



ALASKA CALIFORNIA FLORIDA MID-PACIFIC NORTHEAST NORTHERN ROCKIES
NORTHWEST ROCKY MOUNTAIN WASHINGTON, D.C. INTERNATIONAL

January 15, 2014

VIA ELECTRONIC FILING

Ms. Kimberley Bose, Secretary
Federal Energy Regulatory Commission
888 First Street, NE
Washington, DC 20426

Re: Arlington Storage Company, LLC, Seneca Lake Storage Facility Gallery 2 Expansion Project, Docket CP13-83, Expert Geologist Report

Dear Secretary Bose:

On behalf of Gas Free Seneca, we are submitting the attached report authored by a geology expert, Dr. H.C. Clark, on a number of significant concerns regarding the geology of the area of the proposed Gallery 2 Expansion Project and the propriety of storing natural gas in the caverns comprising Gallery 2. We urge the Federal Energy Regulatory Commission to review the attached submission carefully, ensure that the questions raised by Dr. Clark are addressed by the applicant, and revisit the premature conclusion contained in the Environmental Assessment that storage of nature gas in these caverns is safe.

Sincerely,

Moneen Nasmith
Associate Attorney

January 15, 2014

Moneen Nasmith
Earthjustice
48 Wall Street, 19th Floor
New York, NY 10005

Dear Ms. Nasmith:

Earthjustice asked me to review the Arlington Storage Company LLC (Arlington) proposal to store compressed natural gas in bedded salt caverns in the Watkins Glen brine field adjacent to Seneca Lake in New York. The review included public documents obtained by Earthjustice and literature and data from other projects in the area. In addition, Earthjustice arranged for me to examine confidential material Arlington provided to the Federal Energy Regulatory Commission (FERC) for the development of its own Environmental Assessment (EA); comments about this part of the review are provided separately and confidentially to FERC. The following report is based solely on the publicly available documents and does not contain any information from the confidential materials provided by Arlington.

I have been involved in a number of environmental situations related to salt geology, salt caverns and associated elements; these include the Hockley, North Dayton, Mont Belvieu (Barbers Hill), Daisetta, Stratton Ridge, Boling, Long Point and Blue Ridge salt domes in Texas. My Ph.D. in geophysics is from Stanford University, and I taught geology and geophysics at Rice University for many years (see Vita attached). All geologists are interested in Appalachian geology and I am particularly familiar with the Seneca Lake region, since I had previously reviewed area geology related to a proposal by Finger Lakes LPG Storage, LLC to store liquid petroleum gas (LPG) in caverns near the Arlington site.

I. Background

Arlington plans to store and cycle compressed natural gas in two connected caverns, approximately 2,500 to 2,900 feet below the ground surface. The caverns were created by dissolving salt around and between wells drilled into the section of Silurian interbedded salt and rock; thus, Well 30 became Cavern 30 and Well 31 became Cavern 31 of the Watkins Glen brine field. These two caverns are more than a half-century old, they started as a solutioned brine mine, then were used for storage of LPG, left idle, then were plugged and abandoned for decades, and now are to be used again as new wells have been drilled to re-enter each cavern and the connection between. That extended history alone indicates that calls for special scrutiny must be heeded, as these are not new caverns that were optimally engineered for the express purpose of storing and cycling compressed gas.

There also are geologic features involved with these specific caverns that raise additional concerns about their viability as storage facilities—and these features and concerns are not

addressed in the public part of the Arlington proposal or the FERC EA. For one, both caverns are cut by a bedding plane thrust fault involving a significant disturbed zone. It was this horizontal thrust fault zone that enabled the hydraulic fracturing connection between the original wells (Wells 30 and 31) and thus a pathway to inject fresh water in one well and withdraw solutioned brine from the other: creating the original brine mine system of Caverns 30 and 31, now known as Gallery 2. In addition to the thrust faulting through the section, the Gallery is further complicated by a cavern roof collapse that occurred in Cavern 30 in the sixties when a fault block weighing more than 400,000 tons fell from the roof to the floor of the cavern—then being used for propane storage. Finally, a major strike-slip tear fault, the Jacoby-Dellwig Fault, cuts the geologic section vertically in a north-south direction between Cavern 31 and the next cavern to the east, Cavern 28. It was along this major strike-slip tear fault path that brine flowed to the surface during a hydraulic fracturing attempt at Well 29, a well near the fault and also near these caverns—and situated similarly to Cavern 31 relative to the tear fault.

Clearly, as part of the consideration of the propriety of storing compressed natural gas in Gallery 2, obvious site-specific questions presented by the cavern geology and area faulting must be answered. These questions include: Will the roof of Cavern 30 collapse again? What is the areal extent of the thrust fault? Does the thrust fault serve as a pathway beyond the caverns? Could material from the caverns interact with the tear fault? Are there other faults related to the thrust fault and tear fault that might serve as pathways or zones of weakness? How has half a century of history affected the ability of these caverns to contain compressed natural gas? The list goes on. However, concerns created by these cavern conditions have not been addressed by Arlington or recognized by regulatory reviewers. Moreover, Arlington's answers to the FERC Requests for Engineering Data that are related to these issues are incorrect or incomplete and do not anticipate or answer the obvious concerns created by geology and the caverns' history.

The paragraphs that follow discuss the publicly available information about the project geology, and where Caverns 30 and 31 of the Watkins Glen brine field are concerned, there is a lot of it. Geologic storage is the basis of Arlington's proposed compressed natural gas project at Seneca Lake, and the geology here is not a simple homogeneous, isotropic salt mass; it is a combination of rock and salt layers, folded, fractured and faulted. This particular well system began with the drilling of Well 30 in 1958, followed by Well 31 in 1961. A second attempt at hydraulic fracturing between the two wells was successful, and the two wells, now caverns, and the fracture-created cavity between were solution mined briefly for salt. The system was used for LPG storage from 1964 to 1984. In 1968, Well 45 was drilled into the connection between Caverns 30 and 31 and was used to inject and withdraw brine as LPG was cycled in the system. All three wells were plugged and abandoned in 1989 and left as brine-filled cavities from plugging until now. It is within this geologic and operational history framework that a meaningful evaluation and monitoring plan must be developed.

