Independent High-Level Quantitative Risk Analysis
Schuyler County Natural Gas Storage Proposal

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February 7, 2015

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Quantitative Risk Analysis:
Schuyler County Liquid Petroleum Gas Proposal
February 7, 2015
D. Rob Mackenzie, MD

Executive Summary
An independent, high-level quantitative assessment (QRA) was performed to evaluate the major risks associated with a proposal by Arlington Storage Company, LLC to increase the amount of natural gas (NG) stored in previously abandoned Schuyler County solution-mined salt caverns. The risks of events associated with NG pipeline transmission and salt cavern storage were evaluated using standard methodology, a twenty-five year exposure interval, and publicly available sources.

The likelihood of moderate baseline pipeline transmission events is more than ten percent over 25 years. While pipeline risk reduction efforts should always be considered because of possible moderate consequences, there is little if any incremental risk as pipeline infrastructure will remain nearly unchanged. The probability of serious or extremely serious salt cavern storage events is more than 40 percent over 25 years, including both baseline and incremental risks. The significant possibility of major salt infiltration into Seneca Lake with extreme consequences, and the fact that the salt cavern is located in bedded salt strata rather than salt domes, add to this risk.

From the perspective of community safety based on this analysis, continued salt cavern gas storage in Schuyler County carries a baseline unacceptable risk that would rise even higher under this proposal. Risk mitigation efforts in salt cavern storage have thus far proven unsuccessful in significantly reducing the frequency of serious and extremely serious incidents. Therefore plans to store additional NG in Schuyler County should be denied and strong consideration given to safer forms of gas storage to meet demand.

Introduction

Risk assessment work starts with a prioritization process, based on the likelihood and consequences of identified untoward events.[1] For events of extreme seriousness and high likelihood, the risk is ordinarily deemed unacceptable, and efforts are made chiefly to reduce or eliminate the risk. For events of minor consequence and low likelihood, the risk may be deemed acceptable, and a response plan is developed. A matrix is commonly used to display the combination of consequence and likelihood:[2] [3]

MATRIX FOR RISK ASSESSMENTS at NTNU

CONSEQUENCE	Extremely serious	E1	E2	E3	E4	E5
	Serious	D1	D2	D3	D4	D5
	Moderate	C1	C2	C3	C4	C5
	Minor	B1	B2	B3	B4	B5
	Not significant	A1	A2	A3	A4	A5
		Very low	Low	Medium	High	Very high
		LIKELIHOOD				

Principle for acceptance criteria. Explanation of the colours used in the risk matrix.

Colour		Description
Red		Unacceptable risk. Measures must be taken to reduce the risk.
Yellow		Assessment range. Measures must be considered.
Green		Acceptable risk Measures can be considered based on other considerations.

Figure 1 – Sample Risk Matrix

In a high-level quantitative risk analysis I have applied this process to evaluate the risk of the Schuyler County natural gas (NG) storage proposal submitted by Arlington Storage Company, LLC (Arlington).[4]

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[1] Rob Mackenzie, M.D., FACS, FRCS(C), FACHE was until 2013 the President and Chief Executive Officer at the Cayuga Medical Center, Ithaca, NY where he led statewide CEO taskforces to improve safety performance, leading to 2010 recognition by Consumer Reports as New York State's safest hospital. His safety and risk assessment experience includes being the Chair of VHA-Empire State Healthcare CEO Safety Network; organizational, community, hospital, and industrial safety and risk assessments (both quantitative and qualitative); training in high-reliability science and on-site evaluations of safety practices at high-reliability medical and industrial sites including Sentara, Palo Verde nuclear facility, NASA. See C.V. attached hereto as Attachment 1.

[2] This typical example is from http://www.ntnu.no/innsida, a Norwegian university.

[3] *Guidelines for Chemical Transportation Safety, Security, and Risk Management*, Center for Chemical Process Safety, John Wiley & Sons, 2008.

[4] 147 Federal Energy Regulatory Commission ¶ 61,120: Arlington Storage Company, LLC, May 15, 2014.

Hazard events were scored as either "major accidents" or not using the methodology of the Marcogaz European Underground Gas Storage Study database, derived from Appendix VI of the European Union's SEVESO II Directive 96/82 on the control of major-accident hazards involving dangerous substances.[5] If such "major accidents" per Marcogaz criteria had multiple casualties, multiple evacuations longer than 30 days, or permanent environmental damage they were scored as "extremely serious events;" all other major accidents were scored "serious events." Non-major accidents were scored "moderate," "minor," or "not significant" (see Marcogaz criteria with examples in Attachment 2), and not analyzed further since they were unlikely to significantly impact health and safety.

Likelihood categories were derived by applying the probability definitions of ISO Standard 17776(2000), Petroleum and Natural Gas Industries,[6] to the number and longevity of U.S. underground gas storage industry's facilities. By this standard an event rate of "very low likelihood" is less than 0.1%/year, "low likelihood" between 0.1-1.0%/year, and "medium likelihood" up to 5-20%/year Probabilities were reported using an exposure interval of 25 years (see methodology and examples in Attachment 2).

