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Independent Review of Hydraulic Modeling for Aliso Canyon Risk Assessment

Report prepared for the California Energy Commission (CEC), California Public Utilities Commission (CPUC), California Independent System Operator (CaISO), and the Los Angeles Department of Water and Power (LADWP)

August 19, 2016

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1 Introduction and Project Overview

On October 23, 2015, Southern California Natural Gas Company (SoCalGas) discovered a leaking well at its Aliso Canyon underground gas storage field. Safety concerns resulting from the leak necessitate significant changes to the operating characteristics of the field and its future use. In preparing an Action Plan [1] to preserve reliability for summer 2016, the Action Plan Team entities—California Energy Commission (CEC), California Public Utilities Commission (CPUC), California Independent System Operator (CaISO), and the Los Angeles Department of Water and Power (LADWP)—worked with SoCalGas to understand how SoCalGas utilizes the field and the impact that loss of the field would have on system operations and reliability. Developing that understanding required use of hydraulic modeling. None of the Action Plan Team are proficient in using and applying hydraulic modeling, although one is familiar with its use for planning. The Action Plan Team entities requested assistance from experts at Los Alamos National Laboratory (LANL), in conjunction with Walker & Associates (Walker), in transient modeling and gas system planning to provide more detailed and complete independent review of SoCalGas hydraulic modeling to better assure the public that the team is not relying solely on SoCalGas to perform the needed modeling and analysis. The independent review team has evaluated the hydraulic modeling and reliability analysis methodology and the recommendations made by the Action Plan Team, and this report provides their review. While the findings of the independent review will be public, some of the modeling information is confidential and must be maintained as such so members of the independent review team have signed non-disclosure agreements with SoCalGas. These non-disclosure agreements do not impede or limit the review.

1.1 Scope of Work

LANL, in conjunction with Walker, performed or will perform the following tasks:

- Receive background overview of SoCalGas system characteristics from Energy Commission consultant and separately from SoCalGas
- Review April 5, 2016 Risk Assessment and Technical Report [2] description of the hydraulic modeling and results
- Meet with SoCalGas to discuss set up for winter assessment hydraulic runs
- Meet with SoCalGas to view hydraulic runs in detail
- Recommend changes to modeling as needed
- Participate in conference calls with and interact with the Action Plan Team as needed
- Prepare short report/opinion document documenting activities and findings
- Participate in August 26, 2016, workshop to present findings related to winter assessment

- Review public comments emanating from the August workshop and help the Action Plan Team respond to any issues related to the hydraulic modeling

1.2 Project Schedule

The Action Plan Team is scheduled to present its winter assessment and recommendations at a public workshop on August 26, 2016. Much of the content for the workshop must be developed in time for approval by principals in the respective agencies around July 30. Thus, the timeframe for conducting this independent review runs from start of the project in June 2016 until through the August 2016 workshop date. Major project milestones include:

- Initial data request to SoCalGas 6/23
- Meeting with SoCalGas in Los Angeles 6/29
- Submit draft report 8/5
- Submit final report 8/19

1.3 Project Approach

On June 29, 2016, Walker and LANL technical staff met with SoCalGas personnel for an onsite visit in Los Angeles. They received an overview of the hydraulic modeling method that SoCalGas used to perform the Summer Assessment. They had the opportunity to question SoCalGas engineers about their modeling approach; how it relates to specific structural and operational aspects of the SoCalGas pipeline system; and how it incorporates constraints related to market operations, government regulations, and realities of field operations and gas flow monitoring and control capabilities. The review team also reviewed the Aliso Canyon Risk Assessment Technical Report [2] (here after referred to as the Technical Report) and the Aliso Canyon Action Plan to preserve gas and electric reliability for the Los Angeles (LA) Basin [1], both prepared by the Staff of the California Public Utilities Commission, California Energy Commission, the California Independent System Operator, and the Los Angeles Department of Water and Power. On July 12, 2016, LANL technical staff participated in a conference call with Action Plan Team members, including SoCalGas engineers, during which the results of additional hydraulic modeling analyses were shared and explained. The independent review team assessed the information provided and concluded that it was sufficient to perform a qualitative review of hydraulic modeling method and to recommend additional modeling, if needed. Public comments provided after the August 26, 2016 workshop are to be reviewed as well.

The approach to completing this project will follow the steps outlined below:

- Review scope of work
- Develop and submit initial data request to SoCalGas
- Review documents supplied by CASIO and SoCalGas
- Develop list of questions for onsite meeting with SoCalGas

- Meeting with SoCalGas
- Develop initial list of findings and recommendations for discussion with CaISO
- Discussion with CaISO
- Develop draft report
- Review of draft report by CEC, CPUC, CaISO, and LADWP
- Prepare final report

2 GAS SYSTEM MODELING AND RISK ASSESSMENT REVIEW

In this section, we review the hydraulic modeling performed by SoCalGas for the Summer Assessment. We indicate the capabilities and limitations of the software tools and the hydraulic modeling approach. We then evaluate how the outcomes drawn in the Technical Report correspond to maximal utilization of the software, and how, in turn, they correspond to maximal utilization of the SoCalGas infrastructure under actual operating conditions.

