SPECTRA

SPECTRA ENVIRONMENTAL GROUP, INC.
SPECTRA ENGINEERING, P.C.

CARGILL CAYUGA MINE
MINED LAND USE PLAN

VOLUME I

Prepared for:

Cargill, Inc.
191 Portland Point Road
Lansing, New York 14882

Prepared by:

Spectra Environmental Group, Inc.
19 British American Boulevard
Latham, New York 12110

In Collaboration With:

Sear-Brown
85 Metro Park3824
Rochester, New York 14623

RESPEC
Jet Drive, P.O. Box 725
Rapid City, South Dakota 57709

December 22, 2000

SPECTRA
SPECTRA ENVIRONMENTAL GROUP, INC.
SPECTRA ENGINEERING, P.C.

RECEIVED
DEC 28 2000
DEPT OF ENV CONSERVATION
REG 7 - MINERAL RESOURCES

December 27, 2000

CONFIDENTIAL

Mr. Joseph S. Moskiewicz
Mined Land Reclamation Specialist
NYSDEC - Region 7
615 Erie Boulevard West, Suite 200
Syracuse, New York 13204-2400

Re: Cargill, Inc.
Mined Land Reclamation Permit Renewal
MLR File No. 709-3-29-0052
SPECTRA File #98189

Dear Mr. Moskiewicz:

In accordance with paragraph 2 of the Stipulation between Cargill, Inc. and the New York State Department of Environmental Conservation dated January 14, 2000, we submit the enclosed reports on behalf of Cargill, Inc. Pursuant to a Letter Agreement dated September 13, 2000, the time for Cargill to make this submission under the Stipulation was extended to December 31, 2000. As set forth in the Stipulation, the information is submitted under a reservation of Cargill's rights and is not to be considered a waiver of such rights or an admission, concession, or acknowledgment of the Department's authority to require such submission to regulate Cargill's underground mining operations or to subject the application to review under SEQRA.

The submission consists of the following:

- Volume I - Mined Land Use Plan, with Application Form and Environmental Assessment Form;
- Volume II - Expanded Environmental Assessment.

These reports contain proprietary information. Pursuant to paragraph 5.D of the Stipulation, the Department is to ensure that all information provided to or obtained by its consultant shall be treated by the consultant as confidential and the Department is to maintain the confidentiality of this information to the fullest extent permitted by law. In furtherance of the Department's obligation to maintain the confidentiality of this information, we would ask that the Department's consultant execute a confidentiality agreement in a form to be approved by Cargill's attorneys prior to its

Mr. Joseph S. Moskiewicz
Mined Land Reclamation Specialist
NYSDEC - Region 7
December 27, 2000
Page 2

RECEIVED
DEC 28 2000
DEPT OF ENV CONSERVATION
REG 7 - MINERAL RESOURCES

CONFIDENTIAL

review of this submission

Cargill and its representatives are available to discuss the submission at the Department's convenience.

Very truly yours,

SPECTRA ENVIRONMENTAL GROUP, INC.

Robert C. LaFleur
President

RCL/tjc
Enclosures

cc: Cargill, Inc.(w/Enclosures)
Mr. Stephen M. Potter (w/Enclosures)
Ms. Arlene Lotters, Esq. (w/o Enclosures)
Devorsetz, Stinziano, Gilberti, Heintz & Smith, P.C.

SPECTRA

SPECTRA ENVIRONMENTAL GROUP, INC.
SPECTRA ENGINEERING, P.C.

CONFIDENTIAL

CARGILL CAYUGA MINE MINED LAND USE PLAN

VOLUME I

Prepared for:

Cargill, Inc.
191 Portland Point Road
Lansing, New York 14882

Prepared by:

Spectra Environmental Group, Inc.
19 British American Boulevard
Latham, New York 12110

In Collaboration With:

Sear-Brown
85 Metro Park3824
Rochester, New York 14623

RESPEC
Jet Drive, P.O. Box 725
Rapid City, South Dakota 57709

December 22, 2000

CARGILL CAYUGA MINE

CONFIDENTIAL

VOLUME I

MINED LAND USE PLAN

TABLE OF CONTENTS

Figures

Plates

Appendices

1.0 INTRODUCTION

Cargill Salt, Inc. (Cargill) mines salt from a series of underground mining levels at their Cayuga Mine in the Town of Lansing, Tompkins County, New York. Mining is presently conducted beneath Cayuga Lake, within lands leased from the New York State Office of General Services (OGS). Cargill has historically also mined salt from lands it owns and leases east and west of Cayuga Lake. Cargill has also extended their existing lease hold rights with OGS to include additional lands under Cayuga Lake to both the north and south of previously authorized areas. Virtually all the salt mined from Cargill's Cayuga Mine is sold as road salt for de-icing highways and bridges in the Mid-Atlantic, Northeast and New England states.

Cargill has been authorized to mine salt at the Cayuga Mine under the Mined Land Reclamation Law (MLR) (MLF#7093-29-0052). Previously, the New York State Department of Environmental Conservation (NYSDEC) only regulated the surface features at the Cayuga Mine. Cargill submitted, for informational purposes only, the areas of underground activity. NYSDEC has sought to include the underground workings as part of the regulated activity on the site. Cargill has entered into a stipulation with NYSDEC to provide additional information under a reservation of all historic and legal rights as set forth in the stipulation. This Mining Plan for Cargill includes all lands either owned by Cargill or under lease from the OGS or others. The Plan, as outlined, increases the area to be mined within Cargill's current lease area under Cayuga Lake. Cargill owns approximately 260.04 acres of land on the surface at the Cayuga Mine. Of those 260.04 acres, approximately 67.67 acres of surface land have been affected by mining-related activities (storage, processing, bagging, etc.). To date, NYSDEC has reviewed underground mining over approximately 8,361 acres in the eastern reserves area and beneath Cayuga Lake. This application includes an additional approximately 5,056 acres of reserves area located beneath Cayuga Lake. Mining is not prohibited at this site.

Cargill has engaged Spectra Environmental Group, Inc. (Spectra) to prepare this Mined Land Use Plan (MLUP). A series of consultants has previously been engaged to provide technical consulting services in support of mine planning and design. Most notable, The Sear-Brown Group (Sear Brown) has conducted geologic and hydrogeologic investigations and RESPEC has provided geotechnical and rock mechanics evaluations.

This MLUP, Volume I, and an Expanded Environmental Assessment, Volume II, are a summation of a continuing series of technical evaluations that have been conducted over the previous 30 years and are submitted under a reservation of rights as outlined in the stipulation with the DEC. Both Sear-Brown and RESPEC are primary contributing authors to these volumes. Most figures and plates are derived from and appropriately credited to either Sear-Brown or RESPEC.

2.0 MINING PLAN

2.1 Introduction

The Cargill Salt, Inc. Cayuga Mine is an underground room-and-pillar rock salt mine accessed by three (3) vertical shafts from Cargill's surface complex located off of Portland Point Road. Salt has been mined from a series of salt layers within the Syracuse Formation of the Silurian-age Salina Group. All drilling, blasting and hauling of unprocessed rock/salt occurs underground. Additionally, all primary crushing and screening occurs underground, isolated from the surface environment and potential surface receptors.

This report, Volume I, provides a comprehensive discussion of the mining plan at Cargill's Cayuga Mine. The discussion includes information regarding surface and subsurface facilities in operation at the mine. Also included in the discussion are sections pertaining to the present operation of the mine, the history of mining at the site, an overview of facility layout, measures employed by Cargill for pollution control and the prevention of environmental damage, and a discussion of the planned reclamation at Cargill's Cayuga Mine. This submittal also includes a long form Environmental Assessment Form (EAF) and an Expanded Environmental Assessment included in Volume II. Volume II provides more detailed technical data regarding site and regional geology, geotechnical considerations, underground design and geomechanical modeling, rock mechanics monitoring, subsidence monitoring, microseismic monitoring and pollution control.

2.1.1 Regulatory Setting

The New York State Mined Land Reclamation Law was written for the regulation of surface mines. Specifically, 6 NYCRR Part 420 states:

> "Affected land and land affected by mining means the sum of that surface area of land or land under water which: (i) has been disturbed by mining since April first, nineteen hundred seventy-five and not been reclaimed, and (ii) is to be disturbed by mining during the term of the permit to mine."

Consequently, many of the components of the State Mined Land Reclamation Law are not applicable to Cargill's Cayuga Mine. Although the Cayuga Mine is constantly expanding at depth, its surface extent is limited to the presently affected surface area. Aspects such as concurrent reclamation, grading, slope control, haul roads, etc. are not applicable to the Cayuga mine with the exception of the mine's surface features.

2.1.2 Location Of Mine

Cargill's Cayuga Mine is located in the Town of Lansing, Tompkins County, New York. The mine's surface facilities are located off Portland Point Road on the east side of Cayuga Lake, approximately as shown on the Location Map (Figure 2.1-1) on the following page. The mine itself is located beneath a portion of Cayuga Lake and the surrounding area (including lands owned by Cargill).

2.1.3 Adjacent Land-Use Features

The surface operations of Cargill's Cayuga Mine are located off a dead-end road (Portland Point Road). The predominant land uses in the immediate vicinity are industrial, and include the surface facilities of Cargill's Cayuga Mine and the Cayuga Crushed Stone Quarry, owned by Hanson Aggregates East, on the east side of Portland Point Road.

Land-use features adjacent to Cargill's surface operations include: 1) Cayuga Lake and the Norfolk-Southern Railroad to the west; 2) Portland Point Road and the lands of Cayuga Crushed Stone to the east; 3) Minnegar Brook and the lands of others to the north; and 4) Portland Point, the lands of others and Cayuga Lake to the south. Other lands along Portland Point Road are generally vacant brushland.

The vast majority of the current mining area is located under Cayuga Lake, as shown on the Location Plan Map (Figure 2.1-1). Land-uses in the vicinity, in addition to the lake, include the Norfolk-Southern Railroad (along the eastern shore of the lake), Taughannock Falls State Park (on the west side of Cayuga Lake adjacent to the northernmost workings of the mine), Lansing Park (on the east side of the lake northwesterly of the surface operations of the Cayuga Mine and easterly, southerly and northerly of the extraction areas).

Cargill's lease area from OGS extends under Cayuga Lake to the limits shown on the Site Location Map. The lease area extends easterly of the surface facilities to the area east of N.Y.S. Route 34. The majority of this area is occupied by open space, farmland, rural residential or commercial land uses. Cargill also leases lands to the west of the Cayuga Lake as also shown on the Site Location Map.

2.2 Present Conditions of the Land

The surface lands at the Cargill Mine are occupied by operational features such as hoist houses, salt storage pads, conveyors, a salt storage building, a bagging facility, corporate offices, a railroad siding (complete with rail-bulk loading facilities), surface exposures of shafts, truck-loading facilities, etc. Specifically, the present condition of the land surface at the Cayuga Mine is shown on the Surface Mining Plan Map (Plate 2.2-1).

Portland Point Road, in the immediate vicinity of the Cayuga Mine, runs roughly north south through Cargill's surface operations. Cargill's office is located on the east side of Portland Point Road with the remaining surface features on the west side of the road. The salt storage facilities are concentrated in the northern portion of the property on the west side of the road. The southern portion of the property on the west side of Portland Point Road contains the shafts, hoists, rail bulk-loading facilities, shop and parking areas.

2.2.1 Mining History and Land Use

2.2.1.1 Brine Field

International Salt Co. (most recently AKZO Nobel Salt Co.) operated a salt refinery at Myer's Point about 1 mile northwest of the Cayuga Mine shafts until 1962. This refinery utilized brine (water was pumped into the salt beds to dissolve salt and the resulting brine pumped back to the surface) to manufacture refined salt. During the period of operation, the refinery obtained brine from three cavities. The largest cavity is in the No.1 Salt Layer of the Syracuse Formation, a smaller cavity is in the No.2 Salt Layer, and a third cavity, which was never fully developed for production use, is in the No.4 Salt Layer. The wells have been plugged and abandoned. Cargill plans to mine the area located to the west and south of the cavities developed at Myer's Point.

Information regarding the solution-mined caverns developed by International Salt Co. at the former Myer's Point plant site is sparse. Records were not retained about brine production from the various wells nor are specific data available concerning the original completion depths of the various wells. The refinery was closed before sonar survey technology for surveying caverns was well developed; therefore, no down-hole data on cavern sizes or shapes were ever obtained. Sevenker (1987 and 1992) assembled some information on the cavities and wells in reports prepared for Cargill. Additional information was obtained through discussions held with AKZO Nobel Salt.

Salt was produced primarily from the main cavity with some lesser production from the second cavity both located under Myer's Point. Very minor production came from a third cavity, located north of Myer's Point under the valley wall. The main cavity was developed in the No.1 Salt (uppermost), the second cavity (well 10) in the No.2 salt, and the third cavity (gallery 1) in the No.4 Salt (the same salt as the original Cayuga Mine). The thickness of the No.1 Salt varies from about 80 feet in the southern portion of the former plant property to approximately 150 feet to the north. The No.2 salt is reportedly about 70 feet thick near the second cavity. The roof of the main cavity is at an elevation of about 1,100 feet bmsl (below mean sea level) or at a depth of approximately 1,500 feet. The well 10 cavity roof is about 1,290 feet bmsl (1,690-foot depth), and gallery 1 is located at about

1,500 feet bmsl (2,100-foot depth). The estimated roof depths do not account for possible roof stoping[1] into the overlying Camillus Shale that may have occurred.

The main cavity was used for brine production from the beginning of operations at the plant in 1894 until it shut down in 1962. The main cavity was entered by multiple wells. The early wells drilled for the refinery would have been operated individually for both water injection and brine production. Water would have been injected near the top of the salt and brine produced from near the bottom of the well. The effect of this method of solution mining would have been to create a "morning glory"[2] shaped cavern with a majority of the mining occurring within the top one-half of the cavern and little salt dissolution occurring at the bottom of the cavern.

The second cavity was initially developed in 1945 and operated until the plant shut down in 1962. This cavity was developed only through well 10. The cavity was operated in a similar fashion to that used for the main cavity, again likely producing a "morning glory" shaped cavity.

The third cavity (gallery 1, wells 20 and 21) was to be developed by hydrofracturing between the two wells drilled specifically for that purpose. Attempts to connect the two wells were largely unsuccessful. These attempts did establish a high-pressure connection between the wells and the main cavity. Well 20 may have been operated as a single well cavity for the last year of the plant's production.

The refinery was altered several times in its history to increase its capacity. Estimates of the plant capacity and corresponding brine requirements were used by Sevenker (1987) to develop estimates of the sizes of the cavities. Sevenker estimated the total production from the caverns to have been about 7,736,000 tons (4,275,000 +/- yd^3) of salt. Internal memorandum reports from AKZO Nobel Salt estimate total plant production to have been between 6,000,000 and 9,186,000 tons (3,315,000 to 5,075,000 +/- yd^3) of salt.

[1] Stoping - the loosening and removal of ore in a mine either upward (overhead or overhand) or downward (underhand)

[2] Morning Glory - the shape of the solution cavity is an inverted cone or 'morning glory'

2.2.1.2 Mining Pattern Development – Room-And-Pillar Mining

Multi-seam room and pillar mining has been employed at Cargill's Cayuga mine. Access to the multiple salt layers within the Syracuse Formation of the Silurian-age Salina Group was afforded via a series of shafts sunk from the ground surface. Specifically, room-and-pillar mining has occurred in the Nos. 1, 4, 4a and 6 salt layers of the Syracuse Formation. These layers are shown in schematic section on Plates 2.2-2 through 2.2-6 and are discussed in detail in the accompanying Volume II.

The No. 1 shaft was sunk between 1915 and 1918. Mining began in the No. 1 Salt Level in January of 1923 and ended in January of 1924. The No. 1 shaft was deepened in 1924 to the No. 4 Salt Level where mining commenced in 1924. In the original mine design, mining of the No.4 Salt bed followed the thick rolls or northwest trending folds that deform the bed. Thus, both pillar widths and room (stope) widths varied greatly. Mining continued in the No. 4 level until about 1970. The current limits of mining on Level 4 are shown in Figure 2.2-1 on the following page. In 1968 some mining was done in the No. 4A salt bed. The limits of mining on Level 4A are shown in Figure 2.2-2 on page 9.

Mining began in the No. 6 salt level in 1968. From the opening of the No.6 level in 1968 until about 1976, production was approximately 3,300 tons per day with 3 operating shifts per day. Rooms 32 feet wide and 8–10 feet tall were mined on approximately 120-foot centers (between 88-foot-square pillars) with an extraction ratio of approximately 46 percent.

During the early years of mining on the No. 6 level, there were few ground control problems. Few rock falls occurred from the ceilings. It is theorized that this may have been because of a "protective cover" provided by the overlying No.4 level workings in the multi-seam excavation. The early workings in Level 6 took place under previously mined level 4 workings in the eastern portion of the mine. By the mid-1970s, however, as the mining moved farther eastward, stresses increased due to the increasing thickness of overlying strata. Active mining was no longer occurring beneath mined out portions of Level No. 4 and ground conditions worsened. It was theorized that the large, stiff pillars in the traditional room-and-pillar design caused the instability by punching through the roof strata around the mine openings. This can lead to roof falls and/or floor heave.

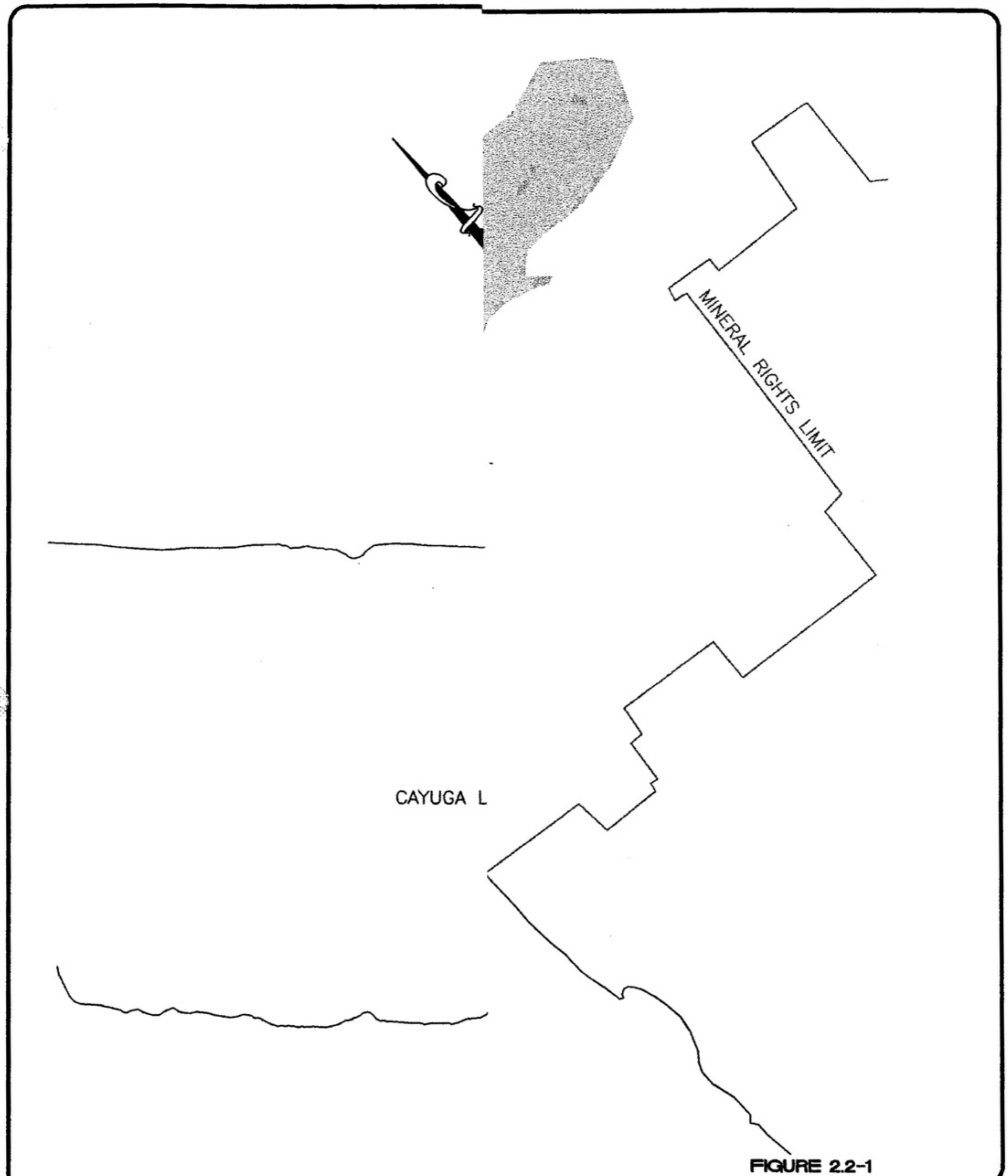


FIGURE 2.2-1

PROJECT
: RCL
98189
BY: PAW
BY: PAW
BY:
BY:
NTERVAL = FEET
0 1000 2000
1"=2000'

LEVEL 4 MINING LIMITS MAP

CARGILL SALT, INC.

CAYUGA MINE

TOWN OF LANSING TOMPKINS COUNTY, N.Y.

SPECTRA ENVIRONMENTAL GROUP, INC.
19 British American Blvd.
Latham, NY 12110

DATE:	11/28/00	SCALE:	1"=2000'	DWG. NO.	98189003	SHEET	OF

The use of yield pillars has been explored industry-wide to resolve safety and operational concerns associated with large pillars in traditional room and pillar mining (Jeremic, 1994). In 1976, Cargill began to experiment with the use of yield pillars as a potential solution to the ground control problems that were plaguing the eastern workings of the No. 6 Level. While actively mining, Cargill initiated a sequence of testing between 1976 and 1984 on the east side of the Level No. 6 workings. The excavation sequences were carefully designed and instrumented. Cargill employed a systematic and methodical mining approach that included measured response, structural calculations, and industry experience. Extensive monitoring including stress, closure and extensometer measurements, and surface subsidence data were used to assess the performance of the developing mine layout over time. Subsequent layouts were developed, evaluated and adopted based on the specific conditions in existence at the Cayuga Mine.

In 1984, Cargill began working the west end of the Level No. 6 workings (i.e. within that portion of the lease area beneath Cayuga Lake), applying all the information, experience and knowledge gained from the mining of the east end. Small pillars within relatively wide panels separated by massive barrier pillars describe the mining layout currently being used at the Cayuga Mine. The layout has evolved since 1976, and represents an approximately 25-year systematic and scientific approach to the establishment of a safe and stable mine through the use of yield pillar panels and massive abutment pillars.

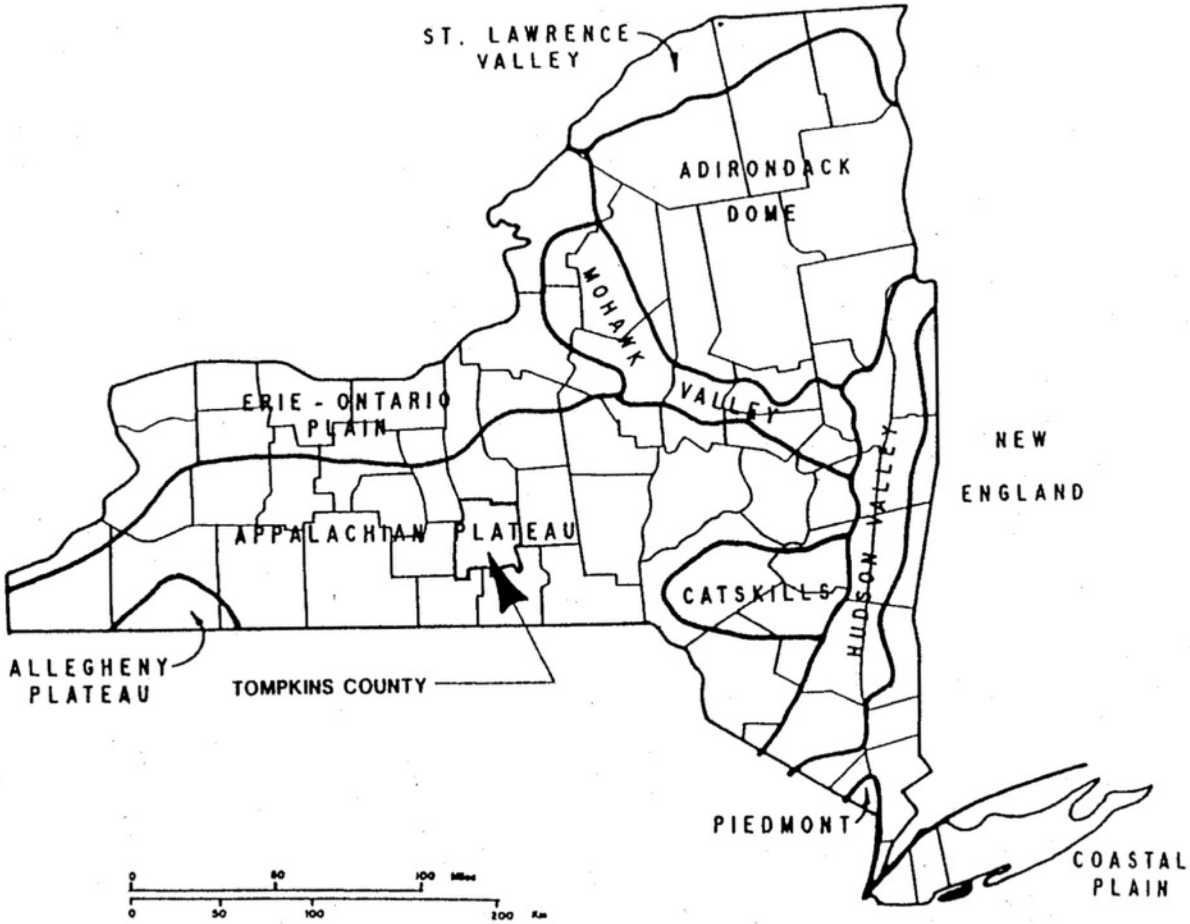
2.2.2 Topography and Physiography

Tompkins County is situated within the Appalachian Plateau physiographic province as shown in Figure 2.2-3 on the following page. The plateau is highly dissected by incising streams and is generally characterized by hill-valley topography with up to 1,000 feet of vertical relief within individual basins.

