CARGILL
SALT DIVISION

191 Portland Point Rd.
Lansing, NY 14882-9013
Mail Address: PO Box B
Lansing, NY 14882-1520
607/533-4221

RECEIVED
SEP 17 1997
DEPT OF ENV CONSERVATION
REG 7 - MINERAL RESOURCES

September 16, 1997.

Mr. Moskiewicz
New York State Dept of Environmental Conservation
Region 7 Division of Mineral Resources
615 Erie Blvd. West
Syracuse, New York 13204-2400

RE: NYS MINE FILE #7093-29-0052

Dear Mr. Moskiewicz:

Please find enclosed a completed Mined Land Reclamation Permit renewal form, an organizational report and maps showing location and planned mining for the 5 year life of the permit. If you have any questions please contact Mike Fabio, or myself at (607) 533-4221.

Thank you for your attention to this matter.

Regards,

Robert J. Supko
Mine Manager

Enclosure

	1 Small to Moderate Impact	2 Potential Large Impact	3 Can Impact Be Mitigated By Project Change
• Construction activity would excavate or compact the soil profile of agricultural land.	☐	☐	☐Yes ☐No
• The proposed action would irreversibly convert more than 10 acres of agricultural land or if located in an Agricultural District, more than 2.5 acres of agricultural land.	☐	☐	☐Yes ☐No
• The proposed action would disrupt or prevent installation of agricultural land management systems (e.g., subsurface drain lines, outlet ditches, strip cropping); or create a need for such measures (e.g., cause a farm field to drain poorly due to increased runoff).	☐	☐	☐Yes ☐No
• Other impacts:____________________________	☐	☐	☐Yes ☐No

IMPACT ON AESTHETIC RESOURCES

11. Will proposed action affect aesthetic resources? ☐Yes ☐No
(If necessary, use the Visual EAF Addendum in Section 617.20, Appendix B.)
Examples that would apply to column 2

	1	2	3
• Proposed land uses, or project components obviously different from or in sharp contrast to current surrounding land use patterns, whether man-made or natural.	☐	☐	☐Yes ☐No
• Proposed land uses, or project components visible to users of aesthetic resources, which will eliminate, or significantly reduce, their enjoyment of the aesthetic qualities of that resource.	☐	☐	☐Yes ☐No
• Project components that will result in the elimination, or significant screening, of scenic views known to be important to the area.	☐	☐	☐Yes ☐No
• Other impacts:____________________________	☐	☐	☐Yes ☐No

IMPACT ON HISTORIC AND ARCHAEOLOGICAL RESOURCES

12. Will Proposed Action impact any site or structure of historic, pre-historic or paleontological importance? ☐Yes☐No
Examples that would apply to column 2

	1	2	3
• Proposed Action occurring wholly or partially within or substantially contiguous to any facility or site listed on the State or National Register of historic places.	☐	☐	☐Yes ☐No
• Any impact to an archaeological site or fossil bed located within the project site.	☐	☐	☐Yes ☐No
• Proposed Action will occur in an area designated as sensitive for archaeological sites on the NYS Site Inventory.	☐	☐	☐Yes ☐No
• Other impacts;____________________________	☐	☐	☐Yes ☐No

IMPACT ON OPEN SPACE AND RECREATION

13. Will proposed Action affect the quantity or quality of existing or future open spaces or recreational opportunities? ☐Yes ☐No
Examples that would apply to column 2

	1	2	3
• The permanent foreclosure of a future recreational opportunity.	☐	☐	☐Yes ☐No
• A major reduction of an open space important to the community.	☐	☐	☐Yes ☐No
• Other impacts:____________________________	☐	☐	☐Yes ☐No

IMPACT ON CRITICAL ENVIRONMENTAL AREAS

14. Will Proposed Action impact the exceptional or unique characteristics of a critical environmental area (CEA) established pursuant to subdivision 6 NYCRR 617.14(g)? ☐Yes ☐NO

List the environmental characteristics that caused the designation of the CEA.

____

____

____

____

____

	1 Small to Moderate Impact	2 Potential Large Impact	3 Can Impact Be Mitigated By Project Change
Examples that would apply to column 2			
• Proposed Action to locate within the CEA?	☐	☐	☐Yes ☐No
• Proposed Action will result in a reduction in the quantity of the resource?	☐	☐	☐Yes ☐No
• Proposed Action will result in a reduction in the quality of the resource?	☐	☐	☐Yes ☐No
• Proposed Action will impact the use, function or enjoyment of the resource?	☐	☐	☐Yes ☐No
• Other impacts:____________________	☐	☐	☐Yes ☐No

IMPACT ON TRANSPORTATION

15. Will there be an effect to existing transportation systems? ☐Yes ☐No

	1 Small to Moderate Impact	2 Potential Large Impact	3 Can Impact Be Mitigated By Project Change
Examples that would apply to column 2			
• Alteration of present patterns of movement of people and/or goods.	☐	☐	☐Yes ☐No
• Proposed Action will result in major traffic problems.	☐	☐	☐Yes ☐No
• Other impacts:____________________	☐	☐	☐Yes ☐No

IMPACT ON ENERGY

16. Will proposed action affect the community's sources of fuel or energy supply? ☐Yes☐No

	1 Small to Moderate Impact	2 Potential Large Impact	3 Can Impact Be Mitigated By Project Change
Examples that would apply to column 2			
• Proposed Action will cause a greater than 5% increase in the use of any form of energy in the municipality.	☐	☐	☐Yes ☐No
• Proposed Action will require the creation or extension of an energy transmission or supply system to serve more than 50 single or two family residences or to serve a major commercial or industrial use.	☐	☐	☐Yes ☐No
• Other impacts:____________________	☐	☐	☐Yes ☐No

	1 Small To Moderate Impact	2 Potential Large Impact	3 Can Impact Be Mitigated By Project Change
NOISE AND ODOR IMPACTS			
17. Will there be objectionable odors, noise, or vibration as a result of the Proposed Action? ☐Yes☐No			
Examples that would apply to column 2			
• Blasting within 1,500 feet of a hospital, school or other sensitive facility.	☐	☐	☐Yes ☐No
• Odors will occur routinely (more than one hour per day).	☐	☐	☐Yes ☐No
• Proposed Action will produce operating noise exceeding the local ambient noise levels for noise outside of structures.	☐	☐	☐Yes ☐NO
• Proposed Action will remove natural barriers that would act as a noise screen.	☐	☐	☐Yes ☐No
Other impacts:____________________	☐	☐	☐Yes ☐No
IMPACT ON PUBLIC HEALTH			
18. Will Proposed Action affect public health and safety? ☐Yes ☐No			
Examples that would apply to column 2			
• Proposed Action may cause a risk of explosion or release of hazardous substances (i.e. oil, pesticides, chemicals, radiation, etc.) in the event of accident or upset conditions, or there may be a chronic low level discharge or emission.	☐	☐	☐Yes ☐No
• Proposed Action may result in the burial of "hazardous wastes" in any form (i.e. toxic, poisonous, highly reactive, radioactive, irritating, infectious, etc.).	☐	☐	☐Yes ☐No
• Storage facilities for one million or more gallons of liquefied natural gas or other flammable liquids.	☐	☐	☐Yes ☐No
• Proposed action may result in the excavation or other disturbance within 2,000 feet of a site used for the disposal of solid or hazardous waste.	☐	☐	☐Yes ☐No
Other Impacts:____________________	☐	☐	☐Yes ☐No
IMPACT ON GROWTH AND CHARACTER OF COMMUNITY OR NEIGHBORHOOD			
19. Will proposed action affect the character of the existing community? ☐Yes☐No			
Examples that would apply to column 2			
• The permanent population of the city, town or village in which the project is located is likely to grow by more than 5%.	☐	☐	☐Yes ☐No
• The municipal budget for capital expenditures or operating services will increase by more than 5% per year as a result of this project.	☐	☐	☐Yes ☐No
• Proposed Action will conflict with officially adopted plans or goals.	☐	☐	☐Yes ☐No
• Proposed Action will cause a change in the density of land use.	☐	☐	☐Yes ☐No
• Proposed Action will replace or eliminate existing facilities, structures or areas of historic importance to the community.	☐	☐	☐Yes ☐No
• Development will create a demand for additional community services (e.g. schools, police and fire, etc.).	☐	☐	☐Yes ☐No
• Proposed Action will set an important precedent for future projects.	☐	☐	☐Yes ☐No
• Proposed Action will create or eliminate employment.	☐	☐	☐Yes ☐No
• Other impacts:____________________	☐	☐	☐Yes ☐No

20. Is there, or is there likely to be, public controversy related to potential adverse environmental impacts?
☐Yes ☐No

If any action in Part 2 is identified as a potential large impact, or if you cannot determine the magnitude of impact, proceed to Part 3

DIVISION OF MINERAL RESOURCES
MINED LAND RECLAMATION PROGRAM

MINING PERMIT APPLICATION

DEC # - - / -

1. MINED LAND FILE NUMBER (If assigned): 7 0 9 - 3 - 2 9 - 0 0 5 2
2. TELEPHONE NUMBER: (607) 533-4221
3. NAME OF APPLICANT: Cargill, Incorporated
4. PERMANENT ADDRESS: 191 Portland Point Road, PO Box B
CITY: Lansing | STATE: NY | ZIP CODE: 14882
5. CONTACT PERSON: Robert J. Supko
6. TELEPHONE NUMBER: (607) 533-4221

7. MINED LAND PROJECT

	Yes	No
a. Will the total acreage affected by mining for the entire mining site exceed 5 acres?	[X]	[ ]
b. Will the vertical depth from the top of the mine face to the floor exceed 20 feet?	N/A	[ ]
c. Will there be on-site processing of mining products (eg. crushing, screening, washing)?	[X]	[ ]
d. Will mining occur within 100 feet of a surface water body (eg. stream, lake) or wetland area?	[X]	[ ]
e. Will any consolidated minerals be mined (eg. limestone, trap rock, sandstone)?	[ ]	[X]
f. Will mining occur within 500' of any dwelling?	[ ]	[X]
g. Will mining ever occur at or below the mean high water table? UG Operation	[ ]	[ ]

8. TAXPAYER ID
If other than individual, provide Federal Taxpayer ID Number 41-0177680

9. APPLICATION TYPE: [ ] New [X] Renewal [ ] Modification

10. a. PRESENT PERMIT TERM — Expiration date 5/ 2 / 98
b. COMING PERMIT TERM — [X] 5 years [ ] Other ____ years

11. COMMON GEOLOGIC NAME OF MINERAL TO BE MINED: Rock Salt

12. LOCAL ORDINANCES
a. Is mining prohibited at this location? [ ] Yes [X] No
b. Does the local government require any type of permit for mining at this location? [ ] Yes [X] No

13. a. ARE ANY OTHER STATE MINING PERMITS CURRENTLY HELD BY THE APPLICANT? [ ] Yes [X] No
b. If YES, give DEC mine file number(s).

14. Has any owner, partner, corporate officer or corporate director of your organization ever held any of these positions in another organization that has had a New York State mining permit **SUSPENDED OR REVOKED** or has had a New York State mined land reclamation bond **FORFEITED**? [ ] Yes [X] No If YES, identify the person(s).

15. ACREAGE SUMMARY (To be filled in by applicant)

			FOR OFFICIAL DEC USE ONLY
a.	Total acreage controlled by owner at this location (Surface)	260.04 acres	acres
b.	Total acreage permitted by DEC prior to this application (Surface & UG)	8,361 acres	acres
c.	Total acreage affected since April 1, 1975 (Surface)	67.67 acres	acres
d.	Total acreage approved by DEC as reclaimed since April 1, 1975	0 acres	acres
e.	Current affected acreage (c minus d) (Surface)	67.67 acres	acres
f.	Acreage included in this application, but not previously approved (5056 UG)	5,056 acres	acres
g.	New acreage to be affected during the coming permit term (0-Surface)	0 acres	acres
h.	Number of acres to be reclaimed during coming permit term	0 acres	acres

16. NAME OF MINING SITE: Cayuga Mine

17. MINE LOCATION
Road: Portland Point Road
Nearest Road Intersection: State Route 34B
Town: Lansing
County: Tompkins

18. MAP LOCATION
a. Quadrangle Name: Ludlowville
b. [ ] 15 minute [X] 7½ minute
FOR DEC OFFICIAL USE ONLY — NYTM'S ____ E. 4 ____ N

19. NAME AND ADDRESS OF SURFACE LANDOWNER
Cargill, Incorporated PO Box 9300, Minneapolis, MN 55440

20. NAME AND ADDRESS OF MINERAL OWNER (If different)
New York State State Royalty Office, Office of General Services, Albany, NY

21. I am the owner [ ] in fee, [ ] of the mineral rights of the property that is to be mined by the above applicant. I have read the contents of the Mined Land Use Plan, which sets forth the applicant's mining and reclamation plan for the property to be mined, and I hereby irrevocably consent and agree to the performance of the Mined Land Use Plan by the applicant, his surety or insurer or the NYS Department of Environmental Conservation. I further agree to allow access to the property to department personnel for the purpose of conducting inspections or investigations in the regular course of their duties.

SIGNATURE OF OWNER: [signature] DATE: 9/9/97

22. I hereby affirm, under penalty of perjury that information provided on this form is true to the best of my knowledge and belief. False statements made herein are punishable as a Class A misdemeanor pursuant to Section 210.45 of the Penal Law.

NAME, TITLE AND SIGNATURE OF APPLICANT OR AUTHORIZED REPRESENTATIVE: Gerald Thornton, Vice President-Salt [signature] DATE: 8-11-97

85-15-12 (8/91)—28b

NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION
DIVISION OF MINERAL RESOURCES
50 WOLF ROAD, ALBANY, NEW YORK 12233-6500

OFFICE FILE NUMBER

ORGANIZATIONAL REPORT

INCOMPLETE FORMS NOT ACCEPTABLE AND WILL BE RETURNED FOR COMPLETION

1. FULL NAME AND COMPLETE MAILING ADDRESS OF THE ENTITY. INCLUDE NAME AND TITLE TO WHOM ALL CORRESPONDENCE SHOULD BE SENT.

Cargill, Incorporated
PO Box B, 191 Portland Point Rd.
Lansing, New York 14882
Attn: Robert J. Supko, Mine Mgr.

TELEPHONE NUMBER (607) 533-4221

FAX NUMBER (607) 533-4501

2. FULL NAME AND COMPLETE MAILING ADDRESS OF AGENT IN NEW YORK WHO CAN BE SERVED ORDERS, NOTICES AND PROCESSES OF THE DEPARTMENT OR OF ANY COURT OF LAW. POST OFFICE BOX ADDRESSES ARE NOT ACCEPTABLE.

Robert J. Supko
PO Box B,191 Portland Point Rd.
Lansing, New York 14882

TELEPHONE NUMBER (607) 533-4221

3. TYPE OF ACTIVITY (Check those That Apply)

- [ ] PRODUCTION—Oil, Gas, Injection or Geothermal Well(s)
- [ ] STORAGE—Underground Gas or LPG facility
- [ ] PURCHASING—Of Oil or Gas From Others
- [ ] TRANSPORTATION—By Truck or Pipeline for Others
- [ ] SALVAGE—Plug and Abandon Wells for Others
- [ ] DRILLING—Drill Wells for Others
- [ ] SOLUTION MINING—Own/Operate Facility
- [ ] BRINE DISPOSAL—Own/Operate Facility
- [ ] STRATIGRAPHIC—Own Well or Hole
- [ ] SURFACE MINING—Own/Operate Facility
- [X] UNDERGROUND MINING—Own/Operate Facility

4. STATE WHETHER THE ENTITY IS A CORPORATION, ASSOCIATION, PARTNERSHIP, INDIVIDUAL, PUBLIC AUTHORITY OR GOVERNMENTAL AGENCY. IF FOREIGN CORPORATION, GIVE STATE AND DATE OF INCORPORATION AND DATE OF AUTHORIZATION TO DO BUSINESS IN NEW YORK STATE. IF PARTNERSHIP, STATE WHETHER GENERAL OR LIMITED AND COUNTY OF FILING. IF DBA, GIVE COUNTY OF FILING.

Corporation

5. IF A NAME CHANGE, GIVE COMPLETE NAME AND ADDRESS OF PREVIOUS ENTITY.

6. IF CORPORATION OR ASSOCIATION, LIST ALL DIRECTORS AND ALL OFFICERS. IF PARTNERSHIP, LIST ALL GENERAL AND ALL LIMITED PARTNERS. ATTACH ADDITIONAL SHEETS IF NECESSARY.

NAME	TITLE
F.G. Bastiaens	Executive Supervisor
Charles Sullivan	President
Gerald Thornton	Vice President
Greg Wold	Manager of Operations
Charles von Dreusche	Mine Operations Manager

7. LIST ALL PERSONS AUTHORIZED BY THE ENTITY TO SIGN ALL SUBMITTALS TO THE DEPARTMENT

NAME	TITLE
Robert J. Supko	Mine Manager

I hereby affirm under penalty of perjury that the information provided in the report is true to the best of my knowledge and belief. I am aware that false statements made in this report are punishable as a Class A misdemeanor under Section 210.45 of the Penal Law.

TYPE OR PRINT NAME OF AUTHORIZED PERSON: Robert J. Supko

SIGNATURE: [signature]

DATE: 9/16/97

SWORN TO AND SUBSCRIBED BEFORE ME, THIS ____ DAY OF ____ 19__

NOTARY PUBLIC

Environmental Assessment Form

Appendix A

State Environmental Quality Review

FULL ENVIRONMENTAL ASSESSMENT FORM

Purpose: The full EAF is designed to help applicants and agencies determine, in an orderly manner, whether a project or action may be significant. The question of whether an action may be significant is not always easy to answer. Frequently, there are aspects of a project that are subjective or unmeasurable. It is also understood that those who determine significance may have little or no formal knowledge of the environment or may not be technically expert in environmental analysis. In addition, many who have knowledge in one particular area may not be aware of the broader concerns affecting the question of significance.

The full EAF is intended to provide a method whereby applicants and agencies can be assured that the determination process has been orderly, comprehensive in nature, yet flexible enough to allow introduction of information to fit a project or action.

Full EAF Components: The full EAF is comprised of three parts:

Part 1: Provides objective data and information about a given project and its site. By identifying basic project data, it assists a reviewer in the analysis that takes place in Parts 2 and 3.

Part 2: Focuses on identifying the range of possible impacts that may occur from a project or action. It provides guidance as to whether an impact is likely to be considered small to moderate or whether it is a potentially-large impact. The form also identifies whether an impact can be mitigated or reduced.

Part 3: If any impact in Part 2 is identified as potentially-large, then Part 3 is used to evaluate whether or not the impact is actually important.

DETERMINATION OF SIGNIFICANCE -- Type 1 and Unlisted Actions

Identify the Portions of EAF completed for this project: ☐ Part 1 ☐ Part 2 ☐ Part 3

Upon review of the information recorded on this EAF (Parts 1 and 2 and 3 if appropriate), and any other supporting information, and considering both the magnitude and importance of each impact, it is reasonably determined by the lead agency that:

☐ A. The project will not result in any large and important impact(s) and, therefore, is one which **will not** have a significant impact on the environment, therefore **a negative declaration will be prepared.**

☐ B. Although the project could have a significant effect on the environment, there will not be a significant effect for this Unlisted Action because the mitigation measures described in PART 3 have been required, therefore **a CONDITIONED negative declaration will be prepared.***

☐ C. The project may result in one or more large and important impacts that may have a significant impact on the environment, therefore **a positive declaration will be prepared.**

*A Conditioned Negative Declaration is only valid for Unlisted Actions

Cargill, Inc., Cayuga Mine Site, Mining Permit Review

Name of Action

Name of Lead Agency

Print or Type Name of Responsible Officer in Lead Agency

Title of Responsible Officer

Signature of Responsible Officer in Lead Agency

Signature of Preparer (if different from responsible officer)

Date

PART 1--PROJECT INFORMATION

Prepared by Project Sponsor

NOTICE: This document is designed to assist in determining whether the action proposed may have a significant effect on the environment. Please complete the entire form, Parts A through E. Answers to these questions will be considered as part of the application for approval and may be subject to further verification and public review. Provide any additional information you believe will be needed to complete Parts 2 and 3.

...expected that completion of the full EAF will be dependent on information currently available and will not involve new studies, ...arch or investigation. If information requiring such additional work is unavailable, so indicate and specify each instance.

Name of Action **Cayuga Mine Site – Mining Permit Renewal**		
Location of Action (include Street Address, Municipality and County) **191 Portland Point Road, Tompkins County, Lansing, New York**		
Name of Applicant/Sponsor **Cargill, Inc.**	Business Telephone **(607) 533-4221**	
Address **191 Portland Point Rd., P.O. Box B**		
City/PO **Lansing**	State **NY**	Zip Code **14882**
Name of Owner(if different) **same**	Business Telephone ( ) **same**	
Address **same**		
City/PO **same**	State	Zip Code
Description of Action **Cayuga Mine Site Permit Renewal**		

P...se Complete Each Question--Indicate N.A. if not applicable

A. SITE DESCRIPTION

Physical setting of overall project, both developed and undeveloped areas.

1. Present land use: ☐Urban ☒Industrial ☐Commercial ☐Residential(suburban) ☐Rural(non-farm) ☐Forest ☐Agriculture ☐Other ____________

2. Total acreage of project area: _13417___acres. 67.67/13417 surface/subsurface

APPROXIMATE ACREAGE (Surface)	PRESENTLY	AFTER COMPLETION
Meadow or Brushland (Non-agricultural)	0 acres	0 acres
Forested	9 acres	9 acres
Agricultural (Includes orchards, cropland, pasture, etc.)	0 acres	0 acres
Wetland(Freshwater or tidal as per Articles 24,25 of ECL)	0 acres	0 acres
Water Surface Area	0 acres	0 acres
Unvegetated (Rock, earth or fill)	0 acres	0 acres
Roads, buildings and other paved surfaces	51 acres	42 acres
Other (Indicate type)__internal open areas__	8 acres	17 acres

3. What is predominant soil type(s) on project site?___Hudson Soil Services, Howard Soil Services ____________

   a. Soil drainage: ☒Well drained___20__% of site ☐Moderately well drained__80_____% of site ☐Poorly drained______% of site

   b. If any agricultural land is involved, how many acres of soil are classified within soil group 1 through 4 of the NYS Land Classification System? ___N/A___acres (See 1 NYCRR 370).

4. Are there bedrock outcroppings on project site? ☒Yes ☐No

   a. What is depth to bedrock? ____0 - 10______(in feet)

5. Approximate percentage of proposed project site with slopes: ☐0-10%__29___% ☐10-15%___59__%
☐15% or greater___12___% *Surface Only

6. Is project substantially contiguous to, or contain a building, site, or district, listed on the State or the National Registers of Historic ...es? ☐Yes ☒No

7. Is project substantially contiguous to a site listed on the Register of National Natural Landmarks?☐Yes☒No

8. What is the depth of the water table?__0 - 20__(in feet)

9. Is site located over a primary, principal, or sole source aquifer? ☐Yes ☒No

10. Do hunting, fishing or shell fishing opportunities presently exist in the project area? ☒Yes ☐No

11. Does project site contain any species of plant or animal life that is identified as threatened or endangered?

☐Yes ☒No According to ________

Identify each species ________

12. Are there any unique or unusual land forms on the project site?(i.e., cliffs, dunes, other geological formations)

☐Yes ☒No Describe ________

13. Is the project site presently used by the community or neighborhood as an open space or recreation area?

☐Yes ☒No If yes, explain ________

14. Does the present site include scenic views known to be important to the community?

☐Yes ☒No

15. Streams within or contiguous to project area:_____Minnegar Brook ________

a. Name of Stream and name of River to which it is tributary___Minnegar Brook; trib. to Cayuga Lake________

16. Lakes, ponds, wetland areas within or contiguous to project area:

a. Name______Cayuga Lake ________ b. Size (In acres)_42,240* ± Approximate__

17. Is the site served by existing public utilities? ☒Yes ☐No

a) If Yes, does sufficient capacity exist to allow connection? ☒Yes ☐No

b) If Yes, will improvements be necessary to allow connection? ☐Yes ☒No

18. Is the site located in an agricultural district certified pursuant to Agriculture and Markets Law, Article 25-AA, Section 303 and 304? ☐Yes ☒No

19. Is the site located in or substantially contiguous to a Critical Environmental Area designated pursuant to Article 8 of the ECL, and 6 NYCRR 617?☐Yes☒No

20. Has the site ever been used for the disposal of solid or hazardous wastes? ☐Yes ☒No

B. Project Description

1. Physical dimensions and scale of project (fill in dimensions as appropriate)

a. Total contiguous acreage owned or controlled by project sponsor _13417__acres. *includes lease area

b. Project acreage to be developed: ________acres initially; _13417__acres ultimately.

c. Project acreage to remain undeveloped ____0___acres.

d. Length of project, in miles: ___NA__(if appropriate).

e. If the project is an expansion, indicate percent of expansion proposed __NA___%.

f. Number of off-street parking spaces existing __NA___; proposed________.

g. Maximum vehicular trips generated per hour ___NA__(upon completion of project).

h. If residential, Number and type of housing units:

	One Family	Two Family	Multiple Family	Condominium
Initially				
Ultimately				

i. Dimensions (in feet) of largest proposed structure ___NA__height; _______width; _______length.

j. Linear feet of frontage along a public thoroughfare project will occupy is? __NA__ft.

2. How much natural material (i.e., rock, earth, etc.)will be removed from the site?___0___tons/cubic yards. *approxmiate (No surface excavation subsurface quantity is proprietary)

3. Will distrubed areas be reclaimed? ☒Yes ☐No ☐N/A

   a. If yes, for what intended purpose is the site being reclaimed?___Industrial________________

   b. Will topsoil be stockpiled for reclamation? ☐Yes ☒No

   c. Will upper subsoil be stockpiled for reclamation? ☐Yes ☒No

4. How many acres of vegetation (trees, shrubs, ground covers) will be removed from site? __NA____acres.

5. Will any mature forest (over 100 years old) or other locally-important vegetation be removed by this project?

   ☐Yes ☒No

6. If single phase project: Anticipated period of construction ____NA___months, (including demolition).

7. If multi-phased:

   a. Total number of phases anticipated _________(number).

   b. Anticipated date of commencement phase 1 _______month_______year,(including demolition).

   c. Approximate completion date of final phase _______month_______year.

   d. Is phase 1 functionally dependent on subsequent phases? ☐Yes ☐No

8. Will blasting occur during construction? ☒Yes ☐No

9. Number of jobs generated: during construction? ___NA___; after project is complete?_______.

10. Number of jobs eliminated by this project? __0____.

11. Will project require relocation of any projects or facilities? ☐Yes ☒No If yes, explain____

    ____

12. Is surface liquid waste disposal involved? ☐Yes ☒No

    a. If yes, indicate type of waste (sewage, industrial, etc.) and amount ________________

    b. Name of water body into which effluent will be discharged ________________

13. Is subsurface liquid waste disposal involved? ☒Yes ☐No Type__Industrial Stormwater__________

14. Will surface area of an existing water body increase or decrease by proposal? ☐Yes ☒No

    Explain________________________________

15. Is project, or any portion of project, located in a 100 year flood plain? ☐Yes ☒No

16. Will the project generate solid waste? ☒Yes ☐No

    a. If yes, what is the amount per month? _< 100__tons.

    b. If yes, will an existing solid waste facility be used? ☒Yes ☐No

    c. If yes, give name ________________________; location________________

    d. Will any wastes **not** go into a sewage disposal system or into a sanitary landfill? ☐Yes ☒No

    e. If Yes, explain ________________________________

17. Will the project involve the disposal of solid waste? ☐Yes ☒No

    a. If yes, what is the anticipated rate of disposal? _________tons/month.

    b. If yes, what is the anticipated site life? _________years.

18. Will project use herbicides or pesticides? ☐Yes ☒No

19. Will project routinely produce odors (more than one hour per day)? ☐Yes ☒No

20. Will project produce operating noise exceeding the local ambient noise levels? ☐Yes ☒No

21. Will project result in an increase in energy use? ☐Yes ☒No

    If yes, indicate type(s)________________________________

22. If water supply is from wells, indicate pumping capacity ___NA___gallons/minute.

23. Total anticipated water usage per day ___NA___gallons/day.

24. Does project involve Local, State or Federal funding? ☐Yes ☒No

    If yes, explain ________________________________

25. Approvals Required:

			Type	Submittal Date
City, Town, Village Board	☐Yes	☒No		
..., Town, Village Planning Board	☐Yes	☒No		
City, Town Zoning Board	☐Yes	☒No		
City, County Health Department	☐Yes	☒No		
Other Local Agencies	☐Yes	☒No		
Other Regional Agencies	☐Yes	☒No		
State Agencies	☒Yes	☐No	Mining Permit	9/16/97
Federal Agencies	☐Yes	☐No		

C. ZONING and PLANNING INFORMATION

1. Does proposed action involve a planning or zoning decision? ☐Yes ☒No

   If Yes, indicate decision required:

   ☐zoning amendment ☐zoning variance ☐special use permit ☐subdivision ☐site plan

   ☐new/revision of master plan ☐resource management plan ☐other__________

2. What is the zoning classification(s) of the site? Industrial

3. What is the maximum potential development of the site if developed as permitted by the present zoning?

   Industrial

4. What is the proposed zoning of the site? N/A

5. What is the maximum potential development of the site if developed as permitted by the proposed zoning?

   N/A

6. Is the proposed action consistent with the recommended uses in adopted local land use plans? ☒Yes ☐No

7. What are the predominant land use(s) and zoning classifications within a 1/4 mile radius of proposed action?

   Industrial (mining, processing, load-out facilities), rural, open space

8. Is the proposed action compatible with adjoining/surrounding land uses within a 1/4 mile? ☒Yes ☐No

9. If the proposed action is the subdivision of land, how many lots are proposed? N/A

   a. What is the minimum lot size proposed?__________

10. Will proposed action require any authorization(s) for the formation of sewer or water districts? ☐Yes ☒No

11. Will the proposed action create a demand for any community provided services (recreation, education, police, fire protection)? ☐Yes ☒No

    a. If yes, is existing capacity sufficient to handle projected demand? ☐Yes ☐No

12. Will the proposed action result in the generation of traffic significantly above present levels? ☐Yes ☒No

    a. If yes, is the existing road network adequate to handle the additional traffic? ☐Yes ☐No

D. Informational Details

Attach any additional information as may be needed to clarify your project. If there are, or may be, any adverse impacts associated with your proposal, please discuss such impacts and the measures which you propose to mitigate or avoid them.

