Blue Ribbon Commission on Bayou Corne and Grand Bayou Public Safety
Three-Day Working Session
Monday, April 29, 2013 – Wednesday, May 1, 2013
Key Outcomes Memorandum

PARTICIPANTS

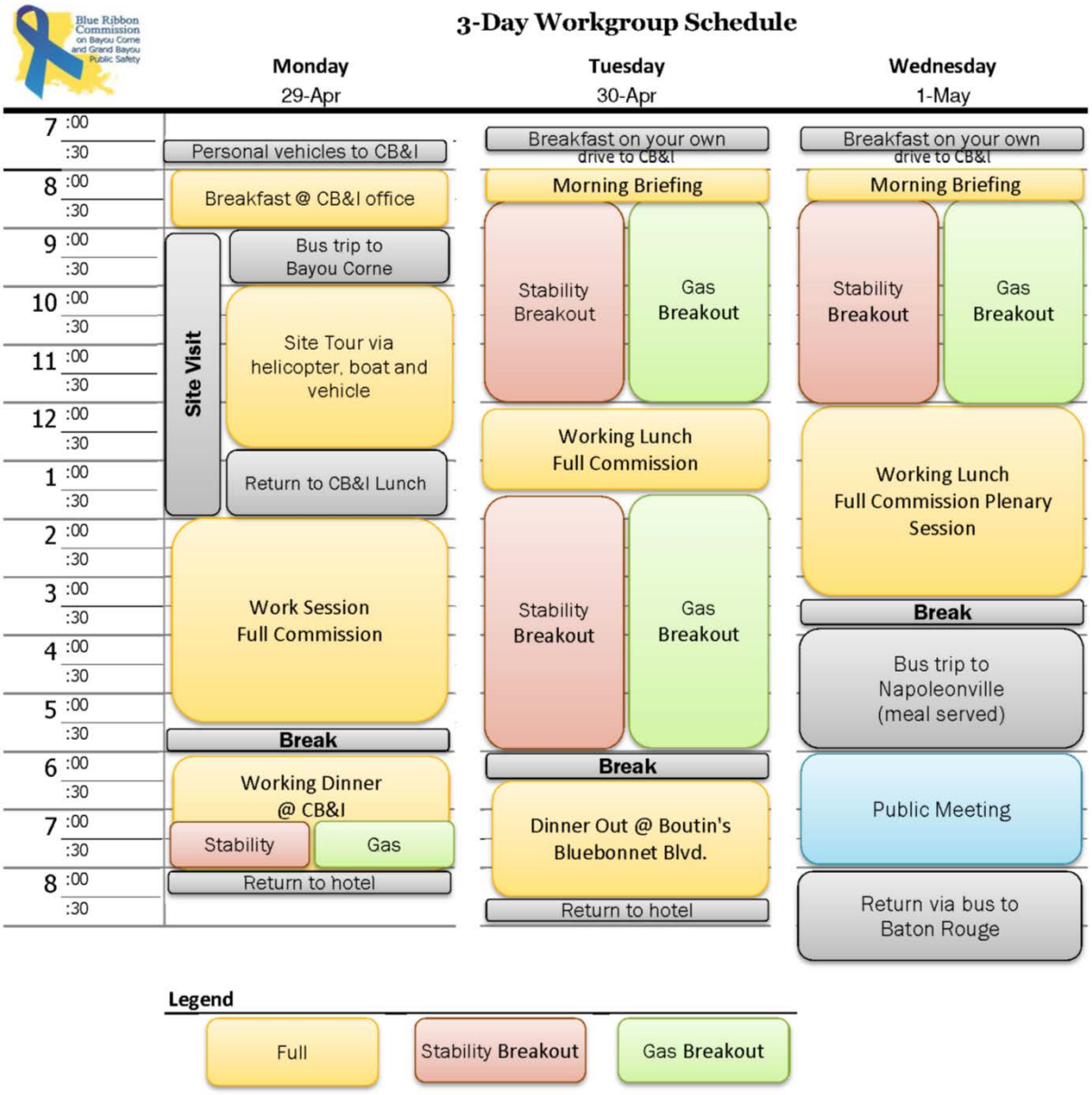
Blue Ribbon Commission (BRC) Members: Pierre Berest, Ph.D. (Ecole Polytechnique), David Borns, Ph.D. (Sandia National Laboratories), J.C. Chamberlain (Bayou Corne resident), Randall Charbeneau, Ph.D. (University of Texas-Austin), Doug Duncan (United States Geological Survey), Gary Hecox, Ph.D. (CB&I), James Linn, Ph.D. (former president of SMRI and former Underground Storage Technology Manager for Sandia National Laboratories), Denis O'Carroll, Ph.D. (University of Western Ontario), Will Pettitt, Ph.D. (Itasca Group), John Rogers Smith, Ph.D. (Louisiana State University), Thomas Van Biersel, Ph.D. (Louisiana Department of Natural Resources), John Voigt (Voigt Mining and Geotechnical)

