QUALITY ASSURANCE AND SURVEILLANCE PLAN

40 CFR 146.90(k)

TRILLIUM CARBON STORAGE COMPLEX (TCSC)

Facility Information

Facility Name: Trillium Carbon Storage Complex (TCSC)
TCSC-1, TCSC-2, TCSC-3, TCSC-4, TCSC-5

Facility Contact: Claimed as PBI [redacted]

Facility Address: Claimed as PBI [redacted]

Well Location: Claimed as PBI [redacted]

Well Name	Latitude	Longitude
TCSC-1	Claimed as PBI [redacted]	[redacted]
TCSC-2	Claimed as PBI [redacted]	[redacted]
TCSC-3	Claimed as PBI [redacted]	[redacted]
TCSC-4	Claimed as PBI [redacted]	[redacted]
TCSC-5	Claimed as PBI [redacted]	[redacted]

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Abbreviations and Acronyms

°C	Degrees Celsius
°F	Degrees Fahrenheit
^{13}C	Carbon-13 (Isotope of Carbon)
^{14}C	Carbon-14 (Isotope of Carbon)
2D	Two-Dimensional
^{2}H	Deuterium (Isotope of Hydrogen)
3D	Three-Dimensional
^{3}H	Tritium (Isotope of Hydrogen)
AoR	Area of Review
AP	Artificial Penetration
Ar	Argon
ASTM	American Society for Testing and Materials
AZM	Above-Zone Monitoring Well
cc	Cubic Centimeters
CFR	Code of Federal Regulations
cm	Centimeter
CO_2	Carbon Dioxide
Cr	Chromium
d	Day
DCS	Distributed Control System
DIC	Dissolved Inorganic Carbon
DOE	Department of Energy
Dol	Dolomite
DTS	Distributed Temperature Sensing
EPA	Environmental Protection Agency
Fm	Formation
FS	Full Span
ft	Foot
g	Gram
Gp	Group
H_2SO_4	Sulfuric Acid
HDPE	High Density Polyethylene
He	Helium
HNO_3	Nitric Acid
hr	Hour
ICP-AES	Inductively Coupled Plasma – Atomic Emission
ICP-MS	Inductively Coupled Plasma – Mass Spectrometry
ICP-OES	Inductively Coupled Plasma – Optical Emission
ISA	International Society of Automation
IZM	In-Zone Monitoring Well
km	Kilometer
Kr	Krypton
lb	Pound

Ls	Limestone
m	Meter
MD	Measured Depth
MDT	Modular Formation Dynamics Tester
meq	Milliequivalents
min	Minute
mL	Milliliter
mm	Millimeter
mt/d	Metric Ton per Day
NACE	National Association of Corrosion Engineers
NaOH	Sodium Hydroxide
Ne	Neon
NELAP	National Environmental Laboratory Accreditation
P/T	Pressure/Temperature
PLC	Programable Logic Controller
PNL	Pulsed Neutron Log
psi	Pounds per Square Inch
psig	Pound per Square Inch – Gauge
PTFE	Polytetrafluoroethylene
pu	Porosity Units
QA	Quality Assurance
QAQC	Quality Assurance/Quality Control
QASP	Quality Assurance and Surveillance Plan
RDT	Reservoir Description Tool
Rn	Radon
SCADA	Supervisory Control and Data Acquisition System
Sh	Shale
SM	Standard Methods
SOP	Standard Operating Procedure
Ss	Sandstone
TBD	To Be Determined
TCSC	Trillium Carbon Storage Complex
TDS	Total Dissolved Solids
Trillium	Trillium Piketon, LLC
TVDSS	True Vertical Depth Subsea
UIC	Underground Injection Control
USDW	Underground Source of Drinking Water
Xe	Xenon
YPIP	Years Post-Injection Phase
μm	Micrometer

7A. QUALITY ASSURANCE AND SURVEILLANCE PLAN

7A.1. PROJECT MANAGEMENT

7A.1.1. Project/Task Organization

7A.1.1.1. Key Individuals and Responsibilities

The project will be owned and operated by Trillium Piketon, LLC (Trillium). Trillium will serve as the lead on all project related tasks and supervise the performance of subcontractors, when required, for individual tasks. The Trillium Carbon Storage Complex (TCSC) Program Manager will be responsible for the implementation of this plan during the pre-injection, injection, and post-injection periods of the project. Tasks related to testing and monitoring at TCSC that will require supervision for purposes of quality control and assurance can be broadly divided into:

1. Mechanical Integrity Testing.
2. Operational Testing and Monitoring.
3. Groundwater Quality and Geochemical Monitoring.
4. Carbon Dioxide (CO_2) Plume and Pressure Front Tracking.

Trillium will assign key personnel, similar to the following examples, for implementation of testing and monitoring activities at TCSC:

1. Project Manager.
2. Environmental Manager.
3. Construction Manager.
4. Site Safety Manager.
5. Project Engineers.

7A.1.1.2. Independence from Project Quality Assurance (QA) Manager and Data Gathering

Various sampling and testing will be performed as part of the testing and monitoring program. These tests and samples will be analyzed, processed, or witnessed by independent third parties outside of the project management structure. Trillium will provide the Environmental Protection Agency (EPA) Region 05 Underground Injection Control (UIC) Program Director with the name and credentials of any vendors, subcontractors, and laboratories used for testing and monitoring activities during each semi-annual reporting period.

7A.1.1.3. Quality Assurance Project Plan Responsibility

Trillium will be responsible for maintaining and distributing an official, approved, **Quality Assurance and Surveillance Plan** (**QASP**). Trillium will periodically review this **Quality Assurance and Surveillance Plan** and consult the UIC Program Director if and/or when changes to the plan are warranted.

7A.1.1.4. Organizational Chart of Key Project Personnel

Claimed as PBI [redacted]

Claimed as PBI [redacted]

Figure 7A-1. Claimed as PBI [redacted] **of key project personnel and their hierarchy.**

7A.1.2. Project Definition and Background

7A.1.2.1. Reasons for Initiating Project

The Trillium Project design is Claimed as PBI [redacted]

7A.1.2.2. Project Overview

The **Testing and Monitoring Plan** has been designed to evaluate TCSC performance, demonstrate the project is operating as permitted, and ensure protection of local Underground Sources of Drinking Water (USDW). To help achieve this, the **Quality Assurance and Surveillance Plan** has been developed to ensure the quality and standards of testing and monitoring activities and to specifically meet the requirements set forth under 40 CFR 146.90(k).

The testing and monitoring program Trillium is to implement consists of four main aspects including (1) mechanical integrity testing, (2) operational testing and monitoring, (3) groundwater quality and geochemical monitoring, and (4) CO_2 plume and pressure front tracking. The mechanical integrity testing and operational testing and monitoring aspects ensure injection operations are being performed safely, efficiently, and as permitted. Both internal and external mechanical integrity will be demonstrated periodically throughout the lifespan of TCSC to ensure all CO_2 injection wells maintain well integrity at all times pursuant to 40 CFR 146.88(d). Operational testing and monitoring includes the analysis of the CO_2 injectate stream's chemical and physical properties (i.e., composition, injection rate, volume, temperature, and pressure, corrosion monitoring, and pressure fall-off testing pursuant to 40 CFR 146.90(a), 146.90(b), 146.90(c), and 146.90(f). The groundwater quality and geochemical monitoring aspect focuses on the safety of USDWs. Groundwater quality and geochemical monitoring will occur in the above confining zone pursuant to 40 CFR 146.90(d), specifically within the first permeable zone above the caprock (i.e., Claimed as PBI [redacted]), to demonstrate CO_2

containment and USDW non-endangerment. In the unlikely event of loss of containment from the storage complex, the groundwater quality and geochemical monitoring strategy will allow for the detection any out of zone fluids prior to them posing risk to shallow USDWs. The CO_2 plume and pressure front tracking aspect, pursuant to 40 CFR 146.90(g), focuses on indirectly imaging the CO_2 plume and directly tracking the pressure front throughout the storage reservoirs to ensure they are moving as predicted.

7A.1.2.3. Regulatory Information, Applicable Criteria, and Action Limits

Trillium, pursuant to 40 CFR 146.90, is required to perform various tests and activities throughout the lifespan of the project to (1) ensure all injection wells maintain mechanical integrity, (2) ensure operations as well as fluid migration and the extent of the pressure front are within the limits described in the permit application, and (3) ensure protection of USDWs, public health and safety, and the local environment. This **Quality Assurance and Surveillance Plan** discusses the methods to be implemented at TCSC as well as the steps Trillium will take to ensure that the quality of all data gathered provides confidence in making project decisions. For a summary of anticipated project action outputs and limits, please reference **Table 7A-3**.

7A.1.3. Project and Task Description

7A.1.3.1. Summary of Work to be Performed

The TCSC **Testing and Monitoring Plan** includes the following work:

- CO_2 stream analysis (40 CFR 146.90(a)).
- Continuous recording of operational parameters (40 CFR 146.90(b)).
- Corrosion monitoring (40 CFR 146.90(c)).
- Groundwater quality and geochemical monitoring above the confining zone (40 CFR 146.90(d)).
- Mechanical integrity testing (40 CFR 146.90(e)).
- Pressure fall-off testing (40 CFR 146.90(f)).
- CO_2 plume and pressure front tracking (40 CFR 146.90(g)).

For a summary of all testing and monitoring activities to be performed at TCSC, please reference **Table 7A-1**. For detailed information on these activities, including their frequencies throughout all project phases (i.e., pre-injection, injection, post-injection), please reference the **Pre-Operational Testing Program**, the **Testing and Monitoring Plan**, and the **Post-Injection Site Care and Site Closure Plan**, respectively.