If any risk analysis of the proposal has been performed by Arlington, it has not been made available to me. However, Arlington's parent company commissioned a risk analysis for a closely related liquid petroleum storage (LPG) project at the same site, which was reported in 2012.[7] Because many of the risks of NG salt cavern storage are similar to those of LPG salt cavern storage, I reviewed that analysis. It evaluated the frequency, severity, and consequences of equipment-related potential gas releases at the proposed LPG facility in great detail, and concluded that the hazards and risk to on-site and nearby individuals were acceptable and "similar to those of LPG storage, transport, and processing facilities worldwide."

However, that QRA did not analyze risks associated with transport to or from the site, even though the transport stage of the energy chain is responsible for a volume of fatalities and injuries several orders of magnitude higher than the facility stage.[8] It did not analyze the potential or consequences of geologic salt infiltration induced by facility operations, even though such infiltration may have major public health consequences and cause irremediable environmental damage (see *Salt brine Infiltration,* below).

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[5] European Union Council Directive 96/82/EC of 9 December 1996 on the control of major-accident hazards involving dangerous substances.
[6] http://www.iso.org.
[7] Quantitative Risk Analysis for the Finger Lakes LPG Storage Facility, prepared for Inergy Midstream by Quest Consultants, Inc., Norman OK 12-02-6822 February 16, 2012.
[8] Evans, D.J. Health and Safety Executive of the United Kingdom*, An appraisal of underground gas storage technologies and incidents, for the development of risk assessment methodology* (2008).

That QRA also greatly underreported salt cavern incidents: It cited a European study that determined the *structural* failure rate to be one in 100,000. Yet that study included depleted oil and gas wells (which have a much better safety track record than salt caverns), omitted facility infrastructure events, and omitted many known salt cavern incidents. The *annual* probability of incidents with casualties *in salt cavern facilities* which by this methodology would be scored "serious" or "extremely serious" events is actually 1.5 in 100 (or 37.5% over 25 years)—a hundred and fifty times more likely than the related company's QRA suggested (see *Salt Caverns*, below).

Brief summary of NG storage proposal:
Arlington's DEC application to expand its Schuyler County NG storage capacity calls for the conversion of two interconnected bedded salt caverns from which salt is no longer being solution-mined, to increase working gas capacity from 1.45 to 2.00 billion cubic feet. NG would be transported to and from the site via existing underground pipeline.[9]

RISK ANALYSIS
This analysis is limited to two contingencies. Stated as questions:
(1) Is NG transmission by pipeline in Schuyler County an acceptable overall and incremental risk?
(2) Is salt cavern storage of NG in Schuyler County an acceptable overall and incremental risk?

Pipeline Transportation Risk:
NG pipeline transportation would occur via the existing network of Schuyler County natural gas pipelines.[10]

The most serious risk in U.S. pipeline transportation in 2013 was pipe disruption caused by failure of material or welds (43%), excavation damage (23%), corrosion (13%), natural force damage (7%), other outside force damage (7%), incorrect operation (3%) or other cause (3%).[11] In the decade 2004-2013 such disruptions in pipelines carrying natural gas resulted in 565 significant incidents with 15 fatalities, 104 injuries, and more than $1 billion in property damage

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[9] 147 Federal Energy Regulatory Commission ¶ 61,120: Arlington Storage Company, LLC, May 15, 2014.
[10] National Pipeline Mapping System map for Schuyler County, New York, at: https://www.npms.phmsa.dot.gov/PublicViewer
[11] Pipeline and Hazardous Material Safety Administration, U.S. Department of Transportation, *Pipeline Safety Stakeholder Communications - Significant pipeline incidents by cause*, at: http://primis.phmsa.dot.gov

according to industry sources.[12]

These “significant incidents,” however, were distributed over an NG pipeline network of approximately 300,000 miles[13]. Because of the lower proximity to population centers in this case, the relatively low potential for evacuation, and the moderate number of casualties, such events would be scored as a **moderate consequence** on the ISO risk matrix. Over a 25-year exposure interval the event risk for Schuyler County’s 24 miles of NG pipeline is approximately 11 percent, or **low likelihood**.[14] Because no significant additional pipeline construction is planned, this would be considered baseline risk, not incremental risk. This baseline risk is in the “assessment range,” so ways to reduce risk further should be still considered **because of the possible consequences** (Figure 3).

CONSEQUENCE						
	Extremely serious	E1	E2	E3	E4	E5
	Serious	D1	D2	D3	D4	D5
CONSEQUENCE	Moderate	C1	**PIPELINE RISK**	C3	C4	C5
	Minor	B1	B2	B3	B4	B5
	Not significant	A1	A2	A3	A4	A5
		Very low	Low	Medium	High	Very high
				LIKELIHOOD		

Color		Description
Red		Unacceptable risk. Measures must be taken to reduce risk
Yellow		Assessment range. Measures must be considered
Green		Acceptable risk. Measures can be considered based on other considerations

Figure 2 – Baseline Pipeline Risk

Salt Cavern Risks:

Event rates

As of 2013 there were 419 underground gas storage facilities in the US.[15] Most are in depleted oil and gas fields; a few are in aquifers, and 40 are in “salt cavern” facilities.[16] Most salt caverns have been developed over several decades from naturally occurring, globular, so-called “salt domes” in the Gulf states. Nine have been added since 2007.[17] A few salt caverns are in “bedded salt” deposits like Schuyler County’s, which itself has been used in the past for gas storage. Safety oversight of underground gas storage is performed by both federal and state agencies.