See attached Volume II Expanded Environmental Assessment

E. Verification

I certify that the information provided above is true to the best of my knowledge.

Applicant/Sponsor Name Cargill, Inc. Robert J. Supko Date 12/31/00

Signature [signature] Title Mine Manager

If the action is in the Coastal Area, and you are a state agency, complete the Coastal Assessment Form before proceeding with this assessment.

Part 2 - PROJECT IMPACTS AND THEIR MAGNITUDE

Responsibility of Lead Agency

General Information (Read Carefully)

- In completing the form, the reviewer should be guided by the question: Have my responses and determinations been **reasonable**? The reviewer is not expected to be an expert environmental analyst.
- The **Examples** provided are to assist the reviewer by showing types of impacts and, wherever possible, the threshold of magnitude that would trigger a response in column 2. The examples are generally applicable throughout the State and for most situations. But, for any specific project or site other examples and/or lower thresholds may be appropriate for a Potential Large Impact response, thus requiring evaluation in Part 3.
- The impacts of each project, on each site, in each locality, will vary. Therefore, the examples are illustrative and have been offered as guidance. They do not constitute an exhaustive list of impacts and thresholds to answer each question.
- The number of examples per question does not indicate the importance of each question.
- In identifying impacts, consider long term, short term and cumulative effects.

Instructions (Read carefully)

a. Answer each of the 20 questions in PART 2. Answer **Yes** if there will be **any** impact.
b. **Maybe** answers should be considered as **Yes** answers.
c. If answering **Yes** to a question then check the appropriate box (column 1 or 2) to indicate the potential size of the impact. If impact threshold equals or exceeds any example provided, check column 2. If impact will occur, but threshold is lower than example, check column 1.
d. Identifying that an Impact will be potentially large (column 2) does not mean that it is also necessarily **significant**. Any large impact must be evaluated in PART 3 to determine significance. Identifying an impact in column 2 simply asks that it be looked at further.
e. If reviewer has doubt about size of the impact, then consider the impact as potentially large and proceed to PART 3.
f. If a potentially large impact checked in column 2 can be mitigated by change(s) in the project to a small to moderate impact, also check the **Yes** box in column 3. A **No** response indicates that such a reduction is not possible. This must be explained in Part 3.

IMPACT ON LAND	1 Small to Moderate Impact	2 Potential Large Impact	3 Can Impact be Mitigated by Project Change
1. Will the proposed action result in a physical change to the project site? ☐Yes ☐No			
Examples that would apply to column 2			
• Any construction on slopes of 15% or greater, (15 foot rise per 100 foot of length), or where the general slopes in the project area exceed 10%.	☐	☐	☐Yes ☐No
• Construction on land where the depth to the water table is less than 3 feet.	☐	☐	☐Yes ☐No
• Construction of paved parking area for 1,000 or more vehicles.	☐	☐	☐Yes ☐No
• Construction on land where bedrock is exposed or generally within 3 feet of existing ground surface.	☐	☐	☐Yes ☐No
• Construction that will continue for more than 1 year or involve more than one phase or stage.	☐	☐	☐Yes ☐No
• Excavation for mining purposes that would remove more than 1,000 tons of natural material (i.e., rock or soil) per year.	☐	☐	☐Yes ☐No
• Construction or expansion of a sanitary landfill.	☐	☐	☐Yes ☐No
• Construction in a designated floodway.	☐	☐	☐Yes ☐No
• Other impacts:____________________	☐	☐	☐Yes ☐No
____________________________			
2. Will there be an effect to any unique or unusual land forms found on the site?(i.e., cliffs, dunes, geological formations, etc.) ☐Yes ☐No			
• Specific land forms:____________________	☐	☐	
____________________________			

IMPACT ON WATER

	1 Small to Moderate Impact	2 Potential Large Impact	3 Can Impact be Mitigated By Project Change
3. Will proposed action affect any water body designated as protected? (Under Articles 15, 24, 25 of the Environmental Conservation Law, ECL) ☐Yes ☐No			☐Yes ☐No
Examples that would apply to column 2			
• Developable area of site contains a protected water body.	☐	☐	☐Yes ☐No
• Dredging more than 100 cubic yards of material from channel of a protected stream.	☐	☐	☐Yes ☐No
• Extension of utility distribution facilities through a protected water body.	☐	☐	☐Yes ☐No
• Construction in a designated freshwater or tidal wetland.	☐	☐	☐Yes ☐No
• Other impacts:____	☐	☐	
4. Will proposed action affect any non-protected existing or new body of water? ☐Yes☐No			☐Yes ☐No
Examples that would apply to column 2	☐	☐	
• A 10% increase or decrease in the surface area of any body of water or more than a 10-acre increase or decrease.	☐	☐	☐Yes ☐No
• Construction of a body of water that exceeds 10 acres of surface area.	☐	☐	☐Yes ☐No
• Other impacts:____			
5. Will Proposed Action affect surface or groundwater quality or quantity? ☐Yes ☐No			☐Yes ☐No
Examples that would apply to column 2	☐	☐	☐Yes ☐No
• Proposed Action will require a discharge permit.	☐	☐	
• Proposed Action requires use of a source of water that does not have approval to serve proposed (project) action.	☐	☐	☐Yes ☐No
• Proposed Action requires water supply from wells with greater than 45 gallons per minute pumping capacity.			☐Yes ☐No
• Construction or operation causing any contamination of a water supply system.	☐	☐	☐Yes ☐No
• Proposed Action will adversely affect groundwater.	☐	☐	☐Yes ☐No
• Liquid effluent will be conveyed off the site to facilities, which presently do not exist or have inadequate capacity.	☐	☐	☐Yes ☐No
• Proposed Action would use water in excess of 20,000 gallons per day.	☐	☐	
• Proposed Action will likely cause siltation or other discharge into an existing body of water to the extent that there will be an obvious visual contrast to natural conditions.	☐	☐	☐Yes ☐No
• Proposed Action will require the storage of petroleum or chemical products greater than 1,100 gallons.	☐	☐	☐Yes ☐No
• Proposed Action will allow residential uses in areas without water and/or sewer services.	☐	☐	☐Yes ☐No
• Proposed Action locates commercial and/or industrial uses which may require new or expansion of existing waste treatment and/or storage facilities.	☐	☐	☐Yes ☐No
• Other impacts:____			☐Yes ☐No
6. Will proposed action alter drainage flow or patterns, or surface water runoff? ☐Yes ☐No	☐	☐	
Examples that would apply to column 2			
• Proposed Action would change flood water flows.			

	1 Small to Moderate Impact	2 Potential Large Impact	3 Can Impact Be Mitigated By Project Change
• Proposed Action may cause substantial erosion.	☐	☐	☐Yes ☐No
• Proposed Action is incompatible with existing drainage patterns.	☐	☐	☐Yes ☐No
• Proposed Action will allow development in a designated floodway.	☐	☐	☐Yes ☐No
• Other impacts:______________________________	☐	☐	☐Yes ☐No

IMPACT ON AIR

7. Will proposed action affect air quality? ☐Yes ☐No

Examples that would apply to column 2

	1	2	3
• Proposed Action will induce 1,000 or more vehicle trips in any given hour.	☐	☐	☐Yes ☐No
• Proposed Action will result in the incineration of more than 1 ton of refuse per hour.	☐	☐	☐Yes ☐No
• Emission rate of total contaminants will exceed 5 lbs. per hour or a heat source producing more than 10 million BTU's per hour.	☐	☐	☐Yes ☐No
• Proposed action will allow an increase in the amount of land committed to industrial use.	☐	☐	☐Yes ☐No
• Proposed Action will allow an increase in the density of industrial development within existing industrial areas.	☐	☐	☐Yes ☐No
• Other impacts:______________________________	☐	☐	☐Yes ☐No

IMPACT ON PLANTS AND ANIMALS

8. Will Proposed Action affect any threatened or endangered species? ☐Yes ☐No

Examples that would apply to column 2

	1	2	3
	☐	☐	☐Yes ☐No
• Reduction of one or more species listed on the New York or Federal list, using the site, over or near site, or found on the site.	☐	☐	☐Yes ☐No
• Removal of any portion of a critical or significant wildlife habitat.	☐	☐	☐Yes ☐No
• Application of pesticide or herbicide more than twice a year, other than for agricultural purposes.	☐	☐	☐Yes ☐No
• Other impacts:______________________________			

9. Will Proposed Action substantially affect non-threatened or non-endangered species? ☐Yes☐No

Examples that would apply to column 2

	1	2	3
• Proposed Action would substantially interfere with any resident or migratory fish, shellfish or wildlife species.	☐	☐	☐Yes ☐No
• Proposed Action requires the removal of more than 10 acres of mature forest (over 100 years of age) or other locally important vegetation.	☐	☐	☐Yes ☐No

IMPACT ON AGRICULTURAL LAND RESOURCES

10. Will the Proposed Action affect agricultural land resources? ☐Yes ☐No

Examples that would apply to column 2

	1	2	3
• The proposed action would sever, cross or limit access to agricultural land (includes cropland, hayfields, pasture, vineyard, orchard, etc.)	☐	☐	☐Yes ☐No

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Vice Presidents
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March 31, 2011
File: 2499.4

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 Podniesinsk
Chief, Resource Development Section
Bureau of Resource Management & Development

Subject: Annual Report Review - 2010
Cayuga Mine, Cargill, Inc.
Seneca and Tompkins Counties, New York

Gentlemen:

On December 30, 2010, Mr. Matthew Podniesinski, Chief, Resource Development Section, Bureau of Resource Management & Development, Division of Mineral Resources, New York State Department of Environmental Conservation (NYSDEC), received the Annual Report[1] from Cargill Deicing Technology (Cargill). John T. Boyd Company (BOYD) received a letter[2] from Mr. David Plumeau on January 31, 2011. Supporting information for this Annual Report on CD was received on February 3, 2011. This CD included electronic copies of maps as AutoCAD® files,

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[1] Cargill Deicing Technology, 2009, "Annual Report for Mine File #709-3-29-0052; Cayuga Salt Mine, Permit ID#0-9999-00075-00001, Towns of Lansing and Ulysses, County of Tompkins, Town of Covert, County of Seneca," from Russell Givens to Matthew Podniesinski of NY Bureau of Resource Development Section.

[2] Plumeau, David, 2010, untitled letter to Vincent A. Scovazzo, John T. Boyd Company, January 29.

extensometer and closure readings, and consultant reports from Rock Mechanics Assist (RMA)[3,4], RESPEC[5,6,7].

On February 15, 2006, Mr. Steven M. Potter, Director, Bureau of Resource Management & Development of the 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 documents were reviewed for their adherence to conditions of the Permit[8] and in regard to discussions held at the Cayuga Mine among NYSDEC, Cargill, and BOYD on September 18, 2010. The Cargill 2010 Annual Report is accepted; however, the report did not include the following maps:

- Cargill Deicing Technology, 2008, "Cayuga Mine Closure (Inches) Sep-2009," showing closure of the 6 Level as file; "Cayuga Mine Contour2009 Closure Sep-2009."
- Cargill Deicing Technology, 2008, "Cayuga Mine Closure Rate (Inches/Year) Sep 2009," showing closure of the 6 Level as file; "Cayuga Mine Contour2009 Rate Sep-2009."

Discussion of Annual Report

The Annual Report submitted by Cargill is in response to special conditions 7 through 13 of Permit Number 0-9999-0075/00001. These special conditions and Cargill's responses are summarized below:

Special Condition 7—requires Cargill to submit an Annual Report, which is required to include items "a" through "g" of Special Condition 7.

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[3] Rock Mechanics Assist, 2010, an untitled letter from Gary Petersen to Dave Plumeau of Cargill Deicing Technology, August 24.

[4] Rock Mechanics Assist, 2010, an untitled letter from Gary Petersen to Dave Plumeau of Cargill Deicing Technology, April 17.

[5] RESPEC Engineering, 2010, "Additional Results of the 2006 Cayuga Mine Stability Assessment For Mohr-Coulomb Factor of Safety in the Nonsalt Beds," from Kerry L. DeVries to David Plumeau, December 23.

[6] RESPEC Engineering, 2011, "Task 2: Revised Geomechanical Study of Asymmetric Mains at Cayuga Mine," External Memoranda from Marc C. Loken to David Plumeau, January 14.

[7] RESPEC Engineering, 2011, "Task 3: Revised Northern Reserves Mine Design Analysis," External Memoranda from Marc C. Loken to David Plumeau, January 14.

[8] New York State Department of Environmental Conservation, Division of Environmental Permits, Region 7, 2003, "Permit" DEC Permit # 0-9999-00075/00001, expiration December 31, 2007, January 6.

Special Condition 7.a.—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 1 §13.a.1. dated December 29, 2010.

Special Condition 7.b.—requires "A summary of all non-routine mining incidents as defined in Special Condition 8. ..." Special Condition 8 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." Special Condition 9 expands on Special Condition 8 by requiring Cargill to submit "all correspondence with the Mine Safety and Health Administration involving non-routine mining incidents...". 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 1, Section 13.a.2 that "[t]he Cayuga Mine is not aware of any non-routine incidents ..." that would affect mine stability, ground and surface water, natural resources, and the general pubic. Noting that "[o]n occasion ... rock structures ... delay or hinder our mining plan" and it " ... continues to encounter a rock formation when mining to the east from the southern development (E-6 and E-7)."

RESPEC[5] addressed the mine stability below this anomaly by reviewing their previous work completed in 2006[9], which assessed thin or eroded carbonate layers. The conclusion was that the shale below the 4A Salt will fail and that the Bertie Formation potential for failure will increase as mining progresses north. BOYD notes that the non-salt beds were modeled as Mohr-Coulomb. However, strength of rock under confinement would not be linear resulting in the approach to failure being more plastic. Shale under these conditions would have a tendency to deform before failure. Thus, in BOYD's view, this was a conservative assessment.

RESPEC[6] addressed the placement of the mains below the anomaly. Two scenarios were examined: to have the mains 2,100 ft off panel center or 3,850 ft off center. RESPEC concluded that both scenarios resulted in similar behavior but the second scenario resulted in less closure and subsidence.

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[9] DeVries, K.L., P.E. Nelson, L.L. Sambeek, and W.M. Goodman, 2007, "Mine Stability Assessment, Cargill Deicing Technology, Cayuga Mine," RSI-1913, RESPEC, for Cargill Deicing Technology.

RESPEC[7] also addressed four panel configurations:

1. Yield pillars in a 500-ft-wide panel and 300-ft barriers,
2. Yield pillars in 300-ft-wide panel and 500-ft barriers,
3. Conventional pillars with a barrier, and
4. Conventional pillars without a barrier.

RESPEC recommended configuration 4 because it increases the strength of the area due to reduced extraction percentage, less closure, and greater stability of non-salt layers. The selection of configuration 4 over 3 was based on increased recovery. BOYD considers not having barriers as poor practice, as barriers offer protection for the rest of the mine in case wide-spread pillar failures occur.

RMA[3] addresses the anomaly by looking at the thinning carbonate area within three panels: U56, U58, and U60. RMA notes, "In summary there is no indication from the panel closure measurements that the area of interest has greater closure due to a weaker bridging beam." However, BOYD views the RMA data as proving the opposite, even when considering the effects of three-entry breakthroughs.

Part of this consideration is that the ESG Canada micro-seismic data points to movement in the thinning carbonate area. BOYD's present view of mining below the thinning carbonate is that Cargill should proceed using the RESPEC recommendations but incorporate barrier pillars. The stability of the area is not guaranteed, but with the constant monitoring of conditions using closure and micro-seismic monitoring, Cargill and its consultant should be able to ascertain developing adverse conditions.

Special Condition 7.c.—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.

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.dwg, which was created on January 27, 2011 and includes a map entitled "Cayuga Mine, 6 Level Workings," by Cargill Deicing Technology. Also included on this map are roof and floor rolls as of December 31, 2010. Other maps provided are:

- The AutoCAD file; Complete Mine Overlay w Surface Subsidence.dwg, created January 27, 2011, containing Cargill Deicing Technology, 2009, "Complete Mine Overlay Map, Cayuga Mine, 6 Level Workings," which shows subsidence monument locations, shore line, and the 6 Level.

- The AutoCAD file; 3 YR MINE PLAN 10-11 2 north - 2 south (updated12-21-10md).dwg, created January 27, 2011, containing the map Cargill Deicing Technology, 2010, "Cayuga Mine, 3 YR Planning Map, 2010/2011 Fiscal Yr." This map shows planned expansion through fiscal year 2013–2014.

- The AutoCAD file; ROYALTY.dwg, created January 27, 2011, containing the map Cargill Deicing Technology, 2011, "Cayuga Mine, Mine Royalty Map, 2010/2011 Fiscal Yr." January. Map shows fiscal year production areas from 6/1/84 through 12/31/10.

- The AutoCAD file; U-40B backfill.DWG, created January 27, 2011, containing the map "Backfill Map – U40B." Map shows filled area and areas "to be filled next" for U40, U40A, U42, U44W, U44E, and U46W.

- The AutoCAD file; 4 Level Pond Map MLRP Version 22Dec10.Dwg, created January 27, 2011, containing the map Cargill Deicing Technology, 2011, "Cayuga Mine, 4 Level Pond Map, Updated: 22 Dec 2010," January. This map shows filled levels to January 1, 2011, and remaining potential pond area.

- AutoCAD file; 4 Level Convergence Map.dwg, created January 27, 2011. This untitled and undated map shows closure station locations.

- The AutoCAD file; 4A Level for JT Boyd.dwg, created January 27, 2011, containing undated, "4A Level Instrumentation Map." This map shows closure stations locations.

- The AutoCAD file; W1 1 Tunnel 8 Door Insp to JT Boyd.dwg, created January 27, 2011, containing undated and untitled map. This map shows extensometer locations.

- The AutoCAD file; 20 Belt Area.dwg, created January 27, 2011, containing undated map "B-20 Belt Drift Mined in 1984." This map shows extensometer locations.

- A hard copy map; undated and untitled, scale 1" = 50' and AutoCAD file; PAMELPASS.DWG, created January 27, 2011, contains the map "4 Level, Pamel Pass – 13 Belt." Map shows locations of extensometers along 13 belt.

- An untitled AutoCAD file; Screen Plant Horizontal Roof Ext.dwg, created January 26, 2011, 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, created January 27, 2011, containing map undated, "Unit # 5 Screenplant," showing instrument locations in and around the screen plant gallery.

- The AutoCAD file; U31 Powder Mag 2009.dwg, created January 27, 2011, containing map undated, an untitled and undated map showing instrument locations in and around the powder magazine.

- The AutoCAD file; undated, "Current Surge Bin Instrumentation Map as of 9-09" and AutoCAD file; Surge Bin instrument Map to JT Boyd.dwg, created January 27, 2011, 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 w-Basemap Outline 2010.dwg, created January 27, 2011, containing the Map Cargill Deicing Technology, undated, "Cayuga Mine, 6 Level Workings." This map shows the locations of convergence stations.

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, and instrument locations and movements. However, maps illustrating recorded mine closure for the reporting period were not provided. Similar type maps received in the past were:

- Cargill Deicing Technology, 2008, "Cayuga Mine Closure (Inches) Sep-2009," showing closure of the 6 Level as file; "Cayuga Mine Contour2009 Closure Sep-2009."

- Cargill Deicing Technology, 2008, "Cayuga Mine Closure Rate (Inches/Year) Sep-2009," showing closure of the 6 Level as file; "Cayuga Mine Contour2009 Rate Sep-2009."

Special Condition 7.d.—requires the annual report to include a "summary of in situ measurements of rock mechanics required by Special Conditions 12." Special Condition 12 requires the measurement and collection of in situ rock mechanics data "in accordance with the approved Mined Land Use Plan." The data is 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 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.

In BOYD's review of the closure stations readings for 2010, it was noted that none of the readings exceeded 230 in. per year. Below is a list of the 10 highest measured closure rates in 2010 for areas of recent mining defined as areas within 1,000 ft of mining that occurred in 2009 or 2010.

Top 10 Closure Rates in Areas of Recent Mining

Closure Station	Rate of Closure (in./yr)	Last Recorded Rate of Closure (in./yr)	Notes
U58PIN#37	98.55	2.50	Initial Reading
U60PIN#17	86.51	12.71	Initial Reading
S3PIN#56	82.49	11.68	Initial Reading
U58PIN#35	73.05	9.65	Initial Reading
U60PIN#19	69.97	8.03	Initial Reading
U58PIN#38	68.05	0.82	Initial Reading
S3PIN#52	65.88	6.24	Initial Reading
S3PIN#55	63.60	17.10	Third Reading
S3PIN#57	62.85	7.93	Initial Reading
E5PIN#8	62.51	0.67	Initial Reading

Also determined are the top 10 closure rates away from mining.

Top 10 Closure Rates Away from Recent Mining

Closure Station	Rate of Closure (in./yr)	Last Recorded Rate of Closure (in./yr)	Notes
U12PIN#101	11.50	0.51	Reset, installed permanent rod
U12PIN#32	1.88	1.16	Installed permanent rod
U54PIN#17	1.87	0.52	Installed permanent rod
NW2PIN#38	1.77	1.14	
U59PIN#5	1.69	0.48	Installed permanent rod
W1PIN#7A	1.62	0.48	Installed permanent rod
NW2PIN#37	1.56	0.91	Gauge stuck, installed permanent rod
U54PIN#5A	1.53	0.37	Installed permanent rod
U54EPIN#5	1.50	0.38	Installed permanent rod
NW2PIN#33	1.49	error	Reset rod

Many of the readings in the list are the resultof the introduction of error due to installing permanent rods or by the instrument's involvement with a mishap. Closure rates throughout the mine are slow. This indicates the mine's global stability. In the past, the closure rates at U-40B panel (the fill area) were considered separately from the top 10 readings since it is being filled due to instability. However, the closure rates in this area are now less than any rate noted in the top 10, showing that this area is now stabilizing. Cargill also notes this occurrence in the Annual Report (Section 13.a.4); "Since backfill placement in the U40B area has been completed the convergence rates have slowed and are trending back toward historical rates." RMA[4] also noted this event: "Closure rates in the U40B area are on the decline... . Notice that the rates began to increase in 2007, peaked in 2008, and are now decreasing."

Cargill also noted in Section13.a.4, "The U-12 panel also shows higher than normal closure near the breakthrough with SW-2 and near the U-12A sub-panel." Only two of these readings are included in the list of 10 highest readings and both of those show a decreasing trend. This may indicate that stability is improving in this area. RMA[4] also notes this: "There are two areas in Panel 12 which are showing higher than expected closure rates ... . Both areas involve intersecting panels at U12/SW2 and U12/U12A."

Two closure stations were monitored on 4 Level and have closure rates of 0.255 to 0.493 in. per year and three closure stations were monitored on 4A Level and ranged from 0.111 to 0.333 in. per year. BOYD offers the following comments:

- Closure readings for recently mined areas are typically high. The highest of these readings near active mining was concentrated in two production areas, with five in the U58 and U60 area and five in the S3 and E5 area. All of the 10 stations show dramatic reduction over time, indicating the ground is stable or is stabilizing.

- Seven of the ten highest closure rates away from active mining were concentrated in the U54 and U59 intersection with NW54. Two were located in U12.

Extensometer data was also evaluated and a top 10 list was developed based on expansion rate of the third Rod. A measurement of 1 in. per year is often accepted as a convenient point in examining extensometer data, as this value is close to, but normally less than, the value required for bed separation (opening of bedding planes). Thus, none of the extensometer readings were alarming.

Top 10 Extensometer Rates

Extensometer Location	Station	Rod 1, in/yr	Rod 2, in/yr	Rod 3, in/yr
Sreen Plant Pillar	SP-H Pillar-Ahole-1tun	0.110	0.183	0.329
Sreen Plant Pillar	SP-G Pillar-Bhole-1tun	0.073	0.183	0.292
Sreen Plant Pillar	SP-H Pillar-Ahole-3tun	0.037	0.073	0.292
Sreen Plant Horizontal	SP HR - 4B	0.000	0.000	0.292
Roof	20 belt 7C	0.256	0.256	0.256
Sreen Plant Pillar	SP-J Pillar-Bhole-1tun	0.037	0.183	0.219
Sreen Plant Horizontal	SP HR - 4A	-0.037	0.000	0.219
Roof	20 belt 3C	0.219	0.219	0.183
Roof	Pamel Pass #5	0.110	0.146	0.146
Sreen Plant Pillar	SP-I Pillar-Bhole-1tun	0.037	0.146	0.146

In the 2009 Annual Report, Cargill noted that they have upgraded "...the microseismic monitoring system to digital format, doubled the number of geophones, and doubled the area being monitored." In the 2010 Annual Report, a series of reports as ESG Canada Inc., 2010, "Remote Data Processing Seismicity Report, Cayuga Mine," Kingston, Ontario, included:

- January 1st – 31st, March 22.
- February 1st – 28th, March 26.
- March 1st – 31st, April 1.
- April 1st – 30th, May 10.
- May 1st – 31st June 1.
- June 1st – 30th, July 2.
- July 1st – 31st August 6.
- August 1st – 31st, September 27.
- September 1st – 30th, October 26.

- October 1st – 31st, November 4.
- November 1st – 30th, December 6.
- December 1st – 30th, January 10, 2011.

A brief overview of these reports shows that seismic events favor areas west of the mains, production areas, and areas of thinning rock in the northern part of the mine. A discussion with Cargill on the significance and use of this data is needed.

Special Condition 7.e.—requires the Annual Report include a "summary of subsidence monitoring data required by Special Condition 11." Special Condition 11 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 Special Condition 7.e. were agreed upon at the August 2004 meeting and are noted above under Special Condition 7.d.

BOYD, in its 2007 annual review, examined the last presented subsidence data discussed in the 2008 Annual Report. These measurements were completed in December 2007, concluding that this data supported an option that the mine is stable.

Section 13.a.5 of the Annual Report noted that "[n]o subsidence surveys were conducted this year."

Special Condition 7.f.—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 4 Level would be included in the Annual Report, noting: "Updates of Level 4 filling including data on shore line advance."

Cargill reported the total water inflow to 4 Level was 8,894,769 gallons, down from 10,401,624 gallons in 2010, the fifth year of decline. With this lower inflow, Cargill estimates that 21.1 years of storage remain on 4 Level. Cargill included a 4 Level pond map, as noted above, and an Excel file, UG Pond Volume Calculation 22Dec10.xls, which was created on December 28, 2010.

Special Condition 7.g.—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."

SPDES data and a discussion of this data are included in the Annual Report. This data is to be reviewed by NYSDEC.

Special Condition 8—addresses non-routine incidents and is discussed under Special Condition 7.b.

Special Condition 9—addresses Mine Safety and Health Administration reporting involving non-routine mining incidents and is discussed under Special Condition 7.b. Cargill includes a statement on section 13.c. of the Annual Report that "[t]he Cayuga Mine has not received any citations from MSHA regarding non-routine mining incidence, but does not note reports or letters from MSHA concerning any non-routine mining incidents."

Special Condition 10—addresses reporting requirements "Prior to undertaking any material change in the approved mining methods or techniques. ..." This condition does not require the reporting to occur in the Annual Report.

Cargill notes, "There have been no changes to the Cayuga Mine layout in the past year."

Special Condition 11—addresses subsidence monitoring, as discussed under Special Condition 7.e. above.

Special Condition 12—addresses rock mechanics monitoring, as discussed under Special Condition 7.d.

Special Condition 13—addresses the reporting and recording of citizen complaints. Cargill notes in the Annual Report that "no written citizen complaints" were received.

Site Visit

A site visit to discuss these findings with NYSDEC, Cargill, and BOYD should be arranged. Suggested areas to visit in the mine are intersections at U12/SW2 and U12/U12A.

Discussions at this meeting should include a brief overview of the seismic reports and the significance and use of this data.

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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March 8, 2012
File: 2499.4

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 - 2011
Cayuga Mine, Cargill, Inc.
Seneca and Tompkins Counties, New York

Gentlemen:

On December 30, 2011, Mr. Matthew Podniesinski, Chief, Resource Development Section, Bureau of Resource Management & Development, Division of Mineral Resources, New York State Department of Environmental Conservation (NYSDEC), received the Annual Report[1] from Cargill Deicing Technology (Cargill). John T. Boyd Company (BOYD) received a letter[2] and CD from Mr. David Plumeau on February 11, 2011. This CD included electronic copies of maps as AutoCAD® files, extensometer and closure readings, and consultant reports from Rock Mechanics Assist (RMA)[3,4,5], RESPEC[6,7,8,9] and Itasca[10].

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[1] Cargill Deicing Technology, 2011, "Annual Report for Mine File #709-3-29-0052; Cayuga Salt Mine, Permit ID#0-9999-00075-00001," from Russell Givens to Matthew Podniesinski of NY Bureau of Resource Development Section, December 27.