7A.1.3.1. Geographic and Stratigraphic Location of Wells

Five CO_2 injection wells and eight monitoring wells (**Table 7A-2**) have been strategically placed spatially and stratigraphically around the TCSC site to accurately monitor all project activities. **Figure 7A-2** displays the locations of all project wells spatially across TCSC relative to project elements whereas **Figure 7A-3** provides a generalized stratigraphic column and depiction of project wells completed within their respective formations. All five injection wells are proposed to be located on one central well pad. Injection wells TCSC-1 and TCSC-2 will be completed within the [redacted] (i.e., storage reservoir) whereas TCSC-3, TCSC-4, and TCSC-5 will be completed within the [redacted] (i.e., storage reservoir). Three in-zone monitoring wells (TCSC_IZM-(1-3)) are proposed to be located along the modeled maximum extent of the CO_2 plume and within the AoR. In-zone monitoring wells will be dual-zone completed and have the capability of monitoring both the [redacted] and [redacted] storage reservoirs. Five above-zone monitoring wells

(TCSC_AZM-(1-5)) are proposed to be completed within the first permeable zone above the caprock (i.e., [redacted]) and will be located in sensitive areas throughout the AoR [redacted] and locations where groundwater is sourced from. The goal of the above-zone monitoring wells is to aid in the protection of USDWs by demonstrating CO_2 containment and USDW non-endangerment. In the unlikely event of loss of containment from the storage complex, the above-zone monitoring strategy will allow for early detection of out of zone CO_2 and/or reservoir fluids prior to them reaching overlying USDWs.

7A.1.3.1. Resource and Time Constraints

Trillium will coordinate deployment and use of the testing and monitoring equipment described in the **Testing and Monitoring Plan** and this **Quality Assurance and Surveillance Plan** appropriately with the respective service companies, subcontractors, and laboratories.

Table 7A-1. Summary of the testing and monitoring activities at TCSC.

Monitoring Category & Parameter		Method or Equipment	Location	40 CFR Reference
Mechanical Integrity Testing	Internal	Annulus pressure test Annulus pressure monitoring	TCSC-(1-5)	146.87(a)(4) 146.88(d) 146.89(a)(1) 146.89(b) 146.91(a)(7) 146.91(b)(1)
	External	DTS fiber-optic or equivalent	TCSC-(1-5)	146.87(a)(4) 146.88(d) 146.89(a)(2) 146.89(c) 146.90(e) 146.91(a)(7) 146.91(b)(1) 146.92(a)
Operational Testing and Monitoring	CO_2 Stream Chemical Analysis	Physical sampling and laboratory analysis	Downstream of CO_2 compression facilities and upstream of TCSC-(1-5)	146.90(a) 146.91(a)(1) 146.91(a)(7)
	Continuous Recording of Injection Rate, Volume, and Temperature	Corolis flow meter or equivalent	Immediately upstream of TCSC-(1-5) on well pad	146.88(e)(1) 146.90(b) 146.91(a)(2)
	Continuous Recording of Injection Pressure	(a) Wellhead pressure gauge(s) (b) Downhole pressure gauge(s)	TCSC-(1-5)	146.88(e)(1) 146.90(b) 146.91(a)(2)
	Continuous Recording of Annulus Pressure	Wellhead pressure gauge(s)	TCSC-(1-5)	146.88(e)(1) 146.90(b) 146.91(a)(2)
	Continuous Recording of Annulus Fluid Volume Added	Annulus monitoring system	TCSC-(1-5) on well pad	146.88(e)(1) 146.90(b) 146.91(a)(6)

Monitoring Category & Parameter		Method or Equipment	Location	40 CFR Reference
	Corrosion Monitoring	Corrosion coupon(s)	Immediately upstream of TCSC-(1-5) on well pad	146.89(d) 146.90(c) 146.91(a)(7)
	Hydrogeologic Characteristics	Pressure fall-off test	TCSC-(1-5)	146.87(e)(1) 146.90(f) 146.91(a)(7)
Groundwater Quality and Geochemical Monitoring	Above-Zone (i.e., First Permeable Zone Above Caprock) Monitoring	a) Fluid sampling and laboratory analysis b) Downhole pressure measurements	TCSC_AZM-(1-5)	146.82(a)(6) 146.90(d) 146.91(a)(7) 146.93(b)
CO_2 Plume and Pressure Front Tracking	Indirect CO_2 Plume Imaging	Surface seismic (2D or 3D) or equivalent	TCSC site	146.90(g)(2) 146.91(a)(7) 146.93(b)
		Pulsed neutron logging	Select wells	146.90(g)(2) 146.91(a)(7) 146.93(b)
	Direct Pressure Front Tracking	Downhole pressure gauge(s)	TCSC_IZM-(1-3) TCSC-(1-5)	146.90(g)(1) 146.91(a)(7) 146.93(b)

Note: For pre-injection, injection, and post-injection phase testing and monitoring frequencies, please reference the **Pre-Operational Testing Program**, the **Testing and Monitoring Plan**, and the **Post-Injection Site Care and Site Closure Plan**, respectively.

Table 7A-2. TCSC well summary.

Well Type	Well Acronym	Well Trajectory	Zone Formation	CCS System Zone	Estimated Depth[A] (ft TVDSS/MD)	Quantity
Above-Zone Monitoring	TCSC_AZM-1 TCSC_AZM-2 TCSC_AZM-3 TCSC_AZM-4 TCSC_AZM-5	Vertical	Claimed as PBI [redacted]	First Permeable Zone	Claimed as PBI [redacted] ft MD	5
In-Zone Monitoring	TCSC_IZM-1 TCSC_IZM-2 TCSC_IZM-3	Vertical	a) Claimed as PBI [redacted] b) Claimed as PBI [redacted]	Storage Reservoir	*TCSC_IZM-1*: a) Claimed as PBI b) Claimed as PBI [redacted] *TCSC_IZM-2*: a) Claimed as PBI b) Claimed as PBI [redacted] *TCSC_IZM-3*: a) Claimed as PBI b) Claimed as PBI [redacted]	3
CO_2 Injection	TCSC-1 TCSC-2	Deviated	Claimed as PBI [redacted]	Storage Reservoir	Claimed as PBI [redacted]	2
	TCSC-3 TCSC-4 TCSC-5	Deviated	Claimed as PBI [redacted]	Storage Reservoir	Claimed as PBI [redacted]	3

[A]Estimated depth of the formation top.

7A.1.4. Quality Objectives and Criteria

7A.1.4.1. Performance and Measurement Criteria

The overall objective of this **Quality Assurance and Surveillance Plan** is to develop and implement procedures for subsurface monitoring, field sampling, laboratory analysis, and reporting which will provide results to meet the testing and monitoring and non-endangerment goals of the TCSC project along with the regulatory requirements set forth by 40 CFR 146.82. Please reference **Table 7A-3** through **Table 7A-6** for project monitoring parameters and their action limits.

7A.1.4.2. Bias

Assessment of analytical bias is to be the responsibility of the individual subcontractors and/or laboratories per their standard operating procedures and analytical methodologies.

Claimed as PBI

[redacted]

Figure 7A-2. Aerial view of TCSC displaying the location of all injection and monitoring wells relative to project elements. A) represents the laterals of TCSC-1 and TCSC-3. B) represents the laterals of TCSC-2 and TCSC-4. C) represents the lateral of TCSC-5. For a zoomed in view of the injection well pad, please reference Figure 7-3 of the Testing and Monitoring Plan. CO_2 plume and pressure front boundaries represent the combined maximum extent from both the Claimed as PBI **and** Claimed as PBI **storage reservoirs.**

Claimed as PBI [redacted]

Figure 7A-3. Generalized stratigraphic column and schematic of the injection and monitoring wells at TCSC. This figure is representative to display formations of interest and monitoring strategies. For official well schematics, please refer to the Well Construction Plan. *Directly under the TCSC injection site lies Claimed as PBI [redacted]**. ****Claimed as PBI [redacted] **the TCSC injection site but exists elsewhere throughout the area of review.**

Table 7A-3. Summary of the actionable testing and monitoring outputs.

Parameter	Method or Equipment	Project Action Limit	Detection Limit/Range[A]	Anticipated Reading
Internal Mechanical Integrity	Annulus pressure test	>10% pressure change	15 to 15,000 psi	<10% pressure change
External Mechanical Integrity	DTS fiber-optic or equivalent	Observation of temperature anomaly	Temperature resolution of <0.09 °C	Temperature to return toward static geothermal conditions
CO_2 Composition	Physical sampling and laboratory analysis	Outside of parameters listed in **Table 7A-4**	TBD, dependent on analytical method	**Table 7A-4**
Injection Rate	Corolis flow meter or equivalent	*Any rate above the following:* TCSC-1: [redacted] mt/d TCSC-2: [redacted] mt/d TCSC-3: [redacted] mt/d TCSC-4: [redacted] mt/d TCSC-5: [redacted] mt/d	Up to [redacted] mt/d	*At average injection rates:* TCSC-1: [redacted] mt/d TCSC-2: [redacted] mt/d TCSC-3: [redacted] mt/d TCSC-4: [redacted] mt/d TCSC-5: [redacted] mt/d
Surface Pressure	Wellhead pressure gauge(s)	*Any pressure above the following:* TCSC-1: [redacted] psi TCSC-2: [redacted] psi TCSC-3: [redacted] psi TCSC-4: [redacted] psi TCSC-5: [redacted] psi	15 to 15,000 psi	*At average injection rates:* TCSC-1: [redacted] psi – [redacted] psi TCSC-2: [redacted] psi – [redacted] psi TCSC-3: [redacted] psi – [redacted] psi TCSC-4: [redacted] psi – [redacted] psi TCSC-5: [redacted] psi – [redacted] psi
Downhole Pressure	Downhole pressure gauge(s)	*Any pressures over the following:* TCSC-1: [redacted] psi TCSC-2: [redacted] psi TCSC-3: [redacted] psi TCSC-4: [redacted] psi TCSC-5: [redacted] psi	200 to 10,000 psi	*At average injection rates:* TCSC-1: [redacted] psi TCSC-2: [redacted] psi TCSC-3: [redacted] psi TCSC-4: [redacted] psi TCSC-5: [redacted] psi

