STATE OF NEW YORK
SUPREME COURT : COUNTY OF TOMPKINS

In the Matter of the Application, CAYUGA LAKE ENVIRONMENTAL ACTION NOW (CLEAN), an Unincorporated Association by President JOHN V. DENNIS, and LOUISE BUCK, BURKE CARSON, JOHN V. DENNIS, WILLIAM HECHT, HILARY LAMBERT, ELIZABETH and ROBERT THOMAS, and KEN ZESERSON

Petitioners,

For a Judgment Pursuant to Article 78 of the New York Civil Practice Laws and Rules

vs.

THE NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION, and CARGILL INCORPORATED

Respondents.

AFFIRMATION OF JOHN K. WARREN IN SUPPORT OF PETITION

Index No.

Adelaide,
State of South Australia, Australia, ss.:

I, JOHN K. WARREN, hereby affirm under the penalties of perjury of the State of New York:

1. I am an evaporite geologist with a Ph.D. in Geology from Flinders University School of Earth Sciences. Evaporite geology, my area of expertise, deals with deposits of salt, gypsum, etc., and the many related practices and technologies involved in salt mining, gypsum mining, etc. In my work and writing, I understand and follow the accepted methodology of evaporite geology. I am the author of four books on evaporite and carbonate geosystems. The first edition of my most recent evaporite book was chosen by the American University Association of University Librarians as one of the "Outstanding Academic Titles for 2006." My fourth book, *Evaporites: a Geological Compendium* was published by Springer in late 2016. This is an updated and expanded version of the previous book and is now an all-color edition that is more than 1800 pages

in length. My CV is attached as Exhibit A *(a shorter online version can be accessed at https://www.saltworkconsultants.com/johns-resume)*.

2. In the fall of 2016, I was contacted by John V. Dennis, Ph.D., who asked me to review and comment on the proposed Shaft #4 for the Cargill Cayuga Salt Mine. I agreed to work as an expert consultant for Dr. Dennis, and in October 2016 I sent him my first work product, a 30-page report entitled *Technical requirements needed to approve construction of Shaft #4 in the Cayuga Salt Mine, New York State* (hereinafter "2016 Technical requirements report," attached as Exhibit B).

3. For this affirmation, I have reviewed the Cayuga Salt Mine permit, Modification # 1, effective 12 February 2021, and have also reviewed related documents such as the June 2021 affidavit of Raymond C. Vaughan ("Vaughan affidavit") and the 22 February 2018 letter report by Vincent Scovazzo of John T. Boyd Co. ("2018 Boyd letter").

4. Based on my review and my experience, I recognize the importance of a 1000-foot protective buffer around the Frontenac Point Anomaly (hereafter "FPA"), surrounding both the oval version and the linear version of the FPA. However, I am also concerned that the problems of mine stability go well beyond the FPA, and involve the trough of thinning bedrock in far greater ways than indicated in the Vaughan affidavit. This has been discussed in *Ferguson, 2017* and *Ferguson and Warren, 2017.*

5. There appears to be no dispute about the existence of one or more faults inthe immediate vicinity of the FPA. For example, about 20 years ago, Boyd reported that the FPA, then called the "disturbed area," appeared to be "a graben-like structure with a vertical displacement of approximately 100 ft." 2018 Boyd letter at p.2. A few years later, based on seismic studies, Cargill's consultant RESPEC suggested "that the anomalyis a deep penetrating, nearly vertical, east-west-trending fault." Id. at p.5. In my opinion, this and other nearby faults were likely influenced by periodic loading due to

the superposition of kilometer-thick successions of several thick glacial ice sheets that came and went during the Pleistocene. Such faults also act as planes of weakness and groundwater entry fed by sediment-filled drainage channels that were formed, partially eroded, and superimposed as each ice sheet melted.

6. It is well known that bedrock throughout the Finger Lakes region of New York is pervasively fractured. Such fractures, known as "joints," occur every few feet in the bedrock under and around Cayuga Lake. For example, see https://epod.usra.edu/blog/2004/01/taughannock-creek-joint-patterns.html and many other sources. Such fractures do not qualify as faults unless the bedrock on one side of the joint has shifted relative to the bedrock on the other side. However, even if no shifting has occurred, joints are *planes of weakness* in the rock and, depending on whether a given joint is slightly open or squeezed tightly shut, may be *gaps or conduits* along which fluids such as water or brine or methane may flow through the rock.

7. In most circumstances, the fractured bedrock at a given location can't shift either vertically or laterally because it's hemmed in by adjacent bedrock. However, as is well known, the bedrock above a large underground void such as a salt mine will gradually sag down into the void over periods of years, decades, and centuries. This well-known process, called *subsidence*, inevitably distorts the sagging bedrock and causes some amount of shifting across joints and some change in the gap or aperture through which relatively undersaturated water may flow and dissolve salt. The effect on any given joint will be small, almost imperceptible, if such shifting is spread out uniformly over the sagging bedrock, but it's usually the case that the shifting and aperture change vary from joint to joint, such that a few joints may undergo measurable/substantial shifting (thus some degree of new faulting) and may also open up substantially, thus creating a much greater opportunity for water and other fluids to flow.

8. The two preceding paragraphs have focused on joints, but similar

openings or small gaps are typically found in the more-or-less-horizontal *bedding openings* between the different layers of bedrock. In combination, the joints and bedding openings respond to the sagging (subsidence) of bedrock into a mine void. In combination, as these pre-existing fractures and openings change, the pathways for groundwater and brine change, and the mechanical strength of the bedrock above the mine also changes. These changes may be interactive, especially where subsidence widens the aperture of a joint or bedding opening, allowing an increased flow of groundwater or brine through the gap, which in turn erodes an even greater gap.

9. Such changes above a mine are ongoing and difficult to track in detail. Recent tests by Cargill under Anomaly C provide some reassurance in the short term but are only snapshots in time. The trough of thin bedrock that's been mapped from Anomaly A through Anomaly E, combined with the inevitable sagging or subsidence into the mine void beneath it, creates a recipe for eventual unwelcome changes, especially in the amount of water entering the mine workings. Continual testing is needed above the areas already mined, and based on my professional experience I recommend that further mining beneath the trough of thin bedrock be discontinued.

10. Some have suggested that large pillar mining resolves the issues summarized above. I disagree as this methodology assumes little potential for unexpected entry into regional surface and groundwater sources with unexpected large volumes of water that may flow catastrophically into the mine workings.

11. Water or brine is known to have already penetrated relatively deeply into the bedrock above the mine. One of our previous reports to CLEAN showed that this was likely, based on evidence of glacial meltwater and groundwater being pumped or driven downward, to depths of hundreds of meters, as documented in the Michigan and Appalachian Basins and other locations worldwide. Relating to the Cayuga mine itself, Boyd's 2015 review of Cargill's 2014 annual report cites a RESPEC opinion that the FPA "may reflect the southern extent of water infiltration" that consists of brine on top of and between beds of rock and salt in the Salina Group, the presence of which has

been recognized further north in the Cayuga Lake Valley.

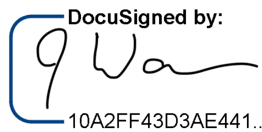
12. More specifically, as noted on p.8 of Boyd's 17 June 2020 review of Cargill's 2019 annual report, brine was encountered in November 2019 in an investigation drill hole above the U-12 mining panel, 133 ft above the #6 salt, in the dolomite layer between the #4A salt and #5 salt layers. Although the brine at this location was drained and depressurized, it remains a reminder of the water and brine that may be encountered at depths similar to the depth of the mine.

13. At the moment, the level of water entry is safely controlled by the company via pumping, but most active salt mines are lost to flooding via the intersection of an unexpected water source. I have detailed examples of salt mine losses to this type of water entry in a recently published paper; *Warren, J. K., 2017, Salt usually seals, but sometimes leaks: Implications for mine and cavern stabilities in the short and long term:* ***Earth-Science Reviews****, v. 165, p. 302-341.*

14. The extent and relevance of water/brine penetration can and should be evaluated by modern methods such as seismic integration with salt-core textural and mineralogical analysis. In my review of available documents, I see too little awareness of integration and use of some of these modern methods, at least in the limited data released into the public realm.

15. In summary, the FPA needs protection and a protective buffer, but there is a larger issue of risks from water entry due to undocumented *thinning bedrock* and *faulting* that goes beyond the FPA. As described above, and based on my professional experience, I recommend that further mining beneath the trough of thin bedrock be discontinued until a full evaluation of the potential negative consequences.

This affirmation is based on information available to me at this time. Should additionalinformation become available, I reserve the right to determine the impact, if any, of the new information on my opinions and conclusions and to modify or supplement this affirmation if necessary.



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March 18, 2015
File: 2499.004

New York State Department of Environmental Conservation
Bureau of Resource Management & Development
Division of Mineral Resources
625 Broadway, Third Floor
Albany, NY 12233-6500

Attention: Mr. Matthew Podniesinski
Chief, Resource Development Section
Bureau of Resource Management & Development

Subject: Annual Report Review - 2014
Cayuga Mine, Cargill, Inc.
Seneca and Tompkins Counties, New York

Gentlemen:

John T. Boyd Company (BOYD) received a CD from Cargill Deicing Technology (Cargill) on January 16, 2015 and post-marked January 14, 2015. The CD included a cover letter[1], the Annual Report[2], maps as AutoCAD® files, extensometer and closure readings as Excel® files, and consultant reports. Two reports are from RockTec

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[1] Plumeau, David B., 2015, untitled letter from Cargill Deicing Technology to Vincent A. Scovazzo, John T. Boyd Company, January 9.

[2] Cargill Deicing Technology, 2014, "Annual Report for Mine File #709-3-29-0052; Cayuga Salt Mine, Permit ID#0-9999-00075-00001," with cover letter from Shawn G. Wilczynskito to Matthew Podniesinski of New York State Department of Environmental Conservation, November 24.

Solutions[3, 4], 13 reports are from ESG Solutions including a velocity model report[5] and 12 monthly reports[6], and one from RESPEC[7].

On February 15, 2006, Mr. Steven M. Potter, then the Director, Bureau of Resource Management & Development, New York State Department of Environmental Conservation (NYSDEC), requested that BOYD review all documents, digital data, and annual reports received by BOYD starting with the 2006 Annual Report.

The recently received documents were reviewed for their adherence to conditions of the revised Permit[8]. §12.8 of this revised permit limit cost for review of annual reports by Consulting Services to $15,000. For this annual review, BOYD is providing the Consulting Services. It is noted that "Funding relating to permit modifications or alterations requiring consultant review shall be not be capped due to the varying nature of potential future applications. Cargill shall fund the cost of the annual meeting/underground inspections, and will share the cost of joint inspections with American Rock Salt Co., LLC."

The Cargill 2014 Annual Report is accepted, however, additional information is required for further evaluations by BOYD and NYSDEC. This includes:

- A map showing the thin rock overburden, Frontenac Point Anomaly, the 1,000 ft set back, and mine projections.
- The well data referencing the presence of brine on top of and within the beds of the Salina Group and seismic data which may show the presence of this brine.

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[3] Petersen, Gary, 2014, "Cargill Deicing Technology, Cayuga Mine, Rock Mechanics Evaluation," report to Dave Plumeau of Cargill Deicing Technology, July 21.

[4] Petersen, Gary, 2014, "Cargill Deicing Technology, Cayuga Mine," report to Dave Plumeau of Cargill Deicing Technology, April 28, with notes attached on MS data.

[5] ESG Solutions, 2014, "Seismic Velocity Model Optimization at the Cayuga Mine," Reference Number: 2015-0111 Version: 2, Cargill Corp., November.

[6] ESG Solutions, 2013, "Remote Data Processing, Seismicity & System Health Analysis Report," Reference Number: 2012-003664, submitted to: Cargill, January 7, February 4, March 4, April 4, May 29, June 11, July 4, August 8, September 5, October 4, November 17, and December 12, 2015.

[7] DeVries, Kerry L., William M. Goodman, and Cody A. Vining, 2014, "Mine Stability Assessment, Cargill Deicing Technology, Cayuga Mine, Lansing, New York," RESPEC Topical Report RSI-2371, prepared for Cargill Deicing Technology, April.

[8] New York State Department of Environmental Conservation, Region 7, 2007, "Permit" DEC ID 0-9999-00075, expiration December 31, 2012, December 31, Modification # I Effective Date: November 8, 2013.

BOYD and NYSDEC request additional assessments, which should be included in the next annual report. These are:

- Salt dissolutioning and pillar undercutting at the injection point on 4-Level.
- Avoid mining intersecting panels and eliminating breakthroughs to contain mine flooding due to a breach.
- A prudent mine subsidence monitoring plan, which includes survey, survey frequency, data assessment, and monument installation schedules.

Discussion of Annual Report

The Permit has several conditions that affect the Annual Report and its review including:

Condition 3

Condition 3 requires all reports required by the permit to be submitted to Region 7.

Condition 9.a.

Condition 9.a. requires investigation into the disturbed salt zone and this investigation to be completed and submitted before mining proceeds into the area. Based upon the additional seismic survey and consultant reports, particularly RESPEC's report[7], Cargill will maintain the planned 1,000 ft setback around the Frontenac Point Anomaly. Further investigation shall be completed and submitted to the Department for review and approval prior to mining within this 1,000 ft buffer.

Condition 9.b.

Condition 9.b. requires investigations and reports on the adequacy of the thin rock overburden where the solid rock overburden is thinner, the glacial till and lake sediments thicken and lake depth increases. The thin rock overburden and Frontenac Point Anomaly may overlap. These Additional investigations and reports have not been performed, and mining in this area should be avoided until reviewed and approved by the NYSDEC.

Condition 12.a.

Condition 12.a. requires an Annual Report to be submitted by Cargill in response to 12.a. sub-conditions 1 through 8 and Condition 12.b through g. These conditions and Cargill's responses are summarized below.

Condition 12.a.1.

Condition 12.a.1. requires the inclusion of the Mine Manager's signed certification that "all mining related activities...were in conformance with this permit and the approved plans, or that variances have been reported and managed."

A certification was included on page 2 §12.a.1. and the certification sent to NYDEC was signed by Mr. Shawn G. Wilczynski, Mine Manager, on November 21, 2014. This certification notes "... that all mining activities, to the best of my knowledge, conducted during the reporting period from November 1, 2013 to present were in conformance with the DEC Permit # 0-9999-00075/00001 and the approved plans. No variances occurred and none were reported."

Condition 12.a.2.

Condition 12.a.2. requires "A summary of all non-routine mining incidents as defined in Special Conditions Part b. ..." Condition 13.b. defines non-routine as "incidents during mining, processing, or other mine related activities that may adversely affect mine stability, ground and surface water or other natural resources, or the health, safety, welfare or property of the general public." During a meeting held on August 17, 2004, with Cargill, NYDEC, and BOYD, it was agreed that statements will be included in the Annual Report "to point out known, encountered, or discovered geologic and geotechnical anomalies and mine action to address such anomalies."

Cargill included a statement in the Annual Report page 2, Section 12.a.2. that "[t]he Cayuga Mine is not aware of any non-routine incidents associated with the mining, processing, or other mine related activities that would have adversely affected any of the following:

- Mine stability.
- Ground and surface water.
- Natural resources.
- Health, safety, welfare or property of the general public".

Condition 12.a.3.

Condition 12.a.3. requires "[a]n updated Mining Plan Map depicting the current extent of mining activities, and the proposed advancement of the working face for the subsequent three years." At the August 2004 meeting, it was agreed that in addition "[a] mine map showing instrumentation location and type and shore line..." will be included in the Annual Report.

Cargill included a statement in the Annual Report, page 2, Section 12.a.3. that "[t]he Cayuga Mine is currently operating in the northern region of the mine. Active mining is located in panels U-62B and U-72 to the west, and NW-3 to the north. As can be seen on the map, mining is proposed to continue east from U-63 under the land, pending acquisition of mineral rights there."

Mine maps as AutoCAD files were supplied by Cargill to fulfill this condition. All AutoCAD maps supplied were overlays and a base map. The base map was included as BASEMAP_WITH_ROCK_LAYER_ROOF ROCK_FLOOR rock rolls (updated 12-18-14.dwg, which was last modified December 23, 2014, and includes a map entitled "Cayuga Mine, 6 Level Workings," by Cargill Deicing Technology. Also included on this map are roof and floor rolls. Other maps provided are:

- The AutoCAD file, COMPLETE MINE OVERLAY W_SURFACE Subsidence (12-2014).dwg, last modified December 23, 2014, and containing untitled, undated map, which shows subsidence monument locations, shore line, and the 1st, 4th, and 6th Level workings.
- The AutoCAD file, ROYALTY.DWG, last modified January 08, 2015, and containing the Cargill Deicing Technology, 2014, "Cayuga Mine, Mine Royalty Map, 2014/2015 Fiscal Yr." December. Map shows fiscal year production areas from June 1, 1984 through May 31, 2014.
- The AutoCAD file, BAKER UPDATE U38-36 DUST FILL MAP.DWG, modified January 08, 2015, containing an untitled, undated map and shows U38 areas filled.
- The AutoCAD file, BASEMAP PLANNING FOR MLRP.DWG, modified December 23, 2014, and containing the map Cargill Deicing Technology, 2014, "Cayuga Mine, 3 Yr Mine Plan, 2014/2015 Fiscal Yr.", November. This map shows planned expansion through fiscal year 2017.
- The AutoCAD file, 4 LEVEL POND MAP MLRP VERSION 18NOV14.DWG, modified December 23, 2014, and containing the map, 2015, "Cayuga Mine, 4 Level Pond Map, Updated: 18 Nov 2014," January. This map shows filled levels to January 1, 2015, and remaining potential pond area.
- AutoCAD file 4 LEVEL CONVERGENCE MAP.DWG, modified December 23, 2014 and contains an untitled and undated map showing closure station locations.
- The AutoCAD file, 4A LEVEL FOR JT BOYD.DWG, modified December 23, 2014 containing undated, "4A Level Instrumentation Map." This map shows closure station's locations.
- A hard copy map, undated and untitled, scale 1 in. = 50 ft and AutoCAD file, PAMELPASS.DWG, modified December 23, 2014, and contains the map "4 Level, Pamel Pass – 13 Belt." This map shows locations of extensometers along 13 belt.

- An untitled AutoCAD file, SCREEN PLANT HORIZONTAL ROOF EXT.DWG, modified December 23, 2014, and showing map and cross-section view of installation locations of near horizontal extensometers in the roof of the screen plant gallery.
- The AutoCAD file, SCREEN PLANT INSTRUMENTATION.DWG, modified December 23, 2014, and containing map undated, "Unit # 5 Screenplant," showing instrument locations in and around the screen plant gallery.
- The AutoCAD file, undated, "Current Surge Bin Instrumentation Map as of 9-09" and AutoCAD file, SURGE BIN INSTRUMENT MAP TO JT BOYD.DWG, modified December 23, 2014, and containing undated, "Current Surge Bin Instrumentation Map as of 9-09," showing instrument locations in and around the screen plant gallery.
- AutoCAD file, CONVERGENCE MAP WITH BASEMAP 2013.DWG, modified December 23, 2014, and containing the map Cargill Deicing Technology, undated, "Cayuga Mine, 6 Level Workings, Convergence Stations" This map shows the locations of convergence stations.
- Adobe Acrobat file Cayuga Mine Contour Dec 2014 for JT Boyd Rate Dec-2014.pdf a conversion of a Sony RAW file Cayuga Mine Contour Dec 2013 for JT Boyd Rate Dec-2013.srf modified December 23, 2014 and containing the undated map "Cayuga Mine Closure Rate (Inches/Year) Dec-2013."
- Adobe Acrobat file Cayuga Mine Contour Dec 2014 for JT Boyd Closure Dec-2014.pdf a conversion of a Sony RAW file Cayuga Mine Contour Dec 2013 for JT Boyd Closure Dec-2013.srf modified December 23, 2014 and containing the undated map "Cayuga Mine Closure Rate (Inches) Dec-2013."

The supplied maps show the extent of mining, proposed mine plan, subsidence monument locations, shorelines of both the 4 Level flooding and of Cayuga Lake, total closure, closure rate, and instrument locations.

Condition 12.a.4.

Condition 12.a.4. requires the annual report to include a "summary of in situ measurements of rock mechanics required by Part f. of this Special Condition." Condition 13.f. requires the measurement and collection of in situ rock mechanics data "in accordance with the approved Mined Land Use Plan." The data are to include "plots of relevant graphs. …" Furthermore, "[e]xceptions to anticipated trends in rock behavior shall be noted and explained. …"

At the August 2004 meeting, it was agreed that "[a]ll rock mechanics data" would be incorporated in the Annual Report, "including, but not limited to, all instrumentation readings and observations from the initial readings to present. Data for subsidence, closure, and extensometers are to be provided electronically. These electronic files are to include raw and processed data, graphs, and explanations of any inconsistencies and anomalous readings including reasons for abandonment, reinstallation, etc., along with applicable observation in the vicinity of the instrument such as floor heave, water inflow, etc. Future reports are to contain comment on whether, in the opinion of Cargill, the instrument readings support or conflict with prior stability models especially in areas employing new mine, panel, or main configurations."

Cargill included a statement in the Annual Report on page 2 and 3, Section 13.a.4. that "Evaluations of weekly and quarterly convergence data indicate that no unusual trends have been identified and the mine is behaving as expected, with the exception of the U-40B and U12 areas. Since backfill placement in the U40B area has been completed the convergence rates have slowed and are trending back toward historical rates. The U-12 panel also shows higher than normal closure near the breakthrough with SW-2 and near the U-12A sub-panel. These areas are being monitored more frequently as we try to understand why the rates are increased. Both of these areas in U-12 were backfilled during the 1990's and both areas show a decreasing rate trend at this time."

Closure measurements can be evaluated to indicate possible instability in three ways:

1. By studying the graphs of the rate of closure over time. The shape of these graphs indicates areas of instability, areas of concern, and areas of stability. Mr. Petersen of RMA (Cargill geotechnical consultant) evaluated the closure in this manner.
2. By establishing trigger values for total closure. This method is applicable in harder, less viscous rock but is not applicable for the Cayuga Mine, as stable closure in salt will continue until the openings are closed.
3. By establishing trigger values for long-term closure rates. Since this is not being completed by the other investigators, BOYD applied such trigger rates in its evaluation of the closure readings.

Closure rate data are significant because they offered insight into the collapses and the inundation of the Retsof Mine. Sustained closure rates of 15 in. per year or less were measured in stable areas of the Retsof Mine, while in the failure areas, closure was regularly measured with sustained rates over 230 in. per year with onset of failure around 600 in. per year. Although Retsof and Cayuga mines have different overburden and material properties, in the general sense, a comparison seems warranted for a relative indicator of stability.

BOYD reviewed the 373 closure stations read in 2014 (365 in Level 6, five in Level 4A, and three in Level 4). Of these, 150 (41%) had the highest closure rate of the year on the last calculated rate of the year, down from 42%. A similar trend was noted over several years by BOYD. Reviewing in-mine humidity data, it can be seen that the highest humidity in the mine occurred between early July to early November which accounts for this trend and for 142 of the 150 readings.

None of these 373 closure stations showed readings that exceeded 230 in. per year. Below is a list of the 10 highest measured closure rates in 2014 for areas of recent mining defined as areas within 1,000 ft of mining that occurred since October 2013.

Top 10 Closure Rates in Areas of Recent Mining

Closure Station	Rate of Closure (in./yr)	Last Recorded Rate of Closure (in./yr)	Notes
U62PIN No. 33	80.54	-	Initial and only reading
U62BPIN No. 3	77.52	11.45	Initial reading
U62BPIN No. 2	67.21	12.67	Struck by equipment, 2nd reading
U62PIN No. 35	65.82	2.43	Initial reading
U62BPIN No. 1	62.88	8.38	-
U68PIN No. 6	60.59	1.22	Initial reading
U62PIN No. 32	59.25	2.33	Initial reading
U68PIN No. 4	53.50	8.33	Initial reading
U62BPIN No. 4	53.33	7.66	Initial reading
U62PIN No.31	52.40	14.44	Initial reading

All of these rates substantially dropped over time showing that the ground is stable or stabilizing. All 10 of these stations are located in the most northern part of the mine where all production is located, with four stations located in U-62, four in U-62A, and three in U-68.

Also determined are the top 10 closure rates away from recent mining activity as shown below:

Top 10 Closure Rates Away from Recent Mining

Closure Station	Rate of Closure (in./yr)	Last Recorded Rate of Closure (in./yr)	Notes
U62PIN No. 17	1.1532	0.91	-
U60PIN No. 23	1.127	1.127	Last reading
U63PIN No. 2U	1.012	0.642	-
U40BPIN No. 8	0.9936	0.967	-
U12PIN No. 32	0.9889	0.9889	Last reading
U12PIN No. 28	0.9507	0.9507	Last reading
2B-U40B	0.9291	0.898	-
U12PIN No. 107	0.9051	0.887	-
U4PIN No. 20	0.9029	0.9029	Last reading
U60PIN No. 20	0.8837	0.8837	Last reading

Rates dropped for five of these stations over 2014. Rates did not drop in five stations where high readings occurred during a period of high humidity. The rate drop indicates the ground is stable.

- Four of these readings (U62PIN No. 17, U60PIN No. 23, U63PIN No. 2U, and 60PIN No. 20) occurred close to two but just outside the 1,000 ft cut off for recent mining.
- Three high-rate stations are clustered in U-12 areas near the U-12A sub-panel, which are the same stations that have been included over the last three years. U-12 areas have been frequently visited in the past by BOYD and NYDEC to observe conditions and each time the area appears globally stable.
- Two in the U-40 fill area.
- The location of station 2B-U40B could not be determined.

Extensometer data were also evaluated. Extensometers were installed in various manners including vertically into the roof, at low angle (near horizontal) into the roof and then over the pillars, and horizontally into pillars. In addition, extensometers were installed in levels 4 and 6. Thus, four populations exist. These data are further complicated by the varying rod and bay lengths. (Bay length is the length difference between rods except for the first bay which is the length of the shortest rod.) Nevertheless, BOYD attempted to ascertain anomalies within these data.

Extensometer Sag or Swell
(anomalous rates are in bold)

Extensometer Location	Station	1st Bay, in.	2nd Bay, in.	3rd Bay, in.
	Roof Horizontal – Level 6			
Screen Plant	1A	0.955	-0.885	0.970
	1B	0.008	0.005	0.920
	2A	0.087	0.316	1.072
	2B	0.083	0.355	1.267
	3A	0.071	0.043	0.448
	3B	0.089	0.037	0.285
	4A	-0.059	1.037	1.558
	4B	0.072	0.025	3.748
	Pillar – Level 6			
Screen Plant	G Pillar, Hole B1	**2.809**	-1.378	-0.784
	H Pillar, Hole A1	**2.891**	-1.203	-0.547
	H Pillar, Hole A3	0.280	0.379	2.016
	I Pillar, Hole B1	1.408	-0.059	-0.778
	J Pillar, Hole B1	1.790	-0.161	-1.321
	Roof – Level 4			
Pamel Pass	No. 1	0.116	0.033	0.021
	No. 2	0.021	-0.009	-0.008
	No. 3	0.198	0.023	-0.020
	No. 4	0.477	0.067	0.024
	No. 5	0.563	0.092	0.009
	Pillar – Level 4			
Surge Bin	No. 20	0.680	0.278	0.084
	No. 25	1.901	1.261	-0.076
	No. 50	1.066	0.750	0.163
	GA-No. 10	-	0.730	0.049
	GA-No. 11	-	0.539	-0.027
	GA-No. 22	-	2.121	0.202
	GA-No. 27	-	2.791	0.087
	GA-No. 29	-	1.092	0.043
	GA-No. 49	-	0.024	0.017
	GA-No. 60	-	0.653	0.124
	GA-No. 80	-	0.001	0.046
	GA-No. 90	-	0.127	0.021
	GA-No. 100	-	0.045	0.010

A measurement of 0.00030 in. per day is often accepted as a convenient point in examining vertical extensometer data, as this value is close to, but normally less than the value required for bed separation (opening of bedding planes). Horizontal roof extensometers are installed at 5 degrees to 15 degrees from the horizontal as measured in the AutoCAD drawings. This angle would multiply any bed separation, thus the trigger used for horizontal extensometers is 0.02 in. per day or about 2 in. of sag. No extensometer readings were considered alarming.