The county has been divided by Neely (1965) into three zones based upon elevation as indicated in Figure 2.2-4 on page 12. Large portions of the county occur at elevations in excess of 1,100 feet above mean sea level (amsl). Included within the high elevation zone is the southern part of the county, which consists of high plateau that ranges between 1500 and 2000 feet amsl and is separated from an intermediate elevation plateau (>1,100 feet) by the Portage Escarpment.

In Tompkins County, three major north-northwest trending valleys and one prominent northeast trending valley dissect the terrain. The westernmost of the northwest-trending valleys extends between Enfield in the north and West Danby in the south and is occupied by Enfield Creek and the Cayuga Inlet. Cayuga Lake and Sixmile

Insert map: FIGURE 2.2-2
in front of this page.



MODIFIED FROM BROUGHTON AND OTHERS (1966)

Note:
Original figure by
The Sear Brown Group.

SPECTRA ENVIRONMENTAL GROUP, INC.
19 British American Blvd.
Latham, NY 12110

Project No.: 98189

FIGURE 2.2-3

CARGILL SALT, INC.
CAYUGA MINE

TOWN OF LANSING

TOMPKINS CO., N.Y.

Creek occupy the central valley. The easternmost valley extends from Groton through Dryden and is occupied by the Owasco Inlet.

The most conspicuous geomorphological feature of the area is Cayuga Lake. The lake is located in a valley that was deepened by Pleistocene glaciers. The glacial erosion removed bedrock over the mine area (within the Cayuga Lake lease area) to about 625 feet below sea level.

The Cayuga Lake Valley contains sizable land areas with elevations below 700 feet amsl. The lowest elevations occur along the margins of the lake (elevation 380 feet amsl), in the Salmon Creek Valley north of Myers Point, and in the Cayuga Inlet Valley south of Ithaca.

Bedrock beneath Cayuga Lake has been eroded to a maximum depth of approximately 358 meters (1,175 feet) below lake level. This is equivalent to an elevation of approximately 242 meters (794 feet) below sea level. Transverse (east-west) geophysical profiles performed by Mullins and others (1991) reveal a deeply scoured bedrock surface. In cross-section, the bedrock profile at the north end of the basin is broadly "U" shaped, a typical geometry for glacially scoured valleys. The cross-sectional profile becomes slightly more V-shaped to the south.

Overlying the bedrock beneath the lake are a series of glacial and lake deposits. Over the mine area under the lake, these glacial and lake deposits are approximately 650 feet thick. These sediments consist of about 100–200 feet of primarily glacially deposited morainal tills, and outwash gravels, sands, and silts. Overlying these ice contact deposits are 300–450 feet of glacial lake-deposited clays and silts. At the top of the lake fill are about 30 feet of deltaic deposits derived from Salmon Creek and the Ithaca area streams and 20 feet of recent (postglacial) lake clays and silts.

The lake has a maximum depth of approximately 325 feet over the northwestern panels of the mine (i.e. the present mining area). The lake becomes progressively shallower to the southeast, so that the depth is about 250 feet over the edge of the southern reserve area (i.e. south of Entry W1).

2.2.3 Bedrock Geology

The bedrock stratigraphy above the mine includes the uppermost Silurian and Devonian sedimentary rocks that outcrop along Cayuga Lake. The bedrock above the mine includes strata as high in section as the Devonian Geneseo Shale. Strata overlying the Geneseo Shale generally outcrop immediately to the south of the mine and extend into southern New York and northern Pennsylvania. The thickness of the Paleozoic bedrock section (that is, the depth to crystalline basement rock) in the vicinity of the mine is approximately 8,000 feet (2,400 meters) (Karig and Elkins, 1986). The bedrock groups, formations and members present between the mined salt units and the ground surface includes those listed in Table 2.2-1 on the following page.

The bedrock stratigraphy and structural geology in the vicinity of the mine records a complex geologic history. The mine is located on the Fir Tree Point Anticline, an east-west trending fold whose geology is fairly well known because of past hydrocarbon exploration. Bedrock beneath the anticline is folded and locally faulted. Salt beds have flowed, in response to compressional, tectonic forces to create pinching and swelling features within the Syracuse Formation.

Within the Cayuga Lake Basin, the glacial scouring of the bedrock at the latitude of the mine shafts left about 575–600 feet of rock above the top of the Syracuse Formation along the bedrock thalweg[3]. The remaining bedrock overlying the Syracuse Formation consists of approximately 90 feet of Camillus Shale, 315 feet of various limestone units (Bertie, Cobleskill, Rondout, Manlius and Coeymans Formations), a thin bed of Oriskany Sandstone with a thickness of about 10 feet, and about 65 feet of Onondaga Limestone. Over the Onondaga Limestone lies a sequence of shales that contain relatively thin, continuous limestone interbeds. This shale and limestone sequence has a minimum thickness of about 100 feet over the axial portion of the mine beneath the bedrock thalweg. The overlying bedrock thickens away from the lake axis to a maximum thickness of about 2,000 feet (over the Syracuse Formation) under the highlands on either side of the Cayuga Lake.

2.2.4 Drainage and Surface Water

The eastern portion of the Finger Lakes region drains through the Oswego River Basin into Lake Ontario. Overall, the Oswego River Basin drains over 5,100 square miles in central New York (Genesee/Finger Lakes Regional Planning Board, 1975). The surface waters of the Oswego River Basin drain to the Seneca River in the west and to the Oneida River in the east. These two rivers ultimately merge to form the Oswego River.

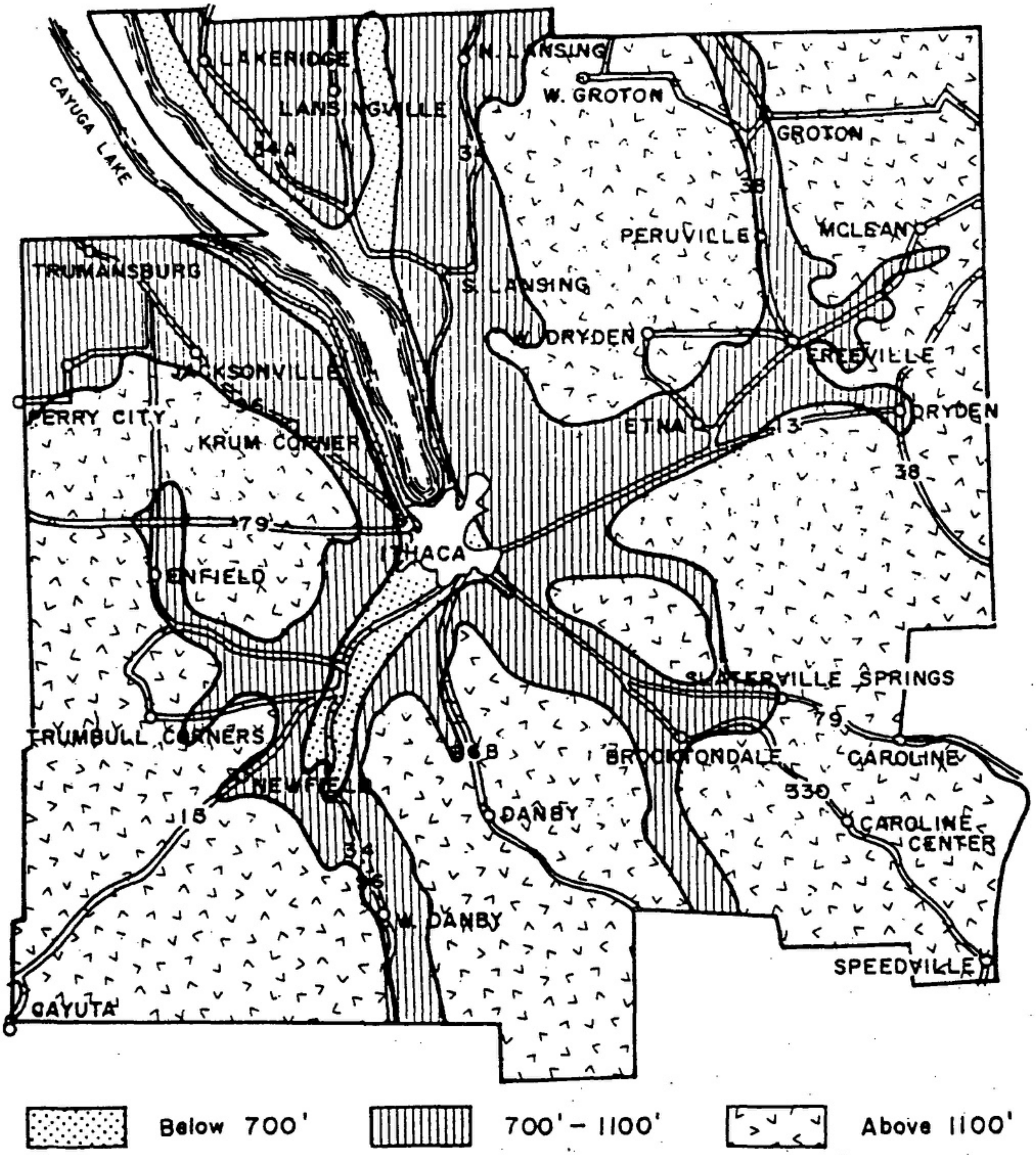
The sub-basins of the Oswego River Basin include Mud Creek, Flint Creek, Cayuga-Seneca Canal, Cayuga Lake, Seneca Lake, Keuka Lake, and Canandaigua Lake. The Cayuga-Seneca Canal drains Keuka Lake, Seneca Lake, and Cayuga Lake.

[3] Thalweg: valley profile; deepest portion of a valley.

TABLE 2.2-1

Bedrock Stratigraphy at Cayuga Mine

Group	Formation	Member
Genesee	Genesee	Ithaca Renwick Sherburne Hubbard Quarry Firtree Geneseo Shale
	Tully	
Hamilton	Moscow	Windom Shale Portland Pont Limestone
	Ludlowville	Spafford Ivy Point Otisco Centerfield
	Skaneateles	Butternut Shale Pompey Delphi Station Mottsville Limestone
Marcellus Subgroup	Marcellus	Oatka Creek Shale Cherry Valley Limestone Union Springs Shale
	Onondaga	Seneca Moorehouse Nedrow Edgecliff
Tristates	Carlisle Center	
	Oriskany	
Helderberg	Coeymans	Deansboro
	Manlius	Jamesville Clark Reservation Elmwood Olney Thacher
Cayugan	Rondout	Chrysler
	Cobleskill	
	Bertie	Oxbow Forge Hollow Fiddlers Green
Salina	Camillus	
	Syracuse	
	Vernon	



SOURCE: SOIL SURVEY OF TOMPKINS COUNTY, 1965

Note:
Original figure by The Sear Brown Group

SPECTRA ENVIRONMENTAL GROUP, INC.
19 British American Blvd.
Latham, NY 12110

Project No.: 98189

FIGURE 2.2-4

CARGILL SALT, INC.
CAYUGA MINE

TOWN OF LANSING

TOMPKINS CO., N.Y.

The Cayuga Lake sub-basin is the largest of the sub-basins and drains a total area of approximately 874 square miles (Genesee-Finger Lakes Regional Planning Board, 1975). The lake is approximately 37 miles in length and varies from one to three miles in width. The total surface area of Cayuga Lake is approximately 66.4 square miles, and its maximum depth is approximately 425 feet. The depth varies considerably across the lake, and there are large shallow areas at both ends that have been built up by silty deposits (Mullins and others, 1991). The outlet of Cayuga Lake is the Seneca River (also known as the Cayuga-Seneca Canal), located at the northern end of the Lake.

The Cayuga Lake Basin is set in a steep valley. The steepest topographic gradients are found on the east side in Cayuga and Tompkins Counties.

Local, on-site surface drainage patterns can be inferred from the Surface Mining Plan Map (Sheet 2.2-1). Man-made features such as buildings, paved surfaces, trenches, diversion ditches, culverts, swales, etc. largely control the on-site drainage.

2.2.5 Groundwater

2.2.5.1 Regional Groundwater System

According to the literature, few, if any, local Quaternary or bedrock units exhibit sufficiently widespread productivity to be considered appreciable aquifers. Glaciolacustrine silts and clays typically possess hydraulic conductivities in the range of 10^{-6} to 10^{-8} centimeters per second and yield less than 1–2 gallons per minute to wells. Glacial tills exhibit hydraulic conductivities in the range of 10^{-3} to 10^{-7} centimeters per second and yield less than 1–5 gallons per minute to wells.

Hanging deltas and lacustrine strandline sands occurring at elevations between 1,100 and 1,000 feet amsl within the Cayuga Lake basin are sufficiently permeable to be aquifer-grade deposits, but they occur at relatively high elevations in the groundwater basin where water resources are least abundant. Furthermore, these deposits commonly stand in positive relief, which leaves them susceptible to rapid drainage and undersaturation. Therefore, these high elevation, permeable, deltaic, and lacustrine deposits do not serve as high yield aquifers.

The shale-dominated bedrock units that predominate the stratigraphy in the vicinity are also of relatively low permeability and yield only low to moderate volumes of water to wells. The upper 30–60 feet of fractured bedrock typically exhibit permeabilities in the 10^{-3} to 10^{-5} centimeters per second range and will yield the highest volumes of groundwater. In high elevation areas, however, the appreciable depth of the water table likely results in the placement of the fractured bedrock profile in the unsaturated zone. Deeper wells in tight, unfractured bedrock likely yield less than 5 gallons per minute. In lower elevation areas, however, well yields from the bedrock fracture zone are sufficiently high, for residential purposes (in the range of 5–30 gallons per minute). These wells may be artesian due to topographic influences.

The only geologic materials suspected to comprise significant potential aquifers are the Pleistocene to Holocene sands and gravels that comprise deltaic foreset beds beneath Myers Point and Portland Point. The hydraulic conductivity values for deposits comprising these deltas probably range between a low of 10^{-4} centimeters per second for delta platform silty facies and a high of 10^{-1} centimeters per second for the underlying foreset sands and gravels. These deposits likely have a direct hydraulic connection with Cayuga Lake, and, therefore, wells can draw from a virtually infinite source of water. Well yields beneath these deltas probably range between a low of tens of gallons per minute for delta platform facies and a high of hundreds to thousands of gallons per minute for the delta foreset sands and gravels.

Although no systematic survey of yields from wells screened in particular geologic formations has been published for Tompkins County, the USGS Water Resources Division maintains a database (GWSI Well Records) that contains information on approximately 150 wells completed in overburden and bedrock formations that occur in the vicinity of the mine. In addition, geologic units of interest in the vicinity of the mine have been the subject of a systematic analysis in adjacent Seneca County by Mozola (1951). This county borders the west shore of Cayuga Lake and shares the same physiographic features as the eastern wall of the Cayuga Valley in the vicinity of the mine.

2.2.5.1.1 Glacial Till

In the Finger Lakes region, Mozola (1951) reports the thickness of glacial till in the upland areas of Seneca County to range between 2 and 30 feet thick. Based upon analysis of 34 wells, the till wells in the region have yields ranging from 2 to 6 gallons per minute and average about 5 gallons per minute. The majority of these wells are likely to be hand-dug, large diameter, stone-lined wells that extend to the bedrock-overburden interface. The majority of the flow to these wells is likely from the contact between the bedrock and overlying till. Given the degree of compaction and overconsolidation of the till deposits, it is likely that only 1 to 2 gallons per minute can be drawn exclusively from the till matrix.

Spring lines are a common occurrence at the toe of slope of the till-dominated valley walls. The springs are an artifact of a process known as throughflow whereby infiltrating precipitation perches at the base of the desiccated, oxidized soil profile or on a hardpan layer and migrates laterally just below the ground surface down the slope. Where a break in slope occurs, this seam of water discharges to the ground surface where it can either be intercepted for consumption or flow overland until it discharges into a surface water body.

2.2.5.1.2 Sand and Gravel

Mozola (1951) did not describe well yields from unconsolidated sand and gravel deposits in much detail. Saturated sand and gravel deposits are not plentiful in Seneca County, particularly in the southern half of the county, which most resembles the hydrogeologic setting of Cargill's Cayuga Mine. To the east of the mine in the Cortland 15-minute quadrangle, Asselstine (1946) indicates that groundwater is abundant in a valley-fill aquifer near Cortland and Homer. In 1946, total groundwater withdrawals from the quadrangle totaled approximately 5 million gallons per day (roughly 3,500 gallons per minute) of which 4 million gallons per day (2,800 gallons per minute) were drawn from the valley-fill aquifer system.

The USGS database for Tompkins County contains data for 79 wells that are partially or wholly screened in sand and gravel. All but one well occur at surface elevations above 1,000 feet amsl. Thus, the majority of these deposits occur in high elevation areas where saturated thicknesses are not sizable over appreciable distances. Thus, well yields are low relative to the spectrum anticipated for outwash and/or lacustrine sand and gravel. Reported well yields range from less than 1 gallon per minute to more than 250 gallons per minute and average about 28 gallons per minute.

Only one well completed near lake level is included in the USGS database. This well yielded 280 gallons per minute and is more reflective of the yield potential of sand and gravel deposits in the vicinity of low elevation discharge zones such as the stream deltas beneath Myers Point and Portland Point.

2.2.5.1.3 Devonian Shales

Wells screened in Devonian shale formations exhibit a wide degree of variation in depth to water and well yield. The USGS database contains information on 66 wells screened in Devonian Shales in Tompkins County. Well yields range between 1 and 40 gallons per minute and average approximately 10 gallons per minute.

Mozola (1951) provides data for wells screened in the Genesee Group and the Hamilton Group. Mozala's hydrologic information pertaining to the bedrock units in the vicinity of Cargill's Cayuga Mine is summarized below.

2.2.5.1.4 Genesee Group

Mozola (1951) reviewed data from 18 wells screened in the Devonian Genesee Group. He found that depths to water varied between 20 and 175 feet below ground surface in these wells. This variation is rather extreme but is likely explained by the prominent vertical fracturing and significant localized relief within the Genesee Group subcrop belt. At Taughannock Falls, as much as 400 feet of relief exists between the top of the gorge walls and the base of the gorge below the falls. The magnitude of relief in the gorge likely produces a sizable groundwater sink (discharge zone) around which the water table probably declines by several hundred feet within a relatively narrow lateral zone.

The width of the lateral zone over which the water table declines is likely to be largely influenced by the depth to which prominent, vertical fractures apparent at the gorge face remain open in the subsurface. These fractures are particularly prominent along the south wall of the gorge. A high density of fractures can be observed extending up the entire height of the gorge face in a narrow zone along strike with the kimberlite dike in the floor of the creek. If the open fractures extend back into the gorge walls for a great distance without becoming till-choked or sealed with secondary calcite cement (or kimberlite), a large lateral zone over which the water table declines will result. Conversely, if the open fracture network apparent on the gorge walls is, superficial (that is, locally exaggerated by stress relief), the lateral distance over which the water table declines will be narrow.

These simple concepts, as theorized using Taughannock Falls as an example, are applicable to the Genesee Group strata above the mine. Comparable zones of prominent, vertical, north-trending fractures are well exposed in the Cayuga Crushed Stone Quarry. In the vicinity of the quarry, these vertical fractures may promote vertical infiltration of precipitation below the floor of the quarry.

Well yields from Genesee Group strata reported by Mozola (1951) span two orders of magnitude, but are generally rather low. Based upon review of data from 18 wells, yields range from approximately 0.2 to 20 gallons per minute and average about 7 gallons per minute. Thus, although these strata may yield sufficient groundwater yields for residential purposes; they are not capable of providing sufficient quantities for municipal supplies.

2.2.5.1.5 Hamilton Group

Based upon the analysis of 81 wells by Mozola (1951), the Hamilton Group shales exhibit water supply characteristics similar to the Genesee Group shales. Wells studied ranged in depth between 18 and 665 feet deep. Depth to water measurements varied widely between 3 and 170 feet below ground surface. Again, some of this variation may be attributable to the steep topography surrounding the Tully Escarpment, which is directly underlain by upper Hamilton strata, and steeply incised stream gorges that locally cut strata of the Moscow and Ludlowville Formations.

Groundwater can be readily observed discharging from seepage faces along the Tully Escarpment and local stream gorges. Thus, these zones may create the significant relief on the water table suggested by the range in reported water levels in wells.

In similar fashion to Genesee Group strata, the Hamilton Group shales provide well yields that vary by two orders of magnitude. Well yields reported by Mozola (1951) range between 0.5 and 60 gallons per minute and average approximately 21 gallons per minute. These yields are marginal to adequate for residential demands, but are, for the most part, insufficient for municipal water supply.

2.2.5.1.6 Limestone Wells

The Tully Limestone is the only carbonate bedrock formation that likely lies within the potable water zone within the shallow subsurface (approximately top 300 feet of bedrock) in the vicinity of Cargill's Cayuga Mine. The Tully is prominently jointed in the region and is locally folded and faulted above the mine. Thus, there are a variety of physical discontinuities in the carbonate beds through which groundwater may flow.

Because of its minimal thickness, no well yield data are available for the Tully Limestone. The unit is generally not screened discretely. Wells intercepting the unit are likely incorporated into the Devonian shale categories of the USGS database and Mozola (1951). The unit is likely more transmissive than adjacent shale units, however. Mozola (1951) reports that small springs discharge from the Tully where it is confined between shales in the ravines and gorges of southern Seneca County.

2.2.5.1.7 Sequence I Quaternary Aquifer

The presence of ice-contact deposits at the base of the Quaternary section within the Cayuga Lake trough (Sequence I of Mullins and others, 1991) suggests that an unconsolidated, artesian aquifer may overlie bedrock beneath the lake. Given the substantial thickness of Sequence I in the vicinity of the mine (approximately 300–350 feet) and the substantial lateral extent along the axis of the valley, there is potential for prolific groundwater resources beneath the lake. Substantial artesian pressures likely exist in Sequence I. Groundwater communication between Sequence I and the bedrock fracture zone that typically occurs in the upper few tens of feet of rock beneath glacial deposits is probable.

2.2.5.2 Site Groundwater

The Cayuga Lake Basin is a classic example of a hill-valley groundwater flow system. In general, groundwater recharge is accomplished by the infiltration of precipitation to the water table at high elevations on or near the topographic divides. Limited recharge may also occur on steep side slopes of the valley at intermediate elevations. However, the steep topography of the valley sidewalls generally promotes runoff and overland flow of precipitation.

Groundwater discharges to both the deeply incised stream gorges on the sides of the valley and beneath Cayuga Lake in the valley center. Artesian wells can occur locally where low permeability till and lacustrine deposits overlie more permeable, fractured bedrock near the valley center.

Within a hill-valley flow system, the depth to water is greatest beneath high elevation recharge areas. In contrast, depth to water is shallowest near discharge zones in topographic low regions. The water table intercepts Cayuga Lake roughly at an elevation of 380 feet above mean sea level.

Because of the fine-grained nature of local lacustrine and till overburden materials, the seasonal high water table would typically be encountered in overburden within 2 to 4 feet of the ground surface beneath all but the highest elevation recharge areas. An unconfined flow system in the glacial overburden follows local topography toward gullies incised in the valley walls or flows downslope and discharges into Cayuga Lake.

Certain heterogeneities exist in the topography and geology of the Cayuga Valley near the Cayuga Mine that result in modifications to a theoretically ideal valley system. These heterogeneities include the following:

The topographic depression created by the Cayuga Crushed Stone Quarry;

The occurrence of an upper bedrock fracture zone that parallels the top of bedrock surface and serves as a higher permeability, preferred flow zone;

A thick sequence of heterogeneous Quaternary sediments in the valley center including a high permeability confined aquifer represented by Sequence I ice contact facies; and

The presence of high permeability deltas beneath Myers Point and Portland Point.

These heterogeneities likely influence shallow groundwater flow patterns. During spring, seasonal-high water table conditions, thin, low permeability glacial overburden deposits are saturated. The water table resides in the overburden and mimics, but is a subdued expression of surface topography.

Beneath the higher elevation, groundwater-recharge areas, the water table seasonally may reside within the fractured bedrock zone. Glacial overburden may become unsaturated during periods of peak evapotranspiration[4] (usually during July and August). Monthly precipitation rates in the region do not vary largely. Consequently, normal summer water level declines are more related to elevated levels of evapotranspiration as opposed to seasonal declines in precipitation rates.