Parameter	Method or Equipment	Project Action Limit	Detection Limit/Range[A]	Anticipated Reading
Annulus Pressure	Wellhead pressure gauge(s)	Surface annulus pressure and/or downhole annulus/tubing differential pressure fall below expected values	15 to 15,000 psi	Annulus/tubing pressure differential of at least 150 psi
Annulus Volume	Annulus monitoring system	>10% loss of volume or continuous fluid make up exceeding 24-hours	Tank fluid level indicator	<10% loss of volume
Corrosion Monitoring	Corrosion coupon(s)	TBD upon baseline results	Mass: 0.0001 g Thickness: 0.001 mm	TBD upon baseline results
Above-Zone Geochemistry	Fluid sampling and laboratory analysis	Action to be taken when geochemical anomaly is observed. TBD upon baseline results	TBD, dependent on analytical method. See **Table 7A-5** for analytical method examples	TBD upon baseline results. See **Table 7A-5** for parameters to be analyzed
Above-Zone Pressure	Downhole pressure gauge(s)	Action to be taken when pressure anomaly is observed. TBD upon baseline results	200 to 10,000 psi	TBD upon baseline results
CO_2 Plume Tracking	a) Surface seismic b) Pulsed neutron logging	a) CO_2 plume is observed outside of storage complex b) Pulsed neutron logging to be performed if CO_2 loss of containment is detected	a) Dependent on geologic conditions b) Dependent on geologic conditions	a) CO_2 within storage complex. Profiles TBD prior to injection b) Profiles TBD prior to injection
Direct Pressure Front Tracking	Downhole pressure gauge(s)	*Injection wells*: TCSC-1: [redacted] psi TCSC-2: [redacted] psi TCSC-3: [redacted] psi TCSC-4: [redacted] psi	200 to 10,000 psi	*Injection Wells:* TCSC-1: [redacted] psi TCSC-2: [redacted] psi TCSC-3: [redacted] psi TCSC-4: [redacted] psi

Parameter	Method or Equipment	Project Action Limit	Detection Limit/Range[A]	Anticipated Reading
		TCSC-5: [redacted] psi *In-zone monitoring wells*: Pressure anomaly (e.g., >90% reservoir fracture pressure)		TCSC-5: [redacted] psi *In-zone monitoring wells*: <90% reservoir fracture pressure

[A]Detection limits and ranges are from example equipment provided throughout this document. Specific detection limits and ranges may vary depending on the selected equipment for testing and monitoring.

Table 7A-4. Summary of the expected physical and chemical characteristics of the CO_2 injectate stream at TCSC.

Parameter[A]	Expected Value	Unit
Physical Characteristics		
Pressure[B]	[redacted]	psi
Temperature[C]	[redacted]	°F
Chemical Characteristics		
Claimed as PBI [redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]

[A]This list is subject to change based on source injectate stream composition results.

[B]Represents pressure at the CO_2 outlet. Injectate pressure will be adjusted accordingly to meet desired injection rate.

[C]Represents the temperature the injectate stream Claimed as PBI [redacted]

Table 7A-5. Summary of analytical parameters for above-zone fluid sampling at TCSC.

Parameters[A]	Analytical Methods[B]
Formation: Claimed as PBI [redacted] *[C]*	
Major Cations	ICP-AES, ICP-OES, ICP-MS, or equivalent *(EPA 6000 Series [1], EPA 200.7 [2], or equivalent)*
Major Anions	Ion Chromatography, Spectroscopy, or equivalent *(EPA 300.0 [3], EPA 300.1 [4], SM 4500 Series [5], or equivalent)*
Ammonia Nitrogen	Colorimetry, Titration, or equivalent *(EPA 350.1 [6], EPA 350.2 [7], or equivalent)*
Dissolved CO_2	Coulometric Titration, Gas Sensing Electrode, or equivalent *(ASTM D513-16 [8] or equivalent)*
Total Dissolved Solids	Gravimetry or equivalent *(EPA 160.1 [9], SM 2540C [10], ASTM D5907-18 [11], or equivalent)*
Alkalinity	pH Meter or equivalent *(SM 2320B [12], ASTM D3875-15 [13] or equivalent)*
pH	pH Meter or equivalent *(EPA 150.1 [14], SM4500H+B [15], ASTM D1293-18 [16], or equivalent)*
Temperature	Thermocouple or equivalent *(SM 2550B [17] or equivalent)*
Conductivity	Conductivity Meter or equivalent *(EPA 120.1 [18], SM 2510B [19], ASTM D1125-23 [20], or equivalent)*
Density	Pycnometer, Hydrometer, Density Meter, or equivalent *(ASTM D1429-13 [21], ASTM D1480-21 [22], ASTM D4052-22 [23], or equivalent)*
Noble Gases: He, Ne, Ar, Kr, Xe, Rn[D]	Mass Spectrometry or equivalent
^{13}C of DIC and CO_2	Isotope Ratio Mass Spectrometry or equivalent
^{14}C of DIC and CO_2[D]	Accelerator Mass Spectrometry or equivalent
^{2}H of Water	Isotope Ratio Mass Spectrometry or equivalent
^{3}H of Water[D]	Accelerator Mass Spectrometry or equivalent

[A]Parameters may be added or subtracted to the sampling and analysis list depending on baseline results.

[B]Specific analytical methods will be selected in collaboration with the laboratory to perform the fluid testing and analysis to ensure parameters are appropriately analyzed. The methods and procedures selected will be provided to the Region 05 UIC Program Director.

[C]Both storage reservoirs (i.e., Claimed as PBI [redacted] and Claimed as PBI [redacted]) and the first permeable zone above the caprock (i.e., Claimed as PBI [redacted]) will be sampled prior to injection for baseline profiles. Only the first permeable zone will be sampled throughout the injection and post-injection phases.

[D]Noble gases, ^{14}C of DIC and CO_2, and ^{3}H of water will be analyzed in the first sampling event prior to injection. If parameters are not present or are non-significant to the project, they will be excluded from future sampling events.

Table 7A-6. Summary of the materials to be monitored for corrosion at TCSC.

Equipment Coupon	Material of Construction	Location
Long String Casing	Claimed as PBI, premium connection	Immediately upstream of TCSC-(1-5) on well pad
Injection Tubing	Claimed as PBI, premium connection	
Wellhead	Carbon, alloy, or stainless steel	
Packers	Claimed as PBI, VAM coupling	

7A.1.4.3. Representativeness

Data representativeness is the degree to which data accurately and precisely represents a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition. The TCSC sampling network has been designed to provide data representative of site-specific conditions; all testing and monitoring equipment will be placed in strategic locations and will monitor parameters at specific frequencies to collect representative data.

Well logging will be performed according to industry standard practices. Quality assurance/quality control (QAQC) procedures will be implemented by the service company performing the logging operations according to their standard operating procedures (SOPs). Surface and downhole gauges will be calibrated according to the manufacturers' guidelines and will be placed in locations on the well pad and downhole representative of the parameters to be monitored. Mass flow meters will be placed upstream of each CO_2 injection well on the shared well pad to collect representative physical data of the CO_2 injectate stream. Corrosion monitoring coupons of equipment to be in contact with CO_2 will be placed and sampled upstream of each injection well to ensure representative exposure to the CO_2 stream. The CO_2 stream will be physically sampled for compositional analyses downstream of the compression facilities and upstream of all injection wells to ensure samples are representative of the CO_2 to be injected in each well. Repeat indirect geophysical methods, such as seismic surveys and/or carbon dioxide detection tools (e.g., pulsed neutron), will be utilized throughout the lifespan of TCSC to obtain representative data on the CO_2 plume. All seismic surveys will be performed according to industry best practices and acquisition parameters will be tailored to the TCSC site to ensure surveys are capable of indirectly imaging the CO_2 plume and are comparable to one another (see section **7A.2.2.6. Non-Direct (indirect) Measurements** for additional information). Well purging will ensure groundwater fluid samples are representative of formation water quality whereas representativeness for their analytical results will be estimated by ion and mass balance calculations.

7A.1.4.4. Completeness

Data completeness is a measure of the quantity of valid data obtained from a measurement system compared to the amount that was expected to be obtained under normal conditions. It is anticipated that data completeness of 90% for groundwater sampling will be acceptable to meet monitoring goals. For direct pressure and temperature measurements, it is expected that data will be recorded no less than 90% of the time.

7A.1.4.5. Comparability

Data comparability is the confidence with which one dataset may be compared to another. The datasets generated at TCSC will be in accordance with a consistent methodology so that each dataset is directly comparable to another allowing for the identification of anomalies if present. Calibrating all field equipment to manufacturer specifications along with following industry standard methods and individual subcontractor SOPs for well logging, seismic acquisition, and groundwater sampling will ensure appropriate data collection and ultimately comparable results.

7A.1.5. Specialized Training and Certifications

7A.1.5.1. Specialized Training and Certifications

All sampling equipment, wireline logging tools, and other testing activities will be performed by trained, qualified, and where required, certified personnel according to the subcontractor providing the equipment and/or service. Subsequent data will be processed and analyzed by technically skilled personnel according to industry standards. Laboratory analyses will be performed and evaluated in NELAP (or equivalent) certified laboratories that employ qualified and experienced personnel who understand and regularly follow environmental sampling/analysis SOPs and QAQC protocols. Trillium will provide relevant certifications for all vendor and/or subcontractor staff upon request.