Condition 12.a.5.

Condition 12.a.5. requires the Annual Report include a "summary of subsidence monitoring data required by Part e. of this Special Condition." Condition 12.e. requires "[s]ubsidence monitoring shall be conducted in accordance with the approved subsidence monitoring plan contained within the approved Mine Land Use Plan." Furthermore, "[e]xceptions to the trends shall be noted and explained…" Points applicable to this condition were agreed upon at the August 2004 meeting and are noted above under Condition 12.a.4.

Cargill included a statement in the 2013 Annual Report page 3, Section 12.a.5 that "A survey of the west shore of Cayuga Lake was performed this year and the data is being evaluated now. Plans are being made to conduct subsidence surveys of the east shore line in the 2014 calendar year. This 2014 Annual Report states on page 3, Section 12.a.5 that "Plans are being made with a new surveying contractor to conduct subsidence surveys of the surface in the 2015 calendar year." A similar statement was included in the 2012 annual report that noted the east line would be completed in 2013.

Cargill includes a statement "Past measurements indicate that the mine is behaving as expected with no anomalous subsidence zones."

Consultant Reports Concerning Conditions 12.a.4. and 5.

Mr. Petersen discussed his visit to the Cayuga Mine on February 25 through 26, 2014. This visit did not include underground observations. He noted that the closure rate for U-40B, U12, and U28 were "… higher than expected, are declining, which is a good thing." And that for U-40B he is "… no longer concerned with excessive closure occurring in this area." He noted that intersections U12/SW2 and U12/U12A closures rates are declining.

Mr. Petersen cautions about mining around the northern anomaly and that Cargill should "… avoid mining intersecting panels in that area." because "This increases the effective panel width, making the intersection more vulnerable for higher closure and problems." He also recommended eliminating the breakthroughs between panels, to contain mine flooding if a breach were to occur.

Mr. Petersen analyzed the microseismic data over the past four years starting with 2010. He noted that when there were periods of no blasting, the frequency of the triggered events declined. "Triggered" events are events recorded by any geophone.

"Large" events are those with a magnitude of 0.5 or greater. The frequency of large events located north of U52, peaked in January 2011 when mining was occurring beneath a line defined by the location of these events. The frequency of large event south of S3 has declined since early 2012.

Mr. Petersen noted in his second report that "... mine-wide closure rate graphs and, except for those areas mentioned in this report, they were all indicating very stable conditions." Drawing the same conclusions for U-40B, U12, and U28, he repeated recommendations for mining near the anomaly in the north, and repeated the microseismic discussion as in the first report.

A RESPEC report was also reviewed. RESPEC discussed the closure rate for U40B which peaked in 2008. The increase in rate started in 2006 and backfilling started in August 2007. RESPEC does not expect closure rates to slow until after the openings close approximately 4 ft. But in contradiction RESPEC noted that closure rates for some stations are less than those before 2006 but they do not expect other stations' closure rate to be below pre-2006 rates for several years to come.

Panel U12 experienced an upturn in closure rates between 2006 and 2008, which was most pronounced in and near the intersections U12A/SW2 and U12/U12A. "The closure rates in U12 have declined since 2011, but are still greater than expected based on pre-2005 measurements ..." and as experienced throughout the mine. U12's 1993 backfill has not compacted enough to curtail closure.

RESPEC also notes "Well data in the northern part of the Cayuga Lake Valley have determined that brine is present on top of and in between beds in the Salina Group. The Frontenac Point Anomaly may reflect the southern extent of water infiltration." RESPEC opines that the planned 1,000 ft buffer around Frontenac Point Anomaly should prevent a hydraulic connection with the mine. Further, "As the mine progresses north, microseismic monitoring to detect anomalies and drilling in advance of the faces to detect an increase in moisture or presence of water is recommended as a precaution."

RESPEC notes that "Salt dissolution near the injection point on the 4-Level is visible and the pillars are being undercut ...", which can possibly result in mine collapse. And noting "A major collapse in this area could have a significant effect on Cayuga Lake's shoreline and the mine shafts. Continued dumping of waste salt at the base of the No. 2 Shaft is encouraged to increase salt saturation before the inflow enters the west pond."

In addressing ESG work in micro-seismic RESPEC opined about select events being located along sets of lines that "Three linear features indicative of echelon tear faults are identifiable by the northern seismic network. In the southern mine workings, the events cluster around a single linear feature." "RESPEC recommends that salt dust and waste rock be backfilled under those areas that are seismically active as a precaution."

RESPEC discussed their numerical analyses related to changes in mine layout and changes in geology as the mine expands northward under the lake. In part, these analyses were addressed by BOYD in 2014[9,10].

In the 2014 Annual Report, a series of reports of ESG Canada Inc. were included along with a report about development of a new velocity model. The original seismic velocity model for the Cayuga Mine was optimized using new velocity log information from corehole No. 18 and No. 17 waypoints located within the No. 6 Salt layer. ESG used 12 calibration blasts.

Condition 12.a.6.

Condition 12.a.6. requires the inclusion of "[i]nformation regarding the source and volume of any water inflow into the mine, and the disposition of such water." At the August 2004 meeting, it was agreed that a discussion about water disposal in Level 4 would be included in the Annual Report, noting: "Updates of Level 4 filling including data on shore line advance." However in 2012 it was noted that "Access to view the pond is not possible due to ground conditions." However, RESPEC appears to have viewed the site in 2014.

Mr. Plumeau notes that "All of the water is directed to a settling pond located on the 4-level of the mine. The water is then pumped from the settling pond to abandoned areas at the far east end of 4-level as well as to various areas of the active mine for dust control. Recent volume calculations indicated that at our current rate of storage (about 16,800,000 gallons per year) we have approximately 7.9 years of storage life remaining on 4-level" These values have changed from the 2013 Annual report that noted "... our current rate of storage (about 12,000,000 gallons per year) we have approximately 13 years of storage life remaining on 4-level."

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[9] Scovazzo, V.A., 2014, "DRAFT Review of Permit Modification Application for Cayuga Mine, Cargill, Inc." prepared for Matthew Podniesinski, New York State Department of Environmental Conservation, John T. Boyd Company File: 2499.004, July 31.

[10] Scovazzo, V.A., 2014, "DRAFT Review of RESPEC's Response Cayuga Mine, Cargill, Inc." prepared for Matthew Podniesinski, New York State Department of Environmental Conservation, John T. Boyd Company File: 2499.004, December 9.

Cargill also notes that an "Action plans are in place to continue to reduce the inflow into the mine. A system for collecting the #1 shaft water inflow and for pumping it to surface for processing has been installed and is now operational. It is being optimized now. Once the processing system is fully operational it is expected to reduce inflow by an additional 3 gpm." This value is down from 6 gpm as noted in last year's annual report. Also reported is that "The shaft water inflows have been increasing over the past 10 years and have become a concern. The Cayuga Mine is now pursuing contractors that can help grout the #1 shaft inflows to reduce them to tolerable levels."

Cargill included a Level 4 pond map, as noted above, and an Excel file, UG Pond Volume Calculation 3Nov14.xls, which was last modified November 03, 2014. This spreadsheet reports the inflow in 2014 at 16,844,053 gallons with 7.9 years of storage remaining.

Condition 12.a.7.

Condition 12.a.7. requires the inclusion of "[a] summary of all other monitoring data required under the terms of this permit or Department SPDES permit issued to Cargill." Cargill included a statement in the Annual Report page 3, Section 12.a.7. that "There were no exceedances of the SPDES limits for the outfalls or the Waste Water Treatment Plant to report during the time of this report." An included spreadsheet last modified November 21, 2014, provides information on outfall water quality including cyanide, chloride, zinc, total dissolved solids, and cooling and treatment water.

SPDES data and a discussion of these data are included in the Annual Report. These data are to be reviewed by NYSDEC.

Condition 12.b. and c.

Condition 12.b and c. addresses Mine Safety and Health Administration (MSHA) reporting involving non-routine mining incidents as defined in Condition 12.b. Condition 12.c. requires Cargill to submit "all correspondence with the Mine Safety and Health Administration involving non-routine mining incidents..."

Cargill includes a statement on page 3 section 12.b. of the Annual Report that "[t]here were no incidents meeting the guidelines for notification as identified in section 12.a.2." and section 12.c. of the Annual Report that "[t]he Cayuga Mine has not received any citations or correspondence from MSHA regarding non-routine mining incidents as identified in section 12.a.2." The Annual Report does not note reports or letters from MSHA concerning any non-routine mining incidents.

Condition 12.d.
Condition 12.d. addresses reporting requirements "Prior to undertaking any material change in the approved mining methods or techniques ... Cargill shall submit to the Department a description of such modification ..." This condition does not require the reporting to occur in the Annual Report.

Cargill notes on page 4 in section 12.d. that, "There have been no changes to the Cayuga Mine layout in the past year."

Condition 13.g.
Condition 13.g. addresses the reporting and recording of citizen complaints.

Cargill includes a statement on page 4 section 13.g. of the Annual Report that "[n]o written complaints from citizens were received since the last report (November 2013)."

Site Visit
A site visit to discuss these findings among NYSDEC, Cargill, and BOYD should be arranged. Suggested areas to visit in the mine are U62 and U62B.

Topics for discussion at the meeting should include:

- Pillars being undercut in Level 4 which possibly can result in mine collapse.
- Subsidence survey schedule.
- Brine present on the top of and within the Salina Group at the Frontenac Point anomaly.
- The potential for a mine breach and flooding referenced in the Peterson report.

Please contact us if you require additional information or if we may be of further service.

Respectfully submitted,

JOHN T. BOYD COMPANY
By:

Vincent A. Scovazzo
Director of Geotechnical Services

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June 17 , 2020
File: 2499.004

New York State Department of Environmental Conservation
Bureau of Resource Management & Development
Division of Mineral Resources
625 Broadway, Third Floor
Albany, NY 12233-6500

Attention: Mr. Matthew Podniesinski
Chief, Resource Development Section
Bureau of Resource
Management & Development

Subject: Revised 2019 Annual Report Review
Cayuga Mine, Cargill, Inc.
Seneca and Tompkins Counties, New York

Ladies and Gentlemen:

The 2019 Annual Report Review completed by John T. Boyd Company (BOYD) and submitted to Mr. Matthew Podniesinski on May 15, 2020 has been revised. On May 28, 2020, Mr. Mark Theisinger, Senior Engineer of Cargill's Cayuga Mine notified BOYD that Cargill's original data set contained some irregularities and calculation issues. The data and calculation changes were made and a final data set was provided via the secured Intralinks website on June 02, 2020.

Initially, Dr. Vincent Scovazzo, Director of Geotechnical Services, and Dr. María Jaime, Senior Geotechnical Engineer, of BOYD, received an email message on March 10, 2020 from Steven Army, Region 8 Mining Program Supervisor, New York State Department of Environmental Conservation (NYSDEC) with the attached Annual Report[1] signed by Shawn G. Wilczynski as file DOC031020-03102020105346.pdf last modified March 10, 2020.

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[1] Wilczynski, Shawn G. of Cargill Deicing Technology, 2020, "Annual Report for Mine File #709-3-29-0052; Cayuga Salt Mine, Permit ID#0-9999-00075-00001" to Matthew Podniesinski of New York State Department of Environmental Conservation, March 4.

Dr. Scovazzo received an email message on April 06, 2020 from Mr. Theisinger advising that the 2019 Annual Report data set could be accessed on Intralinks. This data set contained:

- Maps as Adobe Acrobat® files.
- Extensometer and closure readings as Adobe Acrobat® and Excel® files.
- Seismicity consultant reports from Engineering Seismology Group (ESG).

On February 15, 2006, Mr. Steven M. Potter, then the Director, Bureau of Resource Management & Development, NYSDEC, requested that BOYD review all documents, digital data, and annual reports received by BOYD starting with the 2006 Annual Report.

The received documents were reviewed for their adherence to conditions of the revised Permit[2]. Section 12.8 of the revised permit limits cost for review of annual reports by Consulting Services to $15,000. BOYD is providing the Consulting Services for this annual review. It is noted that "Funding relating to permit modifications or alterations requiring consultant review shall not be capped due to the varying nature of potential future applications. Cargill shall fund the cost of the annual meeting/underground inspections, and will share the cost of joint inspections with American Rock Salt Co., LLC."

The Cargill 2019 Annual Report contained ESG reports but no other consultant reports. Previously, active mining location and mine progress over the last three years were determined from the royalty map. Upon the request from BOYD, Mark Theisinger made the royalty map available on Intralinks on April 28, 2020 as part of the report data set. The file, 9.3 Royalty map2020.pdf, contained the mine advance information required for the 2019 Annual Report review.

Discussion of Annual Report

The Permit has several conditions that affect the Annual Report and its review including:

Condition 9

Condition 9.a.

Condition 9.a. requires investigation into the disturbed salt zone and this investigation to be completed and submitted before mining proceeds into the area. Based upon the additional seismic survey and consultant reports, Cargill will maintain the planned 1,000 ft setback around the Frontenac Point Anomaly. Further investigation is to be

[2] New York State Department of Environmental Conservation, Region 7, 2007, "Permit" DEC ID 0-9999-00075, expiration December 31, 2012, December 31, Modification # I Effective Date: November 8, 2013.

completed and submitted to the Department for review and approval prior to mining within this 1,000 ft buffer.

<u>Condition 9.b.</u>
Condition 9.b. requires investigations and reports on the adequacy of the thin rock overburden where the solid rock overburden is thinner, the glacial till and lake sediments thicken, and lake depth increases. The thin rock overburden and Frontenac Point Anomaly may overlap.

The required additional investigations and reports have been performed for Anomaly C. Undermining of Anomaly C will be completed using a large pillar configuration and not the more yielding production pillar typically used at the Cayuga Mine. Cargill has agreed that no additional mining will occur under Anomaly E and no mining will occur under Anomaly D and the Frontenac Point Anomaly. Additional investigations and reports will need to be undertaken for anomalies A and B, and mining in these areas should be avoided until reviewed and approved by the NYSDEC.

The 2019 Annual Report notes the inclusion of reports by ESG Canada Inc. which were in the Intralinks data set as documents 7.1 through 7.14:

- ESG Solutions, “Seismic Data Processing Results and Health Analysis Report for Cayuga Monitoring System,” prepared for Cargill Salt Division, covering 14 months from November 2018 to December 2019.

  Cargill notes in the annual report that “The Cayuga Mine operates a micro-seismic monitoring network which now has over 120 geophones and covers over 6 square miles of mine workings. The data from this system is reviewed daily in-house, by ESG, and is reviewed weekly by RESPEC. This data indicates the mine is behaving as expected and is stable.”

Condition 15.a.
Condition 15.a. requires an Annual Report to be submitted by Cargill in response to 15.a. sub-conditions (1) through (8) and Condition 15.b. through g. These conditions and Cargill’s responses are summarized below.

<u>Condition 15.a.(1)</u>
Condition 15.a.(1) requires the inclusion of the Mine Manager’s signed certification that “all mining related activities…were in conformance with this permit and the approved plans, or that variances have been reported and managed.”

A certification was included on page 2, Section 15.a.(1) and the certification was signed by Mr. Shawn G. Wilczynski, Mine Manager, on March 4, 2020. This certification notes "…that all mining activities, to the best of my knowledge, conducted during the reporting period from October 1, 2018 through December 31st of 2019 were in conformance with the DEC Permit # 0-9999-00075/00001 and the approved plans. No variances occurred and none were reported."

Condition 15.a.(2)

Condition 15.a.(2) requires "A summary of all non-routine mining incidents as defined in Special Conditions Part b. …" Condition 15.b. defines non-routine as "incidents during mining, processing, or other mine related activities that may adversely affect mine stability, ground and surface water or other natural resources, or the health, safety, welfare or property of the general public." During a meeting held on August 17, 2004, among Cargill, NYSDEC, and BOYD, it was agreed that statements will be included in the Annual Report "to point out known, encountered, or discovered geologic and geotechnical anomalies and mine action to address such anomalies."

Cargill included a statement in the Annual Report page 2, Section 15.a.(2) that "[t]he Cayuga Mine is not aware of any non-routine incidents associated with the mining, processing, or other mine related activities that would have adversely affected any of the following:

- Mine stability.
- Ground and surface water.
- Natural resources.
- Health, safety, welfare or property of the general public."

Condition 15.a.(3)

Condition 15.a.(3) requires "[a]n updated Mining Plan Map depicting the current extent of mining activities, and the proposed advancement of the working face for the subsequent three years." At the August 2004 meeting, it was agreed that in addition "[a] mine map showing instrumentation location and type and shore line…" will be included in the Annual Report.

Cargill included a statement in the Annual Report, page 2, Section 15.a.(3) that "[t]he Cayuga Mine is currently operating in the northern region of the mine. Active mining is located in panels U-78, U-80, U-82 U-84, and NW-3." Mine maps as electronic files were supplied by Cargill to fulfill this condition. Included maps were:

- Adobe Acrobat® file 9.2 3yr mine plan.pdf downloaded from Intralinks on April 28, 2020, containing MBD, 2020, "Cayuga Mine, 3 Yr Mine Plan" January 22. The high-resolution map shows the planned extent of mining through 2023 with pillar configurations.

- Adobe Acrobat® file 6.7 Convergence2020.pdf, downloaded from Intralinks on April 28, 2020, containing the high-resolution map Cargill Deicing Technology, undated, "Cayuga Mine, 6 Level Workings, Convergence Stations" showing the locations of convergence stations.
- Word® document 6.2 Closure Dec-2019.docx downloaded from Intralinks on April 6, 2020, containing two closure maps, undated, "Cayuga Mine Closure (Inches) Dec-2019" and "Cayuga Mine Closure Rate (Inches/Year) Dec-2019." The maps show contours of total closure ranging from 0 in. to 27 in., and contours of closure rates ranging from 0 in. to 4.5 in./year, respectively.

The supplied maps show the extent of mining, proposed mine plan, shorelines of Cayuga Lake, total closure, closure rate, and instrument locations.

Condition 15.a.(4)

Condition 15.a.(4) requires the annual report to include a "summary of in situ measurements of rock mechanics required by Part f. of this Special Condition." Condition 15.f. requires the measurement and collection of in situ rock mechanics data "in accordance with the approved Mined Land Use Plan." The data are to include "plots of relevant graphs. …" Furthermore, "[e]xceptions to anticipated trends in rock behavior shall be noted and explained. …"

At the August 2004 meeting, it was agreed that "[a]ll rock mechanics data" would be incorporated in the Annual Report, "including, but not limited to, all instrumentation readings and observations from the initial readings to present. Data for subsidence, closure, and extensometers are to be provided electronically. These electronic files are to include raw and processed data, graphs, and explanations of any inconsistencies and anomalous readings including reasons for abandonment, reinstallation, etc., along with applicable observation in the vicinity of the instrument such as floor heave, water inflow, etc. Future reports are to contain comment on whether, in the opinion of Cargill, the instrument readings support or conflict with prior stability models especially in areas employing new mine, panel, or main configurations."

Closure Measurements

Cargill included a statement in the Annual Report on page 2, Section 15.a.(4) that "Evaluations of the convergence data indicate that overall, no unusual trends have been identified and the mine is behaving as expected. There continues to be a few slight anomalies, which while showing elevated closure rates, are not elevated enough to be of a concern to global stability. These areas are being monitored more closely and areas are being outfitted with additional electronic instrumentation to help gather more data."

Closure measurements can be evaluated to indicate possible instability in three ways:

1. By studying the graphs of the rate of closure over time. The shape of these graphs indicates areas of instability, areas of concern, and areas of stability. Mr. Petersen of Rocktec Solutions (Cargill geotechnical consultant) has evaluated the closure in this manner in the past.
2. By establishing trigger values for total closure. This method is applicable in harder, less viscous rock, but is not applicable for the Cayuga Mine, as stable closure in salt will continue until the openings are closed.
3. By establishing trigger values for long-term closure rates. Since this is not being completed by the other investigators, BOYD applied such trigger rates in its evaluation of the closure readings.

Closure rate data are significant because they offer insight into the collapses and the inundation of the Retsof Mine. Sustained closure rates of 15 in./year or less were measured in stable areas of the Retsof Mine, while in the failure areas, closure was regularly measured with sustained rates over 230 in./year with onset of failure around 600 in./year. Although Retsof and Cayuga mines have different overburden and material properties, in the general sense, a comparison seems warranted for a relative indicator of stability.

BOYD reviewed the 306 closure stations read during the reporting period (7 more than last year; 300 in Level 6, 4 in Level 4A, and 2 in Level 4) Levels 4 and 4A readings show an overall trend of steady constant closure rates.

None of these 306 closure stations showed readings that exceeded 230 in./year. Table 1 lists the top 10 measured closure rates in 2019 for areas of recent mining, defined as areas within 1,000 ft of the advance face that occurred since October of 2018.

Table 1. Top 10 Closure Rates in Areas of Recent Mining

Station	Closure Rate (in./yr)	Time from Mining to Reading (days)	Total Measured Closure (in.)	Latest Closure Rate (in./yr)	Notes
U78PIN#1	17.8120	1320	7.190	1.4294	[1, 2] 2nd after mining resumed in August 2018
NW3PIN#75	17.7155	28	2.308	2.8157	[1, 2] First reading
NW3PIN#68	13.9542	145	6.403	3.8207	[2]
U78PIN#4	6.9524	63	1.200	6.9524	[1] Only reading reported
NW3PIN#62	3.0170	322	8.145	0.9684	[1, 2]
NW3PIN#56	2.2270	537	7.261	0.5328	[1, 2] Approx. 1,300 ft away from active face
U76PIN#16	1.3849	67	1.285	0.1941	[1, 2]
U78PIN#3	1.3383	63	0.231	1.3383	[1] Only reading reported
U78PIN#2	1.1935	63	0.206	1.1935	[1] Only reading reported
U76PIN#2	0.7682	1296	8.847	0.4718	U78 mining?

[1] First reading in reporting period (October 2018 through December 2019).

[2] Closure rate trend consistently decreasing.

These rates are substantially lower than the comparable rates for 2018. All of these rates substantially decreased over time showing that the ground is stable or stabilizing.

Table 2 provides the top 10 closure rates away from recent mining activity. These results do not include data from panel U-12, as this panel's closure rates are analyzed separately and shown in Table 3.

Table 2. Top 10 Closure Rates Away from Recent Mining (Excluding Panel U-12)

Station	Closure Rate (in./yr)	Time from Mining to Reading (days)	Total Measured Closure (in.)	Latest Closure Rate (in./yr)	Notes
U72PIN#12	0.9751	1729	6.580	0.9751	[1, 2] Only reading reported
NW3PIN#44	0.9006	1365	8.748	0.9006	[2, 3] Only reading reported
U40BPIN#8	0.8948	6435	30.427	0.7883	[3] 71.9°F 67%H, maxed, rod reset on 10/7/19
NW2PIN#44	0.7535	5036	19.878	0.5309	[3] 76.2F, 52%H, rod reset on 12/13/19
U40BPIN#14	0.7182	6295	28.670	0.6286	[3] Rod reset on 10/7/19
W1PIN#4	0.6930	13139	21.341	0.6930	[2] Only reading reported
NW2PIN#50	0.6594	4904	18.012	0.5254	[3]
NW3PIN#50	0.6584	699	7.204	0.4459	[1] Slight decrease of closure rates over time.
NW2PIN#56	0.6387	4934	15.878	0.4356	Rod reset on 11/4/19
U40BPIN#2	0.6123	6546	28.670	0.6286	[2, 3] Rod reset on 10/7/19

[1] Erratic closure rates over time.

[2] Closure rates not decreasing over time.

[3] First reading of reporting period.

These top 10 rates away from recent mining are lower than the comparable rates for 2018, and they are staggered throughout the mine.

Table 3. Top 10 Closure Rates in Panel U-12

Station	Closure Rate (in./yr)	Time from Installation to Reading (days)	Total Measured Closure (in.)	Latest Closure Rate (in./yr)	Notes
U12PIN#49A	989.880	6	22.186	0.0730	[1, 2] 2nd Highest is 10.585 in./yr @195 days
U12PIN#94	34.2188	4	0.666	2.4507	[1, 2] 2nd Highest is 6.4483 in./yr @18 days
U12PIN#91	12.7750	12	2.616	0.5736	[1, 3]
U12PIN#93	10.2200	5	1.796	0.9386	[1, 3]
U12PIN#100.5	9.5421	106	1.063	0.6205	[1] Pole destroyed
U12PIN#92	9.2163	5	0.533	3.1286	[1, 3] 2nd Reading
U12PIN#90	5.6741	130	2.897	3.7230	[1, 3]
U12PIN#61A	3.4675	2	0.637	0.2086	[1, 3] 69.4F, 40%H
U12PIN#32	2.6767	10825 [4]	26.595	0.2738	[1]
U12PIN#61	1.7033	11532 [4]	15.410	0.3650	[1]

[1] Erratic closure rates over time.
[2] First reading.
[3] Slight decrease of closure rates over time.
[4] Time from mining to reading (days).

Station U12PIN#61 shows its closure rate decreased throughout 2019 and is significantly lower than the last rate recorded in 2018. The top eight closure rates listed in Table 3 correspond to stations installed in 2019. With the exception of station U12PIN#49A, all closure rates are considered low and stable. The high rate from closure station U12PIN#49A was the result of the first reading taken, on January 29, 2019. One day later it had decreased by more than three orders of magnitude.

The contour map of closure rates in December 2019 depicts a clear zone of concentrated closure rates up to a maximum of 4.5 in. per year. This concentrated maximum rate is located within panel U-80 and is the result of mining the surrounding panels U-78 and U-82. Its magnitude is considered low and stable.

Another zone of high concentrated closure rates is located in panel U-12, which is a panel that experienced anomalous mine closure rates during 2018 and the first half of 2019. This led to the development of an investigative program focused on finding fluid under pressure within the overlying rock layers above #6 Salt. On November 14, 2019, brine was encountered in one of the investigation drill holes located near closure station U12PIN#49A, 133 ft above #6 Salt, in the Dolomite rock layer between #4A Salt and #5 Salt layers. After measures were implemented to relieve fluid pressure in the roof as anticipated by the program procedures, the closure rates significantly decreased by one order of magnitude.

Extensometers Results

Cargill included a statement in the Annual Report on page 2, Section 15.a.(4) that “Roof sag and wall expansion, measured with extensometers, is also monitored as conditions warrant, and is reviewed internally and externally as well. This data indicates the mine is behaving as expected.”

Data from 19 extensometers that were read in 2019 were evaluated (four more than in 2018). Extensometers were installed in various manners including vertically into the roof; at low angle (near horizontal); at an angle that resulted in the extensometer being installed over the pillars; vertically into the roof, and horizontally into pillars. These data are further complicated by the varying rod and bay lengths. (Bay length is the length difference between rods except for the first bay which is the length of the shortest rod.) Nevertheless, BOYD attempted to ascertain anomalies within these data.