II. Charles Jacoby's publicly available articles describe the development of Caverns 30 and 31.

Charles Jacoby, a geologist who worked for the Arlington predecessor company that created the original Wells 30 and 31, along with colleagues, wrote a number of articles about the salt geology at Watkins Glen, its hydraulic fracturing behavior, the creation of and problems related to cavern development, regional tectonism and Appalachian structural geology, and used site-specific data from Wells 30 and 31 often in his analyses and writing. His papers published in journals and international symposia proceedings included discussions of regional structural development, regional strike-slip tear faulting, thrust faulting found in the various wells, faults and fractures found in these wells and, related to this Appalachian system, the presence of fractures, the role of salt, and a variety of complexities of the involved rock layers. Jacoby's papers were provided to me by Earthjustice and were readily available online.¹

Jacoby also wrote about the hydraulic fracture procedure connecting Wells 30 and 31, about their development as caverns, and then their use for LPG storage. The Jacoby paper titled, "Storage of Hydrocarbons in Cavities in Bedded Salt Deposits Formed by Hydraulic Fracturing" (1969) outlines the development of Arlington Gallery 2, and includes several geologic cross-sections showing the changes in these caverns through the sixties. Jacoby details that Wells 30 and 31 were drilled for brine production as part of an east-west sequence that included Wells 27 and 28. As solutioning took place in the salt section of these wells, they became the caverns of the same numbers. While these wells, their geology and hydraulic fracturing behavior are part of several papers written by Jacoby and co-authors, in his 1969 paper, Jacoby used Wells 30 and 31 together with Wells 27 and 28 and nearby wells to illustrate cavern development and to caution about the role of geology and thrust faulting in hydraulic fracturing and then in cavern development.

The four cross-section figures in the Jacoby 1969 paper illustrate the early history of this part of the brine field. All four wells were cored and geophysically logged as they were drilled, providing the stratigraphic and structural framework of each cross-section. His first cross-section (his Figure 1, attached as Exhibit 1) shows the pre-cavern geology interpreted from the logs and cores. Here, thrust faulting has pushed beds of salt and rock up and over one another, resulting in repeated sequences of several of the beds across the section.² The thrust fault noted in Exhibit 1 appears to continue to the east, though offset, within a Retsof salt bed sequence. In addition, faults oriented north-south, perpendicular to the figure and parallel to the west side of Seneca Lake and with vertical and horizontal offset are shown between Wells 31 and 28 and

¹ The papers previously were available online but have been taken down in the last few months. The symposia volumes, AAPG Bulletins, and AIME publications are available in a number of college libraries and may be found through Worldcat.

² On Exhibit 1, the notation "Thrust Fault" between wells 30 and 31 points out one thrust fault, the fault that enabled the hydraulic fracture connection between Wells 30 and 31.

between 28 and 27.³ The fault shown between Well 31 (the easternmost cavern of Gallery 2) and Well 28 (the westernmost cavern of Gallery 1) is known as the Jacoby-Dellwig Fault,⁴ a major strike-slip tear fault with vertical displacement affecting the salt section as well as 1,200 feet of horizontal offset. The fault offsets and repeated section, or the encounter of the same sets of beds of rock and salt apparently stacked on top of one another in a wellbore and resulting from thrust faulting, shown on the cross-section were developed by correlating rock cores across this section as well as correlating geophysical logs from these wells and wells nearby (Jacoby, 1965, Jacoby and Dellwig, 1973). This work was a valuable contribution to Appalachian geology and the understanding of the complex role of faulting in the salt section. Moreover, the major strike-slip tear fault, together with the complex thrust faulting played a significant role in the determination of hydraulic fracturing direction and cavern development behavior in this part of the Watkins Glen brine field. Jacoby wrote as they observed a variety of hydraulic fracturing behavior: “Gradually, there emerged a theory of a double system of faults which controlled the direction of flow of our fracturing fluid.” (Jacoby, 1965) A map from the Jacoby and Dellwig 1973 paper (their Figure 3 attached as Exhibit 2) illustrates the orientation of the cross-section and the position of the wells with annotations from the same paper about hydraulic fracture connections and location of the Jacoby-Dellwig fault.

The Jacoby-Dellwig Fault also is important in that it and related faulting apparently can serve as a conduit. The 1973 study states: “Well 29: During fracturing, a flow of brine **at the surface 0.5 mi. to the north** must certainly be interpreted as the result of movement of brine from the well along the tear fault.” (Jacoby and Dellwig, 1973) (emphasis added). So, Jacoby’s first cross-section establishes the presence of both thrust faulting through Wells 30 and 31 and the Jacoby-Dellwig Fault next to them and between Galleries 1 and 2.

The next cross-section from the Jacoby 1969 paper (his Figure 2, attached as Exhibit 3) shows the situation in June of 1964. Initially, Well 30 and Well 31 were both hydraulically fractured at the lower B2 salt layer, but the process failed to connect the two wells by way of the lower B2 salt (see near-well fracture at wellbore depicted at the lower B2 of Well 31). “The connection between the two wells was finally completed in the **fault zone** in the **overthrust block** of B2 salt.” (Jacoby, 1969) (emphasis added). Jacoby wrote extensively about using an understanding of this thrust fault geology to design hydraulic fracture programs and to take advantage of a weakened fault zone path to a target well. And with regard to these wells, he notes: “At the points on the cross-section where faulting has been confirmed, fault zones several feet in thickness are present.” (Jacoby, 1969) Following fracturing, communication was established between Wells 30 and 31 and Gallery 2 solutioning development began. The cross-section of Jacoby’s Figure 2 shows that the two connected caverns were being used for LPG

³ “Tear Fault” in Exhibit 1 points to the fault between Wells 31 and 28, there is another fault between Wells 28 and 27.

⁴ See, e.g., New York State Electricity and Gas, Compressed Air Energy Storage Final Report (Dec. 2011) available at <http://www.smartgrid.gov/sites/default/files/doc/files/Exhibit%2013.10%20Geology%20Part%201.pdf>.

storage in 1964 as shown by the propane legend symbol in the upper part of Cavern 31 and at the top of Cavern 30. The vertical extent of the hydraulically fractured fault zone connecting Cavern 30 to Cavern 31 is discussed only qualitatively in the paper, but the areal extent of the hydraulic fracture connection must be significant since publicly available mapping⁵ shows Well 45 to be offset from a straight line connecting Wells 30 and 31, and it intercepts the fractured fault zone connection and will be used in the Arlington plan as a monitor well. While on the subject of the hydraulically fractured connection between Wells 30 and 31, there is a cross-section in another Jacoby paper that shows a connection between Well 30, Well 27, and Well 28 (Jacoby, 1961, Figure 2 attached as Exhibit 4). That paper is a discussion of the brine mining process and the wells are not discussed specifically. If there is or was a connection, that would connect Gallery 2 to Gallery 1, and this would be a significant concern. Arlington must have all the original records, and it could provide that information from the original source to resolve this question. The connection by way of a fault zone that affects both Well 30 and Well 31 and beyond, and perhaps way beyond, is not discussed in the public Arlington documents that I have reviewed.

