ATTACHMENT C

Pre-Operational Logging and Testing Program

Gulf Coast Sequestration, LLC (G1037)

Project Minerva, Cameron Parish
Minerva South CCS Well Nos. 001 & 002

EPA Project Id: R06-LA-0002

LDENR Appl Nos: 45031 & 45032

Date: November 2024

CERTIFICATION

Per LAC 43:VII §3603.H.1, the geoscientific aspects of the Pre-Operational Logging and Testing Program have been prepared by or under the supervision of a licensed Professional Geologist authorized to practice by and in good standing with the Louisiana Board of Professional Geoscientists. A separate certification page will be submitted with the Attachments to the Narrative that require certification.

Kaycee M. Garrett LA License No. 1325 *I, Kaycee M. Garrett, certify that I have personally examined and am familiar with the information submitted in this document and the attached documents, and that, based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the submitted information is true, accurate, and complete.*	
PRE-OPERATIONAL LOGGING AND TESTING PROGRAM (Including applicable Tables, Figures, and Appendices) Section 1 Introduction Section 2.2.1 Open Hole Logging and Testing Plan Section 2.3 Coring Plan and Analysis Section 2.4 Formation Testing Program Section 2.6 Hydrogeologic Testing Section 3.2.1 In-Zone Monitoring Well- Open Hole Logging and Testing	

Per LAC 43:VII §3603.H.2, the engineering aspects of the Narrative have been prepared by or under the supervision of a licensed Professional Engineer (PE) authorized to practice by and in good standing with the Louisiana Board Professional Engineering and Land Surveying. Since the engineering aspects of the applications have been designed by a consulting PE, the required documents will be certified once the technical review is completed by LDENR. A separate certification page will be submitted with the attachments to the Narrative that require certification.

TABLE OF CONTENTS

LIST OF TABLES, FIGURES, AND APPENDICES

TABLES

FIGURES

APPENDIX

FACILITY INFORMATION

Facility Name:	Minerva Facility
Injection Wells:	Minerva South CCS Well No. 001 (MS CCS 1) Minerva South CCS Well No. 002 (MS CCS 2)
Facility Contact:	David Cook, CEO 5599 San Felipe Street, Suite 1450, Houston, Texas 77056 (713) 419-6808; dcook@gcscarbon.com
Well Locations:	Sec 3, T12S, R13W, Cameron Parish, Louisiana

MS CCS 1 (North American Datum (NAD) 1927)

Surface:	30° 02' 34.10"W, -93° 40' 20.63"N
Bottom-Hole:	30° 02' 34.10"W, -93° 40' 20.63"N

MS CCS 2 (NAD 1927)

Surface:	30° 02' 33.84"W, -93° 40' 20.48"N
Bottom-Hole:	30° 02' 13.74”W, -93° 40' 42.07"N

1 INTRODUCTION

The Louisiana Department of Energy and Natural Resources (LDENR) has primary permit and enforcement authority (primacy) over Class VI Injection Wells through their Underground Injection Control (UIC) program. Gulf Coast Sequestration, LLC (GCS) will implement the proposed Pre-Operational Logging and Testing Program for Minerva South CCS Well No. 1 (MS CCS 1) and Minerva South CCS Well No. 002 (MS CCS 2) according to the requirements of LAC 43:XVII §3601-3633 and with approval from the LDENR Commissioner of Conservation (Commissioner).

The two Class VI injection wells were sited to maximize access to the available pore volume of the upper Frio (IZ) and to disperse and maximize the flow of CO_2 from the project area. A topographic map showing the property boundaries of the Minerva Facility, the location of the proposed injection wells, MS CCS 1 and MS CCS 2, and the delineated Area of Review (AoR) is provided at Figure C.1-1. The map also identifies wells used to create maps and cross-sections with Map ID numbers. A type log cross section is provided as Figure C.1-2.

2 PRE-INJECTION INJECTOR WELL TESTING PLAN

The following tests and logging will be conducted during drilling, casing installation, and after casing installation of the injection wells in accordance with the testing required under LAC 43:XVII §3617.B. Figure C.2-1 and Figure C.2-2 show the wellbore schematics of MS CCS 1 and MS CCS 2, respectively.

2.1 DEVIATION CHECKS

Deviation measurements will be conducted approximately every 500’ while drilling the

surface hole, and approximately every 100' during construction of the intermediate and long-string hole sections of each well. The deviation measurement which includes depth, inclination of the wellbore from vertical and the direction of the deviation (azimuth) will be taken using Measurement While Drilling (MWD) technology incorporated into drilling assemblies. Real time deviation surveys will be acquired while drilling and ensure the well is drilled according to the planned well trajectory.

After the installation and cementing of the long-string casing in MS CCS 2, a gyro deviation survey will be run in the tangent section from ~2,200' MD/TVD to 8,600' MD / 7,808' TVD of the cased borehole as a final check of the deviation of the wellbore.

2.2 TESTS AND LOGS

The tests and logs planned to be conducted in the two injection wells during drilling, after drilling in the open-hole prior to casing, and after installation of casing and cement are listed in Table C.2.2-1 and Table C.2.2-2 for MS CCS 1 and Table C.2.2-3 and Table C.2.2-4 for MS CCS 2. Table C.2.2-5 and Table C.2.2-6 list the proposed pre-operational testing schedules for each injection well, respectively. Example tool specification sheets are provided as Appendix C-I.

The Project Minerva Confining Zone system includes the Anahuac Formation as the Upper Confining Zone and the middle Frio Formation as the Lower Confining Zone. Pre-operational testing is not included for the Lower Confining Zone for the following reasons:

1. The middle Frio Formation is over-pressured and will not be penetrated to avoid drilling and completion risks.
2. The middle Frio Formation underlies the Injection Zone and is an over 1,000' thick, over-pressured interval comprised of dominantly shale-rich facies. Leakage downwards is, therefore, highly unlikely and would not cause endangerment of the USDW if it were to occur.

2.2.1 Open Hole Logging and Testing Plan

Logs will be run, surveys conducted, and tests performed to determine/verify reservoir properties such as depth, thickness, porosity, permeability, lithology, and formation fluid chemistry in relevant geologic formations below in accordance with the testing required under LAC 43:XVII §3617.B:

1. Base of the lowermost underground source of drinking water (USDW)
2. Miocene interval (Secondary Confining Zone)
3. Anahuac Formation (Upper Confining Zone)
4. Upper Frio Formation (Injection Zone)

The open-hole logging and test program will include the following:

— **Mudlogging** provides continuous analysis of drilled cuttings and fluid from the well borehole brought to the surface by circulating the drilling medium or mud. Mud

logging also includes drilling operation parameters including depth, pressure, temperatures, mud flow rates, drill rates, rotation speed, rate of penetration, oil, and gas shows (if any), circulated total gas and gas composition. The information is used to assess the formation drilled and help in deciding casing setting and coring depths, downhole pressure changes and to optimize drilling performance.

- **Spontaneous Potential (SP) log** measures the electric potential (in millivolts, mV) difference between an electrode at the surface of the well and the moving electrode in the borehole. The information is processed to display the electric potential (if any) between the drilling mud and formation fluid. Thus, the result and quality are dependent on the mud type and difference in salinity between the mud and formation. The SP log is used to differentiate shale from more permeable sandstone (or carbonate) formation and the interval thickness of these units. The SP can also be used to estimate formation salinities.
- **Gamma Ray (GR) log** measures the natural radioactivity of naturally occurring minerals in the formation (in API units) and used to differentiate shales (which have high gamma counts due to radioactivity inherent in clay minerals) from sandstone and carbonates with low natural radioactivity. The spectral GR version most logged in wells provides both the total gamma ray log and fractional component of potassium (%), thorium (ppm), and uranium (ppm). This information allows for assessment of clay type and minerals in the formation. The GR log is used to determine the shale/clay content of the formation. Furthermore, GR logs from different wells are used for stratigraphic correlation of formation units across target area.
- **Resistivity log** records formation resistivity in ohm-meters and measures formation and/or formation fluid resistivity to electrical current. The resistivity data is interpreted to determine conductive (salt water-bearing) vs. non-conductive (freshwater or hydrocarbon) fluid bearing zones. The resistivity logs provide resistivity measurement to different depths of investigation into the formation, that is used to assess permeable sandstone formation from non-permeable shale or tight interval.
- **Caliper log** measures borehole diameter and is used to assess the shape of the borehole, especially if the caliper is multi-arm caliper. The data from caliper log is used for cement volume calculations, borehole correction of well logs and geo-mechanical analysis.
- **Temperature log** records borehole temperature and is used to generate geothermal gradient for target area and formation.
- **Density and Neutron logs** measures the electron density and hydrogen ion concentration of formation rock and fluids respectively and are used to generate a continuous total and/or effective porosity log of the formation based in well-established industry equations.
- **Acoustic or Sonic log** records the transit time or velocity of a sound wave across

defined formation intervals between a source and a receiver in the tool. The wave form recorded at the receiver comprises different energy modes; the compressional and shear energy modes are generally of primary interest. The compressional sonic data is also used to estimate formation porosity and, along with density logs, for generating synthetic seismic logs to tie seismic data with well logs. The combination of the compressional and shear data is used for geo-mechanical analysis, fracture detection and other geophysical modeling.

- **Borehole Image log** provides an acoustic image or resistivity image of the borehole based on sonic waves or resistivity measured from multiple caliper arms and/or pads. Resistivity based image is more applicable with conductive drilling fluid, while the acoustic image is preferred in oil-based mud. The information from the borehole images is analyzed to assess stratigraphic and structural features including but not limited to structural dips, presence and orientation of faults and/or fractures, and formation stress. This tool also provides positional information such as inclination and azimuths that complement other wellbore deviation surveys.
- **Nuclear Magnetic Resonance (NMR) log** records the induced magnet moment of hydrogen nuclei (protons) contained within the fluid-filled pore space of porous media (reservoir rocks). Hydrogen protons in solids or bound to surfaces show differences in responses compared to bulk fluids in pore space. Hence this log is used to determine the total and effective porosity, permeability, and pore size distribution of target formations.
- **Wireline Formation tester** is a wireline tool used to measure in situ formation fracture pressure and temperature and acquire formation samples at multiple depths of the well borehole.
- **Formation Integrity Test (FIT)** to determine the strength and integrity of a newly drilled section of a well. The FIT is performed by gradually increasing the pressure in the wellbore to a predetermined value and then holding it for a period of time. The test results are used to determine the maximum mud weight that can be used to drill the next section of the well, and to evaluate the bonding strength of the cement around the casing shoe.
- **Sidewall coring tool** is run in the well bore hole to cut and recover plug size formation samples from the side wall of the well bore at multiple depths. The plug size samples are suitable for quantitative core analysis, similar to plugs recovered from whole cores. Rotary and percussion tools will be assessed in the field to determine which is optimum for recovering samples.
- **MWD (Measurement While Drilling)** is used to measure and transmit real time downhole information to surface (including inclination and azimuth) for wellbore position verification. MWD tools provide real time surveys, continuously or on pipe connections, using positive or negative pressure pulse or frequency modulation mud telemetry. Power is provided by either an integral turbine or batteries. Mud-pulse signals are received at the standpipe manifold and decoded. Drill pipe screens are

run in the top tool joint to prevent damage to the downhole components.

- **LWD (Logging While Drilling)** measures and transmits real time formation data to surface. GCS will utilize the following sensors: gamma ray, resistivity, density and pressure while drilling (PWD).

Table C.2.2-1 and Table C.2.2-3 list the logs and other downhole tools run during drilling and in the open-hole sections of MS CCS 1 and MS CCS 2 respectively, and the approximate combination in which they will be run, as well as the technical information that the tools will deliver.

2.2.1.1 Conductor Hole Interval

The 26" conductor is driven to about 150' MD/TVD to secure the surface sediments prior to drilling the surface hole. There is no hole drilling associated with driving the conductor pipe and thus no open-hole data acquisition.

2.2.1.2 Surface Hole Interval

The surface hole is planned to be drilled from approximately 0' - 3,000' MD/TVD in both injection wells. This interval is ideally terminated in a shale bed, which can be located by the mudlogger using cuttings samples circulated back to the drill floor. The deepest USDW in this area has been mapped at around 1,250' MD/TVD, so the surface hole extends far below the USDW. The purpose for drilling so far below USDW is to install surface casing at a depth where the formation compressive strength is adequate to support all future drilling forces (compressive strength generally increases with depth).

Deviation checks will be taken using the MWD in the drilling assembly every 500' to ensure that the well bore is per the planned trajectory. Once the surface hole has reached a suitable depth of around 3,000' MD/TVD, the drilling assembly will be removed, and open-hole wireline tools will be run.

The following logs will be run simultaneously in the Surface Hole section (Table C.2.2-1 and Table C.2.2-3) to delineate the formation lithologies and correlate formation tops (SP/GR), verify the depth of the USDW from resistivity logs, and to assess the wellbore size and condition (caliper). The caliper log will be used for estimating cement volumes required for this interval and assess the borehole temperature.

- Spontaneous Potential ("SP"),
- Gamma Ray ("GR")
- Resistivity
- Caliper
- Temperature

2.2.1.3 Intermediate Hole Interval

The intermediate hole section is planned to be drilled from the surface casing setting depth down to approximately 150' above the top of the Injection Zone (see Figure C.2-1 and Figure

C.2-2). Upon drilling out of the surface casing, a formation integrity test will be conducted after drilling approximately 5 to 10' of new hole. Approximately 2,000psi will be exerted against the formation (combined drilling mud hydrostatic plus applied pressure) to confirm the compressive strength at this depth. This data serves the dual purpose of proving that the formation is strong enough to withstand expected drilling mud weights required to drill to Hole Section TD and providing a data point for estimating formation fracture pressure.

Mud logging is planned to aid in determining when the Upper Confining Zone is reached, and deviation checks will be performed using the MWD in the drilling assembly to ensure hole is as per planned well trajectory.

Wireline logs will be run to assess the formation characteristics of the stratigraphy above the Upper Confining Zone and the section of the Upper Confining Zone drilled in this hole section. The formation characteristics include lithology, petrophysical properties (porosity, permeability), and fluid properties such as salinity. Borehole image logs will identify structural and stratigraphic features such as formation dip, faults, fractures (if any), and provide input for geomechanical modeling. Furthermore, a sidewall core tool (rotary or percussion) will be run to take rock samples (plugs) in shales and sandstone intervals in this hole section

As noted in Table C.2.2-1 and Table C.2.2-3, the wireline logs and tests across the intermediate hole section include the following:

- GR/SP
- Resistivity
- Caliper
- Temperature
- Neutron
- Density
- Acoustic
    - Compression and shear logs in MS CCS 1
    - Compression only in MS CCS 2
- Borehole image log
- Sidewall coring

2.2.1.4 Long String (Injection) Hole Interval

Upon drilling out of the intermediate casing, a FIT will be conducted after drilling approximately 5 – 10' of new hole. Approximately 2,000psi will be exerted against the formation (combined drilling mud hydrostatic plus applied pressure) to confirm the compressive strength at this depth. The long-string interval covers part of the Upper Confining Zone and the injection intervals for both wells.

In MS CCS 1, whole cores will be acquired in the Upper Confining Zone and across sections of the injection intervals. Coring in the second injection well, MS CSS 2 (not currently planned for this well) will be contingent on the core recoveries in the MS CSS 1.

Modeling and frequent deviation checks will be performed while drilling this hole section.

Wireline logs and tests in the long-string hole section have been planned to aid formation characterization of the Upper Confining Zone and Injection Zone. In addition to the logs and tests run across the intermediate hole section, an NMR log is planned to aid assessment of effective porosity, permeability and mineralogy of the target zones. Summary of open-hole wireline logs and tests in the long-string section include:

- GR/SP
- Resistivity
- Caliper
- Temperature
- Neutron
- Density
- Acoustic
    - Compression and shear logs in MS CCS 1
    - Compression only in MS CCS 2
- Borehole image log (only in MS CCS 1)
- NMR log (only in MS CCS 1)
- Wireline formation tester (only in MS CCS 1)
- Sidewall coring

2.2.2 Cased Hole Logging and Testing Plan

Logging and tests are planned upon casing installation and cementing of the different wellbore sections in accordance with the testing required under LAC 43:XVII §3617.B.1.

The cased-hole logging and test program will include the following:

- **Deviation log (Gyro**) is a deviation survey tool run in casing to measure the borehole position relative to the vertical in terms of inclination and direction (azimuth).
- **Temperature log** is like the open-hole temperature logs but run in casing to form a baseline for future assessment of changes in borehole temperature due to fluid movement behind casing or within or into the wellbore. The temperature log in casing can aid in assessing the top of cement behind casing.
- **Cement evaluation logs** provide an assessment of the cement quality radially as part of well integrity and for zonal isolation, particularly the radial distribution of

cement behind the casing, the casing to cement bond (traditionally known as cement bond index) and cement to formation bond in the form a variable density log (VDL). Modern cement evaluation tools provide an assessment of the cement distribution behind the casing to properly evaluate the cement quality around the circumference of the casing.

- **Casing inspection logs** provides an assessment of the condition of the inside casing surface such as roughness, build ups, holes, defects etc., and the casing thickness to assess any possibility of corrosion over time due to the CO_2 sequestration process.
- **Noise log** is a record of sound measured in the cased bore hole to assess well integrity, in particular flow behind and into (leaks) the well bore.
- **Oxygen activation** is also known as a water-flow log, is a method for detecting and measuring water flow in or around a borehole. The process involves activating oxygen with high-energy neutrons to create a nitrogen isotope, which then decays back into oxygen and emits a detectable gamma ray. Detectors placed above or below the tool count the gamma rays.
- **Pulsed Neutron capture log** is used to measure the sigma or capture cross section of a formation (how good a given formation captures thermal neutrons). The information is used to assess fluid saturation in the formation behind casing (independent of resistivity). When this log is run pre-injection (baseline log) and post CO_2 injection, the information gathered is used to assess changes in the fluid (water and CO_2) saturation with time due to CO_2 sequestrations.

Table C.2.2-2 and Table C.2.2-4 list the logs and other downhole tools run upon casing and cementing in the cased-hole sections of MS CCS 1 and MS CCS 2, respectively, and the technical information that the tools will deliver.

