CHAPTER XIII. SOLUTION SALT MINING

A. INTRODUCTION

Salt exists in subsurface formations covering a major portion of south central and western New York. This salt is found in salt beds consisting of horizontal layers of salt usually sandwiched between layers of shale, dolomite and anhydrites. It is estimated that 8,500 square miles of New York State are underlain by salt beds of potential commercial thickness (Kreidler, 1957). These salt beds are part of the Lower Salina Group which includes the Vernon (B) and Syracuse (D, E, F) Formations (Rickard, 1969). The Salina Salt Basin extends across western Pennsylvania, northern West Virginia, eastern Ohio and a large portion of Michigan (Schock, 1985). (See Figure 13.1).

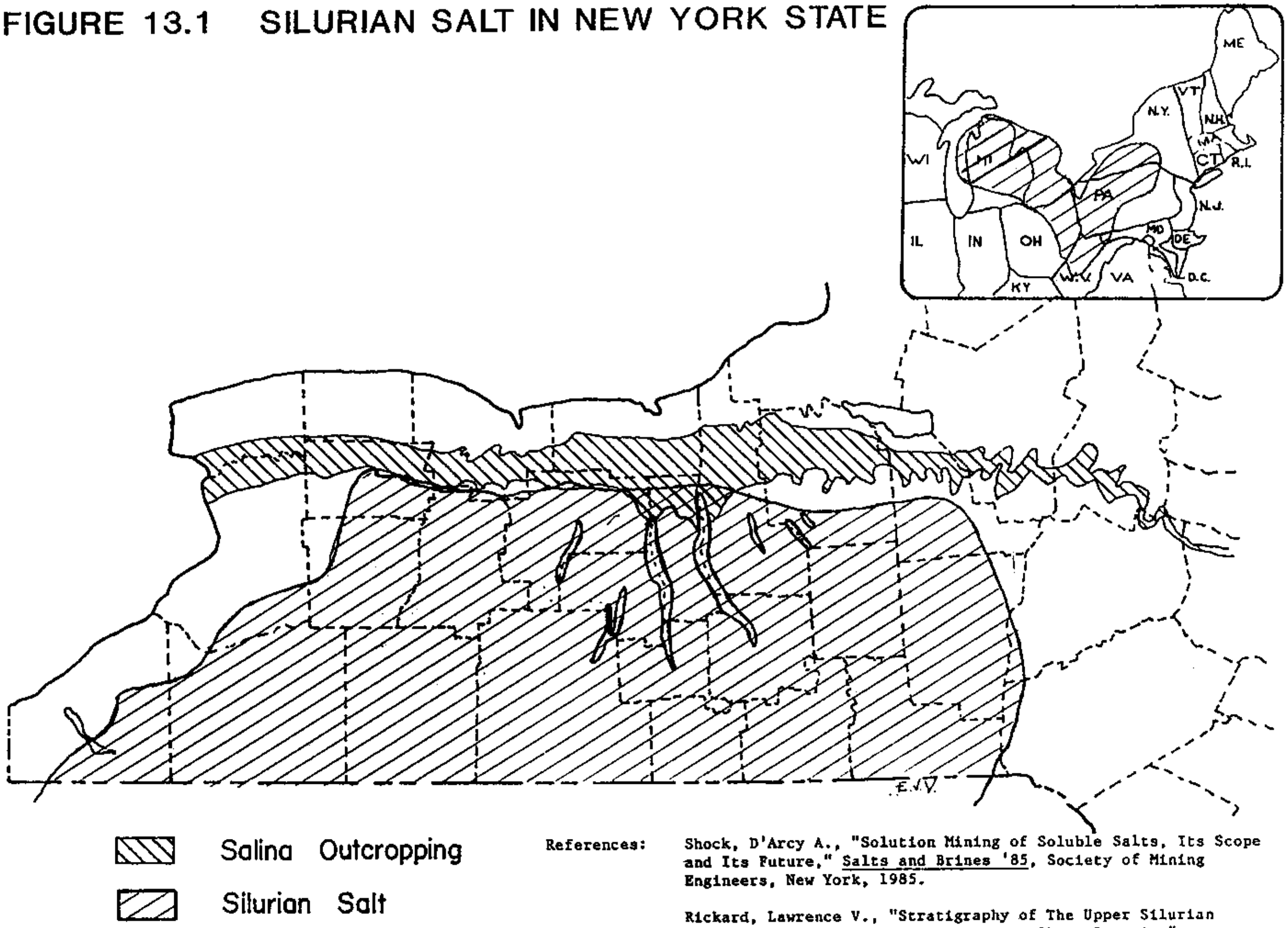
The Salina Group outcrops in an approximate ten mile wide band extending due east in New York from just north of Buffalo passing just north of Rochester, through Syracuse and ending at the southeastern edge of Herkimer County (Rickard, 1969). No beds of rock salt are found in the exposed Salina strata because the salt has been leached out by groundwater. The Salina increases in depth and thickness in a southerly direction in New York funnelling into Cattaraugus, Allegany, Steuben and Chemung counties (Rickard, 1969). Here the top of the salt zone may be located at 3,000 feet below the surface. In Chemung County the salt beds are 1,300 feet thick. The regional dip of the Salina Group is slightly west of south at a rate of 30 to 50 feet per mile (Kreidler, 1957).

Initial recoveries of salt in New York State were obtained from the ocean and later from salt springs located near Syracuse (Werner, 1917). Since the late 1800's most of New York's salt production has come from rock salt by a recovery process called solution mining (Rullen, 1973). This process involves injecting freshwater into the salt beds through wells which are drilled in a

FIGURE 13.1

13-1a

FIGURE 13.1 SILURIAN SALT IN NEW YORK STATE



References: Shock, D'Arcy A., "Solution Mining of Soluble Salts, Its Scope and Its Future," Salts and Brines '85, Society of Mining Engineers, New York, 1985.

