the time of report development.
2. It is not clear whether this species has ever have been present onsite.
3. Available data suggest, although formerly present, that this species may no longer be present in the Hanford Reach.

[72] Please note that this table largely reflects the *availability of information* on these topics, rather than the nature of the information. For example, a "Low" entry in "onsite abundance" does not mean that the species has a low abundance; rather, it means that little or no information is available with respect to the species' abundance onsite. See Exhibit 5-18 for a key to the meanings of the entries in this table.

EXHIBIT 5-22 KEY TO "SUMMARY OF NATURAL HISTORY INFORMATION AVAILABILITY FOR TARGET SPECIES"

CATEGORY	SITE USE PATTERNS	ONSITE ABUNDANCE	REPRODUCTION & LIFE HISTORY	DIET / PREDATION	HUMAN USE	HANFORD-SPECIFIC HEALTH STUDIES
None	N/A	N/A	N/A	N/A	N/A	No Hanford-specific health studies have been identified.
Low	Major elements of the species' life history are not well understood.	Little or no information on abundance is available.	Major elements of the species' life history are not well understood.	Little or no information exists on food web interactions for this species.	Little or no information exists on the human-use value of this species, and/or the species is not considered to have a direct human use value.	A small number (<5) studies have been conducted, and/or available studies have been very limited in one or more respects, e.g., the number of sites and/or numbers of individuals evaluated, as relevant.
Moderate	Major elements of the species' life history are reasonably well understood, although some uncertainty may remain.	Some information is available--e.g., numbers of nests or call survey results, but the population is not actively monitored and/or there is substantial uncertainty about the numbers of individuals that use the Hanford Site, and population trends may not be known.	Major elements of the species' life history are reasonably well understood, although some uncertainty may remain.	The species general diet and predators are well known; however there is some uncertainty in the particular diet, the amount of specific foods, and/or predators on the Hanford Site.	The human-use value is well known and/or the species is fairly important.	>5 studies have been conducted. However, studies are limited in the number of endpoints and/or contaminants studied.

CATEGORY	SITE USE PATTERNS	ONSITE ABUNDANCE	REPRODUCTION & LIFE HISTORY	DIET / PREDATION	HUMAN USE	HANFORD-SPECIFIC HEALTH STUDIES
High	Species habitat and food needs are well-understood, as are normal reproductive processes/rates.	The onsite population is relatively well characterized and population trends are generally understood. The population may be actively monitored (e.g., numbers of individuals, reproductive health).	Species habitat and food needs are well-understood, as are normal reproductive processes/rates.	The species particular diet and predators on the Hanford Site are well known.	The human-use value is well characterized, and/or the species is highly valued.	>10 studies have been conducted on a range of endpoints, contaminants, and sites.

ECOTOXICOLOGY

This section describes available information both on target species, and also reflecting site-specific toxicity testing work.

SENSITIVITY OF TARGET SPECIES TO TARGET CONTAMINANTS

IEc developed a series of eleven profiles on target contaminants selected by the HNRTC. These profiles included information on the contaminants' sources, environmental fate and transport, bioaccumulation, chemical ecotoxicity, and radiological ecotoxicity. Where available, information was provided about the toxicity of the target contaminants to the target species. For some radionuclides, where radionuclide-specific information was not available, general information about the effect of that type of emission (alpha, beta, or gamma) on the target species was provided instead. Similarly, where information specific to the target species was lacking, information about ecotoxicity to related species (e.g., other mammals or other amphibians) was provided.

Exhibit 5-23 presents a matrix of target species and target contaminants, summarizing the extent of information available for each combination as either very low, low, moderate, or high, as defined below.

- **Very low.** No information, or nearly no information, appears to be available about the ecotoxicity of this contaminant or emitter to this species or group.
- **Low.** Data are extremely limited. For example, field correlations may exist but no laboratory toxicity testing; tested concentrations are few and were identified as not being environmentally realistic, or data may be limited to related species (e.g. other anurans or other mammals).
- **Moderate.** Data are available for the species/ contaminant combination but remain significantly limited in some manner. For instance, data may only be available for a few endpoints or for specific life stages; data may reflect exposure to a single exposure route, and/ or reflect only a few different exposure levels.
- **High.** The species/ contaminant combination has been relatively well-studied, with the more sensitive life stages known, and a reasonable range of endpoints and concentration ranges having been evaluated.

As can be seen from this table, ecotoxicological information specific to these species and contaminants is in general quite limited.

EXHIBIT 5-23 SUMMARY OF INFORMATION AVAILABILITY ON THE SENSITIVITY OF TARGET SPECIES TO PROFILED TARGET CONTAMINANTS

SPECIES/GROUP	CCl_4	Cr	Hg	PCBs	U	Tc-99	Cs-137	I-129	Pu	Sr-90	Tritium	Radiation
Effects:	Chemical				Chemical, primarily		Radiological					
Emission:	NA	NA	NA	NA	α	β	β, γ	β, γ	α	β	β	Varies
Primary accumulating tissue(s)	Lipids/ fat (excreted quickly)	Various	NA	Lipids/ fat	Various	Various, in mammals (excreted quickly)	NA (like K)	Thyroid	Bone, liver	Bone, shell, carapace (like Ca)	NA (like water)	Various
Black-tailed jackrabbit	Low	Low	Low	Low	Low	Low	Low	Very Low	Low	Low	Very Low	Low
Bullfrog	Very Low	Low	Low	Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low
Bulrush	Very Low	Low	Low	Very Low	Low	Low	Very Low	Very Low	Very Low	Very Low	Very Low	Low
Caddisfly	Very Low	Low	Very Low	Very Low	Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low
Chinook salmon	Very Low	Moderate	Low	Low	Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low
Great blue heron	Very Low	Low	Low	High	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Low
Mountain cottontail	Low	Low	Low	Low	Low	Low	Low	Very Low	Low	Low	Very Low	Low
Pacific lamprey	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low
Pacific treefrog	Very Low	Low	Low	Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Low
Sculpin	Very Low	Very Low	Low	Very Low	Low	Very Low	Low	Very Low	Very Low	Low	Very Low	Very Low
Western pearlshell	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low
White sturgeon	Very Low	Low	Low	Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low

TOXICITY TESTING (DOE 2011b)

Site-specific toxicity tests have been conducted with site media, particularly in connection with the River Corridor Baseline Risk Assessment (RCBRA, DOE 2011b). Toxicity testing was performed for each of the three habitat types considered in the RCBRA: nearshore, riparian, and upland. Exhibit 5-24 summarizes these efforts, and the following paragraphs discuss these efforts, including preliminarily identified key limitations for NRDA purposes.

Nearshore

Nearshore toxicity testing has encompassed both pore water and sediment exposures. Test organisms have included *Hyalella azteca* (sediments), pak choi (sediments), *Ceriodaphnia dubia* (pore water), and *Xenopus laevis* (pore water). Study sites (34) were selected across three areas where known groundwater plumes enter the Columbia River: a hexavalent chromium plume near the 100-K and 100-D areas, a strontium-90 plume near the 100-N Area, and a uranium plume near the 300 Area. Fourteen study sites were also selected to represent the nearshore environment between the regions influenced by these three major plumes, and nine locations were selected as reference sites.

The 28-day *H. azteca* tests examined survival and growth on sediments from 40 potentially contaminated sites and nine reference sites. For the 22-day pak choi evaluation, 26 study sites and 8 reference sites were included. Test endpoints included germination and measures of growth.

The *C. dubia* pore water bioassays included 50 study sites and 10 reference sites, with site sampling conducted under both high flow (32 samples) and low flow (18 samples) conditions. For each site, 10 organisms (1 per chamber), were tested for survival and reproduction. As the exposure duration was limited to seven days, potential effects of longer-term exposures are unclear.

DOE (2011b) also reports results of pore water testing on frogs via the 96-hour frog embryo teratogenesis assay-*Xenopus* (FETAX), which evaluates mortality and malformation frequencies. Length was also measured as an index of growth. Thirty study sites and 8 reference sites were evaluated. The duration of this toxicity test also limits the potential to make inferences about effects over longer exposure durations.

EXHIBIT 5-24 TOXICITY TESTING REPORTED IN THE RIVER CORRIDOR BASELINE RISK ASSESSMENT (DOE 2011b)

ORGANISM / GROUP	EXPOSURE MEDIUM	TEST DURATION	TEST ENDPOINTS	NO. STUDY SITES	NO. REFERENCE SITES	NO. REPLICATES PER SITE
Nearshore						
Ceriodaphnia dubia	pore water	7 days	Survival and reproduction (young per female)	32 high flow; 18 low flow	10	10 chambers with 1 organism per chamber
X. laevis	pore water	96 hours	Mortality, malformation frequencies, length	30 high flow; 21 low flow	8	Not specified
Hyalella azteca	sediment	28 days	Survival and growth	40	9	5 replicates
Pak choi	sediment	22 days	Shoot wet and dry weights	26	8	4 chambers with 4 seeds per chamber (thinned to one)
Riparian						
Sandberg's bluegrass (*Poa secunda*)	soil	14 days post-germination	Germination, growth (multiple metrics)	8 "study" sites and 8 "rare plant" sites	3	5 chambers per site, with 10 seeds per chamber
Nematode (*C. elegans*)	soil	24 hours	Mortality	11 sites adjacent to known contaminated media; 7 sites between operating areas	7	3 chambers per site with 10 organisms per chamber
Upland						
Sandberg's bluegrass (*Poa secunda*)	soil	14 days post-germination	Germination, growth (multiple metrics)	2 remediated/backfill sites, 5 remediated/native sites	3 native soil sites	5 chambers per site, with 10 seeds per chamber
Nematode (*C. elegans*)	soil	24 hours	Mortality	10 remediated/backfill sites, 10 remediated/native sites	5 backfill sites; 5 native reference sites	5 chambers per site, with 10 seeds per chamber

Riparian

Riparian sites included 18 study sites, including 11 potentially impacted locations associated with Hanford Site operating areas, and seven potentially impacted locations between operating areas. Eight reference sites were also selected.

For these sites, DOE (2011b) reports toxicity testing results for Sandberg's bluegrass (a native species) and the nematode *C. elegans*. The bluegrass test duration was 14 days post-germination, while the nematode study duration was 24 hours, and nematodes were not provided with food (DOE 2011b, Appendix D-8).

Upland

In upland areas, DOE (2011b) also reports toxicity testing results for Sandberg's bluegrass and *C. elegans,* both of which were exposed to soils from remediated waste sites as well as reference site soils. The tests with native grasses were limited to seven upland remediated waste sites where good ecological recovery seemed to have occurred, plus several reference sites. Nematodes were exposed to soils from 10 remediated/backfill sites, 10 remediated/native sites, plus 10 reference sites, again for 24 hours.

Uncertainties and Data Gaps Associated with the Toxicity Testing

For some site media/species combinations, DOE (2011b) reports statistically significant differences at study sites compared to reference areas, and for others, reports finding no statistically significant differences. These findings, however, warrant a more careful review before definitive views can be formed about their utility and applicability in a NRDA, and comprehensively identifying associated data gaps. A preliminary review of certain considerations suggests that their overall utility and applicability for a NRDA is likely to be limited by study design (including site selection) considerations, and may also be limited by other factors.

For example, site selection in upland areas was intentionally biased towards areas of good ecological recovery –i.e., areas with an established vegetative community. This bias was intended to ensure adequate vegetative sample collection for contaminant analysis purposes. However, this focus implies that there is a gap in understanding the extent to which Hanford contaminants in site soils may have affected native plants. In addition, the evaluation of only seven remediated sites, given the large number and disparate history of waste sites at Hanford (including variations in the suite of contaminants present at different locations), suggests that there is a gap in understanding the extent to which Hanford contaminants in site soils may have affected terrestrial plants.

We also note that the scope of a NRDA is not limited to the current timeframe or to remediated locations. Developing information on those topics was beyond the scope of DOE (2011b); however, the result is that a gap remains in understanding the extent to which Hanford contaminants in site soils may have affected terrestrial plants and invertebrates in the past.

Also of note, the relatively short duration of the RCBRA toxicity tests prevents inferences from being made about the potential for lethal or sublethal effects that could occur over longer periods of time, or in the case of nematodes, through additional exposure routes (i.e., via ingestion).

Some implementation specifics suggest that careful, expert review of the toxicity testing results is warranted. For instance, in preliminarily reviewing these results, we note that in sediment toxicity testing using *H. azteca*, the positive control samples should achieve over 90 percent survival (Ingersoll et al. 2008); however, Figure 6-35 in DOE (2011b) indicates that at least some reference site samples did not meet this criterion. From the information presented, it is not immediately clear whether a true positive control (completely clean) sample was included in the testing. If not, it is unclear whether the less-than-ideal results at some reference site sediments might reflect contamination in those areas or whether there might have been problems with the test conditions. A closer evaluation by independent experts, in collaboration with DOE, may help explore the extent to which this issue may or may not affect a determination about overall test acceptability.

We also suggest a careful, expert review of issues of data treatment and interpretation, as our preliminary review raises some questions. For example, evaluation of results from many of the above toxicity assays was conducted similarly: in general, results from study sites as a group were compared to results from reference locations as a group, using t-tests or an ANOVA. We wonder whether this grouping is the best approach, particularly given that the study sites represent different contaminant exposure regimes (e.g., due to proximity to different groundwater plumes containing different contaminants). We are concerned that combining such samples into a single group for purposes of comparison with reference sites may effectively obscure real differences (if present).

We also would suggest that more specifics be provided about the rationale for using t-tests and ANOVAs. DOE (2011b) does not appear to discuss the extent to which the assumptions involved in using these tests have or have not been met (e.g. that the populations follow a normal distribution, equal variances), and the associated implications of possible violations of these assumptions with respect to the interpretation of the results. Non-parametric tests may be worth considering, as an alternative.

DOE (2011b) assesses the relationships of endpoints to site contaminants using many individual linear regressions of contaminant concentrations against endpoints. However, contaminant-response relationships are often neither linear, nor continuous in nature. Multivariate approaches could be a more powerful choice. Using multivariate statistics, many contaminants—or groups of contaminants—along with “confounding” non-contaminant factors (e.g., grain size, TOC, hardness, alkalinity, etc.) can be simultaneously analyzed, and interaction effects considered, to determine which are significantly related to the endpoint in question. Multivariate approaches are designed to address just this kind of situation, where more than one factor may be simultaneously influencing an outcome. Using a multivariate approach, as opposed to multiple individual regressions, relationships that are otherwise obscure may become illuminated, and relationships that seem “real” may in fact be shown to be artifacts.

Finally, DOE (2011b) uses standard hypothesis testing. Under such an approach, failing to detect a statistically significant differences between groups should not be interpreted as evidence for the absence of biologically important differences. In general, to conclude no differences between groups, reverse hypothesis (or bioequivalence) testing (e.g., as described in EPA 1989), may be more suitable.

A more detailed review by independent experts may support or alleviate the above preliminarily identified concerns, and may result in a more definitive determination of gaps in our understanding of the toxicity of site media to these test organisms.

SITE-SPECIFIC FIELD DATA

FITZNER AND GRAY (1991) - A HISTORICAL OVERVIEW

Fitzner and Gray (1991) provides a "historical overview of wildlife research conducted since the early years of Hanford operations through 1989." It aims to "synthesize the data (status, distribution, and seasonal use) collected on terrestrial vertebrates (mammals, birds, reptiles and amphibians) known to have existed at Hanford." The authors note that 40 species of mammals, 187 avian species, 3 amphibian species, and 9 reptilian species have been documented at the site.

As described in this review article, earlier research (1943-1970) was conducted by site contractors and focused primarily on the uptake and transportation of radionuclides. University research began in the early 1970s, and as of the time of publication, 15 graduate research projects had been conducted on wildlife. Research by PNNL also occurred during this time. This research emphasized the role of wildlife in taking up and distributing buried radioactive materials and radioactivity from waste ponds. Research efforts also focused on the abundance, distribution, and behavior of wildlife, with the Canada goose being particularly well studied.

Fitzner and Gray (1991) summarizes available information about a number of target species. With respect to the black-tailed jackrabbit, they note its abundance and that it has been studied "intensively" with respect to radionuclides in tissues as well as radionuclide uptake and dispersal. Its diet is also understood, but data on its longevity, habitat utilization, and dispersal, were lacking.

Nuttall's cottontail is "common across the Site often in association with buildings, particularly where grass and trees are planted for landscaping"; however, no studies of the species had been conducted onsite (*ibid.*).

The great blue heron has also been studied as an indicator of radionuclide exposure: rejecta (feces, food scraps) as well as adults, chicks, and eggs have been monitored for contaminant levels (*ibid.*). Amphibian and reptile abundance and distribution were described as "poorly understood."

COMMUNITY EVALUATIONS

Pacific Northwest National Laboratory (PNNL)

PNNL's more recent research in many ways is a continuation of earlier work summarized by Fitzner and Gray (1991). PNNL's site monitoring work (compiled in their "Characterization" database) includes collecting population-level information on a number of species and communities, including plants and animals in both the terrestrial and aquatic ecosystems. The types of information collected generally include count and location information as well as selected habitat characteristics.

Species targeted by PNNL for study have included some of the target species, as indicated in Exhibit 5-25 below.

EXHIBIT 5-25 OVERVIEW OF INFORMATION IN PNNL DATABASES ON TARGET SPECIES

ORGANISM	RECORDS AND NOTES	DATABASES AND TABLE NAMES
Bulrush	2 records where a % cover value for this species (listed as *Scirpus validus*) is provided.	Vegetation.mdb, tblTNC_Cover
Caddisfly spp.	396 records, of which 331 have coordinates.	Insects.mdb, tblCaddisflyData
Pacific treefrog	No records	N/A
Bullfrog	182 records (most with site IDs but not coordinates) 2 records	Animals.mdb, various tables Aquatic_Community.mdb, tblBenthic_Detail
Western pearlshell	No records	N/A
Chinook salmon	3293 redds records 1418 strandings records	Aquatic_Community.mdb, Salmon_Redds Aquatic_Community.mdb, tblWDFW_SalmonStranding
Sculpin spp.	73 records (62 with coordinates)	Aquatic_Community.mdb, MasterTable_clams.3_5_04[73] and tblBenthic_Detail
White sturgeon	No records	N/A
Pacific lamprey	2 records of "lamprey" (species not provided)	• Aquatic_Community.mdb, tblBenthic_Detail • Downs et al. (2004), Appendix A
Great blue heron	200 records 171 records	AvianSurveys.mdb, various tables HanfordBirds.mdb, tblGenericUpload (excluding studies in AvianSurveys.mdb)

[73] Despite its title, there are sculpin records, as well as records for other finfish, in this table.

ORGANISM	RECORDS AND NOTES	DATABASES AND TABLE NAMES
Mountain cottontail	A. 3 records, one with coordinates B. 1 record (same animal as in (A))	A. Animals.mdb, tblSmall_Mammal_subset B. Animals.mdb, tblTNC_sm_mammal
Black-tailed jackrabbit	No records	N/A

While information in the above databases may be useful in identifying likely locations for animals in the event that future field studies on these species are pursued, it is noteworthy that the program has not been designed to definitively identify species absence, or to quantify population-level metrics such as abundance, and as such may have limited utility for NRDA purposes. (Information on salmon redd locations may represent an exception to this general observation, to the extent that the location of the redds—or absence of redds—may be related to groundwater inflows, as discussed in more detail later in this chapter.)

River Corridor Baseline Risk Assessment

The River Corridor Baseline Risk Assessment (DOE 2011b) also included efforts to gather community-level information on aquatic and terrestrial communities (Exhibit 5-26). Sampling efforts focused on:

i. Benthos, including mussels (through rock basket deployment),

ii. Upland and riparian plant communities, and

iii. The small mammal community.

Our review has preliminarily identified important limitations for NRDA purposes in at least some of these efforts. For example, the plant community comparisons are limited in utility not only because of the study's focus on remediated areas but also because site selection was intentionally biased towards sites with an established vegetative community (to ensure an adequate sample collection for contaminant analysis purposes). In addition, as recognized by DOE (2011b), interpretation of the small mammal community results is limited by the availability of only a single campaign's worth of data collection. We also have concerns with respect to data interpretation that are similar to those previously described. Again, a more detailed review by independent experts may support or alleviate the above preliminarily identified concerns, and may result in a more definitive determination of gaps in our understanding of comparative community structure in the evaluated locations.

EXHIBIT 5-26 FIELD-BASED STUDY RESULTS REPORTED IN THE RIVER CORRIDOR BASELINE RISK ASSESSMENT (DOE 2011b)

ORGANISM / GROUP	EXPOSURE TYPE	EXPOSURE DURATION	ENDPOINTS	NO. STUDY SITES	NO. REFERENCE SITES	NO. REPLICATES PER SITE
Nearshore						
Benthic community (rock baskets)	Field	6 months	Multiple community metrics	32 sites (2006: 9 sites near chromium plume; 10 sites near uranium plume; 2007: 2 sites near 100 B/C, 1 near 100H, 1 near 100N, 9 sites in depositional areas)	2006: 7 sites; 2007: 3 sites	3 baskets
Mussel	Field	N/A	Histopathology	6	3	N/A
Mussel community	Field	N/A	Richness, relative abundance, density	10 sites near chromium plume; 10 sites near uranium plume	7	N/A
Sculpin and juvenile sucker	Field	N/A	Histopathology	26	7	N/A
Asiatic clam *(C. fluminea)*	*in situ*	3 months or 7-8 months	Survival, growth, histopathology	2005-2006: 20 sites; 2006-2007: 8 sites	2006: 7 sites; 2007: 3 sites	6 tubes with 25 clams per tube
Riparian						
Plant community	Field	N/A	Diversity, richness, % cover	11 sites adjacent to known contaminated media; 7 sites between operating areas	7	24 plots per site
Cliff swallows	Field	N/A	Number of eggs laid and hatched	10 nests (split between exposed/reference not specified)		N/A
Eastern kingbird	Field	N/A	Number of eggs laid and hatched	23 nests (split between exposed/reference not specified)		N/A
Western kingbird	Field	N/A	Number of eggs laid and hatched	16 nests (split between exposed/reference not specified)		N/A
Small mammal community	Field	N/A	Relative density, relative abundance, age, sex, reproductive status, general external condition	8	3	10 traps per site
Upland						
Plant community	Field	N/A	Diversity, richness, % cover	10 remediated/backfill and 10 remediated/native soil	10	24 plots per site
Small mammal community	Field	N/A	Relative density, relative abundance, age, sex, reproductive status, general external condition	10 remediated/backfill sites, 10 remediated/native sites	5 backfill sites; 5 native reference sites	10 traps per site

HISTOPATHOLOGY

PNNL Data

PNNL provided us with a database titled SampleAnalysis.mdb, and which the database manager referred to as their "health" database. This database contains histology information for the organisms as described in Exhibit 5-27. Additional sample-specific information such as reproductive status, age, body measurements, and general body condition are also provided.

EXHIBIT 5-27 PNNL HISTOLOGY INFORMATION

ORGANISM	NO. RECORDS	YEAR(S)
Bass	3	2002
Bullfrog	1 adult, 1 tadpole	2003
Catostomus (suckers)	3	2003
Clam	830	2002-2005
Cottus (sculpin)	33	2003, 2005
Crayfish	68	2003
Whitefish	7	2003

Of note, we have not identified any reports that discuss the results of this sampling. The Hanford Site Environmental Report for Calendar Year 2003 (Poston et al. 2004) states that other than radiological results in clams, "Analyses for other species and biological components were still under development when this report was prepared." Subsequent annual environmental reports also do not appear to present the results of this sampling.

Larson et al. (2008) describe a November 2003 to February 2005 *in situ* investigation on exposure of the Asiatic clam, *Corbicula fluminea*, to contaminants in the 300 Area. Growth, survival, and tissue conditions were evaluated at two nearshore locations, one of which was associated with contaminated groundwater upwelling, and the other was an upstream reference location. The authors did not find any effects from contaminant exposure; however, growth overall was poor (negative), which the authors attribute to the type of tubing in which the clams were contained. The study's results may not, therefore, be representative of results under natural conditions.

River Corridor Baseline Ecological Risk Assessment

DOE (2011b) discusses results of sampling in 2006 and 2007 for mussels, sculpin, juvenile suckers, and Asian clams.

- In mussels, the authors found statistically increased observations between study site versus reference site organisms, in two of the 20 measurements: digestive cell vacuolation severity and degraded mantle condition.

- In fish, the authors found statistically increased fish length and weight among study site versus reference area fish. The authors also found four out of 22 histopathological measurements to differ between study and reference sites: the number of liver parasites and the number of muscle granulomas was higher among site fish, and the number of encysted parasites in gills and kidneys were higher among reference fish.
- In clams, the authors found statistically increased observations between study site versus reference site organisms, in two of the 19 measurements: the incidence of digestive system epithileal cell shedding, and reproductive system follicle cyst presence.

For the reasons noted previously, we again suggest an independent expert review of the findings and comparisons made in DOE (2011b).

WCH (2011) also reports histology information associated with several tissues from 30 Hanford white sturgeon (no reference area samples were collected). The authors report that "In general, the findings among all 30 fish examined were remarkably consistent" showing "widespread vasculitis in gill, kidney, liver, and gonad tissues… degeneration and necrosis was minimal compared to inflammation. No parasites or bacteria were found in liver, kidney, or gill tissues." The authors also state: "The immune response of the sampled sturgeon is considered to be active and chronic. The integrity of some blood vessel walls was compromised in fish with moderately severe widespread vasculitis, which could have a negative impact on vascular function. In addition, high numbers of macrophage aggregates or elanomacrophage centers, which are widely used as a biomarker for exposure to environmental stressors (i.e., chemical contaminants), were observed in liver tissue sections, but this characteristic would need to be compared to fish of similar ages from an uncontaminated site and related to body burdens of contaminants, in order to confirm contaminant associations" (ibid.)

ADDITIONAL HANFORD SITE FIELD EFFECTS INVESTIGATIONS

PNNL

Determining the health of Hanford Site biota seems to have been an important but secondary focus of PNNL's environmental monitoring program. For example, Downs et al. (2004) notes "The data generated for this report does not include information regarding abundance [or] health of organisms... ." That said, the PNNL program, on its own and in collaboration with others, has generated some information appertaining to the health of site biota. In addition to the previously-mentioned histology efforts, examples include:

- **A 2005 pilot study on bullfrog and Woodhouse's toad malformations** in animals from two Hanford Reach slough/backwater pools. The authors found a "relatively low" rate of malformations (Poston et al. 2006).
- **Adult male mule deer reproductive health.** Tiller et al. (1997) reported a study stemming from observations of adult male deer with atypical antlers. These deer

were found to have infertile, atrophied testicles. The authors stated that radiation, natural aging, infectious agents, and genetics were ruled out as causes, while other stressors including heavy metals, herbicides/pesticides/insecticides were unlikely to be causative agents. Plant and fungal toxins were not evaluated.

- **Canada geese reproduction.** Fitzner et al. (1991) note that nearly four decades of research on the nesting ecology and behavior of this species have been conducted. Fertility rates in the 1950s and 1960s found reproductive rates "as high or higher than in areas not supporting nuclear operations." Simmons et al. (2010) summarizes Canada goose research at Hanford, concluding that radiological dose rates were "well below applicable guidelines" and that maximum concentrations of a variety of other metals "met or fell below existing toxicological benchmarks, suggesting minimal risk… from exposure."
- **Great blue heron reproduction.** Despite heavy metal concentrations, Tiller et al. (2005) found that in 1996, reproductive health of *A. herodias* nesting along the Hanford Reach to be one of the highest reported in the United States. The authors note that there has been a decline in the numbers of active nests from 94 in 1983 to 37 in 1999, attributing this change to increased human activity near nest trees, wind toppling of trees used as nesting sites, and low subadult/survival ratios (Rickart and Tiller 2003 as cited in Tiller et al. 2005).
- **Chinook salmon behavior.** Chinook salmon may be avoiding areas of groundwater upwelling within the Hanford Reach. For example, Geist (2000) reports that spawning salmon used areas of hyporheic upwelling where the specific conductance indicated a surface water source of the upwelling, whereas they did not use hyporheic discharge zones where the source was ground water. (Dissolved oxygen was higher in the surface water discharge areas, but concentrations in both areas were higher than levels needed for egg/alevin survival. Contaminant concentrations were not measured.)
- **A mussel survey** of the Hanford Reach that found several shells of the western pearlshell but concluded that "the species appears to be largely absent from its historical range" (Mueller et al. 2011).

River Corridor Baseline Ecological Risk Assessment

DOE (2011b) evaluated the survival of clams, a non-native species, at 28 study sites and 10 references sites (Exhibit 5-26). A first set of clams was exposed *in situ* to site conditions for seven to eight months at a subset of these sites, while a second set was exposed for about three months (at different sites). DOE (2011b) found a statistically significant difference in survival between reference (higher) and study site (lower) locations but did not identify relationships between survival and contaminant concentrations. However, there are limitations in the analyses performed, similar to those described for the DOE (2011b) toxicity testing. These include but are not necessarily limited to, the grouping of all "study" sites together regardless of differences in exposure (e.g., to different contaminant plumes), as well as the absence of reliance on multivariate statistical methods to tease out the potential contributions of contaminants, interactions, and potentially confounding factors. In addition, the clam is not a native species, and it is not known whether it is more or less sensitive to site contaminants than native bivalves. These factors suggest that there is a gap in understanding the extent to which Hanford contaminants in site sediments and waters may be affecting (and may have previously affected) native mollusks.

DOE (2011b) evaluated reproduction in cliff swallows, eastern kingbirds, and western kingbirds, but predation was sufficiently high as to render interpretation impossible (*ibid.*).

CONCLUSIONS

CONTAMINANT EXPOSURE

In NRDA, information on contaminant concentrations in target organism tissues is a common way to ascertain both achieved exposure levels and also to help establish a complete pathway between releases and receptors. Exhibit 5-28 summarizes available information for each of the evaluated contaminant databases.

As shown in this exhibit, HEIS contains the largest overall number of records. This database is expected to grow in size as additional information from past as well as ongoing sampling efforts are entered. A major data gap for the biotic information in HEIS, however, is the absence of geographic coordinate information from approximately 80 percent of samples. Frequently, some information is available as to location in other station-specific fields, but it would likely take a considerable effort to develop an approach to consistently approximate sample locations based on the entries in these fields. Consequently, at the current moment it is difficult to draw definitive conclusions about the spatial distribution of available samples in HEIS. An additional data gap in HEIS and in the other databases is the relative lack of records in the years preceding CERCLA's passage (1980 and earlier).

EXHIBIT 5-28 OVERVIEW OF BIOTA CONTAMINANT DATABASES

DATABASE	NO. SAMPLES	SPECIES	GEOGRAPHIC DISTRIBUTION OF TARGET SPECIES	TEMPORAL DISTRIBUTION (# samples in target biota)	ANALYTES
HEIS	16,237	144 types of biota **No samples:** great blue heron, lamprey **Few (<30):** bulrush, caddisfly, frog, mussel, salmon **Most (>100):** cottontail, black-tailed jackrabbit, sculpin, sturgeon	79% lack coordinates, including all black-tailed jackrabbit and nearly all cottontail samples. Sculpin, sturgeon, and mussels are relatively evenly distributed in the Hanford Reach. The distribution of locations for other target species is more limited.	<1981: 124 (10%) 1981-2000: 446 (37%) >2000: 669 (53%)	460 analytes 164 analyzed in at least one target sp. **No target sp.**: carbon tetrachloride, I-129 **Few (<6) target sp.:** Bo, CrVI, dieldrin, PCBs, Pu, Sr-90, H3 **Most target sp. (>=6):** Sb, As, Ba, Cd, Cs-137, Cu, Cr, Hg, Pb, Mn, Se, TPH-diesel, Tc-99, U, Zn
RCBRA / GiSdT	6,607	61 types of biota **No samples: bulrush,** great blue heron, lamprey, black-tailed jackrabbit **Few (<30):** caddisfly, frog, mussel, salmon, sturgeon **More (30-100): cottontail** **Most (>100):**, juvenile salmon, sculpin	All samples have coordinates. Sculpin and mussel locations are distributed throughout the Hanford Reach. The distribution of locations for other target species is more limited.	<1981: 2 (0.4%) 1981-2000: 28 (5%) >2000: 499 (94%)	782 analytes 446 analyzed in at least one target sp. **No target sp.:** carbon tetrachloride, CrVI, I-129, H3 **Few (<6) target sp.:** Ba, Bo, dieldrin, Hg, Pu, PCBs, Tc-99 **Most target sp.** (>=6): Sb, As, Cd, Cs-137, Cr, Cu, Pb, Mn, Se, Sr-90, TPH-diesel, U, Zn
2011 DSR	134	6 fish species, including 30 sturgeon composites.	All samples have coordinates. Sturgeon sampling locations include locations upstream and downstream of the Hanford Reach as well as a number of locations between the 100K area and a location slightly north of the 300 Area.	All samples were collected between 2009 and 2010.	Sturgeon were analyzed for all target analytes except carbon tetrachloride, I-129, and H3.

DATABASE	NO. SAMPLES	SPECIES	GEOGRAPHIC DISTRIBUTION OF TARGET SPECIES	TEMPORAL DISTRIBUTION (# samples in target biota)	ANALYTES
CRC Historic	10,166	153 types of biota **No samples: bulrush,** great blue heron, black-tailed jackrabbit **Few (<30):** lamprey , caddisfly, frog, mussel **More** (30-100): Chinook salmon, cottontail, sturgeon **Most (>100):** juvenile Chinook salmon, sculpin	All samples have coordinates. A number of sampling locations are outside of the Hanford Site, including all Pacific lamprey locations, and many sturgeon and salmon locations. Onsite, sculpin and mussel sites are relatively evenly distributed, while the others are limited to specific areas.	<1981: 4 (1.2%) 1981-2000: 104 (32%) >2000: 216 (67%)	1,445 analytes 452 analyzed in at least one target sp. **No target sp.: carbon tetrachloride,** CrVI, H3, I-129 **Few (<6) target sp.:** Bo, dieldrin, PCBs, Pu, Sr-90, Tc-99 **Most target sp. (>=6):** Sb, As, Ba, Cd, Cs-137, Cr, Cu, Pb, Mn, Hg, Se, TPH-diesel, U, Zn
ERS	1,119	Sage/rabbit brush (95%) and Indian rye grass (5%). No target species were sampled.	3% lack coordinates.	<1981: 0 (0%) 1981-2000: 450 (40%) >2000: 669 (60%)	Most samples were analyzed for Cs-137, Pu, Sr-90, and U, but not for other target analytes, COECs or COPECs.

One observation suggests that, despite the large numbers of records in these databases, not all site-specific information on contaminant concentrations in Hanford biota has yet been incorporated into these databases. For example, Fitzner and Gray (1991) reviews several studies on herons, published between 1978 and 1988, which report contaminant information in great blue heron rejecta, young, and eggs. Tiller et al. (2005) also provides information on metal concentrations in Hanford Reach great blue heron livers and excrement, yet none of the reviewed databases contain contaminant measurements associated with this species. It is not known whether the database developers intentionally omitted these data (e.g., due to issues of scope or data quality).

Overall, a wide range of analytes has been measured in biota; however, for most of the target species/ contaminant combinations that have served as a focus of this report, relatively few measurements are available. Within the target species, the most commonly analyzed target analytes include Cs-137, Cr, Sr-90, and U. Carbon tetrachloride, tritium, and I-129 were analyzed in very few target species.

Maps 5-1 through 5-8 in Appendix A depict, by species, the onsite sampling locations across all databases for which coordinate information is available. Onsite, the sculpin, mussel, and sturgeon sampling locations appear to be relatively evenly distributed within the Hanford Reach. The geographic distribution for other target species is more limited. Of note, not all samples reflect onsite locations: for example, the CRC Historic database contains sample locations from distant offsite locations, including all the lamprey sampling locations, and a number of the sturgeon and salmon records (Map 5-9).

TARGET SPECIES AT HANFORD

For the target species, in general, a reasonable amount of information exists on the species' reproduction and life history, diet/predation, and human use. However, with notable exceptions of the Chinook salmon and great blue heron, site-specific data on the species' use of different parts of the Hanford Site appears to be limited. Furthermore, with the exception of the Chinook salmon, we have identified no Hanford-specific health information, or very limited site-specific health information, on these species.

ECOTOXICOLOGY

Information on the sensitivity of target species to target contaminants is, overall, extremely limited. The species/contaminant combinations for which the most information is available are Chinook salmon/chromium, for which a moderate amount of information exists. For all other combinations, the amount of data was determined to be low or very low.

Some site-specific post-remediation toxicity tests have been conducted with site media from the 100 and 300 Areas, and from the Inter-Areas, as reported in the River Corridor Baseline Risk Assessment (DOE 2011b). Test organisms include Sandberg's bluegrass, *C. dubia*, *X. laevis*, *H. azteca*, a nematode, and pak choi. DOE (2011b) also reports the results of community evaluations of benthic invertebrates (including mussels), vegetation, and small mammals. DOE (2011b) also presents histological evaluations of finfish and shellfish, and results from an *in situ* evaluation of clam survival and growth.

Study design issues likely limit the utility of some of the DOE (2011b) data for NRDA purposes: for example, the upland sites were limited to remediated locations, limiting the ability to draw inferences about potential for impacts prior to remediation. These sites were also selected preferentially for areas with good vegetative recovery, post-remediation: this intentional site-selection bias may have eliminated from consideration areas where contaminants may be affecting the vegetative community. Potential concerns about the interpretation of data also suggest caution in relying on the study's major conclusions for NRDA purposes. A careful, expert re-evaluation of the field and laboratory work in this document is warranted, including study design, test acceptability, test relevance, methodological uncertainties, the adequacy of spatial coverage, statistical methods, and interpretation of results. (That said, we note that undertaking such a review may or may not result in different major conclusions from those currently presented).

WCH (2011) reports histology information from 30 Hanford white sturgeon. The authors found widespread inflammation in several tissues; however, no reference area fish were captured for purposes of comparison. PNNL has also collected samples and subjected them to histology. Results for those samples are available in database form; however, we have not identified any reports that describe the sampling approach or results.

Additional site-specific field research on potential contaminant-related effects include: a pilot study on bullfrog and Woodhouse's toad malformations (Poston et al. 2006), multiple years of research on Canada goose reproduction (Fitzner et al. 1991), an evaluation of adult male mule deer reproductive health (Tiller et al. 1997), an evaluation of great blue heron reproduction (Tiller et al. 2005), and a Chinook salmon spawning habitat selection study (Geist 2000). DOE (2011b) evaluated reproduction in cliff swallows, eastern kingbirds, and western kingbirds, but predation was sufficiently high as to render interpretation impossible.

MONITORING DATA

PNNL's ecological monitoring data comprise a substantial proportion of the identified site-specific field information. Downs et al. (2004) note some data gaps in these data. For one, the authors acknowledge the existence of data sources not included in their collection (e.g., data presented in historical literature, surveys conducted by other site contractors, and data collected by students and universities). In addition, the authors state:

> "As with any compilation of data from various investigations, there may be some uncertainties regarding the quality and consistency of the data. The data compiled for this report were collected under various projects with differing objectives over a number of years, and the methods used to collect the data were often not consistent between studies. There was a wide-ranging level of detail in the location information, and the methods used to collect location information were not standardized."

More generally, the PNNL ecological monitoring data focus on species presence/absence, although it is generally more appropriate to state that these data can demonstrate presence but are unlikely to be sufficient to demonstrate absence: as the authors note, "[m]any sample and survey efforts are not designed to document absence of species." Furthermore, the "data generated… does not include information regarding abundance, health of organisms, or fidelity" (*ibid.*).

Furthermore, general scientific practice as well as the DOI NRDA regulations entails comparisons of potentially affected areas to reference areas. Such comparisons appear to be largely absent in the reports describing the PNNL species count data.

In a natural resource damage assessment, data of this type is most commonly useful for purposes such as:

- Identifying locations where organisms are likely to be present for purposes of sampling them (e.g., to measure contaminant concentrations or to assess any of a variety of potential health metrics);
- Identifying locations where organisms are likely to be present for purposes of studying them in the field (e.g., determining nest productivity); and
- Identifying locations potentially suitable for *in situ* studies (e.g., caged mollusk studies).

Population-level information can sometimes be used to show differences in relative abundance (or, more rarely, absolute abundance) between affected areas and reference areas, differences in community structure, differences in population age structures, or in other metrics of population health. However, because there are typically multiple factors that influence population dynamics and community structure—including, but not limited to, weather conditions, wildfires, predator pressure, fluctuations in forage/prey availability, fishing/hunting pressure, presence of invasive species, infections/parasites, and so forth—natural fluctuations in population sizes are frequently quite large. This can make detecting even ecologically significant changes in population parameters very difficult. Particularly as PNNL's programs are not designed to address these types of questions, we expect that the available data are unlikely to be a sufficient basis on which to base conclusions about population-level endpoints.[74]

SUGGESTED FUTURE STUDIES

The above analyses suggest that several types of studies may be appropriate for purposes of assessing injury to Hanford biota. These include but are not necessarily limited to the following.

- **Tissue chemistry comparisons**. Available tissue data can be compared to relevant thresholds for adverse effects to preliminarily evaluate the likelihood of injury in these organisms.
- **Site-specific toxicity testing.** After careful review of past site-specific toxicity testing results, additional testing may be warranted, potentially including tests using sediments, pore water, surface water, groundwater, and/or soils, using

[74] We note that DOI natural resource damage assessment regulations do not require the identification of impacts at the population or community level in order to determine or quantify injury.

standard test organisms (e.g., *H. azteca*, *C. dilutes*, *C. elegans*) and native biota (Sandberg's bluegrass, Pacific lamprey, white sturgeon, sculpin, Western pearlshell).[75] In addition, Chinook salmon avoidance testing could be continued to further explore the possibility that groundwater contaminants are associated with habitat avoidance, as Geist (2000) has suggested may be occurring in association with areas of groundwater upwelling.

- **Field-based injury assessments.** DOI's NRDA regulations require effects to be observed under field conditions. Potential studies in this category include:
    - **Benthic community survey work,** to include a careful review of existing data (potentially with re-analysis), and potentially additional follow-on fieldwork.
    - **Assessment of plant community health**. A carefully-designed survey of plant community health could evaluate the extent to which plant communities may have been affected by contaminant releases from Hanford.
    - **Mussel and/or sculpin *in situ* toxicity testing.** Exposure to actual site conditions, *in situ*, may help determine the suitability of current habitat conditions to support these species.
    - **Great Basin pocket mouse population assessment**. Significant differences in relative abundance, or occupancy, between un-remediated affected sites and control sites can be indicative of a population-level injury to a species.
    - **Great Basin pocket mouse: carbon tetrachloride and histopathology.** The purpose of this study would be to collect Great Basin pocket mice from areas known or thought to be subject to higher levels of carbon tetrachloride, as well as from reference areas, to determine whether mice from contaminated locations have a higher incidence of pathology of the liver (and potentially other organs).
- **Additional supporting studies.** Some studies are likely to be useful to help explore important scientific issues appertaining to injury determination, including causality of impacts. These studies may include:
    - **Chinook salmon spawning habitat identification.** It may be possible to refine an existing spawning habitat model to explore whether there appears to be a relationship between habitat use and the presence of contaminated groundwater upwelling. It may then be possible to use the revised habitat model to predict the area of otherwise usable habitat that salmon are avoiding due to this upwelling.

[75] We note that some combinations of media and organisms may require methods development, particularly for sediment toxicity testing of the Pacific lamprey, and testing using Western pearlshell.