2.2.2.1 Conductor Pipe

There is no hole drilling associated with this conductor pipe and thus cased-hole logging is not applicable.

2.2.2.2 Surface Casing

Upon installing and cementing the surface casing, and after the required time allowed for the cement to set, cased-hole logs will run inside the casing to evaluate the quality of the cement job and record the borehole temperature as required under LAC 43:XVII §3617.B.1.b

The surface cased-hole logging consists of the following:

- Cased hole GR, for stratigraphic correlation; this log allows correlation with the GR run previously in open-hole, so that the quality of the cement at any depth can be correlated to those formations logged at that depth.
- Cement evaluation log that provides radial assessment of the cement bond casing to cement bond) and variable density log to assess cement to formation bond. In addition, these logs will provide an assessment of top of cement, if not to surface.

- Temperature log

2.2.2.3 Intermediate Casing

Upon installing and cementing the intermediate casing, and after the required time allowed for the cement to set, cased-hole logs will run inside the casing to evaluate the quality of the cement job and record the borehole temperature as required under LAC 43:XVII §3617.B.1.c

The intermediate cased-hole logging and testing consists of the following:

- Cased hole GR
- Cement evaluation log
- Temperature log
- Noise log
- Casing pressure test to assess mechanical integrity of the casing
- Oxygen activation log

2.2.2.4 Long String Casing

Upon installing and cementing the long-string casing, and after the required time allowed for the cement to set, cased-hole logs will run inside the casing to evaluate the quality of the cement job and record the borehole temperature as required under LAC 43:XVII §3617.B.1.c

The long-string cased-hole logging and testing consists of the following:

- Cased hole GR
- Cased hole deviation survey (only in MS CCS 2)
- Cement evaluation log
- Casing inspection log (to assess baseline condition of the casing)
- Temperature log
- Noise log
- Oxygen activation log
- Pulsed Neutron log
- Casing pressure test

2.3 CORING PLAN AND ANALYSIS

Whole cores and side wall cores are planned to be acquired in the proposed Upper Confining Zone and Injection Zone, in accordance to the requirement under LAC 43:XVII §3617.B.2. Whole core will be acquired in the MS CCS 1. At least 15% of gross thickness will be collected in both the Injection Zone and Upper Confining Zone. Acquisition of whole core in MS CCS 2 will occur if core recovery is unsuccessful in MS CCS 1. Sidewall cores will be taken in both wells for geologic characterization where whole core was not collected. Table

C.2.2-1 shows the sidewall and whole cores plan for MS CCS 1.

Whole cores are planned to be acquired in the long-string open-hole section, while sidewall core plugs are planned across the intermediate and long-string hole sections.

2.3.1 Whole Coring Plan

Acquisition of whole core will only occur in MS CCS 1. A contingency plan to acquire whole core in MS CCS 2 will be created, in the event that recovery is unsuccessful in MS CCS 1.

2.3.1.1 Upper Confining Zone

After successful FIT and drilling through the intermediate casing shoe that was set in the Upper Confining Zone, the long-string (injection) hole interval will be drilled to a depth suitable for coring. The conventional core will be large-diameter core (4" core barrel) drilled and subsequently preserved according to industry best practices. ~60' of core is planned to be cut in the Upper Confining Zone.

It is anticipated that core will be cut and handled as follows:

- Conventional core barrel assembly, with sealed inner barrel
- 4" diameter inner barrel
- 30' barrel length (optimum length to be confirmed during core capture operations)
- Mechanism to secure core in place to prevent loss of unconsolidated formation, if any
- Tripping-time schedule, to allow in-situ gases to release slowly as the core barrel is brought to surface, to eliminate damage to the core due to gas expansion
- On-site evaluation of the whole core still contained within the inner barrel, by characterization of the exposed ends as the inner barrel is cut into 3' lengths. A GR log can also be obtained with the core barrel at surface
- Sealing all exposed ends of the whole core at surface, for transportation to the laboratory

On-site evaluation of the recovered core together with comparison to offset well logs will confirm that a suitable section of the Upper Confining Zone was recovered.

2.3.1.2 Injection Zone

Drilling will continue to the next core point within the Injection Zone. This depth will be chosen by evaluating the mud logger cutting samples with comparison to the offset well logs to confirm the Injection Zone has been reached. Approximately 75' of whole core will be collected.

It is anticipated that core will be cut and handled as follows:

- Conventional core barrel assembly, with sealed inner barrel
- 4" diameter inner barrel

- 30’ barrel length (optimum length to be confirmed during core capture operations)
- Mechanism to secure core in place to prevent loss of unconsolidated formation, if any
- Tripping-time schedule, to allow in-situ gases to release slowly as the core barrel is brought to surface, to eliminate damage to the core due to gas expansion
- On-site evaluation of the whole core still contained within the inner barrel, by characterization of the exposed ends as the inner barrel is cut into 3’ lengths. A GR log can also be obtained with the core barrel at surface
- Sealing all exposed ends of the whole core at surface, for transportation to the laboratory

2.3.1.3 Lower Confining Zone

There is no plan to acquire core in this zone.

2.3.2 Sidewall Core Acquisition Plan

Sidewall cores are planned to be acquired across the intermediate and long-string hole sections MS CCS 1 (Table C.2.2-1) and MS CCS 2 (Table C.2.2-2). Sidewall cores will be collected to supplement the whole core. The purpose of running a sidewall coring tool is to sample formations outside the conventionally cored interval, both within the Upper Confining Zone and Injection Zone. Log data will be used to optimize the sample depths for a variety of rock types, textures, and inferred depositional environments. Rotary and percussion coring tools will be tested during operations to determine which provides the highest recovery and sample quality.

2.3.3 Core Analyses

Detailed core analyses of the whole core, plugs taken at select depths from the whole core (Table C.2.3-1), and sidewall core plugs (Table C.2.3-2) will be done by a well-respected, industry leading laboratory to characterize the lithology, mineralogy, petrography, petrophysical and geo-mechanical properties of the all the relevant section samples. See Table C.2.3-3 for details on the Core Analyses Services.

The core analyses will include:

- Lithologic description (whole cores and/or plugs)
  - Texture, depositional and sedimentary features (grain size, shape, sorting, fractures (if any)), rock type and facies
  - CT scan: High-resolution images of the core’s internal structure, helping to identify fractures, bedding planes, and other features.
- Mineralogic and petrologic analyses (core plugs)
  - X-Ray Diffraction ‘XRD’ and/or X-Ray Fluorescence ‘XRF’ for elemental mineral identification and quantification

- Thin section petrography and/or scanning electron microscopy (SEM) for imaging rock fabric and pore geometry

— Petrophysical properties (core plugs)

- Grain and bulk density
- Porosity
- Permeability
- Fluid saturation particularly assessment of residual or trapped gas saturation
- Mercury injection capillary pressure (MICP)
- Effective and relative permeability
- Pore volume compressibility

— Geo-mechanical properties (core plugs)

- Rock strength
  - Tensile Strength: In order to establish the tensile strength of the Upper Confining Zone.
  - Compressive Strength: In order to establish the compressive strength of the Upper Confining Zone, a single stage triaxial Confined and/or unconfined test will be performed at multiple sample points from whole core within the Upper Confining Zone. Triaxial compressive strength tests are commonly used to simulate reservoir stress conditions to measure static mechanical properties (e.g., compressive strength, Young's modulus of elasticity and Poisson's ratio). Dynamic measurements (Vp/Vs) can be made concurrently for acoustic (sonic) log applications.
  - Shear Strength: Shear strength will be calculated using the Mohr-Coulomb equation with inputs from Multi Stage or Multi Sample Triaxial laboratory analysis that will be performed at multiple sample points from whole core within the Upper Confining Zone itself.
  - Impact Strength: In order to establish the impact strength of the Upper Confining Zone (the Anahuac Formation), a Brinell Hardness test will be performed at multiple sample points from whole core within the Upper Confining Zone
- Ductility of the Injection Zone and Upper Confining Zone will be calculated by measuring the uniaxial compressive strength during the triaxial single stage geomechanical test.
- In-situ stress formation tests to determine minimum and maximum horizontal stress

2.3.4 Reporting

Per LAC 43:XVII §3617.B.2, GCS will submit to the Commissioner a detailed report prepared by a log analyst that includes: well log analyses (including well logs), core analyses, and formation fluid sample information. Methodology, notes on quality assurance of samples and calibration of instrumentation will also be included, as appropriate.

2.4 FORMATION TESTING PROGRAM

The formation testing program comprises formation integrity and fluid sampling tests to meet the requirement of LAC 43:XVII §3617.B.4.

2.4.1 Upper Confining Zone

The Upper Confining Zone is defined as the zone overlying the Injection zone that acts as a barrier to fluid movement above an Injection zone. The Upper Confining Zone must have sufficient rock strength, permeability, areal extent, and thickness to confine injected fluids within the Injection zone.

The confining formation overlying the Injection Zone, identified as the Upper Confining Zone, is the Anahuac Formation which conformably overlies the upper Frio Formation. The Anahuac Formation acts as a very effective, thick regional seal to many prolific hydrocarbon fields and so can be assumed to be rich in sealing lithologies (Swanson & Karlsen, 2009).

At Project Minerva, the Anahuac Formation extends from -6,600’ TVDSS near Black Bayou Dome to over -9,200’ TVDSS at the base of a syncline structure located northeast of the AoR. Depth across the AoR varies from -7,000’ TVDSS to -8,400’ TVDSS. The Anahuac Formation thickens from 800’, north of the project area, to over 1,100’, south.

2.4.1.1 Physical/Chemical Parameters

Formation integrity tests are planned to be performed to test the strength of the formations where the surface and intermediate casings are set (See Table C.2.2-1 and Table C.2.2-3). The intermediate casing is set in the Upper Confining Zone and the result of the formation integrity test with provide data for assessment of the fracture pressure and gradient of the Upper Confining Zone.

Upon drilling out of the intermediate casing, a formation integrity test will be conducted after drilling approximately 5 to 10’ of new hole. Approximately 2,000 psi will be exerted against the formation (combined drilling mud hydrostatic plus applied pressure) to confirm the compressive strength at this depth.

The FIT test will be integrated with core analyses (Section 2.3.3) and borehole image logs (Section 2.2.1.4) to provide an assessment of geomechanical properties of the Upper Confining Zone.

2.4.2 Injection Zone (Upper Frio Formation)

The Injection Zone at Project Minerva is the upper Frio Formation. The Injection Zone is comprised of stacked shoreline sandstones interbedded with shales. Gross thickness varies from approximately 1,400’ to approximately 1,700’ in the Project Minerva’s AoR. Depth varies from 8,000’ TVDSS to 10,200’ TVDSS.

2.4.2.1 Physical/Chemical Parameters

The wireline formation tester records the fracture pressure and temperature of the formation at the sampling, and the conductivity of the fluid sample, in addition to acquiring the fluid samples. Multiple samples at different depths can be acquired with the wireline formation tester. The acquired fluid samples will be sent either to an onsite or offsite laboratory to determine fluid properties.

Wireline formation tester will be conducted in MS CCS 1 (Table C.2.2-1) to characterize the chemical and physical properties of the formation fluids in the Injection Zone (LAC 43:XVII §3617.B.4.c).

2.4.2.2 Formation Fluid Properties

Fluid sampling using a wireline formation tester will be conducted in MS CCS 1 (Table C.2.2-1) to characterize the chemical and physical properties of the formation fluids in the Injection Zone (LAC 43:XVII §3617.B.4.c).

The wireline formation tester records the pressure and temperature of the formation at the sampling, and the conductivity of the fluid sample, in addition to acquiring the fluid samples. Multiple samples at different depths can be acquired with the wireline formation tester. The acquired fluid samples will be sent either to an onsite or offsite laboratory to determine fluid properties.

The following information will be recorded and measured from the sampling operation and fluid sample analysis:

- Formation pressure and temperature
- Fluid temperature
- pH
- Fluid specific conductivity
- Fluid density
- Total dissolved solids (TDS – measure of salinity)
- Alkalinity
- Chemical composition
  - Major cations and anions: Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, Cl^{-}, Br^{-}, SO_4^{2-}, and NO^{3-}
  - Other constituents: Sr^{2+}, Fe^{2+}, Fe^{3+}, Al, SiO^{2}
  - Trace elements such as As, Hg, Cu, Zn
  - CO_2 and H_2S content (if any)

The geochemical analysis will be conducted to validate geochemical compatibility assumptions relating to formation water, Injection Zone mineralogy and the injectate (CO_2) stream.

2.5 DEMONSTRATION OF MECHANICAL INTEGRITY

Per LAC 43:XVII §3617.B.1.d and LAC 43:XVII §3627.A, GCS will conduct tests and run logs to demonstrate that:

- There is no significant leak in the casing, tubing, or packer; and
- There is no significant fluid movement into a USDW through channels adjacent to the injection wellbore

Tests and log runs will include:

- Pressure test with liquid or gas
- Temperature or noise log
- Pulsed neutron log
- Casing inspection log

Table C.2.5-1 summarizes all internal and external mechanical integrity tests.

2.5.1 External Mechanical Integrity

In accordance with LAC 43:XVII §3617.B.1.d, external mechanical integrity will be tested in the following ways:

- Pressure test of each casing string upon installation and cementation. Prior to drilling out the plug in each casing string, a casing pressure test will be conducted not to exceed the burst pressure of that casing to assess the external mechanical integrity of that casing.
- Temperature and noise logs to assess for any leakage.
- Pulsed neutron log to provide baseline assessment of fluid saturation behind casing for future post injection comparison.
- Casing inspection log to assess the condition of the casing and also provide baseline for future corrosion assessment.

2.5.2 Internal Mechanical Integrity

2.5.2.1 Annulus Pressure Test Procedures for Injection Wells

Upon completion of the injection wells, an annulus pressure test between the tubing and casing will be conducted to meet the requirement of LAC 43:XVII §3627.A.2.a.

Per LAC 43:XVII §3621.A.3-4, GCS will fill the annulus between the tubing and the long-string casing with a non-corrosive fluid approved by the Commissioner, or a fluid containing a corrosion inhibitor approved by the Commissioner. The initial annulus pressure test will include pressuring the annulus to an authorized injection pressure.

GCS will maintain tubing-casing annulus pressure that exceeds the operating injection pressure, unless the Commissioner determines that such requirement might harm the

integrity of the well or endanger a USDW. If reduced annulus pressure is required, GCS will submit a request in writing for approval.

After the injection tubing and packer is installed, the packer seal against the long-string casing wall will be tested by applying pressure to the annulus between the casing and injection tubing above the packer; the test (second test) will be charted to record that no leakage occurs. In addition, the fiber optic cable attached to the outside of the long-string casing will be able to monitor the temperature along the entire length of the casing (distributed array temperature) and will detect any leakage by showing a temperature change at any leak point. A tubing plug will be installed in an internal profile seat near the bottom of the tubing string, and pressure will be applied above it to test (third test) the tubing integrity. Test pressure will not exceed 80% of the tubing burst rating.

These three pressure tests satisfy the requirements of LAC 43:XVII §3627.A.1.a (40 CFR 146.89(a)(1)), with the first test occurring shortly after the well is drilled and the other two tests (packer and tubing) after all permits for injection have been obtained and the injection well has been completed.

2.5.2.2 Annulus Pressure Maintenance

Per LAC 43:XVII§3621.A.3-4, GCS will fill the annulus between the tubing and the long-string casing with a non-corrosive fluid approved by the commissioner or a fluid containing a corrosion inhibitor approved by the Commissioner.

GCS will maintain tubing-casing annulus pressure that exceeds the operating injection pressure, unless the Commissioner determines that such requirement might harm the integrity of the well or endanger a USDW. If reduced annulus pressure is required, GCS will submit a request in writing for approval by the Commissioner.

2.6 HYDROGEOLOGIC TESTING

Upon completing the injection wells, including perforating the target injection zone, installing tubing and packers, GCS will conduct a pressure fall-off test and step-rate injectivity test to verify the hydrogeologic characteristics of the injection zone as requirement by LDENR (LAC 43:XVII §3617.B.5). The tests will measure transmissibility, skin effects due to well construction and near borehole effect, injectivity of the formation, injection flowing and static pressures of the formation, and determine Maximum Surface Injection Pressures (MSIP) for the well. These tests will provide a baseline for well and reservoir performance over time. The following tests described below will be conducted in cased downhole conditions after perforation.

2.6.1 Static Fluid Level Test

A static fluid level test will be performed on both wells as part of the preoperational testing.

2.6.2 Pressure Fall-Off Test

A short-term injection/falloff test will be performed to analyze reservoir permeability, determine injection potential, and evaluate skin damage (completion efficiency) of the

wellbore. This test will provide a baseline standard to measure the effects of CO_2 injection. Subsequently, a pressure falloff test will be performed every five years or more frequently if required by the Commissioner (LAC 43:XVII §3625.A.6). All this information will help improve the dynamic model and provide learnings for future data collection.

A falloff test is conducted by a long period of injection, followed by a long period of well shut in. Pressures are monitored prior to injection, during injection, and the observed drop of pressure until the formation reaches the initial static pressure. The test will be designed in accordance with the USEPA Region 6 UIC Pressure Falloff Testing Guidance (Third Revision – August 8, 2002). The wells will be shut-in for a sufficient period to allow for static conditions (*i.e.,* no injection prior to test). Two gauges will be installed downhole at the injection interval to obtain the initial bottomhole pressure. Continuous injection will occur at a steady pre-defined rate for an acceptable duration to produce a measurable pressure transient that will produce a falloff test. The gauges downhole will monitor the flowing bottomhole pressures. The well will be shut in at the wellhead (to minimize wellbore storage effects). The pressure falloff will be monitored until the well reaches radial flow (pressure response for the reservoir) and a final bottomhole pressure is measured. Note, no injection will occur from offset wells during the pressure falloff tests. The injection will be isolated to the well actively being tested.

