

PG&E Natural Gas Storage Facilities

Asset and Risk Management



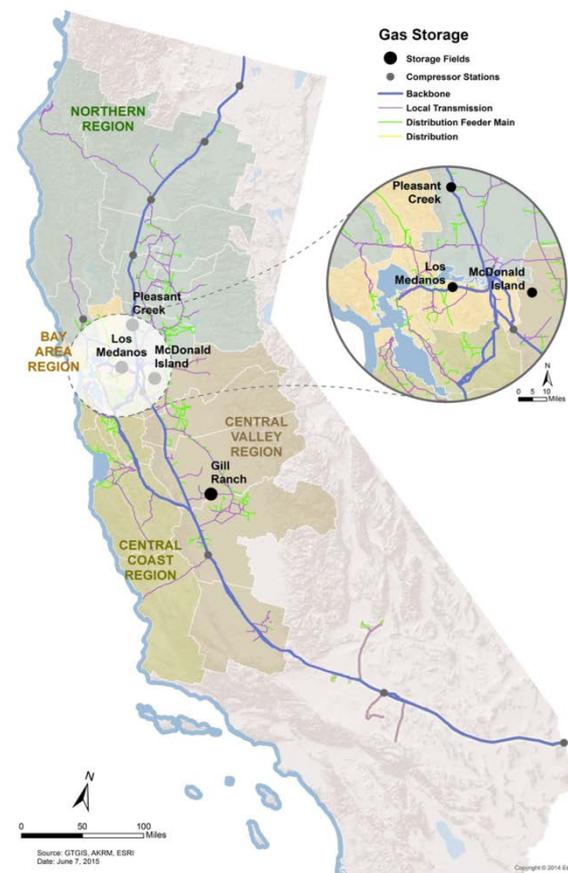
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PG&E Owned Underground Storage Facilities

| Description of Statistic | McDonald Island (operated) | Los Medanos (operated) | Pleasant Creek (operated) | Gill Ranch [1] (non-operated) |
|---|----------------------------|------------------------|---------------------------|-------------------------------|
| Operator | PG&E | PG&E | PG&E | Gill Ranch |
| Location-County | San Joaquin | Contra Costa | Yolo | Madera/Fresno |
| Discovery Date | 1936 | 1958 | 1948 | 1942/1957 |
| Year Placed in Storage Service | 1975 | 1973 | 1960 | 2010 |
| Number of Injection/Withdraw wells | 81 | 21 | 7 | 12 |
| Number of salt water disposal (SWD) wells | - | - | - | 1 |
| Number of Observation wells | 6 | 1 | - | 4 |
| Discovery Pressure-Wellhead (psig) | 2,086 | 1,599 | 1,268 | 2,320 - 2,425 |
| Discovery Pressure-Bottom Hole (psia) | 2,365 | 1,774 | 1,367 | 2,610 - 2,777 |
| Max Storage Pressure-Wellhead (psig) | 2,070 | 1,600 | 1,250 | 3,179 |
| Max Storage Pressure-Bottom Hole (psia) | 2,365 | 1,774 | 1,353 | 3,655 |
| Facility MAOP (psig) | 2,160 | 1,800 | 1,300 | 3,150 |
| Facility MOP (psig) | 2,160 | 1,610 | 1,260 | 3,150 |
| Cushion Gas (Bcf) | 54.5 | 11.2 | 5.1 | 3.5 |
| Working Gas (Bcf) | 82 | 17.9 | 2.3 | 20 |
| Total Inventory (Bcf) | 136.5 | 29.1 | 7.4 | 23.5 |
| Max Withdrawal (MMcf/d) | 1,680 | 400 | 70 | 650 |
| Max Injection (MMcf/d) | 400 | 125 | 32 | 400 |
| Reservoir Depth (feet) | 5,200 | 4,100 | 2,800 | 5,700-6,300 |
| Areal Extent (acres) | 2,760 | 244 | 400 | 5,020 |
| Number of Downhole safety valves (DHSV) | 68 | 21 | - | - |
| Number of Uphole safety valves (UHSV) | 162 | 41 | 14 | 24 |



[1] Gill Ranch capacities listed are 100% of facility (PG&E owns 25%).



