02186946

01. 31. 2011

Operating Plan
Amended

Operating Plan for the Fort Morgan Gas Storage Field
Morgan County, Colorado

Statement of Storage Field Operating Plan Purpose

El Paso Pipeline Group's natural gas storage fields provide peak day gas volumes to its customers as needed. The gas in the storage fields belongs to El Paso Pipeline Group and its customers and is injected, stored and withdrawn as required. Gas storage performance must be safe and reliable. El Paso Pipeline Group has developed this Operating Plan to protect the public, environment and company personnel. The Plan also provides a means to verify that the gas stored in the facility remains contained in the reservoir and protected from migration due to undesired reservoir migration or breaches in the wells.

Regulatory Jurisdiction for Fort Morgan Gas Storage Field

El Paso Pipeline Group's natural gas storage fields are subject to the jurisdiction of the Federal Energy Regulatory Commission ("FERC") which has issued Certificates of Public Convenience and Necessity that state that the facilities have been found to be needed for public necessity and convenience. Additionally, the safety aspects of the surface facilities (lines, compression, processing, dehydration units, etc) are under the exclusive jurisdiction of the Department of Transportation (49 CFR Part 192). El Paso Pipeline Group constructs, drills and operates its storage wells in the FERC designated storage field in consultation with the Colorado Oil & Gas Conservation Commission (COGCC).

Operating Plan Accountability

El Paso Pipeline Group's Reservoir Services department is responsible for operating, monitoring and maintaining the company's storage wells and field integrity (subsurface). These responsibilities include, but are not limited to, the following.

- Construction, drilling and operation of the storage wells.
- Routine monitoring of annulus pressures to identify potential wellhead and well bore leaks.
- Conducting casing inspection and/or monitor logging programs to characterize casing condition and abnormal gas accumulations behind pipe.
- Performing Mechanical Integrity Tests ("MIT") and documenting the results.
- Developing and implementing programs and procedures to repair leaks and maintaining or restoring well bore integrity.
- Performing annual wellhead valve maintenance to confirm proper valve operation and implementing repairs as necessary.
- Storage Inventory Verification:
    - Annually review and verify stored gas volumes.
    - On-going routine monitoring of field pressure/inventory relationship.
    - Coordinate investigations into storage related Loss And Unaccounted For ("LAUF") usage and storage measurement errors.

  - Coordinate and schedule semi-annual field shut-in tests with Gas Control and Field Operations departments. When possible, the testing periods are scheduled at times intended to reflect the actual reservoir pressure decline relationship and to minimize the impact on customer needs and the pipeline system requirements.
  - Prepare reports summarizing results of storage inventory investigations and recommend actions to maintain reservoir integrity. Conduct a review of the results with an outside engineering consultant.
- Identify and acquire necessary storage and mineral rights to maintain adequate buffer acreage and operational integrity.
- Maintenance of Gas Storage Data Base ("GSDB") as a central repository of data collected from the field.

Operating Plan Process

This Operating Plan is divided into two parts: Field Integrity and Well Integrity. While the parts may be separated, they are not mutually exclusive. The following is a list of tasks performed to monitor field and well integrity.

- Field Integrity/Inventory Verification
  - Bottom Hole Pressure ("BHP") Surveys
  - Observation Well Monitoring
  - Monitor Third Party Wells
  - LAUF
  - Measurement Correlation
  - Annual Inventory Verification Study
  - Audit of Inventory report by Consultant

- Well Integrity
  - Downhole Logging
  - MIT
  - Annular Pressure Monitoring
  - Gas Sampling
  - Safety Valve Maintenance/Testing
  - Wellhead Maintenance
  - Remedial Action and Well Construction
  - Well Pressure and Flow Monitoring

<u>Field Integrity/Inventory Verification</u>

Inventory BHP Surveys/Semi-Annual Shut-in Test or Other Pressure Decline Analysis Methods

Annual storage field inventory studies verify the volume of gas in the storage field compared to the company booked volumes. Gas volumes that need reconciliation consist of native base gas, injected base gas, injected and withdrawn working gas (less fuel) and other losses, both measured and estimated. These studies consist of conducting a production pressure-decline analysis for each storage field reservoir as described below. A detailed description of the methodology, terms and definitions related to inventory studies is included in Appendix 1.

