Field Assessment of High-Priority Managed Aquifer Recharge Sites in the Upper Yakima: Streamflow Monitoring Report

Ecology Grant WRYBIP-1921-KittRD-00017

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ACRONYMS AND ABBREVIATIONS

ac-ft	acre-feet
cfs	cubic feet per second
EA Engineering	EA Engineering, Science, and Technology, Inc., PBC
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
Gregory	Gregory Geologic LLC
KRD	Kittitas Reclamation District
MAR	managed aquifer recharge
USGS	U.S. Geological Survey
YBIP	Yakima Basin Integrated Plan

EXECUTIVE SUMMARY

This report describes the second phase of the KRD's Managed Aquifer Recharge (MAR) assessment (EA Engineering 2020), which includes the installation of a streamflow monitoring network at 14 select sites along 13 tributaries in the Upper Yakima Basin to examine flow trends for potential MAR use.

In 2020, the streamflow monitoring network included Big Creek, Little Creek, Naneum Creek, and Taneum Creek. In 2022, the KRD expanded the streamflow monitoring network at Cooke Creek, Dry Creek, Jones Creek, Parke Creek, Reecer Creek, Robinson Creek, Schnebly Creek, Wenas Creek, and Wilson Creek.

Site visits occurred between August 2020 and May 2023 and included up to 14 trips to download data, measure discharge and staff gauge measurements. The streamflow monitoring network consists of pressure transducers set to continuously record water pressure on an hourly basis. Transducer data was augmented by manual field measurements of stage height and stream discharge. During site visits, water pressures from the data loggers were downloaded and later converted to water depths. The depths were then corrected for barometric pressure, and rating curves were used to convert water depths to stream discharge.

To estimate the magnitude of high flows, daily average streamflow discharge at 10 percent exceedance, which is considered high flows, was converted to acre-feet over the period of record. Exceedance trends were then estimated by calculating the difference between the maximum measured discharge rate and the 10 percent exceedance rate. To further understand the trend of high magnitude flows over the period of record, 10-, 15-, 20-, and 25 percent exceedance volumes were calculated and graphed. This allowed for the visualization of high-flow trends by month and year.

A cursory examination of potentially suitable locations for infiltration basins near streamflow monitoring locations and the KRD canals in the Big Creek, Little Creek and Naneum areas were evaluated for suitability by restricting designated tax lots to areas with flat terrain. Taneum Creek was not part of this evaluation, since the Taneum Pilot Project (Gregory and Jacobs 2024) provided aquifer characteristics at that site. Results indicate excess flows are capable of meeting infiltration rates near these 5 sites, while additional data is required to adequately characterize flows at the remaining 9 sites.

This work was funded by Washington State Department of Ecology (Ecology) Grant Number WRYBIP-1921-KittRD-0017 (Environmental Information Management (EIM) Study ID: WRYBIP-1921-KittRD-0017A) and supported by the YBIP Groundwater Storage Subcommittee.

1 INTRODUCTION

Maintaining adequate water supply conditions of the Yakima Basin is paramount to agricultural production in the Yakima Valley (USBR and Ecology 2012). Since municipal use relies mostly on groundwater, irrigation demand and aquatic habitat needs compete for surface water flows. Curtailment of irrigation water threatens economic stability, while reduction in streamflow endangers robust, culturally significant aquatic habitats. Managed Aquifer Recharge (MAR) projects address water scarcity by increasing groundwater supplies through infiltration or injection of excess surface water. Subsequent recovery of stored water via natural process or pumping is timed to improve water supply, enhance habitat, or lessen the impact of groundwater withdrawals. With a goal of reducing competition for surface water in the Yakima Basin, the Kittitas Reclamation District (KRD) assessed MAR potential and identified 57 high-ranking locations (EA Engineering et al. 2020).

The following report describes the next phase of the KRD MAR evaluation which includes the installation of streamflow monitoring equipment at 14 sites along 13 tributaries in the Upper Yakima Basin to understand flow characteristics and determine the extent to which excess surface water may be available for future MAR projects. Results indicate conditions at 5 sites likely maintain sufficient excess streamflows for MAR, while additional data is required to adequately characterize flows at the remaining 9 sites.

This work was funded by Washington State Department of Ecology (Ecology) Grant Number WRYBIP-1921-KittRD-0017 (Environmental Information Management (EIM) Study ID: WRYBIP-1921-KittRD-0017A) and supported by the YBIP Groundwater Storage Subcommittee. EA Engineering, Science, and Technology, Inc., PBC (EA Engineering) led the streamflow monitoring efforts, including equipment installation, site visit data collection, with preliminary data analysis conducted by EA Engineering and Jacobs. Collected data is available at EIM under: WRYBIP-1921-KittRD-00017A.

1.1 Background

In 2020 KRD began collecting streamflow data to evaluate potential sources of MAR water at higher-priority sites: Big Creek, Little Creek, Naneum Creek, and Taneum Creek. In 2022, the KRD expanded the streamflow monitoring network to include stream discharge data collection at Cooke Creek, Dry Creek, Jones Creek, Parke Creek, Reecer Creek, Robinson Creek, Schnebly Creek, Wenas Creek, and Wilson Creek (Figure 1).

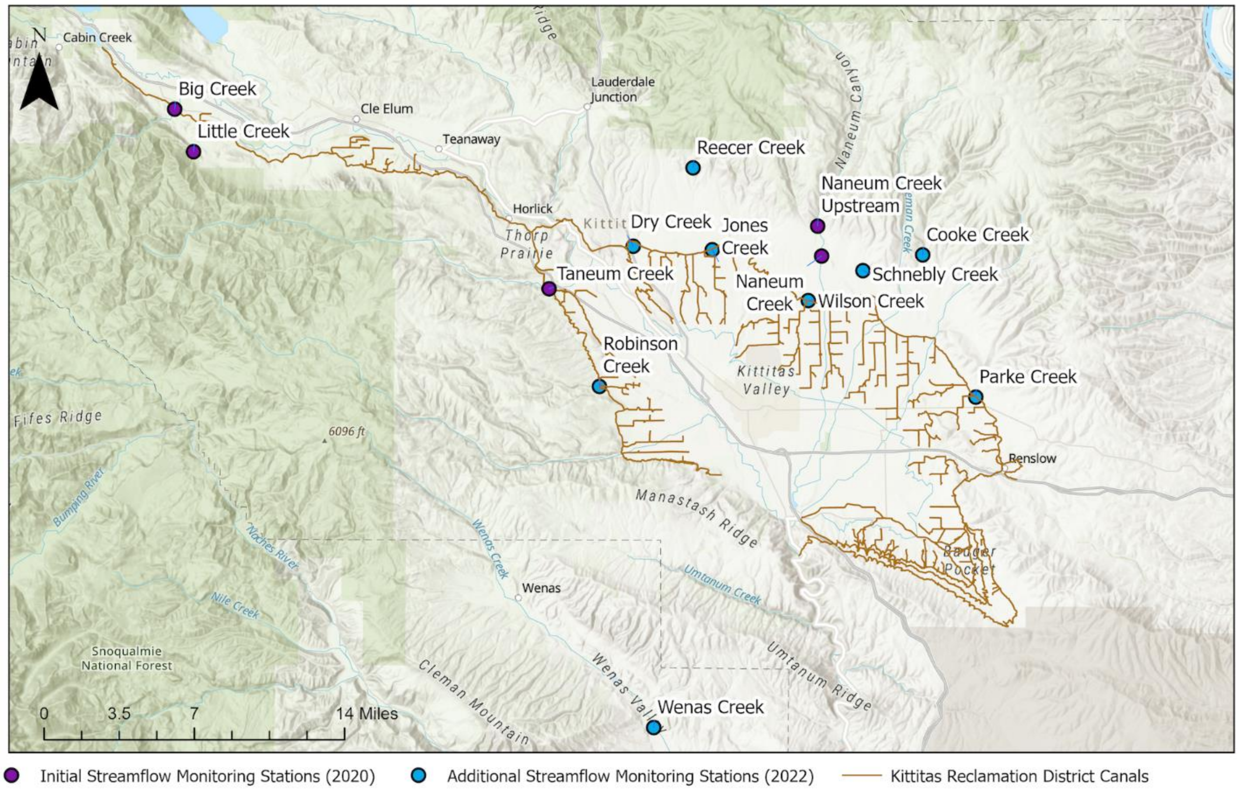


Figure 1. Streamflow monitoring locations in the Upper Yakima Basin

2 STREAMFLOW MONITORING NETWORK

The streamflow monitoring network consists of pressure transducers set to continuously record water pressure on an hourly basis. Transducer data is augmented by manual field measurements of stage height and stream discharge.

Site visits occurred between August 2020 and May 2023 and included up to 14 trips to download data, measure discharge and staff gauge measurements. Not all sites were safely accessible year-round, especially in the Upper Kittitas County where deep snow accumulation leads to seasonal road closures.

2.1 Monitoring Site Descriptions

The following provides a brief description of each site, with site figures provided in Appendix A and site photographs provided in Appendix B. Drainage areas were provided by EA Engineering. All creeks are in Kittitas County except for Wenas Creek, which is located in Yakima County. The Kittitas County creeks, except for Big, Little, Robinson, and Taneum Creeks, generally flow from north to south through the Kittitas Valley and converge near the towns of Ellensburg or Kittitas, eventually combining into either Reecer Creek or Wilson Creek and subsequently flowing into the Yakima River west of Ellensburg or from the east at the southern edge of the Kittitas Valley, respectively. Taneum Creek and Robinson Creek flow from west to east and converge with the Yakima River near the western end of the Kittitas Valley. Big Creek and Little Creek flow from south to north and converge with the Yakima River in the Upper Kittitas Valley.

2.1.1 Taneum Creek

Taneum Creek originates in the foothills of the Cascade Mountains as the North Fork and South Fork Taneum Creek northwest of the Kittitas Valley and flows for 30 miles before its confluence with the Yakima River northeast of Ellensburg (Appendix A, Map 1). The Taneum Creek drainage area covers 76 square miles with a mean annual discharge of 66 cubic feet per second (cfs) (Monk 2015). Taneum Creek has an estimated 2-year daily peak flow of 1,820 cfs (EA Engineering et al. 2020). The stream gauge site is located near the mouth of Taneum Creek, at the west end of the drainage.

2.1.2 Naneum Creek

Naneum Creek originates north of the Kittitas Valley in the Wenatchee Mountains and is 35 miles long with a drainage area of 178 square miles. Naneum converges with Wilson Creek in the Upper Yakima Basin (Appendix A, Map 2). The USGS recorded mean daily flows in the upper Naneum from 1957 to 1977 (2020). The highest annual peak streamflow during that period exceeded 950 cfs in 1964, and the lowest annual peak streamflow of 47 cfs in 1977 (USGS 2020). Naneum Creek has an estimated 2-year daily peak flow of 391 cfs (EA Engineering et al. 2020). Two stream gauges have been established in Naneum Creek in the upper part of the

Naneum Creek drainage above the KRD North Branch Canal and above the reach of stream where Wilson and Naneum Creeks split to the east and west branches.

2.1.3 Little Creek

Little Creek originates in the foothills of the Cascade Mountains northwest of the Kittitas Valley and has an estimated drainage area of 10 square miles (Appendix A, Map 3). A single field measurement taken by the USGS recorded a streamflow of 5.88 cfs on August 9, 2011 (2011). Little Creek has an estimated 2-year daily peak flow of 916 cfs (EA Engineering et al. 2020). The Little Creek stream gauge site is located near the mouth of Little Creek in the northern end of the drainage, about 0.5 mile above the KRD Main Canal.

2.1.4 Big Creek

Big Creek originates in the foothills of the Cascade Mountains northwest of the Kittitas Valley and has an estimated drainage area of 27 square miles (Appendix A, Map 4). Big Creek has an estimated 2-year daily peak flow of 2,370 cfs (EA Engineering et al. 2020) and is located on a private road downstream of Kittitas Reclamation District Canal

2.1.5 Wenas Creek

Wenas Creek originates in the foothill of the Cascade Mountains southwest of the Kittitas Valley and has an estimated drainage area of 129 square miles (Appendix A, Map 5). Wenas Creek has an estimated 2-year daily peak flow of 515 cfs (EA Engineering et al. 2020). The stream gauge is located near the center of the drainage within the Wenas Valley in northern Yakima County.

2.1.6 Wilson Creek

Wilson Creek originates north of the Kittitas Valley in the Wenatchee Mountains and has an estimated drainage area of 91 square miles (Appendix A, Map 6). Wilson Creek has an estimated 2-year daily peak flow of 386 cfs (EA Engineering et al. 2020). The rerouting and diverting of Wilson and Naneum Creeks have resulted in alteration to stream drainages, making the delineation of individual drainages difficult. The stream gauge is located in the central part of the drainage just above the KRD North Branch Canal.

2.1.7 Reecer Creek

Reecer Creek originates north of the Kittitas Valley in the Wenatchee Mountains and has an estimated drainage area of 5 square miles (Appendix A, Map 7). Reecer Creek has an estimated 2-year daily peak flow of 31 cfs (EA Engineering et al. 2020). The stream gauge is located near the center of the drainage.

2.1.8 Robinson Creek

Robinson Creek originates in the foothills to the Cascade Mountains west of the Kittitas Valley and has an estimated drainage area of 10 square miles (Appendix A, Map 8). Robinson Creek has an estimated 2-year daily peak flow of 77 cfs (EA Engineering et al. 2020). The stream gauge is located in Robinson Creek in the central part of the drainage just above the KRD South Branch Canal.

2.1.9 Cooke Creek

Cooke Creek originates north of the Kittitas Valley in the Wenatchee Mountains and has an estimated drainage area of 18 square miles (Appendix A, Map 9). Cooke Creek has an estimated 2-year daily peak flow of 98 cfs (EA Engineering et al. 2020). The stream gauge is located in the central part of the drainage above the KRD North Branch Canal.

2.1.10 Jones Creek

Jones Creek originates north of the Kittitas Valley in the Wenatchee Mountains, is a tributary to Reecer Creek, and has an estimated drainage area of 3.8 square miles (Appendix A, Map 10). Jones Creek has an estimated 2-year daily peak flow of 19 cfs (EA Engineering et al. 2020). The stream gauge is located in the lower part of the drainage just below the KRD North Branch Canal.

2.1.11 Parke Creek

Parke Creek originates north of the Kittitas Valley in the Wenatchee Mountains and has an estimated drainage area of 17 square miles (Appendix A, Map 11). Parke Creek has an estimated 2-year daily peak flow of 48 cfs (EA Engineering et al. 2020). The stream gauge is located in the central part of the drainage just below the KRD North Branch Canal

2.1.12 Schnebly Creek

Schnebly Creek originates north of the Kittitas Valley in the Wenatchee Mountains and has an estimated drainage area of 4 square miles (Appendix A, Map 12). Schnebly Creek has an estimated 2-year daily peak flow of 19.6 cfs (EA Engineering et al. 2020). Transducers were not installed at this location; however, discharge measurements were collected periodically.

2.1.13 Dry Creek

Dry Creek originates north of the Kittitas Valley in the Wenatchee Mountains and has an estimated drainage area of 15 square miles (Appendix A, Map 13). Dry Creek has an estimated 2-year daily peak flow of 49 cfs (EA Engineering et al. 2020). Ecology has monitored discharge in the two branches of Dry Creek at the KRD North Branch Canal for several years, although recently, the gauge on the west branch has been vandalized and is no longer in use. Transducers were not installed at these locations; however, discharge measurements were collected periodically.