Although groundwater in the fractured bedrock zone may flow under unconfined (water table) conditions beneath the recharge areas, flow in the upper 10–30 feet of bedrock commonly becomes increasingly confined as topographic slopes increase on the valley walls and low permeability overburden deposits thicken toward local base level (elevation to which erosion will work to reduce topographic relief). Near groundwater discharge zones, the fractured bedrock zone may become artesian if the thickness of the comparatively low-permeability glacial overburden is adequate to provide confinement of flow. Given the close fracture spacing in the region (commonly less than 10 feet), the shallow bedrock flow system can be viewed as an equivalent porous medium.

Groundwater flow directions are predominantly westward toward Cayuga Lake except in the immediate vicinity of Gulf Creek and near the down gradient and cross-gradient boundaries of the Cayuga Crushed Stone Quarry. West of Route 34, Gulf Creek forms a deeply incised but narrow gorge that serves as a lateral groundwater discharge point. Groundwater seepage along vertical fractures and lithologic changes occurs even during summer months when evapotranspiration is greatest. Similarly, the deep topographic depression created by the quarry produces a correspondingly deep depression in the water table that causes radially inward flow of groundwater. Stains are apparent along the quarry walls where groundwater seasonally discharges at the bedrock-overburden interface. The volumes of groundwater seepage into the quarry are small, however, because of the low permeability and correspondingly low transmissivity of local till and shale bedrock units.

The radially inward flow of groundwater into the Cayuga Crushed Stone Quarry likely produces localized reversal of flow directions along the western, northern, and southern quarry faces.

Groundwater does not migrate vertically into the subsurface indefinitely. There is a base to the hydrosphere (the water-saturated veneer of earth materials). In the vicinity of the Cayuga Mine, the base of the hydrosphere occurs above the Camillus Shale, as shown in the roof of the No.1 Salt mine level where this formation is exposed and is remarkably dry. Additionally, at least one vertical core has been advanced approximately 100 feet up into the Camillus Shale roof rock without encountering groundwater.

[4] Evapotranspiration - the loss of groundwater recharge due to evaporation and consumption/transpiration by plants

It is also known, based upon the minimal seepage of water into the No.1 shaft from the Marcellus Shale Formation that the base of the hydroshere/saturated bedrock section occurs at some level in the Siluro-Devonian carbonate sequence.

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. It logically follows that deep groundwater is also present in the Onondaga Limestone that overlies the Oriskany Sandstone.

Based upon carbonate textures and inferred residual permeabilities, it is estimated that the base of the hydrosphere above the salt zone occurs near the Bertie-Cobleskill contact. In the vicinity of the mine, the Bertie Group formations are fine-grained and would likely exhibit hydrologic properties similar to those of the underlying Camillus Shale. In contrast, the Helderberg carbonates exhibit distinctive bedding, and include biostromal facies that may provide partings for lateral, albeit very slow, deep groundwater flow.

Evidence for minimal fluid migration at depth is largely geochemical. Water is a powerful solvent and it is readily apparent from surface exposures of earth materials and the taste of some well waters that groundwater attacks and dissolves the most soluble mineral phases in both soil and bedrock. Generally groundwaters at shallow depths in most hydrogeologic settings of New York have comparatively short residence times and do not become highly concentrated with dissolved ions. Shallow groundwater flow rates are sufficiently high that the contact time between any specific water molecule and any particular soluble mineral face is only sufficient to release relatively few ions. Even a groundwater flow velocity of a few feet per year is fast compared to the residence time necessary to reach chemical equilibrium between groundwater and minerals.

Because of weathering effects, the fracture (secondary) permeability of sedimentary bedrock is highest near the ground surface and generally decreases progressively with depth. Thus, the flux of groundwater through sedimentary bedrock generally is highest in the zone of prominent fracturing. The prominent partings, both in the form of vertical joints and bedding planes opened by isostatic rebound following glacial loading and unloading, also accommodates a significant percentage of groundwater reaching the bedrock flow system. Thus, below the zone of prominent fracturing, only a small volume of groundwater migrates deeper and does so at progressively smaller volumes and slower flow velocities. Because large volumes of groundwater are not available for dilution and contact times between water and minerals are high, deep groundwater becomes highly concentrated in total dissolved solids. These dissolved solids mostly are dissociated ionic compounds or common salts and carbonates—that is, gypsum, halite, and calcite. Thus, the most common ions in groundwater are calcium, sodium, bicarbonate, sulfate and chloride. When any of these compounds or collective compounds reaches a certain concentration that renders the water unacceptable for consumption or use, the water is considered unpotable.

The natural hydrosphere is located several hundred feet above the active mining area, near the Bertie-Cobleskill contact, within the portion of the Cayuga Lake Basin mined by Cargill. Natural, water yielding and transmitting fractures do not extend into the Syracuse Formation that houses the mined salt layers.

The depth of potable water supplies in the subsurface of the Cayuga Valley is unknown, but is probably on the order of 200–300 feet. Slight weathering of fractures in shale bedrock was observed to a depth of approximately 250 feet in core hole 17. Below this depth, bedrock fractures are almost always filled with secondary calcite cement, suggesting that they are not being aggressively attacked by fresh, potable groundwater. Thus, water probably does not flow abundantly or rapidly below a depth of a few hundred feet. Sulfur-rich or salt-rich groundwater brines, however, may be encountered below this depth.

2.2.6 Climate

The climate of the project area is humid, continental with diverse seasonal weather characteristics. Variations in topography are an important factor in climate conditions in the county. Prevailing winds are typically from the northwest, with a tendency toward southwest in the summer. Average daily temperatures are 20° F to 38° F in the winter and 76° F to 86° F in the summer. Tompkins County receives approximately 36.5 inches of precipitation per year. This is distributed fairly uniformly throughout the year with slightly higher averages occurring from April through October. Potential evapotranspiration is highest during the summer months.

2.3 Description of Facility and Mining Method

2.3.1 Shaft and Underground Facilities

2.3.1.1 Introduction

This section provides information regarding the shafts and underground facilities of Cargill's Cayuga Mine. It describes the operations undertaken to meet Cargill's production requirements at the Cayuga Mine.

As described above, the Cayuga Mine is an underground room-and-pillar rock salt mine accessed by three (3) vertical shafts from Cargill's surface complex located off of Portland Point Road in the Town of Lansing. Processing facilities are also located underground. Bulk loading, bagging and bulk storage facilities are located at Cargill's surface complex.

Cargill's shafts are identified as Shafts 1, 2 and 3 and their surface locations are indicated on the Surface Mining Plan Map (Plate 2.2-1). The shaft details and uses are discussed in greater detail below.

2.3.1.1.1 Shaft 1

Shaft 1 is located in the south portion of Cargill's property near the Old Hoist House, as shown on the Surface Mining Plan Map (Plate 2.2-1). The shaft is attached to the breaker building and has a nominal cross section of 10 feet by 25 feet. The No. 1 Shaft is approximately 1970 feet deep and services mining levels 1, 4 and 5. The No. 1 Shaft contains a timbered frame supporting structure to stabilize the rock walls and support the skip and cage guiderails. The shaft is divided into four (4) "compartments." Two are used as travelways for salt-hoisting skips. The third is used as a travelway for an emergency mancage, and the last contains an abandoned ladderway. Shaft 1 is also utilized to remove exhaust air from the subsurface. The pressure induced in the mine by the main fans causes the air to flow from the No. 6 level, up the 2 slope tunnels to the No. 4 level and thence to the No. 1 Shaft and up to the surface. Shaft 1 also houses the mine power feed cable, fuel oil, hydraulic oil and freshwater transmission lines, a brine water drainpipe and mine intercom and mine radio cables.

2.3.1.1.2 Shaft 2

Shaft 2 is located easterly of the Bulk Salt Storage Building (Building T-4 on the Surface Mining Plan Map - Plate 2.2-1) and northerly of the Bag Production/Storage Building (Building T-3), as shown on the Surface Mining Plan Map (Plate 2.2-1). Shaft 2 is an unlined borehole approximately 2000± feet deep with a 4-foot diameter. Shaft 2 serves as an exhaust airway from the subsurface. A minor amount of air (4 to 5%) flows up the No. 2 Shaft. The shaft is also used to discharge brine water to depth (within Level 4) from the surface.

2.3.1.1.3 Shaft 3

Shaft 3 is approximately 2,312 feet deep with a concrete-lined 11-foot inside diameter. The shaft is utilized to transport personnel and materials (not product) between the surface and the active mining level. Shaft 3 also serves as the principal source for mine-air intake for the underground workings. The Shaft 3 intake-air fan system has a capacity of approximately 300,000 cubic feet per minute (cfm). The mine's main ventilating fans, two Joy Series 2000, 72-30 units are located near the bottom of this shaft.

The No. 3 Shaft also houses a mine radio cable, a telephone cable, a fiber optic cable and a brine drain pipe.

Where water is evidenced flowing into the No. 3 Shaft, holes are drilled into the shaft wall and a cement or chemical grout is injected to fill cracks and voids and preclude water from entering the shaft.

2.3.1.2 Mining Strategy

2.3.1.2.1 Room and Pillar Mining

The Level No. 6 workings began in the eastern portion of the mine using traditional room and pillar (i.e. large pillar) methods. The reason pillars are left in any mine is to support the overburden (overlying strata). 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. A pillar bears a load from an area larger than the plan area of the pillar itself. The load on a pillar can be expressed as the weight of the overburden carried, divided by the area of the pillar. This quantity is the average vertical stress in the pillar.

For mines with wide expanses where each pillar experiences full tributary loading (such as the large pillar extraction areas at Cargill's Cayuga Mine), the load on the pillar is strictly a function of the extraction ratio. The average vertical stress is the pre-mining vertical stress at the mining depth divided by $(1 - E)$, where E is the extraction ratio in the excavated areas.

2.3.1.2.2 Development of Yield Pillar Strategy

In 1974, uncontrolled roof falls began to occur in the active Level 6 area. One miner was seriously injured. In May of 1975, the entire mining front in the eastern portion of Level No. 6 was shut down for safety reasons. After a month of lost production, mining began in another part of the mine in the Number 6 Level. One year later, this mining front was also threatened by failing roof.

At that time Cargill and its rock mechanics consultants began a comprehensive rock mechanics program to assess mine stability. Three principal methods were used to assess mine stability in the underground mine. These included:

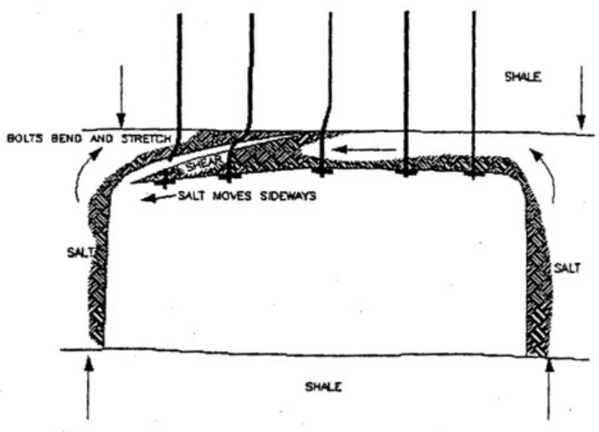
1. Structural calculations;
2. Experience within the salt-mining industry; and
3. Mining trials or experiments during which the mine response is measured.

Cargill engaged all three methods to resolve ground-control problems with the heaviest emphasis on mining trials and mine response measurements. Several months were spent thoroughly mapping roof failures throughout the entire No. 6 level taking note of the mode, shape, and direction of the failures.

Two significant observations were made during the investigations: 1) Mining conditions on the lower level (No.6 Salt bed) were favorably influenced when located beneath the mined upper level (No.4 Salt bed) approximately 91 meters (300 feet) above; and 2) The mode of failure was such that, although the mine floor did not heave and the large, square pillars did not fail, the load was apparently too great for the roof rocks to sustain. This frequently resulted in shearing adjacent to the top of the pillars. Once the shear took place, the roof bolts failed and roof falls occurred.

Some falls observed during the inspection were over 80 meters (220 feet) in length and ranged from 0.9–3.6 meters (3–12 feet) in height. It was theorized that vertical loading on the large, 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 31 centimeters (12 inches). This condition is indicated in the following Figure 2.3-1.

Fig. 2.3-1



A yield pillar approach was considered. It was thought that if the pillars were small enough they would yield and not accept as much vertical loading, thus significantly reducing, if not eliminating, the horizontal thrusting/shearing in the roof. The yield pillar concept relies upon the redistribution of overburden stresses from smaller, individual pillars (i.e. the yield pillars) within a mine panel to the large adjacent abutment pillars located on either side of the mining panel.

2.3.1.2.3 Yield Pillar Concepts

The shape of the yield pillar determines the amount of load that it carries. Yield pillars are narrow compared to their height. Because the pillar height is typically controlled by the thickness of the salt zone, yield pillars are consequently also small, although size by itself does not determine whether or not a pillar is a yield pillar.

Characteristics of yield-pillar panels, such as those at the Cayuga Mine, are:

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

Yield pillars readily deform (shorten) to cause the transfer of the overburden load to surrounding pillars (barrier or abutment) that deform less readily. Deformation is due to creep in salt rocks.

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

Redistribution of the load-bearing responsibility reduces the local vertical stress in roof-floor rock across the width of the panel and, hence, stabilizes the panel containing the yield pillars.

Yield pillars apply a low-magnitude vertical confining stress to the roof-floor rock that may reduce/prevent failure in the rock.

Yield pillars are intended to support only the weight of a fraction of the overburden that might not successfully bridge across the full panel width. The weight fraction depends on the roof-floor rock type (strength and stiffness), the mine depth (in situ stress levels), and panel extraction ratio.

For salt yield pillars, the pillar-shortening rate is controlled both by the shortening rate of the large barrier pillars and by the stiffness and strength of the roof-floor rock spanning the panel.

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. The yield pillars reduce the wide span of the panel to a series of smaller spans, which are less prone to roof-slab falls.

Rock mechanics use the term yield to denote the initiation of failure (deformation in a non-elastic manner) and a diminishment of load bearing capability. All salt pillars deform non-elastically because they creep. Salt pillars do not, however, lose their load-bearing capability as a consequence of this creep. Hard rock and coal pillars require "high" stress levels to initiate yield; salt pillars will creep even with "low" stress levels.

2.3.1.2.4 Yield Pillar Mining at the Cayuga Mine

The Cayuga Mine was used as a field laboratory. Measurements were taken to determine how the rocks in the mine were behaving rather than analyzing rock samples from the mine in a laboratory to provide parameters for a theoretical model. Specimens taken out of a mine for testing purposes do not always provide a true representation of the in situ rock. Additionally, all loading conditions experienced in the mine usually cannot be duplicated in the laboratory. Consequently, it was felt that a better approach would be to get a large number of measurements within the mine, to see how the actual mine was responding.

Closure stations were established in the existing mine and an invar-steel "Reed" type convergence rod was utilized to measure closure within the mined out panels. Background measurements were initially made to assess closure rates. Pillar expansions were also measured by borehole extensometers (B.H.E.) that were built in-house by Cargill. After baseline measurements were made, a monitoring program was undertaken to determine the effect(s) of the yield pillar mining method on mine stability.

The first investigation involved the splitting of several existing large pillars. A site was selected near the mining front far enough from the potential effects of active mining yet close enough to tram the muck to the feeder breaker. The measured closure rates and B.H.E. results clearly indicated that the smaller yield pillars did, in fact, yield to their core and a transfer of load did take place from the smaller yield pillars to the adjacent larger pillars. General observations showed that roof conditions among the newly created smaller (yield) pillars were quite good while conditions in the surrounding area (i.e. where yield-pillar mining was not practiced) deteriorated with a roof fall occurring adjacent to the test (Petersen and others, 1977).

Based on the encouraging results of pillar splitting, a larger test panel (61 x 182 meters or 200 x 600 feet), referred to as the "NE experiment", was mined. Productivity was enhanced by the higher extraction ratio within the intense excavation area. Results were so encouraging that the yield pillars were further reduced by additional undercutting and blasting. The recovered salt was mucked out as extra production. A stress-relief method of mining had been developed, and Cargill made the decision to mine the southeast quadrant in this manner thereby affording more learning opportunities as mining progressed.

During the excavation of the experimental panel, the existing mining front to the south encountered a geological discontinuity that brought production to a halt. With no other area of the mine available for production, it was decided that all production would come from the southeast quadrant utilizing the yielding pillar concept, and the large pillar design was abandoned.

For approximately the next seven years, a variety of yielding pillar configurations was tried off the sides of the main mine entry extending some 2,100 meters (7,000 feet) to the east. The development system consisted of 3 sets of 3 entries. Barrier pillars separated the three (3) entries. Conditions in the center entries were excellent. However, conditions along abutment zones were, in places, poor. This lent credence to the theory that the large pillars did not sufficiently yield and, consequently, they relieved stresses by failure. Softening the edge of the abutment pillars by mining notches into them greatly improved their condition. This practice afforded the salt an area to migrate into, minimizing the potential for shearing of the roof. A total of 15 production units/panels were mined off the main development in search of the best combination of pillar size, panel width, and abutment size.

Rock mechanics measurements and mapped observations led to a number of conclusions about the mine and yield-pillar design. Yield pillar size within the mining unit/panel had the greatest impact on roof conditions. Each time the yield-pillar size was reduced, roof conditions improved. 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 determined that if the width-to-height ratio exceeded a certain amount, the pillars became too stiff and might not yield to the core. However, experience in another rock salt mine showed that if the width to height ratio is too small it can lead to excessive pillar slabbing and ultimately pillar failure.

Entries along stiff abutment zones in the Cayuga Mine 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 excavated side by side, in sequence, the transfer of loads onto abutment was measured at closure points. A minimum abutment-pillar width was established of sufficient size to carry the overburden loads and to isolate one panel from another.

It was also determined that the wider the mining panel, the greater the closure rate 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. This would subject the yielding pillars to excessive loading and closure. An attempt was made to establish this critical width and an area called P3 was mined out to a specific limit. Even though mining pressures at the face were high, initially causing some problems, the area today remains stable. A maximum panel width was thereby established.

In the eastern portion of the mine, roof conditions in the yield-pillars remain much better in comparison to the roof conditions for areas with the large-pillar design. Within the yield pillar portions of the eastern limits of level 6 mining, the roof is still very good in most places and, at last inspection, does not appear to be much different than when it was mined. The roof is described as solid without any scales forming. The domed roof bolt plates are, for the most part, not deformed, indicating the bolts have not experienced much, if any, significant loading. By contrast, in the large pillar areas, there are abundant ground control problems with numerous rock bolts failed and found lying on the ground.

Once the southeast quadrant was no longer economical to mine, plans were developed to mine the northwest quadrant utilizing a design derived from the seven years of development and experimentation in the southeast quadrant. Development of the northwest quadrant began in 1984 starting near the shafts. It was decided to mine the main 4,550 meters (15,000 feet) westerly (W1) and then northwesterly (NW1) to the lease boundary (see Subsurface Mining Plan Map – Plate 2.3-1) utilizing a 6-entry system. The W1 development was mined between 1984 and 1986 and the NW1 development was mined from 1986 through 1990. During the completion of these developments, an occasional production unit was mined on the advance to subsidize production quotas. However, most of the salt deposit was left so to be mined on a retreat from the boundary back to the shaft, leaving any mining-induced problems behind.

2.3.1.3 Underground Mine Layout

As discussed above, Cargill's Cayuga Mine is an underground room-and-pillar rock salt mine that employs a yield pillar panel design. All drilling, blasting and hauling of unprocessed rock and salt takes place underground. Additionally, all crushing and screening takes place underground.

The layout, mining plan and mining method, as employed, have been developed to most efficiently and safely meet Cargill's production demand for the deposit. Presently, the northwest quadrant of the No. 6 Level is worked by means of yield-pillar panel methods. The current excavation areas in the No. 6 Level are accessed through the northwest-southeast trending entry that lies beneath and is parallel to the axis of Cayuga Lake. This main entry, or development, is referred to as NW1.

Since 1990, 19 production panels have been mined to the east and west of the central NW1 entry utilizing yield pillar panels. These production panels are also shown on the Subsurface Mining Plan Map and are identified as production panels U24 through U43.

Mining conditions using the yield pillar panel design in the northwest quadrant (i.e. along NW1 and within the production panels off of NW1) are excellent. The yield pillar panel mining method has improved roof conditions, has lessened the need for roof support, has virtually eliminated roof falls, and has significantly reduced injuries due to falls of ground or scaling. In addition to the better roof conditions, the design has lent itself to easier and more systematic ventilation, shorter and more systematic hauls to the feeder-breaker, and shorter equipment moves from one entry to the next.

Crossovers are periodically mined between production panels. The crossovers are positioned to minimize room closure of the surrounding areas.

In the summer of 2000, the main entry location along the axis of the lease area was altered. Entry or drift NW2 was started off of production panel U43. Entry NW2 is parallel to NW1 but is located approximately 1300 feet further to the east. As excavation proceeds further to the north within the lease area, NW2 will serve as the principal entry. Presently, Cargill is mining panels U40B, U43 and drift/entry NW2.

Future mining is planned to the north and south of the presently permitted area within the limits of Cargill's lease area under Cayuga Lake. These planned future mining areas are shown on the Subsurface Mining Plan Map. The planned future mining areas total approximately 5056 acres.

It is anticipated that multi-seam salt excavation will continue northerly and southerly within the limits of the lease area (i.e. within the areal limits of Cayuga Lake) utilizing the present yield pillar – abutment pillar mining method.

2.3.1.4 Geotechnical Considerations

Cargill, through subcontractors, has conducted extensive geotechnical investigations to assess the stability of the yield pillar panel - room and pillar mining method employed in the active (i.e. Level No. 6) northwest quadrant of the Cayuga Mine. In April, 1994, Cargill commissioned RESPEC to conduct a study to assess the stability of the northwest portion of the mine and the suitability of the yield pillar panel design method in that portion of the mine. In 1995, RESPEC concluded that the Cayuga Mine, employing the yield pillar panel method, was stable at the time of the study. RESPEC also concluded that no significant stability problems were expected in the future, given the mine layout planned.

Since the completion of the 1995 stability assessment by RESPEC, considerable additional data have been collected with respect to the geology, hydrogeology, panel closure, surface subsidence and microseismic events at the Cayuga Mine. The NW1 mining area has expanded such that the mining area is larger than the models previously employed by RESPEC to evaluate barrier pillar width and support of the overburden. As a result, RESPEC was employed in May of 2000 to reassess the stability of Cargill's Cayuga Mine using the more recent data.

RESPEC employed three different methods of evaluation to reassess the stability of the current yield pillar panel design at the Cayuga Mine. These methods included:

1. An Evaluation of Surface Subsidence Data;
2. A Numerical Modeling Geomechanics Study; and
3. An Evaluation of Microseismic Data

2.3.1.4.1 Surface Subsidence Analysis

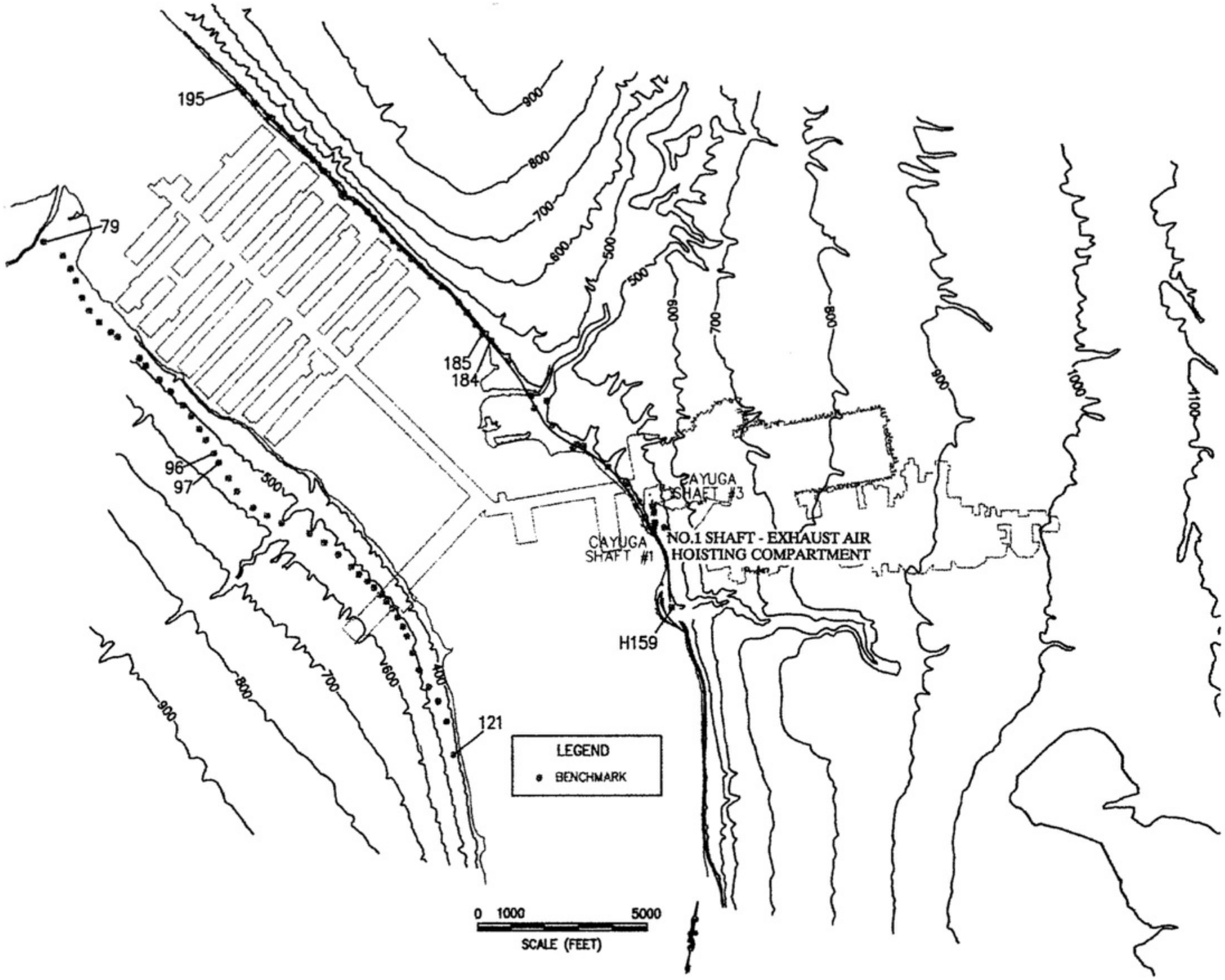
RESPEC was employed to analyze surface subsidence above and in the vicinity of the Cayuga Mine. RESPEC employed the Solution Mining Research Institute (SMRI) computer program **SALT_SUBSID** (Nieland, 1991) to analyze the measured subsidence values. RESPEC's analysis uses measured benchmark locations (with surveyed elevations) and geometric and timing information about the mine to establish site-specific parameters for the subsidence model incorporated in **SALT_SUBSID**. For every benchmark considered, **SALT_SUBSID** superimposes expected subsidence increments from each (and every) area of mining. These modeled increments account for the distance between the benchmark and the mining area, the mining area's size, shape, height, extraction ratio, and the time since the area was mined.