7A.1.5.2. Training Provider and Responsibility

Trillium and/or the designated subcontractor for the data collection activities will provide necessary training for personnel to ensure they are trained, qualified, and certified, where required, in the activity being performed.

7A.1.6. Documentation and Records

7A.1.6.1. Report Format and Package Information

Trillium will provide the UIC Program Director with semi-annual reports, along with required notifications, containing all relevant project data and testing and monitoring information pursuant to 40 CFR 146.91. Please refer to the **Testing and Monitoring Plan** for testing and monitoring reporting frequencies and their procedures.

7A.1.6.2. Other Project Documents, Records, and Electronic Files

Other documents, records, and electronic files such as well logs, test results, plugging reports, and other data will be stored and maintained throughout the life of the project pursuant to 40 CFR 146.91(f). Project data will be provided upon request of the UIC Program Director.

7A.1.6.3. Data Storage and Duration

All monitoring data collected throughout the implementation of the **Testing and Monitoring Plan** will be retained pursuant to 40 CFR 146.91(f):

- All data collected under 40 CFR 146.82 for Class VI permit applications shall be retained throughout the life of the geologic sequestration project and for ten years following site closure (40 CFR 146.91(f)(1)).

- Data on the nature and composition of all injected fluids collected pursuant to 40 CFR 146.90(a) shall be retained until ten years after site closure. The Director may require Trillium to deliver the records to the Director at the conclusion of the retention period (40 CFR 146.91(f)(2)).
- Monitoring data collected pursuant to 40 CFR 146.90(b) through (i) shall be retained for ten years after it is collected (40 CFR 146.91(f)(3)).
- Well plugging reports, post-injection site care data, including, if appropriate, data and information used to develop the demonstration of the alternative post-injection site care timeframe, and the site closure report collected pursuant to requirements at 40 CFR 146.93(f) and (h) shall be retained for ten years following site closure (40 CFR 146.91(f)(4)).

7A.1.6.4. QASP Distribution Responsibility

Trillium will maintain a position with the responsibility of providing the most current copy of the approved **Quality Assurance and Surveillance Plan** to all parties on the distribution list.

7A.2. DATA GENERATION AND ACQUISITION

7A.2.1. Sampling Process Design

This section describes the testing and monitoring network that Trillium will deploy to collect the data necessary to ensure TCSC is operating as permitted and to ensure there is no endangerment of USDWs by injection operations; this testing and monitoring network has been developed based on the current conceptual understanding of the TCSC site. Please reference **Table 7A-1** for a summary of all testing and monitoring activities to be performed at TCSC. For pre-injection, injection, and post-injection phase testing and monitoring frequencies, please reference the **Pre-Operational Testing Program**, the **Testing and Monitoring Plan**, and the **Post-Injection Site Care and Site Closure Plan**, respectively.

7A.2.1.1. Design Strategy

Mechanical Integrity Testing

Mechanical integrity of all CO_2 injection wells (TCSC-(1-5)) will be demonstrated throughout all phases of the TCSC project to protect USDWs and to prevent unintended fluid migration out of each injection wellbore. Internal mechanical integrity testing will demonstrate injection wells have no internal leaks in their casing, tubing, or packer. Internal mechanical integrity will be demonstrated once prior to injection with a standard annulus pressure test whereas the continuous recording of annulus pressure and fluid volume will demonstrate internal mechanical integrity throughout the injection phase. External mechanical integrity testing will demonstrate that fluids have not escaped from the wellbore and are not migrating along channels adjacent to the wellbore. External mechanical integrity testing will be demonstrated through the analysis of distributed temperature sensing (DTS) data prior to injection, throughout the injection phase, and once prior to injection well plugging. For additional information on the internal and external mechanical integrity testing strategies, please reference section **7.3 Mechanical Integrity Testing** of the **Testing and Monitoring Plan**.

Carbon Dioxide Stream Analysis

The CO_2 injectate stream will be monitored throughout the injection phase pursuant to 40 CFR 146.90(a) to yield data representative of its chemical and physical characteristics. To ensure CO_2 samples are representative of what is injected in each well, samples will be collected downstream of the compression facilities and upstream of all injection wells. The chemical components of the CO_2 stream sample will be analyzed via laboratory analysis. The physical components (e.g., pressure and temperature) of the CO_2 stream will be continuously monitored as described in **Continuous Recording of Injection Rate, Volume, Temperature, and Pressure.** For the expected composition of the CO_2 stream, please reference **Table 7A-4**. For additional information on the analysis of the CO_2 injectate stream, please reference section **7.4.1 Carbon Dioxide Stream Analysis** of the **Testing and Monitoring Plan**.

Continuous Recording of Injection Rate, Volume, Temperature, and Pressure

Pursuant to 40 CFR 146.88(e) and 146.90(a) and (b), the injection rate, volume, temperature, and pressure of the CO_2 injectate will be monitored continuously throughout the injection phase to ensure TCSC is operating safely and as permitted. Injection rate, volume, and temperature will be recorded for each injection well via mass flow meters such as a Coriolis flow meter or an equivalent device. Wellhead and downhole pressure gauges will monitor surface and downhole injection pressures for each CO_2 injection well. For specifications on equipment to be utilized for injection rate, volume, temperature, and pressure monitoring, please reference **Table 7A-7, Table 7A-8,** and **Table 7A-9**. For additional information on the continuous recording of injection rate, volume, temperature, and pressure, please reference section **7.4.2 Continuous Recording of Injection Rate, Volume, Temperature, and Pressure** of the **Testing and Monitoring Plan**.

Continuous Recording of Annulus Pressure and Fluid Volume

Pursuant to 40 CFR 146.88(e) and 146.90(b), the pressure on the annulus between the tubing and the long string casing along with the annulus fluid volume added will be continuously monitored throughout the injection phase. Continuous monitoring of annulus pressure and fluid volume will demonstrate internal mechanical integrity in each injection well throughout the injection phase. Annulus pressure will be monitored with pressure gauges ported to the annulus on each CO_2 injection wellhead whereas annulus fluid volume added to each injection well will be monitored with a fluid level indicator on the shared well pad. For specifications on equipment to be utilized for annulus pressure monitoring, please reference **Table 7A-8**. For additional information on annulus pressure and fluid volume monitoring, please reference section **7.4.3 Continuous Recording of Annulus Pressure and Fluid Volume** of the **Testing and Monitoring Plan**.

Corrosion Monitoring

Pursuant to 40 CFR 146.90(c), corrosion coupons will be monitored for corrosion to ensure the integrity of any equipment in contact with the CO_2 injectate. Corrosion coupons will be sampled on the shared well pad upstream of each injection well to ensure representative CO_2 exposure. The samples collected will be sent to a laboratory for analysis which will be conducted in accordance with NACE RP0775-2023 [24] (or similar) to determine and document corrosion wear rates and mass loss. For additional information on corrosion monitoring, please reference section **7.4.4 Corrosion Monitoring** of the **Testing and Monitoring Plan**.

Pressure Fall-Off Testing

Pursuant to 40 CFR 146.90(f), pressure fall-off tests will be performed once prior to injection and intermittently throughout the injection phase to determine reservoir properties (e.g., transmissivity). Intermittent pressure fall-off tests will help confirm site characterization information, ensure operating parameters are optimal for downhole conditions, inform AoR reevaluations, and verify the injection zones are responding as predicted. For specifications on the downhole pressure gauges to be utilized for pressure fall-off testing, please reference **Table 7A-9**. For additional information on pressure fall-off testing, please reference section **7.4.5 Pressure Fall-Off Testing** of the **Testing and Monitoring Plan**.

Groundwater Quality and Geochemical Monitoring

Pursuant to 40 CFR 146.90(d), the groundwater quality and geochemistry of the Claimed as PBI (i.e., first permeable zone above the caprock) will be monitored to protect USDWs. Monitoring the first permeable zone above the caprock will demonstrate CO_2 containment and USDW non endangerment. In the unlikely event of storage complex loss of containment, the groundwater quality and geochemical monitoring strategy will allow for early identification of anomalous quality or geochemical changes associated with out of zone fluids so that corrective actions may be taken before USDWs are endangered. Five above-zone monitoring wells (TCSC_AZM-(1-5)) will be completed within the Claimed as PBI and strategically located throughout the AoR in sensitive areas such as Claimed as PBI where groundwater is sourced from (**Figure 7-2**). Fluid samples will be collected from each above-zone monitoring well via well purging such as the low-flow purge or equivalent method [25]. Groundwater samples will then be sent to qualified laboratories for geochemical analysis. In addition to fluid sampling and analysis, the Claimed as PBI formation pressure will be monitored via downhole pressure gauges; downhole gauges will be used to identify any anomalous pressures that may be associated with unexpected out of zone CO_2 and/or reservoir fluids and therefore act as indirect water quality indicators. For additional information on groundwater quality and geochemical monitoring, please reference section **7.5 Groundwater Quality and Geochemical Monitoring** of the **Testing and Monitoring Plan**. For additional information on sampling equipment and laboratory analysis, please reference sections **7A.2.2. Sampling Methods** through **7A.2.5. Analytical Methods** of this **Quality Assurance and Surveillance Plan**.