Rickard, Lawrence V., "Stratigraphy of The Upper Silurian Salina Group, New York, Pennsylvania, Ohio, Ontario," University of the State of New York, Albany, NY, 1969.

fashion similar to oil and gas wells. Once the salt is dissolved, the resultant brine is brought to the surface for evaporation or chemical manufacturing. There are five solution mining operations in New York State which produce salt from approximately 80 active wells. Approximately 10 new wells are permitted annually in New York and similar numbers are temporarily or permanently abandoned. This chapter will discuss the solution mining process and the existing and proposed State program to regulate the environmentally sound development of the State's salt resource. There are few specific citations to solution mining in the old regulations which were issued in 1966 and updated in 1972. In general, the provisions relating to permit applications, drilling, completion, production and plugging and abandonment contained in the oil and gas regulations, 6NYCRR Parts 552 to 558 have been applied to solution mining, when appropriate. The provisions contained in Section 23-0305.9 of the Oil, Gas and Solution Mining Law give DEC the authority to do so. **The major recommendation contained in this Chapter is that the oil and gas regulations, 6NYCRR Parts 550 to 558, be revised to include solution mining wells, where appropriate, as well as to add certain requirements specific to solution mining.**

On June 24, 1984, solution mining wells in New York also became subject to the U.S. Environmental Protection Agency's Underground Injection Control (UIC) Program with compliance to be enforced within one year. Solution mining wells are classified as Class III wells under this program. The federal program is summarized in Chapter 15.

B. CHOOSING A WELL SITE AND APPLYING FOR A DRILLING PERMIT

Before salt production can begin, a well must be drilled to the salt beds. A drilling site must be carefully selected which will allow the most economic recovery of the resource while causing a minimum of adverse environmental impacts.

Solution mining operations in New York have a long productive life and most of the new salt wells are proposed in close proximity to sites which have been in existence for a number of years. Texas Brine began their operations in Dale over 10 years ago and expects to operate for another 40 years. Morton Salt Company in Silver Springs and Allied Chemical in Tully have been in operation for 100 years and Cargill Salt Company and International Salt of Watkins Glen commenced operations in the late 1800's. Therefore, the environmental considerations for most new solution mining well proposals do not substantially change, although the cumulative impacts of each new well may pose new concerns.

Before a well can be drilled, deepened, plugged back, converted or reconverted for exploration or production, a permit must be obtained from the Department of Environmental Conservation. The permitting process provides the main opportunity for DEC to review the environmental aspects associated with solution salt mining. A standard permit application must be completed and contain the name and address of the well owner and well contact person, well location data, proposed well data, and details about the production interval, casing string and cement job.

The application for a permit must also contain a neat legible plat (map) which has been certified by a licensed land surveyor or civil engineer showing the proposed well location. The plat provides the information necessary for complete analysis of each drilling permit application. This map allows DEC to identify potential environmental problems such as violations of surface restrictions or well spacing requirements or if the site is located on or near an environmentally sensitive area. The plat requirement in the current regulatory program regarding the pool and spacing unit is directed towards oil and gas wells, and would not apply to solution mining. **Specific requirements**

for solution mining well plats need to be addressed in future regulations. It is recommended that these plats include the boundaries of the property under the owner's control, the location and API well identification number of each well on the property, the area proposed to be affected by solution mining, and the location of roads, surface water drainages, groundwater depth, buildings, significant landmarks and topographic features in the affected area.

The scale of the plat needs to be large enough to allow adequate resolution of details. **The scale of the plat for solution mining wells needs to be specified in the regulations. A suggested scale for this plat is one inch equals six hundred feet or less for wells that are spaced at least 1,320 feet from each other or one inch equals 400 feet or less for wells that are spaced less than 1,320 feet from each other.**

C. PERMIT FEE

A permit fee must also be submitted with the solution mining permit application. The amount of this fee is the same as that for oil and gas wells. The existing regulations require a $20 permit fee. However, the current regulations do not yet reflect the changes made in the 1981 amendments to the Oil, Gas and Solution Mining Law which requires fees ranging from $225 to $2,725 depending on the depth of the well. The increased permit fee was adopted by the Legislature in 1981 to more adequately cover the costs associated with the administration of the oil, gas and solution mining program. **The Department's new regulations need to reflect this change in the Law.**

D. FINANCIAL SECURITY

Before a well is permitted, an owner or operator must also secure funds in the form of a surety bond, personal bond or other comparable financial security to offset well plugging and surface restoration costs in the event that an owner fails to carry out these requirements. The amounts vary depending on the depth and number of wells to be drilled. Most, if not all solution mining wells are less than 2,500 feet deep in New York State. This financial security remains in effect until the plugging and surface restoration of applicable wells takes place.

In 1984 the State Legislature adopted new financial security requirements for oil, gas and solution mining wells which are significantly higher than they were in the past. The financial security provisions of the new Law more closely approximate the costs to properly plug and abandon a well. This will have positive environmental affects by ensuring that the proper amount of financial security is available for adequate plugging and abandonment of wells.

E. DEC REVIEW OF PERMIT APPLICATIONS

Before approving a permit application, DEC conducts an environmental, technical and administrative review of the drilling application. During the environmental review, DEC checks to see if the proposed well is located in an environmentally sensitive area and examines drilling, casing and cementing programs during the technical review. The administrative review ensures that all SEQR requirements have been met and coordinates the review of other Department permits necessary for the project. Special conditions may be added to the permit to ensure the drilling program is technically and environmentally acceptable.

Siting requirements and pre-drilling site inspections conducted for solution mining wells are similar to those for oil and gas wells with some exceptions due to the differences between an oil and gas reservoir and a salt cavity and the way in which these resources are recovered. For this reason, state-wide spacing and unitization regulations only apply to oil and gas wells. However, the surface restrictions in the existing regulations apply to all oil and gas, and solution mining wells.