3 METHODS, RESULTS, AND DISCUSSION

3.1 Method

3.1.1 Rating Curves

Data loggers continuously record hourly water pressure. During site visits, water pressures from the data loggers were downloaded and later converted to water depths. The depths were then corrected for barometric pressure, and the rating curve equations (USGS 2023) were used to convert water depths to stream discharge. Prior to conducting site visits, an Ecology-approved Quality Assurance Project Plan, under agreement number WRYBIP-1921-KittRD-00017, Amendment No. 2, guided equipment installation and site visit protocols.

To characterize and determine high flows, field assessments were conducted to obtain discharge rates, staff gauge measurements, and data logger downloads. Rating curves were created to calculate stream-discharge relationships at sites with sufficient data. Rating curve creation required manual staff gage readings (stage height), and streamflow discharge measurements obtained with specialized equipment. The collected data points were plotted, and a linear regression produced a rating curve equation and the coefficient of determination (R^2) for each site. R^2 is a number between 0 and 1 that indicates the degree to which observed data is scattered around the regression line. The closer R^2 is to 1, the better the correlation between stage height and discharge measurements.

3.1.2 Hydrograph Creation

Hydrographs were created for sites when R^2 values were determined to be statistically meaningful ($R^2 > 0.93$) with hourly pressure data converted to daily average discharge rates. The hydrographs were then used to estimate high flows, observe trends in high flow days, and calculate the magnitude of high flows at a 10 percent exceedance threshold.

3.1.3 Percent Exceedance

A 10 percent exceedance, which indicates that only 10 percent of flows are higher, was chosen to define the magnitude of high flows at each site. An exceedance value is generally used to show high flow characteristics of a stream or creek (Searcy 1959). The percent exceedance is a variation of a streamflow percentile, which also uses a scale of one hundred but is typically used to describe flow patterns, rather than targeting high flows rates. The 10 percent exceedance, also known as the 90th percentile, was chosen as the high-magnitude flow threshold since the USGS and others (Richards 1990, Knaak et al. 2015, USGS 2016) describe the percentage as "much above normal" or as "high flows". 10 percent exceedance was used in a California Central Valley water banking study to characterize the magnitude, frequency, duration, and timing of high streamflows for 93 stream gauges (Kocis and Dahlke 2017).

The procedure to estimate the percent exceedance includes sorting and ranking discharge values for the period of record from the largest to the smallest, with a total of *n* values. Each discharge value is assigned a rank, starting with 1 for the largest value. The exceeded probability is expressed as follows:

$$P = 100 * \frac{m}{n+1}$$

where,

P = the probability that a given flow will be equaled or exceeded (percent of time)
m = the ranked position on the list (dimensionless)
n = the number of events for the period of record (dimensionless)

3.1.4 Source Water Availability

To evaluate potential source water for MAR requires understanding the timing and volume of streamflows, especially when demand is low and supply is available. To estimate the magnitude of high flows, daily average streamflow discharge at 10 percent exceedance was converted to acre-feet over the period of record. Exceedance trends were then estimated by calculating the difference between the maximum measured discharge rate and the 10 percent exceedance rate. To further understand the trend of high magnitude flows over the period of record, 10-, 15-, 20-, and 25 percent exceedance volumes were calculated and graphed. This allowed for the visualization of high-flow trends by month and year.

The implementation of MAR requires available source water synced with aquifers capable of accepting water at a complementary rate. High-frequency surface water monitoring conducted in the Upper Yakima Basin provides estimates of available source water and timing for potential MAR use. Local geology, terrain, soils, and tax lots were examined to constrain the volume of water likely needed for MAR and compared against streamflow monitoring data. Considering infiltration basins can percolate higher volumes of water compared to other MAR methods (e.g., infiltration galleries, injection wells, etc.), infiltration basins were targeted as the preferred MAR approach. Since the surface area of an infiltration basin is dependent upon the infiltration rate of the underlying soils and aquifer, to examine infiltration basins requires evaluating available areas suitable against corresponding infiltration rates underlying the location. This refines the KRD's previous ranking of MAR sites (EA Engineering et al. 2020) by including a cursory examination of properties and infiltration rates suitable for MAR that are in close proximity to streamflow monitoring locations and the KRD canals.

Tax lots identified as open space, undeveloped land, and undeveloped governmental service land were initially assumed property suitable to construct infiltration basins. The footprints of each tax lot were further reduced in size to locations with flat terrain (less than 10 percent slope), since steep terrain increases difficulty in the construction of basins.

Infiltration basin size and infiltration rate dictate the volume and timing of water added to an aquifer. Smith and Pollock (2012) describe 20 historical MAR projects and provide a general approximation of infiltration characteristics, including maximum basin footprint and rates of infiltration. The size of basins ranged from less than 1 acre to 32 acres, with an average footprint of 13 acres. Infiltration rates ranged from 0.33 to 8.5 feet per day, with an average rate of 1.8 feet per day. Using average values from Smith and Pollock's recharge date, potential infiltration rates were compared to recharge footprints and ranked as low (less than 2.8 feet per day), moderate (between 2.8 to 5.6 feet per day), and high (between 5.6 to 8.5 feet per day).

After identifying potential infiltration basin locations and respective surface areas against underlying infiltration rates, using soil and geology conditions, a first-order approximation of the volume of water capable of recharge was compared against available surface water (defined as at or beyond 10 percent exceedance).

3.2 Results

3.2.1 Rating Curves

Sufficient data points allowed for the creation of rating curves at Taneum Creek, Upper Naneum Creek, Lower Naneum Creek, Little Creek, and Big Creek. Although measurements were collected at all sites, only those with the longest record (installed in 2020) maintained suitable data points to define rating the curves (Figure 2). The R^2 values for all rating curves were close to one, with the lowest R^2 value of 0.93 and the largest R^2 value of 0.99. This indicated the relationship between discharge measurements and staff gages was sufficient to proceed with calculating discharge at these sites.

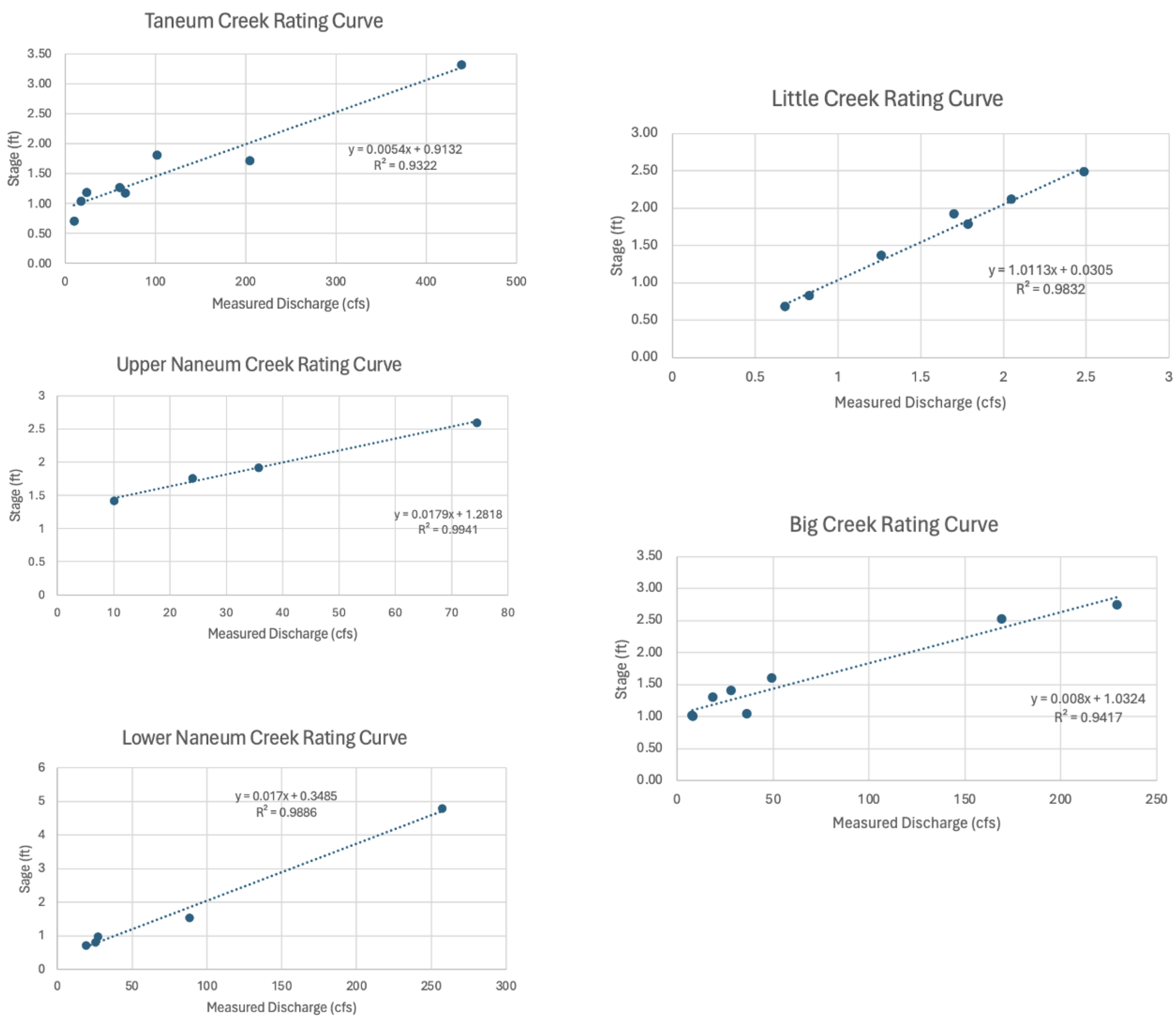


Figure 2. Rating curves: produced for sites installed in 2020 with respective equations and R^2 values. Additional sites lacked sufficient data points to properly define the curve.

3.2.2 Hydrographs

Hydrographs were created for Taneum Creek, Upper Naneum Creek, Lower Naneum Creek, Little Creek, and Big Creek. The high flows were then compared against their respective 10 percent exceedance rate to show the magnitude and duration.

The Taneum Creek hydrograph (Figure 3a) shows maximum flows of up to 400 cfs, with high flow rates occurring throughout February until June, with peak flows in April and May. Although a gap in the data set occurred in late fall to early winter, this did not impact high flow estimates since peak flows were not previously observed during these months in 2021 and 2022.

The Upper Naneum Creek hydrograph (Figure 3b) shows maximum flows of up to 350 cfs, with peak flows occurring in May.

The Lower Naneum Creek hydrograph (Figure 3c) shows maximum flows of up to 300 cfs, peaking in April and May, with the greatest magnitude of high flows, determined by the 10 percent exceedance rate, in May of 2023. Although a gap in data occurred in 2022 and 2023, these data were likely during low flow periods, as seen in the Upper Naneum Creek hydrograph.

The Little Creek hydrograph (Figure 3d) shows maximum flows of up to 120 cfs. Peak flows occurred throughout the spring months, with the lowest flows during the summer and fall months.

The Big Creek hydrograph (Figure 3e) shows high flow peaks throughout the spring months, with maximum flows reaching up to 350 cfs, and the lowest flow period occurring during the summer and fall months.

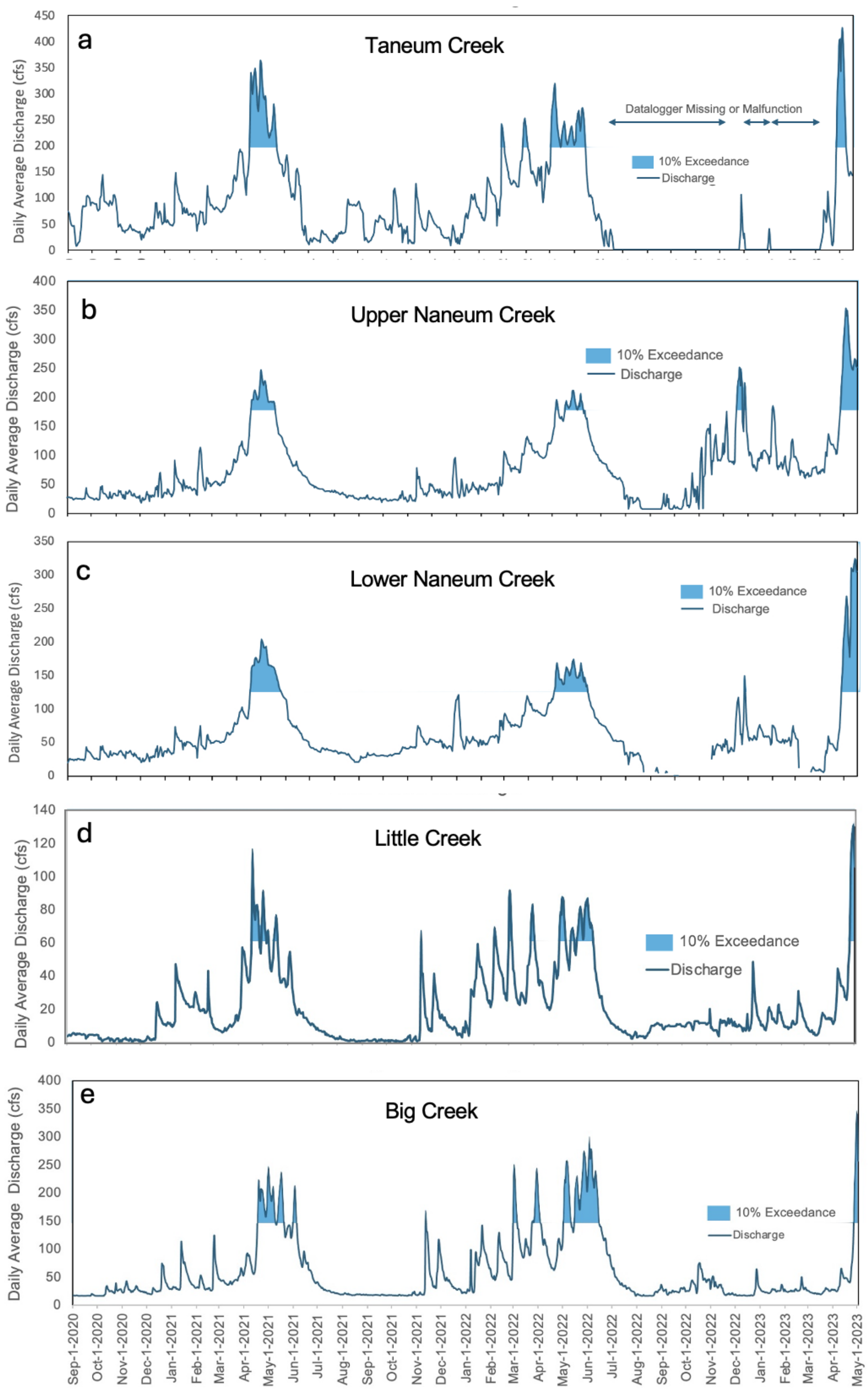


Figure 3. Hydrographs and magnitude of high flows beyond the 10 percent exceedance discharge rate for (a) Taneum Creek, (b) Upper Naneum Creek, (c) Lower Naneum Creek, (d) Little Creek, and (e) Big Creek .

3.2.3 Source Water Availability

To illustrate the timing and rate of high flows, Figure 4 shows the rate above the high flow threshold for each water year from 2021 to 2023 at sites with hydrographs. Although peak flows were greatest in spring of water year 2023, only a partial record of the water year was plotted, since data has not been downloaded and reviewed beyond this time.