2.1 TECHNOLOGY

Hydraulic modeling is used primarily to evaluate pipeline capacity. Transient analysis is used to quantify pipeline flows and pressures under time-varying boundary conditions (i.e., consumer offtakes). Such analysis can be used to estimate the maximum utilization of a pipeline system, however, aspects of flow control operations must be accounted for when estimating capacity given varying flows and actual operating conditions. The analysis must specifically account for how gas control engineers operate the system with the available tools and information.

2.1.1 OPERATIONAL TECHNOLOGY

There are four general options for operators to control the flow of gas through a pipeline system. These are (1) opening or closing valves to change the system connectivity, (2) adjusting regulators that decrease line pressure, (3) running gas compressors to boost line pressure, and (4) injecting gas into or withdrawing gas out of storage fields. Due to the Aliso Canyon storage outage, the last option has been greatly reduced for SoCalGas system operators. Planning engineers must model the ability of controllers to manipulate flows and line pressures using valves, regulators, and gas compressors carefully. These control adjustments are subject to complex system constraints, which include maximum allowable and minimum operating pressures (MAOP and MINOP), maximum flow through city gates, and maximum compressor power and discharge temperature. Finally, the total line pack in the system must be recovered at the end of each operating day. Line pack refers to the total mass of gas in the system, which also corresponds to the amount of energy available from that gas.

2.1.2 System Overview

The SoCalGas system includes large diameter pipelines that transport gas from interconnections from the east via the Transwestern and El Paso systems, and from the north via the Pacific Gas & Electric system (PG&E). Gas controllers may activate or adjust compressor stations (e.g., at Newberry, Blythe, or Wheeler Ridge) on these larger transport pipelines, and adjust flow direction (e.g., at Adelanto or Moreno). These larger lines deliver gas to the high-pressure distribution system in the LA Basin. That part of the system consists of smaller diameter pipes with lower MAOP and is behind city gate regulators. These regulators may, for example, be set to maintain an upstream pressure to keep line pack in reserve to prepare for an increase in demand in the LA Basin.

Key city gate regulators are located to the east and north of the LA Basin. These regulators have limits on flow rates and downstream pressures, which restrict the rate at which gas can be brought into the LA Basin. Another system-specific factor that must be considered is the tradeoff between gas compression at Wheeler Ridge and withdrawal from the Honor Rancho storage. If the Wheeler Ridge pipeline compressor is under high utilization, then pressure on the line from the northern connection to PG&E will be too high to draw gas from Honor Rancho.

The Aliso Canyon storage facility was designed to be an integral part of the system. Aliso Canyon has 114 wells and is the largest storage facility in the SoCalGas network. The facility has a capacity of 86 billion cubic feet (BCF). The facility operators try to fill Aliso Canyon to capacity each summer. When the facility is inactive, the storage capacity of the SoCalGas system is reduced by 64%. SoCalGas has reduced the inventory of the facility to mitigate the well leak. As of the date of this report, the facility holds approximately 15 BCF.

Other physical and engineering restrictions, market structures, and regulatory factors also limit the information and actions that are available to gas controllers. For example, flows at custody transfer points from inter-state pipelines are kept as steady as possible and are generally changed in response to market adjustments. Physical limitations also prevent fast changes in the rate at which flowing supplies are brought into the system. Therefore, while the supply entering the system at custody transfer interconnections must be kept nearly constant throughout each 24-hour gas day, the gas offtakes by customers may be highly variable, especially by electric generation (EG) loads.

2.2 Software Technology

SoCalGas used DNV-GL's Synergi USM gas software application to assess the summer load capabilities of the system with and without the Aliso Canyon facility. This software accurately models complex, integrated multi-pressure level systems and provides its users with information regarding predictions of pressures, flows, valve positions, pipe diameters, compressor powers and speeds, and storage field utilization factors. Synergi USM uses given constants and estimated variables to provide a range of tolerances in which, ideally, equilibrium is maintained. This process is called hydraulic modeling.

The primary capability of commercial transient analysis software is to predict how the pipeline system will behave under given conditions. The inputs to the analysis are offtakes (load) throughout the system and operating protocols of the control points described above. The output of the software is a simulation of what, mathematically, is an initial value problem. From a starting condition, the state of the system is evolved forward in time according to well-defined rules that represent physics and engineering operations.

The software tool can efficiently simulate highly complex pipeline operations, but it cannot determine how the system should be optimally operated. It cannot give the user protocols for compressor and regulator operation that maximize system throughput. An engineer must go through an iterative procedure to approximate such a solution, as described below.

2.3 Human Factors and Decision Processes

In actual system operations, all control points have automatic systems that maintain operating set points. For example, a regulator may adjust through flow to follow a given upstream pressure, or a centrifugal gas compressor station may adjust turbine power to follow a given downstream pressure. These systems were designed for efficient operation under steady flow conditions. When flows vary in time, gas controllers must adjust the operating set points in real time in reaction to changes in system conditions as they are observed. When the system is observed to be approaching problematic conditions, such as dangerously low pressures, certain emergency actions may be taken. The most commonly used such action is the operational flow order (OFO), which requires customers to adhere to strictly specified offtakes.