By July of 1967, the date of the next cross-section, both Gallery 2 (Cavern 30 connected to Cavern 31) and Gallery 1 (Cavern 27 connected to Cavern 28) were being used for LPG storage. (Jacoby Figure 3, attached as Exhibit 5). By this time, the caverns had expanded, leaching salt and accumulating rubble where interbedded unsupported rock layers had fallen. Jacoby depicts the four caverns filled with a combination of brine, propane, and rubble. In perhaps the most striking revelation of this review, there is a large intact block in Cavern 30 with a suspicious jig-saw puzzle fit to the cavern outline above and noted as “Fallen Rock Mass” on the cross-section. That is, Cavern 30’s roof failed, and the rock fall was dramatic. This is explained by Jacoby as a lesson to use saturated brine in cycling product out of the caverns:

Unless saturated brine is used continually in recycling the product, there is distinct possibility of undermining **fault blocks**. Illustrated in (Jacoby) Figure 3 is a large block of rock calculated to weigh over **400,000 tons** which **fell from the roof** even with the use of saturated brine.

(Jacoby, 1969) (emphasis added). Perhaps anticipating, even then, an attempt to discredit this cavern roof rock fall event, he went on to say: “This portion of the cavity was outlined by using sonar surveying equipment.” The parallel between the fault block cavern roof failure in Cavern 30 and the roof collapse in Cavern 58 is obvious. It is clear that researchers working on caverns in the Watkins Glen brine field have encountered cavern roof failures and attributed these failures to fault situations. It is essential that cavern roof failure in the Watkins Glen brine field be recognized.

A cavern roof failure of this magnitude, so fully documented (there may even be a seismic record), offers a remarkable opportunity to test geomechanical modeling. A

⁵ See, for example, Draft Supplemental Environmental Impact Statement, Finger Lakes LPG Storage, LLC, LPG Storage Facility, figure 4 (Aug. 2011).

mathematical model about the future behavior of these caverns was commissioned by Arlington and appears to predict that the caverns will be stable in the future. However, a mathematical model is only useful if it can actually predict that something will or will not happen, or has happened in the past. Can Arlington's mathematical model predict this cavern roof failure? Everything about this cavern at the 1967 point in time was known. The dimensions of the cavern including the open roof span, the dimensions of the block, the properties of the materials (from Wells 58 and 59 and Wells 30A and 31A) and detailed cavern cycling history are well known. Jacoby's 1969 paper calls this a "fault block" so there must be information in Arlington's files⁶ about measurements concerning the fault(s) involved. The mathematical model used in the geomechanical study for the Arlington project must include these conditions in the model to show how the model can predict failure of the cavern roof. This cavern roof failure, and the mathematical model's ability to predict the failure, represents an opportunity to test the model, and this validation should be required. I did not see anything in my review of the public documents that recognized the cavern roof failure involving a 400,000-ton fault block, and the Jacoby 1969 paper was not listed in the references reviewed in the publicly available portions of the Arlington Suitability Report, the Arlington Resource Report 6 documents, or the FERC EA.

The final figure of the Jacoby paper describing the development of Gallery 2, and Gallery 1 as well, shows the condition of the caverns in March, 1968 (attached as Exhibit 6). By this time, there was a small amount of propane at the top of Cavern 30, propane at the top of Cavern 31, and propane in a part of Cavern 27 offset from that well—and on its way to becoming the subject of another Jacoby paper, "Recovery of Entrapped Hydrocarbons" (Jacoby, 1973), where he described the effort to drill an interceptor well to recover product in a part of Cavern 27 that had developed unintentionally and no longer was accessible by the original well. The directionally drilled interceptor well is Well 46 and the paper shows the cavern development significantly displaced west of the original Well 27.

In summary, the caverns and connection of Gallery 2 by the late sixties consisted of two irregularly shaped caverns (caverns that departed from the ideal cylindrical shape, which is the strongest geometry), connected by a solutioned channel created by hydraulic fracturing along a thrust fault that intersected both. Part of the irregularity was due to preferential solutioning into salt layers on the sides and resultant rock layer collapse, but the preferential solutioning does not account for the elliptical shape of these caverns or for the fact that Cavern 30 is substantially offset from its solutioning well. Because of the fault block cavern roof failure, Cavern 30 also was significantly larger than Cavern 31. There is no public record about changes in these caverns since the late sixties. The Jacoby papers describe four areas of concern:

- Thrust faulting—extent, effect on these and nearby caverns, presence of additional faults and studies about the problem.

⁶ According to the publicly available part of Arlington's Resource Report 6, previous owners "produced well records as a result of their development procedure and maintained records."

- Jacoby-Dellwig major strike-slip tear fault—proximity to these caverns, role of fault as a transmission zone along its path, presence of related faults and fractures, effect of brine field history on Jacoby-Dellwig system
- Roof failure event at Cavern 30—400,000-ton fault block fall, extent of faulting involved, effect of roof failure, potential for future failure
- Age of Caverns 30, 31, and 45—historic changes in geometry, cavity condition, gas pathways, and zones of weakness, studies, and monitoring plan

Arlington and FERC do not address these issues. If Arlington wishes to use half-century-old caverns for compressed natural gas storage and cycling, rather than new ones engineered for that express purpose, then the issues that are a part of this history must be recognized and explicitly addressed.

III. FERC’s EA and Arlington’s submissions do not accord with Jacoby’s description and leave open numerous questions

The FERC EA and Arlington’s answers to Requests for Engineering Data posed by FERC would suggest a different picture of the cavern geology than the one developed by Jacoby for these specific caverns and shown in the diagrams from his 1969 paper.

A. Deficiencies in FERC’s EA

First, consider the FERC EA. The FERC EA makes several summary conclusions about the geology of the site area and the Caverns 30 and 31. The EA references Jacoby’s 1963 paper and Jacoby and Dellwig’s 1973 paper, indicating a familiarity with their work, but no concern related to the subjects of these papers and no mention of the 1969 Jacoby paper relating specifically to Caverns 30 and 31. The EA is brief and generally dismisses the concerns expressed by commenters. Key among these concerns are questions about geology, seismicity, and faulting.

i. Geology Questions

The EA geology section begins with a general description of the geology of the site area including its stratigraphy and structural geology, acknowledging the area is “intensely folded.” Intensely folded is an understatement, the region is affected by Appalachian orogenic thrust faulting and the tear faulting, normal faulting, high angle faulting, folding, fracturing, and other associated deformation related to this “intensely folded” geology. Moreover, FERC should have recognized that every element of a geologic repository, particularly at this set of caverns, deserves detailed review for the reasons outlined in Jacoby’s writings.

ii. Seismicity Questions

Commenters asked about the possibility of damaging earthquakes. Their concern is certainly understandable, based on recent quakes in the region and Larry Sevenker’s interpretation that an earthquake triggered the cavern roof failure at Well 58, a part of the nearby

