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Savannah River Site

**Treatability Study Data Report for Groundwater Injection and Discharge
Canal Neutralization at the D-Area Groundwater Operable Unit (OU) (U)**

2022 Data and Information

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LIST OF ACRONYMS AND ABBREVIATIONS

bgs	below ground surface
CaCO ₃	calcium carbonate
CPRB	Coal Pile Runoff Basin
DAG	D-Area Groundwater
DCSA	D-Area Coal Storage Area
ft	feet
gpm	gallons per minute
m	meters
MCL	maximum contaminant level
OU	operable unit
PFAS	per- and polyfluoroalkyl substances
RSER/EE/CA	Removal Site Evaluation Report/Engineering Evaluation/Cost Analysis
SCDHEC	South Carolina Department of Health and Environmental Control
SRNS	Savannah River Nuclear Solutions LLC
SRS	Savannah River Site
USEPA	U.S. Environmental Protection Agency
UTRA	Upper Three Runs aquifer

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1.0 INTRODUCTION

The Savannah River Site (SRS) has continued implementation of a groundwater treatability study in D Area to reduce the acidic conditions in groundwater (Savannah River Nuclear Solutions, LLC [SRNS] 2019a). The acidic conditions were caused by the storage of coal in the former 484-17D D-Area Coal Storage Area (DCSA), and the subsequent runoff into the 489-D Coal Pile Runoff Basin (CPRB). This data report summarizes all actions and data that have been taken during 2022 as presented and required in the *Treatability Study Work Plan for Groundwater Injection and Discharge Canal Treatment at the D-Area Groundwater (DAG) Operable Unit (OU)* (SRNS 2019a) and subsequent data reports (2020 DAG OU Data Report [SRNS 2021a]; 2021 DAG OU Data Report [SRNS 2022a]).

The coal-fired 484-D Powerhouse provided electricity and steam for the D-Area facilities and other areas at SRS. The power plant was put into operation in 1952. The major ancillary facilities associated with the powerhouse are the former DCSA, the 489-D CPRB, and four ash basins (Figure 1). For over 60 years, the DCSA was a staging area for coal prior to its use in the powerhouse. Exposure of the coal to rainwater caused the degradation of iron sulfide (pyrite; a mineral commonly found in coal) to sulfuric acid. As a result, the soils underneath the DCSA, associated storm water runoff, and groundwater underlying the area have been acidified. Due to acidic conditions, metals were leached from the coal and the natural soil minerals in the underlying soils in the vadose zone and aquifer. This has resulted in a metals (such as beryllium) and sulfate groundwater plume in the Upper Three Runs Aquifer (UTRA) (Figures 2 and 3). Currently, acidic groundwater outcrops into the D-Area Effluent Discharge Canal at pH levels generally below 4.

Although maintenance actions conducted in 2012 and 2013 removed virtually all of the coal present at the DCSA, the vadose zone soils beneath the DCSA remained acidified. To address the vadose zone soils, a Removal Site Evaluation Report/Engineering Evaluation/Cost Analysis (RSER/EE/CA) was submitted in 2019 to describe a non-time critical removal action for neutralization of the soils to a depth of 1.2 meters (m) (4 feet [ft]) at the DCSA (SRNS 2018). This removal action was completed in 2020 with subsequent soil pH sampling completed in the summer

of 2022. A Removal Action Report, summarizing the removal action and pH adjustment of the vadose zone soils, was submitted in December 2022 (SRNS 2022b).

This treatability study is designed to address the continuing acidic conditions in the shallow groundwater beneath the DCSA and 489-D CPRB as well as the discharge to surface water in the D-Area Effluent Discharge Canal.

2.0 PROJECT DESCRIPTION

The vadose zone and groundwater within the upper water table aquifer beneath the DCSA and the 489-D CPRB are impacted by low pH conditions (< pH of 4) that are expected to last for decades under natural groundwater conditions. The low-pH groundwater is currently outcropping into the D-Area Effluent Discharge Canal, which later converges with Beaver Dam Creek and flows through the Savannah River floodplain to the Savannah River. If the pH of the aquifer can be raised to more normal, less acidic conditions, the groundwater and surface water conditions in the D-Area Effluent Discharge Canal would improve.

This study is testing the viability of an approach to remediation that contains two relatively simple elements:

- Add higher pH, potable groundwater sourced from production wells in D Area into the water table aquifer upgradient of the low-pH, metals, and sulfate plumes using injection wells. The injected production well water is naturally buffered which will aid in the neutralization of acidic conditions currently present in the water table aquifer. The injected production well water will also create a hydraulic head that will displace the low-pH groundwater within in the aquifer.
- Treat the low-pH surface water that outcrops into the D-Area Effluent Discharge Canal by adjusting the pH with calcium carbonate (CaCO₃) reactive structure(s).

A general schematic of the DAG OU treatability study is provided in Figure 4.

Injection of Production Well Water

Two potable water production wells (PW 3D and PW 136D) are in D-Area northwest of the 484-D Powerhouse. Both production wells were used for operations and are screened approximately 154 - 188 m (508 - 618 ft) below ground surface (bgs) within the McQueen Branch Aquifer. These production wells produce groundwater with a pH of approximately 6.0 to 6.5 containing low, but measurable, levels of carbonate alkalinity. Injecting this water into the upper water table aquifer upgradient of the low-pH, metals, and sulfate plumes will create a hydraulic head and increase groundwater flow velocity horizontally to displace the low-pH groundwater currently present in the aquifer. The alkalinity will buffer the system and partially neutralize acidity in the aquifer. Both production wells are artesian and produce over 60 gallons per minute (gpm) each without the use of pumps. The well head pressure of the wells is approximately 5 to 10 pounds per square inch and supports enough flow and pressure to deliver large volumes of water to the proposed injection field as shown by artesian well flow testing conducted in 2019 on both production wells (SRNS 2021a) as well as the ongoing performance of the groundwater injections and flow from the production well PW 136D.

The production well water has been piped to the DCSA and 489-D CPRB and is being injected into the upper water table aquifer with a series of injection wells (Figure 7). A portion of the injection well field has been installed and is described in Section 5.1. Creating a water mound approximately 1.5 m (5 ft) above current conditions is expected to increase the volume of groundwater outcropping into the D-Area Effluent Discharge Canal. It is expected that the production wells can supply enough water to fill the pore space volume (the space between the sediment grains in the vadose zone) to create the 1.5 m (5 ft) water mound in approximately 100 days. The pore space volume was calculated by multiplying the surface area of the DCSA and the 489-D CPRB by the proposed rise in water elevation (1.5 m [5 ft]) by the porosity (30%) and converting to gallons. A total of approximately 19 million gallons is estimated to be needed to raise the water table 1.5 m (5 ft). Based on aqueous chemical equilibrium modeling software, a total of 10 pore space volumes of injected potable groundwater could significantly displace and raise the pH levels in the upper water table within a three-year study period. The production wells

are expected to support the groundwater injection study in addition to future remedial activities if needed (SRNS 2016a).

Although the water table is expected to rise approximately 1.5 m (5 ft) into the vadose zone, groundwater injection is not intended to be the only treatment for the vadose zone and is not expected to remove all of the acidity from the vadose zone. However, the production well water to be injected within the upper water table aquifer is anticipated to provide an important, but small, buffering interaction to mitigate the low-pH groundwater. The DCSA RSER/EE/CA action that added neutralization amendments to the vadose zone soils (SRNS 2018) is intended to reduce acidity in the vadose zone source that has contributed to groundwater contamination. Due to the higher water table condition created by injection, acidity is expected to be gradually released from the now-saturated lower vadose zone soils. However, the lower vadose zone soils that will not become saturated (i.e, remaining above the elevated water table) are not expected to be neutralized or have much change in pH as a result of the groundwater injection treatability study. The lower vadose zone will eventually see the buffering effects of the upper vadose zone amendments through their dissolution and infiltration over time. The combined (or synergistic) effects of the two actions will be apparent from the measurement of the parameters described in the Treatability Study Work Plan and the DCSA RSER/EE/CA (SRNS 2018), and the regular DAG OU groundwater and surface water monitoring that occur concurrently.

Reactive Structures in D-Area Effluent Discharge Canal

An increase in the amount of acidic water outcropping into the D-Area Effluent Discharge Canal is expected to occur as groundwater elevations rise and low-pH groundwater is displaced. Titration test results using surface water from the D-Area Effluent Discharge Canal indicate that contact of surface water with a high purity CaCO_3 reactive structure will raise the pH of the surface water to over 6.0 (SRNS 2016b). Figure 5 shows the carbonate consumption rates associated with the neutralization of the sulfuric acid and illustrates a titration curve of the test. Although the installation of one reactive structure should be sufficient to raise the pH of the surface water, two reactive structures were installed to further ensure pH adjustment is sufficient over time. CaCO_3 marble chips, placed within the stream in two sections downgradient of the acidic groundwater

discharge point within the D-Area Effluent Discharge Canal, are expected to allow enough contact time with the surface water for pH adjustment to natural conditions (Figure 4, 5, and 6). The use of high purity CaCO₃ (typically greater than 90% CaCO₃) limits the introduction of undesirable materials into the surface water (silt, clay, reactive minerals, etc.). The description of installation and the data collected to date associated with the CaCO₃ reactive structures are summarized in Section 5.2.

3.0 TEST OBJECTIVES

The objective of this treatability study is to determine the effectiveness of injecting higher-pH potable groundwater to:

- Displace the acidic groundwater out of the upper water table aquifer of the UTRA in the vicinity of and downgradient of the DCSA and 489-D CPRB to improve the aquifer conditions (increase the pH) and reduce or eliminate the dissolved metal groundwater plumes.
- Increase the pH level of the D-Area Discharge Canal surface water with CaCO₃ reactive structures prior to discharge into Beaver Dam Creek and the Savannah River floodplain and Savannah River.

The results of the treatability study will be used to support the development of the DAG OU Corrective Measures Study/Feasibility Study, currently scheduled to be submitted by March 10, 2026.

Monitoring of water table elevations and pH measurements in surrounding monitoring wells and streams, as well as metal analyses of groundwater and surface water, will be used to determine the impact of the production well water injections. Stream flow measurements will document any increases in flow in the D-Area Discharge Canal from the groundwater injections.

4.0 SAMPLING AND ANALYSIS

Measurements of water table elevations, stream flow, pH, and sample collection for metal analyses in surface water and/or groundwater are conducted following the *SRS 3Q1 Manual*:

Environmental Requirements and Program Documents, Procedure 9015: Sampling Groundwater Monitoring Wells, Tanks/Vessels (Sample Ports or Spigots) and Surface Water (SRNS 2019b).

Table 1 includes the stations that are to be monitored and identifies the sampling frequency and constituents that will be monitored. Figure 12 shows the locations of the monitored stations. A total of 32 wells and 10 surface water stations outside of the injection field are being monitored. Twenty monitoring wells and all 10 surface water stations will include metals, pH, and other routine field analyses.

A potentiometric surface map of the UTRA during second quarter (2Q)2022 is provided in Figure 16 and a pre-injection water elevation map from 2Q2020 is provided for comparison in Figure 17. Water elevations dropped overall in D-Area in 2Q2022 from the 2Q2020 surfaces; however, the water elevations in the area around the DCSA and 489-D CPRB remained the same. Water elevations were measured on a monthly basis for the first eight months after groundwater injections begin, then quarterly afterwards. A map of the acidic groundwater with pH data is provided in Figure 2 and a map of the sulfate plume is provided in Figure 3.

Stream flow measurements will be collected at all surface water station locations within the D-Area Effluent Discharge Canal and the tributary to the east where safely accessible. Groundwater and surface water samples will be monitored for the metals included in the DAG OU monitoring program. Monitoring will also include field pH measurements and other routine field measurements (i.e., oxidation/reduction potential, dissolved oxygen, specific conductance, total alkalinity [as CaCO₃], turbidity, water temperature, and water elevation [at wells]).

One round of sampling occurred in 2Q2020 for baseline data before production well water injections began. These data were supplied in the 2020 DAG OU Treatability Study Data Report (SRNS 2021a). Groundwater injections began in March 2022 after preliminary testing of the injection wells. Monthly groundwater elevation measurements were conducted and hydrographs of the data are provided in Appendix A, Table A-1. Analytical sampling of monitoring wells and surface water stations were conducted during 2Q, third quarter (3Q), and the fourth quarter (4Q)2022 after the groundwater injections began. Monthly sampling continued to be conducted at the reactive structures at surface water stations DSWM-8, DSWM-8A, and DSWM-9. All 2022

analytical and field data are provided in Appendix A, Table A-1 and discussed in Sections 5.1 and 5.2.

Any adjustments needed to the monitoring based on field conditions or monitoring results will be discussed with the United States Department of Energy Savannah River, United States Environmental Protection Agency (USEPA), and South Carolina Department of Health and Environmental Control (SCDHEC) and approved prior to implementation. The 2Q and 4Q DAG OU monitoring will not be impacted by the treatability study and will continue as normally scheduled. As field conditions warrant, adjustments such as varying injection flow rates or well re-development could also be employed. Any permanent discontinuation of an injection well will be communicated with USEPA and SCDHEC.

5.0 TREATABILITY STUDY PROGRESS AND DATA

Due to the discovery of unfavorable injection sediments within the UTRA, potential interferences with deactivation & decommissioning (D&D) activities in D Area, and delays in field personnel availability due to Covid-19 management practices, a stepped approach has been taken with implementation of the DAG OU treatability study. Ten injection wells have been installed; five were installed during 2020 (DGI007, DGI010, DGI014, DGI016, and DGI019), and five were installed during 2021 (DGI011, DGI012, DGI013, DGI015, and DGI017) (Figure 7). A letter with the request to operate as part of the Underground Injection Control Permit, including the well installation reports, was submitted to SCDHEC and copied to USEPA after installation of the 10 injection wells (SRNS 2011b). The injection wells were originally planned to be screened within the upper water table aquifer at approximately 3.7 – 9.8 m (12 – 32 ft bgs). However, due to the abundance of clays, sandy clays, and silty sands, especially near the DCSA, the wells were installed deeper within the mid to lower zone of the UTRA (Table 2). A cross-sectional view of the sediments including all 10 installed injection wells is shown in Figures 8 and 9. Additionally, the two CaCO₃ reactive structures were installed within the D-Area Effluent Discharge Canal in 2020. Ongoing monthly monitoring of pH and metal analyses within the D-Area Effluent Discharge Canal is performed upgradient, between, and downgradient of the CaCO₃ reactive structures to determine the efficacy of both the CaCO₃ material and structure design. Before

groundwater injections began, SRS collected per- and polyfluoroalkyl substances (PFAS) samples from both production wells PW 3D and PW 136D on December 17, 2021. Samples were analyzed using method EPA533 for 25 constituents. Results from both wells were non-detect for all PFAS constituents. The complete sample results are provided in Appendix A, Table A-2. Details on each portion of the treatability study project are provided below.

5.1 Injection Piping System

Due to Covid-19 related delays and material supply issues, the procurement and installation of the piping system did not start until December 2021. The main piping system consists of 6-inch and 4-inch HDPE (high-density polyethylene) pipes and the installation was completed on February 24, 2022. Figure 7 shows the general layout of the piping system from PW 136D to the injection wells, Figure 10 displays the installation of the piping system, and Figure 11 displays the typical piping setup at the injection wells.

Preliminary testing of the injection wells with the piping system was conducted in February 2022. The artesian water flow was tested through the entire length (approximately 1,128 m [3,700 ft]) of piping. The February 2022 test involved leak testing of the pipe system and ground surface discharge of the water at the end of the piping line which is located past injection well DGI019.

Preliminary injection testing of 11 individual injection wells was conducted on March 14, 2022. At DCB 2A, due to the smaller diameter well construction (4 inches vs 6 inches), smaller screen slot size than the other injection wells, and a shallower screen zone (starting at 5 ft bgs), unrestricted groundwater injections at well DCB 2A cause water to flow around the well casing and within the vadose zone and bubble up to the surface. It was determined that the injection flow rate at DCB 2A has to be lowered to prevent surface discharge of the injected water. The following injection rates were obtained after five minutes of injection testing into the individual wells:

- DGI 007: 26 gpm
- DGI 010: 26 gpm
- DGI 011: 5 gpm
- DGI 012: 2 gpm
- DGI 013: 30 gpm
- DGI 014: 23 gpm
- DGI 015: 32 gpm
- DCB 2A: 6 gpm (without visual surface discharge)
- DGI 016: 6 gpm
- DGI 017: 30 gpm
- DGI 019: 25 gpm

After completion of the initial testing at each of the injection wells, continuous groundwater injection into all 11 wells at once was initiated on March 21, 2022. Initially the injection flow rate was targeted at 5 gpm at each well to observe how wells operated over time. The flow is manually throttled as needed via a valve at each well. Inspections are done routinely, which include checking the entire piping system for leaks or damage, recording flow rates at each of the injections wells, and adjusting the flow valve at each injection well as needed to adjust flow to targeted injection rates. Daily inspections were initially conducted from Monday through Thursday for 2 weeks, and then were switched to twice a week afterwards. After 3 weeks, with most of the 11 injection wells continuing to operate at 5 gpm, the target injection rate was increased to 10 gpm. This increase allowed for a near total injection flow rate of approximately 85 gpm which is closer to the original conceptually designed 120 gpm for 21 injection wells.

Figure 14 shows the flow rates for each of the injection wells. The majority of the wells have been able to keep injection rates at or near the targeted 10 gpm setting. As discussed above, well DCB 2A must be throttled down to prevent surface discharge of the injected water. With all the injection wells being utilized at once, keeping the DCB 2A well at an injection rate of approximately 0.5 gpm prevents any surface water discharges. Injection wells DGI012 and DGI013 accept less than 2 gpm and continue to underperform. The continued performance of production well PW 136D indicates that one production well is likely adequate to support all the groundwater injection needs at this time. If needed, production well PW 3D can be added to the system to support future groundwater injections.

Figure 15 shows the cumulative groundwater injection volume. During 2022, a total of approximately 31 million gallons have been injected into the UTRA. It can be observed that the initial estimate of one pore volume or approximately 19 million gallons of water was injected into the 11 available injection wells in about 180 days. Additionally, Appendix B presents the hydrographs at the monitoring wells over the past 10 years. Although a few wells have shown a continued increase in water elevation from the continuous groundwater injections (e.g., DCB 5A, DCB 6, DCB 8, DCB 49) the majority of downgradient wells have not displayed a significant increase in water elevation. It is evident from the hydrographs that the water levels have not increased significantly over the background levels, and not to the anticipated additional 5 feet, as

had been conceptualized. However, rainfall during much of 2022 has been below average and could be temporarily offsetting any rises in the water table aquifer. The groundwater injections do appear to have kept the water elevations more stable during this drier period as the water elevations downgradient of the injections (i.e., DCB 5A, DCB 6, and DCB087A) have stayed level instead of dropping as is seen at background well DCB 51A as displayed in the hydrographs in Appendix B. Further water elevation trending will continue to be conducted for analysis.

The recorded pH levels at the monitoring wells are presented in Appendix C. The pH levels also do not show any significant increase after about 300 days of groundwater injection for an overall 31 million gallons injected or approximately 1.8 pore volumes of the conceptual estimate. pH levels remain consistent at wells DCB 4A, DCB 6, DCB 34A/C, and DCB087A (Appendix C). Increases in pH are likely to take additional time as overall buildup of water within the aquifer and movement of the groundwater aquifer be gradual.

Groundwater and surface water metal analyses were conducted quarterly after groundwater injections began. These results, as shown in Table A-1, also do not yet show any significant change in concentrations as a result of the groundwater injections, consistent with lack of changes in observed in pH.

Based on the groundwater injection flow rates and totals observed in Figures 14 and 15 and Appendices B and C, the following overall observations can be made:

1. Groundwater injections are working as conceptualized, though deeper than originally designed based on observed site specific hydrogeologic properties, and the aquifer formation is accepting groundwater without much reduction in injection rates over time.
 2. The water levels in downgradient wells have not risen as anticipated, although this may be related in part to the reduced potentiometric surface in D Area that has occurred in 2022.
 3. pH levels are not showing significant changes from the background (pre-injection) levels at most monitoring stations.
-

Based on these observations, the conceptual design was revisited. After preliminary analysis, the following observations were noted:

1. The pore volume calculations might have been underestimated. Based on a visual inspection of Figure 2, the distance to the D-Area Effluent Discharge Canal is approximately 305 m (1,000 ft) and the injection field is about 610 m (2,000 ft) in width (2,000,000 ft²). Such an area would require about 75 million gallons of water to raise the water level by approximately 5 feet. At an injection rate of 120 gpm total, this will take approximately 1 to 1.5 more years to accomplish.
2. The conceptual design assumed static conditions while estimating the increase in water levels due to groundwater injection into the upper water table aquifer. Actual injection has occurred into the middle to lower portion of the water table aquifer. As lower permeability zones are present above the injection zone, horizontal flow likely dominates, and significant flushing of the upper water table may not be occurring. A more detailed hydrogeologic analysis is recommended to better understand the expected hydraulic response to the current injection regime.

Based on the results of these initial groundwater injections over the last 10 months, an increase in injection flow rates may be achievable in some the injection wells. Potential impacts of increasing rates to the existing permits will be evaluated.

5.2 CaCO₃ Reactive Structures

Due to the ongoing and further expected acidic conditions within the D-Area Discharge Canal, two CaCO₃ reactive structures were installed during 2020. To perform initial testing of the design and function of the structures, one reactive structure was installed in February 2020. A surface water pH increase was observed with the first structure, and the second reactive structure was installed downgradient of the first structure in October 2020.

Due to the final placement of the reactive structures, a change in the surface water stations initially proposed to monitor pH/metals was appropriate. Surface water station DSWM-8 now monitors

upgradient of the first structure (originally DSWM-7), DSWM-8A monitors between the first and second structure (originally DSWM-8), and station DSWM-9 monitors downgradient of the two structures (no change) (Figure 12).

Figure 13 displays the field pH measurements collected monthly upgradient, between, and downgradient of the two CaCO_3 reactive structures at these three surface water stations. Surface water pH increases are occurring as water flows through the reactive structures with the pH increasing after each structure. However, during periods of prolonged or heavy rains, stream flow increases and surface water tops over the reactive structures. This is part of the design to not restrict flooding events; however, this consequently reduces the contact time of the surface water with the reactive structures. Additionally, increased sediment and leaf drop litter over the last two years have created a layer of detritus that limits stream flow through the CaCO_3 reactive structures and surface water overtops the CaCO_3 reactive structures, even in low rainfall periods. As part of the DAG OU Treatability Study, if the pH of the surface water downgradient of the two reactive structures at surface water station DSWM-9 is not raised to or above a pH of 5.0 (during times when surface water is not topping over the reactive structures), then remixing, replacement, and/or reconfiguration of the calcium carbonate material will be evaluated. Only four of the 12 pH measurement events in 2022 were >5 . This is not unexpected based on the observed plugging of the system with detritus. Maintenance to remove detritus and remix the existing marble chips that are in place is to be conducted in 2023 to address this reduction in flow through the structures. Subsequent sampling will bolster trending data analyses and help determine if additional actions need to be considered or if redesign is necessary to maximize flow through the structures and meet pH goals.

Appendix A, Table A-1 contains all the surface water data analytical and field results from the 2022 sampling. Some decreases in surface water metal concentrations were observed as a result of the pH changes in surface water. Figure 18 displays concentrations of pH vs aluminum, beryllium, and cobalt at surface water stations DSWM-8, DSWM-8A, and DSWM-9 at the reactive structures. The increases in pH generally cause decreases in surface water metal concentrations.

6.0 DATA COLLECTION AND REPORTING

Data (field measurements, sample results, flow rates, etc.) will continue to be collected and presented in a combination of tabular form, graphs, and time-series plots for calendar year 2023. Maps depicting the water table will also be created and compared to background (pre-injection) levels. SRS will be adding surface water station DSWM-10 to quarterly sampling to allow comparison of pH concentrations and metal concentrations of surface water in Beaver Dam Creek and well DCB 51A for a true background location comparison. The location of station DSWM-10 is downstream of station DSWM-9 and well DCB 51A is located to the northeast in D Area. Both stations are displayed in Figures 2 and 3. To allow for the analysis and interpretation of calendar year 2023 data, SRS recommends that the next report be submitted by April 30, 2024.

7.0 SUMMARY

Baseline sampling was conducted for the treatability study monitoring network in 2Q2020. Ten of the proposed 20 injection wells have been installed in addition to existing well DCB 2A and are currently injecting the production well water at approximately a combined 85 gpm. This is lower than the 120-gpm total flow rate conceptualized in the original design. Rainfall during 2022 was below average; however, the groundwater injections do appear to have kept the water elevations more stable as the levels at or downgradient of the injections have stayed more consistent instead of decreasing like other unaffected areas in D Area. Changes in pH and metals has not yet been observed as a result of the groundwater injections. A stepped approach has been taken with the DAG OU treatability study and an increase in injection flow rates may be achievable in some the injection wells. Potential impacts of increasing rates to the existing permits will be evaluated and targeted injection rates will be increased as appropriate.

Monthly monitoring of pH of surface water in the D-Area Effluent Discharge Canal is occurring upgradient, between, and downgradient of the CaCO₃ reactive structures, with quarterly sampling for metals analyses. The CaCO₃ reactive structures in the D-Area Effluent Discharge Canal are generally raising the pH of the surface water to a pH above 5; with increases in pH some metals concentrations (e.g., aluminum, beryllium, and cobalt) in surface water decrease. However, maintenance to address sediment/leaf detritus will be performed in 2023 to increase flow through

the reactive structures so they remain effective under normal flow or slightly increased flow conditions. Additional maintenance and evaluation of the current design will be determined based on subsequent pH and sampling data collected.

The groundwater and surface water monitoring will continue as scheduled and shown in Table 1 with the addition of quarterly sampling at downstream surface water station DSWM-10 and at background well DCB 51A.

Groundwater injection over the initial 10 months shows that the conceptually estimated one pore volume has been injected into the aquifer formation. However, the water levels have not shown the anticipated increase. This may be due to the decreased rainfall observed during 2022 as well as either an underestimation of the required pore volume or a misinterpretation of static groundwater conditions at the site. The conceptual model will be revisited and a detailed hydrogeologic reevaluation of the site will be conducted to better understand and anticipate the behavior of the injected groundwater. The anticipated length of the treatability study is currently estimated at a minimum of three years of groundwater injection. Analysis of the production well flow rates, injection operation, aquifer acceptance, field data, sample data, and performance of the CaCO₃ reactive structures will determine the optimal length of the treatability study after reevaluation of the conceptual design and monitoring of the fully operational system for another year. To allow for the analysis and interpretation of calendar year 2023 data, SRS recommends that the next report be submitted by April 30, 2024.

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Table 1. D-Area Treatability Study Monitoring Network and Sampling Schedule

Monitoring Well Information				Sampling			
Station	Station Type	Total Depth (ft bgs)	Screened Interval (ft msl)	Before Injection	After Injections start		
					Monthly - First 8 months	Monthly	Quarterly
PW 3D	Production Well	736	-541.25 - -551.25, 651.25 - -601.25	M	WL		WL
PW 136D	Production Well	765	-507.5 - -537.5, -577.5 - -617.5	M	WL		WL
DCB 3A	Monitoring Well	36.8	126.2 - 96.2	WL	WL		WL
DCB 4A	Monitoring Well	37	122.5 - 92.5	M	WL		M
DCB 5A	Monitoring Well	37	115.9 - 85.9	WL	WL		WL
DCB 6	Monitoring Well	23.7	129.5 - 109.5	M	WL		M
DCB 7	Monitoring Well	23.9	128.9 - 108.9	WL	WL		WL
DCB 8	Monitoring Well	26.5	130.3 - 110.3	M	WL		M
DCB 9	Monitoring Well	25	117.3 - 97.3	WL	WL		WL
DCB 10	Monitoring Well	24.1	119.8 - 99.8	M	WL		M
DCB 21A	Monitoring Well	20	120.1 - 110.1	M	WL		M
DCB 21B	Monitoring Well	27	104.7 - 102.2	M	WL		M
DCB 21C	Monitoring Well	44	90.8 - 88.3	M	WL		M
DCB 22A	Monitoring Well	18.5	119.8 - 109.8	M	WL		M
DCB 23A	Monitoring Well	16	115.7 - 105.7	WL	WL		WL
DCB 23B	Monitoring Well	27.5	96.6 - 94.1	M	WL		M
DCB 23C	Monitoring Well	35	89.1 - 86.6	M	WL		M
DCB 26AR	Monitoring Well	26	111.7 - 97.4	WL	WL		WL
DCB 33B	Monitoring Well	37	114 - 104	WL	WL		WL
DCB 34A	Monitoring Well	26	112 - 102	M	WL		M
DCB 34C	Monitoring Well	59.3	80.8 - 70.8	M	WL		M
DCB 35A	Monitoring Well	25	103.4 - 93.4	M	WL		M
DCB 35C	Monitoring Well	44	84.2 - 74.2	M	WL		M
DCB 36A	Monitoring Well	20	114.1 - 104.1	M	WL		M
DCB 36C	Monitoring Well	37	97.3 - 87.3	M	WL		M
DCB 37A	Monitoring Well	25.9	110.8 - 100.8	M	WL		M
DCB 41A	Monitoring Well	33	108.28 - 98.28	WL	WL		WL
DCB 44A	Monitoring Well	26.5	123.3 - 108.3	WL	WL		WL
DCB 45A	Monitoring Well	25.2	125.2 - 110.2	WL	WL		WL
DCB 49	Monitoring Well	16.5	118.65 - 106.15	WL	WL		WL
DCB 53	Monitoring Well	41	87.58 - 77.48	WL	WL		WL
DCB 70A	Monitoring Well	12.5	114.69 - 104.69	M	WL		M
DCB077	Monitoring Well	31.7	118 - 98	M	WL		M
DCB078	Monitoring Well	41.7	107 - 87	M	WL		M
DSWM-4	Surface Water Station	--	--	M			M
DSWM-4A	Surface Water Station	--	--	M			M
DSWM-4B	Surface Water Station	--	--	M			M
DSWM-4C	Surface Water Station	--	--	M			M
DSWM-5	Surface Water Station	--	--	M			M
DSWM-6	Surface Water Station	--	--	M			M
DSWM-7	Surface Water Station	--	--	M			M
DSWM-8	Surface Water Station	--	--	M	M	pH	M
DSWM-8A	Surface Water Station	--	--	M	M	pH	M
DSWM-9	Surface Water Station	--	--	M	M	pH	M

M = Metals and field parameters including pH

WL = Water elevation measurement only

pH = pH reading of surface water only for performance monitoring of the reactive structures

Table 2. D-Area Injection Well Screen Zone Depths

Injection Well	Screen Zone (ft bgs)	Month/Year Installed
DGI007	21.49 - 42.41	December/2019
DGI010	30.51 - 51.43	December/2019
DGI011	24.2 - 45.1	February/2021
DGI012	26.6 - 47.5	February/2021
DGI013	34.1 - 55.0	February/2021
DGI014	34.58 - 55.5	February/2020
DGI015	35.1 - 56.0	February/2021
DGI016	34.26 - 55.18	January/2020
DGI017	34.1 - 55.0	March/2021
DGI019	23.72 - 44.64	January/2020
DCB 2A	5.0 – 35.0	March/1984

Installed during 2020
Installed during 2021
Existing well

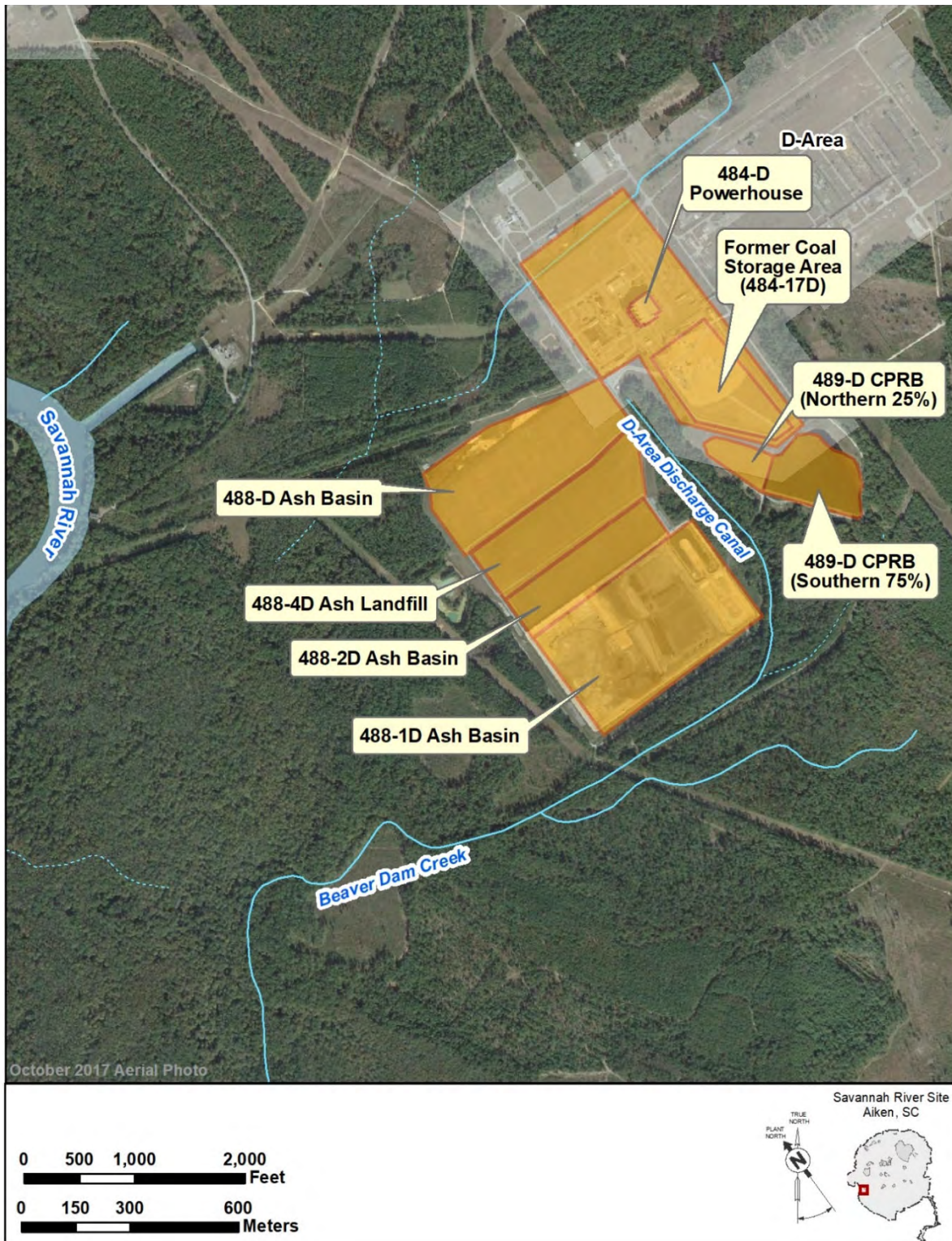


Figure 1. D-Area Powerhouse Associated Facilities

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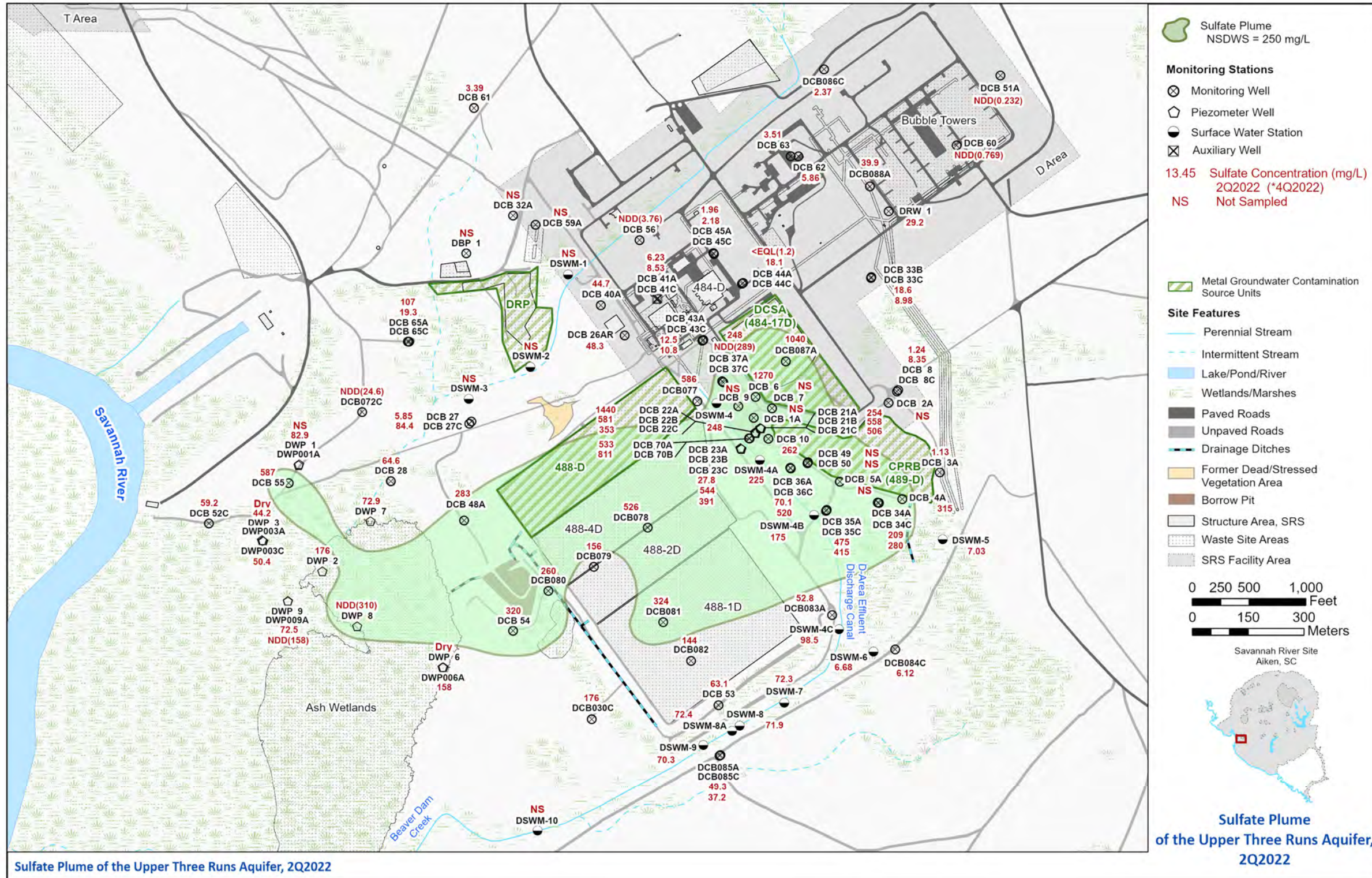