Any adjustments to control set points must account for all system limitations and constraints, which requires substantial operator training and experience. Transient hydraulic analysis must, therefore, account for the human factors of system operations. Specifically, planning engineers must consider the likely actions of gas control operators in reaction to changes in conditions, and recognize situations in which an OFO may be issued.

The observations available to the operator include pressure, flow, and temperature measurements throughout the system. Consumption of natural gas generally follows ambient temperature, so operators have traditionally forecasted load based on the weather. As EG gas loads have grown, such forecasting has become less informative because generators are activated according to the economic day-ahead market clearing practices of independent system operators, such as CaISO. Recently, the removal of regulatory barriers to operational coordination has permitted pipeline operators to receive predictive information about when and where gas-fired generators are activated. Nevertheless, the flow profiles of offtakes by EG customers can be highly uncertain, and information given in “burn sheets” may be insufficient or may become available only after key operational decisions have been made.

Even when full EG gas offtake schedules are available in advance, there is no software tool that can compute time-dependent adjustments to the many system set points for the upcoming day based on known flow profiles. Thus, gas controllers must depend on their training, experience, and detailed knowledge of the SoCalGas system to maintain reliable operations. Further, there are many human factors involved in the process of market clearing, flow scheduling, and gas control, which are difficult to model. These decision processes vary by region and by company, and may be proprietary.

In general, the market and physical operations of natural gas transmission and electric power generation are highly complex. Because data standards for inter-sector interaction are lacking, there is high reliance on human communication at the interface. The hydraulic analysis for capacity planning must, therefore, be conservative to account for uncertainty in human behavior between decision cycles. The possibility of maintenance outages or unplanned contingencies further justify a conservative approach to evaluating capacity.

2.4 Industry Best Practices/Standards

As described above, commercial pipeline simulation software tools provide predictive analysis given a set of defined conditions and operating protocols. SoCalGas uses the Synergi USM software from DNV-GL, which has been in use for over 40 years and is widely accepted as state-of-the-art for hydraulic modeling in the natural gas transmission industry. Furthermore, the methodology with which the software is used meets the standards for industry best practices.

The methodology employed by SoCalGas to assess capacity of its system under transient conditions reflects a full utilization of the capabilities of available software and takes actual operational aspects into account. **The estimates of maximum system utilization obtained by the methodology used by SoCalGas are appropriate, given all of the operational factors involved and the capabilities of commercially available software.** In the sections below, we review modeling outcomes and provide additional recommendations based on the finding that, given a scenario of system conditions, the hydraulic modeling adequately assesses system capacity.

2.5 Methodology

In this section, we focus on how SoCalGas engineers use hydraulic modeling software for gas system analysis and capacity planning. As discussed above, the method must account for the technology used in field operations, including the many human factors involved. We first restate the question that the hydraulic analysis is used to examine, how case studies were formulated, and then review the use of the software to obtain an answer.

2.5.1 Purpose and Scenario Generation

Because of the Aliso Canyon storage outage, the amount and timing of gas consumption by electric generating stations in the LA Basin is constrained by the ability to deliver gas there from outside the basin through pipelines. The purpose of hydraulic analysis, in the present case, is to evaluate the capacity of the system to deliver gas under transient conditions. For the summer assessment, the Action Plan Team developed several scenarios that represent historical days of interest to the electric grid operators, and SoCalGas performed hydraulic transient modeling of its system under each scenario.

The summer scenarios use the flowing supplies for the day of simulation represented by the assumed day-ahead forecast of the demand. The load profiles used in the simulation represented actual demand based on a historical day. Supplies from the Playa del Rey field were not used in the supply planning for the simulated day-ahead forecast in order to represent an operational reserve held in case of unexpected changes. This corresponds to the actual use of this storage resource, which is not typically used as the source of scheduled gas receipts. Nevertheless, use of the Playa Del Rey field was incorporated in the analysis when conditions of significant stress appeared in the modeling and warranted its use. Thus, the analysis did use this reserve resource in a realistic manner. All SoCalGas storage facilities, including Playa del Rey, were fully utilized in the simulation of the actual demand days. For the more extreme cases, total load was significantly above the total incoming supply. Such conditions can be expected to lead to declining line pressures throughout the day, even when all operator actions short of curtailment have been taken.

2.5.2 Iterative Analysis

As mentioned, the software tools available to capacity planning engineers do not provide a solution to controlling flows through a pipeline system. Rather, these tools describe what will happen if a given protocol is applied under specified offtake and supply profiles. The capacity planning group at SoCalGas uses an approach called **iteration** to evaluate maximum system utilization under a given set of conditions.

Iteration involves simulating the system until constraints are encountered, then returning to a point where actions can be determined that prevent constraint violation. For example, if a line pressure is seen to hit a MINOP, the engineer may rewind the simulation by an hour and modify a compressor station set point that will maintain the pressure. The process can be summarized as follows:

1. An initial steady flow state for the simulated system is chosen (at the level of nighttime flows).
2. From the initial state, the simulated system is transitioned to the initial line-pack configuration expected at the beginning of the day by adjusting flows and settings of compressors and regulators.
3. As the simulation proceeds through the 24-hour gas day, whenever situations are encountered for which gas control would take emergency action, such as a curtailment or an OFO, the simulation is returned to an earlier time and a preventative action is programmed in the simulation. Such preventative action would be adjustment of compressor or regulator settings.
4. The steps are repeated until the simulation has gone through the 24-hour operating day, and the procedure is then concluded.