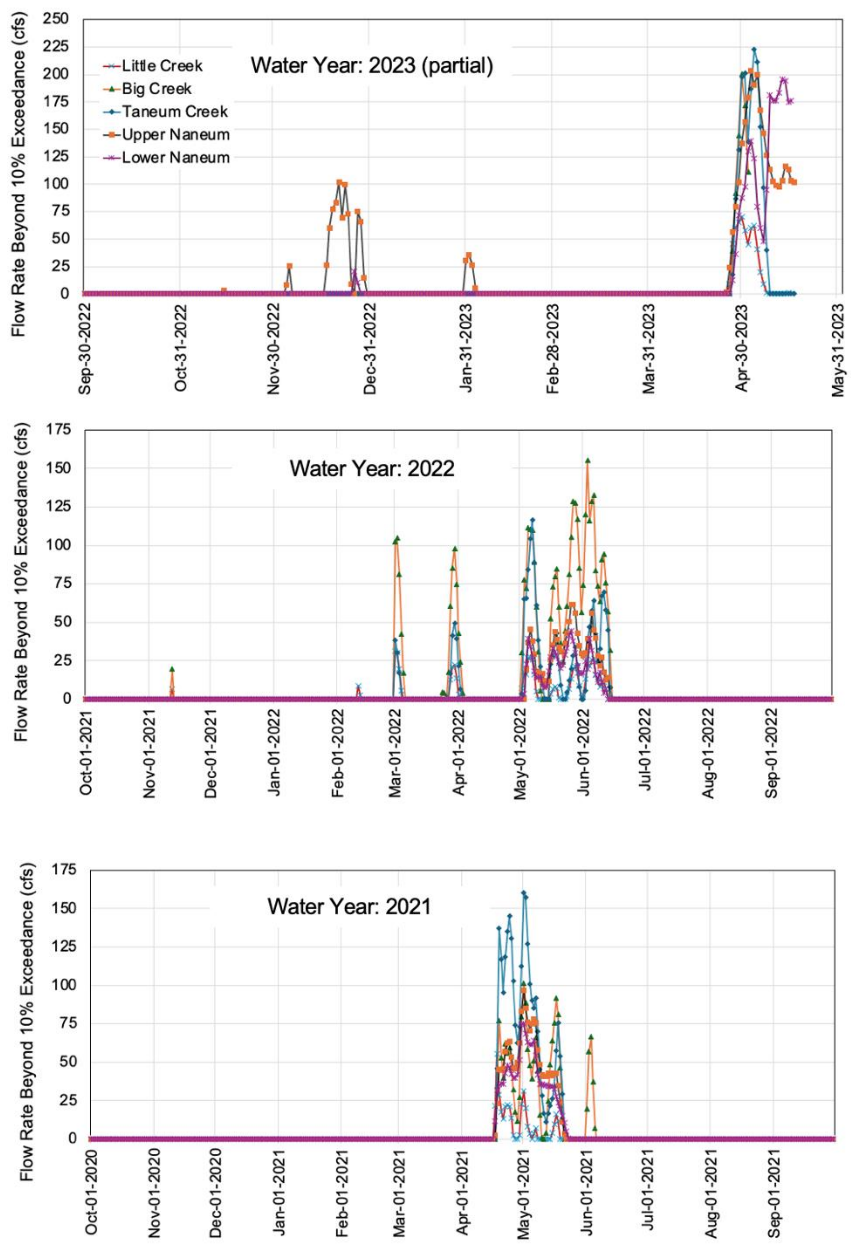


Figure 4. The flow rate profile by water year beyond the 10 percent exceedance rate at Taneum Creek, Upper Naneum, Lower Naneum, Little Creek and Big Creek.

The frequency and magnitude of flows were examined and spatially compared. Figure 5 shows the cumulative flow volume (magnitude) and the number of high-flow days at sites with sufficient data. Although the highest flow volume was observed at Big Creek, the number of high-flow days was greatest at Little Creek. Due to data gaps at the Taneum Creek gage, data during this period were excluded from all sites.

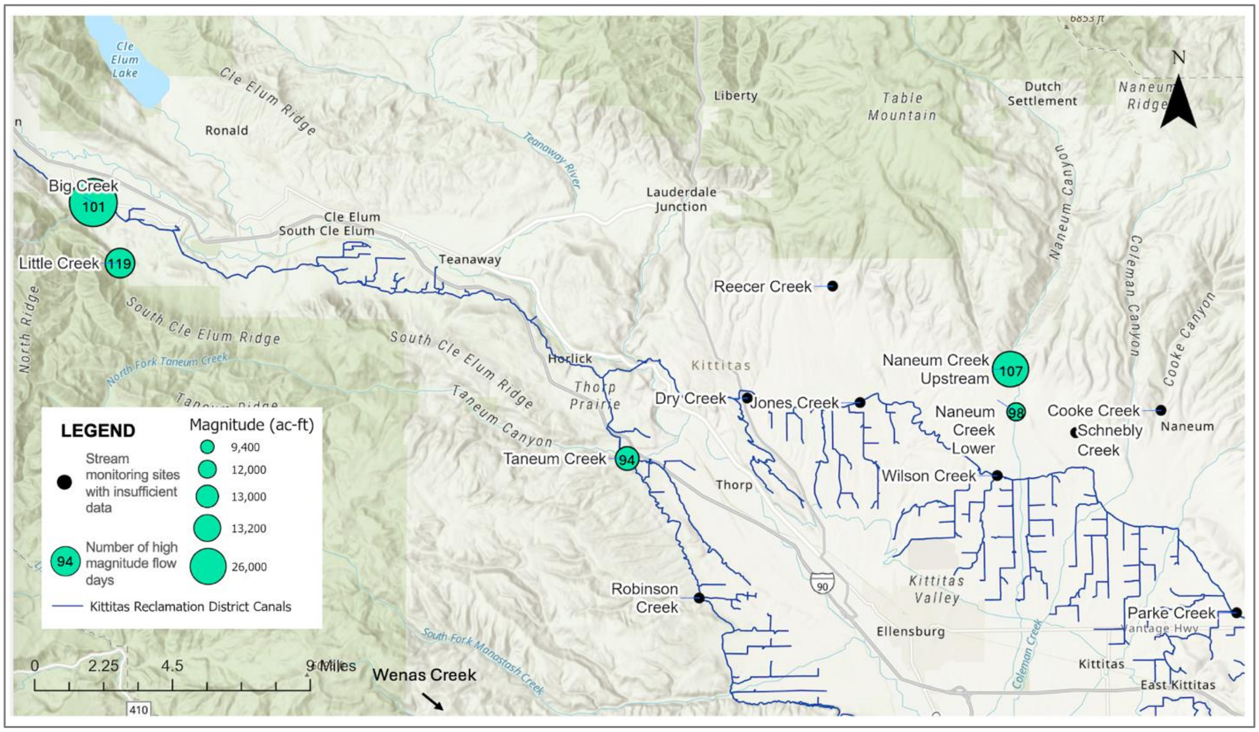


Figure 5. Comparison of the magnitude of high flows and the number of days above the 10 percent exceedance rate at Taneum Creek, Upper Naneum Creek, Lower Naneum Creek, Little Creek, and Big Creek.

To further understand the potential magnitude of MAR source water, each site with available data was evaluated based on 10-, 15-, 20-, and 25 percent exceedance rates. Figure 6 shows results during the period of record.

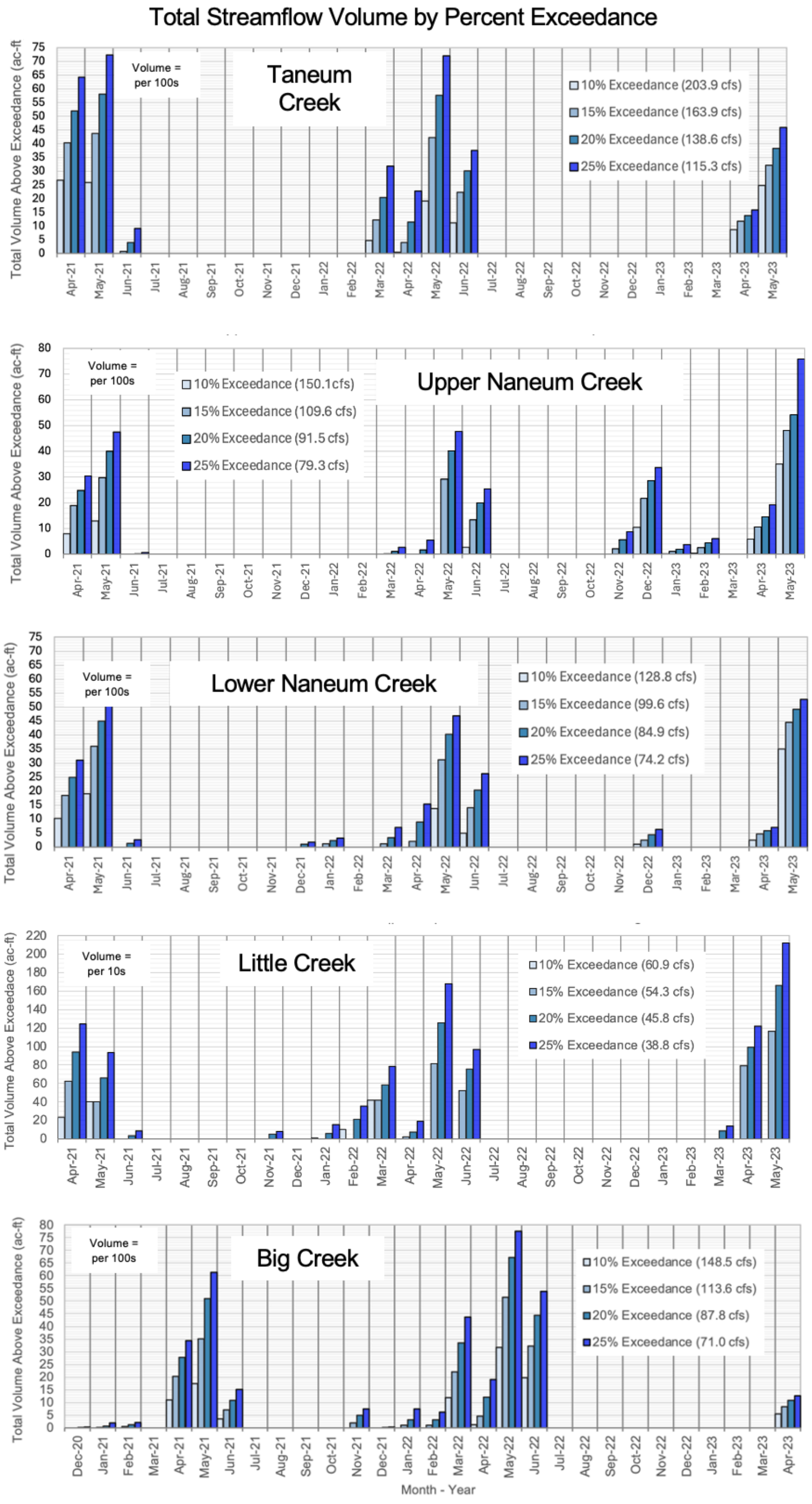


Figure 6. The magnitude of high flow volumes at 10-, 15-, 20-, and 25 percent exceedance rates at Taneum Creek, Upper Naneum Creek, Lower Naneum Creek, Little Creek, and Big Creek. All discharge volumes are per 100 acres, with the exception of Little Creek, which is per 10 acres.

Although the magnitude and timing of high flows occur at each site, a first order approximation of infiltration rates against potential infiltration basin size was examined near streamflow monitoring locations for each location with appropriate data, except Taneum Creek, since the Taneum Pilot Test provided estimates of aquifer properties described in Gregory and Jacobs (2024).

Figure 7 shows the location of potential infiltration basins ranging from 5 to 30 acres near Big Creek and Little Creek that overlie soils (inset map) (USDA 2023) and geologic units (WA DNR 2023). Most of the potential sites are located on group B soils, which are considered to infiltrate at a moderate rate, and alpine glacial drift, which is assumed to infiltrate at a high rate. Although the potential infiltration basin ranged up to 30 acres, a value of 13 acres was assumed as the upper end of a hypothetical basin size. Calculating moderate to high infiltration rates against a basin size of 13 acres produced an estimated maximum infiltration rate of 110 acre-feet per day, equivalent to 55 cfs. To visualize the maximum infiltration rate for the area, it was compared against a combined discharge rate for Big Creek and Little Creek (Figure 7).

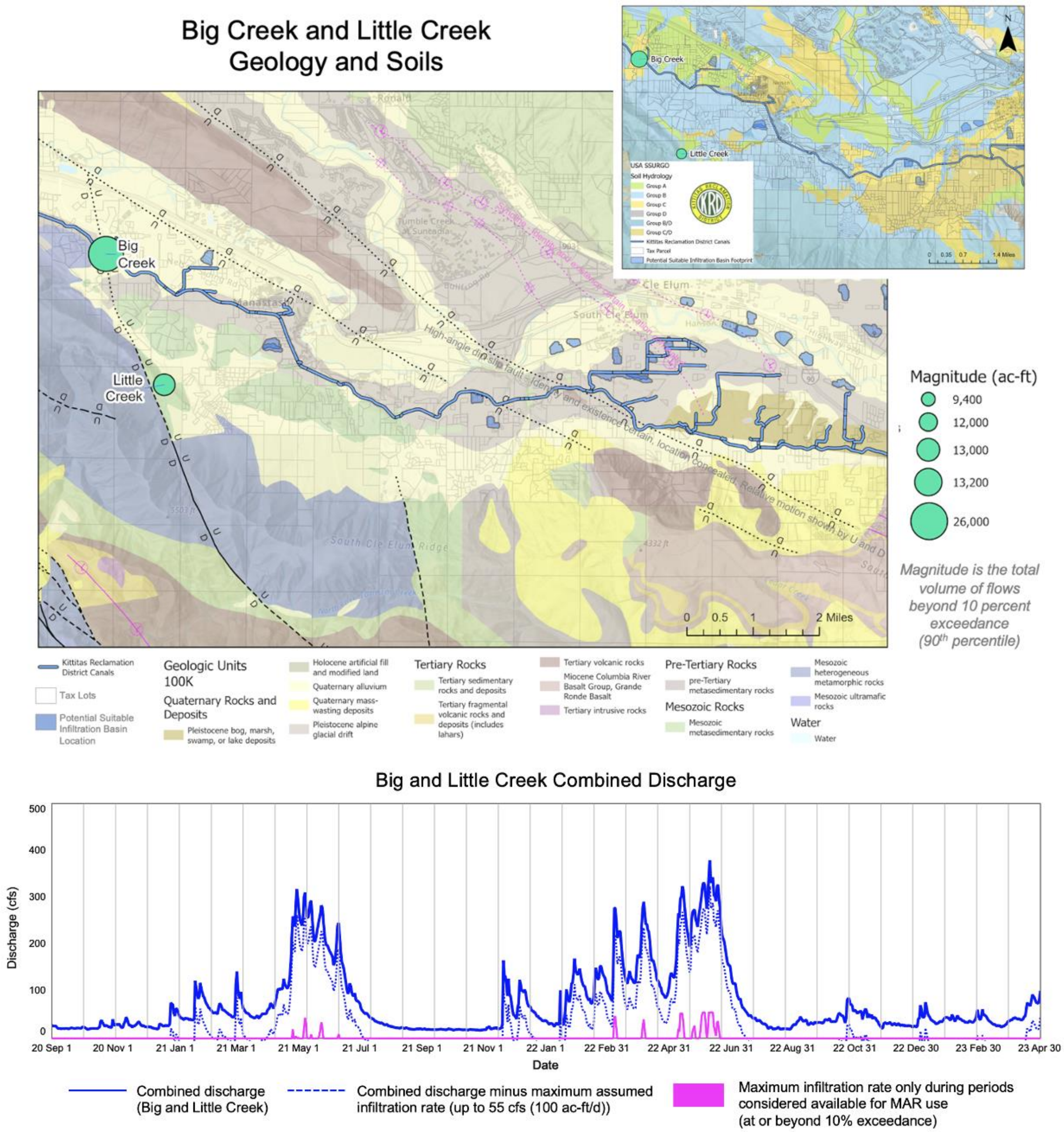


Figure 7. Geologic and soils overlying hypothetical infiltration basins based on suitable conditions near Big Creek and Little Creek and, and the combined discharge rate compared against the maximum infiltration rate of 55 cfs.