Similar to last year, BOYD evaluated the rate measure as strain per year. Using RESPEC’s 1995 Cargill salts values:

Dilation Limit	$J_2^{0.5}/I_1 = 0.36$
Creep Rate	$\dot{\varepsilon}^c = 8.3 \times 10^{-30}(\Delta\sigma)^{5.9}$

BOYD assessed the stress state to estimate that a strain rate greater than 8 $\times 10^{-3}$ (-/yr) is needed for destructive dilation. No calculated strain rate exceeded this standard.

Table 4 lists the five highest extension rates measured during 2019.

Table 4. Top 5 Estimated Strain Rates

Mine Area	Extensometer Label	Displacement Rate (in./yr)	Rod Length (ft)	Strain Rate (-/yr)
Screen Plant Pillar	I-Pillar B-Hole 3 Tun	0.437	10.0	3.64×10^{-3}
Surge Bin 4 Level	STA. #25	0.429	11.0	3.25×10^{-3}
Screen Plant Pillar	G-Pillar B-Hole 3 Tun	0.243	7.0	2.89×10^{-3}
Surge Bin Roof	#27 - Roof ext.	0.596	19.5	2.55×10^{-3}
Screen Plant Pillar	J-Pillar B-Hole 1 Tun	0.145	6.0	2.01×10^{-3}

These strain rates are acceptable.

Consultant Reports Concerning Conditions 15.a.(4).
No consultant reports were available on Intralinks, other than ESG Solutions monthly reports:

- ESG Solutions, 2018 and 2019, “Seismic Data Processing Results and Health Analysis Report for Cayuga Monitoring System,” prepared for Cargill Salt Division, covering 14 months from November 2018 to December 2019.

These reports are discussed in section Condition 9.b. above.

Condition 15.a.(5)

Condition 15.a.(5) requires the Annual Report include a “summary of subsidence monitoring data required by Part e. of this Special Condition.” Condition 12.e. requires “[s]ubsidence monitoring shall be conducted in accordance with the approved subsidence monitoring plan contained within the approved Mine Land Use Plan.” Furthermore, “[e]xceptions to the trends shall be noted and explained…” Points applicable to this condition were agreed upon at the August 2004 meeting and are noted above under Condition 15.a.(4).

Cargill included a statement in the Annual Report page 3, Section 15.a.(5) that “Surface subsidence measurements continue to be performed in accordance with the Mined Land Use Plan. The surface subsidence survey was completed in September of 2019, minor inconsistencies do exist and are being investigated.”

No subsidence data file was included in the data set on Intralinks. BOYD expects to review these data when they are provided.

Condition 15.a.(6)

Condition 15.a.(6) requires the inclusion of "[i]nformation regarding the source and volume of any water inflow into the mine, and the disposition of such water." At the August 2004 meeting, it was agreed that a discussion about water disposal in Level 4 would be included in the Annual Report, noting: "Updates of Level 4 filling including data on shore line advance." However, in 2012 it was noted that "Access to view the pond is not possible due to ground conditions."

Section 15.a.(6) of the Annual Report, notes that "Most the water is directed to a settling pond located on the 4-level of the mine. The water is then pumped from the settling pond to abandoned areas at the far east end of 4-level as well as to various areas of the active mine for dust control. Water labeled as Other Inflows is fully saturated and is stored in various areas on the 6 Level of the mine."

A data file with water volume calculations was not included in the data set on Intralinks.

Cargill lists the following water flows in the Annual Report:

- Production Shaft (#1 shaft) - 25 gallons per minute (gpm).
- Ventilation Shaft (#2 shaft) - Less than 1 gpm.
- Service Shaft (#3 shaft) - 1 gpm.
- ED Plant Concentrate discharge - 3 gpm.
- Other Inflows - 2.5 gpm.
- Total Water Inflow = 32.5 gpm.

The total water inflow rate is 2.5 gpm more than reported in 2018.

Condition 15.a.(7)

Condition 15.a.(7) requires the inclusion of "[a] summary of all other monitoring data required under the terms of this permit or Department SPDES permit issued to Cargill." Cargill included a statement in the Annual Report page 3, Section 15.a.(7) that "For the 2019 calendar year there was no exceedance of the SPDES limits for the storm water outfalls."

Back up data to this statement were not provided on Intralinks. Typically, an Excel spreadsheet, which documents MLRP outfall and provides information on outfall water quality including cyanide, chloride, zinc, total dissolved solids, and cooling and treatment water, is provided.

SPDES data and a discussion of these data were not included in the Annual Report. These data are to be reviewed by NYSDEC. Discussion on June 6, 2019, suggests that direct reporting requirements of SPDES data to the State of New York renders this requirement moot.

Condition 15.b. and c.

Condition 15.b. and c. addresses Mine Safety and Health Administration (MSHA) reporting involving non-routine mining incidents as defined in Condition 15.b. Condition 15.c. requires Cargill to submit "all correspondence with the Mine Safety and Health Administration involving non-routine mining incidents…"

Cargill includes a statement in section 15.b. of the Annual Report that "[t]here were no incidents meeting the guidelines for notification as identified in section 15.a.(2)" and section 15.c. of the Annual Report that "[t]he Cayuga Mine has not received any citations or correspondence from MSHA regarding non-routine mining incidents as identified in section 15.a.(2)." The Annual Report does not note reports or letters from MSHA concerning any non-routine mining incidents.

Condition 15.d.

Condition 15.d. addresses reporting requirements "Prior to undertaking any material change in the approved mining methods or techniques … Cargill shall submit to the Department a description of such modification …" This condition does not require the reporting to occur in the Annual Report.

Cargill notes in section 15.d. that "[t]he mining methods used at the Cayuga Mine have not been changed in the last year."

Condition 15.g.

Condition 15.g. addresses the reporting and recording of citizen complaints.

Cargill includes a statement in section 15.g. of the Annual Report that "[n]o written complaints from citizens were received since the last report (November 2019)."

Site Visit

A site visit to discuss these findings amongst NYSDEC, Cargill, and BOYD is scheduled to take place on August 6, 2020. During this visit the following should be discussed:

- 4 Level monitoring.
- 'Other inflows'.
- Subsidence data.

- Panel U-12 behavior.
- Outside consultant review such as Mr. Petersen of Rocktec Solutions.

BOYD recommends visiting U-12 and U-78 panels.

Please contact us if you require additional information or if we may be of further service.

Respectfully submitted,

JOHN T. BOYD COMPANY
By:

María C. Jaime, Ph.D., P.E.
Senior Geotechnical Engineer

Vincent A. Scovazzo, Ph.D., P.E.
Director of Geotechnical Services

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STATE OF NEW YORK
APPELLATE DIVISION OF THE SUPREME COURT, THIRD JUDICIAL DEPARTMENT

In the Matter of the Application THE CITY OF ITHACA, THE TOWN OF ITHACA, THE TOWN OF ULYSSES, THE VILLAGE OF UNION SPRINGS, CAYUGA LAKE ENVIRONMENTAL ACTION NOW (CLEAN), an Unincorporated Association by President JOHN V. DENNIS, ALFRED THOMAS VAWTER, JOSHUA J. and JENNIFER L. LAPENNA, RODNEY and CYNTHIA HOWELL, KENT and HEATHER STRUCK, JUDITH R. SCOTT, WILLIAM HECHT and JOHN V. DENNIS,

Petitioners-Appellants,

AFFIRMATION OF JOHN K. WARREN IN SUPPORT OF PETITIONERS-APPELLANT'S MOTION FOR PRELIMINARY INJUNCTIVE RELIEF

Appeal from the Decision and Order of the Supreme Court of Tompkins County (Hon. Judge Rowley, A.J.S.C) entered on April 22, 2019

vs.

Index No. EF2017-0285

THE NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION, and CARGILL INCORPORATED,

Respondents.

BANGKOK,
THAILAND:

I, JOHN K. WARREN, hereby affirm under the penalties of perjury of the State of New

York:

1. I am an evaporite geologist with a Ph.D. in Geology from Flinders University School of Earth Sciences. Evaporite geology, my area of expertise, deals with deposits of salt, gypsum, etc., and the many related practices and technologies involved in salt mining, gypsum mining, etc. In my work and writing, I understand

and follow the accepted methodology of evaporite geology. I am the author of four books on evaporite and carbonate geosystems. The first edition of my most recent evaporite book was chosen by the American University Association of University Librarians as one of the "Outstanding Academic Titles for 2006." My fourth book, *Evaporites: a Geological Compendium* was published by Springer in late 2016. This is an updated and expanded version of the previous book and is now an all color edition that is more than 1800 pages in length. My CV is attached as Exhibit A.

2. In the fall of 2016, I was contacted by John V. Dennis, Ph.D., who asked me to review and comment on the proposed Shaft #4 for the Cargill Cayuga Salt Mine. I agreed to work as an expert consultant for Dr. Dennis, and in October 2016 I sent him my first work product, a 30-page report entitled *Technical requirements needed to approve construction of Shaft #4 in the Cayuga Salt Mine, New York State* (hereinafter "2016 Technical requirements report," attached as Exhibit B).

3. In this affirmation, my first point is that the bottom-rearming of Shaft #4 is likely to cause irreparable harm by establishing a hydraulic connection between the shaft and either the water column of Cayuga Lake or between the shaft and the artesian aquifer that a 1995 Cargill map indicates exists between the bottom of Cayuga Lake and the Syracuse formation. Should the reaming of an 18-foot diameter shaft connect with a significant joint or fracture, I believe that the resulting leakage into Shaft 4 could overwhelm the designed storage capacity and flood the mine. This flooding of the mine could result in several irreparable harms:

a. loss of life by miners and/or construction workers

b. creation of a reservoir of saturated brine with a volume estimated to be greater than 15 billion gallons and with a likelihood that such volume of brine will vent into the water column of Cayuga Lake and harmfully increase the salinity of Cayuga Lake for hundreds of years.

4. In this affirmation, my second point is that even if the bottom-reaming of Shaft #4 is successful, i.e., Cargill's capacity to store process and shaft leakage waters is not overwhelmed, the completion of Shaft #4 will—according to Cargill's own application to the Tompkins County Industrial Development Agency— enable "an additional 30 years of mining at the Cayuga Mine" (p. 4 of Cargill's August 30, 2016, application to the Tompkins County IDA). [should this 16-page document be included as an Exhibit?] See Exhibit C.

The problem with the creation of more and more mining voids under Cayuga Lake, or with creating new mined voids under land that are connected to the mine under the lake via the 1-mile tunnel that would connect Shaft #4 to the mine under the lake, is that these mined voids will likely become flooded at some time in the future either intentionally at mine decommissioning or by accident as was the case at the Retsof Salt Mine in 1994 or at the Jefferson Island Salt Mine in 1980.

5. This report is based on information available to me at this time. Should additional information become available, I reserve the right to determine the impact, if any, of the new information on my opinions and conclusions and to modify or supplement this report if necessary.

I affirm this 29th day of June 2019 under the penalties of perjury under the laws of New York, which may include a fine or imprisonment, that I am physically located outside the geographic boundaries of the United States, Puerto Rico, the United States Virgin Islands, or any territory or insular possession subject to the jurisdiction of the United States, that the foregoing is true, and I understand that this document may be filed in an action or proceeding in a court of law.

DocuSigned by:

10A2FF43D3AE441...

June 29, 2019

John K. Warren, Ph.D.
Saltwork Consultants Pty Ltd

Kingston Park
Adelaide SA 5049
AUSTRALIA
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+66 8 9498 1512 (roaming/SMS)
jkw.saltwork@gmail.com

Exhibit A

John K Warren, Ph D, Technical Director
SaltWork Consultants Pte Lte (ABN 068 889 127)
Kingston Park, Adelaide, Australia 5049
(www.saltworkconsultants.com)

The professional career of Dr. Warren spans more than 30 years, of which a total of 20 years are in academia. Dr. Warren currently is Technical Director of Saltwork Consultants, Adelaide Australia and holds a Professorial position in the International Master Program in Petroleum Geoscience at Chulalongkorn University, Thailand, and. Previously he held the Shell Professorial Chair in Carbonate Studies at Sultan Qaboos University, Muscat, Sultanate of Oman. Before this, he was a faculty member in the Department of Petroleum Geosciences at Universiti Brunei (1998-2006) and Professor of Petroleum Geology at Curtin University, Perth, Western Australia (1993-1995). He specializes in Wireline Analysis, Carbonate and Evaporite Reservoir Systems, Production Geology and Reservoir Characterization.

Throughout his career he has worked as an industrial consultant dealing with diagenesis-related issues in reservoir and wireline studies as part of exploration programs conducted by ADNOC, ADCO, Asia-Pacific Potash, BHP Minerals, BHP Petroleum, Chevron, Esso-Mobil, Fortescue Metals, Homestake, Pasminco, PTTEP, Santos Indonesia, Santos Australia, Statoil-Hydro, Schlumberger, Saudi-Aramco, Shell International, Texaco, the World Bank, Geological Survey of The Northern Territory, Geological Survey of South Australia, Geological Survey of Australia and others. He has also served as a technical advisor for the AAPG, BBC, IHRDC, and New World Horizons.

He was chosen as the annual keynote speaker for PESA (Petroleum Exploration Society of Australia) and was the keynote speaker at the IAS meeting in Brazil in 2003, the keynote speaker in the SEPM conference in Aachen in 2004 and has recently ran industry-funded short courses in applied aspects of Carbonate and Evaporite Sedimentology at the Colorado School of Mines and in 2008, in Exxon Mobil Research in Houston, and in 2010-11 for Statoil-Hydro in Norway and PDO in Muscat, in 2014 for Nexen in Calgary, and will be running courses in Adelaide, India and Brazil in 2018. He is currently a retained consultant to PTTEP dealing with carbonate reservoir issues, as well as having recently been a consultant to Exxon Mobil and Statoil dealing with reservoir quality issues in the Middle East and the South Atlantic Salt Basins. He is currently a consultant to Santos Adelaide, looking at the Amadeus Basin, and to Fortescue Metals evaluating potash and lithium brine prospects in Australia and South America.

Dr. Warren has written four books in his area of expertise (evaporite and carbonate geosystems). The first edition of his most recent evaporite book (published by Springer, 2006) was chosen by the American University Association of University Librarians as one of the "Outstanding Academic Titles for 2006". His fourth book on the same subject area was published via Springer in late 2016. This is an updated and expanded version of the previous book and is now an all color edition that is more than 1800 pages in length.

He has contributed chapters on economic aspects of sedimentology in a number of other books and has published more than 60 scientific articles in major refereed journals including: American Association of Petroleum Geologists Bulletin, APEA Journal, Australian Journal of Earth Sciences, Journal of Sedimentary Petrology, Geochimica Cosmochimica Acta, Geotimes, PESA Journal, Sedimentary Geology and Sedimentology. His published and presented material has been chosen for special mentions by SEPM, AAPG, and PESA. He has received teaching awards from the University of Texas and Adelaide University. At various times in his career, he has been selected for guest lectureships to the oil Industry by Nordic Council of Ministers, by PESA, and the AAPG. He has worked extensively and successfully in various cultures including the Americas, Europe, the Middle East, Oceania and Southeast Asia.

Education

Ph.D. 1981 Flinders University, South Australia, School of Earth Sciences – Carbonate Sedimentology
B.Sc. Hon. 1st Class 1975 Flinders University, South Australia, School of Earth Sciences – Marine Geology
B. Sc. 1972 University of Adelaide - Majors in Geology and Palaeontology

Mobile: (668) 9498-1512
mailto:jkwarren@saltworkconsultants.com

Research Interests

Applied evaporite sedimentology
Evaporite sedimentology
Economic geology of evaporite geosystems
Potash and lithium resources in saline settings
Evaporite-related geohazards
Evaporites as source rocks
Use of image logs and seismic in defining reservoir quality in evaporite-sealed and halokinetic systems

Quaternary arid zone carbonates
Arabian Gulf coastlines, Australia and elsewhere
Current projects in eastern Saudi Arabia and Australia

Carbonate reservoir characterization
Core-calibrated wireline studies of evaporite-plugged and leached/dolomitised carbonate reservoirs with a view to predicatively mapping and understanding porosity and permeability distributions with a prime focus in carbonate reservoirs in the Precambrian, Permian, Jurassic and Miocene petroleum systems of the Middle East
Core to wireline calibration of carbonates, especially dolomitised karst systems as in the Miocene gas reservoirs of Vietnam and Indonesia
Modern dolomite deposition in sabkhas of the Coorong and the Middle East
Development of non-actualistic models for greenhouse platform carbonates
Facies and porosity degradation in modern and ancient carbonate reefs

Training and Research Fields

Primary –Wireline Analysis, Carbonate and Evaporite Sedimentology, Petroleum Geology,
Secondary – Presentation Skills for Business Professionals

Employment

August 2014-Present – Technical Director, Saltwork Consultants Pte Ltd, Adelaide, Australia (www.saltworkconsultants.com)

Aug 2009-Present – Full Professor in the International Master Program in Petroleum Geosciences at Chulalongkorn University, Bangkok Thailand (www.cupetrogeoscience.com)

2007-2008 - Shell Chair in Carbonate Studies, Oil and Gas Research Centre, Sultan Qaboos University, Sultanate of Oman

1998-2006 - Contracted Professor, Reservoir Studies, Department Petroleum Geoscience, University Brunei Darussalam, Bandar

1995-2009 - Executive Director, JK Resources Pty. Ltd., Adelaide, Australia.

1992-1995- Professor of Petroleum Geology, School of Applied Geology, Curtin University, Perth, Western Australia.

1989-1992 - Principal Petroleum Geologist, National Centre Petroleum Geology and Geophysics (NCPGG), University of Adelaide, Australia.

1982-1988 - Asst. Professor, Dept Geological Science, University Texas at Austin. USA

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Academic courses offered (*commercial course can be viewed on www.saltworkconsultants.com)*

Graduate – Wireline Analysis, Reservoir Sedimentology, Production Geology and Reservoir Characterization.

Undergraduate – In academic positions prior to current appointment he was involved in teaching aspects of undergraduate courses in Physical Geology, Historical Geology, Field Geology, Environmental Geology, Hydrogeology, Petroleum Geology, Carbonate Sedimentology, Clastic Sedimentology.

Thesis/Dissertation Supervision

Supervised a total of 74 M.Sc. theses and 8 Ph.D. dissertations.

Computer Literacy

Operating systems – All geological software under Windows and OSX, as well as Unix familiarity

Research and teaching – WellCad, Interactive Petrophysyics, MapInfo, Petrel and various Geoframe geological and petrophysical packages

Interactive Petrophysics and WellCad are software packages forming the main training tools and research tools in wireline analysis in the postgraduate unit under Professor Warren's supervision at SQU

Personal

Australian citizen,
Born 12th August, 1951
Married (17 January 1972), 2 adult children
Excellent health

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LIST OF PUBLICATIONS

Four books, numerous papers and abstracts in different national and international journals. The appended publication list does not include numerous technical reports prepared in his role as a consultant to the hydrocarbon and minerals industries.

BOOKS

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Exhibit B

Technical requirements needed to approve construction of Shaft #4 in the Cayuga Salt Mine, New York State

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Executive Summary

What drives significant instability at times of salt mine expansion is the unexpected intersection of zones holding substantial halite-undersaturated pore water volumes located in or immediately out-of-salt. Worse yet, is a hydrological connection scenario where the intersected zones possess high potential inflow rates and are connected to large reservoirs of halite-undersaturated pore waters. This is especially so when such unexpected pore waters are connected to the mine workings via open fracture porosity

To date, the New York State authorities have not required of the mine operator appropriate technical data suitable to make a "best-practice" judgement on whether to grant permission to move forward with Shaft #4. Before a firm decision is made, the following set of documentation and studies should be required of the mine operators.

1) What is the geological situation ("stay in the salt") in the areas where an unknown and possibly significant volume of halite-undersaturated water is to be stored? If the proposed water storage area is such that the water volume is fully encased, and it will not weaken the strength of intervening salt pillars, or while stored, drive dissolution and connection with unexpected aquifers in adjacent "out-of -salt" positions, then such below-ground storage of pilot hole and shaft reaming inflows should be feasible.

2. What is the nature of the permeability and porosity in the aquifer level to be encountered at the Bertie -Oriskany levels during upward reaming of Shaft#4. This interval was sampled via cuttings, not core, in Corehole #18 . At this stage, it is not known if the encountered aquifer poroperm is held in a homogeneous medium or held in a highly inhomogenous host, as is typical of a fractured aquifer reservoir. If it is held in a homogenous bedded host, then the pump test already done to quantify entry rates and discussed in the CoreHole 18 report can be extrapolated reasonably well from the narrow borehole diameter to a 14-foot wide shaft. If the aquifer is fractured, then flow rates and aquifer interconnectedness have not been reliably quantified by pump tests in a narrow borehole. Unexpected water volumes may be encountered during upward reaming of Shaft #4.

3. What do the salt textures captured in the core from Corehole #18 indicate in terms of possible aquifer proximity? The current description of salt textures in the RESPEC report does not define the nature of the various processes likely influencing the formation of various salt textures. Current salt sedimentology allows one to differentiate between tectonic, diagenetic and salt dissolution textures and breccias. Work on the publically-available core from the Himrod Mine shows all these textures are present in the salt layers in the Syracuse Fm; they are distinct and capable of being classified. Such a sedimentological study of the salt core in Corehole #18 would better refine the hydrological situation in the vicinity of Corehole #18 and if there is a possible hydrological connection already in existence between the top of salt and the overlying potential aquifers located in and above the Bertie Formation.

The further integration of the salt texture information derived from the core with the mineralogical information already measured in the wireline data run in Corehole #18 would help to refine such a hydrological model, which could then be tied back to the current understanding of the mine geology and improve the utility of predictive ore quality models.

Contents

Introduction

This report stems from a request for technical comments on the general suitability of the salt geology for the proposed sinking of a new shaft using upward reaming on the property of the Cayuga Salt Mine in New York State. Specifically, how would the known geology interact with the safe disposal of the waste and associated stability in existing underground mine workings? The request to SaltWork Consultants Pte Ltd invited Professor John Warren to be the report's author due to his extensive experience in salt studies (www.saltworkconsultants.com). Dr Warren has more than 30 years expertise in all aspects of salt geology, both academic and applied. He has authored four advanced-level books on the topic of salt, as well as numerous papers in internationally-refereed scientific journals.

The report first documents the salt geology of the region, it then documents the Quaternary glacial history of Cayuga Lake and the Finger Lakes region. It focuses on how active deep aquifers currently flow beneath Lake Cayuga and the surrounds. The briny flows evolved in response to loading, driven by the waxing and waning of ice sheets atop the geology southward-dipping Phanerozoic geology of the region. The report then addresses the specifics of this highly saline geological evolution in terms of future mine stability and the storage of waste materials in worked-out regions of the salt mine.

Throughout the reading of this report, the reader should keep in mind that rock salt (which is mostly composed of the mineral halite –NaCl) is a rock type with unusual physical properties. It possesses an extraordinary combination of high solubility in water, low shear strength and yet is largely impervious if left in an unaltered state in the subsurface. This unique combination of properties makes the mining of salt and the long-term stability of abandoned salt mines and solution wells a field of study with many features indigenous to the unusual nature of the exploited salt (See Warren 2016 and Warren, in press; copies of chapters 7 and 13 from Warren 2016 are available in the Endnote® database that accompanies the hi-res pdf version of this report).

The brief for this report is to focus specifically on what information is in the public realm related to the geology of the Salina Group salt and its relevance to decisions of its use as a host lithology. Possible future problems are outlined and discussed in this report only in a general fashion. The matters raised can only be further addressed if specific detailed site geology documentation, currently unavailable to the author, is integrated into any possible future study. Additional relevant aspects of the regional salt geology of the Finger Lakes region are giving in an earlier scoping report (Warren 2015) and in Goodman et al., 2009, 2011, 2015 and in the references therein.

Cargill's need to commission Shaft #4

A new shaft is required for the safe operation of the Cayuga Salt Mine as the current working faces are located almost 4 miles north under the lake from the existing main access shaft (Figure 1). The current access situation is not only problematic regarding escape protocols, but also because the three existing shafts are now showing signs of age and likely water damage, corrosion and longterm salt heave. Having been in continuous operation since 1924 Cayuga salt mine it one of the older salt mines currently operating in the United States. The oldest salt mine in the US is extracting diapiric, not stratiform salt from Avery Island in the US Gulf Coast (Warren, in press).

Cargill Salt is currently seeking permission to construct a new 14-foot diameter access shaft to be known as Shaft #4 (public notification published Sept 9, 2016, in the Ithaca Journal). Located at 1001 Ridge Road (St. Rte. 34B) in the Town of Lansing, Tompkins County, at an elevation ≈890 ft the site has a proposed surface extent of some 12.3 acres and is located some 3.9 miles north of Cargill's current access shafts. The geology at this planned construction site is based on cuttings and core recovered in a stratigraphic well known as Core-hole 18 (RESPEC, 2013). Much of the geological detail in the vicinity of the proposed shaft comes from a reading of this RESPEC report by the author. It is assumed that Shaft #4 will be constructed in the vicinity of Corehole #18 (42.571830N, 76.582346W)

The most likely method of shaft construction being considered by Cargill involves controlled upward stoping, beginning at the level of current subsurface mine workings and is known as raise boring (Liu and

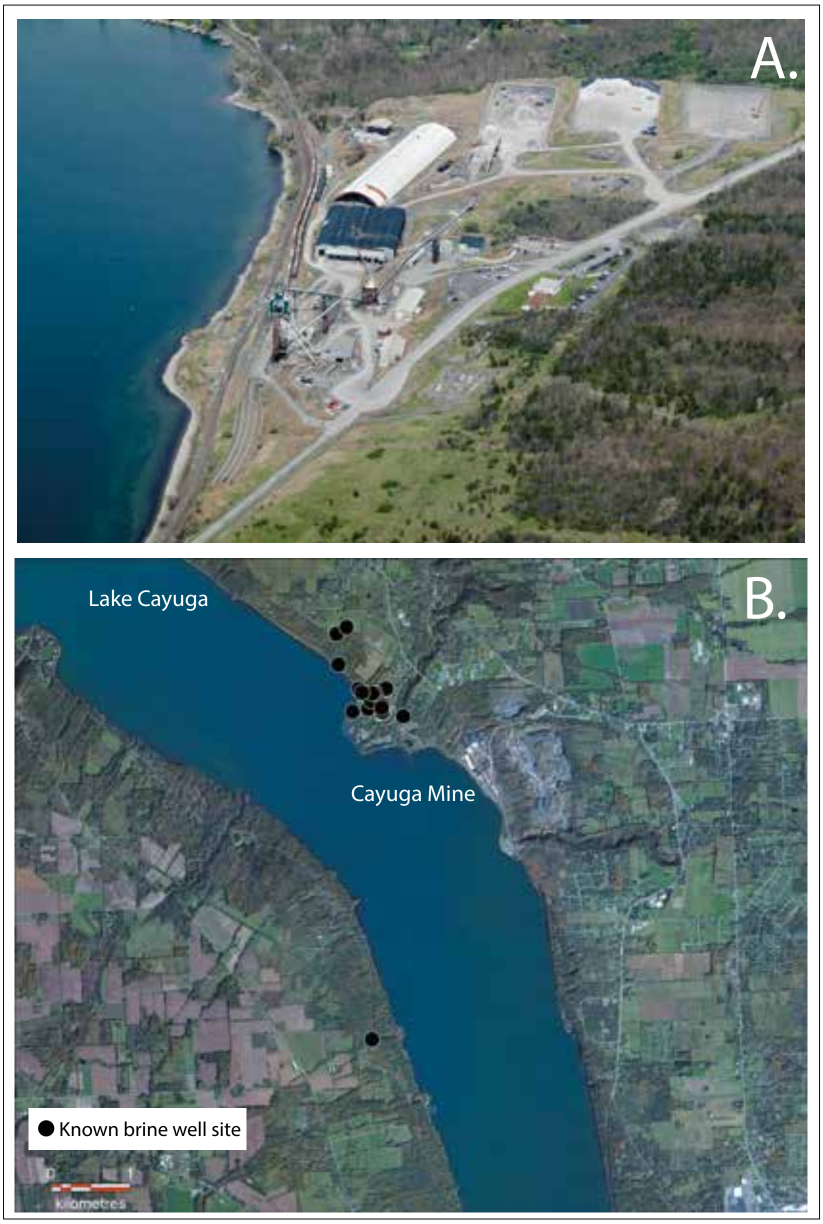


Figure 1. Cayuga Salt mine, New York State. A) Current lake shore position of Cargill Salt's main shaft and surface operations. B) Positions of documented brine wells ranging in age from the 1890s until the 1970s and extending to depths of more than a kilometer.