In actual operations, the gas control department will take action well before the system moves into a state that requires emergency action. When pressures are seen to drop precipitously because of high offtakes in a part of the system, the operator does not know whether the high offtake will end soon, thus keeping pressure above the MINOP. The operator assumes that the pressure will continue to drop unless action is taken. The operator does not have the opportunity to reverse reality to make adjustments, as is done by a capacity planning engineer in the simulation during the iteration procedure.

Because the gas control department has limited information on which to act predictively, actions taken in the field are primarily reactive. In contrast, capacity planners running simulations have predictive information (flow profiles used in the simulation are known). Also, they have the option of returning to previous times and adjusting a simulation. The process of iteration is a reasonable emulation of the actions that the gas control department takes to operate the system; therefore, the procedure leads to a reasonable estimate of maximum system utilization.

2.5.3 Calibration to actual conditions

The simulations performed for the transient analysis provide estimates of theoretical optimal performance of the SoCalGas system under certain conditions. To interpret these analyses and develop a risk assessment, it is necessary to understand that these results incorporate many uncertainties in model and case study parameters, as well as human factors and decision processes. When operators in the gas control department monitor the system, they rely on their training and experience to make real-time decisions about control actions and balancing needs. Furthermore, significant uncertainty in flow profiles can exist, and the sensitivity of the system performance to variations is substantial. Even minor deviations in the timing and volume of forecasted offtakes can lead to a large discrepancy between predicted and observed system flows and pressures.

We note that a solution obtained using the iteration procedure described above is a conservative estimate of maximum capacity that may be lower than the theoretical optimal system performance. It is not intuitive to produce control protocols corresponding to the maximal system utilization because of the time-dependent complexity and the many control points. Producing a reasonable solution using this procedure requires substantial time and experience using the Synergi USM software. However, a conservative solution is warranted because of the significant uncertainty, human factors, and lack of predictive information (particularly with regard to EG gas offtakes) that characterize actual operations, as discussed above. Furthermore, the simulation assumes that there are no unplanned events that cause outages or reductions in capacity or control of the system. Therefore, our assessment is that the estimate of maximum system utilization obtained by the iteration methodology used by SoCalGas is appropriate given all of the operational factors involved. It is a conservative estimate that provides a margin of safety given the uncertainty in calibration to actual conditions.

Finally, the very significant consequences of system depressurization require conservative analysis. If distribution system pressure dropped below the critical levels needed to service residential customers, the result would be catastrophic because of the time and resources required to re-light all the affected appliances [3] [4]. To ensure that network modeling being used by gas companies in the United States and internationally is effective as a flow assurance measure against catastrophic system events, gas company personnel seek to identify specific scenarios for the gas company's system that represents the "worst case" or "perfect storm". These scenarios represent what the company and the public it serves would expect to be a reasonable set of possible events and situations from past historical events and data, future weather forecasts, as well as gas supply and customer load potential swings and trends, i.e., EG gas offtakes. This approach is akin to the 100-year flood planning and similar exercises that ensure measures are in place to prevent and/or mitigate a catastrophic event in other parts of the community.

Industry standard practices for gas companies include planning for a design day. A design day is the annual day or days that represent the "worst case" for the system from the standpoint of loads, flows, demands, weather, and other factors. These factors have and/or can be expected to adversely affect the reliability of the gas system. Consequences such as curtailments, low pressure events, and worst case-outages are possible. Outages are the worst case because of customer interruptions and the amount of time and resources involved in re-lighting gas appliances for core residential and commercial customers.

Gas companies try to avoid system outages all costs. System curtailments for noncore customers are the means to protect the reliability of natural gas supply to core customers. Design day analysis includes running sensitivity analysis around the initial design day to see the effect of other potential factors, i.e., cold/hot weather over an extended period of days, parts of the system down for maintenance, third-party damage events, or some known potential issues that could affect the system. Running multiple probabilistic studies on the myriad of factors that "could go wrong" is not practical nor suggested because the value from these studies is limited to the real world effects of what can be done to avoid the perceived issue. From our experience, unless all of the probable factors are modeled in most or all combinations, which is statistically inefficient and in some ways not possible, one cannot accurately predict the exact combination of conditions that will "trip the system". Therefore, the industry standard practice is to perform sensitivity studies around the design day base case that are practical and closest to what has previously occurred or what is expected to happen. When new events occur, the design base case can be adjusted to see the impact of these new factors on the gas system from a modeling standpoint and required changes to the operations of the gas system infrastructure or system improvements (projects) can be inferred.