Finger Lakes project.⁷ The EA response characterized the seismicity of the region and described low magnitude earthquakes and left it at that. FERC should have expanded on the citizen comments raising this issue and recognized that seismicity is a legitimate concern in the Watkins Glen brine field; in that area, low-magnitude seismic events (both events involved with the overall regional tectonic framework and events related to these caverns and those nearby) tell about stress in the subsurface. Seismic events provide information about things about to happen, and a sensitive seismic network capable of measuring these events should be part of a comprehensive monitoring plan for this project and those caverns nearby. A subsurface microseismic network has recently been installed in the Napoleonville Salt Dome where a salt cavern collapse threatens to affect nearby caverns and, already, numerous microseismic events related to movement in the salt and caverns there have been recorded, analyzed, and used to inform the plan for safety at this salt cavern site.⁸

iii. Faulting Questions

The EA gives faulting in the Gallery 2 area short shrift, and responds only to commenters' concerns about the possibility of a large strike-slip fault passing through one of the caverns—and addresses that concern by noting that the Jacoby-Dellwig Fault is east of the caverns. By discussing the Jacoby-Dellwig fault alone and dismissing it as not passing through a cavern, the reviewers miss an opportunity to address the concerns raised by the thrust faulting through the caverns, the faulting involved with the failed cavern roof and the more than 400,000-ton fault block that fell to the floor of the cavern during cavern operation. The Jacoby-Dellwig Fault does not go directly through a cavern, but it is intimately involved with the geologic issues that the EA should address.

The FERC EA is general and fails to confront the several geologic issues presented by publicly available information. FERC should re-visit this public information about problems with these caverns and ask for, and make public for review, the data that must be available in Arlington's records about these caverns.

B. Deficiencies in Arlington's Submissions to FERC

While the EA is all too brief for a project focused on geologic storage and fails to recognize the very real problems of the caverns, perhaps inadvertently, the publicly available portions of Arlington's Suitability Report,⁹ Resource Report,¹⁰ and its responses to Requests for Engineering Data posed by FERC create a far more serious situation. The difficult questions

⁷ Fax from NY Department of Environmental Conservation Division of Minerals (Feb. 13, 2001), Letter from Larry Sevenker, to Frank Pastore (Oct. 17, 2003), Letter from Larry Sevenker (Jan. 15, 2013).

⁸ http://dnr.louisiana.gov/assets/OC/BC_All_Updates/BCPublic.Briefing.9172013.pdf, <http://lasinkhole.wordpress.com/tag/helicorder-seismic-activity-bayou-corne/>

⁹ A July, 2010, heavily redacted version of the Arlington Suitability Report was included in the material obtained during the Finger Lakes review earlier in 2013.

¹⁰ A version of Resource Report 6 without attachments was made publicly available through FERC.

about this site are about geology. Yet, three particular responses to Engineering Requests for Data related to geology reflect, at best, a lack or loss of information related to the serial change of ownership and recordkeeping at this site. The three requests and comments on the responses are:

Engineering Request 1 (May15, 2013; response June 3, 2013) asks:

“a) How much natural gas is projected to be stored in the **rubble pile which connects** the two caverns?” (emphasis added)

The answer speaks of a rubble pile in general and total gas storage in the gallery based on other estimates—not the concern about the connection between the caverns that was the substance of the question.

“b) What is the size and volume of the rubble pile?”

The question, regardless of whether it is asking about the rubble pile in the conduit connecting the two caverns or the rubble pile in total, is not answered. The answer given is about gas storage, not the rubble concern. The geometry of the rubble pile[s] is known, if only from the Jacoby 1969 paper, and Arlington should have in its files the detailed records that formed the basis of these cross-sections. The fault block that fell from the cavern roof and is thus a part of the present rubble pile of Cavern 30 was outlined by a sonar survey described in the Jacoby article. The rubble in the cavity connecting the caverns could be estimated from the original drilling logs, a knowledge of the hydraulic fracturing along the thrust fault and a minimum width described by Well 45’s intercept of that rubble. The rubble pile remains an unknown. It is particularly important when a cavern system is of this advanced age and is as involved with faulting as this one is, that the dimensions of all components, including the cavity and rubble pile between Caverns 30 and 31, be known to the fullest extent.

“c) Referring to page 21 of the PB-KBB report within Resource Report 6, the hypothetical view of Gallery No. 2, provide...(series of questions about dimensions that are answered in a spreadsheet marked confidential ending with)width of the connection between caverns 30 and 31, and the salt pillar thickness between caverns 30 and 31.”

Two parts of the question are not answered: the width of the connection and pillar and the width of the support between Caverns 30 and 31. The answer does not give the values requested, stating only: “...the horizontal pillar distance between Cavern Nos. 30 and 31 exceeds 60 feet.” The connection between the caverns can be imaged, and there is other information that allows at least some estimates about the connection formed by means of the hydraulically fractured thrust fault. The same is true for the three-dimensional salt pillar between the caverns and its relationship to the connecting cavity. The salt pillar and the hydraulically fractured path along a thrust fault connection are appropriate subjects of concern and simply are not addressed in Arlington’s answer.

Engineering Request 2 (May15, 2013; response June 3, 2013) asks:

“Why were Wells 58 and 59 used for rock mechanics and geomechanical evaluation of Gallery 2? Were any cores taken from Wells 30A and 31A which are being used to update the earlier rock mechanics and geomechanical studies?”

Arlington’s answer is first that the only cores available at permitting time were from wells 58 and 59, second that new caprock cores from 30A and 31A were tested for porosity at the Camillus shale level. The question was about rock mechanics and updates at this specific site, not about the Camillus Shale rock formation that lies well above the caverns that were the subject of the question. The studies were not done, and the question was not answered.

Engineering Request 6 (May15, 2013; response June 3, 2013) asks:

“In response to commenters’ concerns regarding roof failure, please state if this has ever been an issue in either Gallery 1 or Gallery 2 or if you have knowledge of any roof or wall failures in any of the caverns within Watkins Glen Brine Field.”

Arlington responds:

“To Arlington’s knowledge, there have been no cavern roof failures in Galleries 1 or 2, or in any other cavern within the Watkins Glen Brine Field in which natural gas or natural gas liquids have been stored.”

It is difficult to understand how Arlington could make such a categorical statement about the entire brine field, or could miss a cavern roof failure in one of the two caverns of the gallery that is the subject of its application—let alone a 400,000-ton fault block cavern roof failure written about in an international publication by its own geologist. The Jacoby article that contains the cross-sections and illustrates and describes the 400,000-ton fault block cavern roof collapse is not listed in the bibliography that accompanies the Arlington Reservoir Suitability Report that was obtained in redacted form from a Freedom of Information Request to the New York Department of Environmental Conservation, so perhaps the Arlington representative who wrote the answer was unaware of the work Jacoby did on the specific caverns of this proposal. Earthjustice however found the article easily and sent it to me as part of their file of basic background references.

