January 15, 2025

Jonathan Stercho
Deputy Regional Permit Administrator
Division of Environmental Permits, Region 7
New York State Department of Environmental Conservation
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**RE: Technical comments prepared by Andrew Michalski, Ph.D., CGWP, PG on Cayuga Salt Mine, Mined Land Reclamation Permit Modification**

Dear Mr. Stercho:

I have been asked by Cayuga Lake Environmental Action Now (CLEAN) to review Cargill's Mined Land Reclamation Permit Modification application and perform an independent technical analysis of the application.

While I am now retired, I am a hydrogeologist with 50+ years of consulting, academic and research experience in hydrogeology and geological engineering. My salt mining related experience includes evaluations of surface subsidence at Wieliczka salt mine in Poland. In the mid-1980s, I was part of a team that assessed the Richton Salt Dome in Mississippi as a candidate site for the disposal of nuclear waste. I supervised underground salt testing and coring at Avery Island Mine. In 1995, I testified at the hearing on the Retsof Mine collapse held in Albany, NY, regarding hydrogeological aspects of the collapse and flooding of the Retsof Salt Mine in 1994. I have been a consultant to CLEAN on hydrogeological aspects of the Cayuga Salt Mine since 2016. I previously commented on other aspects of Cargill's operations at the mine. A copy of my CV is attached.

I have reviewed the application and other submissions as part of my analysis, including Cargill's annual reports, Boyd's submissions to DEC and a report by Agapito Associates, Inc. (2022). Based upon my review of the application, I have reached the following conclusions:

1. The Agapito modeling study is based on unrealistic assumptions that invalidate its conclusions. Specifically, the model does not reflect the role of in-situ horizontal stress and assumes up-front insignificant effects of pillars dissolution. In addition, the modeling of flooding impacts ignores structural dip effects by selecting a panel in the middle of the area to be flooded rather than the most down-dip panel. Finally, the study does not consider pressurized groundwater in the bedrock section above the mine on global mine stability.

2. The site-specific geologic and hydrogeologic characteristics of the mine area, which project on global mine stability, are inadequately characterized, particularly the area of the mine beneath Cayuga Lake including the area proposed to be flooded.
3. Cargill's application does not address mine impacts on depletion of groundwater resources within a large adjacent area. This includes existing impacts and their further degrading by the planned flooding.

In light of these conclusions, I recommend that 1) the modeling study on flooding impacts on the near-field and global mine stability should be re-done based on realistic model assumptions as outlined above; 2) Cargill should provide, for independent evaluations, data related to the brine "pockets" inflows and inflow distribution along Shaft #1, as specified in the next section; and 3) Cargill should develop a plan addressing the lowering of groundwater levels due to inflows into the shafts and set up a monitoring plan for additional lowering resulting from the proposed flooding.

## NEED FOR ADEQUATE GEOLOGIC AND HYDROGEOLOGIC CHARACTERIZATION BEFORE ANY FLOODING OF S3

In support of its application, Cargill submitted a report prepared by Agapito entitled "Flac3D Stability Analysis of S3 Submains and E5 Panel, Cayuga Mine," dated Apr. 12, 2022 ("Agapito Report"). The Agapito Report states that Agapito was retained "to assess the effect of the planned flooding on the global stability of the subject panels" but the Agapito Report is inadequate for this purpose.

Agapito's computer model assumes for the sake of "simplicity" and "computational efficiency" a horizontal bedrock system.[1] As a result, the Agapito Report ignores in the area to be flooded the structural dip of bedrock beds, as well as the presence of pressurized groundwater in the bedrock section between the mine and the bottom of lake sediments. More importantly, the Agapito Report assumes a simplistic, overburden-weight driven, model of in-situ stresses that ignores actual in-situ stress field. These oversimplifications in the Agapito modeling, coupled with unrealistically low pillar dissolution effects assumed in the model, result in a stability analysis that may grossly overstate the stability of the S3 area to be flooded.