2.3.1.4.1.1 Measured Subsidence Data

Cargill first employed surface-subsidence benchmarks in 1976. Those benchmarks were used to measure subsidence in the eastern portion of the Cayuga Mine (i.e. that portion not located under Cayuga Lake). Since approximately 1984, all excavation has been concentrated in the western portion of the mine, under Cayuga Lake. Consequently, recent subsidence studies have been focused in this area.

Benchmarks have been established along the east and west shores of Cayuga Lake in the vicinity of the Cayuga Mine. A total of 46 benchmarks are located along a railroad grade on the eastern Cayuga Lake shoreline. A total of 43 benchmarks are located along a highway adjacent to the western Cayuga Lake shoreline. The locations of the benchmarks are shown in Figure 2.3-2.

The line of benchmarks along the eastern shore contains two legs. The southern leg includes 20 benchmarks (beginning at H159 to the south and ending at 184 to the north) and was first surveyed in July 1983. The northern leg includes 26 benchmarks beginning at 185 to the south and ending at 195 to the north. This leg was first surveyed in June



Plan View of the Cayuga Mine Showing the East and West Shoreline Benchmark Locations

Note:
Original figure by RESPEC.

SPECTRA ENVIRONMENTAL GROUP, INC.
19 British American Blvd.
Latham, NY 12110

Project No.: 98189

FIGURE 2.3-2

CARGILL SALT, INC.
CAYUGA MINE

TOWN OF LANSING

TOMPKINS CO., N.Y.

1987 with additional benchmarks added in April 1990 and May 1991. A third leg was added to the north of the northern leg and first surveyed in February 1997.

The line of benchmarks along the western shore also consists of two legs. The southern leg includes 24 benchmarks beginning at 121 to south and ending at 97 to the north. This leg was first surveyed in January 1989. The northern leg includes 19 benchmarks beginning at 96 to the south and ending at 79 to the north. This leg was first surveyed in November 1992. A third leg was added to the north of the northern leg and was first surveyed in October 1997.

The most recent northern legs of the benchmarks lines (east and west shore) were not included in the RESPEC analysis because few surveys had been performed to date, and little subsidence had been noted.

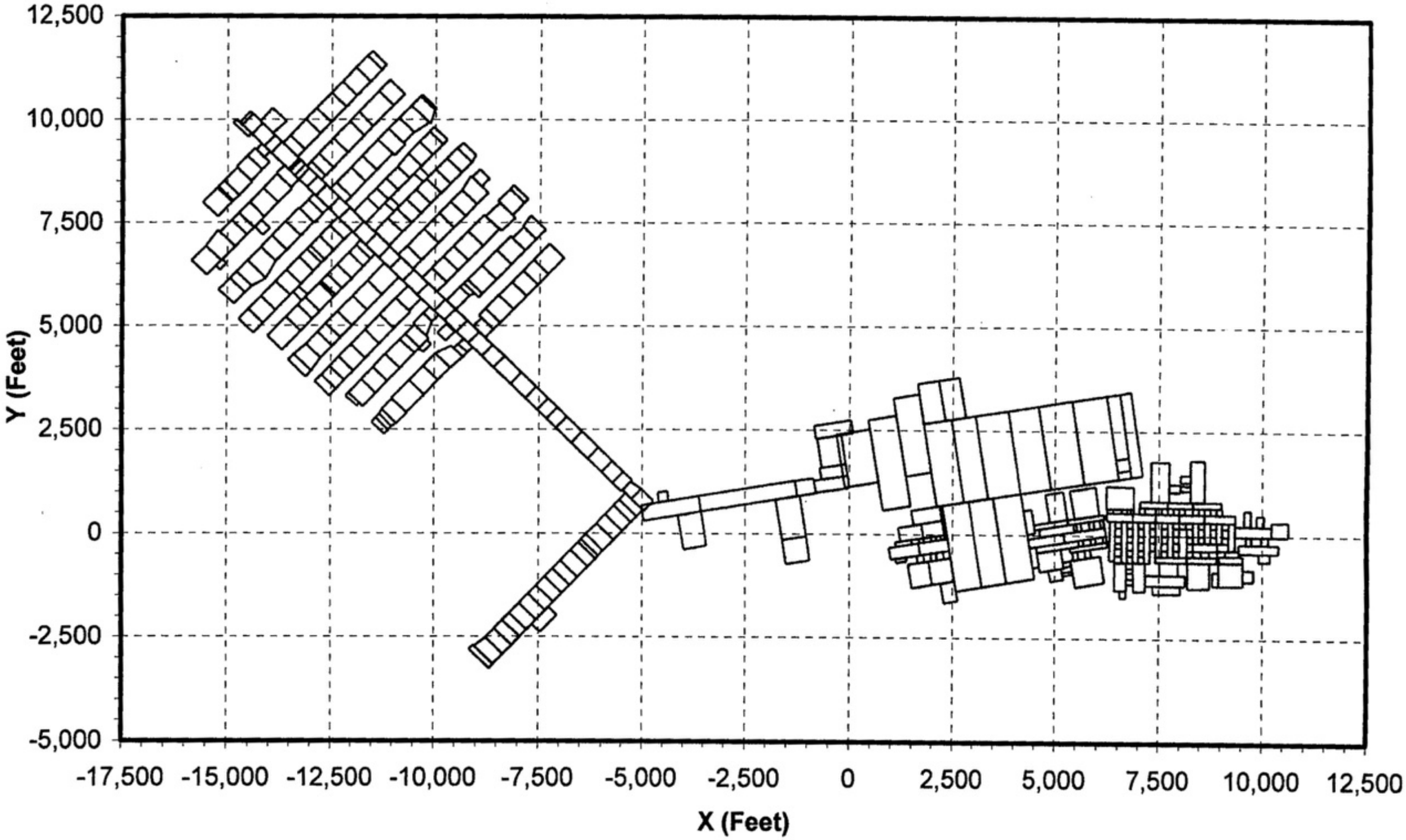
2.3.1.4.1.2 Mine Subsidence Model

The **SALT_SUBSID** model run by RESPEC modeled the effects of mining of both the No. 4 and No. 6 mining levels in the eastern mine area and the mining of the No. 6 level beneath Cayuga Lake. Because detailed information could not be obtained for the nearby solution caverns mined by International Salt Co. at Myers Point until 1962, these caverns were not included in the **SALT_SUBSID** model employed by RESPEC.

SALT_SUBSID requires that the mined area, in its entirety, be divided into a series of rectangular blocks. In addition to the coordinates for each block, **SALT_SUBSID** requires representative values for the depth below the ground surface, room height, extraction ratio, and approximate date that mining was completed for each block.

As stated above, subsidence analyses were made based upon mining on both the No.4 and No. 6 levels. Mining of Level 6 was divided into a series of rectangular blocks, as shown in Figure 2.3-3. According to RESPEC, "mining on Level 4 was very irregular and the information had to be greatly simplified". The Level 4 model was divided into irregular blocks, as shown in Figure 2.3-4. The details used in the model for Levels 6 and 4 are provided in Volume II.

Measured values of subsidence (and subsidence rates), as measured at the benchmarks along the shorelines of Cayuga Lake, were compared with the values calculated using the **SALT_SUBSID** Model. The measured values were then used to correlate (adjust the input parameters to) the model. Specifically, the information about the mine geometry and timing of mining and the measured elevation changes were used to obtain a "best-fit" set of subsidence parameters for the model.



SALT_SUBSID Mining Blocks Representing Level No. 6

SPECTRA ENVIRONMENTAL GROUP, INC.
19 British American Blvd.
Latham, NY 12110

Project No.: 98189

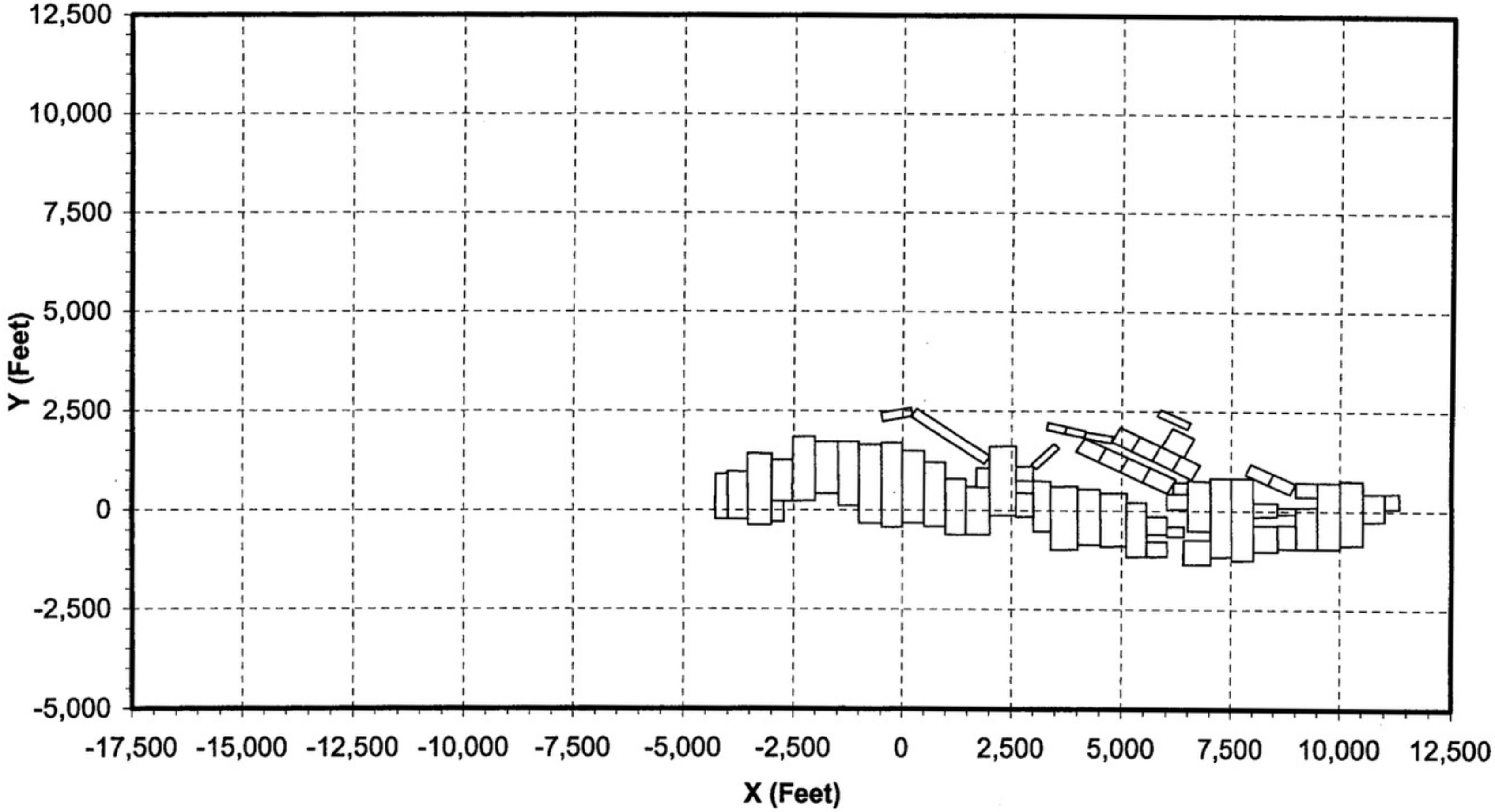
FIGURE 2.3-3

CARGILL SALT, INC.
CAYUGA MINE

TOWN OF LANSING

TOMPKINS CO., N.Y.

Note:
Original figure by RESPEC.



SALT_SUBSID Mining Blocks Representing Level 4

Note:
Original figure by RESPEC.

SPECTRA ENVIRONMENTAL GROUP, INC.
19 British American Blvd.
Latham, NY 12110

Project No.: 98189

FIGURE 2.3–4

CARGILL SALT, INC.
CAYUGA MINE

TOWN OF LANSING

TOMPKINS CO., N.Y.

2.3.1.4.1.3 Subsidence Monitoring and Modeling Results and Conclusions

The measured and model-predicted subsidence and subsidence rates for two distinct and specific benchmarks on the eastern shoreline of the lake and two distinct and specific benchmarks on the western shoreline of the lake are shown in Figures 2.3-5 and 2.3-6 and are discussed in greater detail in Volume II. The dashed lines in these figures represent the predicted ultimate subsidence, at these distinct benchmark locations, when the mine is completely closed, based upon the model.

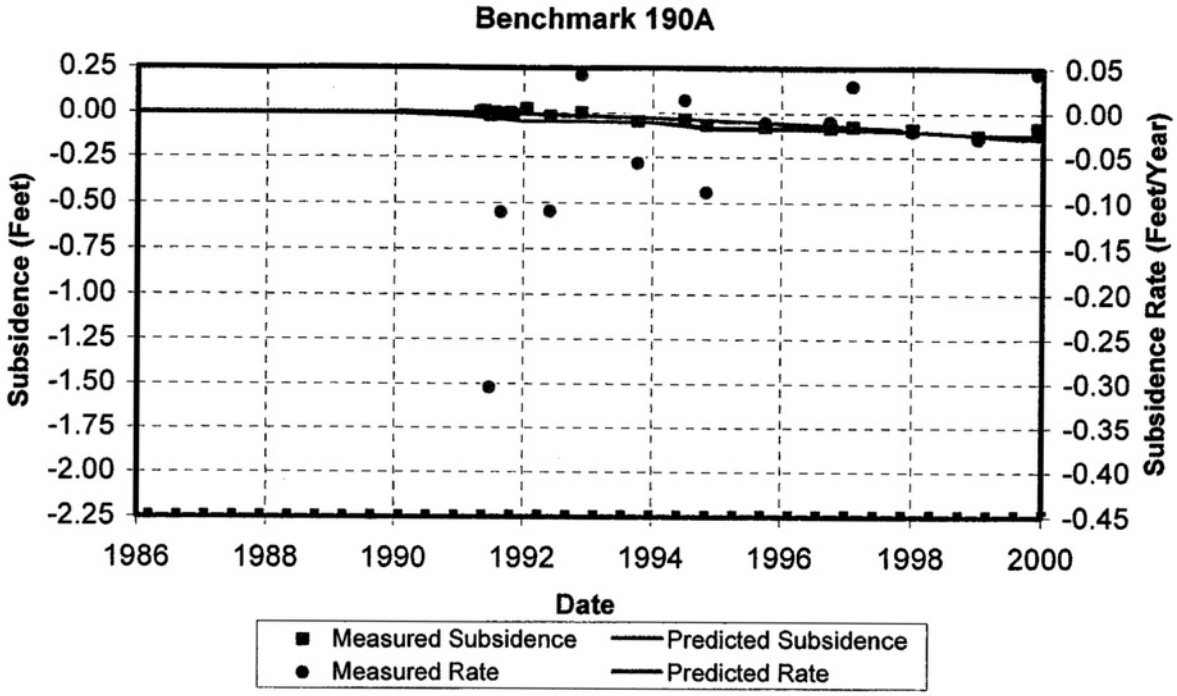
Figure 2.3-7 shows the current measured and RESPEC model-predicted subsidence profiles along the eastern and western Cayuga Lake shorelines. Similarly, Figure 2.3-8 shows the predicted subsidence profiles along the eastern and western shorelines at 5, 10, 20, and 50 years into the future in addition to showing the projected final amount of subsidence above the closed mine.

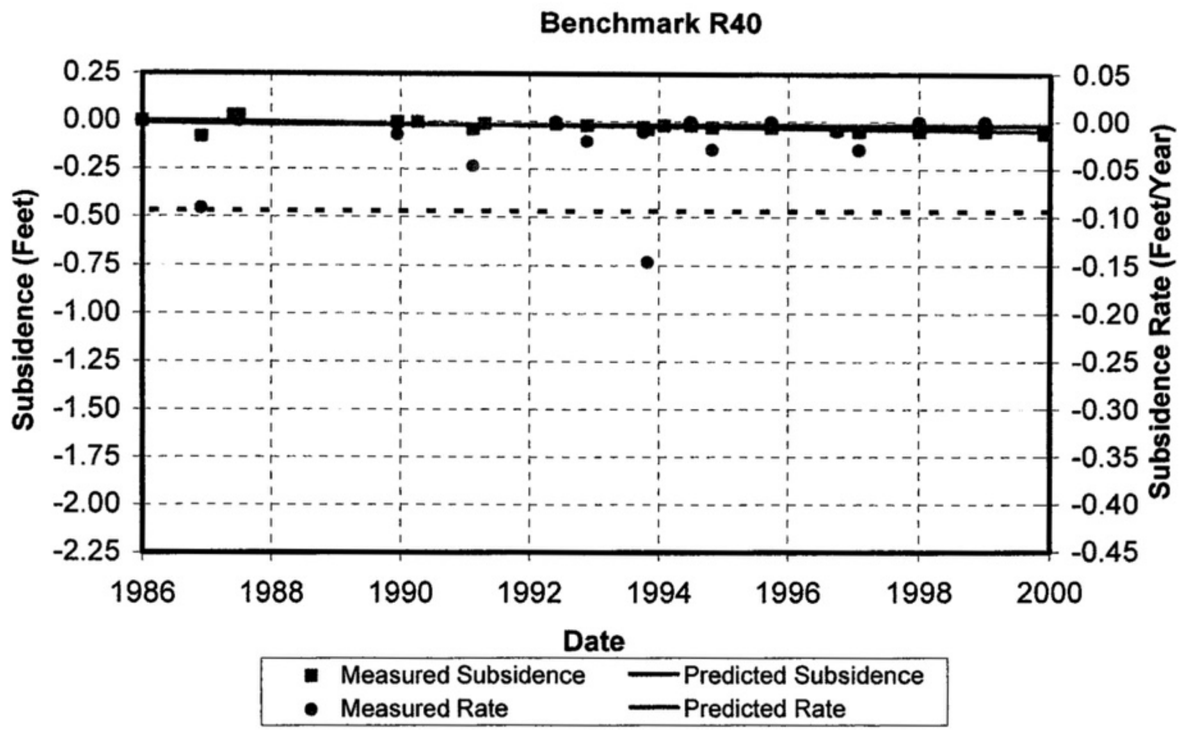
RESPEC's subsidence model using the **SALT_SUBSID** program reasonably reproduces the measured subsidence at Cargill's Cayuga Mine. Analysis of the surface subsidence information leads to the following conclusions:

- 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 maximum subsidence occurs under Cayuga 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.

2.3.1.4.2 Geomechanical Modeling

The geotechnical investigation of Cargill's Cayuga Mine Site performed by RESPEC included a geomechanical assessment of the stability of the underground mine. RESPEC performed both two-dimensional finite element and three-dimensional finite-difference mechanical (structural) modeling. The specifics of the two and three-dimensional modeling are detailed in Volume II.





Measured and Model–Predicted Subsidence and Subsidence Rates for Benchmarks 190A and R40 on the East Shoreline of Cayuga Lake.

Note:
Original figure by RESPEC.

SPECTRA ENVIRONMENTAL GROUP, INC.
19 British American Blvd.
Latham, NY 12110

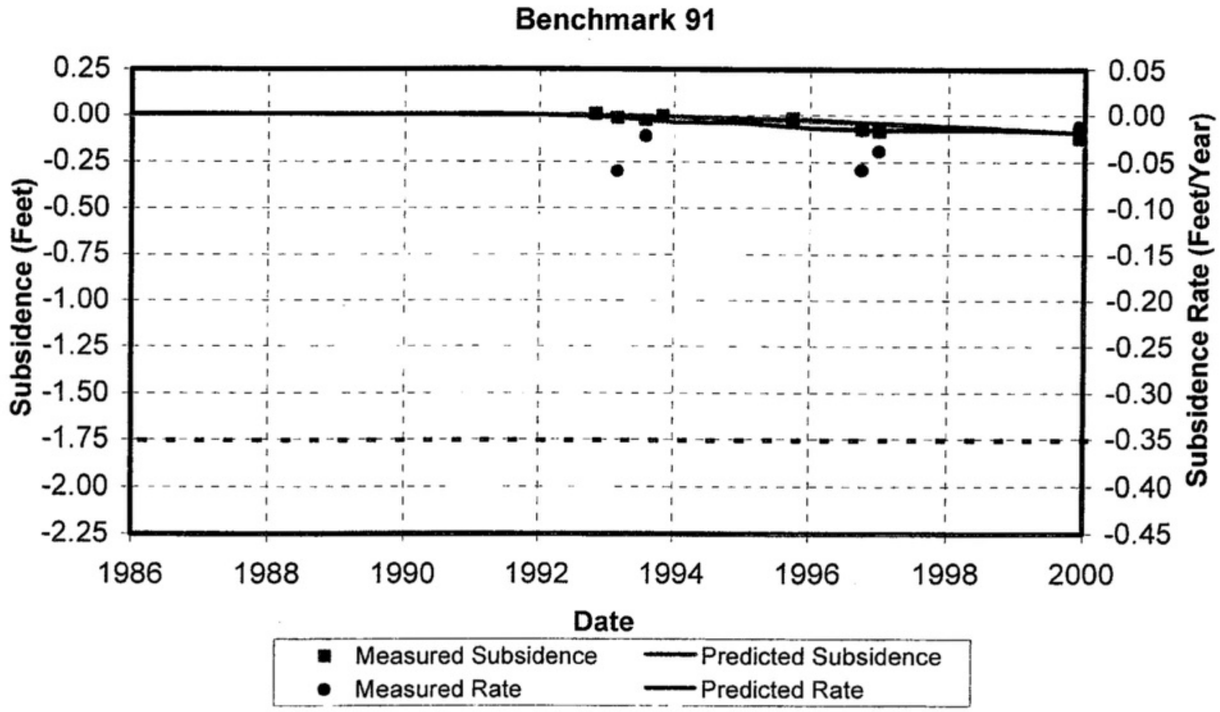
Project No.: 98189

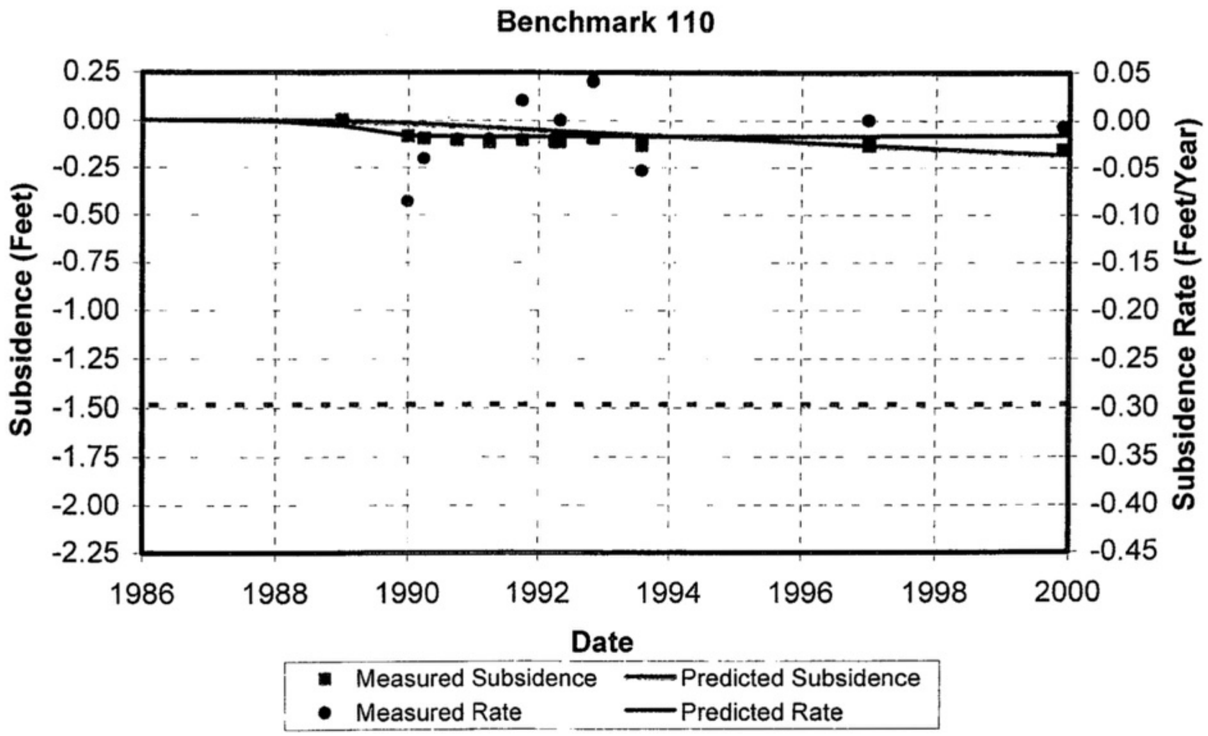
FIGURE 2.3–5

CARGILL SALT, INC.
CAYUGA MINE

TOWN OF LANSING

TOMPKINS CO., N.Y.