Meng, 2015). If chosen, this method involves installing an initial 18-inch pilot hole to the mine level, and then attaching the reaming bit, which is then pulled upward to the surface to create the 18-foot opening for the final shaft construction (Figure 2). Both of these holes will be open to the mine level to allow any cuttings and fluids encountered to fall to the mine for removal.

The advantage of this construction method is that all waste and brine can be immediately removed into storage and disposal in mined out portions of the existing workings. The method is cost effective compared to a surface excavation of an access shaft downward, and has an additional advantage of no unsightly wastepile at the surface during construction. It further reduces costs as there is no need to dispose of any brine or other pumped subsurface fluids into surface storage facilities. Rather, any collected brine or brackish water can be moved directly into subsurface storage sumps located within older already worked parts of the mine.

The disadvantage of this construction method is that if the work encounters severe conditions during shaft construction, such as unexpectedly high volumes of water inflow are intersected, or a loss of roof stability occurs, then it is a system that is not easily plugged or isolated. Roof control is not easily recovered without significant sub-roof damage. If the event is associated with high levels of water influx, there is a strong possibility of ultimate loss of existing underground facilities (see Retsof Mine case history). However, Cargill successfully used the same shaft construction method in building existing facilities to the south.

Cargill is proposing to integrate and store any aquifer leakage waters flowing into the shaft during and after construction (likely from intervals in and above the Bertie Formation), for consolidating fines that will be disposed of within regions of already mine dresidual panels. The plan will also utilise this stored groundwater for reduction of dust in active parts of the mine. To dispose of waste/water/brine generated during the construction of Shaft #4, a temporary sump will be constructed to collect pilot hole, construction, and shaft water. This water/brine then will be pumped to the U60 and U58 regions in the current mine for storage. In the proposed plan up to 75 gpm can be pumped and

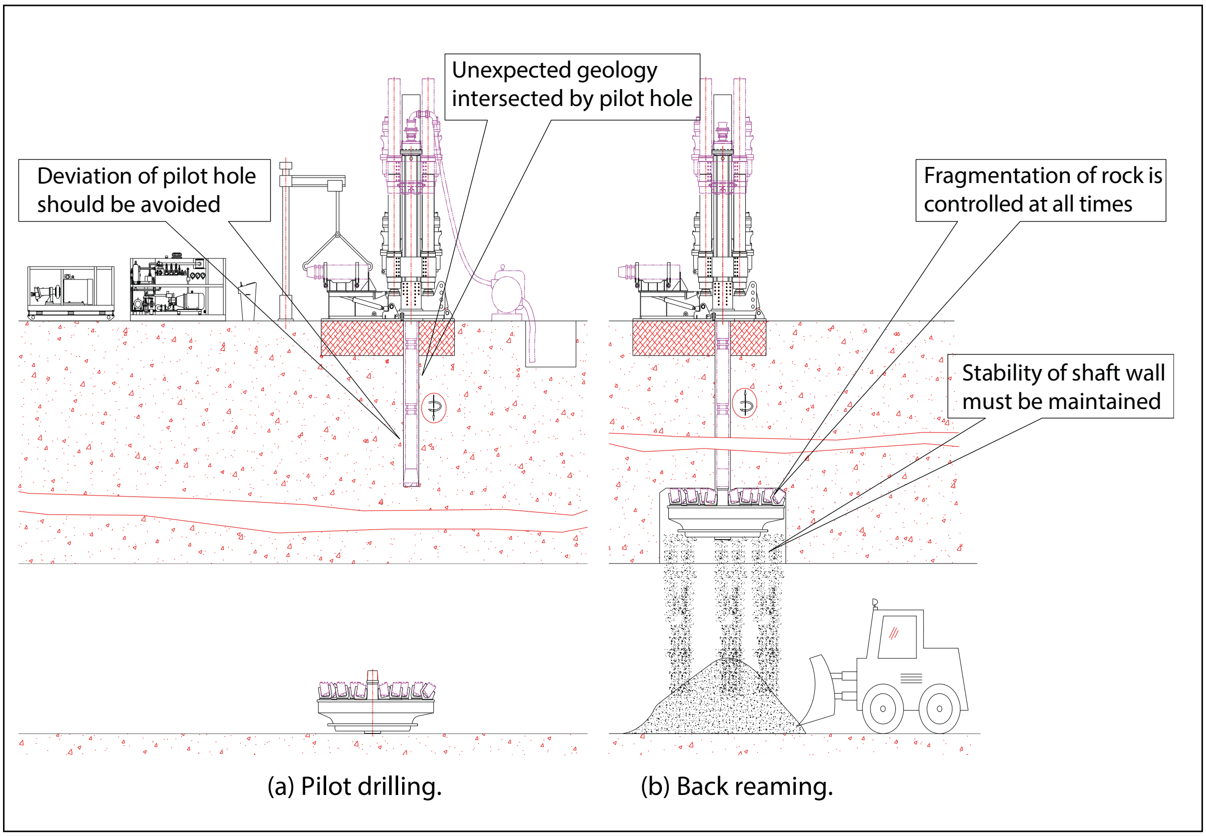


Figure 2. Raise Boring (upward-reaming) method of shaft construction and requirements to maximise stability and control during construction (after Liu and Meng, 2015)

it is expected over the shaft construction period that some 5.5 million gallons will be generated. According to Cargill, regions U58 and U60 can accommodate over 13 million gallons of water without roofing or leakage.

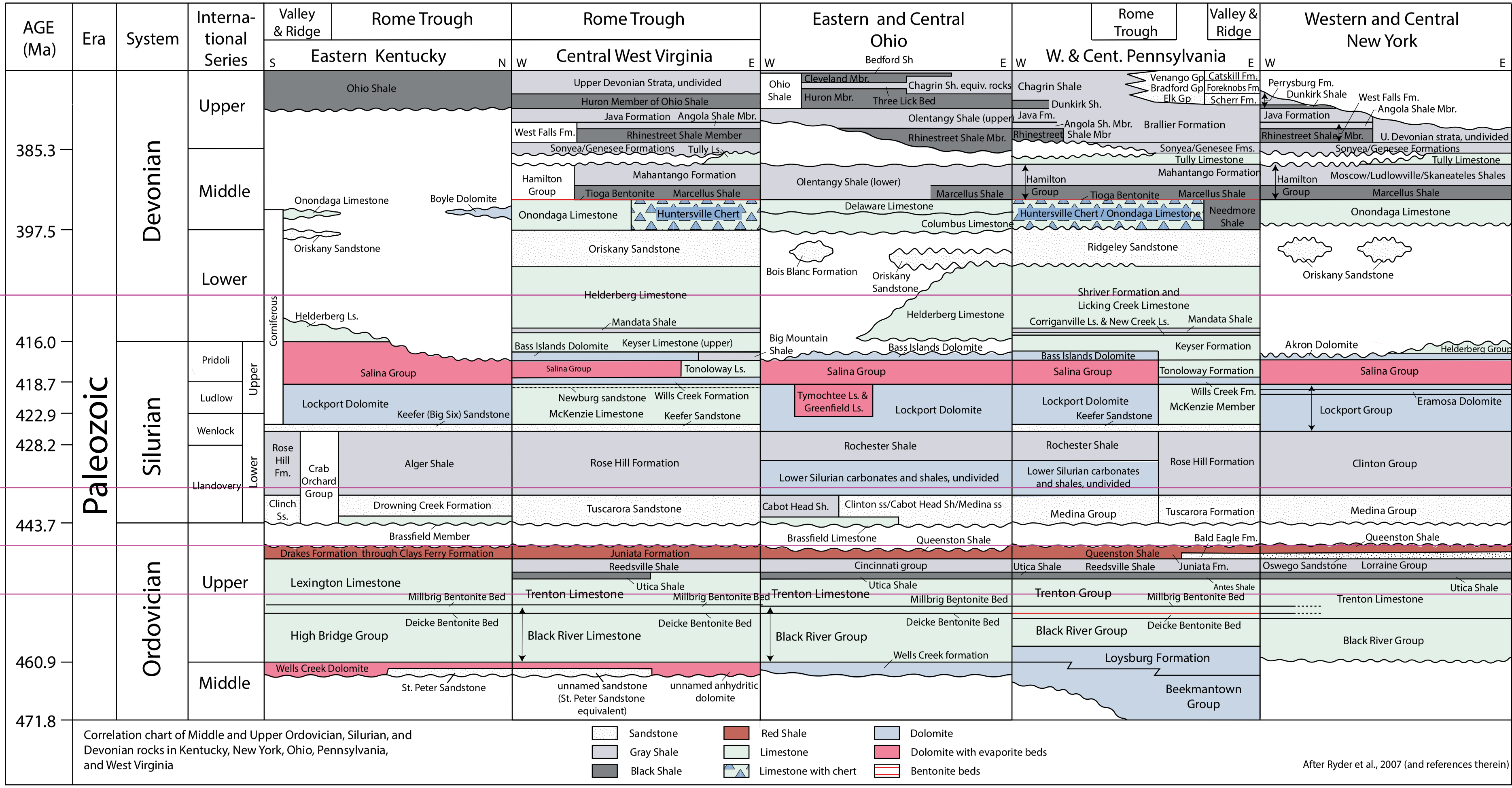
The rate of brine inflow postulated to come mostly from or above the level of the Bertie Dolomite is based on pumping tests conducted after an unexpected aquifer was intersected during the drilling of Corehole #18 (RESPEC, 2013). This level in the stratigraphy is defined by a major regional unconformity (Figure 2). The known salinities of the inflow waters will make the collected water undersaturated with respect to rock salt (halite). Possible effects on roof and pillar stability during the reservoiring of significant volumes of undersaturated water underground are discussed later.

Corehole #18 identified a significant aquifer at approximately 1,490 ft bgs (below ground surface) in the Oriskany Sandstone with a flow rate that was estimated in the field at the time of drilling to be ten gpm (gallons per minute). However, the subsequent pumping test (after two pump failures) suggested that the sustained inflow rate into the borehole was approximately three gpm. Lower in the stratigraphy, in proximity to the mine's current workings beneath the eastern uplands, the base of water can reasonably be expected to be at, or above, the base of the Bertie Group. Gas was observed in the Oriskany Sandstone at 1,505 ft bgs with an estimated production rate of approximately 13,300 cfd.

The proposed final reclamation plan states that when Shaft #4 is decommissioned at some time in the future this will involve removal of any piping or operating systems from the shaft, injecting of a cementitious low-permeability flowable fill (nature of fill not further specified) that will permanently seal the shaft and will also require the filling the uppermost eight to ten feet of the shaft with a high-strength concrete plug. The surface facilities will remain to provide office and commercial facilities for future use. The reviewed additional life-of-mine area is 12.3 acres.

Regional Salt Geology

Salt in the Cayuga Lake region is currently extracted in solid form from the Cayuga salt mine mostly for road de-icing (see Cayuga Salt Mine). The salt source lies in



Correlation chart of Middle and Upper Ordovician, Silurian, and Devonian rocks in Kentucky, New York, Ohio, Pennsylvania, and West Virginia

Figure 3. Stratigraphic correlation panel showing how the rock unit names vary across the region, but the evaporitic Salina Group is regionally extensive (extracted from Ryder et al., 2007)

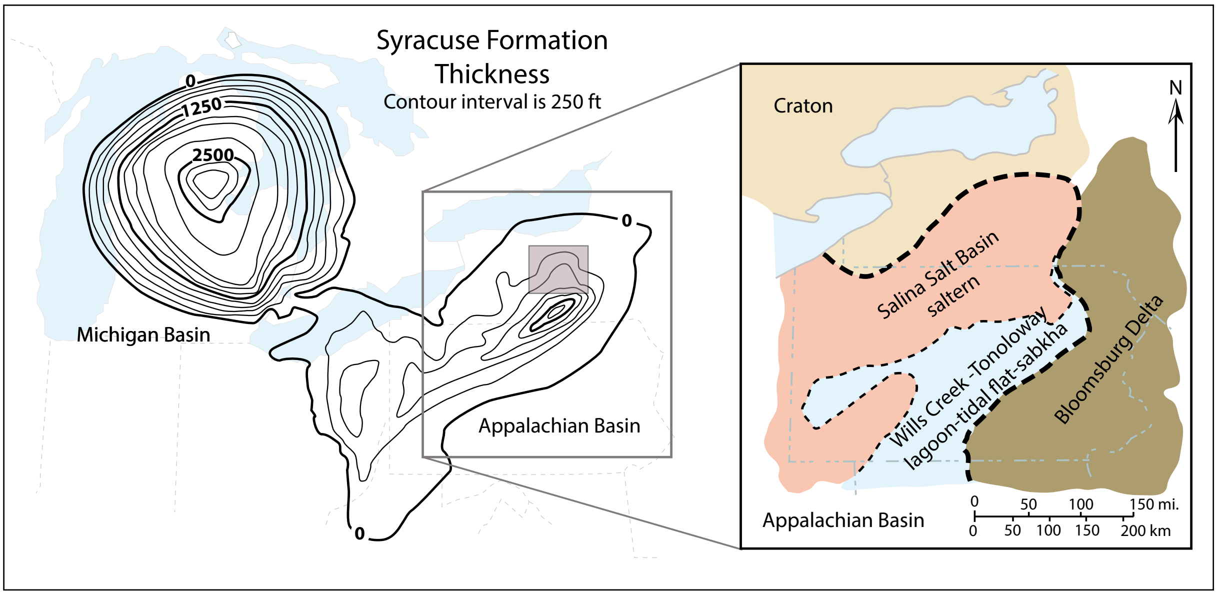


Figure 4, Distribution and thickness of salt in the Salina Group.

variably dissolved and deformed beds of the Vernon and Syracuse formations that together make up the Salina Group. The 416-418 million-year-old (Silurian) Salina Group extends from Michigan through upstate New York and into the Appalachians and south into Indiana (Figures 3, 4).

In the Michigan basin, the Salina Group reaches thickness greater than 2,500 feet (760 m) and consists dominantly of sub-horizontally bedded alternating carbonate rock and salt layers (Figure 3). Southward of the Michigan Basin the Salina Group lacks salts, becomes thinner (both depositionally and erosionally), and extends into a

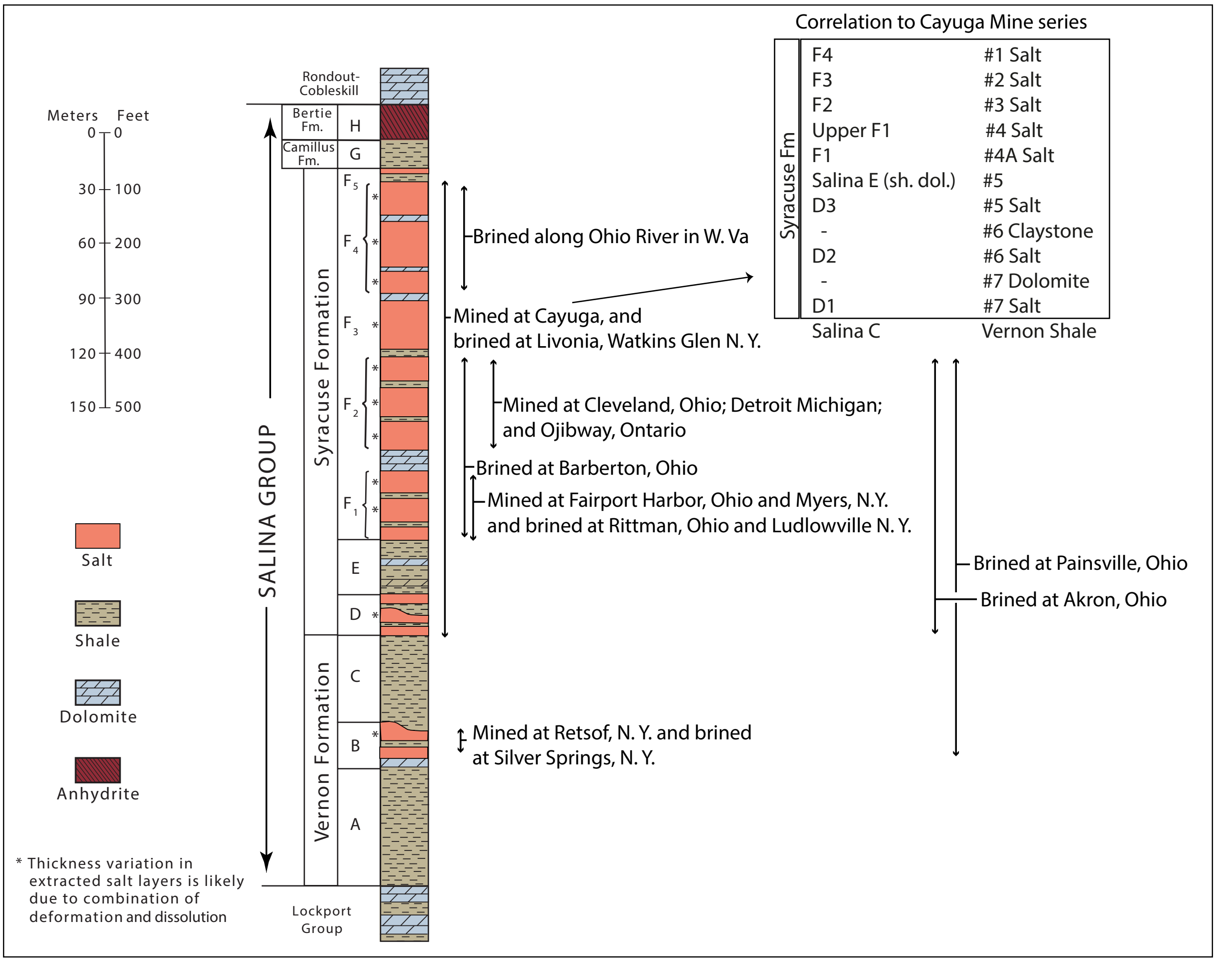


Figure 5. Stratigraphy (rock unit names) used to describe salt units in New York State and surrounds, along with a listing of targeted salt intervals in former and current mining or brine well operations across the region (after Tomastik, 1997) Insert gives the correlation of the regional stratigraphy to units used in the Cayuga Mine.

roughly wedge-shaped unit ranging in thickness from 500 feet (150 m) (northeastern Indiana) to as little as 50 feet (15 m) (central Indiana). To the east of the thick Salina salts in the Michigan basin, the Salina Group transition into the more structurally-deformed Appalachian Basin (Figure 4), it retains its salt units and in total thickness can exceed 1250 ft (380 m), but individual salt unit thicknesses are more variable (Figures 5).

Depth to top of the Salina Group in the Appalachian Basin ranges from 0 along the outcrop in New York and western Ohio to more than 9,000 ft (2,740 m) deep in the center of the Appalachian depositional basin. The top of the Salina Group ranges from about 1,400 ft (430 m) beneath the shore of Lake Erie to more than 10,000 ft (3,050 m) below sea level in the vicinity of Muncy, Lycoming County, PA. The Salina Group ranges in thickness from about 300 ft (90 m) in Erie County to over 2,200 ft (670

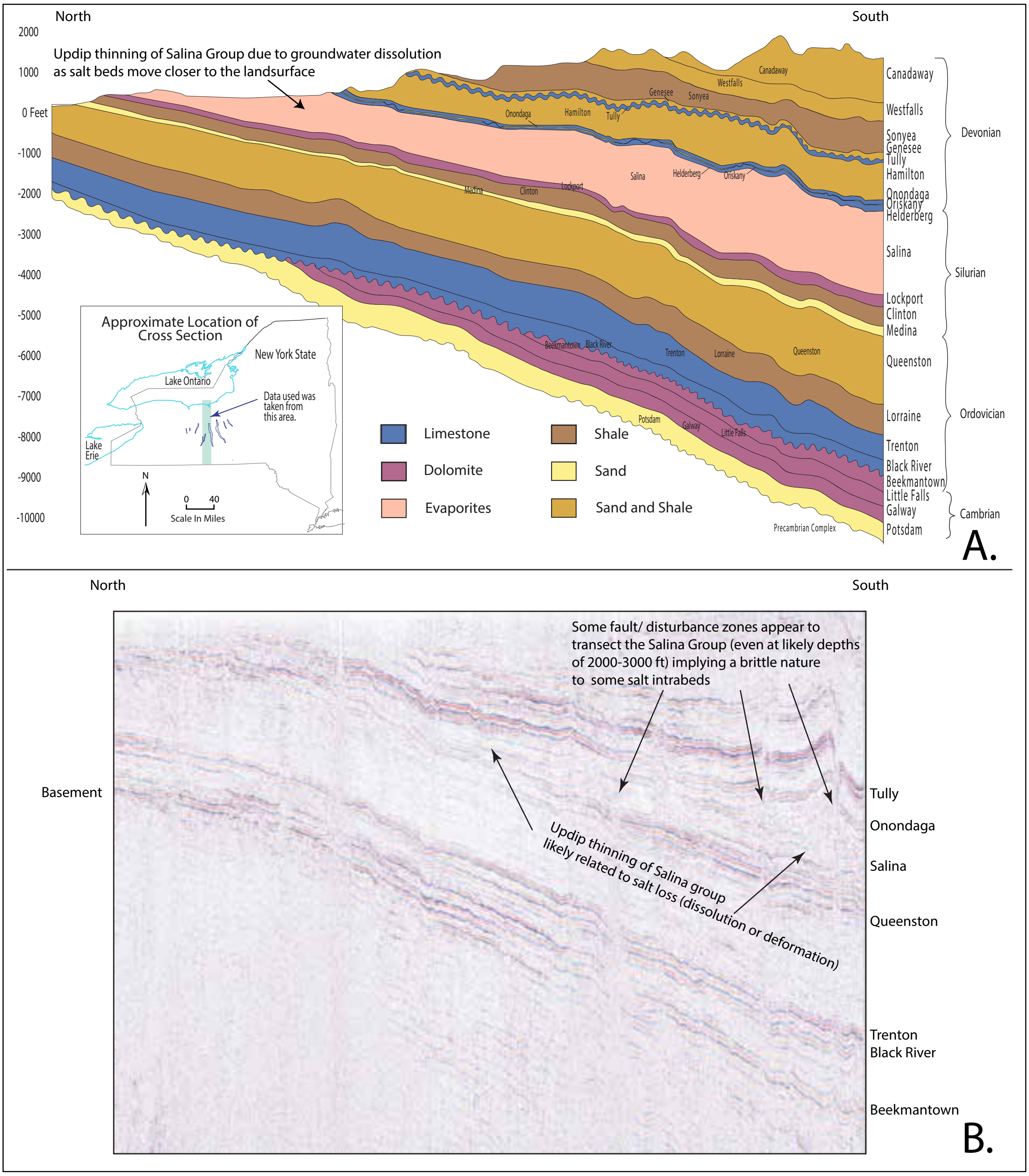


Figure 6. Beds of the Salina Group (including salt layers) dip or deepen to the south, as shown in: A) the stratigraphic cross section and B) a regional seismic line - this line was published without a position or a scale to maintain commercial confidentiality. As the beds of the Salina group approach the surface the total thickness of the unit lessens, likely due to the natural dissolution of the salt layers. This implies there is a natural supply of brine to the shallow parts of the stratigraphy (base images extracted from Smith et al., 2005).

m) in north-central Pennsylvania in Tioga and Bradford Counties (Figure 3). Salt beds in the Salina Group can occur in both the Syracuse and Vernon formations and so are informally termed the Cayugan salts.

All beds in the region of Cayuga Lake show a consistent gentle southerly dip, as seen in the stratigraphic cross section and the north-south seismic line illustrated in Figure 6. This section has a high vertical exaggeration so the beds appear to deepen steeply. This is a standard geological presentation construct, designed to give the viewer maximum visibility of the various rock units and layers that make up the stratigraphy. Actual dip angles in true scale are much less, and beds would appear much thinner in a true-scale section.

What is interesting in the seismic line is the overall thinning in the strata of the Salina Group as the salt beds approach the surface. This is typical of dipping salt beds worldwide and is a direct indication of the dissolution of the salt layers as they get shallower and come into contact with crossflowing undersaturated groundwaters (Warren, 2016; Chapter 7). This geometry implies that the salt at shallower levels beneath the Seneca Lake region is naturally supplying brines to the aquifer system. At deeper levels, the amount of natural dissolution is far less, and the salt in the Salina Group maintains its integrity and overall thickness. This is likely one of the reasons why not all of the salt layers are present in the Salina Group at shallower depths, and one of the main cause of changes in bed thickness at shallower levels (Goodman et al., 2011). The other is deformation related to regional tectonics. Salt dissolution is why any study of the suitability of the salt beds for mining or gas storage in the Finger Lakes will show salt character improves to the south as the salt deepens and is less susceptible to groundwater induced dissolution.

Groundwater dissolution means individual layers and overall salt thickness increase in a southerly direction and why there is a widespread reservoir of dissolution-derived brine beneath and adjacent to the Onondaga Escarpment.

In the past, brine wells drilled to extract a brine feedstock have exploited this brine reservoir (Goodman et al., 2010). Many caverns were created during this time of "wild brining" in the 1800s were allowed to expand to the point where the landsurface became unstable with some cavities daylighting and other exacerbating the creation of "mudboils" still active in the Tully Valley today (Kappel et al., 1996). This landscape instability occurred because "wild-brine" solution caverns were allowed to expand, uncontrolled ,to transect a number of intrasalt beds. Operators continued to operate the brine well as long as the well continued to supply a brine-stock. Once a salt cavern roof was breached (out-of-salt situation) and lost seal integrity, the resultant roof collapse led to a loss of brine well control, so the well was abandoned, and a new brine well was drilled nearby. Since the 1960s, maintenance of solution brine well integrity and minimisation of roof collapse became the aim of most brinefield operators, with the exception of wild-brine well operations in the former Soviet Union and its satellite states (Warren 2016, Chapter 13).

The practice of uncontrolled brinefield expansion and consequent well abandonment has led to later problems atop former brine fields. Worldwide, some brinefield salt cavities, once out of the salt, continued to expand for decades after the causative well was abandoned. Cavities became so large they stoped to the surface to become collapse dolines, with associated loss of life and property (see Warren, 2016; Chapter 13 for case histories). A problem with salt cavity-related collapse and groundwater contamination associated with stoping caverns is that they may not become obvious until many decades after brine or salt extraction operations have ceased. Complete removal of salt layers by uncontrolled brinefield operations in the early part of last century led to the current problems with mud boils in Tully Valley, Onondaga County, New York (Kappel et al., 1996).

Across New York State the buried salt layers in the Salina Group range in purity and thickness, along with the number of intrasalt beds. Targeted layers are ideally more than 95% pure NaCl. Regionally the salt beds beneath New York State contain higher proportions of impurities than their lithostratigraphic equivalents in the Michigan Basin. Salt layers in the Michigan and Appalachian basins are separated by shales and fractured dolomites and variably capped by a unit with abundant anhydrite ($CaSO_4$), which in combination are locally described as the Bertie Formation or the Bertie Group (Figure 5).