The area proposed to be flooded beneath Cayuga Lake has specific geological and hydrogeological characteristics that must be, but which were not, factored into Cargill's stability analysis. At bedrock depths encompassing most of the mine, horizontal stresses are expected to be larger than the vertical stress, often by a factor of 2-3[2]. In the northeastern US, the maximum horizontal compression stress direction is from NE to SW (Zoback & Zoback, 1989). This direction is approximately perpendicular to the axis of the Cayuga Lake valley. In the lake valley area, the vertical stress in bedrock is significantly reduced relative to vertical stress in upland

[1] Agapito Report at pg. 3.
[2] At the Retsof Mine, floor heave and roof sagging were attributed to high horizontal stresses, which inspired an unfortunate switch to small yielding pillars technology.

areas by virtue of the topographic elevation difference between these areas. This stress reduction is further compounded by the lower density of the sediments and lake water relative to upland bedrock density. The resulting disequilibrium of vertical stresses between the upland and valley areas, coupled with the dominance of horizontal stress, promotes halokinesis, or the slow flow of salt beds into the valley area. It produced larger salt thickness there and made that area more attractive for mining. On the other hand, the growth of an anticlinal salt structure in the valley produced some buckling effect on the overlying "carbonate beam", a stratigraphic bedrock zone critical for a global mine stability, as the Retsof collapse case has shown. The extension likely had a negative impact on the structural and hydraulic performance of the beam above the Cayuga Mine.

From a hydrogeologic perspective, in the Cayuga Lake area, the halokinesis is expected to have increased the aperture of bedding plane separations in adjoining upland bedrock from which the salt has been withdrawn. Even a small fracture aperture increase would disproportionally increase bedrock permeability, in accordance with the cubic law of fracture flow[3]. Because bedding plane separations are laterally much more extensive than other fracture types, the gently dipping bedding separation are likely to become principal groundwater flow pathways to the mine, rather than apparently shorter vertical flowlines. The latter would become fully engaged at a collapse stage by providing a direct hydraulic connection to the aquifer in unconsolidated sediments below the lake.

The above considerations provide insight into the anomalous convergence rates and the presence of so-called "pressurized brine pockets" encountered by Cargill in the U12 and U12A panels. DEC's Negative Declaration states that "[i]n 2019, investigative drilling was conducted in the U12 panel after anomalous closure rates … were observed." As indicated by mine maps, U12A is located at the edge of the buried valley, and both these panels are in an area where the valley axis makes a major shift westward. Each of these conditions has the potential for major redistribution of in-situ stresses that prevail in other mine areas, with resulting specific mining problems noted there.

Cargill characterizes the identified fluids in the strata above the roof of the mine as coming from a "pressurized brine pocket," which implies hydraulic isolation of the pocket in U12. However, if penetrated by an upward borehole, the pressure within any isolated pocket would be relieved rather quickly and the flow would diminish over time. But that is not what has appeared to have occurred since the drilling was completed. Rather, the sustained flow of water actually occurring in the U12 and U12A panels indicates a hydraulic connection of the "pocket" with an overlying aquifer. Based on the data from Shaft #4, the Oriskany Formation is the first overlying bedrock aquifer with subcrop at the bottom of the buried valley some distance to the north and updip of U12, where glacial scouring went deep into the carbonate beam. The suggested connection and flowpath are consistent with mining consultant Gary Petersen's (2017) theory, reported in BOYD's March 12, 2018 letter to DEC, "that water from the Oriskany Formation has moved down linears and is increasing closure rates in the U12 and U40B panels. This flow was due to the destressing caused by a yielding production pillar." This quote illustrates the prominent role of groundwater in global mine stability.

[3] The cubic law states that the flowrate is proportional to the third power of the aperture width.

Based on the foregoing, neither Cargill nor DEC appear to have an accurate or adequate characterization of the hydrogeologic or geologic conditions in the areas beneath Cayuga Lake, which include the proposed areas to be flooded. Given the crucial role of groundwater in mine stability, Cargill should be made to obtain and provide data from the brine depressurization borings, including their direction and length, shut-in pressure readings, flowrate and salinity (specific electrical conductance) changes over time. In addition, Cargill should be made to provide to DEC information on vertical distribution of seeps into Shaft #1 generating a total shaft inflow of nearly 30 gpm. Despite several grouting attempts, the shaft inflow appears to increasing over time; most likely due to enlargement of apertures of bedding separations (and thus their permeability) by mining-induced subsidence.

Further, the Agapito Report must be supplemented with a complete stability analysis that reflects realistic assumptions on pillar dissolution effects and in-situ stresses.