In the case of SoCalGas, and specifically the gas system serving the LA Basin, the factors surrounding the "worst case" or design day in the past have always included the supply of gas from the Aliso Canyon storage facility. As of the date of this report, the SoCalGas system is operating under unprecedented conditions; thus, the challenge for SoCalGas and the Action Plan Team in designing the scenarios for the 2016 Summer and Winter assessments is to model the "worst case" or design day without the gas stored in the Aliso Canyon facility. The CPUC mandated a study to identify the range of loads on the gas system that could possibly affect electric generation based on limited historical events and data [5][6]. The outcome of this study is a set of design day standards for the gas supply system, including standards for the winter design day. Accordingly, for the winter assessment SoCalGas has identified the level of demand that its system could reliably support without supply from the Aliso Canyon storage field. This estimate is based on the 1-in-10 year winter design day standard [1][5].

The independent review team finds the Action Plan Team's approach to scenario planning to be reasonable for the 2016 Summer and Winter Assessments, with the caveat that additional analysis should be made to understand what sensitivity studies should be done now that the summer is partially over. The purpose of additional studies is to determine what actual factors that were predicted in the Summer Assessment, leading to an estimated 14 to 16 days of impact on EG customers, either were not in force or were mitigated by other factors that prevented reliability on the gas side from being a critical issue the at time of writing. The new rules regarding supply balancing and OFOs now in effect could have played a critical part in a reliability non-event. Tighter balancing rules may be a particularly important measure for maintaining system reliability because they prevent supply shortfalls, which were found in the pipeline hydraulic analysis to be a key indicator of system stress. The significantly more systematic and regular sharing of operational information, including outage coordination, between the Action Plan Team entities also likely contributed to the maintaining reliable service of their systems. Furthermore, the specific extreme weather event of June 20, 2016, has been evaluated to see how actual conditions lined up with modeling assumptions, and preliminary observations indicate that conditions were similar to the September 9, 2015 scenario that was studied in the summer assessment and prepared for following the Action Plan. Further analysis of the June 20, 2016 event and subsequent extreme days is recommended to determine whether new supply balancing rules prevented curtailment orders.

In addition, the review team suggests that the Action Plan Team should examine the scenarios in the Winter Assessment to see if factors similar to those noted above are being assumed that may affect operations this winter or, conversely, there exist factors that have not yet been considered, i.e., extended periods of cold weather for specific dates from the latest winter weather forecasts. The Action Plan Team's approach to scenario planning is conservative and risk adverse, but similar to approaches taken by many gas companies to ensure measures are in place to mitigate reliability issues, with specific focus on preventing outages to firm customers in accordance with standard industry practice.

2.6 Risk Assessment

Using the outcomes of hydraulic modeling, it is necessary to evaluate the risk of curtailments to gas customers, as well as to quantify the severity of the risk. Based on a hydraulic analysis that estimates maximum system utilization or capacity, historical data may be used to perform a statistical analysis. For the Summer Assessment, SoCalGas used a probabilistic framework for curtailment risk analysis that is described on pages 32 to 41 of the Technical Report. For the analysis, a design day scenario is first constructed using offtake profiles from a peak historical day. Based on this scenario, a hydraulic analysis was completed to simulate the effect on the system that the same peak day conditions would have caused without the ability to utilize the Aliso Canyon storage facility. This demand profile and the expected flowing supply shortfall provided the criteria for a design day when the SoCalGas system is under significant stress and curtailments are possible, then the probability of conditions that exceed these stress criteria were determined from historical data. In addition, probabilities of system stress combined with contingencies, such as planned and unplanned outages of pipelines and storage facilities, are computed from historical data. For each class of conditions, a likely curtailment level is estimated.

3 Summer Assessment

This section provides a review of the specific modeling done in the Summer Assessment. We review the hydraulic modeling scenarios and outcomes, the risk assessment, and discuss the Action Plan as well as its effects to improve system reliability.

3.1 Review of Modeling Outcomes

For their analysis, SoCalGas engineers examined several scenarios that reflect high system stress. These scenarios were chosen in consultation with the Action Plan Team based on historical conditions but modeled without the use of the Aliso Canyon storage.

1. September 16, 2014: LADWP peak demand day
2. July 30, 2015: Largest change in EG hourly demand
3. September 9, 2015: Total peak EG demand day
4. December 15, 2015: Winter day with high EG demand

After a review of the method and technology used; the high uncertainty surrounding unprecedented conditions; and our understanding of SoCalGas system control capabilities, limitations, and operational variables, we have found the process used to obtain initial capacity estimates to be reasonable. Based on the modeling of the SoCalGas network, regulations and operating practices in place when the Technical Report was written, and projected usage for the summer, the review team finds that significant misalignments of supply and demand would have likely led to significant curtailments. There are several primary factors that contribute to this view.

All projections assumed proper function of the remaining non-Aliso components of the system and typical load and utilization. There remains a potential for outages at other facilities–either planned or unplanned–as well as extreme spikes in usage caused by events such as heat waves. Because of the integral nature and size of the Aliso Canyon facility, the heavy reliance of the SoCalGas network on storage fields for holding a reserve of gas, and the potential for other outages or spikes in usage, SoCalGas determined that some changes to the system operation will need to be made in order to achieve necessary gas supply and offtake balance, and to rebuild the gas reserve. Finally, because of the loss of the Aliso Canyon facility as a balancing tool, SoCalGas identified supply shortfalls and outages as key predictors of likely need for curtailments.