[2] Plumeau, David, 2012, untitled letter to Vincent A. Scovazzo, John T. Boyd Company, January 28.

[3] Rock Mechanics Assist, 2011, an untitled Draft Report from Gary Petersen to Dave Plumeau of Cargill Deicing Technology, July 29.

[4] Rock Mechanics Assist, 2011, an untitled letter from Gary Petersen to Dave Plumeau of Cargill Deicing Technology, April 29.

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

The documents were reviewed for their adherence to conditions of the Permit[11] and in regard to discussions held at the Cayuga Mine among NYSDEC, Cargill, and BOYD on September 15, 2011. The Cargill 2011 Annual Report is accepted; however, the report does not include the following maps as Mr. Plumeau[2] noted that these "... maps are not ready yet.":

- Cargill Deicing Technology, 2008, "Cayuga Mine Closure (Inches) Sep-2009," showing closure of the 6 Level as file; "Cayuga Mine Contour 2009 Closure September 2009."

- Cargill Deicing Technology, 2008, "Cayuga Mine Closure Rate (Inches/Year) Sep 2009," showing closure of the 6 Level as file; "Cayuga Mine Contour 2009 Rate September 2009."

Also, no information was included on the subsidence survey of the west shore of Cayuga Lake performed in 2011. It is BOYD's understanding that this data is being evaluated.

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[5]Rock Mechanics Assist, 2011, an untitled letter from Gary Petersen to Dave Plumeau of Cargill Deicing Technology, September 23.

[6]RESPEC Engineering, 2011, "Draft – Carbonates Bedrock Strength Reduction Modeling at the Cayuga Mine," Topical Report RSI-2204 by Marc C. Loken and Sam J. Voegeli for Cargill Deiciing Technology, August.

[7]RESPEC Engineering, 2011, Untitled letter by Kerry L DeVries to Russ Givens of Cargill Salt, Project File 1803, August 4.

[8]RESPEC Engineering, 2011, "Task 2: Revised Geomechanical Study of Asymmetric Mains at Cayuga Mine," External Memoranda from Marc C. Loken to David Plumeau of Cargill Deicing Technology, January 14. (Previously Reviewed)

[9]RESPEC Engineering, 2011, "Task 3: Revised Northern Reserves Mine Design Analysis," External Memoranda from Marc C. Loken to David Plumeau, January 14. (Previously Reviewed)

[10]ITASCA Consulting Canada, Inc., 2011, "Microseismicity Update for Sept. 2010 thru Feb. 2011, Cargill's Cayuga Mine," March.

[11]New York State Department of Environmental Conservation, Region 7, 2007, "Permit" DEC ID 0-9999-00075, expiration December 31, 2012, December 31.

Discussion of Annual Report

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

Condition 4—Requires all reports required by the permit to be submitted to Region 7.

Condition 10.a.—Requires investigation into the disturbed salt zone and this investigation to be completed and submitted before mining proceeds into the area.

Condition 13.a.—Requires the Annual Report submitted by Cargill and response to 13.a. sub-conditions 1 through 8 and Condition 13.b through g. These conditions and Cargill's responses are summarized below:

Condition 13.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 13.a.1 which was signed by Mr. Givens, Mine Manager, on December 28, 2011. This certification notes "... that all mining activities, to the best of my knowledge, conducted during the reporting period from January 1, 2011 to present were in conformance with the DEC Permit ..."

Condition 13.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 13.a.2 that "[t]he Cayuga Mine is not aware of any non-routine incidents "... that would affect mine stability, ground and surface water, natural resources, and the general pubic. Noting that "[o]n occasion ... rock structures ... delay or hinder our mining plan." and "The Cayuga Mine continues to encounter a rock formation when mining to the east from the southern development (E-8 and E-9)." And "... mining has been temporarily suspended in the southern workings pending evaluation of atypical microseismic noises heard there during July." However, RMA[4] reports on this non-routine mining incident that resulted in Gary Petersen's mine visit on July 28, 2011, noting "The visit was prompted by more than usual "pops" heard in the S3 area ... at about 5:30 a.m. on July 15th" These pops were heard about one to two minutes apart. Twenty-four pops were noted. Cargill decided to vacate the area and mining was suspended in the south. RMA speculates that "One likely reason for the unusual number of pops in S3 is mining is causing movement along the pre-existing fault lines." or "Another reason for the numerous pops could be because there is an active seismic linear similar to the northern linears over this area." (See seismicity discussion under Condition 13.a.4.) "Or possibly the intersection of these two features could be the reason for so much seismic activity."

RMA notes that "The worst situation would be re-activating the fault lines which might cause them to become conduits of fresh water from the lake sediments into the mine." Which, according to RMA, may require a "massive concrete bulkhead." "The second worst scenario would be if the closure rates begin to increase in the area it would require it to be backfilled ... The third worst scenario would be if the area remains seismically active and Cargill decides not to risk a Scenario 1 or 2 and permanently abandons the S3 area." RMA recommends microseismic monitoring of this area. These conditions should be discussed further between Cargill, NYDEC, and BOYD at the upcoming site meeting.

RESPEC[7] also addressed these 'pops' noting that the southern area of the mine is typically quiet. RESPEC recommended increasing the frequency of the closure measurements to biweekly at the mine face and monthly for stations beyond two or three entries away from the faces. Also, moisture sampling is recommended to alert Cargill of water bearing structures.

If measurements show that closure rates are accelerating, abnormal microseismic events are occurring, or moisture content of the salt is high, mining should be stopped and a reassessment of mine stability is warranted.

RESPEC notes that "If the microseismic and closure data produce favorable results during the next 2 months (i.e., seismicity is relatively low and located hundreds of feet above the mine back and the closure rates are decreasing at a normal rate based on historical measurements) ..." mining can resume in the south.

RESPEC[7] addressed mining in the vicinity where "... evidence suggests that the carbonate layer may have undergone thinning above the Northern Reserves because of lake scouring." And RESPEC modeling "...suggested that modifications to the mine design may be warranted under this 'zone of thinning carbonate' to maintain its stability."

The carbonate rock is typically 300 ft thick but in this eroded zone likely is fractured with the possibility of formation collapse due to the removal of salt beneath the carbonates.

To address this problem, RESPEC numerically modeled these conditions using a three-dimensional, finite difference code FLAC3D[12] and considered the effects of in situ stress, of reduced shale's modulus, and of reduced carbonate strength. RESPEC also examined the effect of sequential excavation.

The effects of in situ stress were previously modeled by using the stress field in the salt derived from overburden load with no time adjustment. Allowing the stress field within the salt to adjust before the model is run addresses the salts inability to maintain shear. These two models showed a difference over the short term but the difference diminishes over time as a result of salt creep. RESPEC concluded that "the inhomogeneous nature of the in situ stress state within the salt does not significantly affect the long-term creep solutions."

Models were also completed with the shale moduli reduced by 0%, 50%, 75%, and 90%. When closure within the panel is compared from models with 0% adjustment to decreased modulus of 50% and 90%, closure increased by 50% and then 300%. These results indicate that the assumed shale stiffness significantly affects panel closure.

The structural stability of the carbonates bedrock was assessed using laboratory determined parameters for the Mohr-Coulomb failure criterion. The cohesion and friction angle were reduced by 50% and 75% in the models. The models showed a 75% reduction in carbonate bedrock shear safety factor to a minimum "... greater than 1.4 through 100 years, indicating that the formation should remain structurally stable."

In addition, the panel was modeled in one-month and two-month mine advances with the panel being completed in one year. The models showed the long-term stability of the carbonates bedrock is independent of how mining is modeled. Interestingly, the models showed "... that the structural integrity of the carbonates bedrock increases at all locations ahead of the mining face and decreases above any portions of the mined panel." RESPEC recommended a stand-off distance from the 'zone of thinning carbonate' of 500 ft."

[12] Itasca Consulting Group, Inc., 2009, "FLAC3D Version 4.0".

Mr. Plumeau[2] notes that "The microseismic data has been processed by ESG Canada Inc. (ESG) and the results have been analyzed by Itasca Consulting Canada." (ITASCA)[10] slide presentation of this analysis was reviewed. Of interest is ITASCA's Global Observations:

- "The events continue to locate along the linear features (in an XY plane), but new patterns related to the improved vertical location of the events have emerged:
  - The majority of the events are concentrating in the stiffer units (Sandstones, Dolomites, and Limestones) which are located > 700 ft above the mine and in the layers directly beneath the lake sediments; - 64% of the 3031 events are occurring in the Heldeberg (Limestones) formation.
  - Large events seem to be locating more consistently, i.e., re-occurring set of events on the Syracuse/Camillus contact.
  - Complete absence of events in the Syracuse/Salina (Salts and Dolomites), however, we are not sure if this is real or simply a system limitation (very small events in salt cannot be detected by the current system).
- As previously observed, activity increases (rate/magnitude) as mining approaches the planar features, and tends to continue to be active after mining has traversed the planar features, albeit at lower rates/magnitudes.
- Seismic parameters (Es/Ep and Moment Magnitude), along with the diurnal analyses (time of day), tend to suggest the events are related to slip along structures or contacts.
- As with previous analyses, one cluster (NW) is coincident with nearby mining, whereas the second cluster (SE) continues to be seismically active, with no accompanying mining nearby."

Condition 13.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 13.a.3 that "The Cayuga Mine is currently operating in the northern region of the mine. The mining is located in panels U-60 and U-62 to the west and U-63 and U-65 (NW-3) to the east. Upon completion of U-60 mining will be started in U-67. The U-65 panel has turned to the Northwest and is now the NW-3 main development. This unit will be pushed north to open up future mining panels."

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.dwg, which was created on January 31, 2012 and includes a map entitled "Cayuga Mine, 6 Level Workings," by Cargill Deicing Technology. Also included on this map are roof and floor rolls as of December 31, 2011. Other maps provided are:

- The AutoCAD file: Complete Mine Overlay w Surface Subsidence.dwg, created January 30, 2012, containing Cargill Deicing Technology, undated, "Complete Mine Overlay Map, Cayuga Mine, 6 Level Workings," which shows subsidence monument locations, shore line, and the 6 Level workings.

- The AutoCAD file: ROYALTY.dwg, created January 24, 2012, containing the map Cargill Deicing Technology, 2012, "Cayuga Mine, Mine Royalty Map, 2011/2012 Fiscal Yr." January. Map shows fiscal year production areas from June 1, 1964 through December 31, 2011.

- The AutoCAD file: U40A Dust fill map.dwg, created January 30, 2012, containing an untitled map dated December 9, 2011 shows areas filled and to be filled for U-40, U-40A, and U-40B.

- The AutoCAD file: U38-U36 Dust fill map.dwg, created January 30, 2012, containing an untitled undated map shows areas filled and to be filled for U-38.

- The AutoCAD file: Basemap planning for MLRP.dwg, created January 31, 2012, containing the map Cargill Deicing Technology, 2011, "Cayuga Mine, 3 YR Mine Plan, 2011/2012 Fiscal Yr." This map shows planned expansion through fiscal year 2014 to 2015.

- The AutoCAD file: 4 Level Pond Map MLRP Version 28Nov11.Dwg, created December 21, 2011, containing the map Cargill Deicing Technology, 2012, "Cayuga Mine, 4 Level Pond Map, Updated: 28 Nov 2011," January. This map shows filled levels to January 1, 2012, and remaining potential pond area.

- AutoCAD file: 4 Level Convergence Map.dwg, created January 27, 2011. This untitled and undated map shows closure station locations.

- The AutoCAD file: 4A Level for JT Boyd.dwg, created January 27, 2011, containing undated, "4A Level Instrumentation Map." This map shows closure stations locations.

- The AutoCAD file: W1 1 Tunnel 8 Door Insp to JT Boyd.dwg, created January 31, 2012, containing undated and untitled map. This map shows extensometer locations.

- The AutoCAD file: 20 Belt Area.dwg, created January 12, 2012, containing undated map "B-20 Belt Drift Mined in 1984." This map shows extensometer locations.

- A hard copy map: undated and untitled, scale 1 in. = 50 ft and AutoCAD file; PAMELPASS.DWG, created January 31, 2012, contains the map "4 Level, Pamel Pass – 13 Belt." Map shows locations of extensometers along 13 belts.

- An untitled AutoCAD file: Screen Plant Horizontal Roof Ext.dwg, created January 31, 2012, 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, created January 31, 2012, containing map undated, "Unit # 5 Screenplant," showing instrument locations in and around the screen plant gallery.

- The AutoCAD file: U31 Powder Mag 2009.dwg, created January 31, 2012, containing map undated, an untitled and undated map showing instrument locations in and around the powder magazine.

- The AutoCAD file: undated, "Current Surge Bin Instrumentation Map as of 9-09" and AutoCAD file: Surge Bin instrument Map to JT Boyd.dwg, created January 31, 2012, 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 w-Basemap Outline 2010.dwg, created January 30, 2012,, containing the Map Cargill Deicing Technology, undated, "Cayuga Mine, 6 Level Workings, Convergence Stations," This map shows the locations of convergence stations.

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, and instrument locations and movements. However, maps illustrating recorded mine closure for the reporting period were not provided. Mr. Plumeau[2] noted that these "... maps are not ready yet." Similar type maps received in the past were:

- Cargill Deicing Technology, 2008, "Cayuga Mine Closure (Inches) Sep-2009," showing closure of the 6 Level as file; "Cayuga Mine Contour2009 Closure Sep-2009."

- Cargill Deicing Technology, 2008, "Cayuga Mine Closure Rate (Inches/Year) Sep-2009," showing closure of the 6 Level as file; "Cayuga Mine Contour2009 Rate Sep-2009."

Condition 13.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 is 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 page 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 U-12 areas. Since backfill placement in the U-40B 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."

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.

Mr. Plumeau[2] noted that "... all active stations are being read quarterly." It was also noted that, "Closure in the abandoned No. 6 level east workings was last read in October 2008 so that data is not included. It is unlikely that these stations will ever be read again due to deteriorating ground conditions."

BOYD's review of the closure stations readings for 2011, showed that none of the readings exceeded 230 in. per year. Below is a list of the 10 highest measured closure rates in 2011 for areas of recent mining defined as areas within 1,000 ft of mining that occurred in 2010 or 2011.

Top 10 Closure Rates in Areas of Recent Mining

Closure Station	Rate of Closure (in./yr)	Last Recorded Rate of Closure (in./yr)	Notes
Initial Rate	111.69	2.52	Initial Rate
Initial Rate	109.87	14.24	Initial Rate
Initial Rate	96.36	5.16	Initial Rate
Initial Rate	76.65	8.20	Initial Rate
Initial Rate	73.85	3.95	Initial Rate
Initial Rate	72.42	1.04	Initial Rate
Initial Rate	72.32	7.46	Second Rate
Initial Rate	72.17	2.46	Initial Rate
Initial Rate	71.81	2.48	Initial Rate
Initial Rate	70.81	10.34	Initial Rate

These rates are 9.45 in. per year higher than last year. All rates substantially dropped over time showing that the ground is stable or stabilizing. All 10 of these stations are located in the most northern parts of the mine with eight stations located in the same vicinity at the extent of U-60 and U-62. Also determined are the top 10 closure rates away from mining.

Top 10 Closure Rates Away from Recent Mining

Closure Station	Rate of Closure (in./yr)	Last Recorded Rate of Closure (in./yr)	Notes
U-56PIN#5	1.68	0.53	
NW-2PIN#29	1.47	0.47	
U-12PIN#28	1.37	1.26	
NW-2PIN#41	1.32	0.56	
U-12PIN#107	1.20	1.03	
U-12PIN#32	1.20	1.16	
2-B	1.12	0.98	Backfill Area
U-40BPIN#8	1.11	0.88	Backfill Area
S-3PIN#29	1.10	0.32	
U-40BPIN#14	1.01	0.81	Backfill Area

These rates are 1.4 per year less than last year's. All rates dropped over time showing that the ground is stable. These high rate stations are clustered in three areas, U-40B (three stations) and U-12 areas (three stations) near the U-12A sub-panel, which are areas noted as having high closure by Cargill, and three stations in or close to NW-2 between rooms N3 and S4. All three of these areas have been frequently visited in the past by BOYD and NYDEC to observe condition and each time the area appears globally stable.

Mr. Plumeau[2] notes that "The U-40B area convergence continues to trend in a positive fashion with decreasing rates. Backfilling in the U-40 and U-40A areas have been discontinued since the available space has been filled. Back filling has moved to U-38 at this time, and will continue there for the coming 6 – 8 years." In general the closure rates throughout the mine are slowing. This indicates the mine is global stability.

In discussing U-40B, RMA[4] also notes that "Currently the area shows signs of becoming more stable as suggested by the decreasing closure rates." RMA[4] also notes the high closure rates in U-12 and in another document, RMA summarizes closure history in U-12 "The rates (in U12) were in a decline as SW2 advanced away from the U12 until around 2008 when rates began to increase. There was an odd spike in the rates in early 2009 and then a fall off ..., then another increase in rate in the summer of 2009, which follows the humidity trend. Recently the rates have been steadily decreasing, which is encouraging to see. The rates in the U12/U12A intersection jumped in 2009 for no apparent reason ... stations showed that the increase is pretty much limited to the intersection of U12/U12A ... The rates appear to have peaked in 2010 and are now leveled off at just under 1.25 inches per year."

Two closure stations were monitored on 4 Level and have closure rates of 0.255 to 0.494 in. per year. Four closure stations were monitored on 4A Level and ranged from 0.111 to 0.333 in. per year. All rates from levels 4 and 4A are lower than last year.

Extensometer data was also evaluated. Extensometers were installed in various manners including vertically into the roof, at low angle (near horizontal) into the roof, and into pillars. In addition, Extensometers were installed in Levels 4 and 6. Thus, four populations exist but the number of samples for each population is too small to generate a high confidence statistic. This data is further complicated by the varying rod lengths between extensometers. Still BOYD attempted to ascertain anomalous expansion rate readings based on the mean plus one standard deviation.

Extensometer Anomalous Rates
(anomalous rates are highlighted)

Extensometer Location	Station	Rod 1, in/day	Rod 2, in/day	Rod 3, in/day
		Roof – Level 6		
B-20 Belt Drift	7C	0.0007	0.0007	0.0007
B-20 Belt Drift	3C	0.0005	0.0004	0.0005
		Roof Horizontal – Level ^		
Sreen Plant	1A	0.0001	0.0003	0.0003
Sreen Plant	4A	0.0000	0.0006	0.0001
	4B	0.0000	0.0000	0.0006
		Pillar – Level 6		
Sreen Plant	H Pillar, Hole A	0.0003	0.0004	0.0006
		Roof – Level 4		
Pamel Pass	#4	0.0003	0.0003	0.0003
Pamel Pass	#5	0.0003	0.0003	0.0003

A measurement of 0.0020 in. per day is often accepted as a convenient point in examining extensometer data, as this value is close to, but normally less than, the value required for bed separation (opening of bedding planes). Thus, none of the extensometer readings were alarming.

In the 2010 Annual Report, a series of reports as ESG, 2011, "Remote Data Processing Seismicity Report, Cayuga Mine," Kingston, Ontario, included:

- January 1 to January 31, February 7.
- February 1 to February 28, March 4.
- March 1 to March 31, April 6.
- April 1 to April 30, May 4.
- May 1 to May 31, June 3.
- June 1 to June 30, July 7.
- July 1 to July 31, August 10.
- August 1 to August 31, September 2.
- September 1 to September 30, November 2.
- October 1 to October 31, November 3.
- November 1 to November 30, December 9.
- December 1 to December 31, January 12, 2012.

These reports show that seismic events favoring a linear feature or features that extend south from U-58 to the furthest northern extent of U-40B. According to an undated slide presentation "Cayuga Mine Advanced Microseismic Analysis – Phase 3" by ESG, the seismic activities occur along coherent linearly planar zones with some features appearing to cut through each other. And that most events apparently occur at the shale-dolomite layer.

Condition 13.a.5.—requires the Annual Report include a "summary of subsidence monitoring data required by Part e. of this Special Condition." Condition 13.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 13.a.4.

Mr. Plumeau[2] notes that "Subsidence data has been taken along the west shore during December 2011 and is being analyzed at this time. The results will be sent to you when they are ready."

Cargill included a statement in the Annual Report page 3, Section 13.a.5 that "Plans are being made to conduct subsidence surveys of the east shore line in the 2012 calendar year. Past measurements indicate that the mine is behaving as expected with no anomalous subsidence zones."

BOYD, in its 2007 annual review, examined the last presented subsidence data discussed in the 2008 Annual Report. These measurements were completed in December 2007, concluding that this data supported an option that the mine is stable.

Section 13.a.5 of the Annual Report noted 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 2012 calendar year. Past measurements indicate that the mine is behaving as expected with no anomalous subsidence zones.."

Condition 13.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 4 Level would be included in the Annual Report, noting: "Updates of Level 4 filling including data on shore line advance."

Mr. Plumeau[2] notes that "Access to view the pond is not possible due to ground conditions. A pumping system is being installed to bring the production shaft water to the ED plant for processing. This will reduce 16 gpm of shaft water inflow to about 7 gpm (at higher concentration) for mine storage, further extending the life of the ponds. It will come on line when the shaft piping is installed.

Cargill included a statement in the Annual Report page 3, Section 13.a.6 that "The following is a list of sources and associated flow rates of water into the Cayuga Mine:

- Production Shaft (No. 1 shaft) – 16 gpm
- Ventilation Shaft (No. 2 shaft) – 4 gpm
- ED Plant Concentrate discharge – 7 gpm
- Total Water Inflow = 27 gpm

Cargill reported the total water inflow to 4 Level was 10,669,680 gallons, down from 8,894,769 gallons in 2010, the first increase in six years. With this lower inflow, Cargill estimates that 16.6 years of storage remain on 4 Level down from 2010 estimate of 21.1 years. Cargill included a 4 Level pond map, as noted above, and an Excel file, UG Pond Volume Calculation 28Nov11.xls, which was created on February 27, 2012.

Condition 13.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 13.a.7 that "There were two exceedances of the Chloride limit on outfall 001, in February and in July." And included a spreadsheet Outfall DMR Summary Dec 2010 - Nov 2011.xlsx created December 22, 2011 and includes information on outfall water quality including cyanide, chloride, zinc, total dissolved solids, and cooling and treatment water.

SPDES data and a discussion of this data are included in the Annual Report. This data is to be reviewed by NYSDEC.

Condition 13.c.—Addresses Mine Safety and Health Administration reporting involving non-routine mining incidents as defined in Condition 13.b. Condition 13.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 4 section 13.c. of the Annual Report that "[t]he Cayuga Mine has not received any citations from MSHA regarding non-routine mining incidence." The Annual Report does not note reports or letters from MSHA concerning any non-routine mining incidents.

Condition 13.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 section 13.d. of the Annual Report that, "There have been no changes to the Cayuga Mine layout in the past year."

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 "[o]ne written citizen complaint has been received by Cargill concerning the Cayuga Mine. Your office was notified of this complaint on December 12, and Cargill is investigating the concerns at this time. The complainant alleges that Cargill is mining beneath his property which is outside Cargill's mineral rights area. The nearest mining to the property in question was over 4,500 feet away and was abandoned before 1975."

Site Visit

A site visit to discuss these findings with NYSDEC, Cargill, and BOYD should be arranged. Suggested area to visit in the mine is U-60 between s2 and f4 to U-62 between j2 and x2.

Discussions at this meeting should include the 'pops' heard in the southern area of the mine. Also, clarification is needed in the reporting to the NYDEC of incidents when such events may be an indicator of global mine instability.

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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John T. Boyd Company

Mining and Geological Consultants

March 13, 2006
File: 2499.4

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. Steven M. Potter
Director

Subject: 2006 Annual Report Review
Cayuga Mine, Cargill, Inc.
Syracuse Formation
Seneca and Tompkins Counties, New York

Gentlemen:

John T. Boyd Company (BOYD) received a letter[1] and digital data from Cargill Deicing Technology (Cargill) on February 3, 2006 as a supplement to the 2006 Annual Report. The letter contained a supporting report from Rock Mechanics Assist[2]. On February 15, 2006, Mr. Steven M. Potter, Director, Bureau of Resource Management & Development of the New York State Department of Environmental Conservation (NYSDEC), requested that BOYD review the letter, digital data, and the Annual Report. The Annual Report[3] was received by BOYD on February 17, 2006.

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[1] Plumeau, David, 2006, untitled letter to Vincent A. Scovazzo, John T. Boyd Company, January 31.

[2] Rock Mechanics Assist, 2006, an untitled letter from Gary Petersen to David Plumeau of Cargill Deicing Technology, January 17.

[3] Cargill Deicing Technology, 2006, "Annual Report for Mine File #709-3-29-0052; Cayuga Salt Mine, Application ID# 0-9999-00075-00001," signed by Steve Horne, to Joseph Moskiewicz, NYS Department of Environmental Conservation, January 5.

These documents were reviewed for their adherence to conditions of the Permit[4] and in regard to discussions held at the Cayuga Mine among NYSDEC, Cargill, and BOYD on June 20, 2005.

Discussion of Annual Report

The Annual Report submitted by Cargill is in response to Special Conditions 7 through 13 of Permit Number 0-9999-0075/00001. These special conditions and Cargill's responses are summarized below:

Special Condition 7—requires Cargill to submit an Annual Report which is required to include items a through g of Special Condition 7.

Special Condition 7.a.—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 dated January 1, 2005, is included in the annual report and is signed by Steven J. Horne, Mine Manager – Cargill Deicing Technology.

Special Condition 7.b.—requires "A summary of all non-routine mining incidents as defined in Special Condition 8. ..." Special Condition 8 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 of property of the general public." Special Condition 9 expands on Special Condition 8 by requiring Cargill to submit "all correspondence with the Mine Safety and Health Administration involving non-routine mining incidents...." During a subsequent meeting held on August 17, 2004, between 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."

The Annual Report states that Cargill "...is not aware of non-routine incidents..." but goes on to say that "...weak rock in the immediate roof was encountered in the U52 mining panel and this panel was temporarily abandoned." Cargill, in their letter to BOYD[1] notes that 2 ft of the roof was removed "...to stable ground..." to control the instability.

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[4] New York State Department of Environmental Conservation, Division of Environmental Permits, Region 7, 2003, "Permit" DEC Permit # 0-9999-00075/00001, expiration December 31, 2007, January 6.

The Cargill letter to BOYD also notes that monitoring has shown that U40B is closing more rapidly than expected. To address this situation the following action is being taken:

- Backfill the area with waste salt.
- A 700 ft radius no-additional-mining zone has been established around U40B.
- An electronic closure monitoring system has been ordered that will collect data on an hourly basis.

To reduce the likelihood of this occurring again, Cargill will establish a 300 ft barrier between the main and panel and it will only be cut by 5 entries. Such barriers were previously requested by BOYD[5,6]. In addition, Cargill will limit the width of the stress notches to 32 ft.

Mr. Petersen[2] studied and reported on the conditions in the U40B area and concluded that "...the overlying rocks are weaker in this area..." although he does conclude that the "...the mine is globally stable."

Special Condition 7.c.—requires "An 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.

Mine maps in AutoCAD format were supplied by Cargill to fulfill this condition. They are:

- Cargill, 2005, "Cayuga Mine, Mine Planning Map, 2005/2006 Fiscal Yr." December as 3 YR MINE PLAN 05-06.dwg also included as hard copy in Attachment 1A, 1B, and 1C of the Annual report.
- Cargill, undated, "Cayuga Mine, 6 Level Workings," Not to Scale, as Royalty map.dwg.
- Cargill, undated, "Cayuga Mine 6 Level Working, Convergence Stations" as Complete Mine Overlay w_Surface Subsidence.dwg.
- Cargill, 2006, "Cayuga Mine, 4 Level Pond Map," January, as 4 Level Pond Map II.DWG.

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[5] John T. Boyd Company, 1995, "Review of RE/SPEC Inc. Report on the Stability of the Cargill Salt Cayuga Mine," prepared for NYS Department of Environmental Conservation, Report No. 2499.1, December.

[6] John T. Boyd Company, 1998, "Meeting of December 19, 1997, Cayuga Mine," letter to C.B. McGranahan of the NYS Department of Environmental Conservation, File No. 2499.2, January 5.

These maps show the extent of mining, proposed three-year mine plan, instrument locations, subsidence monument locations, and shorelines of both the 4 Level flooding and of Cayuga Lake. A short description of current and planned mining operations aided in understanding these maps.

Special Condition 7.d.—requires the annual report to include a "summary of in situ measurements of rock mechanics required by Special Conditions 12." Special Condition 12 requires the measurement and collection of in situ rock mechanics data "in accordance with the approved Mined Land Use Plan." The data is to include "plots of relevant graphs. ..." "Exceptions to anticipated trends in rock behavior shall be noted and explained. ..."

At the August 2004 meeting, it was agreed that "All 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 forwarded closure stations in the form of Excel files. Mr. Petersen reviewed this data and presented his findings in the 2006 Rock Mechanics Assist letter[2] concluding:

- "...after a review of the rock mechanics data that the mine is globally stable. The general rate trends in the yielding panels are decreasing..."
- A lengthy discussion on the instability in U40B and events (renewed mining, multiple intersections) that lead to the instability.

Closure measurement data are significant because they offered insight into the collapses, and inundation of the Retsof Mine. Sustained closure rates of 0.04 inches/day were measured in stable areas of the Retsof Mine, while in the failure areas, closure was regularly measured with sustained rates over 0.65 inches/ day with onset of failure around 1.65 inches/day. 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.

In BOYD's review of the 533 closure stations read in 2005 and supplied by Cargill, it was noted that none of the readings exceeded 0.65 inches/day. Eighty-six (86) closure stations had at least one reading that exceeded 0.04 inches/day. Of these, 85 closure stations were recently installed (in 2004 or 2005) and all 86 were close to active mining areas where closure rates should be high.