Measured and Model–Predicted Subsidence and Subsidence Rates for Benchmarks 91 and 110 on the West Shoreline of Cayuga Lake.

Note:
Original figure by RESPEC.

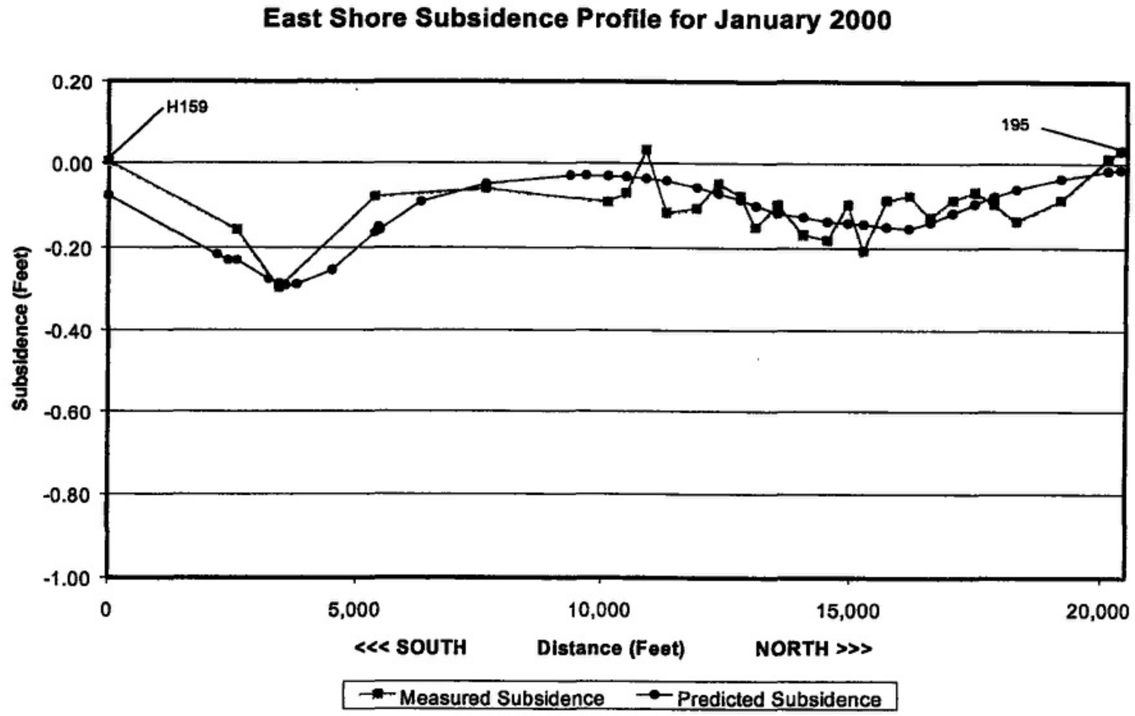
SPECTRA ENVIRONMENTAL GROUP, INC.
19 British American Blvd.
Latham, NY 12110

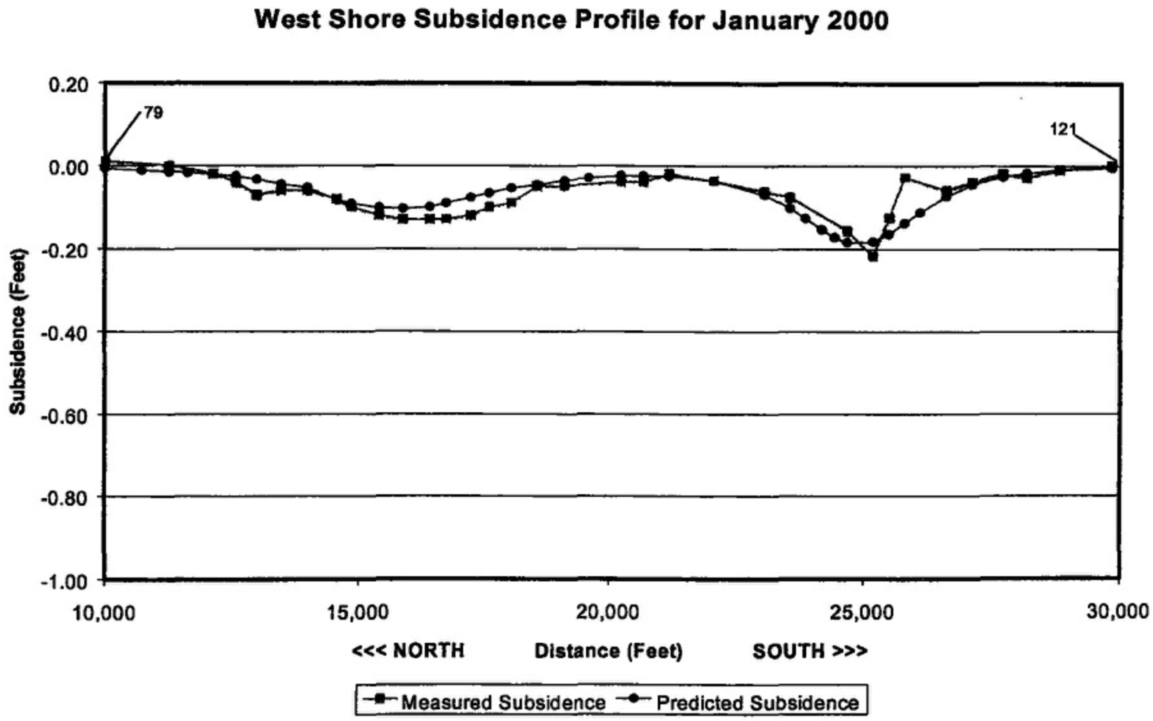
Project No.: 98189

FIGURE 2.3–6

CARGILL SALT, INC.
CAYUGA MINE

TOWN OF LANSING   TOMPKINS CO., N.Y.





Measured and Model–Predicted Subsidence Profiles, Along the Eastern and Western Cayuga Lake Shorelines for January 2000.

Note:
Original figure by RESPEC.

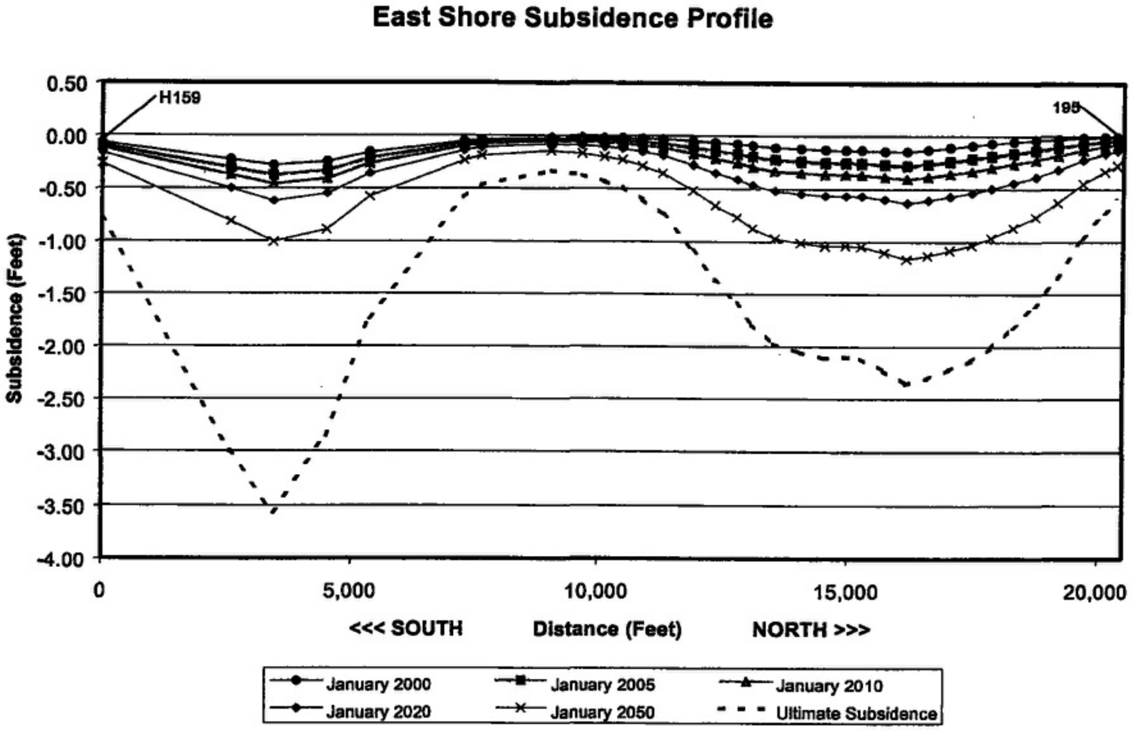
SPECTRA ENVIRONMENTAL GROUP, INC.
19 British American Blvd.
Latham, NY 12110

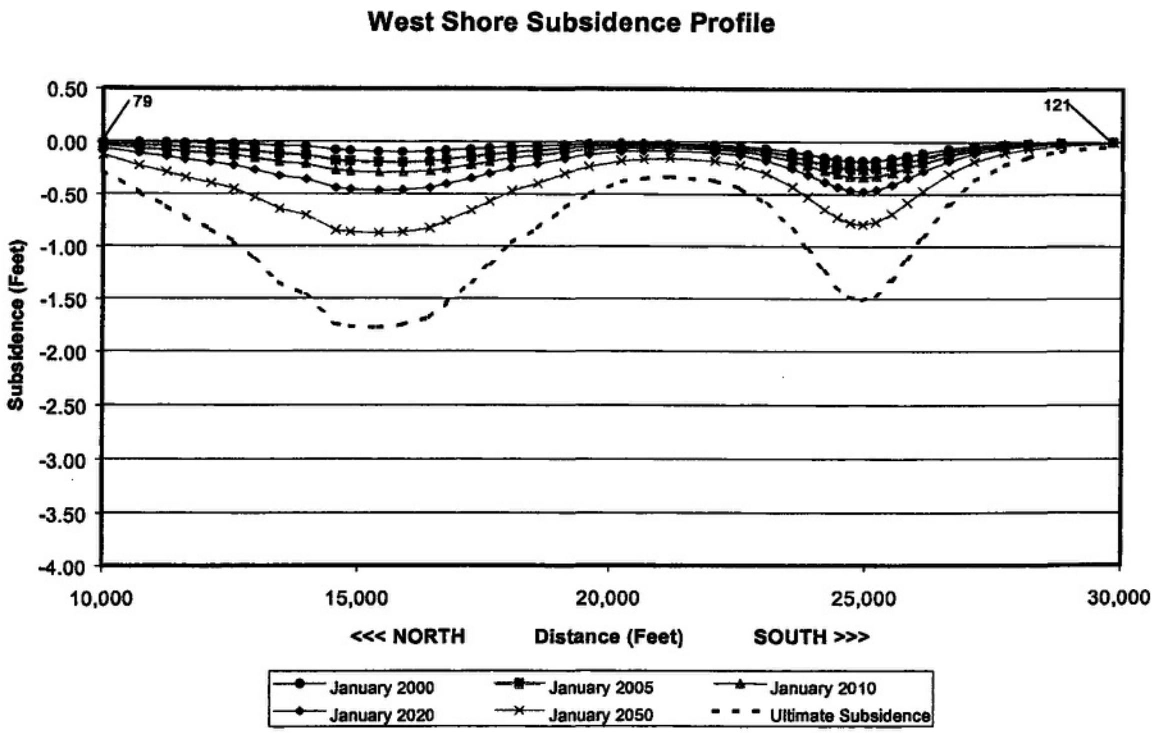
Project No.: 98189

FIGURE 2.3–7

CARGILL SALT, INC.
CAYUGA MINE

TOWN OF LANSING — TOMPKINS CO., N.Y.





Model–Predicted Subsidence Profiles Along the Eastern and Western Cayuga Lake Shorelines 5, 10, 20, and 50 Years in the Future for the Current Mined Area.

Note:
Original figure by RESPEC.

SPECTRA ENVIRONMENTAL GROUP, INC.
19 British American Blvd.
Latham, NY 12110

Project No.: 98189

FIGURE 2.3–8

CARGILL SALT, INC.
CAYUGA MINE

TOWN OF LANSING

TOMPKINS CO., N.Y.

The goal of the modeling effort was to determine/establish a model (including stratigraphy) for the mine that would aid in assessing the stability of the mine. The two-dimensional model was used to reaffirm material (rock) properties, assumptions on the situ conditions, and stratigraphy. As a result, numerous two-dimensional calculations were performed to gain an understanding about the sensitivity of the computed results to different aspects of the mine model. This investigation lead to a better understanding of the interaction of the mine with the local strata and aided in the development of the three-dimensional model of the mine.

2.3.1.4.2.1 Two-Dimensional Modeling

Two-dimensional structural analyses performed by RESPEC of Cargill's Cayuga Mine employed the finite element program **SPECTROM-32.** **SPECTROM-32** is a two-dimensional thermomechanical, finite element program developed by RESPEC for the solution of rock mechanics problems. The program was designed specifically for the simulation of underground openings and structures.

Comparisons were performed between panel closure and, panel closure rates, taken at the mine with those predicted by the two-dimensional **SPECTROM-32** model, after an appropriate model for the mine was determined.

RESPEC's modeling results with the **SPECTROM-32** model include:

1. ***Comparison of measured and predicted panel closures and panel closure rates.*** The measured and predicted results are in good agreement in the fact that panels mined early to have more closure than panels mined later and that the panels located in the center of the mine have more closure than the panels located toward either end of the mine. Also, panel closure rates are initially fast following excavation. Than between 3 and 6 months after a panel is mined, the closure rates stabilized to a near-steady value.

2. ***Predicted horizontal pillar displacements (in the barrier pillars).*** In general, the modeling and measurements show that displacements at both sides of the barrier pillars increase with time, due to salt creep. The majority of the displacement takes place in the first 50 feet in from the rib on either side of the pillar.

3. ***Predicted vertical displacement profiles of the Camillus Shale and shale above the mine roof during mine expansion to 14 adjacent panels in width.*** According to RESPEC, the roof above the mined panels continues to displace over time whereas, the vertical displacement of the barrier pillars at the panel roof-line slows and nearly stops a few years after excavation of the adjacent panels. The roof

displacement of the panels located at either end of the mine are less than the displacement for panels located toward the center of the mine. As mining continues, a uniform deformation of the Camillus shale is expected over the mine.

4. ***Predicted stress history in the barrier pillars during mine expansion to 14 adjacent panels in width.*** Mining a panel results in large increases in the vertical stress within the adjacent barrier pillars. Excavation of panels located farther from the pillar results in successively smaller increases in the vertical pillar stress. RESPEC's modeling suggests that excavation of a panel located more than three panels away has a negligible effect on the vertical stress in any given barrier pillar.

These results of two-dimensional modeling are discussed in greater detail in Volume II.

2.3.1.4.2.2 Three-Dimensional Modeling Results

RESPEC performed a single three-dimensional model calculation of the northwest area of Cargill's Cayuga Mine using the three-dimensional finite difference program **FLAC^{3D}** (Itasca Consulting Group, Inc., 1997). The model developed by RESPEC assumed that the rock beds below Cayuga Lake do not vary in thickness and extend horizontally to the model boundaries approximately 20,000 feet past the edges of the mined panels. The surface topography and top of bedrock below Cayuga Lake, as utilized in the model, were based upon structural contour data of the bedrock at the site as established by The Sear-Brown Group, Inc. (1995).

The model considered future expansion of the mine under the lake toward the north. Additionally, the length of the panels to be mined in the future was selected to correspond with the length of the last completed panel below each shoreline.

According to RESPEC's model, computational considerations necessitated that the mining sequence of excavations be simplified from that which actually occurs at the mine. Mining could not be modeled as a slow steady progression. Instead, the modeled area was divided into six (6) separate excavations. Each of the six excavations was modeled as occurring instantaneously at 2-year increments. Following the simulated mining of the last excavation, the mine response was simulated for a period of 50 years.

The results obtained from the three-dimensional model developed by RESPEC for Cargill's Cayuga Mine include:

1. ***Comparison of measured and model-predicted panel closures and closure rates.*** Measurements and model computations portray that the closure rate NYSDEC decreases with distance away from NW1 and is slowest near the mine boundaries than elsewhere in the mine. RESPEC concludes, "Most of the closure at the mine is a

result of roof sag. The maximum uplift of the floor is approximately 5 inches, compared to 12 inches of roof sag at 10 years. The floor heave occurs mostly upon excavation and remains relatively stationary throughout the modeling; whereas the roof sag continues to increase with time".

2. ***Comparison of surface subsidence with measured subsidence for the January 2000 survey.*** RESPEC modeled surface subsidence at Cargill's Cayuga Mine using the **FLAC^3D** three-dimensional finite difference computer program. The results were compared with the measured subsidence values and the subsidence values obtained using **SALT_SUBSID**. According to RESPEC's modeling, the **FLAC^3D** three-dimensional finite-difference model and the **SALT_SUBSID** two-dimensional finite element model closely predict the subsidence for January 2000. The **FLAC^3D** model predicts significantly less subsidence than the **SALT_SUBSID** model at 10 and 40 years into the future.

3. ***Evaluation of the factors-of-safety in the rock between the mine and the top of bedrock.*** Rock stability at the Cayuga Mine was assessed for the salt and the overlying nonsalt units. Nonsalt rock stability was analyzed based on the Mohr-Coulomb yield criterion and the potential for dilation[5] was used to assess the stability of the salt beds.

   RESPEC computed safety factors for the shale roof rock and overlying strata based on the model predicted stresses. The Mohr-Coulomb failure criterion was employed to quantify the potential for failure. The potential for failure were based upon material cohesion values and angles of internal friction specific to previously tested shale from the Cayuga Mine region. The three-dimensional model predicted factors-of-safety greater than 1 for all nonsalt rock units above the mine throughout the simulation period. Also, the factor-of-safety for the nonsalt units do not decrease substantially with an increase in the lateral dimensions of the mine. The factor-of-safety for the Camillus Shale exceeds 4 throughout the simulation period.

   Dilation, or inelastic volumetric strain, was used to assess factors-of-safety in the salt. All salt intervals, with the exception of the No. 5 salt show a factor-of-safety greater than 1. RESPEC's analysis concludes that, based on the current successful operation of mining in the No. 6 salt, dilation in the No. 5 salt does not pose a stability problem.

These results of the three-dimensional modeling are summarized in greater detail in Volume II.

[5] Dilation: inelastic volumetric strain

2.3.1.4.2.3 Multi-Seam Mining

Multi-seam mining has traditionally been performed at Cargill's Cayuga Mine. Excavation has occurred on the Nos. 1, 4, 4A and 6 salt levels. Multi-seam mining has occurred in the eastern mine areas on the Nos. 4 and 6 salt levels (not since 1970). RESPEC was retained to reassess the feasibility of the continued mining on multiple levels at the Cayuga Mine.

Two separate modeling efforts were performed by RESPEC. The first includes the area of the existing mine where the No. 1 Salt is expected to exist. The second effort included the areas north of the current mining where future mining is planned. Where the No. 1 Salt is expected to exist, the multiseam mining simulations assumed that mining would occur on the Nos. 1, 4, and 6 salts. Where the No. 1 Salt is assumed absent, only mining on the Nos. 4 and 6 salts were simulated. In addition, the modeling effort also assumed depths of cover equivalent to mining below the center of the lake and mining outside the boundaries of the lake to assess the effect of increased vertical stress associated with more overburden.

RESPEC's modeling indicates that the lowest factors-of-safety in the salt beds measured against the potential for damage (microcracking) in the salt occur directly above and/or below the mined panels and entries. In general, RESPEC's modeling predicted factors-of-safety greater than 1.54 for all salt beds except the No. 5 salt. RESPEC predicts a factor-of-safety less than 1.0 in the No.5 salt during the mining of the No. 6 salt. RESPEC has concluded that this is not problematic because numerical simulations of current mining activities also predict dilation of the No. 5 salt, and yet the current mine 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 (i.e. no dilation) during the 30 years of simulation.

The factors-of-safety for the shale beds near the outer edge of the mine are greater (safer) than those predicted near the center of the mine. In general, the calculated factors-of-safety in the nonsalt rocks above the mined panels are greater than 1.6. The analyses did predict factors-of-safety less than 1 for small regions in the shale, centered over the abutment pillars, in the shale separating the No. 2 and No. 3 Salt. The low factor-of-safety in this shale unit occurred after the simulated mining of the No. 1 salt. While no parametric studies were performed, RESPEC concluded these small regions of low factor-of-safety could be prevented through modifications of the assumed mine design. These analyses were performed to determine if multiseam mining was a feasible option. While no detailed designs have been performed, the work showed this to be a viable option.

2.3.1.4.2.4 Geomechanical Modeling Summary and Conclusions

RESPEC's findings and conclusions based upon their geomechanical modeling are as follows:

1. Measured and predicted mine closure behavior agree reasonably well using the United States Bureau of Mines (USBM - now a part of the United States Geological Survey) 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 agreement might be improved by increasing the model refinement.

2. Excellent agreement was obtained between the measured subsidence and the subsidence predicted by both **SALT_SUBSID** and the three-dimensional **FLAC^{3D}** model for January 2000 predictions (see RESPEC Report **Geomechanical Modeling and Reassessment of Cargill Salt Cayuga Mine, Lansing, New York**), 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, predictions using this model will likely underpredict the future subsidence at the Cayuga Mine.

3. 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 (modeled with a 12-panel width) will remain stable well into the future.

4. 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, continued expansion of the mine is possible without failure occurring in the nonsalt beds above the mine.

5. The factors-of-safety predicted for the Camillus Shale exceed 4 throughout the 50 years that were modeled, indicating that sufficient stable overburden exists to isolate the water-bearing rock units above the mine from the mine in absence of any geologic anomaly.

6. The three-dimensional model predicts lower factors-of-safety in the shale beds than does 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 do not indicate failure.

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

8. Numerical analyses of the conceptual multi-seam model indicate that multi-seam mining at the Cargill's Cayuga Mine is possible at the northern boundary of the planned permit area without adversely impacting mine stability.

9. The individual rooms and pillars present in the current design are stable.

10. The production panels, including the excavation areas and the abutment pillars are stable.

11. The overburden/overlying strata is adequately supported and stability is assured based upon the long history of the yield pillar panel method at the mine.

12. Numerical modeling studies of individual panels and combinations of panels indicate a stable situation.

13. Laboratory testing of the Cayuga salt revealed no unusual behavior characteristics.

Based upon these findings, RESPEC believes that Cargill's Cayuga Mine is currently a stable mine, and no significant stability problems are expected in the future, given the existing and planned mine layout.

The results of the two and three-dimensional modeling were used to provide an estimate of a conservative and appropriate "stand-off" distance between the mine and any geologic structure/anomaly of concern such that the presence of the mine would not be "felt" by the structure/anomaly. RESPEC's study concludes that displacements caused by mining become vanishingly small between a distance of 2,000 and 2,500 feet horizontally from the mine limits. RESPEC believes that a distance of 2,500 feet is sufficient to preclude the interaction of the mine with any anomaly. This does not mean that mining could not safely approach an anomaly at distances less than 2,500 feet. It is highly probable that the mine could pass significantly closer to an anomaly and perhaps even go through an anomaly without disrupting mine stability. Before mining *through* an anomaly, however, RESPEC prescribes that a detailed study be performed prior to making a recommendation.