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[12] *Id.*

[13] U.S. Energy Information Administration at : http://www.eia.gov/pub/oil_gas/natural_gas/analysis_publications/ngpipeline/inde x.html.

[14] Calculation: 57 significant incidents/yr/300,000 miles pipeline x 24 miles Schuyler County pipeline x 25 years = 0.114

[15] http://www.eia.gov/dnav/ng/ng_stor_cap_a_EPG0_SAD_Count_a.htm

[16] http://www.eia.gov/dnav/ng/ng_stor_cap_a_EPG0_SA5_Count_a.htm

[17] http://www.eia.gov/dnav/ng/hist/na1393_nus_8a.htm

Despite this supervision, between 1972 and 2012 there have been at least 20 serious or extremely serious incidents in salt cavern storage facilities located in the United States.[18] [19] [20] [21] [22] [23] With the average number of salt cavern storage facilities in operation through most of the last two decades close to 30,[24] the US incidence between 1972 and 2012 is more than 65 percent (compared to 40 percent worldwide[25]), and the frequency more than 1.6% per year. Causes of failure have included corroded casings, equipment failure, brine erosion leading to breach, leakage into other geologic formations, and human error. Worldwide, the percentage of incidents *involving casualties* at salt cavern facilities as a percentage of the number of facilities operational in 2005 was 13.6 percent, compared to 0.63% for gas and oil fields, and 2.5% for aquifers.[26]

Ten of the salt cavern incidents were accompanied by large fires and/or explosions. Six involved loss of life or serious injury. In eight cases evacuation of between 30 and 2000 residents was required. Extremely serious or catastrophic property loss occurred in thirteen of the 20 cases. In one incident in 2008, involving a New York State salt cavern facility owned by the same parent company as Arlington, a drilling rig hired to perform work on an existing inactive salt cavern storage well caused release of gas which ignited at the surface, resulting in injuries to four persons.[27]

The likelihood of a serious or extremely serious event over twenty-five years is more than 40 percent.[28] Per ISO methodology this is at least a **medium likelihood**, with the potential for at least **serious** consequences, and, in this case as discussed below, likely **extremely serious** consequences. It thus

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[18] Evans, 2008 (Appendix V and Table 14).

[19] Warren, J.K. *Evaporites: Sedimentology, resources and hydrocarbons*, Springer (2006, Chapter 12).

[20] Hopper, John M., *Gas Storage and Single Point Risk,* in Natural Gas, at http://gasfreeseneca.com/wp-content/uploads/2011/06/Gas-Storage-Explosions.pdf.

[21] Warren, J.K. *Evaporites: Sedimentology, resources and hydrocarbons*, Springer (2015 in press: pp 1136-1144 available at http://gasfreeseneca.com/wp-content/uploads/2015/01/Warren-J.K.-Evaporites-Ch.13-Solution-Mining-and-Salt-Cavern-Usage-Storage-cavern-problems-pp-1136-1144-2015-in-press.pdf.

[22] Inergy Midstrream, *Inergy Midstream Issues Statement on Bath Incident* (March 10, 2008) (describing an incident at Inergy's salt cavern gas storage facility in Bath, NY).

[23] Events collected from sources 27-31 were categorized as "major accidents" or not by Marcogaz criteria. Major accidents were then scored as serious or extremely serious according to the additional criteria in Attachment 2.

[24] http://www.eia.gov/dnav/ng/hist/na1393_nus_8a.htm shows a stable salt cavern count at approximately 30 fields from 1999 until further growth to 40 started more recently (2007), and http://www.eia.gov/dnav/ng/hist/na1394_nus_8a.htm shows stability in the total storage field count over the prior ten years.

[25] Per Evans (2008, p. 115), the lower world-wide incidence is thought by some to reflect under-reporting in Europe and the former Soviet Union.

[26] Evans, 2008 (Table 2).

[27] Inergy Midstrream, *Inergy Midstream Issues Statement on Bath Incident* (March 10, 2008) (describing an incident at Inergy's salt cavern gas storage facility in Bath, NY).

[28] Calculation: 1.66% incidence per year x 25 yrs = 41.6%.

constitutes an **unacceptable risk**. (See further discussion below on the risks and baseline versus incremental risks).

Salt brine infiltration
In the early 1900s Seneca Lake waters had moderately more chloride than other Finger Lakes,[29] as would perhaps be expected due to the commencement of solution salt-mining on the shores of the lake in 1893,[30] and/or because much of the bed of Seneca Lake intersects bedded salt planes.[31] Chloride levels in Seneca Lake rose gradually from less than 50 ppm in 1905 to approximately 115 ppm in the mid-1960's, in parallel with increased salt mine production at Seneca Lake, strongly suggesting an anthropogenic rise.[32] Seneca Lake chloride levels then surged dramatically, from approximately 110 to more than 180 ppm in the latter half of the 1960s:

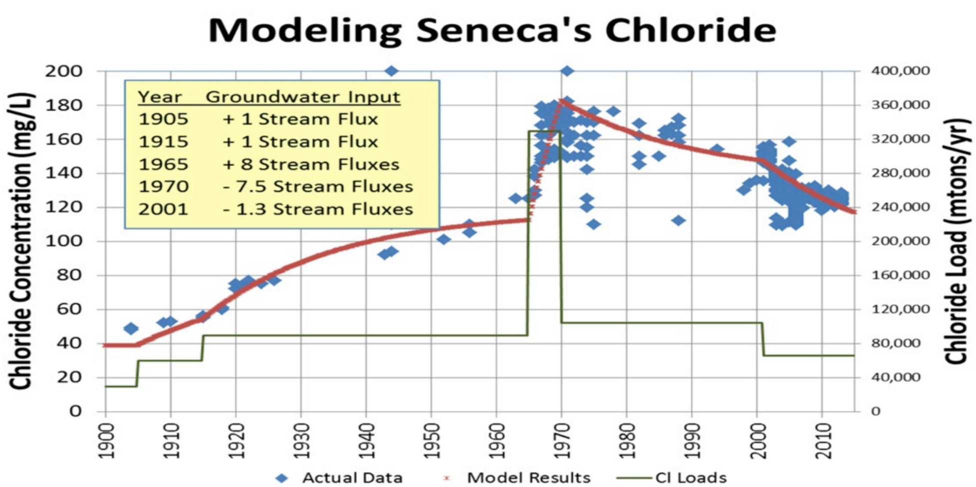

Figure 3. from Halfman, 2014

Ion flux studies show that documented industrial salt waste discharges and road salt stream drainage, taken together, are insufficient by an order of magnitude to explain this exponential chloride increase.[33] [34] This suggests that the onset of

[29] Finger Lakes Inst. et al. March 2012. Seneca Lake Watershed Management Plan.
[30] Jacoby CH & Dellwig LF., Appalachian foreland thrusting in Salina salt, Watkins Glen, New York. 4th International Symposium on Salt. Northern Ohio Society.
[31] Wing, M.R., et al., Intrusion of saline groundwater into Seneca and Cayuga Lakes, New York, Limnol. Oceanogr., 40(4), 1995.
[32] John Halfman, Geneva, NY 2-page memo to Federal Energy Regulatory Commission re Arlington Storage Co, LLC, proposed request to expand gas storage near Wattkins Glen (Docket Number: CP13-83), March 18, 2013.
[33] John Halfman, A 2014 Update on the chloride hydrogeochemistry in Seneca Lake, New York, 12/10/2014, available at: http://people.hws.edu/halfman/Data/PublicInterestArticles/An%20Update%20on%20Major%20Ion%20Geochemistry%20in%20Seneca%20Lake,%20NY.pdf
[34] The company has said it cannot explain the sudden spike in salinity (Barry Moon, Plant Manager, Finger Lakes LP Storage, to Government Operations Committee, Yates County Legislature, October 6, 2014). A local engineer suggested that brine waste from the Morton Salt Himrod salt mine may have been responsible (Dennis Fagan to Timothy Dennis, *RE: Proposed*

gas storage in repurposed salt caverns on the southwest shore of the lake in 1964 greatly accelerated natural seepage of salt brine into the lake.[35]

If further expansion of salt cavern gas storage on Seneca Lake again produces a spike in salinity similar to that seen in the 1960s, that new spike would start from a higher baseline of 120-130 ppm Cl. The chloride content of Seneca Lake—New York's largest body of fresh water wholly within its borders—could then rise dangerously close to the level that would render the lake water dangerous for aquatic life (230 ppm)[36] and uncomfortably close to the level that would violate New York State drinking water regulations (250 ppm)[37] In that event, remediation for large-scale salt contamination could well take decades or be impossible, jeopardizing the source of drinking water for about 100,000 people.[38] Other long-term water sources could be needed, or else large populations would be obliged to move.

Indeed, some persons in the watershed are already advised to seek alternative water supplies, because Seneca Lake's sodium level of 75 ppm is three to four times the 20 ppm level which the NYS Department of Health indicates should not be used for drinking by people on severely restricted sodium diets nor newborn infants.[39]

Even lesser disasters, such as failure of brine pond containment, may not be as benign as some have assumed.[40] Few if any other salt caverns are adjacent to a large lake. A disaster resulting from accelerated geologic brine or salt infiltration, or some other failure of the proposed expansion of the NG storage facility, would have **extreme consequences** because Seneca Lake provides drinking water for approximately 100,000 people and numerous businesses, and numerous people recreate on and in the lake. When considered together with the other extremely serious incidents, it raises the consequence of salt cavern events into the **extremely serious** range.

Geology

Much concern has also been raised about the geology of the solution-mined caverns proposed for natural gas storage. There has been a great deal of discussion over faults, large roof collapses, rubble piles, undiscovered uncapped wells, and so on. I do not have the expertise to evaluate such concerns,

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Yates County Resolution Opposing the LPG Project in the Town of Reading, October 9, 2014), but the spike in salinity predated construction of the Himrod mine by several years.

[35] *See* January 2015 Technical Memorandum of Tom Myers, Ph.D., Hydrologic consultant, at http://www.dcbureau.org/2015020610196/natural-resources-news-service/lpg-storage-ny-salt-cavern-linked-salinity-spike-drinking-water.html#more-10196.

[36] Ambient Water Criteria for Chloride, EPA 440/5-88-001,1988.

[37] NYS Department of Health Drinking Water Regulations Part 5, Subpart 5-1.

[38] Halfman, John D. *Water Quality of Seneca Lake, New York: A 2011 Update.*

[39] NYS Department of Health Drinking Water Regulations Part 5, Subpart 5-1.