3.2 Review of risk assessment

Using the outcomes of SoCalGas hydraulic modeling, the Action Plan Team assessed the risk of significant system stress on the SoCalGas and San Diego Gas & Electric (SDG&E) system in the absence of the Aliso Canyon storage. The task force found that pipeline system stress and the potential of resulting curtailments are difficult to quantify because of the large number of variables and uncertainties in modeling pipeline systems, particularly under transient conditions. To provide some guidance for the Summer Assessment, an estimate of the number of days with high risk of curtailment was developed based on a statistical analysis of operating data, planned maintenance scenarios, and a historical probability of outage events.

The Action Plan Team selected one representative scenario as the design day to be examined using transient hydraulic analysis and used for system risk assessment. The scenario was based on the actual conditions on September 9, 2015, when the system was subjected to a 3.2BCF sendout (daily system load) with peak EG demand and significant supply shortfall based on day-ahead projections. The hydraulic analysis results indicated that without the Aliso Canyon storage, a total system supply shortfall of 150 million cubic feet per day (mmcfd) could have resulted in high risk of curtailment in the LA Basin. Subsequently, historical data was evaluated based on 3.2 BCF as a high summer system utilization and a 150 mmcfd supply shortfall as the threshold for high system stress (or curtailment risk) under those conditions. The historical data examined consisted of 1,095 days in the years 2013–2015, and the same shortfall threshold of 150 mmcfd was applied to each day for all conditions and seasons.

As indicated in the Technical Report, curtailments are possible under many circumstances of load, flowing supply, weather, and outages. In addition to the sendout (daily system load in BCF), the key factors that were identified as affecting system stress were flow imbalance (supply shortfall) and outages. The outages can be classified as planned or unplanned, and as affecting pipelines, storage facilities, or both.

Based on the criteria for likely curtailment risk (>3.2 BCF load and >150 mmcfd supply shortfall), SoCalGas used daily historical load, supply, and outage data from 2013-2015 to compute empirical probabilities for several scenarios. Significant outages of storage and pipelines are defined in the Technical Report as greater than 400 mmcfd and greater than 500 mmcfd impacts, respectively. Table 3 on page 36 of the Technical Report presents the results of the statistical analysis. Probabilities are expressed as the number of days per calendar year when the system is at risk of curtailment.

3.3 Observations

The risk analysis performed by the Action Plan Team is in line methodologically with industry practice under high uncertainty [7]. Pipeline system stress and the potential of resulting curtailments are difficult to quantify because of the large number of variables and uncertainties, particularly given the changing market and regulatory factors that influence how flowing supplies are brought in to balance the SoCalGas system. As presented, the risk scenarios analyzed appear to be interrelated as overlapping subsets, so the analysis may overestimate the likelihood of certain conditions. Specifically, the likelihood of days where the system is under stress and unplanned outages occur appears to have been included in Scenario 1 in the calculations on Table 3 in the Technical Report, and also into conditions that fall under Scenarios 2 or 3. The analysis may, therefore, overestimate the risk of medium-probability, medium-impact events. In the view of the independent review team, the approach of accounting for unplanned outages on high stress days additively could explain why the number of days with curtailments predicted in the Summer Assessment would appear to be, at the time of writing, partially overestimated. Additional Action Plan measures implemented after the Summer Assessment, such as increased coordination and new flowing gas supply balancing requirements, may have resulted in mitigation of the expected curtailment risk.

It is important to note that, based on guidance from the Action Plan Team, the different outage conditions were designated to be individual scenarios of increasing stress impact on the SoCalGas system. The first two scenarios were based on known quantities and planned outages. Scenario 3 consisted of the risk associated with unplanned outages, which by their nature are highly variable. The unplanned outage analysis was based on historical data, which correspond to very different regulatory, market, and operating conditions prior to the Aliso Canyon facility leak. Therefore, SoCalGas could not know precisely when similar scenarios would occur under current conditions. To maintain system integrity, SoCalGas has acted conservatively and reflected this in the analysis by assuming that unplanned outages that place significant stress on the system can occur on days without flowing supply imbalances.

In addition, the analysis may not have included very low probability, high-impact scenarios where unplanned outages occur on a day of high system stress in conjunction with planned outages. Based on the analysis framework used in the Technical Report, the situation of high stress caused by both high load, supply shortfall, planned outages and unplanned outages can be expected once in four years. While the assessment may underestimate risk of high-impact events, the analysis appropriately focuses on medium-probability, medium-impact events, which are of the most immediate concern to the Action Plan Team.

Based on the analysis, the highest likelihood significant impacts occur due to simultaneous planned outages of pipelines and storages, leading to possible curtailment of 1.1 BCF per day. An effective mitigation measure appears to be to schedule maintenance so that planned pipeline and storage outages do not occur simultaneously. Because planned outages, by definition, do not occur randomly, SoCalGas may be able to reduce the six days per year when this situation could be expected to occur, although schedules and requirements that are not under the control of SoCalGas may prevent this approach. Although planned outages are not random, it may not be possible to reschedule them because the maintenance could already be underway, delaying the maintenance could create additional risk, or the work is mandated and cannot be shifted. Pipeline safety practices and regulations require maintenance to take place based on specific response timelines. In-line inspection reports lag planned pipeline outages and can identify deficiencies that require immediate attention, and could in turn lead to unplanned outages.