Figure 8 shows the location of potential infiltration basins ranging from 5 to 25 acres near Naneum Creek that overlie soils (inset map) (USDA 2023) and geologic units (WA DNR 2023). Most of the potential sites are located on group C soils, which are considered to infiltrate at lower rates, and continental sedimentary deposits, also known as Thorp Gravel and considered to infiltrate at a lower rate due to potential cementation content. Although the hypothetical infiltration basins ranged up to 25 acres, a value of 12.5 acres was assumed as the upper end of the basin size. Calculating low infiltration rates against a basin size of 12.5 acres produced an estimated maximum infiltration rate of 13 acre-feet per day, equivalent to 6.5 cfs. To visualize the maximum infiltration rate for the area, it was compared against Lower Naneum Creek discharge rates (Figure 8).

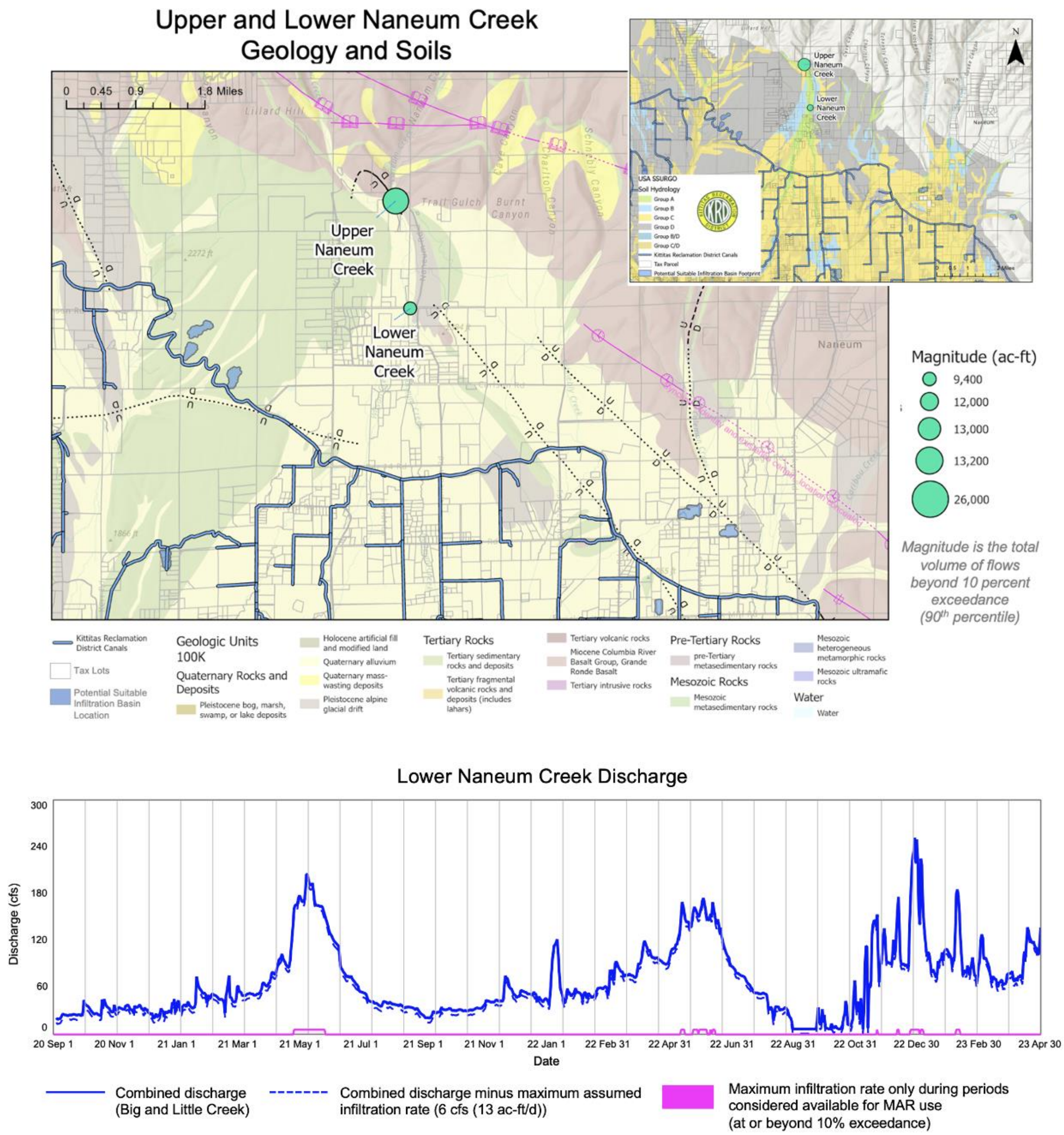


Figure 8. Geologic and soils overlying hypothetical infiltration basins based on suitable conditions near Naneum Creek, and the combined discharge rate compared the against maximum infiltration rate of 6 cfs.

3.2.4 Discussion

Although streamflow monitoring is in place throughout the Upper Yakima Basin with continuous monitoring occurring at the time of this publication, results were based on 5 sites with adequate data suitable for estimating discharge. High flows were estimated at Taneum Creek, Upper Naneum Creek, Lower Naneum Creek, Little Creek, and Big Creek and compared against potential infiltration volumes at hypothetical infiltration basins. Volumetric infiltration rates for MAR purposes were calculated for theoretical basins and ranged from 13 acre-feet per day to 110 acre-feet per day. These volumes are compatible with potential streamflow volumes available at and beyond the 10 percent exceedance rate; however, these are the upper limit of infiltration potential, as most basins are unlikely constructed over an area of 30 acres. Since no ground truthing of the soil, geology, and land use took place, the results are limited in accuracy and scope; however, infiltration volumes do suggest high flows are volumetrically suitable to accommodate future MAR operations, with diversions occurring in April and May.

4 RECOMMENDATIONS, LIMITATIONS, AND OPPORTUNITIES

4.1 Recommendations

Recommendations include continued monitoring to refine current rating curves and to allow for the creation of additional curves at locations where data is available but inadequate. Since transducers were not installed until 2022, there has not been enough data collection on Wilson Creek, Robinson Creek, Cooke Creek, Jones Creek, Park Creek, Schnebly Creek, and Dry Creek to make any recommendations at this time.

Additional monitoring at these sites is needed to provide future recommendations on their suitability for MAR sites. As monitoring continues and flow regimes are continuously refined and characterized, the data can be utilized within the YBIP objectives to strategically place MAR sites in locations within the Upper Yakima Basin. Additional monitoring will also allow for the comparison of different seasonal conditions, such as droughts and flood events. However, site assessment refinements such as location of staff gages and examination of Upper Yakima Basin data logger equipment should be included in future work plans as monitoring continues.

4.2 Limitations

The rating curves are considered preliminary rather than final. A general rule suggests a rating curve may be developed with fewer than six discharge measurements only if a rating shift is detected before six measurements are made and the existing measurements cover most of the range of depths observed during the time period for which the curve will be used. Although some sites contain at least six surveys, field notes need more specific detail to determine if all the rating curve standards have been met.

Additional limitations associated with accuracy of the rating curves stem from missing field measurement timestamps, most notably in the summary field reports and in the Doppler documentation. These are essential in correlating values to gauge height, which can establish confidence in the relationship between gauge and transducer measurements and, subsequently, hydrograph development. Due to changes in project staff, many potential errors are difficult to quantify, as those responsible for collecting data were not involved with processing and analyzing the data.

Calculations of diversion limits did not include measured field conditions such as water table heights, site-specific soil complexities, or on-site geological examination of sediments; therefore, results should be taken as an unvetted approximation of infiltration volume when compared to high flow potential.

4.3 Opportunities

Rating curves should be refined by incorporating additional field measurements, especially during high flow events where traditional measurement techniques (flow meters) are not suitable or safe. Continued use of a Doppler instrument to capture the relationship at high flows will improve the accuracy of the rating curves.

The groundwater storage element of the Yakima Basin Integrated Plan describes the potential to divert excess streamflows to recharge aquifers in order to meet demand or improve instream conditions, such as reducing streamflow temperatures. Care needs to be taken when determining potential diversion trends for MAR purposes. Although diversion of surface flows for MAR generally occurs when demand is low, diversion rates should be done without impacting aquatic habitats. Doing so requires examining ideal flow rates determined through the examination of fish needs based on specific species requirements. Diversion flows for MAR use did not account for fish needs within specific reaches near the streamflow monitoring locations. Future work should integrate the impacts of diversions on existing functional habitats and predictive responses to restorative actions. For example, the Upper Naneum Creek watershed likely maintains significant amounts of habitat restoration potential and is a priority area for steelhead re-establishment (Jacobs 2017); therefore, diverting water for MAR at Naneum Creek should be done in consultation with specialists in aquatic habit conditions and restoration.

Future monitoring will include timely data management practices and procedural policies to eliminate questionable data as a result of unexpected changes in staff and field technicians. Opportunities to improve data management practices include uploading raw data to a platform accessible to all parties, with the expectation that upload occurs within a specific time period after each site visit. When necessary, raw data files with records up to the most recent download, such as Hobo loggers, should be compiled within a centralized spreadsheet throughout the duration of the project. Field notes should be written on designated forms, with detailed descriptions such as instrument drift observations and bank full conditions and include scanned photos. All measurements and raw data should be uploaded to the data-sharing platform in a timely manner, with data processing occurring within a specific time and uploaded to the site. File organization standards, such as file naming and folder organization, should be described in a written document and followed by all who participate in actively utilizing the platform. Furthermore, all files should remain on the platform and be archived when no longer needed.

5 REFERENCES

Creech, J. & Stuart, T., 2015. Upper Yakima Tributaries Temperature Total Maximum Daily Load. Water Quality Improvement Report and Implementation Plan.

EA Engineering, Science, and Technology, Inc., PBC; Gregory Geologic LLC; and Jacobs Engineering (EA Engineering et al.). 2020. *Yakima Basin Managed Aquifer Recharge Assessment*. Prepared for Kittitas Reclamation District. Final.

Gregory and Jacobs, 2024. Field Assessment of High-Priority Managed Aquifer Recharge Sites in the Upper Yakima: Taneum Creek Pilot Test Report. Ecology Grant WRYBIP-121-Kitt-RD-00017. 31 p.

Jacobs, 2017. Naneum, Wilson, and Cherry Creek Watershed Assessment. Project Data Summary and Recommendations. Prepared for Kittitas County Flood Control Zone District. 152 p.

Kennedy, E. 1984. Discharge Rating at Gaging Stations. Techniques of Water-Resources Investigations of the United States Geological Survey. Applications of Hydraulics. Chapter A10. 69 p.

Monk, P., 2015. Steelhead (Oncorhynchus mykiss) return to Taneum Creek Following Habitat Restoration. U.S. Fish and Wildlife Service.

Richards, P. 1990 Measures of flow variability and a new flow- based classification of Great Lakes tributaries J. Great Lakes Res. 16 53–70

Sauer, V. 2002. Standards for the Analysis and Processing of Surface-Water Data and Information Using Electronic Methods. United States Geological Survey. Water Resources Investigations Report 01-4044.

Searcy, J. 1959. Flow Duration Curves. United States Geological Survey. Water Supply Paper. Series 1542. 38 p.

Smith, A., Pollock, D. 2012. Assessment of Managed Aquifer Recharge Potential Using Ensembles of Local Models. Groundwater, 50(1), pp.133-143.

United States Bureau of Reclamation and Washington State Department of Ecology. 2012. Yakima River Basin Integrated Water Resource Management Plan Final Programmatic Environmental Impact Statement. 894 p.

United States Department of Agriculture. Web Soil Survey. Accessed November 2023. https://websoilsurvey.nrcs.usda.gov/app/

United States Environmental Protection Agency (EPA). 2014. *Best Practices For Continuous Monitoring of Temperature and Flow In Wadeable Streams*. U.S. Environmental Protection Agency, Office of Research and Development, National Center for Environmental

Assessment, Washington, DC, EPA/600/R-13/170F. https://cfpub.epa.gov/si/si_public_file_download.cfm?p_download_id=520122&Lab=NCEA.

United States Geological Survey (USGS), 2011. Streamflow Measurement USGS 12477320. Little Creek. Available at: https://waterdata.usgs.gov/nwis/measurements/?site_no=12477320 [Accessed 13 8 2020].

United States Geological Survey (USGS), 2016 Daily Streamflow Conditions, USGS Current Water Data for the Nation (US Department of the Interior, US Geological Survey). http://waterdata.usgs.gov/nwis/rt

United States Geological Survey (USGS), 2020. Washington Water Center. [Online] Available at: https://waterdata.usgs.gov/wa/nwis/inventory/?site_no=12483800&agency_cd=USGS [Accessed 13 9 2020].

United States Geolgoical Sruvey (USGS), 2023. Stage-Discharge Relation Example. https://www.usgs.gov/media/images/usgs-stage-discharge-relation-example

Washington State Department of Ecology (Ecology). 2018a. *Standard Operating Procedure, EAP056, Version 1.3, Measuring and Calculating Stream Discharge*. Ecology Publication No. 18-03-210. March. https://apps.ecology.wa.gov/publications/documents/1803203.pdf.

Washington State Department of Ecology (Ecology). 2018b. *Standard Operating Procedure, EAP042, Version 1.2, Measuring Gage Height of Streams*. Ecology Publication No. 18-03-232. December. https://apps.ecology.wa.gov/publications/documents/1803232.pdf.

Washington State Department of Ecology (Ecology). 2019a. *Standard Operating Procedure, EAP057, Version 1.2, Conducting Stream Hydrology Site Visits*. Ecology Publication No. 19-03-209. February. https://apps.ecology.wa.gov/publications/UIPages/documents/1903209.pdf.