The production pressure-decline analysis involves the following steps.

- Monitoring of BHP/z, where "z" is the gas compressibility factor, versus inventory on a routine basis.
- Individual wellhead pressures are recorded during the field semi-annual shut-in tests which take place every spring (low inventory) and fall (high inventory) but prior to interference from hysteresis effects or changing reservoir pore volumes.
- Well pressures are reviewed for evidence of leaks and/or the presence of fluid in the wellbore. Pressure data is contoured to help identify if any low pressures are observed.
- Surface pressures are converted to BHP by adding the weight of the gas column determined by direct BHP measurements and/or by calculation.
- The factor z is computed using the properties of the stored gas from analyses of field and/or well samples.
- BHP/z pressure values are calculated for each well and an average BHP/z is determined or a single BHP/z is calculated from a field average wellhead pressure.
- The average field pressures are evaluated through the semi-annual shut-in test to establish a field stabilization trend or by using the actual production pressure decline if timing of the shut-test precludes elimination of reservoir effect phenomena.
- The average BHP/z is then plotted versus the company book volumes.

OBS Well Monitoring

Observation "OBS" wells are utilized to monitor gas movement within a storage zone and to monitor the potential for gas migration away from the storage zone or movement to other porous zones above or below the storage zone. Some OBS wells were originally oil/gas production wells that were obtained with the acquisition of the field and others were drilled as part of the development of the field.

Gas samples are obtained and analyzed from OBS wells to determine if changes in gas composition occur over time. The samples may be taken from edge OBS wells completed in the storage zone and/or OBS wells completed in porous zones above or below the storage zone. This information is recorded in the GSDB. Changes in gas composition may indicate movement of storage gas toward storage boundaries. This information is valuable for identification of potential storage gas migration.

Some injection/withdrawal ("I/W") wells that are connected to the gathering systems of the respective storage fields are not utilized to flow gas into or out of the reservoirs but are utilized for reservoir monitoring purposes similar to OBS wells.

The following is a summary of questions El Paso Pipeline Group attempts to answer in its evaluation of the pressure response and gas sample data from an OBS well or an I/W well.

- What is the fluid observed in the well – oil, gas, brine, etc? If gas, does the gas sample reflect native or storage gas?
- Which formation is the OBS well monitoring – the storage zone, fringe area of the storage zone or potential porous zones above or below the storage zone into which gas could migrate?
- Are pressure changes observed at the surface or bottom hole?
- Status of nearby wells – what does the data from offsetting wells provide?
- Well integrity history
    - Does annular pressure monitoring data indicate the integrity of tubing or casing?
    - Are apparent defects present on casing inspection logs? If so, what is the rate of change of apparent defects?
- Well location – is the well near houses, buildings, roads or waterways?
- Does the pressure of this well track closely with the reservoir pressure?
- Is this well being used for gas injection and/or gas withdrawal?
- Is the drainage area from this well a low percentage?
- Is the gas analysis from this well similar to the gas analysis from the remainder of the reservoir?

Monitor Third-Party Existing and New Wells

An important part of maintaining storage field integrity is verifying that any third-party wells within the protection acreage and/or penetrating the storage reservoir are adequately designed to prevent the leakage of gas from the reservoir. El Paso Pipeline Group also attempts to periodically monitor these wells to detect leaks that may develop later in the life of a well.

El Paso Pipeline Group seeks to obtain written access agreements with the operators of existing and new third-party wells to minimize operational misunderstandings and future problems. El Paso Pipeline Group also seeks assurances that all planned third-party wells that will penetrate its storage reservoirs comply with state regulations; El Paso Pipeline Group does not waive any state regulation nor accept attempts to lessen any requirement. If allowed by the operator, El Paso Pipeline Group monitors the drilling, cementing and logging of any third-party well.

The following criteria are used to evaluate existing and new third-party wells that are within the protection acreage and/or penetrate the storage reservoir.