BRC Members Unable to Participate: *Blayne Hartman, Ph.D. (Hartman Environmental Geoscience)*

Facilitator Team: Nick Speyrer (Speyrer Consulting), Perry Franklin (Franklin Associates), Risa Mueller (Franklin Associates), James Taylor (Franklin Associates)

About this Key Outcomes Memorandum: As will be our practice, the Facilitator Team has prepared and distributed this Key Outcomes Memoranda (KOM) to all BRC members as the summary of the abovementioned meeting. The purpose of the KOM is to summarize key decisions made, issues discussed, and the next steps identified. The KOM does not serve as a meeting transcript, nor will it typically attribute comments or suggestions to specific individuals. It does attempt to characterize areas of emerging agreement, and areas requiring future deliberation, as well as important next steps.

AGENDA AND SCHEDULE



MEETING MATERIALS

The Commissioners that were present received two documents when they arrived for the meeting.

1.) Welcoming Materials contained in an 18-page spiral bound booklet that contained:
   a. A letter of appreciation for participating that was signed by Stephen Chustz, the Secretary of the LDNR
   b. An overview summary and a detailed description of the three-day work schedule
   c. An assortment of documents containing comments received from members of the public, some of the Blue Ribbon Commissioners, and messages sent to members of the public who signed up for updates.

2.) A 61-page Bayou Corne Sinkhole Status Report compiled by CB&I that included text, figures, and tables. The document included geologic setting information, timeline, observations and findings made at the site over the previous seven months, and detailed discussions of scientific data related to the ongoing site investigation.

3.) A 4-GB USB thumb drive with digital copies of the Sinkhole Status Report and Report Appendices not included as part of the status report was distributed.

PRE-WORKING SESSION INTERACTION

Prior to the three-day BRC workshop, pre-working session meetings were held to facilitate the process. An initial meeting of the Commissioners was held on April 5, 2013 to provide an overview of the site conditions and brief the commissioners on their tasks and directives of the BRC Charter. This included a technical presentation of the site conditions to facilitate an understanding of the tasks and objectives of the BRC. The public was invited to attend this meeting. On April 11, 2013, an additional teleconference meeting was held with the Commissioners to provide logistics, schedules, and an overview and the expectations for the three-day workshop. In addition to these formal interactions, individual and group

communications were held with Commissioners via e-mail and phone to supplement the onboarding process and assist with preparations for the working session.

SITE VISIT

On the first day of the three-day workshop, the Commissioners visited the site on April 29, 2013, to get a first-hand understanding and observation of the current site conditions. The visit consisted of a brief situational update of the site conditions, a helicopter tour of the sinkhole and surrounding area and on-the-gound inspections of select bubbling sites in Bayou Corne, the Oxy Geismar No. 3 well pad, sinkhole, brine production wells, relief wells and gas flares, and pressure monitor wells. The visit ended with a tour of the Bayou Corne neighborhood.