In performing a falloff test analysis, a series of plots and calculations will be prepared to QA/QC the test, identify flow regimes, and determine well completion and reservoir parameters. It will also be used to compare formation characteristics such as transmissivity and skin factor of the near-wellbore for changes over time. Skin effects due to drilling and completion (possible damage from perforation) will be assessed for the well's injectivity and potential well cleanouts in the future. These tests can also measure drops in pressure due to potential damage/leakage over time. In CO_2, it is anticipated that pressure drops may indicate multiple fluid phases. The analysis will be designed to consider all parameters.

2.6.3 Step Rate Injectivity Test

The step rate injectivity test will also support the requirement in the prior section for fracture pressure measurements.

A step-rate test (usually after the falloff test) will be used to determine the Maximum Surface Injection Pressure (MSIP), which should be less than or equal to the measured fracture closure pressure of the injection interval. A step-rate test will be developed for the Injection Zone in each well. Injection rates will be developed to span the initial pressures (minimum rate) and estimated fracture pressure (maximum rate).

Fluid will be injected in steps, plotting the injection pressure versus the injection rate (unconsolidated formations may require a tubing/packer setup). Injection will be held constant for each step for an equal length of time. Injection steps will be designed with a minimum of 5 steps with 20% rate increases. However, injection steps will be tailored to each well to optimize data collection and may result in more steps and a lower percent increase over time.

Rates and pressures will be recorded downhole and at surface. Injection rates and

pressures will be plotted at the end of each step and analyzed for either a constant slope or a decrease in slope (which identifies when the formation fractures and loses the pressure held).

2.6.4 Reporting

Documentation guidelines will be followed by submitting the requested information at the conclusion of testing. Data submitted for both the fall-off test and injectivity or pump test include:

- Raw pressure data
- Flow data from the injection part of the test. For the Injectivity or pump test, include rate and time
- Test parameters (injection time, shut-in time, fluid viscosity, temperature, wellbore diameter, pressure gauge type and location)
- Semi-log plots used for data analysis
- Parameters calculated from the analysis
- Discussions of the results, including data quality and any anomalous values

2.7 TESTING VIA FIBER OPTIC CABLE

Fiber optic cable will be attached to the outside of the 9 ⅝" long-string casing and will facilitate distributed temperature sensing (DTS) and distributed acoustic sensing (DAS). See WBS diagrams Figure C.2-1 and Figure C.2-2 .

2.7.1 Distributed temperature sensing (DTS)

Implemented via the fiber optic cable and allow temperature to be measured continuously along the entire length of the casing. Leak detection will be achieved by identifying temperature anomalies. See Testing and Monitoring Plan (Attachment D).

2.7.2 Distributed acoustic sensing (DAS)

A baseline vertical seismic profile (VSP) will be recorded prior to injection commencing and will be implemented via distributed acoustic sensing (DAS), conducted in a fiber optic cable. See Testing and Monitoring Plan (Attachment D).

2.8 TESTING SCHEDULE

Internal and external integrity testing and reservoir testing will continue through the operational life of the wells. The proposed testing descriptions, frequency, notifications, and reporting are described in the Testing and Monitoring Plan (Attachment D). See Table C.2.5-1

2.9 REPORTING

GCS will notify LDENR at least 72 hours in advance of a given test/log.

Logging and testing results will be used to update the dynamic model and to modify data collection programs in successive wells. After the conclusions of drilling, GCS will prepare a report that includes an interpretation of the results of the logs. The report will be in electronic format and will include:

- The date and time of each test, the date of wellbore completion, and the date of installation of all casing and cement
- Chart (graphical) results of each log and any supplemental data
- The name of the logging company and log analyst and information on their qualifications
- Interpretation of the well logs by the log analyst, including any assumptions, determination of porosity, permeability, lithology, thickness, depth, and formation fluid salinity of relevant geologic formations
- Any changes in interpretation of site stratigraphy based on formation testing logs

The results of the fluid analyses will help reduce uncertainty, improve the dynamic model, and define the AoR. Documentation guidelines will be followed. When this phase of work is complete, the following information will be submitted:

1. Type of sampling equipment used and field procedures
2. If the sample was pumped, flow rate, type of pump, location of the pump, and geochemical modeling results indicating the likely geochemical makeup of the fluids at downhole conditions
3. Data for field measurements (pH, SC, temperature, pressure)
4. Laboratory results, including QA of samples
5. Notes on any anomalous data

3 IN-ZONE MONITORING WELL PRE-OPERATION TESTING PLAN

GCS will convert an existing wellbore, Stream 34 Well No. 001 (SN 224951, Map Id 1) whose bottom hole location is approximately 0.75 miles north of the Minerva South Well Pad, into an in-zone monitoring well. The converted well will be named Minerva South In-Zone Well No. 001 (MS IZ 1) and will be used to track the CO_2 plume and the presence or absence of elevated pressure within the Injection Zone.

GCS will submit Form UIC-25 (or its replacement), Class V Well Application, to LDENR to convert Stream 34 Well No. 001 to MS IZ 1. A conversion plan can be found in Appendix D-VII of the Testing and Monitoring Plan (Attachment D).

3.1 DEVIATION CHECKS

Deviation checks will not be required for Minerva South In-Zone Well No. 001 (MS IZ 1) as it will be converted from a legacy wellbore.

3.2 TESTS AND LOGS

Testing and logging will be completed in accordance with the applicable regulations set forth in LAC 43:XVII §3617. A detailed conversion plan along with a testing and logging plan will be submitted for approval with the Class V application.

3.2.1 Open Hole Logging and Testing

No open-hole logging/tests will be performed on MS IZ 1, as it will be a converted legacy well. Full details of the logging and testing plan can be found in Testing and Monitoring Plan (Attachment D) and will be submitted for approval in the Class V UIC-25 application.

3.2.2 Cased Hole Logging

Full details of the logging and testing plan can be found in Testing and Monitoring Plan (Attachment D) and will be submitted for approval in the Class V UIC-25 application.

3.2.3 Demonstration of Mechanical Integrity

The mechanical integrity demonstration for MS IZ 1 will be in accordance with the applicable requirements of 3617.B.1.d.i-iv and will be detailed in the conversion plan submitted for approval in the Class V UIC-25 application.

3.2.4 Reporting

Notification and the opportunity to witness these tests/logs shall be provided to LDENR at least 72 hours in advance of a given test/log.

4 ABOVE CONFINING ZONE MONITORING WELL PRE-OPERATION TESTING PLAN

Two (2) new above confining zone monitoring wells will be drilled prior to injection: Minerva South USDW Well No. 001 (MS USDW 1) and Minerva South USDW Well No. 002 (MS USDW 2). These wells will be utilized to monitor ground water quality and geochemical changes above the confining zone(s). Drilling and Logging procedure for MS USDW 1 and MS USDW 2 can be found in Appendix D-III of the Testing and Monitoring Plan (Attachment D).

GCS will submit Form UIC-25 (or its replacement), Class V Well Applications, to LDENR to drill and operate MS USDW 1 and MS USDW 2. A detailed drilling, testing, and logging plan will be submitted for approval with the Class V application.

MS USDW 1 and 2 will be drilled once construction of the injection wells is complete, but prior to commencement of injection.

4.1 DEVIATION CHECKS

Deviation checks will not be required for MS USDW 1 and MS USDW 2 as they will be vertical wells completed at a depth less than 2,000’ below ground level.

4.2 TESTS AND LOGS

Drilling and Logging procedure for MS USDW 1 and MS USDW 2 can be found in Appendix D-III of the Testing and Monitoring Plan (Attachment D).

4.2.1 Demonstration of Mechanical Integrity

A demonstration of Mechanical Integrity is not required on the a

4.2.2 Reporting

Notification and the opportunity to witness these tests/logs shall be provided to LDENR at least 72 hours in advance of a given test/log.

Table C.2.2-1 Open Hole Logging/Testing Plan for MS CCS 1

	Trip	Logging Suite	Target Data Acquisition/Objectives	Open Hole Diameter	Depth of Survey (Ref KB=38' above MSL)
Surface Section	While Drilling	Mud Logs	Drilling parameters, any fluid shows, formation cuttings. Assist with well correlation and casing seating depths decision	26"	150' MD/TVD - 3,000' MD/TVD
		MWD - Directional Survey	Directional survey to determine the location of the borehole		
	Wireline	Spontaneous Potential, Gamma-ray, Resistivity, Multi-Arm Caliper, Temperature	Formation characterization; lithology and rock properties Borehole condition and diameter to aid casing and cementation operations and baseline borehole temperature.	26"	150' MD/TVD - 3,000' MD/TVD
Intermediate Section	Drilling BHA	Formation Integrity test (FIT)	Basis to assess fracture gradient to calibrate geo-mechanical model	17 ½"	~3,015' MD/TVD
	While Drilling	Mud Logs	Drilling parameters, any fluid shows, formation cuttings. Assist with well correlation and casing seating depths decision	17 ½"	3,000' MD/TVD - 8,991' MD/TVD
		MWD - Directional Survey	Directional survey - deviation checks during drilling		
		PWD (pressure while drilling)	Pressure while drilling – used for pore pressure and fracture gradient calibration		
		LWD (GR - Resistivity)	Formation characterization and support to set intermediate casing in the Anahuac (CZ)		8,082 MD/TVD - 8,991' MD/TVD
	Wireline	Spontaneous Potential, Gamma-ray, Resistivity, Neutron, Density, Acoustic (Compressional and Shear). Multi-Arm Caliper,Temperature	Formation characterization: lithology and rock (petrophysical and geo-mechanical) properties, Support to generate synthetic seismic log for well to seismic ties, Borehole condition and diameter to aid casing and cementation operations, Baseline borehole temperature	17 ½"	3,000' MD/TVD - 8,991' MD/TVD
		Borehole Image Log (Includes capability for fracture identification)	Structural and stratigraphic features including fracture detection, borehole shape and input for geo-mechanical analysis		8,082' MD/TVD - 8,991' MD/TVD
		Side Wall Coring (rotary or percussion)	Recover rock samples for geological, petrophysical and geo-mechanical characterization		TBD Coring Point (acquire ~ 60')
Long String Section	Drilling BHA	Formation Integrity Test (FIT)	Basis to assess fracture gradient to calibrate geo-mechanical model	12 ¼"	~9,006' MD/TVD
	Coring	Whole core (Upper Confining Zone)	Porosity and permeability, other petrophysical and sedimentological information in Upper Confining Zone	12 ¼"	TBD Coring Point (acquire ~ 60')
	While Drilling	Mud Logs	Drilling parameters, any fluid shows, formation cuttings. Assist with well correlation and casing seating depths decision.	12 ¼"	8,991' MD/TVD to Well TD
		MWD - Directional Survey	Directional survey - deviation checks during drilling		
		LWD (GR - Resistivity)	LWD - Identify the core points		
	Coring	Whole core (Injection Zone)	Porosity and permeability, other petrophysical and sedimentological information in Injection zone	12 ¼"	TBD Coring Point in Proposed Injection Intervals (acquire ~ 75')
	Wireline	Spontaneous Potential, Gamma-ray, Resistivity, Neutron, Density, Acoustic (Compressional and Shear). Multi-Arm Caliper, Temperature	Formation characterization: lithology and rock (petrophysical and geo-mechanical) properties, Support to generate synthetic seismic log for well to seismic ties, Borehole condition and diameter to aid casing and cementation operations, Baseline borehole temperature	12 ¼"	8,991' MD/TVD to 10,770' MD/TVD
		Borehole Image Log Resistivity	Structural and stratigraphic features including fracture detection, borehole shape and input for geo-mechanical analysis		8,991' MD/TVD to 10,770' MD/TVD
		Wireline Formation Tester	Formation fracture pressure Fluid sample to obtain fluid properties (PVT) and geochemical analysis.		Target proposed Injection Intervals
		Nuclear Magnetic Resonance (NMR)	Formation porosity and permeability.		8,991' MD/TVD to 10,770' MD/TVD
		Side Wall Coring (rotary or percussion)	Recover rock samples for geological, petrophysical and geo-mechanical characterization		Targets defined by real-time drilling data

Table C.2.2-2 Cased Hole Logging/Testing Plan for MS CCS 1

	Trip	Logging Suite	Target Data Acquisition/Objectives	Cased Hole Diameter	Depth of Survey (Ref KB=38' above MSL)
Surface Section	Wireline	Cement Quality and Variable density log	Determine cement bond integrity around casing to assess hydraulic isolation	20" OD CSG 18.130" ID	3,000'MD/TVD to Surface
		GR – Temperature Log	Stratigraphic correlation Cased hole temperature base line		
Intermediate Section	Wireline	Cement Quality and Variable density log	Determine cement bond integrity around your casing to assess hydraulic isolation	13 ⅜" OD CSG 12.415" ID	8991' MD/TVD to Surface
		Casing Inspection	Assess baseline condition of casing to assess any potential future corrosion		
		GR – Temperature/Noise Log	Stratigraphic correlation, Cased hole temperature and noise base line		
		Oxygen activation	Detect and measure water flow in or around a borehole		
	Drilling BHA	Casing Pressure Test	Evaluate the mechanical integrity of a well's casing. The test monitors for pressure loss, which indicates the presence of mechanical integrity, or the absence of leaks	13 ⅜" OD CSG 12.415" ID	8991' MD/TVD to Surface
Long String Section	Wireline	Cement Quality and Variable density log (Cement evaluation)	Determine cement bond integrity around your casing to assess hydraulic isolation	9 5/8" OD CSG 8.681 ID	10,690' MD/TVD (Plug back depth) to surface
		Casing Inspection	Assess baseline condition of casing to assess any potential future corrosion		
		GR – Temperature/Noise Log	Stratigraphic correlation, Cased hole temperature and noise base line		
		Oxygen activation	Detect and measure water flow in or around a borehole		
		Pulsed Neutron log	Baseline assessment of thru casing formation saturation for comparison to post injection logging runs		
	Test BHA	Casing Pressure Test	Evaluate the mechanical integrity of a well casing.	9 ⅝" OD CSG 8.681 ID	10,690' MD/TVD (Plug back depth) to Surface

Table C.2.2-3 Open Hole Logging/Testing Plan for MS CCS 2

	Trip	Logging Suite	Target Data Acquisition/Objectives	Open Hole Diameter	Depth of Survey (Ref KB=38' above MSL)
Surface Section	While Drilling	Mud Logs	Drilling parameters, any fluid shows, formation cuttings. Assist with well correlation and casing seating depths decision	26"	150' MD/TVD - 3,000' MD / 2,991' TVD
		MWD - Directional Survey	Directional survey to determine the location of the borehole		
	Wireline	Spontaneous Potential, Gamma-ray, Resistivity, Multi-Arm Caliper, Temperature	Formation characterization; lithology and rock properties Borehole condition and diameter to aid casing and cementation operations. and baseline borehole temperature.	26"	150' MD/TVD - 3,000' MD / 2,991' TVD
Intermediate Section	Drilling BHA	Formation Integrity test (FIT)	Basis to assess fracture gradient to calibrate geo-mechanical model	17 ½”	~3,015’ MD / 3,005' TVD
	While Drilling	Mud Logs	Drilling parameters, any fluid shows, formation cuttings. Assist with well correlation and casing seating depths decision	17 ½”	9,636' MD / 8,844' TVD - 3,000' MD / 2,991' TVD
		MWD - Directional Survey	Directional survey - deviation checks during drilling		
		PWD (pressure while drilling)	Pressure while drilling – used for pore pressure and fracture gradient calibration		
		LWD (GR - Resistivity)	Formation characterization and support to set intermediate casing in the Upper Confining Zone		
	Wireline	Spontaneous Potential, Gamma-ray, Resistivity, Neutron, Density, Acoustic (Compressional and Shear). Multi-Arm Caliper,Temperature	Formation characterization: lithology and rock (petrophysical and geo-mechanical) properties, Support to generate synthetic seismic log for well to seismic ties, Borehole condition and diameter to aid casing and cementation operations, Baseline borehole temperature	17 ½”	9,636' MD / 8,844' TVD - 3,000' MD / 2,991' TVD
		Side Wall Coring (rotary or percussion)	Recover rock samples for geological, petrophysical and geo-mechanical characterization		TBD Coring Point (acquire ~ 60')
Long String Section	Drilling BHA	Formation Integrity Test (FIT)	Basis to assess fracture gradient to calibrate geo-mechanical model	12 ¼”	~9,650’ MD / 8,858' TVD
	While Drilling	Mud Logs	Drilling parameters, any fluid shows, formation cuttings. Assist with well correlation and casing seating depths decision	12 ¼”	9,636' MD / 8,844' TVD - 11,409' MD/10,617' TVD
		MWD - Directional Survey	Directional survey - deviation checks during drilling		
		PWD (pressure)	Pressure while drilling – used for pore pressure and fracture gradient calibration		
		LWD (GR - Resistivity)	Formation characterization and identify the core points		
	Wireline	Spontaneous Potential, Gamma-ray, Resistivity, Neutron, Density, Acoustic (Compressional). Multi-Arm Caliper, Temperature	Formation characterization: lithology and rock (petrophysical and geo-mechanical) properties, Support to generate synthetic seismic log for well to seismic ties, Borehole condition and diameter to aid casing and cementation operations, Baseline borehole temperature	12 ¼”	9,636' MD / 8,844' TVD - 11,409' MD/10,617' TVD
		Side Wall Coring (rotary or percussion)	Recover rock samples for geological, petrophysical and geo-mechanical characterization		Targets defined by real-time drilling data