Figure 3. D-Area Groundwater 2Q2022 Sulfate Plume

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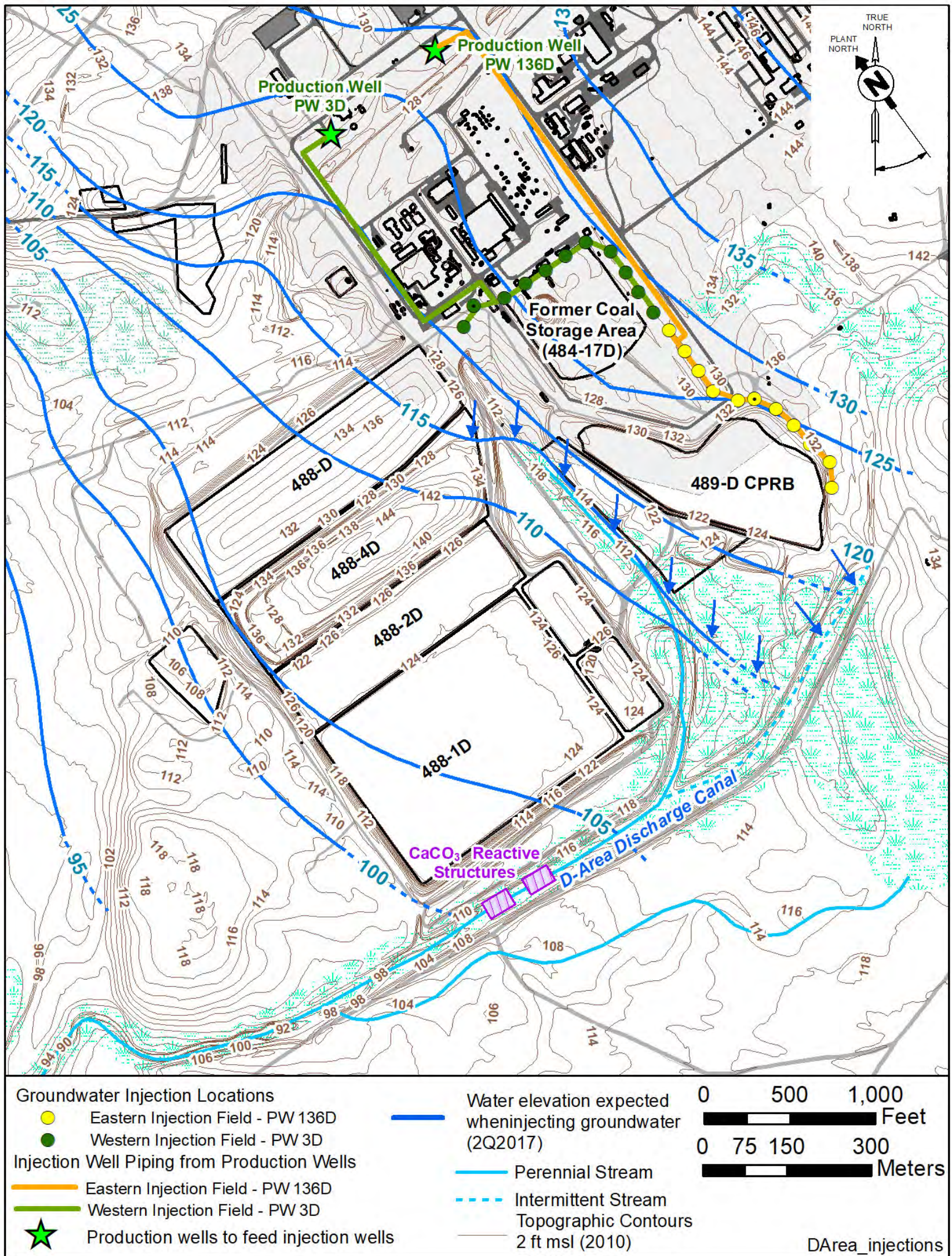


Figure 4. D-Area Treatability Study Injection Wells, Reactive Structure, and Projected Water Table Elevation

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Water Volume, ml	CaCO ₃ Mass, g	Initial pH	Final pH	Mass CaCO ₃ per Water Volume, mg/l
Initial		3		0
200	0.018	3.08	3.99	90
200	0.05	3.05	5.75	250
200	0.1	3.02	6.15	500
50	0.1	2.98	6.64	2,000
50	0.25	2.93	6.50	5,000
50	0.5	2.90	6.60	10,000

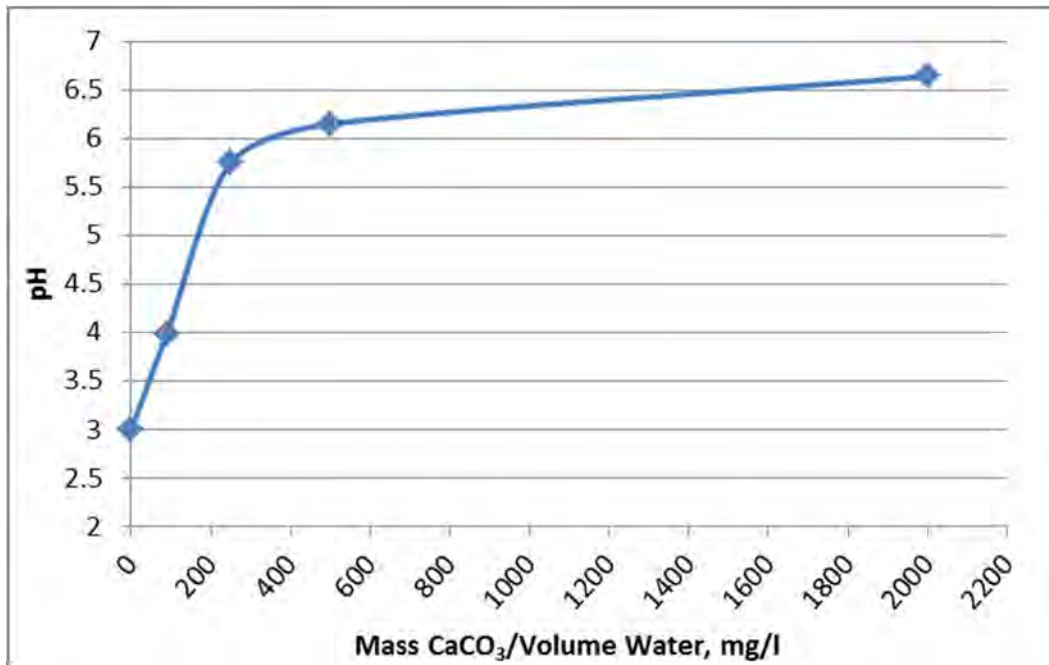


Figure 5. Titration Test Chart and Graph of D-Area Discharge Canal Acidic Surface Water with Calcium Carbonate Additions

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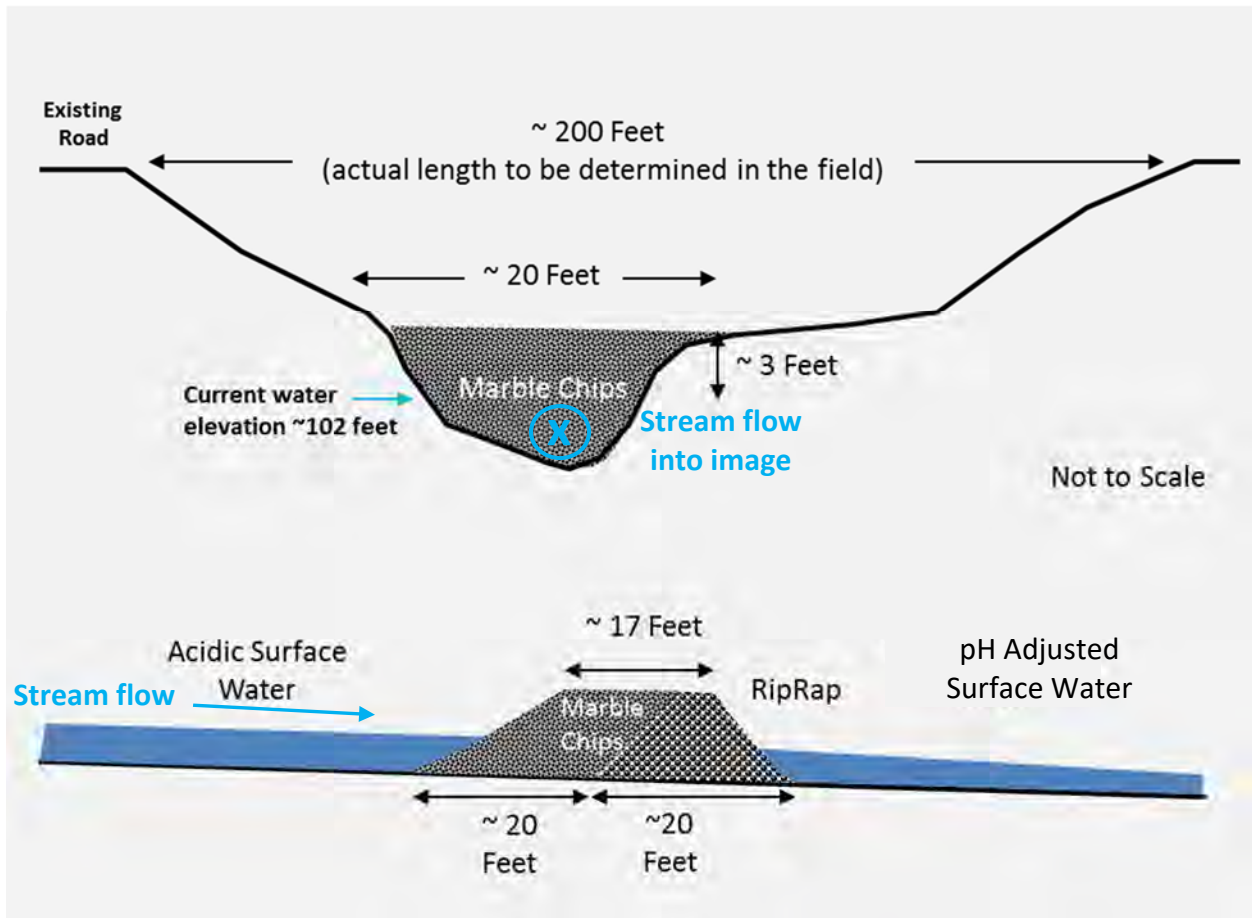


Figure 6. Diagram of CaCO_3 Reactive Structures in the D-Area Discharge Canal

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Figure 7. D-Area Injection Wells Installed and Production Well Piping

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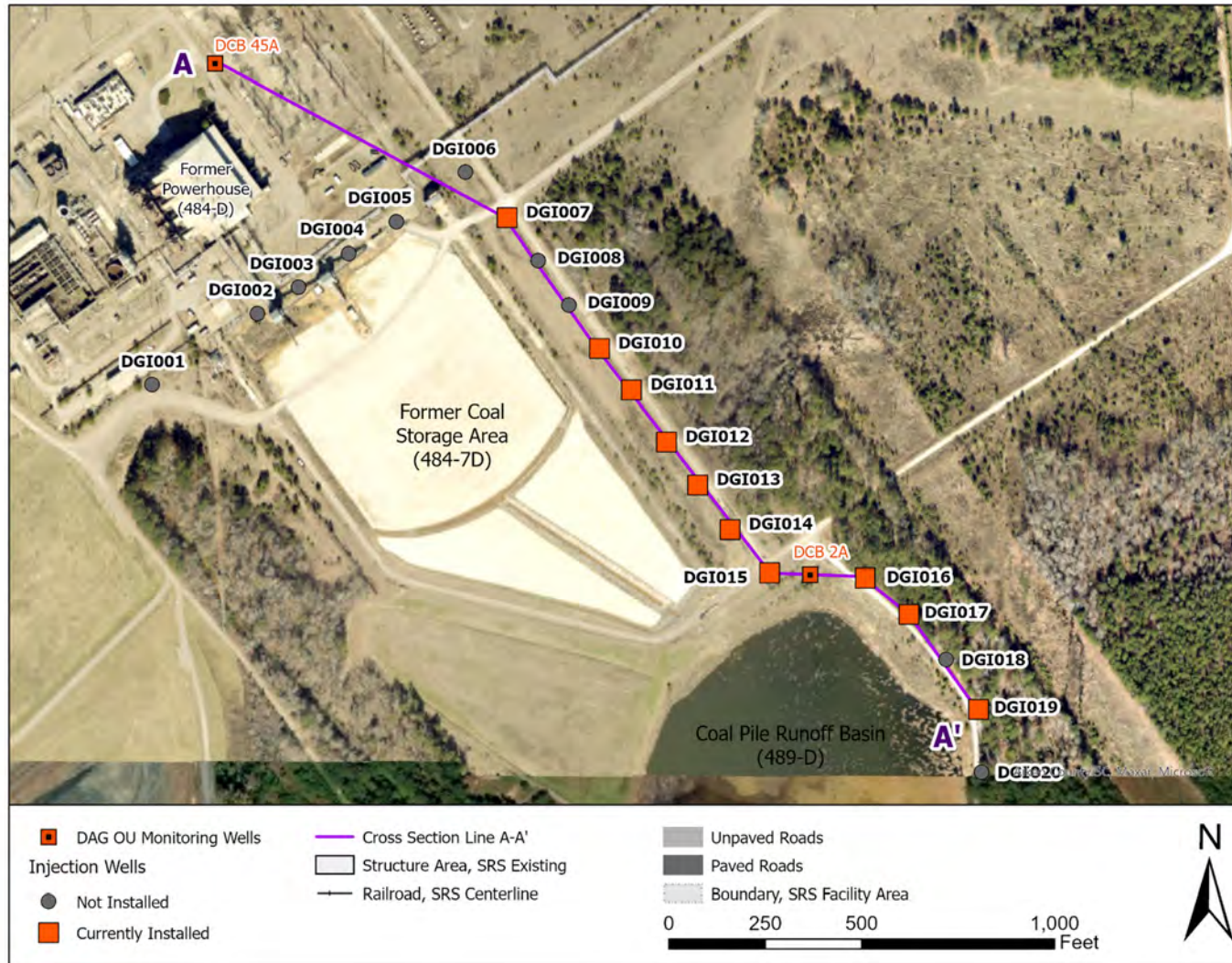


Figure 8. Installed Injection Wells and Cross Section Line A-A'

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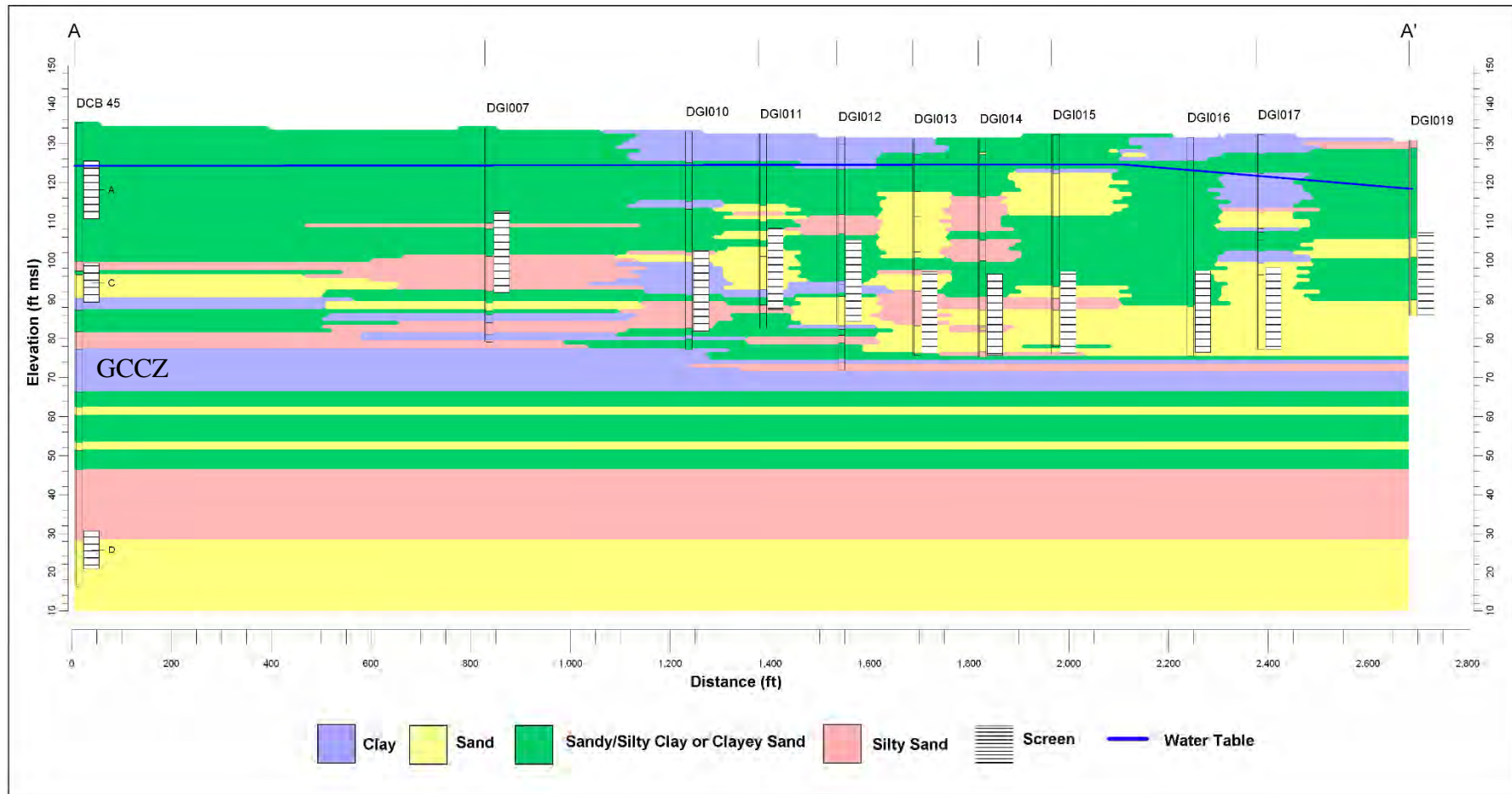


Figure 9. D-Area Injection Well Lithological Cross-Section A-A'

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Figure 10. D-Area Treatability Study Pipeline Installation

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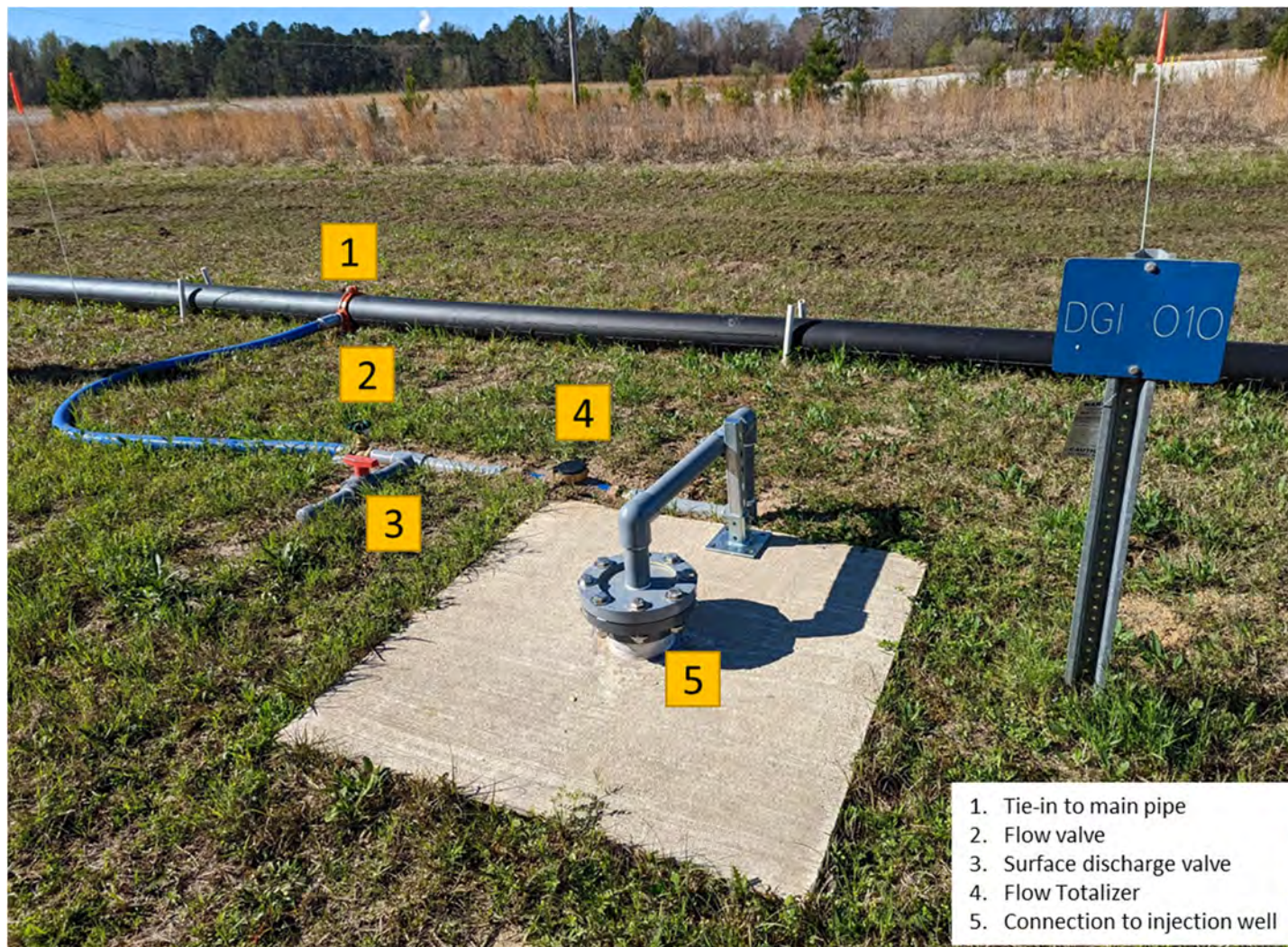


Figure 11. Injection Well Connection to Pipeline (DGI010)

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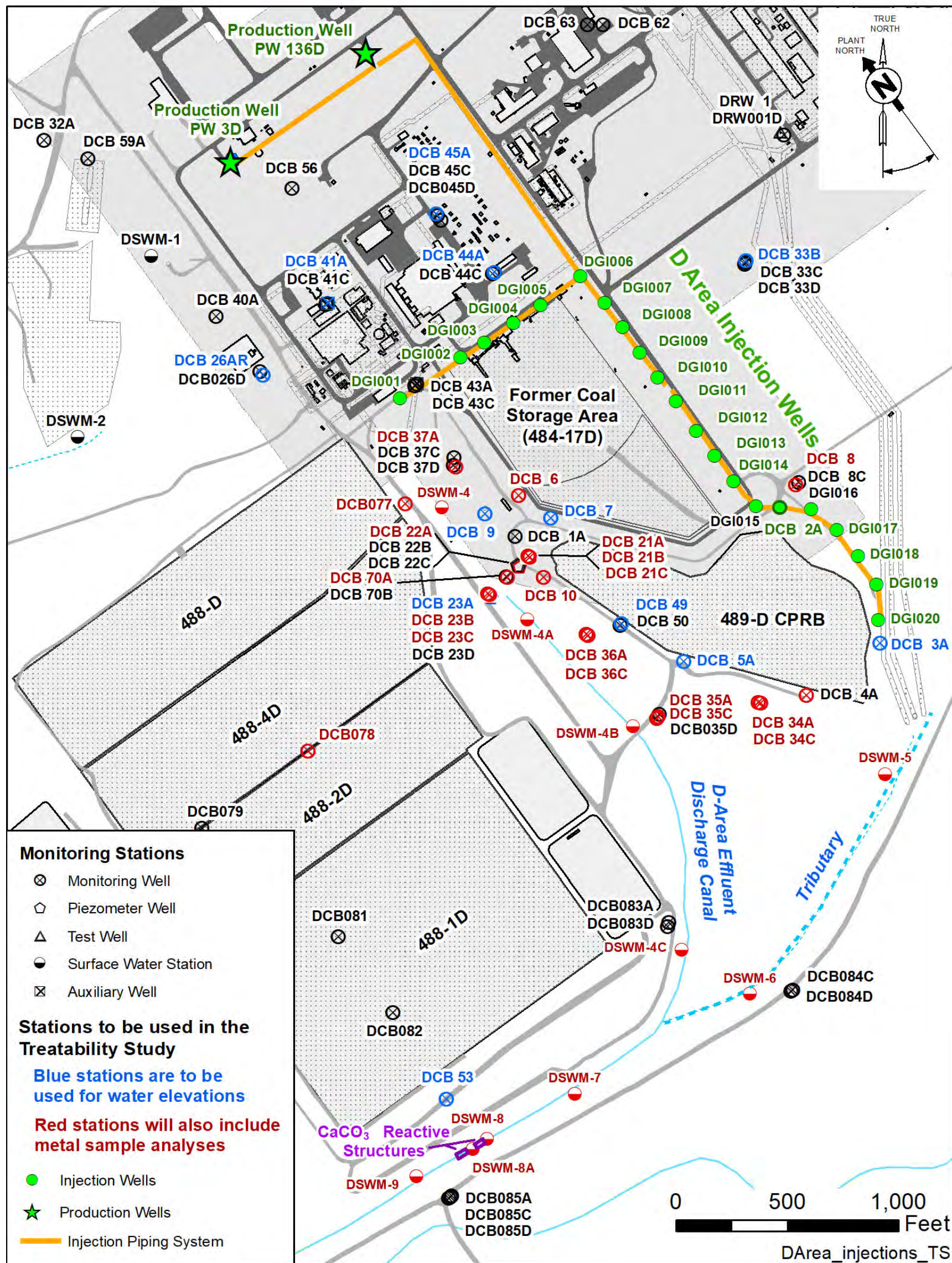


Figure 12. D-Area Treatability Study Monitoring Locations

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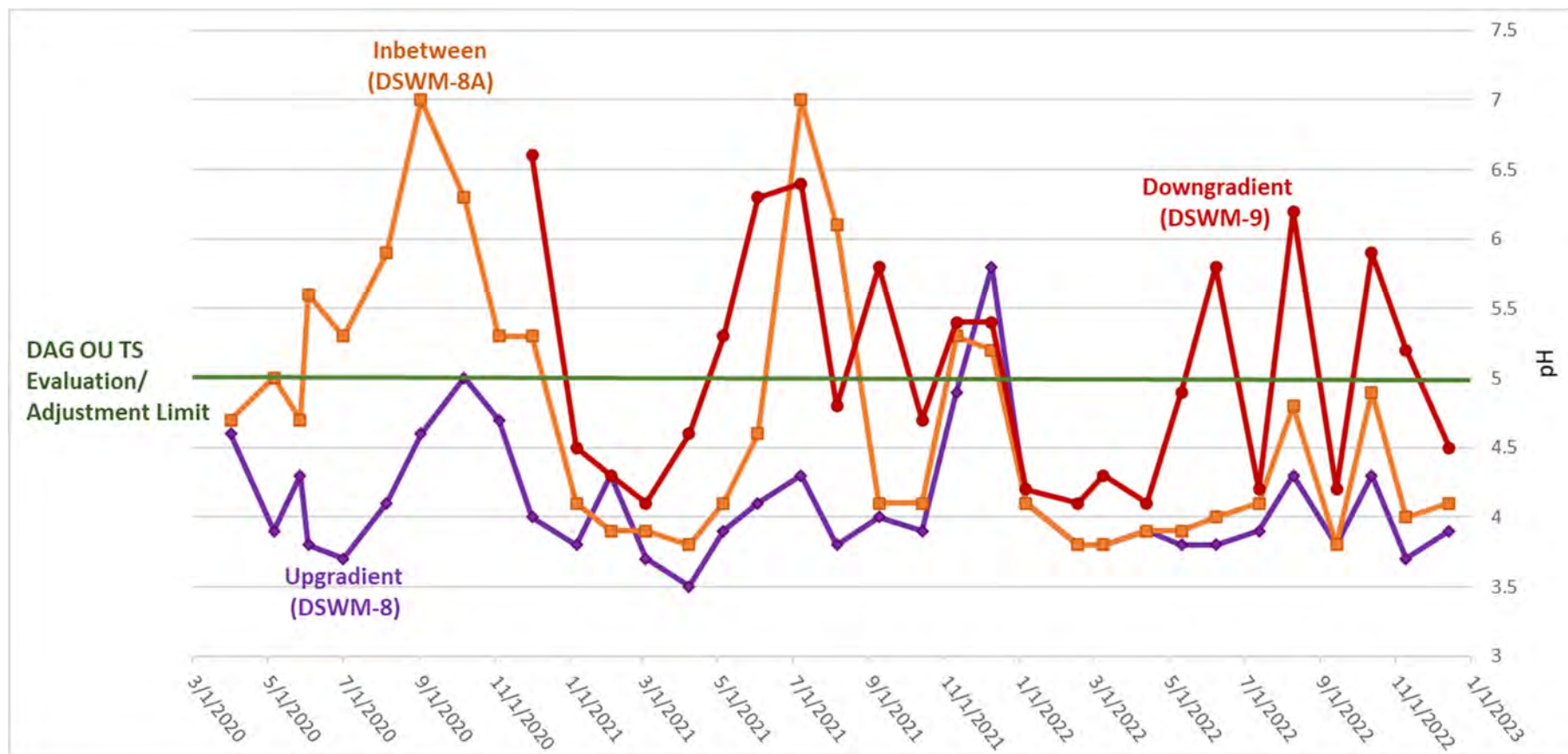


Figure 13. CaCO₃ Reactive Structure Surface Water pH Results

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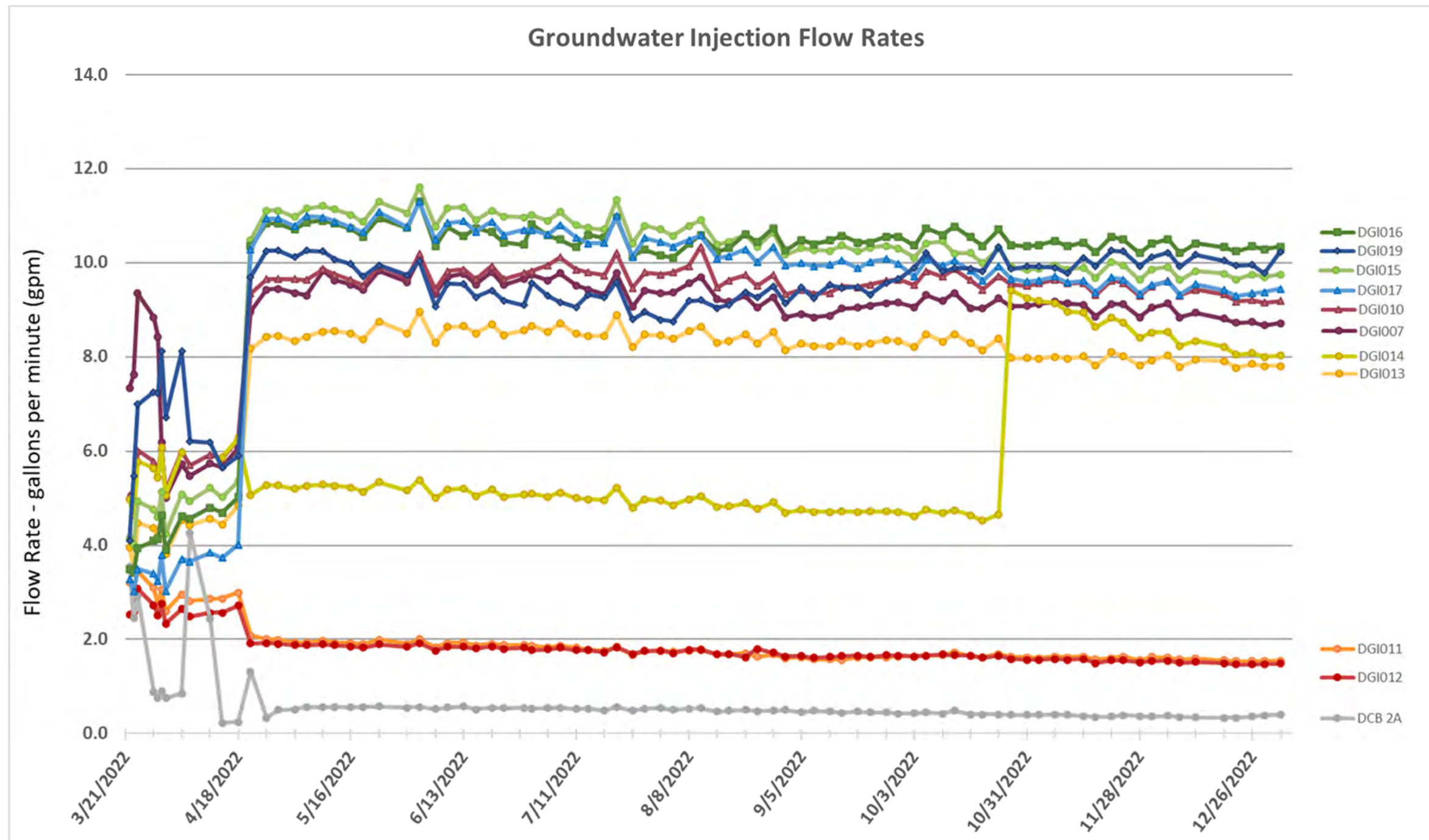


Figure 14. Graph of Injection Well Flow Rates for 2022

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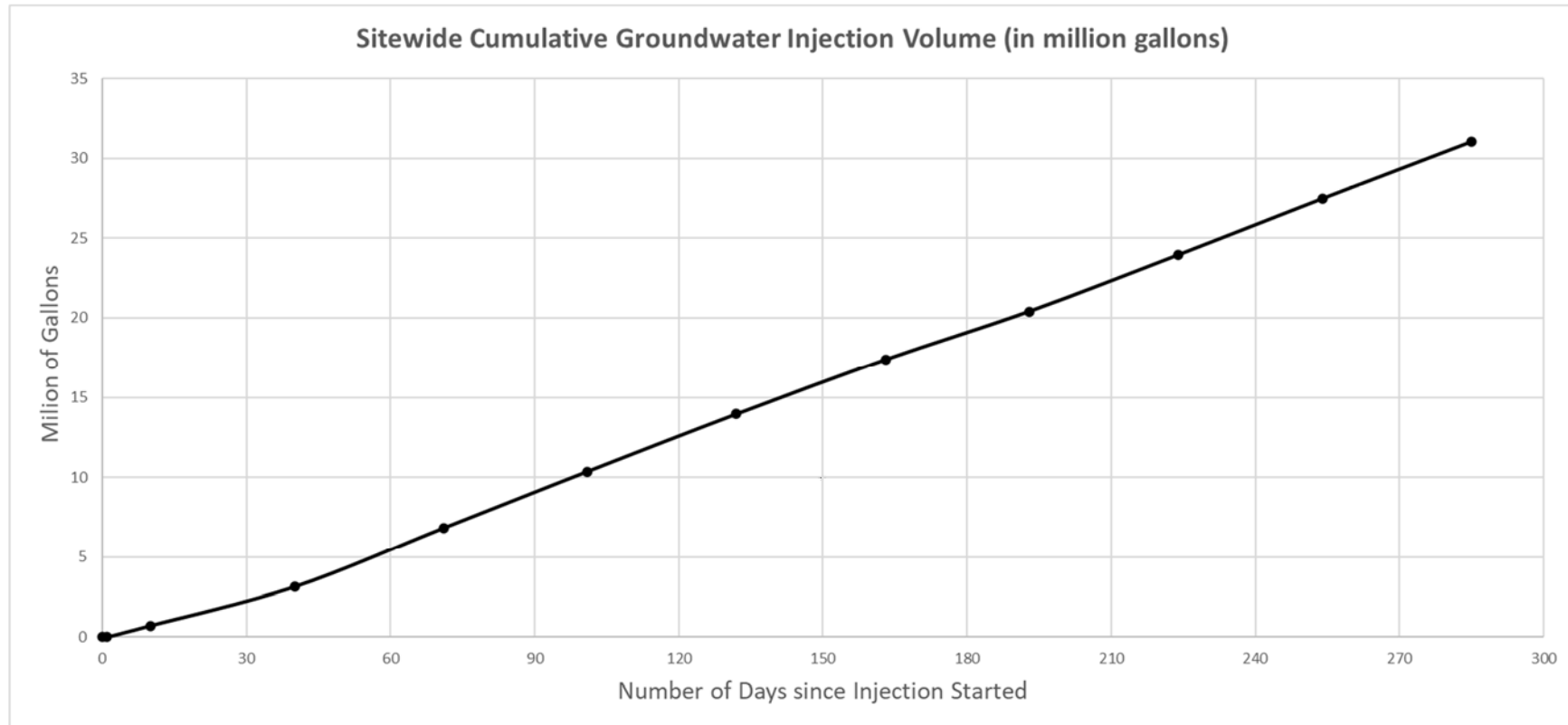


Figure 15. Sitewide Cumulative Groundwater Injection Volumes (in million gallons total)