The following presentations were made to the BRC during the 3-day workshop.

SITUATIONAL UPDATE BY DR. GARY HECOX

Dr. Hecox presented a technical update on April 29, 2013, including:

- Progress since April 5, 2013 update (3-D seismic, Texas Brine Company (TBC) salt seismic array, methane detected below homes)
- Cavern update (proximity of the other caverns in vicinity of Oxy 3, rate of rise of the Oxy 3 cavern floor, location of seismic events since July 2012, recent changes in cavern pressures)
- Sinkhole update (volumetric growth and recent subsidence)
- Gas venting (cumulative flare volume and rate, ORW well performance)

PASSIVE SEISMIC MONITORING PRESENTATION BY JULIE SHEMATA

Julie Shemeta with MEQ Geo Inc. presented to the BRC on the morning of Tuesday, April 30, 2013 via webinar to discuss passive seismic monitoring of the Bayou Corne area, both current practices and long-term monitoring goals. In addition, Ms. Shemeta presented information related to TBC's interpretation of results regarding their 3D seismic survey of the Oxy Geismar 3/Bayou Corne area.

PRELIMINARY ASSESSMENT OF 3-D SEISMIC DATA BY DON MARLIN

On Tuesday, April 30, 2013, Don Marlin presented an initial and preliminary assessment of the 3-D seismic survey initial data release that was provided to him by TBC and compared and contrasted his preliminary findings with the findings released by TBC. Commission members received in advance of the 3-Day Working Session a report produced by TBC detailing its consultant's interpretation of the results of the 3D seismic survey of the Oxy Geismar 3/Bayou Corne area. The report was titled "Bayou Corne 3D – 2013; 3d reflection seismic results in response to LADNR DIRECTIVE 2a, FIFTH AMENDMENT TO THE DECLARATION OF EMERGENCY AND DIRECTIVE" dated April 20, 2013.

SUBGROUPS

The Commission was divided into the following two subgroups to address specific tasks as outlined in the BRC Charter:

- Gas Migration and Removal Subgroup: This subgroup was to assess gas migration and removal in the MRAA and shallow subsurface. This subgroup included the following members: J.C. Chamberlain; Randall Charbeneau, Ph.D.; Doug Duncan, Blayne Hartman, Ph.D. (not present); Gary Hecox, Ph.D.; Denis O'Carroll, Ph.D.; and John Rogers Smith, Ph.D.
- Stability Subgroup: This subgroup was to assess the current and future stability of the cavern and the sinkhole, associated subsidence on the western side of the Napoleonville Salt Dome, and sinkhole containment, including the monitoring and other precautions that should be taken. This subgroup included the following members: Pierre Berest, Ph.D., David Borns, Ph.D., J.C. Chamberlain, James Linn, Ph.D.; Will Pettitt, Ph.D.; Thomas Van Biersel, Ph.D.; and John Voigt.
- Members of each subgroup were encouraged to crossover to the other subgroup and during the break-out sessions, several members did periodically crossover.

The BRC workshop was also attended by others to provide support to the Commission members and facilitate the meeting. Additional technical support was provided by other subject matter experts and individuals that were familiar with the site conditions. Franklin Associates managed the meeting topics and schedule to facilitate achieving the objectives of the workshop. The workshop included times when all the Commissioners from both subgroups were together to discuss common issues and breakout sessions for the individual subgroup members to discuss the topics concerning each of the subgroup's tasks. The approximate times of the group and subgroup meetings during the workshop are provided in previous meeting and schedule section (above).