**EFFECTS OF BRINE SATURATION LEVELS ON PILLARS IN S3 ZONE**

Available information on the proposed diversion of shaft leakage brine and the associated saturation levels into S3 Zone beneath Cayuga Lake is somewhat conflicting, but it appears that Cargill proposes to store under saturated brines in the S3 area. At one point (Boyd, 2023 p.1), Cargill apparently stated that its system will saturate the brine to approximately 24%-25% salt before pumping it to the sump. In a more recent May 3, 2024 submission to DEC, however, Cargill informed the agency that it would activate the brine making system "if brine were to drop below a 22% salinity action level."

While Agapito claims to have incorporated some dissolution effects into its modeling, Agapito's conclusions about the effects of storing under saturated brines are based on assumptions that grossly understate the effects of pillars dissolution. Although the Agapito Report states that "potential dissolution of the pillars is not thought to be significant; the modeled pillars allow for approximately 6 inches of dissolution around the pillar perimeter," (Agapito, 2022, p. 1 and 3) no justification is offered in the Agapito Report for this arbitrary assumption. Further, the Agapito Report was prepared in 2022 at a time when Cargill appears to have proposed a base-line saturation level of 24%-25%, as opposed to the 22% later disclosed to DEC.

A simple calculation shows that the dissolution effects of storing brines at 22% saturation on the small pillars in the S3 area are likely to be significant. Assuming 30 gpm (16,000,000 gal per year) of shaft leakage is disposed in the S3 Zone, a 4% difference to full brine saturation (which is less that a full saturation at 26.6% minus 22%) indicates potential yearly dissolution of ~630,000 gal (or ~84,000 cubic ft) of salt. Assuming small pillar dimensions of 18'x20'x11', a single pillar volume would be ~3,960 cubic ft. It follows that the disposal of the brine would be capable of dissolving an equivalent of ~21 small pillars per year.

According to a 2011 Cargill mining plan, Panel E9, which would be part of the first-flooded portion of the S3 Zone, contains 62 small yielding pillars. Thus, approximately one-third of the pillars volume in the E9 panels would potentially be dissolved within the first year of Cargill's proposed 15-year flooding period[4]. Assuming uniform pillar dissolution within this panel, the cross-section area of each pillar would be reduced by one-third. Thus, the average post-flooding pillar load would increase by the same one-third of pre-flooding load, which is a much greater value than assumed in the Agapito model. Put it another way, Agapito arbitrarily assumed that the dissolution would reduce pillar dimension by less than 1 ft whereas in this more realistic case of 4% under-saturation the small pillar dimension would be reduced *by nearly 4 ft*.

The small pillar panels in S3 area are much more sensitive to flooding dissolution impacts than large pillar areas. It is thus critical to properly evaluate such impacts for a realistic range of brine saturation levels. The Agapito report falls short of this goal, which invalidates the report's conclusions alleging the lack of major flooding impacts, both near-field (claystone in the roof) and far-field (global stability).

## IMPACT ON GROUNDWATER RESOURCES IN THE AREA

Cargill's ongoing operations must have negatively impacted groundwater resources in the areas surrounding the mine, and yet neither Cargill nor DEC appear to have evaluated the significant draining and water depleting impacts of the prolonged shaft inflows on bedrock groundwater resources in the areas near the mine. These impacts are likely to worsen during the flooding of the S3 area when increased closure rates, expected due to pillar dissolution, will enlarge bedding plane separations and the permeability within the overburden section as well as surface subsidence rates.

Because of the low storativity of transmissive bedding fractures, drawdowns resulting from the shaft inflows are likely to extend for miles in the updip and along-strike directions. Such widespread impact would not only affect the Oriskany/Onondaga aquifer unit but also shallower bedrock water-bearing units yet to be identified and characterized. A yield of 60 gpm, originally reported for the Koplinka-Loehr bedrock supply well located to the west of the Shaft #1 location, indicates the presence of significant bedrock groundwater resources that are threatened by the draining mine impacts.

Cargill's consultants conducted a domestic well survey in connection with sinking of Shaft #4. However, this survey focused on a baseline well water quality that is of minor concern here, given the downward groundwater flow imposed by draining effect of the shafts. The depletion/drawdown impact on groundwater resources of the shaft leakage from the mine has not been addressed to date. From what information is available, no water level monitoring is being performed or is proposed notwithstanding the persistence of bedrock groundwater depletion and its likely aggravation during latter days of the mine.

[4] Panel E9 is located farther down-dip than E5 used in the Agapito model; consequently, pillar stresses would be greater in E9 than in E5. Agapito's modeling should have been based on E9.