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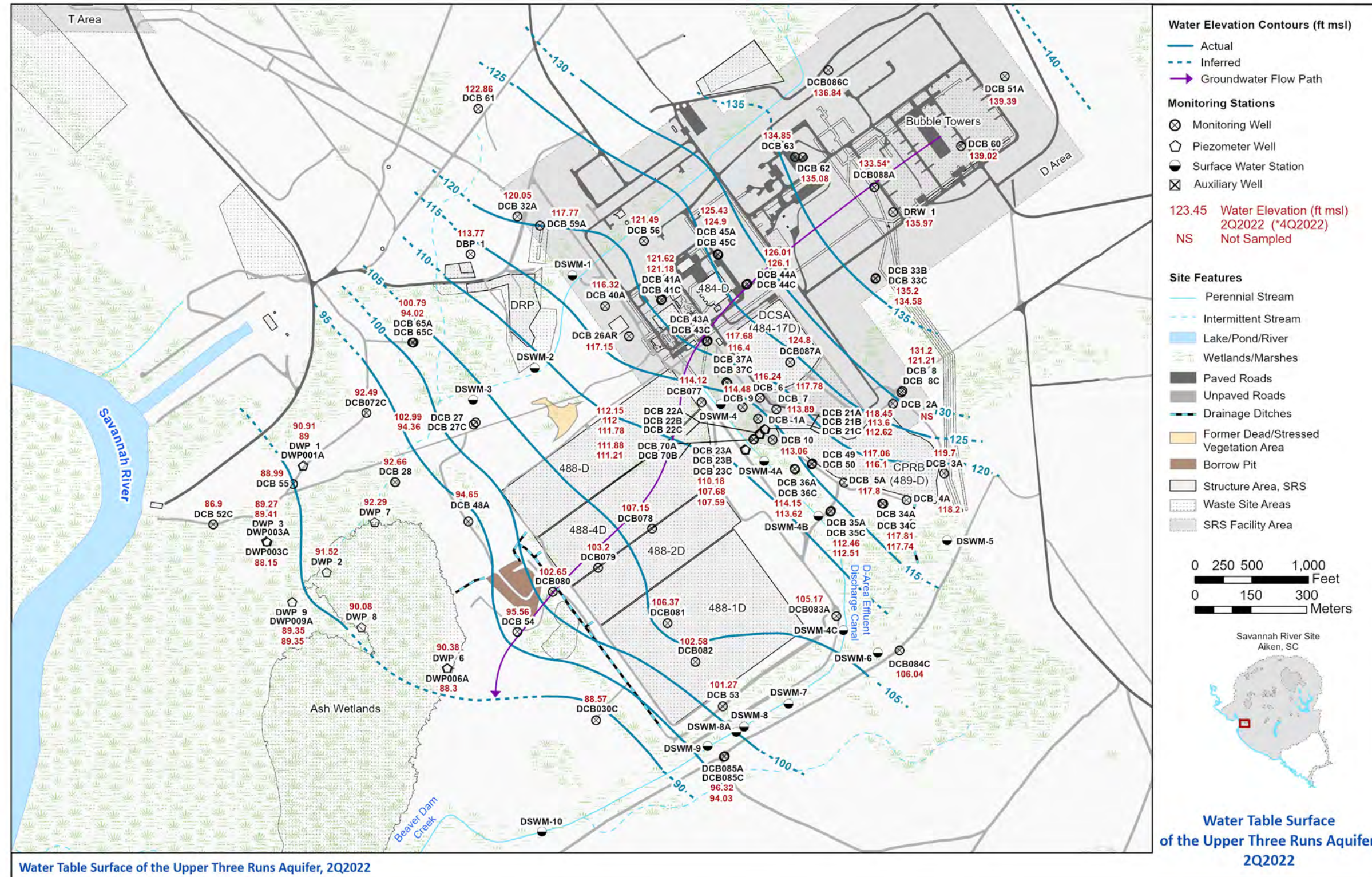


Figure 16. D-Area Groundwater OU UTRA Potentiometric Surface (2Q2022)

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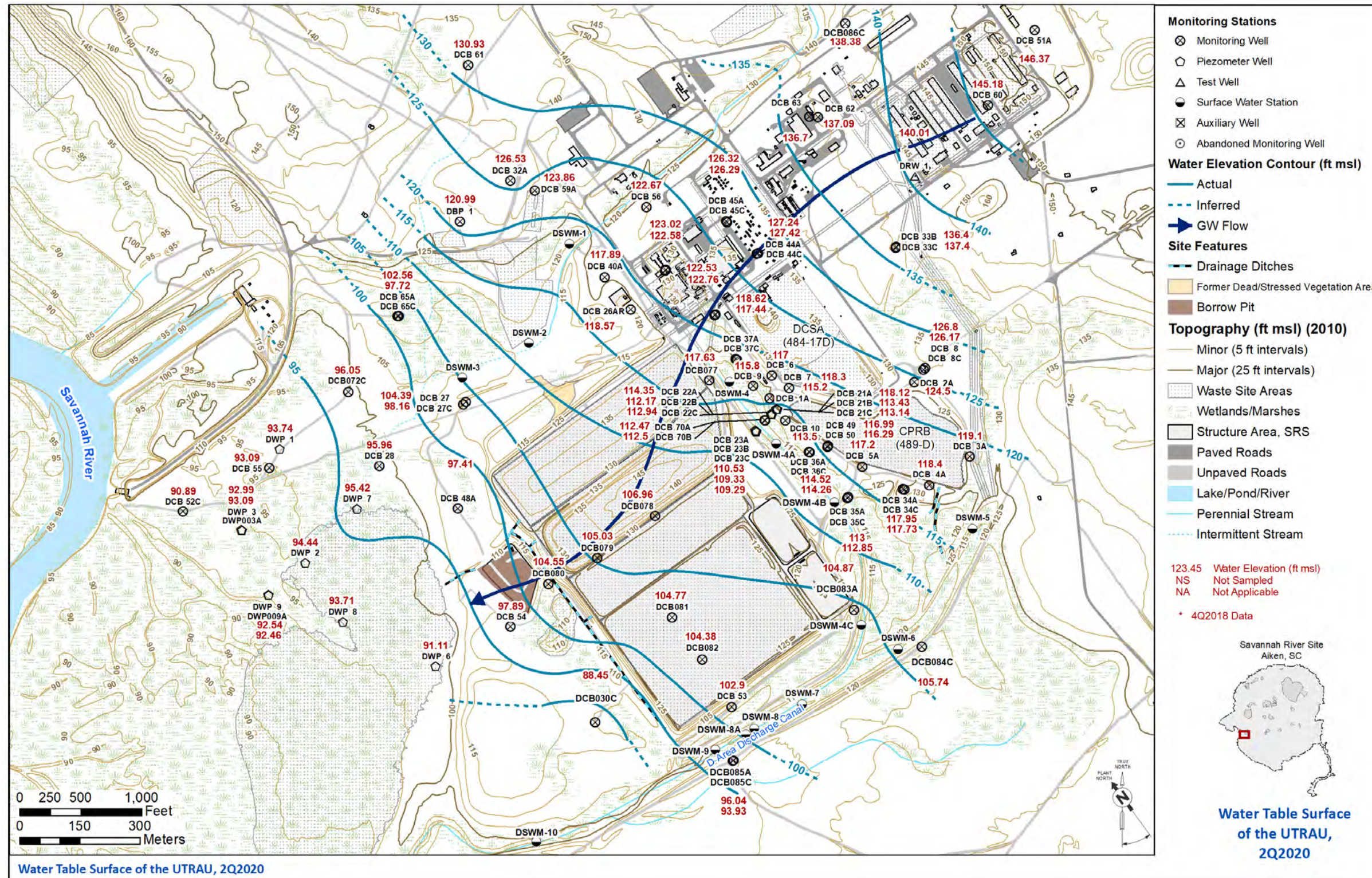


Figure 17. D-Area Groundwater OU UTRA Potentiometric Surface (2Q2020)

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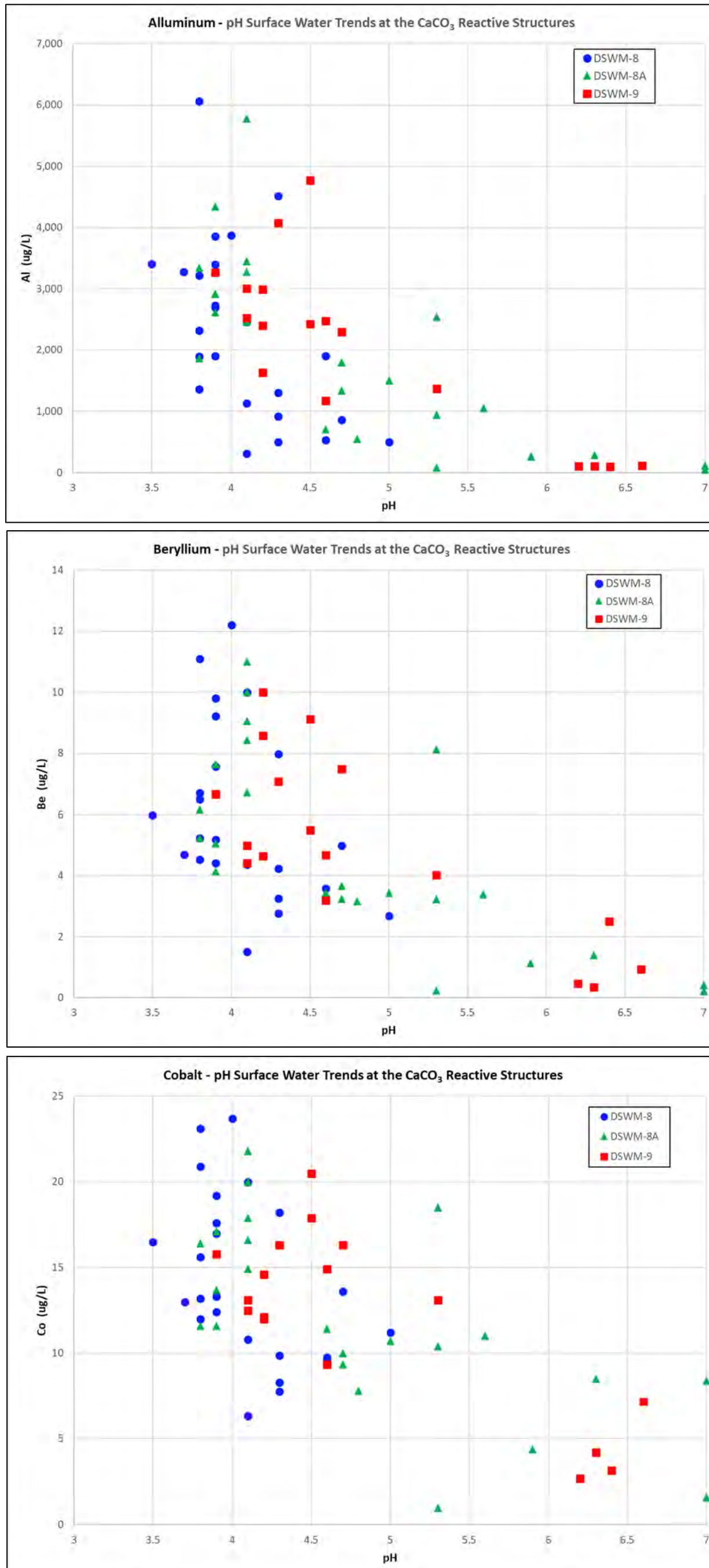


Figure 18. Surface Water Concentrations of pH and Beryllium at DSWM-8, DSWM-8A, and DSWM-9

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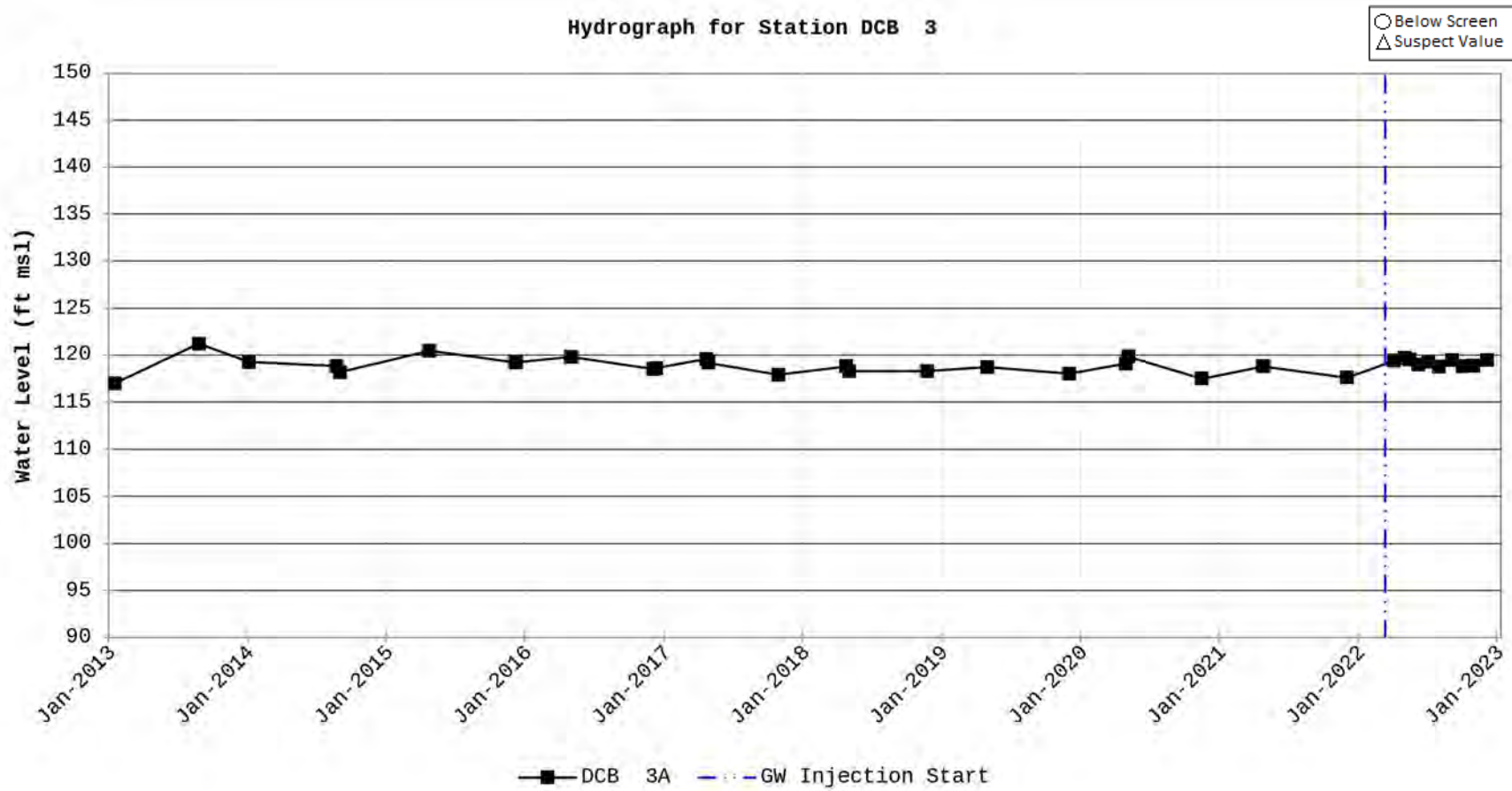
APPENDIX A

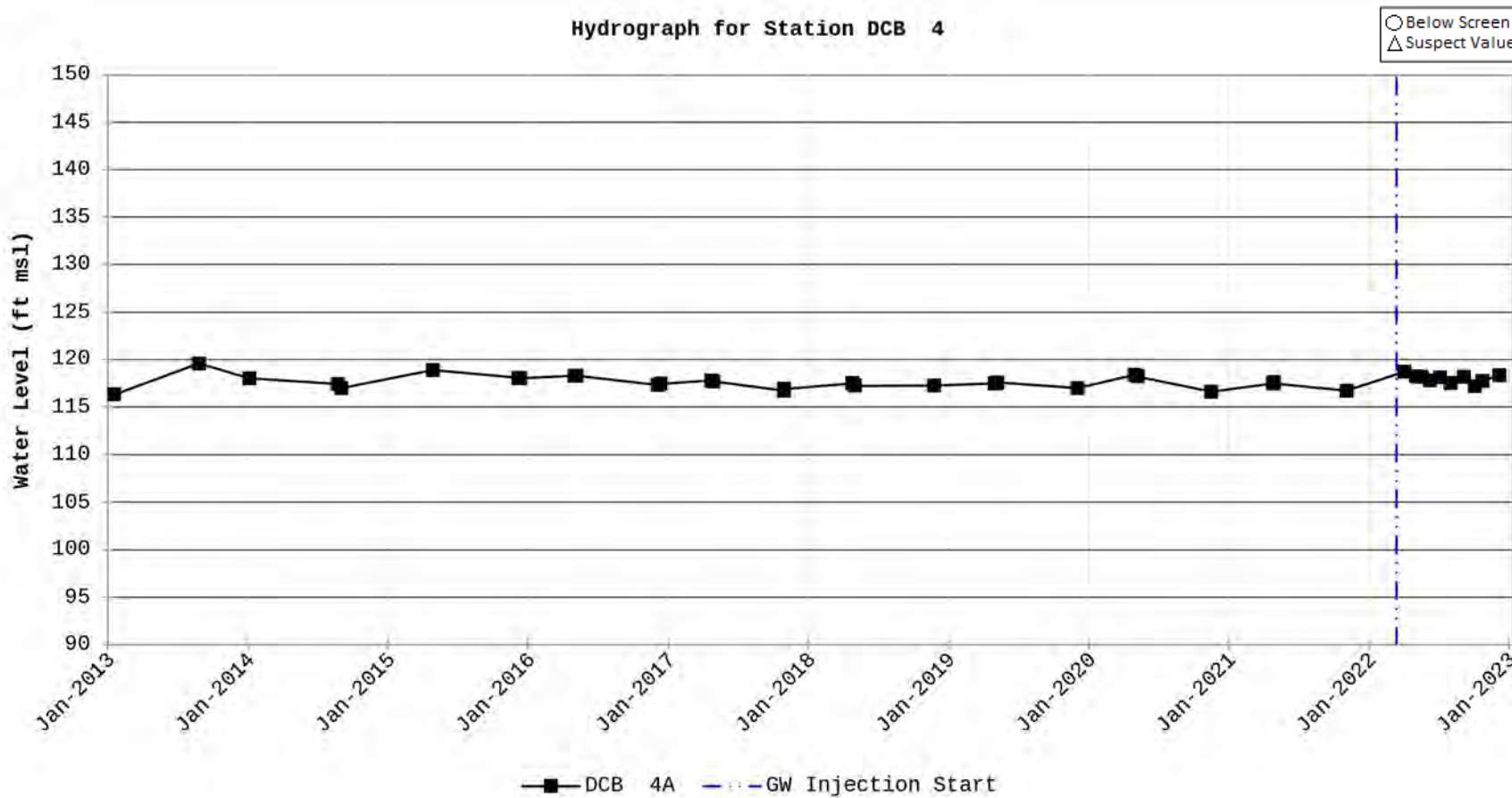
D-Area Groundwater Treatability Study Data Table (2022)

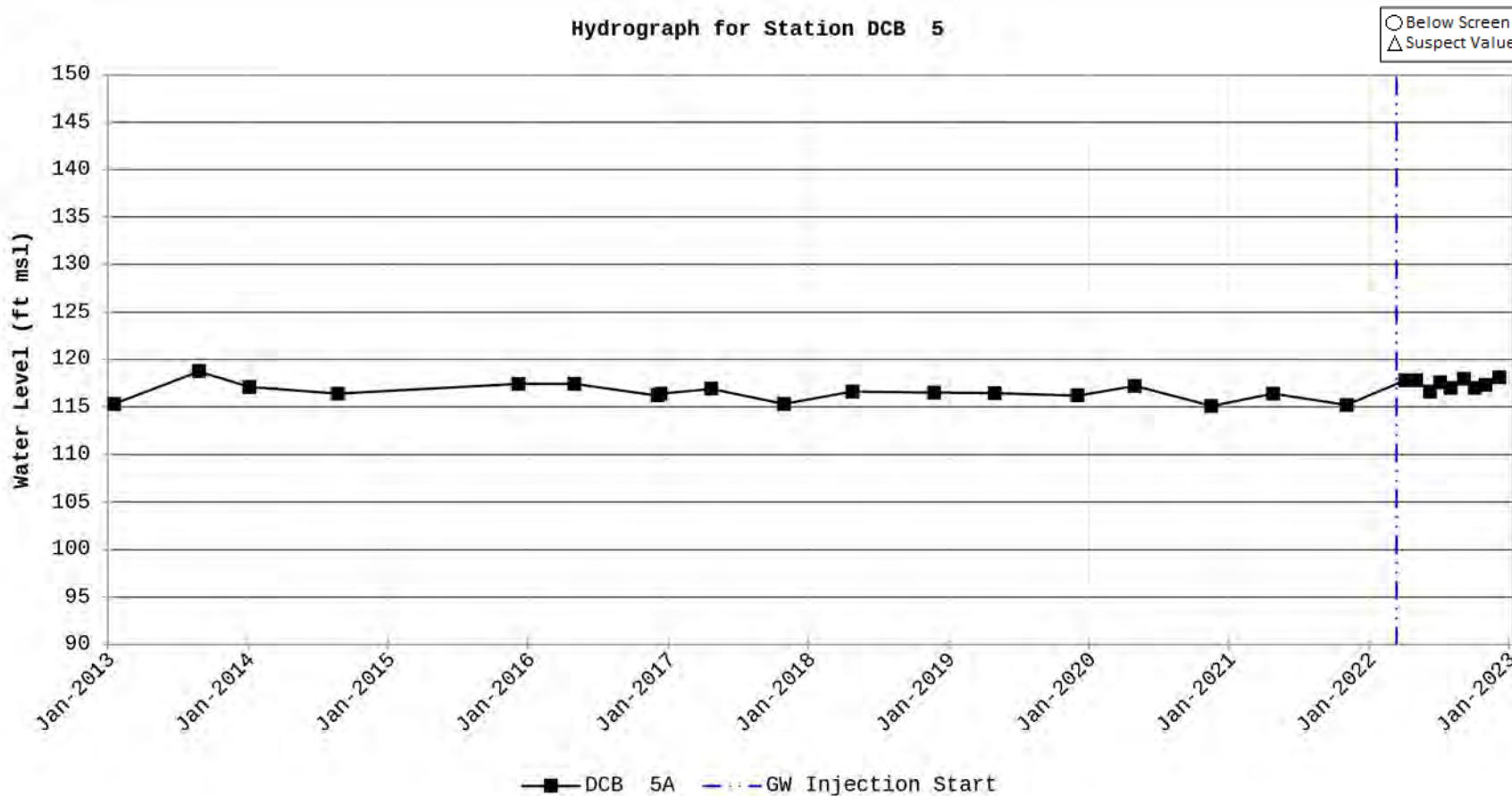
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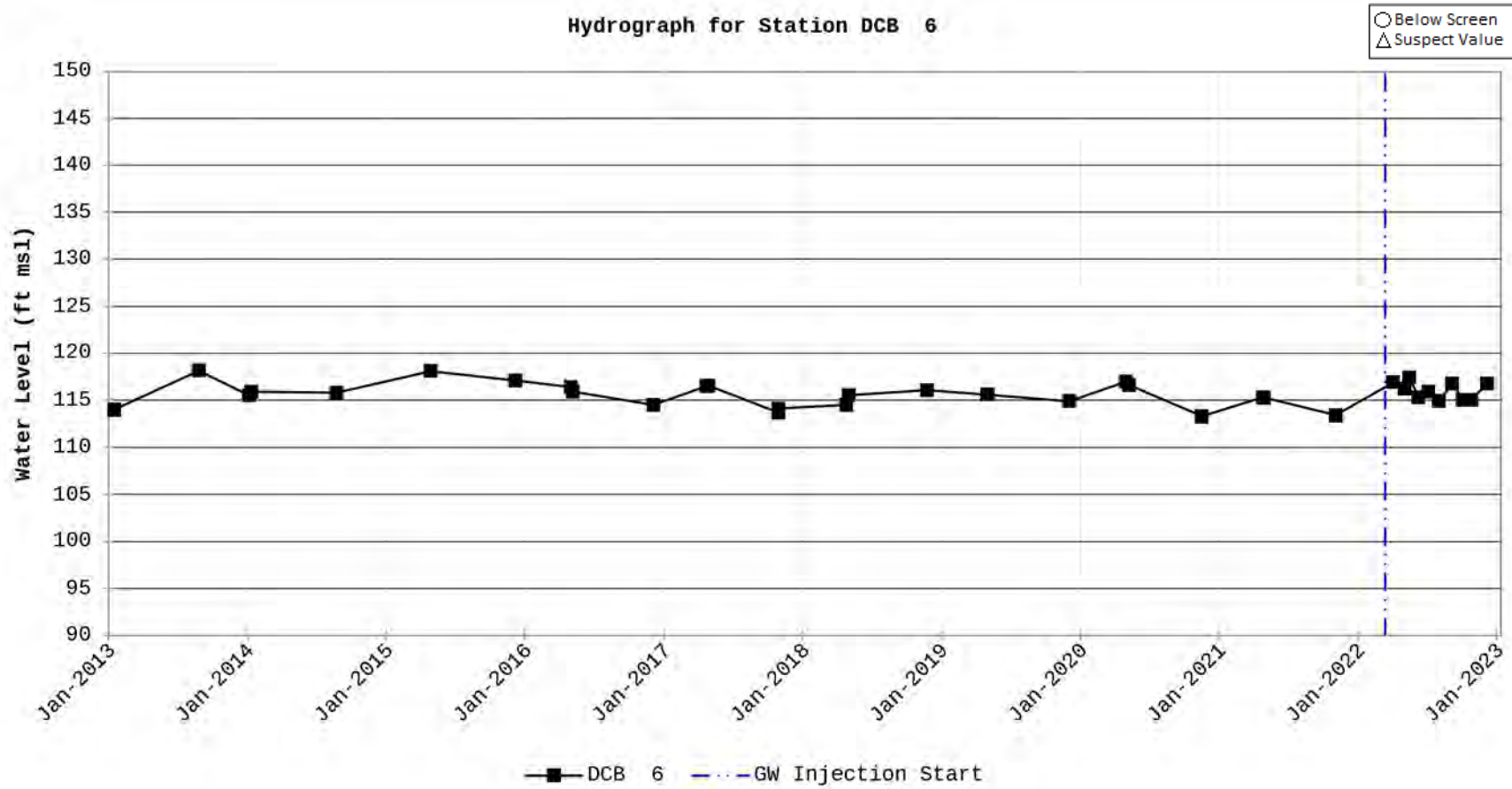
Appendix B