BOYD offers the following comments:

- The closure station program at the Cayuga Mine is one of the most extensive known to BOYD.
- Station locations and frequency of readings are acceptable for giving an indication of global mine and panel stability.
- The monitoring of abandoned panels and levels also aids in understanding global mine stability.
- Closure station results provide a strong indication that the Cayuga Mine is globally stable.

Rock Mechanics Assist provided two maps to aid in review of the closure measurements:

- "Cayuga Mine Closure Rate July 2005"
- "Cayuga Mine Total Closure July 2005"

Special Condition 7.e.—requires the annual report include a "summary of subsidence monitoring data required by Special Condition 11. Special Condition 11 requires "Subsidence monitoring shall be conducted in accordance with the approved subsidence monitoring plan contained within the approved Mine Land Use Plan." "Exceptions to the trends shall be noted and explained. ..." Points applicable to Special Condition 7.e. were agreed upon at the August 2004 meeting and are noted above under Special Condition 7.d.

Mr. Petersen[2] reviewed the subsidence data and made recommendations as to survey grid modifications and frequency of subsidence surveys. Cargill[3] appears to adopt these recommendations as no subsidence readings were completed in 2005 and the next subsidence survey is planned for the spring of 2006. Cargill also plans to rework the subsidence grid in the east area.

Cargill supplied to BOYD, in electronic form, subsidence data. BOYD reviewed this data last year and NYDEC is referred to BOYD's 2004 review[7].

Special Condition 7.f.—requires the inclusion of "Information regarding the source and volume of any water inflow into the mine, and the disposition of such water." At the

[7] John T. Boyd Company, 2005, "2005 Annual Report Review, Cayuga Mine," File 2499.4, April 4.

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".

Cargill reported the sources of the total water inflow that averages 37 gallons per minute. These sources are from the shafts, ED plant, and storm water. This water is moved to a containment pond on Level 4 and then onward to the lower areas of Level 4. Cargill estimates that 19 years of storage remain on Level 4. Shoreline location in Level 4 was not noted.

Special Condition 7.g.—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.

SPDES data and a short discussion are included in the Annual Report.

Special Condition 8—addresses non-routine incidents and is discussed under Special Condition 7.b.

Special Condition 9—addresses Mine Safety and Health Administration reporting involving non-routine mining incidents and is discussed under Special Condition 7.b. Cargill also notes in the Annual Report that Cayuga Mine has not been cited by MSHA in connection with any non-routine mining incidents.

Special Condition 10—addresses reporting requirements "Prior to undertaking any material change in the approved mining methods or techniques. ..." This condition does not require the reporting to occur in the Annual Report.

Cargill notes two changes;

1. 5 tunnels will be used instead of 7 in opening up new panels, and
2. 32-ft-wide crosscuts will be used in the mains of instead 42 ft.

Special Condition 11—addresses subsidence monitoring as discussed under Special Condition 7.e. above.

Special Condition 12—addresses rock mechanics monitoring as discussed under Special Condition 7.d.

Special Condition 13—addresses the reporting and recording of citizen complaints. Cargill notes in the Annual Report that "no written citizen complaints" were received.

Site Visit

A site visit to discuss these finding with NYSDEC, Cargill, and BOYD should be arranged. 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
Senior Geomechanics Specialist

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APPENDIX A

This Appendix A lists the pages in unredacted Volume II and the plates in Volume II Plates where Cargill identified information as a "trade secret." Appendix A notes whether, based on the discussion in the accompanying letter addressing FOIL Appeal No. 02-29-7A, the material should be released or withheld.

Each item is followed by the letter(s) that Cargill used to identify the category(ies) for purposes of its trade secret designations. The letters correspond to the following section headings in the November 22, 2002 Roe letter:

A = Seismic Information
B = Geologic Information Specific to Cayuga Mine
C = Specific Dimensions of Yield Pillar Mine Design
D = Protocol for Stability Analysis
E = Miscellaneous Operational Expense

VOLUME II

Page 4, last 2 paragraphs and top 2 lines on page 5 (A, B) Withhold.

Page 5, last 2 paragraphs and page 6, first paragraph (A, B, E) Withhold.

Figure 3.1-5 (A) Withhold.

Page 58 to page 65, which is all of section 3.1.9.2, Mine Stratigraphy (B) Release.

Page 65, second and third sentences of last paragraph (B, E) Release.

Page 73, third paragraph (B) Release.

Page 76, second, third and fourth paragraphs (end of section 3.1.11.1, Local Structural Conditions in Devonian Strata) (A, B) Release second and third paragraphs; release fourth paragraph, except for the last sentence.

Page 78, last two sentences of third full paragraph, to page 80, end of second full paragraph (end of section 3.1.11.2, Local Structural Conditions in Silurian Strata) (B) A portion of this discussion is based upon a 1968 journal article. Release.

Fig. 3.1-18 (A, B) Withhold.

Page 82, second and third full paragraphs (end of section 3.1.11.3.1) (A, B) Withhold.

Page 82, lower part of page, through first full paragraph of page 90 (all of section 3.1.11.3.2) (A, B) Withhold.

Fig. 3.1-20 (A, B) Withhold.

Fig. 3.1-21 (A, B) Withhold.

Page 90, second full paragraph through page 92, first full paragraph (all of section 3.1.11.4) (A, B) (this section is also marked with the letter C and an arrow pointing to its second paragraph) Withhold.

Page 92, first sentence of last partial paragraph (A, B) Withhold.

Page 94, second paragraph through page 114, fourth paragraph (all of sections 3.1.11.6 and 3.1.11.7) (A) Withhold.

Figure 3.1-23 (A) Withhold.

Figure 3.1-24 (A) Withhold.

Figure 3.1-25 (A) Withhold.

Figure 3.1-26 (A) Withhold.

Figure 3.1-27 (A) Withhold.

Figure 3.1-28 (A). This figure contains descriptive text including the annotation, "Figure modified from: Sanford, B.V., Thompson, F.J. and McFall, G.H., 1985, Plate tectonics - A Possible Controlling mechanism in the development of hydrocarbon traps in southwestern Ontario. Bulletin of Canadian Petroleum Geology, v.33, no.1, p. 52-71." The figure is based upon a published article. Release, except for the narrative in lower left portion of the figure which was added by Cargill's consultants.

Figure 3.1-29 (A) Withhold.

Figure 3.1-30 (A) Withhold.

Figure 3.1-31 (A) Withhold.

Figure 3.1-32 (A) Withhold.

Page 114, last partial paragraph, through page 116, first partial paragraph (all of section 3.1.12.1 and section 3.1.12.2) (A, B) Withhold.

Page 117, various numbers in last partial paragraph (C) Among the reasons discussed in the accompanying letter on the FOIL appeal, certain of these numbers are not trade secrets because Cargill has already released most of them by the release of Volume I (see third paragraph on page 7 of Volume I). Release.

Page 124, various numbers in first full paragraph (C) See prior item (page 117). Release.

Page 125, various numbers in last partial paragraph (C). One of the numbers appears on page 7 of Volume I, which has been released. These numbers are also included in a published article (Petersen et al. 1993). Release.

Page 129, various numbers in first and third full paragraphs (C). Various of the numbers appear in published articles (see Petersen, et al. 1993, Petersen, et al. 1979, Plumeau & Petersen (1981)). Release.

Fig. 3.2-5 (C) Appears in Petersen, et al. 1993. Release.

Page 131, various numbers throughout page (C) Certain of the numbers have been previously released. See Petersen, et al., 1993. Release.

Fig. 3.2-7 (C) Appears in Petersen, et al. 1993. Release.

Page 134, various numbers in first partial paragraph (C) Numbers appear in Petersen, et al. 1993. Release.

Fig. 3.2-8 (C) Release.

Page 136, various numbers in third full paragraph (C) Release.

Page 139, various numbers in last two paragraphs (C) These numbers were also released by Cargill in Volume I (p. 7). Release.

Page 141, various numbers in last two paragraphs (C) Release.

Page 146, two numbers in last paragraph (C) Release.

Fig. 3.2-14 (C) Release.

Page 152, Table 3.2-1 (C) Release.

Fig. 3.2-18 (C) Release.

Page 164, various numbers in last three full paragraphs (C) Release.

Fig. 3.2-27 (C) Release.

Page 169, various numbers in first two paragraphs (C) Release.

Page 177, two numbers (C) Release.

Page 197, two numbers in third and fourth paragraphs (C) Release.

Page 201 through 269 (all of sections 3.2.9, 3.2.10, 3.2.11, 3.2.12, 3.2.13) (B, C, D) Withhold pages relating to the development and implementation of the studies, but release:

- pages 201-202 (all the text under 3.2.9 up to the section that starts 3.2.9.1);
- results that appear at the bottom of page 209 (from "Results provided include:" to the end of the page) and the top of page 210 (top two lines);
- results that appear at the top of page 228 immediately prior to section 3.2.10.2.1;
- results that appear on pages 245-247 (all of section 3.2.11); and
- pages 247-254 (sections 3.2.12 and subsections 3.2.12.1 through 3.2.12.2 (microseismic monitoring)).

Page 274, various numbers in first two full paragraphs (marked for each line, as C, E or as B, C) Release, except withhold the three extraction ratios.

Page 286, one number on last line of page (C) Release.

Page 288, various numbers (marked for each line, as C or as B, C, D) Release.

Supplemental decision 7/19/05

Included in the information that Cargill identified as trade secrets were certain pages and sections in Volume II that it designated under the category "Protocol for Stability Analysis." Pursuant to the FOIL appeal, the Department determined that some of that information did not constitute trade secrets and, accordingly, should be released (see the listing in the July 11, 2005 Determination Letter, at 19-20, and the listing in Appendix A, at page 4 under the heading "Page 201 through 269" [the "Listings"]).

As I advised you by telephone this week, following the issuance of the July 11, 2005 Determination Letter it was discovered that certain pages and sections to be released had been inadvertently omitted from the Listings. Specifically, the Listings should also have included the following two entries:

- "results that appear on pages 257-261, and conclusions that appear on page 261 (all of section 3.2.13.4, which includes Figures 3.2-82, 3.2-83 and 3.2-84, and section 3.2.13.5); and

- "results that appear on pages 263-269 and the conclusions that appear on page 269 (all of section 3.2.13.9, which includes Figures 3.2-85, 3.2-86, 3.2-87, and 3.2-88, and section 3.2.13.10)."

By this letter, the July 11, 2005 Determination Letter and Appendix A are modified to include the above-referenced pages and sections among the information to be released. Some of this information is summarized in section 2.3.1.4.2.3 of Cargill's Mined Land Use Plan (referred to as "Volume I") which Cargill previously made available to the public.

Because this letter modifies the July 11, 2005 Determination Letter, the two letters together now represent the final determination of the Department on Mr. Hecht's FOIL appeal and Cargill's request that the information be withheld as trade secrets. Either party has the right to seek judicial review of the final determination pursuant to article 78 of the New York Civil Practice Law and Rules and Public Officers Law § 89(4)(b).

Pursuant to POL § 89(5)(d) and 6 NYCRR 616.7(d)(2), the Department is required, because of Cargill's previous designation of this information as trade secrets, to hold it for a period of fifteen days. The Department will then release the information unless restrained by a court of competent jurisdiction. Following that fifteen day period and, assuming no restraining order, these records may be reviewed by Mr. Hecht in the DEC Office of Hearings and Mediation Services ("OHMS") or, at his request, copies will be provided to him.

responsible for the subcrop pattern. Local bedrock structure probably plays a secondary role in forming the subcrop patterns. Two small depressions occur near the axis of the Fir Tree Point Anticline where high-angle faults east of Cayuga Lake produce vertical displacements of up to 100 feet on the Onondaga Limestone (section 3.2.3). A second large depression occurs in the region north of the Fir Tree Point Anticline.

Erosional and structural relief on Devonian strata are further illustrated by six geologic profiles (Plates 3.1-11 through 3.1-15). Three cross-sections strike parallel and three strike perpendicular to the lake axis across the northern portion of the study area. Profiles A, B, and C reveal the progressive change from a U-shaped to V-shaped valley cross-section. They also reveal the varying depth of erosion into the south-south-westerly dipping Siluro-Devonian carbonate sequence from north to south.

3.1.9.2 Mine Stratigraphy

3.1.9.2.1 Syracuse Formation

The Syracuse Formation is approximately 824 feet thick in core hole 17 (Plates 3.1-3 and 3.1-4) and 644 feet thick in core hole 15. The thickness variation is attributable to probable thrust fault duplexing of upper Salina F salts in core hole 17. Although the mine's informal stratigraphy recognizes 7 major salt beds, as many as 11 major salt beds separated by thick (10 feet or greater) dolomites or dolomitic shales are present in core hole 17. To maintain consistency with the mining stratigraphic scheme, the following designations are used:

Salt Bed	Core Hole 17		Core Hole 15	
	Depth (feet bgs)	Thickness (feet)	Depth (feet bgs)	Thickness (feet)
No.1	1,936–2,043	7	not present	
No.1A	2,064–2,093	29	not present	
No.2	2,098–2,212	114	2,212–2,242	30
No.3	2,232–2,271	39	2,266–2,370	104
No.4	2,307–2,365	58	2.410–2,508	98
No.4A upper	2,467–2,504	37	2,557–2,588	31
No.4A lower	2,515–2,568	53	2,601–2,657	56
No.4B	2,639–2,644	5	2,735–2,739*	4
No.5	2,686–2,695	9	2,782–2,788	6
No.6	2,729–2,742	13	2,825–2,835	10
No.7	2,752–2,759	7	2,851–2,857	6

* Replaced by salt-vugged dolomite

As can be discerned from the inclined bedding depicted in Plate 3.1-4, the upper Syracuse Formation is tectonically deformed beneath the Fir Tree Point Anticline. Some salt beds and many dolomite/dolomitic shale beds in available cores dip between 10 degrees and 80 degrees off the horizontal axis. The stratigraphically highest zone of dipping beds occurs in the No.1 Salt at approximately 2,010 feet below ground surface. Here, the contact between dark and light bands in the No.1 Salt dips at about 10 degrees.

Deformation of the No.1 Salt bed is also observable in the mine. Southward from the No.1 shaft, salt bedding is progressively obliterated and replaced by mottled-textured salt containing large white salt inclusions. These inclusions were interpreted by Jacoby (1969) to reflect tectonic recrystallization.

Non-salt strata logged in core hole 17 maintain a 10–15 degree dip from the base of the No.1 Salt until about the base of the No.1A Salt at approximately 2,093 feet below ground surface. At this stratigraphic position, dolomite interbeds increase in dip to about 40 degrees (Plate 3.1-4).

Dips between 30 and 45 degrees are common in strata between depths of 2,093 and 2,173 feet below ground surface within the No.2 Salt section. Bedding, including that in the No.3 Salt, returns to horizontal below this interval until a depth of 2,303 feet below ground surface. At this depth, a dolomite bed immediately above the No.4 Salt exhibits slightly inclined bedding.

Due to the abundance of lithic clasts in the No.4 Salt in core hole 17, bedding is not apparent. In the mine, however, the No.4 Salt is highly folded at several scales (Prucha, 1968), and the bedding in the salt locally resembles gneissic banding near the southern limits of the No.4 mine level. Thus, it is reasonable to assume, based upon the abundance of lithic fragments logged in core hole 17 and the southernmost mine exposures, that the No.4 Salt remains tectonically deformed south of the existing mine.

In core hole 17, dolomite beds immediately below the No.4 Salt stand nearly vertical from 2,365 feet below ground surface to 2,410 feet below ground surface (Plate 3.1-4). Below this depth, beds remain inclined at lower angles, but still on the order of 45 degrees until a depth of 2,515 feet below ground surface, which corresponds to the top of the lower No.4A Salt.

Bedding was not discernible in the lower No.4A Salt. However, it appears that the lower No.4A salt served as a local boundary between two differently slipping stratal plates.

Bedding returns to horizontal below the lower No.4A salt until a depth of 2,648 feet below ground surface in core hole 17. This depth corresponds to a stratigraphic position just below the base of the No.4b Salt. At this stratigraphic position, bedding in dolomites changes dip abruptly from near horizontal to about 50 degrees within 2–3 feet of core section, suggesting the position of another differential slippage boundary. Below this structural boundary in dolomite that separates the No.4b and No.5 Salts, bedding dips decrease progressively over a 38 foot interval of core from about 50 degrees to about 10–20 degrees at the upper contact of the No.5 Salt (Plate 3.1-4).

Bedding in the No.5 Salt was not discernible. However, bedding in dolomitic mudstone beneath the No.5 Salt is horizontal in the depth range between 2,711 and 2,729 feet below ground surface. All salt beds and dolomites below this depth (inclusive of the No.6 and No.7 Salts) are also horizontal.

The observation of horizontally bedded lower salts in core hole 17 is consistent with stratigraphic and structural patterns observed in the five core holes drilled during 1999 from the No.6 Salt mine level upward to, and in some cases through, the No.4 Salt bed. Correlated columnar sections of the drill cores are provided in Plates 3.1-16 and 3.1-17. For ease of presentation, the core sections have been divided into lower and upper parts, each presented on separate figures. The lower section (Plate 3.1-16) includes the Salina D-E interval that contains the No.5 Salt and the overlying 120 feet of dolomite that is in contact with the base of the No.4A Salt. The upper section (Plate 3.1-17) that includes part of the Salina F interval contains the No.4A Salt, the No.4 Salt and the No.3 Salt. These sections are described in more detail below.

The Lower Section (Top Salina D and Salina E)

The lower sections of the drill cores are remarkably similar. At all locations but core hole 1, the sections start in the calcareous claystone that overlies the No.6 Salt. Core hole 1 starts in the upper 3 feet of the No.5 Salt. Where complete sections were drilled, the No.5 Salt attains thicknesses of 19–21 feet. The bed maintains its distinctive amber color and relatively high anhydrite content throughout the study area.

The Salina E dolomite is also remarkable in its uniformity of thickness and lithologic facies. The interval ranges from approximately 120 to 127 feet thick in the various core sections. The dolomite includes shaley and argillaceous zones. In addition, there are several "pimple-textured" dolomite beds that contain disseminated halite crystals. The upper 30–40 feet commonly contain abundant bedded and nodular anhydrite.

The Salina E dolomite interval is virtually undeformed. No intense fracturing or folding of strata suggested by inclined bedding were noted in the sections from core holes 3 and 4. Only minor zones of deformation were noted in the other cores. Inclined laminae and vertical salt-filled fractures were noted in core hole 1 in the 80–90 foot interval; the 110–120 foot interval; and at approximately 132 feet. Salt filled fractures were noted in core hole 2 in a 10-foot thick interval immediately below the No.4A Salt. Minor zones of fracturing were noted in the core hole 5 section in the 105–120 foot interval; abundant salt-filled fractures were also noted in the 130–170 foot interval, but no inclined bedding was noted.

The Upper Section (Lower Salina F Salts)

The upper sections of the drill cores are characterized by significant variation in salt thicknesses and purity as well as in thickness and degree of deformation of intervening dolomite sections. The only section that does not reveal obvious signatures of tectonic disruption is core hole 4 that is located at the northwestern limit of the study area. Because of the degree of variation in the sections between core hole locations, the correlations provided on the enclosed figure should be considered preliminary. The preliminary correlations are based upon lithologic attributes such as the characteristic black color of the No.4 Salt, the dark-gray to black color of the dolomite that separates the No.4A and No.4 Salts, and the presence of a stromatolite marker horizon in the dolomite that overlies the No.4 Salt.

The No.4A Salt varies in thickness among the core sections from roughly 47 to 100 feet. This salt bed is characteristically black due to the abundance of anhydrite inclusions. Several of the sections also contain abundant dolomite clasts. The No.4A Salt in core hole 4 exhibited a hydrogen sulfide odor.

The undeformed dolomite section above the No.4A Salt in core hole 4 is 11 feet thick. In core holes 1A, 2, and 3 where the bedding in this dark, laminated-to-stromatolitic, fine-grained dolomite is inclined to angles as high as 40 degrees and the unit is intensely fractured, it maintains a thickness between 10 and 15 feet. Core hole 5 contains an anomalous section that is nearly 54 feet thick with bedding vertically oriented in the lower

30 feet. The dip on bedding gradually and progressively decreases upward to 5–10 degrees at the top of the dolomite sequence.

The No.4 Salt in the core sections ranges in thickness from 27.75 feet in core hole 4 to 60.25 feet in core hole 5. In core holes 2, 3, and 5, the No.4 Salt is deformed and impure. Dolomite clasts and disseminated anhydrite are the major impurities. In the 46-foot thick section penetrated by core hole 2, a 27.5-foot thick, rotated slab of laminated dolomite is suspended in the middle of the salt bed, and the salt is black.

The No.4 Salt sections in core holes 1A and 4 appeared to be the purest. The 47-foot thick section in core hole 1A is free of large dolomite clasts, but retains a black color reminiscent of the deformed sections. The 27.75-foot thick section in core hole 4 has three dolomite stringers in it, but its light-gray to clear color suggests higher purity. Lateral variation in salt thickness and purity appears to be a function of degree of deformation. The thinner the No.4 Salt gets, the higher the purity appears to be. The thickening appears to have occurred by internal shear that obliterated primary rhythmic halite-anhydrite bedding. Where shear planes developed at the boundaries of the salt beds, clasts of the bounding dolomite and mudstone beds dislodged, rotated, and became entrained in the deformed salt bed.

A complete and undeformed section of the dolomite sequence above the No.4 Salt was penetrated in core hole 3. In this section, the dolomite sequence is 51 feet thick. The distinctive stromatolite marker horizon occurs 10 feet above the basal contact with the No.4 Salt.

A partial, undeformed dolomite section was penetrated at the top of core hole 4. The section appears very similar to the complete section in core hole 3. The stromatolite marker horizon occurs 12 feet above the basal contact with the No.4 Salt.

Even though the sections are deformed, the stromatolite marker horizon is discernible in core holes 1A, 2 and 5. In core hole 5, the stromatolite occurs 19–21 feet above the No.4 Salt (15 feet if bed were horizontal) in strata inclined at approximately 40 degrees. The marker horizon occurs immediately above the No.4 Salt in anomalously thin dolomite sections in core holes 1A and 2. The juxtaposition of the salt and the stromatolite horizon in these southern sections possibly suggests detachment of the basal 10–12 feet of dark, laminated dolomite noted below the marker in complete sections and entrainment of the laminated dolomite into the No.4 Salt. Furthermore, if the preliminary stratigraphic correlations are correct, the anomalously thin section above the marker horizon in core hole 1A suggests detachment and entrainment of the upper part of the dolomite into the overlying No.3 Salt. These "lost" dolomite beds have probably been brecciated and driven southeastward in response to salt flow during creation of the salt-cored dome apparent beneath and east of Myers Point in seismic sections.

Observations of horizontally bedded lower salts in core hole 17 and the 1999 core holes are also generally consistent with exposures in the mine. With few exceptions, the extensive mining of the No.6 Salt reveals horizontal "bedding" with little or no structural deformation. Based upon the ubiquitous presence of small angular clasts of dolomite in the No.6 Salt, it is unlikely that this "bedding" is of a primary depositional nature. Instead, the salt fabric and bedding appear to reflect the presence of a myriad of interval shear planes within the salt beds. Based upon observation of the same salt textures in other mines in New York and Ohio, it appears that primary depositional bedding in the salts has been obliterated through much of the northern Appalachian Basin.

The primary exception to the widespread horizontality of bedding in the lower salts occurs at the southern limit of the mine in the area east of Cayuga Lake. In this area, a roughly east-west trending zone of rock-in-salt has been encountered. This type of phenomenon occurs sporadically but widely in most mines in Silurian salts of the Appalachian Basin including Livonia (Luther, 1899, Plates I, III) and Retsof (Jacoby, 1969, Figures 10–12).

Prucha (1968) observed the comparable rock-in-salt features in the No.4 Salt level of the Cayuga Mine and offered hypotheses on the genesis of the structures that also explain the No.6 mine level features. He describes a two-phase process of deformation that transformed originally horizontal, interbedded Syracuse lithologies into salt-cemented tectonic breccias.

The first phase of deformation involved buckling of competent, layered stratal sequences. Prucha notes that this folding stage was produced by a flexural-slip mechanism. This mechanism led to formation of a high degree of polish and non-penetrative striations on the boundaries of salt beds. In the course of the folding phase, however, the highly ductile salt deformed passively, but remained concordant with the buckling dolomite beds.

The second phase of deformation involved failure of the dolomite/dolomitic mudstone beds along extension fractures developed perpendicular to bedding. The extension fractures developed when the radius of curvature of individual folds reached a critical value. Upon the extension of fractures completely through adjacent dolomite beds, the salt became unconfined and flowed upward into the dilatent zones. Increased flowage of salt ultimately detached smaller clasts off the fractured dolomite beds, and ultimately salt enveloped lithic fragments and the large detached blocks of dolomite to produce salt-cemented breccias and rock-in-salt structures.

Prucha's ideas also seem to explain the rock-in-salt features at the No.6 Salt level. For example, the 5-foot thick dolomitic mudstone directly overlying the No.6 Salt appears to have been folded beyond a critical angle of curvature. As a consequence of excessive folding, radial extension fractures penetrated the bed from its upper surface. Some of these fractures extend across the entire thickness of the mudstone bed and serve as boundaries of discrete blocks that, due to upward flow of ductile salt, have been dislodged, rotated, and suspended within the No.6 Salt. Note that the discrete blocks are generally arcuate, supporting Prucha's idea that the dolomitic mudstone bed fractured only after being tightly folded.

Rock-in-salt phenomena are not restricted to roof conditions at the No.6 Salt level. In widely spaced, but localized areas, the floor rock also protrudes upward into the No.6 Salt. These features are referred to as "turtle shells" by the miners. A prominent zone of floor rock is also present in NW1 near panels U40, U42 and U43. There the floor rolls exhibit a northeasterly trend.

The process of turtle-shell formation appears to be similar to that for the roof rock-in-salt phenomenon. Both features involve lateral shortening of a stack of intercalated salt and dolomite/dolomitic mudstone beds possessing alternating degrees of brittle and ductile deformation potential. The differential lateral motions and folding (shortening) to a point of bed failure occurred in non-salt strata between the No.6 and No.7 Salts to produce the turtle shells, whereas the differential motion and folding beyond a critical angle responsible for the roof rock-in-salt occurred between the No.5 and No.6 Salts. Thus, multiple minor decollement surfaces likely exist in the Silurian salts beneath the Fir Tree Point Anticline and lead to rock-in-salt features at various levels in the mine. Again, this type of structure is not unique to the Cayuga Mine setting or the Salina D salts. These features have also been observed in Salina B salts at Retsof and Livonia, and evidence of low-angle shear in Salina salts extends as far north as northern Ohio.

Based upon observation of structure in both core holes 17 and 15, in 1999 core holes 1–5 and in the mine, the stratigraphy of the Syracuse Formation appears to be complicated by tectonic thickening. Although most of the primary salt beds recognized by the mine operators can be identified beneath each limb of the Fir Tree Point Anticline, the uppermost Salina F salt (No.1 Salt) identified in core hole 17 does not appear to have an analogue in core hole 15 located on the north side of the anticline. What was referred to as the No.1 Salt at the historic Ludlowville Salt Works on Myers Point may be correlative to the No.2 Salt in core hole 17.

A primary goal of this geologic study has been to define the structural setting of the mine in order that the detailed observations reported above can be understood in the regional context of Appalachian thin-skinned tectonics. The prevalent structural model for Appalachian-style folding and faulting emphasizes the prominent role of Silurian salt in providing a zone of weakness along which differential, lateral motions occur. If the regional model is supported by detailed geological characterization of the mine area, the model may be used predictively to anticipate structural patterns as the mine expands.

3.1.9.3 Mine Hydrology

3.1.9.3.1 Deep Groundwater Flow and the Base of the Hydrosphere

Groundwater does not migrate vertically into the subsurface indefinitely. In the vicinity of the Cayuga Mine, the base of the hydrosphere clearly occurs above the Camillus Shale, as shown in the roof of the No.1 Salt mine level where this formation is exposed and is dry. In addition, at least one vertical core has been advanced approximately 100 feet up into the Camillus Shale roof rock without encountering groundwater.

Evidence from local hydrocarbon exploration indicates that the saturated bedrock section must extend downward at least as deep as the Oriskany Sandstone. Salt water is often encountered in the gas-depleted portions of this reservoir-grade sandstone. Thus, it follows that deep groundwater is also present in the Onondaga Limestone that overlies the Oriskany Sandstone.

It is also known, based upon seepage of brine into the production shaft (No.2 shaft) that the base of the hydrosphere must occur near the base of the Helderberg Group carbonates. The lowest water ring in the shaft collects brine at a rate of 4 gallons per minute. This ring is situated at an elevation of –792 mean sealevel. Reference to Plate 3.1-18 indicates that the lower boundary of the Helderberg Group is at –809 mean sealevel. These data on the stratigraphy of the shaft would place water in the Cobleskill Formation.

The Fir Tree Point Anticline that strikes roughly east-west across Portland Point and similar scale anticlines located farther to the south have been targets for natural gas prospecting in Tompkins and surrounding counties. Consequently, a fairly large number of well logs are available for Middle Devonian strata between the Tully Limestone and the Oriskany Sandstone. A small number of gas wells extend through the Devonian section and into underlying Silurian strata. A few of these wells penetrate the entire salt-bearing Syracuse Formation and terminate either in the Ordovician Trenton carbonates or in crystalline basement.