[40] SEQR Documents, Accepted DSEIS, Final DSEIS Text at 38-44.

reassurances, rulings, or requirements but have relied upon Dr. Clark's assessment of some of these risks.

However, it is not necessary to get into significant geologic detail for this level of risk analysis. From the risk assessment perspective it is enough to recall that standard and additional regulatory recommendations, routine mechanical integrity testing, and every other careful industry precaution have failed to prevent the eighteen recent serious or extremely serious salt cavern incidents in the United States. Some have been quite recent, and some have occurred in caverns with fairly long safety track records before the accidents.[41] The available literature provides no good reason to assume that regulation, testing, or oversight in today's resource-constrained environment will be more successful in preventing such incidents tomorrow than it was in preventing them yesterday.

Furthermore, salt caverns created in bedded salt deposits like Schuyler County's are known to be less stable, with a higher risk of failure, than the salt domes common in the Gulf.[42] The most instructive incident in this connection occurred at the Yaggy salt cavern facility seven miles northwest of Hutchinson, Kansas, a town of 44,000. Gases that escaped from the salt cavern due to human error traveled along sedimentary layers, erupted in the town itself, and resulted in fire, explosion, two deaths, one injury, and more than 250 evacuations. (See detailed summary, map, and photos in Attachment 3). The unfavorable geology and irregular cavern shapes generally associated with bedded salt deposits, and the fact that failures are much more common in salt caverns than other storage places, push the likelihood of salt cavern events here somewhat higher in the **medium likelihood** category.

Risk tolerance

This level of consequences per facility over twenty-five years--major fires, explosions, collapses, catastrophic loss of product, evacuations--is an unusually high level of risk. Most other regulated industry sub-segments with a persistent serious to extremely serious facility incident rate of this magnitude would be shut down or else voluntarily discontinued, except in wartime. In my view, this is an unacceptable level of risk, and expansion of the proposed NG facility should not be permitted.

Baseline risk versus incremental risk

The company's position appears to be that although the location is not ideal, the baseline risk of salt cavern gas storage adjacent to Seneca Lake has already implicitly been accepted,[43] and that incremental risks from proposals for

[41] See narratives of specific cases in Evans (2008, Appendix V) and Warren (2006, Chapter 12).
[42] Warren (2006, Chapter 12).
[43] McKinley, J., What Pairs Well with a Finger Lakes White? Not Propane, Vintners Say, New York Times 12/25/14.

additional storage are negligible. Regarding baseline risk, however, as shown above, past regulatory approvals are no guarantee against catastrophic risk. In particular, documented experience in salt cavern storage adjacent to a large lake (i.e., this one case) is hardly reassuring, because of the current high salt levels in Seneca Lake and the huge salt flow into the lake in the 1960s when gas storage first took place in the salt caverns. Regarding incremental risk, there also appears to be a direct correlation between the number of salt caverns used for storage per facility and the likelihood of serious and extremely serious events. For example, Mont Belvieu, Texas, the largest gas storage depot of salt caverns in the country, has had more events than any other U.S. facility.[44] Put simply, the use of any salt cavern is very risky; these particular salt caverns seem unusually risky; and the more caverns are used, the higher the risk becomes.

To be sure, there have been advances over the years in assessment, extraction, storage, and transportation technology over the years in which salt caverns have been used for natural gas storage. And there have been scattered reports and articles praising the safety of underground salt cavern storage. Yet those advances and reports have not yet led to a significant reduction in the rate of serious and extremely serious incidents.[45] Experience from NASA, nuclear power plants, car manufacturing, and healthcare consistently shows that to improve safety the critical requirement is not better technology but cultural change.

	Extremely serious	E1	E2	SALT CAVERN RISK	E4	E5
	Serious	D1	D2	D3	D4	D5
CONSEQUENCE	Moderate	C1	PIPELINE RISK	C3	C4	C5
	Minor	B1	B2	B3	B4	B5
	Not significant	A1	A2	A3	A4	A5
		Very low	Low	Medium	High	Very high
				LIKELIHOOD		

Color		Description
Red		Unacceptable risk. Measures must be taken to reduce risk
Yellow		Assessment range. Measures must be considered
Green		Acceptable risk. Measures can be considered based on other considerations

Figure 4 – Pipeline and Salt Cavern Risks

Safer options

As shown above, *gas storage in depleted oil and gas reservoirs has a safety track record twenty times better than storage in salt caverns*. Some salt cavern storage proponents claim that it can offer shorter cycle times with facilities located closer to market, providing better “spot coverage” for demand spikes. But it cannot do so reliably, however, as illustrated most recently by the failure of the Toddhunter, Ohio salt cavern propane storage facility due to gas leakage.[46]

[44] Evans, 2008 (Table 14).
[45] Industry sources cite a reduction in incident frequency in the 1990’s, but this reversed with a spate of incidents in the early 2000s.
[46] LP Gas, *Tracking the Latest Developments in U.S. Propane Supply*, December 2013.

Simply locating underground storage in something other than a salt cavern would be much safer, as would choosing a location that is not adjacent to the drinking water supply for 100,000 people and numerous businesses. One such alternative, which can meet spot coverage for demand spikes, is to use an excavated, lined rock cavern closer to the market. A safer alternative would also be to use a depleted oil or gas reservoir located closer to the market. While other forms of storage can be in some cases more expensive, other storage locations will have a much more acceptable environmental footprint, be reliably safer, and more easily located as close to market as needed.