Besides draining and depleting groundwater resources in the area, this drawing down of groundwater resources may negatively impact the stability of the area in S3 proposed to be flooded. It is because future shaft inflow will likely include a larger component of fresh water and larger inflow rates, posing significantly higher treatment requirements prior to disposal of the inflow. If such freshwater is not sufficiently treated prior to disposal, it may further undermine stability of the S3 area as discussed above.

Sincerely,

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REFERENCES

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### EDUCATION

*Ph.D. Technical Sciences (Geological Engineering),*
*AGH - University of Science and Technology, Krakow, Poland - 1974*

*M.Sc. Hydrogeology and Engineering Geology,*
*AGH - University of Science and Technology, Krakow, Poland - 1969*

### PROFESSIONAL CERTIFICATIONS

-  *Certified Ground Water Professional (CGWP) by the National Ground Water Association - No. 272*
-  *Registered Professional Geologist in Pennsylvania - No. PG003076G*
-  *Licensed Site Remediation Professional New Jersey Lic. #591669 (inactive)*

### SUMMARY OF PROFESSIONAL EXPERIENCE

**Michalski & Associates, Inc.**
**South Plainfield, N.J.**

In 1995, Dr. Michalski formed a specialty environmental consulting firm which provides hydrogeological and environmental remediation services to industrial clients, law firms, consulting engineering firms, government, and citizen groups. Major clients include Merck & Co.; Shell Oil Co.; Consolidated Edison of NY; Dover Twp. NJ; Georgia Pacific Corp.; Groundwater & Environmental Services; Middlesex Water Company; Stepan Chemical; Wayne Twp, NJ; Cattaraugus County, NY; TRC-Raviv Associates; Textile Research Institute; URS Corporation; Matrix Engineering, USEPA and US Attorney District of NJ.

Dr. Michalski has over 50 years of consulting and academic experience in hydrogeology and applied geosciences, with emphasis on groundwater remediation, evaluation of groundwater resources, regulatory compliance, siting of sensitive waste disposal facilities and expert testimony.

Dr. Michalski has extensive project experience in characterization and remediation of unconsolidated and bedrock aquifers. He served as project manager/lead investigator for remediation projects at over 60 contaminated sites. Dr. Michalski is a recognized expert on hydrogeology of sedimentary bedrock formations, particularly the Newark Basin, NJ. He published seminal papers on this subject and has taught professional development course on hydrogeologic characterization of fractured bedrock at Rutgers University for the last 20 years.

He was appointed by the Governor to NJDEP's Standing Committee on Water Quality and Quantity of the Science Advisory Board. He also served in a committee preparing NJDEP's guidance document on groundwater site investigation, remedial investigations and remedial action.

As expert witness, he prepared numerous expert reports, testified in courts and at adjudicatory hearings.

**Rutgers University,**
**New Brunswick, New Jersey**
***Visiting Part-Time Lecturer*** ***1986-1995***

For nine years, Dr. Michalski served as a visiting part-time lecturer of hydrogeology at the Geology Department, Faculty of Arts and Sciences, Rutgers University.

**The Whitman Companies,**
**Inc. East Brunswick, N.J.**
***Director of Hydrogeology*** ***1989-1995***

As director of hydrogeology, Dr. Michalski provided technical expertise, leadership and supervision in the areas of site assessments, geologic and hydrogeologic characterization, remedial investigations, and groundwater remediation projects. Some of his professional accomplishments include:

- He directed and performed numerous groundwater investigations, assessments and cleanups under the ISRA (ECRA), BUST, NJPDES and State Case Management programs in New Jersey.

- He developed an innovative testing methodology to characterize fracture flow and contaminant migration at complex bedrock sites.

- Dr. Michalski designed a successful treatment train for enhanced recovery of residual DNAPL solvents below the water table in northern New Jersey. Record-setting volumes and recovery of DNAPLs were achieved. This project won the national Excellence in Environmental Engineering Award in small project category in 1997.

- Dr. Michalski provided expert hydrogeologist's opinions on proposed low-level radioactive waste disposal sites in New York and Connecticut. As an expert witness, he testified before the Low-Level Radioactive Waste Siting Commission in Illinois on a proposed disposal site in Martinsville. For NRC, he prepared an expert opinion on potential impacts of a release from a nuclear power plant on ground water system.