Aside from the potential disturbance of a larger land area, the procedures followed in approving a location for an access road and well site for solution mining are similar to those for oil and gas wells. The environmental considerations discussed in the oil and gas siting section that also apply to solution mining include: the distance from fresh water wetlands, floodplains, municipal and non-municipal community water supplies, public streams, rivers or other surface bodies of water, erosion and sedimentation potential of the project, and potential impacts on agricultural activities. DEC must also consider the use of tree and brush debris from land clearing and the effect of the project on endangered or threatened species, significant habitats and other fish and wildlife of special concern. Other items that require a similar review as that for oil and gas wells are the impacts of the well on areas of historic or archeologic significance, coastal lands, state lands, or lands under the jurisdiction of OPRHP. In addition, the proximity of the well to any private dwelling, travelled part of any public road and underground mining operations must also be considered. See the siting and pre-drilling site inspections under the oil and gas section for further information.

A major element in the siting of a solution mining operation is availability and accessibility of a freshwater source for dissolving the subsurface rock salt. A large quantity of freshwater is needed for solution mining. Solution mining operations in New York utilize water from drilled freshwater wells, local surface water supplies, purchased water, or any combination of these three options. If a stream bed is a source of freshwater for solution mining, it should contain a high enough water level so that the water withdrawal will not disrupt the life of the stream. An Article 15

Stream Disturbance Permit must be obtained before withdrawing water from protected streams for solution mining. Operators in New York often use an alternate source when surface water withdrawal creates low water levels in the stream. The Oil, Gas and Solution Mining Law gives DEC the authority to regulate the efficient use of ground and surface waters in solution mining [ECL 23.0305.9(b)]. **It is recommended that this authority be reflected in the regulations.**

The siting of pipelines must also be considered if water needs to be shipped to the site or the brine product transported some distance to a manufacturing location by pipeline. The Public Service Commission does not regulate brine transport lines. DEC and other agencies may become involved in the siting of these pipelines for solution mining operations through the SEQR process, if they cross a stream, wetland, or archeological or historic sites. Further restrictions on siting depend upon arrangements between brine operators, landowners, and local jurisdictions whose property the proposed pipeline may cross. DEC has the authority to regulate the siting and integrity of brine pipelines under the Oil, Gas and Solution Mining Law. **It is recommended that this be clearly identified in the regulations.**

The State's regulations need to further specify that solution mining be conducted in such a way that the outer extent of the cavern created by such mining does not affect property outside the boundary line of the lease, integrated lease, or unit in which solution mining is being developed. A specified distance is needed to protect the rights of adjacent landowners and ensure against any environmental impacts on adjacent lands. It is suggested that this distance be at least 150 feet, but should be reviewed on a case-by case basis due to varying geological and operating conditions. Certain companies in New York have their wells setback as much as 500 feet from boundary lines.

An Organizational Report Form must be filed with DEC before any drilling can begin. This standard form must be updated within 10 days of any changes in the organization of a company.

F. PREPARING FOR DRILLING OPERATIONS

Before drilling operations can begin, operators who have received drilling permits must first notify DEC, local governments and adjacent landowners [ECL 23.0305.13]. The procedures and time periods for doing so are the same as those for oil and gas wells. **These requirements contained in the Law need to be reflected in the regulations for solution mining.**

Operators must be sure the drilling and casing program will be such as to prevent pollution and the migration of fluids from one stratum to another. The Oil, Gas and Solution Mining Law further states that the drilling and casing of wells must be done in accordance with the rules and regulations of the Department to prevent escape of oil, gas or brine or water out of one stratum into another; the pollution of fresh water supplies by salt water and other contaminants; and blowouts, cavings, seepages and fires [ECL 23.0305.9].

The casing and cementing programs adopted for a well are the most important aspects of a drilling operation to prevent fluid migration from one subsurface stratum to another and the pollution of surface and subsurface resources. This is checked by DEC as part of the permitting process.

G. DRILLING SAFETY CONSIDERATIONS

The Department's regulatory program addresses some safety concerns for oil, gas and solution mining drilling operations. A sound safety program helps guard against drilling accidents which may cause further environmental damage and danger to employees. The safety program considerations for drilling a solution mining well are similar to those for oil and gas well drilling. See the oil and gas drilling section for more information.

H. DRILLING SOLUTION SALT MINING WELLS

The drilling of a solution mining well is similar to that of an oil and gas well except most solution wells are shallower and require smaller rigs. Rotary rigs or cable tool rigs are used for drilling in New York. The existing regulations establish separate requirements for each type of drilling rig. In addition, the regulations and cementing guidelines issued in March 1986, establish the required minimum depths and cementing requirements for conductor, surface, intermediate and production casing. These requirements and guidelines have been applied where appropriate to solution mining wells through permit conditions. **The regulations and guidelines should be revised to state that these requirements apply to solution mining.** See the oil and gas well drilling section for more information on these drilling requirements.

DEC conducts drilling and post-drilling inspections to monitor permit compliance and to ensure that the environment is being adequately protected. Corrective action may be required if problems are detected. Regions 8 and 9 utilize inspection forms to document site conditions of the wells located in their respective regions.

Often a second companion well is drilled for salt production in New York. A two-well or multi-well method of producing solution salt is now common practice. The two well system allows for greater flowrates and brine concentrations and is not as subject to corrosion. The last single salt well derrick owned by Cargill Salt Company and located on the main street in Watkins Glen, is being established as an historic landmark (Marshall, 1984, personal communication #45). The single well method began in the late 1800's, and included a string of wrought iron casing, some type of pumping device and tubing (Callaway, 1986, personal communication #9). The casing was not cemented in place but it was occasionally galvanized or wrapped to prevent corrosion. Freshwater was pumped into the wellbore to dissolve the salt, and then compressed air was injected down the same wellbore to force the brine to the surface. (See Figure 13.2). Air lift was necessary due to the lack of a seal behind the casing.