Other risks:
Diesel air pollution, noise pollution, loss of jobs in tourism and wineries from "industrialization," and many other risks have been discussed widely in community forums. They are not included in this analysis because they seem somewhat unlikely to require emergency response, but they will have health and other consequences.

Risk summary and Conclusion:
The baseline risk of pipeline events of moderate consequence within the county over twenty-five years is approximately 10 percent. Ways to further mitigate this risk should be considered.

The risk of a salt cavern facility event of serious or extremely serious consequence within the county in the next twenty-five years, including both baseline and incremental risks, is more than 40 percent. Worst-case scenarios are not hard to imagine. They would involve some combination of loss of life, loss of the lake as a source of drinking water, and/or temporary or permanent evacuation. Each of these scenarios has happened in other salt cavern facilities. Fortunately for the nation, but of no help to Schuyler County, most of the other events occurred in locations more isolated from population centers than this one.

From the perspective of health safety, based on this independent analysis, I conclude that continued and/or expanded operation of NG storage in the bedded salt caverns adjacent to Seneca Lake carries an unacceptable risk of extremely serious consequences, that Arlington's proposal should be denied, and that safer gas storage alternatives should be considered.

Rob Mackenzie, MD, FACHE

ATTACHMENT 1
C.V.

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PROFESSIONAL EXPERIENCE

2003 to 2013 — President and Chief Executive Officer, Cayuga Medical Center, Ithaca, NY

Led this 204-bed, $130M revenue, benchmark independent community medical center in Ithaca, New York. Led statewide CEO taskforces to improve safety performance, leading to 2010 recognition by Consumer Reports as New York State's safest hospital.

Safety and risk assessment experience includes:

- Chair of VHA-Empire State Healthcare CEO Safety Network
- Organizational, community, hospital, and industrial safety and risk assessments (both quantitative and qualitative)
- training in high-reliability science
- on-site evaluations of safety practices at high-reliability medical and industrial sites including Sentara, Palo Verde nuclear facility, NASA

2002 Oct-Dec — Chief Operating Officer, Cayuga Medical Center, Ithaca, NY

Responsible for hospital operations during three-month transition period prior to becoming President / CEO.

1993 to 2002 — Vice President for Medical Affairs, Cayuga Medical Center. Ithaca, NY

Responsible for quality assurance, utilization management, credentials, regulatory compliance, strategic planning, and physician liaison functions.

1991 to 2002 — President, Finger Lakes Management Associates, Inc. (MD Org.), Ithaca, NY

Founding member of 150-member, for-profit association of independent physicians to address health care quality, medical business, hospital relations, and third-party reimbursement issues.

1995 to 2002 — Medical Director, Cayuga Area Plan, Inc. (MD-Hospital Org.), Ithaca, NY

Founding leader of physician-hospital organization to address health care quality, do joint strategic planning, and unify payer negotiations.

1984 to — General and Vascular Surgeon, Surgical Associates of Ithaca, P.C., Ithaca, NY

2002	Senior partner until 2002 retirement in an esteemed four-member general, vascular, and thoracic surgery private practice.

EDUCATION

BA	Harvard College, Cambridge, Massachusetts, 1975
MD	Albany Medical College, Albany, New York, 1979
Internship / Residency	University of Toronto general surgery internship, residency, Toronto, Ontario 1979-1984

LICENSURE AND BOARD CERTIFICATION

Diplomate, National Board of Medical Examiners
Diplomate, American Board of Surgery
Diplomate, Royal College of Surgeons of Canada
Diplomate, American College of Healthcare Executives
Medical License: New York 1984

ACADEMIC AFFILIATIONS

Instructor in surgery, Weill Medical College of Cornell University, 1993-2002

PROFESSIONAL ASSOCIATIONS

Albany Medical Center Class of 1979, President
Alpha Omega Alpha Medical Honor Society
American College of Healthcare Executives
American College of Physician Executives 1993-2007
American College of Surgeons, Fellow
American Red Cross, Tompkins County, Board of Directors 1997-2000
Cayuga Medical Center Medical Staff President, 1993
Cornell University College of Veterinary Medicine Advisory Council 2006-2012
Governance Institute, Editorial Board 2003-6
Health Planning Council, Tompkins County, Advisory Board 2003-2012
Iroquois Healthcare Association, Board of Directors, Vice Chair 2011
Legacy Foundation of Tompkins County, Board of Directors 2006-2010
Lifetime Healthcare Companies, Board of Directors 2004-2011
Medical Society of the State of New York
Medical Society of the County of Tompkins, Board of Directors 1997-2012
Paleontological Research Institution, Board of Directors, President 2010-11
Royal College of Surgeons (Canada), Fellow
Tompkins Health Network, Board of Directors
VHA Empire-Metro, Board of Directors Chair 2006-9
VHA CEO Safety Network Chair 2008-9