- **Western pearlshell habitat preliminary characterization.** This study would rely on available information with the objective of identifying all areas within the Hanford Reach that appear to provide suitable habitat for the species. Potentially, it could help evaluate the extent to which contaminants vs. habitat availability (or potentially other factors) could have contributed to the species' local extirpation, as well as providing information potentially useful in site selection for an *in situ* study.
- **Evaluation of exposure to avian species.** Relatively few avian species, particularly terrestrial species, have been evaluated for contaminant exposure at Hanford. Without specific evidence or information that indicates that a particular species has been subjected to significant exposure and injured as a result, it may not be prudent at this time to narrow study efforts to one or a few species. An exposure study that attempts to evaluate exposure across many species, may help identify one or more species with significant exposure that may be a suitable subject for further investigation.

For additional background and detail on these suggested future studies, please refer to the *Aquatic Resource Review Report* (Industrial Economics, Inc., November 9, 2011), and the *Terrestrial Resource Review Report* (Industrial Economics, Inc., November 9, 2011).

This page intentionally left blank.

CHAPTER 6 | GROUNDWATER

This chapter provides a summary of data types most commonly relied upon for purposes of determining injury to groundwater resources. The chapter begins with a brief characterization of Hanford Site groundwater, including groundwater flow and plume characterization. It then summarizes available information on the exposure of site groundwater to contaminants, as indicated through measurements of contaminant concentrations in groundwater samples. Measurements of exposure are relevant in establishing a complete pathway from releases to receptors, as described in 43 CFR 11.63. Contaminant information is also important in determining groundwater injury in accordance with DOI's NRDA regulations (43 CFR 11.62(c)).

Subsequent sections provide an overview of groundwater remedial actions to date as well as a description of groundwater models currently in use at the Hanford Site. This chapter concludes with a summary of the presented information, highlighting areas where information appears to be limited or absent.

GROUNDWATER CHARACTERIZATION

GROUNDWATER FLOW AND AQUIFER CHARACTERIZATION

Groundwater flow directions are determined on the Hanford Site using observed groundwater level elevations, known barriers to flow such as basalt or mud units, and the distribution of contaminants (DOE 2010a). In general, groundwater enters the unconfined aquifer from elevated recharge areas near the western boundary of the site and eventually flows north, northeast and east to discharge into the Columbia River (DOE 2010a). The Columbia River temporarily recharges groundwater near the river during periods of high flow. Water from precipitation and leaking pipes also infiltrates through the vadose zone beneath the site (DOE 2010a). However, due to the arid climate, natural recharge from precipitation is very low, generally in the range of less than one centimeter to 50 centimeters per year. During the Site operational period (1943 through the 1980s) considerable volumes of waste waters were discharged to the ground, providing artificial recharge to the unconfined aquifer and causing substantial increases in water levels during that period. Since waste water disposal has ceased, water levels have continually declined in the areas affected by artificial recharge. This, in turn, has caused vertical groundwater gradients to be upward between the basalt confined aquifer and the overlying unconfined aquifer.

Total discharge of groundwater from the aquifer to the Columbia River is estimated to range between 1.1 and 2.5 cubic meters per second, which is less than 0.1 percent of the average flow of the Columbia River (approximately 3,400 cubic meters per second) (DOE 2010a).

The aquifer systems beneath the Hanford Site are generally classified as the confined basalt aquifer system and the overlying unconfined and unconsolidated or semi-consolidated sedimentary aquifer system. The vast majority of contaminated groundwater resides in the upper, unconfined aquifer system.

Volcanic basalts of the Columbia River Basalt Group form the bed rock underlying the unconfined sediments. The basalts in general have much lower permeability and porosity than the unconsolidated and semi-consolidated sediments of the unconfined aquifer system. Only limited zones of the basalts have sufficient permeability to be considered aquifers. These zones are generally the more fractured ruble zones forming the tops and bottoms of major basalt lava flows. Although nearly all of the contamination of concern resides in the unconfined sedimentary aquifer, there are limited zones of the upper basalt that have been penetrated by contaminants.

The unconfined aquifer system has been studied extensively by DOE over the past 30 years, primarily because of concerns regarding contaminants in the aquifer from past operations (1943 through the 1980s). Information from hundreds of borings and wells, together with geophysical surveys has provided considerable detail on the hydrogeology of the unconfined aquifer system. The system is comprised of the three following major formations:

- *Ringold Formation*: This is the lower-most formation of the unconfined aquifer system. It is composed of interlayered sands, silts, gravels and clays deposited by ancestral Columbia/Salmon/Clearwater Rivers 11 to 4 million years ago. The Ringold has been subdivided into nine distinct sub-units on the Site. The on-Site thickness of the Ringold formation ranges from zero to several hundred feet.
- *Cold Creek Formation*: This formation overlies the Ringold in some parts of the Site area. It is comprised primarily of alluvial sands, silts, and gravels and is generally considerably thinner than the underlying Ringold and the overlying Hanford Formation.
- *Hanford Formation*: This is the uppermost unit of the unconsolidated aquifer system. It is composed primarily of fluvial sands, silts, and gravels (up to boulder-size) deposited by cataclysmic Pleistocene-age floods originating from ancient glacial Lake Missoula and pluvial Lake Bonneville. The present Great Salt Lake is the remaining remnant of Pleistocene Lake Bonneville.

PLUME CHARACTERIZATION

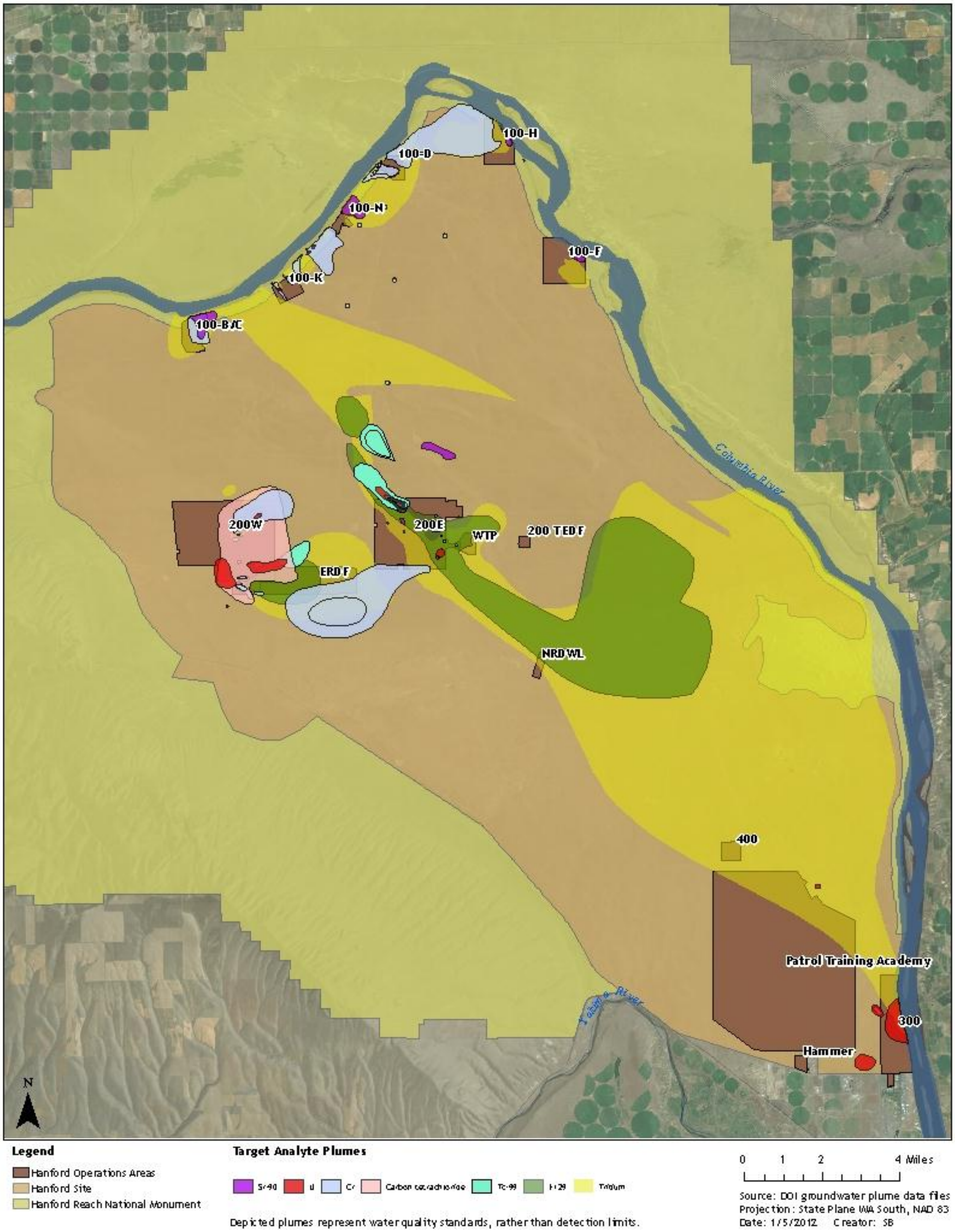
Major Hanford groundwater contaminants include carbon tetrachloride, chromium, cyanide, iodine-129, nitrate, strontium-90, technetium-99, tritium, and uranium. Hanford contaminant plumes are described below, and a map of contaminant plumes is provided in Exhibit 6-1. DOE has created the plume maps by hand, using visual interpolation methods and other relevant knowledge of source areas, hydrogeology, and chemical characteristics. The depicted contaminant plume boundaries were developed using specific standards or guidelines for each contaminant. Standards include but are not limited to, the Model Toxics Control Act (MTCA), Method B cleanup levels for groundwater, drinking water standards, and other aquatic thresholds.

- The tritium and iodine-129 contaminant plumes contain the largest areas with concentrations above drinking water standards (DOE 2010a). Sources for the largest of these plumes are in the 200 East Area, which generated plumes that extend toward the east and southeast.
- Relatively smaller tritium and iodine-129 plumes exist in the 200 West Area (DOE 2010a). Smaller tritium plumes also exist in some of the 100 Areas.
- Technetium-99 plumes in the 200 East and 200 West Areas contain concentrations above drinking water standards. One technetium-99 plume also extends northwest, beyond the 200 East Area boundary (DOE 2010a).
- Uranium plumes exist in the 200 East, 200 West, and 300 Areas and strontium-90 plumes are found in the 100 Areas, 200 East Area, and beneath the former Gable Mountain Pond (DOE 2010a).
- Cesium-137 and cobalt-60 concentrations exceed drinking water standards in a few individual wells in the 200 East Area and chromium exceeds standards (>100 µg/L) in portions of the 200 West, 100-K, and 100-D Areas (DOE 2010a).
- Nitrate, the most widespread chemical contaminant in Hanford groundwater, is observed in plumes originating from the 100 and 200 Areas and from offsite industrial and agricultural sources near the 300-FF-5 and 1100-EM-1 operable units (DOE 2010a).
- A carbon tetrachloride plume is present beneath the 200 West Area (DOE 2010a).

The contaminant plumes have been delineated over the past 30 years through the collection of thousands of samples from hundreds of monitoring wells, piezometers, and aquifer tubes, distributed throughout the Site area. A map showing the monitoring wells used for the 2009 Groundwater Monitoring and Performance Report (DOE/RL-2010-11, 2010) is presented in Exhibit 6-2. Appendix A contains additional maps at higher resolution.

Although the Site is generally well covered by monitoring wells, there are many places where there are gaps of two miles or more between wells. Thus, when sampling data is mapped and interpreted for delineating plume boundaries, interpolated concentration contours or plume boundaries are subject to errors of a mile or more in some places. Nonetheless, the areal delineation of major plumes (such as tritium and iodine-129) is probably adequately accurate for estimating plume areas within an uncertainty range of approximately 10 percent.

EXHIBIT 6- 1 GROUNDWATER PLUMES 2009



Plume area is only one of several parameters that are needed to reliably estimate injured volumes of groundwater. Additional important parameters include the vertical distribution of plumes, aquifer effective porosity values, adsorption effects, and matrix diffusion effects. Data gaps exist with respect to all these parameters, which are discussed in more detail below.

Vertical contaminant distribution (i.e., plume thickness). Although there is considerable information available regarding areal distributions of contaminants, data regarding vertical distributions and plume thicknesses is less abundant. Monitoring data indicate that nearly all of the contamination is contained within the unconfined aquifer system. Within the past two years, multiple-depth samples have been collected in numerous wells within the Central Plateau area (200 Areas) and in the river bank operable units (100-series units). The 2010 Annual Monitoring Report presents vertically-distributed data in cross-sectional form for the following areas and contaminants:

- 100-N: Strontium-90;
- 200-BP-5: Nitrate;
- 200-UP-1: Technetium-99, uranium, iodine-129, nitrate, chromium-6, and carbon tetrachloride;
- 200-ZP-1: Carbon tetrachloride and technetium-99; and,
- 300 Area: Uranium and TCE.

These new data help delineate the vertical distribution of contaminants, but data gaps remain pertaining to those contaminants and locations for which there is yet adequate vertical distribution data. For example, only the vertical distribution of nitrate was characterized using samples from the 200-BP-5 area; other potential contaminants of concern in this operable unit including iodine-120, uranium, technetium-99, and tritium were not characterized in the 2010 Annual Monitoring Report. Similarly, tritium has not been vertically characterized in the 300 Area, and chromium, uranium, tritium, and TCE have not been vertically characterized in the 200-ZP-1 area.

The thickness of the saturated portion of the unconfined system generally ranges from 100 to 250 feet. It is therefore possible to estimate conservative upper limits for likely plume thicknesses. However, such estimates could significantly over-estimate the volume of injured groundwater. Because there is an upward hydraulic gradient between the basalt and the overlying unconfined aquifer system over most of the Site area, contaminants that may have previously penetrated into the basalt have moved upward into the sediments (or are in the process of doing so). The upward gradient also prevents contaminants contained in the unconfined aquifer from moving downward into the basalt. It is our understanding that RI/FS reports are scheduled to be released later this year for some Operable Units on the Site and that these reports will contain some additional data on vertical contaminant distributions for some plumes.

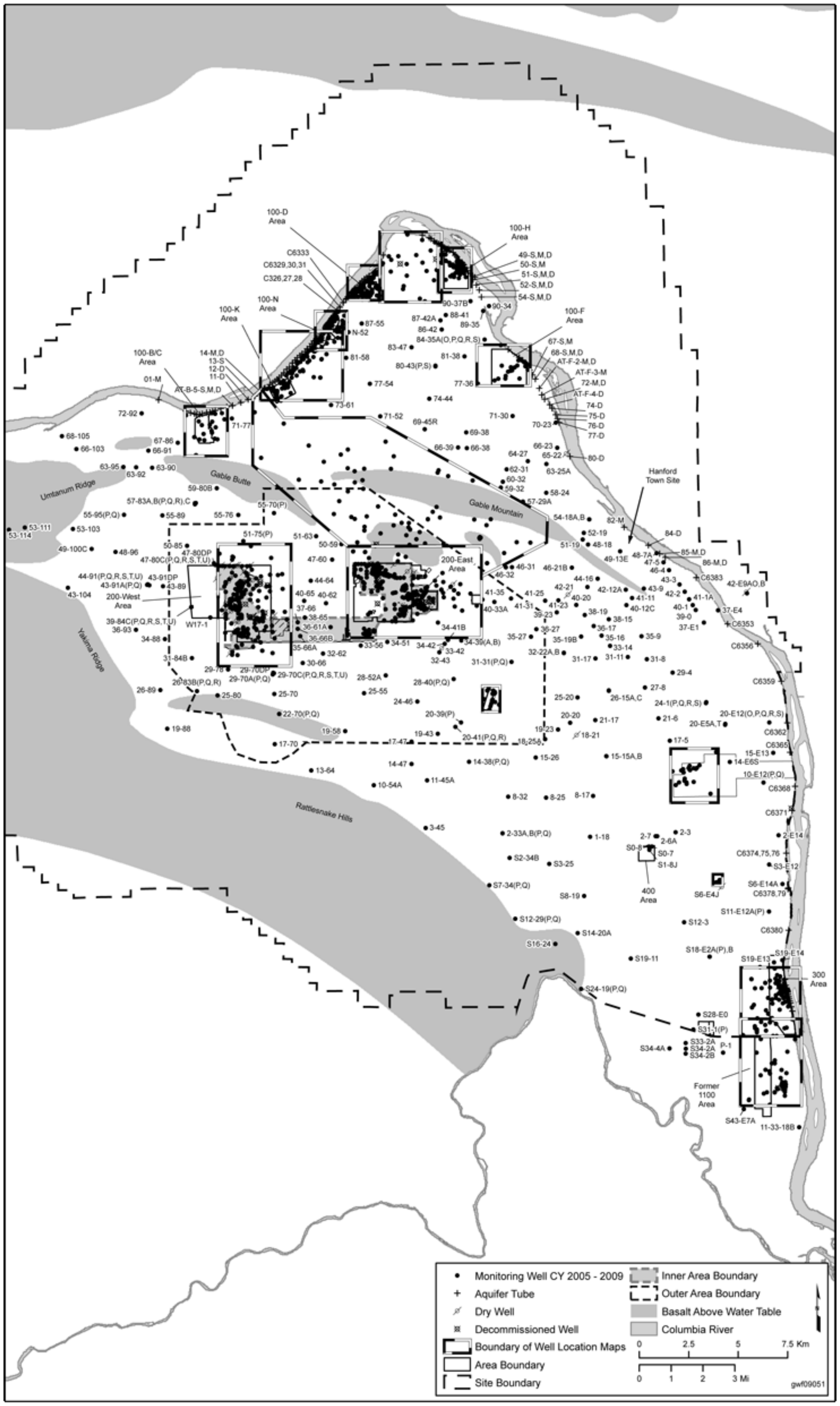
In addition to the limited vertical distribution data, available data are based on only a limited number of wells or well clusters with the capability of repeated multi-depth sampling. For example, the cross-sectional data for area 200-BP are based only on two or three multi-depth wells for each cross section. Due to the limited number of wells and vertical data, vertical concentration contours for much of the Hanford Site have to be interpolated using the existing data, resulting in significant uncertainties.

Aquifer effective porosity: This parameter is needed to determine the portion of the total contaminated aquifer volume that is occupied by contaminated water. The porosity of sediments in the unconfined aquifer has considerable variability, but generally can be expected to range from about 5 percent to 30 percent. DOE used a value of 15 percent for a computer groundwater model being used in the 200 Areas for evaluating potential remediation options (Central Plateau Version 3 MODFLOW Model, ECF-Hanford-10-0371, 2010). Although 15 percent may be a reasonable value, it is subject to an unknown degree of uncertainty. Hundreds of reports have been produced for the Site over the past 30 years describing hydrogeologic investigations. For instance, the PNNL-11801 document reports effective porosity values estimated from specific yields obtained from well-aquifer tests, in the range of 0.01 to 0.37 (Cole et al. 1997). Porosity values were also estimated using laboratory measurements, and these ranged from 0.19 to 0.41 (Cole et al. 1997).

Adsorption effects: Some dissolved contaminants, particularly cations such as strontium-90 and certain forms of uranium tend to adsorb to aquifer mineral grain surfaces. This phenomenon can significantly increase the potential for continued contamination of the groundwater as the adsorbed contaminants dissolve into the water. Over time, the concentration of contaminants in the groundwater will decrease through a combination of dispersion, reduced sources of contamination, clean water percolating into the groundwater, and the groundwater moving towards the river. As the concentration of dissolved contaminants decreases, adsorbed particles will dissolve into the groundwater to maintain equilibrium between the concentrations of contaminants adsorbed versus those in the water. There has been considerable work at the Site on addressing adsorption processes. For instance, distribution coefficients (i.e., the ratio of concentrations at equilibrium) for a number of contaminants including uranium and strontium-90 are reported in Cole et al. (1997). However, since the Hanford Site is so large, additional data could provide more certainty on the adsorption effects of each contaminant in all major plumes on Site. Adsorption effects are probably not significant for some of the major contaminants, such as tritium, technetium-99, nitrate, and chromate since these contaminants are anions and less likely to adsorb to minerals.

Matrix diffusion effects: Another process that can affect contaminant migration patterns is molecular diffusion of the dissolved contaminant into low-permeability clay/silt lenses and layers. This process, referred to as matrix diffusion, has an effect similar to that of adsorption/desorption in slowing contaminant migration and delaying remedial actions, such as pump-and-treat systems. Unlike adsorption, matrix diffusion impacts all dissolved contaminants in a similar manner. The effects of matrix diffusion could be evaluated using appropriate groundwater flow and contaminant transport models; however, based on our preliminary research, we have not found documentation of any such studies at the Hanford Site.

EXHIBIT 6-2 HANFORD GROUNDWATER MONITORING WELL LOCATIONS (Figure 2-1 from the 2009 Site Monitoring and Performance Report)



EXPOSURE TO CONTAMINANTS

We identified groundwater contaminant information in three Hanford databases:

- Hanford Environmental Information System (HEIS);
- The River Corridor Baseline Risk Assessment database (RCBRA / GiSdT); and,
- The Columbia River Component (CRC) Historic Database.

Because of the challenges associated with the partial overlap of information among the various databases, we evaluated information within each database separately, as described below. Maps of all groundwater sampling locations are provided in Appendix A.

HANFORD ENVIRONMENTAL INFORMATION SYSTEM (HEIS)

Data Exploration

Evaluation of data from HEIS focused on groundwater samples downloaded from HEIS on December 12, 2011. Because HEIS is frequently updated, later downloads may include additional information.

The groundwater data table, provided by Bill Webber, MSA, consists of a combination of fields from numerous tables from HEIS (including results, samples, well locations, and constituents), and was designed to mimic the Media Specific View tables available for other site media. The data consisted of 3,095,802 records, including 239,945 unique samples. We define a unique sample as a discrete unit of sampled groundwater, based on the "SAMP_NUM" field in HEIS.

Data Excluded from Analysis

Unique instances of a sample being analyzed for one particular constituent can often be identified as a combination of sample ID ("SAMP_NUM") and contaminant ("STD_CON_ID") fields. However, many contaminants and other characteristics, including hexavalent chromium, uranium-235, parathion, 1,4-dichlorobenzene, turbidity, and conductivity were measured using two or three different methods. Other contaminants, such as technetium-99, have duplicate records from two different lab codes ("QTESRL" and "FIELD"). Each of these duplicates represents a unique record in the database. Therefore for purposes of counting numbers of records, the primary key often consists of a combination of the "SAMP_NUM", "STD_CON_ID", "METHOD_NAME" and/or "LAB_c" fields. For purposes of tabulating total records, the record associated with the first lab code and first method was retained.

Lab quality control samples are identified in the field "LAB_QC_TYPE" or with the entry "QC_SAMPLE" in the "SAMP_ITEM" field. We excluded from analysis all records for which the "LAB_QC_TYPE" field had the value of "S", "R", or "B", indicating splits, replicates, or both. There were no QC samples identified in the "SAMP_ITEM" field. We similarly exclude field quality control samples, identified in the field "FIELD_QC_TYPE".

Data were not excluded based on laboratory or review qualifiers. However, future users of this data may wish to consider excluding information based on these qualifiers.

After selecting data as described above, the resulting list of records is reduced from 3,095,802to 2,828,322, comprising 239,945 samples. These samples were collected during 123,187 sampling trips, as described in Exhibit 6-3.

Data Analysis

The majority of records do not have any information in the “SAMP_FROM” field (a field describing the type of sample); however, this field is primarily used to designate the type of a biota sample and can be left blank for other media. The remaining records (representing 190 unique samples) are identified as from an aquifer tube.

Samples are also taken from a range of depths. Sample interval top depths range from 0 to approximately 778 feet (0 to 237 meters) and sample interval bottom depths range from approximately 0 to 833 feet (0 to 254 meters). Most samples (96 percent) do not contain information describing sample depth (in either the sample bottom or top depth fields). However, the depth of groundwater samples can often be estimated using the open interval. When only one depth measurement is taken, it is the sample bottom depth measurement. The numbers of samples per bottom depth ranges are shown in Exhibit 6-3.

EXHIBIT 6-3 NUMBER OF HEIS GROUNDWATER SAMPLES BY DEPTH TO BOTTOM OF SAMPLE

DEPTH TO BOTTOM OF SAMPLE (m)	NO. TOTAL SAMPLES	% OF TOTAL NO. SAMPLES
Blank	234,172	98
0 - 1	11	<0.01
>1 - 25	1,716	0.72
>25 - 50	1,591	0.66
>50 - 75	356	0.15
>75 - 100	1,004	0.42
>100 - 125	742	0.31
>125 - 150	287	0.12
>150	66	0.03
TOTAL NO. SAMPLES	**239,945**	**100**
TOTAL NO. SAMPLING TRIPS*	**123,187**	--

*Sampling trip refers to the number of unique combinations of space and time and is determined by grouping records using “WELL_NAME” and “SAMP_DATE_TIME” fields. The TOTAL NO. SAMPLES row refers to unique samples as units of groundwater, and are defined using the “SAMP_NUM” field. Numerous sample numbers can be associated with the same sampling trip.

We also explored the data as a function of well type. The numbers of samples taken from each well type are shown in Exhibit 6-4. The majority of samples (90 percent) were identified as from a groundwater well. The aquifer tube samples are collected to monitor groundwater along the Columbia River (DOE 2010a). The aquifer tubes are implanted into the shallow aquifer along the river shore.

EXHIBIT 6-4 COUNT OF HEIS GROUNDWATER SAMPLES BY WELL TYPE

WELL TYPE	NO. SAMPLES
Aquifer Tube	9,970
Boring	70
Grounding Well	16
Groundwater Well	216,531
Hosted Piezometer	2,776
Independent Piezometer	945
Instrument Boring	1
Piezometer Host	9,257
Proposed Site	26
Soil Tube	30
Unclassified	192
Vadose Well	131
TOTAL NO. SAMPLES	**239,945**

We examined data availability by contaminant. A total of 143,343 unique samples were tested for at least one of the target analytes or COEC/COPECs. Exhibit 6-5 shows the numbers of samples tested for each target analyte, and Exhibit 6-6 shows and the numbers of samples in which COEC/COPECs were measured.

EXHIBIT 6-5 COUNT OF HEIS GROUNDWATER SAMPLES TESTED FOR EACH TARGET ANALYTE

TARGET ANALYTE	NO. SAMPLES
Carbon tetrachloride	19,596
Cs-137	21,788
Cr	45,160
CrVI	26,518
I-129	8,018
Hg	16,687
PCBs*	2,246
Pu	408
Pu -238	2,828
Pu -239	317

TARGET ANALYTE	NO. SAMPLES
Pu -239/240	2,580
Pu -241	45
Sr-90	18,390
Tc-99	16,565
Tritium	50,109
U	22,477
U-233/234	740
U-234	1,304
U-235	2,328
U-236	9
U-238	2,438
TOTAL	**239,945**
*Samples tested for Aroclors, PCB congeners, or both.	

EXHIBIT 6-6 COUNT OF HEIS GROUNDWATER SAMPLES BY COEC/COPEC[76]

TARGET ANALYTE	NO. SAMPLES
Sb	43,029
As	19,722
Ba	44,633
B	3,777
Cd	44,553
Cu	44,295
Dieldrin	3,333
Pb	21,734
Mn	44,515
Se	16,079
TPH-diesel	330
Zn	43,706
TOTAL NO. SAMPLES	**239,945**

All records have a date and geographic coordinate information, and therefore can be mapped. The number of samples by well type and timeframe is shown in Exhibit 6-7.

[76] The depicted analytes represent COECs from the River Corridor Baseline Risk Assessment (DOE 2011b) and COPECs from the Columbia River Component Screening-Level Ecological Risk Assessment (DOE 2011a). Counts for COECs/COPECs previously presented in Exhibit 6-5 are not repeated here.

However, not all data may be suitable for use in the NRDA. In addition, the Trustees may wish to reject data based on qualifier information or for other reasons. For instance, 25,054 records lack a value in the "STD_VALUE_RPTD" field (i.e., the result field). The majority of the records lacking a value in the "STD_VALUE_RPTD" field are samples collected prior to 2000, and have a lab qualifier of "U".

EXHIBIT 6-7 NUMBER OF GROUNDWATER SAMPLES IN HEIS BY WELL TYPE AND TIMEFRAME

WELL TYPE	TOTAL NO. SAMPLES	<1981	1981 - 2000	>2000
Aquifer Tube	9,970		664	9,306
Boring	70			70
Grounding Well	16			16
Groundwater Well	216,531	32,282	76,532	107,717
Hosted Piezometer	2,776	1,339	837	600
Independent Piezometer	945	522	392	31
Instrument Boring	1			1
Piezometer Host	9,257	4,203	3,753	1,301
Proposed Site	26		1	25
Soil Tube	30		29	1
Unclassified	192	35	97	60
Vadose Well	131	11		120
TOTAL	**239,945**	**38,392**	**83,305**	**119,248**

Geographic Distribution

The 239,945 unique samples were collected from 3,733 sampling sites (i.e., wells, defined using the "WELL_NAME" field). HEIS groundwater samples are distributed across the site, but concentrated along the Columbia River near the 100 Areas, around the 100 Area operational facilities, around the 200 Areas, NRDWL, and the 300 Area. The number and percent of samples around operational facilities are shown in Exhibit 6-8.

EXHIBIT 6-8 COUNT OF HEIS GROUNDWATER SAMPLES WITHIN 500 METERS OF HANFORD OPERATIONAL AREAS

OPERATIONAL AREA	NO. SAMPLES	% OF TOTAL*
100 Areas	63,828	27
200 Areas	104,821	44
300 Area	16,521	7
400 Area	1,260	0.5
All other operational areas	9,402	
TOTAL	**195,832**	**82**
*% calculated out of total number of samples, 239,945.		

RIVER CORRIDOR BASELINE RISK ASSESSMENT DATABASE (RCBRA / GiSdT)

Data Exploration

Evaluation of data from this source focused on a data query for all usable groundwater samples from the RCBRA data management website (http://rcbra.neptuneinc.org/rcbra/home/index.xml), accessed on December 6, 2011. The downloaded data included 120,293 records, including 13,104 unique sample numbers.

Data Excluded from Analysis

Unique instances of a sample being analyzed for one particular constituent can often be identified as a combination of the sample ID ("samp_num") and contaminant ID ("gisdt_std_con_id") fields. However, we identified exceptions to this rule. A number of samples tested for specific conductance applied two different methods, each of which represents a unique record in the table. In addition, there were a number of completely duplicate records. For purposes of summarizing counts of records, the record associated with the first ID for the relevant sample/contaminant combination was retained.

There was no information provided in the "lab_qc_type" field, and therefore no samples were excluded from analysis based on the laboratory QC type. For purposes of tabulating numbers of records, data were not excluded based on laboratory qualifiers. However, future users of this data may wish to consider excluding information based on these qualifiers.

After selecting data as described above, the resulting list of records is reduced from 120,293 to 119,831, comprising 13,104 samples collected during 6,902 sampling trips[77].

Data Analysis

Sample type is not indicated in the database and there are no sample depth fields. However, samples are identified by operable unit, well, and source. Most of the samples (99 percent) have "HEIS" listed in the "source" field, and therefore these samples likely overlap with HEIS samples. All samples are identified as from the 100 and 300 Areas or from "1U 2&6" in the "source" field. Samples were taken from a number of different wells from the 199-B, 199-D, 199-F, 199-H,199-K, 199-N, 399-, and 699- series. We examined the data as a function of operable unit, shown in Exhibit 6-9.

[77] A sampling trip is a unique combination of sample date and time ("samp_date_time") and sample location ("well_id").

EXHIBIT 6-9 COUNT OF GiSdT GROUNDWATER SAMPLES BY OPERABLE UNIT

OPERABLE UNIT	TOTAL NO. SAMPLES
100-BC-5	**381**
100-FR-3	**392**
100-HR-3	**3,787**
100-IU-2 and 6	**209**
100-KR-4	**2,615**
100-NR-2	**2,695**
300-FF-5	**3,025**
TOTAL	**13,104**

We also examined data availability by contaminant: a total of 5,332 samples test for one or more of the target analytes or COEC/COPECs. Exhibit 6-10 depicts the number of samples testing for each target analyte by operable unit, while Exhibit 6-11 shows the same information by COEC/COPEC.

EXHIBIT 6-10 COUNT OF GiSdT GROUNDWATER SAMPLES BY TARGET ANALYTE AND OPERABLE UNIT

TARGET ANALYTE	OPERABLE UNIT							
	100-BC-5	100-FR-3	100-HR-3	100-IU 2&6	100-KR-4	100-NR-2	300-FF-5	TOTAL
Carbon tetrachloride	8	96		16	17	5	1,068	1,210
Cs-137	2	15	21	36	180	210	134	598
Cr	35	49	368	7	207	38	97	801
CrVI	20	16	1,041		241	18	10	1,346
I-129	2	2		57	2	1	54	118
Hg		11	20	1	17	15	10	74
PCBs		11	20	1	11	15	17	75
Pu-238					2		11	13
Pu -239/240					2		11	13
Sr-90	116	125	110	32	203	384	46	1,016
Tc-99	14	4	60	27	120	1	59	285
Tritium	151	147	396	84	714	348	494	2,334
U [inorganic]		46	164	1	43	15	1,152	1,421
U-233/234		12	21	2	15	15	74	139
U-235		12	21	2	15	15	74	139
U-238		12	21	2	15	15	74	139
TOTAL	**381**	**392**	**3,787**	**209**	**2,615**	**2,695**	**3,025**	**13,104**

EXHIBIT 6-11 COUNT OF GiSdT GROUNDWATER SAMPLES BY COEC/COPEC[78] AND OPERABLE UNIT

TARGET ANALYTE	OPERABLE UNIT							
	100-BC-5	100-FR-3	100-HR-3	100-IU 2&6	100-KR-4	100-NR-2	300-FF-5	TOTAL
Sb	35	49	362	7	180	38	97	768
As		11	34	1	37	19	16	118
Ba	35	49	366	7	180	38	96	771
B		11	20		11	15	10	67
Cd	35	49	366	7	180	38	97	772
Cu	35	49	368	7	180	38	97	774
Dieldrin		11	20	1	11	15	10	68
Pb		11	58	1	54	19	17	160
Mn	35	49	366	7	204	38	92	791
Se		11	24	1	11	15	11	73
TPH-diesel						77	32	109
Zn	35	49	366	7	180	38	92	767
TOTAL NO. SAMPLES	**381**	**392**	**3,787**	**209**	**2,615**	**2,695**	**3,025**	**13,104**

All records have coordinate information, a value in the "gisdt_std_value_rptd" field (i.e., results field), and a date. Exhibit 6-12 presents the number of samples by timeframe. For purposes of NRDA, the Trustees may wish to exclude data based on laboratory qualifiers, or other reasons such as location or type of sample.

EXHIBIT 6-12 NUMBER OF GiSdT GROUNDWATER SAMPLES BY TIMEFRAME

TIMEFRAME	TOTAL NO. SAMPLES
<1981	**0**
1981 - 2000	**2,418**
>2000	**10,686**
TOTAL	**13,104**

[78] The depicted analytes represent COECs from the River Corridor Baseline Risk Assessment (DOE 2011b) and COPECs from the Columbia River Component Screening-Level Ecological Risk Assessment (DOE 2011a). Counts for COECs/COPECs previously presented in Exhibit 6-10 are not repeated here.

Geographic Distribution

The 13,104 unique samples were collected from 331 wells or sampling sites (based on the "well_id" field). Sampling locations are concentrated within the Hanford Operations Area along the Columbia River. Approximately 68 percent of samples are within 500 meters of the on-site portion of the Columbia River. In addition, many of the samples (68 percent) are within 500 meters of the 100 Areas.

CRC HISTORIC DATABASE

Data Exploration

This database contains a "RESULT_DATA" table and a "SAMPLE_DATA" table. The original result table includes 306,931 records spanning multiple media. Overall, there are 12,963 groundwater records, comprising 339 unique samples (identified as having "GW" value in the media field in the "SAMPLE_DATA" table).

Data Excluded from Analysis

Unique instances of a sample being analyzed for one particular constituent are primarily identifiable as combinations of the sample number ("samp_num") field and the contaminant field ("con_id") . However, we identified an exception in one sample where conductivity was measured at different labs and using two different analytical methods.

For purposes of counting records, the one methodological duplicate record, mentioned above, was excluded from analysis. Twenty-five records (~0.2 percent) lacked a value in the "WC_STD_VALUE_RPT" field and were also excluded. A "DUP" field identified duplicates; however, none of the records contained any information in this field. All records either contained no information or were identified as "NA" in the "SAMP_ITEM" field (which often describes sample type detail in HEIS and other tables), "GiSdT_field_qc_type" and "GiSdT_lab_qc_type" fields. For purposes of tabulating numbers of records, data were not excluded based on laboratory, review, or validation qualifiers. However, future users of this data may wish to consider excluding information based on these qualifiers.

After excluding records as described above, the number of records was reduced from 12,963 to 12,937, comprising 339 samples collected during 141 sampling trips[79].

Data Analysis

Samples could not be readily characterized by depth: the "SAMP_DEPTH_TO", "SAMP_DEPTH_FROM", and "WC_SAMP_DEPTH_TO" and "WC_SAMP_DEPTH_FROM" fields did not contain any information, and all samples were identified as "NA" in the "GiSdT_rcbra_sample_depth" field.

Samples were not associated with sample type information in the "SAMP_ITEM" and "SAMP_FROM" fields; records either did not contain any information or were identified as "NA" in these fields.

---

[79] A sampling trip is defined as a unique combination of sample date ("SAMP_DATE") and sample location ("SAMP_SITE").

For roughly 40 percent of samples, the area from which a sample was collected is identified using the "SAMP_AREA" field. About two-thirds of samples have an entry in sample type field. Exhibit 6-13 shows the number of samples per sample type and sample area.

EXHIBIT 6-13 COUNT OF CRC GROUNDWATER SAMPLES BY SAMPLE TYPE AND AREA

SAMPLE AREA	SAMPLE TYPE			
	BLANK	DISCRETE	GRAB	TOTAL
Blank	105	96		201
100 DDR			18	18
100 F			22	22
100 H			22	22
100 K			23	23
100 N			30	30
300 Area			19	19
Columbia River	4			4
TOTAL	**109**	**96**	**134**	**339**

Approximately 40 percent of samples (134 samples) are identified as from a "GW Well" in the "GiSdT_environment", "GiSdT_site_type", and "GiSdT_category" fields, and the remaining samples do not contain information in these fields. None of the depth fields ("SAMPLE_DEPTH_TO" and "SAMPLE_DEPTH_FROM", "GiSdt_rcbra_sample_depth", and "WC_SAMPLE_DEPTH_TO" and "WC_SAMPLE_DEPTH_FROM" fields) contain any information on depth of groundwater samples; hence, we could not characterize the data based on depth.

We examined data availability by target analyte and COEC/COPECs. Exhibits 6-14 and 6-15 present the results.

EXHIBIT 6-14 COUNT OF CRC HISTORIC GROUNDWATER SAMPLES BY TARGET ANALYTE

TARGET ANALYTE	NO. SAMPLES
Carbon tetrachloride	12
Cs-137	74
Cr	210
CrVI	105
I-129	13
Hg	68
PCBs*	67

TARGET ANALYTE	NO. SAMPLES
Pu-238	1
Pu -239/240	1
Sr-90	83
Tc-99	11
Tritium	123
Calculated total U	67
U	68
U-234	67
U-235	67
U-238	67
TOTAL	**339**
*Samples measured as Aroclors.	

EXHIBIT 6-15 COUNT OF CRC HISTORIC GROUNDWATER SAMPLES BY COEC/COPEC[80]

TARGET ANALYTE	NO. SAMPLES
Sb	104
As	67
Ba	105
B	67
Cd	104
Cu	104
Dieldrin	67
Pb	68
Mn	105
Se	68
Zn	104
TOTAL NO. SAMPLES	**339**

We also examined the data by timeframe. Exhibit 6-16 shows the numbers of samples taken within each timeframe.

[80] The depicted analytes represent COECs from the River Corridor Baseline Risk Assessment (DOE 2011b) and COPECs from the Columbia River Component Screening-Level Ecological Risk Assessment (DOE 2011a). Counts for COECs/COPECs previously presented in Exhibit 6-14 are not repeated here.

EXHIBIT 6-16 NUMBER OF CRC GROUNDWATER SAMPLES BY AREA AND TIMEFRAME

SAMPLE AREA	TOTAL NO. SAMPLES	NO. SAMPLES WITH COORDINATES	<1981	1981 - 2000	>2000
Blank	**201**	201		57	144
100 DDR	**18**	18			18
100 F	**22**	6			22
100 H	**22**	18			22
100 K	**23**	21			23
100 N	**30**	26			30
300 Area	**19**	19			19
Columbia River	4	4		4	0
TOTAL	**339**	**313**	**0**	**61**	**278**

Note: All samples lacking geographic coordinate information were sampled in 2006 from the 100F, 100H, 100K, and 100N areas.

Of note, not all of the data summarized above may be suitable for use in the natural resource damage assessment. For instance, 26 samples lack geographic coordinate information (Exhibit 6-13). Although general locational information is provided (e.g., all records missing coordinates have information in the “SAMP_SITE” and “SAMP_AREA” fields, which indicates the operable unit from which the sample was taken), the absence of easting and northing in the database at a minimum makes mapping the precise locations of those datapoints a more complicated exercise. Trustees may also wish to reject data based on laboratory or review qualifiers or for other reasons.

Geographic Distribution

The 339 unique CRC groundwater samples were collected from 100 sampling sites (as defined using the “SAMP_SITE” field). Similarly to the GiSdT data, most groundwater samples were taken along the Columbia River, and are concentrated around the 100 and 300 Areas. Exhibit 6-17 presents the percentage of samples within 500 meters of operational areas.

EXHIBIT 6-17 PERCENTAGE OF CRC HISTORIC GROUNDWATER SAMPLES WITHIN 500 METERS OF OPERATIONAL AREAS

OPERATIONAL AREA	NO. OF SAMPLES	% OF TOTAL*
100 Areas	130	41
200 Areas		0
300 Area	37	12
400 Area		0
All other operational areas		0
TOTAL	**167**	**53**
*% calculated out of total number of samples with coordinates, 313.		

REMEDIATION

Groundwater remediation on the Hanford site is organized by operable unit. There are eleven operable units: 200-BP-5, 200-PO-1, 200-UP-1, 200-ZP-1, 100-BC-5, 100-KR-4, 100-NR-2, 100-HR-3, 100-FR-3, 300-FF-5, and 1100-EM-1. Groundwater remedial actions currently being undertaken onsite include pump-and-treat systems, apatite barriers, and groundwater extractions systems. The 100-K and 100-D Areas have pump-and-treat systems to decrease the amount of chromium reaching the river. The 100-N Area has a pump-and-treat system intended to remove strontium-90 (DOE 2010a). The 200 West Area has a soil vapor extraction system to reduce carbon tetrachloride movement to groundwater, and a pump-and-treat system to prevent carbon tetrachloride from spreading (DOE 2010a). Another system removes technetium-99 from the aquifer in Waste Management Area T in the 200 West Area. An additional pump-and-treat system removes technetium-99 and uranium from the aquifer in 200-UP-1 in the 200 West Area. The uranium plume in the 300-FF-5 operable unit continues to be monitored, and concentrations were lower than target values during 2010 (DOE 2011).

Remediation in the 1100-EM-1 operable unit has been completed and trichloroethene concentrations have remained under 5 µg/L since 2001. Additional detail on remediation of groundwater on the Hanford site can be found in the groundwater monitoring reports.

MODELING

In a NRDA, injury to groundwater resources is typically quantified as the volume of groundwater injured per year. Models frequently play a critical role in this quantification: data on past contaminant levels may be few or absent (but may be approximated through models), and models are of course also necessary to estimate future concentrations.