This absolute, region-wide and unqualified answer to FERC’s question about roof failure means that Arlington has not considered the roof collapse failure mechanism and thus its conceptual model of cavern development is fundamentally flawed. The unsupported roof of Cavern 30 at the time of the cavern roof failure in the sixties was roughly the size of a football field. What are the dimensions of the unsupported span now? The roof failure was a fault block, where are the faults in Arlington’s characterization? Are there other faults? How is this fault block incorporated in Arlington’s geomechanical study? It is not. What information from

failures at other sites, like the failure at Retsof or the one at Bayou Corne¹¹ going on now, can be used to evaluate the roof situation? The roof failure in Cavern 30 was hardly trivial, and Jacoby wrote of sonar measurements on this fault block; if Arlington's predecessor was concerned enough then to perform a sonar survey of the fault block, there must be a lot additional information about this event in company files. Salt fall in caverns (Loof and Loof, 1999 and Munson, et al, 2003) is a serious concern in salt caverns in general and the roof fall in Cavern 30 makes the concern site-specific. The complete absence of any mention of this 400,000-ton fault block cavern roof failure in FERC's EA and Engineering Requests and Arlington's responses is an incredible error. Indeed, Arlington went so far as to submit supplementary comments "...dispelling the possibility of cavern roof collapse,"¹² a summary statement that says the applicant is unaware of what has happened at the very caverns where it proposes to store and cycle compressed natural gas. Clearly, Arlington's application and FERC's conclusions are compromised by this error. Detailed studies required to address the cavern roof fall problem should be made available to the public as well as the regulatory agencies.

IV. Recommendations and Summary

At this point, there are serious questions about the Arlington site that must be answered. The material reviewed by FERC is incomplete, and its impressions about the caverns are incorrect. The first thing that should be required of Arlington is an accurate characterization of the site area. The cross-sections prepared by Jacoby are a starting point, but there is much more information that must be available in company records that should be made a part of the Reservoir Suitability Report and made available to the public. A partial list of things to do for the characterization should include the following.

A full evaluation of:

- The roof fault block fall event with documents and records of the event itself along with any precursor events noted in company records at the time and in retrospect, the sonar survey of the fault block described in the Jacoby article, sonar surveys before the event, information about the faults involved, pressure recordings at the time, earthquake seismic records at the time, any studies about precursor events that might have signaled the imminent collapse and studies made about how to prevent future cavern failure.
- An accurate geologic description of the site area that should include faults, fracture zones, physical properties (new coring may be necessary) of site specific materials above, below and making up the walls of the caverns, thrust faulting intersecting the caverns, the Jacoby-Dellwig Fault and related features including those shown on the Jacoby cross-sections.

¹¹ The Bayou Corne Sinkhole was created from the collapse of an underground salt dome cavern in Assumption Parish, Louisiana. It was discovered in August 2012 and resulted in the evacuation of 350 nearby residents. The sinkhole was caused by cavern failure at the edge of the Napoleonville Salt Dome.

¹² Arlington Reply Comments on EA, 11/7/2013.

- A three-dimensional seismic survey of the cavern area including the Jacoby-Dellwig Fault is, of course, a necessary element of the geologic description, along with other geophysical measurements in order to develop a full understanding of this geology. The Engineering Request about the rubble pile in the conduit that connects the caverns was not answered and imaging this feature and the related salt pillar is a priority.

Once a satisfactory geologic characterization is developed, the next step is to examine the history of the caverns to see how they have developed through time and how they behaved during initial hydraulic fracturing, mining, subsequent LPG storage and cycling, and now an extended period of inactivity. The history of nearby caverns should be a part of this study, and a serious examination of what happened at Well 58 should provide invaluable insight. The applicant apparently owns the historical data files, and the information should be readily available.

The information from these studies is critical in itself for a comprehensive evaluation, but the information will also be necessary for a detailed site-specific geomechanical analysis. The modeling involved should simulate the caverns' behavior over time as well as predict future behavior and indicate situations that should be considered for monitoring. The fault block that fell from the roof of Cavern 30 represents an event that the finite difference (or finite element) modeling work can predict and use to affirm the model's accuracy. Here was a fault block of known dimensions that fell intact at a known point in time due to the undermining in the cavity. There is likely a seismograph record of the event. This is an unusual opportunity. Arlington's denial that such fault block cavern roof fall event ever took place, as well as Arlington's characterization of faulting in the area "if it exists" as "sealing" means that the present analysis of Gallery 2 fails to even consider mechanisms most likely to develop as pathways, and the project should be suspended until the basic questions about geology and the caverns are answered.

Once Caverns 30 and 31 are properly characterized, and if the project is allowed to go forward, monitoring plans should be tailored to the information developed from the studies outlined above:

Frequent sonar surveys are necessary and the FERC EA states that periodic sonar surveys are planned; yet Arlington states in the unredacted portions of the Arlington Reservoir Suitability Report (July 1, 2010) provided with the Finger Lakes materials that once gas storage begins, no further sonars are planned.¹³ Arlington's plan should be corrected to reflect its obligation to do periodic surveys, and those should include cavern roof views and be made available to the public.

Meaningful subsidence monuments and periodic surveys are an expected part of cavern monitoring. Arlington's application agrees to monitor surface subsidence, but notes that the

¹³ Arlington Reservoir Suitability Report, July 1, 2010, page 14, redacted and included with Finger Lakes files.

current experience is that as many subsidence monuments have risen as fallen over time and attributes the behavior to the ambient surface temperature. If that's the case, the subsidence program is ineffective—the goal is to measure movement related to the caverns, not the weather, monument design is available for this purpose, and there are companies qualified to do the work.

The state of stress related to the tectonic framework is not perfectly understood, so strain measurements and borehole microseismic recording devices in boreholes arrayed around the Watkins Glen brine field, now storage area, should be part of the monitoring program. Local universities can design such a system, and the monitoring experience at Bayou Corne, Louisiana, provides an example of current state-of-the-art measurements, although regrettably after the fact.