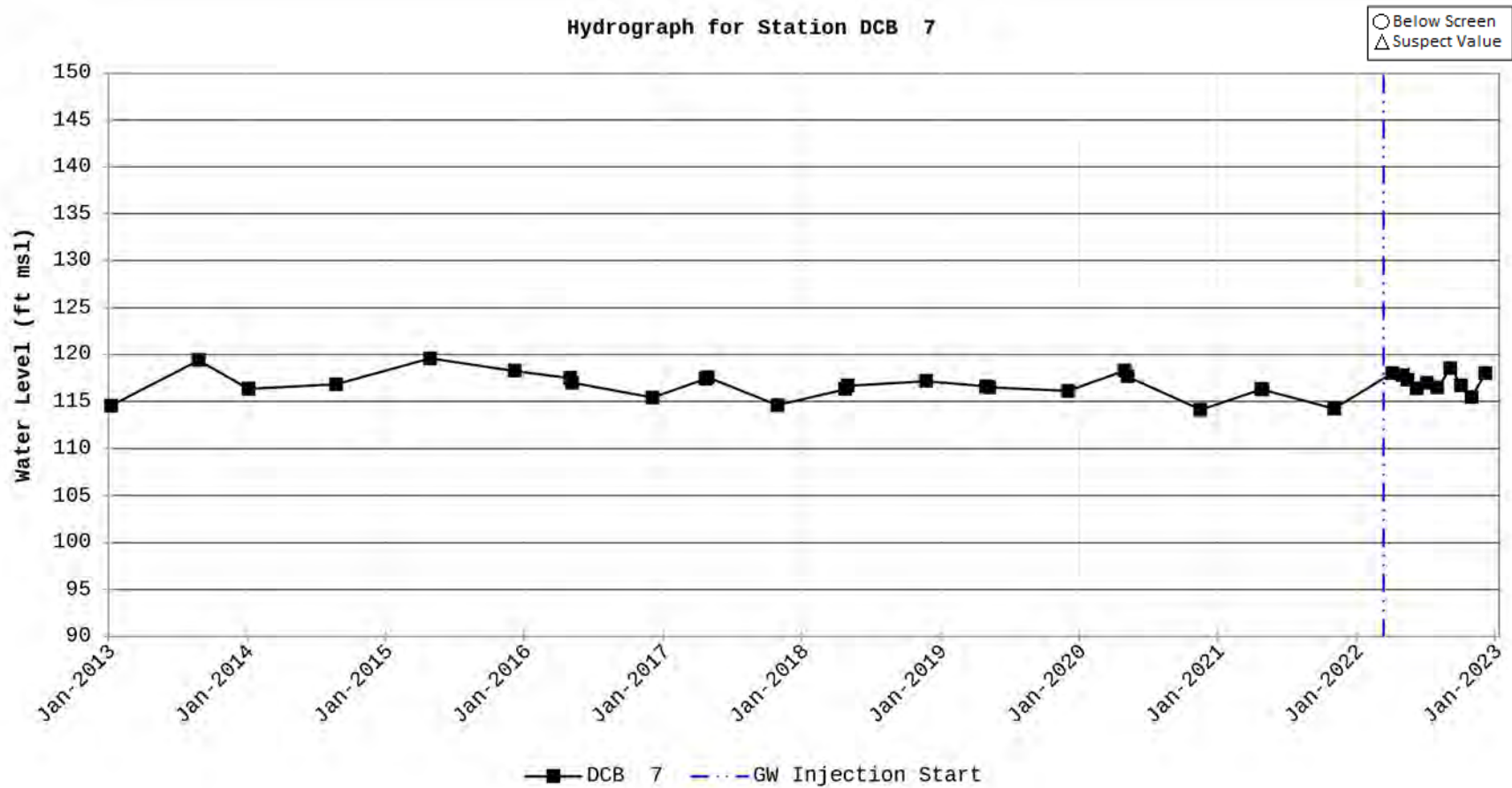
Hydrographs

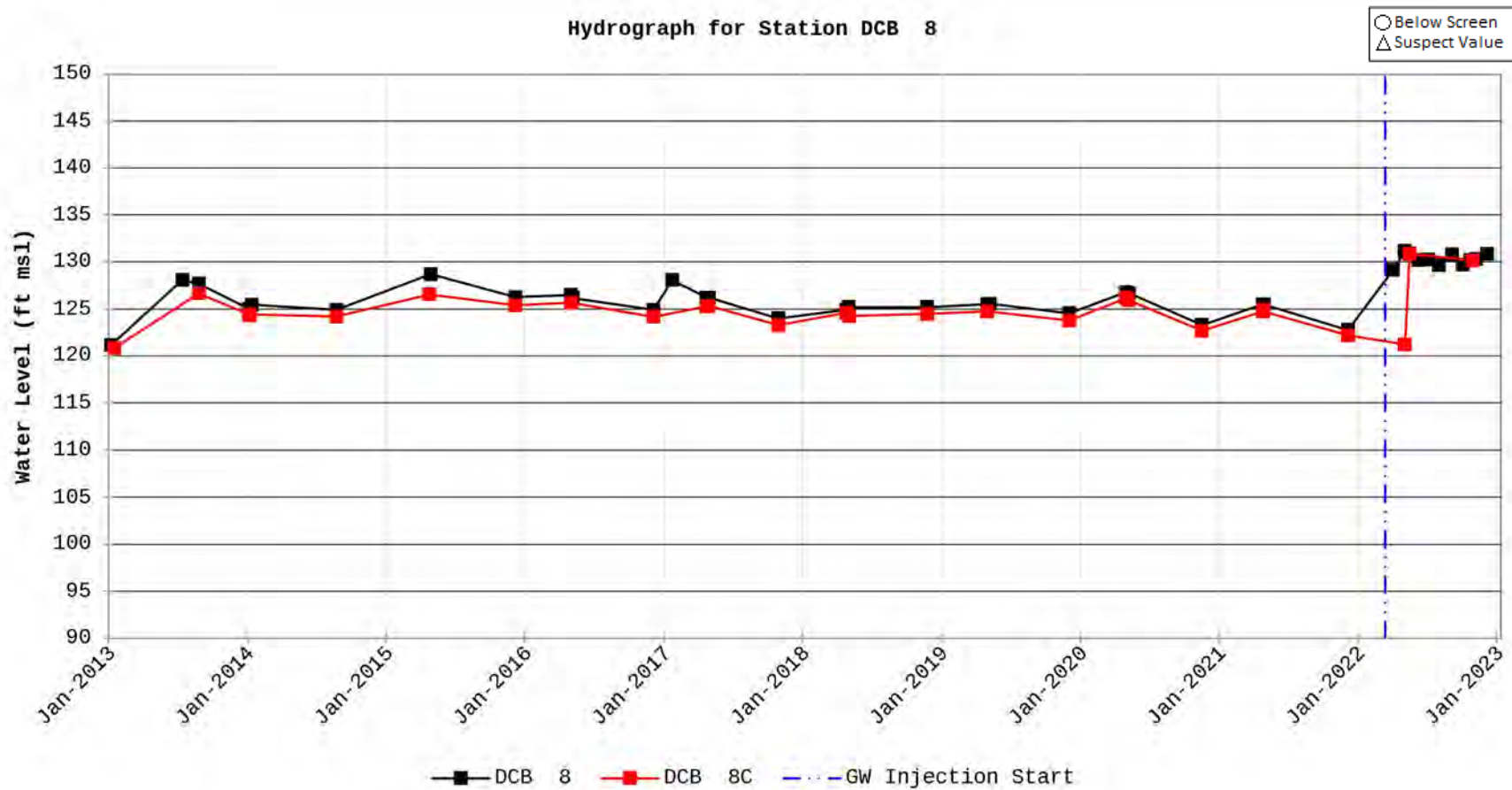


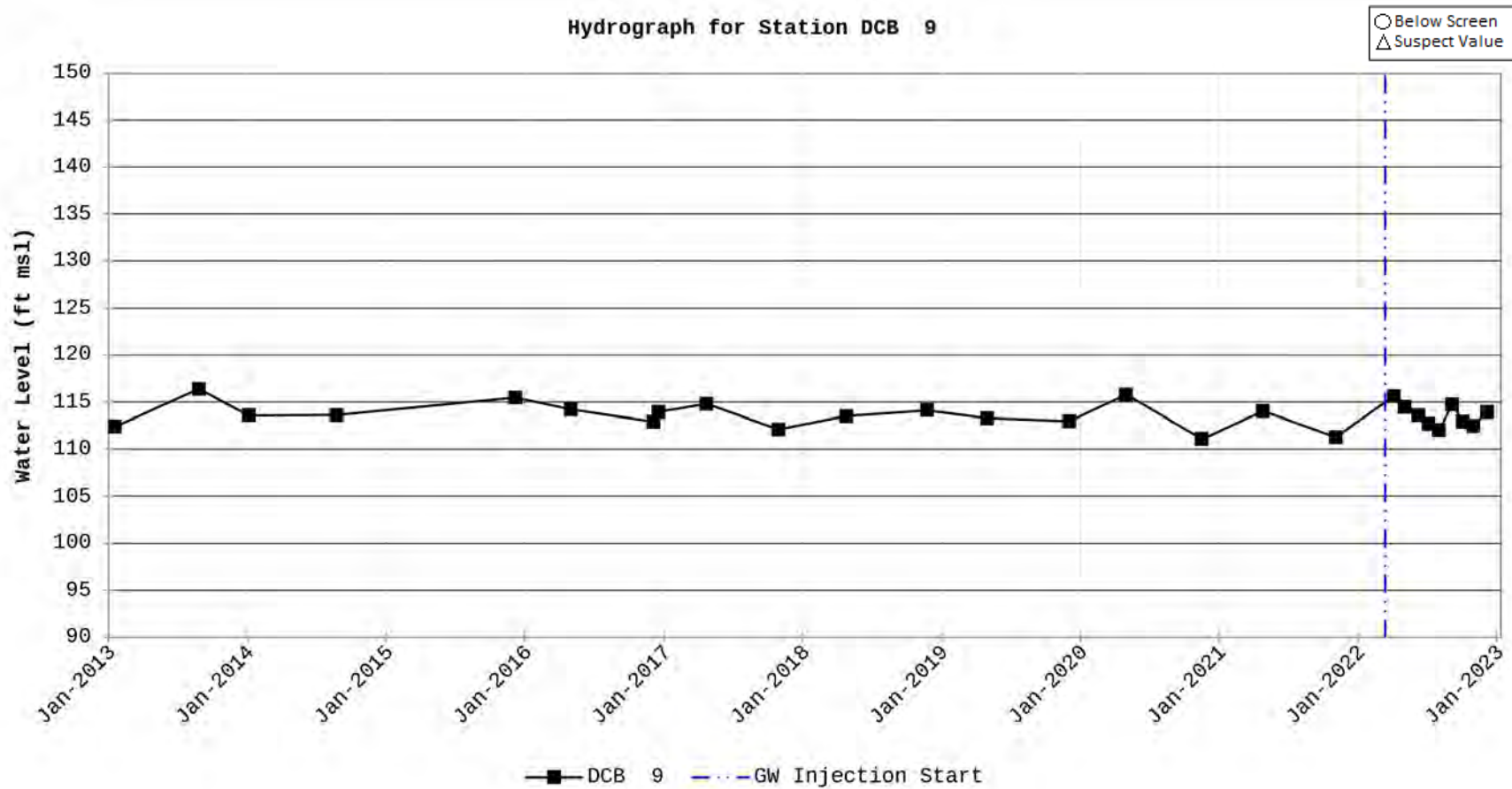


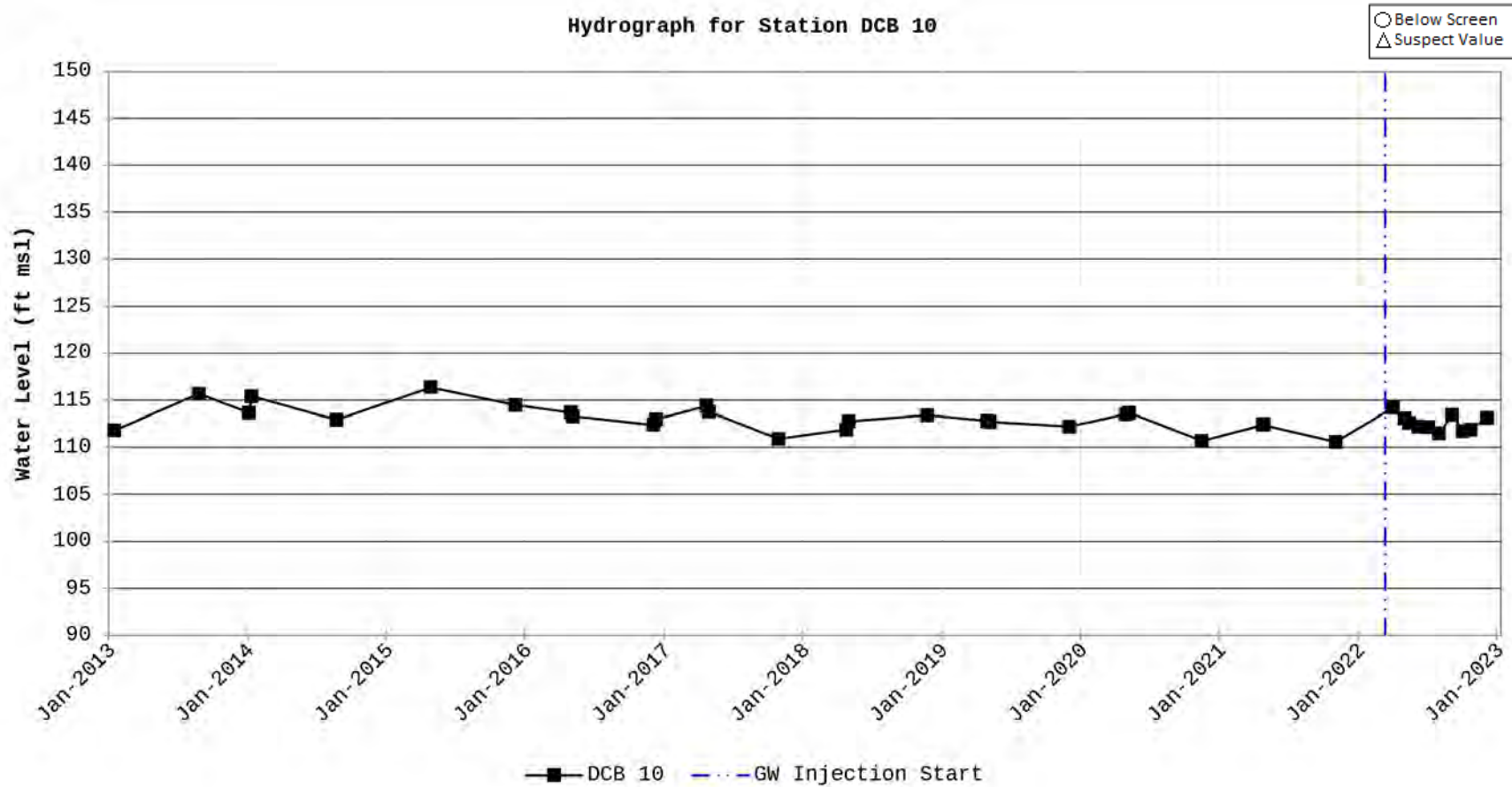


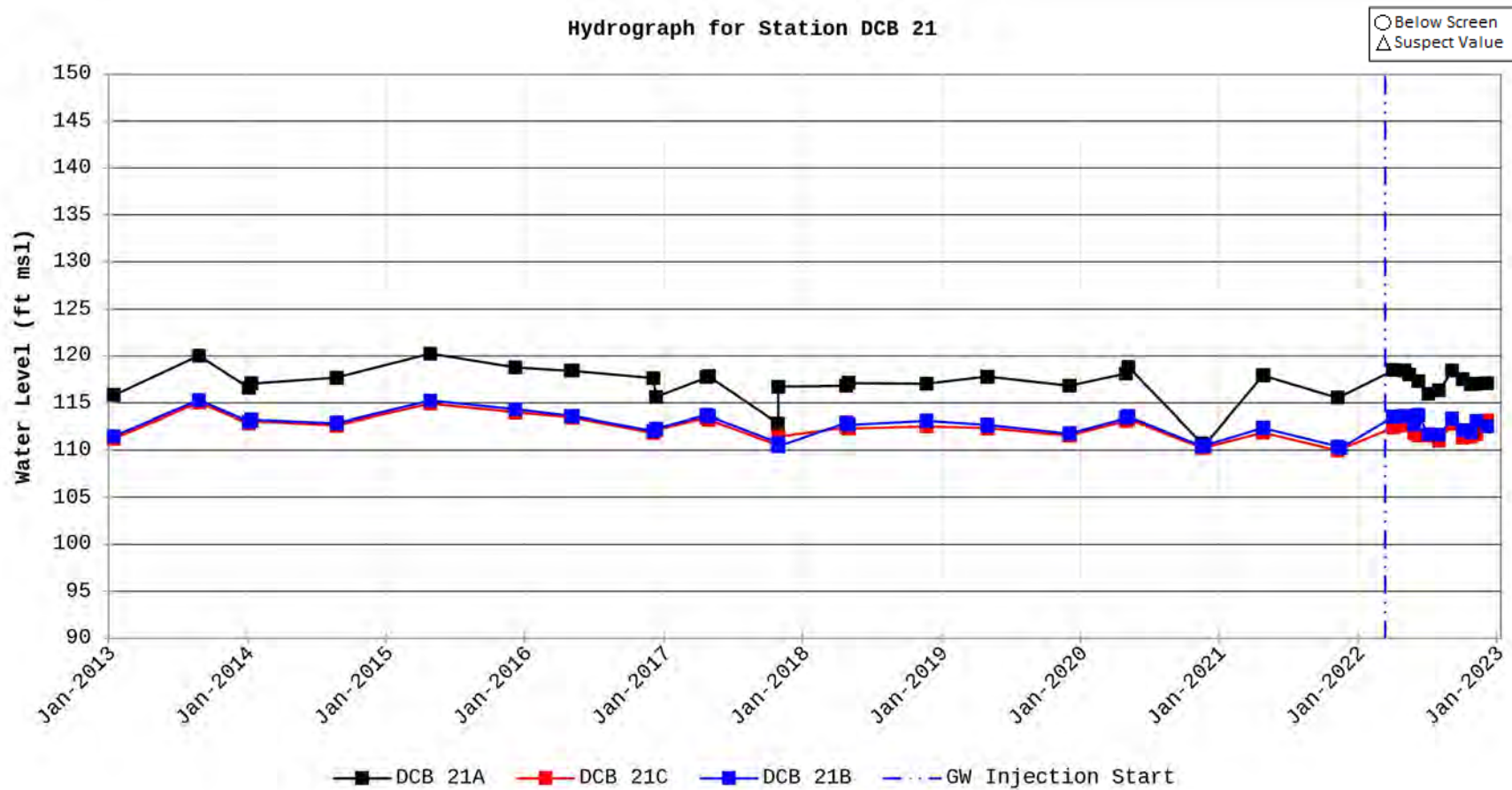


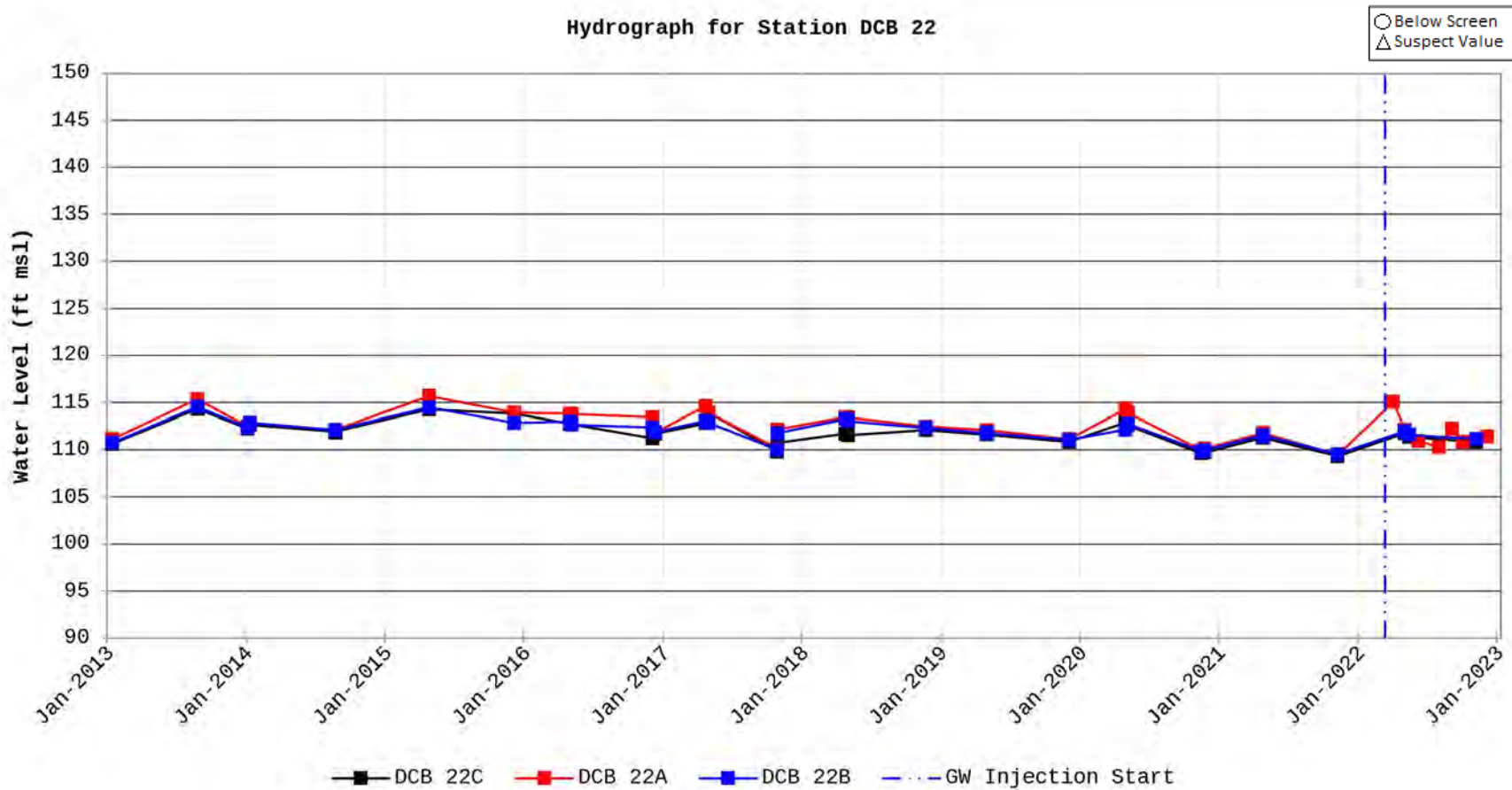


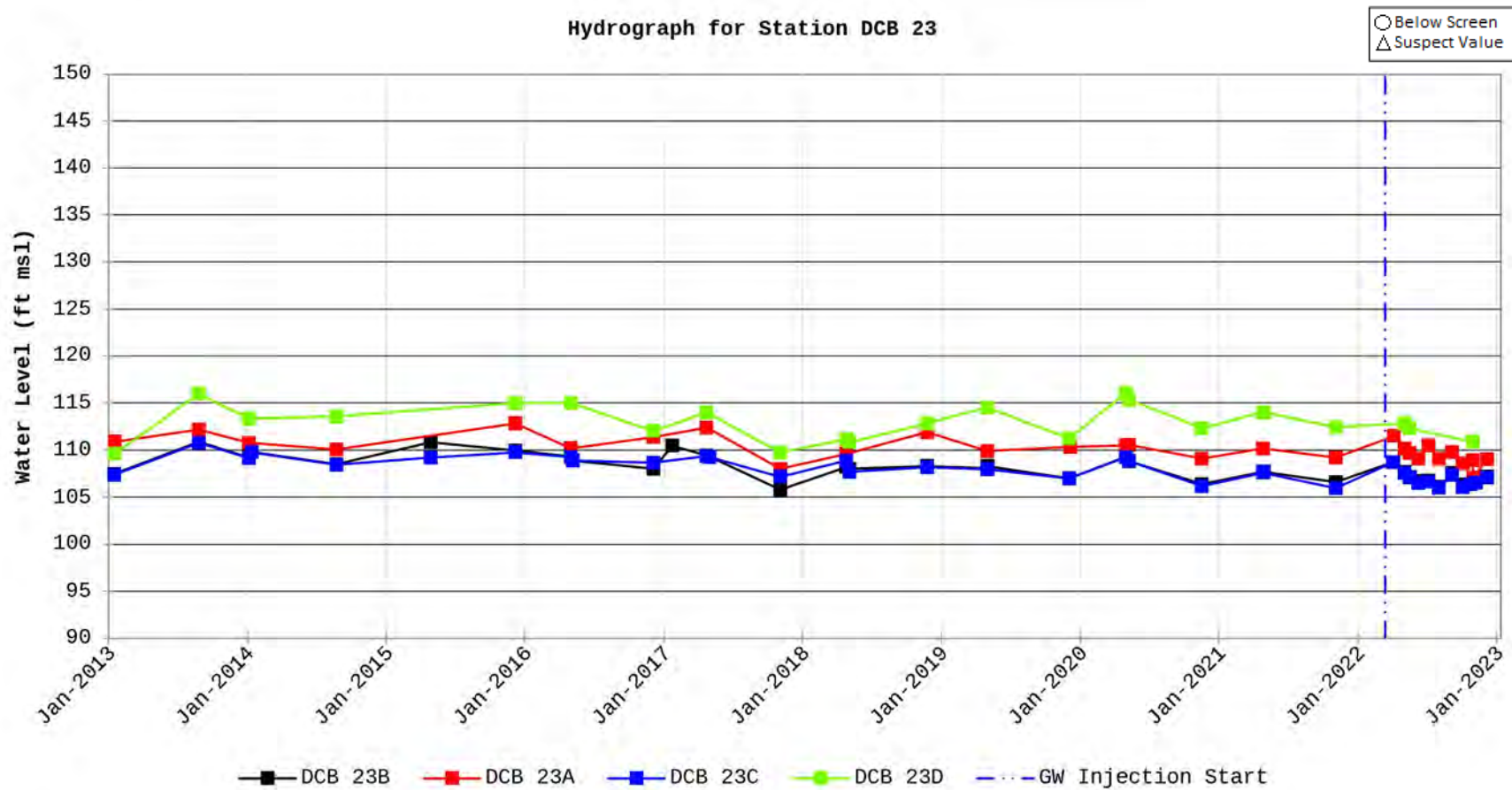


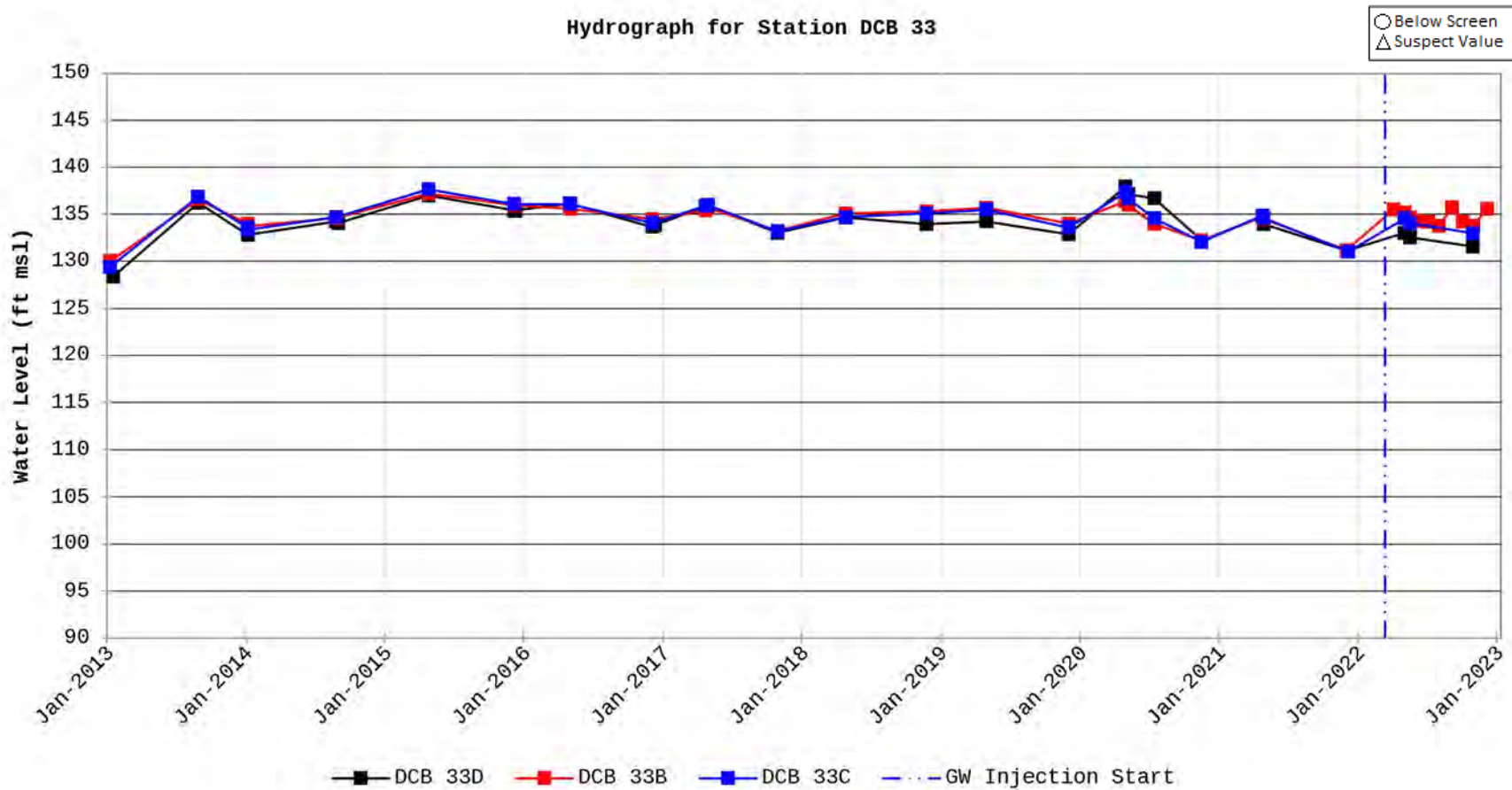


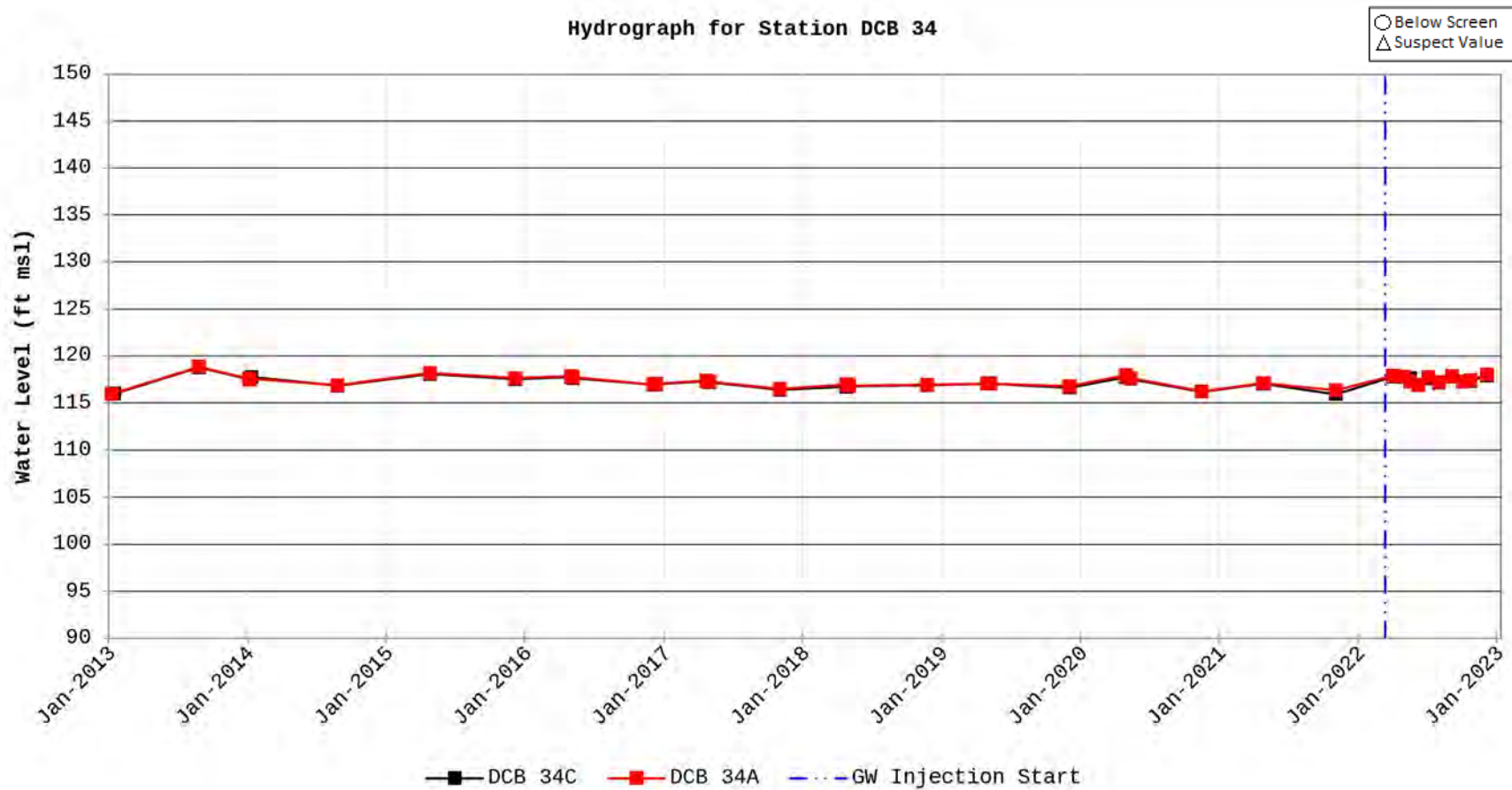


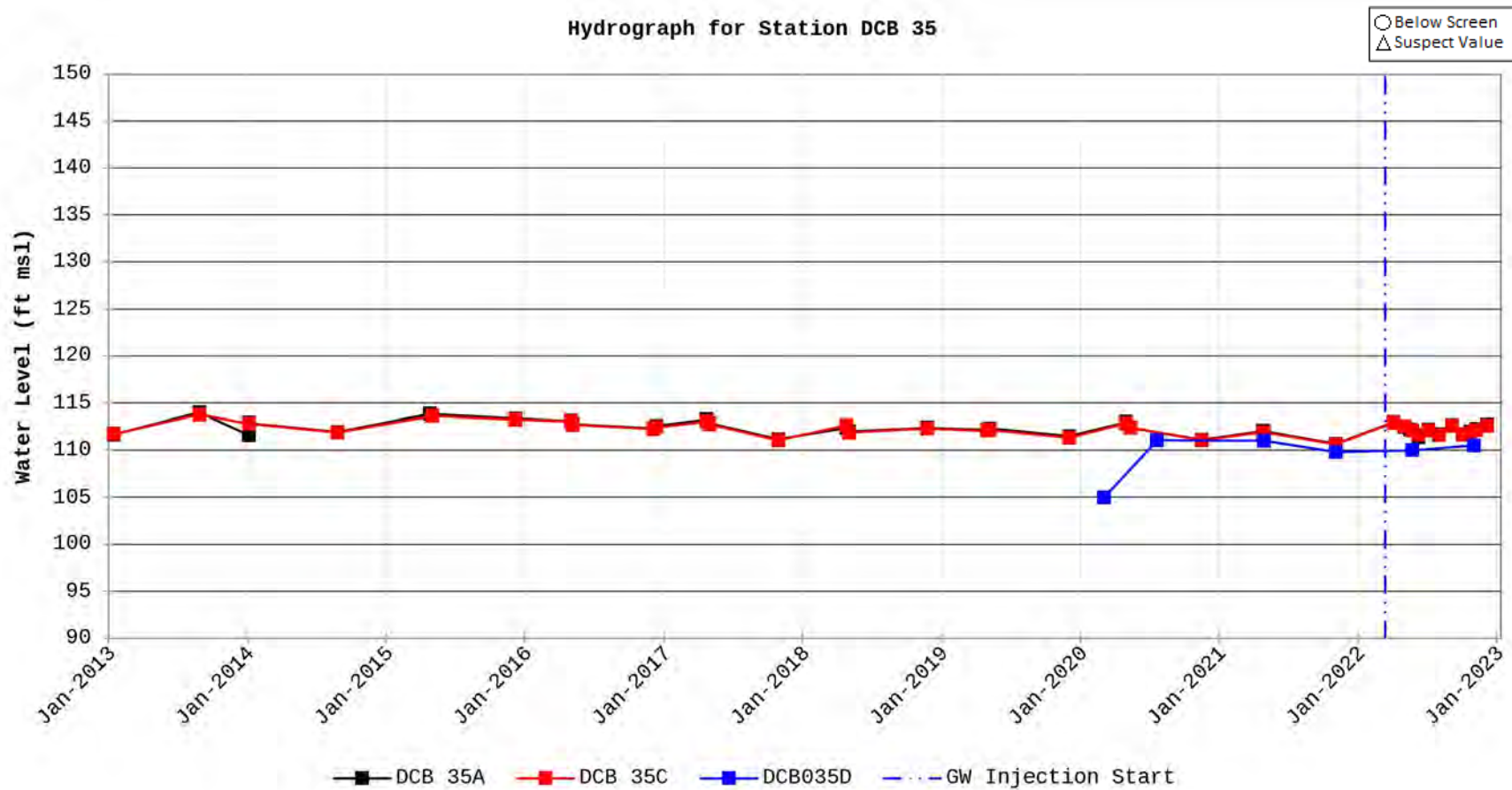


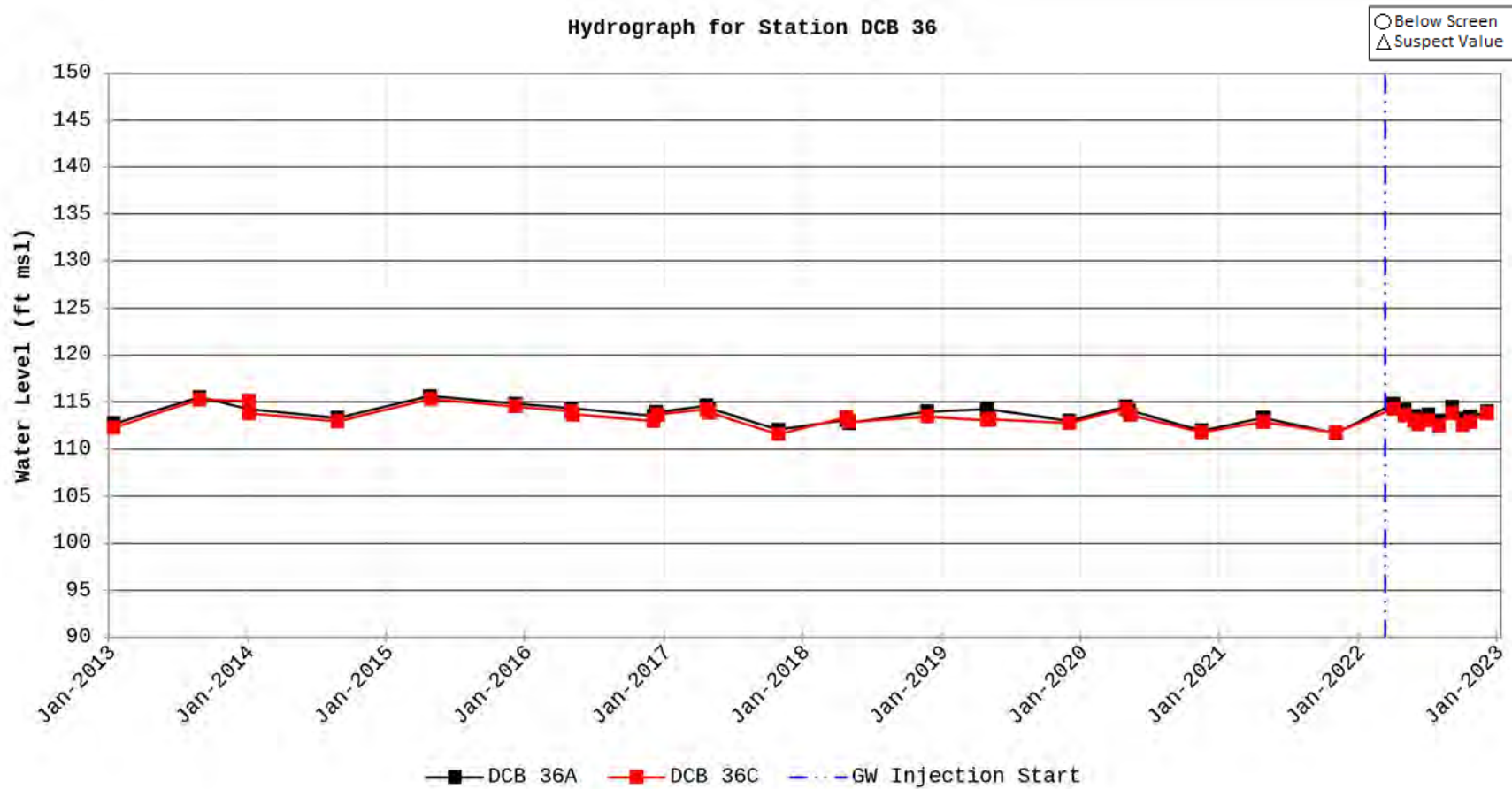


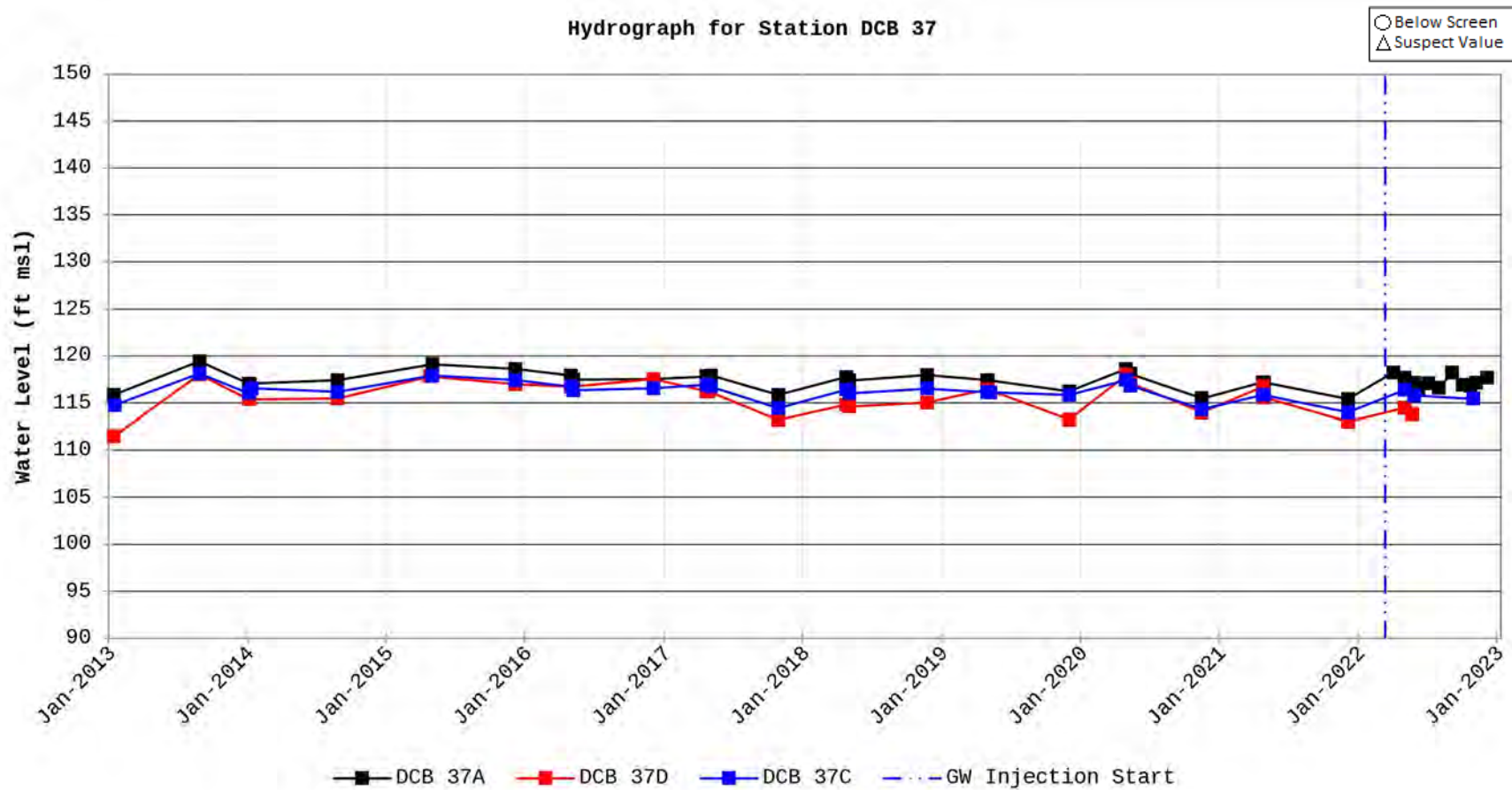


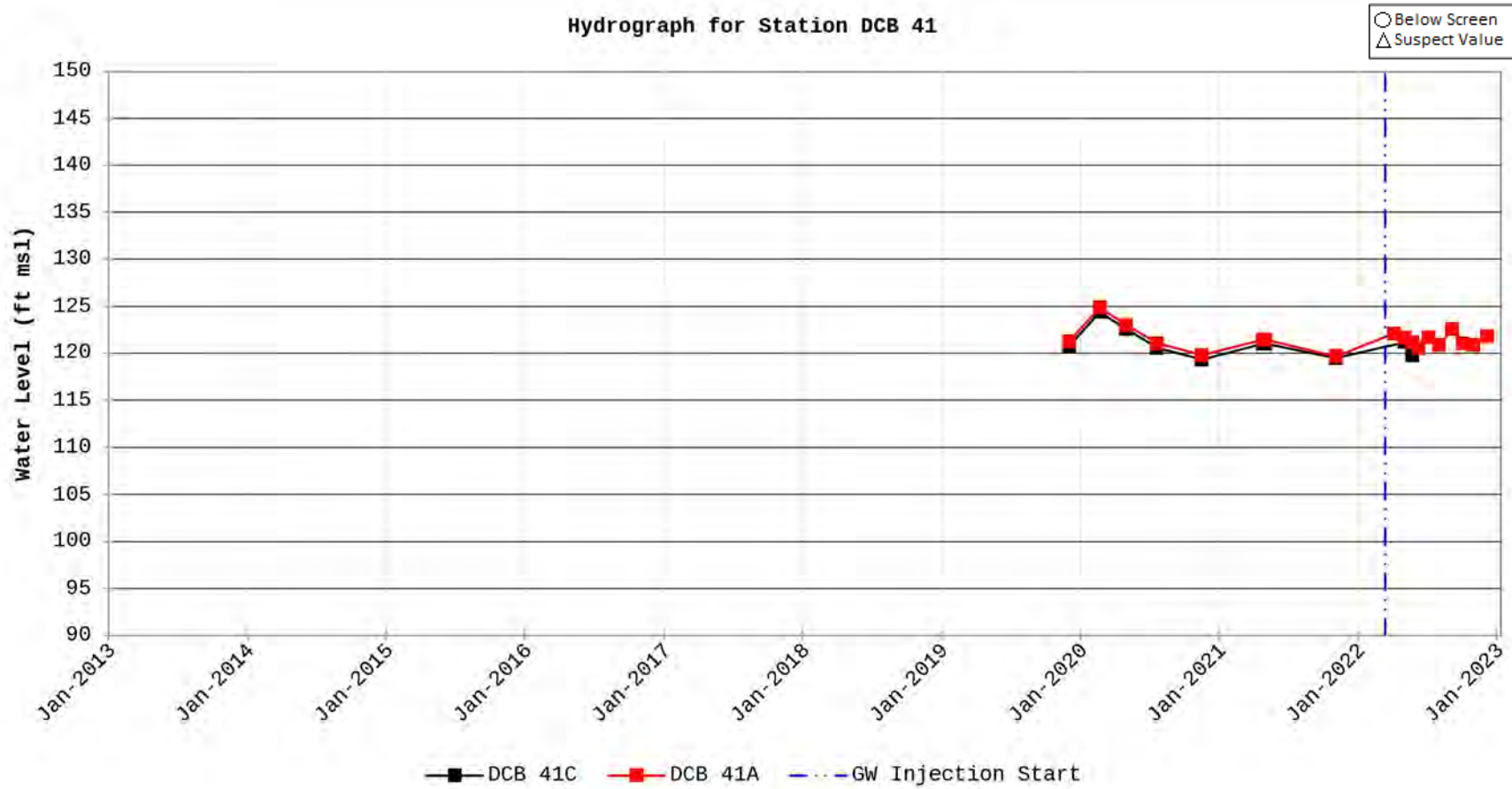


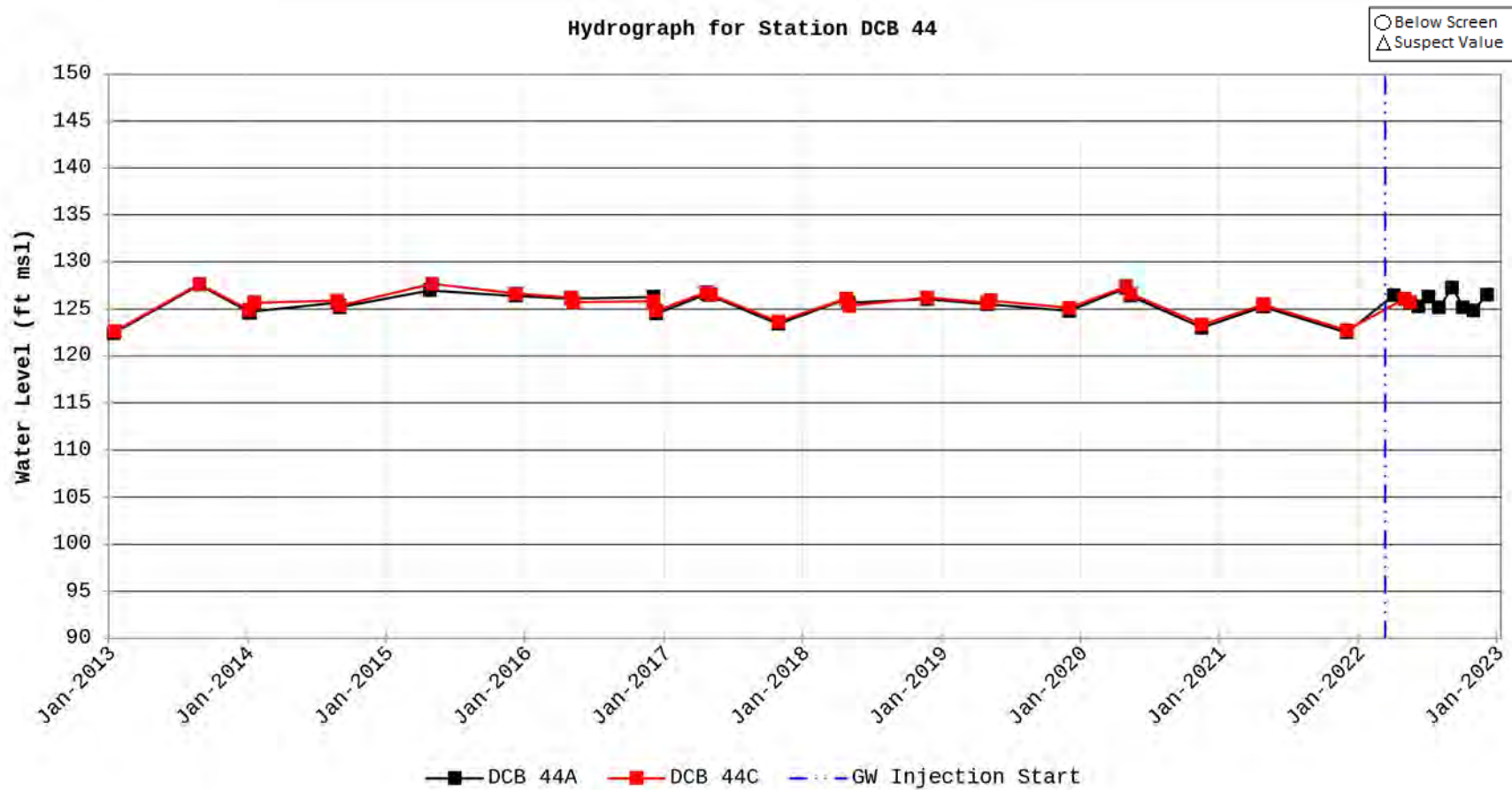