Groundwater computer models have been applied at the Hanford Site to examine and simulate groundwater flow patterns, water budgets, aquifer responses to hydraulic stresses, migration of contaminant plumes, and the performance of groundwater remediation systems. These models are helpful in interpolating hydrogeology conditions between wells, in conducting sensitivity analyses regarding data gaps, in prioritizing future data gathering steps, in testing remediation alternatives, and in assessing exposures under various assumed scenarios. They can also be useful in estimating groundwater injury under various past, present and future scenarios. Two of the more significant models available at the Site include:

- *Central Plateau Model*: This model covers the central area of the Site including the 200 Areas, which are large sources of groundwater contamination. The model includes six hydrostratigraphic layers of the unconfined aquifer. Versions of this model have been used to examine remedial alternatives at Operable Units 200-UP-1 and 200-PO-1 (ECF-Hanford-10-0371; ECF-200UP1-10-0374; ECF-200PO1-09-2352). Subsets of this model have been created in particular for the 200 East and 200 West areas, described below. These models cover a smaller area, but use many of the same input values as the larger Central Plateau Model.
    - *200 East Area Conceptual Groundwater Model:* Primary components are 1) the static elements of the subsurface that form the hydrostratigraphic framework, and 2) groundwater that moves through this framework in response to stresses within the aquifer (Williams et al. 2000).
    - *Large-scale stratigraphic model of Central Plateau (focusing on 200 West Area)* was developed (Last et al. 2009). Best-estimate stratigraphic contact data and ground-surface elevation data were used in EarthVision software to create a 3D model of the major stratigraphic units beneath the 200 West Area. Of note, uncertainties exist in the stratigraphic interpretations, including the identification of geologic units and contacts, vertical survey and depth control, and in the depth and thickness of sedimentary units (Last et al. 2009).
- *Site-Wide Groundwater Model*: This model covers the entire Site and could potentially be useful in modeling contaminant plume conditions at any subarea of the Site (Transient Inverse Calibration of Site Wide Model to Operational Impacts 1943-1996, PNNL-13447, 2010).

Both of these models use the USGS MODFLOW code to simulate groundwater flow, and include multiple layers to examine three-dimensional flow patterns among the hydrogeologic units of concern (i.e., aquifer and aquitard units). These flow models have been coupled with the contaminant transport code, MT3DMS to simulate plume migration and remedial action design and performance. In addition, a three-dimensional interpolation software package, Leap Frog, is currently being used at the site to contour contaminant data in three dimensions, to compute plume volumes, and to sub-divide plume zones into finite-difference grid blocks for incorporation into the MODFLOW/MT3D flow and transport models.

The computer codes being employed by DOE at the site are widely used and accepted in the technical community and are appropriate for the intended applications. However, there are uncertainties and limitations with these models. In particular, some of the most sensitive parameters for which there is some uncertainty include:

- *Hydraulic conductivity*. Data exists on hydraulic conductivity on the Hanford Site; however, the data is spotty across the Site. This forces modelers to make assumptions about locations for which there is no data. Hydraulic conductivity values are important in determining the velocity of groundwater plumes, and the average values used could be off by as much as a factor of 10.
- *Effective porosity*. Effective porosity is also directly related to the velocity of plumes. There is significant data on effective porosity values on Site, but these values can vary considerably across the Site. Models should take this variation into account, and incorporate a range of effective porosity values.
- *Boundary conditions*. Boundary conditions refer to the properties assigned to the boundaries of the model. These variables are based on assumptions and can be highly uncertain.

DATA GAPS AND CONCLUSIONS

CONTAMINANT EXPOSURE

Exhibit 6-18 summarizes available information for each of the evaluated contaminant databases. As indicated in this table, HEIS (by far the predominant source of Hanford groundwater contaminant data) contains measurements for all target analytes and COEC/COPECs. Tritium is the most frequently analyzed analyte with 50,109 samples; in addition, chromium, hexavalent chromium, carbon tetrachloride, cesium-137, mercury, strontium-90, uranium, technetium-99, and all of the COEC/COPECs are analyzed in over 15,000 samples, while plutonium, plutonium-239 and 241, uranium-233/244 and 236, and TPH-diesel are the least frequently analyzed (hundreds of samples).

Data on sample depths is lacking: 98 percent of HEIS samples do not contain information on depth, and there is no information on groundwater sample depths in the CRC Historic or GiSdT databases. However, sample depth for DOE groundwater samples collected after a well has been drilled could potentially be estimated from the open interval of the well, which is not captured in the sample table view. Sample depth information could also potentially be obtained from other HEIS-related databases or the Hanford Wells database through the Environmental Dashboard Application, and the pump depth or screen interval could provide an indication of the depth of the sample.

Groundwater contaminant samples were taken from across the Hanford Site. Samples are concentrated around the 100 and 200 Areas; however, groundwater samples are also distributed across the site and along the Columbia River. The databases also contain a number of offsite samples taken within the Paco Basin.

PLUME CHARACTERIZATION AND HYDROGEOLOGY

As noted previously, DOE has created a series of groundwater plume maps by hand, using visual interpolation methods and other relevant knowledge of source areas, hydrogeology, and chemical characteristics (the 2010 Annual Monitoring Report contains the most recent examples). The generation of the maps relies on professional judgment. Re-creating these maps by one or more independent groundwater geologists would provide an alternate interpretation of current nature and extent of plumes and could help characterize the potential uncertainty in, or accuracy of, the plume maps. The HNRTC has contracted the USGS to undertake an independent evaluation of Hanford plume maps.

Vertical Distribution Data

A particularly significant data gap for NRDA purposes appertains to the vertical distribution of the plumes. Although known plumes have been fairly well delineated on an areal (i.e., horizontal) basis, their vertical extent has not been as well characterized. This information is necessary to estimate the volume of injured groundwater.

Among the data gaps obvious from these examples is that not all contaminants within each of the five areas have been characterized in the vertical direction. This is partly due to the fact that not all samples were analyzed for all potential contaminants of concern. There is no multiple-depth sampling data for large areas of several plumes, such as the large northeastern sector of the extensive tritium and iodine-129 plumes from the 200 East Area. In addition, there are very few multi-depth wells; therefore, vertical concentration contours have to be interpolated using the existing data, resulting in uncertainties in areas without multi-depth wells.

Temporal Vertical Data

For those plumes that have some vertical distribution data (such as those in the 200 Areas, as presented in the 2010 Annual Monitoring Report), there is insufficient temporal data vertically. Most of the multi-depth sampling has been conducted only since 2009. The resulting dataset forms an insufficient basis generating reliable projections many years into the future. In some cases, only one or two sets of vertically-distributed samples have been collected in the 2009-2010 period. Additional sampling is needed to establish reasonable temporal trends.

Effective Porosity of the Aquifer

Information on aquifer effective porosity distributions is limited. The 2010 Annual Monitoring Report presents data indicating that effective porosities in the primary plume areas are in the range of 25 to 30 percent and total porosities range from 21 to 41 percent, which are reasonable for these types of sediments. However, porosity measurements were not presented for all plume areas of concern. This is not as significant a data gap as some of the others because measured porosities and average porosities for these strata do not vary over a wide range. The likely error range in computed plume volumes attributable to error in the assumed porosity is not likely to be greater than about 20 percent.

Adsorption and Matrix Diffusion Effects

Adsorption distribution coefficients for potential contaminants of concern and plume-specific sediments may not be adequately known. Additional (but undetermined) field and laboratory investigations may be needed to fill this data gap. This information is necessary to project future migration patterns of contaminants subject to significant adsorption effects, such as strontium-90 and uranium.

Similarly, all dissolved contaminants in mobile plumes are subject to molecular diffusion into adjacent fine-grained clay/silt layers and lenses. This phenomenon is referred to as matrix diffusion and can have significant impacts on the migration rates and patterns of plumes moving in coarser-grained aquifers. For example, contaminants in contact with the Upper Mud Unit of the Ringold formation diffuse into the fine-grained mud unit, and then can later diffuse out of the unit back into the aquifer. The potential impacts of matrix diffusion may need to be quantitatively assessed using appropriate computer models.

Cumulative Health Risks for Multiple Contaminants

Many of the Hanford contaminant plumes include two or more contaminants. Plume delineations presented in the 2010 Annual Monitoring Report are for single individual contaminants, based on drinking water health standards (such as MCLs) or other guidelines based on health risk. In that case, concentrations of the particular contaminant of concern that are below the standard are not included within the delineated boundary of the plume, even though some of the concentrations may be very near the standard. If a second or third contaminant is also present within or contiguous with the plume of the first contaminant, the cumulative exposure effects of each of the contaminants must be considered. Consider this example: a well near a tritium plume and a strontium-90 plume has a tritium concentration of 18,0000 pCi/L, which is below the drinking water standard of 20,000 pCi/L. However, the well also has a strontium-90 concentration of 6 pCi/L which is below the drinking water standard of 8 pCi/L. Based on the individual risk posed by either contaminant, the well would not be included within the boundary of either plume. But if the cumulative risk posed by the sum of both contaminants is considered, the well should be included in the combined tritium/strontium-90 plumes and the combined plume would be larger than either of the individual plumes. The effect of this consideration would be to significantly expand the areas of many of the plumes, as well as their respective thicknesses in some cases. In reviewing the plume maps presented in the 2010 Annual Monitoring Report, it appears that this might be a significant factor for consideration in the following plumes:

- Strontium-90, tritium, and chromium 100-B/C;
- Strontium-90, tritium, carbon-14, chromium and TCE, 100-KR Area;
- Strontium-90 and tritium, 100-NR-2 Area;
- Strontium-90, chromium, and TCE, 100-FR-3 Area;
- Iodine-129, technetium-99, uranium , strontium-90and tritium, 200-BP-5 Area;
- Tritium and iodine-129, 200-PO-1 Area;
- Technetium-99, uranium, tritium, iodine-129, and chromium, 200-UP-1 Area;

- Carbon tetrachloride, TCE, chromium, iodine-129, tritium, and technetium-99 200-ZP-1 Area; and
- Tritium and uranium, 300-FF-5 Area.

GROUNDWATER MODELS

The groundwater models mentioned previously can potentially be useful tools in assessing past, present and future degrees of injury to groundwater. These models include those used for Operable Units in the 200 Areas for remedial investigations (based on the Central Plateau Model) and the Site-Wide Model. It is unlikely that new models would need to be created for assessing groundwater injury. However, these existing models (as do all groundwater modes) have degrees of uncertainty and limitations associated with them, based on assumptions used and uncertainties in input data. As mentioned previously, some of the more sensitive input variables include hydraulic conductivity, effective porosity, and boundary conditions. More generally, the following recommendations would help reduce the uncertainties in the groundwater models:

- Conduct an independent peer review to evaluate model adequacy and appropriateness;
- Evaluate the models' ability to adequately account for adsorption and matrix diffusion processes;
- Acquire and use data from a longer period of time, particularly when modeling vertical transport processes; and
- Conduct sensitivity analyses to characterize the effect of uncertainties in inputs, on model outputs.

CONCLUSIONS

The distribution of groundwater contaminant plumes have been reasonably well characterized on an areal basis for all of the major plumes, but vertical distribution data may not be sufficient. The forthcoming River Corridor Remedial Investigation/Feasibility Study (RI/FS) and other reports, listed below, may provide information useful in characterizing the vertical extent of plumes and thus in estimating plume volumes.

- Deep Vadose Zone RI/FS Work Plan – 200-DV-1-OU (due 9/2012).
- Feasibility Study and Proposed Plan (FS/PP) – 200-DV-1-OU (due 9/2015).
- 200 East Groundwater FS/PP (due 12/2012).
- Remedial Design/Remedial Action Work plan for 100-HR-3 Groundwater Operable Unit Interim Actions (due 9/2011).

Cumulative effects of contaminants are not currently incorporated into plume delineations, which will likely enlarge the areas and thickness of many plumes for total volume computations.

Lastly, additional capabilities and calibration against longer-term field data in the models used for assessing injury to groundwater could increase the reliability of results and better characterize uncertainties.

SUGGESTED FUTURE STUDIES

The above analyses suggest that several studies may be appropriate to support an injury assessment of Hanford groundwater. These include (but are not necessarily limited to):

- Installing additional multi-depth wells to be sampled for a number of years to gather vertical distribution data on contaminant plumes. This data would reduce uncertainties in groundwater plume volumes and estimates of injured groundwater.
- Verify the validity and limitations of Hanford groundwater models, including the ability and limitation of current models to characterize contamination in the vadose zone. This could help determine how Hanford models can aid in estimating the volume of injured groundwater, and how vadose zone models can help estimate the affect vadose zone contamination may have on groundwater.
- Characterize groundwater upwellings in the Columbia River and the geology of the Columbia River bed. This study may help in determining the nature, extent, and frequency of upwellings as well as the movement of plumes beneath the River, and therefore help determine the impact of groundwater contamination on aquatic biota in the River.
- Synoptic sampling of selected river corridor wells. This study may help determine the effectiveness of groundwater data to develop plume maps and the effect river stage and timing of groundwater samples has on groundwater plume estimates.
- Gather, organize, and relate information on groundwater wells to sampling data. This could provide additional information associated with groundwater samples, including water depth, and reduce the uncertainty of parameters used to estimate the volume of contaminated groundwater.
- Determine baseline services that would be provided by groundwater at Hanford, and the extent to which these services are affected by the presence of contamination. Once an adequate understanding of Site groundwater contamination is gained, it is important to determine the groundwater services that have been affected by the contamination in order to develop an estimate of damages.

The Trustees have already begun a study with USGS to validate Hanford groundwater contaminant plumes and the calculation of plume volumes. For additional background and detail on these suggested future studies, please refer to the *Groundwater Resource Review Report* (Industrial Economics, Inc., November 9, 2011).

EXHIBIT 6-18 SUMMARY OF GROUNDWATER DATA GAPS WITHIN EACH DATABASE

DATABASE	NO. GW SAMPLES	DEPTH DISTRIBUTION	SAMPLE TYPE AND SAMPLING LOCATION	GEOGRAPHIC DISTRIBUTION	TEMPORAL DISTRIBUTION	SAMPLES PER ANALYTE
HEIS	239,945	Sample bottom depths range from 0 254 meters. 98% of samples do not contain any information about sample depth within the database.	Samples were taken from a number of well types including aquifer tube, boring, proposed site wells, and vadose zone wells. However, 90% are from a groundwater well.	All samples have coordinates. Samples are concentrated around Hanford operational areas, particularly the 100 and 200 Areas.	**<1981**: 16% **1981-2000**: 35% (20,235) **>2000**: 50% (106,005)	**No samples**: NA **Few (<1,000)**: Pu, Pu-239, Pu-241, U-233/234, U-236, TPH-diesel **Most**: Tritium (50,109); >15,000: C-tet, Cs-137, Cr, CrVI, Hg, Sr-90, Tc-99, U, Sb, As, Ba, Cd, Cu, Pb, Mn, Se, Zn **All other analytes:** 1,000 - 15,000
RCBRA / GiSdT	2,430	There were no sample depth fields in the groundwater table.	Samples were taken from different operable units in the 100 Area including 100-BC-5, 100-FR-3, 100-HR-3, and 100-KR-4.	All samples have coordinates. All samples are concentrated around the 100 Areas.	**<1981**: 0 **1981-2000**: 25% (614) **>2000**: 75% (1,816)	**No samples**: NA **Few (<15):** Pu-238, Pu-239/240 **Most**: Tritium (2,334); >500 - 1,500: C-tet, Cs-137, Cr, CrVI, Sr-90, U, Sb, Ba, Cd, Cu, Mn, Zn **All other analytes:** -50 - 500
CRC Historic	339	No sample depth information was provided in depth fields.	40% of samples were identified as grab, 28% as discrete, and 32% left blank in sample type field. Samples were taken from the 100 DDR, F, H, K, and N areas as well as the 300 Area and Columbia River.	26 (8%) of samples lack coordinates. Most samples are concentrated around the 100 Areas, with others further downstream along the Columbia River.	**<1981**: 0 **1981-2000**: 18% (61) **>2000**: 82% (278)	**No samples**: TPH-diesel **Few (<15):** C-tet, I-129, Pu-238, Pu-239/240, Tc-99 **Most**: Cr (210) **All other analytes:** -50 - 125

This page intentionally left blank.

REFERENCES

Bechtel Hanford, Inc. (BHI). 2002. Hanford Environmental Information System – Detailed Design Specification. (BHI-01639, Rev. 0). Prepared by Bechtel Hanford, Inc. for the U.S. Department of Energy, May 2.

Bechtel Hanford, Inc. (BHI). 2003. 100-B/C Area Ecological Risk Assessment Data Quality Objectives. BHI-01673.

Bechtel Hanford, Inc. (BHI). 2005. Data Quality Objectives Summary Report for the 100 Area and 300 Area Component of the RCBRA. BHI-01757. January.

Bisping, L.E. 2010. Hanford Site Environmental Surveillance Master Sampling Schedule for Calendar Year 2010. Prepared for the U.S. Department of Energy by Pacific Northwest National Laboratory. PNNL-19079. January.

Caldwell, L.L. 1995. Wildlife Studies on the Hanford Site: 1994 Highlights Report. Prepared for the U.S. Department of Energy. Pacific Northwest Laboratory PNL-10552. April.

Cole, CR, SK Wurstner, MP Bergeron, MD Williams, and PD Thorne. 1997. Three-dimensional analysis of future groundwater flow conditions and contaminant plume transport in the Hanford Site unconfined aquifer system: FY 1996 and 1997 Status Report. PNNL-11801 UC-903.

Downs, J.L., M.A. Simmons, J.A. Stegen, A.L. Bunn, B.L. Tiller, S.L. Thornsten, and R.K. Zufelt. 2004. Ecological characterization data for the 2004 Composite Analysis. Prepared for the U.S. Department of Energy. Pacific Northwest National Laboratory PNNL-14884. November.

Fitzner, R.E. and R.H. Gray, 1991. The Status, Distribution and Ecology of Wildlife on the U.S. DOE Hanford Site: A Historical Overview of Research Activities. Environmental Monitoring and Assessment 18:173-202.

Geist, D. R. 2000. Hyporheic discharge of river water into fall Chinook salmon (*Oncorhynchus tshawytscha*) spawning areas in the Hanford Reach, Columbia River. Canadian Journal of Fisheries and Aquatic Sciences 57: 1647-1656.

Gilbert, R.O. 1987. Statistical Methods for Environmental Pollution Monitoring. Van Nostrand Reinhold Company Inc., New York, New York.

Ingersoll CG, Mount DR, Field L, Ireland S, MacDonald DD, Smorong DE. 2008. Compilation of control performance data for laboratories conducting whole-sediment toxicity tests with the amphipod *Hyalella azteca* and the midge *Chironomus dilutus* (formerly *C. tentans*). Presented at the 29th meeting of SETAC, Tampa FL, November 16-20, 2008.

Kaputska, L. 2007. Letter to Dr. Jim Markwiese, Neptune and Company, Inc. Re: Review of Phytotoxicity Tests Per Contract dated 28 February 2007. Golder Associates. March 1.

Larson, K.B., T.M. Poston, and B.L. Tiller. 2008. Evaluation using caged clams to monitor contaminated groundwater exposure in the near-shore environment of the Hanford Site 300 Area. Pacific Northwest National Laboratory. PNNL-17270. Prepared for the U.S. Department of Energy.

Last, G.V., P.D. Thorne, J.A. Horner, K.R. Parker, B.N. Bjornstad, R.D. Mackley, D.C. Lanigan, and B.A. Williams. 2009. Hydrogeology of the Hanford Site Central Plateau – A status report for the 200 West Area. Pacific Northwest National Laboratory, PNNL-17913 Rev. 1.

Mueller, R.P., B.L. Tiller, M.D. Bleich, G.K. Turner, and I.D. Welch. 2011. Assessment of the Species Composition, Densities, and Distribution of Native Freshwater Mussels along the Benton County Shoreline of the Hanford Reach, Columbia River, 2004. PNNL-19933. Prepared for the U.S. Department of Energy. January.

Perkins, C.J., M.C. Dorsey, S.M. McKinney, and J.W. Wilde. 2010. Hanford Site Near-Facility Environmental Monitoring Data Report for Calendar Year 2009. PNNL-19455, Appendix 2. Mission Support Alliance. September. Prepared for the U.S. Department of Energy.

Poston, T.M., R.W. Hanf, R.L. Dirkes, and L.F. Morasch (eds.). 2004. Hanford Site Environmental Report for Calendar Year 2003. PNNL-14687. Prepared for the U.S. Department of Energy. September.

Poston, T.M., R.W. Hanf, R.L. Dirkes, and L.F. Morasch (eds.). 2005. Hanford Site Environmental Report for Calendar Year 2004. PNNL-15222. Prepared for the U.S. Department of Energy. September.

Poston, T.M., R.W. Hanf, J.P. Duncan, and R.L. Dirkes (eds.). 2006. Hanford Site Environmental Report for Calendar Year 2005. PNNL-15892. Prepared for the U.S. Department of Energy. September.

Poston, T.M., J.P. Duncan, and R.L. Dirkes (eds.). 2009. Hanford Site Environmental Report for Calendar Year 2008. PNNL-18427. Prepared for the U.S. Department of Energy. September.

Rokkan, D.J. 2011. Statement of Work for Services Provided by the Waste Sampling and Characterization Facility for the Effluent and Environmental Monitoring Program during Calendar Year 2011. HNF-EP-0835 Rev. 17. Prepared by Mission Support Alliance for the U.S. Department of Energy under Contract DE-AC06-09RL-14728. January.

Simmons, M.A., A. Stegen, T.M. Poston, K.D. Hand, B.L. Tiller, and J.M. Brandenberger. 2010. Canada geese at the Hanford Site—Trends in reproductive success, migration patterns, and contaminant concentrations. PNNL-19212. Prepared for the U.S. Department of Energy. Pacific Northwest National Laboratory.

Soll J, JA Hall, R Pabst, and C Soper (eds.). 1999. Biodiversity Inventory and Analysis of the Hanford Site – Final Report 1994-1999. The Nature Conservancy of Washington, Seattle, Washington.

Tiller, B.L., G.E. Dagle, L.L. Cadwell, T.M. Poston, and A. Oganesian. 1997. Investigation of Anatomical Anomalies in the Hanford Site Mule Deer. PNNL-11518, Pacific Northwest National Laboratory, Richland, WA.

Tiller, B. L., Marco, J. D., and W. H. Rickard. 2005. Metal concentrations, foraging distances, and fledging success of great blue herons nesting along the Hanford Reach of the Columbia River. *Environmental Monitoring and Assessment* 104: 71-79.

U.S. Department of Energy (DOE). 1997. Screening Assessment and Requirements for a Comprehensive Assessment: Columbia River Comprehensive Impact Assessment. DOE/RL-96-16, Rev. 0. April.

U.S. Department of Energy (DOE). 2003. 100-B/C Area Ecological Risk Assessment Sampling and Analysis Plan. DOE/RL-2003-08. May.

U.S. Department of Energy (DOE). 2005. 100-NR-2 Study Area Ecological Risk Assessment Sampling and Analysis Plan, DOE/RL-2005-22, Rev. 0.

U.S. Department of Energy (DOE). 2006. 100 and 300 Area Component of the River Corridor Baseline Risk Assessment Sampling and Analysis Plan. DOE/RL-2005-42, Revision 1. June.

U.S. Department of Energy (DOE). 2007. Risk Assessment Report for the 100 Area and 300 Area Component of the River Corridor Baseline Risk Assessment. DOE/RL-2007-21. Draft A. June.

U.S. Department of Energy (DOE). 2008. Remedial Investigation Work Plan for Hanford Site Releases to the Columbia River. DOE/RL-2008-11 Rev. 0.

U.S. Department of Energy (DOE). 2009. Tri-Party Agreement Databases, Access Mechanism, and Procedures. December. DOE/RL-93-69. Revision 5.

U.S. Department of Energy (DOE). 2010a. Hanford Site Groundwater Monitoring and Performance Report for 2009, Volumes 1 & 2. Richland Operations Office. DOE/RL-2010-11 Revision 1.

U.S. Department of Energy (DOE). 2010b. River Corridor Baseline Risk Assessment. Volume II: Human Health Risk Assessment. Part 1, Draft C. December. DOE/RL-2007-21.U.S. Department of Energy (DOE). 2011a. Columbia River Component Risk Assessment Volume I: Screening-Level Ecological Risk Assessment. DOE/RL-2010-117. Volume I, Part 2, Draft A. September.

U.S. Department of Energy (DOE). 2011b. River Corridor Baseline Risk Assessment Volume I: Ecological Risk Assessment. DOE/RL-2007-21. Volume I, Part 1, Draft C. August.

U.S. Department of Energy (DOE). 2011c. Hanford Site Groundwater Monitoring and Performance Report for 2010, Richland Operations Office. DOE/RL-2011-01 Revision 0.

U.S. Environmental Protection Agency (EPA). 1989. Methods for Evaluating the Attainment of Cleanup Standards. Volume 1: Soils and Solid Media. Statistical Policy Branch (PM-223), Office of Policy, Planning, and Evaluation, U. S. Environmental Protection Agency, 401 M Street, S.W., Washington, DC 20460.

Washington Closure Hanford (WCH). 2006a. Columbia River Component Data Evaluation Summary Report. WCH-91. July.

Washington Closure Hanford (WCH). 2006b. Existing Source Information Summary Report Compilation/Evaluation Effort: December 2004 to September 2005. WCH-64. January.

Washington Closure Hanford (WCH). 2006c. 100 Area and 300 Area Component of the River Corridor Baseline Risk Assessment Spring 2006 Data Compilation. WCH-139 Rev.0. November.

Washington Closure Hanford (WCH). 2006d. Sampling and Analysis Instruction Guide for the 100 Area and 300 Area Component of the RCBRA Project. WCH-47 Rev. 0. July.

Washington Closure Hanford (WCH). 2007. Columbia River Component Data Gap Analysis. WCH-201. October.

Washington Closure Hanford (WCH). 2008. Inter-Areas Component of the River Corridor Baseline Risk Assessment Sampling Summary. WCH-274 Rev. 0. February.

Washington Closure Hanford (WCH). 2010. Data Quality Assessment Report for the Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington. WCH-381 Rev. 1. September.

Washington Closure Hanford (WCH). 2011. Data Summary Report for the Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington. WCH-398, Rev. 0. January.

Webber, W.D. 2010a. Media Specific Views for Biota: Software Design Description. HNF-45729 Rev. 0. July 17.

Webber, W.D. 2010b. Media Specific Views for Miscellaneous Materials: Software Design Description. HNF-45731 Rev. 0. July 17.

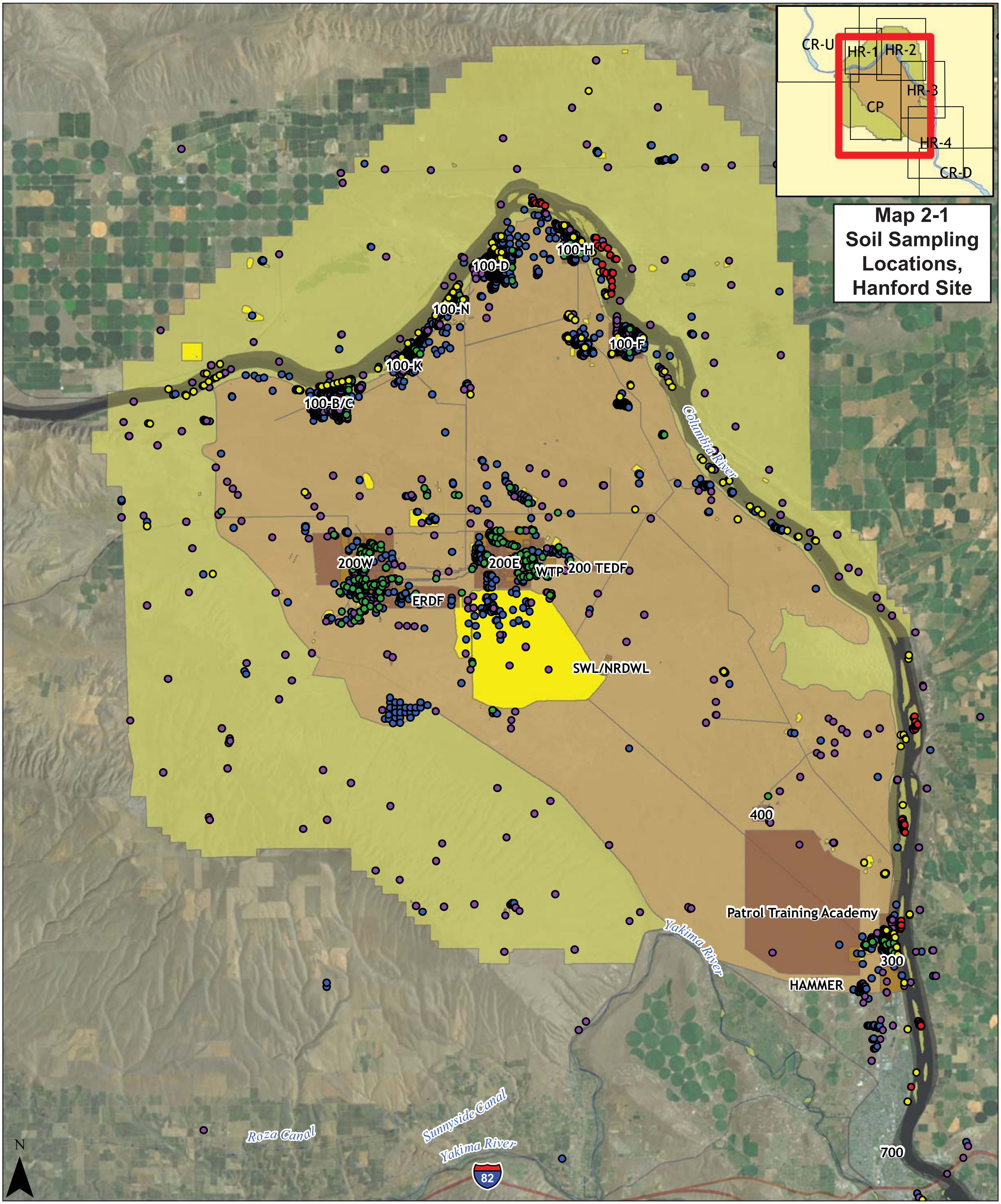
Webber, W.D. 2010c. Media Specific Views for Soil: Software Design Description. HNF-45733 Rev. 0. July 17.

Webber, W.D. 2010d. Media Specific Views for Soil Gas: Software Design Description. HNF-45735 Rev. 0. July 17.

Webber, W.D. 2010e. Media Specific Views for Surface Water: Software Design Description. HNF-44989 Rev. 0. July 17.

Williams, B.A., R. Schalla, B.N. Bjornstad, and W.D. Webber. 2000. Revised hydrogeology for the suprabasalt aquifer system, 200-East Area and vicinity, Hanford Site, Washington. Pacific Northwest National Laboratory, PNNL-12261.

APPENDIX A



Map 2-1 Soil Sampling Locations, Hanford Site

Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

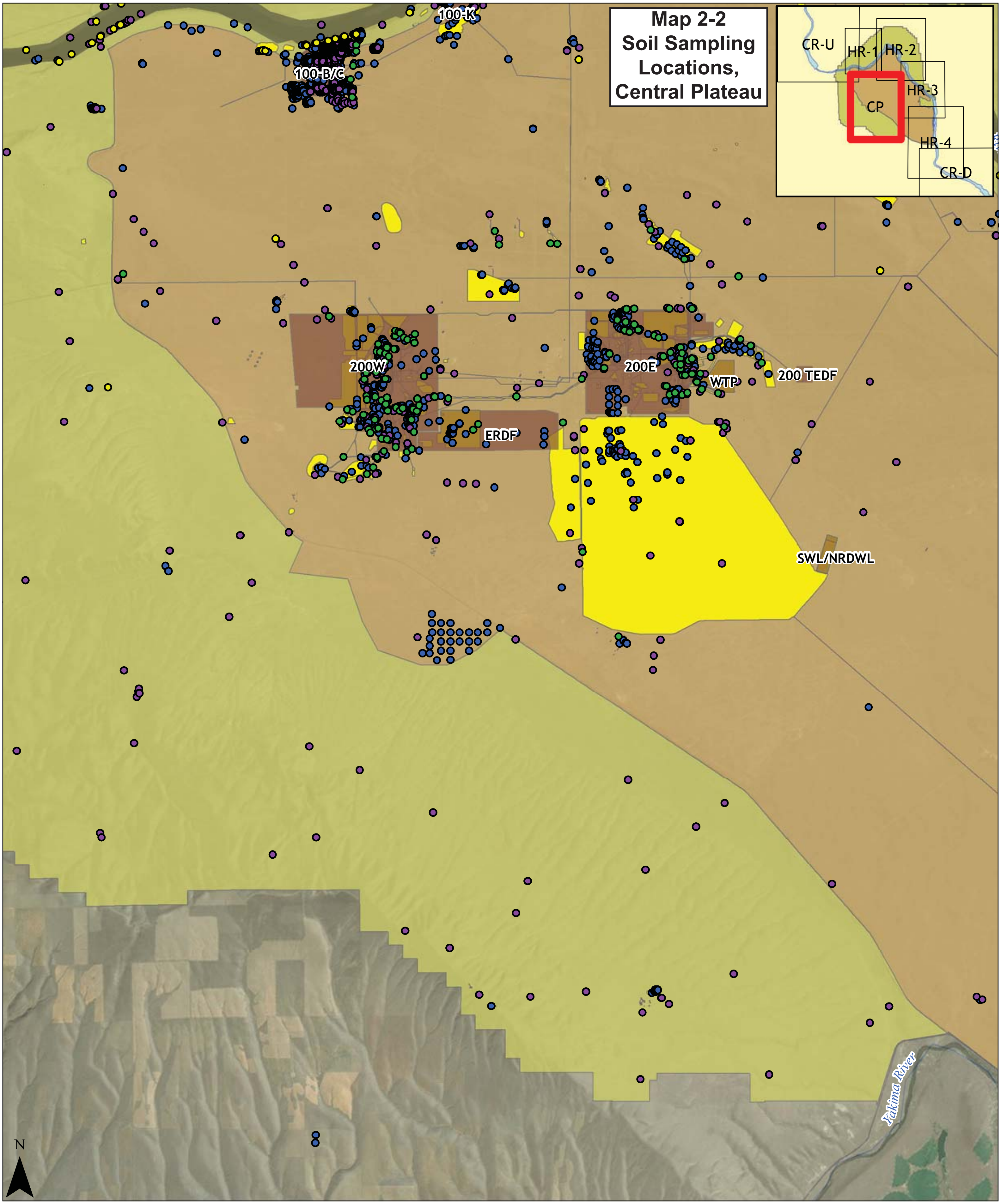
Soil Sampling Locations

DSR CRC ERS GiSdT HEIS

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 1.5 3 6 Miles

Source: HEIS, GiSdT, CRC, DSR, and ERS Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB



Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

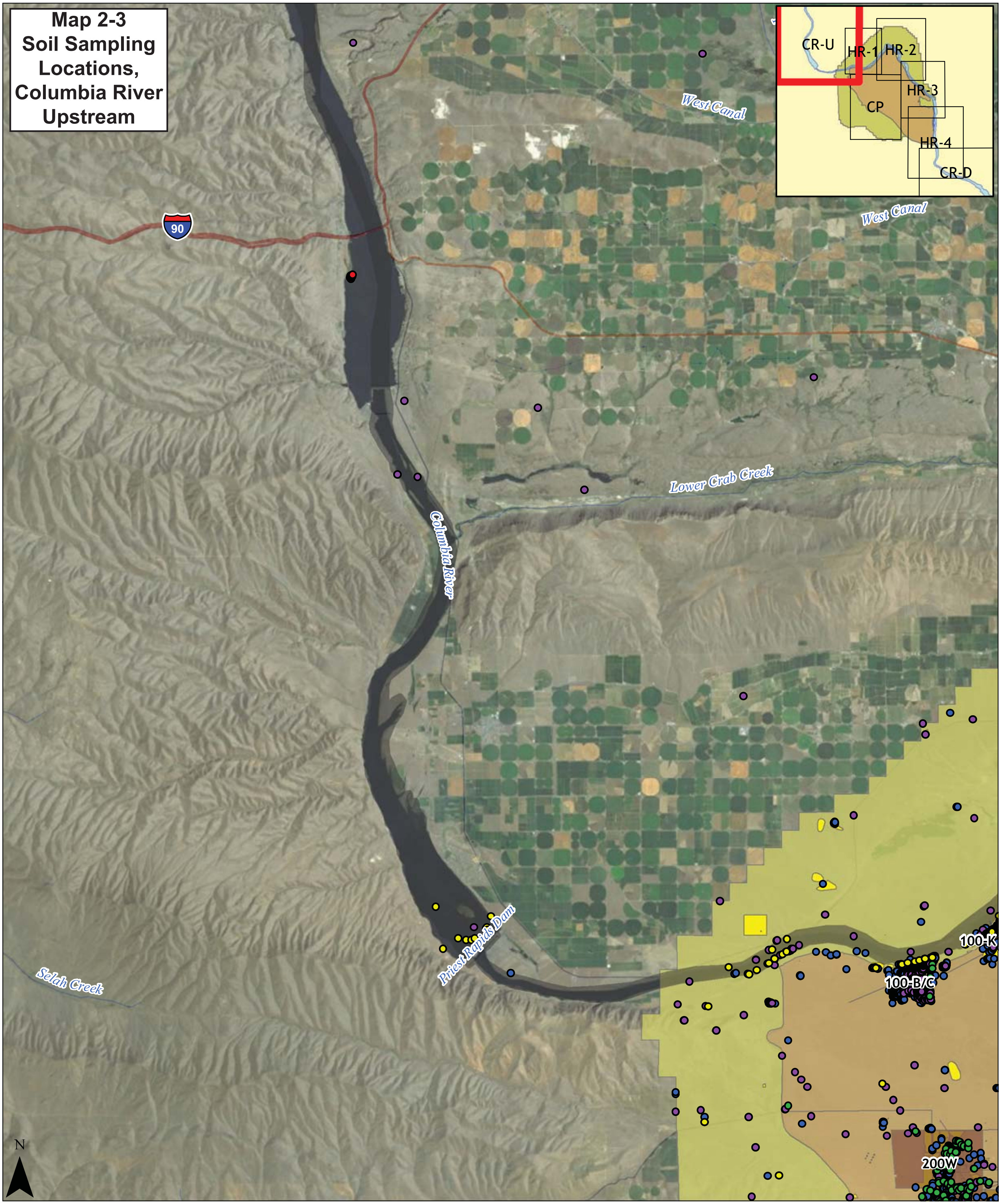
Soil Sampling Locations

DSR CRC ERS GiSdT HEIS

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 0.5 1 2 Miles

Source: HEIS, GiSdT, CRC, DSR, and ERS Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB



Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

Soil Sampling Locations

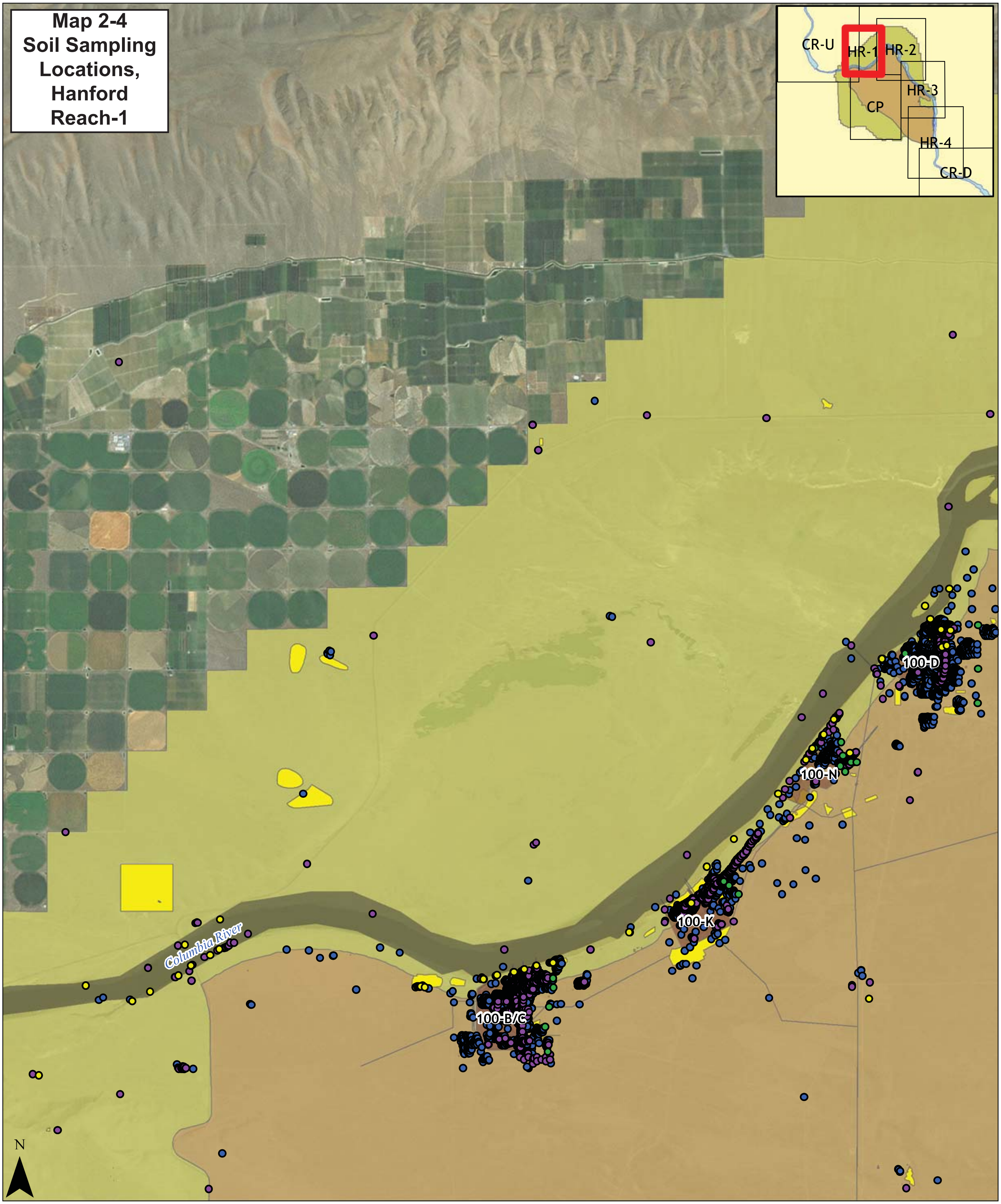
DSR CRC ERS GiSdT HEIS

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 1.25 2.5 5 Miles

Source: HEIS, GiSdT, CRC, DSR, and ERS Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB

Map 2-4 Soil Sampling Locations, Hanford Reach-1



Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

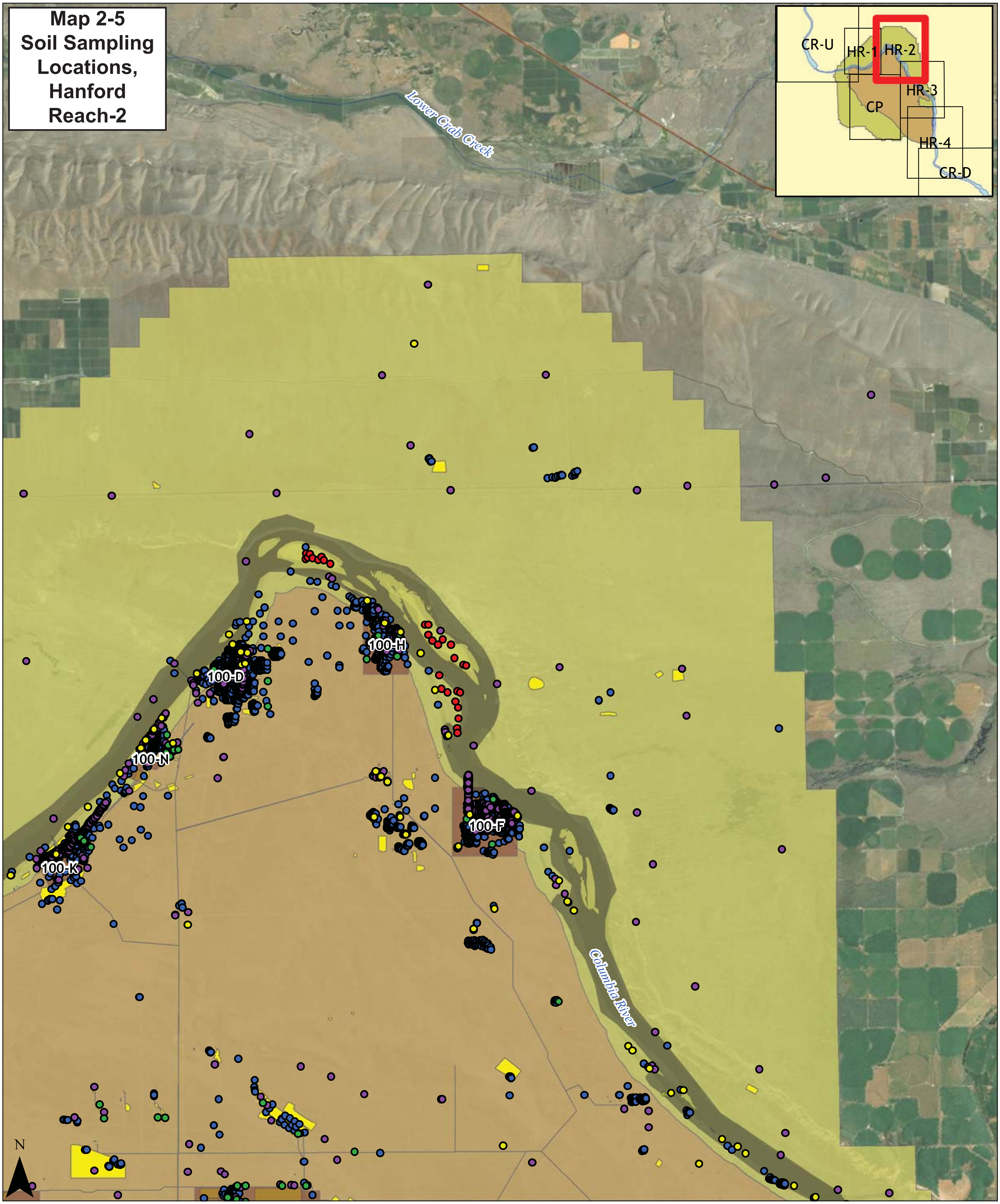
Soil Sampling Locations

DSR CRC ERS GiSdT HEIS

Only sample locations with coordinate information are depicted.
Some sample locations may not be visible because of proximity
to (or identity with) sampling locations in other databases.