In the two well system, one well is used as an injection well for inserting freshwater into the salt bed and the other as a production well for extracting the dissolved salt. (See Figure 13.3). This is sometimes referred to as gallery solution mining. Most of New York's solution mining operations have been in existence for a number of years and in many instances the salt cavities have merged. In these cases, the inside wells along a row of wells are plugged and only the two end wells are used for injection and production.

I. SALT COMPLETION OPERATIONS

If the drilled well(s) are determined to be adequately situated for salt production, the wells are completed. Completion procedures for solution mining wells are similar to those for oil and gas wells. Although different types of casing cement, fracturing techniques and some variations in the design of the producing well may be used.

Large horizontal stresses can develop in salt zones and shear off wells that lack enough structural strength. In addition, solution salt wells are highly susceptible to corrosion. For these reasons, special types of cements are usually employed by solution mining operators and often the surface, intermediate (if used) and production casings are cemented to the surface with the required calculated volume of cement plus 20 to 100 percent excess. Through permit conditions the Department requires: 1. conductor casing be set in competent bedrock and grouted in conjunction with surface casing, 2. surface casing extend 75' below the freshwater level or 75' into bedrock, whichever is deeper and 3. surface casing be cemented back to the surface. If there are no cement returns, then a 3-D bond log may also be required to