- Existing Wells
  - o Thoroughly review the state regulations for third-party wells penetrating gas storage reservoirs and specific state regulations pertaining to individual reservoirs and verify that these rules are strictly followed.
  - o Identify well location, serial and state permit or API number, production interval, total depth and operator.
  - o Obtain available well data, schematics and logs and conduct a thorough review of state files.
  - o Obtain gas, oil and water production data from the state and/or well data from service companies.
  - o Monitor production data annually and look for anomalies.
  - o Sample the storage reservoir gas and, if necessary, obtain a gas analysis from the existing well to be used for comparison purposes.
  - o Open dialogue with outside operator and obtain written permission to perform the following, if practicable:
    - Routinely monitor all annular and tubing pressures.
    - Sample the gas streams including the tubing and the tubing-casing annuli (“TCA”) and perform a gas analysis at least once but more often if anomalies are identified. Resample if the producing horizon changes.

- New Wells
  - o Review the design and completion of the well. Verify that the storage zone will be properly isolated by cement and that the casing design is adequate for storage field pressures.
  - o To the extent practicable, monitor the drilling, cementing, logging and perforating operations of third-party wells.
  - o Review all available logs, and identify any anomalies.
  - o If El Paso Pipeline Group suspects that the integrity of its storage reservoir has been breached by a new well, El Paso Pipeline Group will contact the operator and attempt to negotiate a plan for remedial action.

Measurement Correlation and LAUF Studies

Metering errors and fuel/station gas usage for underground gas storage operations represent gas “losses” from inventory and are accounted for monthly. The following potential gas losses are considered to verify gas inventory.

- Engine starting gas utilized (number of starts times the volume of a typical start).
- Venting volume of compressor piping each time a unit is shut down and the number of times it is shut down each month.

- Emergency Shut Down ("ESD") blow down volumes.
- Other equipment depressurizing (volume of each event).
- Station fuel.
- Well blow downs (number of wells, starting pressure and volume of each).
- Gathering system header blow downs.
- Relief valve discharge occurrences and estimate of volume.
- Flash gas from atmospheric tanks.
- Flare gas, where applicable.
- Diffuse gas losses from leaking valves, flanges and screwed pipe.

Well Integrity

Gas storage wells may be in service for 75 or more years. Therefore, it is prudent to design the wells to remain intact for that time period and to monitor and maintain the integrity to prevent well leakage. Methods utilized to assess and prevent future casing failures and gas releases include storage well logging, cathodic protection monitoring, MIT and annular pressure monitoring.

Storage Well Logging

Wells are logged to identify potential problems and may include the following types of logs (type of log/survey identified in parenthesis).

- Reductions to casing wall thickness (MFL Casing Inspection Tools)
- Identification of gas presence behind the casing (Gamma Ray-Neutron – "GRN")
- Presence of a corrosion cell (Casing Protection Profile – "CPP");
- Temperature logs
- Noise Logs
- Downhole video cameras and/or downhole video side view cameras;
- E-Log-I surveys

In addition, for future new storage wells, the following list of logs shall be considered to be run during drilling and completion. The principle (how the log works) and the identification (purpose of the log) are presented in Appendix 2 along with the list of logs.

- Open Hole Logs
  - Caliper
  - Density w/Pe (Litho-Density)
  - Compensated Neutron ("CNL")
  - Spontaneous Potential ("SP")
  - Gamma Ray ("GR")
  - Resistivity Logs (Dual-Induction or Array Induction)
  - Microlog ("ML")

- Cased Hole Logs

- MFL Casing Inspection Tools (i.e., Vertilog, MicroVertilog, High-Resolution Vertilog)
- Cement Bond Log/Cement Mapping Tool with Gamma Ray and Casing Collar Locator or Segmented Bond Tool with Gamma Ray and Casing Collar Locator
- Base line TDT/PDK with Gamma Ray and Casing Collar Locator or Gamma Ray Neutron with Casing Collar Locator

MFL Casing Inspection Tools and CPP
MFL Casing Inspection Tools and CPP are beneficial to get a baseline on the condition of the casing and the following criteria summary should be utilized (see Appendix 3 for further details).