Summary of Asset Management Plan

Scope of the Asset Family

- 3 owned and operated (McDonald Island, Los Medanos, Pleasant Creek) underground gas storage fields and Gill Ranch (PG&E owns 25%)
- 116 injection and withdrawal wells
- 200 miles of casing and tubing
- 306 surface and downhole safety valves
- 179 well meters
- Wellhead separators and flow controls
- 14 miles of transmission pipe

Asset Condition

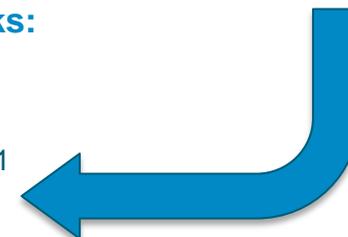
- Vintage of Storage wells range from 1936 – 2012 and are steel cased
- Age of transmission pipe ranges from 30 – 40 years old at Los Medanos and Pleasant Creek; replaced in 2005 at McDonald Island
- 29 of 89 downhole safety valves require replacement



| 36 risks identified, examples include: |
|---|
| Rupture of pipeline due to internal corrosion and/or erosion may result in loss of containment, and/or uncontrolled gas flow that may lead to significant impact on public or employee safety, prolonged outages or net replacement of supply, property damage and/or environmental damage. |
| Loss of well integrity due to well casing corrosion (internal or external, or stress corrosion cracking) that may result in an uncontrolled flow of gas outside of well casing with ignition source, drinking water contamination, gas migration, or gas loss. This may lead to major impact on public or employee safety, facility outage or net replacement of supply, property damage and/or environmental damage. |
| Loss of reservoir integrity due to 1st and 2nd party drilling through storage field or reworking 1st and 2nd Party well that may result in an improper completion of the well or uncontrolled flow or loss containment with ignition source that can lead to significant impact on public or employee safety, prolonged outages or net replacement of supply, property damages and/or environmental damage. |

2016 – 2019 major programs of work to mitigate known risks:

- Internal corrosion site-specific plans
- McDonald Island Assessment
- Well Integrity Management Program (WELL) comparison to API RP 1171
- Downhole safety valve and gravel pack replacement
- Develop 10 year pipeline assessment/replacement plan
- Well Condition Assessments complete baseline by 2025
- Continue development of data management systems