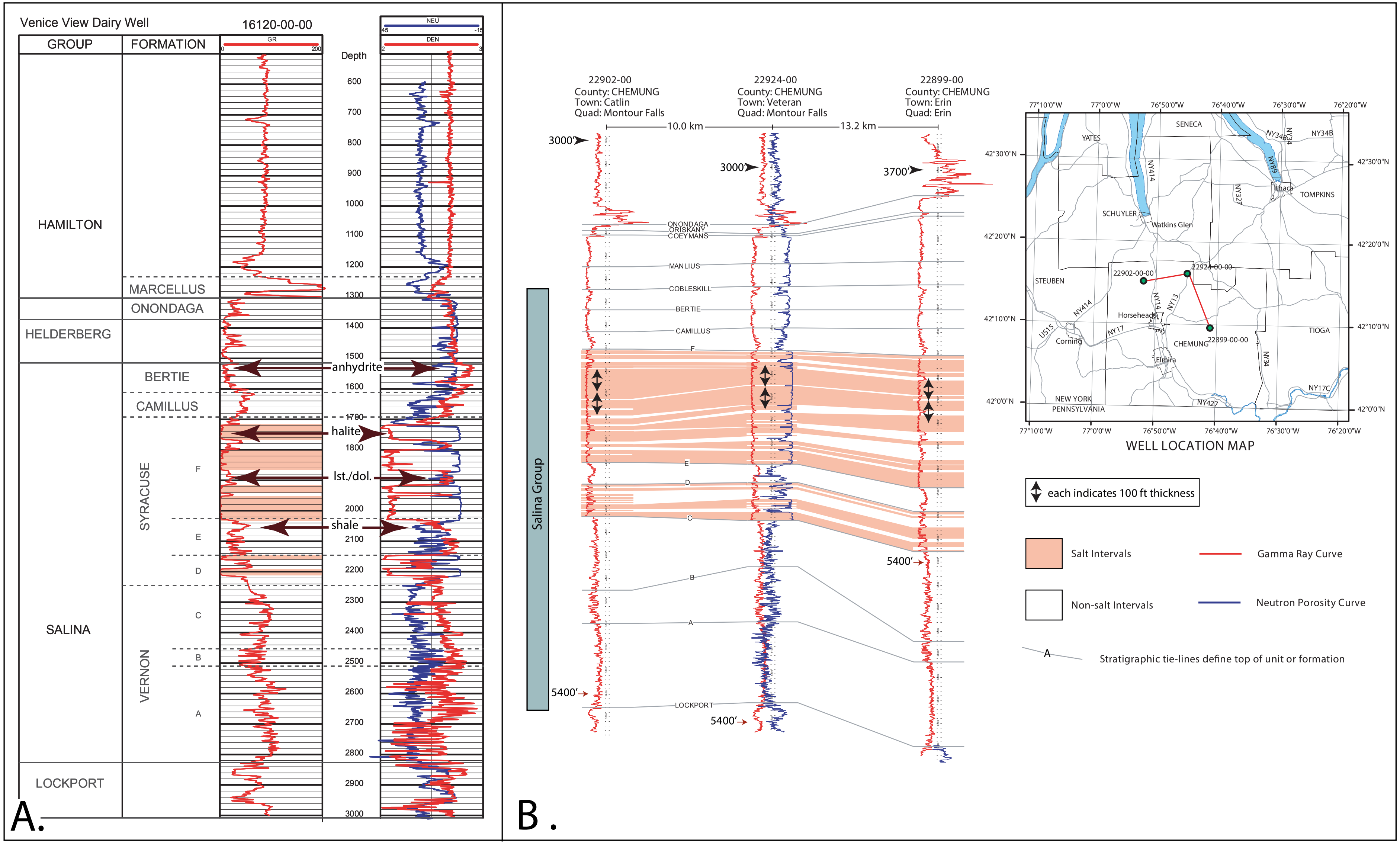


Figure 7 Wireline character of the Syracuse Formation. A) Wireline interpretation of salt interval in Venice View Dairy well, with intervals selected to demonstrate wireline determinants of mineralogy (Base log image extracted from Smith et al., 2005). B) Salt correlation panel based on wireline log measures in three wells located south of Cayuga Lake (base images extracted from Smith et al., 2005).

The lateral and vertical extent of impurities and thickness of salt intrabeds south of the Cayuga Lake region is given in published examples of wireline log data, as in Figure 7a, b. Wireline logs are geophysical measurements of rock properties in a well bore. They are measured by a string of tools lowered on a cable (or wire) into a wellbore and then raised to the surface at a constant rate of rising, as measurements of rock properties are made.

The gamma log measures natural radioactivity in the rock, values tend to be high in shales and low in salt and carbonates (limestones and dolomites) that lack impurities. The density log measures electron density and converts it to equivalent rock densities. Anhydrite has a characteristic high-density value around 3, halite is around 2, while the densities of the other rock types vary according to porosities and matrix constituents. The neutron log measures hydrogen content. When the neutron log and density logs are overlain on a standardised scale, as done in Figure 7a, then regions where the two trackways overlap indicates a likely limestone, some separation indicates dolomite, while a broader separation of tracks indicates shale. A reversal of the dolomite and shale overlap direction indicates a likely sandstone. Wireline interpretation techniques are used to better understand lithology throughout the oil industry and is increasingly in use by the mining industry. Wireline interpretation minimises the need to collect core, which is an expensive process. However, cores preserve rock textures indicative of strength properties and vectors that need to be understood for reliable and safe mining practice.

Figure 7b is an example of the use of the wireline data to correlate the extent of the salt and nonsalt intervals between three wells south of Cayuga Lake. It clearly shows that the salt thickness is not consistent between wells and that the amount and thickness of nonsalt beds vary between wells. The diagram is drawn with the intent of maximising a bed-parallel correlation of intrasalt units between the various wells. There is no control on the orientation of the beds between the wells other than an assumption that the intrasalt beds are aligned sub-horizontally. This is standard geological practice in the oil industry. However, regional observations as seen in published seismic and public-domain core and mine-based observations (detailed in Warren 2015) all suggest intrabed extents and dips within the Cayugan salt are far less predictable than such highly interpretive correlation panels suggest. A comprehensive suite of logs was collected in the drilling of Corehole #18 and paper copies of the log outputs are in the public domain as part of the contents of the RESPEC (2013) report.

The seismic line illustrated in Figure 8 shows the Salina Group geometry in the vicinity of a fault zone and how the salt body it carries can show substantial thickness changes, especially in zones of tectonic disturbance and deformation. This is clearly unlike the evenly-bedded near-constant-thickness salt layers that typify salt occurrences in the Michigan Basin. The salt in the Salina Group in its current eastern extent beneath New York State and Pennsylvania is variably deformed, with resulting thickness changes in individual salt layers (as can be seen locally in the Cayuga Mine (Prucha, 1968) and discussed further in next section of this report. This deformed region includes strata beneath the Fingers Lake region, as indicated by the shaded rectangle in Figure 8.

Thus, the salt beds of the Seneca Lake region and its surrounds are intensely folded into a series of local east-west anticlines and synclines, with elevation differences of more than tens of feet from crest to crest in local folds in the Cayuga mine area (Jacoby, 1963). However, as the published seismic shows, there are much greater lateral thickness changes in the salt across faulted regions, and it is likely that some of these faults have locally penetrated the Salina Group (Figure 8).

Regionally, as first expressed by Gwinn (1964), the various anticlines in the Finger Lake region, and regions further south, are the principal products of halokinetic deformation. The various salt-cored anticlines and synclines (including the Firtree Anticline which transects Lake Cayuga in the vicinity oof the Salt mine - Prucha, 1968) extend downward to the décollement (slippage) surface near the base of the salt layers in the Salina Group. Currently, a dip slightly in excess of 1° is present at the base of the Salina Group; this is true from the vicinity of the Finger Lakes region to the structural front of the collision belt at the Muncy anticline in Sullivan County, Pennsylvania. In this distance of approximately 85 miles, the base of the Salina Group drops from 1,000 ft below sea level near Himrod, New York, to more than 10,000 ft below sea level west of the Muncy anticline.

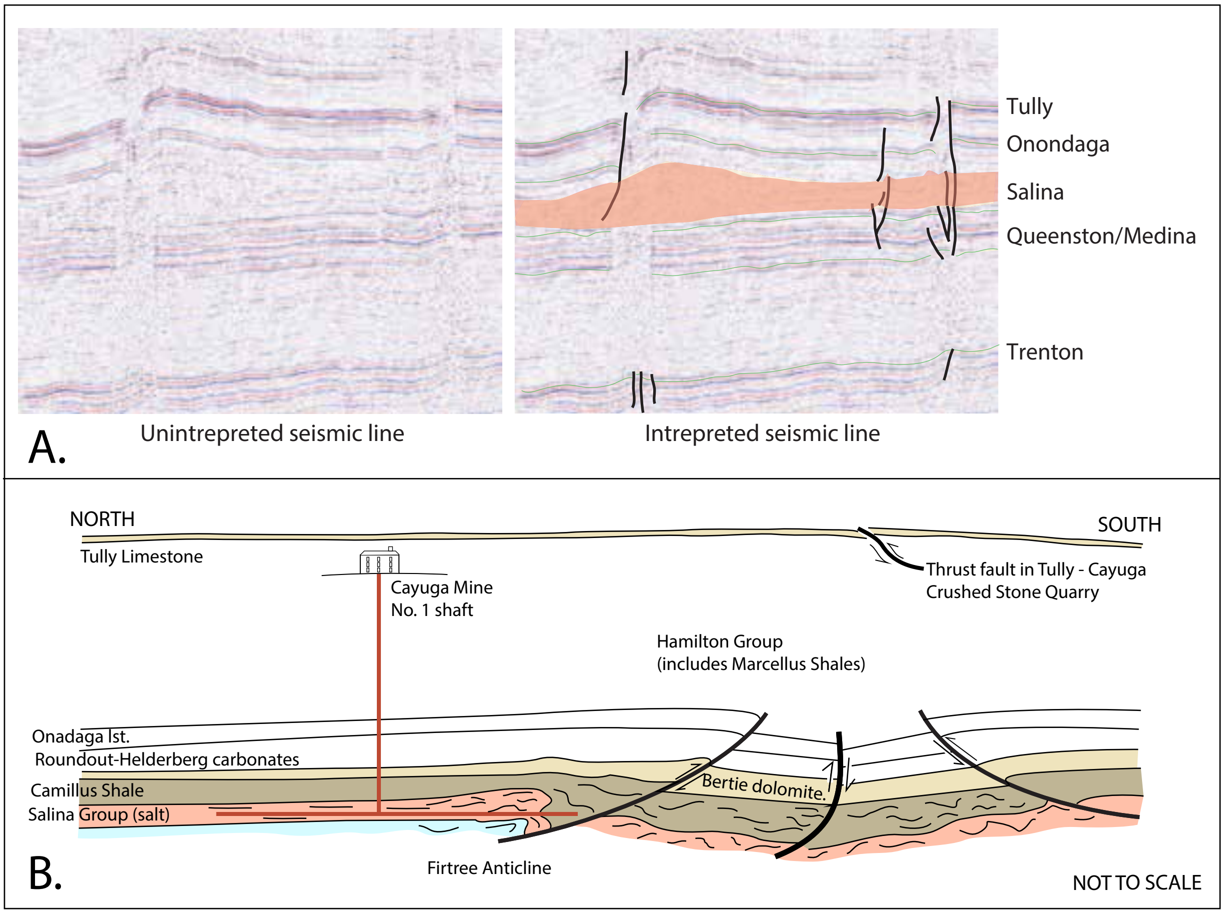


Figure 8. Regional variations in salt thickness (in the Salina Group) as interpreted in A) Seismic (from Smith et al., 2005) and B) an interpretive schematic based on regional thickness changes seen in wells and observations in the Cayuga Mine (after Goodman and Plumeau, 2004a, b).

Down this incline, sliding of post-salt beds likely formed the salt-core anticlines, with characteristically over-steepened and thrust-faulted south-east limbs (Figure 8; Frey, 1973). This leads to the contrast in deformation style seen in Figure 8. Above the base of salt, the beds are folded and deformed, while below the base of salt the beds are gently dipping. Hence, salt and incompetent shales in the Salina Group have flowed plastically during regional tectonic events in the Mesozoic era. This gives rise not only to the intense folding in and above the salt level but also to faulting of the salt and supra-salt section (Figure 8a).

The upper surface of the salt and its overlying sediments in the vicinity of Cayuga and Seneca lakes are characterised by broad, east-west synclines and anticlines, with axes paralleling the sharp folds and salt-cored deformation zones in the underlying evaporites. In contrast, beds below the décollement or slippage layer near the base of salt are not folded. This structural contrast, in combination with ongoing natural salt dissolution in the shallower regions, and an earlier episode of dissolution tied to the Alleghanian Orogeny explains why the wedge-shaped plate of post-salt rocks thins from about 12,000 ft thick near the structural front to less than 2,000 ft in the Cayuga Rocksalt Mine (Frey, 1973; Harrison et al., 2004). Based on a regional study of fault trends and seismic events in New York State, Jacobi (2002) concluded, "...It thus appears that not only are there more faults than previously suspected in NYS, but also, many of these faults are seismically active..." This question of ongoing fault activity should be addressed in terms of mine expansion toward the north of the current operational area of the Cayuga Salt Mine and we shall return to it once we have discussed the nature of the brine hydrology within its evolving Quaternary glacial-interglacial context.

Lake	Length (km)	Width (km)	Elevation (m msl)	Water volume (10^6 m^3)	Surface area (SA) (km^2)	Drainage area (DA) (km^2)	DA/SA	Maximum depth (m)	Max sedt. thickness (m)	Erosion below lake level (m)	Erosion rel. sea level (m)
Conesus	13	1	249	157	14	168	12	18	n.a.	n.a.	n.a.
Hemlock	11	1	276	106	7	96	14	29	149	173	103
Canadice	5	1	334	43	3	32	11	27	68	94	240
Honeoye	7	1	245	35	7	95	14	9	n.a.	n.a.	n.a.
Canandaigua	25	2	210	1,640	42	407	10	84	202	261	-51
Keuka	32	3	218	1,434	47	405	9	57	146	193	25
Seneca	57	5	136	15,540	175	1,181	7	186	270	442	-306
Cayuga	61	6	116	9,379	172	1,870	11	132	226	358	-242
Cwasco	18	2	217	781	27	470	17	52	95	140	77
Skaneateles	24	3	263	1,563	36	154	4	84	140+	255	8

Table 1. Finger lake dimensions, sediment fill, glacial scour depths and water volume statistics (after Mullins et al. 1996) See figure 9a for lake locations

Quaternary Geology of the Finger Lakes region of New York State.

The Finger Lakes of central New York State consist of 11 elongate, glacially scoured lake basins Mullins et al., 1996). Located south of Lake Ontario (Figure 9a) along the northern margin of the glaciated Appalachian Plateau, the Finger Lakes have been eroded into undeformed, but well-jointed, Devonian sedimentary rocks (chiefly shale) that dip gently to the south-southwest. The seven larger, eastern Finger Lakes (Otisco, Skaneateles, Owasco, Cayuga, Seneca, Keuka, Canandaigua) form a radiating pattern that projects northward into the eastern basin of Lake Ontario, whereas the four smaller, western Finger Lakes (Honeoye, Canadice, Hemlock, Conesus) project northward to a point near the city of Rochester (Figure 9a). The lakes vary considerably in size, ranging in length from 5 to 61 km, in lake-water elevation from 116 to 334 m, and in maximum water depth from 9 to 186 m (Table 1). Lakes Cayuga (133 m, 435 feet) and Seneca (188 m, 618 feet) are among the deepest lakes in the United States, with bottoms well below current sea level. They are also the longest of the Finger Lakes, though neither's width exceeds 5.6 km (3.5 miles); Lake Cayuga is 61 km (38.1 miles) long with a surface area of 172 km^2 (66.4square miles), while Seneca at 175 km^2 (66.9 square miles) is the largest of the lakes in of water surface area (Table 1). Glacially-driven sub-ice base erosion was most intense beneath Seneca and Cayuga lakes, where maximum depths to bedrock are 304 m and 249 m below sea level, respectively. The ice-retreat model currently used to explain the formation and filling of the various Finger Lakes is illustrated in Figure 9c (Mullins et al., 1989, 1996).

North of the Finger Lakes, is the Ontario Lowland characterised by an extensive drumlin field and an elaborate system of meltwater channels including Montezuma wetlands north of Cayuga Lake (Figure 9a, b). The uplands between the Finger Lakes are covered by a thin layer of till with a series of distinct chevron-shaped till moraines (Figure 9b), which become more laterally continuous to the north. Immediately south of the Finger Lake basins, and restricted to the valleys, are kame moraines (Figure 9a) collectively referred to as the Valley Heads Moraine. The Valley Heads kame moraines are thick (locally >200m in the deeper parts of the lake valley fill) and are permeable accumulations of largely coarse-grained, water-laid drift (Figure 10a).

Hydrology of the Cayuga Lake region

Deep subsurface brine hydrology and hydrochemistry in the Cayuga Lake region is strongly influenced by a combination of two process sets; 1) longer-term ongoing deeper salt unit dissolution and natural aquifer salinization and, 2) a shallower set of hydraulic flow reversals responding to pressurization changes driven by loading and unloading fluctuations, in response to the to and fro and ultimate retreat of Late Quaternary ice sheets (Laurentide sheet; Goodman et al., 2011).

The two process sets are now discussed and then their significance outlined in terms of depths of associated induced brine permeability and implications for possible aquifer connection between deep saline aquifers and shallower fresh water units.

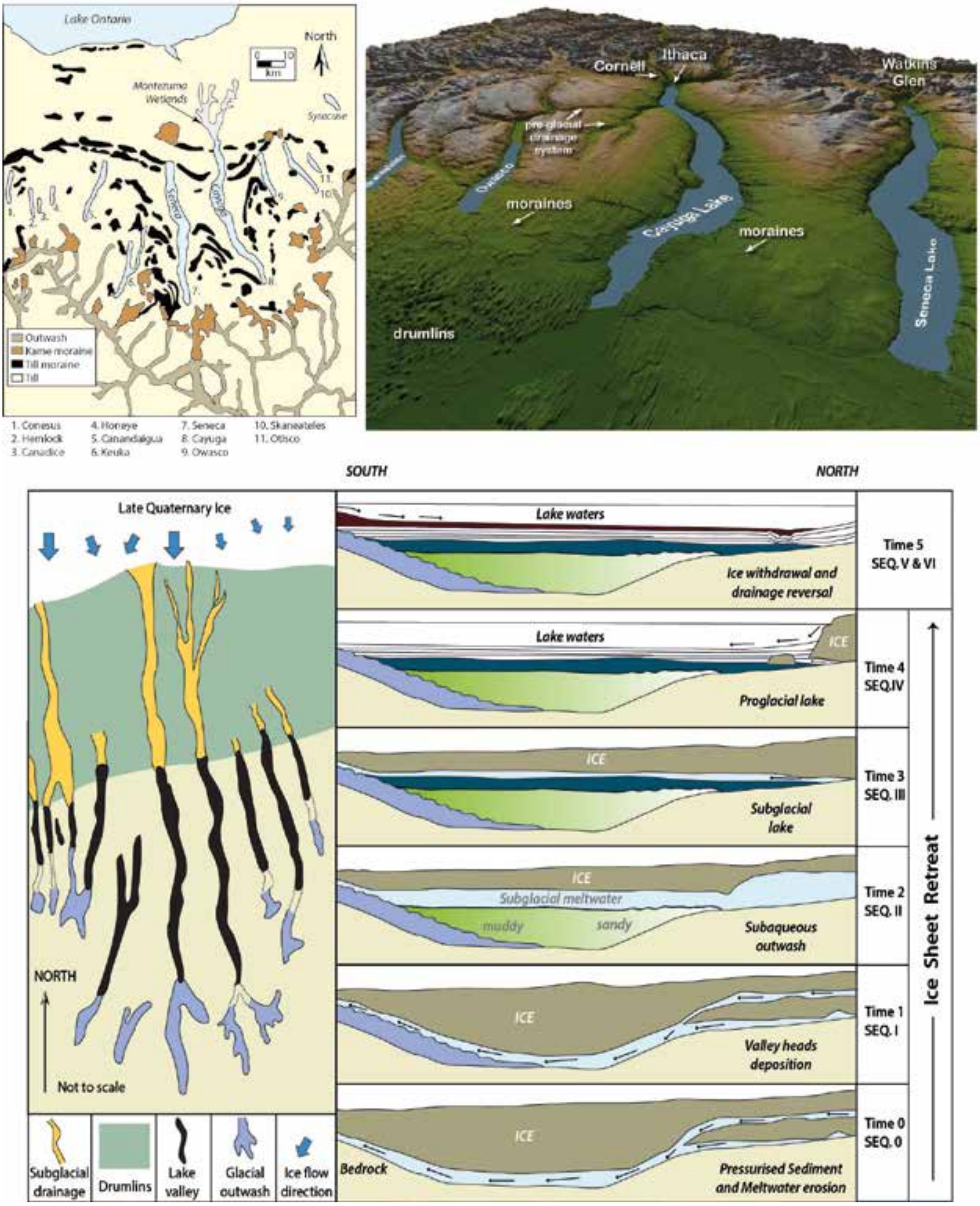


Figure 9. Finger Lakes, upper New York State. A) locality and general surface geology (after Mullins et al., 1996). B) Topography of the Cayuga Lake region looking South (extracted from images downloadable John Allmendinger's website <www.geo.cornell.edu/geology/faculty/RWA>. C) Geological model explaining Finger Lake formation as subglacial scour freatures (after Mullins et al., 1989).

Saline aquifers and glacial drivers of fluid entry

Worldwide, wherever bedded or halokinetic salt approaches the land surface it dissolves and, unless in an extremely arid region, the salt unit rarely makes it to the surface (Warren, 2016). Accordingly, regions of salt sub-crop are typically characterised by saline groundwaters and suprasalt depressions in the landscape, with adjacent ridges composed of less soluble sediments such as limestones or sandstones. This is the case where the Silurian Saline Group saline sediments subcrop downdip of the Onondaga escarpment, which is located immediately north of the Finger Lakes region (Figure 11; Goodman et al., 2011)

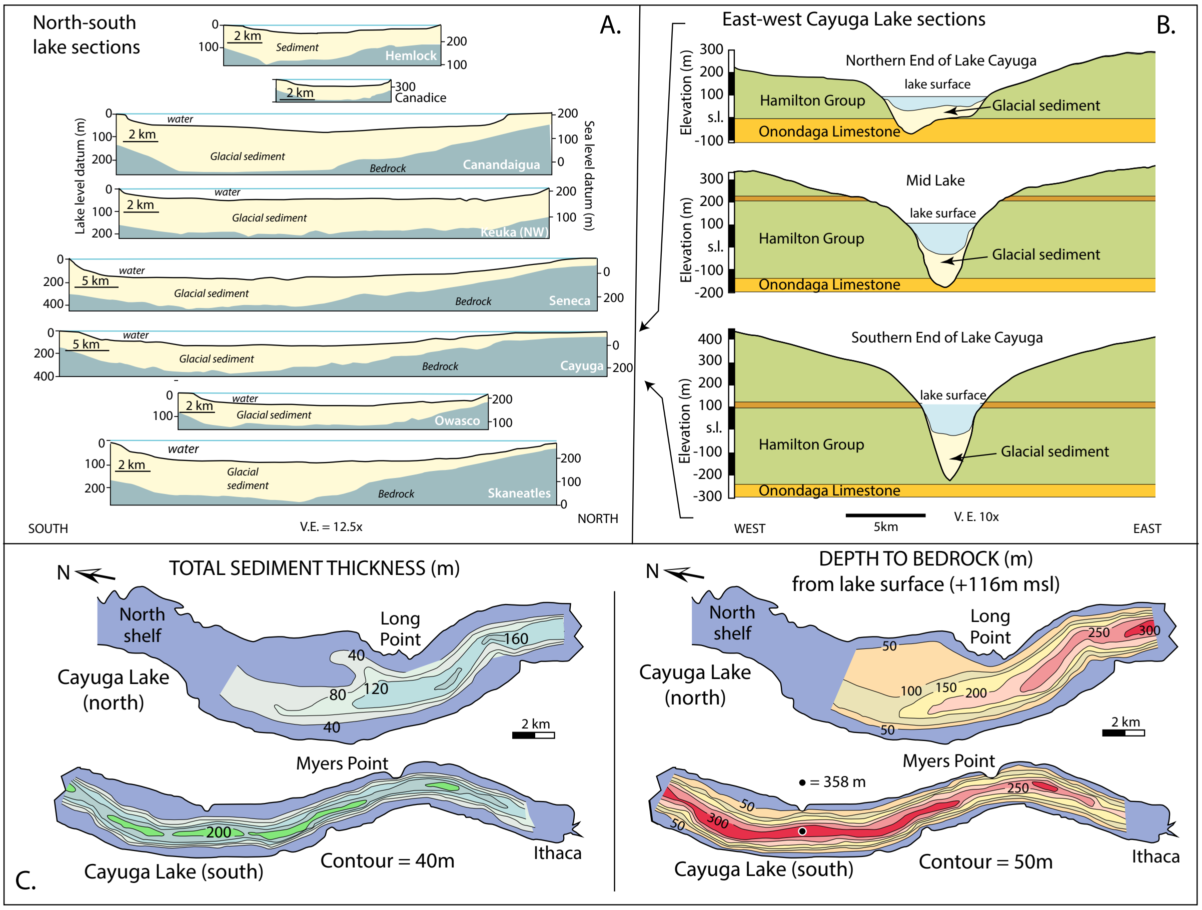


Figure 10. Section and map views of sediment fill statistics (after Mullins et al., 1995) A) Total thickness of the glacial sediment fill in the various Finger Lakes. B) Variation in position of penetration in the Phanerozoic stratigraphy of the glacially scoured valley-base in east-west sections (based on seismic) at the northern, medial and southern end of Lake Cayuga. C) Total thickness isopach of glacial sediment fill (m) and depth to bedrock isoclines relative to lake water surface (based on seismic interpretation).

This region of saline groundwaters, created by Salina salt unit dissolution, and accessible by the brine technologies of the time defines the area where salt was manufactured from various natural salt springs and shallow wells, beginning in the 1790s and ongoing throughout the 1800s (Merrill et al., 1893)

Work by Goodman et al. (2011) described the brine aquifer of this region as being of likely glacial origin and associated with downdip salt dissolution. The system is situated in the up-dip portions of the Silurian Salina Group subcrop belt, south of the historical salt manufacturing center at Montezuma, Cayuga County, New York (Figure 11). Well completion records report saline formation water in the interbedded shale, carbonate and salt sequence. If accurately reported, fluid emplacement in these strata was not vertical driven; rather an iceweight-induced lateral down-dip migration is required to emplace undersaturated fluid beneath and between partially intact salt beds which acted as aquitards or aquicludes. Increased hydraulic gradients imposed by glacial ice during the Pleistocene Epoch likely promoted enhanced, southward-directed downward fluid flow along bedding-parallel transmissive horizons within the Salina Group. Such saline fluids of variable salinity are reported in Salina Group strata to subsurface depths of about 1,500 feet. At more substantial depths, most Salina Group strata do not flow water. These hydrogeological patterns are in conflict with a Tothian model of basin-scale fluid flow that requires meteoric recharge (rain and snow-melt) in the Appalachian Plateau (Southern Tier) Province of western New York to infiltrate as deeply as the Salina Group salts before migrating northward and discharging as brine in the Lake Ontario Plain. Instead, water-bearing Salina Group strata are restricted to a belt approximately 18 miles south of, and parallel to, the Onondaga Escarpment. Hence, the saline aquifer, referred to herein as the Montezuma Brine Aquifer System (MBAS), more likely owes its origin to Pleistocene paleohydrological processes that affected the escarpment.