- Run baseline logs (MFLs and/or GRN) on every well (see Appendix 4).
- Follow-up MFLs are required on casing completed wells to assess the rate of change in pipe corrosion at time intervals to be determined by the condition of the pipe (see Appendix 5 for current logging schedule).
- Follow-up MFLs on tubing and packer completed wells are required when tubing is pulled for other remedial work and with consideration of the time interval between the remedial work and the last MFL run.
- Follow-up GRN logs will be run on tubing and packer completed wells that do not have baseline MFLs to identify changes in gas accumulation behind pipe.
- Coordination and communication with the Operations department to verify that wells are protected by a cathodic protection system.
- Periodically, E-Log-I surveys to be conducted by Corrosion department in an attempt to ensure that sufficient bond current is being applied to each well's production casing string.

Casing Pressure Tests and Annulus Monitoring

MIT
Wellbore MIT are hydrostatic tests that demonstrate that the well casing is capable of holding a pressure at the time the test was conducted. Performing MIT on wells completed with tubing and packer is relatively simple due to the nature of the completion. A pump truck is connected to the casing valve and fluid is slowly pumped until the annular pressure reaches the desired pressure, normally 300 to 500 psig. The casing valve is closed and the pressure is monitored for 15 to 30 minutes. Such tests are to be performed on wells that are completed with tubing and packers at the rate of not less than one test every five years. If, during the five years the tubing and packer is removed and replaced, a MIT will be conducted prior to returning the well to service.

Annulus Monitoring
Monitoring of well surface casing annuli ("SCA") and TCA should be completed monthly and more frequent if determined necessary. To minimize corrosion in

the surface casing and casing for wells where the surface casing is not cemented to surface, the SCA should be liquid filled and shut-in to prevent atmospheric corrosion in the annular space. Any anomalous SCA or TCA pressures must be reported immediately to the manager, supervisor and engineer. A plan of action should be developed to assess the anomalous pressure and could include shutting in the well, collecting gas sample(s) and conducting a blow down test. Based on results, remedial action will be determined and the well will remain shut-in until repairs are completed or the well will be placed back in service. All documentation will be kept in the well file.

TCA Monitoring

Monitoring of TCA should be completed monthly, and if a well exceeds it historically observed pressures by 100 psi, it will be reported on the monthly field reports and scheduled for a blow down test. If it is a new event within the documented history of the well, a blow down test will be conducted immediately. The only exception will be in the case of elevated pressures following a MIT that utilized water as opposed to natural gas. It is common with MIT that utilizes water to observe elevated pressure anomalies immediately following the MIT due to expansion caused by high bottom hole temperatures. If it is not a new event within the documented history of the well, a blow down test will be conducted during the next collection of monthly manual well pressure readings.

Initial pressure, final pressure and blow down time should be recorded on all blow down testing and submitted to engineer. Based on blow down test results, any required remedial action including gas analysis and workovers will be determined and a decision to keep the well in service will be made by the manager, supervisor and engineer. If a well decreases in pressure by 100 psi or goes on vacuum, it will be reported on the monthly field reports and evaluated for the cause, i.e., packer fluid leaking from the annulus versus cooling effects.

SCA Monitoring / Bradenhead Test Procedure

Monitoring of SCA should be completed monthly, and if a well exceeds its Maximum Allowable Surface Casing Pressure (MASCP) it will be reported on the monthly field reports and the following procedure followed. MASCP is equal to the surface casing depth (ft) x 0.25 psi. A list of wells shall be posted with their calculated MASCP based on this formula.

Monthly Surface Casing Pressure Monitoring/Bradenhead Test Procedure

- Record surface casing pressures once per month while collecting tubing and casing pressures.
- If a the surface casing pressure exceeds the MASCP then;
    - o Any anomalous pressures must be reported immediately to manager, supervisor and engineer.
    - o Develop a plan of action that could include the following:
        - Shut-in the well.

    - Collect gas sample(s).
    - Conduct a surface casing blow down test.
    - Based on the plan of action results, remedial action will be determined. The well will remain shut-in until repairs are completed or placed back in-service.
  - All documentation should be kept in the well file.

Also refer to Appendix 6 for additional requirements.

Valve Maintenance

Storage wellhead valves need to be maintained in order to shut off gas flow or close a well in the event of an emergency. All wellhead valves should be inspected and the inspection may include three components.

- Visual inspection of the external condition of the valve (corrosion, cracks, etc)
- Observance of packing leaks
- Determine if the valve isolates the well (proper operation, grease valve, etc)

The level of inspection varies depending on whether the visit to a well site is for routine data gathering or during the semi-annual shut-in test when valve isolation is typically evaluated. If an inspection includes all three components, it is considered a full inspection.