FIGURE, 13.2
13–10a

FIGURE 13.2 ONE–WELL METHOD OF SOLUTION MINING

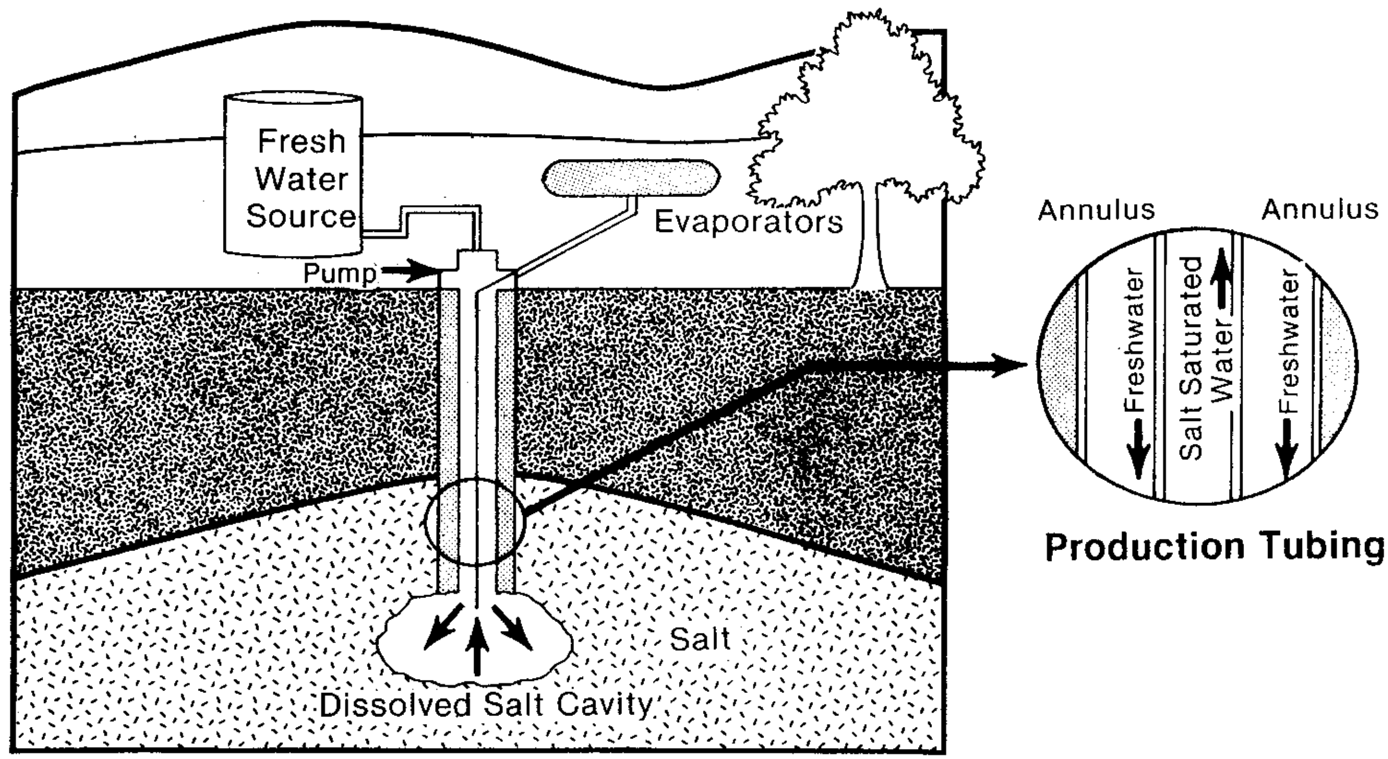


FIGURE 13.3 TWO-WELL METHOD OF SOLUTION MINING

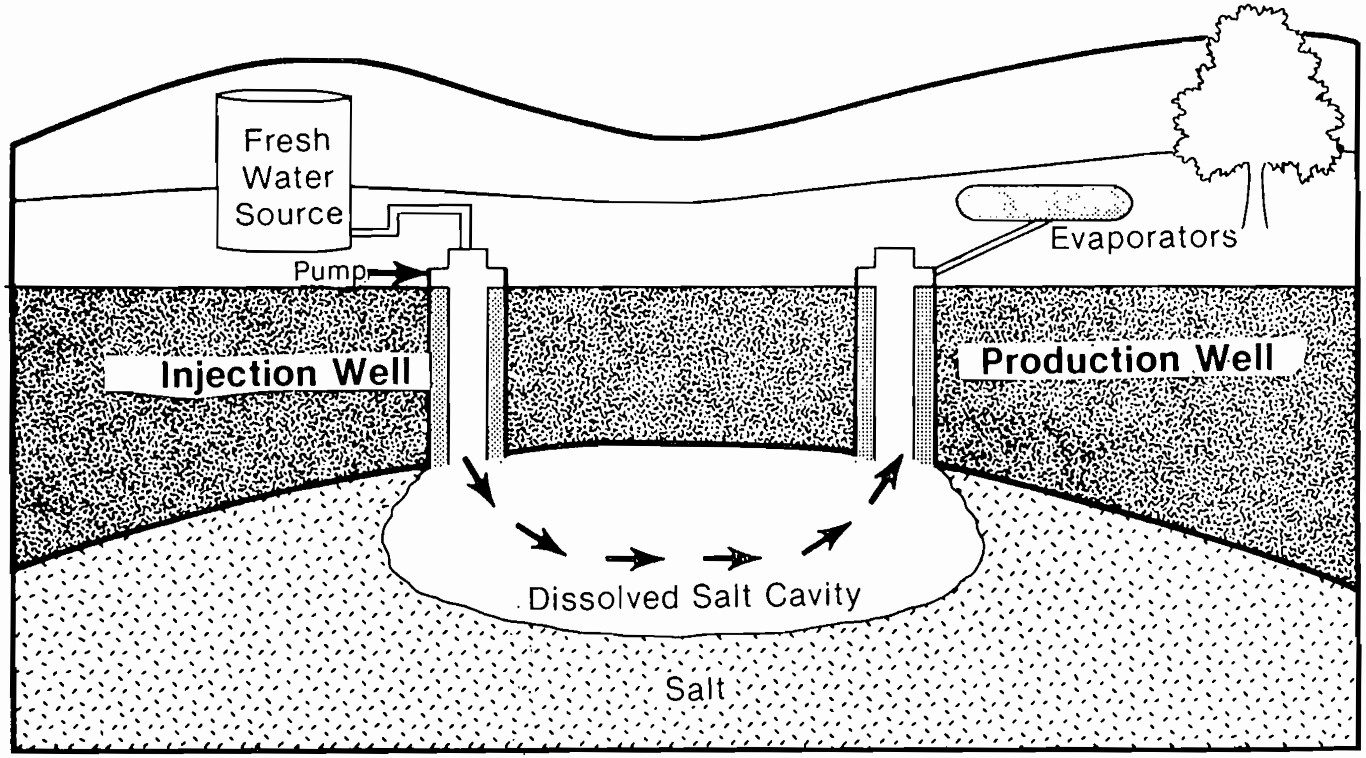


FIGURE 13.3
13-10b

check the quality of the cement job. Many operators also cement the intermediate and production casing back to the surface and set a smaller tailpipe at the base of the production string or production tubing which is often installed on a packer. (See Figure 13.4).

Drilling fluids need to be completely removed from the wellbore with mud flushes and/or spacers before the well is cemented. In addition, cement must be chosen that adheres to the casing, wellbore and salt formation. Salt formations can be more effectively cemented with salt slurries. Freshwater slurries applied to salt formations bond poorly since the water leaches away the salt at the interface. Cementing handbooks describe the levels of salt that should be added to the cement under various conditions. Three cement additives of special application are: 1. a chemical that gels on contact with brine, 2. hollow inorganic spheres that lighten the slurry with little sacrifice of strength and, 3. nitrogen-foamed cement (George, et. al., 1985).

When two separate wells are used for the production process, completion work includes connecting the two wells by fracturing if these wells have not already merged from previous production. Two different completion methods are commonly used; these are cased and open hole. In the cased hole completion, the casing is set through the salt section and perforated for stimulation. In the open hole completion, the casing is set just above or into the salt section and a short tail pipe is run. Cased hole completions are preferred by some operators for greater control when fracturing.

The most common method used to establish communication between the injection well and the production well is to hydrofracture the salt with freshwater or brine under high pressures, of up to 2,400 pounds of pressure (Marshall, 1984, personal communication #45). Brine is used until communication is achieved. Freshwater is then used to prevent closure stresses from healing the fractures and so that the solution cavity can be