Indirect CO_2 Plume Tracking

Pursuant to 40 CFR 146.90(g)(2), the CO_2 plume will be tracked indirectly across the TCSC site to ensure it is appropriately stored and is moving throughout the storage complex as predicted. Repeat surface seismic (2D or 3D) will be utilized to track the evolution of the CO_2 plume throughout time. In addition to surface seismic, three in-zone monitoring wells (TCSC_IZM-(1-3)) are proposed to be located along the maximum modeled extent of the CO_2 plume and within the AoR. All in-zone wells will be dual-zone completed and capable of monitoring each storage reservoir (i.e., Claimed as PBI and Claimed as PBI). CO_2 detection tools, such as pulsed neutron logs (PNLs), will be utilized in select monitoring wells on an as needed basis to verify the presence and extent of the CO_2 plume within the storage reservoirs. For additional information on the indirect methods to be utilized for CO_2 plume tracking, please reference section **7.6 Carbon Dioxide Plume and Pressure Front Tracking** of the **Testing and Monitoring Plan** and section **7A.2.2.6. Non-Direct (indirect) Measurements** of this **Quality Assurance and Surveillance Plan**.

Direct Pressure Front Tracking

Pursuant to 40 CFR 146.90(g)(1), the elevated pressure front associated with CO_2 injection operations will be directly monitored across the TCSC site via downhole pressure gauges deployed in all in-zone monitoring wells TCSC_IZM-(1-3)). Each in-zone monitoring well will be dual-zone completed and will be capable of tracking pressure front propagation throughout the Claimed as PBI and Claimed as PBI storage reservoirs throughout time. Downhole pressure measurements will inform operational parameters and the computational model to ensure TCSC is operating as permitted and that models are accurately predicting the migration of CO_2 injectate. For additional information on direct pressure front tracking, please reference section **7.6 Carbon Dioxide Plume and Pressure Front Tracking** of the **Testing and Monitoring Plan**. For downhole pressure gauge specifications, please reference **Table 7A-9**.

7A.2.1.2. Type and Number of Samples/Test Runs

Please reference **Table 7A-1** for information on the sampling and testing activities. For sampling and testing frequencies during the pre-injection, injection, and post-injection phases, please reference the **Pre-Operational Testing Program**, **Testing and Monitoring Plan**, and **Post-Injection Site Care and Site Closure Plan**, respectively.

7A.2.1.3. Sampling Site Contingency

All testing and monitoring activities will occur Claimed as PBI [redacted] If inclement weather conditions or other unforeseeable events make site access difficult, sampling schedules will be revised, and alternate dates may be selected for monitoring to meet permit-related requirements.

7A.2.1.4. Activity Schedule

Please reference **Table 7A-1** for an overview of all testing and monitoring activities. For information on pre-injection, injection, and post-injection phase testing and monitoring frequencies, please reference **Table 5-11** of the **Pre-Operational Testing Program**, **Table 7-2** of the **Testing and Monitoring Plan**, and **Table 9-2** of the **Post-Injection Site Care and Closure Plan**, respectively.

7A.2.1.5. Critical/Informational Data

Field and laboratory activities will be recorded in forms and/or notebooks during the respective testing and monitoring event. Information to be documented during field and laboratory testing and monitoring includes date of activity, person(s) performing activity, location of activity, instruments utilized and their calibration data, and results of the testing and monitoring activity. All necessary data will be collected and reported pursuant to 40 CFR 146.91, and as outlined in section **7.2.4 Reporting Procedures** of the **Testing and Monitoring Plan**.

7A.2.1.6. Sources of Variability

Potential sources of variability related to testing and monitoring activities include:

- Natural variation in fluid quality, formation pressure and temperature, and seismic activity.
- Variation in fluid quality, formation pressure and temperature, and seismic activity as a result of project operations.
- Changes in recharge due to precipitation (e.g., rainfall, drought).
- Changes in instrument calibration during sampling or analytical activity.
- Different personnel collecting and/or analyzing data.
- Variation in environmental conditions during field testing and monitoring.
- Changes in analytical data quality during the life of the project.
- Data entry errors.

The previous sources of potential variability may be eliminated, reduced, or reconciled via the following methods:

- Collecting baseline data to observe and document natural variations of monitoring parameters.
- Evaluating data in a timely manner upon its collection to identify any anomalies that can be addressed by resampling or reanalyzing the data.
- Conducting statistical analyses of data to determine whether variability is the result of natural variations or project activities.
- Maintaining weather-related data using on-site data or data collected from nearby locations.
- Verifying instrument calibration before, during, and after testing and monitoring.
- Ensuring personnel are appropriately trained and capable of operating equipment or interpreting data associated with testing and monitoring activities.
- Performing activities pursuant to their SOPs and following QAQC protocols.
- Utilizing a systematic review process of data that may include sample-specific data quality checks.

7A.2.2. Sampling Methods

7A.2.2.1. Sampling Standard Operating Procedures

All sampling activities will be performed by qualified and appropriately trained personnel in accordance with industry standard best practices and/or the SOPs of the individual subcontractor.

7A.2.2.2. Mechanical Integrity Testing

Internal Mechanical Integrity

Internal mechanical integrity will be demonstrated in all CO_2 injection wells via an initial annulus pressure test followed by the continuous monitoring of annulus pressure and fluid volume. Surface pressure gauges ported to the injection tubing and annulus will be utilized for the initial annulus pressure test. Following the annulus pressure test, the surface gauges will continuously record injection and annulus pressures whereas a fluid level indicator a part of the annulus monitoring system will monitor fluid volume to continuously demonstrate internal mechanical integrity throughout injection.

External Mechanical Integrity

External mechanical integrity will be demonstrated in all CO_2 injection wells prior to injection, periodically throughout the injection phase at the frequencies stated in the **Testing and Monitoring Plan**, and prior to well plugging. External mechanical integrity will be demonstrated with DTS data collected from fiber-optic cables deployed from at least the base of each storage reservoirs caprock to the surface within each injection well. DTS fiber-optic cables record temperature throughout the wellbore. DTS data, similar to temperature data collected via wireline logging, can be utilized to identify temperature anomalies associated with leaks in casing and fluid movement along the wellbore therefore demonstrating external mechanical integrity pursuant to 40 CFR 146.89(a)(2).

7A.2.2.3. Carbon Dioxide Stream Chemical Composition Sampling

To analyze the chemical composition of the CO_2 stream, the injectate will be physically sampled downstream of the compression facilities and upstream of all injection wells. CO_2 samples will be collected in gas cylinders or equivalent and sent to a qualified and capable laboratory for chemical analysis.

7A.2.2.4. Injection Well Operating Parameters

Continuous Recording

Data related to injection operations will be continuously recorded throughout the injection phase of the project. CO_2 injectate rate, volume, and temperature will be continuously recorded via Coriolis mass flow meters or equivalent immediately upstream of each injection well on the shared well pad. Injection pressure will be continuously recorded via surface pressure gauges ported to the injection tubing on each wellhead; additionally, downhole pressure gauges will record bottomhole injection pressures within the storage reservoirs.

Annulus pressure (i.e., the pressure between the injection tubing and long string casing) and fluid volume will be continuously recorded throughout the injection phase. Surface pressure gauges ported to the annulus on each injection wellhead will record annulus pressures whereas a fluid level indicator will monitor the fluid volume of the annulus.

A distributed control system (DCS) will be utilized to control operational parameters to ensure they remain within their permitted ranges. A supervisory control and data acquisition (SCADA) system will be utilized for real-time monitoring and project decision making; the SCADA will be utilized to monitor operations and identify any anomalous trends in data. If specific parameters are observed to exceed their allowable operating limits, an automatic alarm will be triggered, operations will be shut down, and an investigation will be performed to identify the cause of the shutoff pursuant to 40 CFR 146.88(e) and 146.88(f).

Corrosion Sampling

Well materials that are to be in contact with CO_2 will be sampled and monitored for corrosion to ensure their integrity. Corrosion coupons will be placed immediately upstream of each injection wellhead to ensure representative exposure to the CO_2 injectate stream. Corrosion coupons will be a part of a loop system which consists of coupons inserted into the main pipeline with a parallel section or pipeline bypass adjacent. During corrosion coupon sampling, the main-line will be shut in and the CO_2 injectate will be routed through the bypass pipeline section so that coupons can be retrieved without needing to cease injection operations. Coupons will be sampled and analyzed following the NACE RP0775-2023 [24] standard or a similarly accepted practice. If corrosion monitoring results indicate corrosion of certain downhole equipment, wireline logs may be utilized for further downhole inspection.

7A.2.2.5. In-Situ Sampling

In-situ groundwater samples will be collected from the Claimed as PBI (i.e., first permeable zone above the caprock) to monitor the groundwater quality and geochemistry above the confining unit. Groundwater samples will be collected from all above-zone monitoring wells (TCSC_AZM-(1-5)) via well purging such as low-flow purging or equivalent methods [25] best suited for the depths of the above-zone monitoring wells. Well purging will ensure that samples collected are representative of formation water quality. For additional details regarding groundwater sampling methods and sample homogenization, please reference section **7A.2.4.1. Sample Homogenization, Composition, and Filtration**. Once samples are collected, they will be sent to a qualified and capable laboratory for geochemical analysis following the protocols described throughout section **7A.2.4. Sample Handling and Custody** through section **7A.2.5. Analytical Methods**. The anticipated parameters to be sampled and analyzed are listed in **Table 7A-5** and will be refined upon baseline results.

Additionally, fluid samples will be collected from the Claimed as PBI and Claimed as PBI storage reservoirs prior to injection for baseline profiles. Storage reservoir fluids samples will be collected during the drilling and construction of the TCSC-3 stratigraphic wellbore via wireline formation testers such as the modular formation dynamics tester (MDT), reservoir description tool (RDT), or equivalent. For additional information on pre-injection testing, please reference the **Pre-Operational Testing Program**.

7A.2.2.6. Non-Direct (indirect) Measurements

Data Sources

CO_2 plume development will be indirectly imaged and monitored with repeat surface seismic (2D or 3D) or equivalent. Additionally, pulsed neutron logging may also be utilized in select wells on an as needed basis to verify the presence and extent of the CO_2 plume.