0 0.5 1 2 Miles

Source: HEIS, GiSdT, CRC, DSR, and ERS Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB



Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

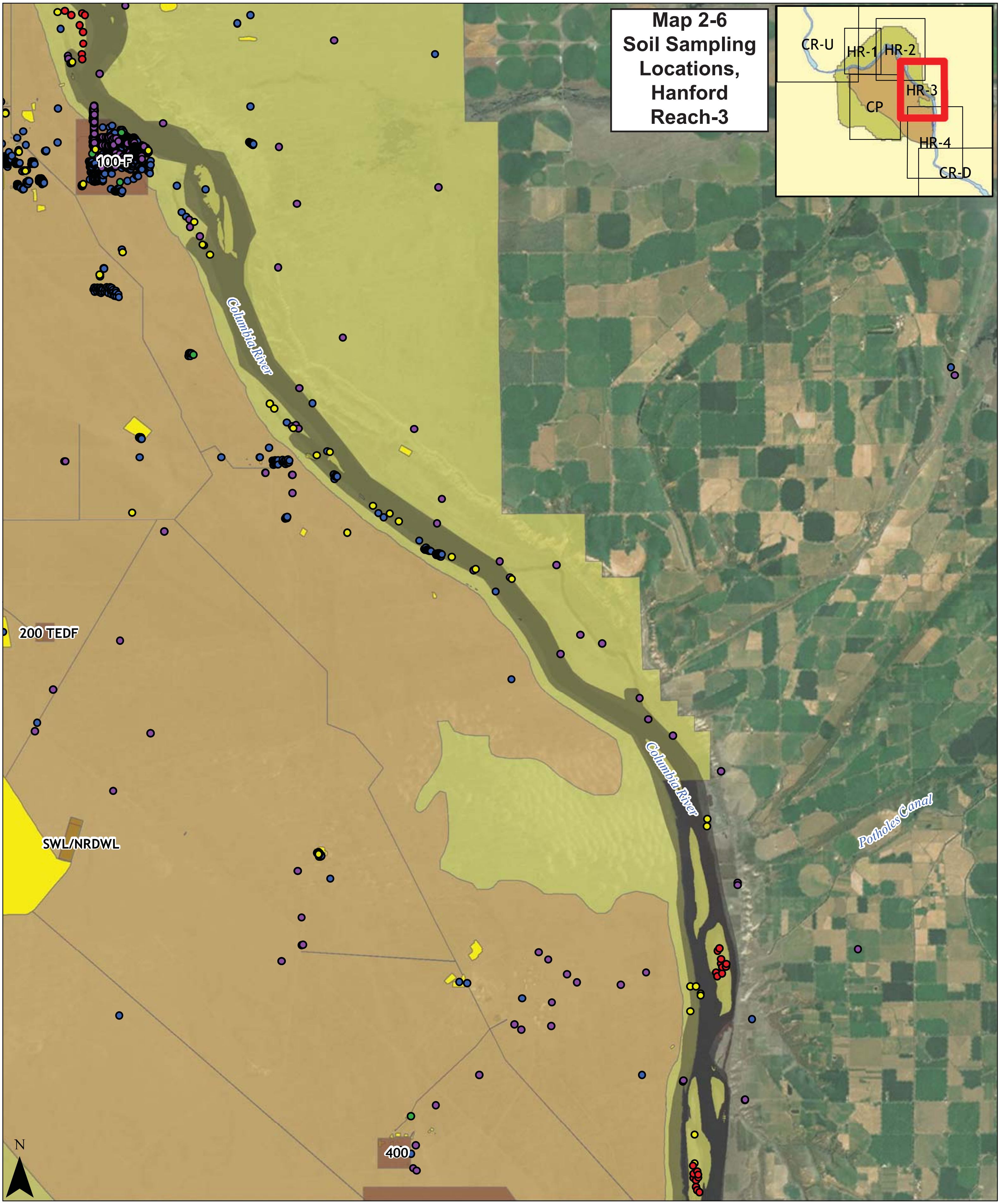
Soil Sampling Locations

DSR CRC ERS GiSdT HEIS

Only sample locations with coordinate information are depicted.
Some sample locations may not be visible because of proximity
to (or identity with) sampling locations in other databases.

0 0.5 1 2 Miles

Source: HEIS, GiSdT, CRC, DSR, and ERS Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB



Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

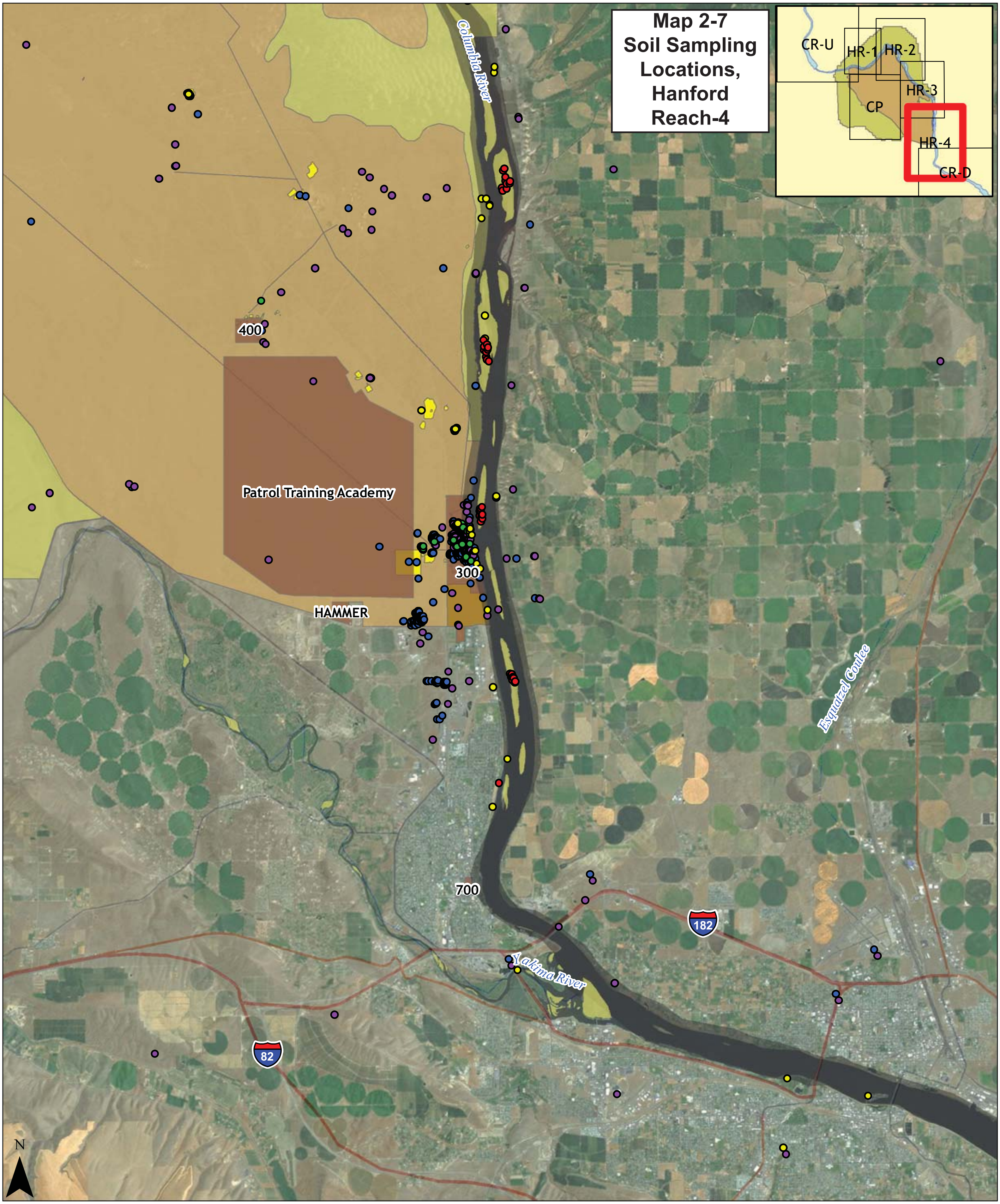
Soil Sampling Locations

DSR CRC ERS GiSdT HEIS

Only sample locations with coordinate information are depicted.
Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 0.5 1 2 Miles

Source: HEIS, GiSdT, CRC, DSR, and ERS Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB



Legend
- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

Soil Sampling Locations
- DSR
- CRC
- ERS
- GiSdT
- HEIS

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 0.5 1 2 Miles

Source: HEIS, GiSdT, CRC, DSR, and ERS Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB

Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

Soil Sampling Locations

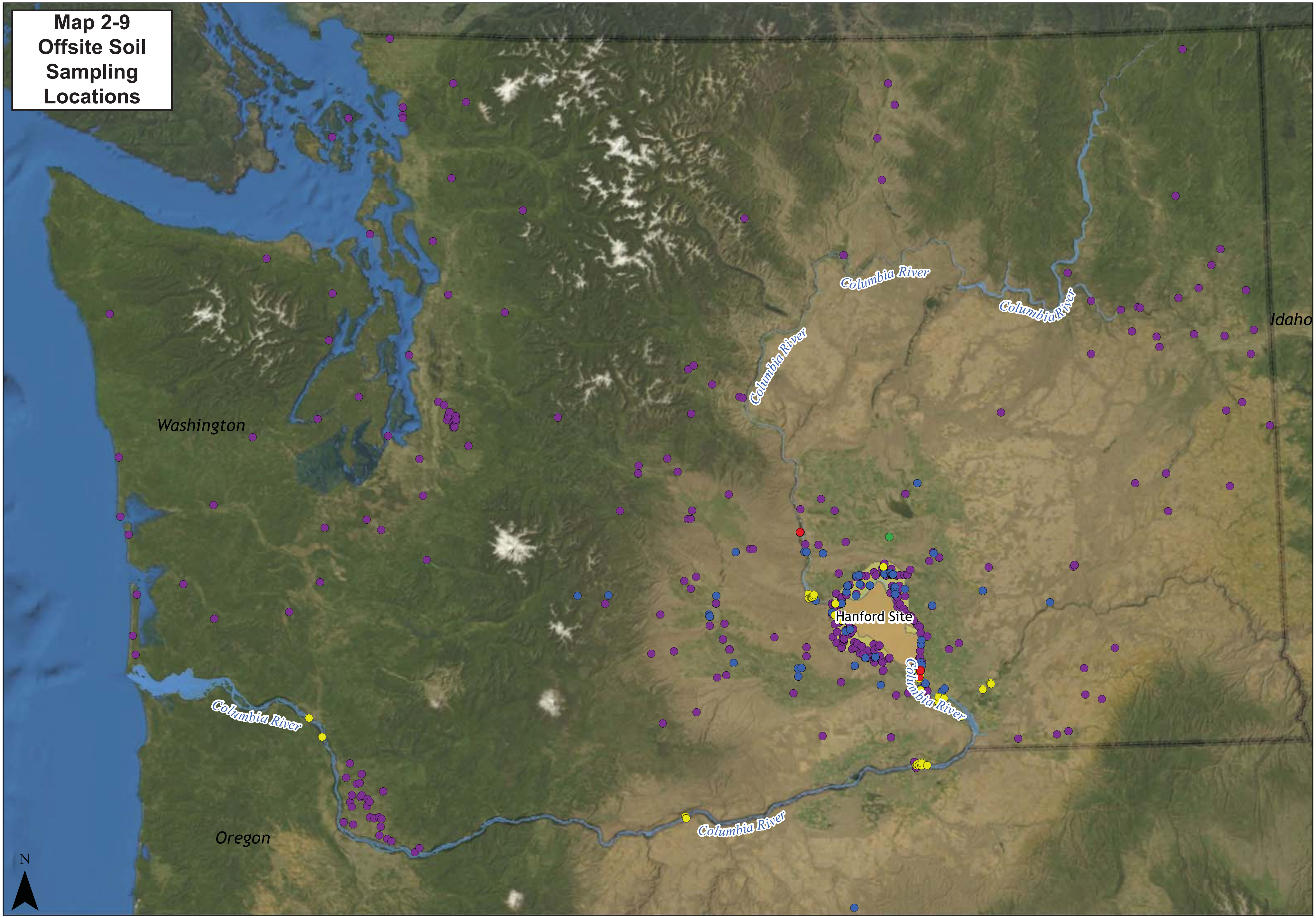
- DSR
- CRC
- ERS
- GiSdT
- HEIS

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 1.5 3 6 Miles

Source: HEIS, GiSdT, CRC, DSR, and ERS Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB

Map 2-9 Offsite Soil Sampling Locations



Legend

Hanford Site

Hanford Reach National Monument

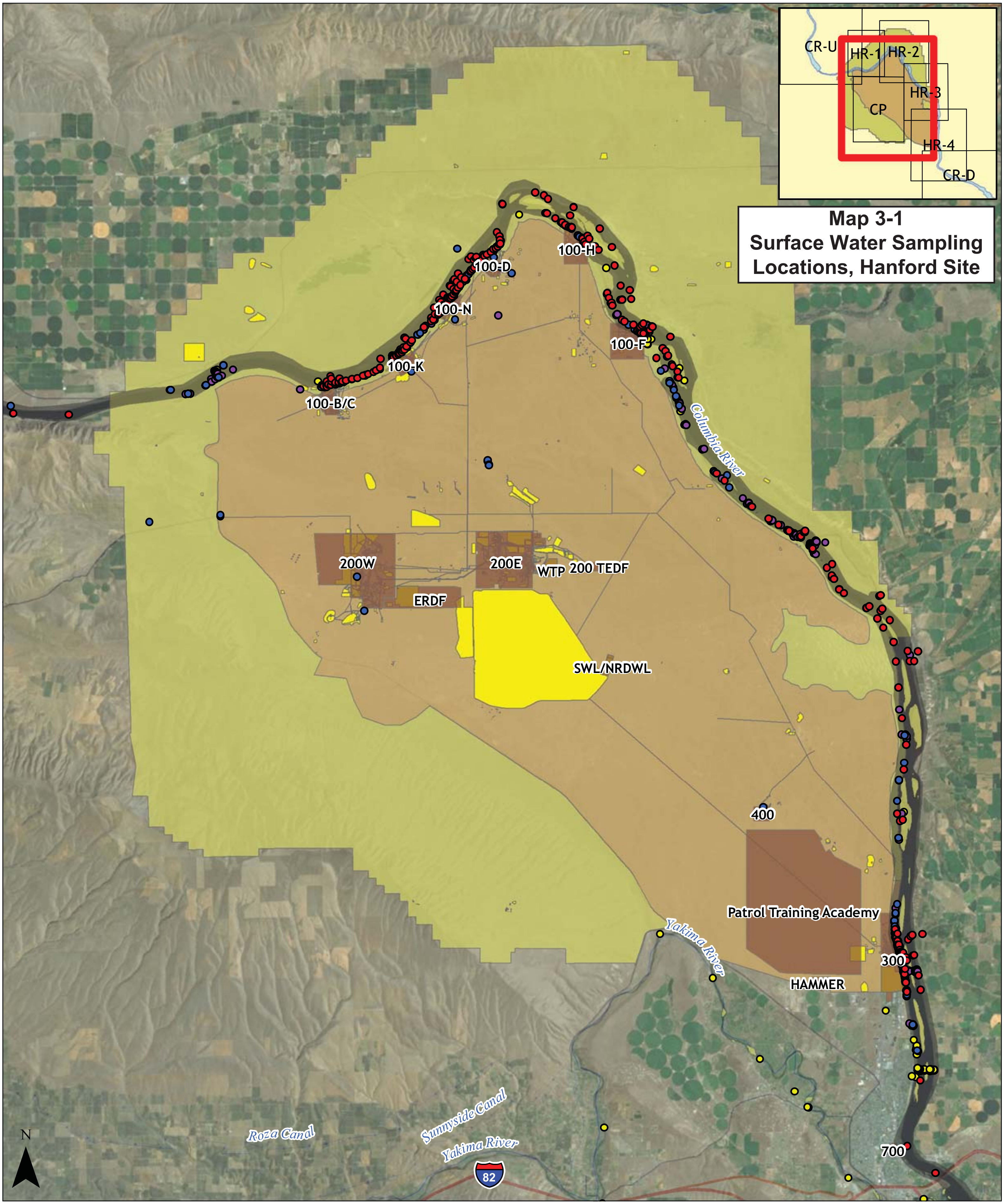
Offsite Soil Sample Locations

ERS DSR CRC HEIS GiSdT

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 10 20 40 Miles

Source: HEIS, GiSdT, CRC, DSR, ERS Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB



Map 3-1 Surface Water Sampling Locations, Hanford Site

Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

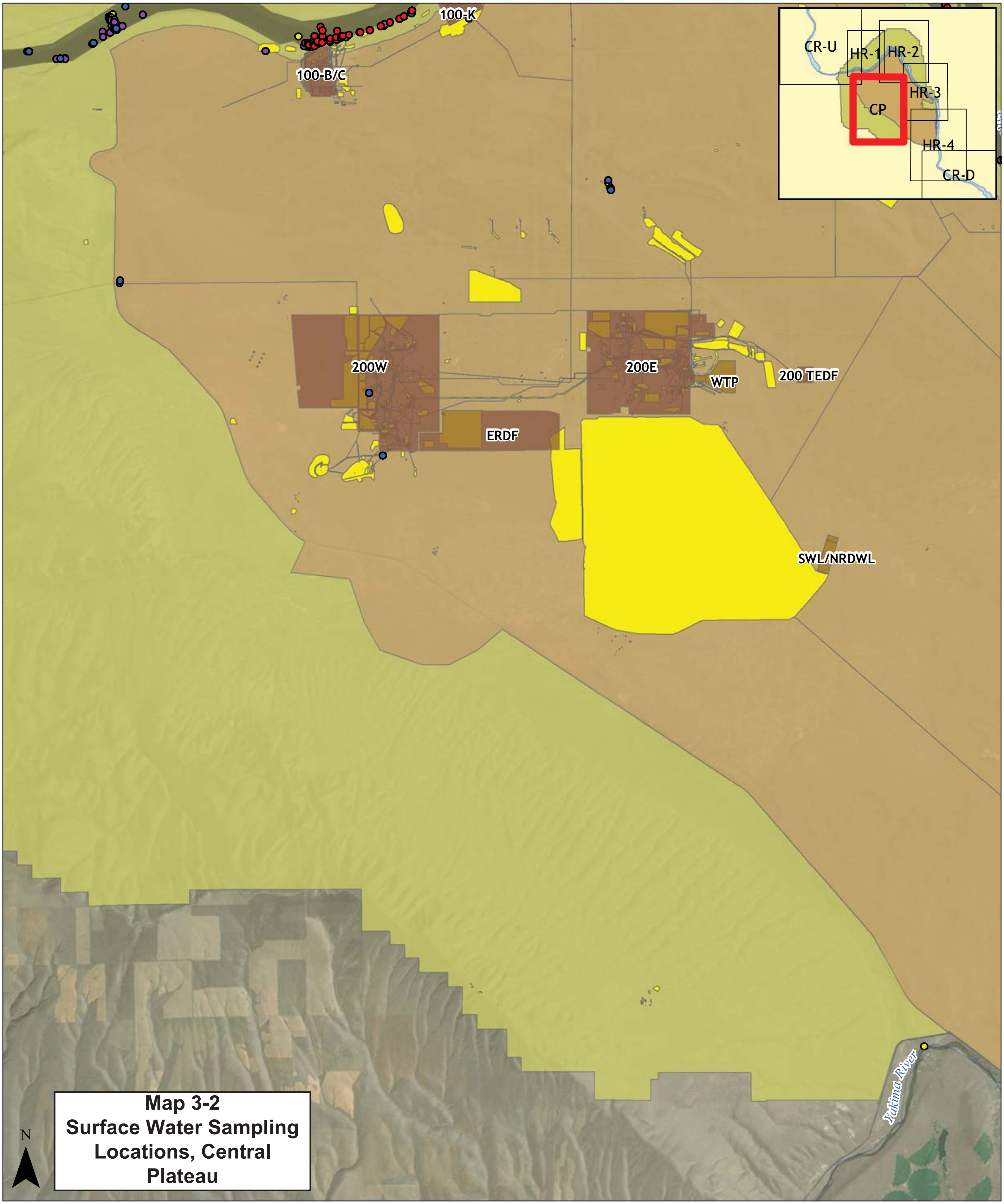
Surface Water Sampling Locations

DSR HEIS GiSdT CRC

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 1.5 3 6 Miles

Source: HEIS, GiSdT, CRC, and DSR Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB



Map 3-2
Surface Water Sampling Locations, Central Plateau

Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

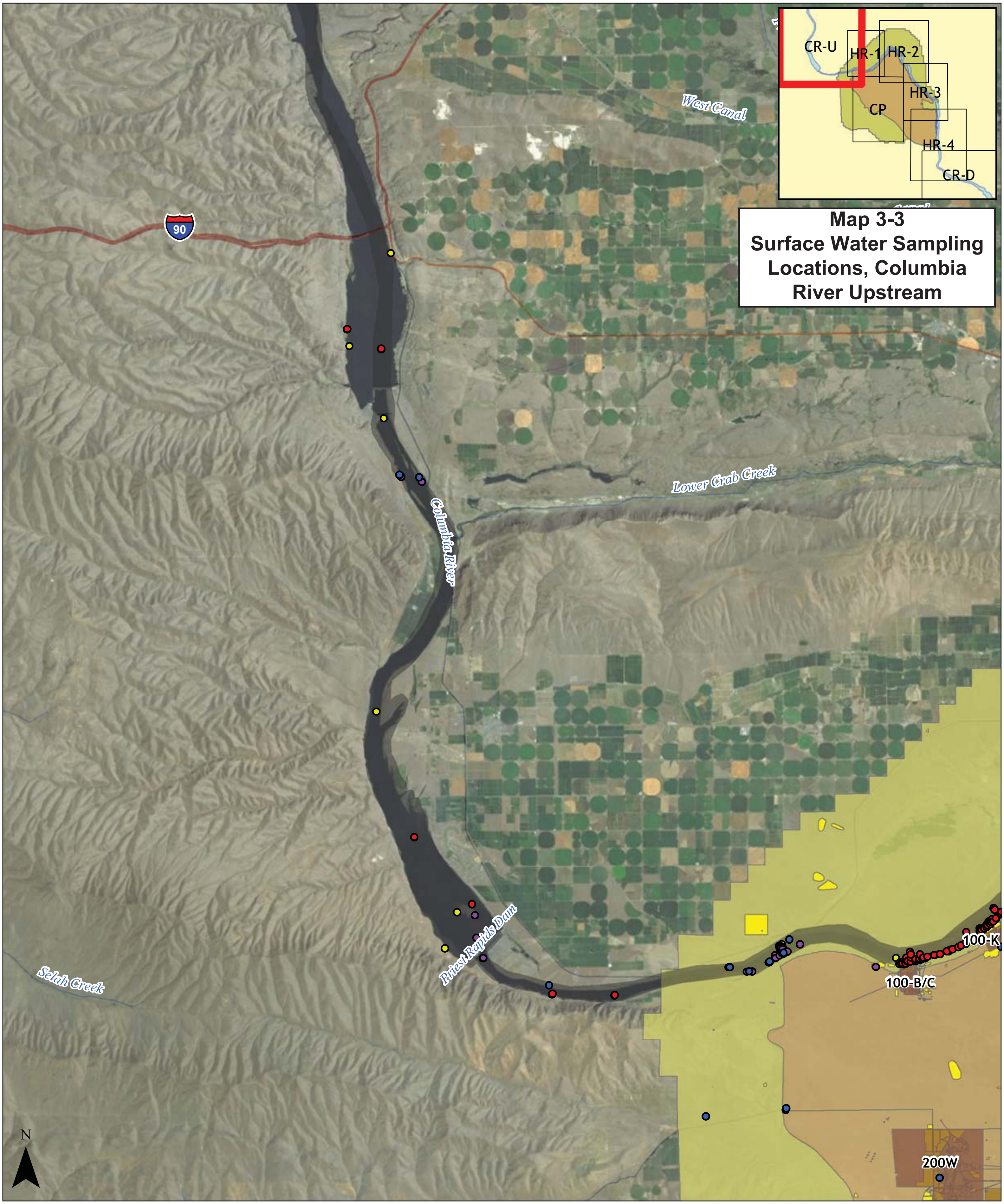
Surface Water Sampling Locations

- DSR
- HEIS
- GiSdT
- CRC

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 0.5 1 2 Miles

Source: HEIS, GiSdT, CRC, and DSR Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB



Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

Surface Water Sampling Locations

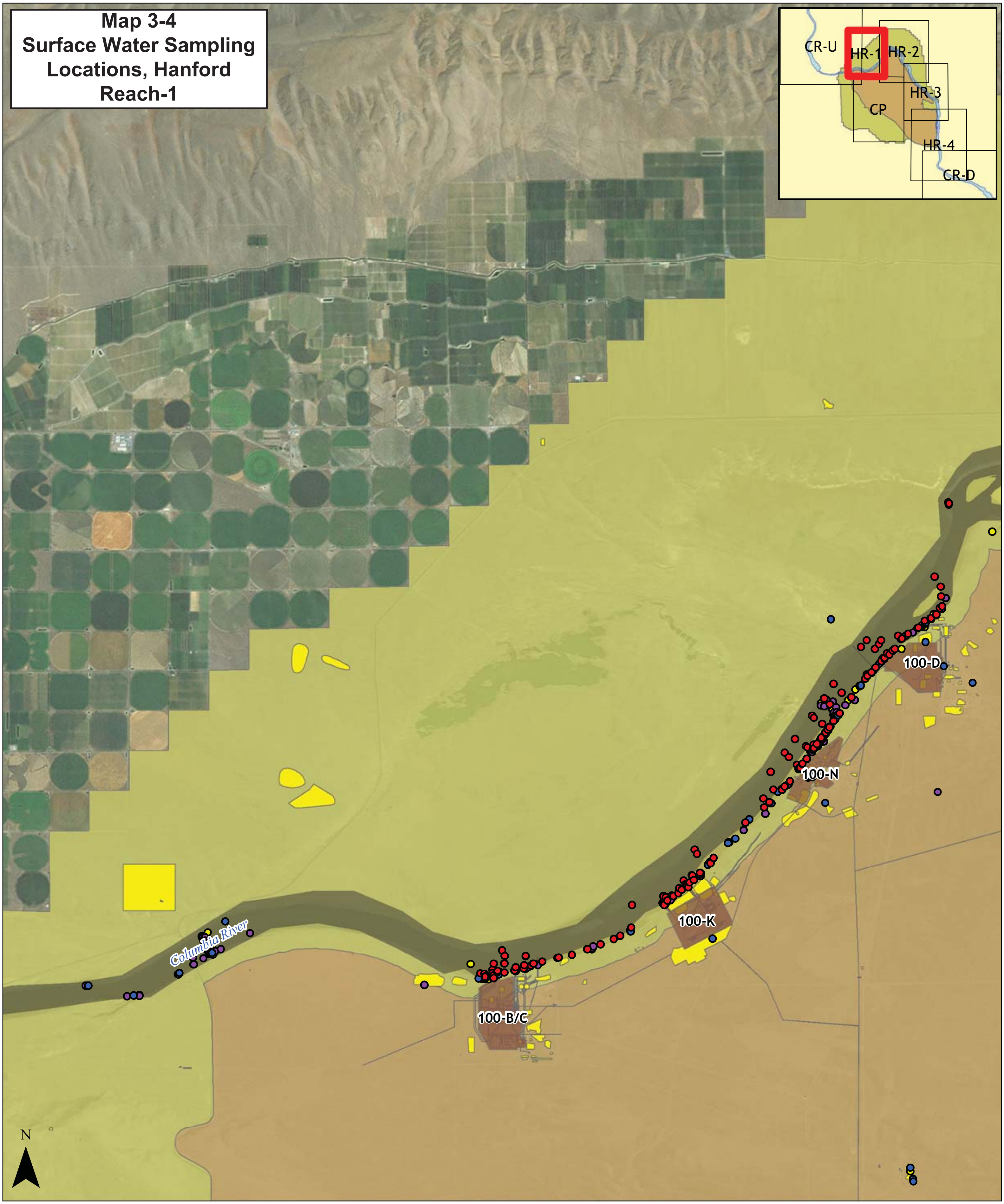
DSR HEIS GiSdT CRC

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 1.5 3 6 Miles

Source: HEIS, GiSdT, CRC, and DSR Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB

Map 3-4 Surface Water Sampling Locations, Hanford Reach-1



Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

Surface Water Sampling Locations

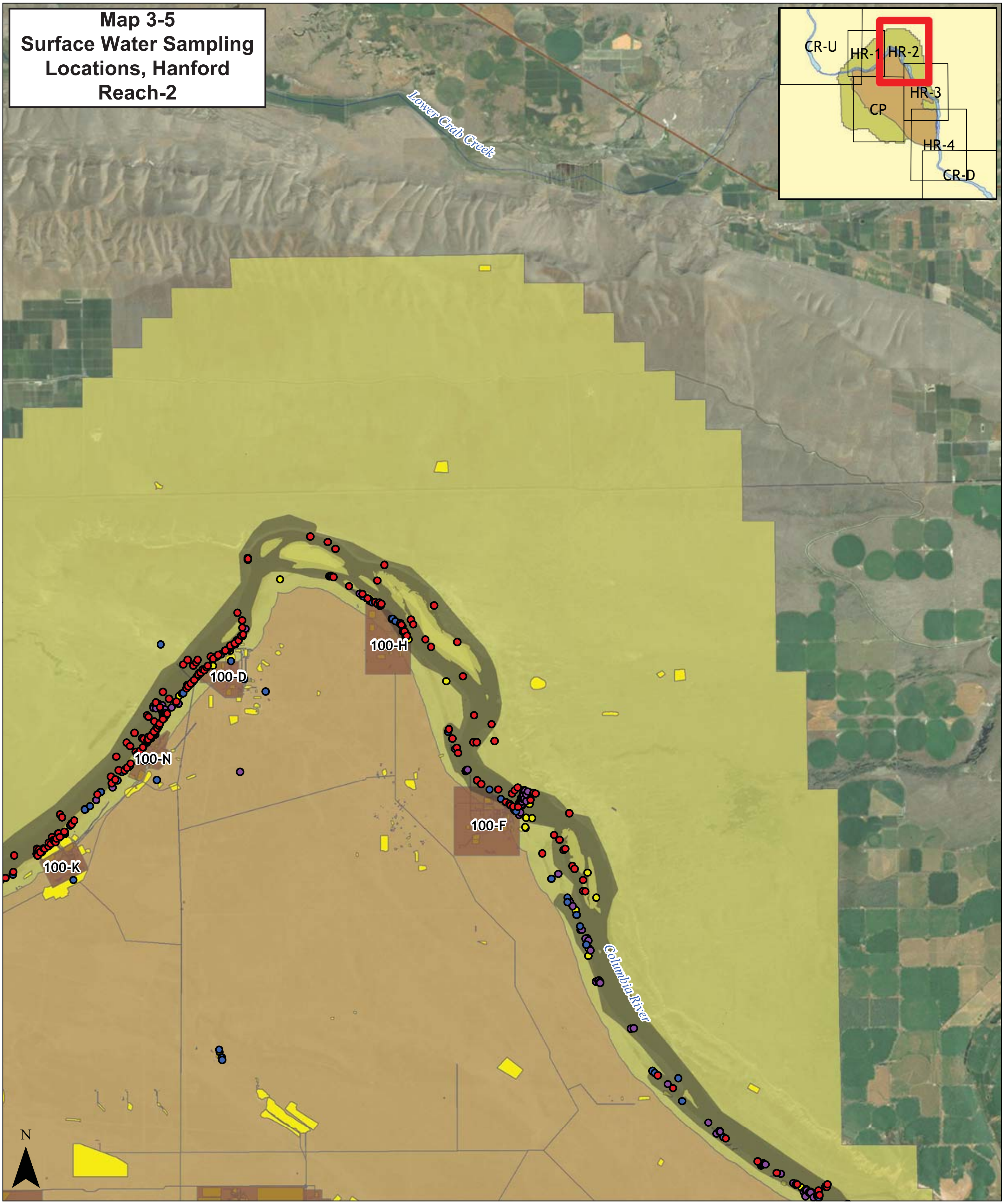
DSR HEIS GiSdT CRC

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 0.5 1 2 Miles

Source: HEIS, GiSdT, CRC, and DSR Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB

Map 3-5 Surface Water Sampling Locations, Hanford Reach-2



Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

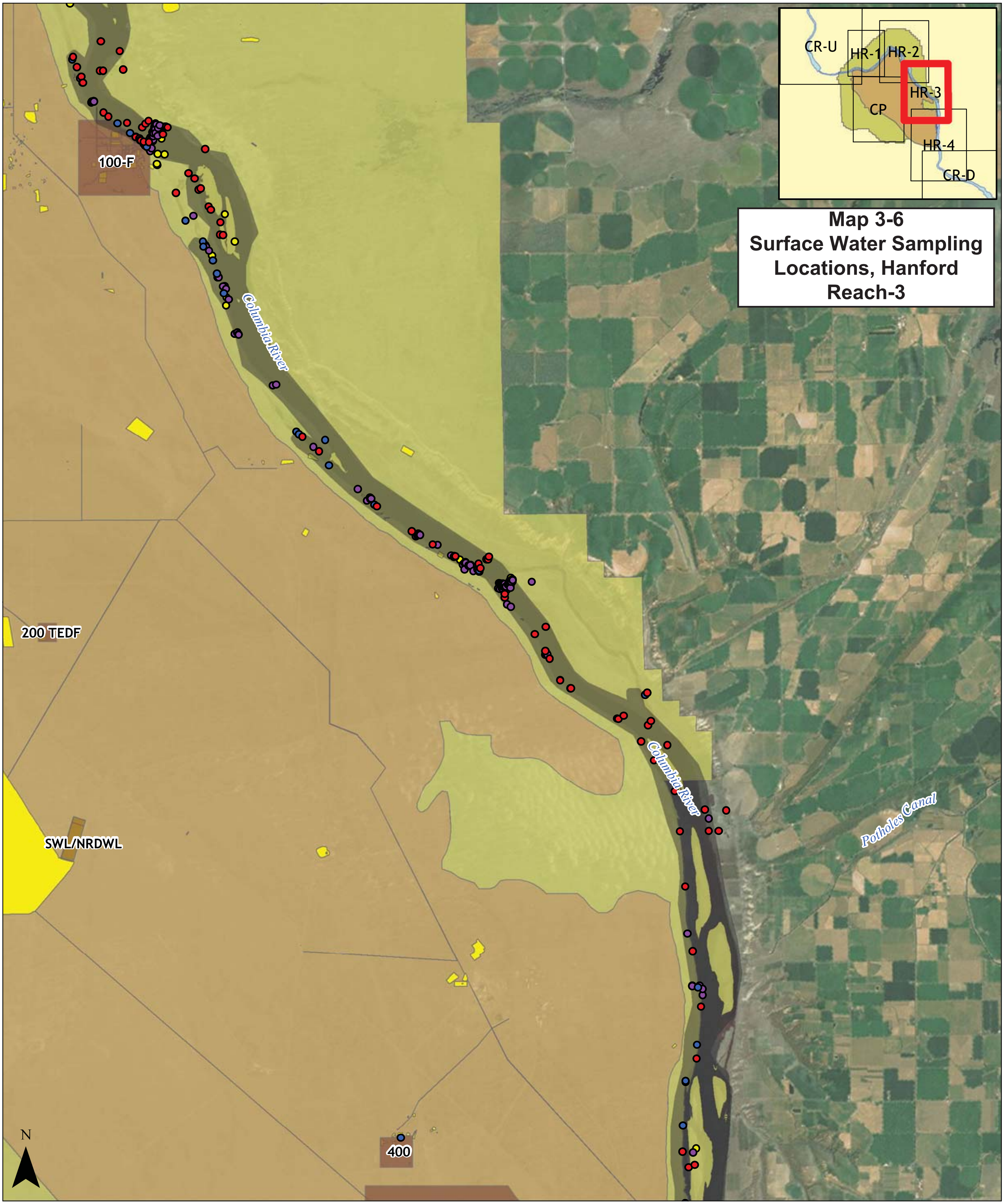
Surface Water Sampling Locations

DSR HEIS GiSdT CRC

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 0.5 1 2 Miles

Source: HEIS, GiSdT, CRC, and DSR Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB



Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

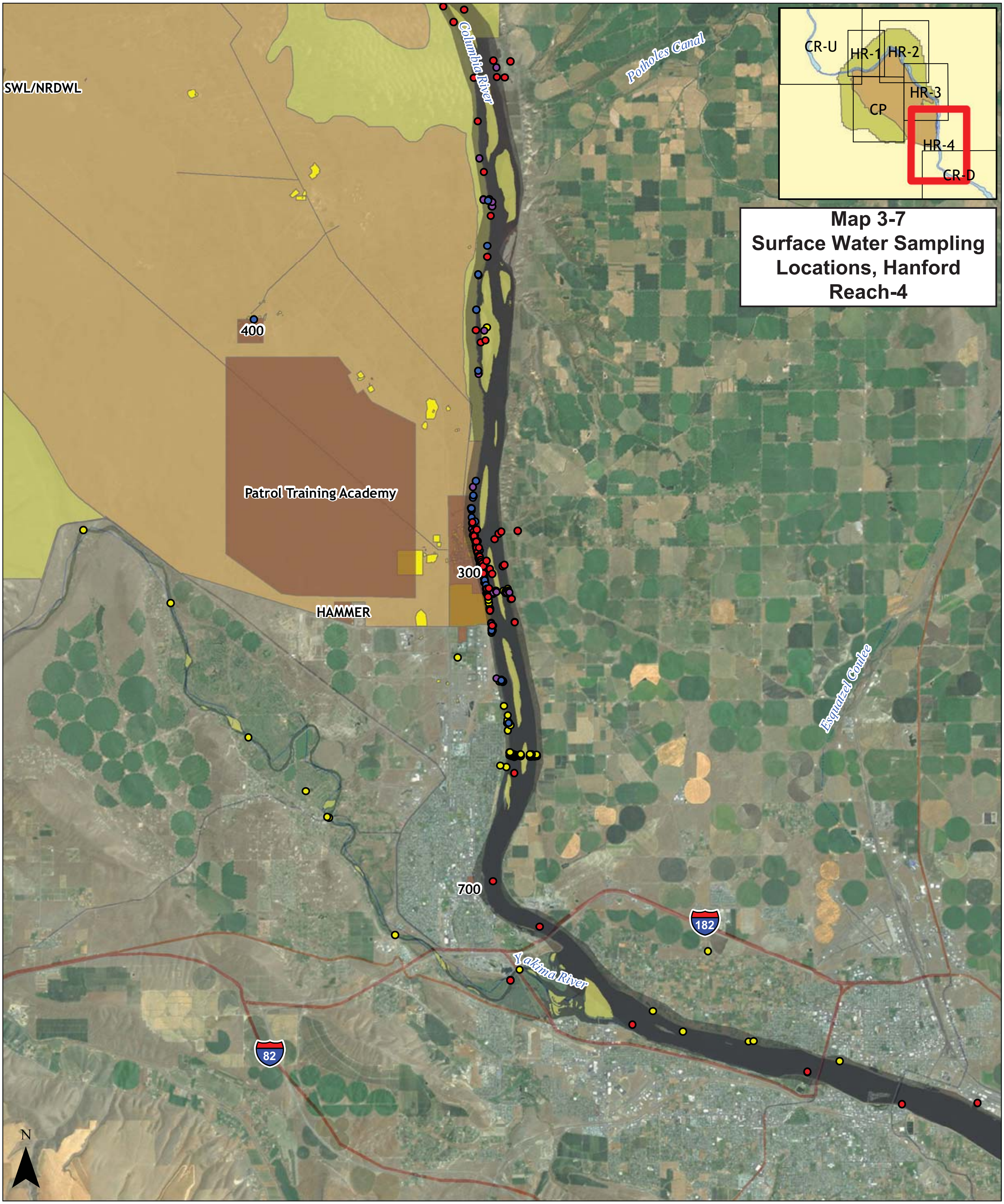
Surface Water Sampling Locations

DSR HEIS GiSdT CRC

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 0.5 1 2 Miles

Source: HEIS, GiSdT, CRC, and DSR Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB

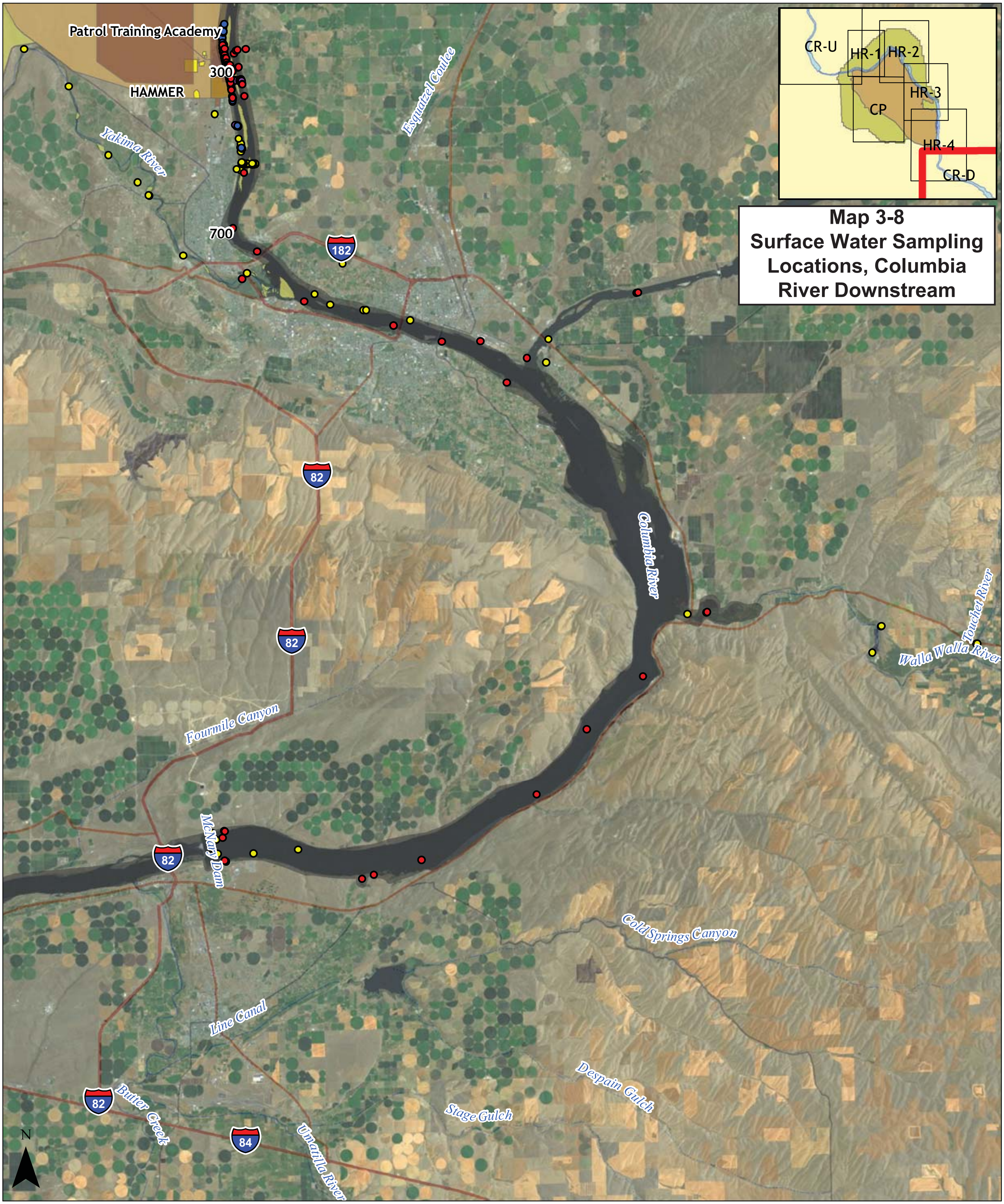


Legend
Hanford Operations Areas
WIDS sites (mapped waste sites)
Hanford Site
Hanford Reach National Monument

Surface Water Sampling Locations
DSR HEIS GiSdT CRC
Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 1 2 4 Miles

Source: HEIS, GiSdT, CRC, and DSR Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB



Map 3-8
Surface Water Sampling Locations, Columbia River Downstream

Legend
- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

Surface Water Sampling Locations

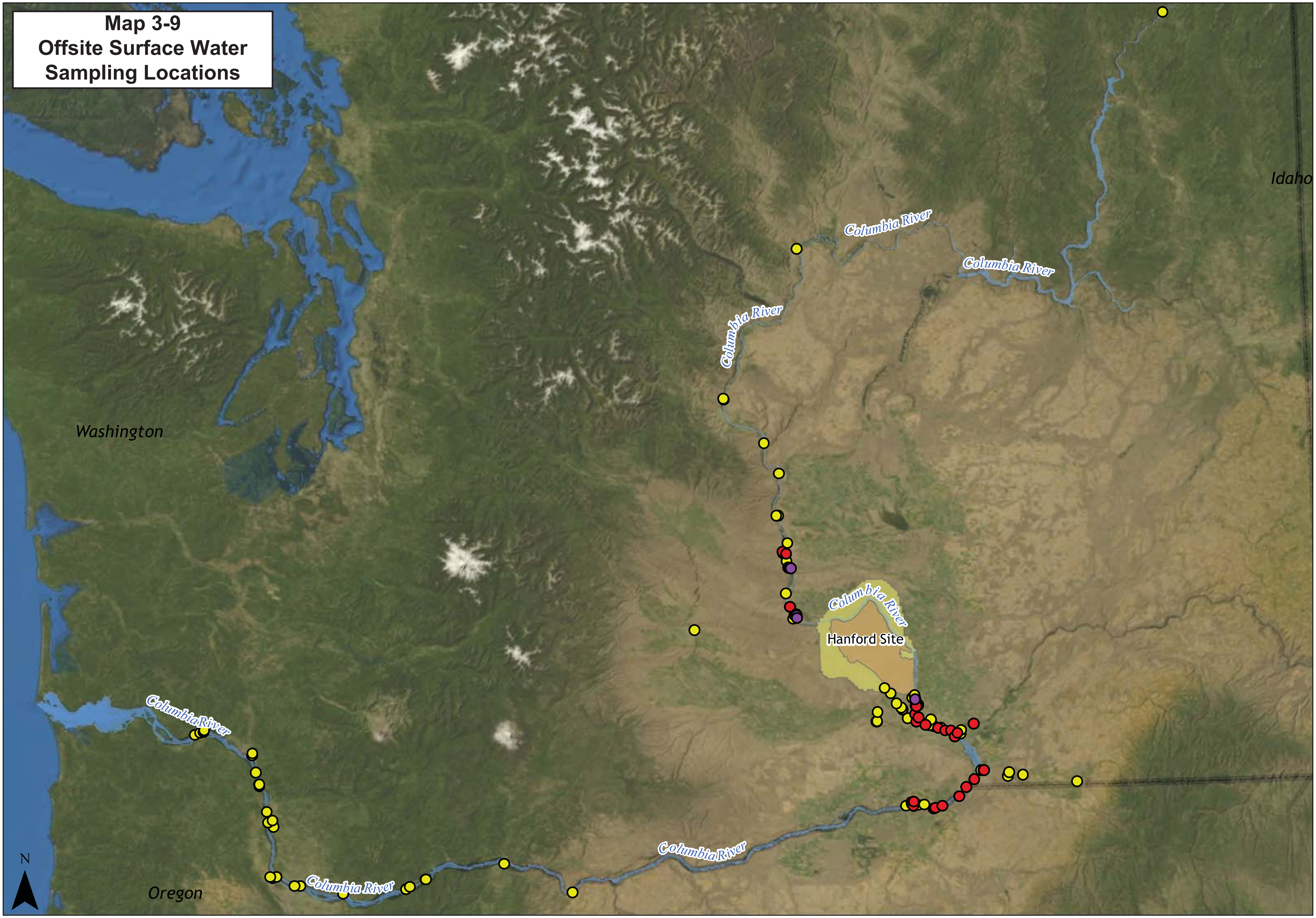
DSR HEIS GiSdT CRC

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 2 4 8 Miles

Source: HEIS, GiSdT, CRC, and DSR Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB

Map 3-9
Offsite Surface Water Sampling Locations



Legend

- Hanford Site
- Hanford Reach National Monument

Offsite Surface Water Sample Locations

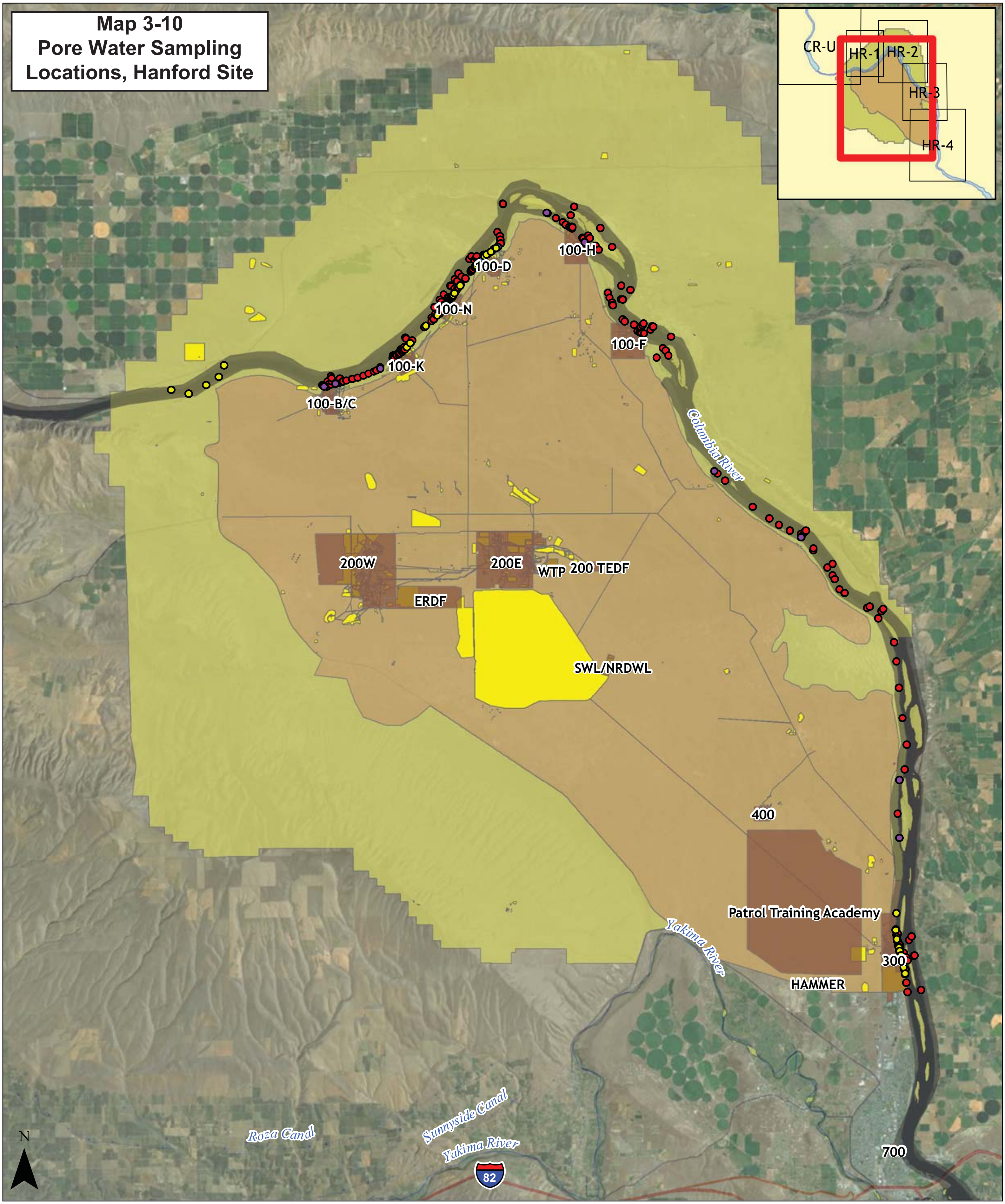
GiSdT DSR HEIS CRC

Only sample locations with coordinate information are depicted.
Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 10 20 40 Miles

Source: HEIS, GiSdT, CRC, DSR Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB

Map 3-10
Pore Water Sampling Locations, Hanford Site



Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

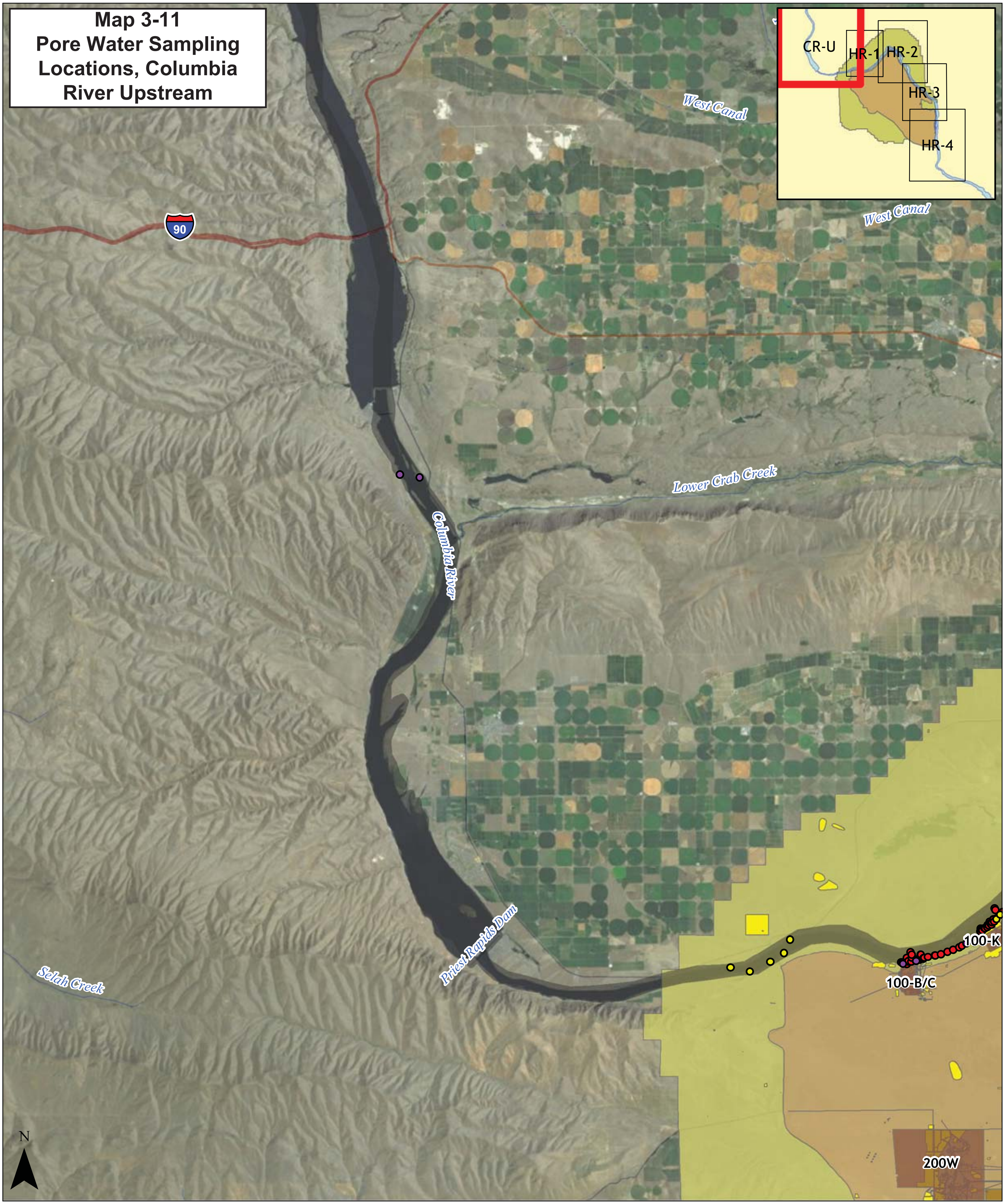
Pore Water Sampling Locations

CRC GiSdT HEIS DSR

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 1.5 3 6 Miles

Source: HEIS, GiSdT, CRC, and DSR Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB



Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

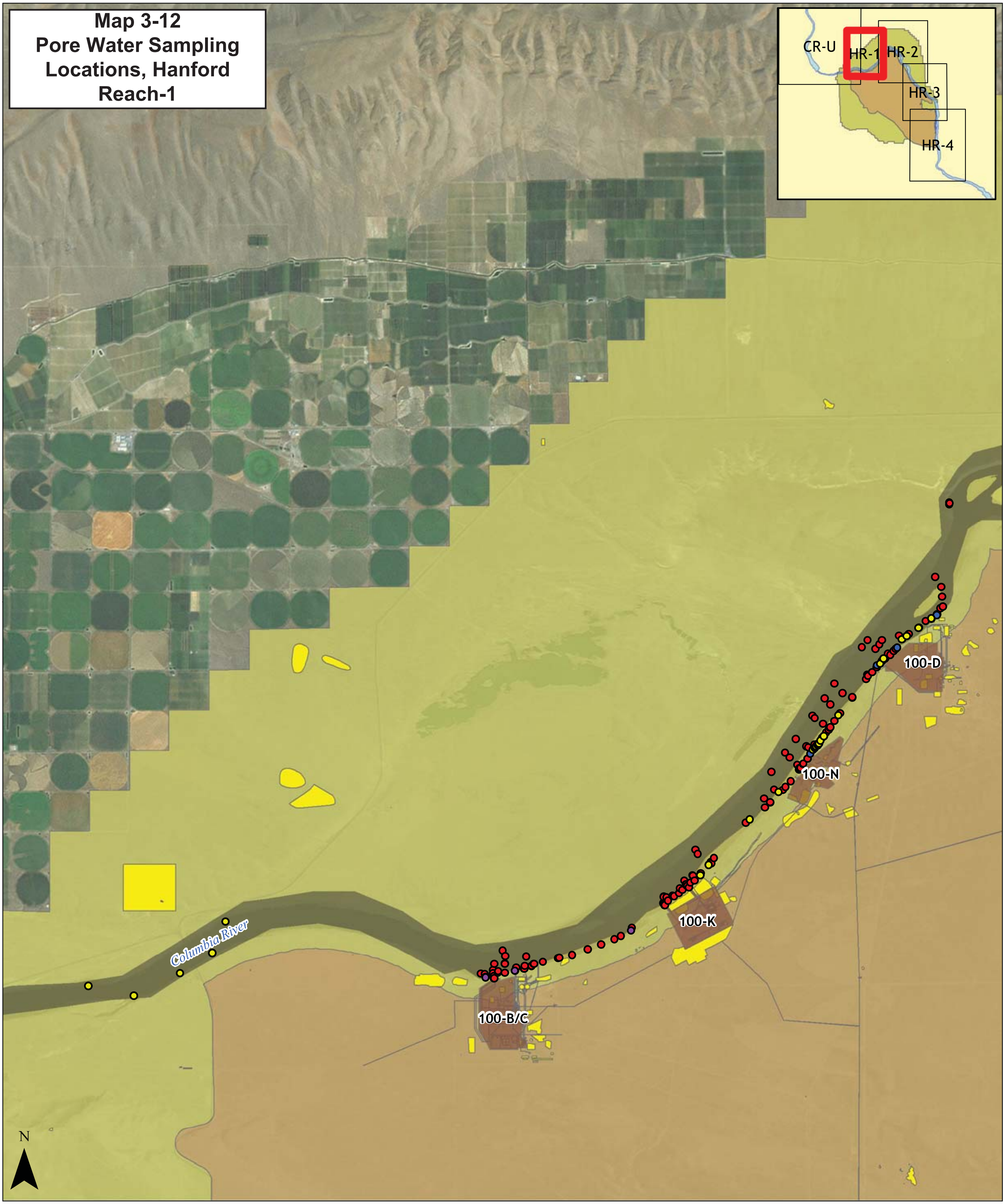
Pore Water Sampling Locations

- CRC
- GiSdT
- HEIS
- DSR

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 1.5 3 6 Miles

Source: HEIS, GiSdT, CRC, and DSR Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB



Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

Pore Water Sampling Locations

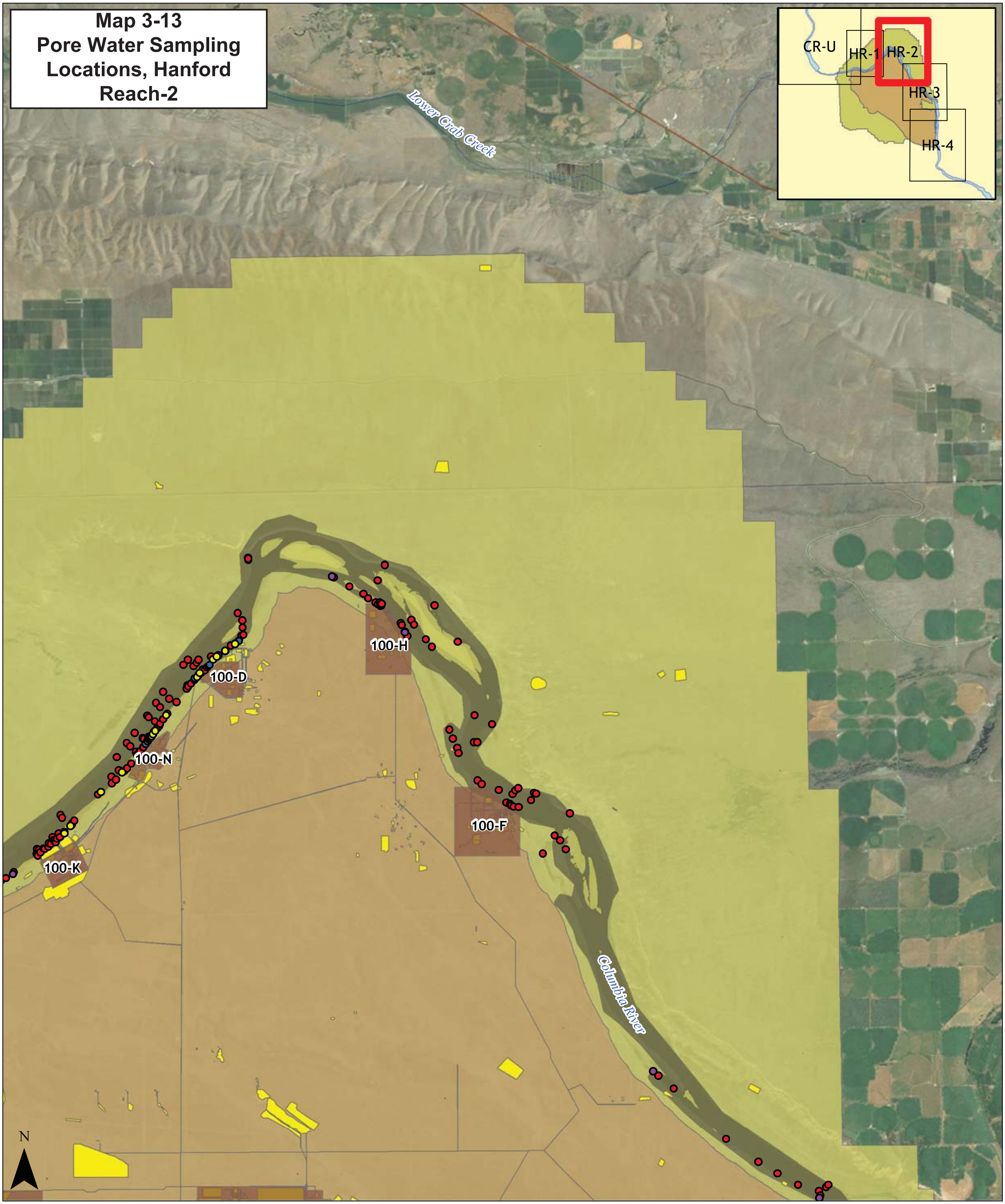
CRC GiSdT HEIS DSR

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 0.5 1 2 Miles

Source: HEIS, GiSdT, CRC, and DSR Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB

Map 3-13
Pore Water Sampling Locations, Hanford Reach-2



Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

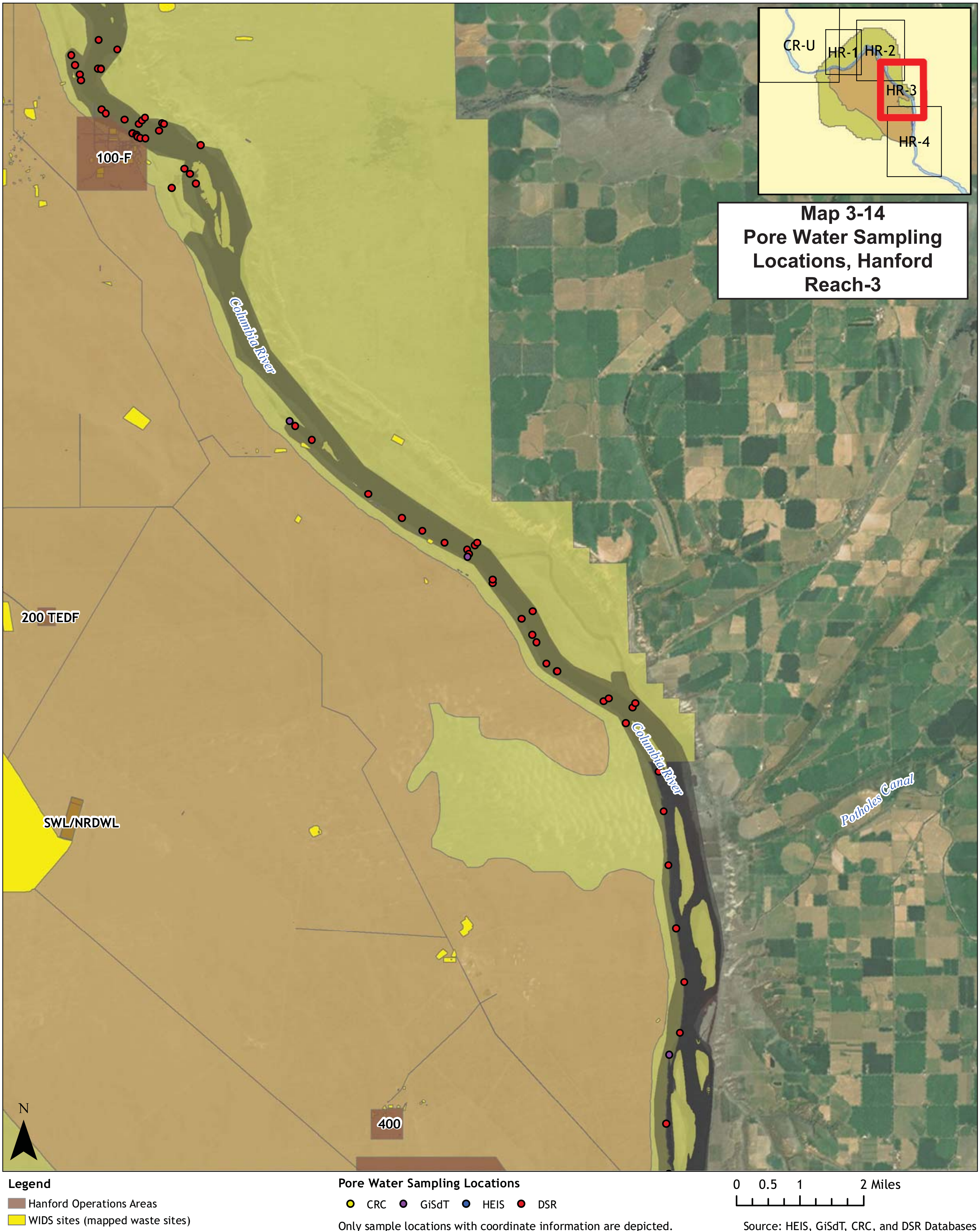
Pore Water Sampling Locations

CRC GiSdT HEIS DSR

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 0.5 1 2 Miles

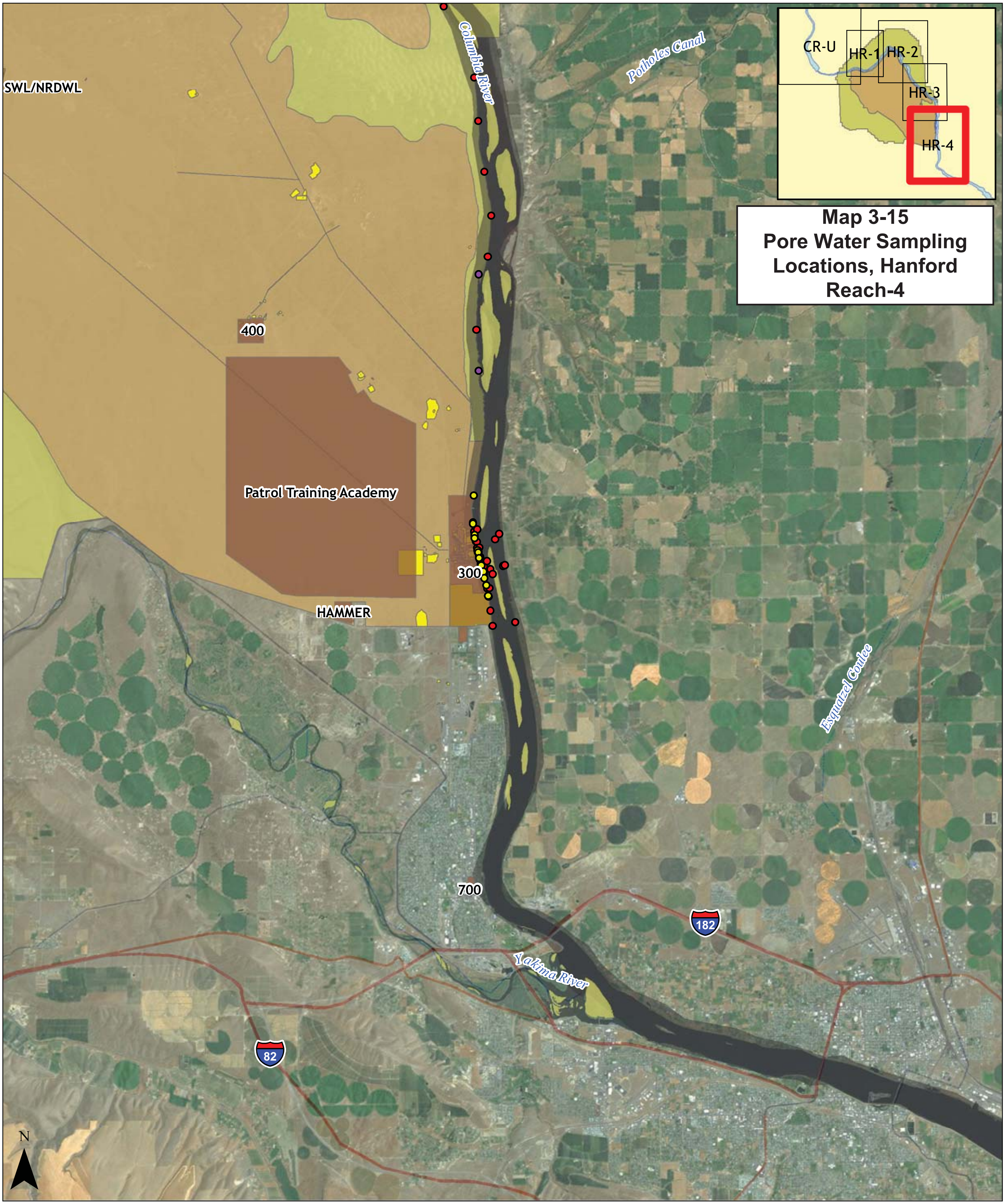
Source: HEIS, GiSdT, CRC, and DSR Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB



Map 3-14
Pore Water Sampling Locations, Hanford Reach-3

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

Source: HEIS, GiSdT, CRC, and DSR Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB



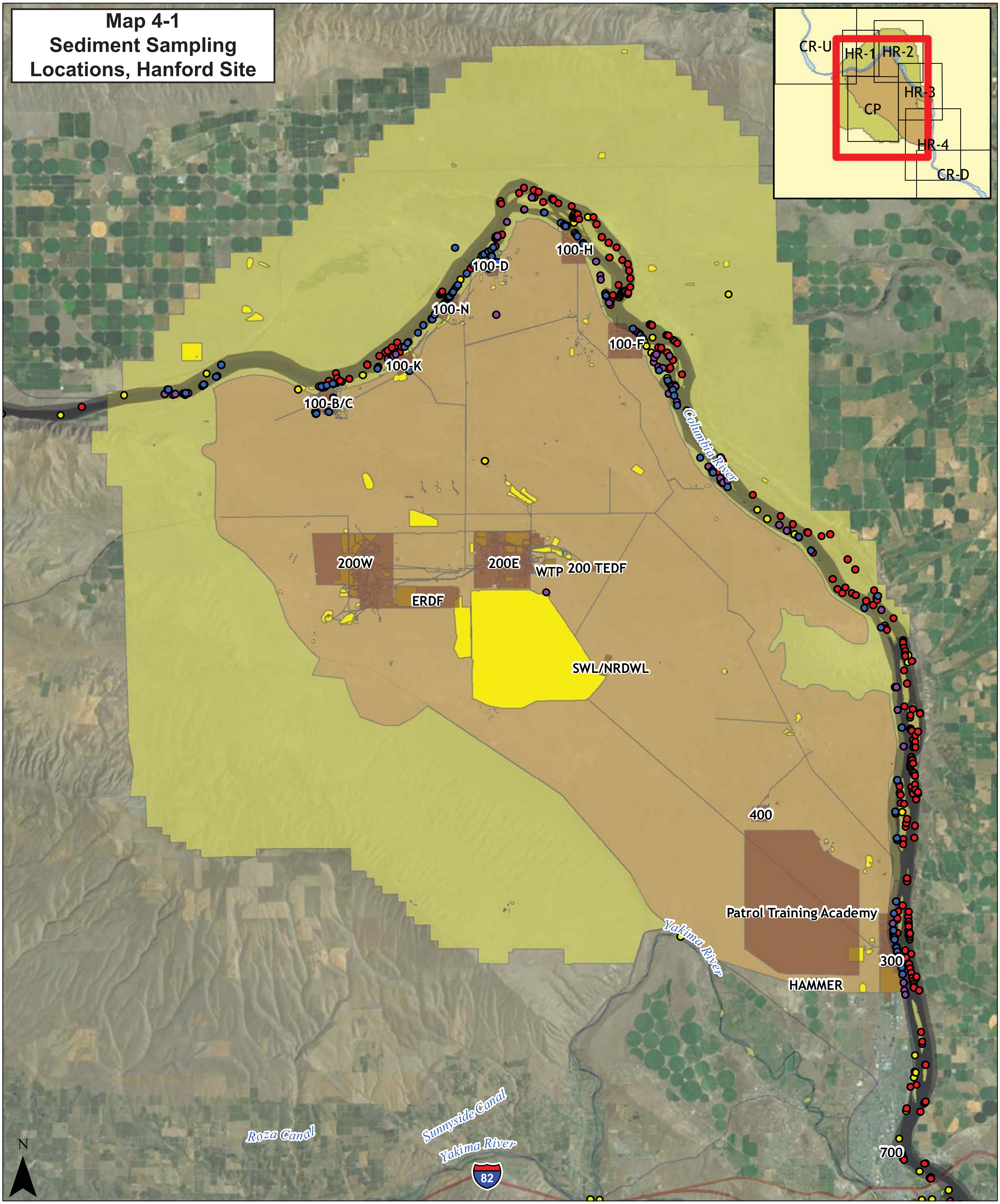
Legend
- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

Pore Water Sampling Locations
- CRC
- GiSdT
- HEIS
- DSR

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 1 2 4 Miles

Source: HEIS, GiSdT, CRC, and DSR Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB



Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

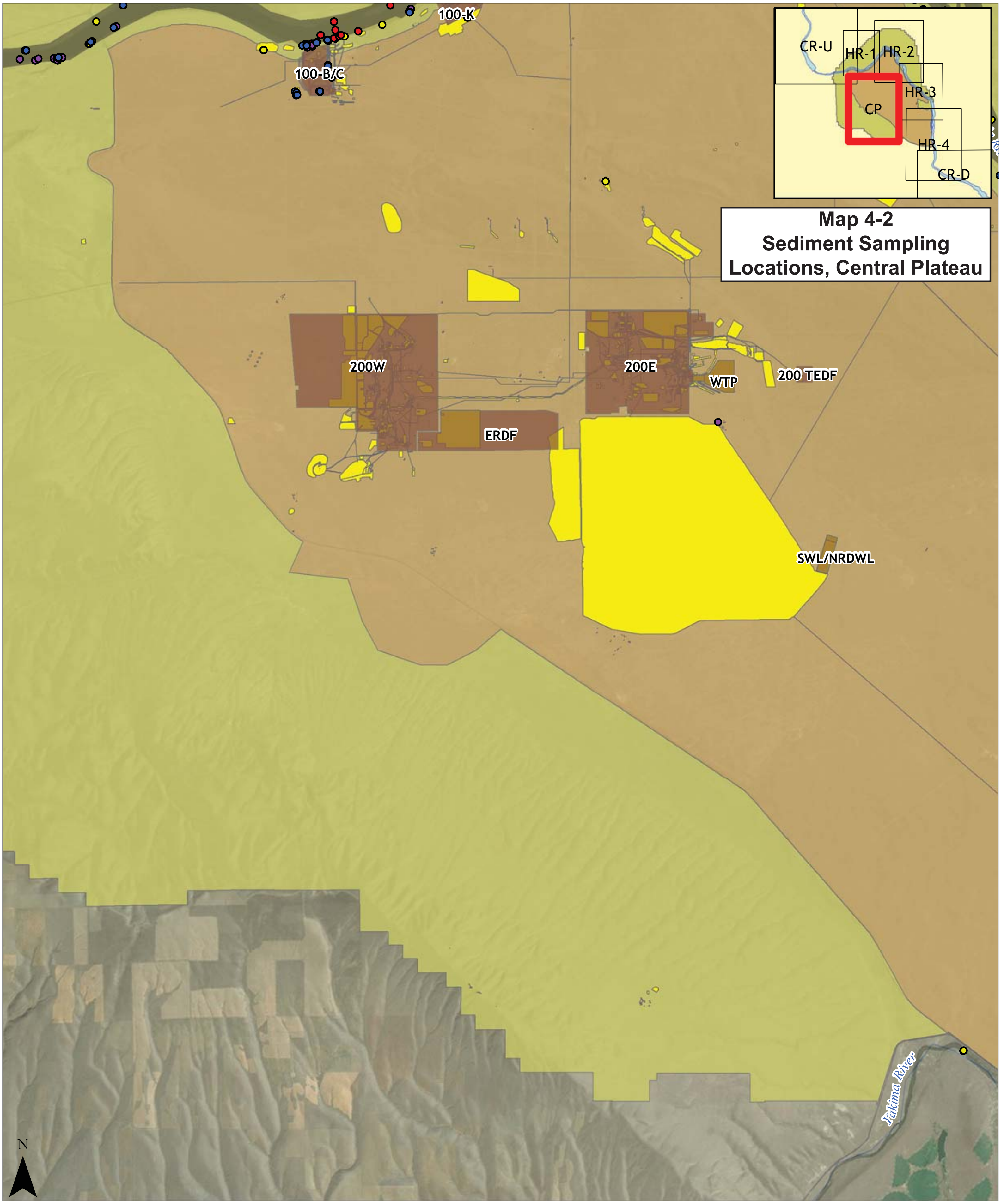
Sediment Sampling Locations

HEIS GiSdT DSR CRC

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 1.25 2.5 5 Miles

Source: HEIS, GiSdT, CRC, and DSR Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB



Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

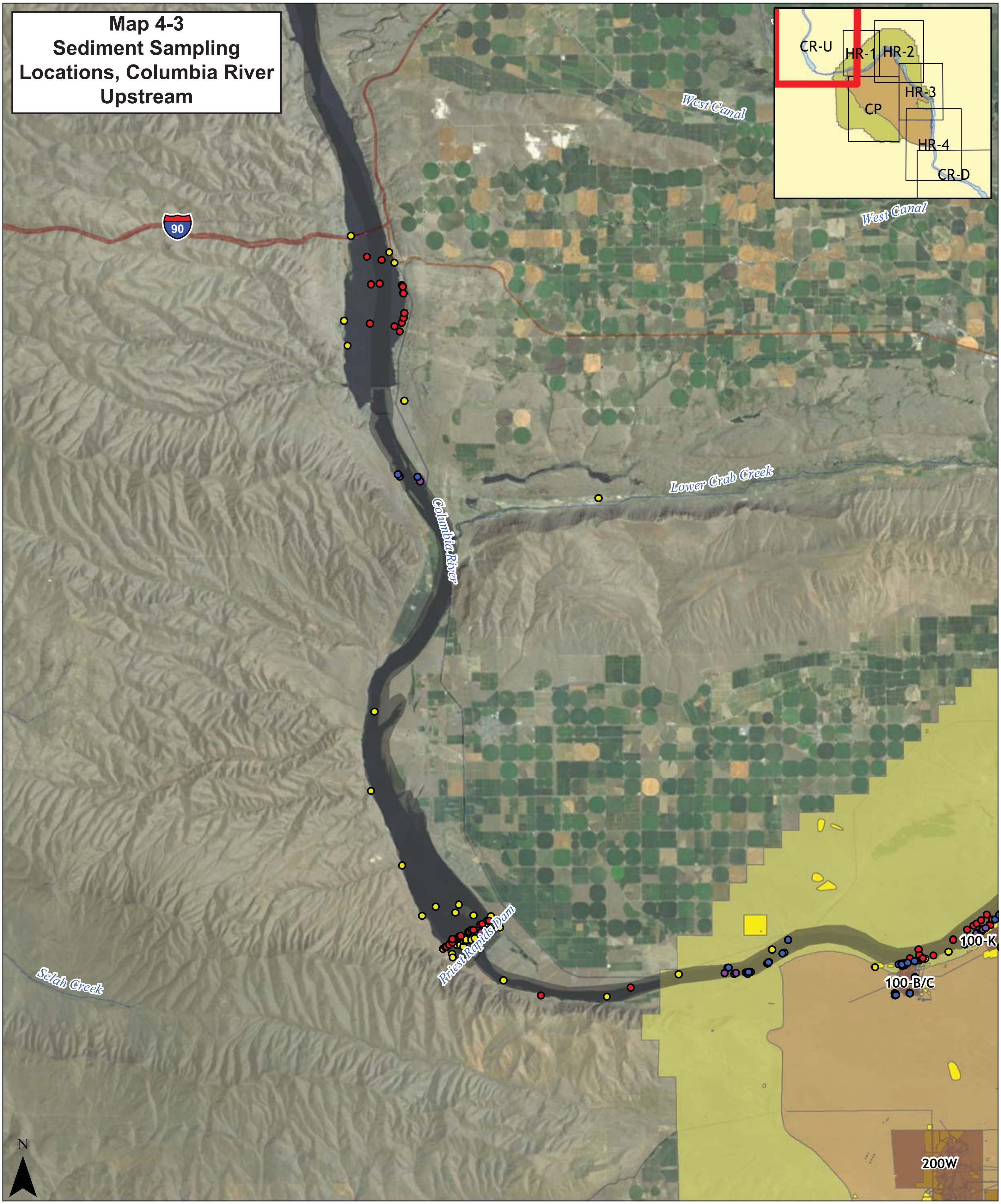
Sediment Sampling Locations

HEIS GiSdT DSR CRC

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 0.5 1 2 Miles

Source: HEIS, GiSdT, CRC, and DSR Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB



Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

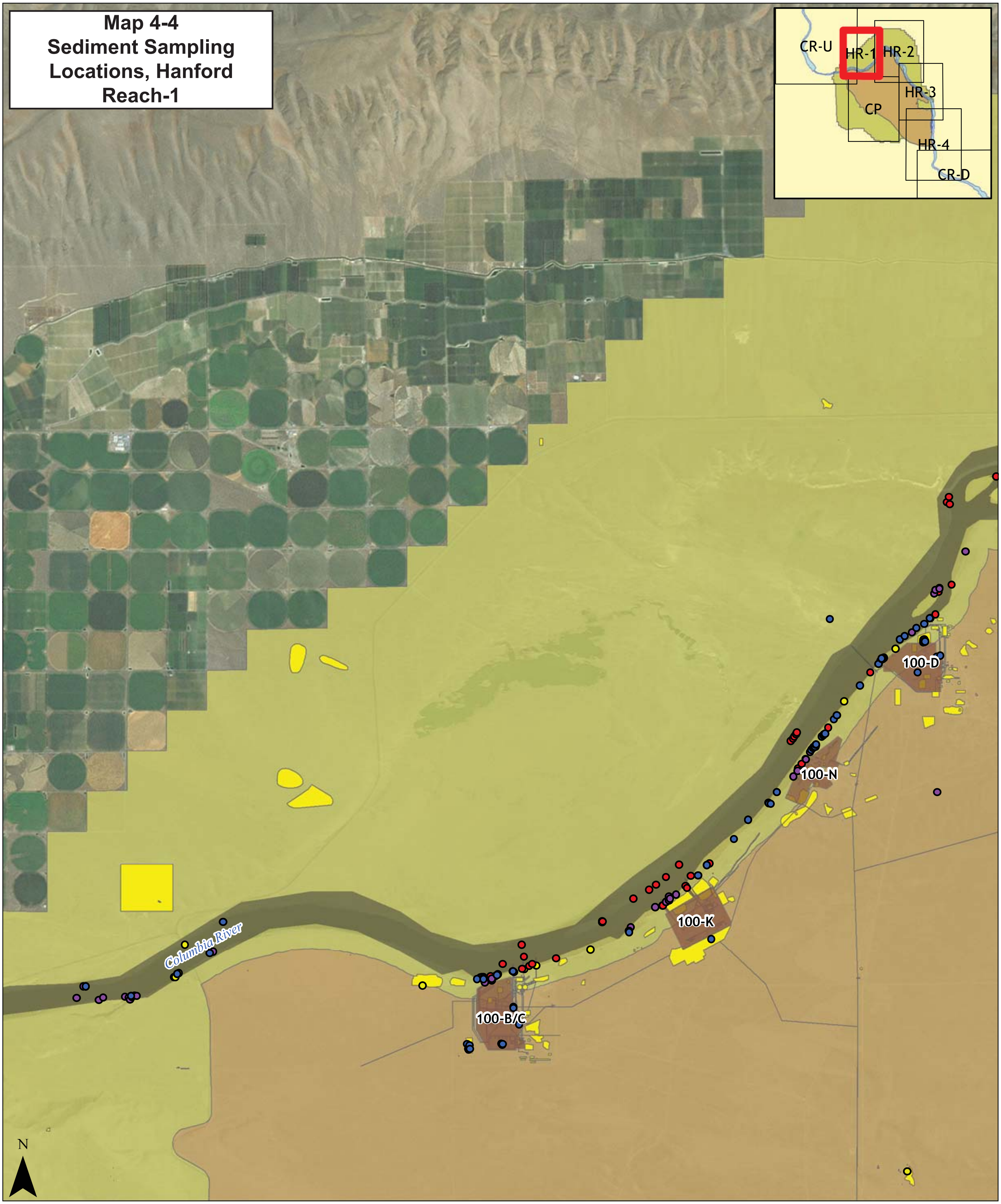
Sediment Sampling Locations

HEIS GiSdT DSR CRC

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 1 2 4 Miles

Source: HEIS, GiSdT, CRC, and DSR Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB



Legend
Hanford Operations Areas
WIDS sites (mapped waste sites)
Hanford Site
Hanford Reach National Monument

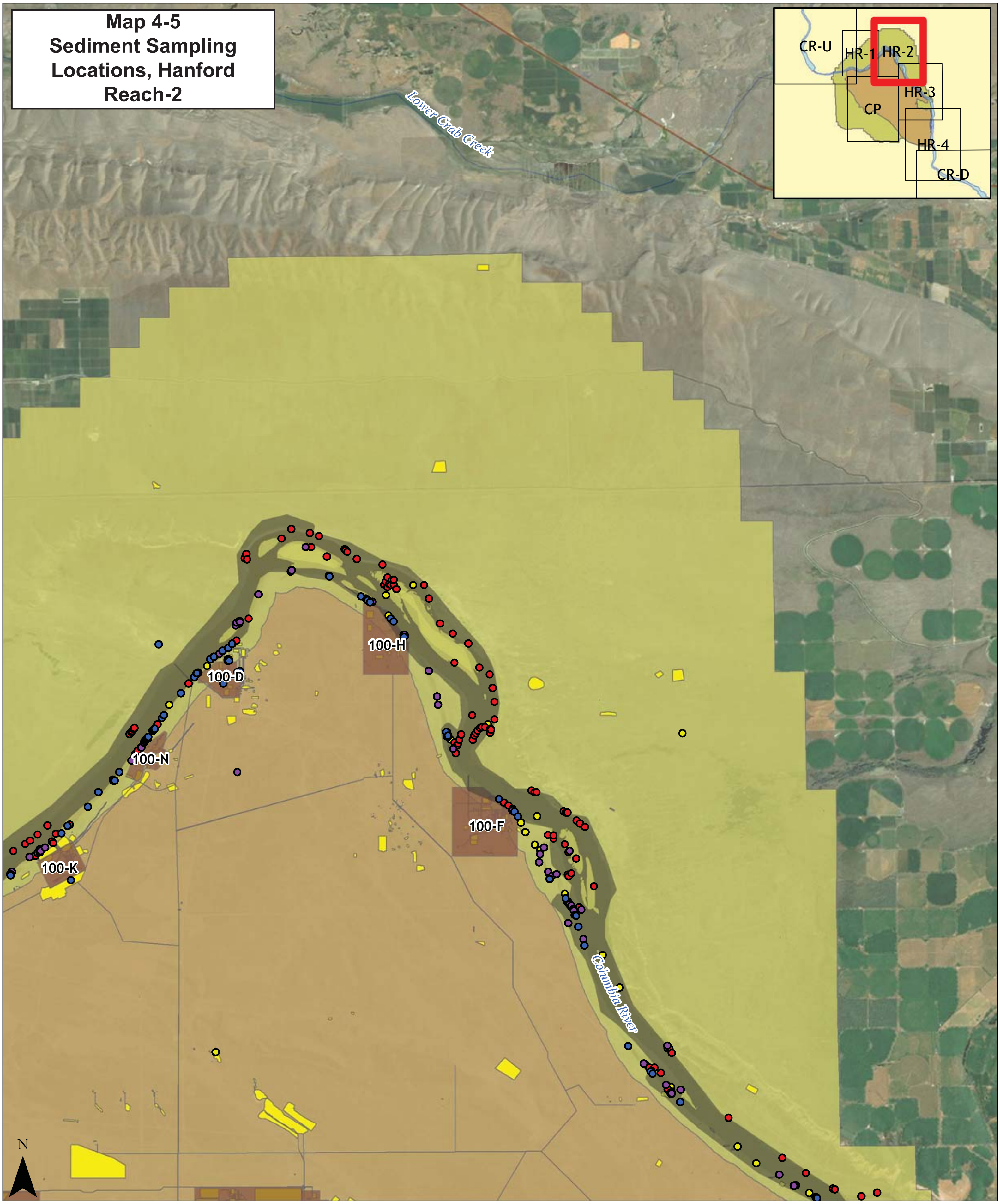
Sediment Sampling Locations
HEIS GiSdT DSR CRC

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 0.5 1 2 Miles

Source: HEIS, GiSdT, CRC, and DSR Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB

Map 4-5 Sediment Sampling Locations, Hanford Reach-2



Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

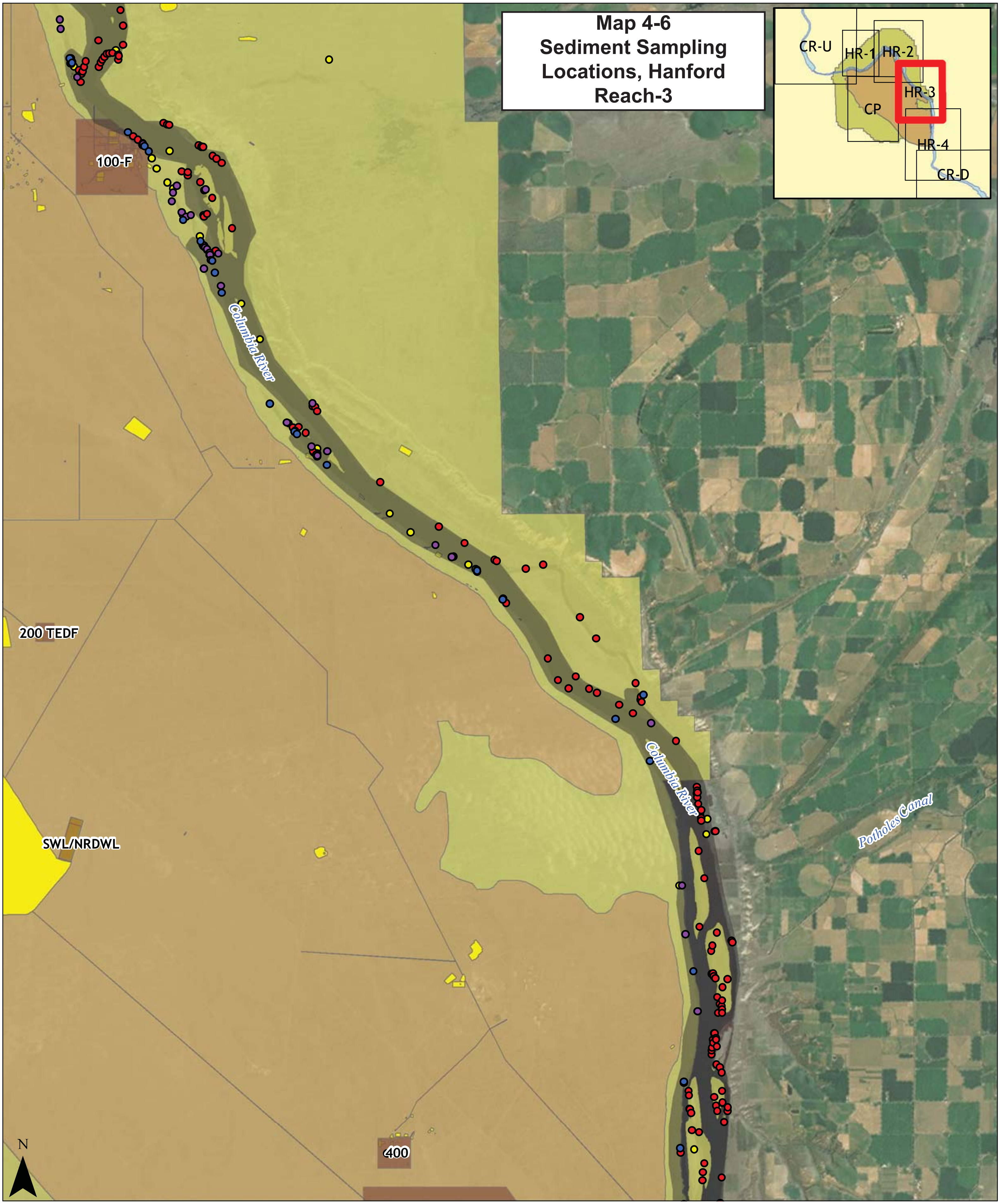
Sediment Sampling Locations

HEIS GiSdT DSR CRC

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 0.5 1 2 Miles

Source: HEIS, GiSdT, CRC, and DSR Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB



Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

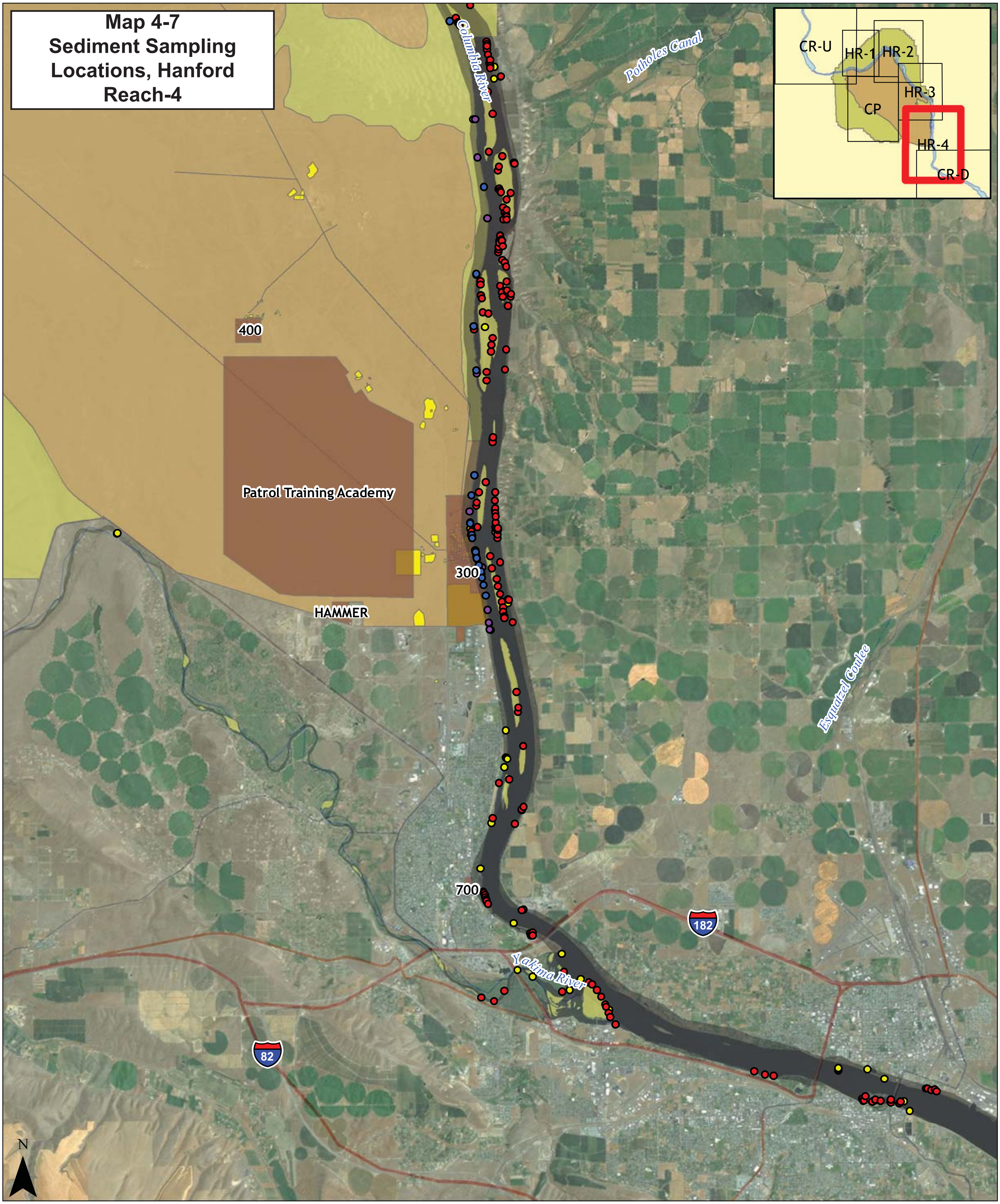
Sediment Sampling Locations

HEIS GiSdT DSR CRC

Only sample locations with coordinate information are depicted.
Some sample locations may not be visible because of proximity
to (or identity with) sampling locations in other databases.

0 0.5 1 2 Miles

Source: HEIS, GiSdT, CRC, and DSR Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB



Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

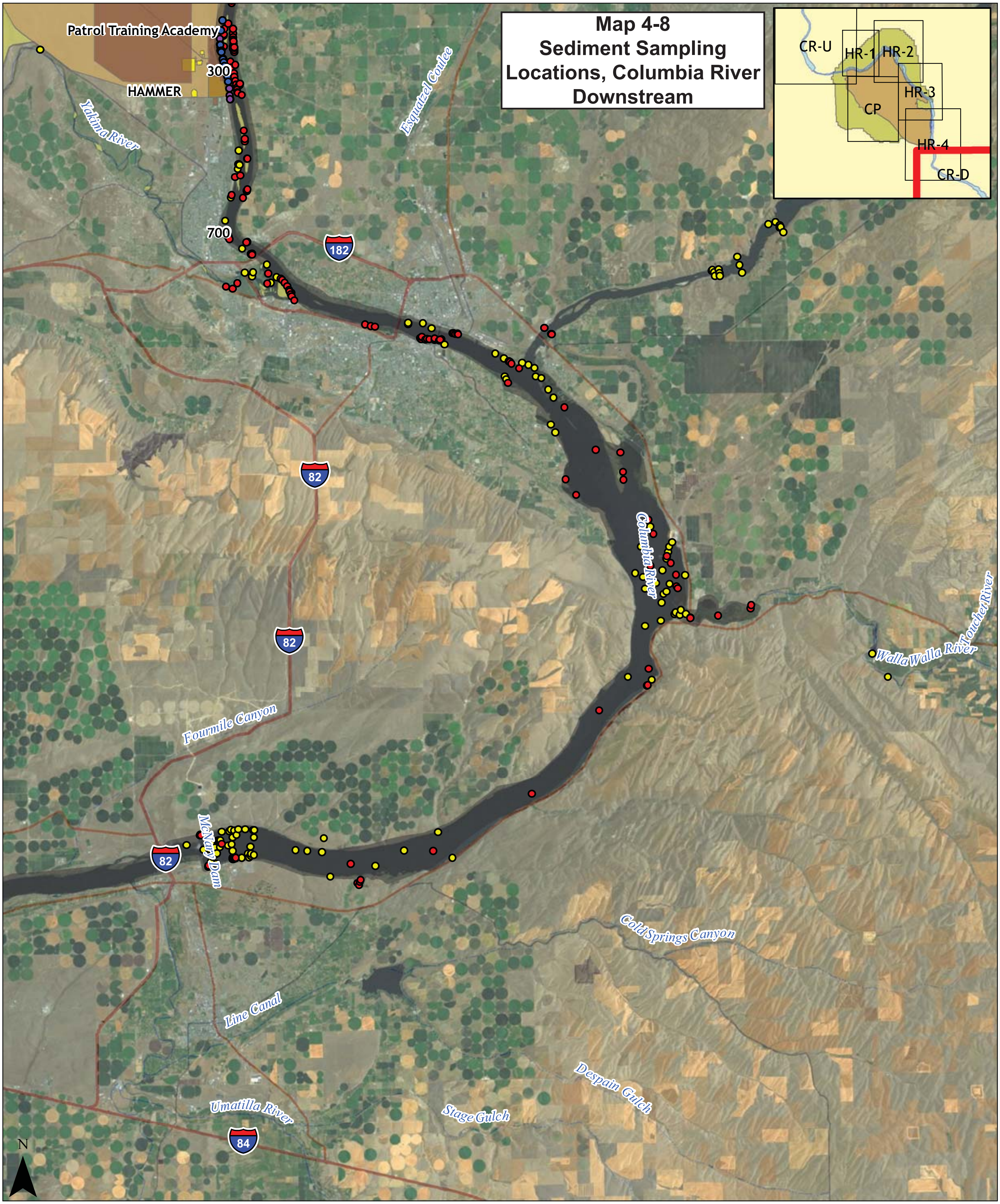
Sediment Sampling Locations

HEIS GiSdT DSR CRC

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 0.5 1 2 Miles

Source: HEIS, GiSdT, CRC, and DSR Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB



Legend

Hanford Operations Areas
WIDS sites (mapped waste sites)
Hanford Site
Hanford Reach National Monument

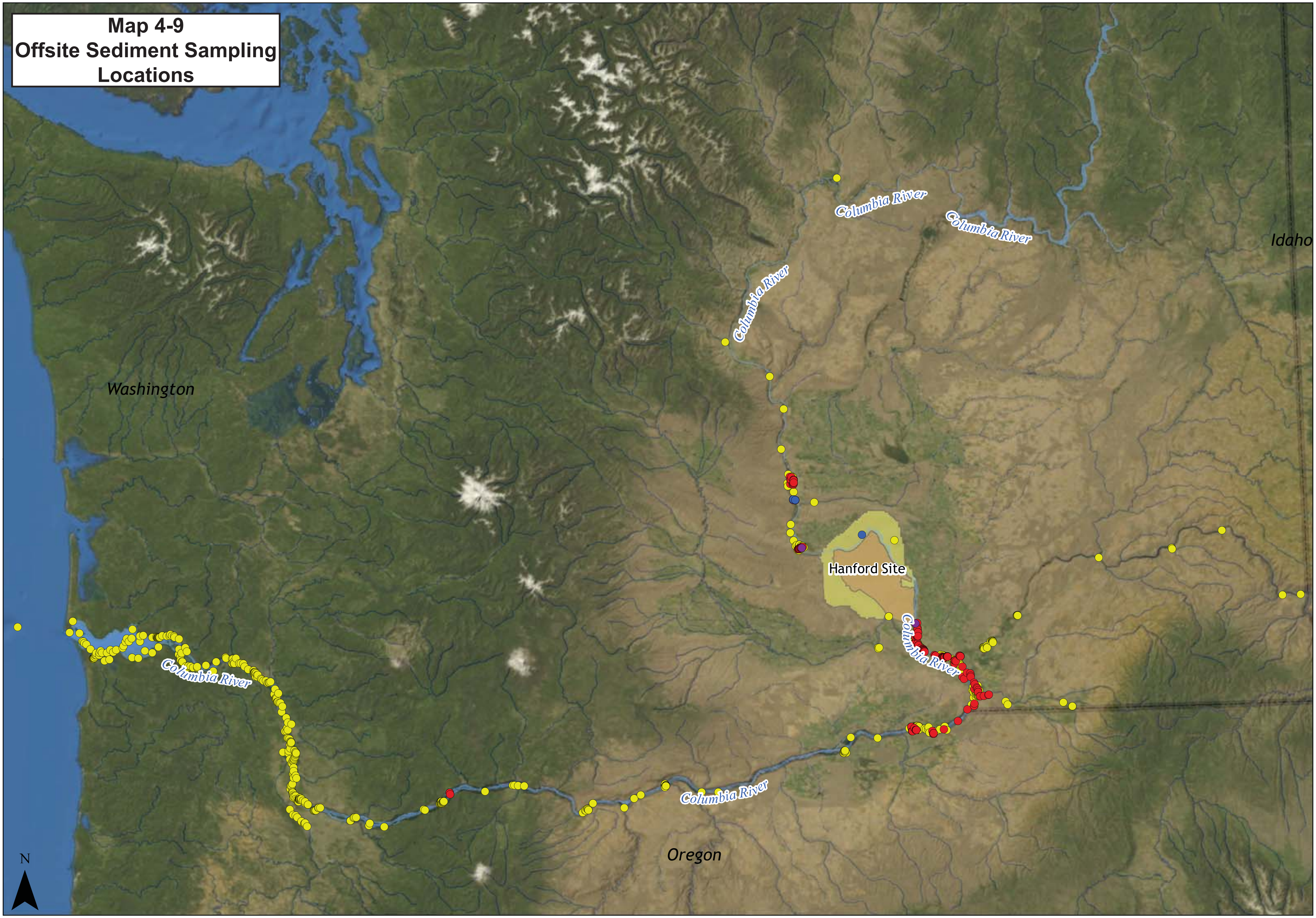
Sediment Sampling Locations

HEIS GiSdT DSR CRC

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 1.5 3 6 Miles

Source: HEIS, GiSdT, CRC, and DSR Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB



Legend

- Hanford Site
- Hanford Reach National Monument

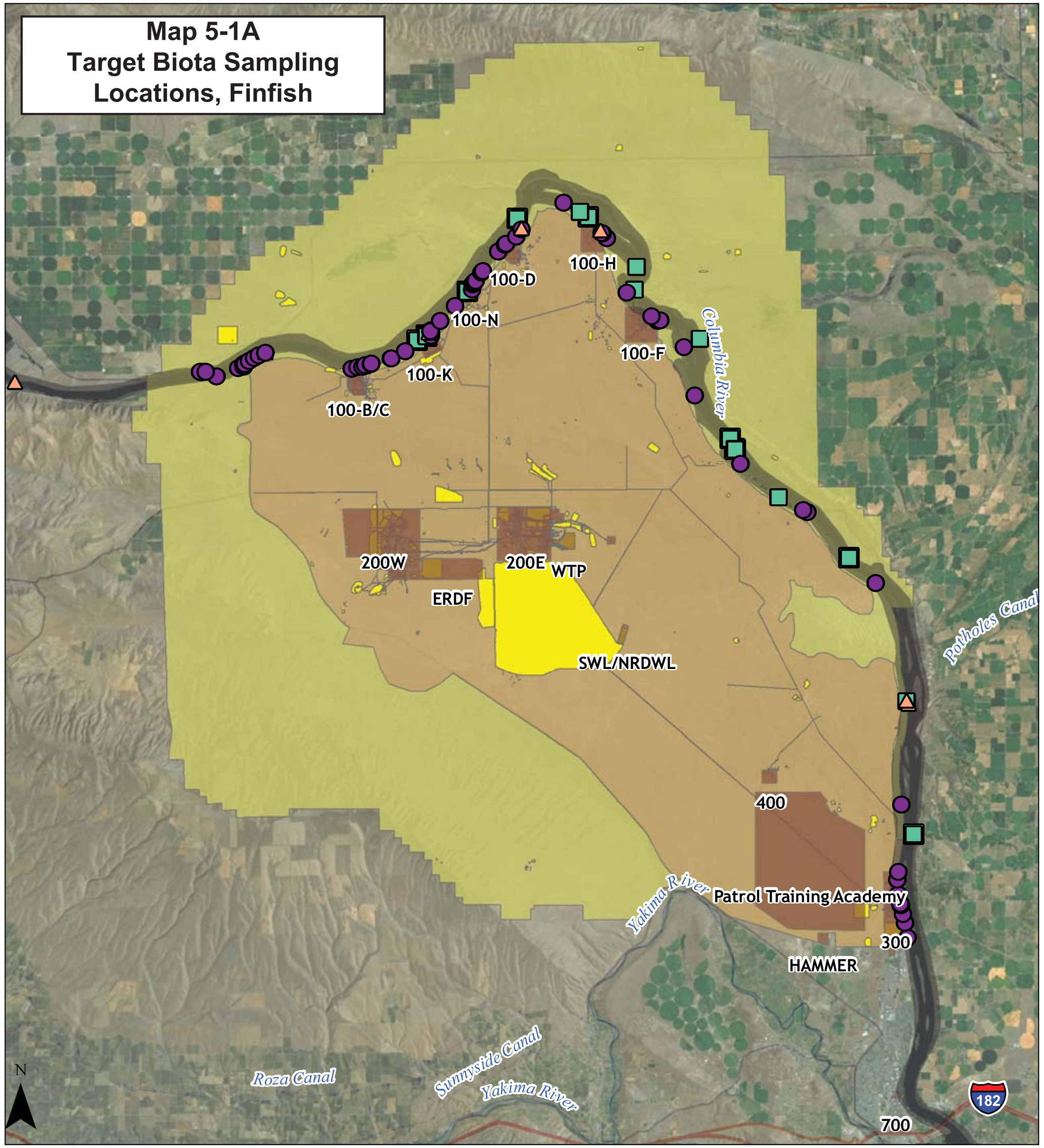
Offsite Sediment Sample Locations

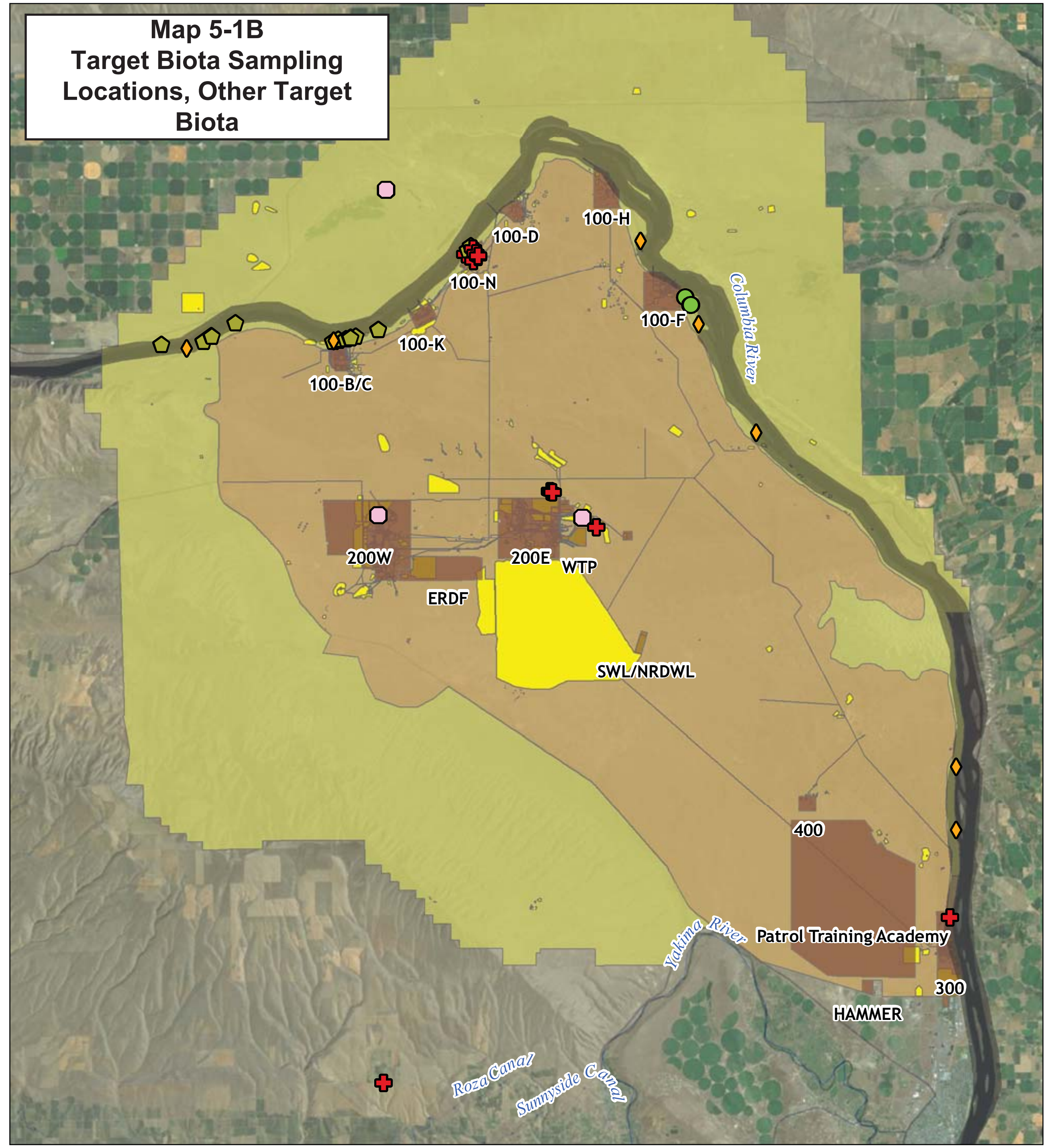
- HEIS
- GiSdT
- DSR
- CRC

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 10 20 40 Miles

Source: HEIS, GiSdT, CRC, DSR Databases
Projection: State Plane WA South, NAD 83
Date:1/9/2012 Creator: SB





Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

Target Biota Sampling Locations

Bulrush, Caddisfly, Cottontail Rabbit, Frog, Mussel, Salmon, Sculpin, Sturgeon

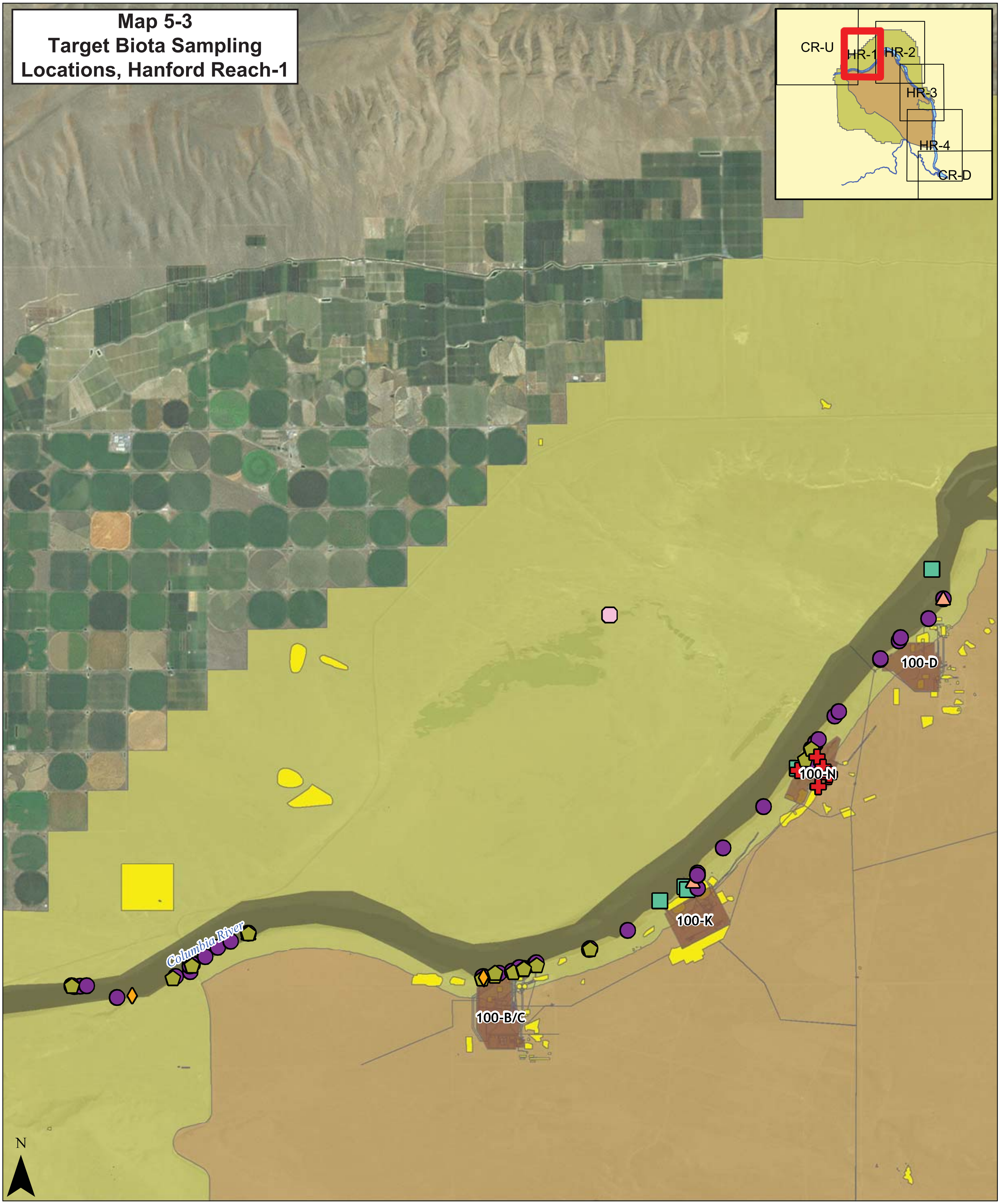
Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 1.5 3 6 Miles

Source: HEIS, GiSdT, CRC, DSR Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB

Map 5-2
Target Biota Sampling Locations, Columbia River Upstream
CR-U
HR-1
HR-2
HR-3
HR-4
CR-D
West Canal
West Canal
90
Lower Crab Creek
Columbia River
Priest Rapids Dam
Selah Creek
100-K
100-B/C
200W
N
Legend
Hanford Operations Areas
WIDS sites (mapped waste sites)
Hanford Site
Hanford Reach National Monument
Target Biota Sampling Locations
Bulrush
Caddisfly
Cottontail Rabbit
Frog
Mussel
Salmon
Sculpin
Sturgeon
Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.
0
1.25
2.5
5 Miles
Source: HEIS, GiSdT, CRC, DSR Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB

Map 5-3
Target Biota Sampling Locations, Hanford Reach-1



Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

Target Biota Sampling Locations

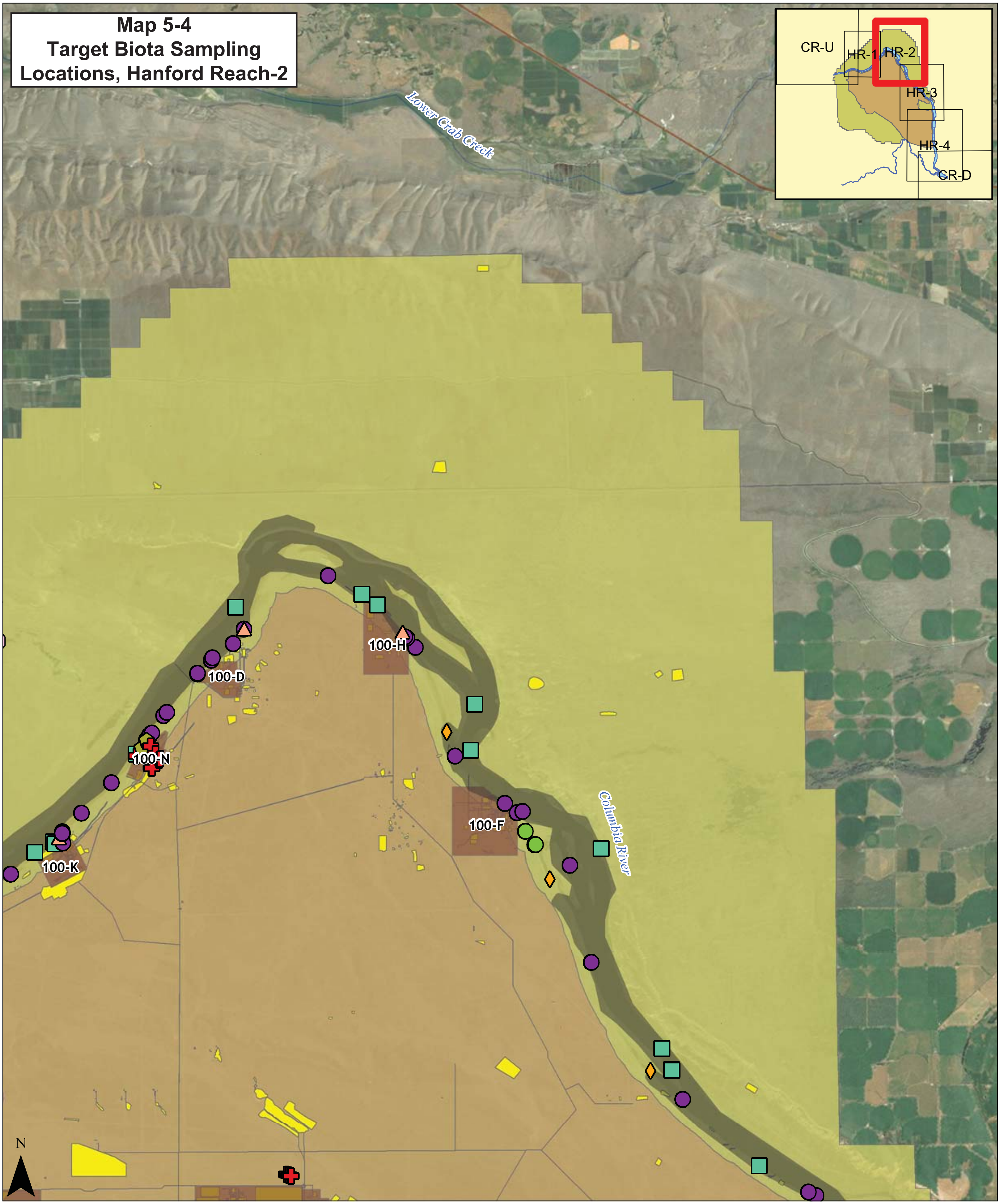
Bulrush, Caddisfly, Cottontail Rabbit, Frog, Mussel, Salmon, Sculpin, Sturgeon

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 0.5 1 2 Miles

Source: HEIS, GiSdT, CRC, DSR Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB

Map 5-4 Target Biota Sampling Locations, Hanford Reach-2



Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

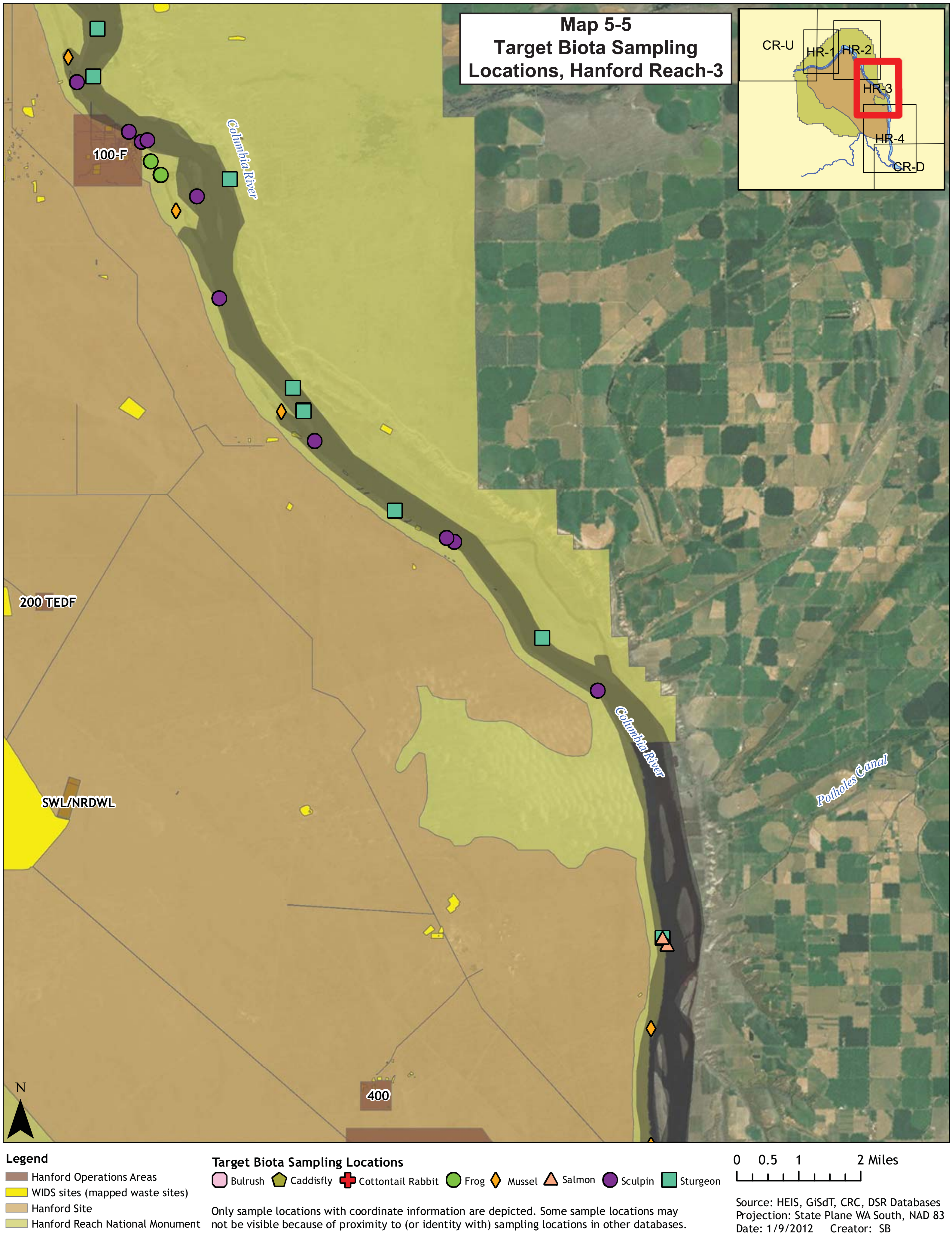
Target Biota Sampling Locations

Bulrush, Caddisfly, Cottontail Rabbit, Frog, Mussel, Salmon, Sculpin, Sturgeon

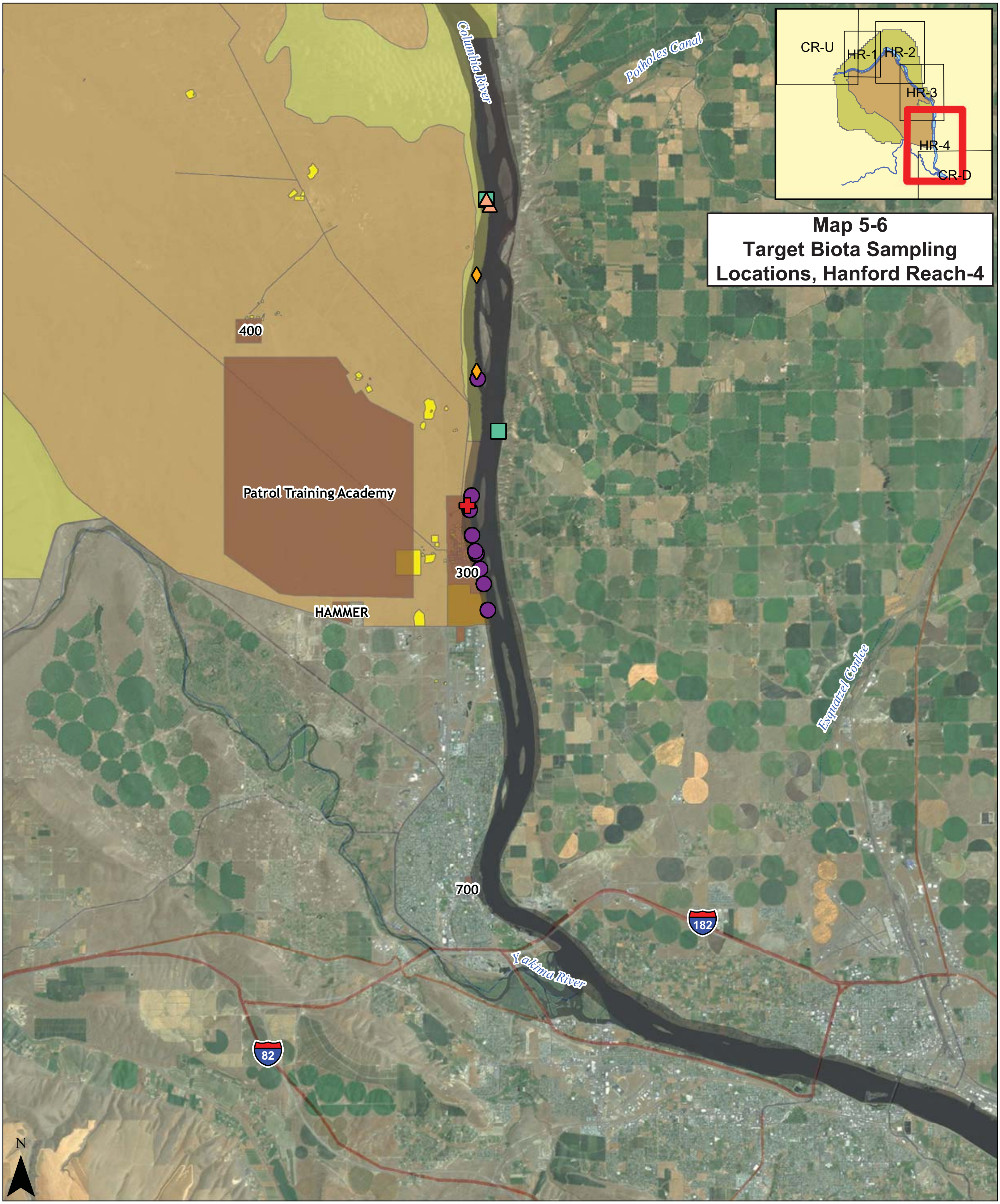
Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 0.5 1 2 Miles