All wellhead valves (including downhole[1]) in the direct line of gas flow have a full inspection conducted annually, but the period between inspections should not to exceed 15 months. All other valves that are not in the direct line of gas flow should have a full inspection once every two years, but the period between inspections should not exceed 24 months (these valves are typically installed on surface casing annulus and tubing/packer completed well annulus).

[1] Downhole valves can only be tested for proper operation and isolation of the well.

Appendix 1
Inventory Studies

The following definitions are consistent with Corporate Policy ACC 119.1 which relates to the accounting and treatment of storage gas.

Inventory: All gas molecules in the storage reservoir expressed in a volume at standard temperature and pressure.

Adjustment(s): A volume of gas that impacts storage Inventory deriving from meter errors, fuel usage, diffuse gas losses and/or other operational factors.

Non-Recoverable Gas: A volume of gas which supports the storage cycle under stabilized pressure conditions but cannot be recovered economically upon field abandonment. The initial determination of Non-Recoverable Gas will be made at or after the abandonment of the storage reservoir begins excluding volumes previously deemed Non-Recoverable Gas and written down. Any identified gas volume which is deemed Non-Recoverable Gas shall be written down at the time a determination of such volume is made (pursuant to Section V in Corporate Policy ACC 119.1).

Migrated Gas: A volume of gas believed to have been present in a storage reservoir which subsequently has left the storage reservoir and no longer supports its cyclic storage operation. Any Identified gas volume which is deemed Migrated Gas shall be written down.

Identified: The nature or the origin of the Adjustment, Non-Recoverable or Migrated Gas volume(s) is known to a Reasonable Engineering Certainty. No further research is required.

Inconsequential: To a reasonable person, there is lack of worth or importance, and it is trivial in relation to the lowest level of external financial reporting. Or, lacking in worth or importance as deemed by a reasonable person.

Consequential: To a reasonable person, it has magnitude or importance. Or, having magnitude or importance as deemed by a reasonable person.

Unresolved/Loss Contingency: Items that require further research and/or additional data to determine proper classification as to a possible gain or loss and whose ultimate resolution depends upon whether one or more future events occur or fail to occur. The occurrence of such events can range from Probable to Remote as follows:

1. *Probable*. The future event or events are likely to occur.

2. *Reasonably Possible*. The chance of the future event or events occurring is more than Remote but less than Probable.
3. *Remote.* The chance of the future event or events occurring is slight.

Annual Inventory Report: An annual analysis of the gas storage Inventory including, where applicable, Adjustments, Migrated Gas and Non-Recoverable Gas in each storage reservoir owned and/or operated, or in which an interest is owned by El Paso Corporation, based on operating data and engineering studies.

Reasonable Engineering Certainty: A conclusion arrived at by a qualified engineer using all the pertinent available information and employing industry accepted engineering techniques and scientific concepts.

Additional Definitions

In addition to the terms identified above, a number of practical terms are used in this report to describe operational issues related to management of storage inventory. These terms identify portions of the booked gas volume which do not exhibit a pressure response in the storage reservoir during the semi-annual shut-in tests. The terms and their definitions are as follows.

Non-Effective Gas: The volume of gas that does not exhibit a pressure response in the storage reservoir when a pressure decline analysis (PDA) is performed based on the fall and spring shut-in pressure data which, in general, are not indicative of fully stabilized storage reservoir conditions.

Impounded Gas: That portion of the Non-Effective Gas which supports the storage cycle under stabilized pressure conditions but is not readily producible during the operating withdrawal cycle.

Non-Effective Gas Calculation: The volume of Non-Effective Gas for an operating cycle is determined graphically by performing a PDA. The analysis involves measuring the volume of gas withdrawal from a storage reservoir and well shut-in pressures before and after withdrawal takes place. After plotting the starting and ending total Inventory with the corresponding bottom hole pressures corrected to account for the departure from the ideal gas law, a straight line is drawn through the points and extrapolated to zero psi. This line is used to determine the Non-Effective Gas volume for the operating cycle.