Relevance to Project

Time-lapse seismic surveys will be used to indirectly image the CO_2 plume and track its movement throughout the Claimed as PBI and Claimed as PBI storage reservoirs. Processing and comparing repeat injection phase surveys to the baseline survey will allow for CO_2 plume development to be monitored throughout time to ensure the injectate does not exceed the boundaries of the intended storage reservoirs. Additionally, the data collected will be used in numerical modeling efforts to better predict CO_2 plume growth and migration over time.

Operating Conditions, Acceptance Criteria, and Validity Limits

The repeatability of seismic surveys and/or downhole measurements for timelapse monitoring is critical for accurate comparison between events. Seismic data will be collected via industry standard best practices to ensure accuracy in acquisition, processing, and interpretation. Similar ground conditions, shot point locations within acceptable limits, carefully inspected geophones, and uniform seismic input signals will be used for each survey to ensure repeatability. Processing of seismic data will occur using industry standard practices with QC checks conducted periodically throughout. Similarly, wireline logging tools utilized will be carefully calibrated to the manufacturer's specifications and be deployed according to well logging best practices to ensure repeatability between wireline measurements. Technically trained and capable personnel will interpret results of surveys and downhole measurements. Intraorganizational verification by trained and experienced personnel will ensure all surveys, downhole measurements, and modeling efforts are performed according to industry standard best practices.

Resources/Facilities Needed

All necessary resources for seismic monitoring, well logging, and any other downhole indirect measurements will be subcontracted to highly skilled and capable vendors.

7A.2.2.7. Direct Measurements

The elevated pressure front associated with CO_2 injection operations will be monitored directly within each storage reservoir via downhole pressure gauges deployed in all injection and in-zone monitoring wells. Downhole pressure measurements from the CO_2 injection wells will be monitored to guide operational parameters. In-zone monitoring wells TCSC_IZM-(1-3) will be dual-zone completed to monitor formation pressures in both the Claimed as PBI and Claimed as PBI storage reservoirs. Pressure measurements from each in-zone monitoring well will be used to validate or update the site model to allow for better prediction of CO_2 plume and pressure front evolution throughout the storage complex.

7A.2.3. Instrumentation

All DCS, SCADA, flow meters, pressure/temperature gauges, wireline logging tools, and fiber-optic cables will be maintained according to their respective manufacturer's specifications and best practices. All groundwater sampling field equipment will be maintained, factory serviced, and factory calibrated per the equipment manufacturer's recommendations. Any laboratory equipment utilized for sampling and analysis will be maintained by the analytical laboratory selected per their standard practices, method specific protocols, or NELAP or equivalent requirements.

7A.2.3.1. Method Sensitivity and Precision

All equipment used to monitor the CO_2 injectate stream's physical and chemical characteristics along with surface and downhole conditions will have a sufficient detection range for accurate monitoring. Monitoring tools and/or field devices will be calibrated according to the respective manufacturer's specifications. For groundwater quality and geochemical monitoring, data accuracy will be assessed by the collection and analysis of field blanks to test sampling procedures and matrix spikes to test laboratory procedures. **Table 7A-7** through **Table 7A-11** provide example specifications for equipment that may be utilized throughout the **Testing and Monitoring Plan**.

Table 7A-7. CO_2 mass flow meter specifications.

Specification	Value
Calibrated working flow rate range	Up to 13,063 mt/d
Mass flow rate accuracy	±0.10% of rate (liquid) and ±0.35% of rate (gas)
Mass flow rate repeatability	±0.05% of rate (liquid) and ±0.20% of rate (gas)
Volume flow accuracy (liquid)	±0.10% of rate
Volume flow repeatability (liquid)	±0.05% of rate
Density accuracy (liquid)	±0.0005 g/cm^3
Density repeatability (liquid)	±0.0002 g/cm^3
Temperature accuracy	±1°C ±0.5% of reading
Sensor maximum working pressure	2,973 psig

Note: Specifications from an *Emerson CMF400P Coriolis Meter* are provided as an example of flow meter specifications from a vendor. A similar device best suited for the injection rate, volume, temperature, and pressure of CO_2 will be selected.

Table 7A-8. Wellhead pressure gauge specifications.

Specification	Value
Pressure measurement range	15 to 15,000 psi
Accuracy	0.025% FS
Compensated temperature range	-10 to 50 °C

Note: Specifications from a *Wika CPG1500* pressure gauge are provided as an example of pressure gauge specifications from a vendor. A similar device best suited for the injection pressure and temperature of CO_2 will be selected. FS = full span.

Table 7A-9. Downhole pressure-temperature gauge specifications.

Specification	Value
Pressure measurement range	200 to 10,000 psi
Pressure accuracy	±0.015% (1.5 psi at FS)
Pressure resolution	0.0001 psi
Pressure stability	0.02% FS
Temperature measurement range	25 to 150 °C
Temperature accuracy	0.15 °C
Temperature resolution	0.0001 °F
Temperature stability	<0.01 °C per year

Note: Specifications from a *Baker Hughes SureSENS QPT Elite* permanent downhole gauge are provided as an example of downhole gauge specifications from a vendor. A similar device best suited for the injection pressure and temperature of CO_2 will be selected. FS = full span.

Table 7A-10. Wireline well logging tool specifications.

Tool	Logging Speed	Vertical Resolution	Depth of Investigation	Temperature Rating	Pressure Rating
Pulsar	1,000 ft/hr	15 inches	10-16 inches	350°F	15,000 psi
Ultrasonic Imager Tool	1,800 ft/hr	6 inches	Casing-to-cement interface	350°F	20,000 psi
Cement Bond Log	3,600 ft/hr	3 feet	Casing and cement interface	302°F	14,000 psi
Temperature Log	Dependent on application	Point of measurement	Borehole	302°F	15,000 psi

Note: Specifications from *SLB* tools are provided as an example of wireline logging tool specifications from a vendor. Similar tools best suited for the specific application will be selected.

Table 7A-11. Geophysical fiber-optic technology specifications.

Specification	Value
Nominal range	5 km
Operating temperature	0 to 40 °C
Spatial resolution	1 m
Sampling resolution	0.5 m
Accuracy	±2 °C
Temperature resolution	<0.09 °C
Measurement time per channel	10-second minimum
Optical channels	1,2,4,8,12, or 16

Note: Specifications from *Halliburton (Pinnacle) FiberWatch DTS Hydrogen Tolerant System* are provided as an example of DTS fiber-optic technology specifications from a vendor. A similar device best suited for the injection pressure and temperature of CO_2 will be selected.

7A.2.3.2. Calibration Methodology and Frequency

All CO_2 mass flow meters will be calibrated prior to installation according to the manufacturer's specifications and recalibrated as needed throughout the life of the project per the manufacturer's recommendations.

All field wellhead and downhole gauges will be calibrated prior to use by the equipment manufacturer. Gauges will be recalibrated as needed based on the calibration frequencies and methods recommended by the manufacturer and after any repairs and/or maintenance performed on such equipment.

Logging tool calibration and fiber-optic calibration will be performed following the standard procedure of the service company and/or vendor providing the equipment. Calibration frequency will be determined by industry standard best practices and vendor recommendations.

Any portable field meters or multiprobe tools used to determine the field parameters of groundwater samples (e.g., pH, temperature, specific conductance) will be calibrated according to manufacturer recommendations and equipment manuals prior to sample collection events. Any errors in calibration will be noted and recalibration will be performed if any component fails to meet calibration standards or do not stabilize during sampling.

7A.2.3.3. Cleaning and Decontamination of Sampling Equipment

The cleaning and decontamination of surface equipment, if necessary, will be performed following the equipment manufacturer's recommendations. Any logging tools will be cleaned, maintained, and decontaminated by the respective service company.

7A.2.3.4. Corrective Action and Documentation

It will be the responsibility of the TCSC field staff to ensure the equipment used for operational testing and monitoring is calibrated, operating correctly, and if broken or malfunctioning, perform corrective actions on the faulty equipment. If field personnel are unable to perform corrective actions, the faulty equipment will be sent to a qualified technician or back to the manufacturer for service, repair, or replacement. Any substantial corrective actions taken that affect analytical data will be documented. If the defective equipment is expected to disrupt the permitted testing and monitoring schedule, Trillium will notify the UIC Program Director of any revisions required. Any actions required to correct faulty wireline logging tools and/or equipment used for geophysical surveys will be up to the service company per their standard operating procedures.

7A.2.3.5. Support Facilities

Samples of the CO_2 injectate and groundwater will be taken to, and analyzed in, capable analytical laboratories. Additionally, field activities may also take place in vehicles or in portable on-site trailers. Trillium personnel and/or subcontracted service providers will provide the necessary resources for testing and monitoring activities.

7A.2.4. Sample Handling and Custody

7A.2.4.1. Sample Homogenization, Composition, and Filtration

Groundwater sampling via well purging methods, consistent with ASTM D6452-18 [25], will be performed in all above-zone monitoring wells (TCSC_AZM-(1-5). Field parameters will be measured in grab samples when a flow-through cell is not used. Prior to any purging or sampling activities, static water levels will be measured using an electronic water level indicator. Wells will then be purged prior to sample collection to ensure the groundwater sampled is representative of the formation water quality. Each above-zone well will contain a dedicated pump to minimize potential cross contamination between wells. Field parameters such as groundwater pH, specific conductance, and temperature will be recorded using portable probes and a flow-through cell consistent with standard methods [26]. During sampling, field parameters (i.e., pH, specific conductance, temperature) will be monitored continuously and considered stable when three consecutive measurements made three minutes apart meet the criteria of **Table 7A-12**.