Locations of gas wells are depicted in a variety of state publications and unpublished drawings obtained from Cargill's files. State publications that report locations of wells include Kriedler and others (1972), Peterson and Van Tyne (1979), and Rickard (1989). Furthermore, the NYSDEC Division of Mineral Resources maintains a file of USGS quadrangle maps that identify the locations of oil and gas wells on file with the State.

In addition to the state publications and NYSDEC maps, local gas wells are identified on unpublished drawings generated by Brayton Foster (drafted 1977) and by Charles Fralich (drafted 1936) that are on file at the mine. These maps focus upon local geologic structures surrounding Portland Point.

The reported locations of gas wells vary slightly between some published and unpublished references. After multiple attempts to reconcile all databases, locations of wells reported by Brayton Foster and the NYSDEC depictions placed directly on USGS quadrangle maps along the Fir Tree Point Anticline are adopted. Locations of wells around the periphery of the local study area were adopted from Peterson and Van Tyne (1979) and the NYSDEC depictions placed directly on USGS quadrangle maps (Plate 3.1-20).

Based upon both published and unpublished references identified above, a formation-scale, numerical model of the stratigraphic interval between the Tully Limestone and the Vernon Formation was developed (Plate 3.1-19). The elevations of formation boundaries were estimated to the nearest foot based upon available well logs, structural contour maps and formation isopach maps. The benefit of this analysis is the ability to model relief on uppermost Silurian and Devonian strata within the vicinity of the mine. The numerical model was also used to interpret the relationship between bedrock stratigraphy and pre-Holocene erosion beneath the Cayuga Lake trough (Plates 3.1-11 – 3.1-15).

A 1932 structural contour map of the Moscow-Tully formation boundary in the southwest corner of the Cayuga Crushed Stone Quarry further indicates smaller-scale, along-strike variation. The position of the kimberlite dike and the mine's coordinate grid were provided on this contour map for reference. The contour map depicts a southwest dip on the formation boundary in the area west of the kimberlite dike. This area of the quarry is now back-filled with residual Geneseo Shale waste product. The southeast corner of the quarry, however, is still open, and strata there (east of the kimberlite dike) exhibit a gentle south-east dip. Thus, the irregular saddle and dome asymmetry documented in the deep subsurface formations is also apparent in surface exposures.

Bedrock structure at the Oriskany Sandstone-Onondaga Limestone stratigraphic interval has long been of interest to oil and gas prospectors because of the reservoir properties of the Oriskany. Consequently, structural contour maps for these units can be generated based upon data collected during extensive hydrocarbon exploration on the Fir Tree Point Anticline east of Cayuga Lake (Plates 3.1-20 and 3.1-21).

The structural contour map of the Onondaga Limestone shown in Plate 3.1-21 was based upon local gas well logs and the positions of brittle structures interpreted by Van Tyne and others (1980). This map indicates local up-turning of strata produced by a single fault plane possessing a throw of 100 feet or less. Similar faults were known by Van Tyne and others (1980) to occur beneath the Watkins and Alpine Anticlines located farther south. Interpretation of a single fault beneath the Fir Tree Anticline, however, varies with the fault couplets depicted by these researchers beneath other anticlines (Figure 3.1-16).

The fault zone beneath Portland Point produces an approximate two-fold thickening of Onondaga Limestone from the regional norm of 65–75 feet to greater than 140 feet (Plate 3.1-23). The thickening is probably reflective of a change in the local dip angle produced by drag folding or rotation of strata between fault planes beneath the Fir Tree Point Anticline. [redacted]

3.1.11.2 Local Structural Conditions in Silurian Strata

Geometric constraints dictate that shallow subsurface folds observed in Devonian strata must die out at some depth in the subsurface (Gwinn, 1964) (Figure 3.1-17). Usually folded strata in the Appalachian Basin detach along a bedding-parallel zone of weakness below which strata are relatively undeformed. Many researchers (Gwinn, 1964; Prucha, 1968; Jacoby, 1969; Frey, 1973; Wiltschiko and Chapple, 1977; Murphy, 1981; Davis and Engelder, 1985) agree that the Salina Group salt beds provide a zone of weakness along which a regional decollement (bedding-parallel surface of differential slippage) developed. The decollement developed in response to compressional forces generated by the late Paleozoic Alleghanian Orogeny during which present day North Africa collided with eastern North America.

Lateral shortening of rigid Siluro-Devonian carbonates above the salt is accommodated by folding and the formation of north- and south-dipping faults on the limbs of anticlines (Figure 3.1-18). These faults are relatively high-angle features in the carbonates, but become listric (that is, bedding-parallel and cryptic) in the upper part of the salt sequence.

Frey (1973) concluded that because of the decollement, well-documented regional folds in strata above the salt zone produced during the Alleghanian Orogeny bear no relation to older structures preserved beneath the salt. Consequently, thickness patterns in the highly deformable salt should reflect infilling of structural relief created by folding at the base of the overlying Siluro-Devonian carbonate sequence. A regional-scale isopach map of the Syracuse Formation based upon data compiled in Plate 3.1-19 indicates that the salt zone thickens into domes or ridges beneath anticlines and thins beneath intervening synclinal troughs (Plate 3.1-22). These patterns are attributed by Frey (1973) and Davis and Engelder (1985) to lateral salt flow driven by northwest slippage on the decollement in salt during the Alleghenian Orogeny.

Prucha (1968) demonstrated, through structural mapping of mine exposures and drill cores, a progressive decline in intensity of deformation down-section within the salt zone and interpreted the regional decollement to be located near the base of the No.4 Salt. Based upon recent logging of core hole 17, it appears that the dolomite between the No.4B and No.5 Salts is also deformed. This deformation suggests that the primary decollement, as it occurs south of the mine, may be variably located between the top of the No. 5 Salt and the base of the lower No.4A Salt.

The abrupt decrease in intensity of folding below the No.4B salt level is readily apparent in structural contour maps generated from mine roof elevations and core hole data. Plate 3.1-23 contains a structural contour map of a black salt zone at the top of the No.4 Salt. This map was digitized from Figure 2 of Prucha (1968). The contour map and the profiled model inset map clearly depict second-order folds superimposed on the first-order Fir Tree Point Anticline. The second-order folds tend to be doubly plunging and disharmonic, but

Insert Map FIGURE No. 3.1-28
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Alleghenian Orogeny (roughly 250–365 million years ago). In contrast, radiometric dating and magnetic polarity analyses of the kimberlite dikes suggest two possible emplacement episodes during the early Cretaceous Period (113–140 million years ago) (Kay and Foster, 1986).

The emplacement mechanism appears to have been fluidization of mantle-derived xenoliths (exotic rock clasts) during entrainment in hot gas eruptions (diatremes) at temperatures ranging between 500 degrees and 850 degrees centigrade (Flynn and others, 1996). The occurrence of kimberlite dikes in close association with the Greene-Potter Fault Zone (Parrish and Lavin, 1982) suggests that the mantle-derived intrusions exploited preexisting, deep-seated fractures to reach the salt section. Above the salt section, the dikes follow the Alleghenian cross-fold joint set 000° parent joint set of Younes and Engelder (1999).

The elevated heat flow data in the Cayuga Lake area may reflect residual heat from kimberlite intrusion during incipient openings of the Proto-Atlantic Ocean. Heat flow data from the north end of the Cayuga Lake trough are consistent with values presented for Mesozoic-Cenozoic orogenic areas by Stacey (1977).

All kimberlites mapped at ground surface are near-vertical dikes. Jacoby (1969), however, asserts that a 16-inch thick kimberlite sill rests atop the No.1 Salt over a large area behind Myers Point depicted on Plate 3.1-34. Interpretation of the sill was based upon results of a magnetometer survey and logging of ISCO brine well 20 (API No.3939) located near Myers Point. Jacoby also interpreted metamorphism of the salt around the purported sill. These interpretations remain to be tested by confirmatory investigations.

3.2 Salt Mining Operations and Mechanics

Executive Summary

At the Cargill Cayuga Mine a systematic room-and-pillar mining pattern in the unfolded No.6 Salt was initiated in 1968. Rooms 32 feet wide and 8 to 10 feet high were mined between 88-foot-square pillars with an extraction rate of 46 percent. In 1974–1975, the mine reached a 2,800-foot depth. Mine-ground conditions worsened at that time, and significant roof failures necessitated suspension of mining. A mine redesign led to a yield-pillar configuration in the mining panels. A practical, in-the-mine rock mechanics investigation was initiated to evaluate actual rock performance by instrumental measurements. This program of closure monitoring continues today and provides the basis develop estimates of the sizes of the cavities. Sevenker estimated the total production from the caverns to have been about 7,736,000 tons of salt. Internal memoranda from AKZO Nobel Salt estimate total plant production to have been between 6,000,000 and 9,186,000 tons of salt.

3.2.2 Cayuga Mine (1915–Present)

3.2.2.1 Mining Pattern Development

In the original mine design, mining of the No.4 Salt bed followed the thick rolls or north-west trending folds that deform the bed. Thus, both pillar widths and room (stope) widths varied greatly. In contrast, the mining pattern throughout the unfolded No.6 level has been a systematic room-and-pillar layout. From the opening of the No.6 level in 1968 until about 1976, production was 3,300 tons per day operating three shifts per day. Rooms 32 feet wide and 8–10 feet tall were mined between 88-foot square pillars with an extraction ratio of 46 percent. In the early years of mining on the No.6 level, there were few mine ground control problems, perhaps because of the protective cover provided by the overlying No.4 level workings. However, by the mid-1970s, mining had reached depths of 2,800 feet. Particularly as the mining moved eastward and was no longer beneath the No.4 level, mine-ground conditions worsened.

In about 1974, uncontrolled roof falls began to occur, seriously injuring one miner. In May 1975, the entire mining front was shut down for safety reasons. After a month of lost production, mining began in another part of the mine. One year later, this mining front was also threatened by failing roof. The operators then turned their attention to rock mechanics to seek improvement in mine-ground control. At that time, the engineer on staff, along with Jack Parker and Associates, began a rock mechanics program that would prove to be instrumental to the success of the mining operation. Several months were spent thoroughly mapping roof failures throughout the entire lower level, taking note of the mode, shape, and direction of the failures. Two significant observations were made: 1) Mining conditions on the lower level (No.6 Salt bed) were favor-ably influenced by the mining on the upper level (No.4 Salt bed) 300 feet above. 2) The mode of failure was such that, although the floor did not heave and the pillars did not fail, the load was apparently too great for the roof rocks, resulting in shearing along the top of the pillars. Once the shear took place, it was a matter of time until roof bolts failed and a roof fall occurred. Some falls were over 220 feet in length and ranged from 3 to 12 feet in height. It was theorized that vertical loading on the stiff pillars resulted in horizontal stresses in the roof rocks great enough to fail the roof rocks in shear. Horizontal shifts in the roof rocks were observed to be as much as 12 inches (Figure 3.2-2).

The problem and its solution seemed to be related to the stiffness of the pillars. It was thought that if the pillars were small enough they would yield and not accept as much vertical loading, thus significantly reducing the horizontal thrusting in the roof (Barrientos and Parker, 1974). There were some critical questions to be answered. Could loads be transferred from an area of yielding pillars to an area of stiffer pillars, resulting in a bridging effect over the yielding pillar zone? If so, could a stress-relief style of mining be utilized by manipulating the sizes of the pillars? In essence, could high production areas with very high extraction be created without roof problems? Could abutment zones be created in such a way that they would handle high vertical loads without the roof hazards experienced in the old design of larger stiff pillars? The answers to these questions could mean the solution to a very serious problem. The success of the operation was hinging on better mine design.

A practical approach to rock mechanics was taken. It was thought that it would be better to use the mine as a field laboratory by taking many simple measurements to determine how the rocks were behaving rather than thoroughly analyze rock samples in a laboratory elsewhere to provide parameters for a theoretical model. The latter approach tends to be costly and at times is not very useful. Specimens taken out of the mine do not always represent the true nature of the rock *in situ*, and loading conditions experienced in the mine usually cannot be duplicated in the laboratory. It was thought that a better approach would be to take many crude but inexpensive measurements in the mine.

3.2.2.2 Techniques

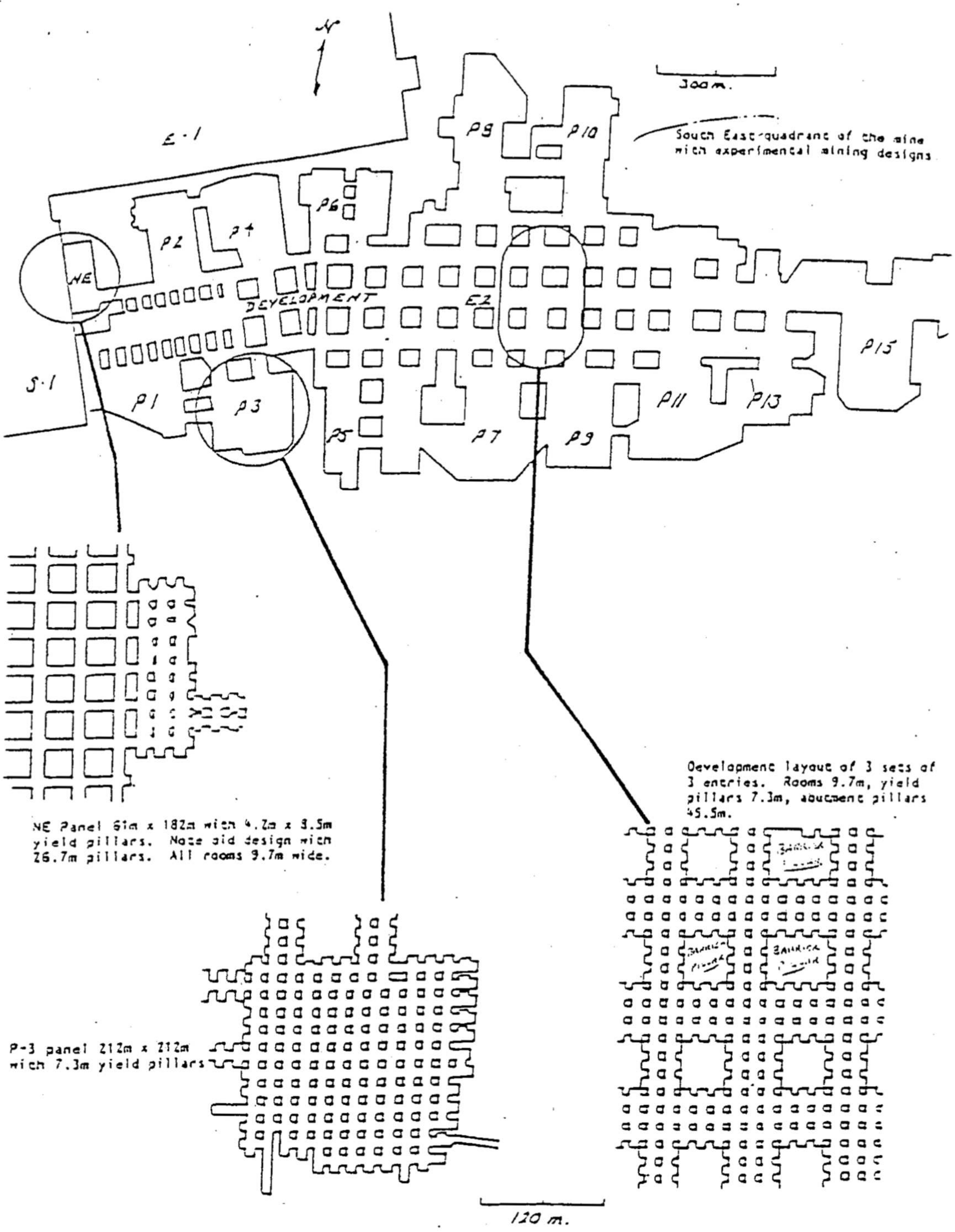
An invar steel "Reed" type convergence rod (Figure 3.2-3) was purchased and closure stations were installed in the existing mine. Background measurements were needed to compare the results of any changes. Pillar expansion was also measured by bore hole extensometers as shown in Figure 3.2-4, which were built in-house at very little cost. After some base line measurements were taken, an experiment was set up to try to determine the effect(s) of yielding pillars. A summer student was hired to help install and monitor instruments.

The first experiment involved splitting existing large pillars 88 x 88 feet into smaller yielding pillars 28 x 28 feet. A site was selected near the mining front far enough from the effects of mining yet close enough to tram the muck to the feeder breaker. The measured closure rates and bore hole extensometer results clearly indicated that the smaller pillars did yield to their core and a transfer of load did take place from the smaller pillars to the adjacent larger pillars. General observations showed that roof conditions among the newly created smaller pillars were quite good, while conditions in the surrounding area deteriorated with a roof fall occurring adjacent to the test (Petersen and others, 1977).

Based on the encouraging results of pillar splitting, a panel 200 x 600 feet, and referred to as the "NE experiment," was mined utilizing 28-foot square pillars and 32-foot wide entries. The results were equally encouraging, and productivity was enhanced by the higher extraction ratio and shorter trams. In fact, results were so encouraging that 28 x 28 foot pillars were further reduced to 14 x 28 feet by undercutting and blasting (Figure 3.2-5). The additional salt was mucked out as extra production, enhancing the miners production bonus, which also created enthusiasm among the miners (Petersen and others, 1979). Management was convinced, based on measurements and visual observations, that the yielding-pillar concept was in fact doing what was presupposed. It was evident that a stress-relief style of mining had been developed, and the decision was made to mine the southeast quadrant in this fashion, thereby affording more learning opportunities as mining progressed.

In the meantime, the existing mining front to the south had hit a major geological discontinuity bringing production to a grinding halt. With no other area of the mine ready for production, it was decided that all production would come from the southeast quadrant using the yielding-pillar concept, and the large-pillar design was abandoned.

For the next 7 years, a variety of yielding-pillar configurations were tried off the sides of a development system extending 7,000 feet to the east. The development consisted of 3 sets of 3 entries 32 feet wide with pillars being 24 x 24 feet. Each set of 3 entries was separated by a barrier pillar roughly 150 x 150 feet as shown in Figure 3.2-5. Conditions in the center entry were excellent. However, conditions along abutment zones were, at times, poor. Softening the edge of the abutment pillars by mining notches into them greatly improved their condition. A total of 15 production units were mined off the development in pursuit of the best combination of pillar size, panel width, and abutment size. This mining design is shown in Figure 3.2-5.



Southeast Quadrant of the Mine with Experimental Mining Designs.

Note: Original Figure by Peterson.

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FIGURE 3.2–5

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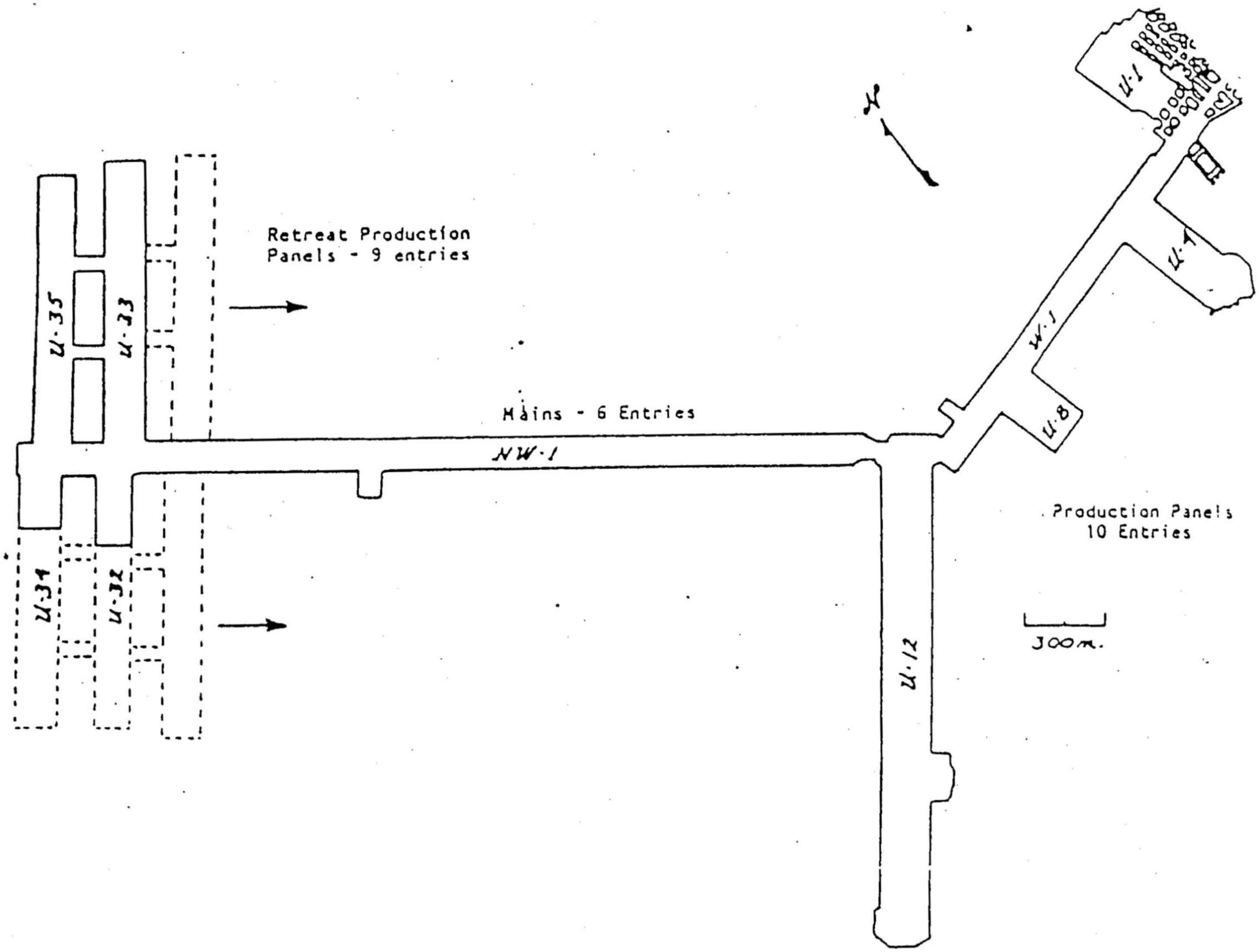
3.2.2.3 Results

Rock mechanics measurements and mapped observations led to the following conclusions about mine design. Pillar size within the mining unit had the greatest impact on roof conditions. Each time the pillar size was reduced, roof conditions improved. Currently, mining is done with 15 x 15 foot pillars in a mining height of 12 feet. The performance of a yielding pillar is mostly dependent upon the width-to-height ratio. Therefore, mining height must be taken into account when designing the yielding pillar. It was found that a width-to-height ratio (W/H) greater than 3 was too stiff. Experience in another rock salt mine showed that a width-to-height ratio of less than 1 can lead to excessive pillar slabbing and ultimately pillar failure.

Entries along stiff abutment zones tended to perform poorly and at times would fail. It was found that notching the abutment was an effective stress-relief technique, and when done right, abutment entry conditions greatly improved (Plumeau and Petersen, 1981). The primary purpose of the abutment zone is to provide support for the transferred load. As panels were stacked side by side in sequence, the load transfer across various abutment widths to the next panel was measured by closure points. As shown in Figure 3.2-6, it was found that a minimum width of 250 feet was a good size to use to carry the overburden loads and to isolate one panel from another.

It was also found that the wider the mining panel, the greater the closure within the panel. It was theorized that if the zone of yielding pillars got too wide, the bridging effect over the panel would be lost, subjecting the yielding pillars to excessive loading, which would be undesirable. An attempt was made to approach this critical width, and an area called P3 was mined out 700 x 700 feet with 24 x 24 foot pillars (Figure 3.2-5). Even though mining pressures at the face were high, causing some problems, the area remains stable 13 years later. It was concluded that a maximum panel width of 500 feet was a good rule of thumb to follow.

Once the southeast quadrant was no longer economical to mine, plans were made to mine the northwest quadrant using a design derived from the 7 years of development and experimentation in the southeast quadrant. Development of the northwest quadrant began in 1984, starting near the shafts, and was, in essence, the start of a new mine. It was decided to mine the main 15,000 feet to the boundary using a 6-entry system with 20 x 20 foot pillars on 50-foot centers. This was completed in 1990 and is shown in Figure 3.2-7. During development, an occasional production unit was mined on the advance to subsidize



Northwest Quadrant Mining.

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FIGURE 3.2-7

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production quotas. However, most of the salt deposit was left to be mined on a retreat from the boundary back to the shaft, leaving mining-induced problems behind. The latest production panel was a 9-entry system using 15 x 15 foot pillars on 45-foot centers. The panel is 490 feet wide including 50 feet of notching on each side. The abutment zone is designed to be 300 feet wide.

Mining conditions with the yielding-pillar design in the northwest quadrant are excellent, even in the outside entries along the abutment zones. Productivity has been increased by over 60 percent and is at an all time high, in part due to the new mine design. The improved roof conditions have lessened the need for roof support, have virtually eliminated falls of ground, and have significantly reduced injuries due to falls of ground or scaling. In addition to better roof conditions, the design has lent itself to easier ventilation, shorter hauls to the feeder-breaker, and shorter equipment moves from one entry to the next.

3.2.2.4 Current Mining Strategy

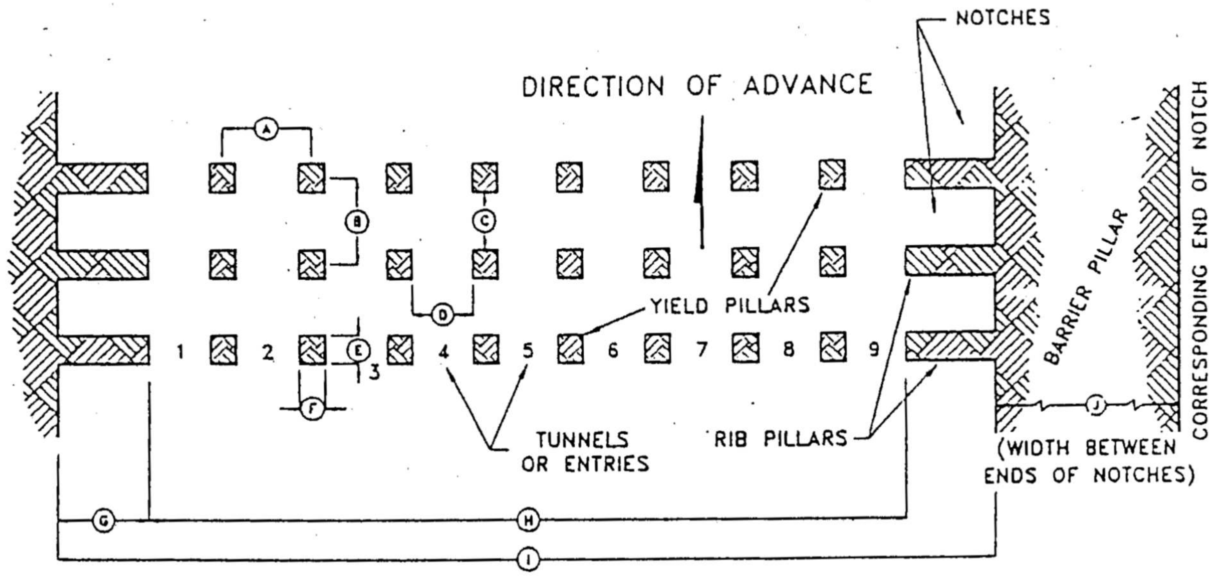
Small pillars within relatively wide panels separated by massive barrier pillars is the mining layout currently being used at the Cayuga Mine. A representative section of a mining panel is shown in Figure 3.2-8. Cargill is currently mining the seventh and eighth such panels in the northwest part of the mine, which is under Cayuga Lake.

In the preceding and following discussions, specific names for different types of pillars are used: two examples are **yield pillars** and **barrier (or abutment) pillars**. The precise definitions for these different pillars are not universally accepted; therefore, definitions are given here as the names apply to the Cayuga Mine. The reason pillars are left in any mine is to support the overlying rock and unconsolidated deposits (here termed, collectively, overburden). Because material is removed by mining, the pillars must be capable of bearing both the overburden directly above the pillar and the overburden above the mined areas. This concept is called tributary loading—the load on a pillar is contributed to by an area larger than the plan area of the pillar itself. The load on a pillar is conveniently expressed as the weight of the overburden carried, divided by the area of the pillar. This quantity is called the average vertical stress in the pillar.

For mines with wide expanses where each pillar experiences full tributary loading (such as 80-foot square pillars in the Cayuga and Retsof, New York, salt mines), the load on the pillar is strictly a function of the extraction ratio. The average vertical stress is the

TYPICAL YIELD PILLAR PANEL DIMENSIONS

(A) 45 FT.	(E) 15 FT.	(I) 488 FT.
(B) 45 FT.	(F) 13 FT.	(J) 300 FT.
(C) 30 FT.	(G) 48 FT.	
(D) 32 FT.	(H) 392 FT.	



Typical Yield–Pillar Panel Layout and Dimensions.

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FIGURE 3.2–8

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premining vertical stress at the mining depth divided by (1 – E), where E is the extraction ratio.

A **yield-pillar** panel is a combination of small pillars within a mined area and large barrier pillars (abutments) surrounding the mined area. The barrier pillars are large enough that they are capable of carrying the full weight of the overburden, according to tributary loading for the entire panel. The yield pillars are left to prevent falls of the immediate roof for worker safety. The yield pillars reduce the wide span of the panel to a series of smaller spans, which are less prone to roof-slab falls.

The terminology for yield pillars and barrier pillars evolved from the coal mining and hard-rock mining industries. Rock mechanics uses the term "yield" to denote the initiation of failure (deformation in a nonelastic manner) and a reduction of load-bearing capability. All salt pillars deform nonelastically because they creep. Salt pillars do not, however, lose their load-bearing capability as a consequence of creep. Hard rock and coal pillars require "high" stress levels to initiate yield; salt pillars will creep even with "low" stress levels.