Born September 14, 1953

Retired January 1, 2013

ATTACHMENT 2
Methodology

A. CONSEQUENCE

The most widely used criteria for reporting major-accident hazards involving dangerous substances were promulgated by the European Union in Appendix VI of the SEVESO II Directive (Dir. 96/82 in 1999. These were adapted in 2000 by Marcogaz, a consortium of eight companies involved in underground storage activity, for use in a database for major accidents**.** The scope of the Marcogaz database is concerned with all parts of the infrastructure at storage plants, i.e. wells, compressors, treatment & measuring facilities and pipework systems that have led to any particular incident. The criteria are as follows:

1. Fire, explosion or accidental discharge involving at least 10 tons of gas (5% of 200 tons).
2. One death or,
    a. injuries inside establishment or,
    b. 1 injury outside establishment or,
    c. housing damaged or made unavailable outside establishment or,
    d. evacuation or confining of people for more than 2 hours (persons x hours >=500) or,
    e. interruption of drinking water, electricity, gas or telephone supply for more than 2 hours (persons x hours >= 1000)
3. Effects on environment
    a. permanent damage: 0.5 hectares of a protected area or 10 hectares of a larger area
    b. significant damage: 1 hectare of a groundwater aquifer, 10 km or more along a river, 1 hectare or more of a lake, or 2 hectare or more of a coastal area or sea
4. Material damage
    a. More than 2 Million Euros inside establishment
    b. More than 0.5 Million Euros outside establishment
5. Transboundary damage

For this study hazard events were scored as either “major accidents” or not using these criteria. If “major accidents” had multiple casualties, multiple evacuations longer than 30 days, or permanent environmental damage they were scored as “extremely serious events”; all other major accidents were scored “serious events.” For examples:

Extremely serious case examples:

1. Brenham, Texas: LPG leak in April 1992 causing fire and explosion, 3 dead, 23 injured, 50 evacuated, 26 homes destroyed, 33 homes damaged.
2. Conway, Kansas: Propane leakage into groundwater and domestic wells between 1980 and 2002 required purchase of 30 homes and relocation of 120 people.
3. Hutchinson/Yaggy, Kansas: Natural gas leak in January 2001 causing fire and explosion, 2 dead, 1 injured, >250 people evacuated for more than two months.

Serious case examples:

1. Mineola, Texas: Propane leak from casing in 1995 causing blowout and fire.
2. Mont Belvieu, Texas: Propane leak from casing in 1984 causing fire and explosion and several million dollars damage.
3. Moss Bluff, Texas: Natural gas fire and explosion in 2004 causing evacuations

Non-major accidents were scored “moderate,” “minor,” or “not significant” and rejected for further analysis, as being unlikely to have significant health and safety implications.

B. LIKELIHOOD

Likelihood categories were derived by applying the probability definitions of ISO Standard 17776(2000), Petroleum and Natural Gas Industries, to the number of U.S. underground gas storage industry's facilities, using an average of 30 facilities over the past six decades, the current number of about 40 facilities, and a ten to twenty-year operating history for an average company:

A: Very low likelihood (or has rarely occurred in industry)—for example, twice in sixty years among an average of 30 UGS facilities = 2/60/30 < 0.1% /year or < 2.5% /25 years.

B: Low likelihood (or happens several times per year in industry)—for example, four times a year among current 40 UGS facilities = 4/40 = 0.1-1% /year or 2.5-25% / 25 years.

C: Medium likelihood (or has occurred in operating company)—for example, once or twice in ten to 20 years = 5-20% /year or many times in 25 years.

No hazard events were scored higher than medium likelihood over 25 years.

C. EXPOSURE INTERVAL

While cumulative risk is a function of time, choice of a particular exposure interval for reporting is somewhat discretionary. In this report, an exposure interval of twenty-five years was chosen because (a) it is expected that the community likely will be subject to the various risks described for at least twenty-five years, (b) use of the caverns in question has changed and may continue to change over time, (c) the expected life of the NG storage facility may be longer than 25 years but I wanted to use a relatively conservative time estimate for this analysis; and (d) risks may be more likely to change over longer intervals.

D. ACCEPTANCE CRITERIA

Standard community health acceptance criteria as shown in the figures were used:

MATRIX FOR RISK ASSESSMENTS at NTNU

CONSEQUENCE	Extremely serious	E1	E2	E3	E4	E5
	Serious	D1	D2	D3	D4	D5
	Moderate	C1	C2	C3	C4	C5
	Minor	B1	B2	B3	B4	B5
	Not significant	A1	A2	A3	A4	A5
		Very low	Low	Medium	High	Very high
		LIKELIHOOD				

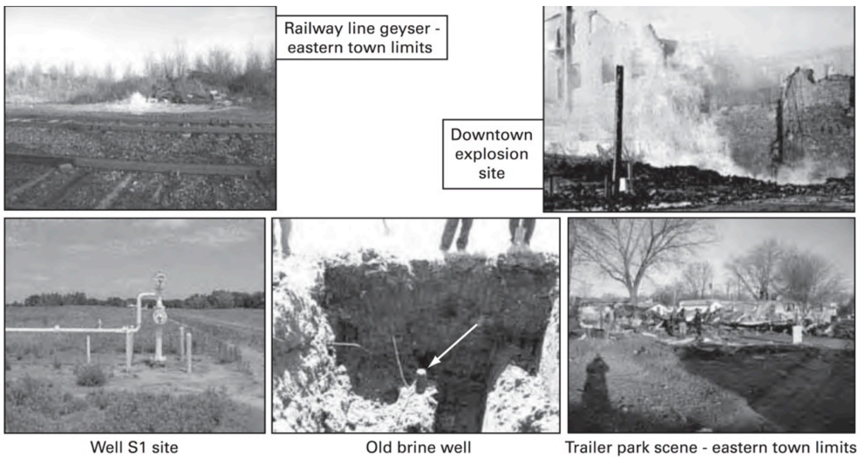
Principle for acceptance criteria. Explanation of the colours used in the risk matrix.