Table 7A-12. Stabilization criteria of water quality parameters during shallow well purging.

Field Parameter	Stabilization Criteria
pH	Remains constant within 0.1 standard unit
Specific Conductance	≤5% variance
Temperature[A]	N/A

[A]Because groundwater temperature is subject to rapid changes when collected, temperature will not be officially included in the stabilization criteria; however, temperature is important to record as it can be used to interpret other chemical parameters [27].

Groundwater samples will be collected after field parameters have stabilized. Flow-through filer cartridges (e.g., 0.45 µm) will be utilized consistent with ASTM D6564-17 [28] or equivalent. Prior to sample gathering, filters will be purged with a minimum of 100 mL of well water (or more if required by the filter manufacturer). In the case of alkalinity and total CO_2 samples, exposure to the atmosphere will be minimized throughout filtration, collection, transportation, and analysis of samples. For a summary of the parameters to be targeted for fluid sampling and analysis along with their potential analytical methods, please reference **Table 7A-5**.

7A.2.4.2. Sample Containers

All samples will be collected in new containers using industry standard methods. All sampling bottles, containers, or cylinders will be received in a ready-to-use state from the vendor and/or analytical laboratory conducting the analysis. Examples of container types to be utilized for CO_2 stream and above-zone groundwater sampling are summarized in **Table 7A-13**. Specific sample containers will be selected in collaboration with the analytical laboratory to ensure container materials are compatible with the analytical parameter being measured and any reagents used for preservation.

7A.2.4.3. Sample Preservation, Holding Times, and Transportation

Table 7A-13 summarizes common sampling containers, recommended preservation treatments, and holding times for CO_2 stream and groundwater samples. All samples collected will be preserved in new sample bottles or cylinders from the vendor and/or analytical laboratory contracted for sampling and analysis. Samples will be transported in coolers and preserved according to their recommended preservation treatments; specific preservation treatments will be selected in collaboration with the analytical laboratory to ensure samples are appropriately stored until their analysis. Sample analysis will be completed within the recommended holding times of which **Table 7A-13** provides common examples of.

Table 7A-13. Summary of parameters, sampling containers, preservation treatments, and holding times for CO_2 and groundwater samples.

Parameter	Example Containers	Preservation Technique	Sample Holding Time
CO_2 Injectate Stream			
CO_2 Stream (**Table 7A-4**)	75cc stainless steel cylinder or equivalent	Pressurized sampling container	TBD
Groundwater			
Major Cations	HDPE, PTFE, glass, or equivalent	Filter, HNO_3 to pH<2, cool to 4°C	6 months
Major Anions	HDPE, PTFE, glass, or equivalent	Cool to 4°C	28 days
Ammonia Nitrogen	HDPE, PTFE, glass, or equivalent	H_2SO_4 to pH<2, cool to 4°C	28 days
Dissolved CO_2	HDPE, PTFE, glass, or equivalent	Filter, carbonate-free NaOH to pH 8-9	Analyze as soon as possible
Total Dissolved Solids	HDPE, PTFE, glass, or equivalent	Cool to 4°C	Analyze as soon as possible, 7 days
Alkalinity	HDPE, PTFE, glass, or equivalent	Store in airtight containers, cool to 4°C	Analyze as soon as possible, 14 days
pH	HDPE, PTFE, glass, or equivalent	N/A	Analyze as soon as possible, preferably upon sampling
Temperature	HDPE, PTFE, glass, or equivalent	N/A	Analyze as soon as possible, preferably upon sampling

Parameter	Example Containers	Preservation Technique	Sample Holding Time
Conductivity	HDPE, PTFE, glass, or equivalent	Filter, cool to 4°C	24 hours unpreserved, 28 days preserved
Density	HDPE, PTFE, glass, or equivalent	Cool to 4°C	28 days
Noble Gases: He, Ne, Ar, Kr, Xe, Rn	HDPE, PTFE, glass, or equivalent	Store in airtight containers, cool to 4°C	Indefinite
^{13}C of DIC and CO_2	HDPE, PTFE, glass, or equivalent	Store in airtight containers, cool to 4°C	Indefinite
^{14}C of DIC and CO_2	HDPE, PTFE, glass, or equivalent	Store in airtight containers, cool to 4°C	Indefinite
^{2}H of Water	HDPE, PTFE, glass, or equivalent	Store in airtight containers, cool to 4°C	Indefinite
^{3}H of Water	HDPE, PTFE, glass, or equivalent	Store in airtight containers, cool to 4°C	Indefinite

Note: Specific sampling containers, preservation techniques, and holding times will be selected in collaboration with the analytical laboratory based on the nature of the sample to ensure proper analysis.

7A.2.4.4. Sampling Documentation and Identification

All field documentation for sampling activities will be collected and archived for future reference. Sample containers will have waterproof labels attached that provide relevant project information such as the project name, sampling date/time/location, a sample identification number, type of sample, volume, analyte, filtration used if applicable, and any preservative used. Personnel performing the field sampling are responsible for the sample documentation.

7A.2.4.5. Chain of Custody

A standardized form will be used to document CO_2 stream and groundwater sample chain of custody. Copies of the form will be provided to relevant personnel such as those performing the sampling, transferring/transportation, and analysis. The chain of custody forms will be archived for future reference. Personnel performing the sampling, transferring/transportation, and analysis are responsible for the chain of custody forms and record maintenance.

7A.2.5. Analytical Methods

7A.2.5.1. Analytical Standard Operating Procedures

Upon selection of an analytical laboratory, specific SOPs will be identified best suited for each analyte. The UIC Program Director will be provided with the selected SOPs for specific parameters upon request. All laboratory technicians performing the analyses on samples will be trained on the SOP developed for the specific parameter.

7A.2.5.2. Equipment and Instrumentation Needed

Equipment and instrumentation used for laboratory analysis will be capable of appropriately analyzing the desired parameters listed in **Table 7A-4** and **Table 7A-5**. Specific analytical equipment to be used will be further specified by the subcontractor selected to perform the laboratory analysis.

7A.2.5.3. Method Performance Criteria

It is anticipated that nonstandard method performance criteria will not be required for this project.

7A.2.5.4. Analytical Failure

The selected laboratory performing analyses will be responsible for properly addressing analytical failure pursuant to their respective SOPs.

7A.2.5.5. Sample Disposal

The proper sample disposal method is the responsibility of the selected laboratory performing the analyses.

7A.2.5.6. Laboratory Turnaround

Sample analysis turnaround times will vary by laboratory. All samples will be analyzed within their respective holding times listed in **Table 7A-13**. A turnaround time of verified analytical results within approximately two months is expected to meet project needs.

7A.2.5.7. Method Validation for Nonstandard Methods

It is anticipated that nonstandard methods will not be required for this project. If nonstandard methods do become necessary in the future, the UIC Program Director will be consulted to determine any additional actions required.

7A.2.6. Quality Control

7A.2.6.1. Quality Control Activities

<u>Blanks</u>

Field blanks will be utilized for above-zone groundwater samples to identify any contamination as a result of the collection and transportation process. Field blanks will be collected and analyzed for inorganic analytes at a frequency of 10% or more. Field blanks will be subject to the same field and transportation conditions as those of the above-zone groundwater samples.

<u>Duplicates</u>

Throughout the above-zone groundwater sampling process, a duplicate sample will be collected from a well based on a rotating schedule. The duplicate sample will be collected at the same time, from the same source, and in an identical sampling container as the original sample. Duplicates will be processed like all other samples and will be used to determine sample heterogeneity and analytic precision.

7A.2.6.2. Exceeding Control Limits

Further examination of samples will be performed if the sample's analytical results do not fall within control limits (i.e., ion balances > ±10%). Based on the mass balance ratio, cations or anions will be considered suspect. Suspect ion analyses can then be compared to historical data and interlaboratory results if available. Resulting analyses will be brought to the attention of the analytical laboratory for ion balance recalculation or verification. If any discrepancy is still unresolved, suspect data will be noted and may be given less significance in data interpretations.

7A.2.6.3. Calculating Applicable Quality Control Statistics

Charge Balance

To determine the correctness of groundwater analyses, analytical results are evaluated based on the anion-cation charge balance calculation. All potable waters are electrically neutron and therefore the chemical analyses should produce similar negative and positive ionic activity. Anion-cation charge balance will be calculated using the following formula:

$$\%\ \text{difference} = 100\,\frac{\Sigma\text{cations} - \Sigma\text{anions}}{\Sigma\text{cations} + \Sigma\text{anions}}$$

where the sums of the ions are given in milliequivalents (meq) per liter and the acceptable charge balance is ±10%.

Mass Balance

If charge balance acceptance criteria is not acceptable, the ratio of measured total dissolved solids (TDS) to the calculated TDS will be determined using the following formula:

$$1.0 < \frac{measured\ TDS}{calculated\ TDS} < 1.2$$

where values between 1.0 and 1.2 are expected.

Outliers

Determining potential statistical outliers is necessary before the evaluation of samples. The project will refer to US EPA guidance [29], [30], or equivalent for the selection of recommended statistical methods to identify outliers in groundwater chemistry datasets; methods for identifying outliers in groundwater chemistry datasets include probability plots, box plots, Dixon's test, and Rosner's test.

7A.2.6.4. Inspection and Acceptance for Supplies, Consumables, and Responsibilities

It will be the responsibility of the vendor and/or laboratory selected by Trillium to ensure all supplies and consumables for field and laboratory operations are inspected and capable of data collection activities.