The PDA involves the following steps:

1. Individual wellhead pressures are recorded during the semi-annual shut-in tests which take place every spring and fall and/or representative indicator well pressures are periodically recorded during storage operations. If inconsistencies are observed for individual pressures, estimates are made.

2. The wellhead pressures are converted to absolute by adding the barometric pressure.
3. These pressures are converted to BHP by adding the weight of the gas column using the well bore gas gradient and/or by calculation.
4. The compressibility factor z is computed using the properties of the stored gas.
5. The BHP/z pressure values are calculated for each well or a single BHP/z is calculated from field average wellhead pressures and/or representative indicator wells.
6. The BHP/z values are weighted to obtain a weighted average field BHP/z.
7. The weighted average field pressures are evaluated through the semi-annual shut-in test.
8. The final spring and fall BHP/z pressure values are plotted versus the total field inventory for those days. A straight line is drawn through the points and extrapolated to zero psi.
9. The Non-Effective Gas volume is determined at zero psi rather than the BHP at abandonment.
10. Pressure decline lines are plotted for the six most recent consecutive years of operation and are evaluated in terms of continuing or revising the operating mode to improve field performance.

<u>Gas-Per-Pound (Apparent/Effective Pore Volume)</u>: Reservoir gas-per-pound (GPP_r) or Apparent Pore volume (PV) is the slope of the line connecting an individual BHP/z versus total field content and zero psi versus zero total field content. This is done for both the spring and fall shut-in test points and/or two other points determined by the intersection of the production decline trend (BHP/z) and two constant BHP/z's (generally one at maximum working inventory and one at low inventory). Cyclic Gas-Per-Pound (GPPc) or Effective Pore Volume (PVe) is the slope of the line that connects the current shut-in point and the previous shut-in point.

<u>Gas-Per-Pound Calculations</u>: GPP_r is calculated using the following steps. Note that steps 1 – 8 in the Non-Effective Gas calculation have previously been performed.

1. For each semi-annual shut-in point, calculate total content divided by BHP/z and/or use points determined by production decline trend and the intersection of two constant BHP/z points.
2. Graphically connect all calculated points.

GPP_c is calculated using the following steps. Note that steps 1 – 8 in the Non-Effective Gas calculation have previously been performed.

1. After each semi-annual shut-in test, calculate previous total field content less the current total field content divided by the previous BHP/Z less the

current BHP/z and/or use the production decline trend and the corresponding inventories consistent with the two constant BHP/z points.

2. All calculations that are performed using a spring shut-in as the current shut-in generate one set of data (the slope of all fall – spring cycle lines). Calculations performed using the fall shut-in as the current shut-in generate a second set of data (the slope of all spring-fall cycle lines) and/or in the case of the production decline trend use the two other points determined by the intersection of the production decline trend (BHP/z) and the two constant BHP/z points (one high and one low).
3. Graphically connect calculated points of the same cycle, for example, all of the calculated slopes for the fall – spring cycle are connected and/or the two but constant BHP/z points.

Operations from cycle to cycle can impact the storage reservoir pressure response data that is gathered during the semi-annual shut-in test. Thus, it is the trend over several cycles that could indicate what may be occurring in the storage reservoir.

<u>Pore Volume Ratio</u>: The ratio of current pore volume compared to the original pore volume.

<u>Pore Volume Ratio Calculation</u>: Pore Volume Ratio (PVR) is calculated using the following steps. Note that steps 1 – 8 in the Non-Effective Gas calculation have previously been performed.

1. Calculate the original BHP/z times the current total content divided by the original total content times the current BHP/z for each semiannual shut-in and/or the two points generated by the production decline trend and the constant BHP/z points.
2. Graphically connect all calculated points.

<u>Inventory Variance</u>: The difference between book (or metered) total inventory and total content calculated using a pressure-volume material balance relationship.

<u>Inventory Variance Calculation</u>: Inventory Variance is calculated using the following steps. Note that steps 1 – 8 in the Non-Effective Gas calculation have previously been performed.

1. Calculate the total content using the original discovery line and the current BHP/z.
2. Subtract the calculated total content from the current metered total content.

Graphically connect all calculated points. However, there may be merit in connecting spring points as one data set and fall points as a second data set.

Appendix 2
Well Logging Criteria for New Wells

The following list of logs shall be run on newly drilled storage wells (vertical).