Another effective mitigation measure is the implementation of tight balancing rules that require shippers to bring enough supplies into the system to balance their offtakes each day. Without the reduced availability of storage resulting from the outage at the Aliso Canyon facility, fewer storage resources are available to compensate for system imbalances. In particular, during times of peak system utilization, all of the remaining storage facilities available to SoCalGas may be called into service to meet demand, making them unavailable to make up for shortfalls in supplies shipped into the system. We note that no supply shortfalls of over 150 mmcfd were observed, and no curtailments were necessary, during summer of 2016 at the time of writing.

3.4 Review of Action Plan

The high system stress days and large number of natural gas and electric power curtailments predicted in the Technical Report have not occurred, likely because of the successful mitigation measures that the Action Plan Team adopted to reduce the magnitude and need for gas curtailments. In particular, prudent use of Aliso Canyon and other storage facilities, tariff changes, tighter balancing rules, and increased operational coordination have significantly reduced imbalances that were identified as key predictors of system stress.

4 Winter Assessment

In this section we examine aspects of the hydraulic modeling and analysis done for the Winter Assessment that were communicated to the review team prior to public release of the Winter Assessment report.

4.1 Initial Assessment

To characterize the limits on system utilization, SoCalGas performed an iterative hydraulic analysis process for a winter design day scenario in a manner similar to the approach to the Summer Assessment. The recovery of total line pack in the three areas of the system—the LA Basin, the Northern system, and the Southern system—was examined explicitly as part of the transient hydraulic analysis. The goal of the analysis is to model the behavior of the gas transmission system under varying conditions and performing actions following the procedures of the gas control department. SoCalGas controllers will act to recover line pressures and pack at the end of every gas day, rather than allow pressures and pack to continuously decrease over several days. The approach used in the hydraulic modeling process is to start the transient analysis with acceptable system pressures/pack, and to iterate the simulation (adjusting valves, compressors, and regulators and making curtailments) until an acceptable outcome is obtained. Specifically, an acceptable outcome is for pressures to remain between minimum and maximum allowable pressures at all times and for line pack to be recovered at the end of the day. For the purpose of reliability assessments, 24-hour transient analysis is justified because it reflects the operating policy of the gas department.

Because extreme events that span more than one gas day are possible, hydraulic analysis of multi-day scenarios, such as extreme cold weather, is useful for understanding the effects of such conditions on the gas system. Such analysis can be informative to demonstrate how system stress could cause cumulative curtailment to non-core EG customers on subsequent days. However, multi-day hydraulic analysis may not be informative for reliability planning because of a proliferation of combinatorial scenarios and extreme specificity of the results. The value of insights from multi-day analysis is questionable because of the many ways to examine alternating days of various levels of load and the uncertainty in timing between market and operational decisions.

For their hydraulic analysis, the SoCalGas engineers initiated the iteration procedure using a scenario that represents the 1-in-10 year winter day design standard that corresponds to conditions preceding the Aliso Canyon facility outage [5]. The initial results showed that line pressure would drop significantly, such that SoCalGas system controllers would likely issue curtailment orders. The critical low pressure conditions occurred in the LA Basin and also at the Moreno station, so that curtailments to SDG&E would be likely.

After the iteration procedure, results showed that a 4.7 BCF load level is the maximum that the system is able to support and also recover line pack at the end of the day in the three areas of the system. This utilization level assumes no other outages or contingencies; however, as in the Summer Assessment, this is a conservative estimate of the maximum system capacity that accounts for uncertainties and operational factors. For the system model that SoCalGas has implemented in Synergi USM, it may be possible to maintain system pressures and line pack in the LA Basin while accommodating a higher system-wide utilization, but we note that it is crucial to consider when and where the offtakes from the system occur when estimating capacity.

Because the geographic distribution of customers determines the ability to service them under high load circumstances, it is important to examine conditions localized to the LA Basin and San Diego, as suggested in the recommendations below. The actual maximum utilization obtained from the hydraulic analysis assumes, by definition, precise actions by the gas control operator, including predictive actions to preempt pressure drops by using flow forecasts. As explained previously, this assumption cannot be made, given the tools and information available to gas controllers.

As described in our review of gas system operations and hydraulic modeling methodology, many factors affect transport capacity of a system consisting of pipelines and storage facilities under transient conditions. It is not reasonable to expect all of these complexities to be reflected in a single firm number for total system load. **The maximum load level estimate obtained by SoCalGas is intended to be a reasonable, conservative estimate of system utilization under expected high load conditions, supported by a transient hydraulic analysis that accounts for operational procedures used by the gas control department.**

Based on our understanding of the uncertainties and human factors involved, it is appropriate to use the 4.7 BCF number as a conservative estimate, but it is not a firm threshold technically. We believe that, although there is a statistically evaluated probability of a certain number of days with curtailments based on the analysis, the actual number of such days will be somewhat lower than this conservative estimate because of improved coordination, tighter supply balancing rules, and other Action Plan mitigation measures. Again, this conclusion comes with the caveat that unplanned outages or required maintenance could lead to decreased capacity. Thus, there is a possibility of curtailments even if the system-wide utilization is only 4.3 to 4.5 BCF, depending on timing of necessary maintenance outages and possible supply imbalances. The location and scale of any curtailments depends on the location and severity of any contingencies, so the Action Plan Team cannot quantify the probabilities of different levels of curtailments based on hydraulic analysis alone. Further analysis to estimate these probabilities is underway in cooperation with the members of the Action Plan Team. We note that enforcement of balancing rules reduces the uncertainty in statistical analysis of historical load data in relation to capacity estimates obtained from hydraulic analysis.