Dr. William Goodman, Senior Hydrogeologist with Sear Brown, has identified what appears to be a near vertical fault approximately 10,000 feet or more northwest of the current mining area (Goodman, 2000b) and beneath the lake basin. RESPEC's geomechanics analysis did not evaluate the potential for direct interaction (and associated structural response) between the mine and the apparent fault identified by Goodman. RESPEC recommends that a 2500-feet standoff distance be maintained between the mine limits and the approximate location of the fault, until a more detailed rock mechanics investigation is completed.

Should Cargill elect to mine closer to, or perhaps through, the potential fault zone, it will first conduct a detailed rock mechanics investigation to establish the viability of such.

2.3.1.4.3 Microseismic Monitoring

The final component of the geotechnical assessment performed by RESPEC for Cargill's Cayuga Mine was review of microseismic events. Whenever rock is subject to stress changes (like those caused by mining) the rock will emit acoustical signals that can be related to the load the rock is "seeing". These microseismic events, may result from rock movements associated with changes in stresses or slow deformations caused by mining-induced subsidence.

In March 1995, Engineering Seismology Group Canada, Inc. (ESG) installed a microseismic monitoring system in the Cayuga Mine. The monitoring network consisted of 15 accelerometers located in 10 or 30-foot-deep boreholes drilled into the roof of the active mine area. The accelerometers were distributed between Panels U26 and U34 in the northwest part of the mine beneath Cayuga Lake. The purpose of the monitoring was to determine level and locations of mining-induced seismicity. To date, ESG has collected a considerable amount of microseismic data at the Cayuga Mine. For the purpose of the geotechnical/geomechanical analysis, RESPEC reviewed the microseismic data collected between March 24, 1995 and October 5, 1997.

The majority of the seismic events (excluding blast events) recorded by the monitoring network at the Cayuga Mine and reported by ESG was confined to a horizon located between 1,100 and 1,500 above the mine. According to RESPEC, this corresponds to the approximate location of the Siluro-Devonian carbonate sequence capped by the Onondaga Limestone.

In plan view, the majority of the seismic events tended to cluster above the NW1 entry. A significant number of events were also located immediately outside the mine limits. The NW1 drift is located at the center of the current mining activity and 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 (i.e. in the unmined areas).

RESPEC believes the Siluro-Devonian carbonate sequence to be stiffer than the other 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 formation would be expected to experience substantial induced stresses as a result of deformations from mining-induced subsidence.

Mining-induced subsidence leads to deformation of the "beam" that encompasses the carbonate rock units overlying the mine. The carbonate beam would deform elastically until deformation-induced stresses at a point exceed the strength at that point. If fracturing of the carbonate sequence occurred, the location of fracturing would correspond to those points where the strength of the material was exceeded.

Small failures in the overlying strata are not necessarily a cause for concern. Failures are a process of relieving the built-up stresses due to mining-induced deformations. As long as the failures occur at a relatively constant frequency and at a relatively constant and low magnitude, stability of the overlying strata is indicated. According to RESPEC, the seismic events recorded to date do not indicate instability Seismic events will continue to be monitored for any indications a instability such as a linear vertical trend or occurrences away from the area where current events are clustered.

2.4 Underground Mining Methods

Currently mining of salt is performed with barrier/abutment and yield pillars with a total mining height of approximately 12 feet.

The No.6 level salt at Cargill's Cayuga Mine is presently mined using conventional mining equipment in a room-and-pillar layout (the yield-pillar method described above). The salt is undercut to a depth of approximately 14 feet with a Joy 16 RU undercutter.

Two (2) general blasting patterns/methods are used are used at the Cayuga Mine - the undercutter method and the burn hole method. The undercutter method was developed in coal mines after the beginning of the 20th century and was adapted to salt mining shortly after. The burn hole method was developed in hard rock mines in the 1980's and was adapted to salt mining in the 1990's.

The undercutter method involves using a chainsaw-like machine to saw a slot in the floor, horizontally across the face of a tunnel in a production panel. The slot penetrates below the salt that is to be blasted. This kerf is generally about 6" wide (high), and extends forward under the salt face about 13 feet. The purpose of the kerf is to give the salt space to fracture into and to give the blast a "free face" (less confinement) to allow good fragmentation with lesser amounts of explosive. A "jumbo" drills a pattern of blast holes 1 ¾" diameter into the face, penetrating about 13 ½' forward above the undercut. The drill holes are loaded with pneumatically placed ANFO blasting agent. Each hole also has a "Primadet™" cap with a booster (a small tube of high explosive slid over the end of the cap). The caps have a series of delay periods so that the individual holes will blast at precise times to control the breakage of the salt. Each hole receives a cap of the appropriate delay for the pattern being shot. Approximately 200 lbs. of blasting agent are charged into the 28 holes of each face (about 7 lb. per hole). This face has a series of 4 delay periods, with a maximum of 9 holes or 63 lb. of agent per delay. Approximately 275 tons of salt are blasted with a typical shot using the undercut method. This equates to a powder factor of approximately 0.73 lb./ton.

The burn hole method uses a group of large diameter holes drilled into the center of the face to provide the free face for the blasting. A group of 6 parallel holes, 11 inches in diameter are drilled approximately 22 feet horizontally into the face, near the center of the face. Subsequently, 39 blast holes are drilled around and parallel to the burn holes to a depth of approximately 22 feet. The blast holes are then pneumatically loaded with ANFO and outfitted with "Nonel™" caps with boosters in them. Each cap has the appropriate delay for the hole to shoot in proper sequence. Each face is charged with approximately 450 lb. of agent, or about 11½ lb. per hole. This face has a series of 12 delay periods, with a maximum of 6 holes or about 70 lb. of agent per delay. Approximately 410 tons of salt breaks with each of the burn hole faces shot. This equates to a powder factor of approximately 1.09 lb./ton.

The amount of overbreak, which is the fracturing of rock beyond the desired area, must be minimized since fracturing decreases the ability of the immediate roof to span the rooms without excessive scaling. This is the common practice at Cargill's Cayuga Mine.

LHD's haul the salt to the Stamler feeder breakers. The raw material is there fed to the Stamler feeder breakers and transported, via conveyor, to the underground processing plant in the No. 6 level. Processing is discussed in greater detail in Section 2.4.4.

In the past approximately 10 percent of the processed salt was too fine for marketing. The installation of a new, more efficient processing plant has reduced this percentage to approximately 3 percent. Unmarketable fines are disposed of in mined out production panels. Because of the porosity of the fines, and the relatively slow closure/convergence rates of the mined-out panels, the stowed fines do not serve as structurally significant backfill.

2.4.1 Planned Mining Areas

Cargill plans to continue underground salt mining activities within its active lease area as shown on the Subsurface Mining Plan Map. Excavation will continue as a series of production panels (with associated yield pillars) located between massive abutment pillars.

The production panels will branch off of a main drift or entry, as the existing panels extend from entry/drift NW2. Excavation will continue in this manner to the north of the existing production area.

The planned expansion area to the north along the axis of Cayuga Lake includes the area of the fault, as discussed earlier. Before choosing to mine through this region, Cargill first will conduct a detailed and extensive rock mechanics investigation as recommended by RESPEC. Should Cargill not elect to mine through the area of the potential fault, the company will progress a drift around the eastern limits of the fault identified by Dr. Goodman. The drift, or entry NW2, will maintain a minimum separation distance of 2,500 feet from the fault trace, as identified by Goodman and recommended by RESPEC.

In addition to the northern planned expansion area, Cargill plans to mine, within its approved lease area, to the southern mining limits shown on the Subsurface Mining Plan Map (Plate 2.2-1). Cargill plans multi-seam mining (i.e. salt mining on Levels 1 (where present), 4 and 6 within the permitted area).

2.4.2 Roof Reinforcement - Rock Bolting Practices

Cargill employs a roof-rock bolting program to assist in the maintenance of a safe working condition in the Cayuga Mine. Where necessary, Cargill employs a combination of roof-rock bolting and the suspension of chain link/welded steel mesh to restrain pieces of loose salt in the roof.

Occasionally, and in certain areas, the immediate roof must be suspended from stronger, overlying strata. This is largely accomplished by rock bolting in the roof. This is common practice in the vast majority of underground mines operating in laminated rock masses.

The rock bolt system employed at the Cayuga Mine has been developed over a period of approximately 25 years using research and practical experience within the mine. The system has been designed with safety and productivity to provide the most effective ground support for the conditions present in the mine.

Tensioned rock bolts are employed at the Cayuga Mine, consisting of an anchorage, a bolt, a roof plate and a spherical washer under the bolt head. Specifically, the rock bolts employed at the Cayuga Mine include a mechanical expansion shell anchor, a 5/8 "-inch diameter grade 75 bolt, a deformable bearing plate (domed roof plate) and spherical washers.

A hole is drilled into the salt and overlying rock in the roof (upward and vertically for roof support). A rock bolt (5/8"-diameter rod fitted with an expansion shell anchor) is then inserted into the drill hole. As the bolt is tightened, a wedge that is attached to the end of the bolt in the hole is drawn out into a conical anchor shell (F&J F5F or D5 Anchor). This action forces the anchor shell to expand against the drill holes walls. Prior to tightening, a "domed-roof" faceplate and spherical washer are placed over the rock bolt. The rock bolt is then tightened which draws the domed roof plate up against the roof. A schematic diagram of a typical roof bolt (Figure 2.4-1) appears on the following page.

The domed roof plates are used for a variety of reasons, including:

1. they are shaped in a manner that when correctly installed the dome will just begin to dimple, giving a clear indication of proper setting of the anchor and pre-tensioning of the bolt;

2. the dome will collapse when the bolts take on additional load, allowing the roof to move and relax without decreasing the support to the roof; and

3. the collapsed dome gives a visual indication that the bolts are taking on extra load, which is usually associated with failing roof.

The spherical washers are used to reduce the bending of the bolt when the bolts are installed in an area with uneven roof. The washer is shaped so that the plate can be at an off angle, but the bolt is not being bent by it. When the roof is not flat and the plate is at an angle to the bolt it can cause bending in the bolt near the bolt head. The added stress in the bolt due to bending can cause the bolt to fail at a lower load than normal.

2.4.2.1 Typical Bolting Patterns

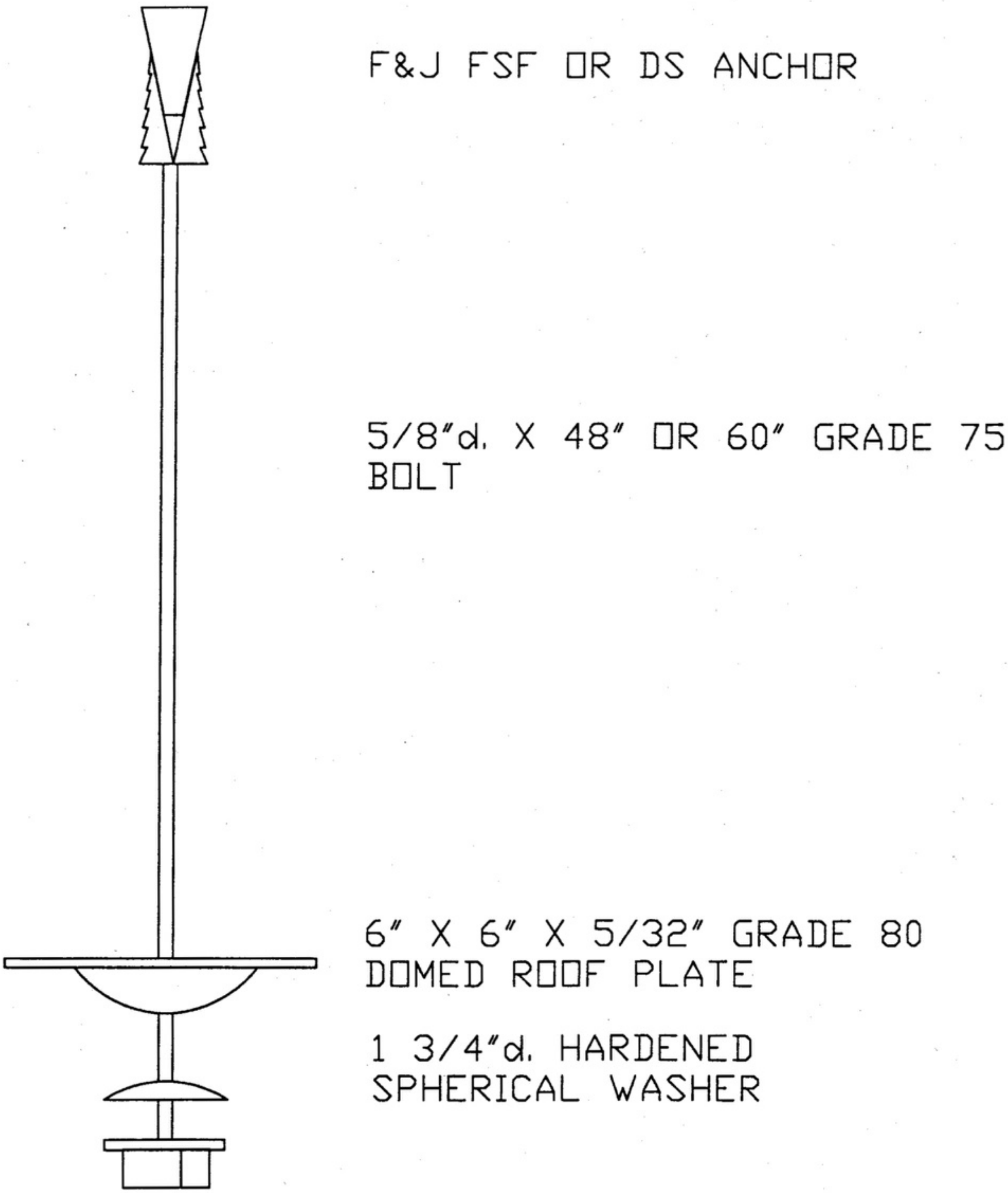
The rock bolting patterns employed at Cargill's Cayuga Mine are dependent upon roof conditions (e.g. scaling, etc.), roof separation patterns in the salt and/or overlying shale, the width and length of individual mining advances, whether or no the area lies within a production or development panel, etc.

Cargill's many years of studies of roof separations within the Cayuga Mine have shown several tendencies:

1. The roof will typically have numerous minor separations with the first 12 inches. These are likely due to localized blasting effects to the roof ;

2. The roof may demonstrate a separation just above the salt/roof contact; and

3. The roof rarely exhibits a separation higher than 3 feet or 4 feet above the ceiling.



SPECTRA ENGINEERING, P.C.
19 British American Blvd.
Latham, NY 12110

TYPICAL ROCKBOLT ASSEMBLY

CARGILL SALT, INC.
CAYUGA MINE

TOWN OF LANSING — TOMPKINS CO. NY

PROJ. No.: 98189	DATE: 12/18/00	SCALE: NTS	DWG. NO. 98189BOLT	FIGURE 2.4-1

Based upon conditions in the vast majority of the roof area at Cargill's Cayuga Mine, 4-foot long bolts provide adequate roof support. To support up to 3 1/2 feet of roof thickness (the roof rarely exhibits separations higher than 3 or 4 feet into the roof), with the strengths of the 5/8 inch-diameter bolts being used, the bolts must be spaced no more than approximately 5 1/2 feet apart.

Cargill has developed a detailed production rock bolting guideline for the Cayuga Mine that specifies the spacing and number of rock bolts needed for a specific advance. However, the guidelines must be applied judiciously, and the spacing and depths may, occasionally, be altered to reflect localized roof conditions.

The standard rock bolt system for production panels at the Cayuga Mine consists of 4-foot long, 5/8 - inch diameter rock bolts anchored with F5F 1 3/8 - inch diameter expansion shells. The domed-head roof plates are tightened against the ceiling (roof) with a spherical washer and nut to a pre-determined torque.

Within development panels or entries, such as NW1 or NW2, the standard bolt system consists of alternating 4-foot long and 5-foot long, 5/8-inch diameter bolts anchored with D5 1 5/8-inch diameter expansion shells. Again, domed-head roof plates are tightened against the mine ceiling with a spherical washer and nut to a pre-determined torque. Longer bolts and larger expansion shells are used within the development panels because these areas must remain open for the life of the mine.

Rock bolts are installed at the Cayuga Mine in accordance with Mine Safety and Health Administration (MSHA) requirements with respect to the torque of installed roof bolts.

Wire mesh and/or chain link is rock-bolted to the mine ceiling, as needed, to restrain small pieces of displaced salt and prevent falls. Where roof conditions within individual cuts necessitate greater attention due to scaling, etc., repair methods (e.g. rock bolting and/or chain-link/steel mesh installation) are selectively applied on a case-by-case basis.

2.4.3 Ventilation System Details

The use of diesel equipment and the routine blasting to break the salt necessitates the use of a mechanical ventilation system to dilute fumes, replenish oxygen and control work place temperatures.

The mine vent system at Cayuga utilizes several primary components to accomplish the ventilation of the mine. The No. 3 shaft is the conduit for fresh air to be drawn down from the surface to the mine level. Electrically driven fans cause the air to flow through the mine, while walls direct the air through the mine. The No. 1 shaft is the primary conduit that carries the "return" air from the mine level back to the surface.

The No. 3 shaft is an 11-foot diameter; concrete lined shaft that serves as the travel way for the man/materials "cage" and as the "intake" airway for the mine. The main fans are located near the bottom of this shaft and cause air to flow down the shaft and into the mine.

The main fans, located about 250 feet from the bottom of the No. 3 shaft in the No. 6 salt level, provide the force necessary to cause air to flow through the mine. The 2 fans are Joy Series 2000, 72-30 vane axial units powered by 350 HP electric motors. The fans are mounted in a bulkhead side by side and run simultaneously. When running, the low pressure induced by the fans near the bottom of No. 3 shaft causes air to flow from the surface down the shaft and through the fans. The now pressurized air flows from the fans and, guided by ventilation walls, travels to the working areas of the mine. After diluting the fumes generated by the mining activities, the air returns through the mine, travels up the two slope tunnels to the No. 4 level and exhausts from the mine via the No. 1 shaft (refer to the map showing the mine-ventilating plan). The fans typically draw 260,000 cubic feet per minute (CFM) down the No. 3 shaft.

Ventilation walls or "stoppings" are constructed throughout the mine to force the air to follow a prescribed path. The stoppings are built to block off specific tunnels while leaving others open for airflow. These walls also isolate the fresh intake air from the mine return so it is as clean as possible when it reaches the working places. Construction methods and materials change from time to time as better technologies are developed, but the walls are built for minimum leakage and maintenance, maximum durability and "squeezeability" (to accommodate the roof to floor closure), while maintaining non-flammability.

Within the mining panels, "brattice" curtains are used rather than stoppings. The curtains serve the same purpose, but are rapidly installed and recovered, highly flexible to withstand air overpressures caused by blasting, and are low in cost. Because ventilation differential pressures are very low in the mining panels, the curtains do not leak significantly. The panel ventilation system has a life requirement of about 16 months where as the stoppings must function for 1 to 2 decades as part of the permanent ventilation system.

Each mining area (panel) is ventilated with its own "split" of fresh air from the main supply. This allows blasting to be conducted (with its associated large volume of fumes) in one mining area while an adjacent area continues to work. The return air from each panel is routed to the common main return airway for exhausting from the mine.

The No. 1 shaft is 10' X 25' in section and extends from the No. 4 mine level to the surface. This shaft contains a timbered frame supporting structure to stabilize the rock walls and support the skip and cage guide rails. The shaft is divided into 4 "compartments". Two are used as travelways for salt hoisting skips, one is used as a travelway for an emergency mancage, and one contains a ladderway (abandoned). The pressure induced in the mine by the main fan causes the air to flow from the No. 6 level; up the 2 slope tunnels to the No. 4 level and thence to the No. 1 shaft and up to the surface. A minor amount of air (4-5%) flows up the No. 2 shaft, which is an unlined borehole 4 feet in diameter with no facilities or conveyances in it.

Within the operating mining areas, the fresh air delivered by the main fans is distributed and swirled into the working tunnel "faces" by portable electrical auxiliary fans. These facilitate the mixing of fresh air with fumes prior to the air exiting the panel, and provide a breeze to increase the comfort of the miners.

2.4.4 Subsurface Processing

The salt processing sequence is discussed in detail below. The process is shown on the Plant Flow Diagram (Figure 2.4-2) on page 58.

2.4.4.1 Cargill Plant Flow Information

- Blasted salt is excavated from the production mining panel(s) via 9 yd^3 scoop trams.
- Raw product is hauled from the active mine face via scoop trams to stamler feeder breakers located within the active mine area. Stamler feeder breakers are relocated approximately once every five (5) weeks as the active mine faces advance.
- At the stamler feeder breakers, the raw product is reduced to -8" in size. The reduced product is then moved, via a series of conveyor belts (individual panel belts and the belts along entry or drift NW1 or NW2) to a single, 800-ton raw-salt surge pocket. The pocket location is shown on the Subsurface Mining Plan Map.
- The salt is there discharged to a conveyor belt system (1 Belt and 2 Belt) for transport to the underground screening plant. Belt 1 takes the salt into the underground screening plant where the salt drops to 2 Belt that leads to a roll crusher, which reduces the product to -4" in size.
- The crushed product from the roll crusher is then transported, via 3 Belt to #1 Screen. The material retained on #1 Screen Deck is routed to an impact crusher for additional reduction. That which passes through the #1 Screen Deck is conveyed via 7 Belt to the en masse distributing conveyor B - 8 for distribution to additional screen decks.
- The salt that is processed through the impact crusher is conveyed via a series of conveyor belts (4 Belt, 5 Belt and 6 Belt) to #2 Screen (a double-deck screen). The material retained on the top deck is transferred to the impact crusher for recrushing.

Ca art

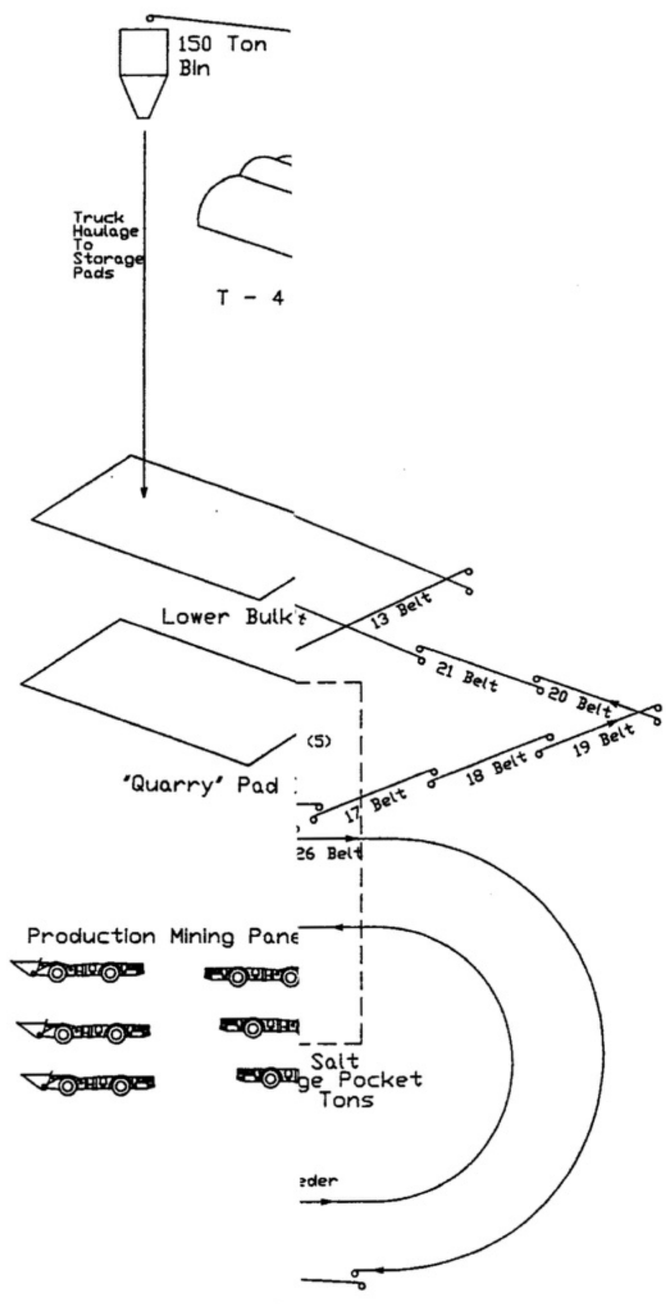


FIGURE 2.4-2

PROJECT
: RCL
98189
BY: PAW
BY: PAW
BY:
BY:
NTERVAL - FEET

Material Flow Chart

Cargill Salt, Inc.

Cayuga Mine, Inc.

Town of Lansing — Tompkins Co., NY

SPECTRA ENVIRONMENTAL GROUP, INC.
19 British American Blvd.
Latham, NY 12110

DATE: 12/19/00 | SCALE: nts | DWG. NO. 98189flow | SHEET OF

NOTE:
FIGURE PROVIDED BY CARGILL SALT, INC.

- The material retained on the lower deck is transferred to the distributing conveyor B-8.