The shape of the yield pillar determines the amount of load it carries. Yield pillars are narrow compared to their height. A common ratio between the width of square yield pillars and their height is 1:1 to 2:1. Because the pillar height is typically controlled by the thickness of the ore zone, yield pillars are consequently also small, although size in and of itself does not determine whether or not a pillar is a yield pillar. At the Cayuga Mine, yield-pillar sizes have ranged from 28 feet square to about 13 x 15 feet.

3.2.2.5 Characteristics of Yield-Pillar Panels

Yield pillars are a shape that prevents substantial confining stress (horizontal stresses) from developing (that is, low width to height). Barrier pillars are wide, which allows substantial horizontal stresses to develop and provide confinement within the pillars.

Yield pillars readily deform (shorten) to cause transfer of tributary loading from themselves to surrounding pillars that deform less readily. The deformation may be because of failure (hard rocks and coals) or creep (salt, potash, and trona).

Yield pillars are "small" only because of the width-to-height constraint. The extraction ratio between barrier pillars is typically high to sustain the deformation process.

subcontracted geological and engineering services from The Sear-Brown Group, Rochester, New York; International Mining Services, Rolla, Missouri; Engineering Seismology Group Inc., Kingston, Ontario; and GeoData, Tulsa, Oklahoma.

3.2.4 Underground Convergence

Cargill salt has a long history of measuring convergence (room closure) in the No.6 level of the mine. Results of the measurements are reported elsewhere (for example, Petersen and others, 1977, 1979, 1993; Plumeau and Petersen, 1981). The program has provided closure information that influenced the evaluation of the mine design as described above. In this section, closure measurements in the current mining area under the lake are discussed.

3.2.4.1 Overview of Conditions in 1995

Two mine inspections by RESPEC personnel and Cargill staff were made, one in January 1995 and one in May 1995. The January trip was spent on the west end of the mine looking at mining conditions in West 1, NW1, the production panels, and shop area. The May trip was primarily focused on the east end of the mine, which can only be accessed by foot. A convergence rod was used to make as many measurements as possible in the allotted time. Conditions were evaluated in the large pillar areas (S-1), northeast test area, most of the yielding-pillar panels, the continuous miner section in P8, abutment zones, and East 2 development.

In general in the east end of the mine, the conditions in the yielding-pillar areas are extremely good compared to the larger production pillars (88 x 88 feet) and the entries along or through abutment pillars. Most of the yielding-pillar panels have experienced 15–20 inches of pillar (panel) closure. The roof, however, is still very good in most places, and it does not appear to be much different than when it was mined. The roof is solid without any scales forming to speak of. The domed roof bolt plates are, for the most part, not deformed, indicating that the bolts have not taken much, if any, load. The impression was that the roof would have looked the same with or without the bolts.

In the larger pillar and abutment areas, it was a very different picture, especially out from under No.4 level mining. In these areas, numerous bolts have failed and lay on the ground. Unbroken bolts were heavily loaded as indicated by the collapsed dome plates. Several roof falls were encountered, some adjacent to abutment pillars, and were several hundred feet long. Some of the areas through the 88 x 88 foot pillars of the original mine design were difficult to get through due to deteriorating conditions.

Most of the pillars observed appeared to be in good condition with evidence of some pillar slabbing. Typically, as the pillars shorten due to panel closure, they begin to shed their outer shells. Usually, the outer skin of the pillar is weakened by the blast and undercut; and as the pillar shortens, it also expands laterally. This lateral expansion of the pillar causes the outer shell of the pillar to slough and slab off. This shedding process is normal for yielding pillars and may occur several times depending on the amount of yield the pillar undergoes. The pillar from just under the skin to the core appears to be solid and intact. Pillars in Unit 12 and parts of NW1 of the mine have seen 16 inches of panel closure and are still in good condition. Pillars on the east end of the mine have seen 20 inches of panel closure and are still in good condition.

Figure 3.2-9 plots the behavior of U32 and U34. Between mid-March 1992 and mid-July 1992, mining was suspended in the two panels because of excessive salt inventory. When the face stopped advancing, the closure rate immediately began to decrease and continued to decrease until mining was restarted. A similar, although less obvious, deceleration occurs as the face location moves beyond the distance-of-influence. From this, the conclusion can be drawn that a significant amount of the early closure is a direct result of additional mining—not creep.

Figure 3.2-10 illustrates the behavior of four adjacent panels. U35 is a 7-entry panel, and the other three are 9-entry panels. U35 and U33 were mined first; and U31 and U29 followed about 2 years later. The closure rate of U35 barely changed when U31 and U29 were mined. In contrast, the closure rate in U33 more than doubled. This shows that when the barrier pillar is isolated by mining of the adjacent panel, it becomes more heavily stressed (more load), and the creep rate in the barrier pillar increases in response to the added load. The closure rates in the yield-pillar panel increase in response to the increase in the barrier pillar creep rate. The acceleration in closure rates within the panel is not an indictment of yield pillars; rather, it is validation that the barrier pillar is one of the controlling structures in the system.

Figures 3.2-11 and 3.2-12 show the similarity in total closures of four panels as a function of time since mining. In Figure 3.2-12, U35 shows the smallest closure for two reasons: U35 is a 7-entry panel, and it has solid salt (an infinitely wide barrier pillar) on its left side. The closure in U31 accumulates at a faster rate than either adjacent panel U33 or U29 because U29 was developed ahead of U31 such that U31 split a very wide (greater than 1,000-foot wide) barrier pillar. (The total closure in U29, U31, and U33 will likely converge toward the same magnitude during or soon after mining panel U27 is mined.)

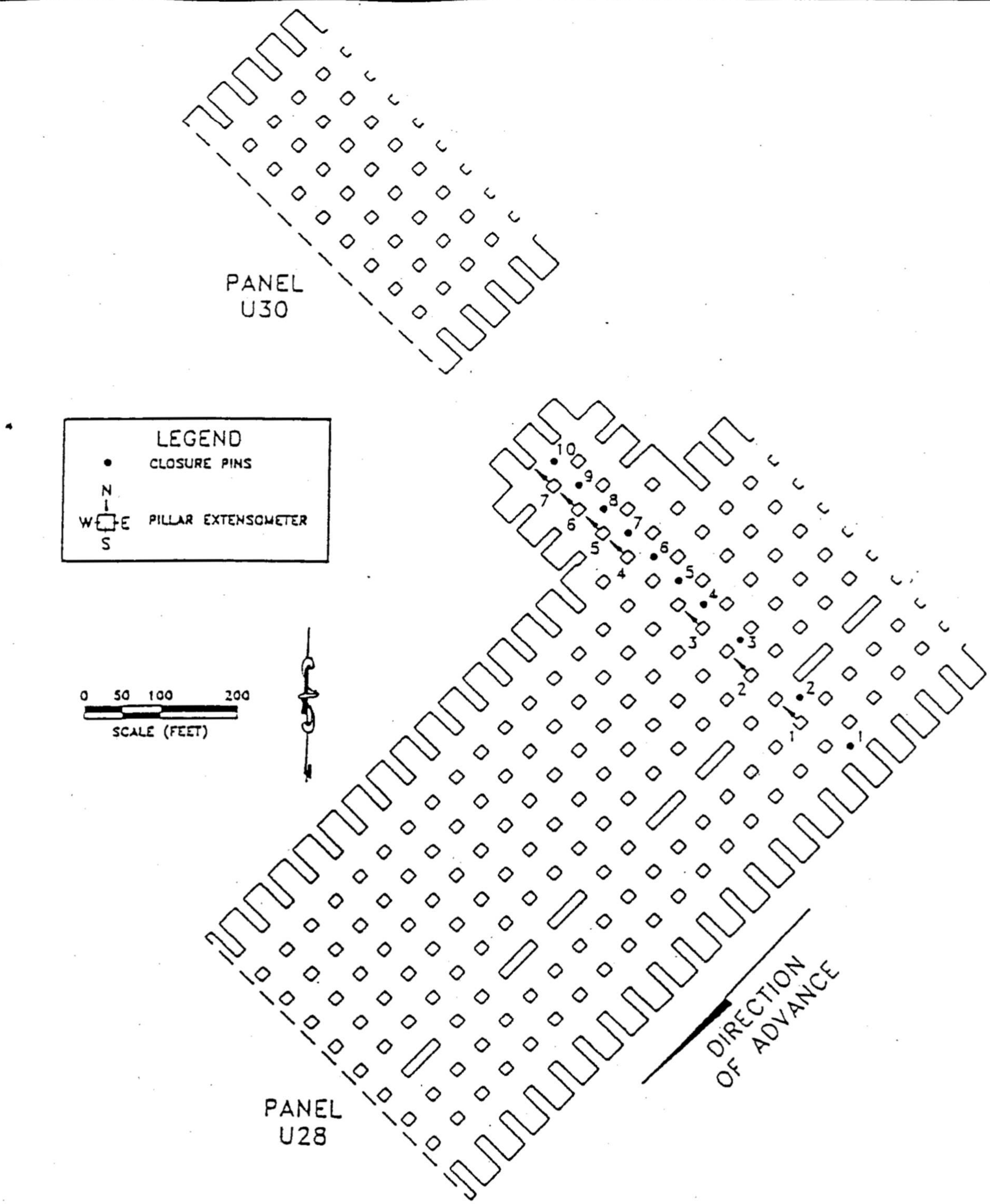
Figure 3.2-13 shows the closure for stations in the NW1 entries. These stations reflect a first episode of closure when the NW1 entries were isolated entries in virgin ground followed by a second (and third) episode when mining panels were excavated adjacent the stations.

3.2.4.2 Panel U28 Closure Profile

During the summer of 1995, 10 special closure stations and 26 pillar extensometers were installed in mining panel U28. The locations of the instruments and face positions at the time of installation are shown in Figure 3.2-14. The closure stations were all installed at the same face position and spread across the panel and into an incomplete breakthrough to panel U30. The extensometers were installed shortly after the closure station. The instrumentation provides profile information from the solid abutment to the southeast of U28 into the barrier pillar between U28 and U30. The stations were installed more than a month after mining, so some deformation in U28 was not measured; the influence of advancing U30 toward and past the profile line was captured only in part. Figures showing summary information and a discussion of the behavior follow.

Figure 3.2-15 shows the measured closure and closure-rate profiles from the solid abutment (tunnel 1), across the panel (tunnels 2 through 9), and into the breakthrough toward U30 (tunnels 10 through 13). The stations were installed in late May, so the profiles show the closure on 2-week intervals. The profiles for July 17 and July 31 are influenced by the driving of the breakthrough from U30 to connect with the earlier mined partial break-through from U28 toward U30. The amount of closure in the breakthrough is almost double that in the mining panel.

Figure 3.2-15 also shows the closure-rate profiles for the same time periods. As was expected, the closure rates decreased between June 14 and June 30 as the mining face moved farther away from the closure pins, and then the closure rates increased when the break-through was extended from mining panel U30. Of particular significance are the later rate profiles. These profiles show that the closure rates returned to their earlier magnitudes and a resumption of decreasing closure rates. (The 1995 closure rates are less than 0.01 inches per day, whereas the long-term, steady-state closure rate is expected to be about 0.0015–0.002 inches per day.) The closure rates in the breakthrough are similar to the closure rates in the panel. An explanation for this is that the 300-foot wide barrier pillar influences the closure rate in the 500-foot wide yield-pillar panel. The closure rates near the solid abutment are similarly smaller than the closure rates near the barrier pillar.



Location of Special Closure Pins and Pillar Extensometers in Mining Panel U28.

Note: Original Figure by RESPEC.

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FIGURE 3.2–14

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Table 3.2-1. Panel U28 Extensometer Information

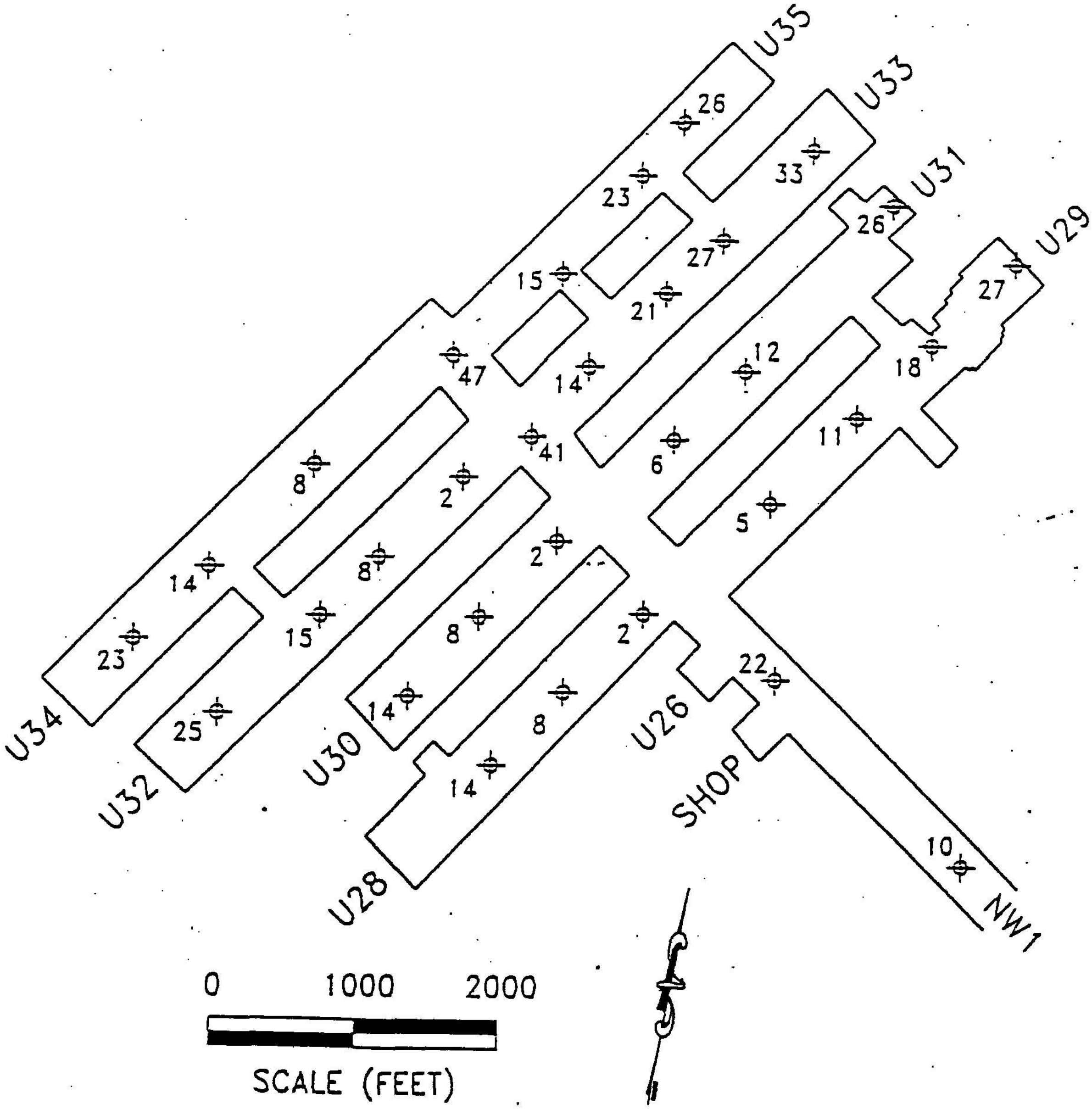
Station	Pillar Between Tunnels	Pillar Dimensions (feet) Width		Height	Exten-someter Direction	Anchor Depths (feet) Shallow	Middle	Deep
		N-S	E-W					
1	2–3	9.0	12.8	11.9	N & S E & W	2 3	4 6	6 8
2	4–5	10.6	13.1	11.9	N & S E & W	2 3	4 6	6 8
3	6–7	8.7	15.6	11.5	N & S E & W	2 3	4 6	6 8
4	9–10	11.0	14.3	11.1	N & S E & W	2 3	4 6	6 8
5	10–11	19.9	15.3	10.3	N & S E & W	3 2	6 4	8 6
6	11–12	15.1	15.0	10.8	N & S E & W	3 2	6 4	8 6
7	12–13	21.3	10.0	11.5	N & S E & W	3 2	6 4	8 6

The measured zone expansions were converted to strain rates and are plotted in Figure 3.2-17 relative to the zone locations in the pillars. For the graphs in Figure 3.2-17, each extensometer is referenced to the center of the pillar. The sizes of the pillars are listed above the graphs; the lengths of the extensometers are listed in Table 3.2-1 and are plotted relative to the rib of the pillar in Figure 3.2-17. In some instances, intervals are omitted when it is obvious that the measurement is bad; for example, extensometer No.2-E-2. In general, the zone nearest the rib shows a greater strain rate than deeper zones, and the middle and deepest zones have about the same strain rate. The average strain rate for the middle and deep zones during August 1995 was 50 x 10^{-6} per day (50 microstrain per day).

The special measurements made in panel U28 indicate that the cores of the yield pillars are deforming in a volume-increasing manner (dilating slightly). The volumetric strain rate is the algebraic sum of the vertical strain rate (negative) and twice the average horizontal strain rate (positive); volumetric strain rate equals 15 microstrain per day. This magnitude is small and does not cause concern because the yield pillars are expected to dilate.

3.2.5 Mining Panel Closure Stations

Closure stations are routinely installed in each of the mining panels as they are mined. These closure stations are installed within one shot or undercut of the mining face and



Location of Long-Term Closure Stations in Panel Under Cayuga Lake.

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FIGURE 3.2-18

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The data on the east side of the mine are current as of August 1994. A few updated readings were taken in May 1996 and are noted on the maps in parenthesis (Figures 3.2-21 and 3.2-22). The highest room closure on the east side is in the P8 panel at a little over 20 inches. Most of the other production panels have seen 15 inches or more. The higher closures are usually associated with wider panels and the absence of No.4 level mining directly above. Other isolated areas are usually a result of localized roof and/or floor deformation.

Closure rates on the east side of the mine have settled down to a very low value from around 0.1–0.5 inch per year. Recent measurements show that closure rates are continuing to decrease showing the east end of the mine to be stable.

3.2.5.2 Panel-to-Panel Comparison

Unit 12 was chosen to be a "standard" closure curve to which to compare the other panels. It was chosen because it is the first production panel that was mined with significant length away from other mining. It was well instrumented, and the data are consistent in nature. Being the first, there are around 8 years of data to evaluate. Unit 12 is 5,400 feet long and 560 feet wide from back of notch to back of notch. It consists of 10 entries each 32 feet wide, and the pillars are 18 x 18 feet. (See Figure 3.2-27 for a recap of panel dimensions.) The curve chosen from Unit 12 is station U12–15 because it is under the lake and not influenced by Unit 12A mining, and it best represents the mining unit.

Figure 3.2-28 shows a comparison of NW1 and Unit 35 to Unit 12. The differences in total closure are simply a result of panel width. NW1 is 350 feet wide; Unit 35 is 445 feet wide; and Unit 12 is 560 feet wide. Unit 35 is proportionately a little high due to the effects of mining Unit 33 at the same time. In other words, twin panels will see comparatively higher closures than a single panel.

Figure 3.2-29 shows a comparison between Units 34, 35, and 12. Again, the effects of mining width are apparent. U35 is 445 feet wide, U34 is 490 feet wide, and U12 is 560 feet wide. Notice the effects of a 120-day shutdown in the early stages of U34. Also, notice the increase in closure at the tail end of U34 and U35. This is a result of mining Units 29–31.

Figure 3.2-30 shows a comparison between Units 32, 33, and 12. The interesting feature here is that all three units up to 100 days are performing nearly identically. Unit 32 is a bit lower at around 350 days due to the effects of the 4-month shutdown. Units 32 and 33

PANEL COMPARISON RECAP

PANEL LOCATION	PANEL WIDTH*	PANEL LENGTH	ROOM WIDTH	ROOM CENTER	PILLAR SIZE	NO. OF ENTRIES	DATE MINED
NW1	350'	10,200'	30'	50'	20'X20'	6	3/86-4/90
U 12	560'	5,700'	32'	50'	18'X18'	10	6/86-1/90
U 28	490'	3,300'	30'	45'	13'X15'	9	6/94-10/95
U 29	490'	3,100'	30'	45'	13'X15'	9	4/93-7/94
U 30	490'	2,400'+	30'	45'	13'X15'	9	11/94-
U 31	490'	2,800'	30'	45'	13'X15'	9	11/93-11/94
U 32	490'	3,200'	30'	45'	15'X15'	9	7/91-5/93
U 33	490'	3,000'	30'	45'	15'X15'	9	3/90-9/91
U 34	490'	3,000'	30'	45'	15'X15'	9	10/91-7/93
U 35	400'/445'	1,800'/2,800'	30'	45'	15'X15'	7/8	4/90-7/91

* BACK OF NOTCH TO BACK OF NOTCH

Panel Comparison.

Note:
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FIGURE 3.2–27

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are 490 feet wide as compared to Unit 12, which is 560 feet wide. However, Units 32 and 33 are part of twin mining panels. In other words, two 490-foot panels side by side will perform almost identically as one 560-foot wide panel. The added closure at around 1,200 days is due to the mining of additional panels (U28 through U31) adjacent to U32 and U33.

Figure 3.2-31 shows a comparison between Units 28, 29, 30, 31, and 12. Units 28 through 31 are 490 feet wide as compared to Unit 12, which is 560 feet wide. The greater closure in this case is due to stacking 4 panels side by side. Figure 3.2-32 is a composite of all the representative stations from the 10 mining units.

3.2.5.3 The Effects of Mining Two Panels Adjacent to Two Existing Panels

Units 33 and 35 were mined simultaneously from NW1 eastward to the lake shore. In the same manner, Units 32 and 34 were mined westward to the lake shore. Then, Units 29 and 31 were mined adjacent to Units 33 and 35, and likewise, Units 28 and 30 were mined adjacent to Units 32 and 34 (see Figure 3.2-33 for layout). It has already been demonstrated that mining twin panels will have the same effect on closure as a single wider panel. The question becomes: What happens when four mining units are stacked side by side?

Figures 3.2-34 and 3.2-35 show there is an effect on the two existing panels when two additional adjacent panels are mined. These figures show the effect of mining Units 29 and 31 on Units 33 and 35 and the effects of mining Units 28 and 30 on Units 32 and 34. Notice the effects on Units 32 and 33 are much greater than Units 34 and 35. This effect is due to the distance the unit is to active mining. Units 32 and 33 being closer to the mining are affected the most.

The same phenomenon can be seen in the rate graphs presented in Figures 3.2-36 and 3.2-34. The rate graphs also bring to light the fact that the effect of adjacent mining is very similar on both sides of NW1. If one overlays Figures 3.2-36 and 3.2-37, one will see the effect on Unit 32 is nearly identical to Unit 33, and the effect on Units 34 and 35 is also nearly the same.

3.2.5.4 The Effects of Mining Future Panels

The next question to answer is: What will happen when two more mining units are mined adjacent to the existing four units? Units 24 and 26 are in the process of being mined, and

Units 25 and 27 are being set up for future production mining. What effect will these units have on the existing units?

To answer this question, one needs to project the closure for future mining. In looking at the characteristics of closure rates for various panels, it was discovered that 500 days after mining, closure rates begin to seek nearly the same rate. Because of this, future rates appear to become predictable (Figures 3.2-38 and 3.2-39). As shown in Figure 3.2-39, Units 29, 31, 33, and 35 are all bracketed between Unit 12 and NW1. Both Unit 12 and NW1 are approaching nearly the same rate, that is, about 0.1–0.2 inches per year. It is believed that reasonable rates can be projected based on this information.

Using the worst case scenario, projections were based on the Unit 12 curve. Figures 3.2-40 through 3.2-43 are projected closure curves of the various mining panels assuming no more additional panels are mined, for instance Units 24 and 26. The projections are for 3,500 days or nearly 10 years. The projection for two 490-foot wide panels side by side as represented by Unit 12 is about 10.2 inches. The two center panels of a 4-panel system averages 12.8 inches, and the outside panels average 11.7 inches. These projections were compared to the computer modeling performed by IMS and were found to be about 25–30 percent lower than those projected by the computer. (See Figure 3.2-44 for a comparison.)

Based on these assumptions, the effects of mining two more adjacent panels (Units 25 and 27) on Unit 33 are shown in Figure 3.2-45. This figure shows Unit 33 without an effect from adjacent mining, the effects of two additional units (U29 and U30) and the effects of two more units (U25 and U27). The effects of Units 25 and 27 are projected from the effects experienced by Units 34 and 35. Since most of the effect is determined by distance from active mining, the effects of future mining can be projected with some confidence. The effects of additional units are additive as shown. The difference between no additional mining effects and the effects of four additional panels on Unit 33 is about 3 inches of additional closure over a 10-year period or about 30 percent additional closure.

The same scenario was used for Unit 29 and is shown in Figure 3.2-46. Actually, in this scenario, the effects of an 8-panel system are projected with total closure exceeding 15 inches. Figure 3.2-47 shows a graph of total closures for various panel systems. Notice that as additional panels are added, the effects of each addition decreases.

No adverse ground behavior with stacking additional mining units is anticipated in the first 10 years or so. Accumulating 15 inches of closure will not create any real problems.

suggests that the overburden is sufficiently thick even below the lake that additional overburden is not involved in the load redistribution onto the barrier pillars.

The calculated subsidence effects extend beyond the shorelines. Some of the "tensile" effects associated with subsidence are outside the perimeter of the mine, therefore, in the thicker bedrock sections.

Analysis of the numerical modeling results leads to the following recommendations:

- Maintain the width of the barrier pillar at 300 feet.

Do not increase the panel widths beyond the current width of about 500 feet after notching the abutments.

Continue to monitor the closure in adjacent panels to determine whether or not additional adjacent panels influence the behavior in existing panels.

Continue the surface subsidence measurements along the lake shorelines, but recognize that the incremental surface subsidence will be small and perhaps undetectable by conventional optical surveys.

Continue the numerical modeling using the longer-term closure data from the current four adjacent mining panels to further calibrate or validate the modeling procedure and rock-mass properties.

3.2.7 Stability of Panels

The stability of the Cayuga Mine can be evaluated from three perspectives.

The rooms and pillars within each mining panel must be stable. That is, the roof must not exhibit uncontrollable roof falls, and the pillars (in current mining, these pillars are yield pillars) must not exhibit pillar splitting or uncontrolled spalling. Inspections did not reveal instances of gross instability in the roof or yield pillars. Calculations of the stress magnitudes in the pillars suggest average vertical stresses of about 2,100 psi in the yield pillars and 5,500 psi in the barrier pillars. The average horizontal stress across the barrier pillar is larger than the pre-mining stress, but still less than the average vertical stress borne by the barrier pillar.

significantly so. The microscopic characteristics are similar to other salts in New York and Ohio, for instance.

The International Salt Co. (ISCO) wells are not a significant stability concern so long as an unmined buffer zone is left. A review of available data indicates that the wells are not as close to the mine as previously thought and that there is no cavity in the No.6 Salt. Based on three-dimensional structural modeling, the interaction will be small between the ISCO wells and Cargill's future mining.

Based on these considerations, RESPEC's opinion is that the Cayuga Mine is currently a stable mine, and no significant stability problems are expected in the future, given the mine layout currently planned.

3.2.9 Continued Reassessments, 2000 Study

In April 1994, Cargill Salt commissioned a study to assess the stability of the northwest part of the mine and the suitability of the mine design. Based on the aforementioned assessment study, Van Sambeek *et al.* (1995) concluded that the Cayuga Mine was a stable mine at the time of the study. Additionally, Van Sambeek *et al.* (1995) concluded that no significant stability problems were expected in the future, given the mine layout planned. These results are given in the previous sections.

Since the 1995 assessment study, a significant amount of additional data has been collected regarding the geology, hydrogeology, panel closure, surface subsidence, and microseismic events of the Cayuga Mine. Moreover, the mining area has expanded to the point that the mine is wider than the largest models used to evaluate barrier pillar width and support of the overburden. Consequently, RESPEC was engaged to reassess the Cayuga Mine stability using the most recent information.

This specific 2000 study is a supplement to the 1995 assessment study of the Cayuga salt mine (Van Sambeek *et al.*, 1995). Three tasks were performed for this study to reassess the stability provided by the current mine design. Each task is outlined below, along with a brief description of the work performed.

1. Evaluation of surface-subsidence data (see section 4.0):

Update existing database of surface monument subsidence.

Update SALT_SUBSID database to reflect current mined area.

Evaluate surface subsidence using SALT_SUBSID to identify if any subsidence anomaly is present through a comparison with the measured data.

2. Numerical modeling geomechanics study (see section 3.2.9.1):

Assess the adequacy of the existing numerical models used to predict subsidence and subsurface subsidence for the 1995 assessment.

Update the model to improve agreement between the calculated behavior and the measured behavior.

Conduct a numerical modeling study to evaluate the effect of increasing the number of adjacent panels from 6 to 12.

Build a three-dimensional model of the Cayuga Mine that includes surface topography features and conduct a numerical modeling study to determine expected panel closure; surface subsidence; and overburden stress now, 10, and 50 years into the future.

Review the numerical modeling results for potential problems or concerns that may affect the stability of the mine now or in the future.

3. Evaluation of microseismic data (see section 3.2.12):

Interact with Engineering Seismology Group Canada, Inc., to evaluate what types of seismic events are being generated as a result of mining.

Describe the significance of the seismic events as it relates to rock mechanics issues.

3.2.9.1 Geomechanical Modeling

Results provided include:

Comparison of measured and predicted panel closures and panel closure rates.