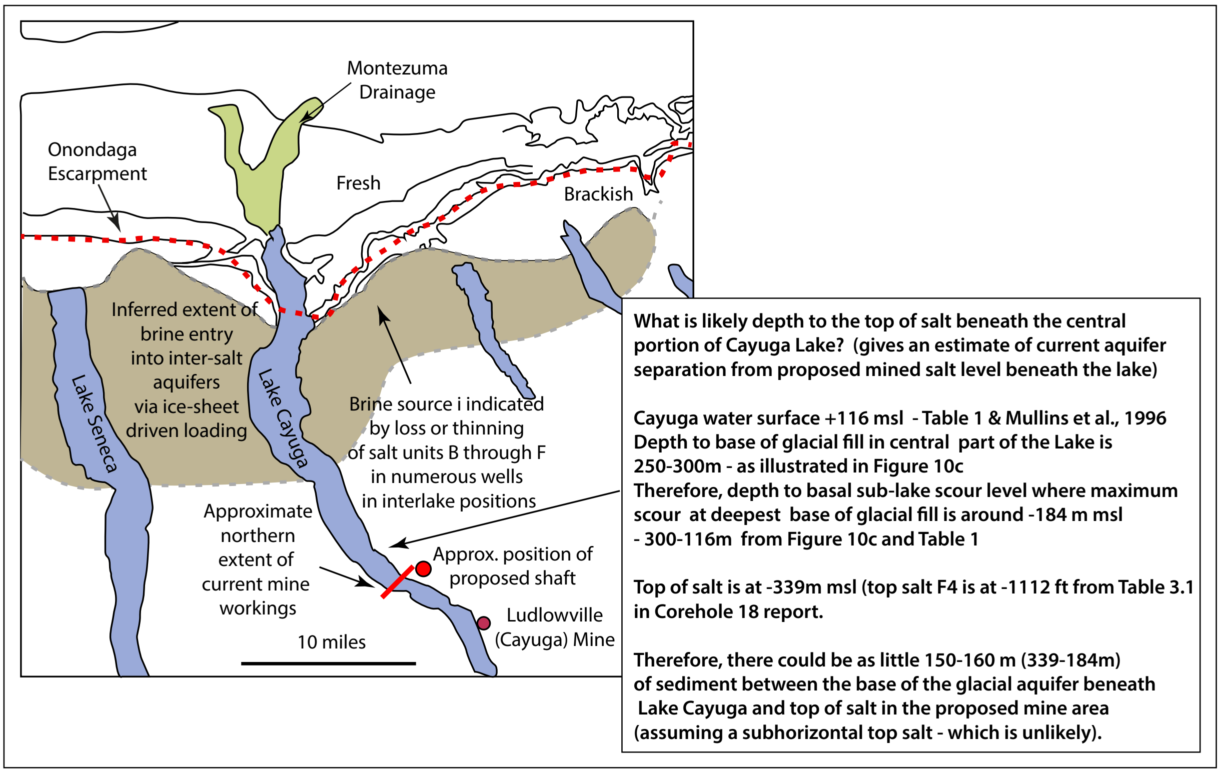


Figure 11. The extent of subsurface dissolution of various Syracuse Fm salt beds as the regional geology shallows toward the north infleunce region is shaded brown. The intersalt hydrology was periodically pressurised and released by expansion and retreat of glacial ice (after Goodman et al., 2011). The extent of the brown shade area is based on wireline signatures in wells drill in interlake positions. None of these wells (which are petroleum wells) were drilled into saline sediments below the glacial scour base thalweg. The inset box gives a calculation of the likely distance separating active undersaturated pore waters held in aquifers in the glacial sediments and the top salt unit, beneath the central part of Cayuga Lake, based on material presented in this report.

During the period of Pleistocene glacial advance, the MBAS was mainly closed-ended along its southern boundary, i.e. the aquifer had no discharge zone but maintained its high salinity by dissolving the upper and lower edges of the southward-dipping salt beds. Recharging sub-glacial meltwater simply may have infiltrated further down-dip through bedding-parallel transmissive zones and remained in storage maintained in position by the ice loaf at its up-dip end. The term "pocket" aquifer is proposed for this type of closed-ended, glacio-hydrogeological system.

Following glacial retreat, the steepened, southward-directed hydraulic gradient dissipated, and the source of cold water recharge was removed. Thus, according to the glacial pocket aquifer hypothesis, the Salina Group outcrop belt changed behaviour over time from a Pleistocene recharge zone to a Holocene discharge zone. Today, the Salina Group outcrop belt is populated by brine springs, confirming its status as a discharge zone for the modern MBAS.

In proximity to the Onondaga Escarpment, a localised, shallow subsurface, topographically controlled flow system contains fresh water. The saline water in the deeper subsurface MBAS is likely driven up-dip to the line of saline springs by a gradual release of residual Pleistocene fluid pressure. Fresh water and saline water springs can be closely juxtaposed, and the waters from the shallow and deeper flow systems likely mix in many areas along the southern margin of the Lake Ontario Plain.

According to Goodman et al. (2011), the presence of brine in subsurface Salina Group strata south of the Onondaga Escarpment in western New York is commonly reported in the vintage scientific literature. Hence, the saline aquifer system is likely more extensive than the Seneca and Cayuga Lake valleys near Montezuma. Nineteenth-century descriptions of salt wells in Wyoming, Livingston, Genesee, Erie and Cattaraugus Counties indicate artesian brine conditions in a zone parallel to, and south of, the up-dip terminus of the salt beds in the Salina Group. The salt beds are preserved just south of the Onondaga Escarpment beneath much of western New York. North of the escarpment, the Salina

Group strata are so shallow in the subsurface that they are thoroughly leached by actively circulating groundwater, and the salt beds have been fully dissolved.

This ice-load driven flow of brine in and out of beds in contact with the fluctuating edges of glacial ice sheets does not just occur in the Finger Lakes region, but also occurs in fractures in hard-rock (granite and granodiorite) terrains in the cratonic shield regions of Canada, Greenland and Antarctica where it drives seawater-derived brines into the craton to depths of 1 km or more (Figure 12; Warren, 2016, Chapter8; Starinsky and Katz, 2003). In such cases the load induced by a kilometer or more of ice cover drove additional fracturing in the underlying strata, This mechanism drives fluid entry further into rock areas that would otherwise be impermeable.

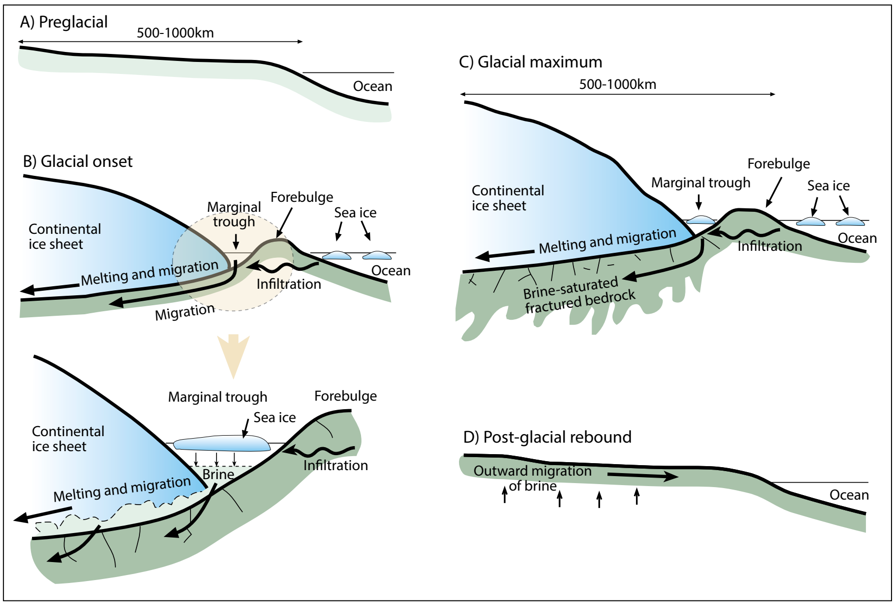


Figure 12. Isostatic and hydrological evolution of a marine-cryogenic basin aquifer system: A) Continent-ocean boundary before the onset of a glacial cycle. B) An ice sheet develops on the continent, depressing the crust underneath and forming a forebulge along the coast. Seawater infiltrates into the marginal trough between the ice edge and the forebulge and sea ice crystallizes on its surface. The resultant brine sinks to the bottom and infiltrates the underlying sediments and rocks via cracks and shear zones and by non-equilibrium melting of the ice sheet base. Then, it migrates inland, along the inclined ice-rock contact, towards the center of the depression. Loss of brine from the trench is compensated by fresh seawater flow through the forebulge. C) During the glacial maximum the basement rocks below the ice sheet become saturated with brine. D) Increased melt water head developing during glacial decline, accompanied by postglacial lithospheric rebound, drive the brines outwards from the center of the glaciostatic depression to their present sites (after Starinsky and Katz, 2003).

What makes the Finger Lakes region unique in terms of its ice-load driven hydrology is the fact that the brine entry is penetrating and dissolving a set of soluble sediments (dissolving salt layers separated by the carbonate and shale aquifers). This is somewhat different the more commonly invoked sea-edge ice sheet setting driving brine entry (Figure 12). This style ice sheet loading enhancing salt bed dissolution is active along the northern end of Lake Cayuga and explains the complete disappearance of shallower salt beds in the northern part of the subsurface geology beneath Lake Cayuga (Figure 11). Ice sheet loading may also have enhanced fracturing of intrasalt carbonate beds and perhaps driven a degree of recent salt flow in regions of significant local differences in salt thickness. These thickness differences were originally due to earlier folding and deformation (Warren, 2016; Chapter 6 for a summary of the physics of salt deformation).

Salt mine problems due unforeseen water entry

Salt mining is usually safe and predictable. However, there are some situations, illustrated by the following case histories that are relevant to the Cayuga mine situation. We shall consider three salt mines, namely; 1) loss of the Retsof Mine, 2) the Lake Pegnieur collapse and loss of the Jefferson Island Salt Mine 3) the flooding of the Patience Lake Potash Mine. All three mines were lost to flooding due to workings interacting with unexpected aquifer systems (See Warren 2016, Chapter 13 for other examples).

Retsof Mine, New York State, USA

The 1994 flooding of the Retsof Mine, New York State USA, took place over a period of weeks. Before abandonment, the 24 km^2 area of subsurface workings made it the largest underground salt mine in the USA and the second largest in the world (Figures 13, 14). The mine had been in operation since 1885, exploiting the Silurian Salina Salt and each year it produced a little

Figure 13. Location of the collapse dolines atop the former Retsof Mine to the east of the town of Cuylerville. The doline occupies a pre-existing low that had also captured Beard Creek (Bing® 2012 image mounted and scaled in MapInfo).

over 3 million tons of halite. It supplied more than 50% of the total volume of salt used to de-ice roads across the United States.

The eventual loss of the Retsof Salt Mine began in the early morning hours of March 12, 1994, with a magnitude 3.6 earthquake. The quake was caused by the catastrophic breakdown of a small mine pillar and panel section some 340 meters below the surface and was accompanied by the surface collapse of an area atop the mine that was some 180 by 180 meters across and 10 meters deep. This all occurred at the southern end of the mine near the town of Cuylerville. A month later, on April 18, an adjacent mine room collapsed to form a second collapse crater (Figure 13) The initial March 12 collapse in the mine was accompanied by an inrush of brine and gas (methane) and by a sustained intense inflow of water at rates in excess of 70 m^3/min, via the overlying now fractured limestone back (Gowan and Trader, 1999).

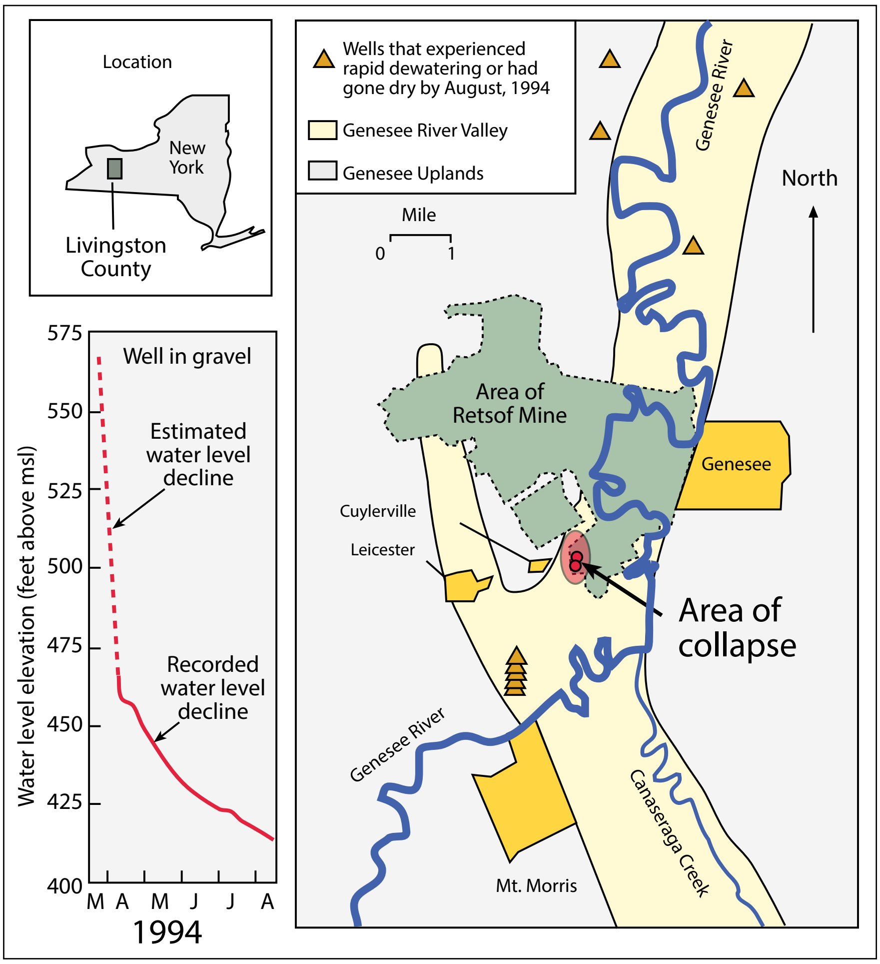


Figure 14. Locality plan of the Retsof mine and the area of collapse along with a selected hydrograph from a well in the Genesee River valley (March 12 to August 12 1994; after Tepper et al., 1997).

In a little more than a month, two steep-sided circular collapse features, some 100 meters apart, had indented the landscape above the two collapsed mine rooms (Figure 14. The northernmost feature, which was more than 200 meters across, included a central area that was about 60 meters wide and had subsided about 6 to 10 meters. The southernmost feature, which was about 270 meters in diameter, included a central area that was about 200 meters wide and had subsided about 20 meters (Figure 13). Fractures extending up from the broken mine back created hydraulic connections between aquifers, which previously had been isolated from each and so provided new high volume flow routes for rapid migration of perched groundwaters into the mine level.

Water flooded the mine at rates that eventually exceeded 60,000 litres per minute and could not be controlled by pumping or in-mine grouting. By January 1996 the entire mine was flooded. Associated aquifer drawdown caused inadequate water supply to a number of local wells in the months following the collapse; some dried up (Figure 14; Tepper et al., 1997). Aside from the loss of the mine and its effect on the local economy, other adverse effects included abandonment of four homes, damage to other homes (some as much as 1.5 kilometers from the sinkholes), the loss of a major highway and bridge, loss of water wells and prohibition of public access to the collapse area. Land subsidence, possibly related to compaction induced by aquifer drainage to the mine, even occurred near the town of Mt. Morris some 3 miles southwest of the collapse area.

Post-mortem examination of closure data from the two failed mine panels showed an anomalous buildup of fluid pressure above the panels in the period leading up to their collapse. The initial influx of brine and gas following the first collapse coincided with the relief of this excess pressure. Gowan and Trader (1999) demonstrated the existence of pre-collapse pressurised brine cavities and gas pools above the panels and related them to nineteenth-century solution mining operations. They also documented widespread natural gas and brine pools within Unit D of the Syracuse Formation approximately 160 ft above the mined horizon in the Retsof Mine. The satellite image also shows that collapse occurred in the landscape low that defined the Beard Creek valley (Figure 13). Brine accumulations apparently formed in natural sinks, long before solution mining began in the valley, driven by the natural circulation and accumulation of meteoric waters along vertical discontinuities, which connected zones of dissolving salt to overlying fresh water aquifers. Subsequent work by Gowan and Trader (2003) showed that

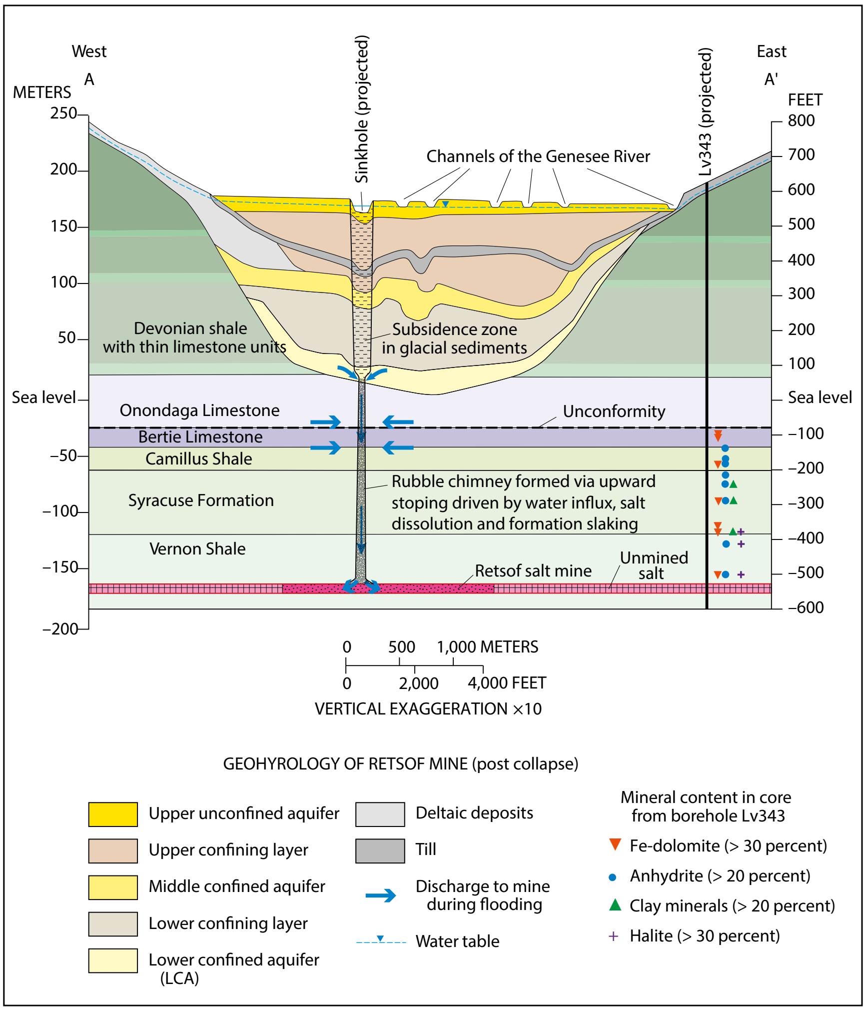


Figure 15. Stratigraphic section depicting rubble chimney above collapsed room in Retsof salt mine, Livingston County, N.Y. Also shown are the main aquifers that facilitated water influx into the flooding mine (inflow also drained natural and artifical brine filled solution cavities in the stratigraphic levels above the working mine level (after Yager et al., 2009)

daylighting sinkholes had formed by the down-dropping of the bedrock and glacial sediments into voids created by the dissolution of salt and the slaking of salt-bearing shale upon exposure to fresh water.

This collapse took place in a salt-glacial scour stratigraphy and hydrology near identical to that in the Cayuga Mine region. In this context, it is of interest to note that there are a number of documented plugged and abandoned brine wells located in the vicinity of the Cayuga Mine that were drilled from the 1890s to the 1950s. Figure 1b plots the positions of these known wells.

One wonders if there are older undocumented wells on the eastern lakeshore located in areas where the salt brine target was shallower further north. Such undocumented brine wells would likely have been sited near the lake shore to facilitate the transport of the brine product. Current salt mining below the lake avoids the possibility of intersecting solution cavities associated with any such undocumented old brine wells. But, the drive needed to position the pilot hole for Shaft #4 will transect a salt region that may have been solution-mined more than a century ago. A seismic or a less disruptive "mini-sosie" survey should be undertaken to identify any possible solution cavities in the region that will connect the current workings to the Shaft #4 pilot hole.

Lake Peigneur, Jefferson Island, Louisiana

On November 20, 1980, one of the most spectacular sinkhole events associated with oil-well drilling occurred atop the Jefferson Island salt dome. On that day Lake Peigneur disappeared as it drained into the workings of the underlying Jefferson Island salt mine. In a few hours a collapse sinkhole, some 0.91 km^2 in area, had daylighted in the southeast portion of the lake (Figures 16, 17; Autin, 1984, 2002; Warren, 2016). In the 12 hours following the first intersection of the drill hole with the mine workings, the underlying mine was completely flooded, and Lake Peigneur was completely drained.

Drainage and collapse of the lake began when a Texaco oilrig, drilling from a pontoon in the lake, breached an unused section of the salt mine some 1000 feet (350 meters) below the lake floor (Figure 17). Witnesses working below ground described how a wave of water instantly filled an old sump in the mine measuring some 200 feet across and 24 feet deep. This old sump was in contact with a zone of anomalous "black" salt (a boundary shear zone - see Warren, in press, for further discussion of black salt anomalies). The volume of suprasalt floodwater engulfing the mine corridors couldn't be drained by the available pumps. Some 23-28 million m^3 of salt were extracted during the preceding 58 years of mine life. The rapid flush of lake water into the mine, probably augmented by the drainage of natural solution cavities in adjacent anomalous salt zones and associated collapse grabens beneath the lake floor, meant landslides and mudflows developed along the perimeter of the overlying Peigneur sinkhole, so that post flooding the lake was enlarged by 28 ha.

With water filling the mine workings, the surface entry hole in the floor of Lake Peigneur quickly grew into a half-mile-wide crater. Eyewitnesses all agreed that the lake drained like a giant unplugged bathtub—taking with it trees, two oil rigs (worth more than $5 million), eleven barges, a tugboat and a sizeable part of the Live Oak Botanical Garden. The drained lake didn't stay dry for long, within two days it was refilled to its normal level by Gulf of Mexico waters flowing backwards into the lake depression through a connecting bayou (Delcambre Canal, aka Carline Bayou) forming what was a short-term waterfall with the highest drop in the State of Louisiana. Associated ground movement and subsidence left one former lake-front house aslant under 12 feet of water (Autin, 1984).

The Peigneur - Jefferson Mine disaster had wider resource implications as it detrimentally affected the

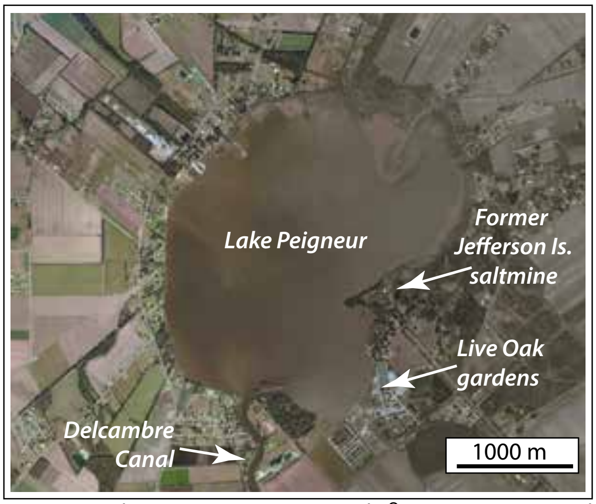


Figure 16. Lake Peigneur, Louisiana (scale ®Bing image mounted in ®MapInfo) see also Warren 2016.

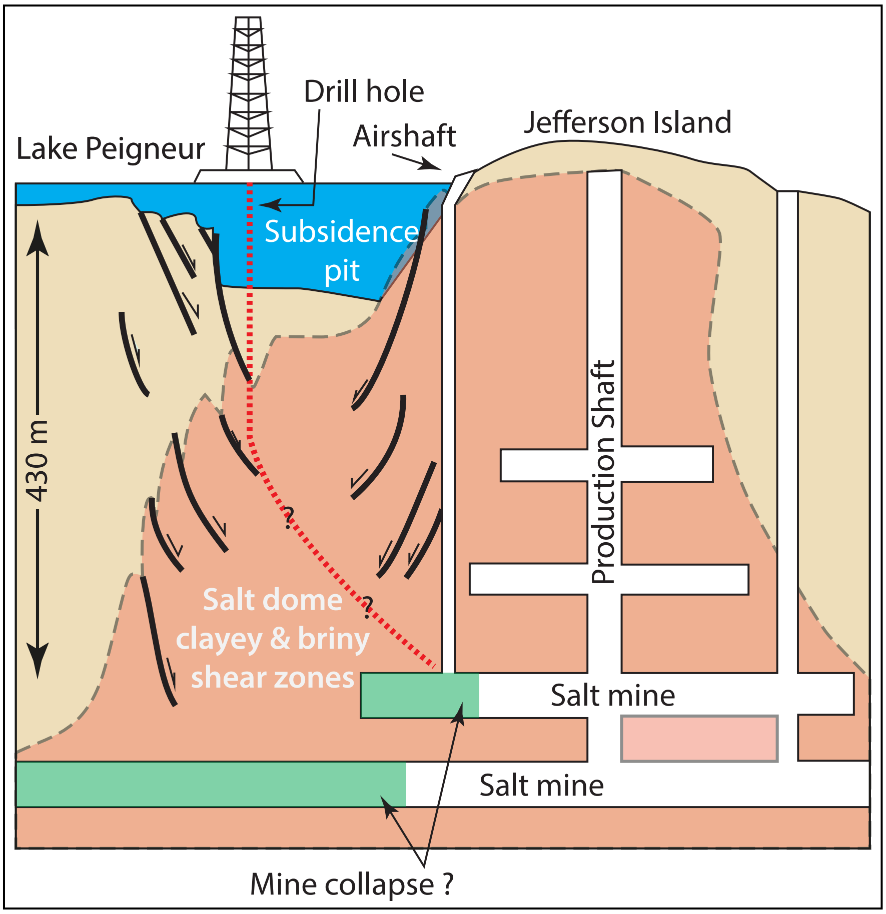


Figure 17. Lake Peigneur, Jefferson Island, cross section showing the cause of the flooding of the mine and the temporary draining of the lake (in part after Keller and Blodgett, 2006)

profitability of other salt mines in the Five Islands region (Autin, 2002). Even as the legal and political battles at Lake Peigneur subsided, safe mining operations at the nearby Belle Isle salt mine came into contention with public perceptions questioning the structural integrity of the mine roof. During ongoing operations, horizontal stress on the mineshaft near the level where the Louann Salt contacts the overlying Pleistocene Prairie Complex across a zone of anomalous salt-defined aquifer proximity had caused some mine shaft deterioration and salt leakage. Broad ground subsidence over the mine area was well documented and monitored, as was near continuous groundwater leakage into the mine workings. The Peigneur disaster meant an increased perception of continued difficulty with mine operations and an increased risk of catastrophic collapse related to salt anomaly intersections was considered a distinct possibility. In 1985, a controlled flooding of the Belle Isle Salt Mine was completed, as part of a safe closure plan.