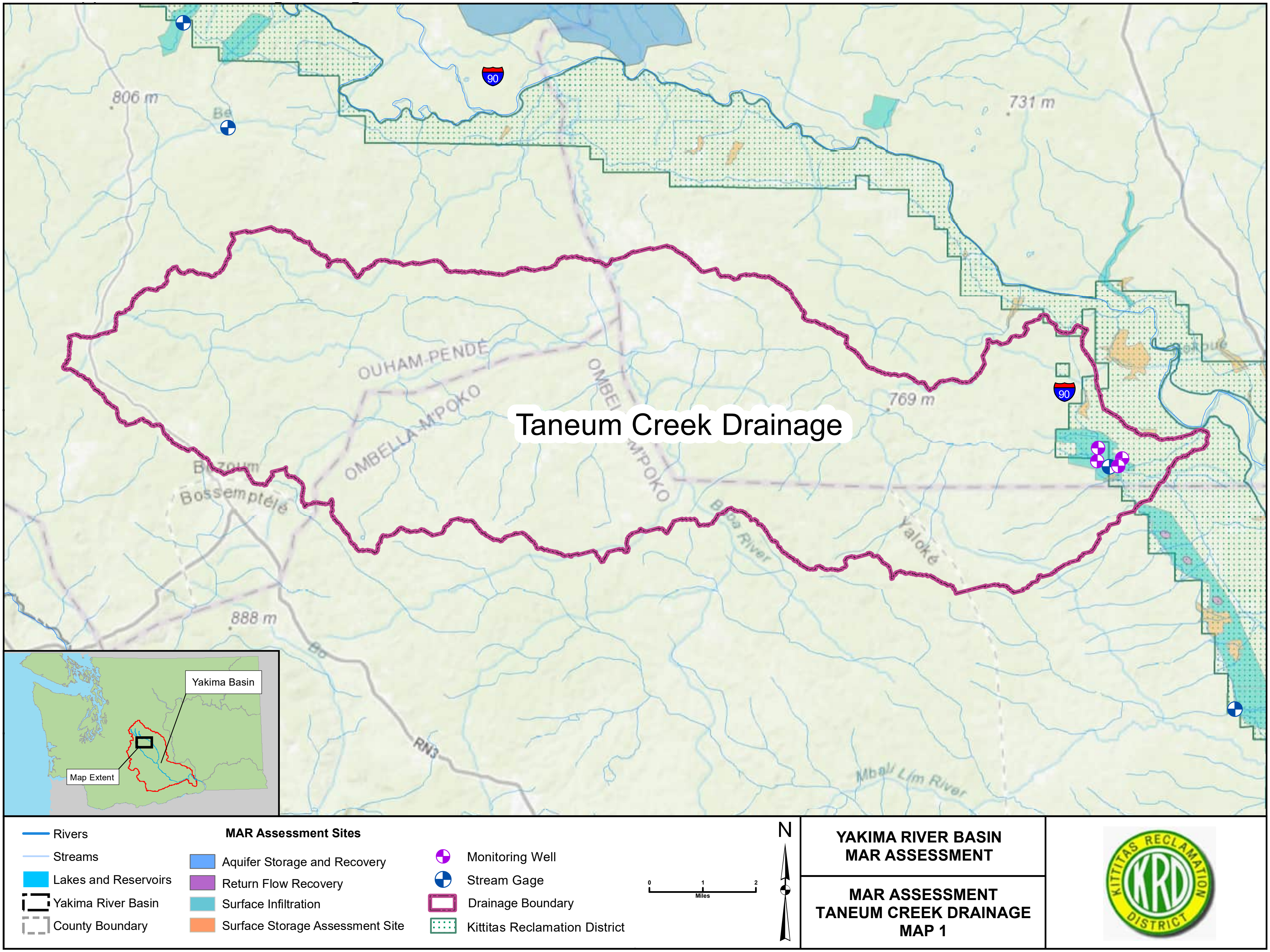
Washington State Department of Ecology (Ecology). 2019b. *Standard Operating Procedure, EAP082, Version 1.2, Correction of Continuous Stage Records Subject to Instrument Drift*. Ecology Publication No. 19-03-203. March. https://apps.ecology.wa.gov/publications/documents/1903210.pdf

Washington State Department of Natural Resources (WA DNR). Geology GIS and Databases. Accessed March 2023. https://www.dnr.wa.gov/programs-and-services/geology/publications-and-data/gis-data-and-databases

APPENDIX A

MONITORING SITE FIGURES

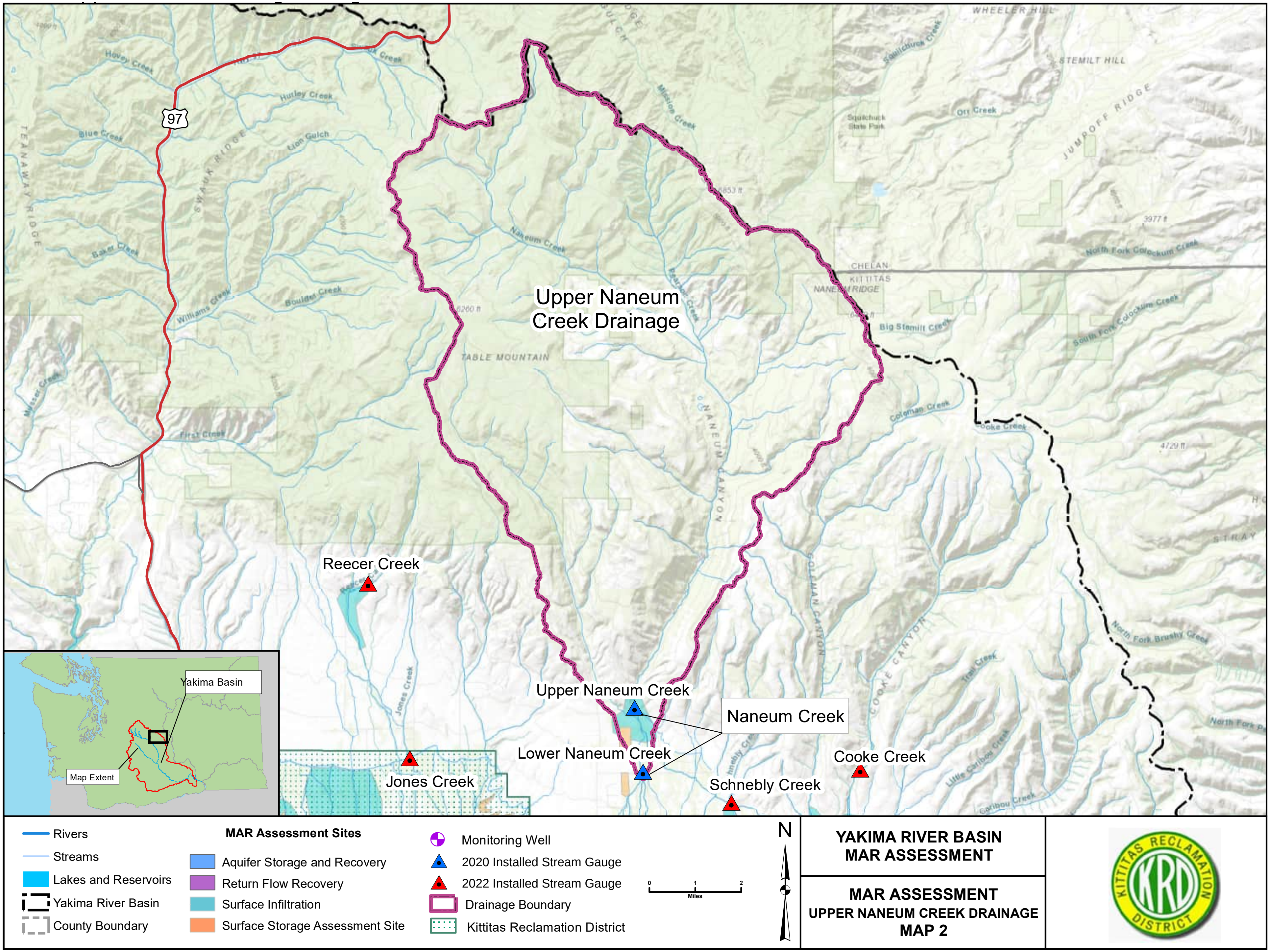
Appendix A. Monitoring Site Maps



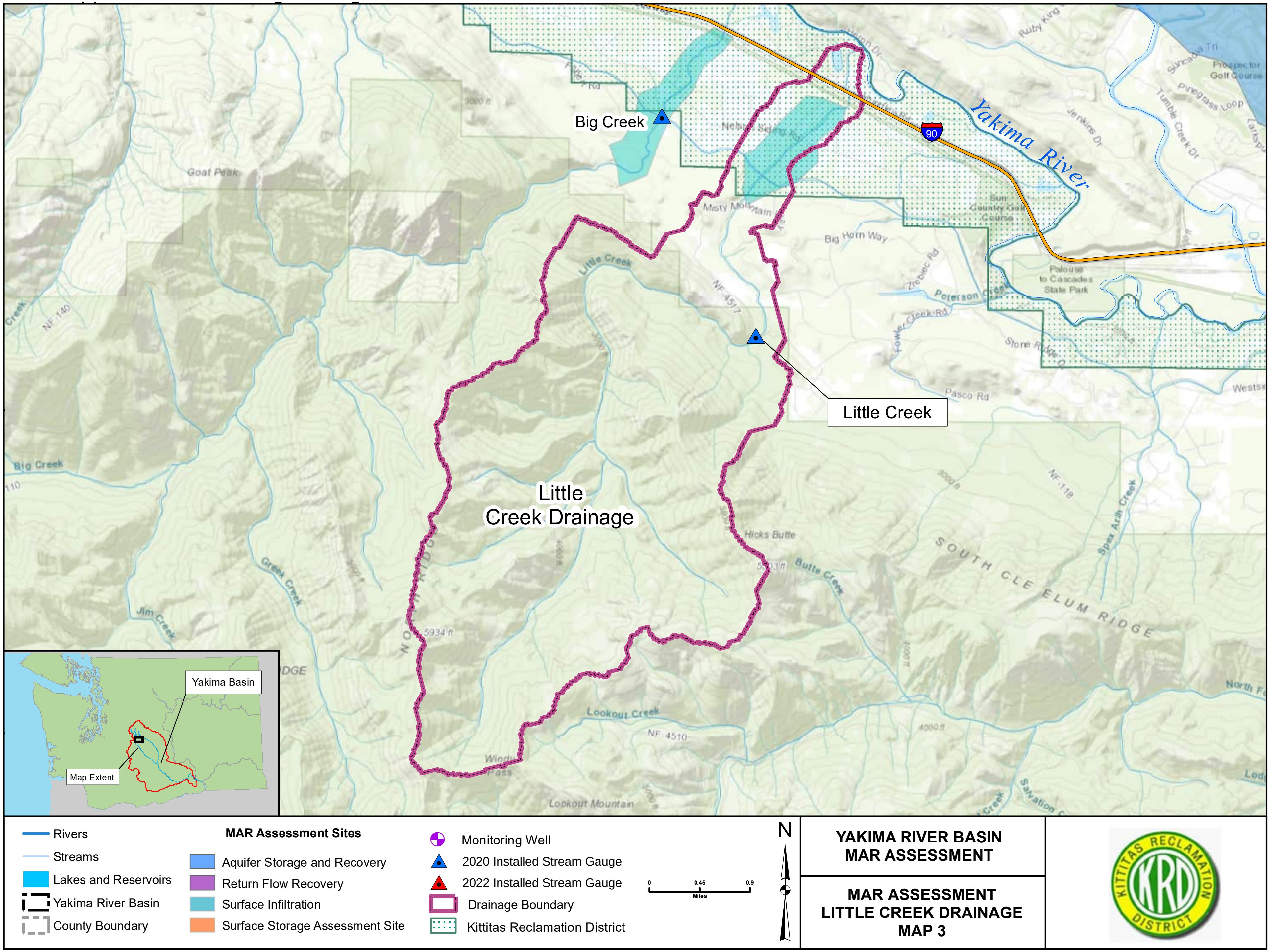
YAKIMA RIVER BASIN
MAR ASSESSMENT

MAR ASSESSMENT
TANEUM CREEK DRAINAGE
MAP 1

Appendix A. Monitoring Site Maps



Appendix A. Monitoring Site Maps



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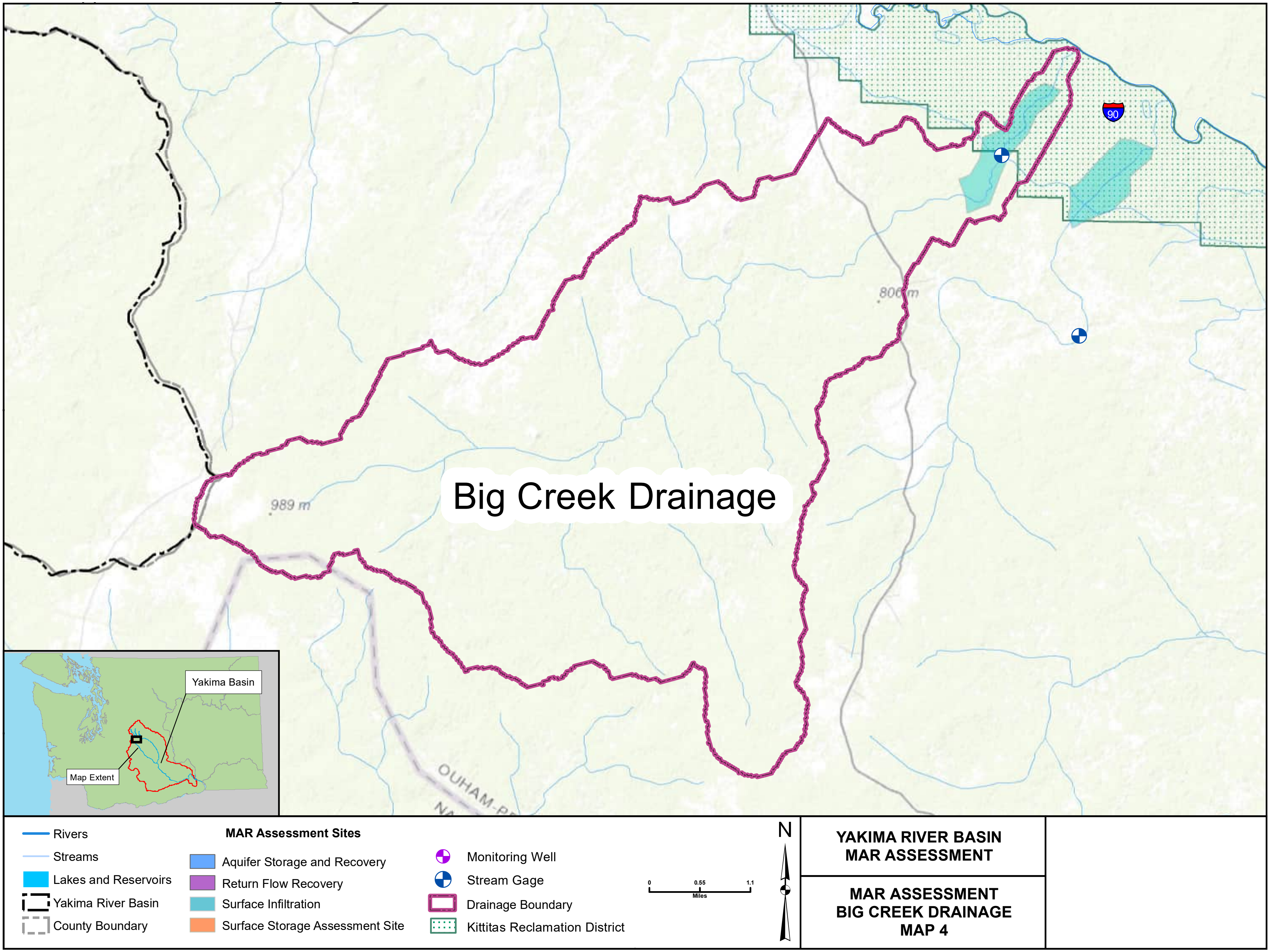