Predicted horizontal pillar displacements.

Predicted vertical displacement profiles of the Camillus Shale and shale above the mine roof during mine expansion to 14 adjacent panels in width.

Predicted stress history in the barrier pillars during mine expansion to 14 adjacent panels in width.

3.2.10.1.1 Panel Closure and Closure Rates

Results provided include:

1. Comparison of measured and predicted panel closures and closure rates.
2. Predicted vertical displacement profiles of the Camillus Shale and shale above the mine roof during mine expansion.
3. Comparison of surface subsidence with measured subsidence for the January 2000 survey.
4. Evaluation of the factors-of-safety in the rock between the mine and the top of bedrock.

3.2.10.2.1 Panel Closure

3.2.11 Summary and Conclusions Based on Geomechanical Modeling Results 2000

As a part of the reassessment study, two-dimensional and three-dimensional geomechanical analyses of the Cayuga Mine were performed. Before the analyses were performed, a stratigraphy had to be determined that was representative of the rock mass at the Cayuga Mine. The stratigraphy within the Syracuse Formation used for this study is significantly different from that used in the 1995 mine assessment. The resulting numerical models provide significantly more detail than those used in the 1995 assessment and are believed to be more representative of the conditions at Cayuga Mine. The findings and conclusions drawn from the analyses are:

Measured and predicted mine closure behavior agree reasonably well using the United States Bureau of Mines and RESPEC laboratory testing rock properties. After adjustment to compensate for early closure discrepancies, excellent agreement was obtained for room closure and closure rate by the two-dimensional model. The three-dimensional model underpredicts the panel closure and closure rates; however, the predictive capability might be improved by increasing the model refinement.

The factors-of-safety for the shale and carbonate beds above the mine are greater than 1.0 throughout the 50-year simulation period, indicating that the current mine configuration with a 12-panel width will remain stable well into the future.

The factors-of-safety for the shale above the mine do not decrease substantially when the mine is expanded from 2 to 12 panels in width. Therefore, it is probable that continued expansion of the mine is possible without failure occurring in the nonsalt beds above the mine. The factors-of-safety predicted for the Camillus Shale exceed 4 throughout the 50 years simulated, indicating that sufficient overburden exists to isolate the water-bearing members above the mine from the mine in absence of any geologic anomaly.

The three-dimensional model predicts lower factors-of-safety in the shale beds than the two-dimensional model. Although greater mean stresses because of the plane-strain assumption is the likely reason, the lower factors-of-safety predicted by the three-dimensional model may also be partially the result of geometry, surface topography, and/or model refinement. It is evident from the results obtained from the three-dimensional model that the area with the lowest factors-of-safety will be in the vicinity of NW1. The lowest factors-of-safety still do not indicate failure.

Factors-of-safety predicted for the salt with respect to dilation are less than 1.0 in the No.5 Salt. Based on the current successful operation of mining in the No.6 Salt, this does not pose a stability problem.

3.2.12 Microseismic Monitoring

In March 1995, Engineering Seismology Group Canada Inc. (ESG) installed a microseismic monitoring system in the Cayuga salt mine. This monitoring network consisted of 15 accelerometers located in 10- or 30-foot deep boreholes in the roof of the mine. The accelerometers were distributed between panels U26 and U34 in the northwest part of the mine. This area of the mine is located in the No.6 Salt at a depth of about 1,750 feet below sea level. The purpose of the monitoring was to delineate regions of mining-induced seismicity, if any.

ESG began seismic monitoring on March 24, 1995. Regular reports were prepared by ESG documenting the time, location, and magnitude of seismic events (excluding blast events). In addition to the regular seismic monitoring reports, ESG prepared reports in July 1995 and November 1996 that included a detailed analysis of the location and orientation of the failure planes generating the seismic events recorded by the monitoring network. Inferences on the principal stress directions were included in the July 1995 and the November 1996 reports. The November 1996 report also contained inferences on the orientation of the principal strain axes and the principal strain rates.

ESG has collected a considerable amount of microseismic data at the Cayuga Mine. This section summarizes the data collected between March 24, 1995, and October 5, 1997, and presents RESPEC's interpretation from a geomechanical perspective.

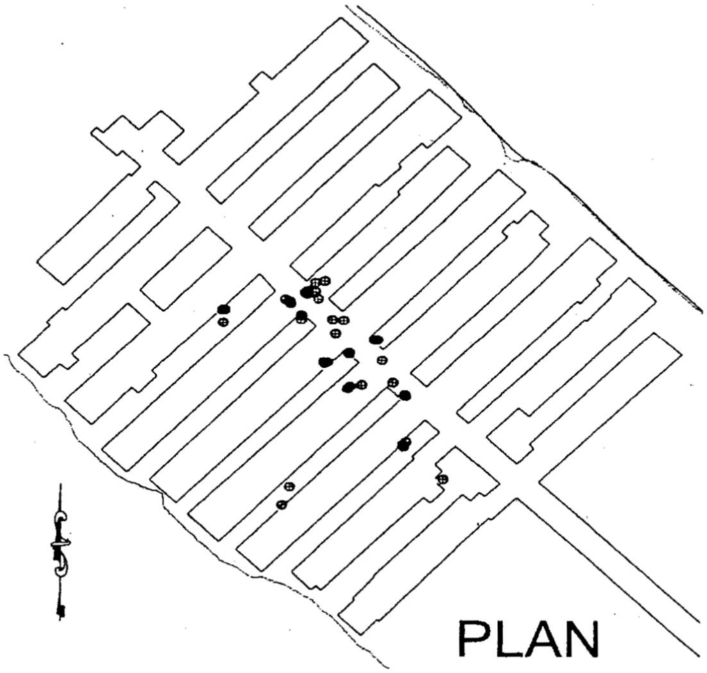
3.2.12.1 Summary of Results

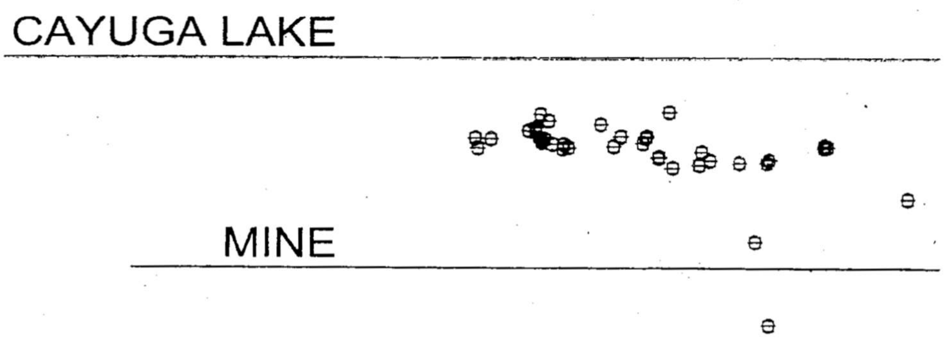
3.2.12.1.1 Location of Events

The majority of the seismic events (excluding blast events) recorded by the monitoring network at the Cayuga Mine and reported by ESG were confined to a horizon located about 1,300 feet above the mine. The error associated with a seismic event at this distance is ±100 feet in northing and easting and ±200 feet in elevation. This elevation corresponds to the upper portion of an approximately 400-foot thick (based on a log of core hole No.17) sequence of predominately carbonate Siluro-Devonian strata (Bertie-Helderberg-Oriskany-Onondaga). The carbonate sequence is presumably stiffer than the strata lying above and below. The mineralogy and thickness of this sequence suggest that it is a main load-carrying unit overlying the mine. Therefore, this carbonate sequence would be expected to experience substantial induced stresses as a result of deformations from mining-induced subsidence. This assumption was verified by the FLAC^{3D} model of the Cayuga Mine that indicated a region in the carbonate sequence, centered above the NW1 drift, with reduced factors-of-safety.

With only one exception (that occurring on January 17, 1997), there were no series of seismic events that were spatially and temporally related that showed a linear vertical trend. A series of events with a linear vertical trend may indicate the propagation of a fracture that could create a pathway for water to enter the mine. On January 17, 1997, a series of nine events was recorded that follow a vertical trace from about 300 feet below the Onondaga Limestone to the mine between panels U30 and U32. These events occurred over a 30-minute time period and ranged in magnitude between 0.5 and 1.0. Since January 17, 1997, no reoccurring microseismic events have been recorded in this area, indicating that this was a one-time event and not a stability issue. Because no further events have been seen in this area, the issue was not studied further. However, if activity were to be observed along this zone in the future, the situation would warrant additional consideration.

In plan view, the majority of the seismic events tended to cluster above the NW1 entry. Figure 3.2-81 shows the inferred locations of 40 microseismic events recorded between





Locations of 40 Microseismic Events Occurring Between March 25 and April 5, 1995

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FIGURE 3.2-81

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March 24 and April 5, 1995. The relative locations of these events are typical of the events recorded during the monitoring period. A significant number of events were also located immediately outside the mine limits. These locations are not unexpected. The NW1 drift is located at the center of the current mining activity. Therefore, the maximum mining-induced subsidence would be anticipated to be above the NW1 drift. The occurrence of seismic events outside the mine limits is probably due to the "stretching" of the overburden across the relatively "stiff" pillar of salt immediately outside the mine limits. It is expected that normal-type (extensional) failures or movement along a pre-existing fracture would occur in this region; whereas, reverse-type (compressional) failures would be expected above the NW1 drift due to a "shortening" of the overburden.

The exception to the spatial observations noted above was the recording of events located above the crosscut between panels U28 and U30 beginning in October 1995 and lasting until March 1996. The reason for this occurrence is unclear. The most likely explanation is the presence of a pre-existing plane of weakness at this location.

Mining-induced subsidence leads to deformation of the "beam" that represents the carbonate sequence overlying the mine. The carbonate beam will deform elastically until deformation-induced stresses at a point exceed the strength at that point. If fracturing of the carbonate sequence occurs, the location of fracturing will correspond to those points where the strength of the material is exceeded. In all likelihood, those points will correspond with the locations of highest deformation-induced stresses or along pre-existing failure planes. This is not always the case because weaker materials will fail at lower stresses than stronger materials. To be able to accurately predict potential locations where seismic events are expected to occur would require the testing of core taken from the carbonate sequence to develop strength properties and numerical modeling to predict the stresses. The results of the modeling can be compared with microseismic data to determine if they agree. If they do not agree, pre-existing planes of weakness could be identified that were not accounted for by the numerical models. The numerical modeling presented in previous sections did not take into account different strength properties for the carbonate sequence. As a result, the lowest factors-of-safety were not limited to a single formation within the carbonate sequence. However, the lowest factors-of-safety within the carbonate sequence were predicted directly below the center of the lake well above the Camillus Shale, which agrees with the microseismic data. Nevertheless, modeling in conjunction with the information obtained from the microseismic data produced useful in-sights into the behavior of the strata overlying the Cayuga Mine.

3.2.12.1.2 Timing of Events

The seismic events reported by ESG are not related in time to blasting at the mining faces. This indicates that seismic events result from rock movements brought about by gradual changes in stresses due to slow deformations caused by mining-induced subsidence.

The daily frequency of events varies. The event frequency at a given time is probably related to the number of panels actively being mined at that time, the relative location of the panel faces, and the proximity of the panels to each other. All of these factors also influence the subsidence rate at a given point at a given time.

Failures in the overlying strata are not in themselves a cause for concern. Failures are a process of relieving the buildup of stresses due to mining-induced deformations. As long as the failures occur at a relatively constant frequency and at a relatively constant magnitude, stability of the overlying strata is indicated. When failures do occur, the load is necessarily transferred to the surrounding rock. As a result, the possibility exists that the seismic events might migrate away from the current cluster above NW1 in the future or that additional events will occur beyond the current zone of activity (either vertically or horizontally).

The seismic events recorded to date do not indicate instability. Seismic events will continue to be monitored for any indications of instability, such as a linear vertical trend or occurrences away from the area where current events are clustered. Seismic events at locations other than those currently being recorded could be the result of stress redistribution caused by mining. Therefore, it is important to continue to monitor regions beyond the current zone of activity with the existing microsceismic monitoring system. The current mine boundary is near the limit that the existing microseismic system can monitor. Therefore, the rock overlying future expansion areas of the mine cannot be monitored with the existing system. The changing conditions in the overlying rock between the current mining area and the future expansion area to the north may not respond identically to the presence of the mine. Expansion of the current microsceismic system to monitor events above future mine workings would be beneficial to the continued assessment of the structural stability of the Cayuga Mine.

3.2.12.1.3 Orientation of Failure Planes

Seismic events are generated when movement occurs along a new or pre-existing failure plane. ESG used two analysis methods to determine the orientation of these failure planes.

The first method is referred to as the Principal Component Analysis (PCA). This method uses a search criterion to identify seismic events that are related in space and time. An ellipsoid is then fit around these events. If the distribution of these related events is planar rather than spherical (that is, the distribution takes on the shape of an ellipsoid rather than a sphere), a strike and dip can be obtained from the plane passing through the major and minor axes of the ellipsoid.

The second method of determining the orientation of a failure plane is referred to as a fault-plane solution. This method maps the first motions (either compressional or dilational) for each seismic event as recorded by several accelerometers. These first motions can be mapped in space into four quadrants. Two orthogonal planes separate these quadrants; one is the failure plane and the second is referred to as the auxiliary plane.

Under stable regional stress conditions, the principal stress directions can be inferred from the orientation of the failure and auxiliary planes. The intersection of these planes defines the orientation of the intermediate principal stress axis. The maximum principal (most compressive) stress axis bisects the planes in the direction of the dilational motions. The minimum principal (least compressive) stress axis bisects the planes in the direction of the compressional motions.

These two methods were used by ESG to identify the likely orientation of the failure planes generating the seismic events recorded at the Cayuga Mine. An analysis of the events that occurred above NW1 indicates a northwest-southeast strike for the failure planes and a subvertical dip. An analysis of a group of events that occurred above the crosscut between panels U28 and U30 also indicates a northwest-southeast strike. These northwest-southeast strikes approximately parallel the NW1 drift and the long dimension of the mine. This is also the approximate strike of mapped joint sets in the Cayuga region. In consideration of these two factors, the failure plane orientations calculated from the PCA and the fault-plane solutions are as expected.

3.2.12.1.4 Principal Stress Orientations

Shear fractures are systematically related to the principal stress axes. Furthermore, the intermediate stress axis lies on the failure plane and the failure plane makes an angle with the maximum principal stress axis of approximately 30 degrees. Observations of laboratory tests of bench-scale specimens confirm these relationships. Therefore, it is possible to use the orientations determined from the fault-plane solutions to predict the likely orientation of the principal stress axes.

The orientations of the principal stress axes inferred from the fault-plane solutions of the seismic events occurring above the NW1 drift are given in Table 3.2-5. Several *in situ* stress measurements have been performed in western New York (Lindner and Halpern, 1978; United States Geological Survey and Schlumberger-Doll Research, 1984). Principal *in situ* stresses are generally assumed to be aligned with an axis system that is vertical and horizontal. The maximum stress measured at these sites was horizontal with an azimuth that varied from N64°E to N101°E. The orientation of the maximum principal stress axis inferred from the fault-plane solutions of the microseismic data agree favorably with the measured *in situ* maximum stress direction.

Table 3.2-5. Azimuth and Plunge of the Principal Stress

Principal Stress	NW1				U28 and U30 Crosscut			
	Microseismic Data		FLAC3D Model		Microseismic Data		FLAC3D Model	
	Azimuth	Plunge	Azimuth	Plunge	Azimuth	Plunge	Azimuth	Plunge
Maximum	N70°E	26°SW	N35°E	8°SW	N40°E	33°NE	N59°E	15°NE
Intermediate	N30°W	18°SE	N53°W	4°NW	N50°W	1°NW	N32°W	1°NW
Minimum	N30°E	57°NE	N31°E	80°NE	N37°E	57°SW	N53°E	75°SW

The orientation of the principal stress axes inferred from the fault-plane solutions of the seismic events occurring above the crosscut between panels U28 and U30 are given in Table 3.2-5. Based on the data supplied by ESG, the principal stress axes rotate approximately 60 degrees more or less about the intermediate stress axis relative to the inferred orientations above NW1. Assuming the orientation of the principal stress axes predicted by ESG are correct, the rotation in the principal stress axes may be caused by the near-surface stress fields of the glacial valley (Cayuga Lake) above the mine.

Table 3.2-5 also includes the principal stress orientations predicted by $FLAC^{3D}$. The model predicted principal stress orientations agree favorably with stress orientations inferred from the microseismic data. Note that the $FLAC^{3D}$ model predicts a rotation of the maximum principal stress direction of 25 degrees about the intermediate principal stress axis similar to the observation made of fault-plane solutions of the microseismic data.

3.2.12.1.5 Strain Rates

Mining-induced subsidence creates deformations (strains) in the overlying strata. These strains are directly related to the induced stresses in the rock. The assumption can be made that the magnitude and number of seismic events in a given period of time in a given region of space are related to the strain rate. In this manner, strain rates can be inferred.

ESG performed a Deformation State Analysis to approximate the strain rates and the principal strain orientations above the NW1 drift and above the crosscut between panels U28 and U30. The orientations of the principal strain axes indicate near vertical-type movement. This correlates well with the orientation of the failure planes determined from the PCA and the fault-plane solutions. However, the strain rates reported by ESG (on the order of 1×10^{-10} inches/inches per day) appear quite low.

3.2.12.2 Conclusions and Recommendations of Microseismic Monitoring Results

The recording and analysis of microseismic data at the Cayuga Mine provide useful insights into the behavior of the overlying strata. It is recommended that the monitoring of microseismic data be continued at the Cayuga Mine. Particular attention should be paid to the mapping of seismic events and the recording of seismic frequency and magnitude. The location, frequency, and magnitude of the microseismic events recorded by ESG indicate only localized activity well above the mining horizon.

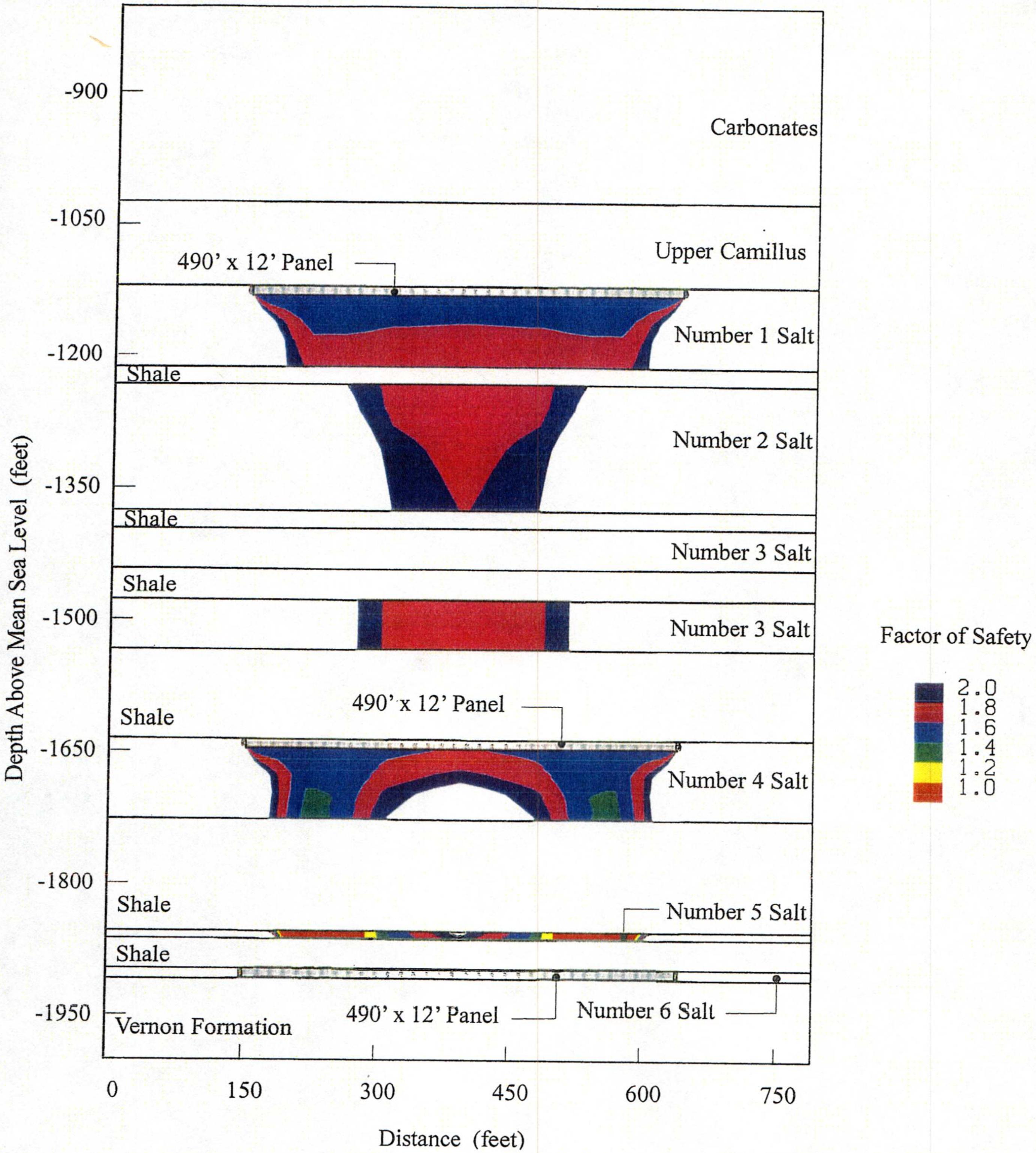
3.2.13.4 Results

The stability assessment results are provided in terms of factors-of-safety for the salt and shales near the mined openings. With regard to the salt, the factor-of-safety is measured against the potential for damage (microcracking) in the salt fabric (Van Sambeek *et al.*, 1995). In the shales, the factor of safety is calculated assuming a friction angle of 30 degrees and a measured unconfined compressive strength of 10,000 psi (United States Department of Interior, 1980). It was assumed that other rock types present in the model (limestones, sandstones, etc.) were at least as strong as the shale. By definition, a factor of safety greater than 1.0 indicates a mechanically stable condition.

Figure 3.2-82 shows the factor of safety in the salt beds near a panel at the center of the mine at 10 years after the No.1 Salt is mined (simulation time of 30 years). The factors of safety predicted near this panel are representative of all 20 of the panels simulated. The results of this figure are from the model used to simulate mining beneath Cayuga Lake. The lowest factors of safety in the salt beds occur directly above and/or below the mined panels. In general, the factors-of-safety are greater than 1.5 for all the salt beds except for the No.5 Salt. A factor-of-safety less than 1.0 is predicted in the No.5 Salt during the mining of the No.6 Salt. The factor-of-safety of the No.5 Salt decreases slightly following the mining of the No.4 Salt. Based on the current successful operation of mining the No.6 Salt, however, this does not pose a stability problem.

The factors-of-safety for the shale beds near the center panel of the mine located under the lake are illustrated in Figure 3.2-83. The results presented in this figure are typical of the shale beds near the other panels modeled with the exception of the outside panels. The factors of safety in the shale near the outer edge of the mine are greater (safer) than those predicted near the center of the mine. As shown in Figure 3.2-83, small zones of failure (factors-of-safety less than 1.0) are predicted in the shale unit separating the No.2 and No.3 Salts. The factor-of-safety became less than 1.0 in this unit following the mining of the No.1 Salt. Since mining of the No.6 and No.4 Salts precedes mining the No.1 Salt, localized failure of this bed, which would be located below the current mining horizon in the No.1 Salt, would not be deleterious to mining. The factors of safety in all the shale units could be increased by reducing the extraction ratios in the No.4 and No.1 Salt.

Figure 3.2-84 is similar to Figure 3.2-83 except results are presented for the analysis of a mine beyond the lake boundaries. The results shown in Figures 3.2-83 and 3.2-84 are nearly identical. The results are similar because the increased overburden load was offset



Factors of Safety in the Salt Near the Center Panel of the Model Assuming the Mine is Located Under Cayuga Lake.

Note:
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FIGURE 3.2-82

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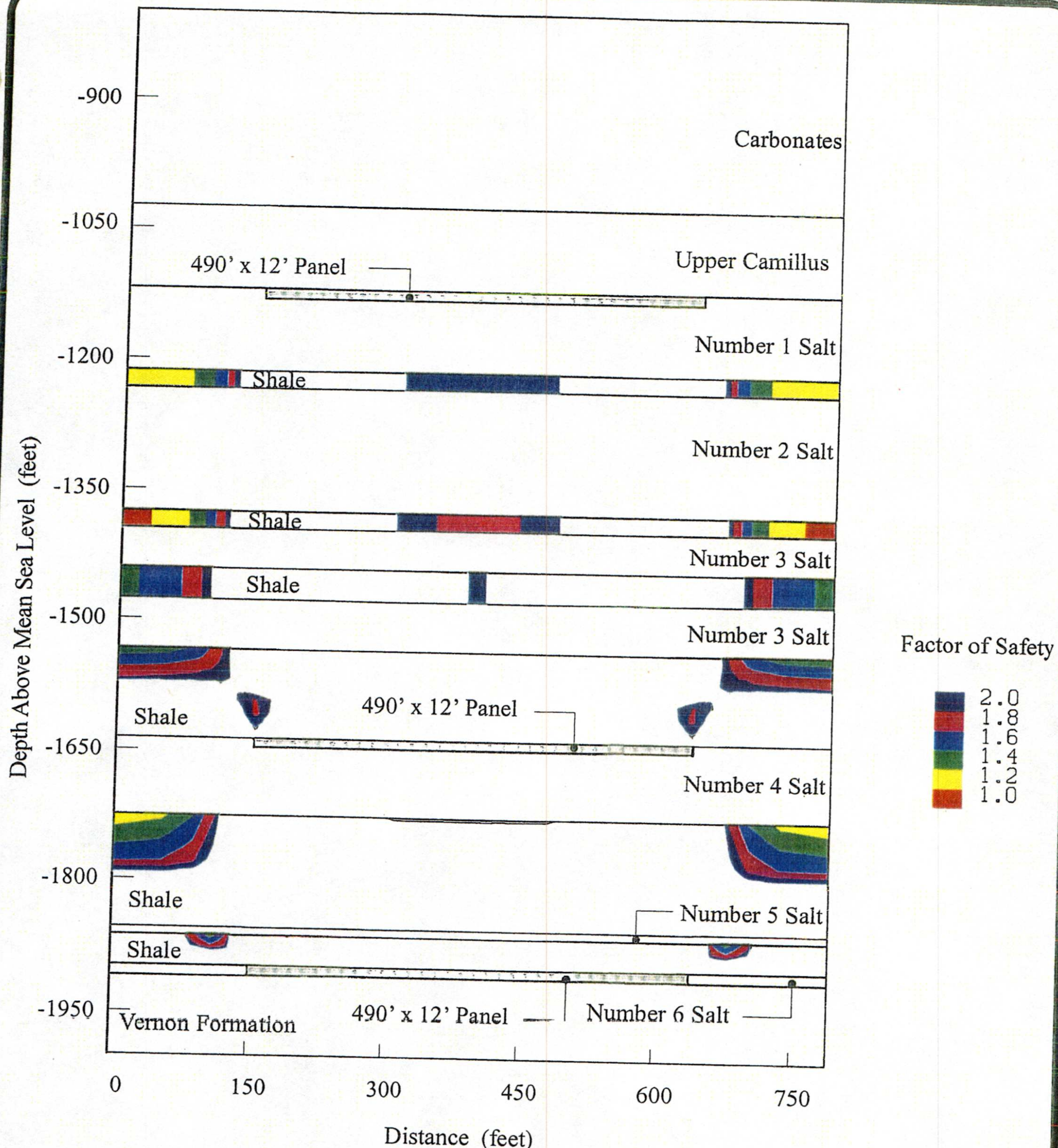

Factors of Safety in the Shale Near the Center Panel of the Model Assuming the Mine is Located Under Cayuga Lake.