Table C.2.2-4 Cased Hole Logging/Testing Plan for MS CCS 2

	Trip	Logging Suite	Target Data Acquisition/Objectives	Cased Hole Diameter	Depth of Survey (Ref KB=38' above MSL)
Surface Section	Wireline	Cement Quality and Variable density log	Determine cement bond integrity around casing to assess hydraulic isolation	20" OD CSG 18.130" ID	3,000'MD / 2,991'TVD to Surface
		GR – Temperature Log	Stratigraphic correlation Cased hole temperature base line		
Intermediate Section	Wireline	Cement Quality and Variable density log	Determine cement bond integrity around your casing to assess hydraulic isolation	13 ⅜" OD CSG 12.415" ID	9,636' MD / 8,844' TVD to Surface
		Casing Inspection	Assess baseline condition of casing to assess any potential future corrosion		
		GR – Temperature/Noise Log	Stratigraphic correlation, Cased hole temperature and noise base line		
		Oxygen activation	Detect and measure water flow in or around a borehole		
	Drilling BHA	Casing Pressure Test	Evaluate the mechanical integrity of a well's casing. The test monitors for pressure loss, which indicates the presence of mechanical integrity, or the absence of leaks	13 ⅜" OD CSG 12.415" ID	9,636' MD / 8,844' TVD to Surface
Long String Section	Wireline	Gyro Deviation Survey	Cased Hole deviation check	9 ⅝" OD CSG 8.681 ID	~ 2,200' MD/TVD - 8,600' MD/ 7,808' TVD
		Cement Quality and Variable density log (Cement evaluation)	Determine cement bond integrity around your casing to assess hydraulic isolation		
		Casing Inspection	Assess baseline condition of casing to assess any potential future corrosion		11,329' MD / 10,537' TVD (Plug back depth) to Surface
		GR – Temperature/Noise Log	Stratigraphic correlation. Cased hole temperature and noise base line		
		Oxygen activation	Detect and measure water flow in or around a borehole		
		Pulsed Neutron log	Baseline assessment of thru casing formation saturation for comparison to post injection logging runs		
	Test BHA	Casing Pressure Test	Evaluate the mechanical integrity of a well's casing. The test monitors for pressure loss, which indicates the presence of mechanical integrity, or the absence of leaks	9 ⅝" OD CSG 8.681 ID	11,329' MD / 10,537' TVD (Plug back depth) to Surface

Table C.2.2-5 Proposed Pre-Operational Testing Schedule for MS CCS 1

Section	Hole	Trip	Logging Suite	Target Data Acquisition/Objectives	Open/ Cased Hole Diameter	Depth of Survey (Ref KB=38' above MSL)
Surface Section	Open	While Drilling	Mud Logs	Drilling parameters, any fluid shows, formation cuttings. Assist with well correlation and casing seating depths decision.	26"	150' MD/TVD - 3,000' MD/TVD
			MWD - Directional Survey	Directional survey to determine the location of the borehole		
		Wireline	Spontaneous Potential, Gamma-ray, Resistivity, Multi-Arm Caliper, Temperature	Formation characterization; lithology and rock properties Borehole condition and diameter to aid casing and cementation operations. and baseline borehole temperature.		
	Cased	Wireline	Cement Quality and Variable density log	Determine cement bond integrity around casing to assess hydraulic isolation	20" OD CSG 18.130" ID	3,000'MD/TVD to Surface
			GR – Temperature Log	Stratigraphic correlation Cased hole temperature base line		
Intermediate Section	Open	Drilling BHA	Formation Integrity test (FIT)	Basis to assess fracture gradient to calibrate geo-mechanical model	17 ½"	~3,015' MD/TVD
		While Drilling	Mud Logs	Drilling parameters, any fluid shows, formation cuttings. Assist with well correlation and casing seating depths decision.		3,000' MD/TVD - 8,991' MD/TVD
			MWD - Directional Survey	Directional survey - deviation checks during drilling		
			PWD (pressure while drilling)	Pressure while drilling – used for pore pressure and fracture gradient calibration		
			LWD (GR - Resistivity)	Formation characterization and support to set intermediate casing in the Anahuac (CZ)		8,082' MD/TVD - 8,991' MD/TVD
		Wireline	Spontaneous Potential, Gamma-ray, Resistivity, Neutron, Density, Acoustic (Compressional and Shear). Multi-Arm Caliper,Temperature	Formation characterization: lithology and rock (petrophysical and geo-mechanical) properties, Support to generate synthetic seismic log for well to seismic ties, Borehole condition and diameter to aid casing and cementation operations, Baseline borehole temperature		3,000' MD/TVD - 8,991' MD/TVD
			Borehole Image Log (Includes capability for fracture identification)	Structural and stratigraphic features including fracture detection, borehole shape and input for geo-mechanical analysis		8,082' MD/TVD - 8,991' MD/TVD
			Side Wall Coring (rotary or percussion)	Recover rock samples for geological, petrophysical and geo-mechanical characterization		TBD Coring Point (acquire ~ 60')
	Cased	Wireline	Cement Quality and Variable density log	Determine cement bond integrity around your casing to assess hydraulic isolation	13 ⅜" OD CSG 12.415" ID	8991' MD/TVD to Surface
			Casing Inspection	Assess baseline condition of casing to assess any potential future corrosion		
			GR – Temperature/Noise Log	Stratigraphic correlation, Cased hole temperature and noise base line		
			Oxygen activation	Detect and measure water flow in or around a borehole		
		Drilling BHA	Casing Pressure Test	Evaluate the mechanical integrity of a well's casing. The test monitors for pressure loss, which indicates the presence of mechanical integrity, or the absence of leaks		

Table C.2.2-5 Proposed Pre-Operational Testing Schedule for MS CCS 1

Section	Hole	Trip	Logging Suite	Target Data Acquisition/Objectives	Open/ Cased Hole Diameter	Depth of Survey (Ref KB=38' above MSL)
Long String Section	Open	Drilling BHA	Formation Integrity Test (FIT)	Basis to assess fracture gradient to calibrate geo-mechanical model	12 ¼”	~9,006’ MD/TVD
		Coring	Whole core (Upper Confining Zone)	Porosity and permeability, other petrophysical and sedimentological information in Upper Confining Zone		TBD Coring Point (acquire ~ 60')
		While Drilling	Mud Logs	Drilling parameters, any fluid shows, formation cuttings. Assist with well correlation and casing seating depths decision.		8,991' MD/TVD to Well TD
			MWD - Directional Survey	Directional survey - deviation checks during drilling		
			LWD (GR - Resistivity)	LWD - Identify the core points		
		Coring	Whole core (Injection Zone)	Porosity and permeability, other petrophysical and sedimentological information in Injection zone		TBD Coring Point in Proposed Injection Intervals (acquire ~ 75')
		Wireline	Spontaneous Potential, Gamma-ray, Resistivity, Neutron, Density, Acoustic (Compressional and Shear). Multi-Arm Caliper, Temperature	Formation characterization: lithology and rock (petrophysical and geo-mechanical) properties, Support to generate synthetic seismic log for well to seismic ties, Borehole condition and diameter to aid casing and cementation operations, Baseline borehole temperature		8,991' MD/TVD to 10,770' MD/TVD
			Borehole Image Log Resistivity	Structural and stratigraphic features including fracture detection, borehole shape and input for geo-mechanical analysis		
			Wireline Formation Tester	Formation pressures Fluid sample to obtain fluid properties (PVT) and geochemical analysis.		Target proposed Injection Intervals
			Nuclear Magnetic Resonance (NMR)	Formation porosity and permeability.		8,991' MD/TVD to 10,770' MD/TVD
			Side Wall Coring (rotary or percussion)	Recover rock samples for geological, petrophysical and geo-mechanical characterization		Targets defined by real-time drilling data
	Cased	Wireline	Cement Quality and Variable density log (Cement evaluation)	Determine cement bond integrity around your casing to assess hydraulic isolation	9 ⅝" OD CSG 8.681 ID	10,690' MD/TVD (Plug back depth) to Surface
			Casing Inspection	Assess baseline condition of casing to assess any potential future corrosion		
			GR – Temperature/Noise Log	Stratigraphic correlation, Cased hole temperature and noise base line		
			Oxygen activation	Detect and measure water flow in or around a borehole		
			Pulsed Neutron log	Baseline assessment of thru casing formation saturation for comparison to post injection logging runs		
		Test BHA	Casing Pressure Test	Evaluate the mechanical integrity of a well casing		

Table C.2.2-6 Proposed Pre-Operational Testing Schedule for MS CCS 2

Section	Hole	Trip	Logging Suite	Target Data Acquisition/Objectives	Open/ Cased Hole Diameter	Depth of Survey (Ref KB=38' above MSL)
Surface Section	Open	While Drilling	Mud Logs	Drilling parameters, any fluid shows, formation cuttings. Assist with well correlation and casing seating depths decision.	26"	150' MD/TVD - 3,000' MD / 2,991' TVD
			MWD - Directional Survey	Directional survey to determine the location of the borehole		
		Wireline	Spontaneous Potential, Gamma-ray, Resistivity, Multi-Arm Caliper, Temperature	Formation characterization; lithology and rock properties Borehole condition and diameter to aid casing and cementation operations. and baseline borehole temperature.		
	Cased	Wireline	Cement Quality and Variable density log	Determine cement bond integrity around casing to assess hydraulic isolation	20" OD CSG 18.130" ID	3,000'MD / 2,991'TVD to Surface
			GR – Temperature Log	Stratigraphic correlation Cased hole temperature base line		
Intermediate Section	Open	Drilling BHA	Formation Integrity test (FIT)	Basis to assess fracture gradient to calibrate geo-mechanical model	17 ½”	~3,015’ MD / 3,005' TVD
		While Drilling	Mud Logs	Drilling parameters, any fluid shows, formation cuttings. Assist with well correlation and casing seating depths decision.		9,636' MD / 8,844' TVD - 3,000' MD / 2,991' TVD
			MWD - Directional Survey	Directional survey - deviation checks during drilling		
			PWD (pressure while drilling)	Pressure while drilling – used for pore pressure and fracture gradient calibration		
			LWD (GR - Resistivity)	Formation characterization and support to set intermediate casing in the Upper Confining Zone		
		Wireline	Spontaneous Potential, Gamma-ray, Resistivity, Neutron, Density, Acoustic (Compressional and Shear). Multi-Arm Caliper,Temperature	Formation characterization: lithology and rock (petrophysical and geo-mechanical) properties, Support to generate synthetic seismic log for well to seismic ties, Borehole condition and diameter to aid casing and cementation operations, Baseline borehole temperature		
			Side Wall Coring (rotary or percussion)	Recover rock samples for geological, petrophysical and geo-mechanical characterization		TBD Coring Point (acquire ~ 60')
	Cased	Wireline	Cement Quality and Variable density log	Determine cement bond integrity around your casing to assess hydraulic isolation	13 ⅜" OD CSG 12.415" ID	9,636' MD / 8,844' TVD to Surface
			Casing Inspection	Assess baseline condition of casing to assess any potential future corrosion		
			GR – Temperature/Noise Log	Stratigraphic correlation, Cased hole temperature and noise base line		
			Oxygen activation	Detect and measure water flow in or around a borehole		
		Drilling BHA	Casing Pressure Test	Evaluate the mechanical integrity of a well's casing. The test monitors for pressure loss, which indicates the presence of mechanical integrity, or the absence of leaks		

Table C.2.2-6 Proposed Pre-Operational Testing Schedule for MS CCS 2

Section	Hole	Trip	Logging Suite	Target Data Acquisition/Objectives	Open/ Cased Hole Diameter	Depth of Survey (Ref KB=38' above MSL)
Long String Section	Open	Drilling BHA	Formation Integrity Test (FIT)	Basis to assess fracture gradient to calibrate geo-mechanical model	12 ¼"	~9,650' MD / 8,858' TVD
		While Drilling	Mud Logs	Drilling parameters, any fluid shows, formation cuttings. Assist with well correlation and casing seating depths decision.		9,636' MD / 8,844' TVD - 11,409' MD/10,617' TVD
			MWD - Directional Survey	Directional survey - deviation checks during drilling		
			PWD (pressure)	Pressure while drilling – used for pore pressure and fracture gradient calibration		
			LWD (GR - Resistivity)	Formation characterization and identify the core points		
		Wireline	Spontaneous Potential, Gamma-ray, Resistivity, Neutron, Density, Acoustic (Compressional and Shear). Multi-Arm Caliper, Temperature	Formation characterization: lithology and rock (petrophysical and geo-mechanical) properties, Support to generate synthetic seismic log for well to seismic ties, Borehole condition and diameter to aid casing and cementation operations, Baseline borehole temperature		9,636' MD / 8,844' TVD - 11,409' MD/10,617' TVD
			Side Wall Coring (rotary or percussion)	Recover rock samples for geological, petrophysical and geo-mechanical characterization		Targets defined by real-time drilling data
	Cased		Gyro Deviation Survey	Cased Hole deviation check		~ 2,200' MD/TVD - 8,600' MD/ 7,808' TVD
			Cement Quality and Variable density log (Cement evaluation)	Determine cement bond integrity around your casing to assess hydraulic isolation		
		Wireline	Casing Inspection	Assess baseline condition of casing to assess any potential future corrosion	9 ⅝" OD CSG 8.681 ID	11,329' MD / 10,537' TVD (Plug back depth) to Surface
			GR – Temperature/Noise Log	Stratigraphic correlation. Cased hole temperature and noise base line		
			Oxygen activation	Detect and measure water flow in or around a borehole		
			Pulsed Neutron log	Baseline assessment of thru casing formation saturation for comparison to post injection logging runs		
		Test BHA	Casing Pressure Test	Evaluate the mechanical integrity of a well's casing. The test monitors for pressure loss, which indicates the presence of mechanical integrity, or the absence of leaks		

Table C.2.3-1 Whole Core Test & Analyses Plan

	Tests & Analyses	Details
Geologic Review	Lithologic Information	Rock Type, Depositional Environment, Pore Type, and Mineralogy/Geochemistry
	Geologic Maps	
	Fracture Orientation	
Petrophysical and Reservoir Engineering	Permeability Information	Permability / Porosity Correlation and Relative Permability
	Capillary Pressure Data	
	Data for Refining Log Calculations	Electrical Properties, Grain Density, Core Gamma Log and Mineralogy and Cation Exchange Capacity
	Storage Estimate	Porosity and Fluid Saturations
Drilling and Completions	Fluid/ Formation Compatibility Studies	
	Rock Mechanics Data	

Table C.2.3-2 Sidewall Cores Test & Analyses Plan

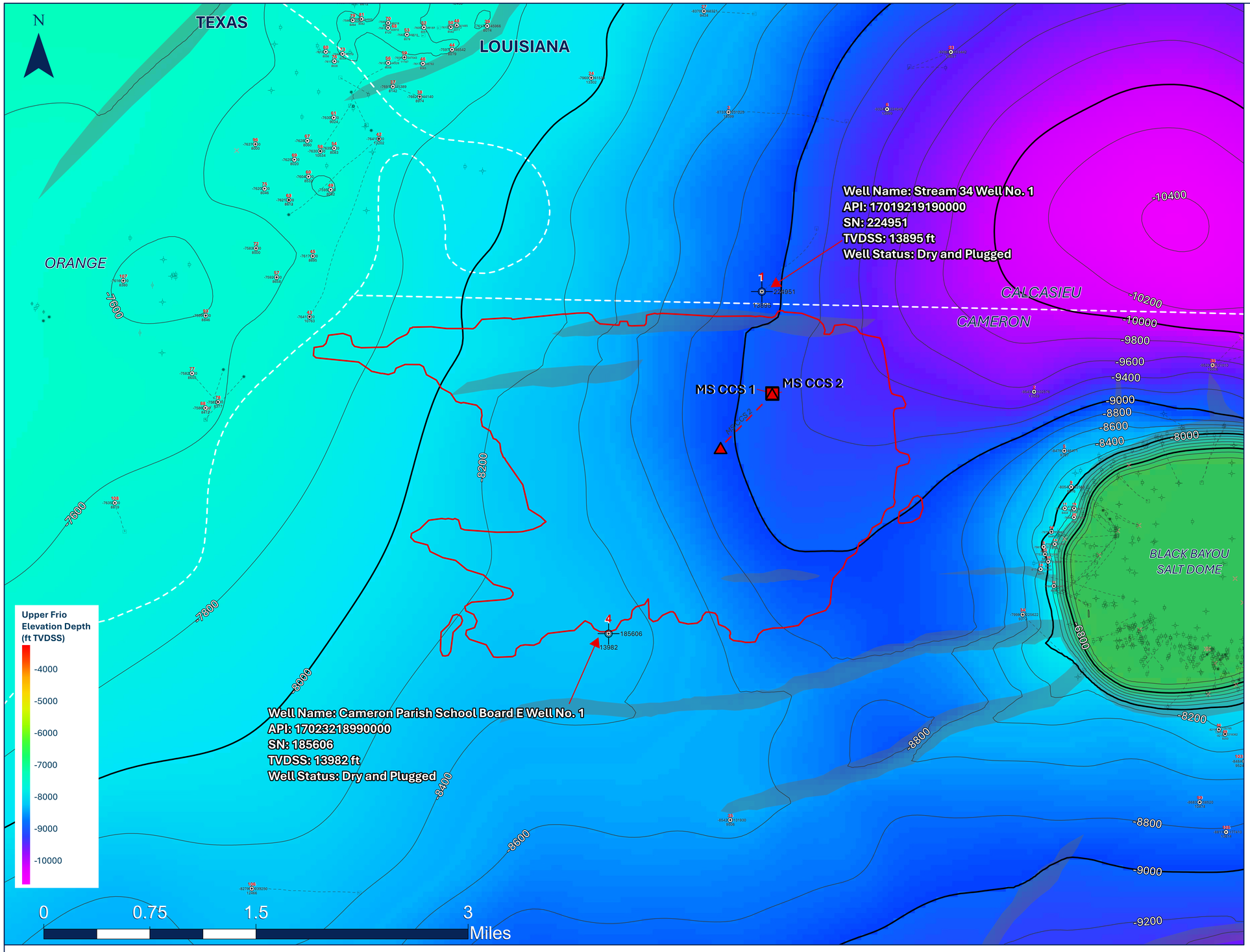
Logs/Test	Interval	Details
Sidewall Core	At least 1 sample for every minor sandstone in the Injection Zone (not whole cored) and interbedded shales	Verification of log analysis calculations
Mudlog	Conductor casing to TD	Monitor and collect drilling parameters including depth, pressure, temperatures, mud flow rates, drill rates, rotation speed, rate of penetration, oil and gas shows, cutting rate, and gas trends. Interpretation of examination of formation cuttings. Monitor and collection of drilling fluid including basic chemical and mechanical parameters of drilling fluid or drilling mud such as chlorides and temperature. Assistance with well correlation.