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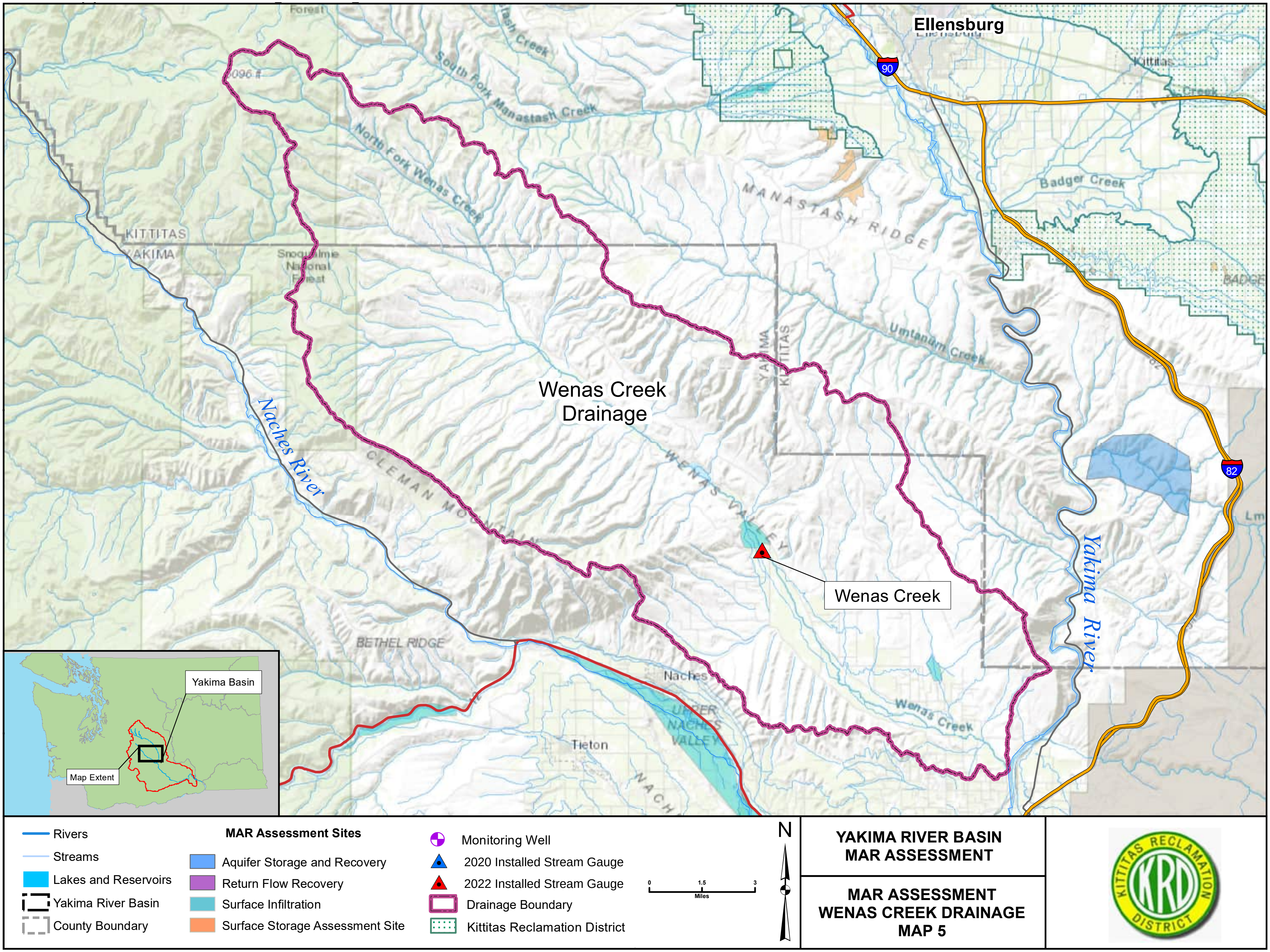

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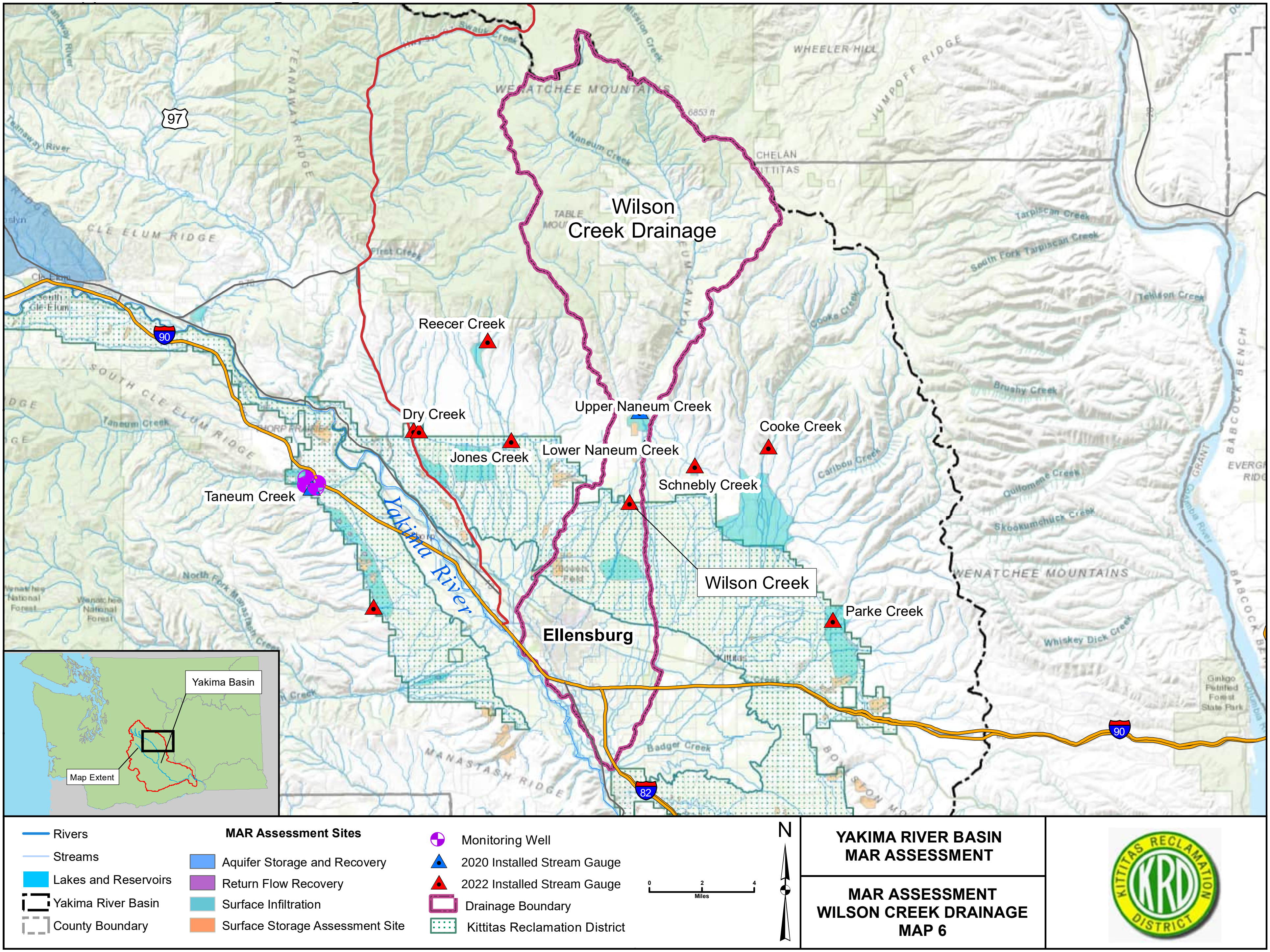

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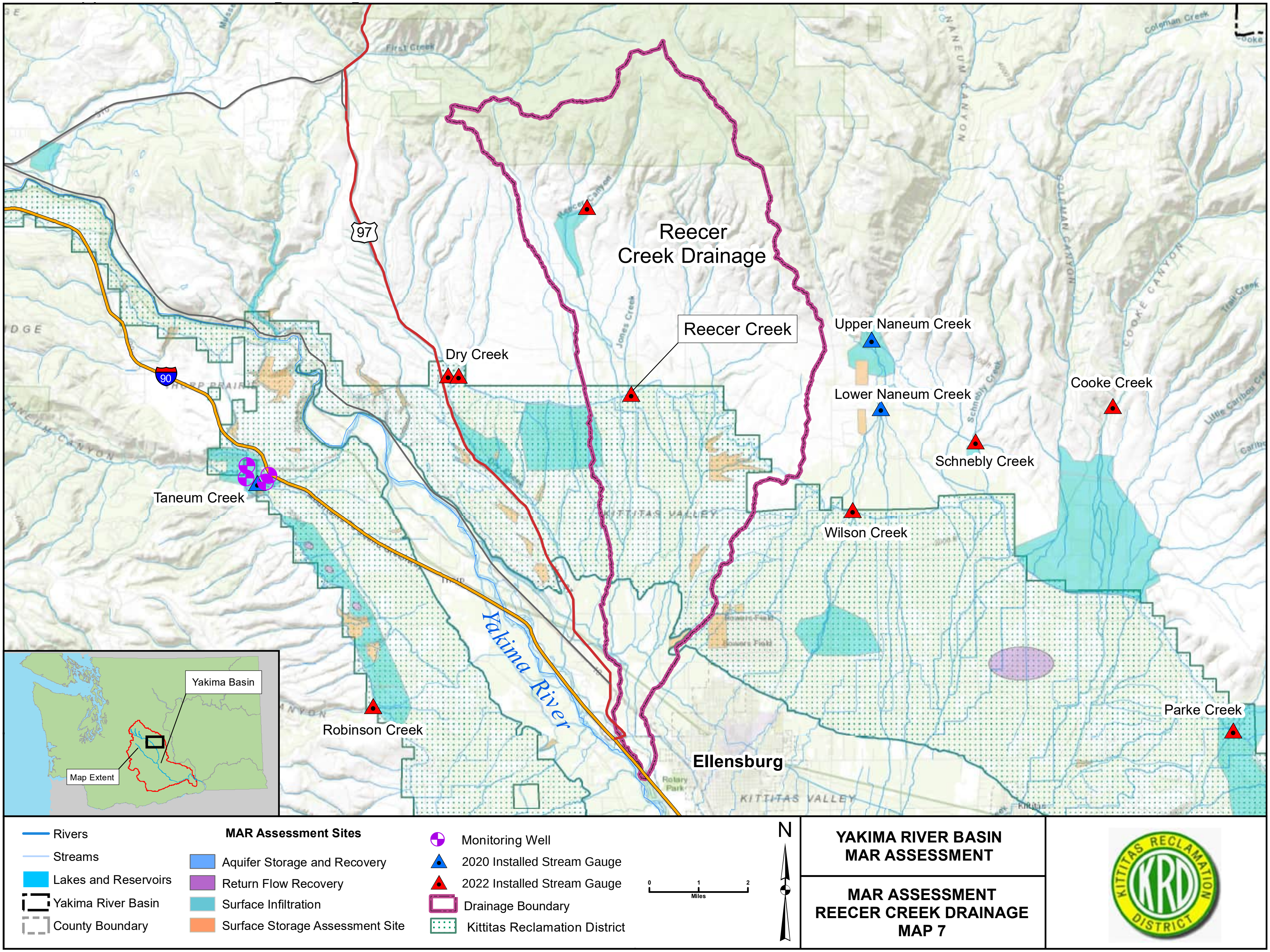

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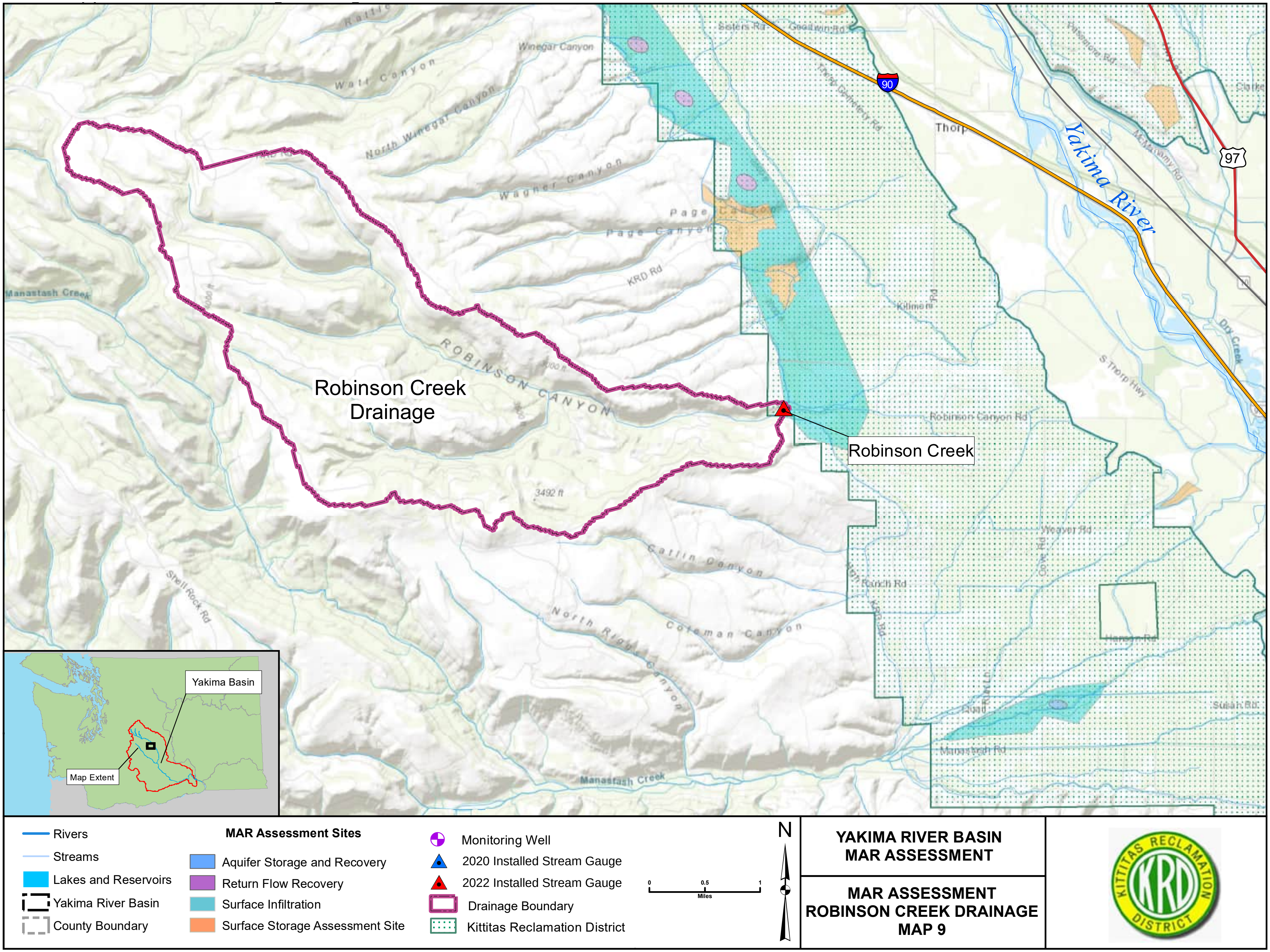