- The product routed to the en masse distributing conveyor B-8 is there split to five (5) separate Rotex screen decks. Product retained on the screens is conveyed, via a series of conveyors (15 Belt, 16 Belt, 17 Belt, 18 Belt, 19 Belt, 20 Belt, 21 Belt, 22 Belt and 42 Belt) to a tripper feeding the Finished Salt Surge Bin (8,000 tons). Fine salt passing through the screens is fed to a compacting system or to the waste belt system for disposal in abandoned mining units.

- The Finished Salt Surge Bin discharges to a series of conveyors (43 Belt, 13 Belt, 36 Belt) to the Skip Loading Point at the base of the No. 1 Shaft. Skips are hoisted up the No. 1 Shaft to the surface where they are discharged to a 50-ton bin.

- Product from the 50-ton bin is conveyed (via M-11 belt) to the 750-Ton Bin. Product from the 750-Ton Bin is split - a portion is conveyed (via M-13 belt) to the Bulk Loading Tower on the rail siding and the remainder is conveyed to the either the bulk storage or bagging facilities.

- Product is conveyed to the bagging facility via M-14A belt and M-15 belt.

- Product is conveyed to the bulk storage building via M-14A belt, M-14B belt, and M-16 belt.

- The remaining product is conveyed via M-14A belt, M-14B belt, and M-14C belt to a 150-ton bin from which the product is hauled, via truck, to the Lower, Middle, Upper and Quarry bulk storage pads for loading and sale.

2.4.5 Hours of Operation

Rail bulk loading occurs between the hours of 10:00 p.m. and 6:00 a.m., year round. Loading of trucks takes place between the hours of 6:00 a.m. and 10:00 p.m., September through March and from 7:00 a.m. to 4:00 p.m., April through August. Underground blasting for removal of salt from the active mining panels occurs at 5:30 a.m., 1:30 p.m., 5:30 p.m. and 1:30 a.m. Processing occurs 24 hours per day, Monday through Friday. Cargill does not operate the bulk loading rail or truck facilities on major holidays (New Year's Day, Memorial Day, Independence Day, Labor Day, Thanksgiving Day and Christmas Day), with the exception of times of emergency.

Periodically, due to the nature of the mined material and its intended use, Cargill must operate its bulk-loading facilities on a round-the-clock basis. The mined salt is used almost exclusively as de-icing salt for roadways, bridges, etc. If conditions warrant, Cargill operates around-the-clock to meet these needs.

2.5 Pollution Control and Prevention of Environmental Damage

2.5.1 Air Impacts

Particulate generation is the only potential air pollutant to be generated from mining, processing and associated activities at the Cayuga Mine. The Cayuga Mine has been operated/worked/designed to minimize impacts to air resources. Measures taken to minimize impacts include:

1. Processing operations (primary crushing, secondary crushing, screening, etc.) are housed wholly underground;
2. Loading bins for truck and rail loadout are covered and conveyor-fed;
3. Service roads for incoming and outgoing trucks are paved;
4. Surface handling facilities (conveyors, bagging facilities, transfer towers, etc.) are enclosed.
5. Vehicle speed on surface roadways is controlled;
6. Water sprays or NYSDEC-approved dust suppressants are used on roadways when necessary;
7. Roadways are swept, as needed; and
8. Cargill requires that all of its trucks comply with the NYS Tarp Law, and encourages all independent or non-Cargill trucks visiting the Mine site to comply as well.

2.5.2 Vegetation and Wildlife Impacts

There are no anticipated vegetation or wildlife impacts owing to the continued operation of Cargill's Cayuga Mine.

There is no vegetation or wildlife within the existing underground mine or future reserves areas. There are no endangered, threatened, or special concern species within the mine area.

Portions of Cargill's surface area may be a habitat for such small animals as squirrels, rabbits, woodchucks and other rodent species. Larger game animals such as deer may feed within the open areas but seek refuge in the wooded areas on the other side of Portland Point Road. There are no endangered species, threatened species, or species of special concern identified within the project property.

2.5.3 Noise Impacts

All mining and processing activities at Cargill's Cayuga Mine are housed in excess of 2000 feet beneath the ground surface. The only mining-related activities at the ground surface include conveying of final product, storage of final product, and the facilities for the loadout of final product..

Because all processing facilities are located below ground, they have no potential to create noise at the ground surface. Conveying, storage and loadout facilities at the ground surface are consistent with those employed at the site since prior to enactment of the New York State Mined Land Reclamation Law.

All underground and surface equipment is and will continue to be muffled and/or otherwise mitigated to meet MSHA standards.

Noise attributable to air blast is minimal to non-detectable at the ground surface due to the intervening rock strata. Vibration attributable to blasting and the minimal potential air blast will be further discussed below.

With respect to the generation of noise associated with surface activities:

1. Employees have been and will continue to be instructed in the proper operation and maintenance of all equipment;

2. Employees are instructed not to "race" the engines of any equipment;

3. Employees are instructed to report any operating irregularities in equipment that may increase the level of noise generated by that equipment; and

4. Vehicle speeds are controlled to reduce engine noise during the transport of material.

2.5.4 Blasting Impacts

The purpose of blasting at Cargill's Cayuga Mine is to displace salt from the underground mine active mining face and to break up the displaced salt (i.e. produce fragmentation) to sizes that permit efficient processing (crushing and screening). In a blast, almost all energy is expended in the immediate vicinity of the blast holes in breaking and displacing the salt. A very small fraction of the blast energy is dissipated as ground and/or air vibrations within the mine.

Explosives at Cargill's Cayuga Mine are detonated with non-electric millisecond delays. This method or other equivalent methods that are available or may be developed in the future will be employed at the Cayuga mine.

Production blasts in Cargill's Cayuga Mine take place, on average, approximately 4 times per day. Although somewhat variable in size, blasts typically average approximately 250 to 450 tons.

Pursuant to the applicable requirements of the State of New York and federal governments, a qualified licensed blaster oversees all blasting.

2.5.4.1 Ground Vibration

Blasting at Cargill's Cayuga Mine employs blasting caps that detonate a split second apart in adjacent holes. The result is that the vibrations from the detonation of explosives in one shot hole are attenuated by detonation of explosives in an adjacent hole. Manipulation of blast delay[6] times is done to produce minimal ground vibrations. Optimum delays are those that create destructive (out-of-phase) interference of waves from adjacent blast holes in a production blast.

The United States Bureau of Mines (USBM - now a branch of the United States Geological Survey - USGS) has prepared guidelines to minimize the potential impact of ground vibration associated with blasting at mining operations. The USBM guidelines recommend that the peak particle velocity (PPV) remain at or below the levels shown in Figure 2.5-1 **(USBM standards)** on page 67. This PPV is normally measured at the closest receptor structure. Cargill routinely operates within these guideline values.

Limits on ground vibration and air blast have been imposed in many cases to reduce to the maximum possible extent, the potential for damage from blasting activities. These limits are usually based upon the recommendations prepared by the then USBM. The USBM standards are based on the prevention of cosmetic damage to the weakest building materials. This is considered to be plaster on laths for older homes and gypsum board joints for newer homes. The USBM guidelines limit vibrations so as not to cause cosmetic damage to structures. Studies indicate that the best single descriptor for assessing vibration damage from a blast is the peak particle velocity (PPV). PPV is correlated, not with the total amount of explosives detonated in a blast, but instead with the maximum number of holes detonated per delay and the charge weight contained in those holes. The USBM guidelines include limiting PPV according to ground frequency of vibrations attributed to blasting. Ground vibration is generally measured in three components, longitudinal (forward and backward), transverse (side to side), and vertical (up and down).

[6] delay: the time period between the sequential detonation of explosives in blast holes in a designed blast.

The three components combine, at any given time, to produce the resultant particle[7] velocity. The maximum-recorded resultant particle velocity is called the PPV (the vector sum of the longitudinal, transverse and vertical components). PPV is the maximum speed of translocation movement of a reference particle in the ground or a structure as the dissipating energy of a blast moves outward through the ground and/or through the structure. PPV is the measure of the rate of propagation of deformation (strain) through the rock and is measured in inches per second (in./sec.).

According to the USBM, safe vibration levels from blasting activities on residential–type structures are:

SAFE BLAST VIBRATION LEVELS

Type of Structure	**Vibration at Low Frequency (< 40 Hz.)**	**Vibration at High Frequency (> 40 Hz.)**
Modern homes, drywall interiors	0.75 in./sec.	2.0 in./sec.
Older homes, plaster on wood lath construction for interior walls	0.50 in./sec.	2.0 in./sec.

The United States Office of Surface Mining (OSM) has blasting regulations for coal mines that may be extrapolated for use at underground salt mines. These regulations include three methods to meet blast-ground vibration performance standards to prevent property damage. These methods include: 1) Limiting Particle Velocity Criterion, 2) Scaled Distance, and 3) Blast Level Chart Criterion.

[7] particle: a theoretical, infinitesimally small reference point in a mass.

Method 1 requires that all blasts be monitored by a seismograph capable of measuring PPV. The maximum OSM-permitted PPV varies with distance from the blast site as follows:

Distance from Blast Site	Maximum PPV (inches/second)
0 - 300'	1.25
301 – 5,000'	1.00
> 5,000'	0.75

Using this method, the operator is considered to be in compliance if the PPV does not exceed the OSM limits. It is noted that these limits exceed the USBM Guidelines for all distances less than 5,000 feet.

Method 2 requires that blasts be designed in accordance with the following OSM-permitted Scaled Distance (SD) factors:

Distance from Blast Site	Scaled Distance Factor
0 - 300'	50
301 – 5,000'	55
> 5,000'	65

Scaled distance is the distance in feet from the blast to the receptor/structure divided by the square root of the maximum pounds of explosives detonated per delay in the shot. The higher the scaled distance, the lower the vibration, all other factors remaining the same.

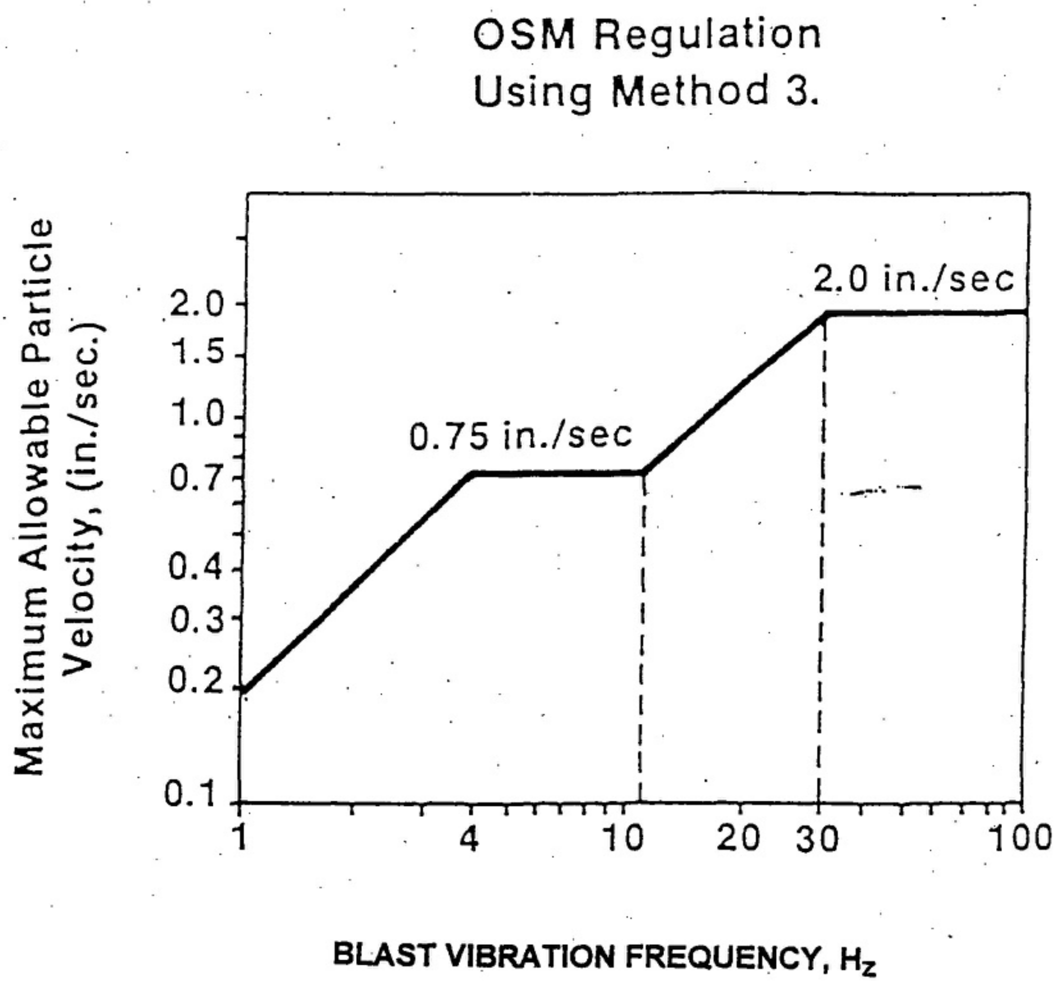
The scaled distance method has been used by Cargill to establish that potential vibrations attributable to production blasts at the Cayuga Mine are well below the vibration guidelines of the USBM/USGS.

Method 3 requires frequency analysis and particle velocity measurement of ground vibration for each blast. The operator is considered to be in compliance if the PPV at each vibration frequency does not exceed the OSM guidelines shown on the graph on Page 68. These guidelines are based on the USBM recommendations. The USBM monitored underground and surface mining operations throughout the country and sponsored numerous studies on the impacts of blasting. Based on these studies, the USBM established recommended ground vibrations and air blast limits for the entire country.

These recommendations are based on threshold limits that would cause cosmetic damage in weak building materials. Cosmetic damage due to ground vibration is considered to be loosening of paint, small plaster cracks at joints between construction elements or the lengthening of old plaster cracks. The damage threshold is considerably higher for load bearing or other structural portions of a building. Typical threshold damage limits for various structures are listed below.

THRESHOLD DAMAGE OF TYPICAL STRUCTURES

Type of Structure	Type of Damage	Particle Velocity at Which Damage Starts
Rigidly mounted	Trip outmercury switches	0.5 in./sec.
Houses	Plaster Cracking	2.0 in./sec.
Concrete block in a new home	Cracks in block	8.0 in./sec.
Cased drill holes	Horizontal offset	15.0 in./sec.
Mechanical equipment, pumps, compressors	Shafts misaligned	20.0 in./sec.
Prefabricated metal building on concrete pads	Cracked Pads	60.0 in./sec.



PARTICAL VELOCITY VERSUS FREQUENCY AS A BLAST-DAMAGE INDICATOR

FROM ATLAS (1987)

SPECTRA ENVIRONMENTAL GROUP, INC.
19 British American Blvd.
Latham, NY 12110

Project No.: 98189

FIGURE 2.5–1

CARGILL SALT, INC.
CAYUGA MINE

TOWN OF LANSING — TOMPKINS CO., N.Y.

Scaled distance calculations for blasts at Cargill's Cayuga Mine indicate that blasting vibration levels attributable to the mine are well below these vibration levels at off-site sensitive locations.

Blasting guidelines and regulations usually focus on the potential for blasting/vibration impacts to homes, buildings and other aboveground structures. However, concern remains regarding the potential impact of blasting on underground structures. As a whole, underground structures and facilities are far less susceptible to vibration damage than are aboveground structures. Damage or breakage beneath the ground surface is associated with the permanent displacement or movement of the soil or rock enclosing or surrounding the underground structure. This breakage or displacement usually only occurs within the first 20 to 30 feet from a blast (i.e. well within the active mining panel).

The Blasting Information Checklist contains information relative to typical shot design, monitoring and decibel levels. Please note that the referenced information is for typical shots at the Cayuga Mine. Some shots are slightly larger. Others are somewhat smaller. All shots are designed to conform to USBM standards.

Unlike blasting operations at surface mines, blasting at the Cayuga Mine site is performed wholly underground. Such blasting contributes to negligible increases to ambient surface noise levels. Additionally, each blast lasts less than one second. Consequently, if the blasts are even heard, they are very short-lived. Proper and efficient blast design help to minimize dust generation and excess noise production within the mine. Minimal ground vibrations may occur off-site but would not adversely affect any existing structures. Adherence to USBM standards effectively eliminates off-site vibration impacts.

Blasting Information Checklist

1. How often will blasting occur? 4 times daily
2. What will be the average number of holes per blast? 25 to 40
3. What will be the average total weight of shot rock per blast? 250-450
4. What type of ignition will be used? Non-electric delay detonators
5. How many pounds of explosive per delay will be used? Generally 70 lbs or less
6. How often will shots be monitored by seismograph? Not required
7. What will be the peak particle velocity (ppv) be in inches per second? <0.5
8. What will the decibel (dB) level of the air blast be? Compliance with RI No. 8485
9. Do any local ordinances governing blasting apply? No

2.5.4.2 Air Blast

When a blast is detonated, a series of events that can lead to or cause air blast begin. Upon detonation, the ingredients of an explosive begin an extremely fast transformation into high-pressure and high-temperature gases that ultimately assist in fracturing and fragmenting of the rock (salt in this case). This detonation progresses at a rate that greatly exceeds the speed of sound. Because the velocity of detonation, and the associated initial shock wave in the adjacent rock exceed the speed of sound, the detonation and associated rock movement can contribute to air blast, in particular, within the underground mine.

The air blast component of the blast energy consists of short-lived increases in atmospheric pressures that are generally termed overpressure. This overpressure, or air blast, is composed of two (2) types of waves: 1) noise that is audible – the higher frequency waves of the air blast; and 2) the concussion transmitted at lower, inaudible frequencies – the lower frequency waves of the air blast.

Audible noise from air blasts generally consists of those generated sound waves with frequencies of 20 to 25 cycles per second (Hz.) or greater. The inaudible component of air blasts consists of those sound waves with frequencies less than 20 to 25 Hz.

Air blast is usually generated by four (4) mechanisms.

1. Direct rock displacement at the face or mounding at the blast hole collar:

2. Vibrating ground;

3. Gas escaping from the detonating explosive through the fractured ground; or,

4. Gas escaping from blown-out stemming in the blast holes.

A component of air blast is generated by the vertical components of the ground vibration taken over the entire area that vibrates vertically. Ground, which is vibrating vertically, acts as a very large vibrating piston with very small vertical displacements. This vertical ground movement, however, creates compressional waves in the air that constitute a component of air blast.

Because the mining and blasting areas are located some 2,000+ feet underground, however, the air blast has no viable mechanism for propagation to the ground surface. The ground vibration levels at the surface are much too small to generate any significant amount of audible, or inaudible airblast. Additionally, the underground nature of the blast and the presence of approximately 1200 to 2000 feet of intervening strata precludes air blast generation from direct rock displacement at the face, gas escaping from the explosives through the fractured ground, or gas escaping from blown out stemming.

Nonetheless, a report (RI No. 8485) of the United States Bureau of Mines (USBM) (now a part of the United States Geological Survey) provides recommended limits of air blast for mining activities. These recommendations are widely recognized throughout the mining industry and are frequently cited by state and local regulatory agencies. The New York State Department of Environmental Conservation (NYSDEC) routinely cites the USBM recommendation in the conditions that it applies to Mining Permits.

RI No. 8485 states, "Safe levels of air blast were found to be 134 dBL (0.1 Hz.), 133 dBL (2.0 Hz.), 129 dBL (6 Hz.) and 105 dBL C-slow at the receptor location. These four air blast levels and measurement methods are equivalent in terms of structure response, and any one could be used as a safe-level criterion." Due to the minimal ground vibration, the potential for air blast generation at the Cayuga Mine does not approach these levels.

The USBM guidelines were developed to prevent cosmetic damage to the weakest building materials. In the case of air blast, the weakest building materials are poorly installed windows. The levels outlined above would preclude damage to poorly designed windows.

RI 8485 also states, ... "It is necessary to emphasize that the safe levels specified in this report for both airblast and ground vibration levels are based on the worst cases of damage and response, and are therefore conservative levels for typical modern homes and the average blast effects."

"The recommended maximum 134 dB (0.1 Hz) peak air blast for minimum damage risk to structures and window glass is also low enough to meet the most strict Committee on Hearing and Bioacoustics (CHABA) criteria for human health. Furthermore, 134 dB (0.1 Hz) is a maximum level rather than a designed level, which gives an additional factor of safety in actual practice."

The air blast levels evidenced at the ground surface at Cargill's Cayuga Mine are barely, if at all, perceptible and are well beneath the guidelines promulgated by the U.S. Bureau of Mines and the U.S. Geological Survey.

2.5.5 Drainage and Impacts to Waters

The operation of the Cayuga Mine by Cargill minimizes, to the greatest extent practicable, the potential for interaction with and pollution of surface waters (including drainage and erosion impacts) and groundwaters in the vicinity of the site.

2.5.5.1 Surface Waters

The Cayuga Mine is an underground mine overlain by both Cayuga Lake and upland areas to the east of Cayuga Lake. Because the mine is located some 2000' + below ground surface, the mine itself has no potential to directly impact surface waters. Cargill has undertaken extensive actions at its surface operations to minimize the potential for impacts to surface waters.

Salt that is transported to the surface via skips is either conveyed to the Bulk Loading Tower on the rail siding or conveyed to the bulk storage and/or bagging facilities. At the surface, Cargill employs numerous measures to minimize the potential for contact of surface waters and potential pollutants. These include:

1. Loading bins for truck and rail loadout are covered and conveyor-fed;

2. Surface handling facilities (conveyors, bagging facilities, transfer towers, etc.) are enclosed;

3. Bulk storage facilities are either covered/enclosed (Building T-4) or underlain by low permeability soils, bentonite soil or plastic (Upper, Middle, Lower and Quarry Bulk Storage Pads). Specifically, the Upper Bulk Storage Pad is underlain by plastic, the Middle and Lower Bulk Storage Pads are underlain by low permeability clay soil, and the Quarry Bulk Storage Pad is underlain by a bentonite soil membrane. Cross-sectional details of the bentonite soil membrane are shown in Figure 2.5-2 on the following page;

4. Stormwater runoff is routed around the bulk salt storage facilities to minimize the potential for contact with the stockpiled salt.

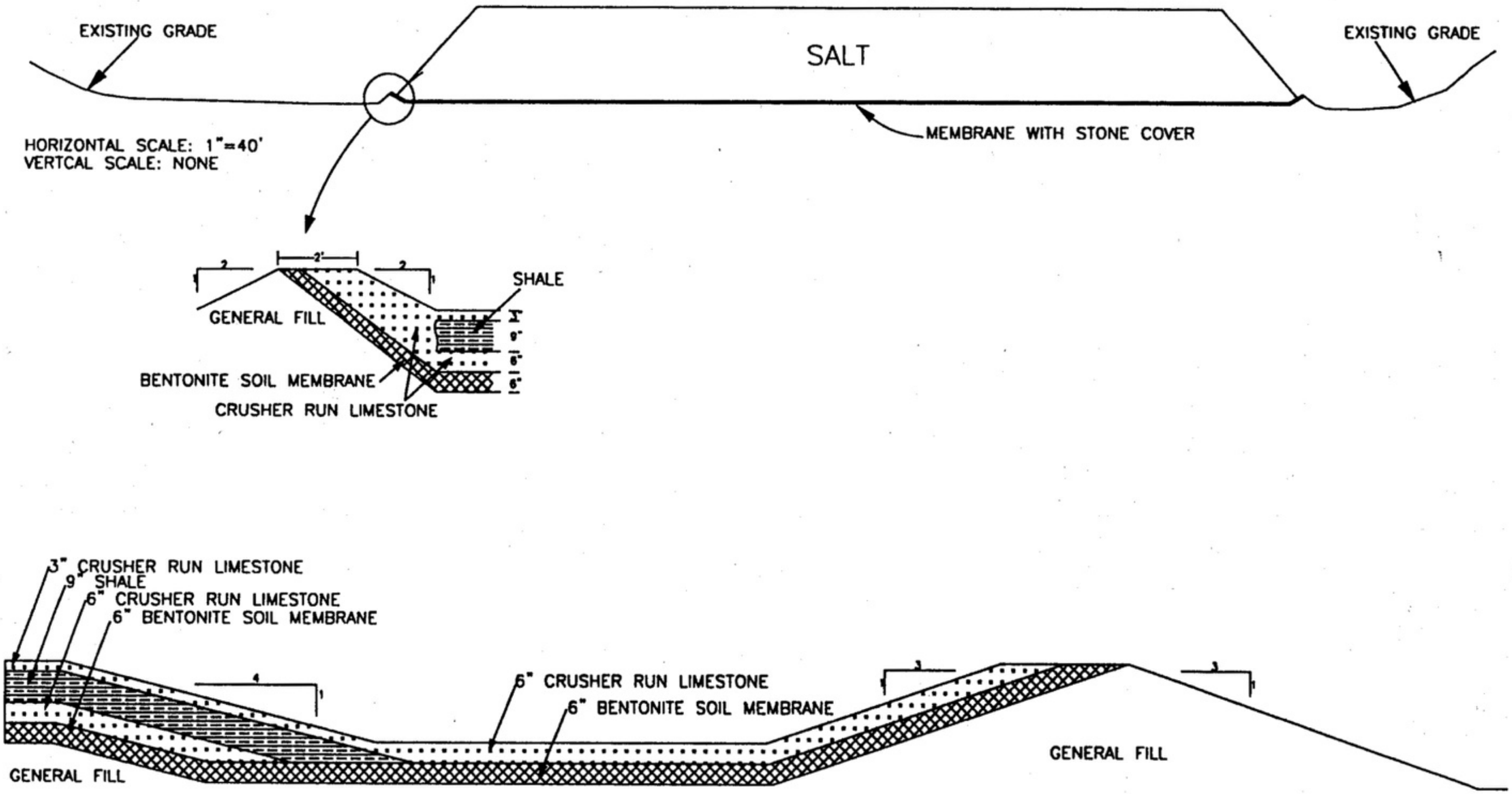
5. Stormwater is directed via a series of conveyances including open ditches, High Density Polyethylene (HDPE) culverts, reinforced concrete pipes, CMP's, etc., as indicated on the Surface Mining Plan Map;

6. Cargill practices bulk-product stockpiling and tarping measures to minimize the potential for contact between salt and precipitation;

7. Stormwater/precipitation falling within the confines of the bulk storage pads is collected and not allowed to commingle with other stormwater conveyances;

8. Cargill has installed a plant (the E.D. Plant) to treat the runoff from the bulk storage facilities such that it meets standards of Cargill's SPDES permit. This permits the direct discharge of stormwater to SPDES Permit outfalls; and

9. That runoff which is not treated for discharge to the outfalls or with treatment still cannot meet SPDES permit standards is discharged to the subsurface for disposal in the mined out portions of the No. 4 Salt Level.