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FIGURE 3.2-83

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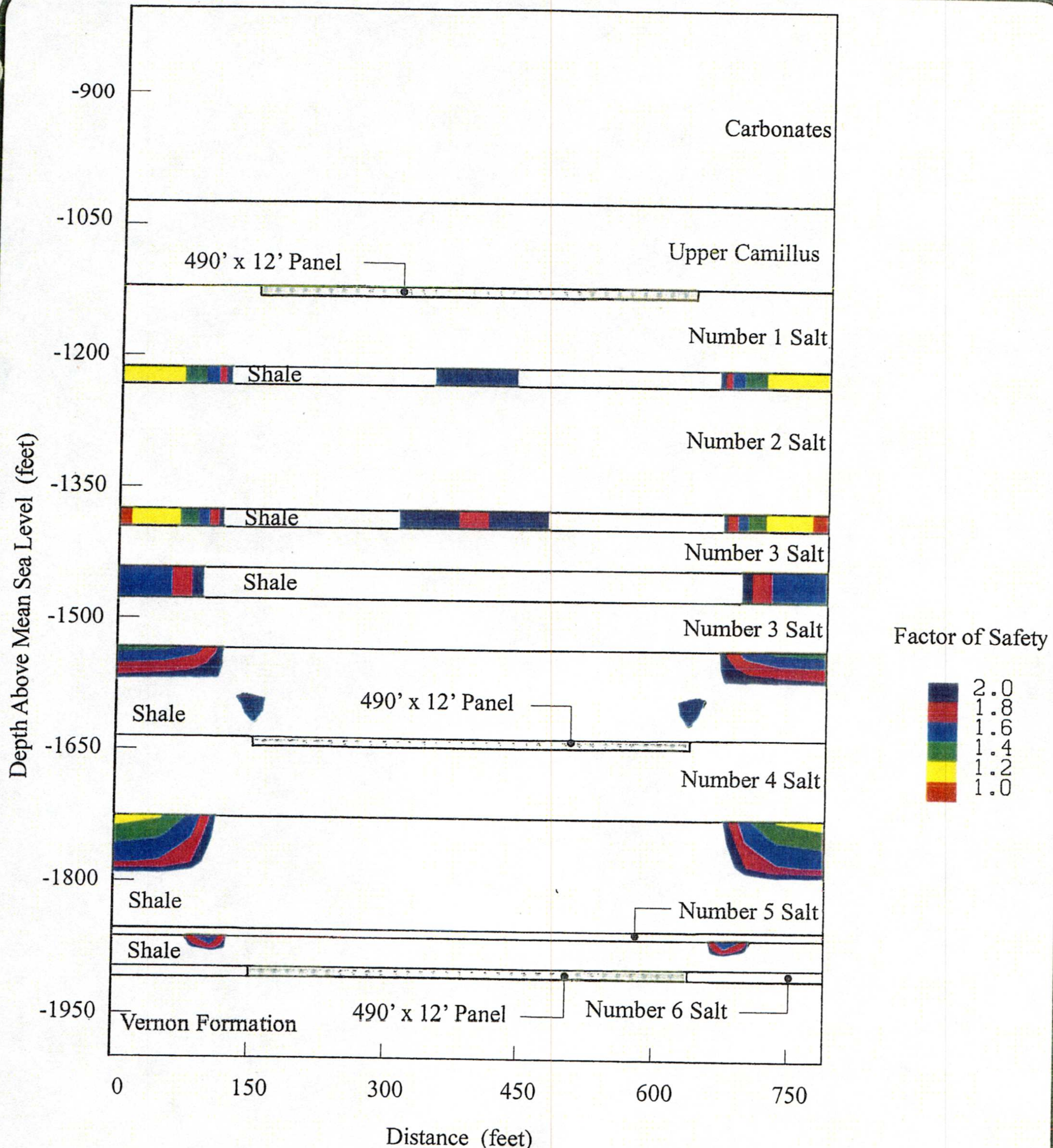

Factors of Safety in the Shale Near the Center Panel of the Model Assuming Mining Beyond the Cayuga Lake Shore Boundary.

Note:
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FIGURE 3.2-84

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by an increase in the vertically directed pressures that simulate the small in-panel pillars. Again, the increase in the effective pillar pressure was used to maintain constant room closure rates both beneath and beyond the boundaries of Cayuga Lake. The increase in pressure is essentially equivalent to a reduction in the extraction ratio. For the mine beyond the lake boundary to perform structurally in the same manner as the mine below the lake, the panel extraction ratio would have to be reduced to approximately 70 percent. It is important to note that the factors-of-safety in the Upper Camillus Shale are greater than 2.0 for both of the analyses presented. Similarly, the factors of safety in the carbonate sequence above the Upper Camillus Shale remain greater than 3.0 throughout the entire simulation period.

3.2.13.5 Conclusions

Two-dimensional finite element analyses were performed as part of a proof-of-concept study to evaluate the feasibility of multiseam mining at the Cayuga Mine. Numerical analyses of the conceptual model indicate that multiseam mining at the Cayuga Mine is possible within the previously approved mine boundaries without jeopardizing mine stability. Although the potential for failure in a shale bed and dilation of the No.5 Salt were predicted to occur by the numerical model, the location and timing of these events make them inconsequential from a stability standpoint.

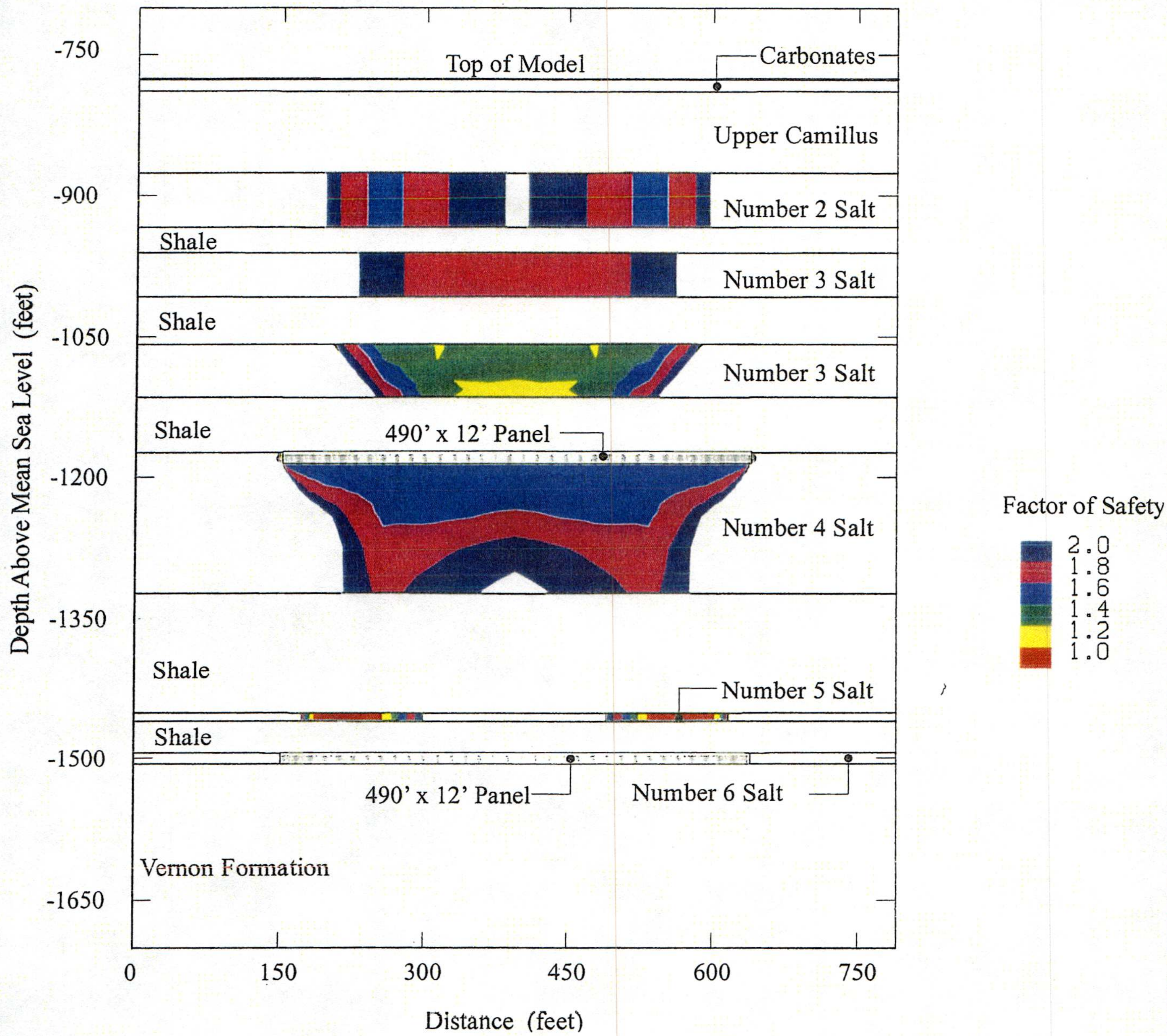
The intent of this study was to determine if multiseam mining is feasible at the Cayuga Mine within the previously approved mining areas. As demonstrated in this section, it is confirmed that multiseam mining is indeed a viable option. However, this work should not be construed as a mine design. RESPEC can only endorse moving to multiseam mining after a more detailed examination of proposed operations. Specifically, design of a multiseam mining operation should include location-specific stratigraphic information, more detailed testing of important rock members, yield pillar designs, etc. Such detailed mine design issues were not part of this proof-of-concept effort.

3.2.13.6 Mining on Multiple Levels in the Proposed Permit Modification Area

3.2.13.9 Results

The stability assessment results are provided in terms of factors-of-safety for the salt and shales near the mined openings. With regard to the salt, the factors-of-safety are measured against the potential for damage (microcracking) in the salt fabric (Van Sambeek *et al.*, 1995). In the shales, the factors-of-safety are calculated assuming a friction angle of 30 degrees and a measured unconfined compressive strength of 10,000 psi (United States Department of the Interior, 1980). It was assumed that other rock types present in the model (limestones, sandstones, etc.) were at least as strong as the shale. By definition, a factor-of-safety greater than 1.0 indicates a mechanically stable condition.

Figure 3.2-85 shows the factor-of-safety in the salt beds near a panel at the center of the mine at 20 years after the No.4 Salt is mined (simulation time of 30 years). The factors-of-safety predicted near this panel are representative of all 20 of the panels simulated. The



Factors-of-Safety in the Salt Near the Center Panel of the Model Assuming the Mine is Located Under Cayuga Lake.

Note:
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FIGURE 3.2-85

CARGILL SALT, INC.
CAYUGA MINE

TOWN OF LANSING

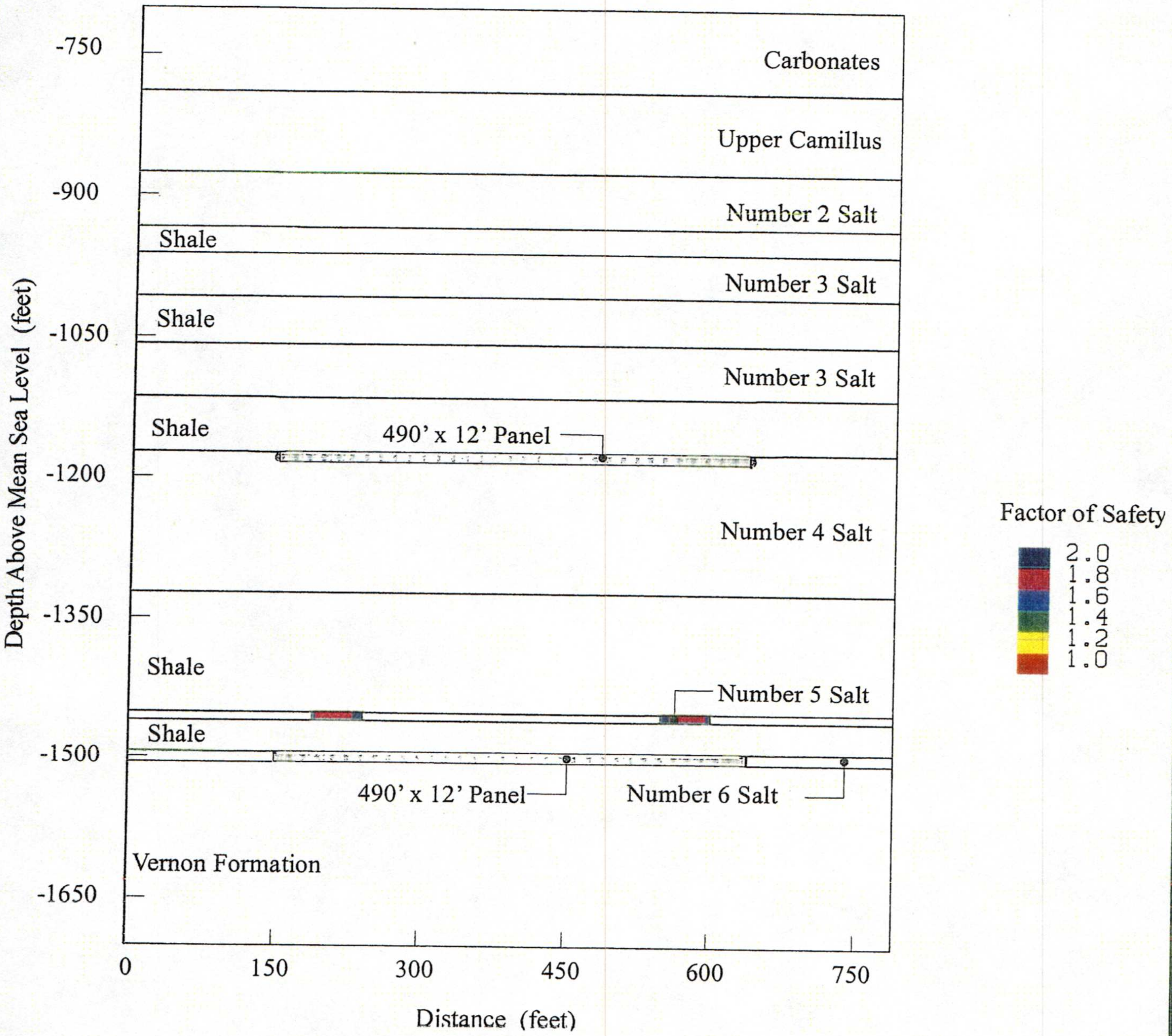
TOMPKINS CO., N.Y.

results presented in this figure are from the model used to simulate mining beneath Cayuga Lake. The lowest factors-of-safety in the salt beds occur directly above and/or below the mined panels. In general, the factors-of-safety are greater than 1.0 for all the salt beds except for the No.5 Salt. A factor-of safety less than 1.0 is predicted in the No.5 Salt during the mining of the No.6 Salt. This is not believed to pose a stability problem because numerical simulations of current mining in the northwest area also predicted dialation of the No.5 Salt (DeVries *et al.*, 2000), and yet the mine in the northwest area is stable. The factors-of-safety in the salt beds above the No.4 Salt decrease with time following the mining of the No.4 Salt but remain greater than 1.0 during the 30 years of simulation.

The factors-of-safety in the salt beds are greater than 1.6 in all locations for the model used to simulate mining beyond the boundary of the lake, as illustrated by Figure 3.2-86. Thus, the potential for damage in the salt is lower beyond the lake boundaries than below the lake.

The factors-of-safety for the shale beds near the center panel of the mine determined in the simulation of the model with the mine located under the lake are illustrated in Figure 3.2-87. The results presented in this figure are typical of the shale beds near the other panels modeled with the exception of the outside panels. The factors-of-safety in the shale near the outer edge of the mine are greater (safer) than those predicted near the center of the mine. As shown in Figure 3.2-87, no failure is predicted in the shale, and the factors-of-safety are greater than 1.4 at all locations. Lower factors-of-safety were predicted in the carbonate layer than were determined by the previously reported models. The lower factors-of-safety are a result of the smaller thickness specified for the carbonate layer in the current model. However, the factors-of-safety are greater than 1.0, indicating a safe and stable condition.

Figure 3.2-88 is similar to Figure 3.2-87 except results are presented for the analysis that simulated mining beyond the lake boundaries. The results shown in Figures 3.2-87 and 3.2-88 are nearly identical, except for the factors-of-safety in the carbonates. The factors-of-safety are greater for the carbonates beyond the lake boundary than they are below the lake because the carbonates beyond the lake boundary are thicker. Factor-of-safety results for the shales are similar for the two models because the increased overburden load of the model beyond the lake boundary was offset by an increase in the vertically directed pressures that simulate the small in-panel pillars. Again, the increase in the effective



Factors-of-Safety in the Salt Near the Center Panel of the Model Assuming Mining Beyond the Cayuga Lake Shore Boundary.

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FIGURE 3.2-86

CARGILL SALT, INC.
CAYUGA MINE

TOWN OF LANSING

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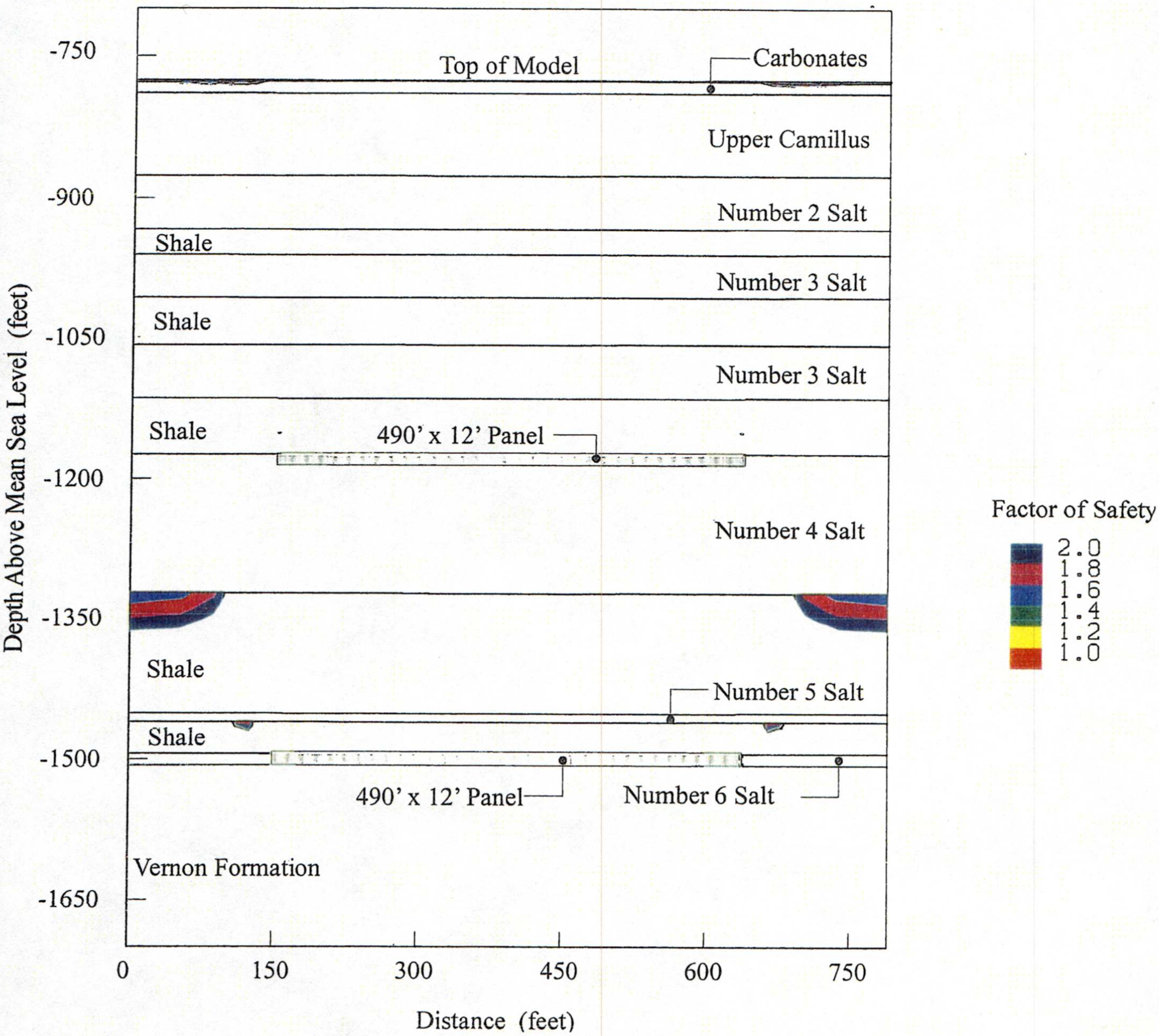

Factors of Safety in the Shale Near the Center Panel of the Model Assuming the Mine is Located Under Cayuga Lake.

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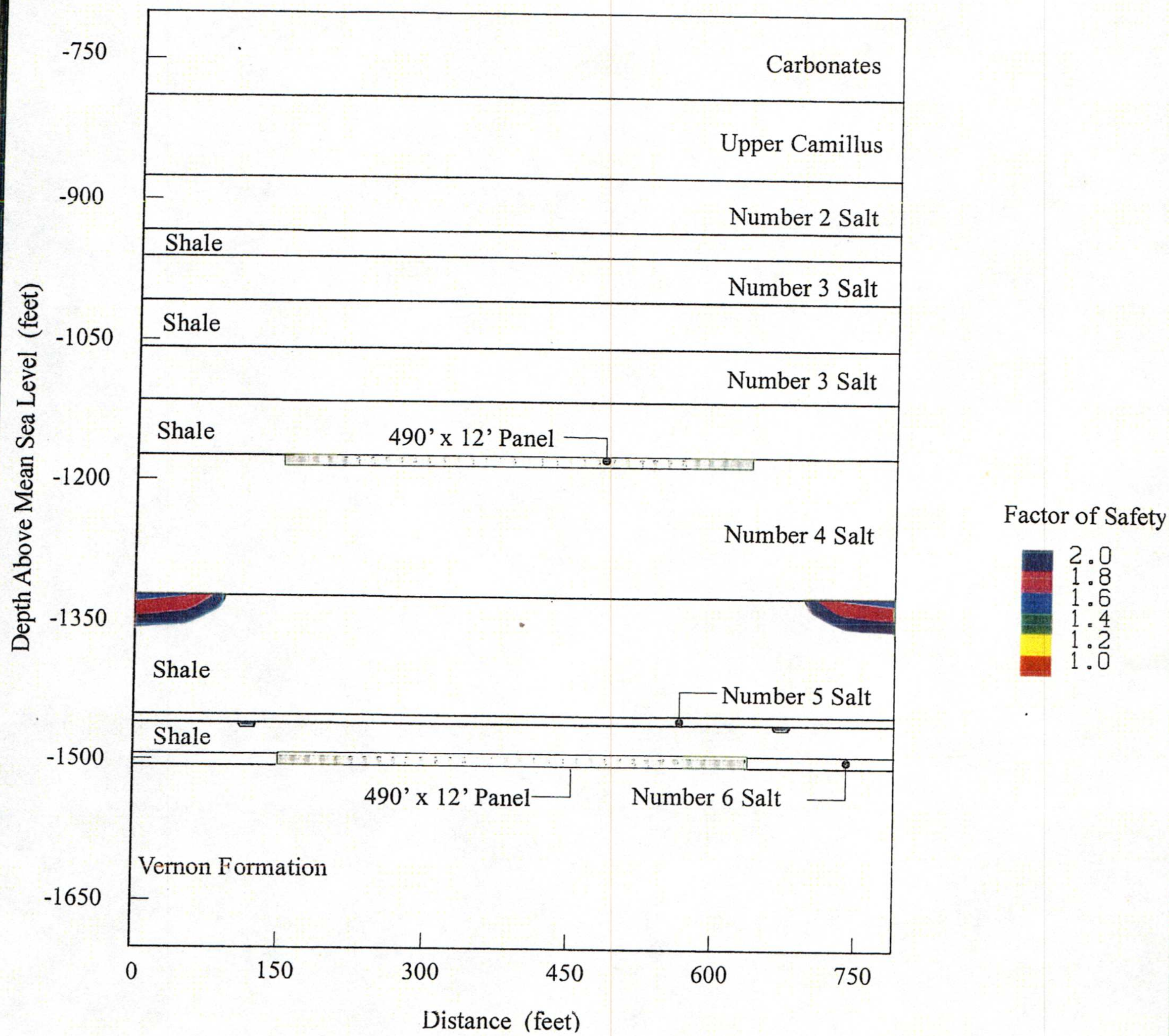
FIGURE 3.2-87

CARGILL SALT, INC.
CAYUGA MINE

TOWN OF LANSING

TOMPKINS CO., N.Y.



Factors of Safety in the Shale Near the Center Panel of the Model Assuming Mining Beyond the Cayuga Lake Shore Boundary.

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FIGURE 3.2-88

CARGILL SALT, INC.
CAYUGA MINE

TOWN OF LANSING TOMPKINS CO., N.Y.

pillar pressure was used to maintain constant room closure rates both beneath and beyond the boundaries of Cayuga Lake. The increase in pressure is essentially equivalent to a reduction in the extraction ratio. For the mine beyond the lake boundary to perform structurally in the same manner as the mine below the lake, the panel extraction ratio would have to be reduced.

It is important to note that the factors-of-safety in the Camillus Shale are greater than 2.0 for both of the analyses presented.

3.2.13.10 Conclusions

Two-dimensional finite element analyses were performed as part of a proof-of-concept study to evaluate the feasibility of multiseam mining at the northern boundary of the proposed permit area at Cayuga Mine and by extension, throughout the requested permit area. *Numerical analyses of the conceptual model indicate that multiseam mining at the Cayuga Mine is possible at the northern boundary of the proposed permit area without jeopardizing mine stability.* Although the potential for dilation of the No.5 Salt was predicted to occur by the numerical model, this does not pose a stability problem because numerical simulations of current mining in the north west area also predicted dialation of the No.5 Salt (DeVries *et al.*, 2000), and yet the mine in the north west area is stable.

As demonstrated by the analysis described in this section, it is confirmed that multiseam mining is indeed a viable option. However, this work should not be construed as a mine design. RESPEC can only endorse moving to multiseam mining at the northern boundary of the proposed permit area after a more detailed examination of proposed operations. Specifically, design of a multiseam mining operation should include location-specific stratigraphic information, more detailed testing of important rock members, and yield-pillar designs. Such detailed mine design issues were not part of this proof-of-concept effort.

height, extraction ratio, and approximate date that mining was completed for each block. A total of 429 mining blocks was defined for the eastern and NW1 mine.

Mining on level No.6 was divided into rectangular blocks, as shown in Figure 4.1-2. The entire mine was assumed to have a room height of 11.25 feet. The extraction ratio for areas with the larger 90-foot pillars (regions mined before 1977) was estimated to be about [redacted] The extraction ratio for areas with the smaller (yield) pillars was estimated to be about [redacted] The depth of each mining block was calculated according to the elevation of level No.6 (1,928 feet below mean sea level) and the surface elevation of Cayuga Lake (382 feet above mean sealevel). Because the benchmarks used in this analysis were located along the Cayuga Lake shoreline, the surface elevation across the model was assumed to be constant at 382 feet above sea level. Completion dates for the mining blocks were obtained from mine maps obtained from Cargill Salt.

Mining on level No.4 was very irregular, and the information had to be greatly simplified. This mine was divided into rectangular blocks, as shown in Figure 4.1-3. The extraction ratio for the entire mine was estimated to be approximately [redacted] percent. The room height was estimated from maps provided by Cargill Salt and was assumed to vary from 9 to 15 feet. Mining block depths were estimated from the elevation of level No.4 (1,535 feet below mean sealevel) to the surface in a manner similar to that for level No.6 mining blocks. Completion dates for the mining blocks were taken from mine maps obtained from Cargill Salt.

4.1.5 Subsidence Modeling Results

The information about the geometry and timing of mining and the measured elevation changes were used to obtain a "best-fit" set of the parameters in the subsidence equation above. For the Cayuga Mine analysis, n in the equation was assumed (fixed) to have a value of 4.0, based on experience in evaluating subsidence over other salt and potash mines. In addition, the parameter γ in the equation was assumed to have a value of 1.0. The parameter γ represents the ratio of surface-subsidence volume to the mine-closure volume. Setting γ equal to 1.0 implies that 100 percent of the mine-closure volume will be expressed on the ground surface in the form of subsidence, yielding a conservative estimate for ultimate subsidence. This parameter was fixed to avoid numerical problems because of its high correlation with parameter β for this relatively short-term data set. The subsidence model reproduced the measured subsidence (according to a weighted least-squared error approach) when the parameter β in the equation was 0.020 per year.

simulated for an additional 38 years. The effect of future mining is apparent in Figure 4.1-6 as noted by the difference between the 2000 subsidence profile and the other predicted profiles near the north end of benchmark network. The effect of future mining is not as apparent along the west shoreline (Figure 4.1-10) since panels U40, U42, U44, and U46 were not extended as close to the benchmarks as the other panels along this edge of the lake shore. As shown in Figures 4.1-9 and 4.1-10, 38 years of creep closure does not contribute significantly to the total subsidence at the benchmark positions. Because the FLAC3D model underpredicts the closure rate of the mine, the model would also be expected to underpredict future subsidence. Although a direct comparison is not provided, the FLAC3D model does predict significantly less subsidence than the SALT_SUBSID model at 10 and 40 years into the future.

Surface-subsidence contours are shown in Figure 4.1-11 10 years after the simulated excavation of panel U32. The lake and sediments are not shown in this figure; thus, contours shown below the lake outline are displacement contours of the top of the bedrock. Figure 4.1-11 illustrates that the maximum subsidence occurs directly above NW1 between panels U32 and U30. The maximum subsidence 10 years after excavation of panel U32 is approximately 0.55 foot at this location below the bottom of the lake. The subsidence bowl rises quickly near the edge of the mine and becomes less than 0.1 foot within a distance of approximately 1,000 feet from the mine edges.

4.1.6 Conclusions Based on the Subsidence Modeling Results

Simplifications and assumptions were necessary to describe the mining history. Also, elevation data for some benchmarks were considered suspect. Despite these concerns, the subsidence model obtained from the analysis reasonably reproduces the measured subsidence.

An analysis of the surface-subsidence information leads to the following conclusions:

The measured subsidence patterns are in agreement with the model-predicted subsidence patterns. No anomalies appear to exist that would indicate unexpected or unexplained behavior in the salt. The subsidence model indicates that almost 200 years is required to reach 90 percent of the total subsidence created by the mining of yield pillar panels separated by 300-foot-wide barrier pillars.

The subsidence model indicates that almost 200 years is required to reach 90 percent of the total subsidence created by the mining of yield pillar panels separated by 300-foot-wide barrier pillars.

The model parameters previously fit by Van Sambeek *et al.* (1995) tend to overpredict the current subsidence and predict complete subsidence sooner.

The maximum subsidence occurs under the lake and would ultimately become 5.5 feet when the mine is completely closed, assuming no further mining.

The ultimate subsidence along the northern legs of the shoreline benchmarks will range from a fraction of an inch to nearly 2.5 feet, assuming no further mining.

Excellent agreement was obtained between the measured subsidence and the subsidence predicted by both SALT-SUBSID and the three-dimensional $FLAC^{3D}$ model for the January 2000 predictions, which serves to validate the numerical models developed for the Cayuga Mine. Because the $FLAC^{3D}$ model underpredicts the closure rate measured at the mine, future predictions using this model will likely underpredict the subsidence at the Cayuga Mine.