Table C.2.3-3 Core Analyses Services

	Service	Service Description
Injection & Confining Zone(s)	Routine Core Analysis	Determination of storage capacity, fluid types and saturations, and fluid flow capability via permeability.
	Special Core Analysis	Determination of capillary pressure, relative permeability, wettability, surface and interfacial tension, and electrical properties.
	X-Ray Diffraction (XRD)	Determine the presence and amounts of minerals and their species in a sample. Analyze phase composition and structure.
	Scanning Electron Microscopy (SEM)	High Resolution and high magnification imaging of pore geometry and distribution of clay and/or other antigenic minerals associated with the pore system of a rock.
	Core Description	Description of lithology and features, detailed sedimentological log, and a weathering profile. This includes grain size analysis, crucial for understanding reservoir quality and sedimentary processes.
	CT scan	Provide high-resolution images of the core's internal structure, helping to identify fractures, bedding planes, and other features.
	Mercury Injection Capillary Pressure (MICP)	Provides detailed pore throat size distribution and helps in understanding the capillary pressure characteristics.
	Fluid Analysis	Complete Water Analysis all metals with acid digestion and all Water Ions measurable by vendor.
Confining Zone(s)	Unconfined compressive strength test	Record the maximum axial load sustained at the point of failure.
	Pore volume compressibility	Measures relationship between pore volume and external stresses. Key factor in characterizing fluid transport and stress.
	Triaxial Compressive Strength Test	Evaluate shear strength conditions.

Table C.2.5-1 Injection Well Integrity Testing Summary

Regulatory Citation	Rule Description	Test Description	Program Period
LAC 43:XVII§3627.A.1.a	No significant leak in casing, tubing, or packer	– Casing pressure test after drilling out cement stage tool; test between surface BOP and cemented shoe track. – Tubing pressure test after running tubing with packer; test from pump down to sealed nipple set in profile. – Packer test; pressure test above packer, in casing/tubing annulus.	– Drilling & casing well – Workover rig re-entry of well to drill-out cement stage tool to provide access to long string for logging/testing. – Completion rig re-entry of well to run injection tubing and packer.
LAC 43:XVII§3617.B.1.d	Internal mechanical integrity proof via logging, survey, or test	– Casing pressure test after drilling out cement stage tool; test between surface BOP and cemented shoe track.	– Workover rig re-entry of well to drill-out cement stage tool to provide access to long string for logging/testing.
LAC 43:XVII§3617.B.1.d	External mechanical integrity proof via logging, survey, or test	– Fiber optic cable attached to outside of long string casing; temperature survey along casing length. Temperature anomaly indication of leak.	– Workover rig re-entry of well to drill-out cement stage tool to provide access to long string for full-length pressure testing.
LAC 43:XVII§3617.B.5	Injection zone pressure fall-off test	– Reservoir characterization log, tool set above injection zone perforations.	– Workover rig re-entry of well to drill-out cement stage tool to provide access to long string for logging operations.
LAC 43:XVII§3617.B.5	Injection Zone step rate injectivity test	Used to determine the Maximum Surface Injection Pressure (MSIP) of Injection Zone	– Workover rig re-entry of well to drill-out cement stage tool to provide access to long string for logging operations.



Gulf Coast Sequestration, LLC (G1037)
5599 San Felipe, Suite 1450, Houston, TX 77056
(713) 997-3145 | www.gcscarbon.com

FIGURE C.1-1
Injection Wells in Relation to Type Log Wells

MAP LEGEND

- Injector Well Pad
- Injector Bottom Hole
- Injector Schematic Well
- Trajectory
- Upper Frio Structure Control Point
- Delineated Area of Review
- SONRIS Parishes
- Top Upper Frio Faults

Upper Frio Structure Contour Interval (ft TVDSS)

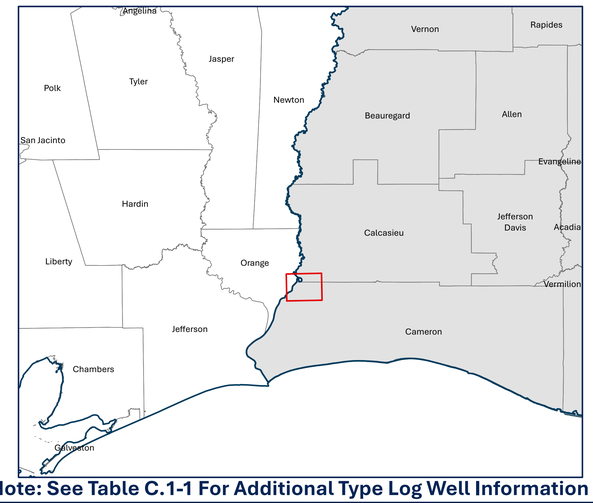
- 200 ft Contour Interval
- 1000 ft Contour Interval

Well Status

- Other
- Active - Producing
- Drilled
- Dry & Plugged
- Inactive
- Orphan
- Permit Expired
- Plugged & Abandoned
- Reverted
- Shut In
- Temporarily Abandoned
- Unable to Locate

Control Point Labels

Map ID
Structure Depth (ft TVDSS) ● Serial Number
Total Depth (TVDSS)



MAP DETAILS

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APPROVED BY	K GARRETT	**DATE**	11/XX/2024
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PAGE SIZE	A0 (46.81 W X 33.11 H)		

SPATIAL REFERENCE

PCS	NAD 1927 State Plane Louisiana South (FIPS 1702)
GCS	GCS North American 1927
DATUM	North American 1927
PROJECTION	Lambert Conformal Conic

PROJECT MINERVA DETAILS

WELLS	Minerva South CCS Well Nos. 001 and 002
LOCATION	Cameron Parish, Louisiana
EPA PROJECT ID	R06-LA-0002
LDENR APPL NOS	45031 & 45032

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KAYCEE GARRETT
1325
Est. 2011

Note: See Table C.1-1 For Additional Type Log Well Information

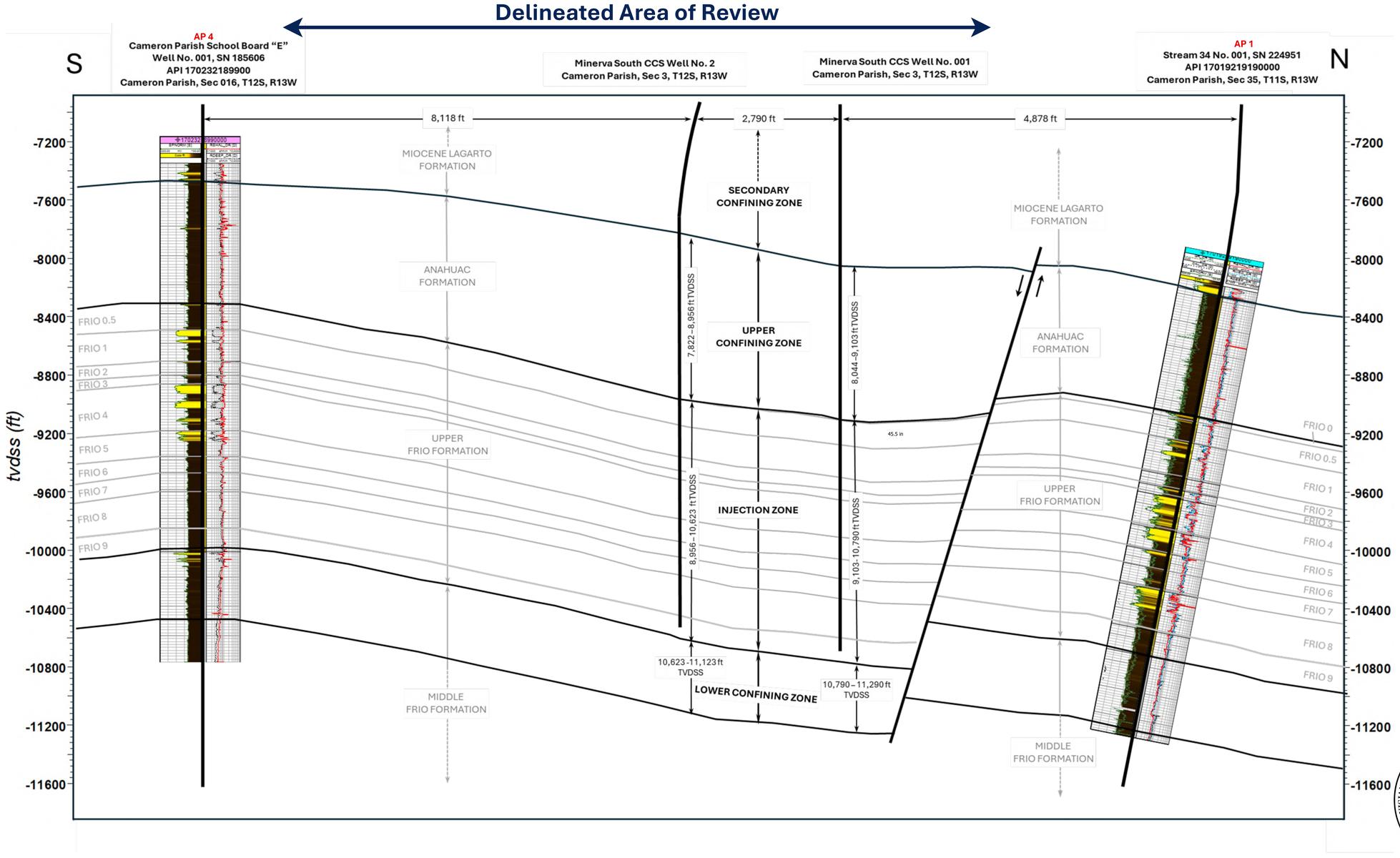

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FIGURE C.1-2

N-S Regulatory Zones Type Section

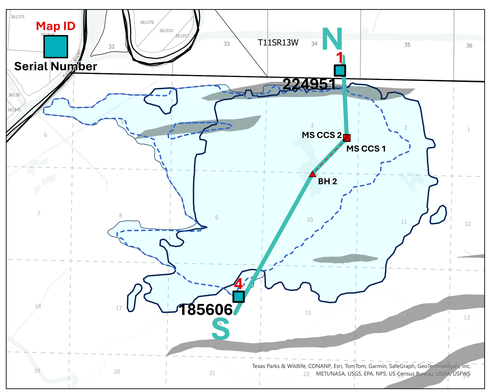
PROJECT MINERVA

MINERVA SOUTH CCS WELL NOS. 001 & 002

CAMERON PARISH, LA

PROJECT ID: R06-LA-0002

LDENR APPL NOS: **45031 & 45032**



Note: See Table C.1-1 For Additional Type Log Well Information

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MAP DETAILS

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APPROVED BY	K GARRETT
DATE APPROVED	11/XX/2024
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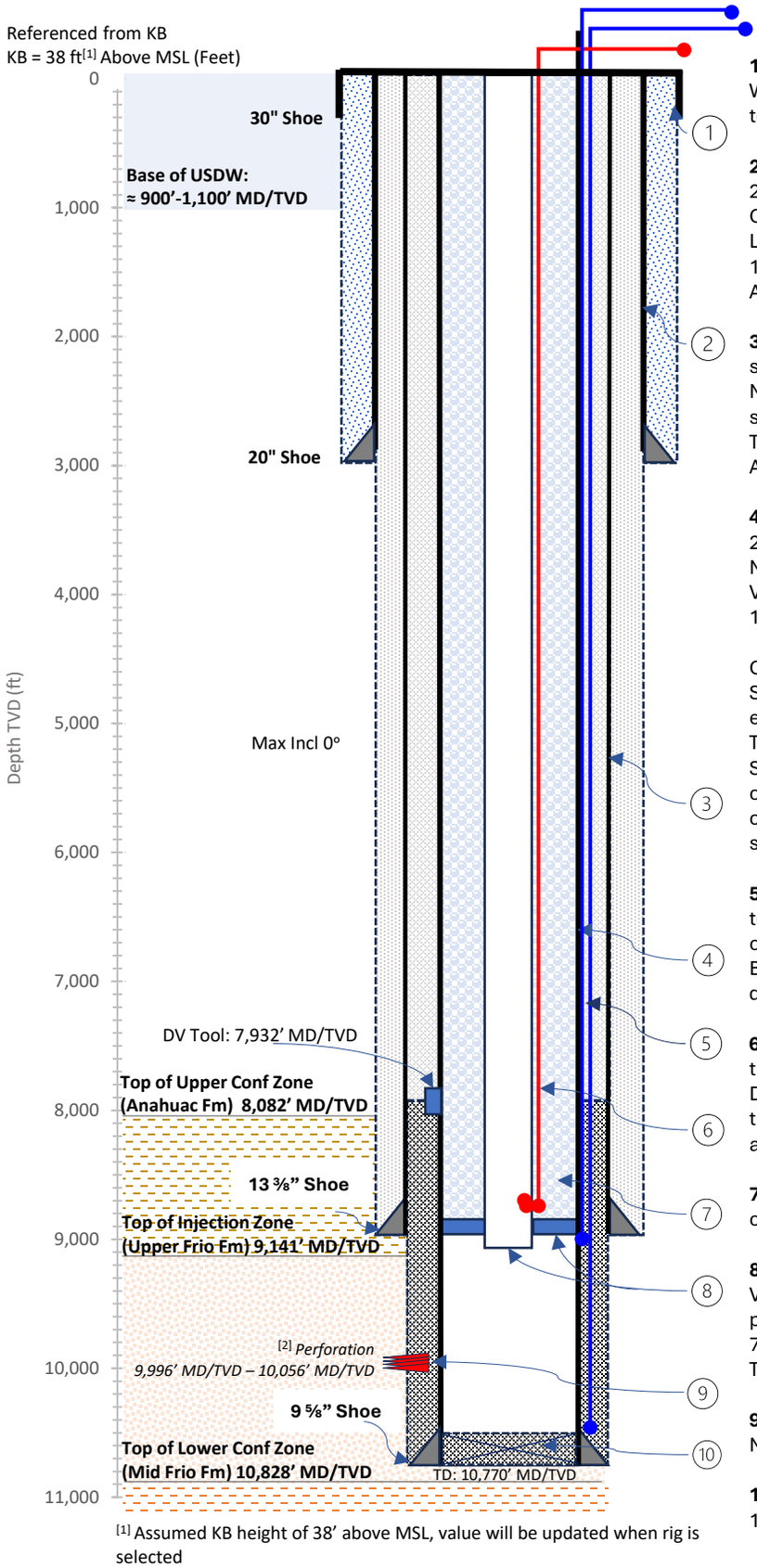
Figure C.2-1 Proposed Wellbore Schematic for Minerva South CCS Well No. 001



[1] Assumed KB height of 38' above MSL, value will be updated when rig is selected

1. 30" Conductor Pipe: 1.0" WT, 28" ID, 310.3 lb/ft, X-56 Welded, plain-end, beveled conductor with drive shoe driven to refusal at 150' MD/TVD

2. 20" Surface Casing: 133 lb/ft, L-80, ER at 3,000' MD/TVD
26" Hole, expected MW 9.00 ppg WBM
Cemented with Type-1 cement up to the surface
Lead slurry 11.80 ppg (2,616 sacks, 2.71 cuft/sack); Tail slurry 14.8 ppg (1,421 sacks, 1.33 cuft/sack)
Assumed 100% excess volume.

3. 13 ⅜" Intermediate Casing: 13 ⅜", 68 lb/ft, L-80 BTC from section TD to surface. 17 ½" Hole at 8,991' MD/TVD. Expected MW 10.00 ppg WBM. Cemented with Class H cement up to surface. Lead slurry 12.80 ppg (3,356 sacks; 2.10 cuft/sack); Tail slurry 14.8 ppg (1,433 sacks; 1.33 cuft/sack)
Assumed 50% excess volume in open hole section.

4. 9 ⅝" Injection Casing: 9 ⅝", 53.5 lb/ft, 25CRW-125 VAM-21, Prem Connection from 10,770' MD/TVD (Well TD) to 7,932' MD/TVD (150' above Top of Confining Zone) & 53.5 lb/ft, L-80 VAM-21, Premium connection from 7,932' MD/TVD to surface. 12 ¼" Hole to 10,770' MD/TVD. Expected MW 13.50 ppg WBM.

Cemented in two stages:
Stage #1: CO_2 corrosion-resistant cement slurry (PermaSet or equivalent) 14.8 ppg (1,013 sacks; 1.12 cuft/sack). Expected TOC at 7,932' MD/TVD. (DV tool). Assumed 20% excess.
Stage #2: 14.3 ppg (2,055 sacks; 1.24 cuft/sack) Class H cement lead slurry + 14.8 ppg (100 sacks; 1.12 cuft/sack) CO_2 corrosion-resistant cement tail slurry. Cement up to the surface. No volume excess is assumed.

5. DTS/DAS Fiber Optic Cable: Downhole cable with a 150 °C temperature rating, 2 single-mode fiber acrylate clamped outside the 9 ⅝" casing from surface to TD.
Back-up fiber optic cable will be set up from surface to the depth of the 13 ⅜" casing shoe.

6. TEC (Electrical Line): Downhole cable attached outside of the tubing, with pressure/temperature gauge carriers. Downhole measurements in two locations – annulus and tubing; minimum pressure and temperature ratings of 10k psi and 150° C.

7. Packer Fluid: 8.5 ppg $CaCl_2$ inhibited brine with corrosion control (98% MgO, magnesium oxide).

8. Tubing and Packer: 4 ½" Tubing, 15.1 lb/ft, 25CRW-125, VAM-21. End of tail at 9,100' MD/TVD; Removable Production packer at 9,050' MD/TVD; if required a SCSSV 4 ½" with a 7.403" OD, 3.688" ID at base of USDW ≈ 1,100' MD/TVD; Tubing hanger at ground level.