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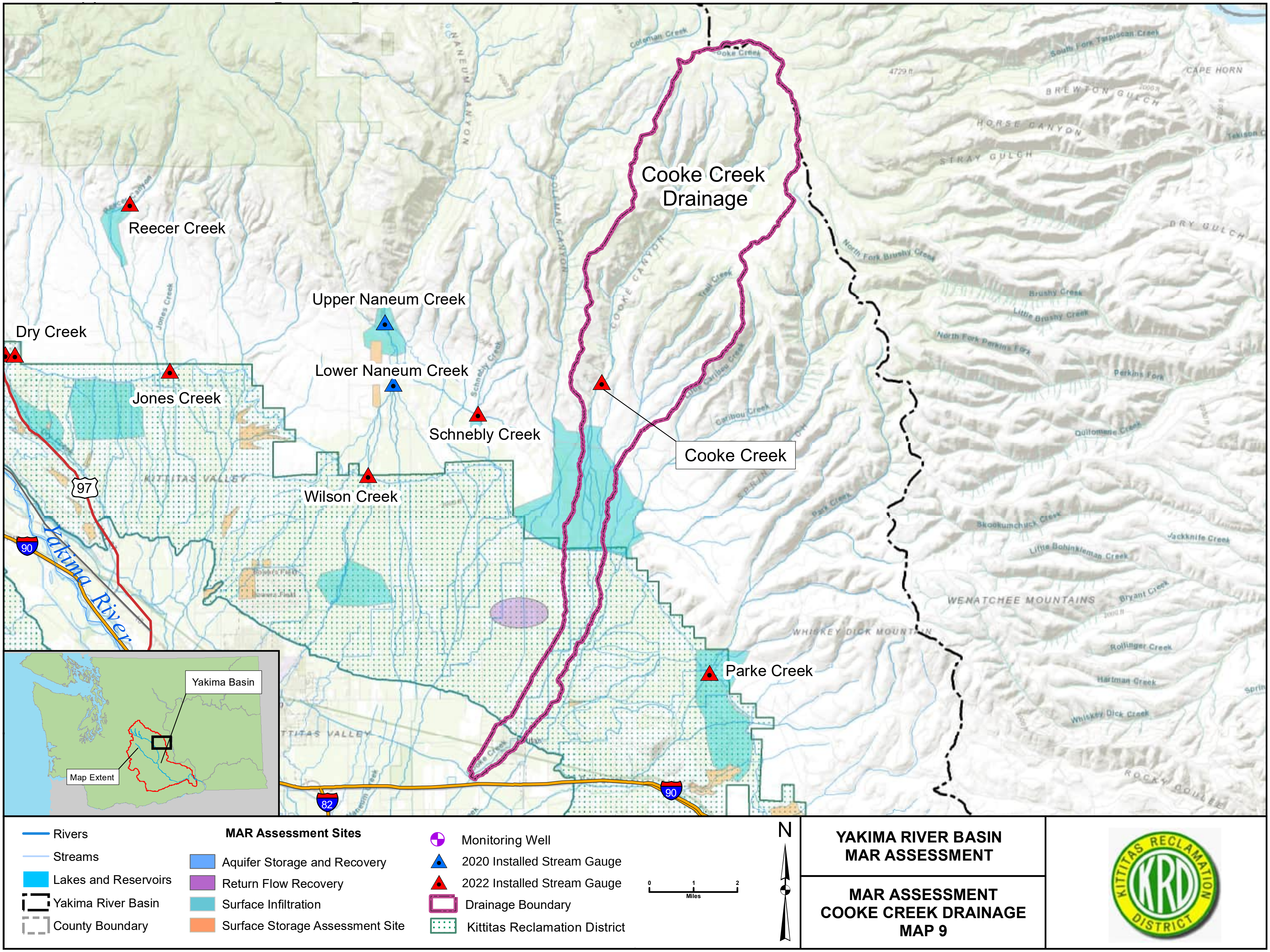

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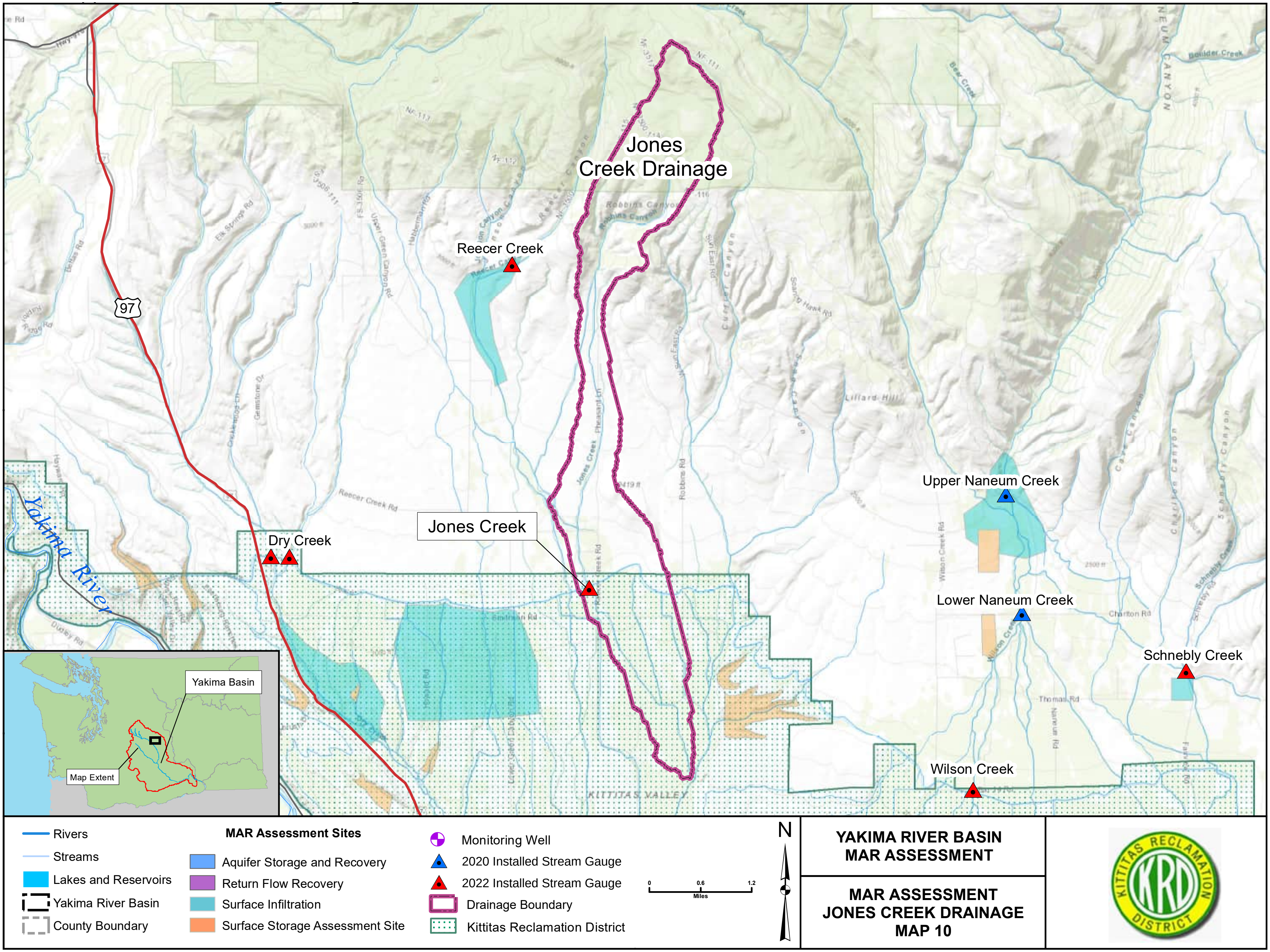

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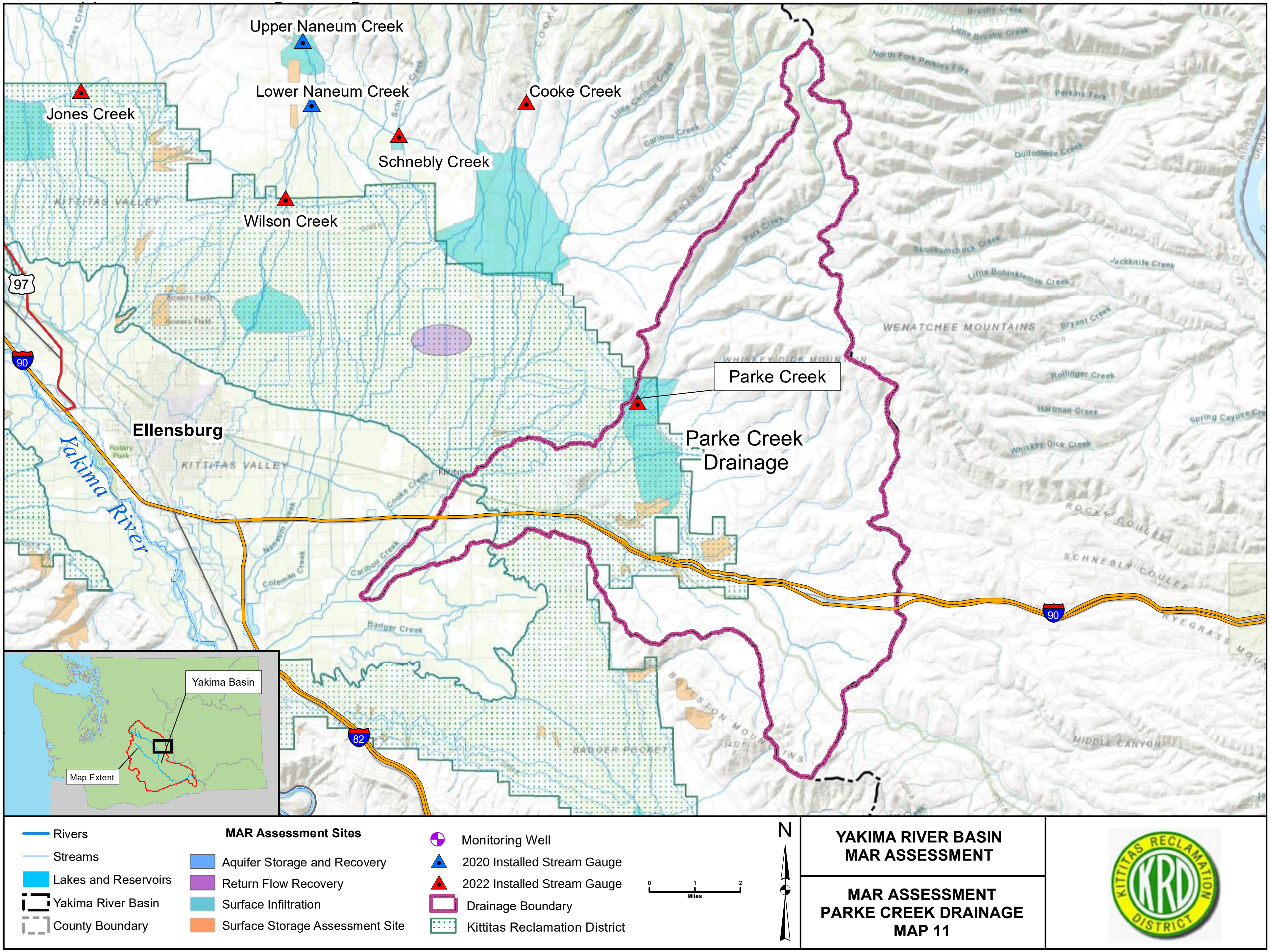

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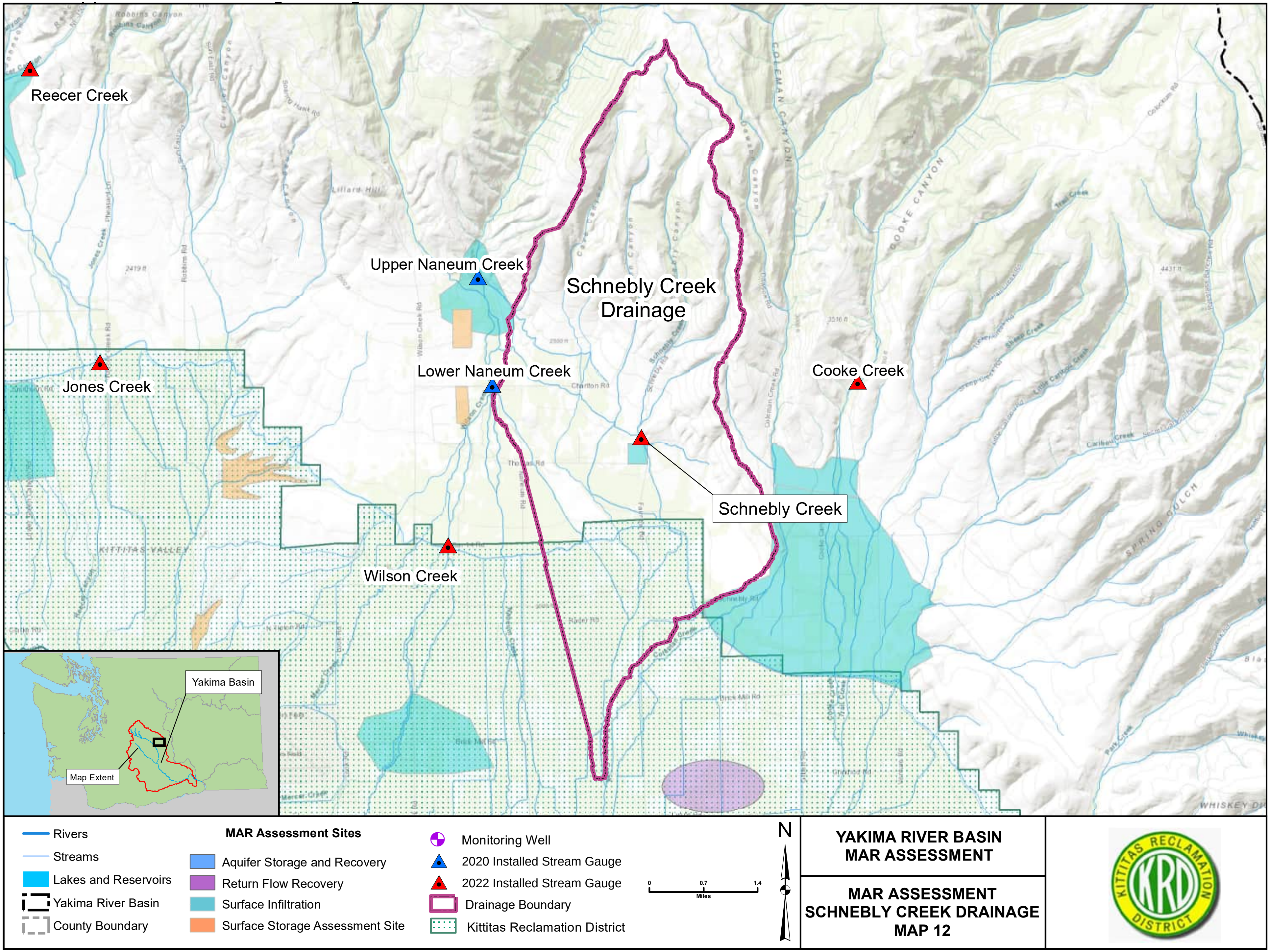

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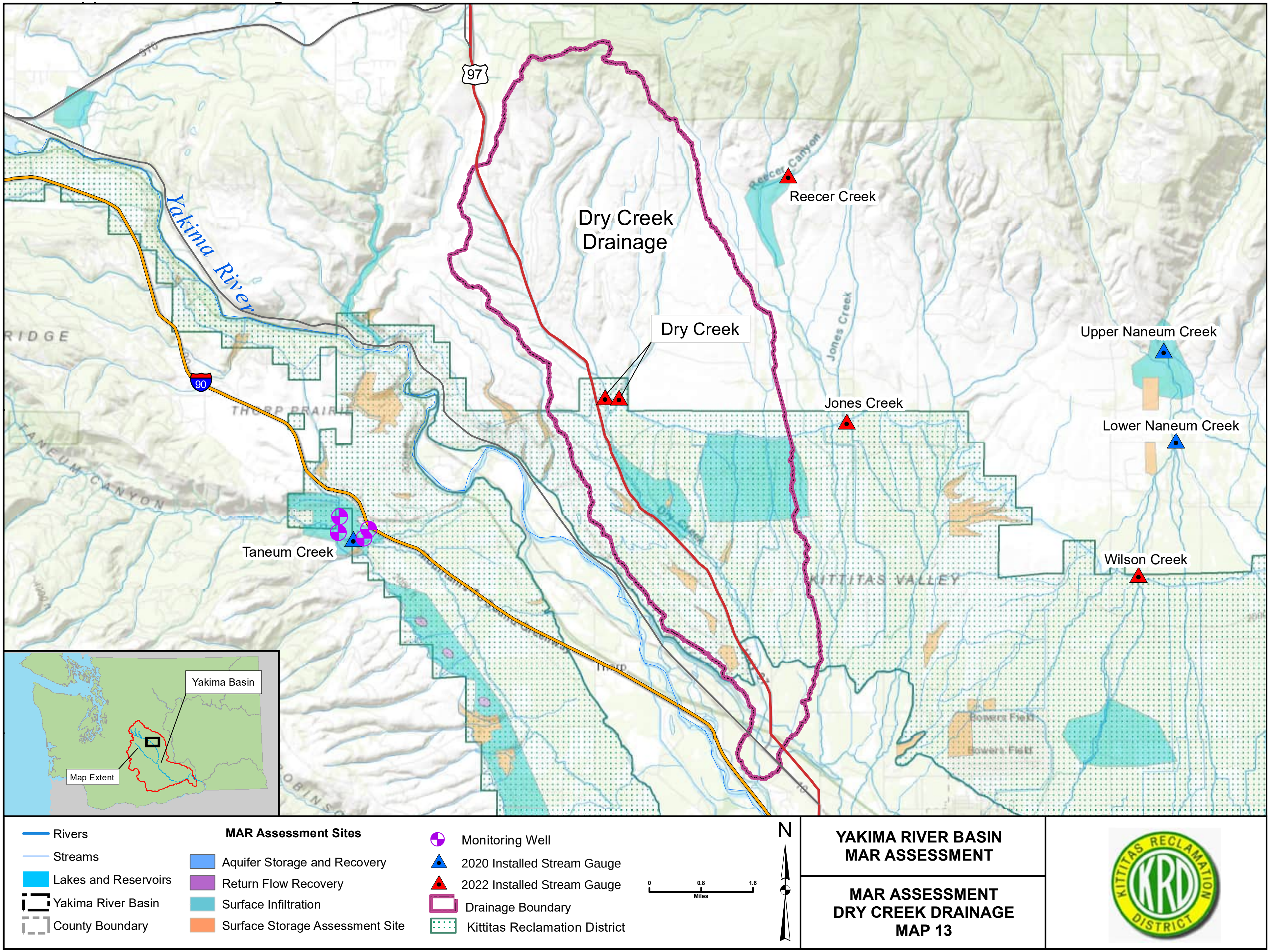


APPENDIX B

MONITORING SITE PHOTOGRAPHS

Photograph 1: Taneum Creek looking upstream. Photo taken July 2022.