Subsidence over the nearby Avery Island salt mine (operated by Cargill Salt) has been monitored since 1986 when small bead-shaped sinkholes were initially noticed in the above mine region. Subsidence monitoring post-1986 defined a broad area of bowl-shaped subsidence, within associated areas of gully erosion, likely underlain by BSZ's (Autin, 2002). Avery mine is today the oldest operating salt mine in the United States and has been in continual safe operation since the American Civil War. After the Lake Peigneur disaster, the mine underwent a major reconstruction and an improved safety workover. Subsidence is still occurring today along the active mine edge, which coincides with a topographic saddle above an anomalous salt zone, which is located inside the mined salt area. At times, ground water has seeped into the mine, and there are a number of known soil-gas anomalies and solution dolines on the island above but not in contact the mine. These are natural features that predate mining and are continually monitored.

Much of the subsidence on Avery Island is a natural process as differential subsidence occurs atop any shallow salt structure with the associated creation of zones of anomalous salt (Warren, 2016, Chapter 7). Dating of middens and human artefacts around salt-solution induced, water-filled depressions atop the dome, shows dissolution-induced subsidence is a natural process, as are short episodes of catastrophic lake floor collapse, slumping and the creation of water-filled suprasalt dolines (circular lakes). Such landscape events and their sedimentary signatures have histories that extend back well beyond the 3,000 years of human occupation documented on Avery Island (Autin, 2002).

What the Peigneur-Jefferson Island collapse illustrates, once again, is how an unexpected water breach can have disasters effects on a safely operating salt mine. In this case, the mine operation was not to blame, but the volume of breach waters was probably augmented by the proximity of some parts of the no-longer-active areas in the mine workings to anomalous salt zones and natural brine-filled solution cavities within salt boundary positions.

Patience Lake Potash Mine flood

In the 1970s the Patience Lake potash mine operation, located on the eastern outskirts of Saskatoon, Canada, encountered open fractures tied to a natural collapse structure. Grouting managed to control the inflow and mining continued. Then, in January of 1986, the rate of water inflow began to increase dramatically from the same fractured interval (Figure 18; Gendzwill and Martin 1996).

At its worst, the fractures associated with the structure and cutting across the bedded ore zones were leaking 75 m3/min (680,000 bbl/day) of water into the mine. The water was traced back to the overlying Cretaceous Mannville and possibly the Duperow formations. Finally, in January 1987 the mine was abandoned. It took another six months for the mine to fill with water. Subsequent seismic shot over the offending structure suggested that the actual collapse wasn't even penetrated; the mine had merely intersected a fracture within a marginal zone of partial collapse (Gendzwill and Martin 1996).

Part of the problem was that the water was undersaturated and quickly weakened pillars and supports, so compromising the structural integrity of the workings. The unexpected intersection of one simple fracture system resulted in the loss of a billion dollar conventional potash mine. Patience Lake mine now operates as a cryogenic solution mine by pumping warm KCl-rich brine from the flooded mine workings to the surface. Harvesting of the ponds takes place during winter af ter cryogenic precipitation of sylvite in the at-surface potash ponds (Fig. 19).

Unlike the Patience Lake Mine flood, there was a similar episode of water inflow in the nearby Rocanville Potash Mine. But there a combination of grouting and bulkhead emplacement in succeeded in sealing off the inflow, thus saving the mine (see Warren 2016 for detail). Unlike

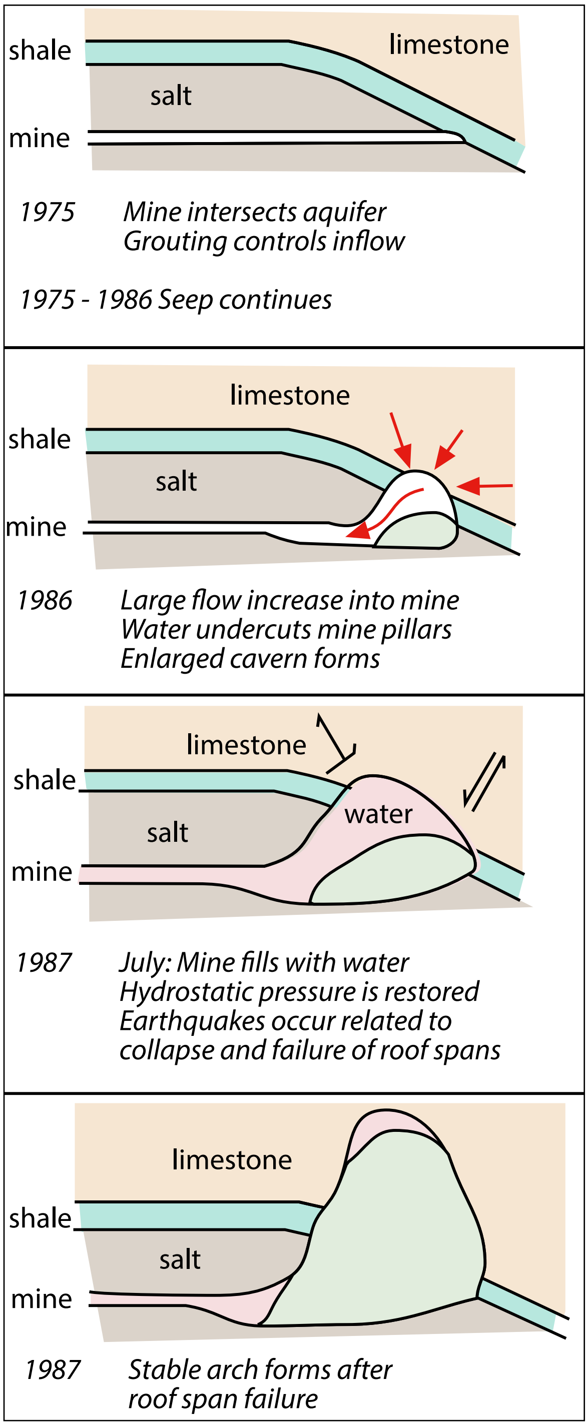


Figure 18. Sequence of events controlling the flooding of the Patience Lake Mine (after Gendzwill and Martin, 1996).

Patience Lake, the brine from the breached structure in Rocanville was halite-saturated, so limiting the amount of dissolution damage in the mine walls. Different outcomes between the loss of the Patience Lake Mine and recovery from unexpected flooding in the Rocanville Mine likely reflects the difference between intersecting a natural brine-filled dissolution chimney that had made its way to the Cretaceous landsurface and is now overlain by a wide-draining set of aquifer sediments, versus crossing a blind dissolution chimney in a saline

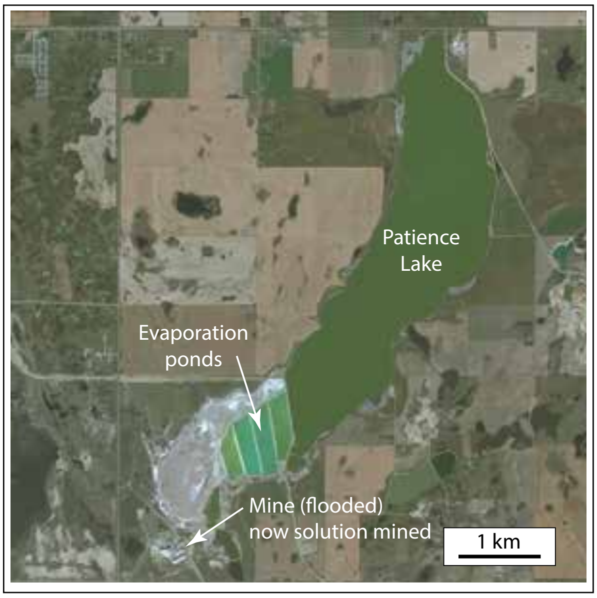


Figure 19. Patience Lake - PCS solution mine, Saskatchewan, Canada

Devonian sediment surround that never broke out at the Cretaceous landsurface. Understanding the nature of the potential hydrological drainages and water source is a significant factor in controlling unexpected water during any mine expansion.

Implications for the Cayuga Salt Mine expansion

The supreme rule for safe, conventional salt mining in bedded and halokinetic ore hosts is "stay in the salt" (Figure 20). Problem areas encountered in most halite and potash mines are related to thinning or disappearing salt-ore seams, usually in zones showing evidence of water-related dissolution and solution collapse. In other words, problems tend to occur when there is an unexpected intersection with a precinct of anomalous salt features (Woods, 1979; Boys, 1990, 1993; Warren, 2016). Uncontrollable water inflow is the greatest threat to any operating salt/potash mine in both bedded and halokinetic ore hosts, as can be seen in the three previous case histories and numerous other examples, as detailed in Warren 2016; Chapter 13.

"Stay in the salt"

As the Cayuga Mine operating face steadily moves further north below Lake Cayuga, the possibility of approaching a sub-lake aquifer increases. This should generate caution in terms mine planning and possible challenges if ongoing operations place parts of the salt mine workings in a condition of aquifer proximity. The same caution should also be considered to be an integral part of the approval process for construction of Shaft #4, which will involve the excavation of a drive across some lateral distance between an existing portion of the mine workings and the base of the construction site for the pilot hole that will ultimately evolve into Shaft #4 (Figure 11).

Current discussion of the geological conditions in the vicinity of Shaft #4 and clarification requests from New York state authorities do not deal with the fact that the floor of the deep glacial scour channel, defining the base of the water filled glacial sediments beneath Lake Cayuga and its overlying water column, has been downcut to depths greater than 300 m below the lake water surface. This is a conservative downcut estimate as Mullins et al. (1996) document a maximum scour depth of 358m in the Lake Cayuga erosional valley (position indicated by the black circle in Figure 10c). The documented level of glacial scour and fill geology is presented as Figure 10b (after Mullins et al., 1996)

The likely vertical distance of separation between top of salt and the lowest scour position of the glacial valley trace (thalweg) beneath the central portions of Cayuga Lake is possibly as little as 150-200 m (see calculation inset in Figure 11). This aquifer-to-salt separation is less than normally considered a safe separation from a potential fresh-water aquifer. A minimum vertical distance of 200 meters+ is considered necessary if the possibility of unwanted water entry into the mine workings is to be minimised. Without knowledge of the lateral discontinuities at the mine level and if any potential intersalt fracture zones are to be intersected during the construction of Shaft #4, reliable prediction of mine stability is problematic.

Cargill Mine operators are already aware of the need to stay away from possible salt anomaly areas, as evidenced by their informed decision to keep a safe working distance from Anomaly D in the Cargill subsurface operations.

What needs further consideration before the construction of Shaft #4 via upward reaming is the possibility of an aquifer connection between the lake waters and the intersected aquifer in Corehole #18. As mentioned earlier, and documented in the RESPEC 2013 report detailing conditions in Corehole #18, the main aquifer intersection occurred at 1,490 ft (bgs) in the Oriskany Sandstone, with the base of water reasonably be expected to be at, or above, the base of the Bertie Group.

In the RESPEC 2013 report, no information was given as to the nature of the porosity and permeability distribution in the aquifer (intergranular or fracture?). This is because at the level of the main aquifer intersection samples were being collected as drill cuttings, not whole core.

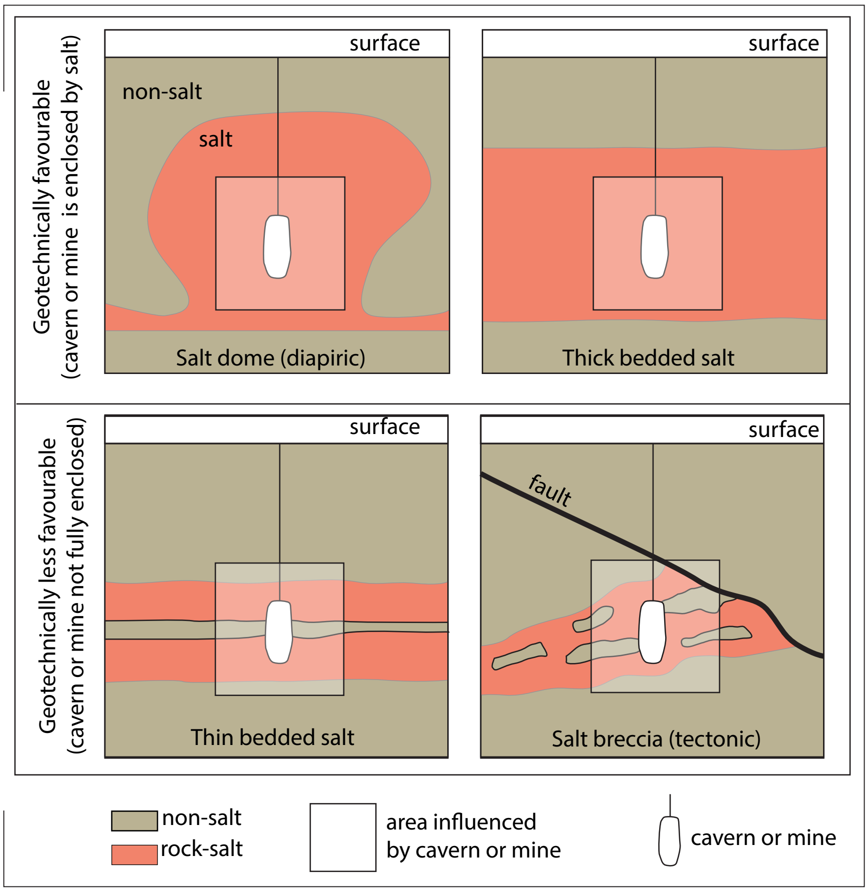


Figure 20. Schematic summarising geotechnically favourable and less favourable scenarios for mines and storage caverns in salt (after Gillhaus, 2010; Warren in press). The figure is not to scale. Ideally, a storage cavity or mine working should not intersect a salt anomaly and be located well away from the edge of a salt unit or any pen.etrative aquifer system in the target salt system.

If the undersaturated water in the main aquifer is held in a homogenous bedded host typified by intergranular porosity, then the pump test already done to quantify entry rates and discussed in the CoreHole 18 report can probably be extrapolated reasonably well from pump measurements in a narrow borehole diameter (inches across) to a 14-foot wide shaft. If the aquifer is fractured, then flow rates and aquifer interconnectedness have not been reliably quantified in the Corehole. Unexpected water volumes may be encountered during upward reaming of Shaft #4.

The Cayuga Lake margin aquifer setup has many similarities to the aquifer system in the region above the former Retsof mine (Figure 15). A complete study of the nature of the hydrology in the region between the base of the Shaft #4 pilot hole and the current sub-lake mine working is needed before permission to construct Shaft #4 is granted. Likewise, possible positions of undocumented brine wells should be documented.

In addition to these concerns with the current set of available information, there is also the unknown but possibly substantial effect of storing a significant volume of halite-undersaturated water in the current mine workings. In the author's opinion, without more study, it is unwise to store what may be a significant (as yet unquantified) volume of reactive and penetrative water in a slurry capable of salt dissolution in an already mined portion of the mine (see Patience Lake case history).

Conclusions with recommendations

Joffe effects, in my opinion, may not drive or even broadly indicate regions with potentially significant salt mine stability problems (see Addendum 1 for detail on Joffe effects as documented in the Cayuga Salt Mine). Joffe effects tend to operate at near-homogenous intracrystal scales, as atmospheric moisture enters and leaves with the seasonal changes in the mine atmosphere. They are part and parcel of any salt mine operation, as are slightly changing rates of roof closure and salt heave. Rapid changes in roof closure rates are often registered only after collapse has initiated or even occurred.

What drives significant instability at times of salt mine expansion is the unexpected intersection of zones holding substantial halite-undersaturated pore water volumes located in or immediately out-of-salt. Worse yet, is the connection scenario when the intersected zones possess high potential inflow rates and are connected to large reservoirs of halite-undersaturated pore waters . This is especially so when such unexpected pore waters are connected to the mine workings via open fracture porosity

Further rock typing and hydrological information needs to be collected and technical considerations made of this data before permission to the construct Shaft #4 is granted. To date, the New York State authorities have not required of the mine operator appropriate technical data suitable to make a "best-practice" judgement on whether to grant permission to move forward with Shaft #4.

Before a firm decision is made, the following set of documentation and studies should be required of the mine operators.

1) What is the geological situation ("stay in the salt") in the areas where an unknown and possibly significant volume of halite-undersaturated water is to be stored? This is not the typical situation in water sumps in salt mines excavating bedded salt, although it has been done in thicker salt bodies in mines in some diapiric structures in eastern Europe.

If the proposed water storage area is such that the water volume is fully encased, and it will not weaken the strength of intervening salt pillars, or while stored, drive dissolution and connection with unexpected aquifers in adjacent "out-of -salt" positions, then such below-ground storage of pilot hole and shaft reaming inflows should be feasible.

2. What is the nature of the permeability and porosity in the aquifer level to be encountered at the Bertie -Oriskany levels during upward reaming. This interval was sampled via cuttings, not core, when Corehole #18 was drilled. At this stage, it is not known if the encountered aquifer poroperm is held in a homogeneous medium or held in a highly inhomogenous host, as is typical of a fractured aquifer reservoir. If it is held in a homogenous bedded host, then the pump test already done to quantify entry rates and discussed in the CoreHole 18 report can be extrapolated reasonably well from the narrow borehole diameter to a 14-foot wide shaft. If the aquifer is fractured, then flow rates and aquifer interconnectedness have not been reliably quantified by pump tests in a narrow borehole. Unexpected water volumes may be encountered during upward reaming of Shaft #4.

3. What do the salt textures captured in the core from Corehole #18 indicate in termsof possible acquifer proximity? The current description of salt textures in the RESPEC report does not define the nature of the various processes likely influencing the formation of various salt textures. Current salt sedimentology allows one to differentiate between tectonic, diagenetic and salt dissolution textures and breccias. Work on the publically-available core from the Himrod Mine shows all these textures are present in the salt layers in the Syracuse Fm; they are distinct and capable of being classified (e.g. Figures 18, 19 in Warren 2015).

Such a sedimentological study of the salt core in Corehole #18 would better refine the hydrological situation in the vicinity of Corehole #18 and if there is a possible hydrological connection already in existence between the top of salt and the overlying potential aquifers located in and above the Bertie Formation.

The further integration of the salt texture information derived from the core with the mineralogical information already measured in the wireline data run in Corehole #18 would help to refine such a hydrological model, which could then be tied back to the current understanding of the mine geology and improve the utility of predictive ore quality models.

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Addendum: How important is is short term humidity variation in terms of mine stability?

This section was added to the report on Shaft #4 as state authorities made an additional data request to the mine operator as to the possible influence of increased humidity on the measured Jolle effect and any observed increased closure rates tied to regions of current waste water ponding. In my opinion, observations of the Jolle effet are not relevant to predicting regions of the mine edges where possible unexpected aquifer influxes may occur.

The effect of humidity changes on rates of roof subsidence in the Cayuga Mine is normal and was documented and succinctly explained by van Sambeek (2012). Figure 21 summarises some of his relevant long-term closure measurements in the Cayuga Mine over a 23-year period in selected yield-pillar panels. During the period 1994 to 2003, monthly closure measurements plotted according to date of the year (Figure 21a). Obvious seasonality exists in the closure rate and, because of its long distance from the air intake shaft, this panel is buffered from temperature changes, so the seasonality is most likely caused by humidity changes (van Sambeek, 2012).

Another yield-pillar panel had room closure measurements made over five years (2006-2012), in conjunction with simultaneous temperature and humidity measurements (Figure 21b). The figure illustrates two types of normal salt relaxation and closure behaviour. When measurements started in 2006, the panel had been mined five years earlier, and it was inactive but still ventilated. As shown, the temperature was nearly constant, and the humidity varied with the seasons. The measured room-closure rate tracked the relative humidity.

Then beginning in March 2007, backfilling of the panel began using the waste product from the underground mill (a mixture of rock particles and salt fines). The waste comes into the panel on a conveyor, is moistened to lessen dust and improve compaction, and then spread around using heavy diesel equipment. A combination of the seasonal humidity in the ventilation air, the water added, and water vapour in the diesel equipment

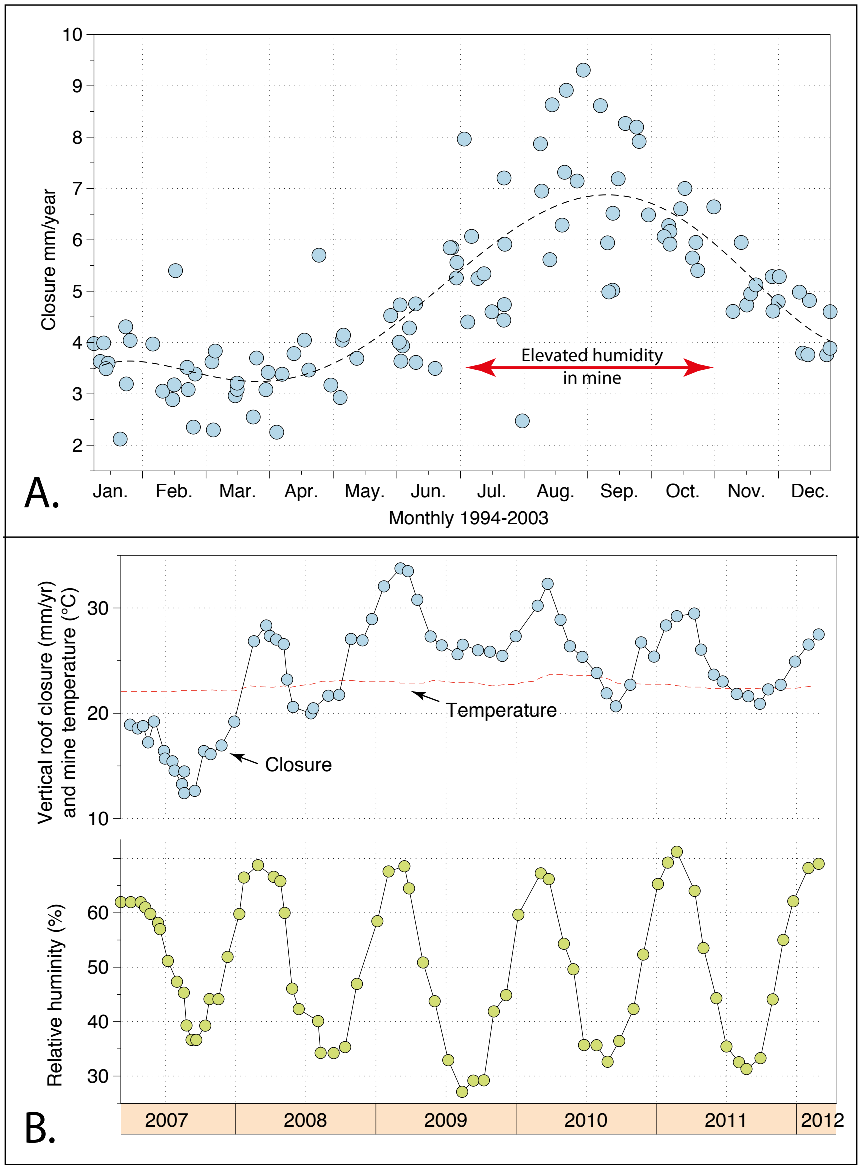

Figure 21. Closure rates in Cayuga Mine (replotted from Van Sambeek, 2012). A) Closure rates (mm/year) complied from monthly measurements across 1994-2003. B) Room closure rate (mm/yr), ambient temperature (°C) and relative humidity (%) at a long term closure station.

exhaust pushed the humidity level in the panel above the previous maximum level of 60 percent. The relative humidity approached (but of course could not exceed) the nominal 75 percent critical humidity threshold for deliquescence of water vapour on salt. The annualised room-closure rate simultaneously increased with the greater humidity level. Moreover, since Figure 21b shows the temperature was nearly constant throughout this period (and there was no nearby mining), the closure rale changes are attributed to humidity changes.

Five complete annual cycles are shown in Figure 21b. The first cycle (mid-2006 to March 2007) occurred while the panel was inactive and quiet (before backfilling operations started). The later annual cycles (after March 2007) are measured during backfilling activities, so the room-closure rates are greater than their earlier values. The correlation trend is that closure during the humid months will be nominally 75 percent faster than during the drier months.

Van Sambeek (2012) concludes that humidity-enhanced salt creep (rightly or wrongly called the Joffe effect) has historically been considered a phenomenon mostly observed in laboratory tests on small test specimens that were probably in a state of dilation. The laboratory tests showing the most pronounced Joffe effect were unconfined and exposed to the atmospheric humidity changes, particularly greater humidity, although the phenomenon was reversible. In contrast, van Sambeek (2012) documented several examples of long-term in-mine deformation measurements showing an in situ change in rock-salt creep rates occurs as the seasonal humidity changes, thus proving the Joffe effect occurs even on a large scale. Additional extensometer measurements in both salt pillars and salt around a shaft show that the Joffe effect influences salt even at depths of several meters.

Exhibit C

Tompkins County Industrial Development Agency / Tompkins County Development Corporation

Application for Incentives

Date: August 30, 2016

I. APPLICANT INFORMATION (company receiving benefit)

Name of Company/Applicant: Cayuga Mine

Owner: Cargill Incorporated

Address: 191 Portland Point Road

City: Lansing State: NY Zip: 14882

Primary Contact (First, Last): Shawn Wilczynski

Phone: (607)533-3700 Email: shawn_wilczynski@cargill.com Fax: (607)533-4501

If a separate company will hold title to/own the property, please provide the name and contact information for that entity:

Name of (Holding) Company: ____________________

Owner: ____________________

Address: ____________________

City: ________ State: ________ Zip: ________

Primary Contact (First, Last): ____________________

Phone: ( ) - Email: ____________ Fax: ( ) -

Describe the terms and conditions of the lease between the applicant and the owner of the property:

Select the type of incentives being requested (select all that apply):

- ☐ Tax-Exempt Bonds
- ☐ Taxable Bonds
- ☐ Real Property Tax Exemption
  - ☐ Standard Tax Exemption (7-year)
  - ☐ Other (attach justification)
  - ☐ CIITAP: ☐ 7-year
  - ☐ CIITAP: ☐10-year (requires determination of financial need – see CIITAP for details)
- ☒ Sales Tax Exemption
- ☐ Mortgage Recording Tax Exemption

Applicant Attorney: Gilberti Stinziano Heintz & Smith, P.C.

Address: 555 East Genesee Street

City: Syracuse State: NY Zip: 13202

Primary Contact (if different from above:): John F. Klucsik, Esq.

Phone: ( ) - Email: jklucsik@gilbertilaw.com Fax: ( ) -

Applicant Accountant: Vanessa Fey

Address: 191 Portland Point Road

City: Lansing State: NY Zip: 14882

Primary Contact (if different from above:):

Phone: (607)533-3787 Email: vanessa_fey@cargill.com Fax: ( ) -

Applicant Engineer/Architect (if known): Barton & Loguidice, D.P.C.

Address: 443 Electronics Pkwy

City: Liverpool State: NY Zip: 13088

Primary Contact (if different from above:): Matthew C. Fuller, P.E.

Phone: (315)457-5200 Email: Mfuller@bartonandloguidice.com Fax: ( ) -

Applicant Contractor (if known):

Address:

City: State: Zip:

Primary Contact (if different from above:):

Phone: ( ) - Email: Fax: ( ) -

II. BUSINESS HISTORY

Year company was founded: 1865 NAICS Code: 212399

Type of ownership (i.e. C-Corp, LLC): C-Corp

Describe in detail company background, products, customers, goods and services: Cargill is a privately held corporation based in Minnesota. Cargill provides food, agriculture, and industrial products and services worldwide. The company is over 150 years old and has 149,000 employees in 70 countries.