BLUE RIBBON COMMISSION: AREAS OF EMERGING AGREEMENT REGARDING SAFETY BENCHMARKS

The Blue Ribbon Commission was charged with establishing appropriate remediation/monitoring benchmarks or conditions to ensure sustained public safety and to define additional data needed to assess current conditions and define remediation/monitoring benchmarks. During the three day working session, the commissioners agreed that the highest priorities are associated with the following topics:

- Higher priority safety issues for the public are related to methane and hydrogen sulfide, while stability issues are more long-term in nature. More specifically, the basic framework for recommendations related to issues associated with methane and hydrogen sulfide are as follows:
    - In order to lift the evacuation order, gas pressure in the MRAA and overlying aquitard has to be maintained at or below hydrostatic pressure.
    - Mitigation (such as barrier creation, sub-slab depressurization, ventilation) at each dwelling that is slab-on-grade or has enclosed crawl spaces needs to be defined as

second line of defense against gas accumulation. If conditions do not allow an effective mitigation system, indoor air monitoring is required.
    - Criteria need to be established for concluding that the threat from hydrogen sulfide gas is not a concern or is adequately controlled.
- 3D Seismic results and modeling is needed to establish and determine the timeframes necessary to meet safety benchmarks.
- Independent review of the 3D seismic results is required and critical for assessing the reliability of the data and interpretations derived from those data.
- Long-term monitoring programs for both gas and stability issues need to be developed and implemented. Commissioners specifically noted the need for uninterrupted flow of data in each type of monitoring, asking that contingency planning be in place to assure that these monitoring efforts continue regardless of situational changes in the area.

GAS SUBGROUP

The gas subgroup was tasked with assessing gas migration and gas removal from the Mississippi River Alluvial Aquifer (MRAA) and shallow subsurface, including a review of existing data and identification of additional data needs to establish benchmarks and determine when conditions are sufficiently met to recommend to Assumption Parish officials and the Unified Command Group that site conditions are safe for the evacuation order to be lifted and community members to safely return to their homes. Specific charge of the gas subgroup from the charter included addressing the following items:

1. Identify sources of shallow gas.
2. Determine the volume and rate of gas migration into the MRAA.
3. Identify reductions in pressure and volume required to prevent gas migration to surface.
4. Determine effectiveness of current vent well operations.
5. Establish monitoring and performance metrics to ensure gas poses no future threat to public safety.
6. Address concerns with hydrogen sulfide gas from the cap rock and deep formations.

Presentation by Dr. Jonathan Myers

Dr. Jonathan Myers presented a summary of pertinent information concerning the results of over 200 gas samples collected from the bubble sites, relief wells, water wells, shallow monitor wells, sinkhole, residential drinking-water wells, and sub-slab gas samples, including:

- Gas samples have been analyzed for standard gases, hydrocarbon gases, and compound specific isotope ratios to identify the gas compositions and source of the gas as biogenic, thermogenic, and/or a hybrid of these two sources.
- Sinkhole, cavern, and relief well gas samples have been identified as thermogenic, the residential and some of the shallow monitor well samples as biogenic, and the bubble sites and some of the shallow monitor well samples as thermogenic and/or mixtures of biogenic and thermogenic.

- Sub-slab gas samples at two residences indicate the source of gas at one residence is (landfill-like) biogenic gas and the other residence exhibits a mixed landfill-like biogenic/thermogenic source or oxidation of landfill-like gas source.
- Based on the gas data, the proposed model of gas migration indicates deep thermogenic gas is migrating upward into the MRAA via collapse zone and sinkhole and then into the overlying shallow aquitard through subsidence-induced fractures and other preferential pathways near the sinkhole. It is interpreted that this thermogenic gas is mixing with and sweeping shallow native biogenic gas with it in the aquitard resulting in lower percentages of thermogenic gas and higher percentages of biogenic gas emissions at the surface at greater distances from the sinkhole.