- He consulted PACE, a concerned citizen group opposing the use Retsof Salt Mine working for waste disposal. Subsequently, he testified at the Brodsky Hearing on issues related to the collapse of this salt mine located in Upstate New York.

- He prepared expert reports on dating contaminant discharges and allocating of cleanup responsibility for several industrial sites and seven gasoline service stations in New Jersey. Dr. Michalski also served as an expert witness before an AAA panel in a case involving cleanup responsibility for a 600,000 gallon fuel oil spill in southern New Jersey.

- Other cases for which he prepared expert hydrogeologist's opinions include contaminated municipal wells in Wallington, NJ, and a proposed commercial sanitary landfill in Cattaraugus County, NY.

**TRC Environmental**
**Consultants, Somerset, N.J.**
***Principal Hydrogeologist*** ***1987-1989***

Responsible for the technical supervision and management of diverse groundwater projects for industrial clients, developers and government. Other responsibilities pertained to hydrogeologic training of technical staff and development of internal standards for conducting hydrogeologic investigations at hazardous waste sites. Dr. Michalski's major projects included:

- Contaminant assessments and development of cleanup plans for an industrial bedrock site in North Jersey contaminated with chlorinated hydrocarbons and for a large chemical plant site in Central Jersey contaminated with a myriad of compounds.

- Remedial ground-water investigations and remediation of two contaminated UST sites.

- Expert hydrogeologist's services for proposed solid waste landfill sites in Somerset County, NJ, and two counties in New York State.

**The Earth Technology Corporation,**
**Somerset, N.J.**
***Senior Hydrogeologist*** ***1983-1987***

Responsibilities included planning, management and technical supervision of hydrogeologic investigations at hazardous waste facilities, landfills, superfund sites, industrial (ECRA) sites, and a nuclear power plant. Selected projects include:

- Development of groundwater supply for a nuclear power plant in Missouri.

- For the USEPA, Dr. Michalski performed technical reviews of ground water monitoring systems and landfill designs of RCRA Part B Permit Applications. Designed and implemented groundwater investigations at two CERCLA sites.

- As part of an Environmental Assessment for a candidate high level nuclear waste site at Richton Salt Dome, Dr. Michalski authored technical memoranda on fluids in salt deposits, anomalous zones, and in-situ stresses in salt domes. He also investigated worldwide occurrences and mechanisms of gas outbursts in salt and potash mines and supervised an underground salt coring project at the Avery Island Salt Mine.

- Dr. Michalski was responsible for technical management of extensive ground water and subsidence studies for RCRA regulated facilities located in the karst terrain of Puerto Rico. The studies involved numerous borings and deep monitoring wells, use of several geophysical methods, geomorphologic and geotechnical analyses, and dye tracing. He developed an innovative analysis of water level response to storm water discharge through on site sinkholes.

**University of Port Harcourt, Nigeria**
***Senior Lecturer and Director of***
***Studies in Geology*** ***1977-1982***

- Taught hydrogeology, geology, engineering geology, and soil mechanics courses.

- As director of studies at a newly established university, he developed applied geology curriculum, organized teaching and research facilities, and initiated regional studies of sea water intrusion into coastal aquifers of the Niger Delta.

**University of Mining &**
**Metallurgy, Krakow, Poland**
***Assistant Professor*** ***1969-1977***

- Taught engineering geology, hydrogeology, and mining geology courses.

- Dr. Michalski performed an extensive physical modeling of coupled fluid and heat flow in the process of underground smelting of sulfur deposits for variable hydrogeological conditions and well layouts. He used finite element modeling to investigate stress and elastic energy distributions in the vicinity of mining face approaching faults.

- Dr. Michalski served as geotechnical and hydrogeologic consultant to sulfur, coal, and salt mining industries in Poland. The latter included evaluation of surface subsidence at the Wieliczka Salt Mine.

## PROFESSIONAL ORGANIZATIONS

*Association of Ground Water Scientists and Engineers - Member since 1984*
*Association of Engineering Geologists - Member since 1984; Past Vice President of NY-Philadelphia Section*
*Geological Association of New Jersey - Past Counselor-at-large.*

## PUBLICATIONS

The most recent of his over 40 technical publications include:

Michalski, A. *Plume Delineation Strategy for Contaminated Sites in Dipping Sedimentary Bedrock.* In: 2015 NGWA Fractured Bedrock Conference, Sep. 28-29, 2015. Burlington, VT.

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