Source: HEIS, GiSdT, CRC, DSR Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB



Map 5-5
Target Biota Sampling
Locations, Hanford Reach-3
CR-U
HR-1
HR-2
HR-3
HR-4
CR-D
100-F
Columbia River
200 TEDF
SWL/NRDWL
400
Potholes Canal
N
Legend
Hanford Operations Areas
WIDS sites (mapped waste sites)
Hanford Site
Hanford Reach National Monument
Target Biota Sampling Locations
Bulrush
Caddisfly
Cottontail Rabbit
Frog
Mussel
Salmon
Sculpin
Sturgeon
Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.
0 0.5 1 2 Miles
Source: HEIS, GiSdT, CRC, DSR Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB



Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

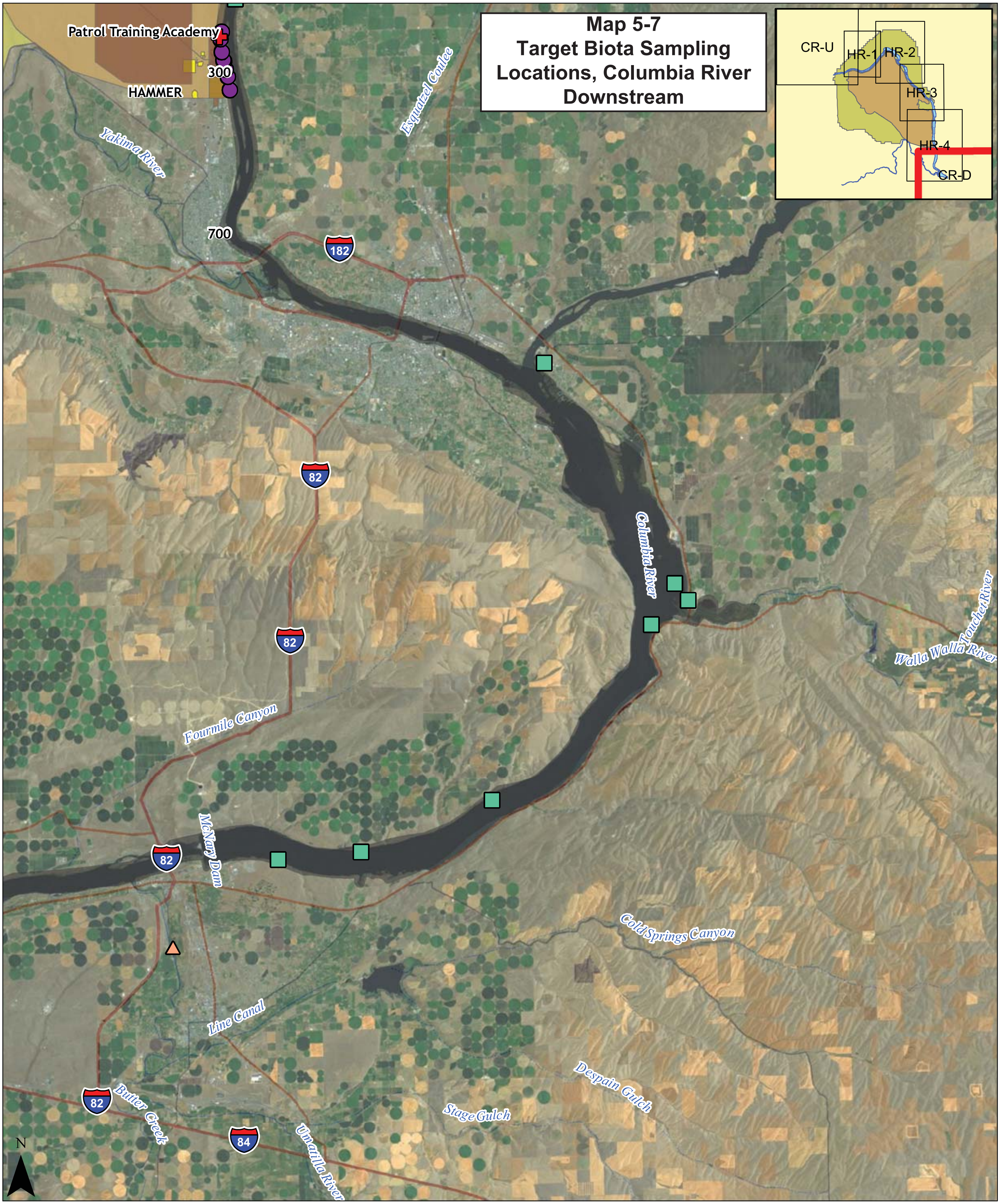
Target Biota Sampling Locations

Bulrush, Caddisfly, Cottontail Rabbit, Frog, Mussel, Salmon, Sculpin, Sturgeon

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 0.5 1 2 Miles

Source: HEIS, GiSdT, CRC, DSR Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB



Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

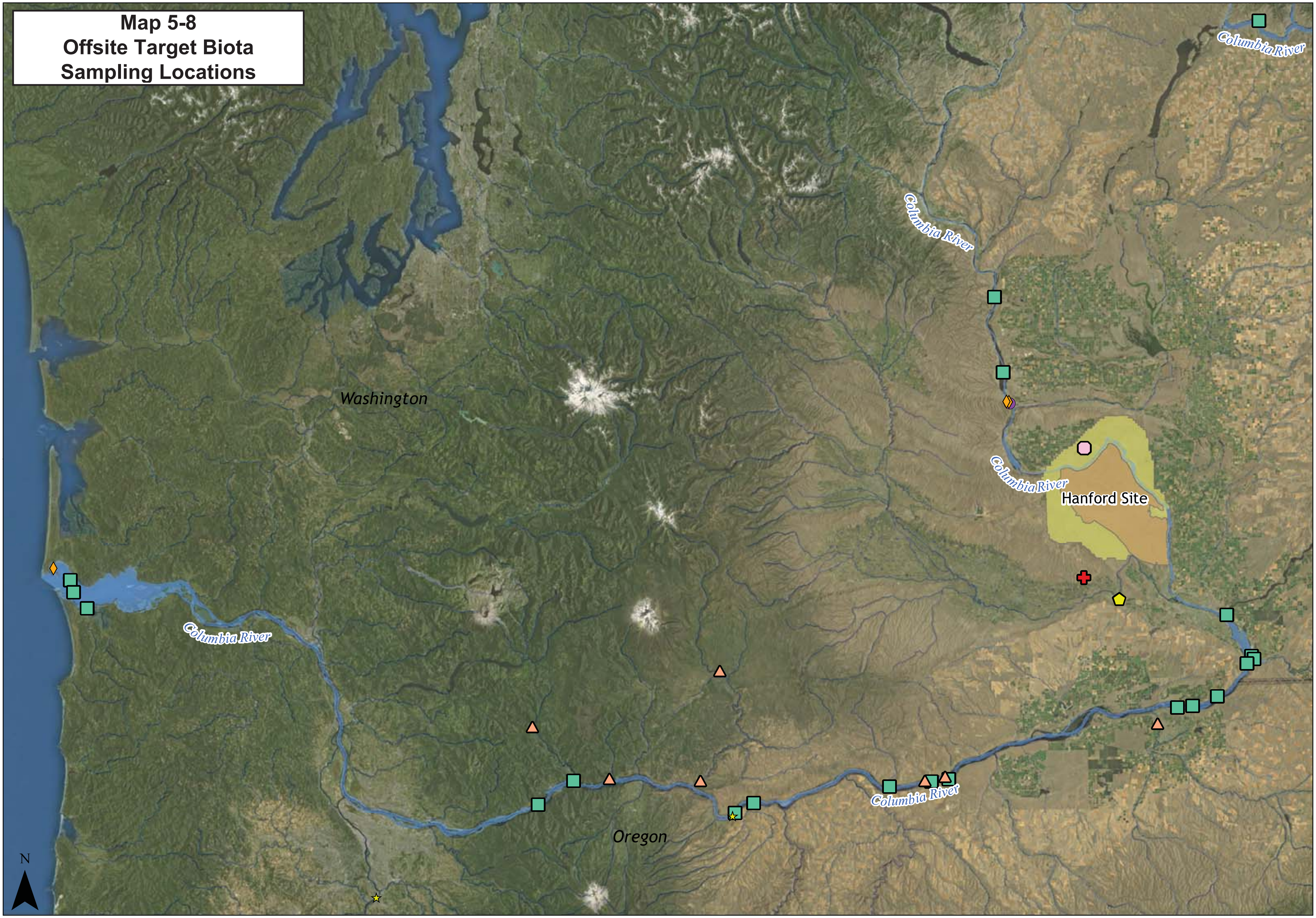
Target Biota Sampling Locations

Bulrush, Caddisfly, Cottontail Rabbit, Frog, Mussel, Salmon, Sculpin, Sturgeon

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 1.5 3 6 Miles

Source: HEIS, GiSdT, CRC, DSR Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB



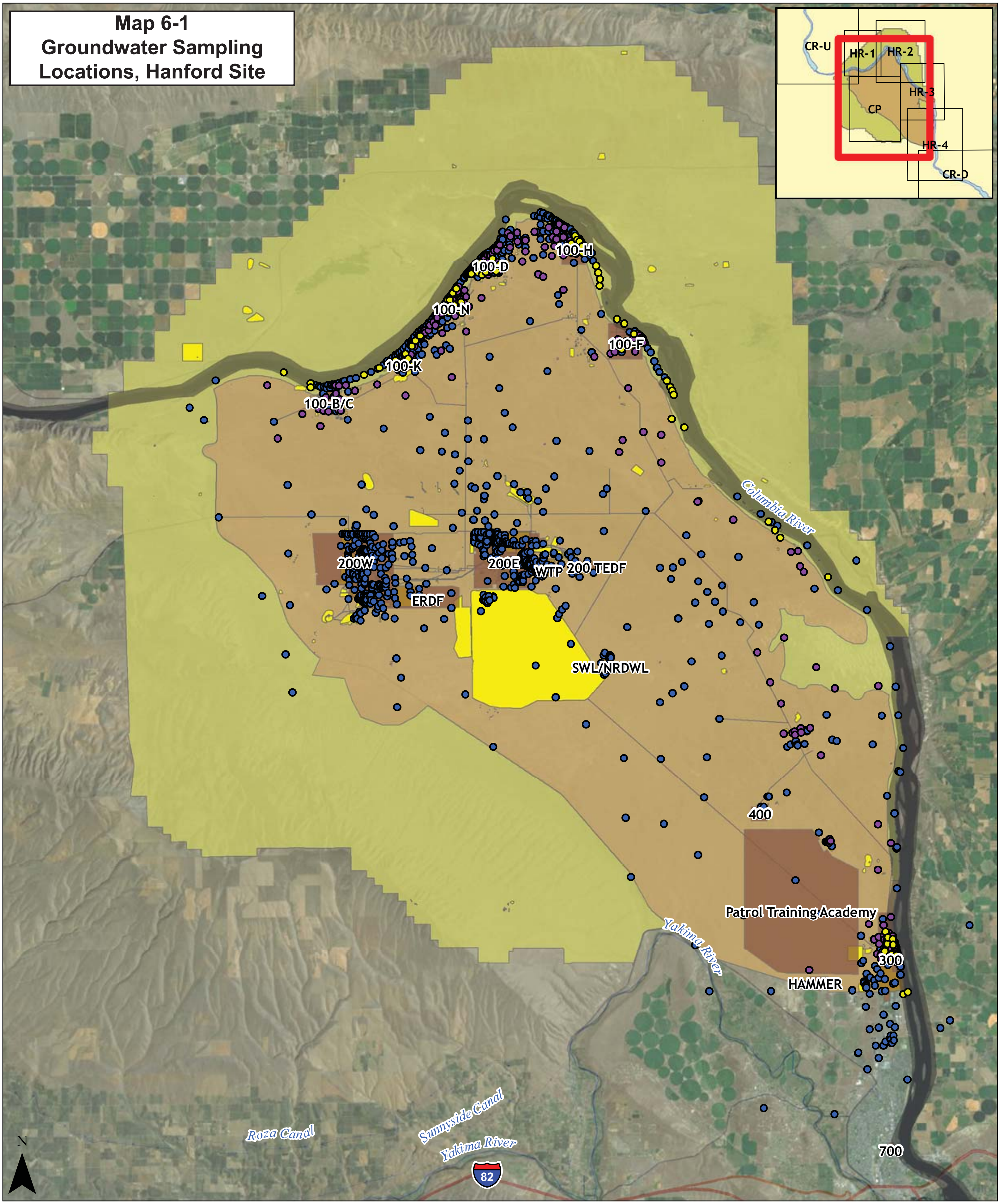
Legend
Hanford Site
Hanford Reach National Monument

Offsite Target Biota Sample Locations
Bulrush
Caddisfly
Cottontail Rabbit
Mussel
Pacific lamprey
Salmon
Sculpin
Sturgeon

0 5 10 20 Miles

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

Source: HEIS, GiSdT, CRC and DSR Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB



Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

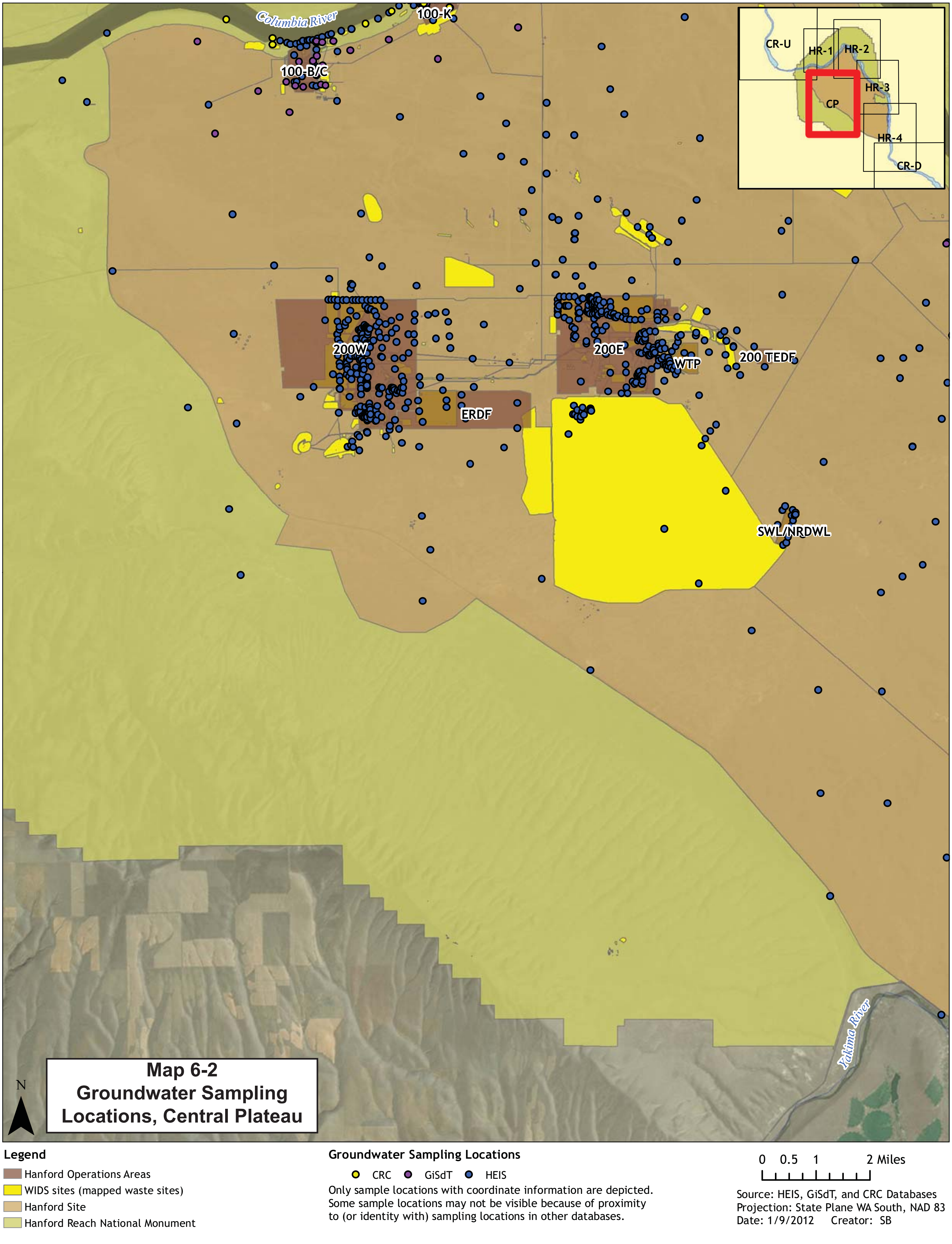
Groundwater Sampling Locations

CRC GiSdT HEIS

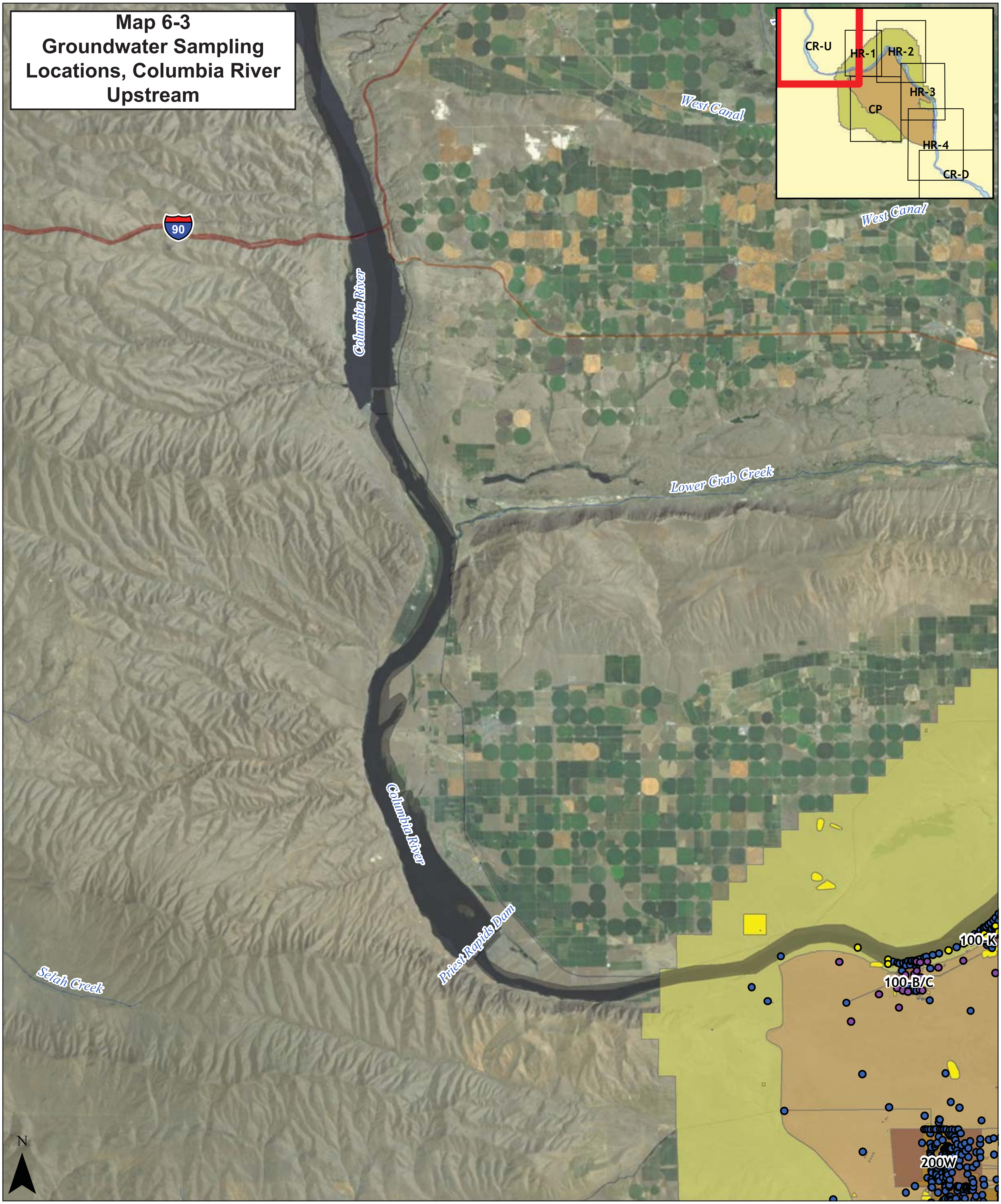
Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 1.25 2.5 5 Miles

Source: HEIS, GiSdT, and CRC Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB


Columbia River
100-K
100-B/C
200W
200E
WTP
200 TEDF
ERDF
SWL/NRDWL
Yakima River
CR-U
HR-1
HR-2
HR-3
CP
HR-4
CR-D
N
Map 6-2
Groundwater Sampling
Locations, Central Plateau
Legend
Hanford Operations Areas
WIDS sites (mapped waste sites)
Hanford Site
Hanford Reach National Monument
Groundwater Sampling Locations
CRC
GiSdT
HEIS
Only sample locations with coordinate information are depicted.
Some sample locations may not be visible because of proximity
to (or identity with) sampling locations in other databases.
0 0.5 1 2 Miles
Source: HEIS, GiSdT, and CRC Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB

Map 6-3 Groundwater Sampling Locations, Columbia River Upstream



Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

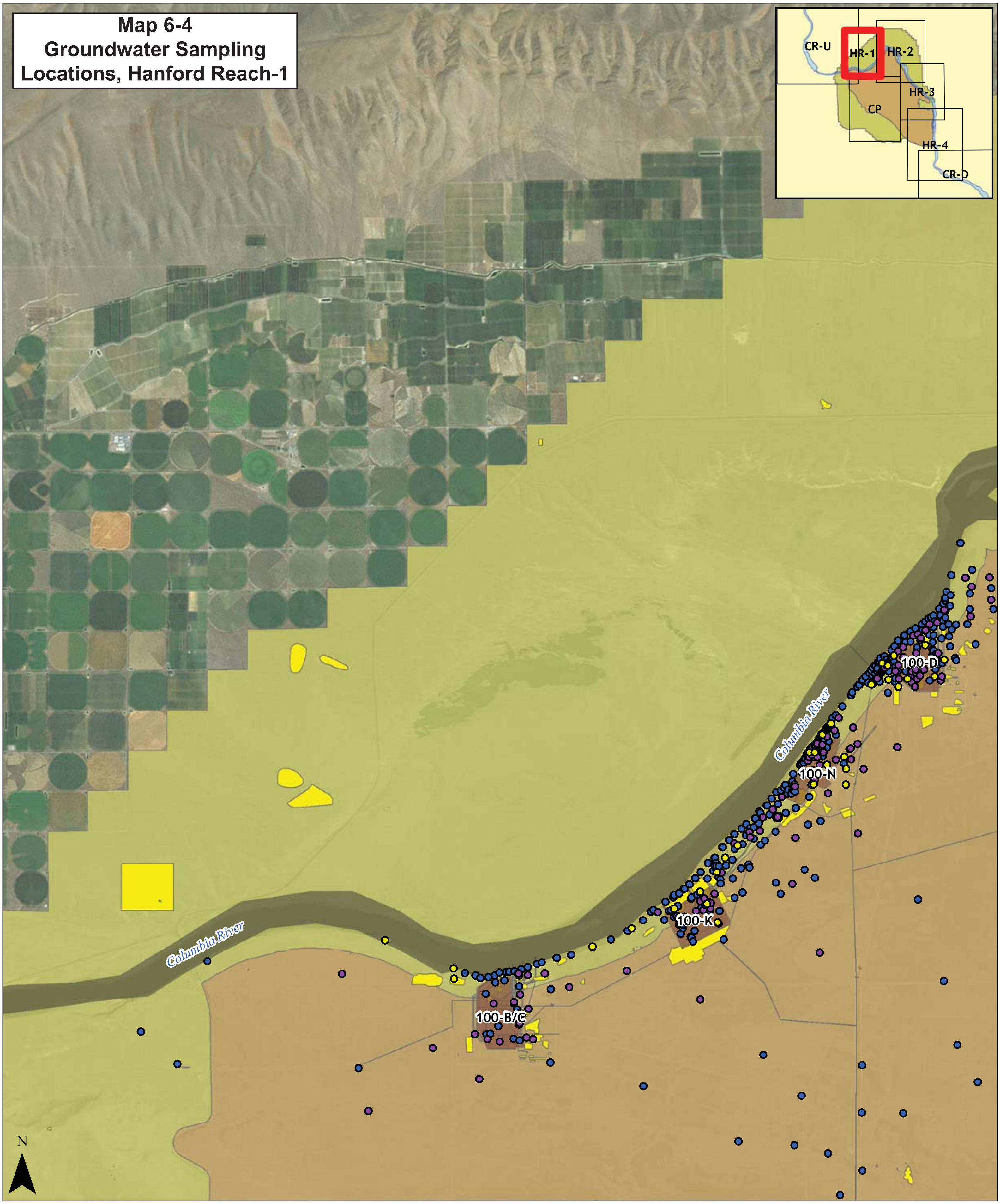
Groundwater Sampling Locations

CRC GiSdT HEIS

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 1 2 4 Miles

Source: HEIS, GiSdT, and CRC Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB



Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

Groundwater Sampling Locations

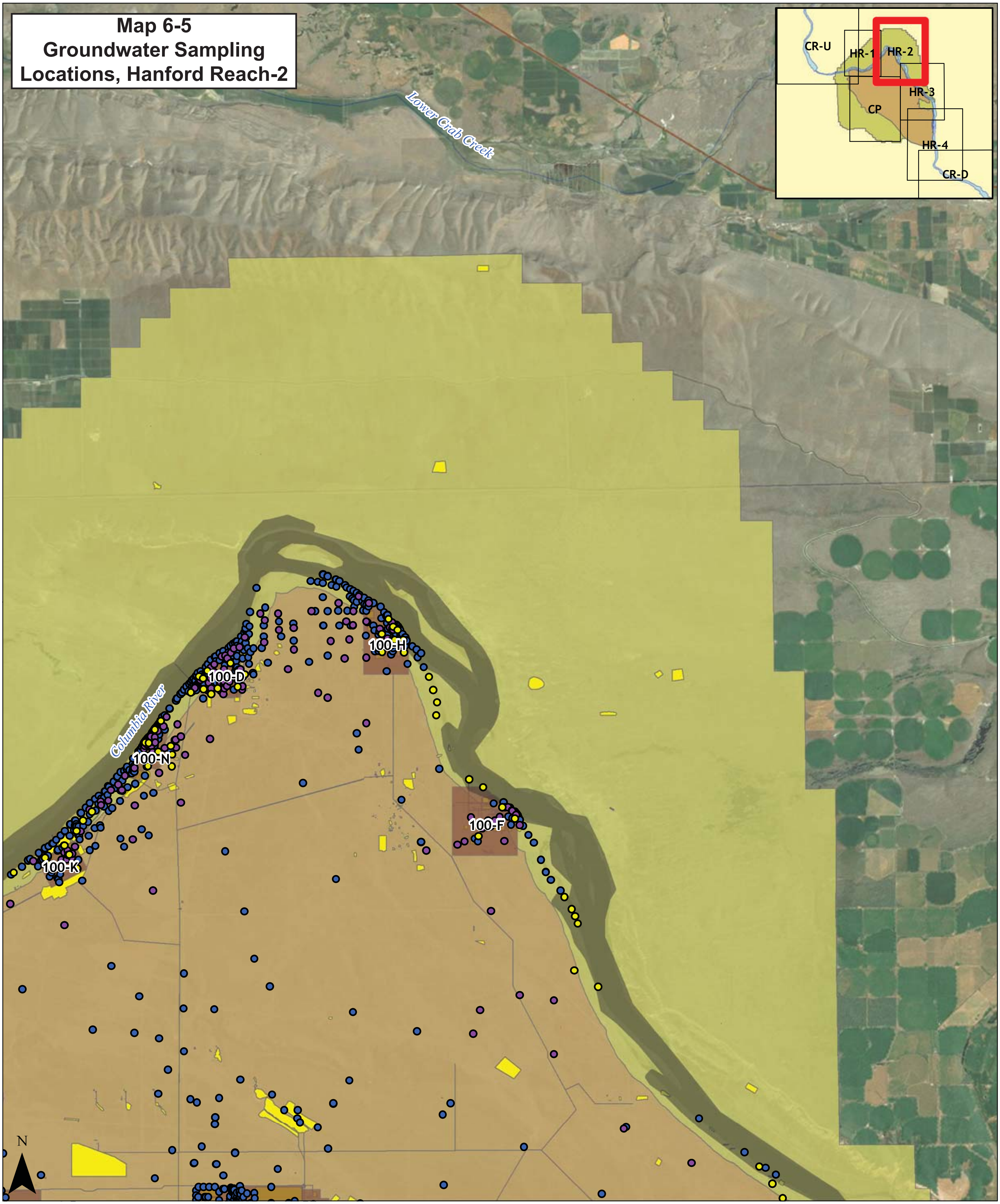
CRC GiSdT HEIS

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 0.5 1 2 Miles

Source: HEIS, GiSdT, and CRC Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB

Map 6-5
Groundwater Sampling Locations, Hanford Reach-2



Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

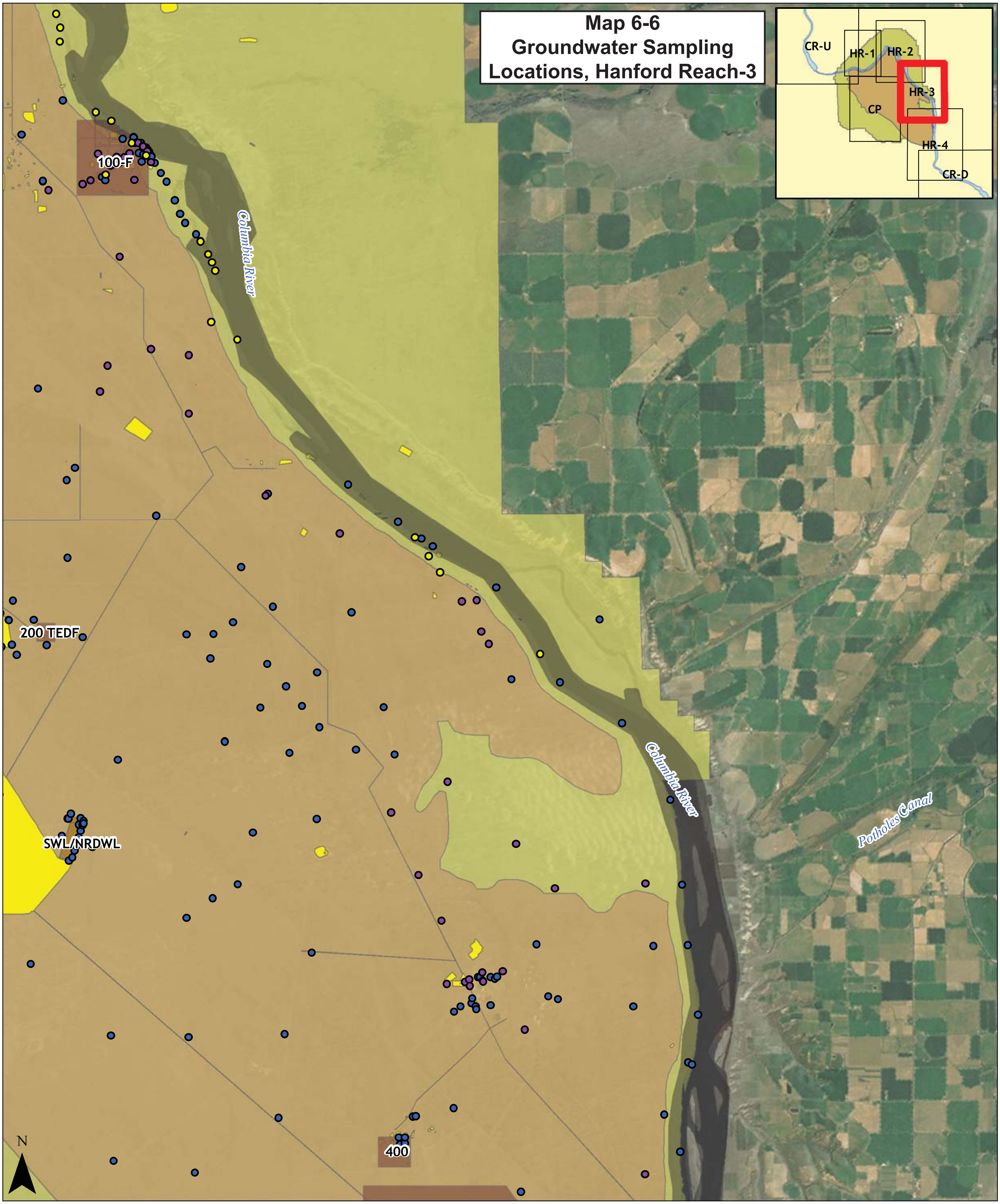
Groundwater Sampling Locations

CRC GiSdT HEIS

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 0.5 1 2 Miles

Source: HEIS, GiSdT, and CRC Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB



Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

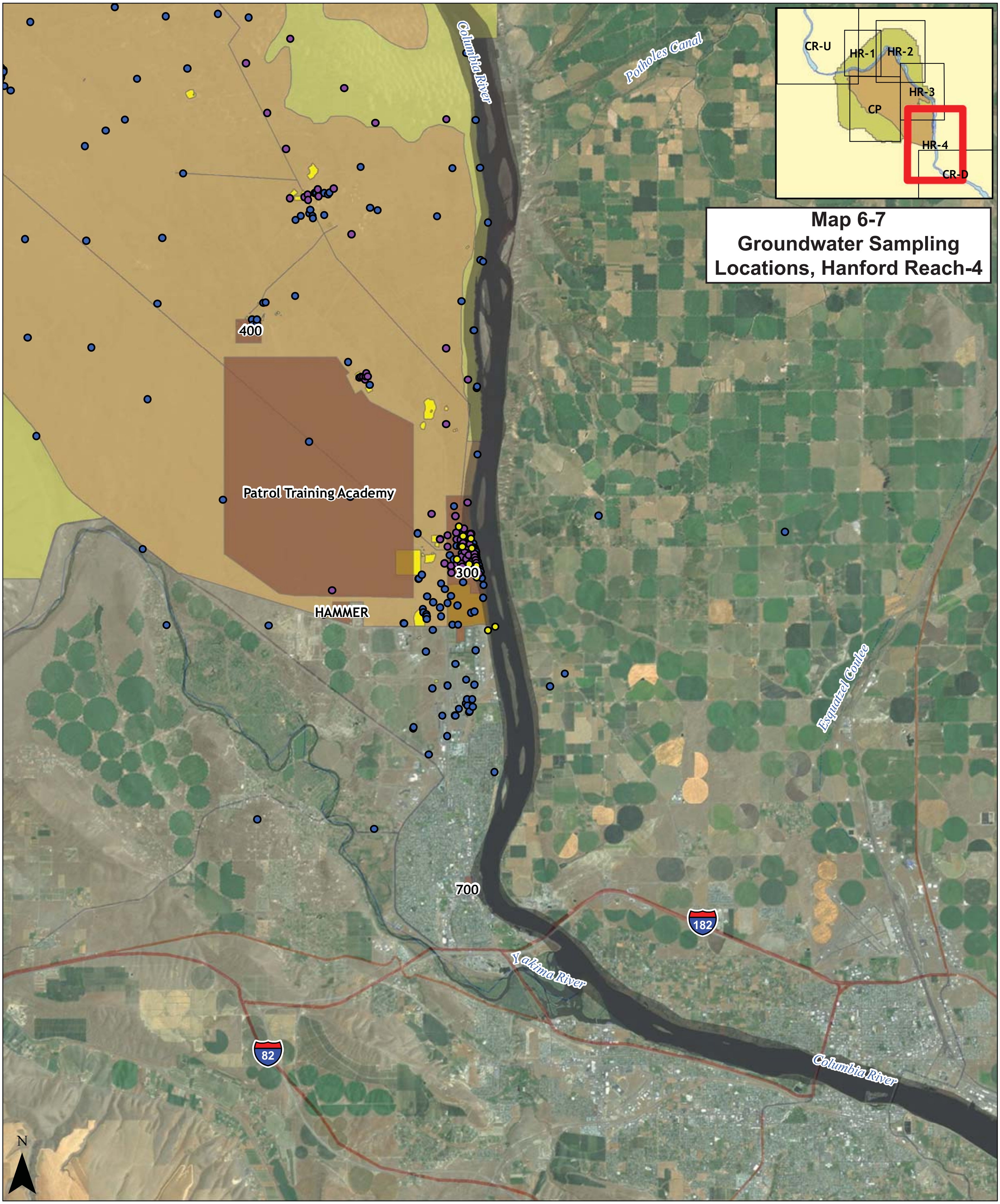
Groundwater Sampling Locations

CRC GiSdT HEIS

Only sample locations with coordinate information are depicted.
Some sample locations may not be visible because of proximity
to (or identity with) sampling locations in other databases.