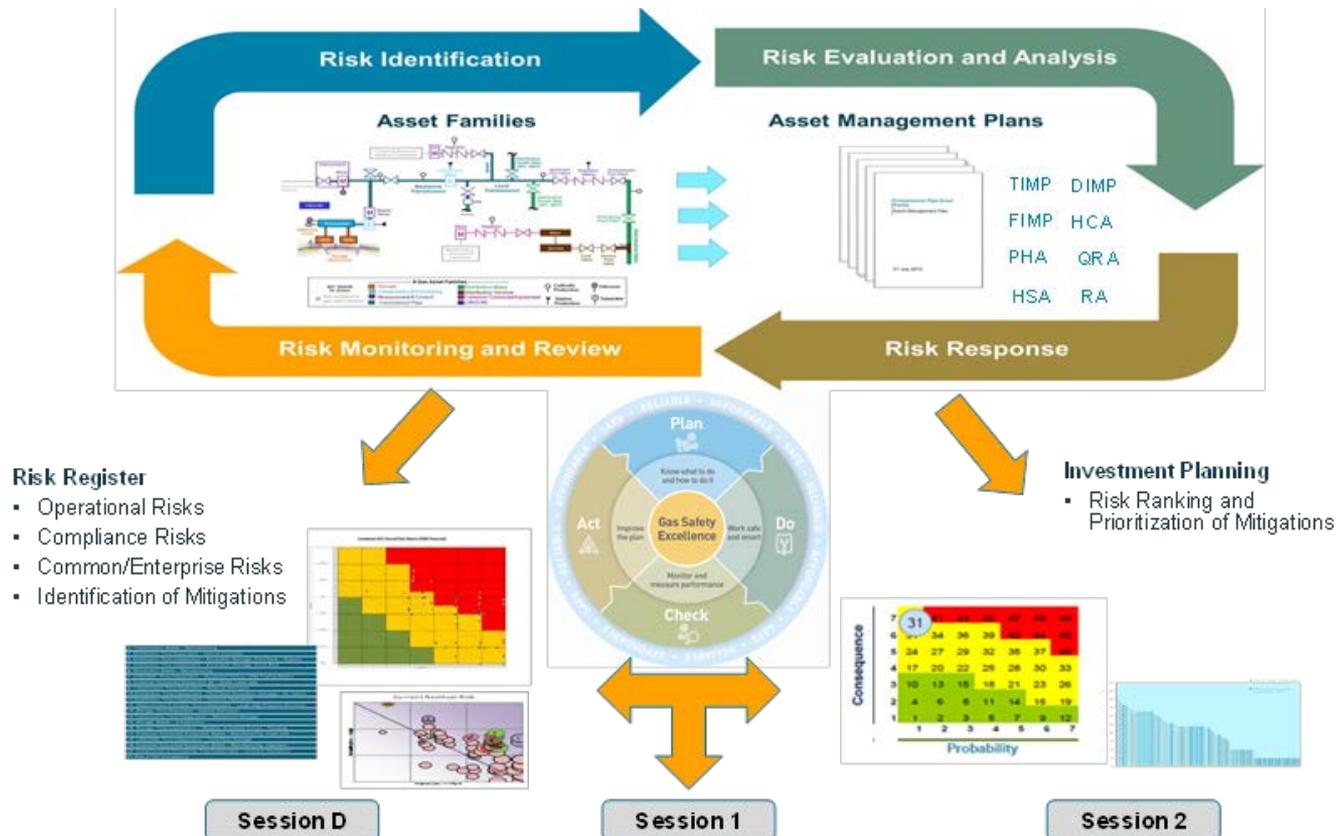


Back Ground Risk and Asset Management

- In mid-2012, PG&E's Gas Operations divided assets into 8 asset families and appointed Asset Family Owner (AFO) to each family who is accountable for managing the asset health.
- Implemented risk and asset management process and oversight through the Risk and Compliance Committee.
- Aligns Integrated Planning Process with risk management through three major phases:
 1. (1) identify asset threats and assess asset risk,
 2. (2) develop proposed mitigation programs within Asset Families, and
 3. (3) develop executable investment plan which encompasses work proposed by all Asset Families.



- Strategy is to make well-informed decisions for investments based on risk and prioritization of mitigations based on the PAS 55 / ISO 55001 framework
- Strategy looks to optimize the balance between risk and performance, embedding a culture of continuous improvement to operate more effectively





Asset Management Plan

- **Asset Management Plan (AMP) describes: the physical characteristics and location of the assets, asset health indices reflecting the asset condition, the risk assessment process, the overall quality, maturity, comprehensiveness and quality of data used to assess the threats and risks, and a vision for the desired asset condition.**
- **The plan identifies the potential threats particular to that asset family as well as the mitigation programs to reduce the risks posed by such threats.**
- **The AMPs also include Key Performance Indicators, which are metrics intended to measure progress and improvement in asset performance and the effectiveness of mitigation programs.**

| Storage Fields | Asset Subcategories |
|-----------------|---|
| McDonald Island | - Storage Reservoirs |
| Los Medanos | - Storage Wells |
| | - Transmission Pipe (between wellheads and processing equipment) |
| Pleasant Creek | - Surface Equipment (e.g. safety valves, well flow measurement, and controls) |



Risk Management

Risk Register and Threat Matrix

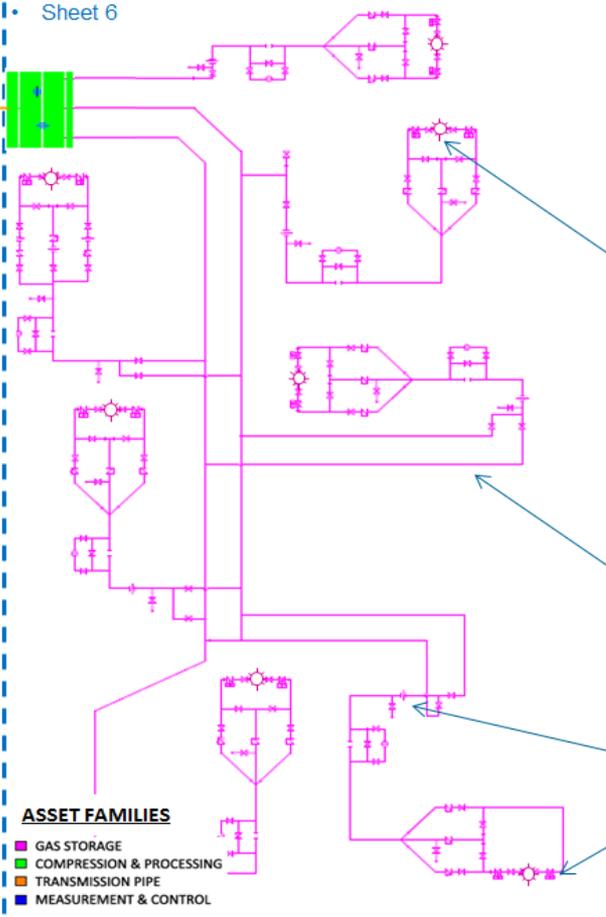
- Oversight by Risk and Compliance Committee
- Management of risk basis for categorizing and evaluating the threats and risk:
 - Section 8 of API RP 1171.
 - American Society of Mechanical Engineers (ASME) Standard B31.8S and 49 Code of Federal Regulations (CFR) Part 192, Subpart O
- Relative risk is determined by calculating the likelihood of failure multiplied by the consequence of failure
- Risks are calibrated and validated, documented in a Risk Register, which is updated and refined as additional information is obtained and evaluated.
- Threat Matrix developed to identify risks (causes of failures) and mitigations measures