Photograph 2: Taneum Creek looking downstream. Photo taken May 2023.

Photograph 3. Naneum Creek Upstream location looking upstream. Photo taken July 2022.

Photograph 4: Naneum Creek Upstream location looking downstream. Photo taken May 2023.

Photograph 5: Naneum Creek Downstream location looking downstream. Photo taken July 2022.

Photograph 6: Naneum Creek Downstream location looking downstream. Photo taken May 2023.

Photograph 7: Little Creek looking downstream. Photo taken July 2022.

Photograph 8: Little Creek looking downstream. Photo taken May 2023.

Photograph 9: Big Creek looking downstream. Photo taken July 2022.

Photograph 10. Big Creek looking downstream. Photo taken May 2023.

Photograph 11. Wenas Creek. Photo taken July 2022.

Photograph 12. Wenas Creek looking upstream. Photo taken May 2023.

Photograph 13: Wilson Creek looking upstream. Photo taken July 2022.

Photograph 14: Wilson Creek. Photo taken May 2023.

Photograph 15: Reecer Creek. Photo taken July 2022.

Photograph 16: Reecer Creek looking upstream. Photo taken May 2023.

Photograph 17: Robinson Creek looking upstream. Photo taken July 2022.

Photograph 18: Robinson Creek looking downstream. Photo taken May 2023.

Photograph 19: Cooke Creek looking downstream. Photo taken July 2022.

Photograph 20: Cooke Creek looking downstream. Photo taken May 2023.

Photograph 21: Jones Creek looking downstream. Photo taken June 2022.

Photograph 22: Jones Creek looking downstream. Photo taken May 2023.

Photograph 23: Parke Creek looking upstream. Photo taken June 2022.

Photograph 24: Parke Creek looking downstream. Photo taken May 2023.

Photograph 25: Schnebly Creek looking downstream. Photo taken June 2022.

Photograph 26: Schnebly Creek looking upstream. Photo taken May 2023.

Photograph 27: Dry Creek Upstream location. Photo taken July 2022.

Photograph 28: Dry Creek Upstream location. Photo taken May 2023.

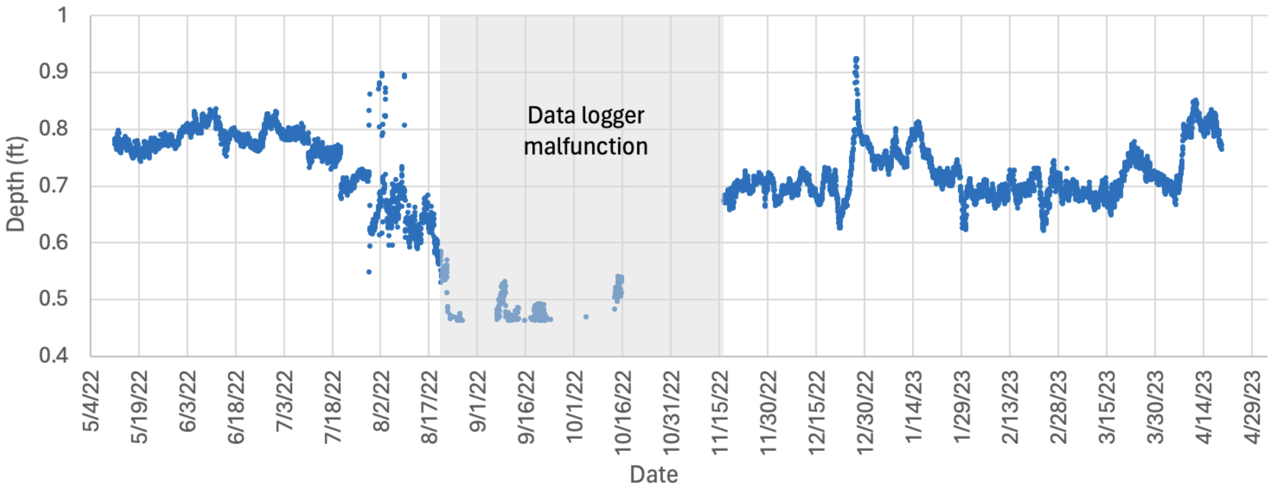
Photograph 27: Dry Creek Downstream location. Photo taken July 2022.

Photograph 28: Dry Creek Downstream location. Photo taken May 2023.

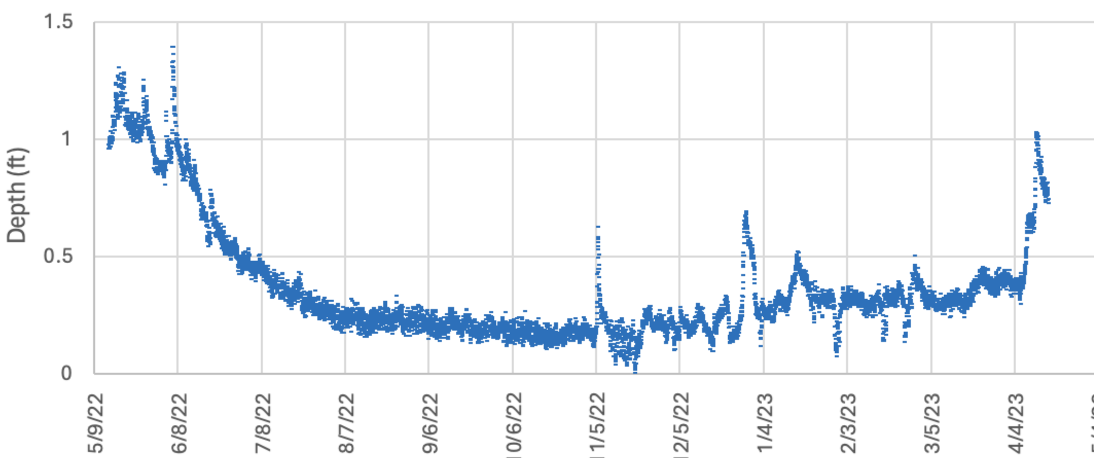
APPENDIX C
MONITORING STATION DATA:
STAGE HYDROGRAPHS AND SITES WITHOUT DATA LOGGERS

Monitoring Stations without Discharge Hydrographs[1]

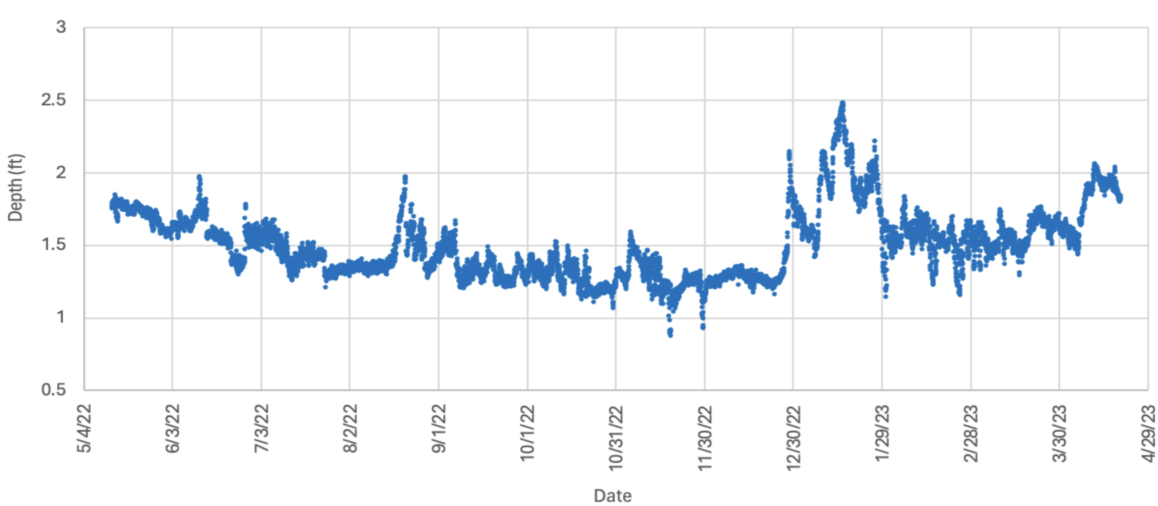
Reecer Creek Hydrograph



Cooke Creek Hydrograph

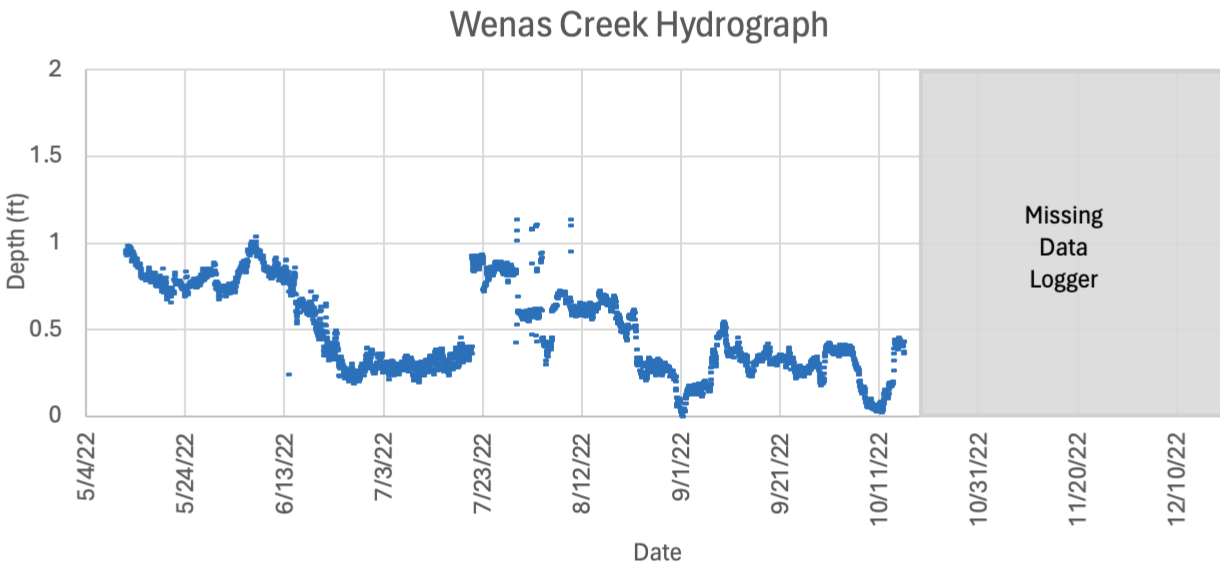


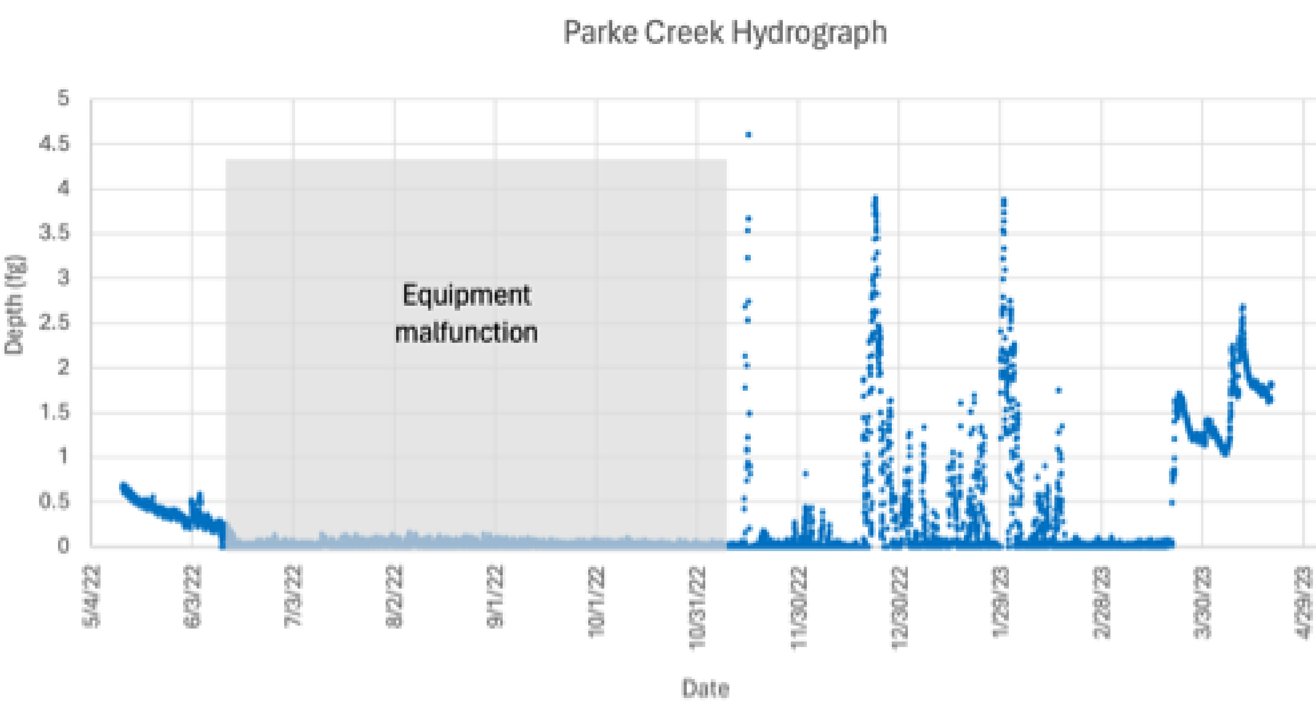
Jones Creek Hydrograph



[1]Hydrograph at Wilson Creek is unavailable at this time due to a lack of reliable transducer data

Monitoring Stations without Discharge Hydrographs, cont.





Monitoring Stations without Transducers