Presentation by Calvin Wiggs

A summary of information concerning the extent of gas migration and monitoring and ongoing gas recovery activities was presented, including:

- The extent of the gas in the MRAA based on the relief wells and bubble site locations covers an area greater than 2 square miles and with a volume estimated at approximately 45 million standard cubic feet.
- Documentation, methods used, and results of the tracking of the bubble site locations, bubble site intensities, and estimations of gas flow-rates from the bubble sites was summarized. Over 50 bubble sites have been identified and tracking of selected bubble sites indicates no significant changes in intensity since October 15, 2012. The gas emission rate from the bubble sites is estimated at 22,000 standard cubic feet per day (excluding the sinkhole as a source).
- The results of a previous EPA aerial survey for natural gas emissions and radiological survey indicated neither gas emissions nor radiological sources were identified.
- The status of operation and maintenance (O&M) of the observation relief wells (ORWs) indicate the well construction and O&M activities need to be better documented and tracked to determine the effectiveness of the ORWs.
- Potential data gaps were identified with respect to the geology of the MRAA (gravel zones) and permeable zones in the overlying aquitard that need to be filled to better understand the site conditions and potential pathways for gas migration.

Areas of Emerging Agreement:

The Gas Subgroup agreed to the following items:

- Reduction of gas pressure in the MRAA and overlying aquitard is the primary factor in establishing monitoring and performance metrics to ensure gas poses no future threat to public safety.
- In order to lift the evacuation order, gas pressure in the MRAA and overlying aquitard has to be maintained at or below hydrostatic pressure.
- Independent review of the 3D seismic results is required and critical for assessing the reliability of the data and interpretations derived from those data.

- Independent review of the raw 2013 3-D seismic data is a critical component of BRC evaluations. This review will be used as a key subsurface data component for answering some of the major outstanding questions, though initial analyses will be conducted concurrently in the interest of time.
- Site-specific multi-phase flow data and modeling are the critical next steps in terms of gas migration/vent well performance data collection and identify actions to be taken to meet benchmarks and time to completion.
- Additional, higher-quality gas migration and gas removal data are needed to develop the safety benchmarks (e.g. hydrostatic) and monitoring metrics for the site, and enhance the remediation plan.
- Current gas removal and formation pressure data are not adequate for evaluation of current site conditions and the effectiveness of the gas removal operations.
- Improved monitoring of the sinkhole water levels is necessary.
- Better documentation on the construction and current operation and maintenance of the existing relief wells is needed to evaluate their effectiveness and determine the potential for use of alternative gas recovery technologies to determine the most effective approach for removing gas and reducing gas pressures in the MRAA and overlying aquitard.
- There is a need for further hazard identification on the subject of hydrogen sulfide.
- Need to monitor and record both pressures and fluid levels in vent wells.
- Mitigation (such as barrier creation, sub-slab depressurization, ventilation) at each dwelling that is slab-on-grade or has enclosed crawl spaces needs to be defined as second line of defense against gas accumulation. If conditions do not allow an effective mitigation system, indoor air monitoring is required.
- Criteria need to be established for concluding that the threat from hydrogen sulfide gas is not a concern or is adequately controlled.

Areas for Continued Deliberation:

The Commissioners agreed that additional discussions need to be conducted on the following topics:

- The need for enhanced monitoring of the sinkhole conditions, especially gas bubbling conditions and water level monitoring in the sinkhole. The methods for this monitoring need to be established.
- Overall recognition of potential issues with how the relief well installation technology being used by TBC (rotosonic drilling) may be creating conditions that are inhibiting the removal of gas and additional thought needs to be given on how to remedy this situation using an improved well design and/or installation methods.
- Identified that further analysis may be needed to address potential concerns related to the occurrence of hydrogen sulfide gas and the origin of hydrogen sulfide gas in Oxy Geismar No. 3. Identified that further analysis is required to design, construct, and operate better vent wells to improve gas removal performance and reduce the potential for sand build up and water control.

- Identified that further analysis is required to evaluate the use of combined water and gas pumping to improve gas removal rates from the vent wells. Specific expertise may be needed to evaluate the viability of using multi-phase gas/water extraction systems to improve vent well performance.
- Investigate potential for collection and venting/producing migrating gas from deeper horizons.