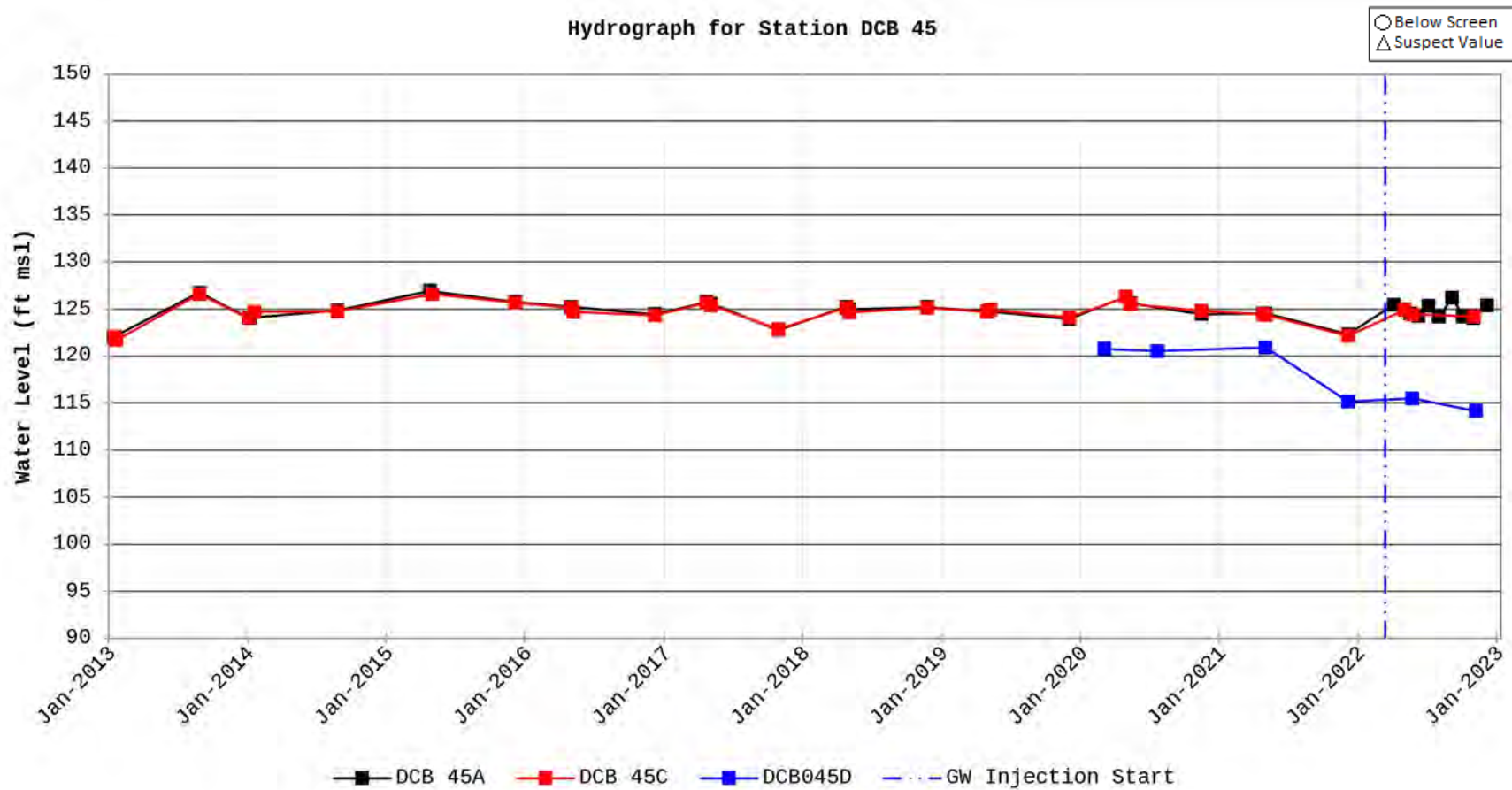


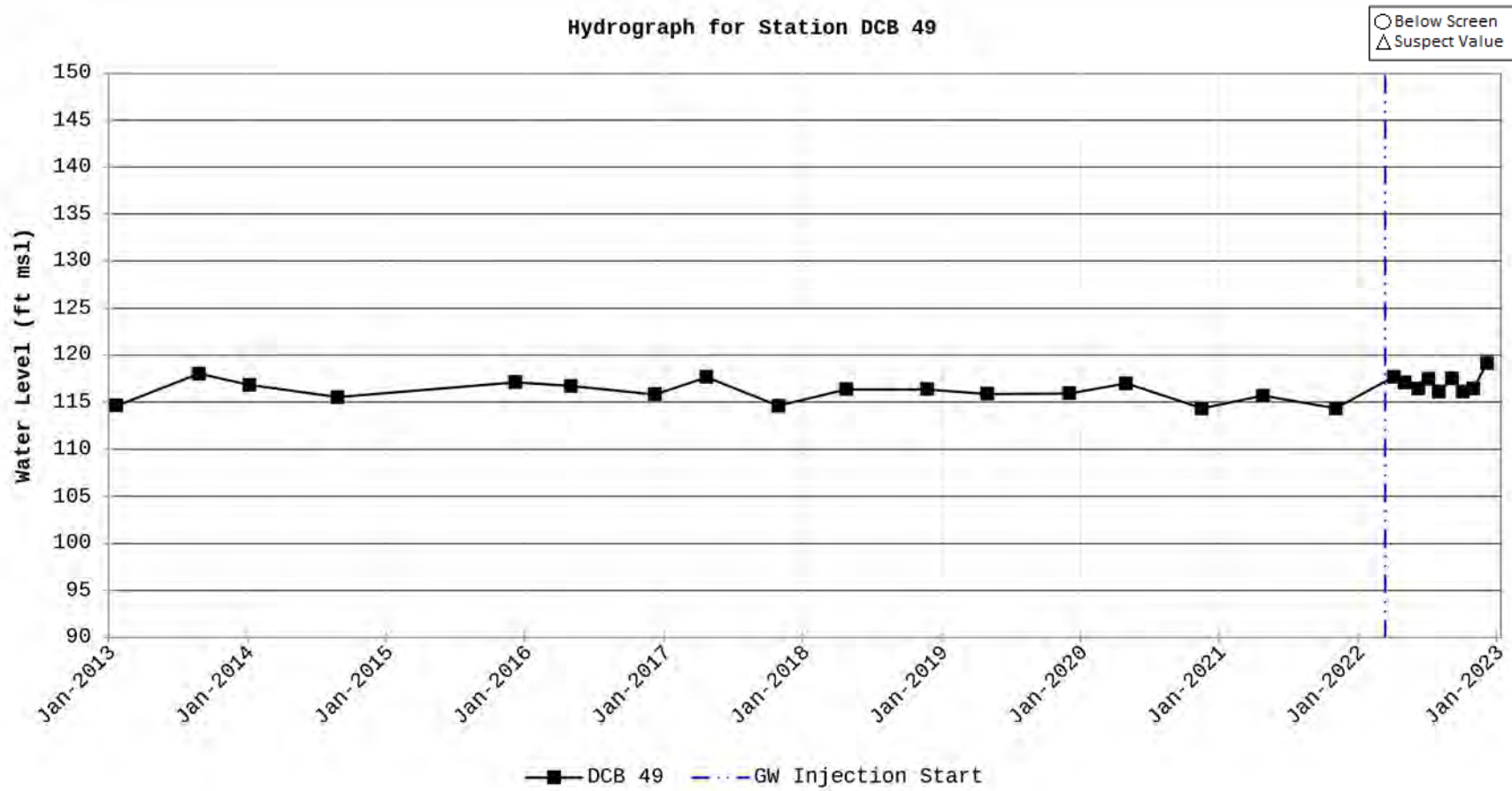


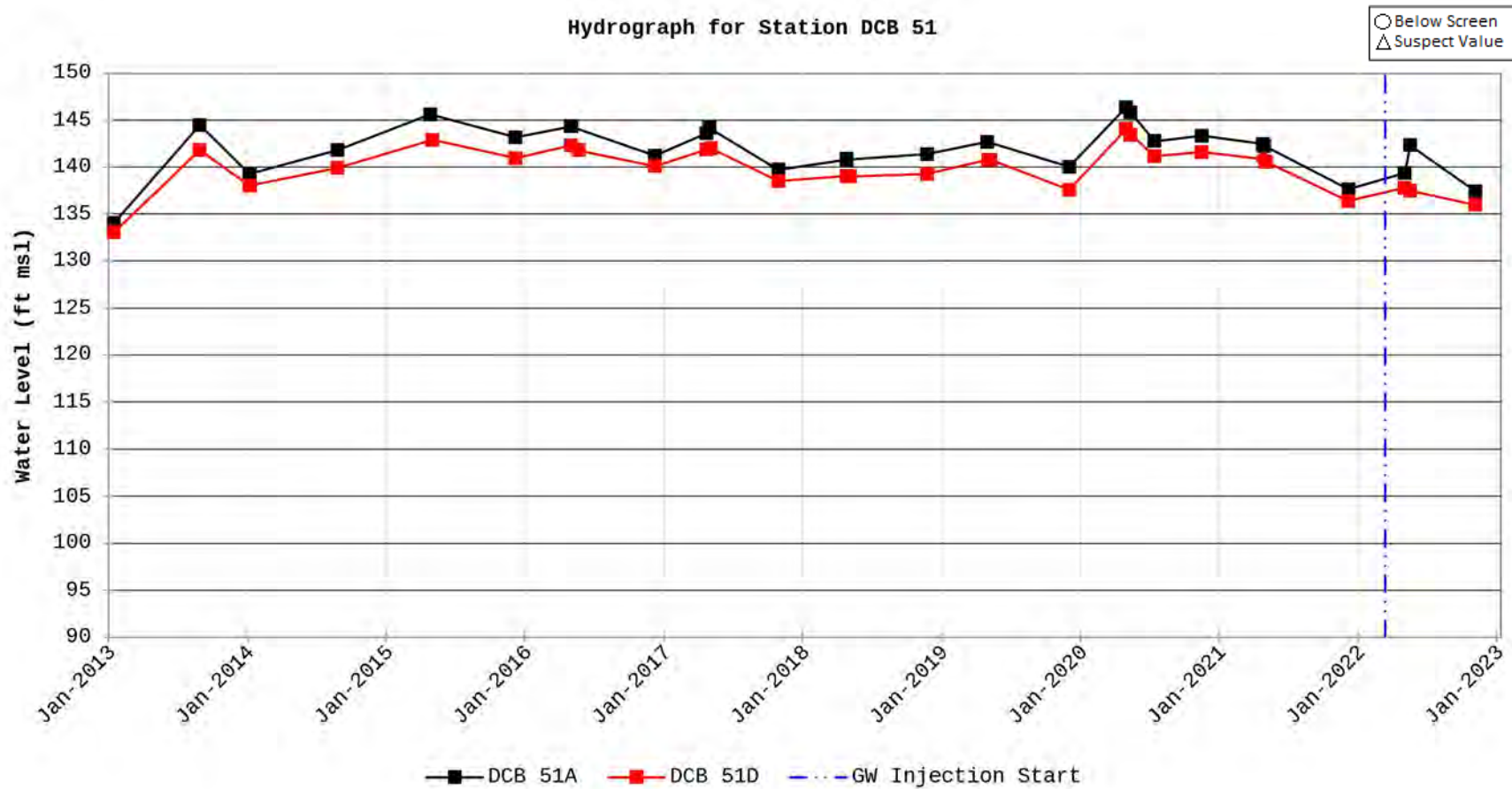


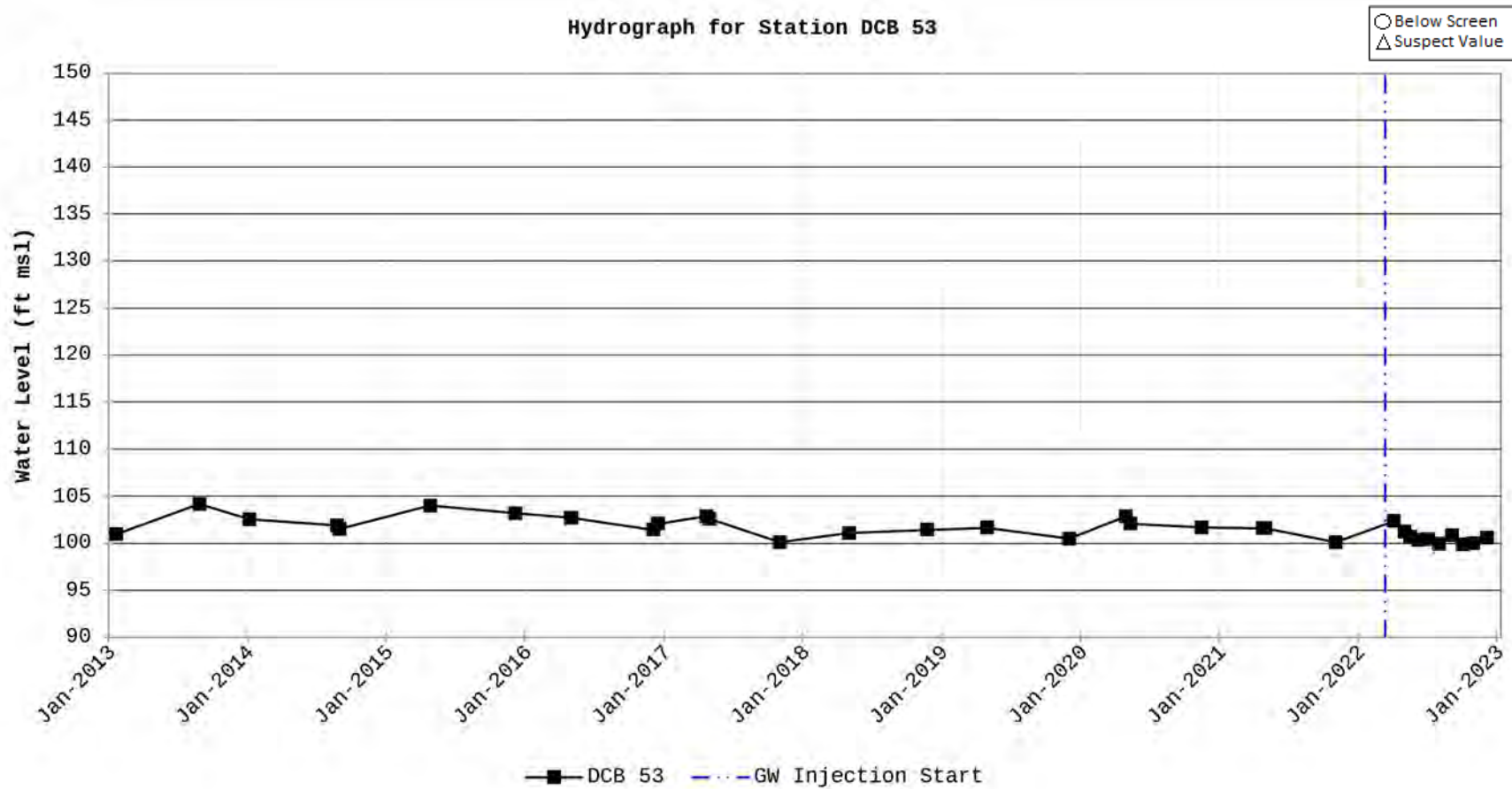


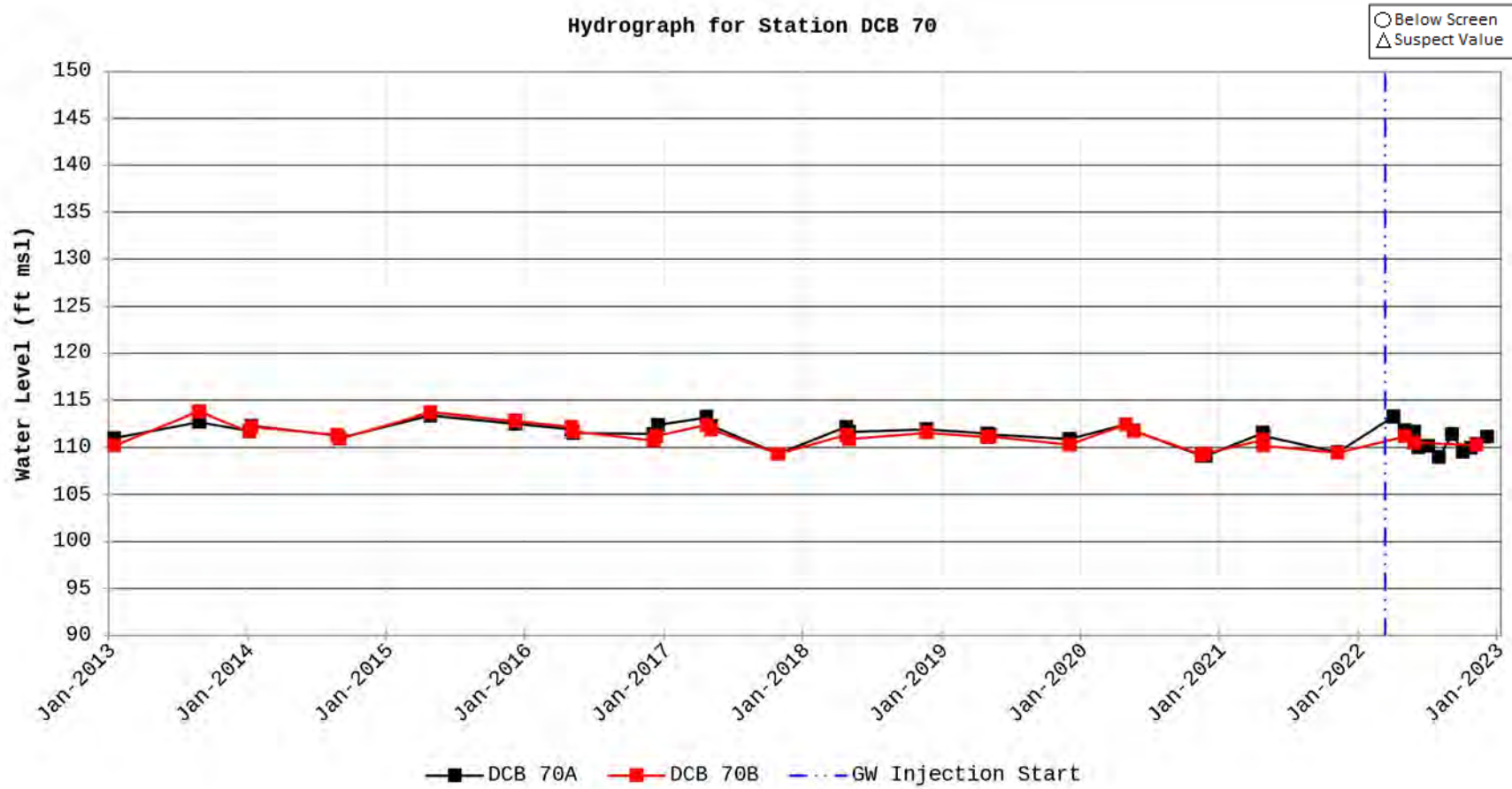


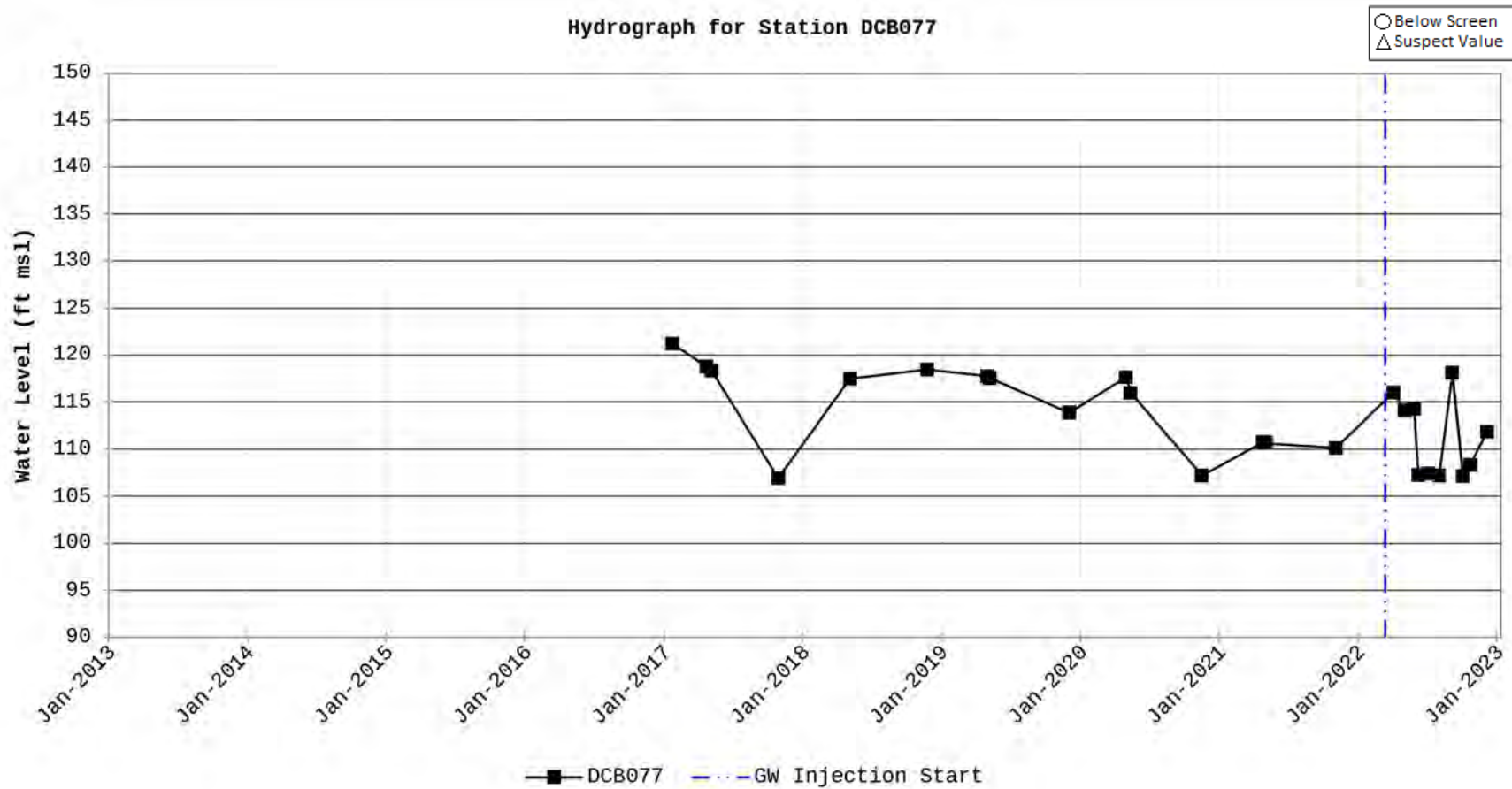


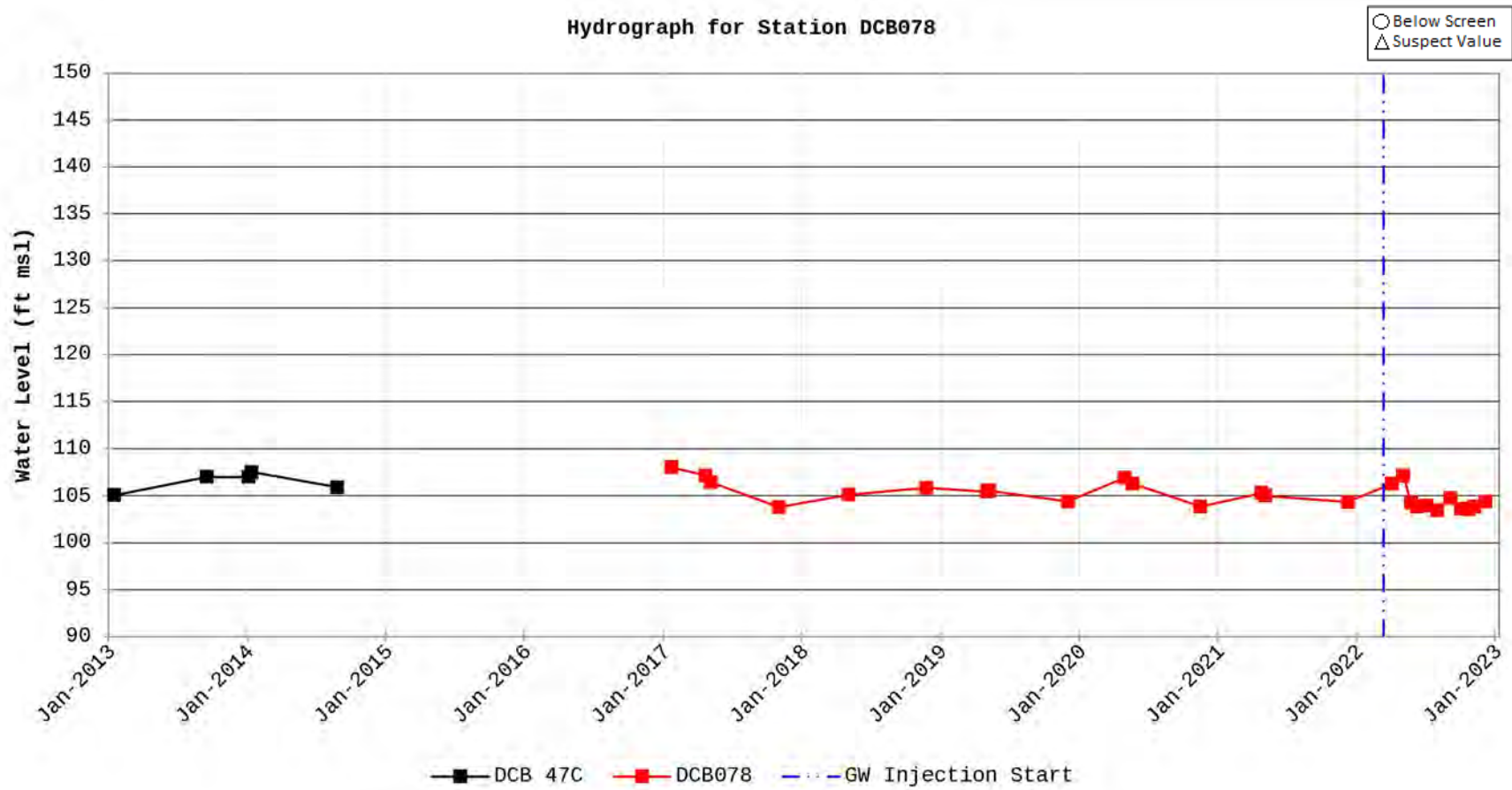


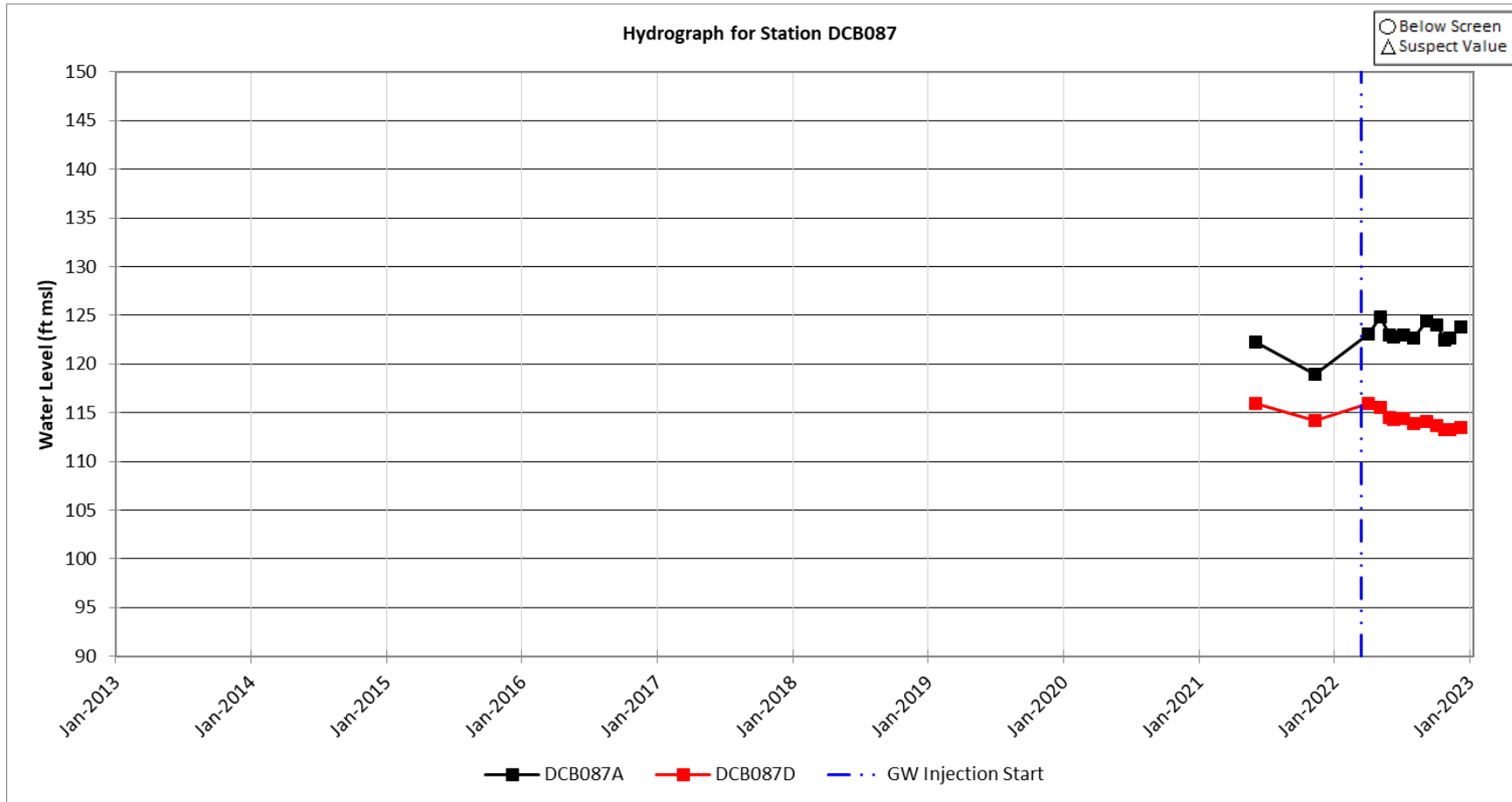






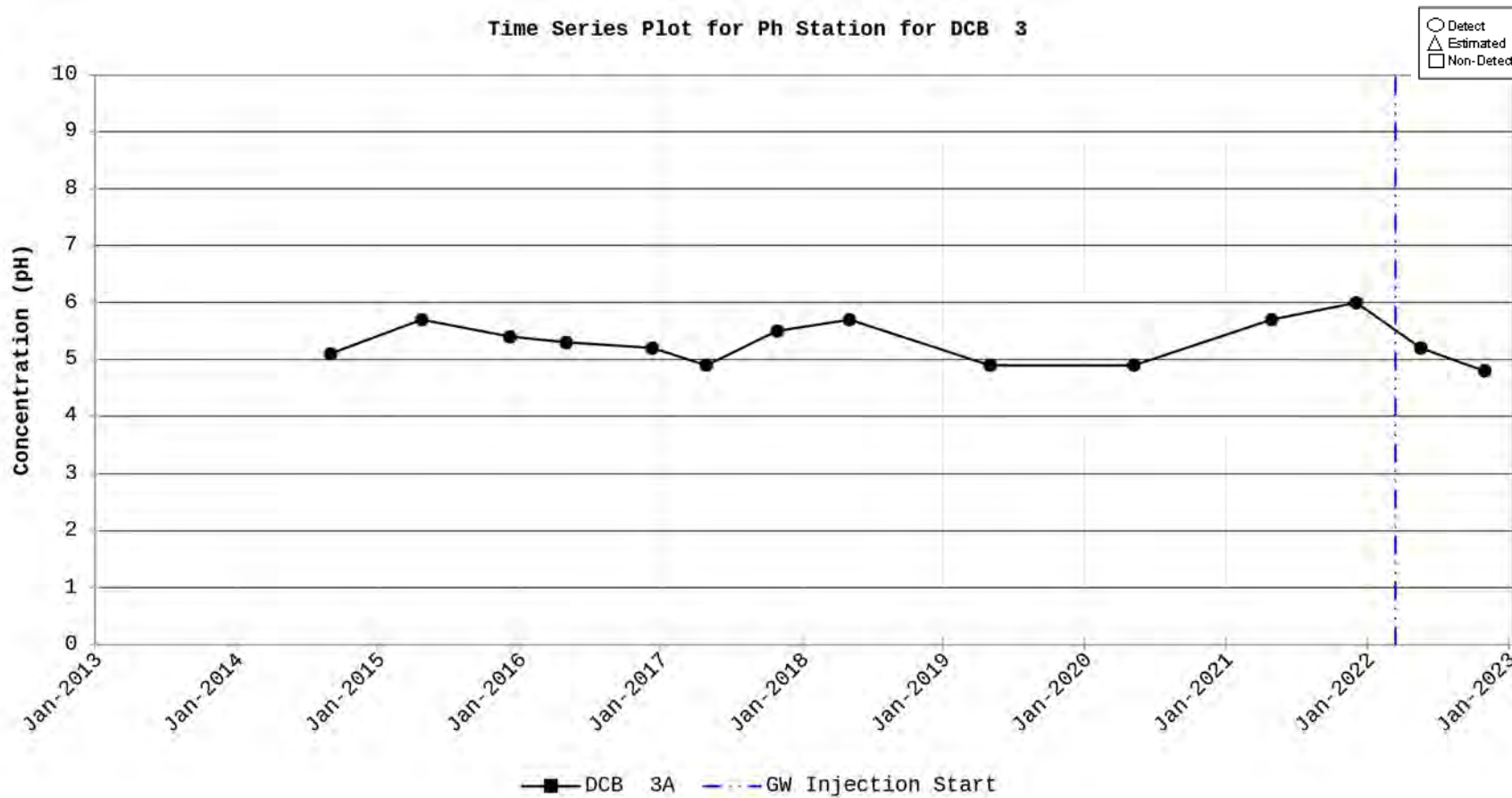


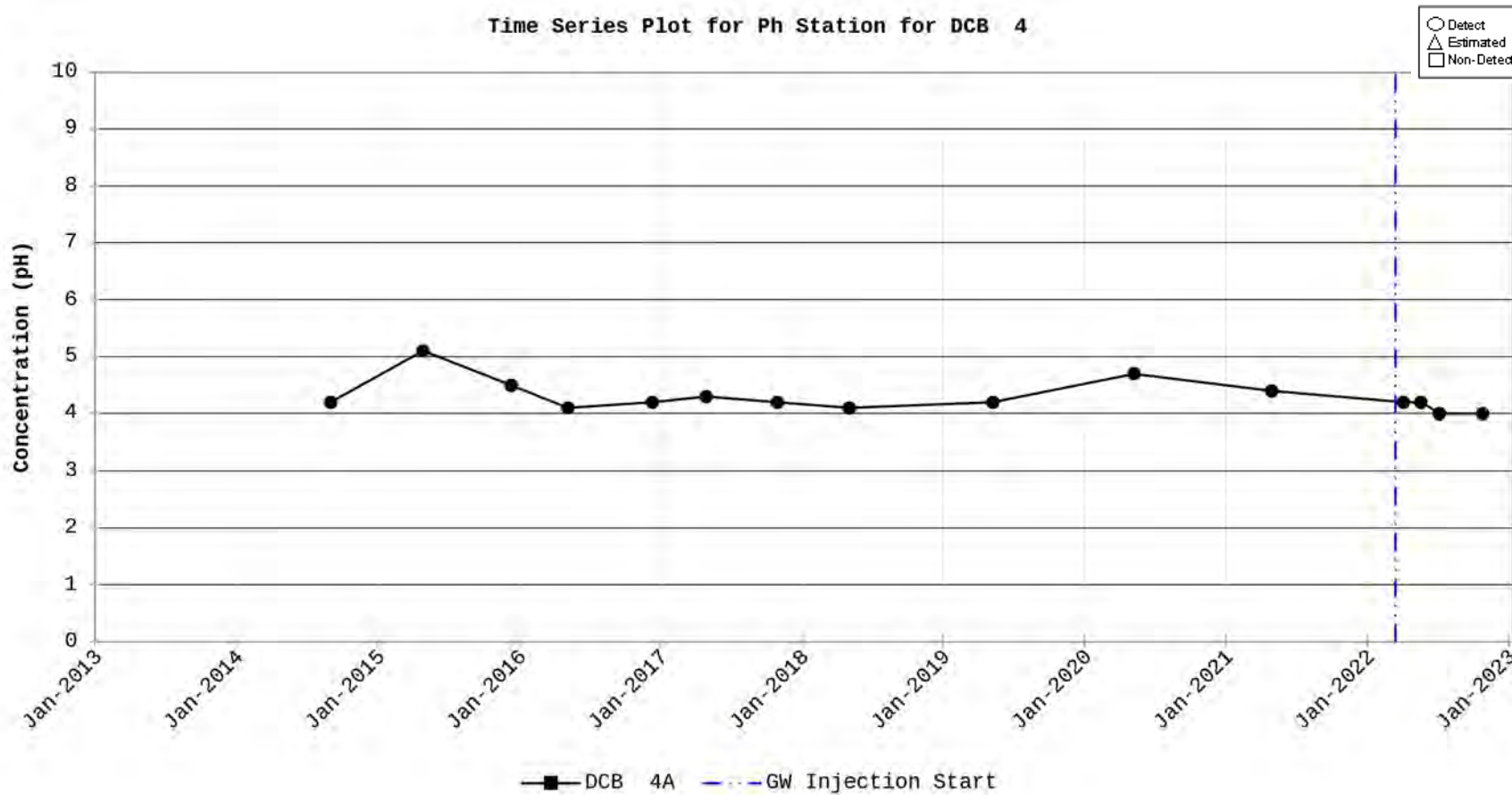


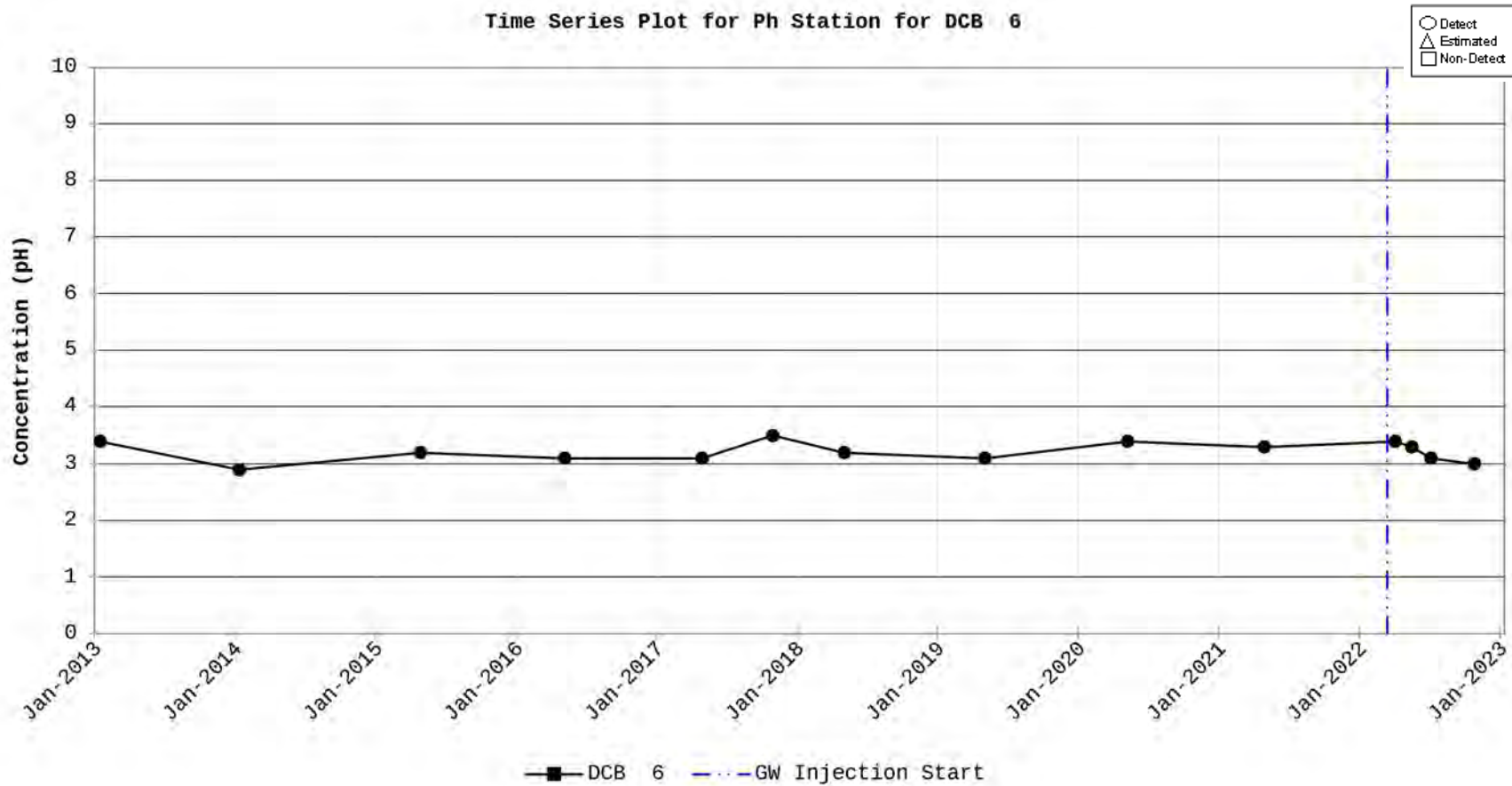


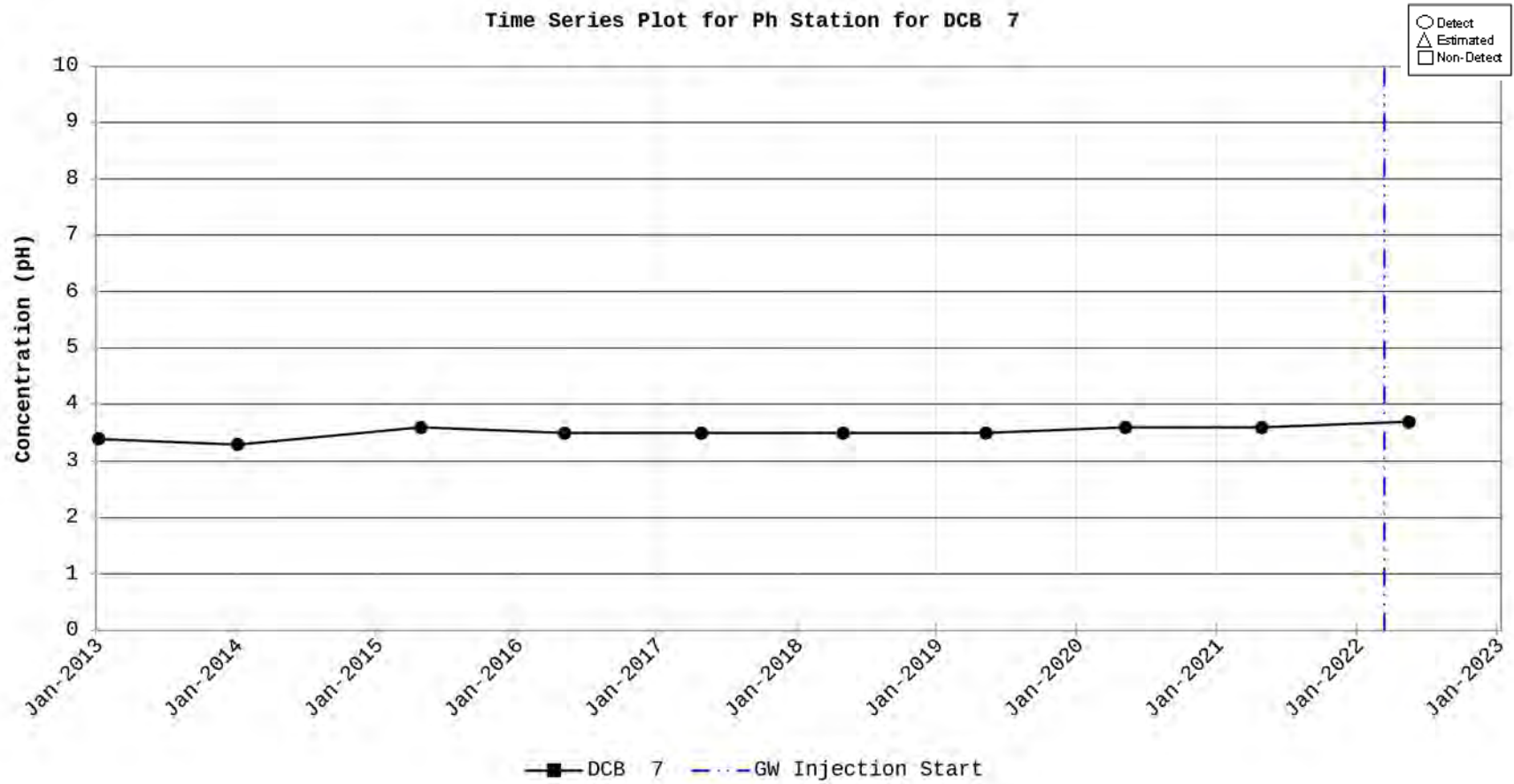
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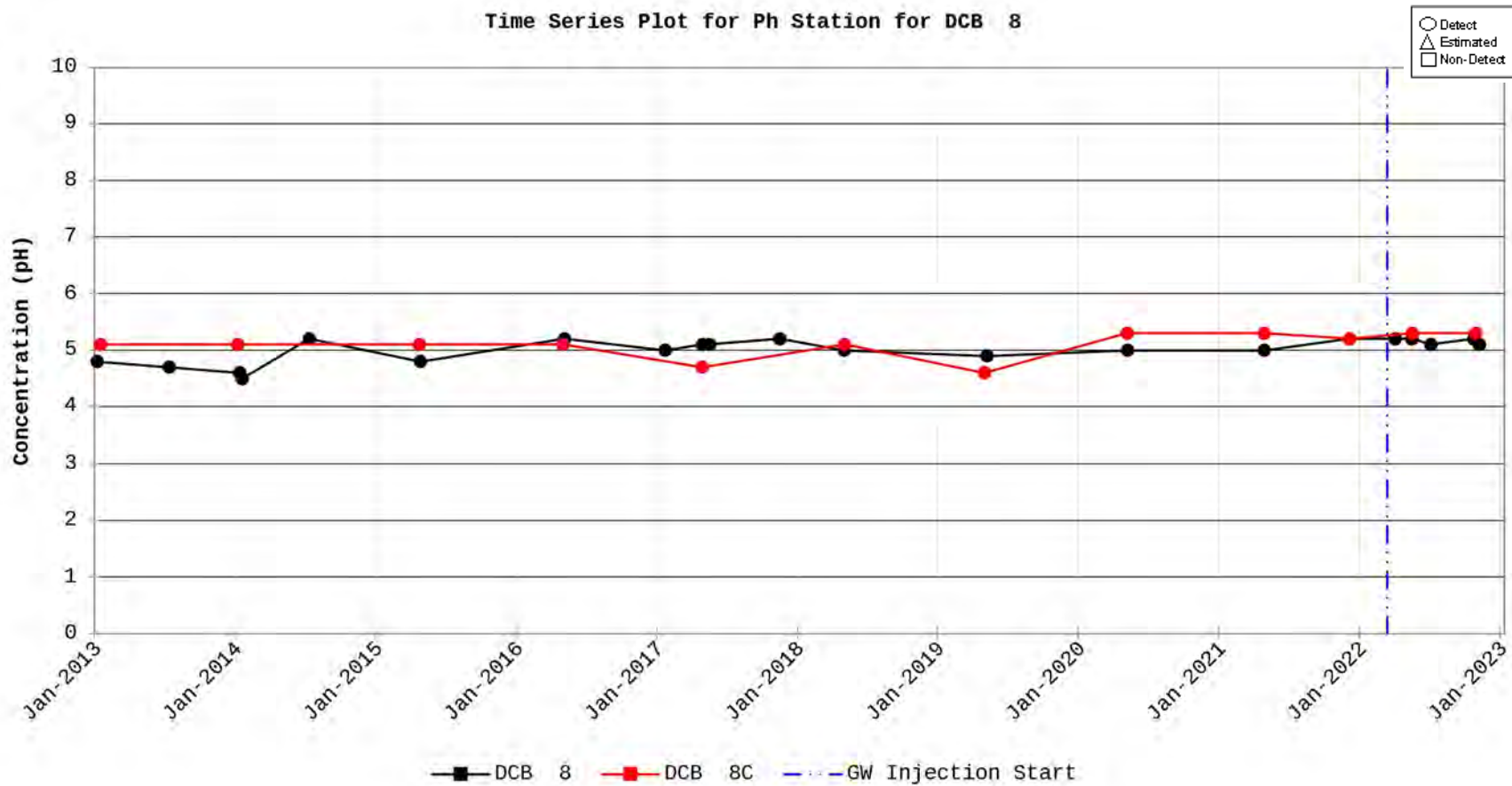
pH Times-Series Plots