4.2 Review of Modeling Outcomes

The most critical concern for the winter season is the availability of the reserve in the Aliso Canyon storage facility. Using the gas stored in Aliso Canyon is very important to reducing the risk of gas curtailments and electrical service interruption this coming winter. Because in the past the Aliso Canyon facility has provided a large reserve supply of gas in the winter, SoCalGas was previously able to supply the LA Basin with that supply while servicing areas outside of the LA Basin with flowing supplies from pipeline interconnections. Without this reserve available, SoCalGas will have to choose whether to maintain service to their peripheral customers or to supply those within the basin.

To evaluate the risk of curtailment to EG customers, the Action Plan Team will need to perform a risk analysis based on the adjusted hydraulic modeling done for the Winter Assessment. Based on our study of the Summer Assessment curtailment risk analysis, we recommend that SoCalGas could improve their probabilistic framework for statistical analysis of historical load and outage data. We note that given the significant and ongoing changes to regulations regarding SoCalGas balancing requirements and operations, studies using historical data can only provide limited insights. Nevertheless, when historical data analysis is relevant, examining more scenarios and categorizing historical data by impact level could provide a more informative estimate of curtailment risk at different levels of impact, i.e., expected level of curtailment to EG customers in the LA Basin.

5 Findings and Recommendations

5.1 Findings

The following findings are the result of the preceding review and assessment of all available and relevant information.

- SoCalGas is not operating Aliso Canyon because of a leak on one well and the facility will not be in service for some time until an Action Plan is completed and SoCalGas is allowed to reopen the facility.
- Aliso Canyon's storage capabilities have been reduced to 15 BCF to mitigate damage and danger caused by the leak.
- The technology used to assess the summer load capabilities of the system with and without the Aliso Canyon facility is DNV-GL's Synergi USM, a software application for detailed transient analysis of pipeline systems.

- The software used by SoCalGas is widely accepted as meeting the industry standard to accomplish the modeling and projections required by this situation.
- The method in SoCalGas' initial report appears to be adequate for estimating the availability of gas and assessing the potential for curtailments.
- The Aliso Canyon facility is an integral part of the SoCalGas system, without which the system cannot function at maximal utilization or handle potential shortages of gas in the LA Basin and other areas.
- The method employed by SoCalGas to assess its system capacity under transient conditions reflects a full utilization of available software and appropriately accounts for operational factors.
- Maximum SoCalGas system capacity estimates for given scenarios are appropriate.
- No modifications to the hydraulic analysis methodology are needed.
- The method used for statistical risk assessment should be evaluated for potential changes because of new operating conditions.
- The statistical analysis framework used for the Summer Assessment can be improved with respect to categorizing combinatorial factors related to the impacts of unplanned outages that could affect the risk of curtailment.
- The risk assessment method could be evaluated for changes to incorporate more hydraulic analysis outcomes that reflect varying levels of impact on customers, and/or actual conditions such as multi-day events.

5.2 Recommendations

The review team recommendations are provided below.

5.2.1 Hydraulic modeling recommendations

- Examine the aggregate offtakes and deliveries to LA Basin to determine whether flows through city gates can be controlled to more closely balance loads within the LA Basin.
- Using two design days for hydraulic analysis to determine two sets of system stress criteria may provide a sensitivity analysis to better quantify curtailment risk at different impact levels.

5.2.2 Risk analysis recommendations

- For clarity, a table of all examined scenarios and corresponding probabilities should be provided to ensure consistency of the statistical risk analysis and to provide a clear understanding of the risk of curtailments according to frequency and impact.

- In the summer assessment, one set of criteria (>3.2 BCF offtake and >150 mmcfd supply shortfall) based on a single design day (September 9, 2015) was used to determine system risk. Given the unique situation in the LA Basin, it may be prudent to go beyond the industry practice of using a single design day to assess risk. We recommend that two sets of criteria, based on the hydraulic modeling scenario, be used to better categorize historical data with respect to impact (low and high) and risk (low and high).
- The reduction in risk that results from the mitigation measures could be estimated by, for example, performing risk analysis assuming flowing supply balance.

5.2.3 Action Plan recommendations

- An effective mitigation measure appears to be tightening of balancing rules to more closely align with standards for interstate pipelines that do not rely on storage facilities, and which are subject to daily balancing requirements [8].
- An effective mitigation measure appears to be the deferral of maintenance so that planned pipeline and storage outages do not occur simultaneously, especially during times of peak Winter demand, if possible.

6 REFERENCES

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