Next Steps

- A list of the data needs that were identified by the gas subgroup of the Commissioners will be compiled and provided to the LDNR, the Governor's Office of Homeland Security and Emergency Preparedness (GOHSEP), and the Assumption Parish Office of Emergency Preparedness so that requests can be made to appropriate sources to obtain the data.
- Commission members will be reviewing and evaluating existing data as it is obtained.
- Ongoing meetings will be scheduled both as a full commission and follow-up focus group meetings. It is anticipated that at least two conference calls per month during May, June and July will be needed as the commission continues to move toward a final report with recommendations.
- A final report will be issued by the Commission following acquisition, review, and analysis of the identified additional data needs that are necessary for development of the criteria to establish benchmarks.

STABILITY SUBGROUP

The stability subgroup was tasked with assessing the current and future stability of the caverns and the sinkhole, associated subsidence on the western side of the Napoleonville Salt Dome and sinkhole containment, including monitoring and other precautions that should be undertaken to allow for the safe return to and long-term habitation of the evacuation area. Specific charge of the stability subgroup from the charter included addressing the following items:

1. Determine Effect Of Oxy 3 Cavern Collapse On Current & Future Stability
2. Develop Short And Long-Term Monitoring To Assure Stability Of Salt Dome & Caverns
3. Define Measures To Ensure Surface Releases Will Be Contained Within Bermed Area
4. Analyze Void Spaces For Threats
5. Evaluate Current/Future Damaged Areas For Threatening Subsidence
6. Identify Additional Monitoring Measures For Public Safety

Presentation by Dr. Will Pettit

Dr. Will Pettitt presented a summary of passive seismic monitoring at Bayou Corne, including:

- Reviewed the passive seismic monitoring performed since July 2012 using surface, shallow, and deep instrumentation.
- Two types of seismic events have been identified: "classical" MEQ (micro earthquakes) and VLP (very long period)

- Distribution of events–"shallow" (<1,500 feet) associated with sinkhole and "deep" associated with the Oxy 3 cavern.
- The current seismic monitoring system may not be able to detect deep VLPs.
- Shallow MEQs could be in sedimentary layers, cap rock, or top of salt or any combination of the three.
- Shallow MEQs are directly related to gas or fluid movement and are probably driven by elevated pore pressures.
- Deep MEQs likely in the salt around the upper ~400 feet of the failing cavern and may extend out between Oxy 3, Oxy 2, and Oxy 1.
- Deep MEQs cannot be located using the surface array.
- Deep MEQs could be caused by mechanical failure and/or elevated fluid pressures
- A new microseismic array is being installed in the salt to better image deep MEQs.

Presentation by Terje Brandshaug

Terje Brandshaug presented a summary of geomechanical model investigations to evaluate the ground response surrounding the collapse of the Oxy 3 cavern, including:

- Analytical model used to reconcile the volume balance between the accumulated debris volume in the cavern and the sinkhole
- Numerical model of a single cavern using FLAC3D to estimate the location and size of the DRZ that propagates from the collapse to the ground surface.
- Numerical model using PFC2D to evaluate fragmentation of the DRZ and the possibility of large void spaces being created during development and propagation of the DRZ.
- Numerical model of multi caverns using FLAC3D to evaluate the mechanical stability and interactions between caverns when accounting for creep in the salt and changes in ground stresses from the presences of the propagating DRZ.
- Analytical model of multi caverns using FLAC3D to predict the width and depth of a potential sinkhole in the event that Oxy 1 should fail in a similar manner to Oxy 3
- Numerical model of multi caverns using FLAC3D to evaluate the mechanical stability of Oxy 1 for conditions where the salt/sedimentary rock contact is in close proximity to Oxy 1.
- Numerical model of multi caverns using FLAC3D to evaluate the long-term ground surface subsidence associated with the collapse of Oxy 3.