- Open-hole logs
  - Array Induction or Dual Induction
  - Density w/Pe (Litho-Density)
  - Compensated Neutron (“CNL”)
  - Spontaneous Potential (“SP”)
  - Gamma Ray (“GR”)
  - Microlog (“ML”) or equivalent

Type of Log	Principal	Identification
Array Induction	A high frequency current of constant intensity is sent through a transmitter coil. The magnetic field induces currents in the formation surrounding the borehole. The currents are proportional to the conductivity of the formation.	Deep formation investigation to minimize borehole influences and measure resistivities. Fluid Contacts. Water Saturation.
Density .	Medium energy gamma rays are emitted to the formation and scattered, if the formation is very dense the more scattering takes place and more gamma rays are absorbed, less dense formation the less scattering and less absorption.	Primarily used to measure bulk density. Can be related to porosity when lithology is known, gas detection, hydrocarbon density, and evaluation of shaly sands.
Compensated Neutron Logs (“CNL”)	Neutron logs measure the formation’s ability to slow the movement of neutrons through the formation. This measurement reflects the amount of hydrogen in the formation indicating	The compensated neutron log is recorded as apparent limestone, sandstone or dolomite porosity. It has the advantage of reduced borehole influences and is used to evaluate

	the porosity of the formation. This log requires a fluid filled hole.	formation porosity and identify gas zones and gas/liquid contacts.
Gamma-ray ("GR")	Gamma-ray logs measure the natural gamma radiation	Used to identify lithology (distinguish shales from sandstones and carbonates). Also used for geologic correlations and for calculating the volume of shale in sandstone.
Spontaneous Potential ("SP")	The SP curve records the electrical potential produced by the interaction of formation water, conductive drilling fluid, shales.	The SP is used to identify permeable beds, locate boundaries of permeable beds, aid in determining water resistivity and as an indicator of formation shaliness.
Resistivity Logs	Electric current is passed through the formation, and voltages are measured between electrodes. The measured voltages provide the resistivity.	Various formation resistivities are calculated: flush zone, uninvaded zones, fluid contacts and water saturation.
Microlog ("ML")	Electric current is passed through the formation, and voltages are measured between two short-spaced electrodes with different depths of investigation. The measured voltages provide the resistivity	Comparison of the curves identifies mudcake which indicates invaded zones, thus permeable formations

- Cased Hole Logs
    - MFL Casing Inspection Tools (i.e.Vertilog, MicroVertilog, High-Resolution Vertilog)
    - Cement Evaluation Tool with Gamma Ray and Casing Collar Locator
    - Base line Gamma Ray-Neutron with Casing Collar Locator to be used in the analysis of gas migration.

Type of Log	**Principal**	**Identification**
MFL Casing Inspection Tools	The tool uses magnetic flux leakage measurements to identify corrosion and defects in casing	Evaluation of casing apparent metal loss or gain and internal or external corrosion defects
CBL-VDL (casing bond and variable density log)	The principle of the measurement is to record the transit time and attenuation of an acoustic signal after moving though the borehole fluid and the casing wall. This log requires a fluid filled hole.	The CBL is used to evaluate hydraulic seal, cement to casing bond and coverage. The VDL is used to assess the cement to formation bond and to detect the presence of channels and gas intrusion.
CMT or CET (cement mapping or cement evaluation tool) or SBT	The tool uses the casing resonance in its thickness mode to give a very fine resolution.	The tool is used to identify cement presence and quality.
CCL (casing collar log)	The CCL is a magnetic device which is sensitive to the increased metal at a casing collar.	It is run with cased hole logs and is primarily used for depth control.
GRN (gamma ray-neutron)	Gamma ray logs record the natural radioactivity of the formation, less dense formations will appear to be slightly more radioactive.	The GR is used for correlation and gives lithology control. Neutron identifies gas behind pipe, porosity and fluid contacts.

Operating Plan for the Fort Morgan Gas Storage Field
Morgan County, Colorado

APPENDIX 3
Casing Inspection Decision Tree Spreadsheet

APPENDIX 4
Summary of Baseline Casing Inspections

APPENDIX 5
Well Work Plan Spreadsheet

APPENDIX 6
Gas Storage Field Specific Considerations or Left Blank Intentionally