Example of 36 risks for Storage Asset Family:

| Threat and Risk | Risk Description |
|---|---|
| Threat: Corrosion Risk: STO005 - Corrosion - Well Casing | Loss of well integrity due to well casing corrosion (internal or external, or stress corrosion cracking) that may result in an uncontrolled flow of gas outside of well casing with ignition source, drinking water contamination, gas migration, or gas loss. This may lead to major impact on public or employee safety, facility outage or net replacement of supply, property damage and/or environmental damage. |

Storage Facility

• Sheet 6



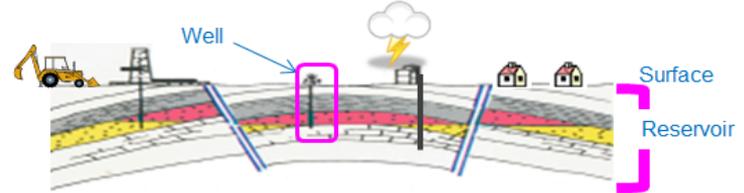
ASSET FAMILIES

- GAS STORAGE
- COMPRESSION & PROCESSING
- TRANSMISSION PIPE
- MEASUREMENT & CONTROL



Well Threat Matrix

- Sheet 2
- Based on API Recommended Practice 1171
- Categories include: Well, Reservoir, Surface



Pipe Threat Matrix

- Sheet 3
- Aligned with Transmission Pipe asset family

Surface Equipment Threat Matrix

- Sheets 4 & 5
- Aligned with Compression & Processing asset family



Threat Matrix



Approved: 5/12/15

Threat Matrix (STORAGE – Well)

Sheet 2 of 6

Primary Causes of Failures

Primary Mitigation Measures

(highest impact on risk reduction - from left to right)

| Category | Primary Causes of Failures | Primary Mitigation Measures |
|-----------|--|---|
| Well | Corrosion / Erosion, Manufacturing, Equipment ST05, 5.1, 11, 33, 34 <ul style="list-style-type: none"> Corrosion / Erosion Material Defects Equipment Failure | Cathodic Protection Guidance Documents (Drilling / Completion Design Standards and PSM) Active and P&A Well Evaluation (Well Schematics and Records) Casing Inspections (CBL, GRN, N/T, MPL Tools) Monitor Well Performance Data Monitor Casing Annular Data |
| | Construction / Fabrication ST03 <ul style="list-style-type: none"> Inadequately Completed or Plugged Wells Failure of Cementing Component Pressure Ratings | Active and P&A Well Evaluation (Well Schematics and Records) Guidance Documents (Drilling / Completion Design Standards and PSM) |
| | Incorrect Operations ST010 <ul style="list-style-type: none"> Operations & Maintenance (Incorrect, Lack of, Failure to Follow Procedures) Inadequate Training | Guidance Documents (O&M) OQ / Training and Development (O&M) |
| | Incorrect Operations ST03 <ul style="list-style-type: none"> Well Intervention (Drilling, Rework, Logging) | Active and P&A Well Evaluation (Well Schematics and Records) Guidance Documents (Drilling / Completion Design Standards and PSM) OQ / Training and Development (Reservoir Engineering) Blowout Prevention Systems |
| Reservoir | Construction / Fabrication, 1st, 2nd, 3rd Party Damage ST01, 2, 3 <ul style="list-style-type: none"> Drilling Well Completion Workovers Production Operations | Rules & Regulations Location Design Requirements Equipment Design Requirements Land Rights Monitor Permit Activity Inspection During Construction Gas Sampling |
| | Outside Forces (Geological) ST035 <ul style="list-style-type: none"> Uncertainty of Boundary Expansion, Contraction, Migration | Geological and Well Evaluation of Records Protective Boundary Land Rights Observation Wells Inventory Verification |
| | Incorrect Operations ST04 <ul style="list-style-type: none"> Drilling & Completion Fluids Failure of Caprock Water / Chemical Floods | Guidance Documents (Design Standards for Fluids) Gas Quality Studies Fluid Compatibility Studies Internal Corrosion Studies |
| Surface | 1st, 2nd, 3rd Party Damage ST01, ST02 <ul style="list-style-type: none"> Surface Encroachments | Land Rights Public Awareness & Damage Prevention Patrolling / Surveillance |
| | 1st, 2nd, 3rd Party Damage ST029, 30, 30.1 <ul style="list-style-type: none"> Vandalism Terrorism Delayed Damage | Physical Security Systems Public Awareness & Damage Prevention Patrolling / Surveillance |
| | Weather & Outside Forces ST022, 23, 24, 26 <ul style="list-style-type: none"> Heavy Rains/Floods Earth Movement Groundwater Table Changes | Design Process Patrolling / Surveillance Remote Control Capabilities |