Presentation by Brad Barré

A summary of the site-specific details regarding the Oxy 3 cavern and data collected since the formation of the sinkhole was presented, including:

- Details of Oxy 3 well (casings, depths, period of operation)
- Pre-collapse shape/size of Oxy 3 cavern
- Casing diagram before and after milling
- Pressure loss during failed MIT
- Plug and Abandonment diagram and records

- Post-collapse shape/size of Oxy 3 cavern
- Rate of infilling
- Bottom solids sample analysis
- Tubing and casing pressure record
- Pressure recovery after venting
- Sinkhole size and depth over time
- Tilt/inclinometer/water level station locations
- Estimated unstable area
- Shapes of caverns near Oxy 3
- Recent pressure record from nearby caverns

Areas of Emerging Agreement:

The Stability Subgroup discussed the multitude of reports already received from various entities which provide a great deal of information on the existing cavern structures and subsidence in the area. This subgroup agreed that:

- Independent review of the raw 2013 3-D seismic data is critical for answering major outstanding questions regarding the collapse and formation of the sinkhole and subsequent stability issues.
- Subsidence, seismic (both shallow and at depth), cavern pressure, and nearby cavern shape/size monitoring, were deemed suitable ongoing metrics for evaluation of current and future stability of the impacted area. Commissioners specifically noted the need for uninterrupted flow of data in each type of monitoring, asking that contingency planning be in place to assure that these monitoring efforts continue regardless of situational changes in the area.
    - It was the consensus of the Stability subgroup that the microseismic array, installed in the 3,000 foot geophone well in the salt, must be operational for the indefinite future. This operational requirement includes ongoing repair and maintenance of geophones and cables, potential removal and replacement of the geophone string, and potential upgrade of the array in the future.
- The Commissioners agreed that specific additional/better subsidence, seismic, and cavern data is needed to develop the monitoring metrics and safety benchmarks for the site.

Areas for Continued Deliberation:

The Stability Subgroup continues to pursue concurrence on details regarding the physical mechanisms of the failure and their effects on stability, including:

- Size, shape, and propagation mechanism of the DRZ.
- Influence of domal sheath on the DRZ.
- Mechanism for cavern filling.
- Source for pressure in the cavern and what is driving pressure changes.
- The pathway for brine outflow.

Next Steps

- The Commissioners expressed a desire to have better data in a number of subject areas. A list of the data needs that were identified by the Stability Subgroup will be compiled and provided to the LDNR, the Governor's Office of Homeland Security and Emergency Preparedness (GOHSEP), and the Assumption Parish Office of Emergency Preparedness so that requests can be made to appropriate sources to obtain the data.
- Commission members will be reviewing and evaluating existing data.
- Ongoing meetings will be scheduled both as a full commission and follow-up focus group meetings.
- A final report will be issued by the Commission following acquisition, review, and analysis of the identified additional data needs that are necessary for development of the criteria to establish benchmarks.

PUBLIC MEETING

The three-day BRC workshop culminated with a public briefing that was held in Napoleonville, Louisiana on May 1, 2013. The meeting agenda included a summary of the Commission's assigned tasks for the gas and stability subgroups and an update on the current site conditions that was followed by period of questions for the Commission members from the audience. Dr. Denis O'Carroll presented the Gas Subgroup's update and Dr. Will Pettitt presented the Stability Subgroup's update. Dr. Hecox presented a situation awareness update. At the request of Assumption Parish, the meeting also included an update from TBC on the current situation, the preliminary results of the recently acquired 3-D seismic survey, and an update on the status of the home buy-out/settlement program.

BLUE RIBBON COMMISSION NEXT STEPS

In the short term, the next step for the BRC is to continue to work together to define the schedules and technical scopes of work for evaluation of the data to address the identified tasks and additional data needs. Additional details on the next steps for each subgroup are provided in the "Next Step" sections under the previous subgroup section discussions.

In the long term, the Commissioners will evaluate the historical and newly acquired data to establish benchmarks and determine when conditions are sufficiently met to recommend to Assumption Parish officials and the Unified Command Group that site conditions are safe for the evacuation order to be lifted and community members to safely return to their homes.