9. Perforation Interval: From 10,056' MD/TVD to 9,996' MD/TVD. Oriented perforation system.

10. Plug back TD: From 10,770' MD/TVD (Shoe Depth) to 10,690' MD/TVD (Float Collar). Shoe Track

LEGEND

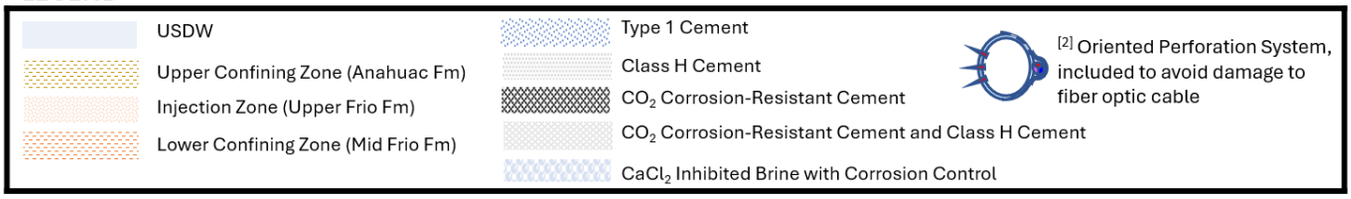
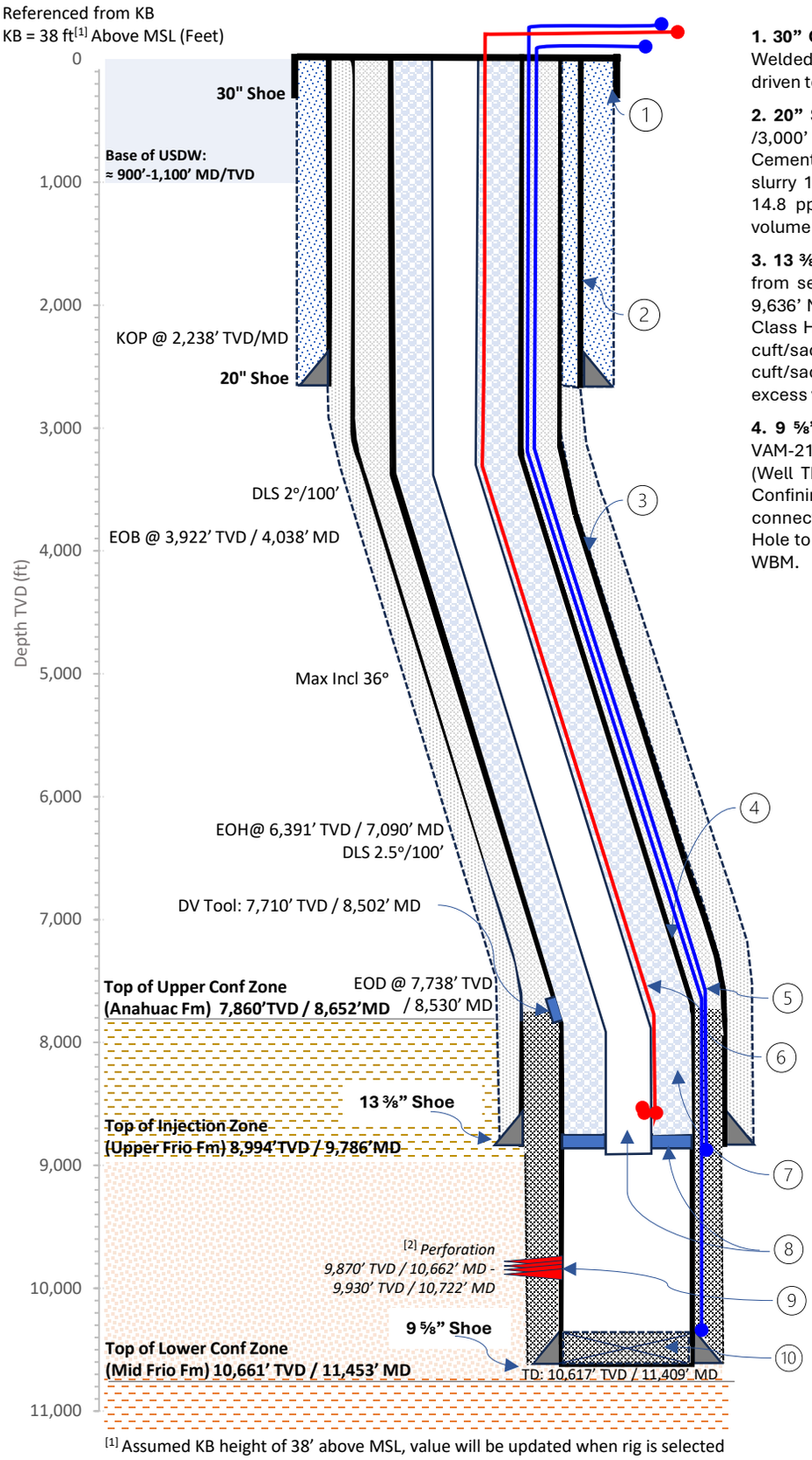


Figure C.2-2 Proposed Wellbore Schematic for Minerva South CCS Well No. 002



[1] Assumed KB height of 38' above MSL, value will be updated when rig is selected

1. 30" Conductor Pipe: 1.0" WT, 28" ID, 310.3 lb/ft, X-56 Welded, plain-end, beveled conductor with drive shoe driven to refusal at 150' MD/TVD.

2. 20" Surface Casing: 133 lb/ft, L-80, ER at 2,991' TVD /3,000' MD. 26" Hole, expected MW 9.00 ppg WBM. Cemented with Type-1 cement up to the surface. Lead slurry 11.80 ppg (2,616 sacks; 2.71 cuft/sack); Tail slurry 14.8 ppg (1,421 sacks; 1.33 cuft/sack). Assumed 100% volume excess.

3. 13 ⅜" Intermediate Casing: 13 ⅜", 68 lb/ft, L-80 BTC from section TD to surface. 17 ½" Hole at 8,844' TVD / 9,636' MD. Expected MW 10.00 ppg WBM. Cemented with Class H cement. Lead slurry 12.80 ppg (3,609 sacks; 2.10 cuft/sack) + Tail slurry 14.8 ppg (1,538 sacks; 1.33 cuft/sack). Cement up to the surface. Assumed 50% excess volume in open hole section.

4. 9 ⅝" Injection Casing: 9 ⅝", 53.5 lb/ft, 25CRW-125 VAM-21, Prem Connection from 10,617' TVD / 11,409' MD (Well TD) to 7,710' TVD / 8,502' MD (150' above Top of Confining Zone) & 53.5 lb/ft, L-80 VAM-21, Premium connection from 7,710' TVD / 8,502' MD to surface. 12 ¼" Hole to 10,617' TVD / 11,409' MD. Expected MW 13.50 ppg WBM.

Cemented in two stages:
Stage #1: CO_2 corrosion-resistant cement slurry (PermaSet or equivalent) 14.8 ppg (1,029 sacks; 1.12 cuft/sack). Expected TOC at 7,710' TVD / 8,502' MD. (DV tool). Assumed 20% excess volume in open hole section.
Stage #2: 14.3 ppg (2,209 sacks; 1.24 cuft/sack) Class H cement lead slurry + 14.8 ppg (100 sacks; 1.12 cuft/sack) CO_2 corrosion-resistant cement tail slurry. Cement up to the surface. No excess volume was considered.

5. DTS/DAS Fiber Optic Cable: Downhole cable with a 150 °C temperature rating, 2 single-mode fiber acrylate clamped outside the 9 ⅝" casing from surface to TD.
Back-up fiber optic cable will be set up from surface to the depth of the 13 ⅜" casing shoe.

6. TEC (Electrical Cables): Downhole cable attached outside of the tubing, with pressure/temperature gauge carriers. Downhole measurements in two locations – annulus and tubing; minimum pressure and temperature ratings of 10k psi and 150° C.

7. Packer Fluid: 8.5 ppg $CaCl_2$ inhibited brine with corrosion control (98% MgO, magnesium oxide).

8. Tubing and Packer: 4 ½" Tubing, 15.1 lb/ft, 25CRW-125, VAM-21, End of tail at 8,938' TVD / 9,730' MD; Removable Production packer at 8,888' TVD / 9,680' MD; if required a SCSSV 4 ½" with a 7.403" OD, 3.688" ID at base of USDW ≈ 1,100' MD/TVD; Tubing hanger at ground level.

9. Perforation Interval: From 9,870' TVD / 10,662' MD to 9,930' TVD / 10,722' MD. Oriented perforation system.

10. Plug back TD: From 11,409' MD / 10,617' TVD (Shoe Depth) to 11,329' MD / 10,537' TVD (Float Collar). Shoe Track

LEGEND

- USDW
- Upper Confining Zone (Anahuac Fm)
- Injection Zone (Upper Frio Fm)
- Lower Confining Zone (Mid Frio Fm)
- Type 1 Cement
- Class H Cement
- CO_2 Corrosion-Resistant Cement
- CO_2 Corrosion-Resistant Cement and Class H Cement
- $CaCl_2$ Inhibited Brine with Corrosion Control
- [2] Oriented Perforation System, included to avoid damage to fiber optic cable

APPENDIX C-I

Pre-Operational Logging and Testing Tool Specification Sheets

Acoustic Borehole Image

6.7.9 UltrasonicXplorer (UXPL)

TECHNICAL DATA SHEET ELECTRIC WIRELINE/ LOGGING	DOWNHOLE EQUIPMENT AND INSTRUMENTS
Contractor:	Baker Hughes
Equipment/instrument name:	UltrasonicXplorer
Type/series no.	1673
Standard abbreviation - service/tool	**UXPL**
Application - open/cased hole	OH/CH
Parameters measured	Acoustic borehole image, borehole geometry
Range of measurement	N/A
Sensitivity	N/A
Accuracy	N/A
Calibration - none/shop/rig/downhole	shop/rig
Maximum operating pressure	20,000 psi
Maximum operating temperature	204° C for 30 minutes
Maximum borehole/casing/tubing size	16”
Minimum borehole/casing/tubing size	6.0”
Min./max. opening size (if applicable)	N/A
Mud type or weight limitations	Use mud excluder in heavy muds
Outside diameter (max. , closed)	3 5/8”
Length	4.6 m
Weight (in air)	122 kg
Fishing neck OD.	3 3/8” cablehead
Radioactive source type and size	N/A
Logging speed min./max.	recommended 3 m/min
Surface acquisition system requirements	ECLIPS
Cable requirements (no. conductors, etc.)	7 conductor cable
Special capabilities: CBIL-C.100: SBM/WBM imaging capability. Mud excluder option for heavy muds. CBIL-D.100: SBM imaging capability. Mud excluder option for heavy muds.	

TECHNICAL DATA SHEET ELECTRIC WIRELINE/ LOGGING	DOWNHOLE EQUIPMENT AND INSTRUMENTS
Combination possibilities/limitations: Fully WTS combinable. Optional: can be combined with HDIP, STAR,, Earth Imager or GeoXplorer for simultaneous data acquisition.	

Bulk Density

6.3.4 ZDL- Dual Spectrum Density

TECHNICAL DATA SHEET ELECTRIC WIRELINE/ LOGGING	DOWNHOLE EQUIPMENT AND INSTRUMENTS
Contractor:	Baker Hughes
Equipment/instrument name:	Compensated Z-Densilog
Type/series no.	2234
Standard abbreviation - service/tool	**ZDL**
Application - open/cased hole	OH
Parameters measured	Formation bulk density, photoelectric abs. index, borehole diameter
Range of measurement	ZDEN: 1.3 - 3.0 g/cc, PE: 1.3 - 6.0 B/E CAL: 5 1/2" - 22"
Sensitivity	N/A
Accuracy	ZDEN: +/-0.025 g/cc, PE: +/- 0.2 B/E, CAL: +/-0.3"
Calibration - none/shop/rig/downhole	shop
Maximum operating pressure	20,000 psi
Maximum operating temperature	177° C
Maximum borehole/casing/tubing size	22"
Minimum borehole/casing/tubing size	6.0"
Min./max. opening size (if applicable)	4 7/8" - 24"
Mud type or weight limitations	N/A
Outside diameter (max. , closed)	4.88"
Length	3.42 m
Weight (in air)	165.6 kg
Fishing neck OD.	3 3/8" cablehead
Radioactive source type and size	Cs 137, 2 curie
Logging speed min./max.	up to 9 m/min
Surface acquisition system requirements	ECLIPS
Cable requirements (no. conductors, etc.)	7 conductor cable
Special capabilities: N/A	

TECHNICAL DATA SHEET ELECTRIC WIRELINE/ LOGGING	DOWNHOLE EQUIPMENT AND INSTRUMENTS
Combination possibilities/limitations: Full WTS Combinability	

Caliper

6.7.7 WGI- Well Geometry Instrument

TECHNICAL DATA SHEET ELECTRIC WIRELINE/LOGGING	DOWNHOLE EQUIPMENT AND INSTRUMENTS
Contractor:	Baker Hughes
Equipment/instrument name:	Wellbore Geometry Instrument
Type/series no.	4253
Standard abbreviation - service/tool	WGI / W6CAL
Application - open/cased hole	OH
Parameters measured	Borehole Radii
Range of measurement	N/A
Sensitivity	0.05″
Accuracy	0.1″
Calibration - none/shop/rig/downhole	Rig
Maximum operating pressure	20,000 psi
Maximum operating temperature	200° C for> 10 hours
Maximum borehole/casing/tubing size	5.5″
Minimum borehole/casing/tubing size	5.5″
Min./max. opening size (if applicable)	5.5″ / 26″
Mud type or weight limitations	N/A
Outside diameter (max. , closed)	3 5/8″
Length	2.31 m
Weight (in air)	52.2 kg
Fishing neck OD.	3 3/8″ cablehead
Radioactive source type and size	N/A
Logging speed min./max.	N/A
Surface acquisition system requirements	ECLIPS
Cable requirements (no. conductors, etc.)	7 conductor cable
Special capabilities:	
Combination possibilities/limitations: Full WTS combinability.	

Casing Inspection

6.12.35 Ultrasonic Cement Evaluation (ULTeX)

Table 6.3 No Title

TECHNICAL DATA SHEET ELECTRIC WIRELINE LOGGING	DOWNHOLE EQUIPMENT AND INSTRUMENTS
Contractor:	Baker Hughes
Equipment/instrument name:	Ultrasonic Isolation eXplorer
Type/series no.	1674 EA, MA
Standard abbreviation - service/tool	ULTeX
Application - open/cased hole	CH
Parameters measured	Cement Integrity, Casing ID, Casing Thickness
Range of measurement	0 - 10 Mrayl
Sensitivity	N/A
Accuracy	Cement Impedance: 0 - 3.3 Mrayl +/- 0.50 Mrayl > 3.3 Mrayl +/- 15% Casing Thickness: +/- 6%
Calibration - none/shop/rig/downhole	Shop & Downhole
Maximum operating pressure	20,000 psi
Maximum operating temperature	175° C for 4 Hrs.
Maximum borehole/casing/tubing size	13-3/8"
Minimum borehole/casing/tubing size	5.0”
Min./max. opening size (if applicable)	N/A
Mud type or weight limitations	OBM, 1.6 g/cc (12 db/cm per MHz)
Outside diameter	3-5/8”
Length	3.92 m (EA + MA sections)
Weight (in air)	98 kg (EA + MA sections)
Fishing neck OD.	3 3/8” cablehead
Radioactive source type and size	N/A
Logging speed min./max.	3 m/min (10ft/min)
Surface acquisition system requirements	ECLIPS
Cable requirements (no. conductors, etc.)	Multiconductor cable
Special capabilities:	High circumferrential resolution cemet bond,

TECHNICAL DATA SHEET ELECTRIC WIRELINE LOGGING	DOWNHOLE EQUIPMENT AND INSTRUMENTS
	casing ID and casing thickness measurement. Simultaneous Cement and casing evalution.
Combination possibilities/limitations:	GR/CCL/ORIT. Combinable with INTeX.

Cement Bond

6.12.8 Segmented Bond Tool (SBT)

TECHNICAL DATA SHEET ELECTRIC WIRELINE/ LOGGING	DOWNHOLE EQUIPMENT AND INSTRUMENTS
Contractor:	Baker Hughes
Equipment/instrument name:	Segmented Bond Tool
Type/series no.	1424 EA, MB
Standard abbreviation - service/tool	**SBT**
Application - open/cased hole	CH
Parameters measured	Cement integrity, segmented inspection, borehole deviation
Range of measurement	0 - 22 dB/ft compensated attenuation
Sensitivity	N/A
Accuracy	+/- 0.50 dB/ft
Calibration - none/shop/rig/downhole	rig
Maximum operating pressure	20,000 psi
Maximum operating temperature	177° C for 30 minutes
Maximum borehole/casing/tubing size	16"
Minimum borehole/casing/tubing size	4.2"
Min./max. opening size (if applicable)	3 3/8" - 16" (16" – 24")
Mud type or weight limitations	N/A
Outside diameter (max. , closed)	3 3/8"
Length	7.62 m
Weight (in air)	157.8 kg
Fishing neck OD.	3 3/8" cablehead
Radioactive source type and size	N/A
Logging speed min./max.	up to 9 m/min
Surface acquisition system requirements	ECLIPS or CASE
Cable requirements (no. conductors, etc.)	Single conductor cable
Special capabilities: Direct attenuation measurement, 6 sectors, unaffected by mud type or mild decentralisation, cement map imaging, separate VDL measurement. SBT Beyond service extends range from 16 – 24".	

TECHNICAL DATA SHEET ELECTRIC WIRELINE/ LOGGING	DOWNHOLE EQUIPMENT AND INSTRUMENTS
Combination possibilities/limitations: GR/CCL/CN. Combinable with XMAC-F1, Multi-Finger Caliper (MFC), RPM and HRVRT.	