Colour	Description
Red	Unacceptable risk. Measures must be taken to reduce the risk.
Yellow	Assessment range. Measures must be considered.
Green	Acceptable risk Measures can be considered based on other considerations.

For example, using such criteria Schuyler County would accept the risk of an extremely serious event, (such as happened in Hutchinson, Kansas, with deaths, injuries, and long-term evacuations) if the 25-year risk is less than 2.5%, but not if it were as much as 25%.

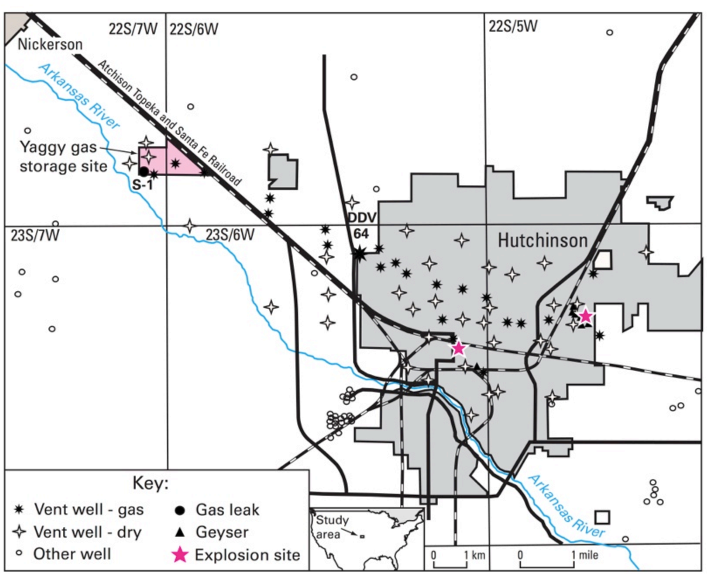
ATTACHMENT 3
HUTCHINSON / YAGGY EVENT

On January 17, 2001, a gas explosion and fire destroyed two businesses in downtown Hutchinson in central Kansas. The next day in the Big Chief mobile home park 3 miles away another explosion occurred and 2 residents died of injuries received. The explosions were tied to geysers spewing gas and water, and their appearance caused the excavation of hundreds of Hutchinson residents.



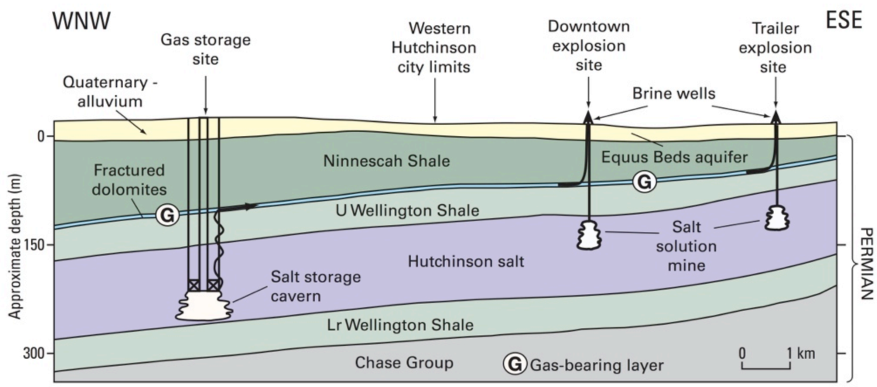
(photos, map, and diagram from Evans, 2008)

The January 17-18, 2001 eruptions of gas and brine, driving 30-ft geysers in the town, resulted from the loss of 3.5 Mcf of gas from the Yaggy natural gas storage facility located 7 miles down the road from the town community of 40,000 people.



The Yaggy field of salt caverns was originally developed in the early 1980s to hold propane. Because the company had difficulty making a financial success of the operation, the storage wells were filled with brine and then plugged by partially filling them with concrete. However, a second company acquired the facility in the early 1990s, converted it to natural gas storage, and the plugged wells were drilled out to return the caverns to use.

It is thought that cavern over-pressurization cause rupture through a previously undocumented area of damage to a well casing. The route followed to the surface by the escaping gas is thought to be a fractured shale layer that facilitated drainage to the crest of the anticlinal culmination that underlies the town of Hutchinson, where gas escape to the surface via old unplugged brine wells:



After Hutchinson Fire Department, Kansas Geological Survey, CUDD Drilling and Shannon Pope of RPC Inc) BGS©NERC. All rights reserved

Like Seneca Lake, the Hutchinson region had been an area of solution mining since the late 1800s with numerous unplugged brine wells, long ago drilled and abandoned without appropriate documentation. Likewise, it has a mix of bedded salt and permeable rock formations with natural dissolution irregularities similar to those in Seneca County, which facilitated the escape of gas to the surface and the subsequent fires, explosions, deaths, injuries, and evacuation.

(from Evans, 2008 and Warren, 2006)