availability and the quality of the asset data

complete partial weak

ST0# - Risk Register Name

Mitigation Color Key

| |
|---|
| Meets or exceeds industry best practices AND controls are adequate |
| Partially meets industry best practices OR controls are being strengthened |
| Does not meet industry best practices AND current controls are not adequate |
| Pending evaluation *Not yet implemented |

Threat Matrix based on API Recommended Practice 1171



PG&E Storage Facilities: Risk & Integrity Management

Storage Asset Management Plan (AMP) provides an assessment of the condition and risk of the asset, and includes a program plan detailing risk mitigations based on strategic objectives and asset maintenance, applied over the life cycle of the assets. The Storage AMP uses the PAS 55 / ISO 55001 framework.

Threat Categories:

- Time-dependent
 - Potentially increases over time
(*e.g., Corrosion*)
- Stable or “Resident”
 - Inherent in the asset and typically influenced by another condition
(*e.g., manufacturing / construction*)
- Time-independent
 - Not influenced by time
(*e.g., 3rd-Party and outside forces*)

Primary Mitigation Measures:

- Monitoring
 - Daily pressure monitoring and leak survey
 - Inventory verification (Semi-Annual) and Annual Reporting
 - Annual Noise/Temperature Logging
 - Gamma Ray Neutron Logging*
- Inspections
 - Production casing condition inspections (18% complete with MFL). Inspection types expanded.
 - Expansion of Surf. Casing Monitoring
- Prevention systems
 - Data Systems
 - Maintenance on Safety valves
 - Conduct annual emergency response drills
 - Developed Site Specific Blowout Contingency Plans (Well Control Tactical Consideration & relief well planning)
 - Site Specific Corrosion inspection plans for pipeline and facilities



Well Integrity Management WELL

- Used to assess the risk related to the storage wells and prescribe action to prevent or mitigate the identified risks
- Feeds condition, risk, and mitigations into the Gas Storage AMP
- The initiatives within WELL are built upon practices adopted from industry benchmarking and those developed in API RP 1171 to assess threats to the storage well assets :

| Mitigation Examples | Activity | Purpose |
|--------------------------------|---|---|
| CP | Cathodic Protection | Protect production casing from corrosion |
| Documents | Records | Know the storage wells construction and equipment installed |
| Casing Inspections and Logging | Noise / Temperature Logging | Detect loss of integrity of well production casing |
| | Magnetic Flux Leakage (MFL) Logging, Caliper, and Pressure test | Production casing condition baseline and reassessment Expanding to include Aliso Canyon Criteria |
| | Gamma Ray Neutron (GRN) Cement Bond Logging (CBL) | Assess gas behind production casing Evaluate cement behind production casing |
| Monitor Well Performance Data | Performance and Annular | Detect loss of integrity of well production casing |



Ending Comments

- **PG&E appreciates the opportunity to meet and share its experience in operating natural gas storage facilities within the State of California and its knowledge of operations in the US and API RP 1171**
- **Benefits recognized by PG&E using Assessment and Risk Management**
 - **Accountability established for each asset type**
 - **Identifies assets threats and assess asset risk**
 - **Development of proposed mitigation programs to eliminate or reduce threats**
 - **Development of an executable investment plan which encompasses work proposed by all Asset Families**
 - **Opportunities for continuous improvement identified and put into action (probabilistic risk evaluation)**