Conductivity

6.2.1 HDIL- High Definition Induction Log

TECHNICAL DATA SHEET ELECTRIC WIRELINE/LOGGING	DOWNHOLE EQUIPMENT AND INSTRUMENTS
Contractor:	Baker Hughes
Equipment/instrument name:	High Definition Induction Log
Type/series no.	1515 EA, MA
Standard abbreviation - service/tool	**HDIL**
Application - open/cased hole	OH
Parameters measured	Formation conductivities at multiple spacing's
Range of measurement	0.2 ohm-m - 1,000 ohm-m
Sensitivity	N/A
Accuracy	+/- 1 mmho, +/- 2 % reading in homogeneous zone
Calibration - none/shop/rig/ downhole	shop
Maximum operating pressure	20,000 psi
Maximum operating temperature	204° C for 30 minutes
Maximum borehole/casing/tubing size	24"
Minimum borehole/casing/tubing size	4.5"
Min./max. opening size (if applicable)	N/A
Mud type or weight limitations	For 6" Hole Rt/Rm < 10,000 For 8" Hole Rt/Rm < 2,000 For 12" Hole Rt/Rm < 1,000
Outside diameter (max. , closed)	3 5/8"
Length	8.27 m
Weight (in air)	200 kg
Fishing neck OD.	3 3/8" cablehead
Radioactive source type and size	N/A
Logging speed min./max.	60 ft/min (18 m/min)
Surface acquisition system requirements	ECLIPS only
Cable requirements (no. conductors, etc.)	7 conductor cable

TECHNICAL DATA SHEET ELECTRIC WIRELINE/LOGGING	DOWNHOLE EQUIPMENT AND INSTRUMENTS
Special capabilities: 6 apparent conductivity spacing's, 8 frequencies per channel, up to 12" vertical resolution. Standard mode, up to 90" standard array mode. Optional 120" deep array, VRM. Vertical resolutions of 1 ft, 2 ft, and 4 ft.	
Combination possibilities/limitations: WTS combinable, feed-through.	

Gamma Ray

Baker Hughes Wireline Services
Technical Tender Standard
Technical Tender Standards Guideline
PFS

6.12.32 Digital Gamma Ray (DGR)

TECHNICAL DATA SHEET ELECTRIC WIRELINE/LOGGING	DOWNHOLE EQUIPMENT AND INSTRUMENTS
Contractor:	Baker Hughes
Equipment/instrument name:	GR – Gamma Ray
Type/series no.	8220XA
Standard abbreviation - service/tool	**DGR**
Application - open/cased hole	CH
Parameters measured	Formation GR
Range of measurement	0 – 1500 API
Sensitivity	5 API
Accuracy	+/- 5 API
Calibration - none/shop/rig/downhole	rig
Maximum operating pressure	15,000 psi
Maximum operating temperature	177° C for 30 minutes
Maximum borehole/casing/tubing size	N/A
Minimum borehole/casing/tubing size	1.81"
Min./max. opening size (if applicable)	N/A
Mud type or weight limitations	N/A
Outside diameter (max. , closed)	1 11/16"
Length	4.64 m
Weight (in air)	41 kg
Fishing neck OD.	1 3/8" cablehead
Radioactive source type and size	N/A
Logging speed min./max.	Up to 9 m/min
Surface acquisition system requirements	ECLIPS or CASE
Cable requirements (no. conductors, etc.)	Single conductor
Special capabilities: NAI scintillation detectors	
Combination possibilities/limitations: SPL Telemetry sensors	

Measurement While Drilling

Baker Hughes

MEASUREMENT WHILE DRILLING

OnTrak

Integrated MWD and LWD service

The Baker Hughes **OnTrak™ integrated measurement-while-drilling (MWD) and logging-while-drilling (LWD) service** delivers a suite of directional and formation evaluation measurements. Along with pressure and drilling dynamics monitoring, the service provides operators with the most accurate propagation resistivity in the industry. The integrated design offers increased reliability, fewer connections, and optimized sensor-to-bit spacing to complement a suite of real-time downhole measurements. Power and mud-pulse telemetry are provided by the BCPM module. The OnTrak module serves as a platform for advanced rotary steerable and formation evaluation services.

Applications

- Onshore, offshore, and deepwater
- Complex directional targets
- Geosteering
- Leak Off and Formation Integrity Testing

Features and benefits

- Real-time directional information
  - Allows accurate wellbore placement
  - Meets regulatory survey requirements
- Azimuthal gamma ray with imaging capability
  - Identifies bed boundaries and orientation
- High-frequency phase resistivity
  - Increases vertical resolution
  - Identifies thin beds and fluid contacts
- Low-frequency attenuation resistivity
  - Increases depth of investigation
  - Estimate Rt with a greater immunity to environmental effects
- Fast two-way communication between the surface and downhole
  - Reduces drilling risk, using real-time downhole information
  - Minimizes nonproductive time through optimized drilling parameters

Tool Specifications

Tool size	4¾-in. (121 mm) 6¾-in. (172 mm) 8¼-in. (210 mm) 9½-in. (241.3 mm)	
Hole size*	5¾-in. to 26-in. (146 mm to 669 mm)	
Tool weight*	2200 lb to 7275 lb 998 kg to 3300 kg	
Tool length*	27.7 ft to 31.3 ft (8.4 m to 9.6 m)	
Maximum temperature	302°F (150°C)	
Maximum pressure*	25,000 psi to 30,000 psi (1725 bar to 2068 bar)	
Flow range*	125 gmp to 1,600 gpm (475 lpm to 6050 lpm)	
Azimuthal gamma ray range	0 to 500 API	
Inclination accuracy	±0.1°	
Resistivity range	2MHz Phase difference: 2MHz Attenuation: 400 kHz Phase difference: 400 kHz Attenuation:	0.1 to 3,000 ohm-m 01. to 500 ohm-m 0.1 to 1,000 ohm-m 0.1 to 200 ohm-m
Azimuth accuracy	±1.0°	
Toolface accuracy	±1.5°	

**Specifications and ranges applicable to multiple tool sizes. Final specifications are dependent upon bottomhole assembly (BHA) configuration. Please contact your Baker Hughes representative for more detailed technical information.*

Neutron Porosity

6.3.3 CN-Compensated Neutron

TECHNICAL DATA SHEET ELECTRIC WIRELINE/ LOGGING	DOWNHOLE EQUIPMENT AND INSTRUMENTS
Contractor:	Baker Hughes
Equipment/instrument name:	Compensated Neutron Log
Type/series no.	2446
Standard abbreviation - service/tool	**CN**
Application - open/cased hole	OH/CH
Parameters measured	Neutron porosity
Range of measurement	-3 to 100 Limestone porosity units
Sensitivity	N/A
Accuracy	+/- 0.5 p.u. below 7 p.u. +/- 7 % of reading above 7 p. u.
Calibration - none/shop/rig/downhole	shop
Maximum operating pressure	20,000 psi
Maximum operating temperature	204° C for 120 minutes
Maximum borehole/casing/tubing size	24" (limited by decentraliser)
Minimum borehole/casing/tubing size	4.75"
Min./max. opening size (if applicable)	N/A
Mud type or weight limitations	N/A
Outside diameter (max. , closed)	3 5/8"
Length	2.31 m
Weight (in air)	68 kg
Fishing neck OD.	3 3/8" cablehead
Radioactive source type and size	Am - Be, 18 curie
Logging speed min./max.	up to 9 m/min
Surface acquisition system requirements	ECLIPS
Cable requirements (no. conductors, etc.)	7 conductor cable
Special capabilities: N/A	
Combination possibilities/limitations: Full WTS combinability.	

Nuclear Magnetic Resonance

6.5.1 MREX-Magnetic Resonance eXplorer

TECHNICAL DATA SHEET ELECTRIC WIRELINE/ LOGGING	DOWNHOLE EQUIPMENT AND INSTRUMENTS
Contractor:	Baker Hughes
Equipment/instrument name:	Magnetic Resonance eXplorer
Type/series no.	3218EA / MA / PA / QA
Standard abbreviation - service/tool	**MREX**
Application - open/cased hole	OH
Parameters measured	Formation porosity, permeability, bound water and movable fluid, grain size distribution, hydrocarbon typing and quantification.
Range of measurement	N/A
Sensitivity	N/A
Accuracy	N/A
Calibration - none/shop/rig/downhole	shop
Maximum operating pressure	20,000 psi
Maximum operating temperature	175° C for < 4 hrs, 165° C continuous
Maximum borehole/casing/tubing size	17.5"
Minimum borehole/casing/tubing size	5.875"
Min./max. opening size (if applicable)	N/A
Mud type or weight limitations	Rm 0.015 ohm.m
Outside diameter (max. , closed)	5"
Length	7.4 m
Weight (in air)	291 kg
Fishing neck OD.	3 3/8" cablehead
Radioactive source type and size	N/A
Logging speed min./max.	Up to 6.7 m/min mode dependant
Surface acquisition system requirements	ECLIPS only
Cable requirements (no. conductors, etc.)	7 conductor cable
Special capabilities: Permeability estimate. Salt sleeve option for salty muds. Energy sub	

TECHNICAL DATA SHEET ELECTRIC WIRELINE/ LOGGING	DOWNHOLE EQUIPMENT AND INSTRUMENTS
available for certain modes. MREX-A.100: Bound Water, MREX-A.200: PoroPerm, MREX-A.400: PoroPerm+Gas, MREX-A.500: PoroPerm+HeavyOil, MREX-A.600: PoroPerm+Medium Oil, MREX-A.700: PoroPerm+Light Oil Optional – Special acquisition sequences are available for boreholes > 14" diameter.	
Combination possibilities/limitations: WTS slam, feed-through.	

Noise

Sondex™
a Baker Hughes business

Noise Tool (NTO)

Detects liquid or gas movement sounds in leaks, channels, or perforations

Application

- Evaluate flow profiles
- Locate channels behind a well case
- Locate gas-liquid interfaces
- Locate leaks in a well case
- Locate gas entries

Features

- Several NTO can be combined in one string
- Real time fast Fourier Transform (FFT) spectrum monitor
- Color variable-density log (VDL) style spectral log
- Road noise filter
- Configurable sampling modes (average, minimum, and maximum)
- Combinable with all Ultrawire tools
- No cable attenuation
- Configurable frequency cuts
- SRO or memory operation quantitative measurement

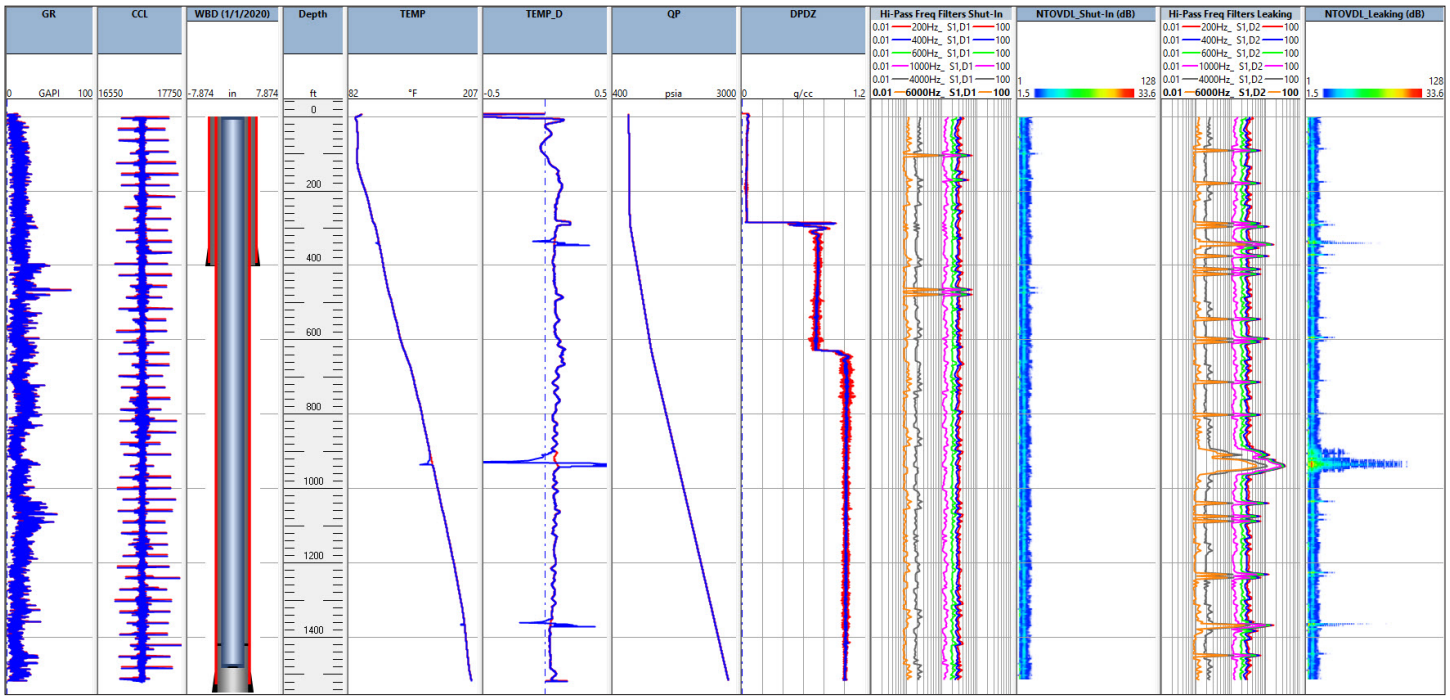
A leaking well can damage the environment and result in lost production. The **Noise Tool (NTO)** houses a sensitive hydrophone that is highly effective in the detection of flow inside and outside the cased well. The electronics digitize the noise downhole and sends a frequency spectrum to the surface to be recorded. Both the frequency spectrum and six high-pass frequency cuts are displayed on a log, providing a quantitative measurement of the downhole noise.

The NTO can be combined with other **Sondex Wireline tools** and logs data in both memory or surface readout tool strings. Consequently, any cased-hole logging intervention, such as production logging, cement evaluation, or pipe inspection, becomes an opportunity to verify the integrity of downhole components at minimal additional cost.

Multiple NTO can be combined within a single toolstring, thereby making it possible to pinpoint the depth of any particular noise source effectively and efficiently. The NTO is typically run in combination with a casing collar locator and temperature tool as well as any other **Sondex Ultrawire tool** such as Gamma ray, pressure, cement bond, calliper, metal thickness, or production log.

Specifications

	FlexSand LS
Temperazture rating	350°F (177°C)
Pressure rating	20,000 psi (138 MPa)
Tool diameter	$1^{11}/_{16}$ in. OD (43 mm)
Tool length	24 in. (609.6 mm)
Tool weight	10 lb (4.53 kg)
Frequency range	100 Hz to 12,700 Hz
Amplifier gain	22.4 to 67.8 dB (or x13 to x2455)
Resolution	16 bit
Dynamic range	72 dB
Data reading rate	0.5 sec
Sample length	10 ms
Sample rate	25.6 kHz
Number of spectral channels	128



Combined plot of NTO data with other measurements like pressure and temperature. Comparison of shut-in and leaking surveys allow identification of leak location

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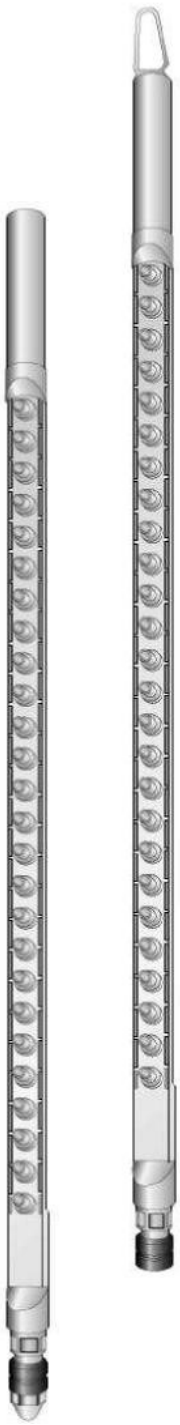
Percussion Sidewall Core

6.14.1 SWC- Side Walls Cores

Sidewall Corgun Tool



Conventional methods of coring are used during the well-drilling operation. Often, however, formation cores are desired after the total depth is drilled and the basic openhole logs are complete. The Sidewall Corgun™ (SWC™) tool provides a means for recovering a depth-specific sidewall formation sample suitable for hydrocarbon and lithology confirmation.

Operation

The operating principle of the SWC instrument is relatively simple. A core barrel, which is a hollow cylinder, is shot into the formation by a powder charge ignited by an electric current. The core barrel, containing a formation sample, is retrieved by means of a steel cable attached between the gun and the core barrel. Only one core barrel is fired at a time. A tandem gun can selectively core up to 50 samples on a single run using the 4-in. (101.6-mm) SWC tool and up to 44 samples on a single run using the 3-in. (76.2-mm) SWC tool. The SWC tool can collect a maximum of 74 cores by running three SWC tools in tandem.

Core barrels are available to sample formations ranging from soft to very hard. The core samples are generally large enough to allow a comprehensive core analysis. Cores range in size from 0.85 in. (21.6 mm) to 0.69 in. (17.5 mm).

The spontaneous potential (SP) or gamma ray curve, run simultaneously with the SWC tool, provides depth correlation with the primary suite of logs.

Highlights

- Paleontological dating (microfaunal/microfloral and spore content)
- Determine or confirm hydrocarbon shows

Benefits

- Cost-efficient acquisition of core samples suitable for hydrocarbon and lithology confirmation
- Up to 74 cores can be acquired in a single trip using standard guns

Specifications—Series 1812*

Description	Specification	
Length	10.12 ft	3.09 m
Diameter	4 in.	101.6 mm
Pressure rating	20,000 psi	137.9 MPa
Temperature rating	400°F	204°C
Weight	300 lb	136.1 kg

*Contact your Baker Hughes representative for additional series.

TECHNICAL DATA SHEET ELECTRIC WIRELINE/LOGGING	DOWNHOLE EQUIPMENT AND INSTRUMENTS
Contractor:	Baker Hughes
Equipment/instrument name:	Sidewall Corgun (Percussion)
Type/series no.	1812
Standard abbreviation - service/tool	SWC-A.100
Application - open/cased hole	OH
Parameters measured	Formation core recovery
Range of measurement	N/A
Sensitivity	N/A
Accuracy	N/A
Calibration - none/shop/rig/downhole	None
Maximum operating pressure	25,000 psi
Maximum operating temperature	204° C for 20 hours
Maximum borehole/casing/tubing size	N/A
Minimum borehole/casing/tubing size	5 7/8”
Min./max. opening size (if applicable)	N/A
Mud type or weight limitations	N/A
Outside diameter (max. , closed)	4”
Length	3.12 m
Weight (in air)	136 kg
Fishing neck OD.	3 3/8” cablehead
Radioactive source type and size	N/A
Logging speed min./max.	Stationary
Surface acquisition system requirements	CLS or ECLIPS
Cable requirements (no. conductors, etc.)	7 conductor cable
Special capabilities: Can be run in tandem configuration for 50 core attempts.	
Combination possibilities/limitations: PFC or SP for positioning.	