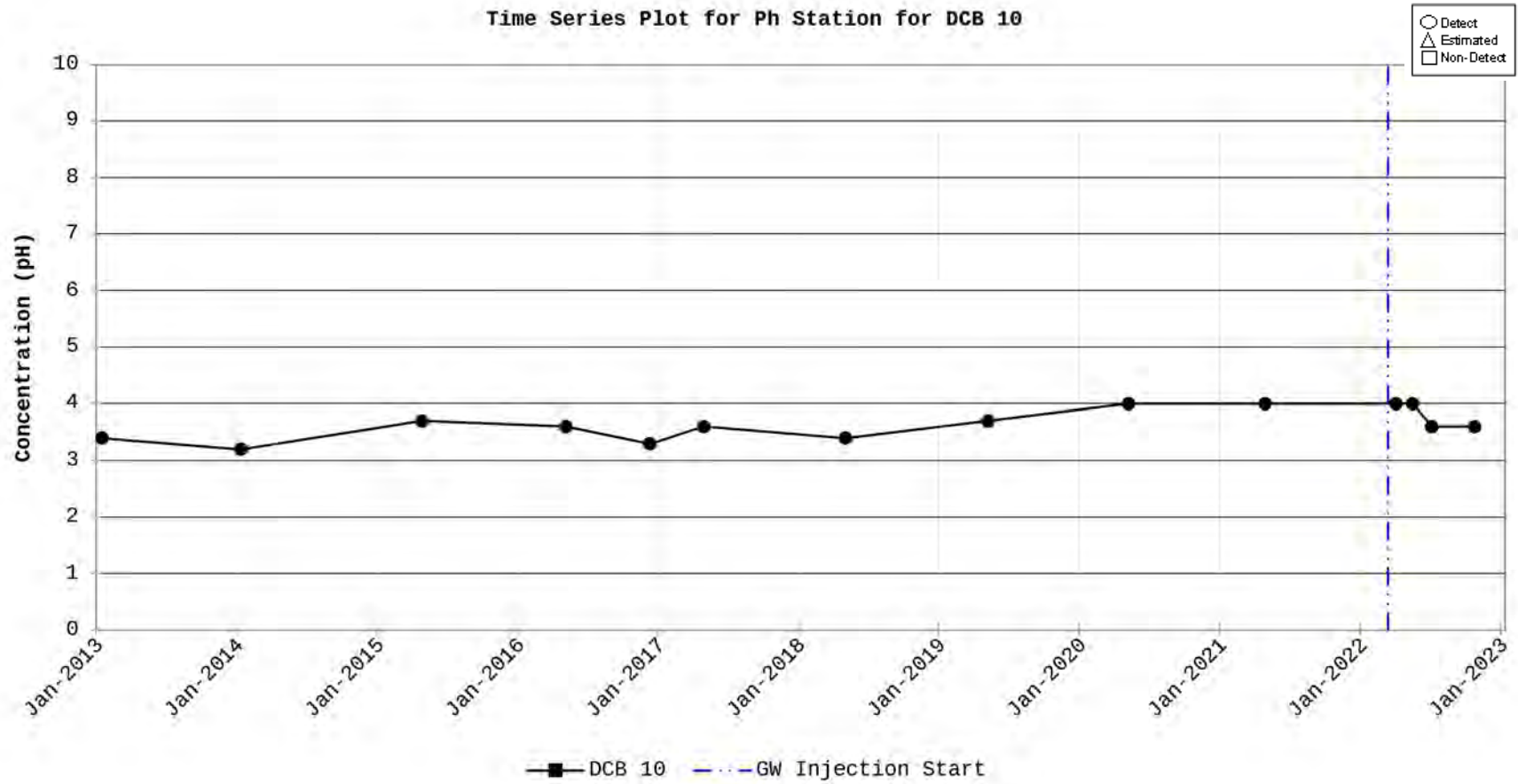


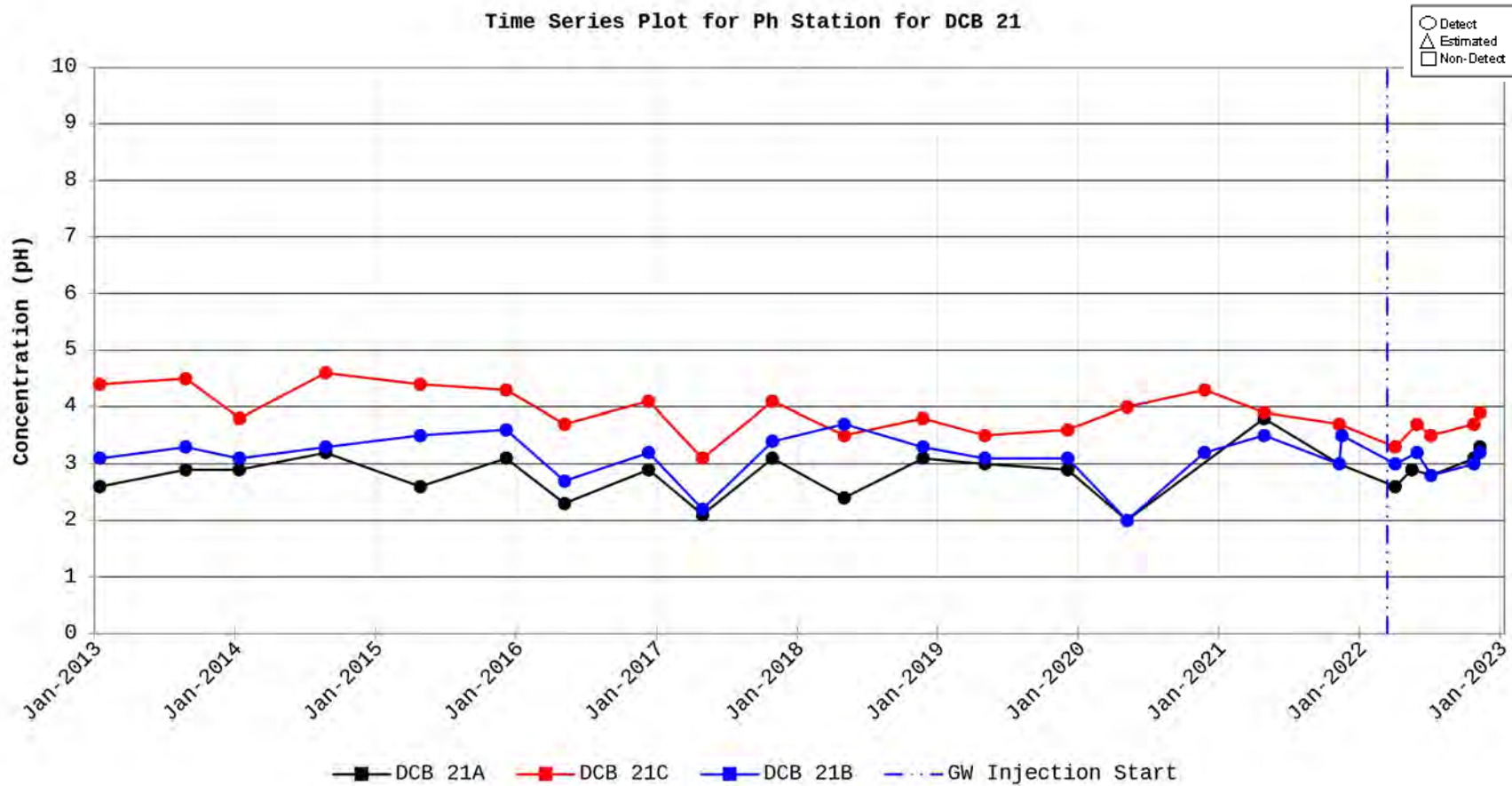


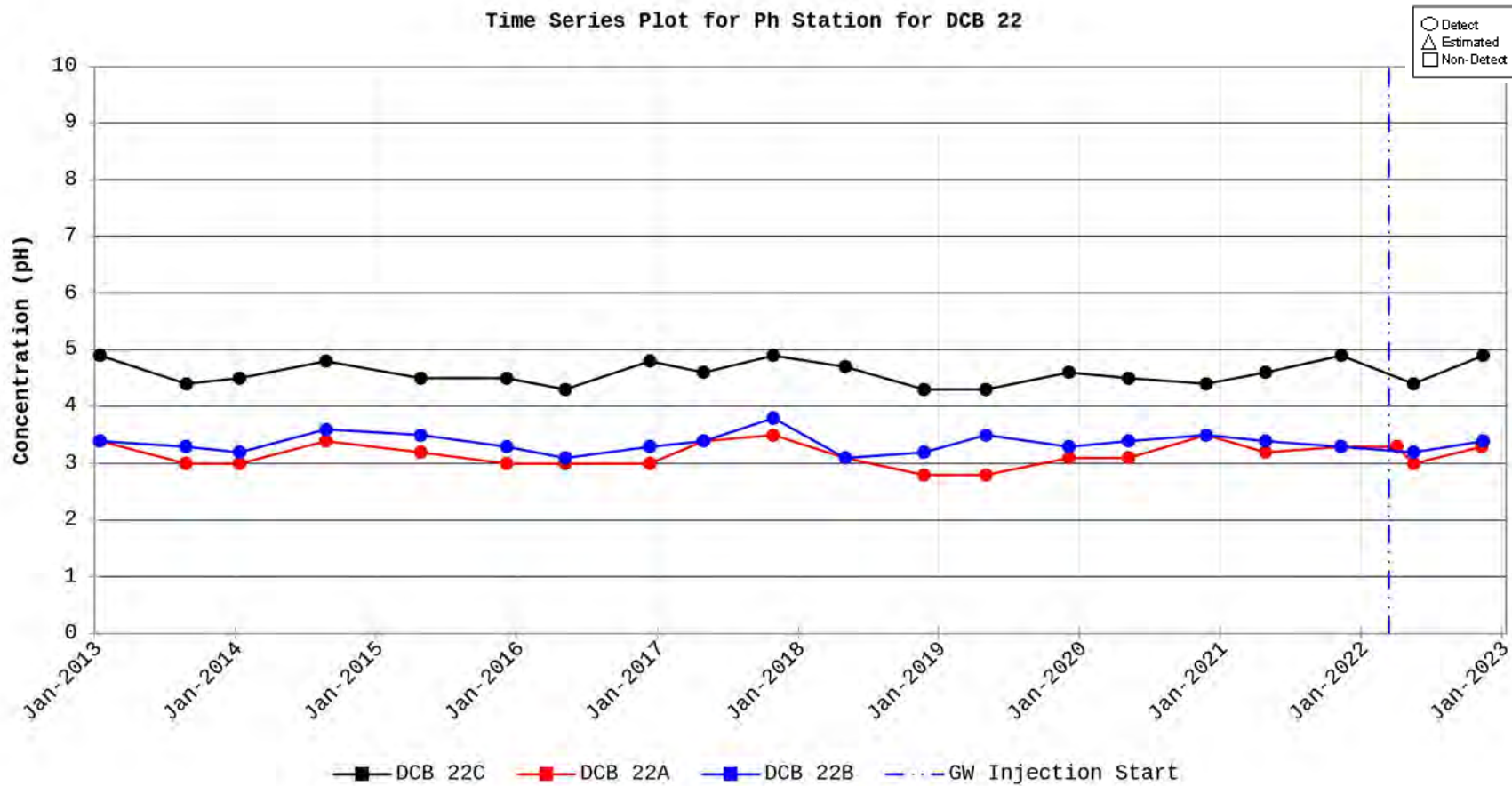


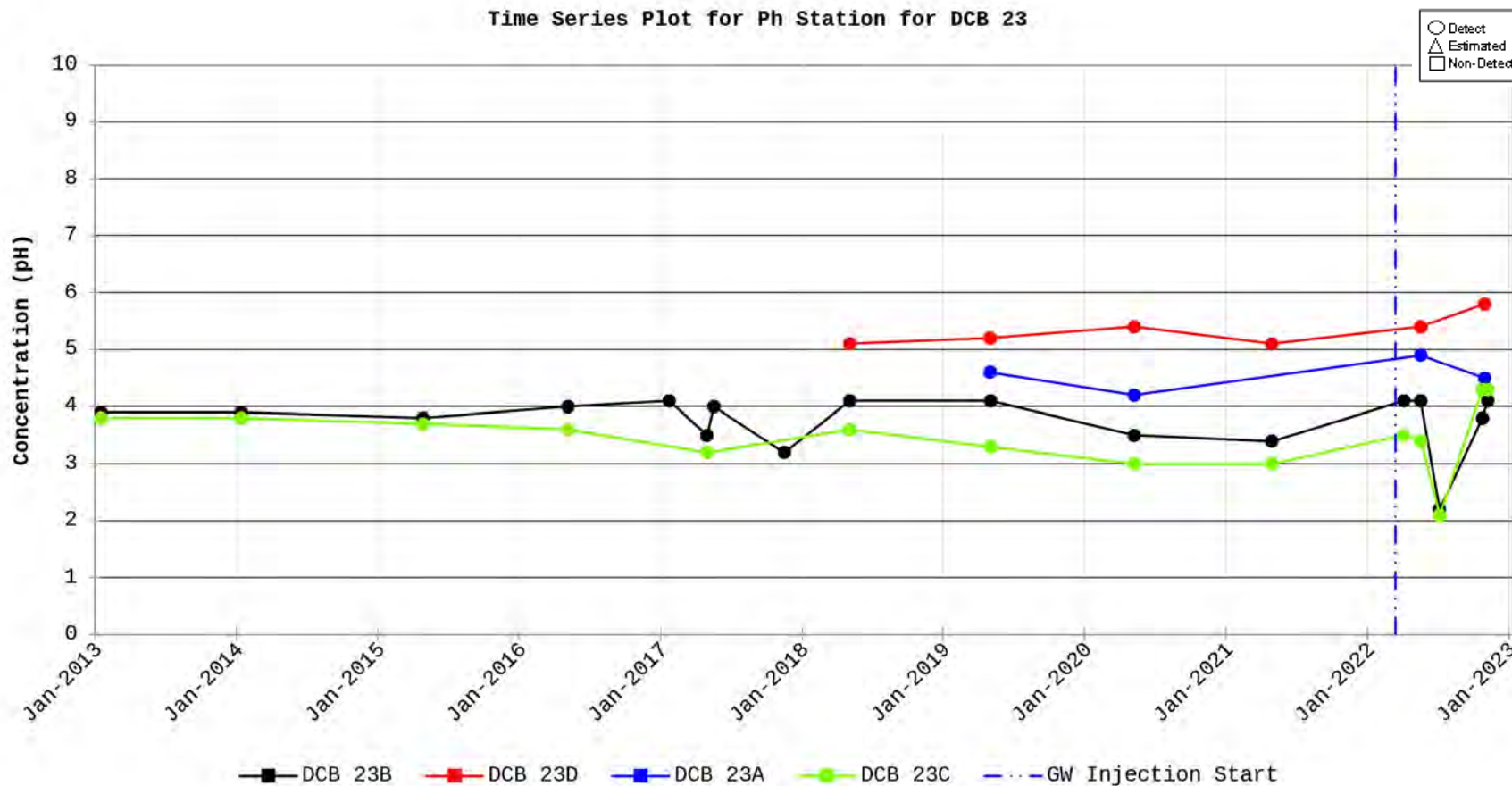


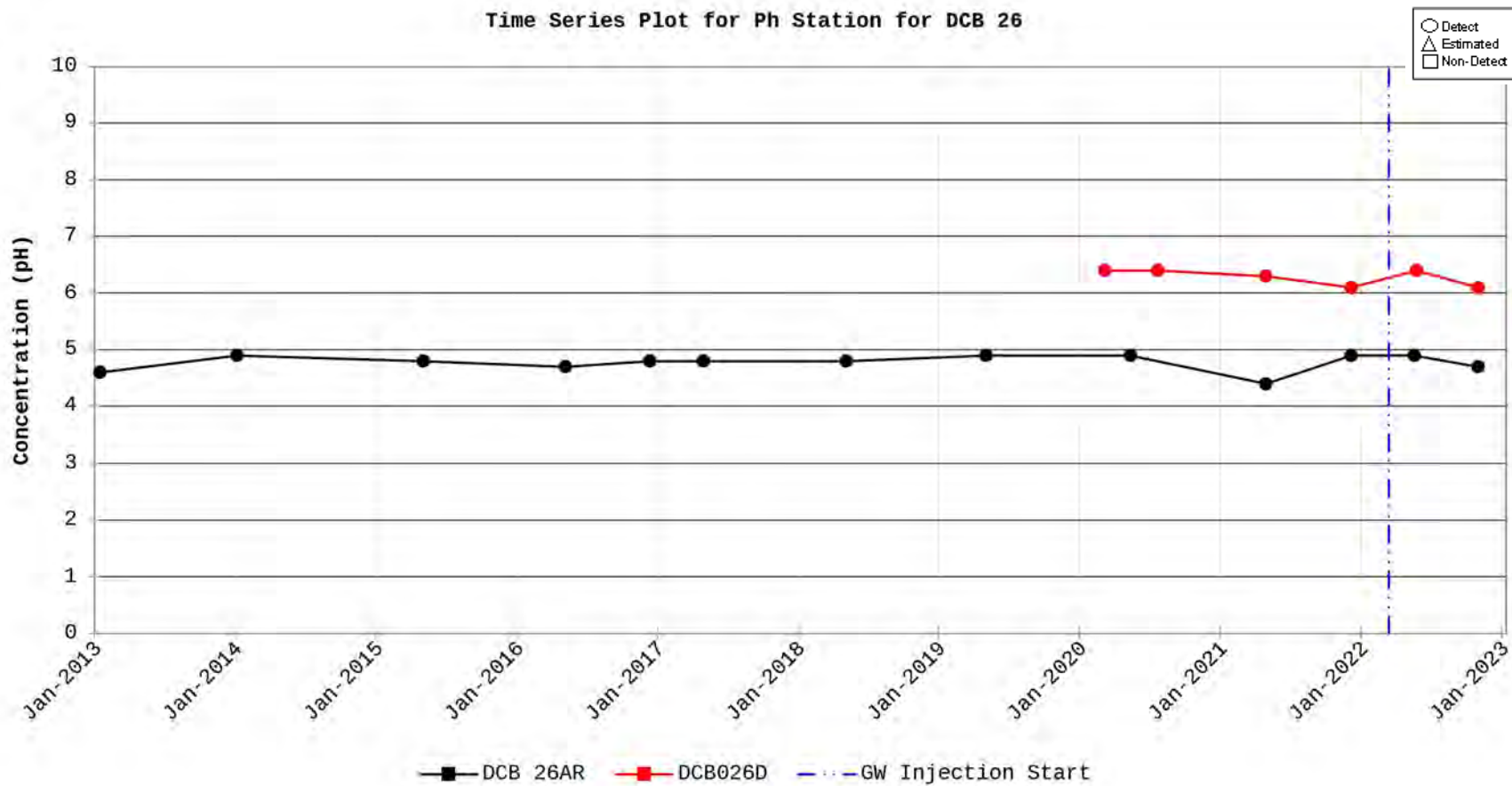


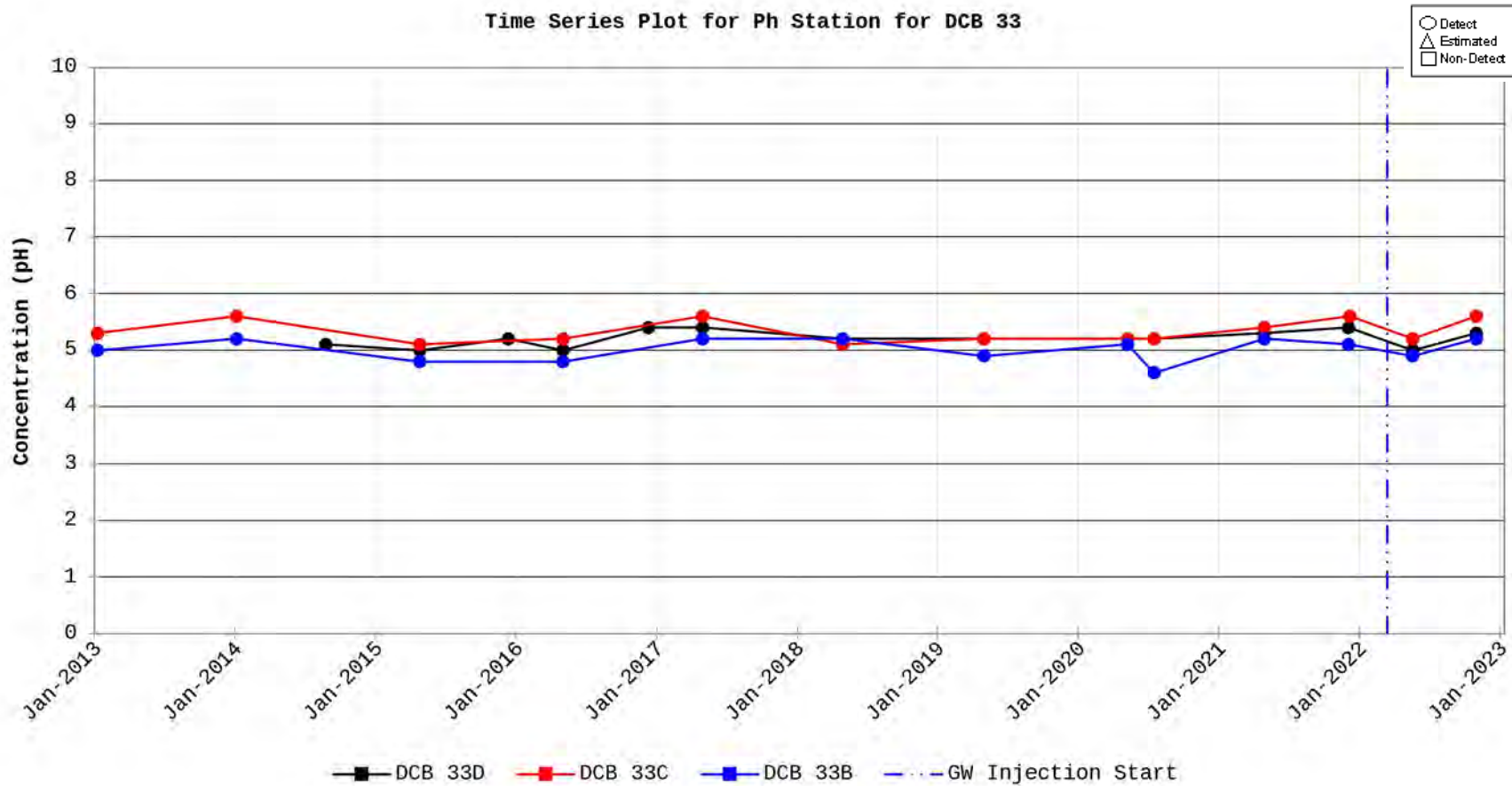


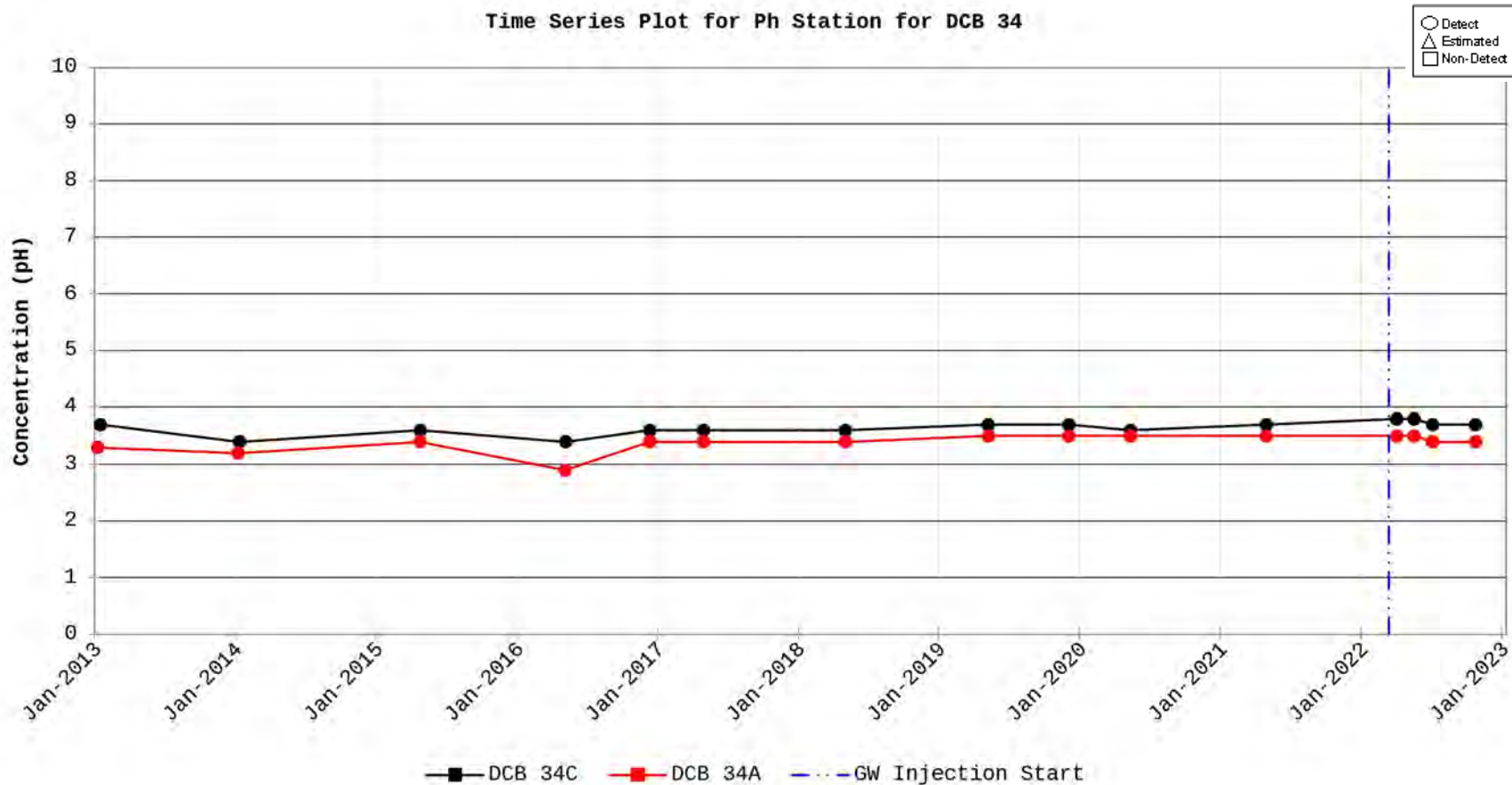


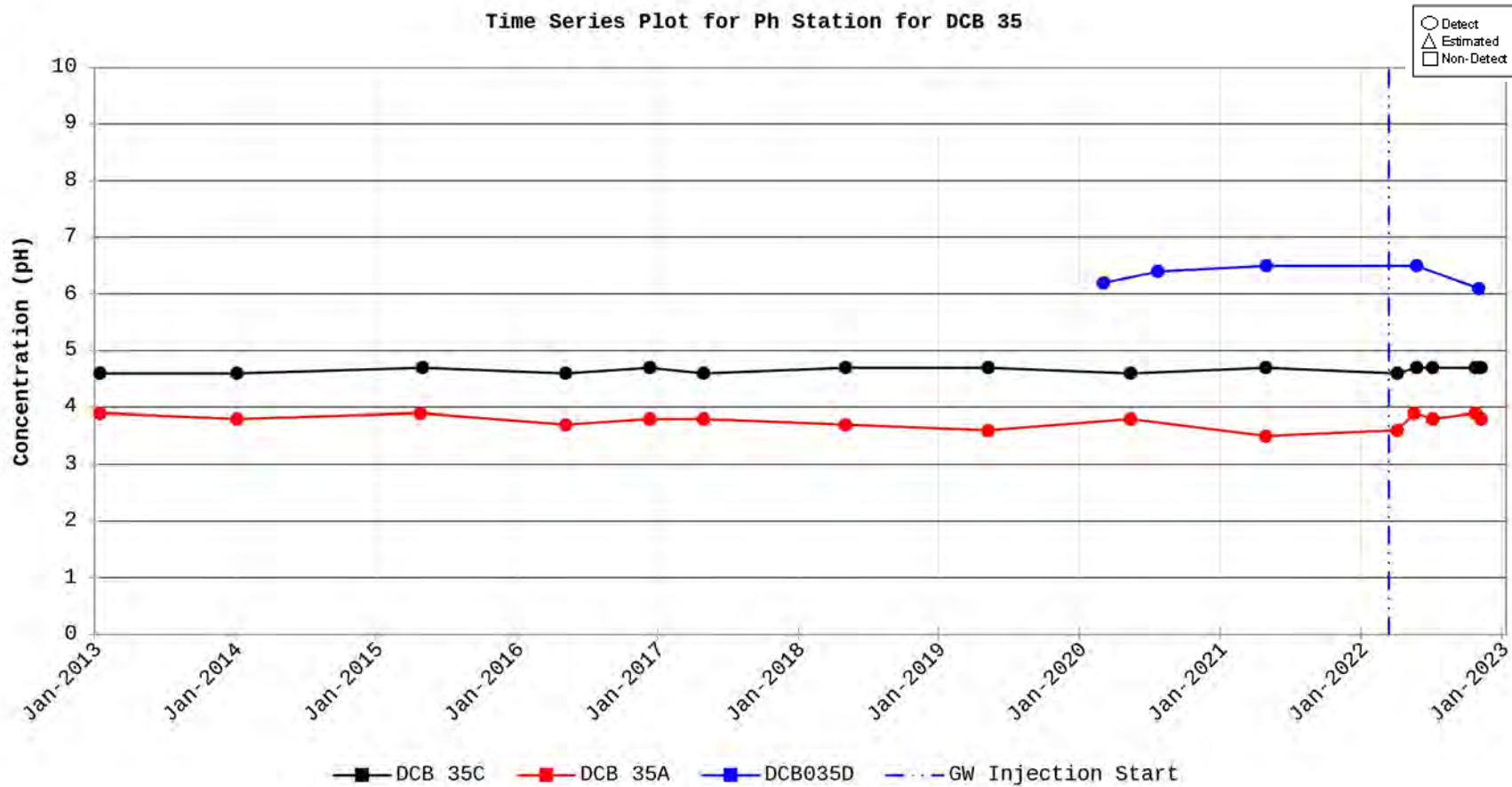


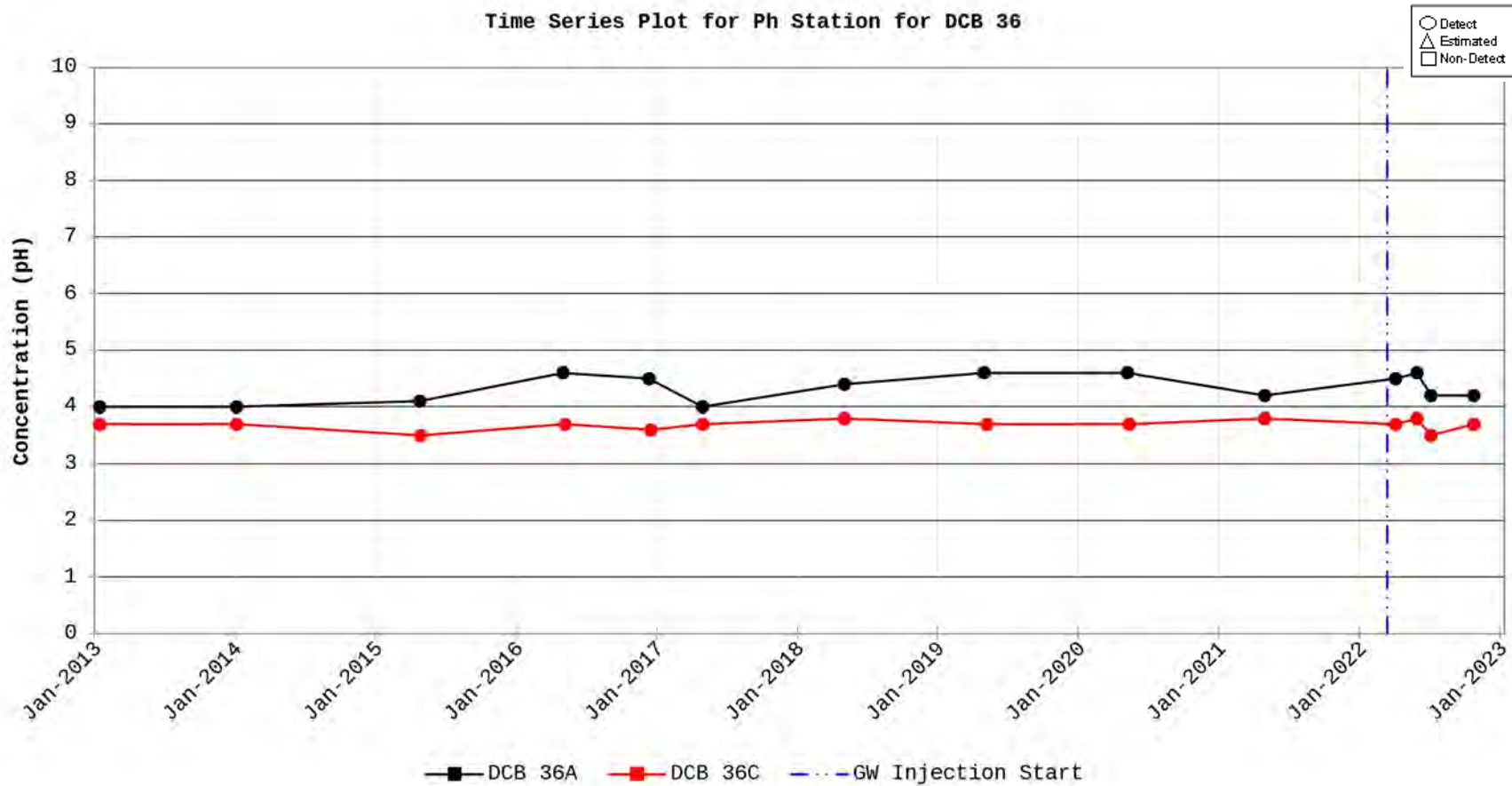


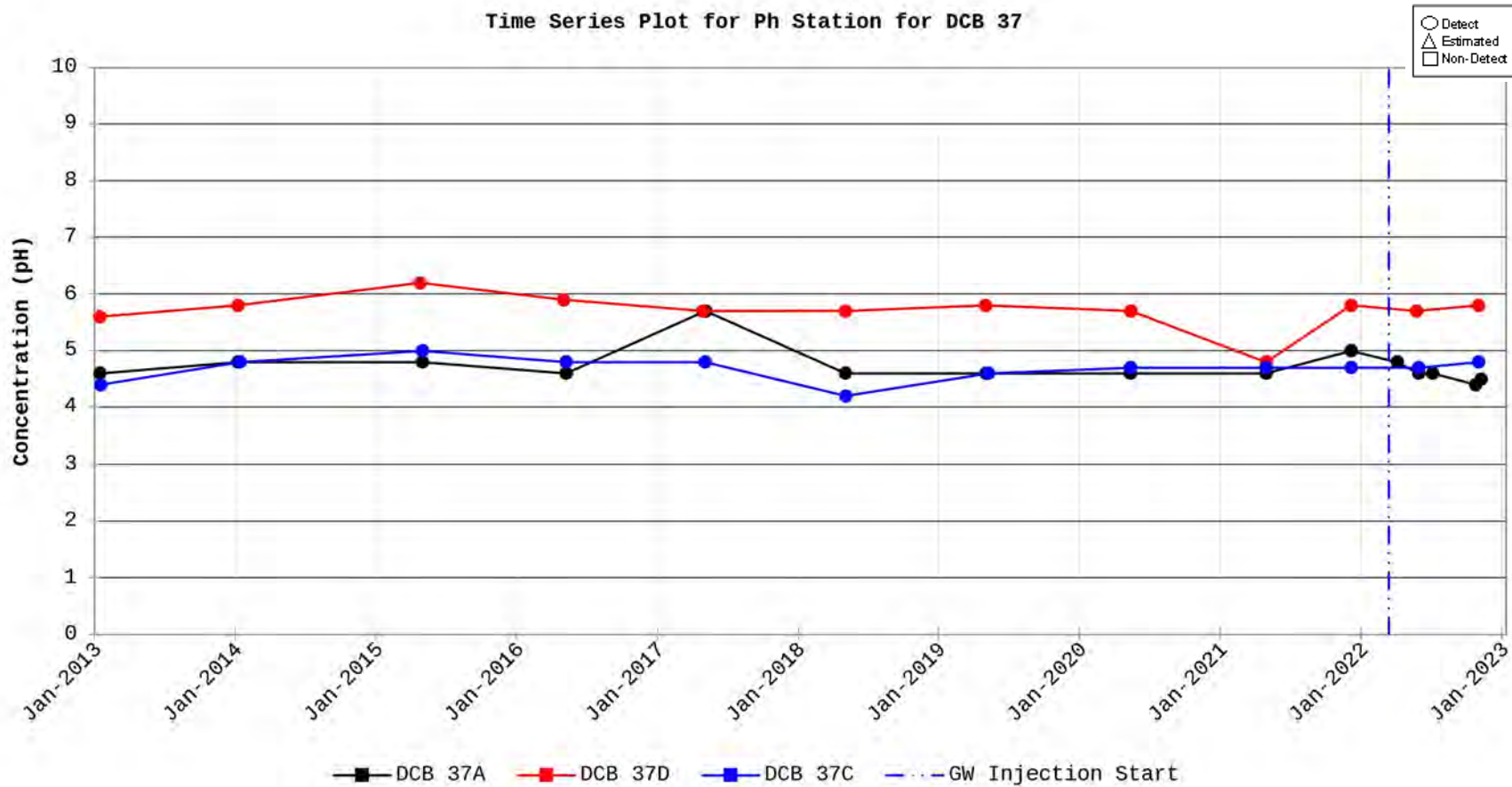