7A.2.7. Data Management

7A.2.7.1. Data Management Scheme

All data storage equipment will be maintained and operated according to industry standard techniques. The ISA-95 [31] model or equivalent will be followed to develop an automated interface between control and enterprise systems. The system will aid in reducing risk, cost, and error throughout the TCSC project. The ISA-95 model consists of various levels of activities within an organization (**Figure 7A-4**). Level 0 defines the actual physical process that will generate data required for system automation. Levels 1 and 2 define the field and automation functions. Field functions involve equipment such as sensors, actuators, and valves that collect data and transmit it to higher levels. Automation, or control functions, define equipment and systems such as programmable logic controllers (PLCs), DCS, and SCADA systems. These systems will be used to control processes, record and process data, and monitor operations in real-time. Information from Levels 1 and 2 will be used for project decision making and management described in Level 3 (i.e., operations management) and Level 4 (i.e., business planning and logistics) to reduce risk, cost, and error throughout the project.

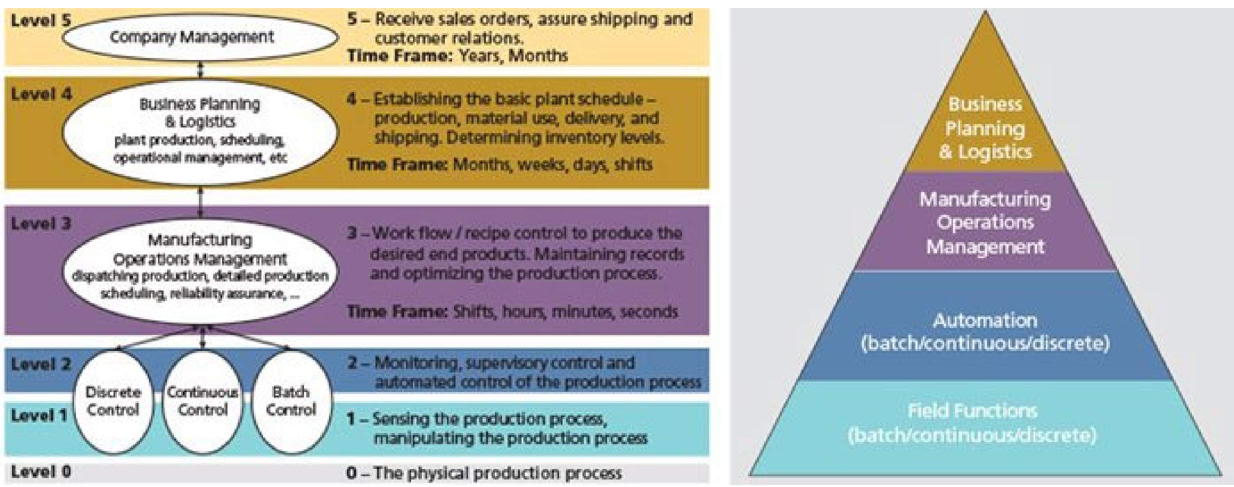

Figure 7A-4. ISA-95 model for automizing the interface between control and enterprise systems [32].

7A.2.7.2. Data Handling Equipment and Procedures

Trillium and/or a selected subcontractor will maintain all project data specified within this permit. Data will be kept and backed up on secure servers.

7A.2.7.3. Responsibility

Trillium or a selected subcontractor will be responsible for ensuring project data is managed properly.

7A.2.7.4. Data Archival and Retrieval

All project data will be compiled and stored by Trillium or a selected subcontractor. Data will be retained pursuant to 40 CFR 146.91(f).

7A.2.7.5. Hardware and Software Configurations

All TCSC and third-party hardware and software configurations will interface appropriately.

7A.2.7.6. Checklists and Forms

Any checklists and forms will be generated and completed, as necessary.

7A.3. ASSESSMENT AND OVERSIGHT

7A.3.1. Assessments and Response Actions

7A.3.1.1. Activities to be Conducted

Activities to be conducted throughout the lifespan of TCSC include mechanical integrity testing, operational testing and monitoring, groundwater quality and geochemical monitoring, and CO_2 plume and pressure front tracking. Please refer to **Table 7A-1** for a complete summary of the testing and monitoring activities to be conducted. For baseline, injection, and post-injection phase testing and monitoring frequencies, please reference the **Pre-Operational Testing Program**, the **Testing and Monitoring Plan**, and the **Post-Injection Site Care and Site Closure Plan**, respectively.

7A.3.1.2. Responsibility for Conducting Assessments

Each organization gathering data will be responsible for conducting their own internal assessments. All stop work orders will be handled internally within each organization.

7A.3.1.3. Assessment Reporting

All assessments will be reported to the TCSC Program Manager as specified in **7A.1.1.1. Key Individuals and Responsibilities**.

7A.3.1.4. Corrective Action

Trillium shall address any corrections. Corrections that may affect an organization's data collection responsibility will be addressed, verified, and documented by the individual project manager and be communicated to involved parties, as necessary. Corrective actions affecting multiple organizations will be addressed by all project managers and be communicated to all members of the **Quality Assurance and Surveillance Plan** distribution list. Integration of different monitoring parameters (i.e., mechanical integrity, operational, groundwater quality and geochemistry, and CO_2 plume and pressure front) may be required to determine whether data and/or monitoring method corrections are required along with the most cost-efficient and effective action to implement. Trillium will coordinate multi-organizational assessments and correction efforts as needed.

7A.3.2. Reports to Management

Quality assurance status reports will only be required if there are significant adjustments to the methods and procedures described throughout the **Testing and Monitoring Plan** and this **Quality Assurance and Surveillance Plan**. If any testing and monitoring methods are changed, the documents will be reviewed and appropriately updated after consultation with the UIC Program Director. Revised **Quality Assurance and Surveillance Plans** will be distributed by Trillium to the distribution list.

7A.4. DATA VALIDATION AND USABILITY

7A.4.1. Data Review, Verification, and Validation

7A.4.1.1. Criteria for Accepting, Rejecting, or Qualifying Data

Trillium or a selected subcontractor will hold copies of all analytical test results, operational data, and any monitoring data collected by subcontractors (e.g., well log data, seismic surveys, etc.). Testing and monitoring results will be reported regularly in accordance with 40 CFR 146.91.

7A.4.1.2. Data Verification and Validation Process

Data verification will include a review of:

- Documentation and maps verifying the boundaries of the project.
- Location of testing and monitoring equipment.
- Procedures for data QAQC.
- All plans, assessments, and reports to ensure conformance with the UIC regulations and requirements.

7A.4.1.3. Data Verification and Validation Responsibility

Trillium or its designated subcontractor will verify and validate testing and monitoring data.

7A.4.1.4. Issue Resolution Process and Responsibility

Trillium will designate a Program Manager to oversee all pre-injection, injection, and post-injection phase testing and monitoring. All staff involved with the testing and monitoring program will consult with the Program Manager to determine actions required to resolve any issues.

7A.4.1.5. Checklists, Forms, and Calculations

Checklists and forms will be developed to meet permit requirements. The documents will depend on parameters being monitored as well as the SOPs of subcontractors performing tests, gathering samples, or conducting analyses. Trillium will provide these forms and checklists to the UIC Program Director upon request.

7A.4.2. Reconciliation with User Requirements

7A.4.2.1. Evaluation of Data Uncertainty

Appropriate statistical software will be utilized for the determination of data consistency.

7A.4.2.2. Data Limitations Reporting

Each organization's project manager will be responsible for ensuring data presented by their respective organization is developed with the appropriate data-use limitations. Trillium will ensure these data-use limitations are known and presented properly.

7A.5. REFERENCES

[1] Collection of methods for analyzing trace elements and major cations in solution. EPA 6000 Series.

[2] *Determination of Metals and Trace Elements in Water and Wastes by Inductively Coupled Plasma – Atomic Emissions Spectrometry*, EPA Method 200.7, rev. 4.4, 1994.

[3] *Determination of Inorganic Anions by Ion Chromatography*, EPA Method 300.0, rev. 2.1, 1993.

[4] *Determination of Inorganic Anions in Drinking Water by Ion Chromatography*, EPA Method 300.1, rev. 1.0, 1999.

[5] Collection of methods for analyzing specific parameters of water and wastewaters, SM 4500 Series.

[6] *Determination of Ammonia Nitrogen by Semi-Automated Colorimetry*, EPA Method 350.1, rev. 2.0, 1993.

[7] *Nitrogen, Ammonia (Colorimetric, Titrimetric, Potentiometric Distillation Procedure)*, EPA Method 350.2, 1974.

[8] *Standard Test Methods for Total and Dissolved Carbon Dioxide in Water*, ASTM D513-16, 2016.

[9] *Residue, Filterable (Gravimetric, Dried at 180°C)*, EPA Method 160.1, 1971.

[10] *Solids in Water*, SM2540C, 2015.

[11] *Standard Test Methods for Filterable Material (Total Dissolved Solids) and Nonfilterable Matter (Total Suspended Solids) in Water*, ASTM D5907-18.

[12] *Titration Method*, SM 2320B, 2005.

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[21] *Standard Test Methods for Specific Gravity of Water and Brine*, ASTM D1429-13, 2013.

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[23] *Standard Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter*, ASTM D4052-22, 2022.

[24] *Preparation, Installation, Analysis, and Interpretation of Corrosion Coupons in Hydrocarbon Operations*, NACE-SP0775-2023, 2023.

[25] *Standard Guide for Purging Methods for Wells Used for Ground Water Quality Investigations*, ASTM D6452-18, reapproved 2023.

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[28] *Standard Guide for Field Filtration of Groundwater Samples*, ASTM D6564/D6564M-17, 2017.

[29] U.S. EPA, "Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities," *Unified Guidance EPA 530/R-09-007*, 2009.

[30] U.S. EPA, "Data Quality Assessment: Statistical Methods for Practitioners," *EPA/240/B-06/003*, 2006.

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