NOTE:
DETAILS GENERATED FROM "SALT STORAGE FACILITY DETAILS" BY GREGG F. TRAVIS, P.E. 2/28/80 DRAWING NO. 79110 S-2 AND S-3

SPECTRA ENVIRONMENTAL GROUP, INC.
19 British American Blvd.
Latham, NY 12110

SALT STORAGE FACILITY DETAILS

CARGILL SALT, INC.

TOWN OF LANSING | TOMPKINS CO., N.Y.

PROJ. No.: 98189	DATE: 11/27/00	SCALE: NTS	DWG. NO.	FIGURE 2.5-2

2.5.5.2 Groundwaters

There should be no significant impacts to the local or regional groundwater resources as a result of the continuing mining activity at Cargill's Cayuga Mine. Specifically, the stability of the mine was assessed, by RESPEC, for the purpose of establishing the potential for interaction (and associated impacts) between the mine and the overlying groundwater regime. The principal concern is the potential for the creation of a hydrologic connection between the lake and the mine, due to stress-induced fracturing of the intervening strata. To establish that the Cayuga Mine was stable, RESPEC evaluated several different aspects of concern, including:

1. The rooms and pillars within each mining panel must be stable;
2. The individual panels must remain stable as the number of panels increases; and
3. The entire mine must be stable from a global perspective.

RESPEC's investigation shows that the mine is stable. Geotechnical data, including subsidence monitoring and modeling, geomechanical measurements and modeling and microseismic monitoring all indicate that the mine is stable, and closure is occurring in a slow and predictable manner. The weight of the overlying strata is being slowly, smoothly and systematically shed to the adjacent barrier (abutment) pillars without breaking and/or fracturing of the overlying strata. The absence of failure means that no hydrologic connections are being created between the mine and Cayuga Lake.

Additionally, the bedrock strata overlying the mine are, in turn, overlain by low permeability lacustrine sediments that underlie Cayuga Lake. These lacustrine sediments (silts and clays) are a low-permeability medium that serve as an additional hydrologic barrier between the mine and the lake.

The site and regional hydrogeology are discussed in greater detail in the accompanying Expanded Environmental Assessment (Volume II).

The existing mining practices have not adversely impacted groundwater resources in the vicinity of Cargill's Cayuga Mine. Cargill will continue to adhere to the following practices to minimize the potential for groundwater impacts associated with the operation of the Cargill Mine and surface loadout facilities:

1. Cargill will continue to practice the present mining configuration (yield pillar panels separated by massive abutment pillars) to maximize mine stability;

2. Cargill will continue to monitor and model mine closure, mine closure rates, subsidence amounts, subsidence rates, microseismic events, etc. to ensure that the mine remains stable. In the event that any of these factors exhibit significant

variation from long-term stable behavior, the mining plan and sequence will be reassessed;

3. Where water is evidenced flowing into the No. 3 Shaft, holes are drilled into the shaft wall and a cement or chemical grout is injected to fill cracks and voids and preclude water from entering the shaft;

4. Loading bins for truck and rail loadout are covered and conveyor-fed. This precludes potential contamination of groundwater as well as surface water;

5. Surface handling facilities (conveyors, bagging facilities, transfer towers, etc.) are enclosed;

6. Bulk storage facilities are either covered/enclosed (Building T-4) or underlain by low permeability soil, bentonite soil, or plastic membranes (Upper, Middle, Lower and Quarry Bulk Storage Pads);

7. Cargill practices bulk-product stockpiling and tarping measures to minimize the potential for contact between salt and precipitation that may ultimately serve to recharge groundwater;

8. Stormwater/precipitation falling within the confines of the bulk storage pads is collected and not allowed to commingle with other stormwater conveyances;

9. Cargill has installed a plant (the E.D. Plant) to treat the runoff from the bulk storage facilities such that it meets standards of Cargill's SPDES permit. This permits the direct discharge to SPDES Permit outfalls;

10. That runoff which is not treated for discharge to the outfalls or with treatment still cannot meet SPDES permit standards is discharged to the subsurface for disposal as a brine in the mined out portions of the No. 4 Salt Level; and

11. Prior to discharging any runoff to depth for disposal within Level 4, the runoff is conditioned to maximize its saturation. Specifically, conditioning raises the chloride saturation of the runoff from approximately 30 percent to approximately 80 percent. This minimizes the potential for solutioning within the Level 4 workings.

In addition to the concerns over the potential for hydrologic connection between the mine and the lake, homeowners who rely on groundwater for their water supply may be concerned that blasting activities associated with the mine may affect the water quality or quantity in their wells.

There have been numerous studies and investigations sponsored by governmental and academic research organizations that have addressed the issue of potential impact on wells and aquifers due to mine blasting. One of the leading studies, known as the Berger Research (1980 and 1982), studied the effects of blasting on low-yield, fractured water table aquifers. Factors that were evaluated included water quality, water quantity, and well integrity. Wells were monitored prior to, during, and after blasts that ranged from 1,000 feet to 50 feet from the wells. Ground vibrations from these blasts ranged from 0.84 to 5.44 inches per second; levels of vibrations significantly greater than that which typically occurs at the Mine Site. The results of the Berger studies indicated that there is no correlation between blasting and water quality, quantity, and well integrity (Berger, 1980 and 1982).

Another study conducted by the University of North Dakota evaluated the effects of blasting on shallow water wells and aquifers including such factors as well hydraulics and aquifer characteristics. Blasts were detonated from 10 to 50 feet from the wells to assess the well structure and determine effects. Results of this study indicated that the well integrity remained intact and that no chemical changes in water quality were attributed to blasting. The research also showed that physical changes from blasting often resulted in increased permeability (Radnor, et. al., 1981).

Yet another relevant study, conducted in 1979 by the University of Alabama in conjunction with the Alabama State Geological Survey, studied the effects of blasting on faulted carbonate rocks of Cambrian-Ordovician Age, which are very similar to the geologic setting in the area of the Mine Site. The study, initiated by rural residents' reports of problems in their water wells, concluded that no changes in water quality or quantity were detected in any wells as a result of blasting activity.

The research represented in these studies by non-partisan groups supports the following conclusions with regard to integrity of wells, water quantity, and water quality (Berger, 1980 and 1982, Moore and Hughes, 1979, Beaver, 1984, Rosenthal and Morlock, 1987):

1. Large scale mine blasting (much larger blasts than those detonated at Cargill's Cayuga Mine) did not reduce or have a negative effect on the quantity or quality of water produced by groundwater wells. Therefore, there was no correlation found between well performance and blasting.

2. With larger ground vibrations, there was a minor, temporary effect on water levels in wells when blasting was conducted below the water table. With regard to long-term effects, beyond one-quarter mile there was no effect; at a distance of about 500 feet, water levels may see a temporary fluctuation of one-tenth of one foot (0.1 feet); between 50 and 100 feet, the water levels may rise up or down rapidly by as much as one to two feet but quickly recover to its previous level;

and there was no alteration of water levels when blasts occurred above the water table.

3. At depths of 140 to 160 feet below the surface, ground vibrations from blasting were considerably reduced.

4. PVC and corroded steel well casings are capable of sustaining high intensity vibration impacts without structural failure.

5. All studies indicated that there are no long-term impacts of blasting on water quality or quantity in groundwater wells.

Environmental and construction factors that may affect water quantity and quality in residential wells that are not related to blasting or mining activity include:

1. Local domestic use of water from a bedrock aquifer with a fracture system may exceed the volume of water and the rate at which water moves through the fractures in the rock into the wells. High production rates may NYSDECline as more residential wells are installed into the bedrock aquifer. While bedrock aquifers are reliable sources of groundwater, the rate of recharge in wells is a primary factor that governs the rate at which water may be drawn from a well.

2. Water levels in bedrock and unconsolidated aquifers will fluctuate due to natural seasonal changes in recharge. Yields of certain wells may fall off if they lack sufficient storage capacity or are too shallow.

3. Well casings and pumps are subject to deteriorating conditions such as buildup of silts and fine sands, and iron and sulfur bacteria. Older wells typically have to be chemically treated or redeveloped to regain original yields.

4. Turbid or muddy water can be related to water-level fluctuations as a result of groundwater recharge or lack of recharge. Turbid or muddy water may result from heavy rainfall. During heavy rainfall, the rapid movement of water through the fracture systems may increase the erosive action and capacity to transport material through the groundwater. During extended dry periods, the walls of the well may dry out and flake into the well causing the water to be turbid.

2.6 Reclamation Plan

2.6.1 Introduction

This Reclamation Plan has been prepared specifically for use at Cargill's Cayuga Mine. Facilities at Cargill's Cayuga Mine include both surface and subsurface operations. The surface workings have been previously shown on the Surface Mining Plan Map (Plate 2.2-1) and the Surface Reclamation Plan Map (Plate 2.6-1). The planned limits of the underground workings have also previously been shown on the Subsurface Mining Plan Map (Plate 2.3-1).

A consequence of underground mining at Cargill's Cayuga mine is the slight, gradual subsidence of the overlying surface topography.

When mining and associated activities cease at Cargill's Cayuga Mine, both surface and subsurface reclamation activities will occur.

2.6.2 Subsidence

Whenever rock is removed from the underground, the ground surface subsides. The amount of the subsidence and the rate at which subsidence occurs depends upon the amount of rock removed, the area of the extraction, the depth of the extraction, and the deformational characteristics of the pillars and overlying rock. Surface subsidence over salt mines is strongly time-dependent because subsidence accumulates from the time of mining until the underground openings are completely closed. Subsidence, at increasingly slower rates, may continue for centuries.

Because rock salt creeps, the rock surrounding the mine is continuously (but usually very slowly) moving toward and into the mine openings. The time required for the creep to completely close the openings can be as great as thousands of years, depending upon extraction ratios, room size, pillar size, geologic setting, depth and the time since mining ceased.

The ultimate volume of the depression created on the ground surface from subsidence will be about the same (or smaller) than the volume of material removed from the underground. The amount of subsidence of the ground surface that occurs over a salt mine can be calculated based upon a few general principles. These include:

1. The salt strata around an underground opening will creep toward and into the opening until the opening is completely closed.

2. The largest amount of subsidence occurs over areas with the widest spans. The maximum amount of subsidence that can occur is always less than the height of mining (i.e. the thickness of the mined seam).

3. A point on the ground surface subsides because of both the mining directly beneath that point and any mining that occurs in the general area.

4. The area above the mine with measurable surface subsidence will be larger than the area outlined by the mine workings. A distance equal to the depth of the mine is a reasonable estimate of the lateral extent of surface subsidence beyond the mine perimeter.

5. The ultimate volume of the depression on the ground surface from subsidence will never exceed the volume of material removed from the underground.

Cargill has modeled the anticipated subsidence attributable to the excavation of the Level No. 6 Salt along the shores of Cayuga Lake.

2.6.3 Reclamation of Subsurface Features

The New York State Mined Land Reclamation Law (MLRL) does not regulate or require the reclamation of the subsurface workings of underground mines. No reclamation is planned for the subsurface workings at Cargill's Cayuga Mine. Slow, long-term subsidence of the ground surface over the mine will continue as the mined out underground panels close.

At the time of reclamation, however, shaft access to the underground workings will be sealed and the underground rooms, drifts and cavities will be allowed to close over the next century or more. Long-term slow, gradual subsidence will continue over this time period with both the mine closure rate and the subsidence rate becoming less over time. Differential subsidence, at the scale of a potentially impacted structure, is not expected during the active or post-closure life of the Cayuga Mine.

Prior to final closure of the shafts, Cargill will remove any remaining fuels, oils, solvents, blasting agents and any other potential liquid pollutants from the mine. Additionally, any equipment or materials with a salvage value exceeding the recovery cost to remove it from the Cayuga Mine will be removed.

2.6.3.1 Shaft Closures

The production, service and auxiliary (air intake) shafts at the locations indicated on the Surface Mining Plan Map will be abandoned and closed as a component of reclamation at the facility. Shaft abandonment and closure will necessitate the removal of any piping or operating systems from the shafts prior to backfill. Closure or abandonment will involve the injection of an NYSDEC-approved cementitious, low-permeability flowable fill that will permanently seal the shafts. This material will prevent the closed shafts from becoming potential conduits for downward migrating waters.

Prior to the backfilling of the shafts with a flowable fill material, all drifts or entries leading away from the shafts at the various mine levels (i.e. Nos. 1, 4 and 6 salts) will be sealed off with bulkheads, walls, etc., to prevent the migration of the flowable fill away from the shaft into the underground workings. The bulkheads, etc., will be of sufficient strength so as to sustain the initial hydrostatic pressures(s) exerted by the emplaced flowable fill materials. Due to the depth of the shafts, the fill materials will be emplaced in a series of installments. During the emplacement process, an interval of emplaced fill will be allowed to cure for several days (to attain strength) prior to the emplacement of subsequent lifts. The shafts will be backfilled to the surface in this manner. The uppermost eight to ten feet of each shaft will be filled with a high-strength concrete plug to the ground surface. The concrete will be reinforced and anchored to the natural, in-place earth and concrete shaft linings to prevent future settlement.

A brass plate will be anchored in the concrete plug, detailing Company name, the mine name, the shaft number, and the date of final closure.

2.6.4 Reclamation of Surface Lands

Approximately 67.67 acres of Cargill's surface lands (260.04 acres) have been affected by activities related to mining. These 67.67 acres will be reclaimed in accordance with the New York State Mined Land Reclamation Law. Lands to be reclaimed include surface distribution facilities, surface storage facilities, parking areas, stormwater conveyances and control features, surface expressions of shafts, structural elements, etc.

Upon completion of mining, all processing and accessory structures (e.g. hoist houses, conveyors, transfer points, hoppers, etc.) will be dismantled and removed from the site. Any remaining waste, refuse or debris will be removed to an approved landfill. Buildings will remain as Cargill may continue to utilize the site in an industrial capacity.

All product stockpiles will be removed from the site in their entirety. Surface structures and paved surfaces will be dismantled and removed from the project site. The bulk rail and truck loading facilities will be dismantled and removed from the project site.

Surface soils located in the vicinities of former staging and/or bulk storage areas will be sampled for chlorides and flushed or excavated to ensure that runoff from the soils contains chlorides in concentrations less than 250 mg/l. The flushed water will either be collected for treatment, or routed for subsurface disposal prior to shaft closure.

Once areas have been sampled and tested to demonstrate removal of chloride–rich soil materials, the surfaces will be graded in accordance with the New York State Mined Land Reclamation Law. Surfaces that are not needed for future use will be contoured to facilitate an aesthetically appealing landform. Following this contouring, topsoil, if it is available on site, will be spread across the affected areas. The surface lands have been affected for many decades. Consequently, topsoil was removed during the construction phase long before the inception of the Mined Land Reclamation Law.

Prior to seeding, the top two inches of soil in affected areas to be reclaimed will be disked or dragged. Once topsoil (if it is available) is placed on the contoured landform, the soil will be tested by the Tompkins County Soil and Water Conservation District and will be limed and fertilized according to their records. Soil fertility tests will be conducted by Cargill prior to the seeding of the contoured areas to insure that the soil fertility is sufficient to sustain the growth of grasses used in the reclamation. The results of these tests will be furnished to the NYSDEC Region 7 Mined Land Reclamation Specialist and utilized in formulating the final reclamation.

Surface bulk storage tanks will be closed in accordance with the applicable bulk storage regulations in effect at the time of reclamation. Specifically, permanent tank closures, in accordance with NYSDEC Guidelines, will be performed on all petroleum bulk storage tanks serving the surface or underground facilities and on any additive systems for the bulk salt process.

2.6.4.1 Revegetation

Affected surface areas to be reclaimed will be covered with at least six inches of topsoil overburden capable of sustaining vegetative growth and prepared for seeding. Prior to seeding, the top two inches of soil in all above water areas to be reclaimed will be disked or dragged. A complete soil fertility test will be conducted by the permittee prior to seeding of reclaimed areas. The results of this test will be furnished to the NYSDEC Region 7 Mined Land Reclamation Specialist and utilized in formulating the reclamation. After fertilizing and liming according to the recommendations of the above described soil fertility test, an additional soil fertility test will be made to insure that the soil fertility is sufficient to sustain the growth of the plants used in the reclamation.

The Natural Resource Conservation Service will be contacted prior to final seeding to ensure that the most appropriate and effective seeding mixture is utilized.

2.7 References

Asselstine, E.S., 1946, Progress report on groundwater conditions in the Cortland Quadrangle, New York. New York Water Power and Control Commission Bulletin GW-16.

Baird, G.C., and C.E. Brett, 1986, Submarine erosion of the dysaerobic seafloor: Middle Devonian corraisional disconformities in the Cayuga Valley region. *In* J.L. Cisne, ed., Field Trip Guidebook, New York State Geological Association, 58th Annual Meeting, Cornell University, p. 23–80.

Berger, Phillip R. and Associates, Inc., 1980. Survey of Blasting Effects on Groundwater Supplies in Appalachia. Part 1, U.S. Department of the Interior, Bureau of Mines Publication 82-152125, Washington, D.C.

Berger, Phillip R. and Associates, Inc., 1982. Survey of Blasting Effects on Ground Water Supplies in Appalachia. Part 2, U.S. Department of the Interior, Bureau of Mines Publication 84-113182, Washington, D.C.

Brady, B.H.G., and E.T. Brown, 1985. "Rock Mechanics for Underground Mining", George Allen & Unwin Publishers, Ltd., London, 537 p.

Brett, C.E., G.C. Baird, and K.B. Miller, 1986, Sedimentary cycles and lateral facies gradients across a middle Devonian shelf-to-basin ramp, Ludlowville Formation, Cayuga Basin. *In* J.L. Cisne, ed., Field Trip Guidebook, New York State Geological Association, 58th Annual Meeting, Cornell University, p. 81–127.

Callahan, G.D., A.F. Fossum, and D.K. Svalstad, 1989. Documentation of SPECTROM-32: A Finite Element Thermomechanical Stress Analysis Program, DOE/CH/10378-2, prepared by RE/SPEC Inc., Rapid City, SD, for the U.S. Department of Energy, Chicago Operations Office, Argonne, IL, Vol. 1 and II.

Cole, W.S. 1959, Geology of the Cayuga Lake Basin. Guidebook, New York State Geological Association, 31st Annual Meeting, Cornell University, p. 36.

DeVries, K.L., and N.T. Skaug, 2000. Multiseam Mining Stability Analyses for Mined Land Reclamation Permit Renewal, RSI-(RCO)1091/6-00/4, Letter Report to Schultz, DeVorsetz Stinziano Gilberti Heintz & Smith, P.C., Syracuse, NY, June 6.

DeVries, K.L., P.E. Nelson, N.T. Skaug, and L.L. Van Sambeek, 2000. Geomechanical Modeling and Reassessment of Cargill Salt Cayuga Mine, Lansing, New York, RSI-1372, prepared by RESPEC, Rapid City, SD, for DeVorsetz Stinziano Gilberti Heintz and Smith, P.C., Syracuse, NY.

Genesee/Fingerlakes Regional Planning Board, 1975, Environmental study of the Finger Lakes. Technical Study Series Report Number 21, p. 61.

Itasca Consulting Group, Inc., 1993. FLAC – Fast Lagrangian Analysis of Continua, Version 3.2, Volumes 1–3, prepared by Itasca Consulting Group, Inc., Minneapolis, MN.

Itasca Consulting Group, Inc., 1997. FLAC^{3D} – Fast Lagrangian Analysis of Continua in 3 Dimensions, Version 2.0, Volumes 1–5, prepared by Itasca Consulting Group, Inc., Minneapolis, MN.

Jeremic, M.L., 1994. "Rock Mechanics in Salt Mining", A.A. Balkema Publishers, Rotterdam, Netherlands, 532 p.

Karig, D.E., and L.T. Elkins, 1986, Geological summary of the Cayuga region. *In* J.L. Cisne, ed., Field Trip Guidebook, New York Geological Association, 58th Annual Meeting, Ithaca, NY, p. 1–22.

Miller, T.S., 1987, Unconsolidated aquifers in upstate New York – Finger Lakes Sheet. USGS Water Resources Investigation Report 87-4122.

Mozola, A.J., 1951, The ground-water resources of Seneca County, New York. State of New York Department of Conservation, Water Power and Control Commission Bulletin GW-26, p. 57.

Mullins, H.T., R.W. Wellner, J.L. Petruccione, E.J. Hinchey, and S. Wanzer, 1991, Subsurface geology of the Finger Lakes region. *In* J.R. Ebert, ed., Field Trip Guidebook, New York State Geological Association, 63rd Annual Meeting, Oneonta, NY, p. 1–54.

Persson, Pers-Anders et. al., 1994. Rock Blasting and Explosives Engineering, CRC Press, Inc., Boca Raton, Ann Arbor, London, Tokyo.

Peterson, G. B., Plumeau, D. B. and Parker, J., 1977. Yielding pillars and pressure arches at the Cayuga Rock Salt Mine. In: Fun-Den Wang and C. B. George (Editors), Energy Resources and Excavation Technology. Proceedings of the 18th U.S. Symposium on Rock Mechanics, 4c6-1-4c6-5.

Plumeau, D. B. and G. B. Peterson 1981. "Abutment Pillar 'Notching' Improves Abutment Tunnel Roof Conditions at the Cayuga Rock Salt Mine," Proceedings, 1st Conference on Ground Control in Mining, West Virginia University, Morgantown, WV, S.S. Peng (ed.), pp. 35-43.

Prucha, J.J. 1968, Salt deformation and decollement in the Fir Tree Point Anticline of central New York. Tectonophysics v. 6, p. 273–299.

Rickard, L.V., 1962, Late Cayugan (upper Silurian) and Helderbergian (lower Devonian) stratigraphy in New York. New York State Museum and Science Service Bulletin Number 386, p. 157.

Rickard, L.V., 1969, Stratigraphy of the Upper Silurian Salina Group, New York, Pennsylvania, Ohio, Ontario. New York State Museum and Science Service Map and Chart Series Number 12.

Rickard, L.V., 1989, Stratigraphy of the subsurface Lower and Middle Devonian of New York, Pennsylvania, Ohio and Ontario. New York State Museum Map and Chart Series Number 39.

Rosenthal, Michael F. and Morlock, Gregory L., Blasting Guidance Manual, Office of Surface Mining Reclamation and Enforcement, U.S. Department of the Interior, March, 1987.

Sevenker, L., 1987. International Salt Company Ludlowville Brine Field Study, June 23, 1987 (rev. September 14, 1987), prepared for Cargill, Inc., Cayuga Mine, Lansing, NY.

Sevenker, L., 1992. Old International Wells at Ludlowville, Letter report to David Plumeau, Cargill, Inc., Lansing, NY, September.

The Sear-Brown Group, 1995. Geological Characterization Study, Cayuga Salt Mine, Lansing, N.Y., Project 12335, prepared by The Sear-Brown Group, Rochester, NY, for RESPEC Inc., Rapid City, SD.

The Sear-Brown Group, 2000. Geology/Hydrogeology of the Cayuga Salt Mine, Lansing, New York, Vol. 2, Report Figures, prepared by The Sear-Brown Group, Rochester, NY, for Cargill Salt Division, Lansing, NY.

Van Sambeek, L.L., J.L. Ratigan, and F.D. Hansen, 1993. Dilatancy of Rock Salt in Laboratory Tests. *In* International Journal of Rock Mechanics Mining Science and Geomechanics Abstracts, v. 30, n. 7, p. 735–738.

Van Sambeek, L.L., T.J. Eyermann, T.W. Pfeifle, W.M. Goodman, H.D. Miller, and T. Urbancic, 1995. Stability Assessment of the Cargill Salt Cayuga Mine, Lansing, New York, RSI–0629, prepared by RESPEC Inc., Rapid City, SD, for Cargill Law Department, Wayzata, MN.

Mining Permit Application