FIGURE 13.4 SCHEMATIC OF A TYPICAL SOLUTION SALT MINING WELL

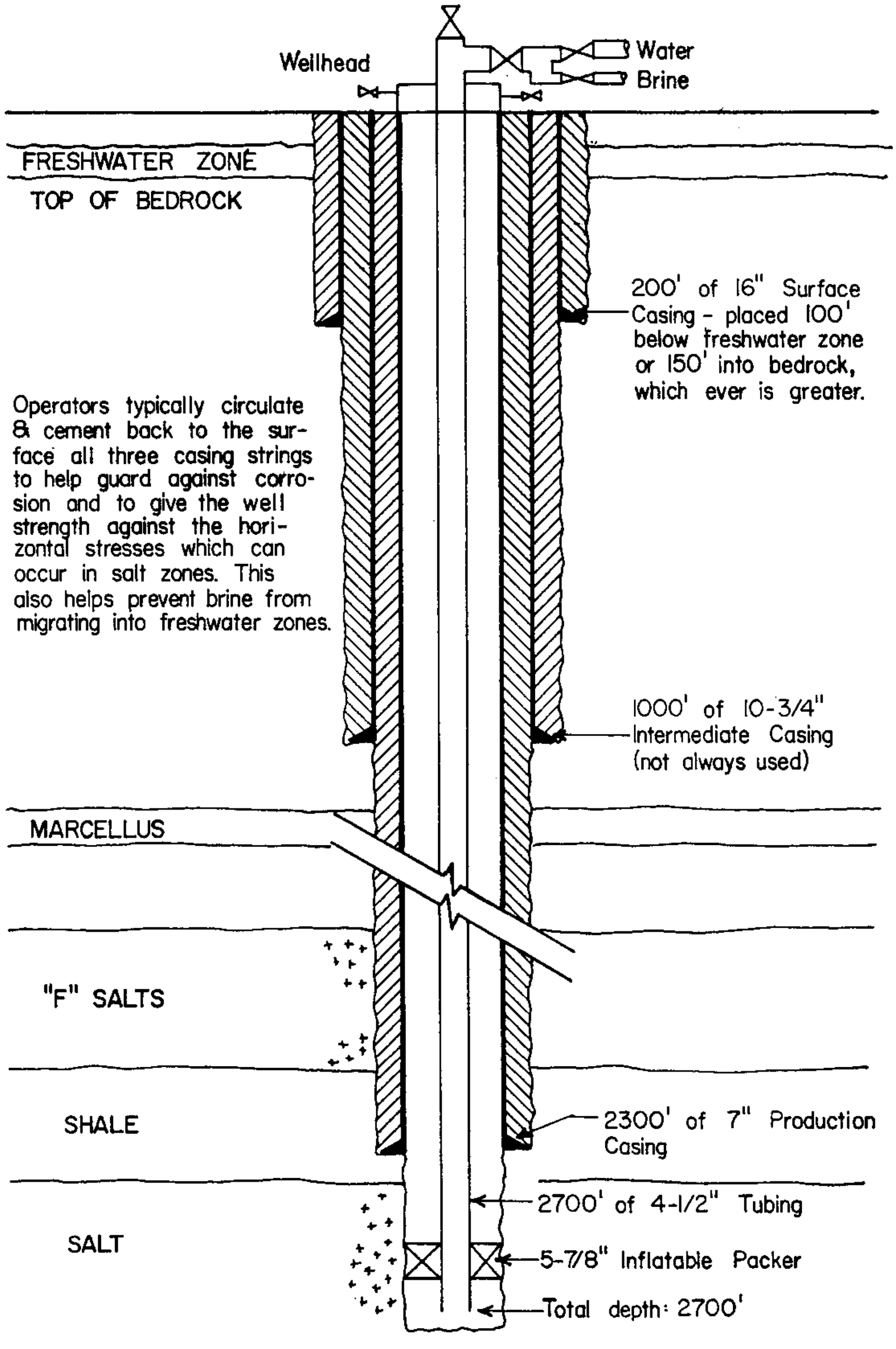


FIGURE 13.4

developed. One of the first such frac jobs done in New York was in Watkins Glen in approximately 1957 (Jacoby, 1961).

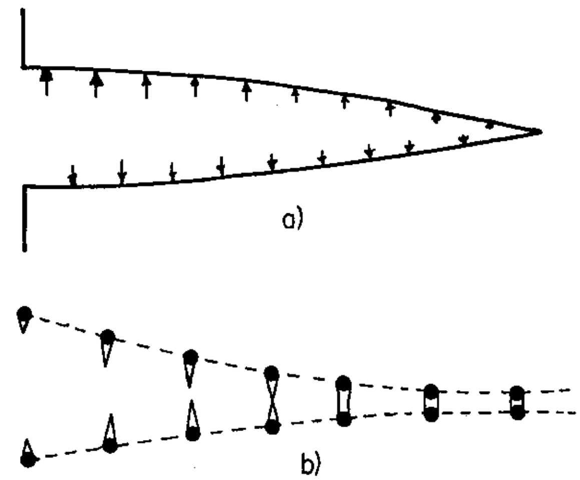
Wells to be hydrofractured may first be notched at the depth and in the direction of the desired fracture so as to direct the inclination and direction of the fracture (Haimson, 1974). (See Figure 13.5). A notch is a voided out area extending into the salt. Notches serve to develop stress fields at the wellbore different from those of a smooth-walled cylinder when the fluid is pressured-up, thus causing the fracture to initiate from the notch.

In salt zones, horizontal fractures usually result due to the rock properties of salt zones, which can have a poisson's ratio as high as .5 (dimensionless) (Allen and Roberts, 1982). Therefore, the horizontal matrix stress can be equal to the vertical matrix stress because of the plastic response of salt to overburden pressures.

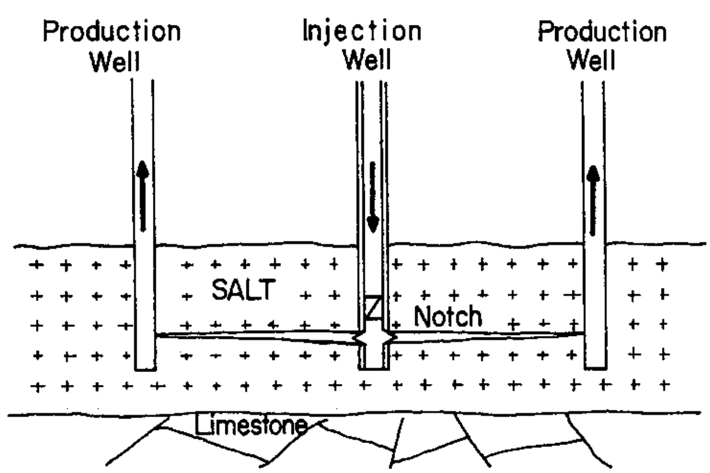
The success of a frac job depends on the geology of the salt formation, the well location, and the design of well completion and fracturing sequence. A thorough geological investigation is the key to success in formations disturbed by folding, faulting or other discontinuities. Wells are now usually cored and logged by operators in order to better understand the local geology, the probable directional response to hydraulic fracturing and as an aid in locating future salt wells.