The Cayuga Mine has been in operation since 1918. It currently mines approximately 2 million tons of salt per year. The mine is under Cayuga Lake, in lands leased from New York State on a royalty basis. Deicing road salt is the primary product of the mine, with a small portion of the salt being used in industrial, chemical, and animal feed applications.

Major Customers: NY State DOT, local towns and municipalities, PA DOT, and landscapers & commercial snow removal contractors.

Major Suppliers: Longhorn Trucking, Riccelli Enterprises, Independent Explosives, Coldiron Fuel, Cayuga Crushed Stone, Blair Construction, G&L Trucking, and Motion Industries

Has your business every received incentives tied to job creation? ☐ Yes ☒ No

If yes, please describe: ____________________

Were the goals met? ☐ Yes ☐ No

If no, why were the goals not met? NA

Annual sales to customers in Tompkins County: $1600000.00

Percent of annual sales subject to local sales tax: 9%

Value of annual supplies, raw materials and vendor services are that purchased from firms in Tompkins County: $2,785,000.00

III. PROJECT DESCRIPTION AND DETAILS

Project Location (all addresses and tax parcels): 1001 Ridge Road, Lansing, NY 14882. Map 23 / Parcel 6.2

Property Size (acres): existing: 57.47 proposed: 57.47

Building Size (square feet): existing: 0 proposed: 14,135

Proposed Dates: start: January 2017 end: January 2020

Please provide a narrative of the Project and the purpose of the Project (new build, renovations, and/or equipment purchases, etc.). Identify specific uses occurring within the Project. Describe any and all tenants and end users: The Cayuga Mine in Lansing, NY produces approximately 2 millon tons of rock salt per year. The salt is primarily used as a bulk road deicer by highway departments, but is also sold under the Diamond Crystal and Agway brands as packaged deicing salt, used in animal feeds, and in chemical processes. The mine is 2,300' below Cayuga Lake, and has been in continuous operation since 1918. Currently, the Cayuga Mine employees over 200 full time employees in operations, maintenance, engineering, finance, management, and support positions.

Due to the age of the mine, the underground mine workings are currently over 7 miles from the elevator shafts. Because of the distance, providing fresh ventilation air and safe access to surface in the event of an emergency is becoming increasingly more difficult. A new ventilation and access shaft is required to safely and productively mine the northern reserves.

The #4 Shaft project will be constructed on a 55 acre plot of land owned by Cargill, approximately 5 miles north of the current Cayuga Mine Site. The key objective of the project will be to provide an escapeway 30 minutes closer for the underground miners and the infrastructure and fresh air for an additional 30 years of mining at the Cayuga Mine.

The #4 Shaft Project will include a 14' diameter mine shaft that is 2,500' deep with a heavy duty mine elevator. This shaft will allow miners to evacuate 30 minutes faster in an emergency and will provide fresh ventilation air to ensure a safe and healthy work environment. The project will also include change room facilities for the miners, an electrical upgrade for the mine, and a small maintenance shop for equipment.

Is there a likelihood that the Project would not be undertaken but for the financial assistance provided by the Agency? ☒ Yes ☐ No

If yes, describe the reasons why the Agency's financial assistance is necessary and the effect the Project will have on the Applicant's business or operations. Focus on competitiveness issues, project shortfalls, etc.: The new shaft project is required to ensure long term operations at the Cayuga Mine. There is not a planned increase in production at the Mine due to this project. The project is currently under funded at the corporate level, and the additional costs of this project directly impact the economics of this operation. Strong support from local and state government will aid in ensuring the shaft project is completed in a safe and efficient manner, in order to ensure long term operations at the Cayuga Mine.

If no, provide a narrative indicating why the Project should be undertaken by the Agency: .

If the Applicant is unable to obtain financial assistance for the Project what will be the impact on the County/City/Town/Village? The main goal of this project is to ensure long term operations at the Cayuga Mine. If this project is not completed, the life of the Cayuga Mine will be significantly reduced. Long term operations at the Cayuga Mine has a large positive impact on the local community. Per an independent economic study conducted in 2014 using the IMPLAN method, the Cayuga Mine supports an additional 159 regional jobs and has an annual economic impact of:

Town of Lansing: $4.6 Million

Tompkins County: $173 Million

New York State: $221 Million

Describe what green building practices you plan to use: With the new shaft, the ventilation system of the mine will be more efficient. A 2.7MM Kilowatt hour reduction in power usage per year for ventilation is expected with the #4 Shaft Project.

Additionaly, the project has been designed to meet or exceed all relevant building and environmental codes.

Will this project result in a regular increase in overnight visitors to your facility (e.g. for training programs)? ☐ Yes ☒ No

If yes, number of visitors per year: ________

Average duration of stays (days): ________

Occupancy

Select Project type for all end users at Project site (select all that apply):

☒ *Industrial*	☐ *Service*, ***
☐ *Acquisition of existing facility*	☒ *Back office*
☐ *Housing*	☐ *Mixed use*
☐ *Multi-tenant*	☐ *Facility for aging*
☐ *Commercial*	☐ *Civic facility (not for profit)*
☐ *Retail*, ***	☐ *Other*

** For Purposes of this question, the term "retail sales" means (1) sales by a registered vendor under Article 28 of the Tax Law of New York (the "Tax Law") primarily engaged in the retail sale of tangible personal property (as defined in Section 1101(b)(4)(i) of the Tax Law, or (2) sales of a service to customers who personally visit the project location.*

*** If Applicant checked "retail" or "service," complete the Retail Questionnaire contained in Section **X**.*

List the name(s), nature of business of proposed tenant(s), and percentage of total square footage to be used for each tenant (additional sheets may be attached, if necessary):

	Business	***Nature of Business***	***% of total square footage***
1.	Cayuga Mine	Salt Mining	100
2.			
3.			

IV. PROJECT COSTS AND FINANCING

Project Costs

			Amount ($)
Land and/or Building Acquisition:	0 acres	________ square feet	$0
New Building Construction:	14,135 square feet		$8,500,000

Building Addition(s):	0	square feet	$0
Infrastructure Work:			$3,000,000
Reconstruction/Renovation:	0	square feet	$0
Manufacturing Equipment:			$0
Non-Manufacturing Equipment (furniture, fixtures, etc.):			$16,000,000
Soft Costs (professional services, etc.):			$2,500,000
Other (Specify):	Mine Shaft		$15,000,000
		TOTAL:	$45,000,000

Have any of the above costs been paid or incurred as of the date of this application? ☒ Yes ☐ No

If yes, describe particulars: To date $2,500,000 has been spent on feasability, front end engineering, a test hole, and permitting.

Sources of Funds for Project Costs

Bank Financing	$0
Equity	$37,000,000
Tax Exempt Bond Issuance (if applicable)	$0
Taxable Bond Issuance (if applicable)	$0
Public Sources (Include sum total of all state and federal grants and tax credits)	$8,000,000

Identify each State and federal grant/credit:

Empire State Development Grant (Applied for, but not awarded yet)	$8,000,000
______	$
______	$

Total sources of funds for Project costs:	$45,000,000
Project refinancing of existing debt only (estimated):	$0
Amount of anticipated financing from a lending institution:	$ 0

Note: The applicant must inform the TCIDA/TCDC at the time of issuance of commitment letter if the financing will exceed the amount stated here.

V. VALUE OF INCENTIVES

Property Tax Exemption: *(Agency staff will fill out property tax exemption information based on information submitted by the applicant).*

Assumptions: $_____ Value of increase in assessment

4% Annual increase in assessment and tax rate

	New taxes paid:	$ ________				**Taxes Abated:**	$ ________			
Year	**County**	**School**	**City/Town**	**Village**	**Total**	**County**	**School**	**City/Town**	**Village**	**Total**
1										
2										
3										
4										
5										
6										
7										
Totals										

If the applicant is requesting incentives that are greater than the Agency's Standard Tax Exemption (7 years), please provide a description of the incentive and a justification:

Sales and Use Tax Benefit:

Gross amount of costs for goods and services that are subject to State and local sales and use tax – said amount to benefit from the Agency's sales and use tax exemption benefit: $ 8,000,000

Estimated State and local sales and use tax benefit (product of sales and use tax amount as indicated above multiplied by 8%) $ 640,000

Note: The estimate provided above will be provided to the New York State Department of Taxation and Finance and represents the maximum amount of sales and use tax benefit that the Agency may authorize with respect to the application.

Mortgage Recording Tax Benefit:

Mortgage Amount (include construction/permanent/bridge financing/refinancing): $ 0

Estimated mortgage recording tax exemption benefit (product of mortgage amount as indicated above multiplied by .0025%): $ 0

Complete for bond applicants only: *(Projected 25 year borrowing term)*

	Without Bonds	**With Bonds**
First Year Debt Service	$_____	$_____
Total Debt Service	$_____	$_____

Percentage of Project costs financed from public sector:

A.	Total Project Cost	$45,000,000
B.	Estimated Value of PILOT	$0
C.	Estimated Value of Sales Tax Incentive	$640,000
D.	Estimated Value of Mortgage Tax Incentive	$0
E.	Total Other Public Incentives (tax credits, grants, ESD incentives, etc.)	$8,000,000

Calculation of percentage of Project costs financed from public sector: 19%
(Total B + C + D + E above / Total Project Cost)

VI. EMPLOYMENT INFORMATION

Note: Annual employment reporting will be required during the course of the abatement.

Describe the benefits you offer to your employees: The Cayuga Mine offers health, vision, and dental care plans, 401K retirement plans, paid holidays, paid life insurance, 24 hour per year of paid volunteer leave, short & long term disabilty insurance, annual holiday events for employees and families, summer family events, and paid vacation time for all employees.

Describe the internal training and advancement opportunities you offer to your employees: Cargill utilizes NourishingU, an on-line training system that is availabe to all employees. NourishingU allows employees to customize a development plan. The Cayuga Mine has also offered maintenace, troubleshooting, diesel repair, welding, and power & controls training. Cargill has partnered with BOCES in the past to develop training programs.

All employees receive 40 hours of initial safety training and 8 hours annualy of refresher safety training. Cargill also utilizes and trains all employees on the BST behavioral based safety system.

Cargill has a tuition reimbursement program available to all employees. All open jobs are posted internally in order to encourge internal advacement. The mine also offers paid summer internships and co-op work opportunities for college students.

Employment Plan

Occupation in Company	Current (Retained) Permanent Full Time Jobs		Projected New Permanent Full-Time Jobs			
	Average Annual Salary Ranges/ Hourly Wage	Number of Employees	Year 1	Year 2	Year 3	Total New Jobs
Professional	55,000-149,000	50				
Clerical	14.53-25.67	8				
Sales						
Services						
Construction						
Manufacturing						
High Skilled	19.21-29.63	46				
Medium Skilled	18.76-26.50	43			4	4
Basic Skilled	18.57-26.64	36				
Other (describe)						
Total		183			4	4

What percentage of your current positions are occupied by women? 6 %

What percentage of your current positions are occupied by minorities? 10 %

Estimated percentage of new hires who would be unemployed at time of hire: 30%

Estimate the number of residents of the labor market area in which the Project is located that will fill the projected new jobs to be created. *(The Agency defines the labor market area as Tompkins County and the contiguous counties; Cayuga, Seneca, Schuyler, Chemung, Tioga, and Cortland Counties)* 4

Are you willing to pay a livable wage, as defined by the Alternatives Federal Credit union (AFCU) of Ithaca, NY (http://www.alternatives.org/pdf/AFCU-2015-1055_FINAL2.pdf) to all employees for the duration of the abatements? ☒ Yes ☐ No

If no, estimate the percentage of the current workforce whose wages meet or exceed the livable wage, as defined by AFCU. 100%

Please describe your strategy for ensuring diversity in hiring: Cargill has a proactive approach to diversity recruitment. We have resources that are trained in sourcing methods to attract diverse talent, have the opportunity to post to diversity recruiting websites and also work with a group of national minority organizations for both branding and recruitment events. Additionally, we have active networks to focus on engagement after hire.

Cargill Deicing Technology in Lansing, NY actively sponsors action oriented programs, at both corporate and local levels, designed to create positive work environment for all employees. Leaders and employees across Cargill demonstrate their commitment to Cargill's Vision, Equal Employment Opportunity and Affirmative Action by championing and participating in a variety of employee focused and community outreach initiatives. We will continue to recruit at college and adult education campus' to increase female and minority applicants in the technical areas, as well as continue to enhance public awareness in our community of our commitment to Equal Employment Opportunity and Affirmative Action.

VII. CONSTRUCTION LABOR

Note: Applicants will be required to comply with the Agency's Local Labor Utilization Policy.

Will you use contractors who:

Have a certified apprenticeship program	☐ Yes	______ %	☒ No
Pay a prevailing wage	☐ Yes	Unknown %	☐ No
Use local labor	☐ Yes	Unknown %	☐ No

VIII. ENVIRONMENTAL REVIEW AND PERMITTING

Environmental Assessment Form – ☐ *Short Form* ☒ *Long Form*

Submitted to: ______

Agency Name: NY Department of Environmental Conservation

Agency Address: 1285 Fisher Ave

City: Cortland State: NY Zip: 13045

Date of submission: 10/21/2015 Status of submission: In Public Comment period.

The Applicant must comply with the State Environmental Quality Review Act (SEQRA) before the Agency can vote on proposed financial incentives. It is the applicant's responsibility to provide a copy of the-SEQRA determination by another entity.

Permits: Describe other permits required and status of approval process.

	Permit	*Status*
1.	NYS DOT Curb Cut Permit	Not applied for
2.	Town Special Use Permit	Not applied for
3.	County Health Waste Water Permit	Not applied for
4.		

IX. OTHER

Do you have anything else you would like to tell the TCIDA regarding this project?
Contractors: Final Contractors have not been choosen, but will use local labor for non-mining portions of the construction.

Permitting: The mining permit amendment to add the shaft and surface structures to current mining permit was applied for 10/21/2015. The application was ruled complete on 8/29/2016 and is currently in the Public Comment Period. Approvals are in progress and the permit is expected to be issued in late Nov. 2016. The project received a Negative Decleration of Environmental Impact.

The Cayuga Mine is committed to the Lansing area community. Last year 125 employees donated over 3,600 hours in the community. The mine also supports 18 volunteer EMS/Fire Fighters in 13 communities around the area.

The Shaft Project is critical to ensuring long term operation at the Cayuga Mine. The Cayuga Mine is an employer of choice in the area and has multiple 2nd and 3rd generation miner families working at the mine.

X. RETAIL QUESTIONNAIRE (Fill out if end users are "retail" or "service" as identified in Section III)

To ensure compliance with Section 862 of the New York General Municipal Law, the Agency requires additional information if the proposed Project is one where customers personally visit the project site to undertake either a retail sale transaction or to purchase services.

A. Will any portion of the Project (including that portion of the cost to be financed from equity or other sources) consist of facilities or property that are or will be primarily used in making sales of goods or services to customers who personally visit the project site? ☐ Yes ☒ No

If yes, please continue. If no, do not complete the remainder of the retail questionnaire and proceed to the next section of the application.

For Purposes of this question, the term "retail sales" means (1) sales by a registered vendor under Article 28 of the Tax Law of New York (the "Tax Law") primarily engaged in the retail sale of tangible personal property (as defined in Section 1101(b)(4)(i) of the Tax Law, or (2) sales of a service to customers who personally visit the project location.

B. What percentage of the cost of the Project will be expended on such facilities or property primarily used in making sales of goods or services to customers who personally visit the Project? _____ %

If the answer is less than 33.33% do not complete the remainder of the retail determination and proceed to the next section of the application.

If the answer to Question A is Yes AND the answer to Question B is greater than 33.33%, indicate which of the following questions below apply to the Project:

1. Will the Project be operated by a not-for-profit corporation? ☐ Yes ☐ No

2. Is the Project location or facility likely to attract a significant number of visitors from outside Tompkins County? ☐ Yes ☐ No

If yes, please provide a third party market analysis or other documentation supporting your response.

3. Will the Project make available goods or services which are not currently reasonably accessible to the residents of the municipality within which the proposed Project would be located? ☐ Yes ☐ No

   If yes, please provide a third party market analysis or other documentation supporting your response.

4. Will the Project preserve permanent, private sector jobs or increase the overall number of permanent, private sector jobs in the State of New York? ☐ Yes ☐ No

   If yes, explain: ______

XI. INTER-MUNICIPAL MOVE DETERMINATION

The Agency is required by State law to make a determination that, if completion of a Project benefiting from the Agency financial assistance results in the removal of an industrial or manufacturing plant of the Project occupant from one area of the State to another area of the State or in the abandonment of one or more plants or facilities of the project occupant located within the State, Agency financial assistance is required to prevent the Project occupant from relocating out of the State, or is reasonably necessary to preserve the Project occupant's competitive position in its respective industry.

Will the Project result in the removal of an industrial or manufacturing plant of the Project occupant from one area of the state to another area of the State? ☐ Yes ☒ No

Will the Project result in the abandonment of one or more plants or facilities of the Project occupant located within the State? ☐ Yes ☒ No

If yes to either question explain how notwithstanding the aforementioned closing or activity reduction the Agency's financial assistance is required to prevent the Project from relocating out of the State or is reasonably necessary to preserve the Project occupant's competitive position in its respective industry:

Does the Project involve relocation or consolidation of a Project occupant from another municipality:

Within New York State: ☐Yes ☒No

Within County/City/Town/Village: ☐Yes ☒No

If yes to either question above, please explain: ______

REPRESENTATIONS, CERTIFICATIONS AND INDEMNIFICATION

Russ Givens(name of CEO or other authorized representative of Applicant) confirms and says that he/she is the AVP (title) of Cargill Incorporated (name of corporation or other entity) named in the attached Application (the "Applicant"), that he/she has read the foregoing Application and knows the contents thereof, and hereby represents, understands, and otherwise agrees with the Agency and as follows:

A. Job Listings. In accordance with Section 858-b(2) of the New York General Municipal Law, the applicant understands and agrees that, if the proposed Project receives any Financial Assistance from the Agency, except as otherwise provided by collective bargaining agreements, new employment opportunities created as a result of the proposed Project must be listed with the New York State Department of Labor Community Services Division (the "DOL") and with the administrative entity (collectively with the DOL, the "JTPA Entitle") of the service delivery area created by the Federal Job Training Partnership Act (Public Law 97-300) ("JTPA") in which the proposed Project is located.

B. First Consideration for Employment. In accordance with Section 858-b(2) of the General Municipal Law, the applicant understands and agrees that, if the proposed Project receives any Financial Assistance from the Agency, except as otherwise provided by collective bargaining agreements, where practicable, the applicant must first consider persons eligible to participate in JTPA programs who shall be referred by the JTPA Entities for new employment opportunities created as a result of the proposed Project.

C. Employment Reports. The Applicant understands and agrees that, if the proposed Project receives any Financial Assistance from the Agency, the Applicant agrees to file, or cause to be filed, with the Agency, at least annually or as otherwise required by the Agency, reports regarding the number of people employed at the project site, salary levels, contractor utilization, local construction labor utilization and such other information (collectively, "Employment Reports") that may be required from time to time on such appropriate forms as designated by the Agency. Failure to provide Employment Reports within 30 days of an Agency request shall be an Event of Default under the PILOT Agreement between the Agency and Applicant and, if applicable, an Event of Default under the Project Agreement between the Agency and Applicant.

D. Labor Utilization Reporting. The Applicant understands and agrees that, if the proposed Project receives any Financial Assistance from the Agency, the Applicant agrees to comply with the Labor Utilization Policy, which requires providing documentation that construction bids were solicited from local firms and monthly construction labor reporting as outlined in the Policy.

E. Hold Harmless Provision. The Applicant acknowledges and agrees that the Applicant shall be and is responsible for all costs of the Agency incurred in connection with any actions required to be taken by the Agency in furtherance of the Application including the Agency's costs of general counsel and/or the Agency's bond/transaction counsel whether or not the Application, the proposed Project it describes, the attendant negotiations, or the issue of bonds or other transaction or agreement are ultimately ever carried to successful conclusion and agrees that the Agency shall not be liable for and agrees to indemnify, defend, and hold the Agency harmless from and against any and all liability arising from or expense incurred by: (i) the Agency's examination and processing of, and action pursuant to or upon, the attached Application, regardless of whether or not the Application or the Project described therein or the tax exemptions and other assistance requested therein are favorably acted upon by the Agency, (ii) the Agency's acquisition, construction and/or installation of the Project described therein and (iii) any further action taken by the Agency with respect to the Project; including without limiting the generality of the foregoing, all causes of action and attorneys' fees and any other expenses incurred in defending any suits or actions which may arise as a result of any of the foregoing.

F. Sales Tax. In accordance with Section 874(8) of the General Municipal Law, the Applicant understands and agrees that, if the proposed Project receives any sales tax exemptions as part of the Financial Assistance from the Agency, in accordance with Section 874(8) of the General Municipal Law, the applicant agrees to file, or cause to be filed, with the New York State Department of Taxation and Finance, the annual form prescribed by the Department of Taxation and Finance, describing the value of all sales tax exemptions claimed by the applicant and all consultants or subcontractors retained by the applicant. Copies of all filings shall be provided to the Agency.

Applicant hereby understands and agrees, in accordance with Section 875(3) of the New York General Municipal Law and the policies of the Agency that any New York State and local sales and use tax exemption claimed by the Applicant and approved by the Agency in connection with the Project, may be subject to recapture and/or termination by the Agency under such terms and conditions as will be established by the Agency and set forth in transaction documents to be entered into by and between the Agency and the Applicant.

G. Fees. By executing and submitting this Application, the applicant covenants and agrees to pay the following fees:

(i) An Administrative Fee in accordance with the Administrative Fee Policy effective as of the date of this application, to be paid at transaction closing (unless otherwise outlined in the Project Agreement or authorizing resolution). This fee will be equal to 1% of the total value of expenses that are positively impacted by the Agency incentives. The Agency may reduce the administrative fees from 1% to .50% of project costs if the total project cost is less than $1 million. For total project costs greater than $1 million but less than $2 million, the fees may be reduced from 1% to .75% of project costs;

(ii) All fees, costs and expenses incurred by the Agency for (1) legal services, including but not limited to those provided by the Agency's general counsel or bond/transaction counsel, and (2) other consultants retained by the Agency in connection with the proposed Project; with all such charges to be paid by the Applicant at the closing or, if the closing does not occur, within ten (10) business days of receipt of the Agency's invoices therefore please note that the Applicant is entitled to receive a written estimate of fees and costs of the Agency's bond/transaction counsel;

(iii) The cost incurred by the Agency and paid by the Applicant, including bond/transaction counsel and the Agency's general counsel's fees and the processing fees, may be considered as a cost of the Project and included in the financing of costs of the proposed Project, except as limited by the applicable provisions of the Internal Revenue Code with respect to tax-exempt bond financing.

If the Applicant fails to conclude or consummate necessary negotiations, or fails, within a reasonable or specified period of time, to take reasonable, proper or requested action, or withdraws, abandons, cancels or neglects the Application, or if the Applicant is unable to find buyers willing to purchase the bond issue requested, or if the Applicant is unable to facilitate the sale/leaseback or lease/leaseback transaction, then, upon presentation of an invoice, the Applicant shall pay to the Agency, its agents or assigns, all costs incurred by the Agency in the processing of the Application, including attorneys' fees, if any.

H. FOIL. The Applicant acknowledges that the Agency is subject to New York State's Freedom of Information Law (FOIL). Applicant understands that all Project information and records related to this application are potentially subject to disclosure under FOIL subject to limited statutory exclusions.

I. Financial Review. The Applicant acknowledges that the Agency shall undertake an assessment of all material information included in connection with the Application for Financial Assistance as necessary to afford a reasonable basis for the decision by the Agency to provide Financial Assistance for the Project, including, but not limited to qualification of the proposed project under the GML (including any retail analysis, as applicable), conducting a full application review, review of applicant financial history and project pro-formas, and consideration of all local development priorities.

J. The Applicant represents and warrants that the information contained in this Application, to the best of the Applicant's knowledge, is true, accurate and complete.

K. The Applicant confirms and acknowledges that the owner, occupant, or operator receiving Financial Assistance for the proposed Project is in substantial compliance with applicable local, State and federal tax, worker protection and environmental laws, rules and regulations.

L. The Applicant confirms and hereby acknowledges that as of the date of this Application, the Applicant is in substantial compliance with all provisions of Article 18-A of the New York General Municipal Law, including, but not limited to, the provisions of Section 859-a(5) and Section 862(1) of the New York General Municipal Law.

M. The Applicant confirms and acknowledges that the submission of any knowingly false of knowingly misleading information may lead to the immediate termination of any Financial Assistance and the reimbursement of an amount equal to all or part of any tax exemption claimed by reason of the Agency's involvement in the Project.

N. The Applicant and the individual executing this application on behalf of Applicant acknowledge that the Agency and its counsel will rely on the representations and covenants made in this application when acting hereon and hereby represents that the statements made herein do not contain any untrue statement of a material fact and do not omit to state a material fact necessary to make the statements contained herein not misleading.

Name: Russ Givens [signature]

Title: AVP Operations

Company: Cargill Incorporated

Date: 8/31/2016

STATE OF NEW YORK)
) SS.:
COUNTY OF TOMPKINS)

On the 31 day of August in the year 2016 before me, the undersigned, personally appeared Russ Givens, personally known to me or proved to me on the basis of satisfactory evidence to be the individual(s) whose name(s) is (are) subscribed to the within instrument and acknowledged to me that he/she/they executed the same in his/her/their capacity(ies), and that by his/her/their signatures on the instrument, the individual(s), or the person upon behalf of which the individual(s) acted, executed the instrument.

[signature: Gail Hubbell]
Notary Public

GAIL HUBBELL
Notary Public, State of Ohio
My Commission Expires April 26, 2020
Recorded in Lorain County

NEW YORK STATE FINANCIAL REPORTING REQUIREMENTS FOR INDUSTRIAL DEVELOPMENT AGENCIES

Please be advised that the New York General Municipal Law imposes certain reporting requirements on IDAs and recipients of IDA financial assistance. Of particular importance to IDA applicants is Section 859 (copy attached). This section requires IDAs to transmit financial statements within 90 days following the end of an Agency's fiscal year ending December 31, prepared by an independent, certified public accountant, to the New York State Comptroller, the Commissioner of the New York State Department of Economic Development. These audited financial statements shall include supplemental schedules listing the following information:

1. All straight-lease ("sale-leaseback") transactions and whether or not they are obligations of the Agency.
2. All bonds and notes issued, outstanding or retired during the period and whether or not they are obligations of the Agency.
3. All new bond issues shall be listed and for each new bond issue, the following information is required:
   a. Name of the project financed with the bond proceeds.
   b. Whether the project occupant is a not-for-profit corporation.
   c. Name and address of each owner of the project.
   d. The estimated amount of tax exemptions authorized for each project.
   e. Purpose for which the bond was issued.
   f. Bond interest rate at issuance and, if variable, the range of interest rates applicable.
   g. Bond maturity date.
   h. Federal tax status of the bond issue.
   i. Estimate of the number of jobs created and retained for the project.
4. All new straight lease transactions shall be listed and for each new straight lease transaction, the following information is required:
   a. Name of the project.
   b. Whether the project occupant is a not-for-profit corporation.
   c. Name and address of each owner of the project.
   d. The estimated amount of tax exemptions authorized for each project.
   e. Purpose for which each transaction was made.
   f. Method of financial assistance utilized for each project, other than the tax exemptions claimed by the project.
   g. Estimate of the number of jobs created and retained for the project.

Please sign below to indicate that you have read and understood the above.

Name: [signature]

Title: AVP Operations, Cargill Deicing Technology

Company: Cargill Incorporated

Date: 8/30/2016