The FERC EA states that: “Arlington would be required to routinely monitor the caverns to ensure cavern integrity, including mechanical integrity tests that are designed to monitor the cavern dimensions and shape, including the cavern roof and an estimate of pillar thickness between caverns; annual inventory verification; pressure monitoring; and ground-level subsidence monitoring.” If “routinely” means to do the things on the list periodically and on a set schedule, there is a disconnect between FERC’s understanding and Arlington’s plan. While pressure monitoring is planned (and should be comprehensive) and periodic ground-level subsidence monitoring is planned (though it should be improved), it is not clear that these monitoring measures will be continued once operation begins. The publicly available but heavily redacted Arlington Suitability Report, says that initial well mechanical integrity tests, nitrogen-brine interface tests and sonars are planned but will not be repeated once operation begins.¹⁴ Granted that, after operation begins, there will be no brine for a nitrogen-brine interface test, but the rest of the testing should be done, and done often, and for some measurements, continuously. Periodic mechanical integrity testing captures only a brief time sample and far more expansive monitoring of these particular caverns is required. Advanced cement bond logging can provide a picture of the casing condition as well as the cement and the cement bond to the casing and formation, and this is particularly important in this region where “blackwater” has attacked both cement and casings.¹⁵ This log should be a part of the periodic evaluation of the integrity of the caverns and casing. Arlington should revise its sonar and mechanical integrity testing plans to meet FERC’s expectation.

Since gas under pressure is the subject of the storage plan, gas escaping from the caverns or the associated well casing is always a possibility and area gas monitoring should be a priority. Soil gas surveys should be conducted first for a baseline map, then periodically as part of the monitoring program. The area around the Jacoby-Dellwig Fault should receive special attention and be periodically tested using a variety of geophysical and geochemical approaches. Since

¹⁴ Arlington Suitability Report, July, 2010, pages 14 and 17.

¹⁵ See for example, NYSEG Compressed Air Energy Storage Seneca Lake Project, PB Energy Storage, ex. 13.10.

escaping natural gas is part of the problem at the Bayou Corne Sinkhole, their experience with gas detection may be helpful in designing a monitoring system at Watkins Glen.¹⁶

Salt cavern evaluation requirements developed decades ago that form a part of the historical regulatory framework are often outdated and new technology is available that can provide a more accurate picture of cavern integrity. The Bayou Corne Sinkhole is being monitored now in a number of ways that should be applied to the Arlington site. In addition to two-dimensional, three-dimensional, and vertical seismic profiling seismic surveys, researchers in Louisiana are using tiltmeters, downhole microseismic measurements, a surface seismic array, and GPS surveys to monitor movement at the surface and at depth. The information is made public by Louisiana agencies, much of it in real time.¹⁷ The work going on now to evaluate the continuing salt cavern failure at Bayou Corne should be used to design a study and monitoring system for Caverns 30 and 31 and a comprehensive monitoring network of the entire Watkins Glen brine field area.

Sincerely,

A handwritten signature in black ink, appearing to read "H.C. Clark". The signature is fluid and cursive, with the first letters of the first and last names being capitalized and prominent.

H.C. Clark, PhD

¹⁶ <http://assumptionla.com/bayoucorne>

¹⁷ <http://dnr.louisiana.gov/index.cfm?md=pagebuilder&tmp=home&pid=939>,
<http://www.deq.louisiana.gov/portal/bayoucorne.aspx>, <http://www.assumptionla.com/bayoucorne/usgs>,
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Exhibit 1

Exhibit 2

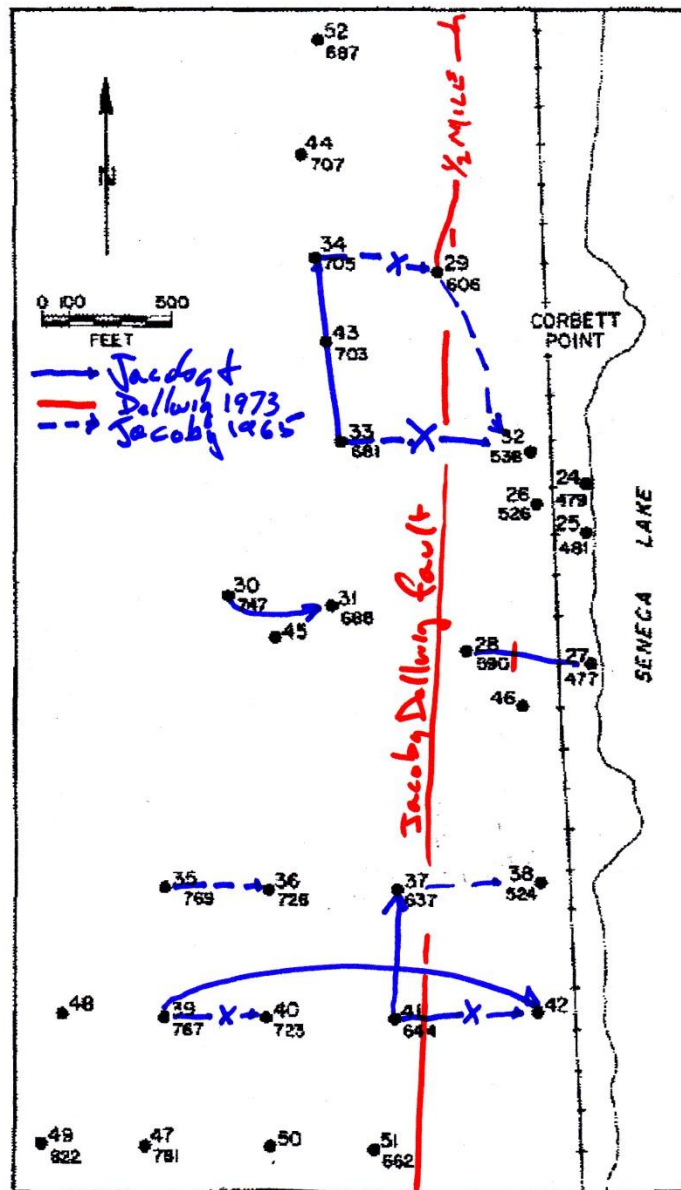


Figure 2. Index map, Watkins Glen, New York, brine field, International Selt Company. Upper number of each pair is well number, lower is surface elevation (where known).