After the cessation of drilling operations, drilling fluids should be disposed of within 45 days and partial surface restoration should be made. Erosion problems can occur if the site is not properly restored. Diversion and drainage ditches and culverts both around the location and along access roads can help prevent erosion problems if built into the well site preparation plan. Partial surface restoration includes disposal of fluids

FIGURE 13.5 NOTCHING OF SOLUTION MINING WELLS



(a) A sharp-edged notch with fluid pressure distribution.
(b) The leading edge of an extension fracture showing stretching and rupture of rock grain bonds as the fracture advances due to the "wedging" action of the fluid.



Fracturing which had previously been done through perforations is initiated by more precise notching, resulting in near perfect fracturing and rapid low-pressure connections.

References = Aughenbaugh, N.B. and M. William Pullen, "Directional Hydrofracturing," in Third Symposium on Salt Vol. 2, Northern Ohio Geological Society, Inc. 1966. (top figure).

Haimson, Bezalel C., "Well Communication in Salt Formations," in Fourth Symposium on Salt Vol. 2, Northern Ohio Geological Society, Inc., 1974. (bottom figure).

used or encountered while drilling; the backfilling of all mud pits, earthen water tanks, and auxiliary holes; removal of equipment; and regrading and seeding of the entire area disturbed while drilling. The restoration of the site helps prevent erosion and prepares the site for regrowth. **It is recommended that partial surface restoration after the cessation of drilling operations and disposal of drilling fluids of within 45 days after the cessation of drilling operations be required for solution mining wells as for oil and gas wells.** See the oil and gas section for more information.

Within 30 days after the completion of a solution mining well, a completion report must be filed with the Department. This notification aids the Department in monitoring the drilling program. The completion report includes general well information on drilling, coring, well logs, casing, final completion, treatment or stimulation, initial production, pre-completion tests and a record of the formations penetrated. **It is recommended that completion report filing requirements on solution mining wells be specifically cited in regulation.**

DEC conducts a post-drilling inspection to be sure drilling and completion operations were properly conducted. The access roads, well site restoration, and wellhead and production equipment are all checked by Regional staff. Additional corrective action may be required if any problems are encountered.

J. SALT PRODUCTION OPERATIONS

Wellhead attachments, storage tanks, associated surface equipment, and pipelines are installed to prepare the well for production. The well is also connected to a source of freshwater for the salt dissolving process.

For the production stage of solution mining, as with drilling and completion, pollution of the land and/or surface or ground water in connection with solution mining is prohibited [ECL 23-0305.9]. Generally, additives are not added to the fresh water used for dissolving the rock salt which reduces potential environmental problems associated with this mining process. However, well casings, pipelines and storage tanks are highly subject to corrosion due to the high salt content of produced brines. Without adequate prevention measures, this corrosion can lead to leaks and spills. Major problems may result if brine leaks onto land or into surface or groundwater. Chloride contamination can inhibit plant growth for a long time and cause fish kills if spilled into surface waters. If sodium chloride enters an aquifer, there are no economically feasible methods to remedy the situation in any reasonable period of time. The existing regulatory program gives DEC authority to monitor the condition of wells, pipelines and storage tanks. **This authority should be reinforced in the regulations and exercised through permit conditions as needed.**

Well casings can be protected using cathodic measures on production wells. Cathodic protection at 2 to 3 volts will retard the movement of electrons and thus slow down the rate of corrosion. DEC can also check for leaks in the casing, tubing or packer by monitoring the annulus pressure. Suspected fluid movement through vertical channels can be determined by several logging methods such as noise, radioactive tracer and spinner surveys. Some methods are more sensitive than others and the investigation methods chosen must be tailored to each situation.

Companies need to carefully monitor the condition of pipelines used to transport produced brine to storage areas and to distant locations. Sections of pipelines that have become excessively corroded need to be replaced. One company in New York keeps their pipeline oxygen free and cleans it every 2 to 3 weeks with a pig to guard against corrosion. Pigs have rubber cups and scrubber brushes with the same dimensions as the pipeline in order to clean it of built-up depositions and oxygen. Cathodic protection can also be used on sections of the pipeline. Some pipelines contain flowmeters to detect leaks which automatically close pipeline valves to prevent major spills (Woodward-Clyde Consultants, 1985). It is recommended pipelines crossing roads and streams have thicker walls and concrete coating for added protection. **It is also recommended that operator's be required to have a spill contingency plan with an emphasis on freshwater protection in the event a pipeline leak occurs.**

Corrosion of storage tanks for brine must also be kept under control by cathodic protection or by the use of corrosion resistant storage tanks. DEC Division of Water has published a report entitled, "Recommended Practices for Underground Storage of Petroleum" which can be applied in part to brine storage. The report explains how cathodic protection can help minimize deterioration and corrosion of a tank which is exposed to corrosive conditions. This is achieved by supplying an electric current to the structure which is greater in strength and opposite in direction to the flow of current which causes corrosion. For example, if steel is exposed to corrosive soil, it would normally emit a current and corrode over time. When a sacrificial anode is connected to the tank electrically (via wires), the anode produces a stronger current that flows to the tank, and the anode, not the tank, corrodes.

Brine storage tanks in New York are generally made of steel, fiberglass-lined steel or reinforced fiberglass. Reinforced fiberglass tanks may contain cable wrapped through its side walls to give it strength for holding large quantities of brine. All tanks should be factory tested under pressure to ensure competency. Corrosion on the interior of tanks can be lessened when the tanks are kept filled to capacity which prevents oxygen from entering the tank and reacting with the brine to cause corrosion. Operators in New York who utilize this method claim it is responsible for steel tanks, with a capacity of 200,000 gallons or more, lasting over 30 years (Marshall, 1985, personal communication #44).