6.14.2 PCOR- PowerCOR

PowerCOR Service

Retrieve 60 samples in one run with advanced sidewall coring technology

The PowerCOR™ service is an advanced, computer-controlled, and electrically powered coring device for cutting and retrieving up to 60 sidewall core samples in a single run. These samples help oil and gas producers better evaluate their reservoirs and maximize hydrocarbon recovery.

Reliable, versatile service

The PowerCOR service acquires uniformly sized sidewall cores under a wide range of formation conditions. It can operate reliably in HP/HT conditions up to 25,000 psi and 400°F (204°C). In addition, it is a versatile service that can be deployed to a variety of borehole sizes (from 5⅞ to 17 in.), borehole orientations (from vertical to horizontal well), and formation types—from soft to hard rocks and from sand and shale to carbonate.

A graphical surface system continuously monitors and allows real-time control of the coring and sample storage operations. A scintillation detector is built into the instrument, providing a gamma ray (GR) log for correlation and precise depth control of coring points.

Fast, high-quality core delivery

The PowerCOR service implements new engineering improvements to provide more horsepower at the bit. A powerful direct-drive electric motor provides maximum power transfer efficiency. Advances in electric power management keep the bit moving consistently with variable power (torque) requirements encountered during the coring operation.

In addition, the bit design is optimized to make the most of the high rotational speed achieved with the electric motor power system. The bit is engineered to provide more efficient removal of the cutting debris during the coring operation. All these enhancements allow higher-quality rotary sidewall core samples to be acquired using much less rig time with greater core recovery efficiency.

Applications

- Geochemistry
- Geomechanics
- Biostratigraphy
- Reservoir geology/petrology
- Routine and advanced rock properties
- Wireline log calibration

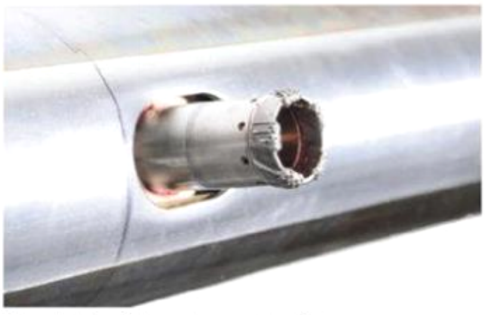
Features and benefits

- Up to 60 1-in.-outside diameter (OD) samples per run
  - Efficiently acquires industry-standard cores for reservoir rock analysis
- Direct-drive electric motor for maximum power transfer
  - Consistently retrieves quality core samples with less coring time
- Operating pressure of up to 25,000 psi and 400°F (204°C)
  - High core-recovery efficiency even under hostile environments
- Graphical user interface
  - Provides reliable service with high core-recovery efficiency
  - Monitors and controls the operation
- A wide range of borehole sizes, including small borehole sizes down to 5⅞ in.
  - Provides versatile service

Specifications

Description	Specification	
Core diameter	1 in.	2.54 cm
Core length	1.8 in.	4.57 cm
Minimum tool OD	4.75 in.	12.07 cm
Minimum borehole size	5.875 in.	14.92 cm
Maximum borehole size	17 in.	43.18 cm
Maximum temperature	400°F	204°C
Maximum pressure	25,000 psi	1723,689 bar
Maximum capacity	60 cores	
Positioning	High-resolution scintillation gamma-ray detector	

High-quality, uniformly sized core samples.



Slim tool design for boreholes as small as 5⅞ in.

TECHNICAL DATA SHEET ELECTRIC WIRELINE/LOGGING	DOWNHOLE EQUIPMENT AND INSTRUMENTS
Contractor:	Baker Hughes
Equipment/instrument name:	PCOR – Power Rotary Coring Tool
Type/series no.	1826
Standard abbreviation - service/tool	PCOR
Application - open/cased hole	OH
Parameters measured	1.0" Diameter Rotary Sidewall core sample
Range of measurement	N/A
Sensitivity	N/A
Accuracy	N/A
Calibration - none/shop/rig/downhole	None
Maximum operating pressure	25,000 psi
Maximum operating temperature	204° C for 6 hours
Maximum borehole/casing/tubing size	17"
Minimum borehole/casing/tubing size	5 7/8"
Min./max. opening size (if applicable)	5 7/8" - 17"
Mud type or weight limitations	N/A
Outside diameter (max. , closed)	4 3/4"
Length	11.6 m
Weight (in air)	686 kg
Fishing neck OD.	3 3/8" cablehead
Radioactive source type and size	N/A
Logging speed min./max.	Stationary
Surface acquisition system requirements	ECLIPS
Cable requirements (no. conductors, etc.)	7 conductor cable

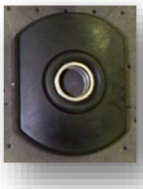
Pressure and Fluid Samples

6.10.3 Reservoir Characterization eXplorer (RCX)

TECHNICAL DATA SHEET ELECTRIC WIRELINE/ LOGGING	DOWNHOLE EQUIPMENT AND INSTRUMENTS
Contractor:	Baker Hughes
Equipment/instrument name:	Reservoir Characterization eXplorer
Type/series no.	1979 CA, EA, MA, BA, RA
Standard abbreviation - service/tool	**RCX**
Application - open/cased hole	OH
Parameters measured	Formation Pressures / Samples
Range of measurement	Quartz Pressure: 0 - 30,000 psi
Resolution	0.01 psi
Repeatability	≤0.01% FS
Calibration - none/shop/rig/downhole	shop
Maximum operating pressure	25,000 psi
Maximum operating temperature	375°F (190C)
Maximum borehole/casing/tubing size	24" (requires special kit)
Minimum borehole/casing/tubing size	6.0" (requires special kit)
Max. Pump Rate	~85 cc/s @ 100 psi drawdown (with VDP)
Maximum Drawdown Pressure (OB)	10,000 psi
Mud type or weight limitations	N/A
Outside diameter (closed)	4.75" (mandrel OD varies with kit)
Length	Varies
Weight (in air)	Varies
Fishing neck OD.	3 3/8" cablehead
Radioactive source type and size	N/A
Logging speed min./max.	Stationary Reading
Surface acquisition system requirements	ECLIPS only
Cable requirements (no. conductors, etc.)	7 conductor cable
Std Configuration: Std Packer, variable drawdown volume and drawdown rate, 30kpsi gauge, 56cc drawdown pump and 500 cc large pump, and fixed displacement pump. Optional capabilities: Downhole bubble point / phase separation determination / Other Packer	

TECHNICAL DATA SHEET ELECTRIC WIRELINE/ LOGGING	DOWNHOLE EQUIPMENT AND INSTRUMENTS
Options, additional drawdown and sampling pump sizes, CA variable displacement pump.	
Combination possibilities/limitations: Full WTS combinability with adapter sub.	

RCI / RCX Packer Options:

RCI / RCX Standard Packer Flow Area: 0.41 in2 Tool(s): RCI / RCX	**Applications:** -Testing and Conventional Sampling - Applicable in all formation types, preferred packer for boreholes with high rugosity.	
RCI / RCX Large Face Packer Flow Area: 0.41 in2 Tool(s): RCI / RCX Provides larger sealing area.	**Applications:** - Testing and Conventional Sampling - Unconsolidated Formations	
RCI / RCX Elongated Packer Flow Area: 1.94 in2 Tool(s): RCI / RCX Large inflow-area packer	**Applications:** -Testing and Conventional Sampling - Low-Mobility Formations - Highly Laminated Formations	
RCI / RCX **Extra -Elongated Packer** Flow Area: 8.00 in2 Tool(s): RCI / RCX Larger inflow-area packer	**Applications:** -Testing and Conventional Sampling - Low-Mobility Formations - Highly Laminated Formations - Fractured Formations (e.g. Carbonates)	
RCX XL Packer Flow Area: 33.00 in2 for Std and Large Kits 25.00 in2 for slim kit Tool(s): RCI / RCX Largest Packer in RCI / RCX platform. Can be run with or without sand support plate.	**Applications:** -Testing and Conventional Sampling - Ultra Low mobility Testing / Sampling - Laminated / Heterogeneous Formations - Fractured Formations - Heavy Oil Sampling	

Pulsed Neutron

Sondex™
a Baker Hughes business

Ultrawire RPM

Comprehensive formation evaluation and reservoir monitoring

Applications

- Formation evaluation
- Reservoir monitoring and management
- Borehole diagnostics
- Workover applications
- Production profiling
- Location of bypassed oil
- Quantification and identification of water production

Benefits

- Multiple modes depending on acquisition or answer product required
- Deployable on any type of electric line (e-line) or coiled tubing

The Sondex **Ultrawire™ reservoir performance monitor (Ultrawire RPM™)** tool is an advanced, slimhole, multifunction, pulsed neutron reservoir monitoring instrument. Its instrumentation combines multiple nuclear measurements in one system enabling Carbon/oxygen (C/O) and pulsed neutron capture (PNC) measurements to provide for water saturation while oxygen activation measurements allow detection of water flow and channels.

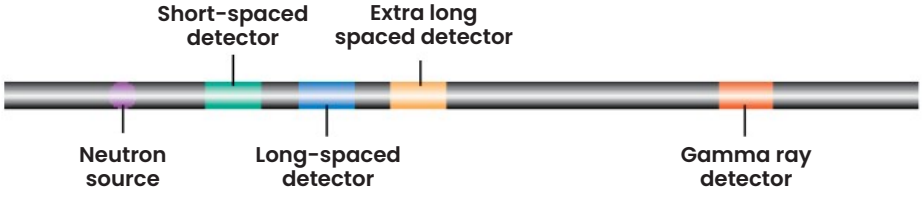
The Ultrawire RPM uses three high resolution gamma ray detectors above an efficient and reliable neutron generator. State of the art detector electronics are employed to measure the arrival time and energy of detected gamma rays. The generator is pulsed at distinct frequencies and the data acquisition system operates in various timing modes to obtain different logging measurements.

Flexibility and operating efficiency make the Ultrawire RPM tool a complete multi-mode, multi-sensory, solution-based system. All operating modes are selectable by surface commands.

The Ultrawire RPM tool was be run in combination with any Sondex Ultrawire production logging or well integrity tool to provide a complete picture of a well's production and reserves in a single trip and leverages Baker Hughes experience of operating, characterizing and interpreting pulsed neutron data.

The Ultrawire RPM tool addresses a broad scope of reservoir evaluation and management applications, including reservoir saturation and produced fluids monitoring, formation evaluation, production profiling, workover, and well abandonment evaluation, borehole diagnostics, location of bypassed oil, and identification of water production.

Contact your On-Demand Solutions representative to learn how the Sondex Ultrawire RPM tool can also be supported by Baker Hughes' Geoscience team to plan, execute and interpret complex operations. This includes pre-job Monte Carlo N-Particle (MCNP) modeling to provide accurate quantitative fluid saturation and can also include Baker Hughes' industry leading experience in delivering **GasView™** (gas saturation), **OilView™** (two-phase fluid saturation service), **FluidView™** (three-phase saturation) and **OmniView™** (salinity independent three-phase saturation) **services**.



Specifications

Temperature rating (standard)	350°F (177°C)
Pressure rating (standard)	20,000 psi (138 Mpa)
Tool OD	1.69 in. (42.9 mm)
Tool weight	75 lb (34 kg)
Minimum restriction	1.80 in. (45.7 mm)
Maximum hole size	12.25 in. (311.2 mm)
Tool compressive strength	570 lb (259 kg)
Tool tensile strength	22,000 lb (9,979 kg)
Maximum bend rate	30˚/100 ft (30˚/30.5 m)

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Resistivity Borehole Image

6.7.3 STAR-XR

TECHNICAL DATA SHEET ELECTRIC WIRELINE/LOGGING	DOWNHOLE EQUIPMENT AND INSTRUMENTS
Contractor:	Baker Hughes
Equipment/instrument name:	STAR-HD Resistivity Imager
Type/series no.	4236XB
Standard abbreviation - service/ tool	**STAR-XR**
Application - open/cased hole	OH
Parameters measured	Resistivity borehole images, borehole geometry, Rxo resistivity
Range of measurement	Buttons: 0.1 to >50,000 ohm-m Calipers: 5.5 to 21" Orientation: see ORIT-B.100
Sensitivity	N/A
Accuracy	N/A
Calibration - none/shop/rig/ downhole	shop/rig
Maximum operating pressure	20,000 psi
Maximum operating temperature	177° C for 30 minutes
Maximum borehole/casing/ tubing size	21"
Minimum borehole/casing/tubing size	6"
Min./max. opening size (if applicable)	N/A
Mud type or weight limitations	Conductive muds only (water-based and low ES oil-based muds). Salt saturated muds (0.01 ohmm+)
Outside diameter (max. , closed)	5.25"
Length	9.7 m
Weight (in air)	310 kg
Fishing neck OD.	3 3/8" cablehead
Radioactive source type and size	N/A
Logging speed min./max.	recommended 8 m/min
Surface acquisition system requirements	ECLIPS only

TECHNICAL DATA SHEET ELECTRIC WIRELINE/LOGGING	DOWNHOLE EQUIPMENT AND INSTRUMENTS
Cable requirements (no. conductors, etc.)	7 conductor cable
Special capabilities: 6-Arm resistivity imager **STAR-XR** available, providing 74% in 8.5" bit size. S	
Combination possibilities/limitations: Can be combined with acoustic imager for simultaneous data acquisition. acq	

Rotary Sidewall Core

6.10.11 Rotary Core Tool (MaxCOR)

TECHNICAL DATA SHEET ELECTRIC WIRELINE/LOGGING	DOWNHOLE EQUIPMENT AND INSTRUMENTS
Contractor:	Baker Hughes
Equipment/instrument name:	MaxCOR
Type/series no.	1828 MA 1826 PB/QA/EB
Standard abbreviation - service/tool	**MAXCOR**
Application - open/cased hole	OH
Parameters measured	Rotary Sidewall sample
Range of measurement	N/A
Sensitivity	N/A
Accuracy	N/A
Calibration - none/shop/rig/downhole	None
Maximum operating pressure	25,000 psi
Maximum operating temperature	400F
Maximum borehole/casing/tubing size	14″
Minimum borehole/casing/tubing size	7.5″
Min./max. opening size (if applicable)	7.5″ - 14″
Mud type or weight limitations	N/A
Outside diameter (max. , closed)	6.25″
Length	16.18m
Weight (in air)	1840 lbs
Radioactive source type and size	N/A
Logging speed min./max.	Stationary
Surface acquisition system requirements	CLS or ECLIPS
Cable requirements (no. conductors, etc.)	7 conductor cable
Special capabilities: Maximum 60 cores using a 30 core extension. Core dimensions: OD = 1.5″, Length=2.5″.	
Combination possibilities/limitations: Positioning – High Resolution Gamma Ray.	

Sonic

6.4.2 Cross Multipole Array Acoustic (XMAC)

TECHNICAL DATA SHEET ELECTRIC WIRELINE/LOGGING	DOWNHOLE EQUIPMENT AND INSTRUMENTS
Contractor:	Baker Hughes
Equipment/instrument name:	Cross Multipole Array Acoustic
Type/series no.	1678
Standard abbreviation - service/ tool	**XMAC F1**
Application - open/cased hole	OH/CH
Parameters measured	Formation acoustic properties
Range of measurement	Compression: 40 usec/ft - 300 usec/ft Shear: 60 usec/ft - 1,900 usec/ft Stoneley: borehole fluid dependent
Sensitivity	N/A
Accuracy	+/- 3% on compressional slowness, +/- 5% on shear and Stoneley slowness
Calibration - none/shop/rig/ downhole	None
Maximum operating pressure	20,000 psi
Maximum operating temperature	177° C
Maximum borehole/casing/ tubing size	21"
Minimum borehole/casing/ tubing size	4.5"
Min./max. opening size (if applicable)	N/A
Mud type or weight limitations	N/A
Outside diameter (max. , closed)	3 7/8"
Length	11.0 m
Weight (in air)	313.2 kg
Fishing neck OD.	3 3/8" cablehead
Radioactive source type and size	N/A
Logging speed min./max.	9m/min cross dipole mode, 30 m/min for T_c

Temperature

6.8.3 Tension, Temperature, and Mud Resistivity sub (TTRM)

TECHNICAL DATA SHEET ELECTRIC WIRELINE/LOGGING	DOWNHOLE EQUIPMENT AND INSTRUMENTS
Contractor:	Baker Hughes (Baker Atlas)
Equipment/instrument name:	Tension, Temperature, and Mud Resistivity sub
Type/series no.	3981 XA
Standard abbreviation - service/tool	**TTRM**
Application - open/cased hole	OH/CH
Parameters measured	Tool tension/compression/temp./mud resistivity
Range of measurement	Tension : 0 - 12,000 lb Compression : 0 - 10,000 lb Temp : 0 - 230° C Mud Resistivity : 0.01 - 10 ohm-m
Sensitivity	+/- 100 lbs Tension/Compression +/- 2° C +/- 0.01 ohm-m
Accuracy	+/- 800 lbs Tension/Compression +/-2° C +/- 5 % 0.01 ohm-m +/- 5 %
Calibration - none/shop/rig/downhole	Rig
Maximum operating pressure	20,000 psi
Maximum operating temperature	200° C for 30 minutes
Maximum borehole/casing/tubing size	N/A
Minimum borehole/casing/tubing size	4 1/2"
Min./max. opening size (if applicable)	N/A
Mud type or weight limitations	N/A
Outside diameter (max. , closed)	3 5/8"
Length	1.11 m
Weight (in air)	36 kg
Fishing neck OD.	3 3/8" cablehead
Radioactive source type and size	N/A
Logging speed min./max.	up to 30 m/min
Surface acquisition system requirements	ECLIPS
Cable requirements (no. conductors, etc.)	7 conductor cable
Special capabilities: N/A	

TECHNICAL DATA SHEET ELECTRIC WIRELINE/LOGGING	DOWNHOLE EQUIPMENT AND INSTRUMENTS
Combination possibilities/limitations: Fully WTS combinable.	