Exhibit 3

Exhibit 4

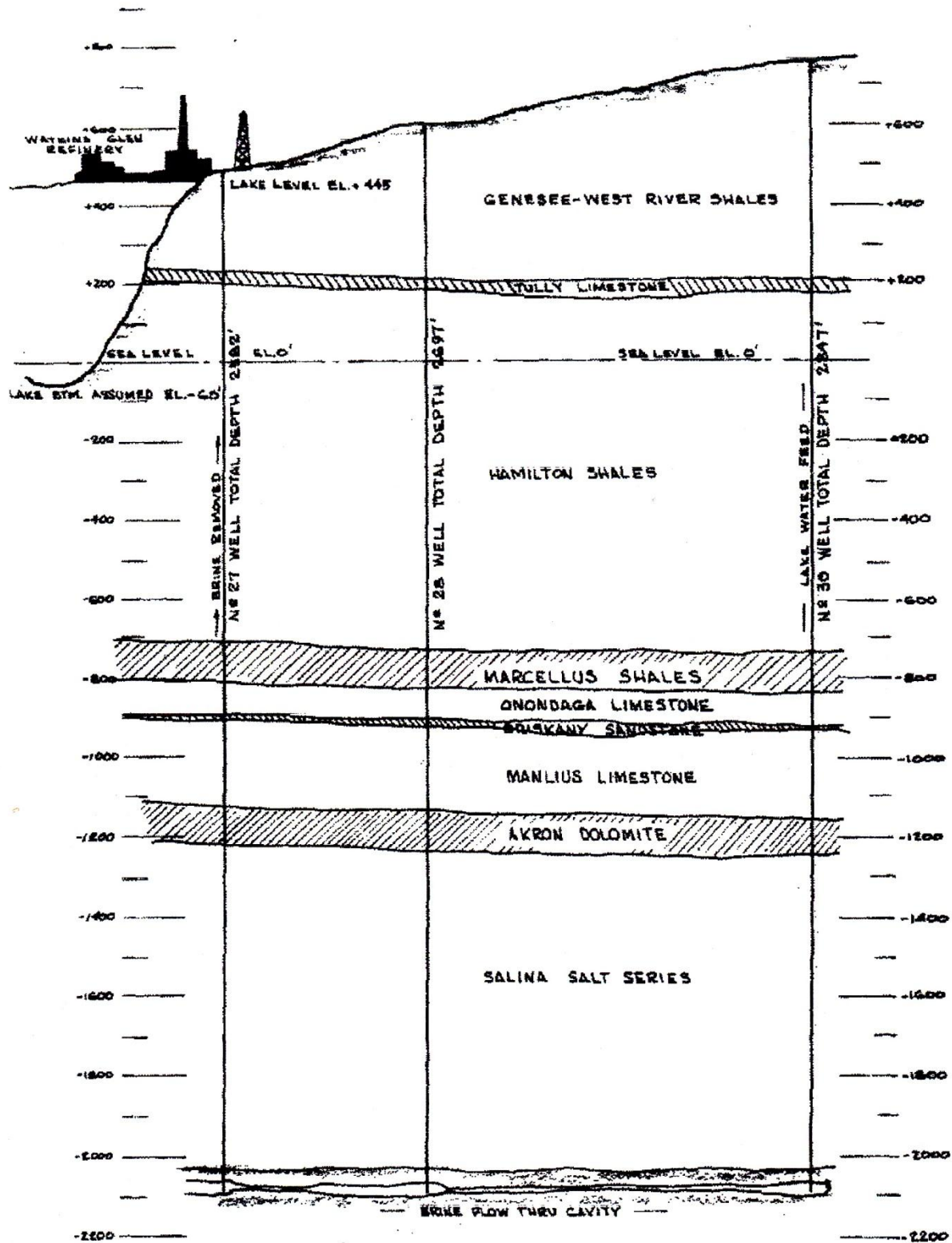


FIGURE 2

PROFILE OF WATKINS GLEN
BRINE WELLS NO. 27, 28, & 30

Exhibit 5

Exhibit 6



H.C. Clark
2300 Bolsover
Houston, Texas 77005
hcclark@rice.edu;

Consulting Geology and Geophysics

Rice University, Geology and Geophysics, retired faculty

Education

PhD, Geophysics, Stanford University, 1967

MS, Geophysics, Stanford University, 1966

BS, Geology and Geophysics, University of Oklahoma, 1959

Teaching: courses in geophysics and geology, geologic hazards, engineering geology and geophysics

Research Interests: Current - Geophysical techniques applied to the study of shallow features, geophysical measurements and hydrogeologic problems, sustainability and agriculture; Past - paleomagnetism, geophysical measurements and crustal studies, analysis of geologic hazards

Texas Registered Professional Geoscientist, number 1777.

Municipal Solid Waste and Resource Recovery Advisory Council of the Texas Commission on Environmental Quality, 2003, re-appointed in 2007 to term ending 2013, representing the Public

Director of Student Advising at Rice in 1979 and served in various combinations with Susan Clark until retiring in 1989.

Organizations — American Geophysical Union, Society of Exploration Geophysicists [and Near Surface Section], Houston Geological Society, Geophysical Society of Houston

Appointed to Task Force 21 of the Texas Natural Resource and Conservation Commission

Appointed to EPA/ASTSWMO Industrial Waste Management Guidance Stakeholders Group [1997-completion]

At Rice University from 1966 to 1989

Consulting Projects

Browning Ferris- CECOS Gulf West Hazardous Waste Landfill, Chambers Co., Seismic study of active fault, groundwater geology

BFI 521 Municipal Landfill, Fort Bend Co., Texas, Geology, groundwater, active faulting and salt dome

BFI McCarty Road Municipal Landfill, Harris Co., Texas, Geology, active faulting

BFI Stratton Ridge Injection Well, Brazoria Co., Texas, Geology, fracture potential

CECOS Livingston Hazardous Waste Landfill, Livingston Parish, Louisiana, Geology

BFI Galveston County Landfill, Galveston Co., Texas, Resistivity study, baseline data

City of Houston, Crystal Chemical Injection Well, Harris Co., Texas, Active faulting, geology of reservoir