0 0.5 1 2 Miles

Source: HEIS, GiSdT, and CRC Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB



Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

Groundwater Sampling Locations

CRC GiSdT HEIS

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 0.5 1 2 Miles

Source: HEIS, GiSdT, and CRC Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB

Legend

Hanford Operations Areas
WIDS sites (mapped waste sites)
Hanford Site
Hanford Reach National Monument

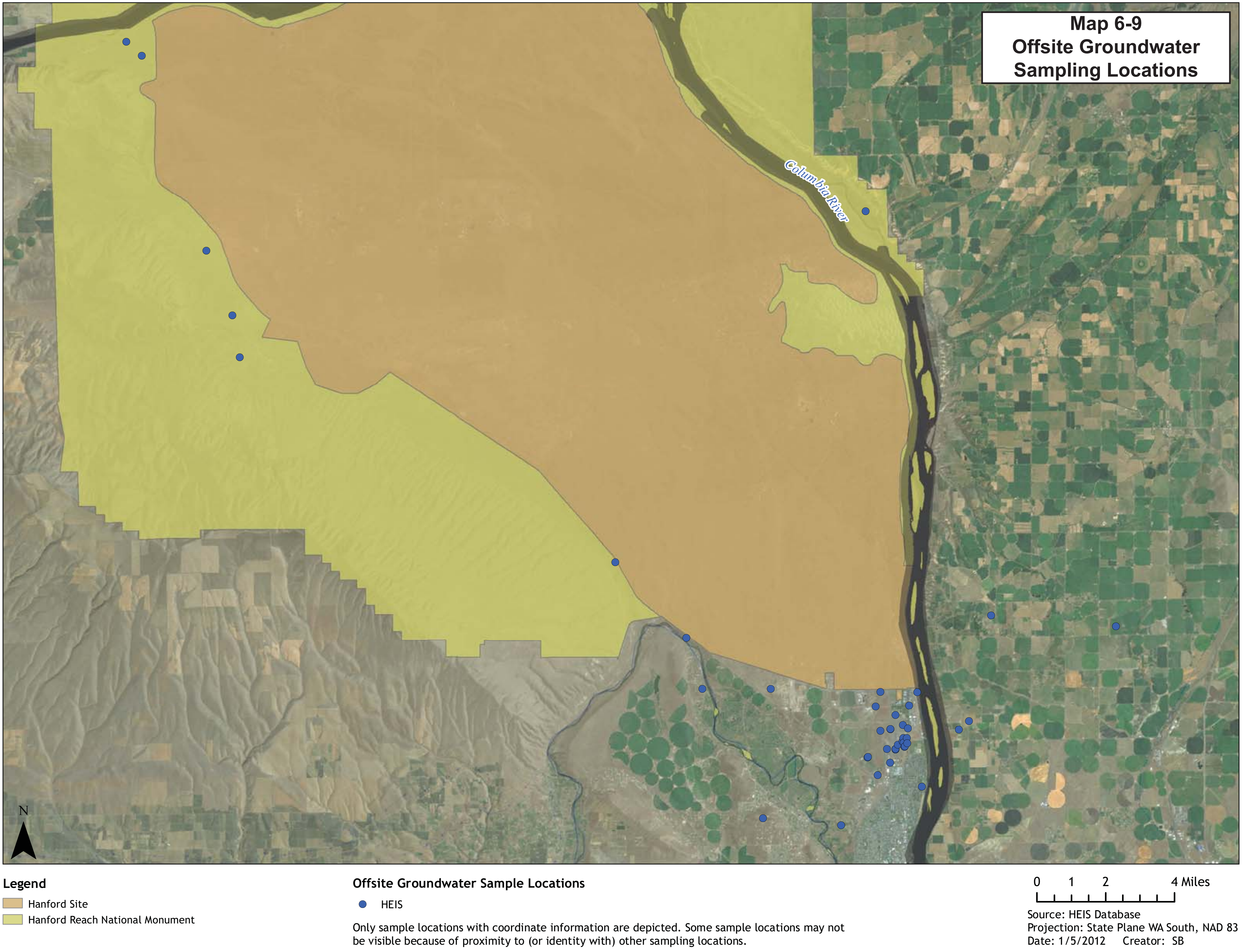
Groundwater Sampling Locations

CRC GiSdT HEIS

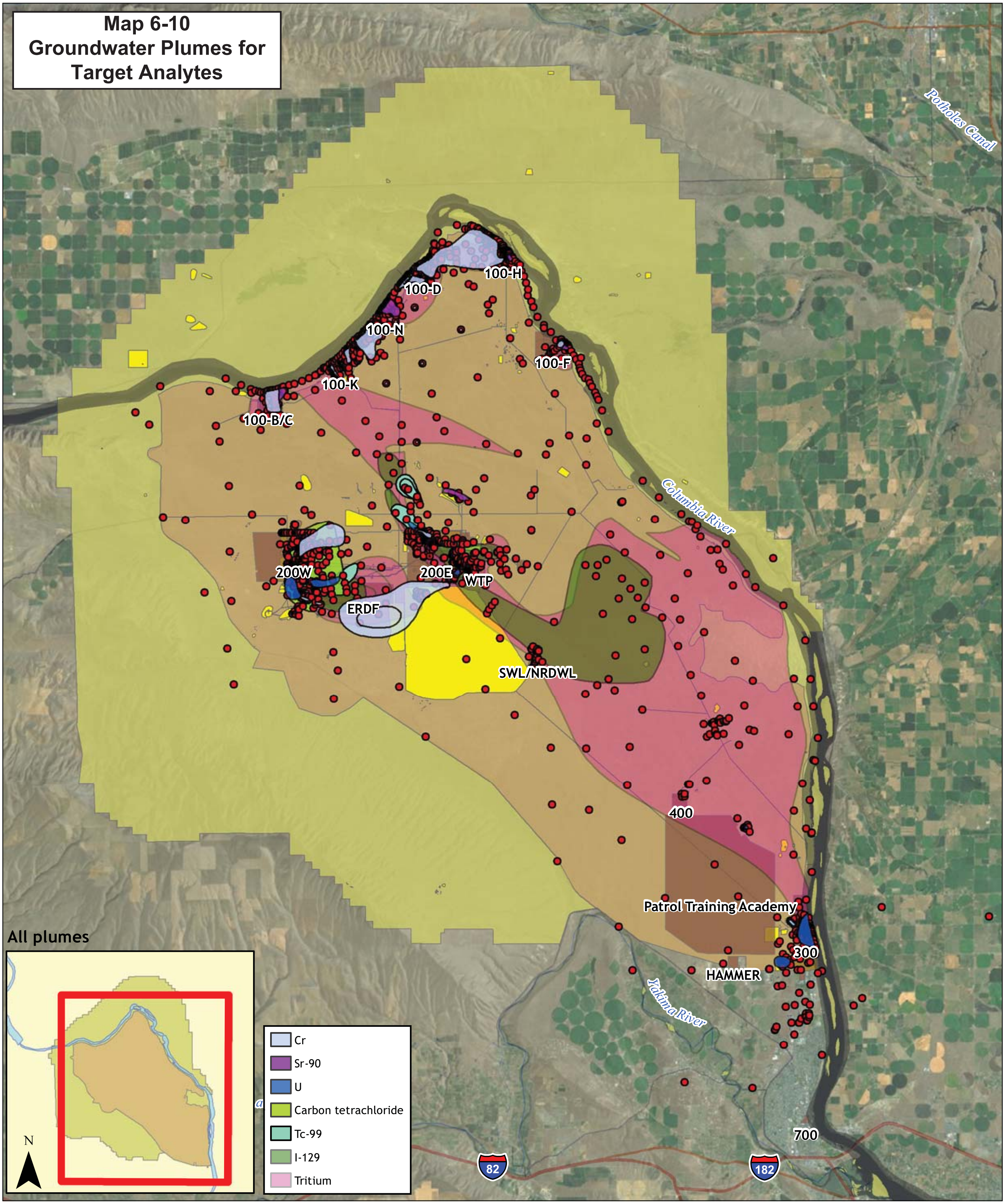
Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.

0 1.5 3 6 Miles

Source: HEIS, GiSdT, and CRC Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB


Map 6-9
Offsite Groundwater
Sampling Locations
Columbia River
N
Legend
Hanford Site
Hanford Reach National Monument
Offsite Groundwater Sample Locations
HEIS
Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) other sampling locations.
0 1 2 4 Miles
Source: HEIS Database
Projection: State Plane WA South, NAD 83
Date: 1/5/2012 Creator: SB

Map 6-10 Groundwater Plumes for Target Analytes



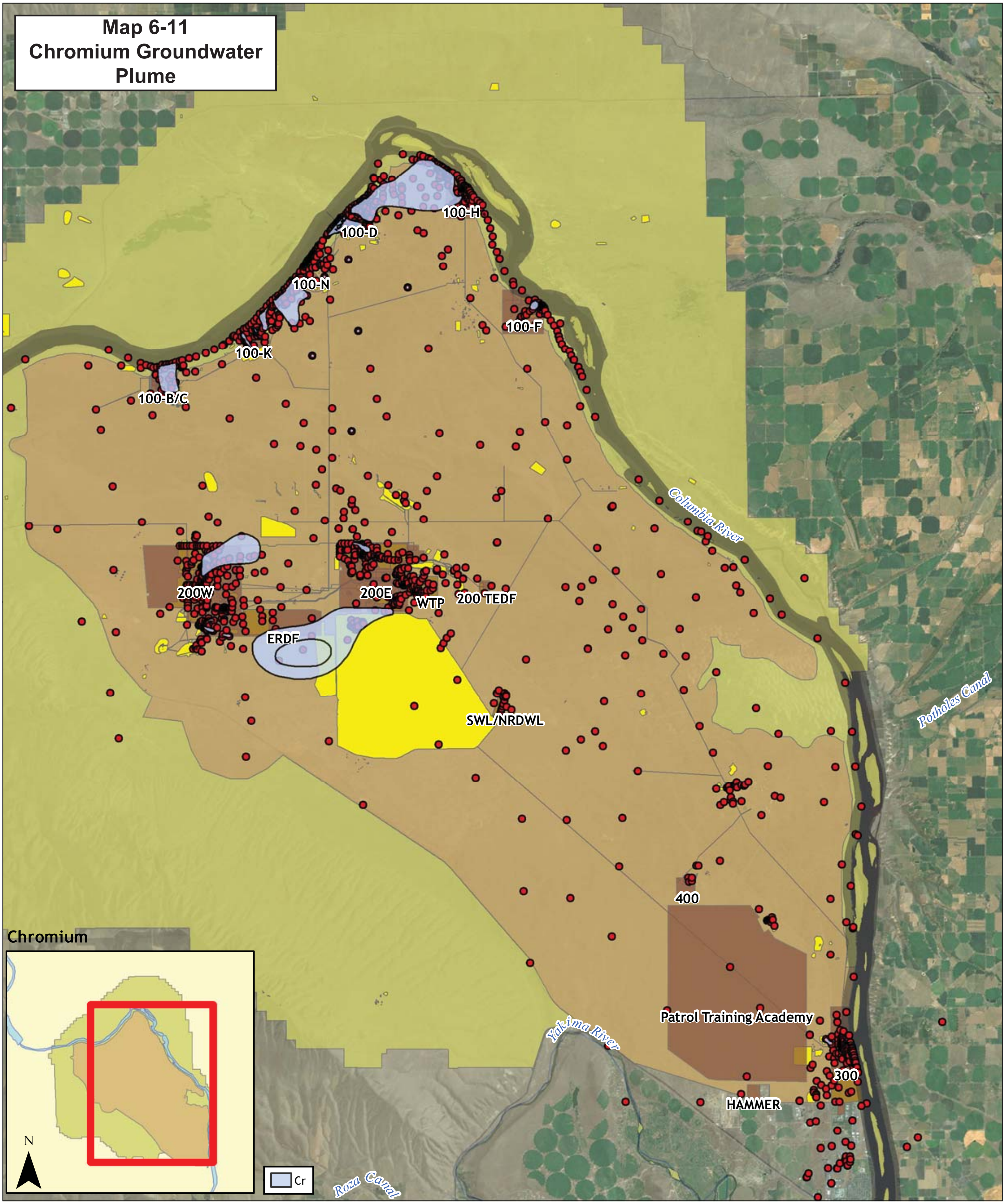
Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument
- Groundwater Sample Locations

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.
Depicted plumes represent water quality standards, rather than detection limits.

0 1.25 2.5 5 Miles

Source: HEIS, GiSdT, and CRC Databases
Projection: State Plane WA South, NAD 83
Date: 12/28/2011 Creator: SB



Legend

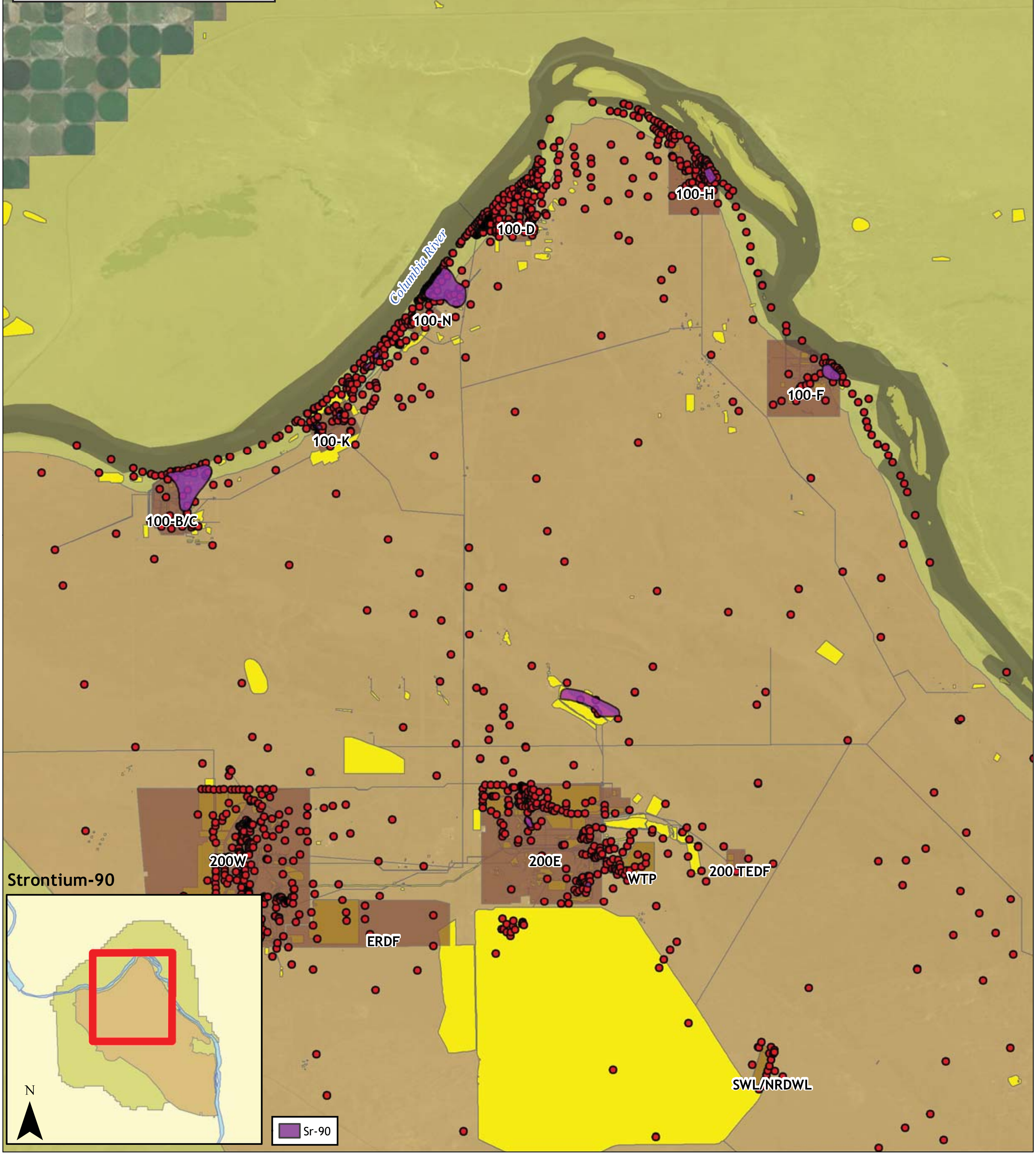
- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument
- Groundwater Sample Locations

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.
Depicted plumes represent water quality standards, rather than detection limits.

0 1 2 4 Miles

Source: HEIS, GiSdT, and CRC Databases
Projection: State Plane WA South, NAD 83
Date: 12/28/2011 Creator: SB

Map 6-12 Strontium Groundwater Plume



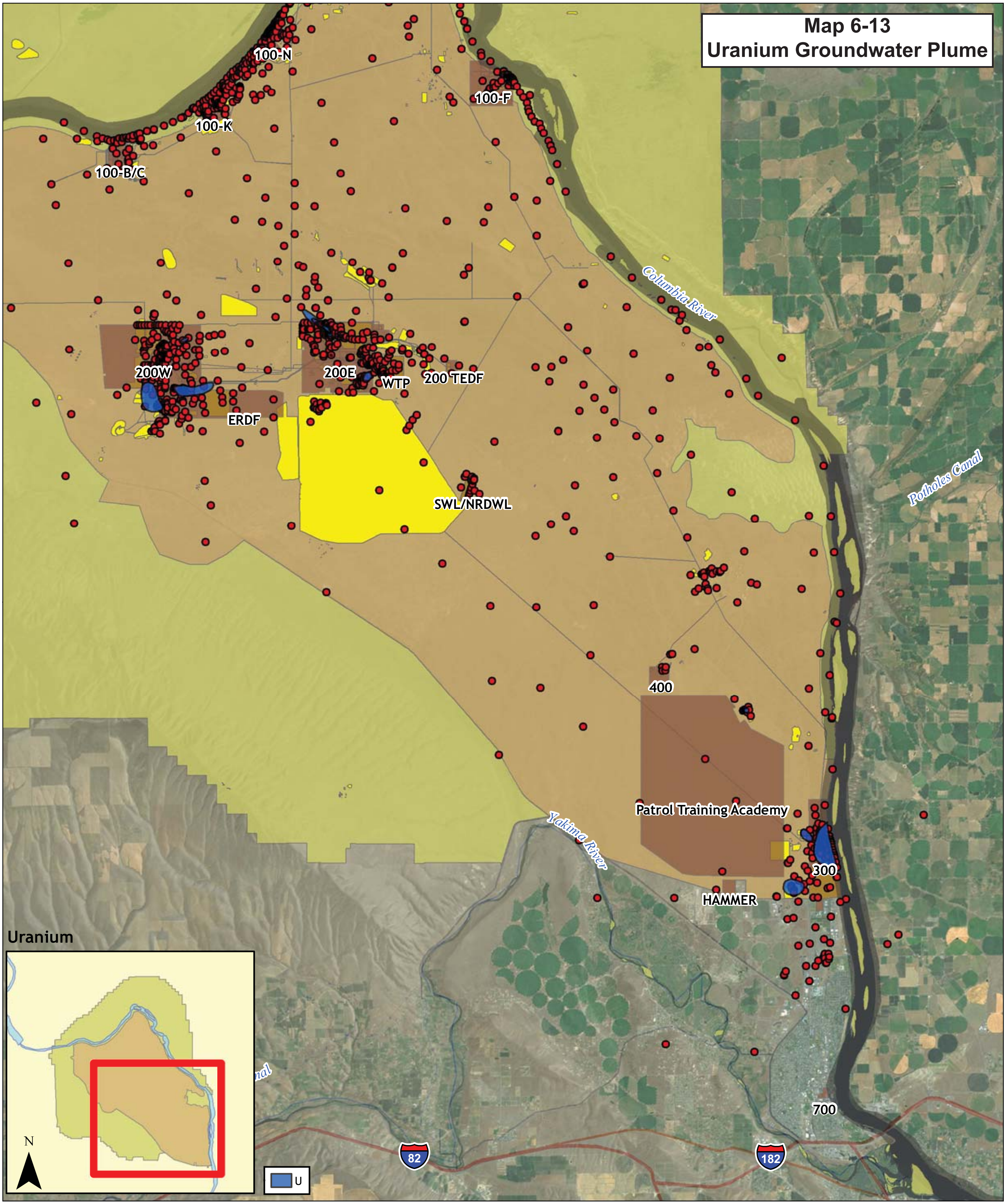
Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument
- Groundwater Sample Locations

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.
Depicted plumes represent water quality standards, rather than detection limits.

0 0.5 1 2 Miles

Source: HEIS, GiSdT, and CRC Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB



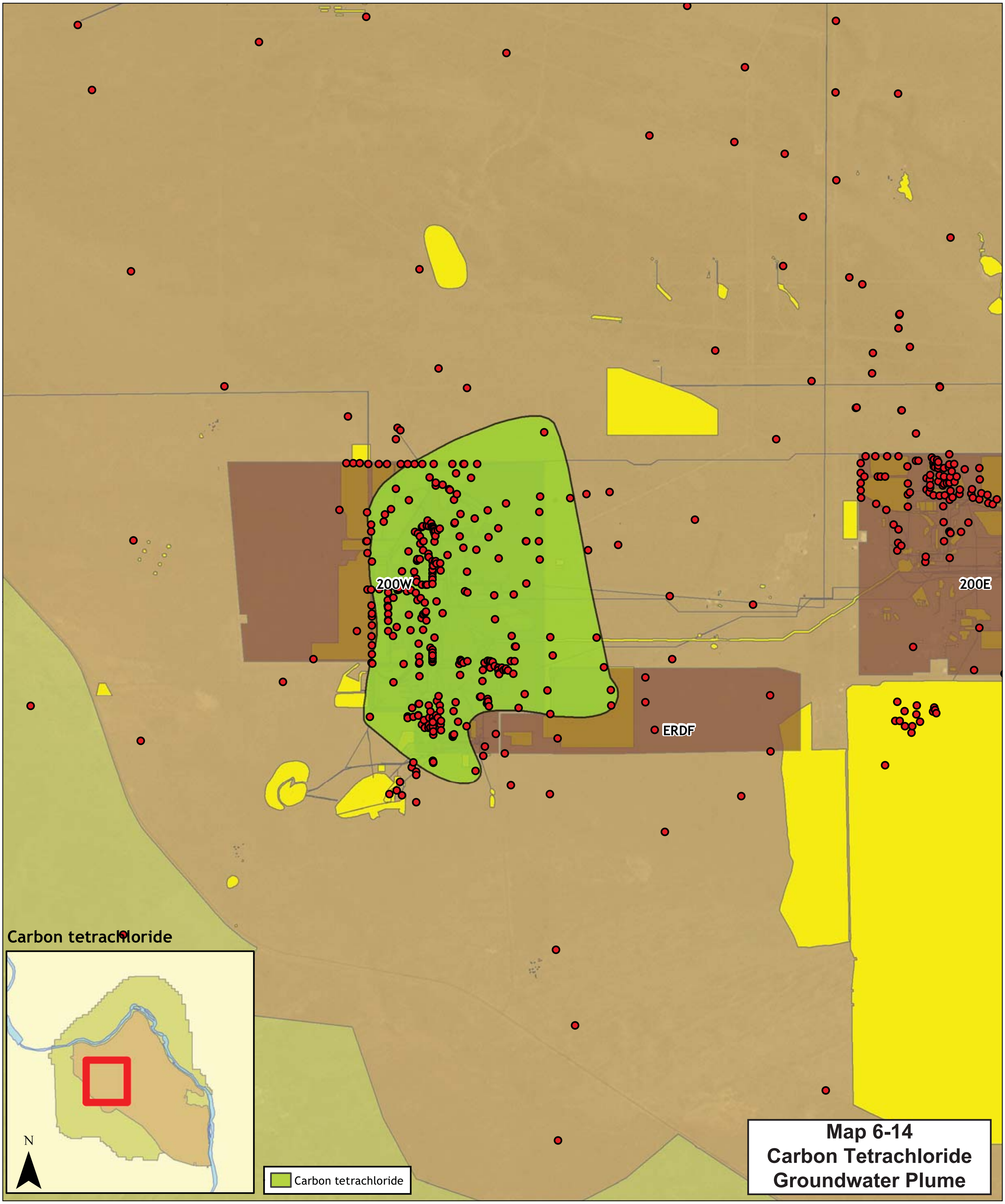
Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument
- Groundwater Sample Locations

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.
Depicted plumes represent water quality standards, rather than detection limits.

0 0.5 1 2 Miles

Source: HEIS, GiSdT, and CRC Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB



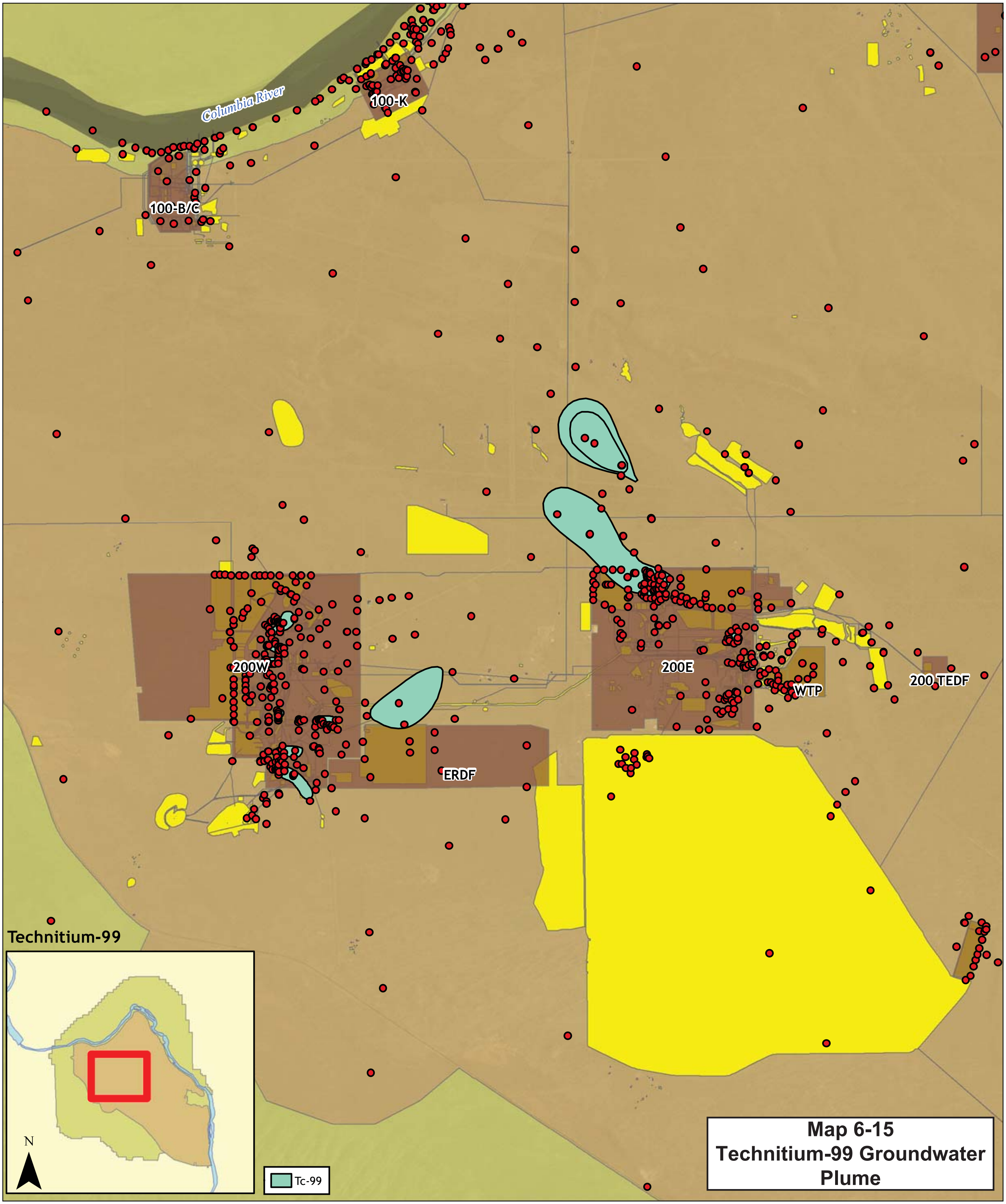
Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument
- Groundwater Sample Locations

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.
Depicted plumes represent water quality standards, rather than detection limits.

0 0.3 0.6 1.2 Miles

Source: HEIS, GiSdT, and CRC Databases
Projection: State Plane WA South, NAD 83
Date: 12/28/2011 Creator: SB



Legend

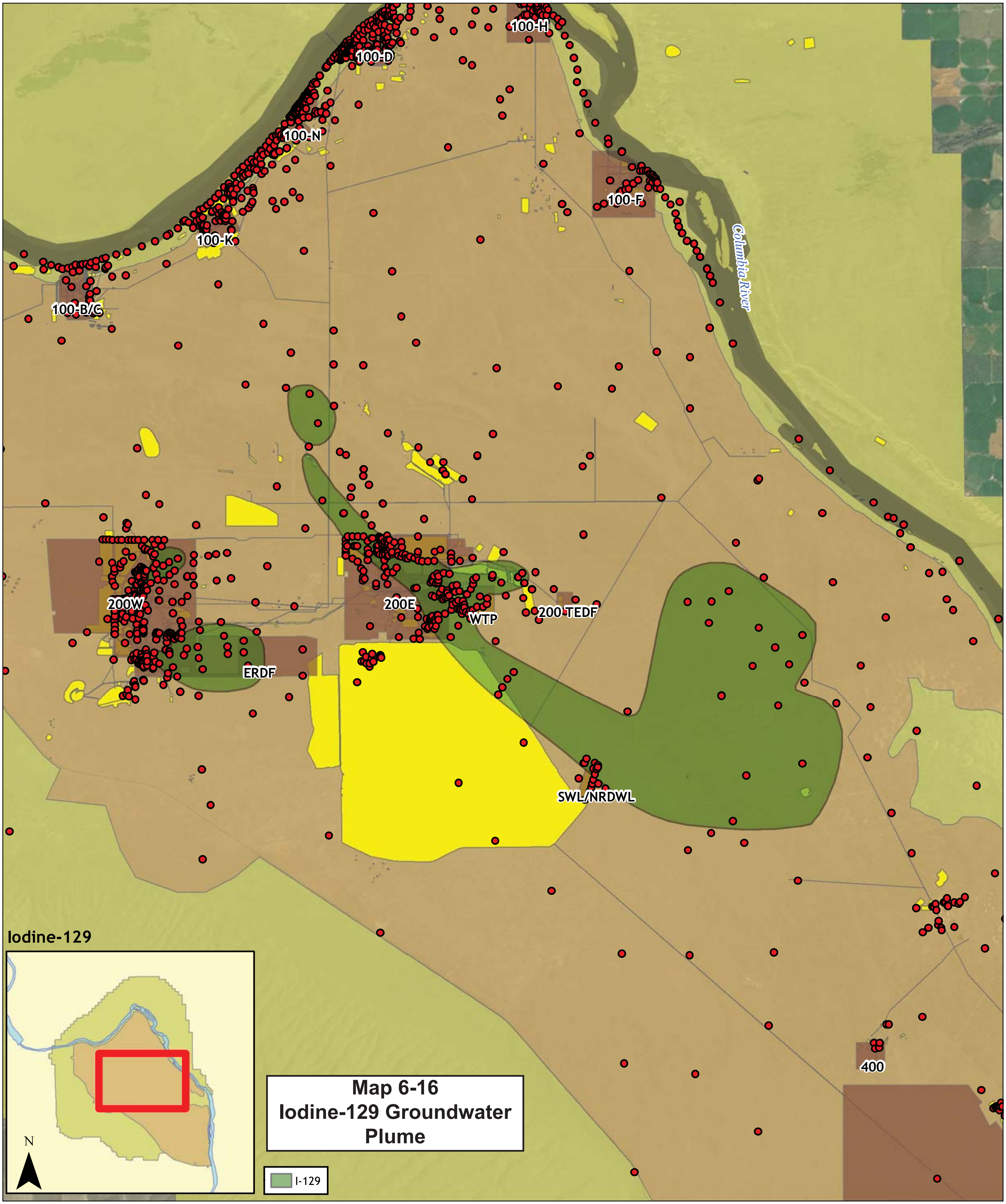
- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

● Groundwater Sample Locations

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.
Depicted plumes represent water quality standards, rather than detection limits.

0 0.45 0.9 1.8 Miles

Source: HEIS, GiSdT, and CRC Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB



Legend

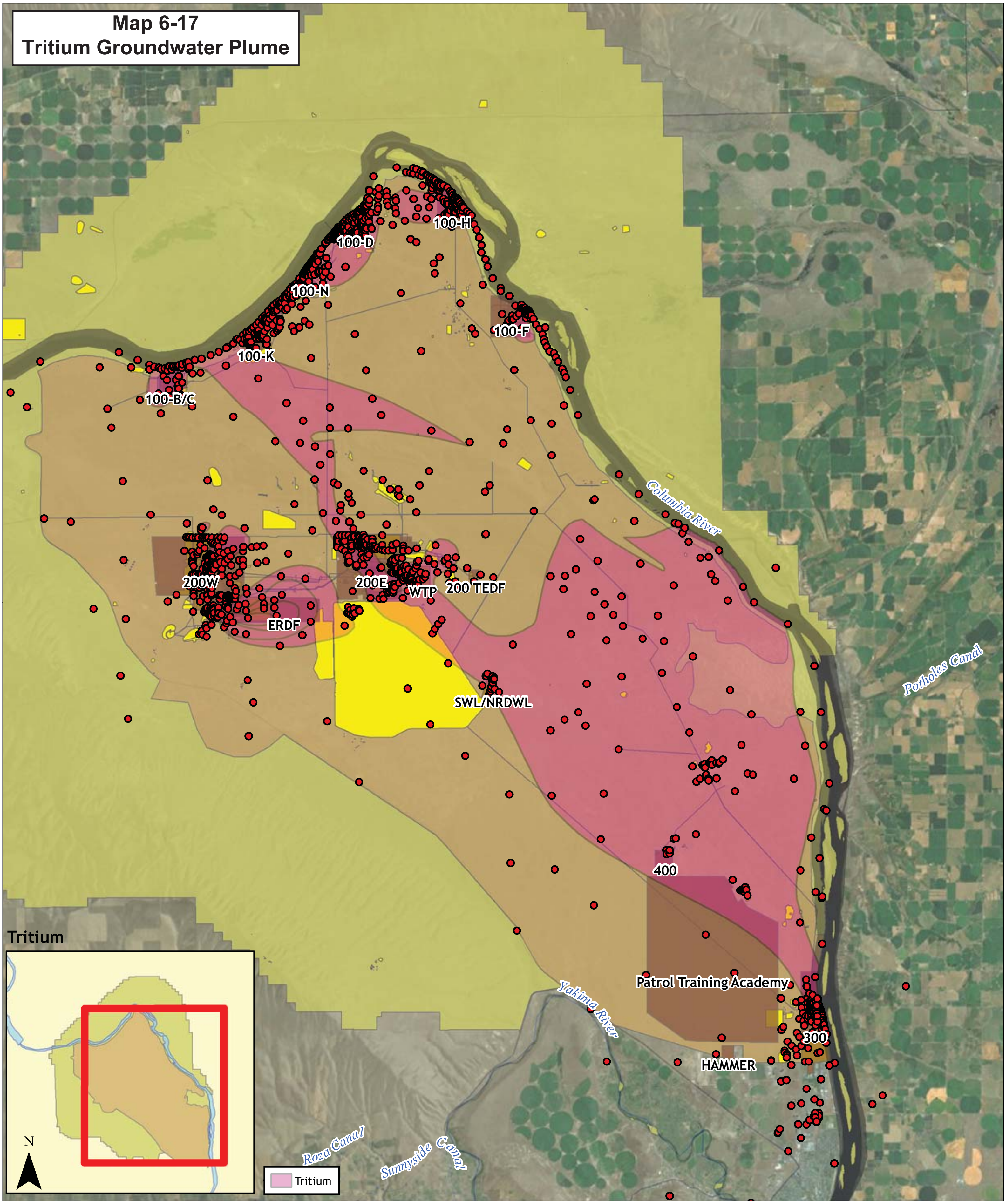
- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument

Groundwater Sample Locations

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.
Depicted plumes represent water quality standards, rather than detection limits.

0 0.5 1 2 Miles

Source: HEIS, GiSdT, and CRC Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB



Legend

- Hanford Operations Areas
- WIDS sites (mapped waste sites)
- Hanford Site
- Hanford Reach National Monument
- Groundwater Sample Locations

Only sample locations with coordinate information are depicted. Some sample locations may not be visible because of proximity to (or identity with) sampling locations in other databases.
Depicted plumes represent water quality standards, rather than detection limits.

0 1 2 4 Miles

Source: HEIS, GiSdT, and CRC Databases
Projection: State Plane WA South, NAD 83
Date: 1/9/2012 Creator: SB

APPENDIX B: ADDITIONAL SOURCES OF HANFORD DATA

The purpose of this appendix is to provide a list of data sources that may contain information not present within the databases analyzed in the Hanford Natural Resource Damage Assessment Ecological Data Gaps Report. This appendix lists repositories of Hanford documents and also notes specific items that have been selected by Trustee representatives as potentially containing relevant information. A number of these sources are also listed in the Data Management Report, Appendix C of the STRATUS Hanford Site Natural Resource Damage Assessment, Phase 1 Summary Report (2009). This appendix is not intended to serve the purpose of a literature review, or to be an exhaustive representation of all potentially relevant information.

DOCUMENT and DATA REPOSITORIES

Repository	Description	Access
Hanford Soil & Groundwater Remediation Project site	Contains soil and groundwater documents including recent annual groundwater monitoring reports.	http://www.hanford.gov/page.cfm/SoilGroundwaterAnnualReports
DOE Hanford Official Documents	Contains Hanford vadose zone documents, NEPA documents, and other official documents.	http://www.hanford.gov/page.cfm/OfficialDocuments
Ridolfi Literature Database	A database produced by Ridolfi Inc., that contains a bibliography of 1,401 documents of relevance to the Hanford Site. Of these, Ridolfi reviewed and evaluated 652 documents deemed to be of highest relevance, in more detail.	This database is available on the Hanford SharePoint site.
Washington Closure Hanford (WCH) River Corridor Closure library	Contains WCH-origin documents relevant to the River Corridor Closure Project.	http://www.washingtonclosure.com/projects/overview/ http://www.wch-rcc.com/projects/environmental_protection/mission_completion/project_library/

CH2M HILL Plateau Remediation Company Database	As a main contractor for Hanford cleanup, CH2M HILL has collected soil and groundwater remediation data.	http://www.plateauremediation.hanford.gov/
Hanford Declassified Document Retrieval System (DDRS)	The DDRS contains declassified Hanford documents and over 77,000 declassified photographs of early Hanford (1943-1960).	http://www5.hanford.gov/ddrs/index.cfm
PNNL Library	Documents published since 1998 by PNNL staff or by external researchers using PNNL facilities as well as vegetation and biota GIS layers.	http://www.pnnl.gov/publications/ *and* http://energyenvironment.pnnl.gov/research_areas/research_area_description.asp?id=181
Tri-Party Agreement (TPA) Administrative Record and Public Information Record	Documents produced under the TPA that are in the public information record or administrative records, including DOE work plans and CERCLA and RCRA documents.	http://www.5.hanford.gov/arpir/
DOE Energy Citations Database	This database provides free access to over 2.3 million science research citations and over 209,000 electronic documents from 1943 forward.	http://www.osti.gov/energycitatons/
DOE Science and Technology Information Bridge	This website provides free public access to over 200,000 full-text documents and bibliographic citations of DOE research report literature, primarily from 1991 forward.	http://www.osti.gov/bridge/
Energy Technology Data Exchange (ETDE)	This website contains energy research and technology information collected as part of an international information exchange.	http://www.etde.org/etdeweb/

U.S. Environmental Protection Agency (EPA) Region 10 sites	Contain a variety of documents including CERCLA, Toxics Substance Control Act documents, and others.	(1) http://yosemite.epa.gov/R10/OWCM.NSF/webpage/Hanford+Federal+Facility+RCRA+and+TS; (2) http://yosemite.epa.gov/r10/cleanup.nsf/9f3c21896330b4898825687b007a0f33/2f133ac95a7d2684882564ff0078b367?OpenDocument; and (3) http://yosemite.epa.gov/r10/ecocomm.nsf/34090d07b77d50bd88256b79006529e8/1462d20f2774a259882571d4006ba346!OpenDocument
Washington Department of Ecology Nuclear Waste Program website	Provides summaries of Hanford history, tank waste information, groundwater and surface water programs, and links to other sites and documents.	http://www.ecy.wa.gov/programs/nwp/
Columbia River Inter-Tribal Fish Commission (CRITFC)	A joint fisheries management commission of the Yakama Nation and the Nez Perce, Umatilla, and Warm Springs tribes. The website contains links to several scientific papers related to Columbia River fisheries and salmon projects.	http://www.critfc.org
Environmental Dashboard Application (EDA)	A publicly accessible query interface to Hanford groundwater and soil data, requires a username and password.	http://environet.hanford.gov/eda
Hanford Environmental Dose Reconstruction (HEDR)	HEDR included estimates of the spatial extent of iodine-131 fallout from Hanford releases and information on Hanford contaminant releases to the Columbia River. Lawrence Berkeley Laboratory created an online map servicer that displays estimates of hanford fallout between 1945 and 1951 (a 20 year old model, but does provide a quantitative estimate of spatial extent of hanford fallout).	http://cedrgis2.lbl.gov/Hanford/viewer.htm

EPA STORET	Database that contains raw biological, chemical, and physical data on surface water and groundwater collected by federal, state, and local agencies, Tribes, volunteer groups, academics, and others.	http://www.epa.gov/storet/dbtop.html
USGS National Water Information System (NWIS)	Includes historical and real-time hydrological information and water quality data.	http://waterdata.usgs.gov/nwis
NOAA Office of Response and Restoration Query Manager and MARPLOT site	Contains sediment chemistry, sediment toxicity, and tissue residue data for specific watershed projects.	http://response.restoration.noaa.gov/watersheddownloads

REPORT SERIES OR COMPILATIONS

Series Title	Description	Access
Hanford Site Annual Environmental Reports	Annual reports summarizing the results of Hanford's environmental monitoring.	Some of the reports from 1981 to 2009 can be found here: http://hanford-site.pnnl.gov/
Evaluation of Radiological Conditions in the Vicinity of Hanford	Annual reports summarizing information on Hanford's radiological conditions and monitoring for the Columbia River, vegetation, and the air.	Reports from 1959 to 1969 can be found here: http://hanford-site.pnnl.gov/
Environmental Surveillance at Hanford Reports	Document offsite environmental sampling data and any onsite data that pertain to the assessment of offsite radiation doses, date back as far as 1968.	Some of the reports from 1968 to 1983 can be found here: http://hanford-site.pnnl.gov/
Environmental Status of the Hanford Site Reports	Annual reports that summarize data collected during the respective year from within the Hanford plant boundaries (i.e., on-site) for the Environmental Surveillance program, date back as far as 1967.	Some of the reports from 1967 to 1982 can be found here: http://hanford-site.pnnl.gov/

Groundwater Monitoring Reports	Groundwater monitoring data has been documented in various reports for many years including the BNWL series prepared annually for the Energy Research and Development Administration, which provides an evaluation of the status of groundwater contamination resulting from Hanford's onsite discharges including BNWL-2199, BNWL-1392, and BNWL-1970, and others.	Some of these documents can be accessed through the DOE Energy Citations database, Information Bridge, or the ETDE website.
PNNL Ecological Reports	Various reports on the ecology and contamination on the Hanford Site and surrounding areas.	Many reports can be accessed through the PNNL technical library, http://libraryweb.pnnl.gov/ or publications site, http://www.pnnl.gov/publications/

SPECIFIC REFERENCES

Citation	Description
Myers, D.A., Fix, J.J., Raymond, J.R. (1977). Environmental Monitoring Report on the Status of Ground Water Beneath the Hanford Site January-December 1976. BNWL-2199.	Report in the series prepared annually, provides an evaluation of the status of groundwater contamination resulting from Hanford's onsite discharges during 1976.
Becker, C.D. (1990). Aquatic Bioenvironmental Studies: The Hanford Experience 1944-84.	A book reviewing Hanford studies that examined various potential adverse effects from Hanford operations.
Becker and Gray (1989)	This document is a compilation of abstracts from approximately 500 environmental reports published in the 1980s.

Hall, R.B. (1991).Letter Report: references for radioactive releases to the atmosphere from Hanford operations, 1944-1957. And Letter Report: references for radioactive releases to the Columbia River from Hanford operations, 1944-1957. PNNL-7868 HEDR and PNNL-7869 HEDR.	Provide lists of reports relating to: source term timeline for releases to air and Columbia River, tritium releases from Hanford, regional monitoring reports, reactor effluent water analyses, fuel failure data, and routine sampling and counting methods.
Haushild, W.L., Stevens, H.H., Nelson, J.L., and G.R. Dempster, Jr. 1973. Radionuclides in Transport in the Columbia River From Pasco to Vancouver, Washington.	USGS paper on the transport of radionuclides in the Columbia River.
Haushild, W.L., Dempster, G.R., Stevens, H.H. (1975). Distribution of radionuclides in the Columbia River streambed, Hanford Reservation to Longview, Washington.	USGS paper on the transport of radionuclides in the Columbia River.
Johnson et al. (1994). Historical records of radioactive contamination in biota at the 200 Areas of the Hanford Site. WHC-MR-0418 Rev. 0.	Document summarizing a literature search of 85 environmental monitoring records of wildlife and vegetation at the 200 east and 200 West Areas of the Hanford site since 1965.
Singlevich, W. (1948). Radioactive contamination in the Columbia River and in the air and radiation levels measured in the air at Hanford Works and vicinity for 1945, 1946, 1947, and early 1948. HW-9871.	Technical report summarizing the radioactive contamination measured in the Columbia River and the air, and the radiation levels measures in the air at the Hanford Works and vicinity from 1945 to 1948 including mostly monthly averages but also weekly averages in some cases.
Nelson, JL and WL Haushild. 1979. Accumulation of Radionuclides in Bed Sediments of the Columbia River between the Hanford Reactors and McNary Dam. Water Resources Research Vol. 4(1).	Published article documenting radionuclides from Hanford reactors in bed sediments of the Columbia River. Radionuclide amounts were estimated using data on radionuclide concentrations in sediments and from data on radionuclide discharge for river stations.

Robertson, DE and JJ Fix. 1977. Association of Hanford Origin Radionuclides with Columbia River Sediment, BNWL-2305, PNL.	PNL document reporting on the results of measurements of radionuclides in Columbia River sediments and description of the rates and mechanisms governing the decrease in radioactivity levels in the river sediments between 1971 and 1976. The report also characterizes the areal and depth distribution of fine grain, silty sediments in the McNary Reservoir by sub-bottom seismic surveying and reports the results of a deep piston core study.
Columbia River Impact Evaluation Plan. 1994. DOE/RL-92-28 Rev. 1	This report satisfies Milestone M-30-02, and is a plan submitted to EPA and Ecology to determine cumulative health and environmental impacts to the Columbia River. It incorporates results obtained under M-30-01.