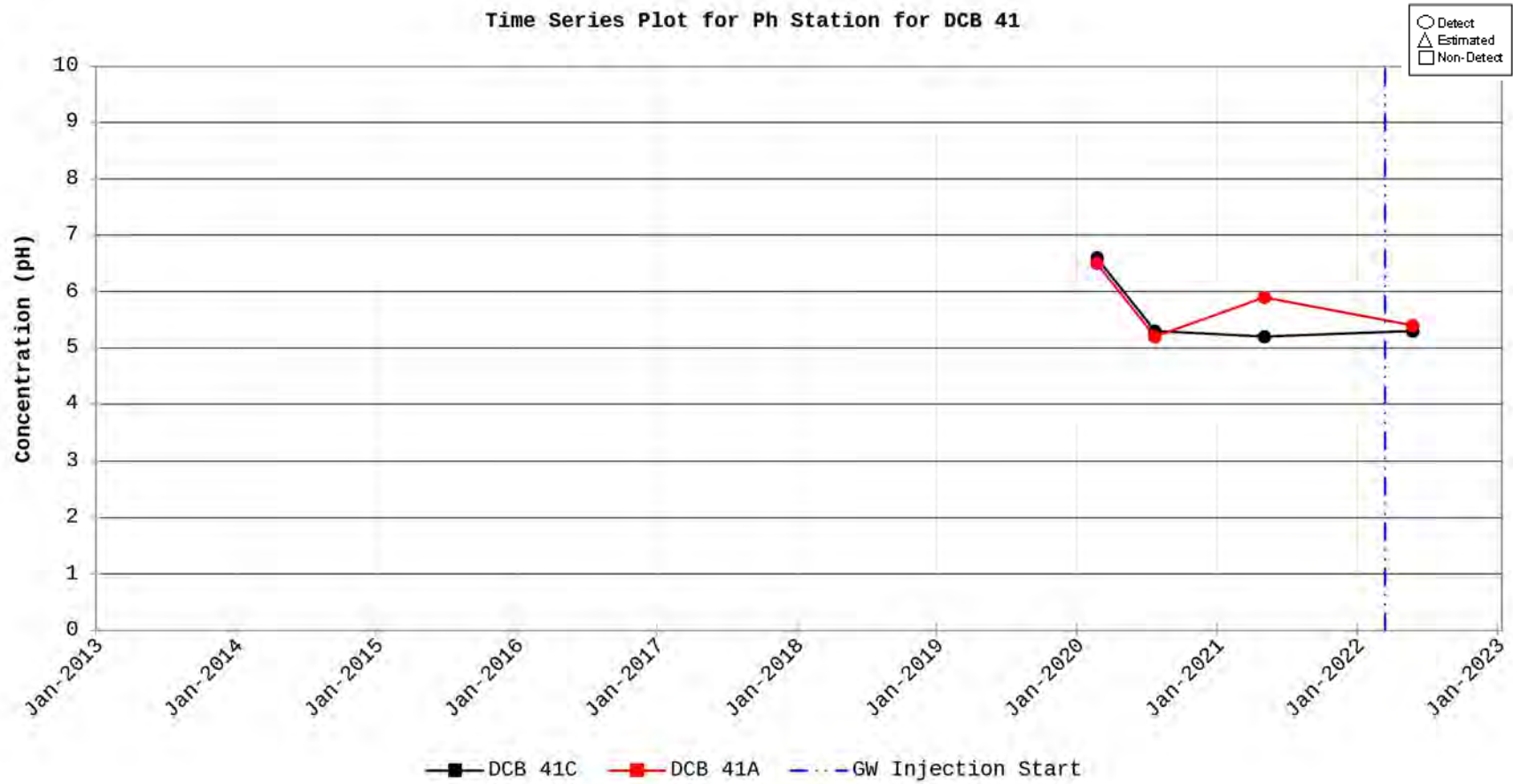


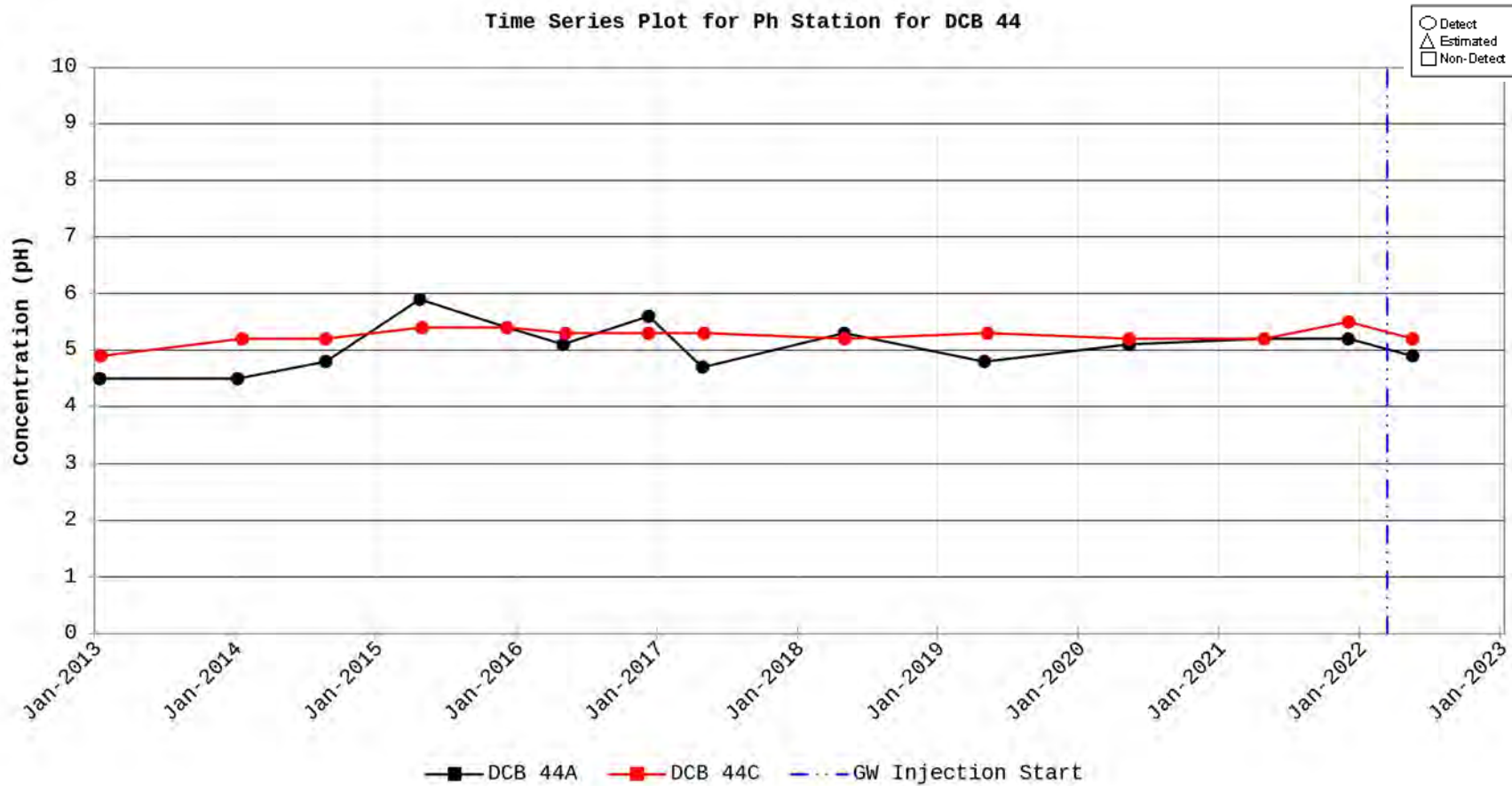


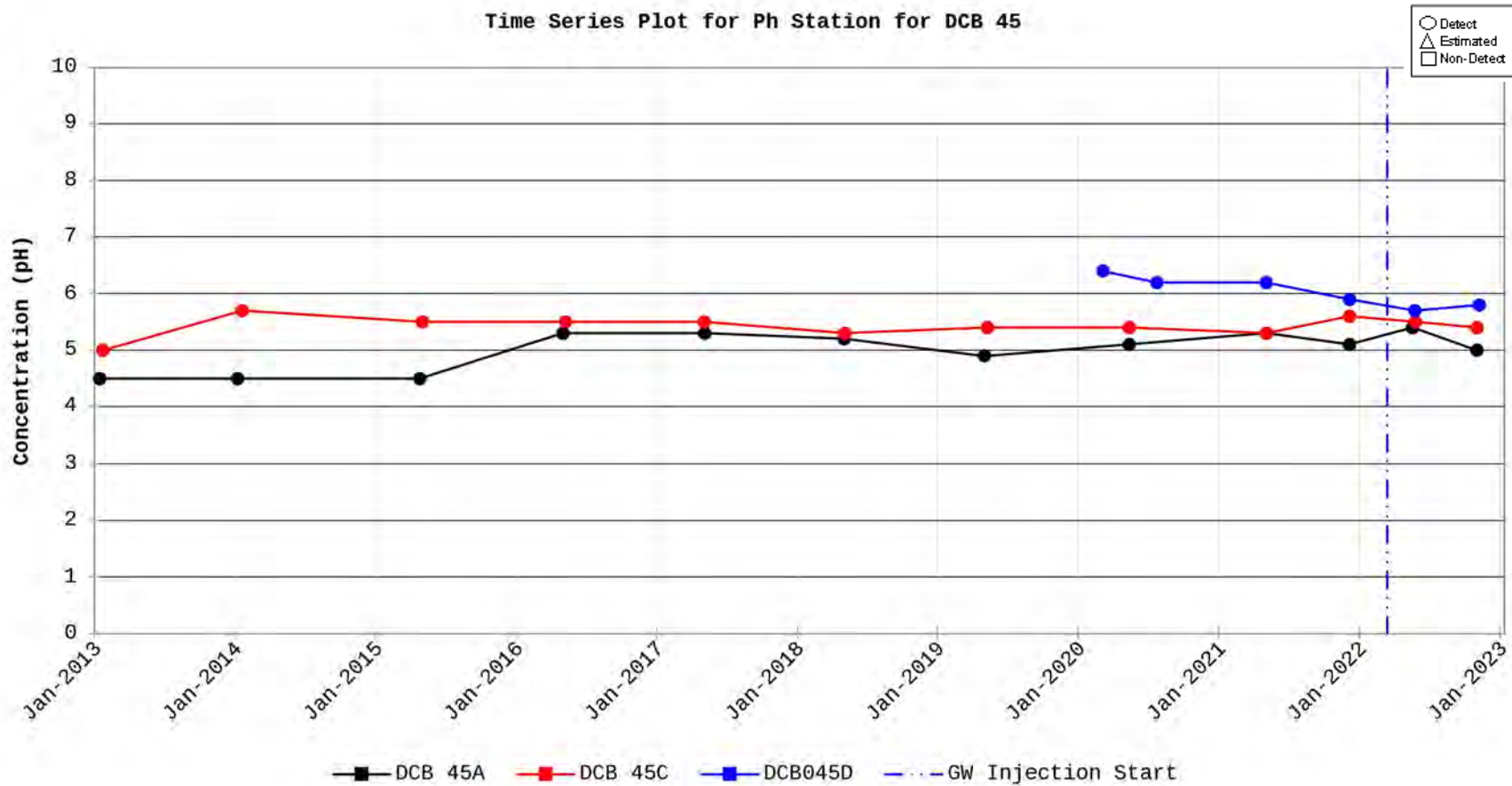


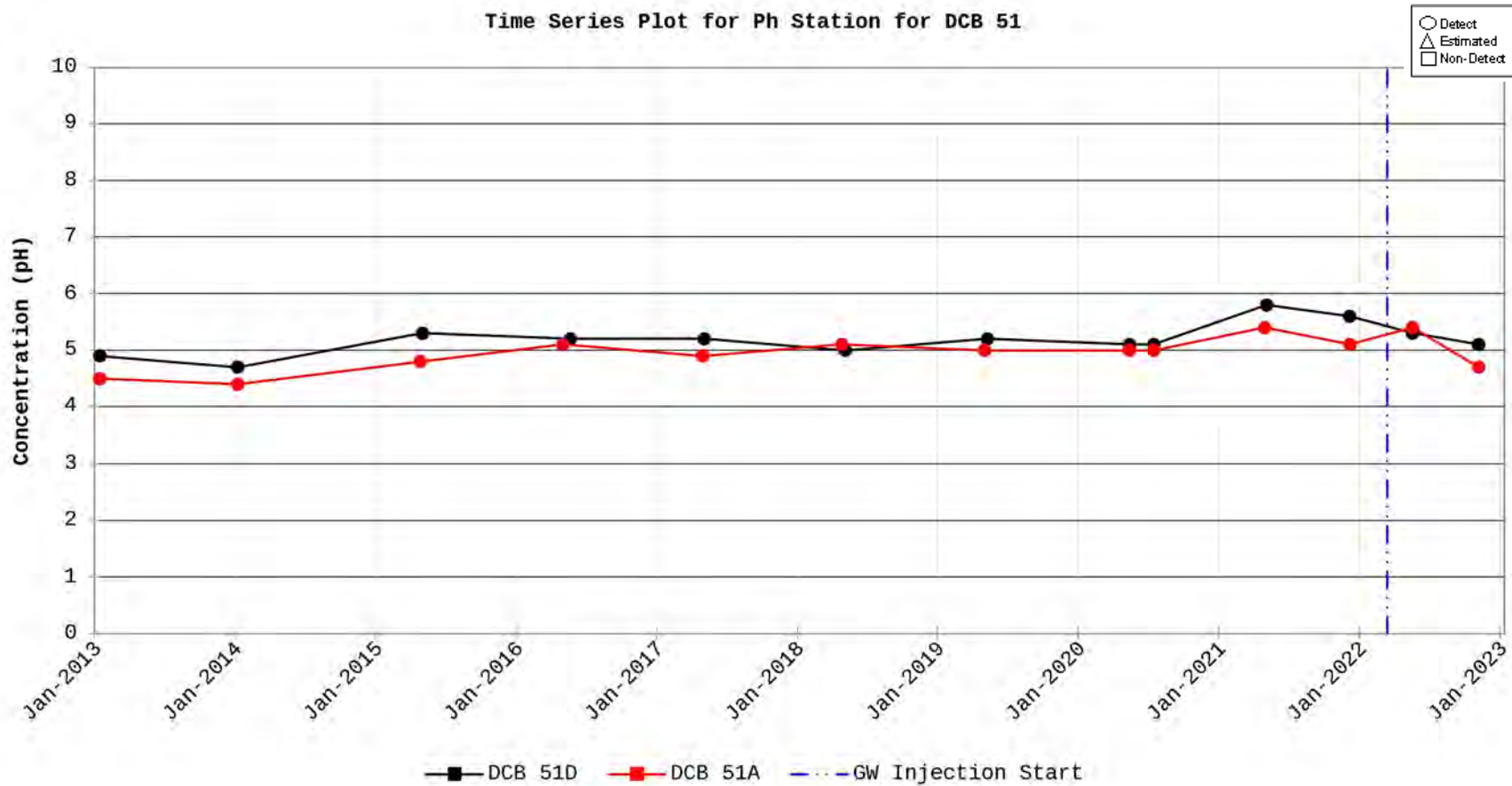


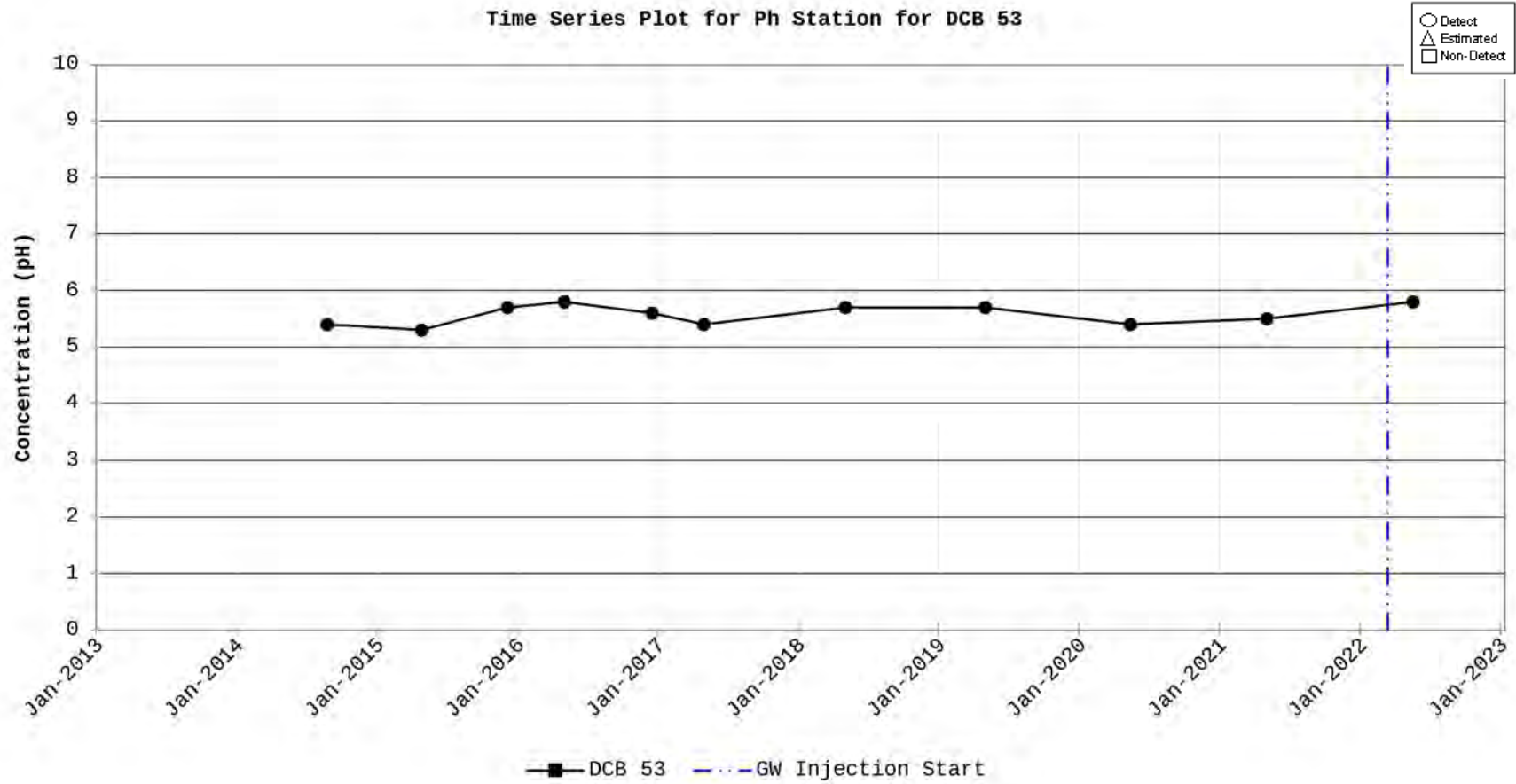


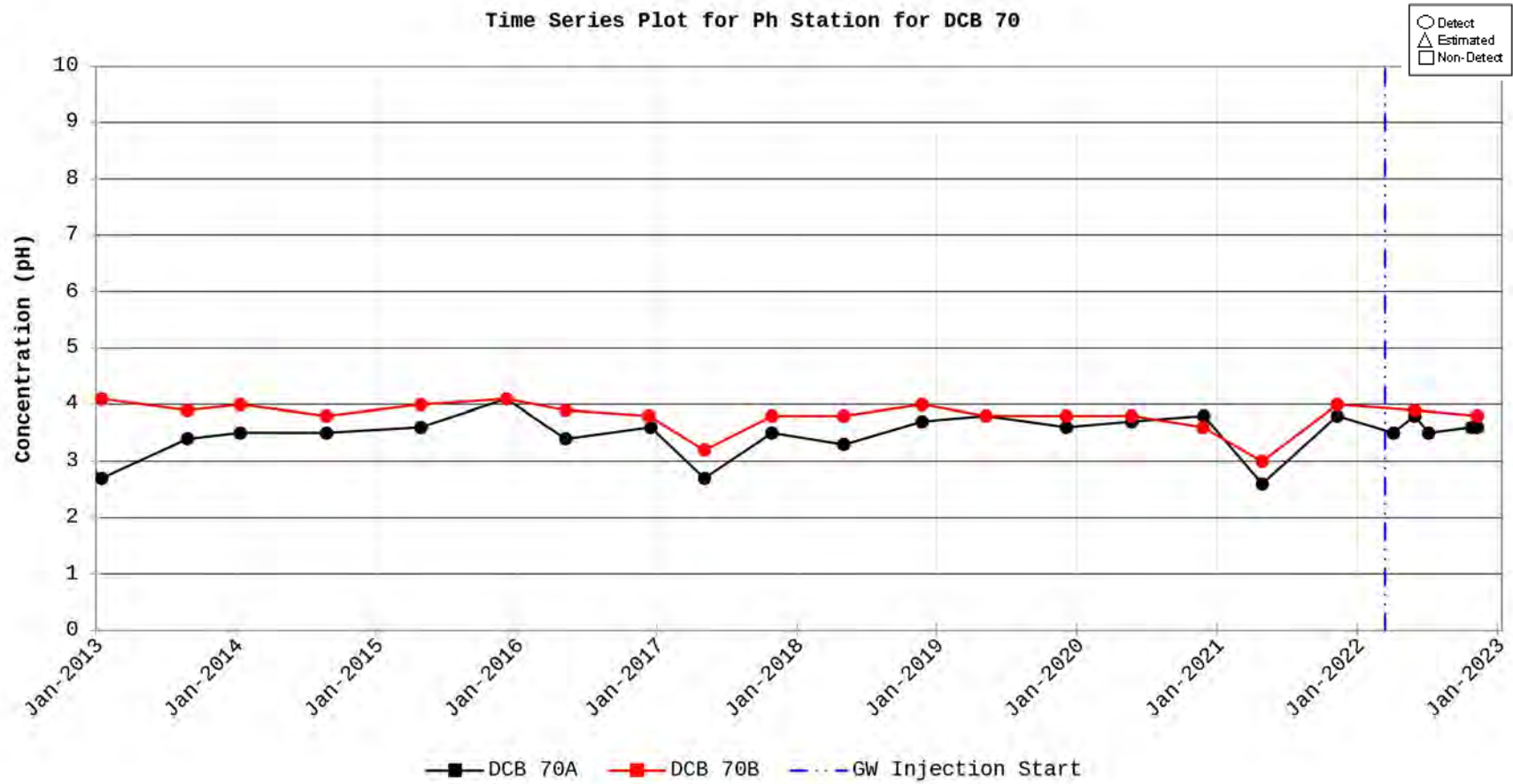


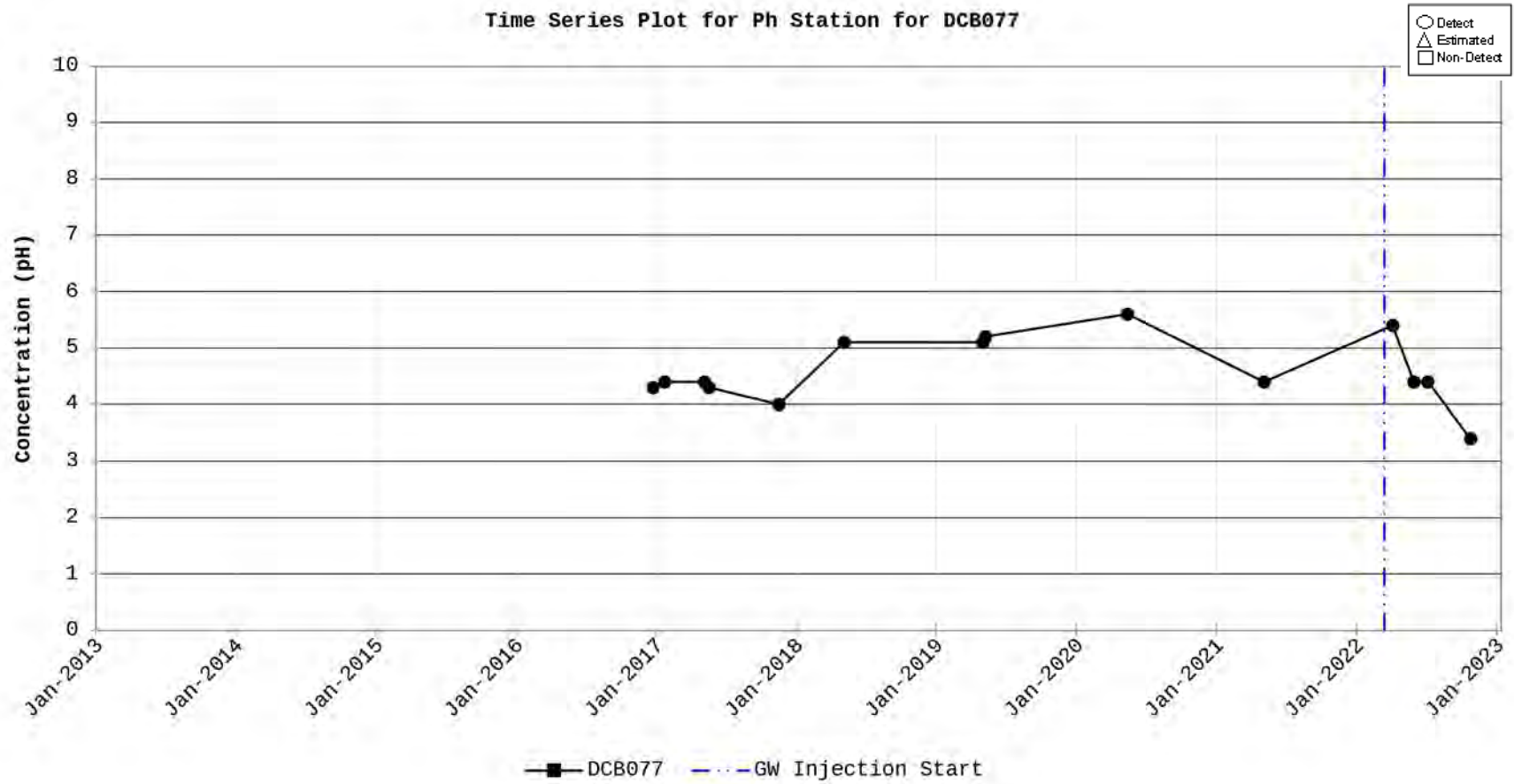


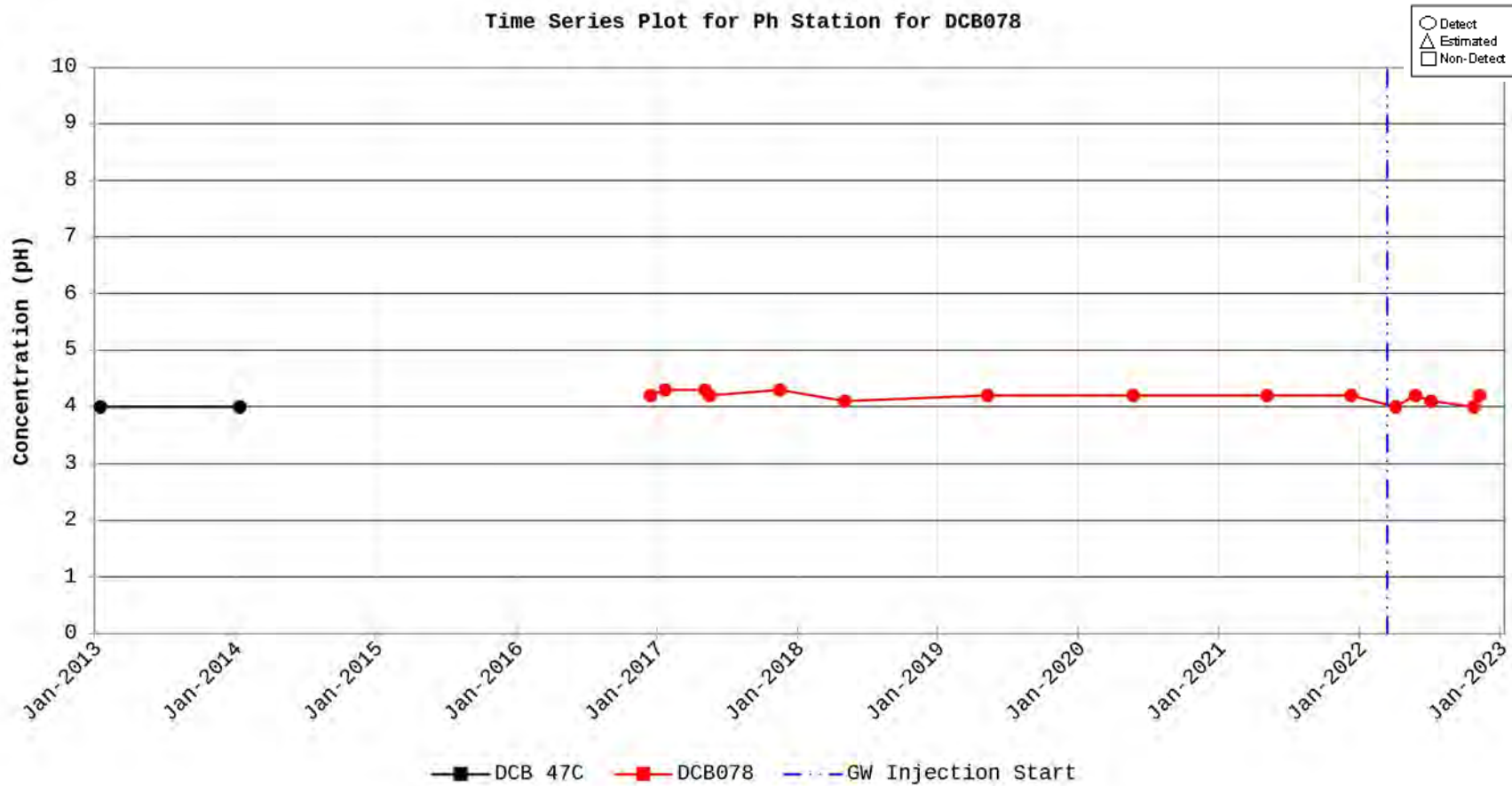


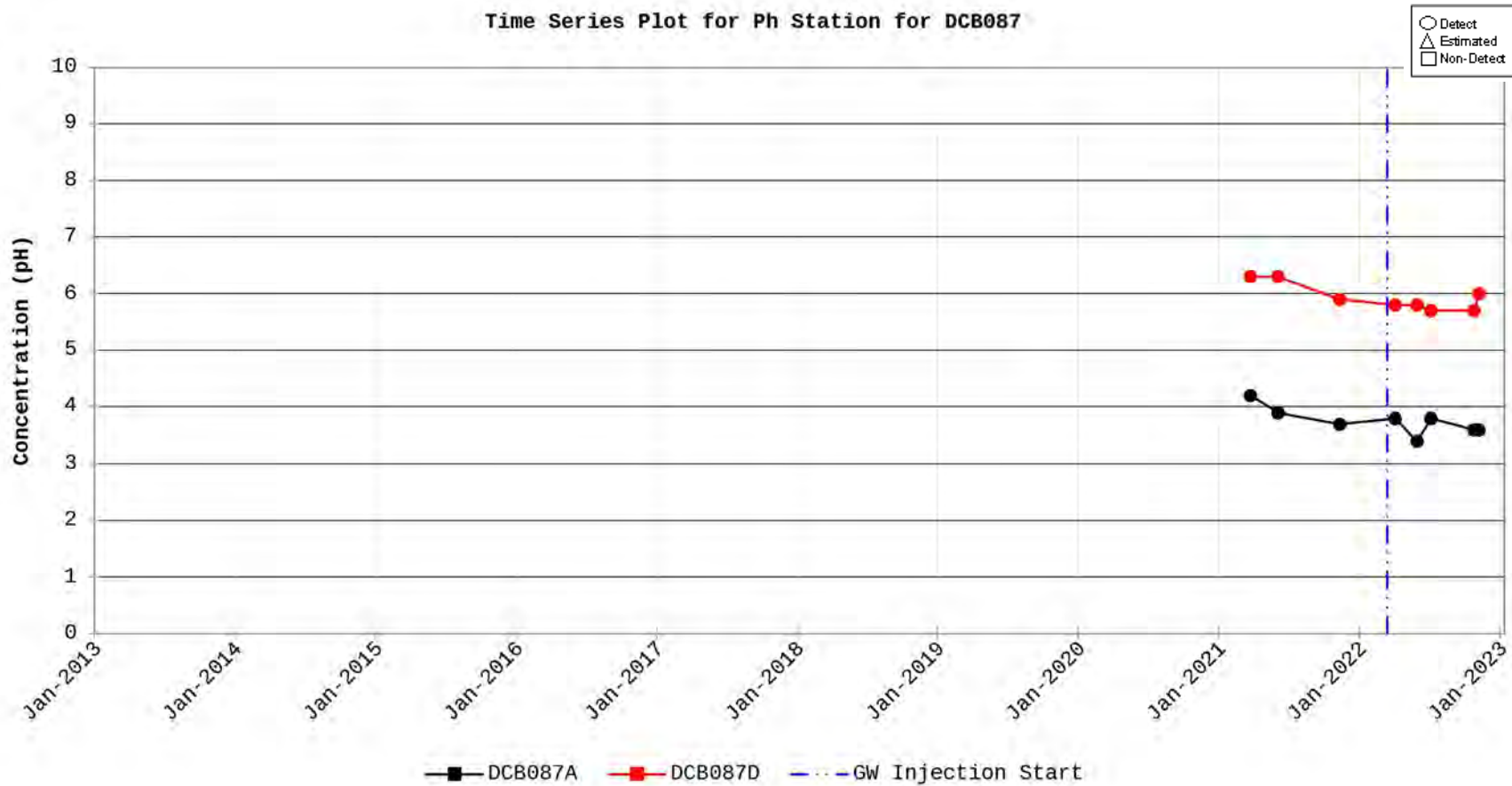


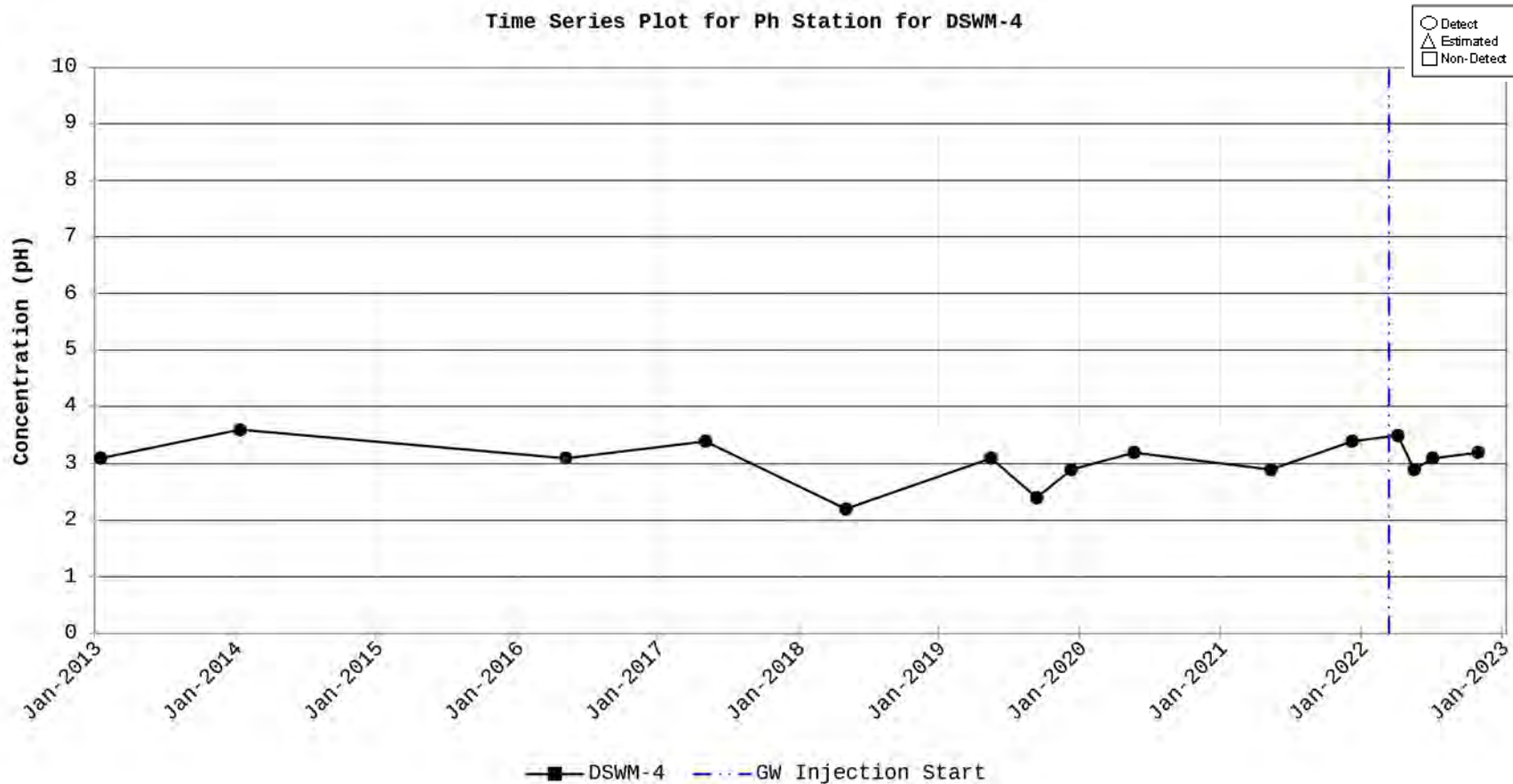