Rice Center for Community Design and Research, Chambers County Natural Factors Study, Chambers Co., Texas, Geology components
 Texas Coast Project, Two County Tier, Texas, Geology components
 Metropolitan Transit Authority Project, Harris Co., Texas, Composite fault map metropolitan area
 Citizens, Willis, Montgomery Co., Texas, Municipal Landfill, Geology and groundwater
 Citizens and County, Matagorda Co., Texas, Phillips 66 Landfarms, Landfills, Contaminated Water Ponds, Geology, groundwater, systems design
 Fayette County Resource Watch, Fayette Co., Texas, Cummins Creek Lignite Mine Geology, geophysics and groundwater
 Citizens, Katy, Texas, CMI Municipal Landfill, Cypress Creek, Geology, faulting
 Citizens, East Houston, Texas, Municipal Landfill—Negev, now Bluebonnet, Geology, faulting
 Citizens, North Houston, Texas Municipal Landfill—Atascocita, Geology, geophysics
 Citizens and Power Systems Equipment, Chappel Hill, Washington Co., Texas Municipal Landfill, Geology, geophysics, groundwater
 CASE, Beaumont-Port Arthur, Jefferson County, Texas, CWMI Injection Well
 Campbell, Foss, and Buchannan, Inc. Eureka, Nevada, Mine Exploration
 Magnetic measurements and interpretation Norse-Windfall Mines, Eureka, Nevada
 Magnetic and seismic refraction measurements and interpretation
 Anderson and Frierson, Geologists Central Texas Oil Exploration
 Gravity and magnetic measurements and interpretation
 U S Army Corps of Engineers, Galveston, Texas Galveston Bay Sand Supply Study
 Data compilation and interpretation
 U S Air Force, Office of Ballistic Missile Research Micro-blast rapid tunnel excavation. Sunburst Recovery Seismic recording, CSM Experimental Mine, Golden, Colorado
 Tenneco Oil, Exploration and Production, Houston, Texas
 Magnetic ranging system for detection of well blowout, patent
 Allied Chemical, Norfolk, Virginia, Magnetic survey, steel tank construction site
 San Jacinto Development Corp., Landslide and groundwater influence, downstream Livingston Dam; San Jacinto Co., Texas
 Vinson and Elkins, Attorneys, Houston, Fault study. West Houston
 Keplinger Associates, Petroleum Engineers, Houston, Oil Mining Study, Ohio, Geophysical measurements and interpretation Mining Prospect, Alaska, laboratory magnetic measurements and interpretation
 Universal Savings Association, Houston
 Hazardous waste study—former pipeline terminal and sludge storage pits
 Soil borings, monitor well installation; soil, sludge, groundwater sampling, interpretation of chemical test results
 Hazardous waste study—former manufacturing facility
 Waste disposal audit, supervision of testing program
 Active surface fault study—former manufacturing complex Field surface study and interpretation of surface, photo, and subsurface data
 Hazardous waste study—office park and landfill area
 Soil borings, monitor well installation; soil, sludge, groundwater sampling, interpretation of chemical test results
 ERM Southwest, Houston, Texas, Pesticide Manufacturing Plant, Dallas County, Texas
 Seismic refraction interpretation
 Testing Unlimited, Houston, Texas, Conroe Jail, Montgomery County, Texas, Seismic study, basement

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 General Dynamics, Fort Worth, Texas Air Force Plant 4, Fort Worth, Texas, Seismic reflection study, groundwater problem
 McClelland Engineers, Houston, Texas, Bosque Dam Construction Planning, Seismic refraction study, outlet works
 Police Jury, Calcasieu Parish, Louisiana Chemical Waste Management Hazardous Waste Landfill, Lake Charles Facility-Geologic and hydrologic study
 Commissioners Court, Matagorda County, Texas -Phillips 66 Landfarm- geohydrologic study of landfarm operation
 Citizens of Security, Texas-Montgomery County Contractors Type 1 Landfill, geology and geohydrology — Permit amendment for special wastes
 Texas Environmental Coalition, Concerned Citizens of Winona-Land Banned Waste Exemption Petition - WDW 186, Gibraltar Chemical Resources, Winona, Texas
 Citizens, Fort Bend County, Texas-Fort Bend County Landfill - proposed expansion
 Resolution Trust Corporation-Former Industrial Facility - ground water contamination
 Fault study - seismic reflection profile study-splay faults and contaminant transport
 City of League City, Texas-Waste oil processor-Hazardous waste and ground water
 Calhoun County Resource Watch, Texas-Union Carbide Plant Hazardous Waste Landfill Faulting, geology, and ground water; British Petroleum Plant-Hazardous waste landfill geology and performance
 Mitchell Development Corporation-Bald Head Island Beach erosion and relationship to Wilmington Channel Dredging
 Allen County [Ohio] Citizens for the Environment Workshop on deep well injection
 Louisiana Department of Environmental Quality-Workshop on deep well injection
 Law Engineering, Houston, Texas-Workshop on landfills
 Citizens, Fort Bend County, Texas-Fort Bend County Landfill - methane migration and groundwater
 Citizens, Waco, Texas-City of Waco Landfill Expansion, geological and geophysical analysis
 City of Petronila, Nueces County, Texas Texas Ecologists Hazardous Waste Disposal
 Analysis of application for two injection wells
 Numerous groups in Texas, Louisiana, Ohio: Critical comments on hazardous waste injection wells including: Gibraltar Chemical; Chemical Waste Management, Port Arthur and Corpus Christi, Texas; Vickery, Ohio; DSI, Empak, Waste Water Inc., Dupont, Celanese, American Cyanamid, Cecos, Rollins, BP Green Lake, IMC Fertilizer, BP Lima Harris County, Texas-Westbelt Landfill, geological and geophysical analysis; American Envirotech Hazardous Waste Incinerator, geological and geophysical analysis
 City of Houston and Harris County-Hunter Industrial Facilities salt dome storage of hazardous waste, geological and geophysical analysis City of Wilmer, Texas Laidlaw Wilmer Landfill Remand Hearing, geological analysis
 Citizens, Lacy-Lakeview(Tirey Trust) Lacy-Lakeview Landfill Expansion, groundwater and geology
 CASE-CWMI Port Arthur Landfill-audit of landfill documents-geologic analysis
 Citizens, Fairview (COFF),McKinney Landfill Expansion, geological and geophysical analysis
 Lower Colorado River Authority-Tricil Landfill, Altair, Texas geological and geophysical analysis
 City of Del Rio-CWMI Dryden Landfill, Dryden, Texas
 CONTROL [Citizens of Justin, Texas] Sentry Landfill Proposal, Denton, Texas-geological analysis
 West Harris County MUDS-Madden Road Landfill geological and geophysical analysis
 Sierra Club, Eagle Pass, DOS Republicas Coal Mine

geological and agricultural analysis of alluvial valley floor
 Citizens Live Oak County, Texas IEC Injection Wells 156, 159, geological and geophysical analysis
 Citizens Winnsboro, Texas East Texas Landfill, geological analysis
 Citizens East Fort Worth, Laidlaw Landfill, MSW 2145, geological analysis
 City of Lancaster, Texas WMX Skyline [Ferris] Landfill, 42-C, geological analysis
 Citizens Walker County, Texas DDI Landfill, geological analysis
 Citizens Palo Pinto County and Fawcett XO Ranches-Blue Flats Landfill, geological analysis
 MOSES [Mothers Organized to Stop Environmental Sins] Injection Wells 186 and 229, Smith County, Texas-injection well, geological and geophysical analysis
 Citizen groups Jefferson County NORM facility, geological and geophysical analysis
 CCAP Wharton County-Hazardous waste caverns, injection, geology and geophysics
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 ABLE, Canyon, Texas-BFI Canyon Landfill expansion proposal geological analysis
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Patent: Waters; Robert L. (Austin, TX); Roberts; George F. (Georgetown, TX); Walters; Philip H. (Austin, TX); Clark; Howard C. (Houston, TX); Fitzgerald; Don D. (Houston, TX); Stelly, II; Otis V. (Lafayette, LA), 1988, Downhole Combination Tool, 5,064,006 USPO, 1991.