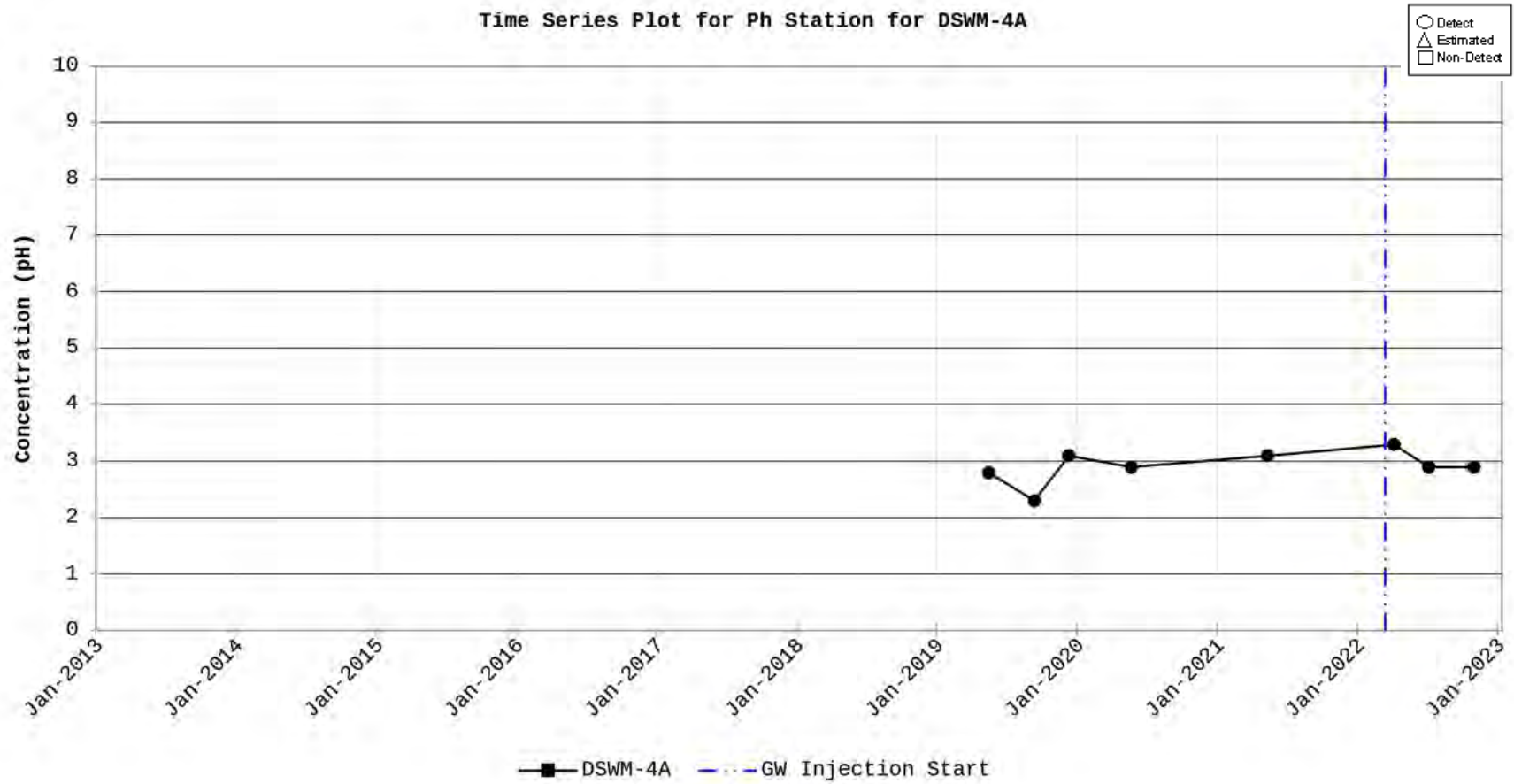


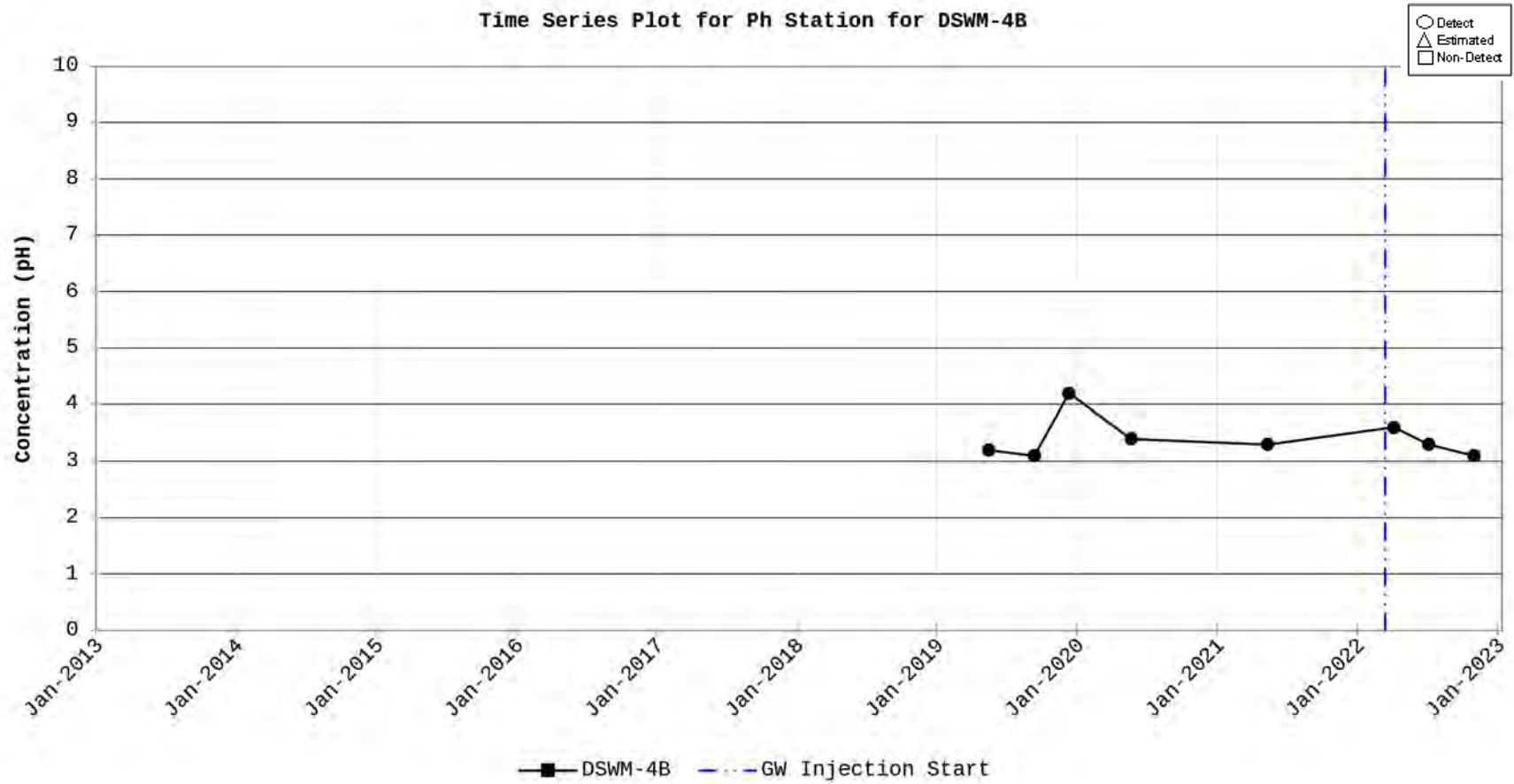


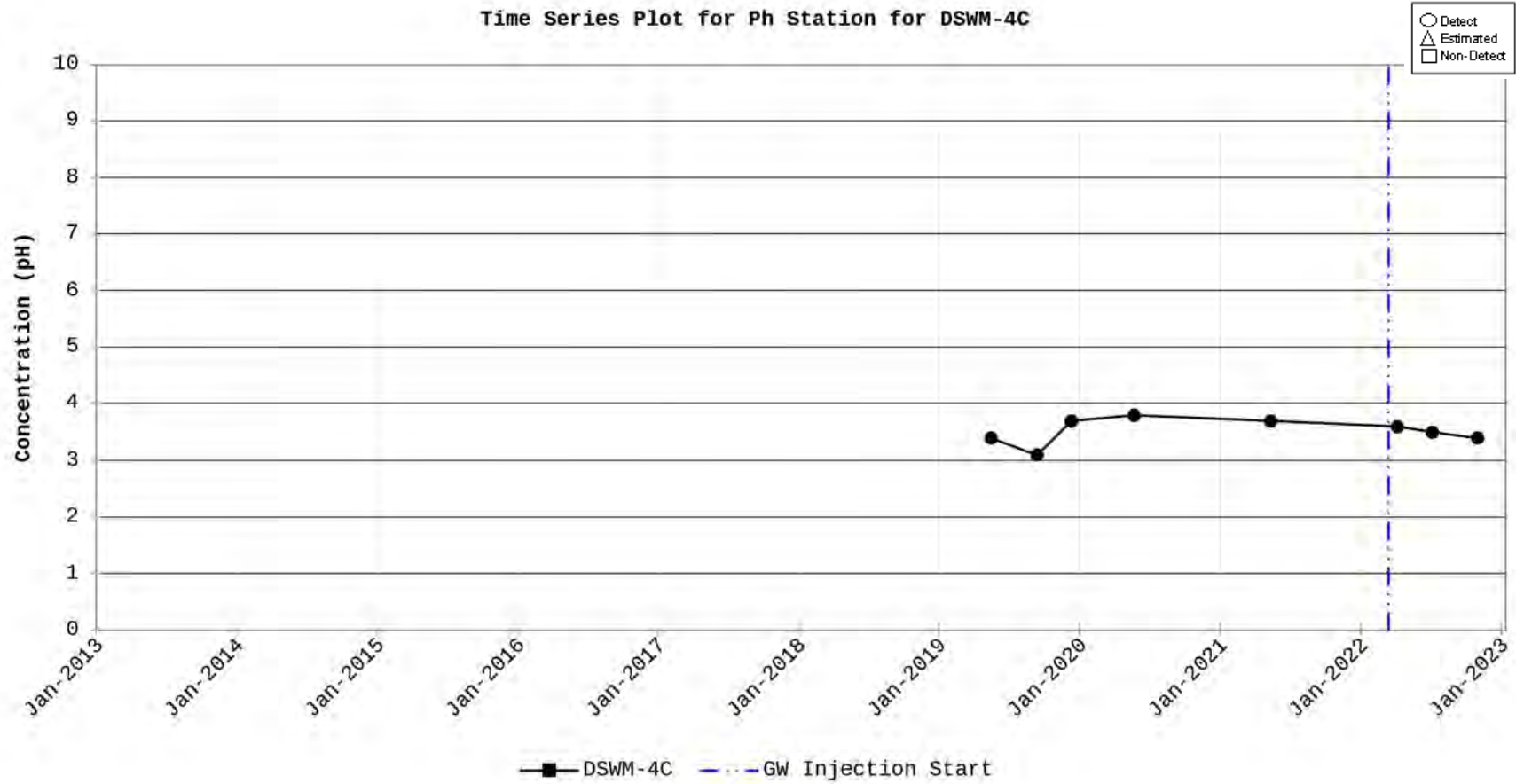


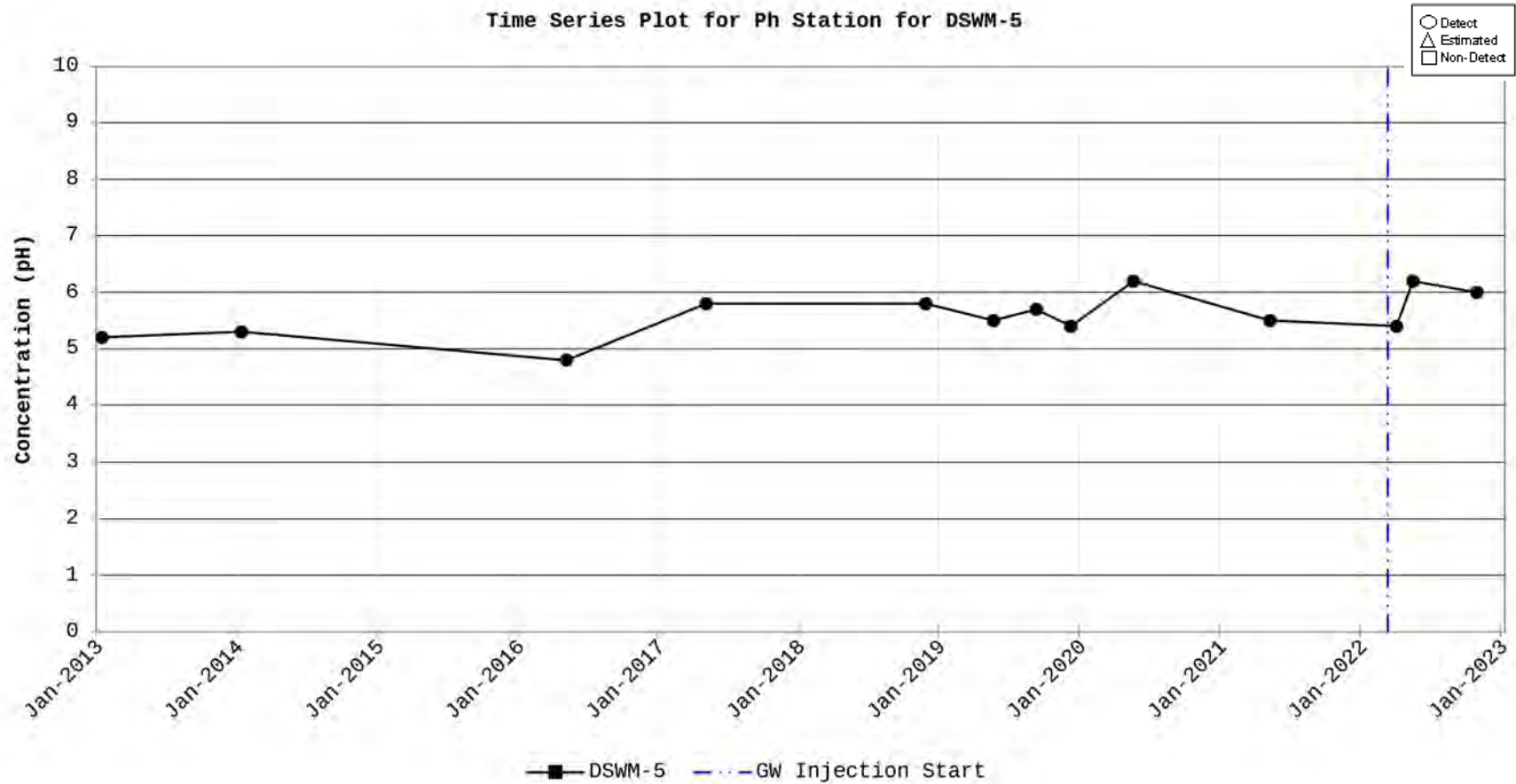


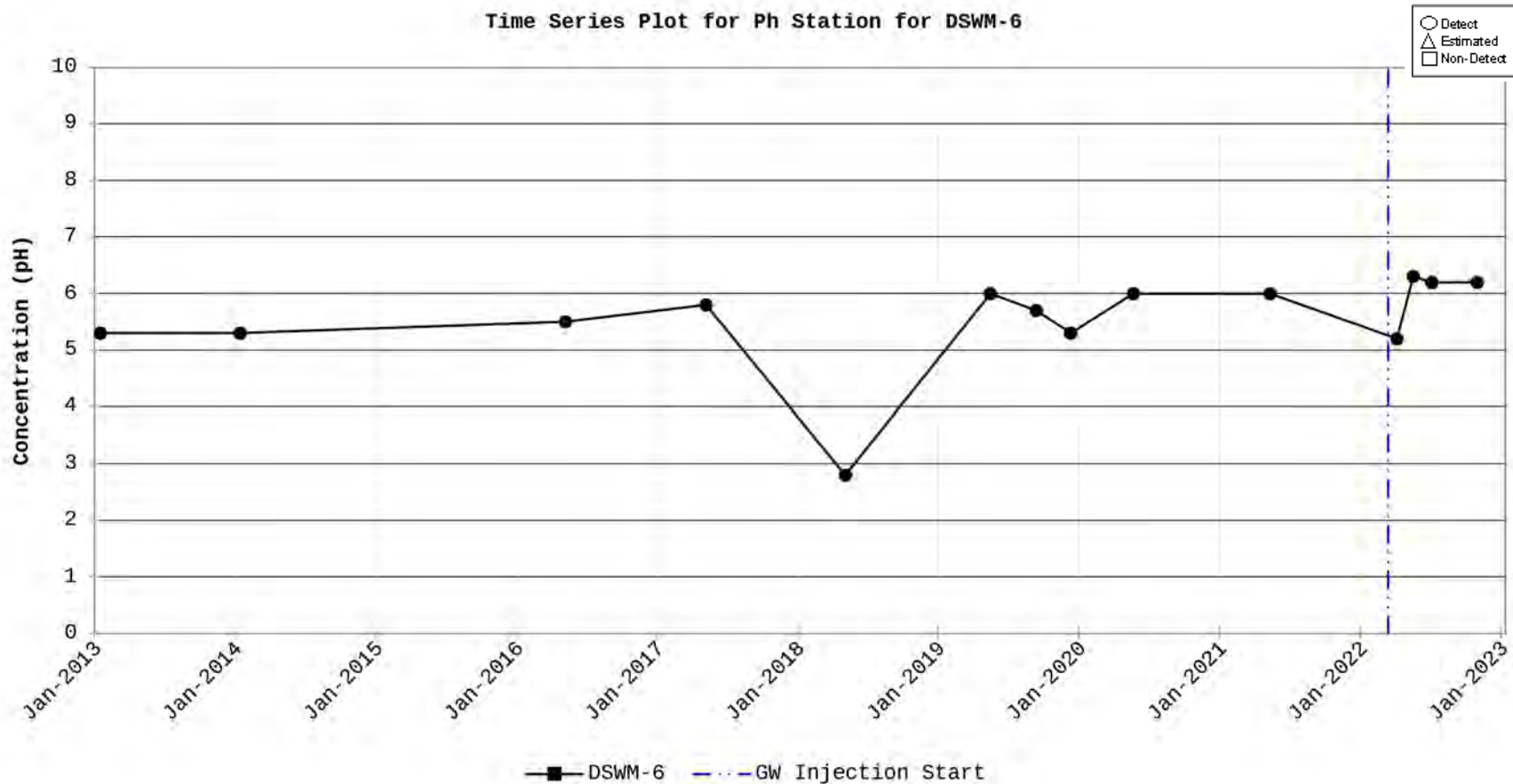


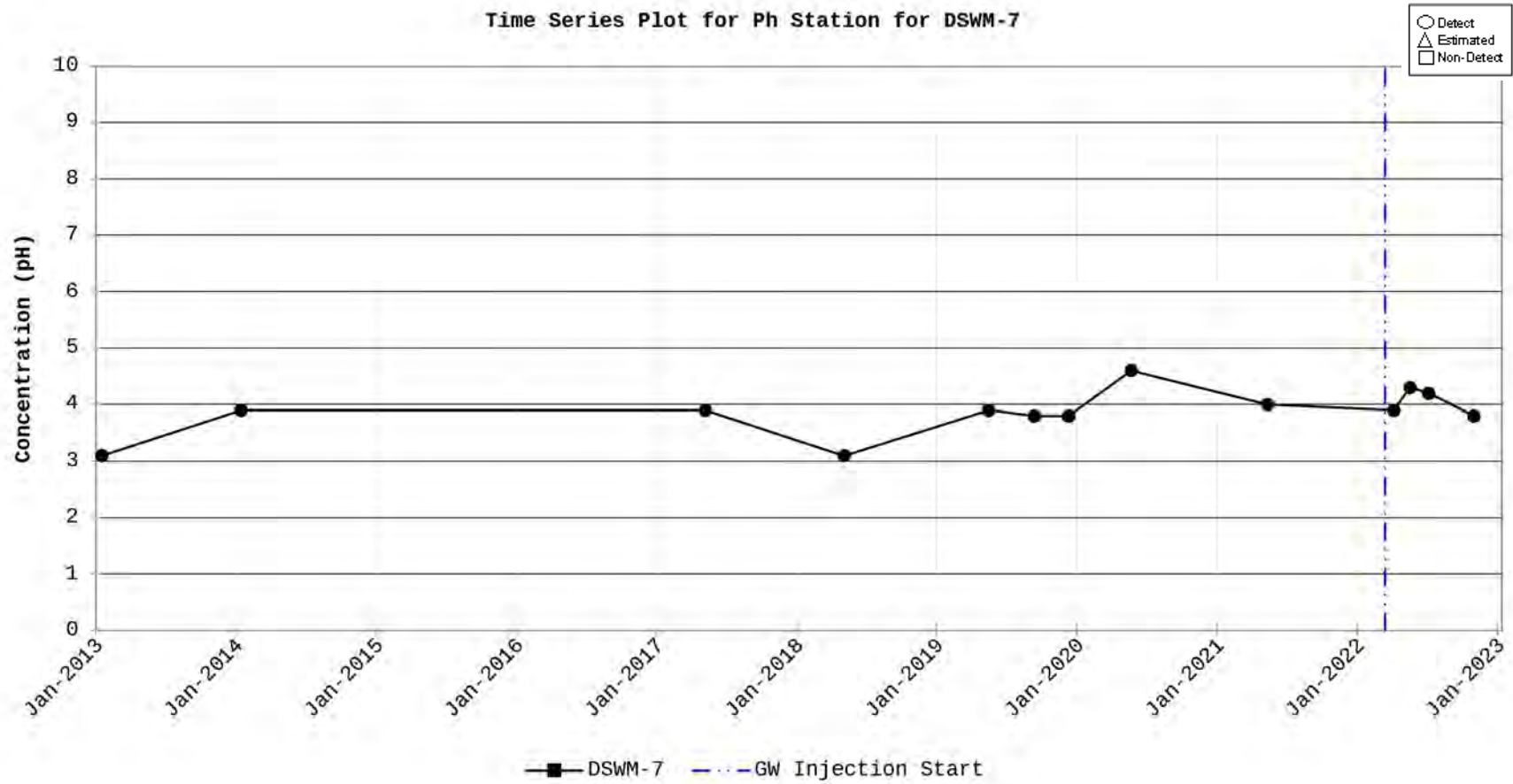


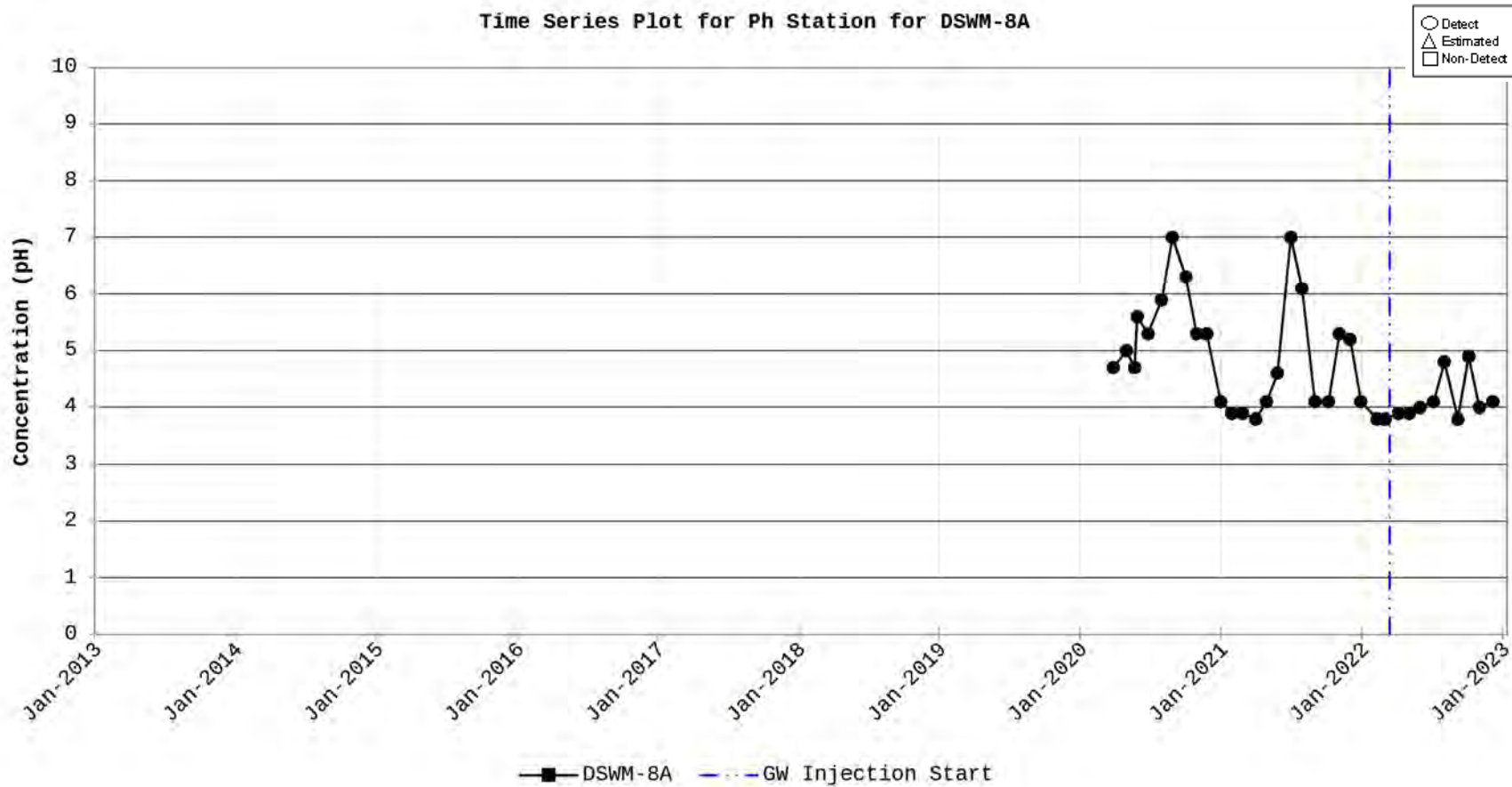


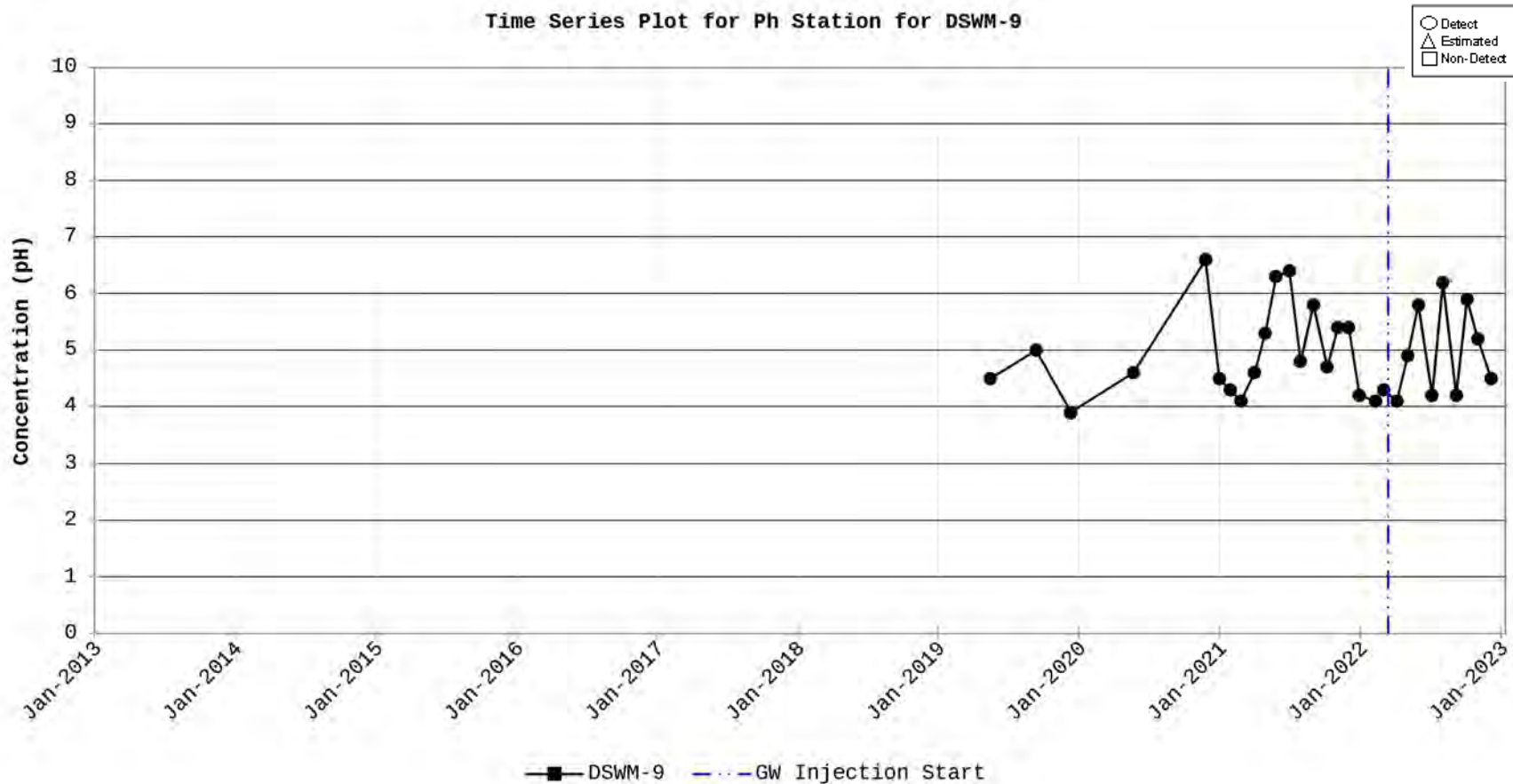












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