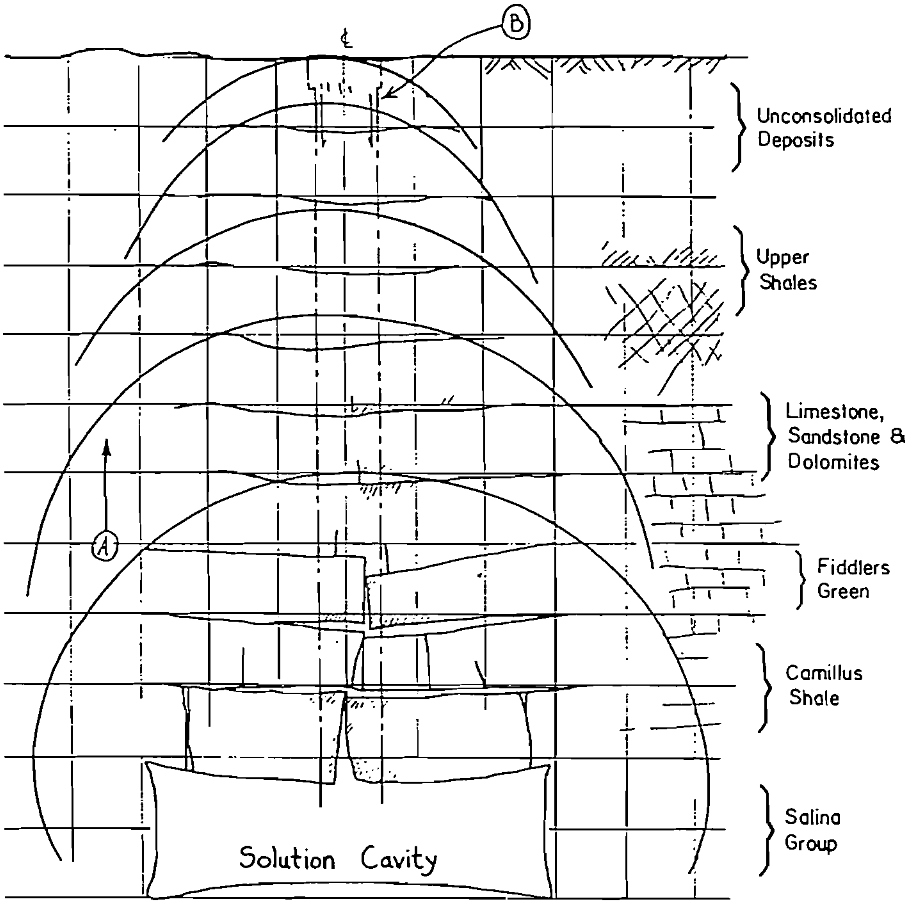
K. CONTROLLING THE SHAPE OF THE SALT CAVITY DURING PRODUCTION

It is important to carefully plan the production program for a salt bed in order to guard against potential ground subsidence problems, sink holes and mud boils. The geology of the well location must be studied and carefully analyzed in order to determine what size cavity can be safely developed in a particular area. If the size of the cavity becomes too large or extensive and exceeds the tensile strength of the overlying rocks, ground collapse will occur. (See Figure 13.6). Subsidence can also cause fractures in the overlying strata which may form channels for the movement of brine into ground freshwater supplies. Additionally these fractures can provide channels for the movement of surface waters into salt cavities, causing further solution and subsidence. This creates uncertainty about the future stability of the land and may make it unsafe to build on or use this land for other purposes for some time in the future. There is concern about subsidence from solution mining operations in New York, particularly for shallower salt beds, older brine fields, and areas where the over-burden is structurally weak.

According to the Solution Mining Research Institute, cavities formed in bedded salt, "are frequently extensive in the horizontal dimensions and in mature stages of development are frequently obscured by rubble". The cavity may actually be a fluid filled void in the salt and overlying rock beds, sometimes fully occupied by the insoluble residue and caved material from overlying beds. The cavity may also feather out to nothing in random directions controlled by such variables as dip of confining bed, natural fractures, etc. Sometimes several beds are dissolved in the same system forming stacked cavities.

The shape of the cavity formed from solution mining operations can be

FIGURE 13.6 SCHEMATIC ILLUSTRATING HOW SUBSIDENCE SINKHOLES AND MUDBOILS MAY OCCUR



(A) Stress Envelope Rising Upwards Caused by Time-dependent Brittle Failure, (B) Chimney Concept of Sinkhole Development.

Reference: Serata, Shosei, "Utilization of Stress Envelopes in Design of Solution Cavities," Fourth Symposium on Salt, Northern Ohio Geological Society, Inc., Cleveland, Ohio, 1974.

FIGURE 13.6

predicted and controlled to a certain degree depending on:

- the well casing and tubing arrangement
- injection and withdrawal patterns (production and injection wells can be altered so that a more uniform shape is formed)
- flow rates (volume and rate of injection)
- chemical and physical characteristics of the formation
- height of the water in the cavity
- salt concentration
- salt solubility

In a single well system, the variables will cause either a round or morning glory shaped cavity. The morning glory shape is a cavity with a large unsupported roof. Non-vertical holes, an obstruction or an opening, crack or crevice in the salt can change the shape of the cavity. Certain techniques are available to check the size and shape of a cavity such as sonar tests. Surface reflection seismic profiles can locate the areal extent and depth of underground solution mining cavities. When uncertainty exists, these tests may be employed as another measure to monitor against subsidence or catastrophic collapse.

Several operators in New York voluntarily utilize subsidence monitors for guarding against land collapse. These monuments are built at least 4 feet into the ground with an outer casing to protect against frost heaving. See Figure 13.7 of a subsidence monument employed by Texas Brine Corporation in Dale, New York. These monuments are surveyed periodically to observe changes in elevation. Subsidence is known to have occurred at several of the solution mining sites in New York State. **It is recommended that subsidence monitoring be required for all operations and that operations be halted if subsidence occurs which may cause significant adverse environmental impacts.**

FIGURE 13.7 SUBSIDENCE MONUMENT USED BY

TEXAS BRINE CORPORATION

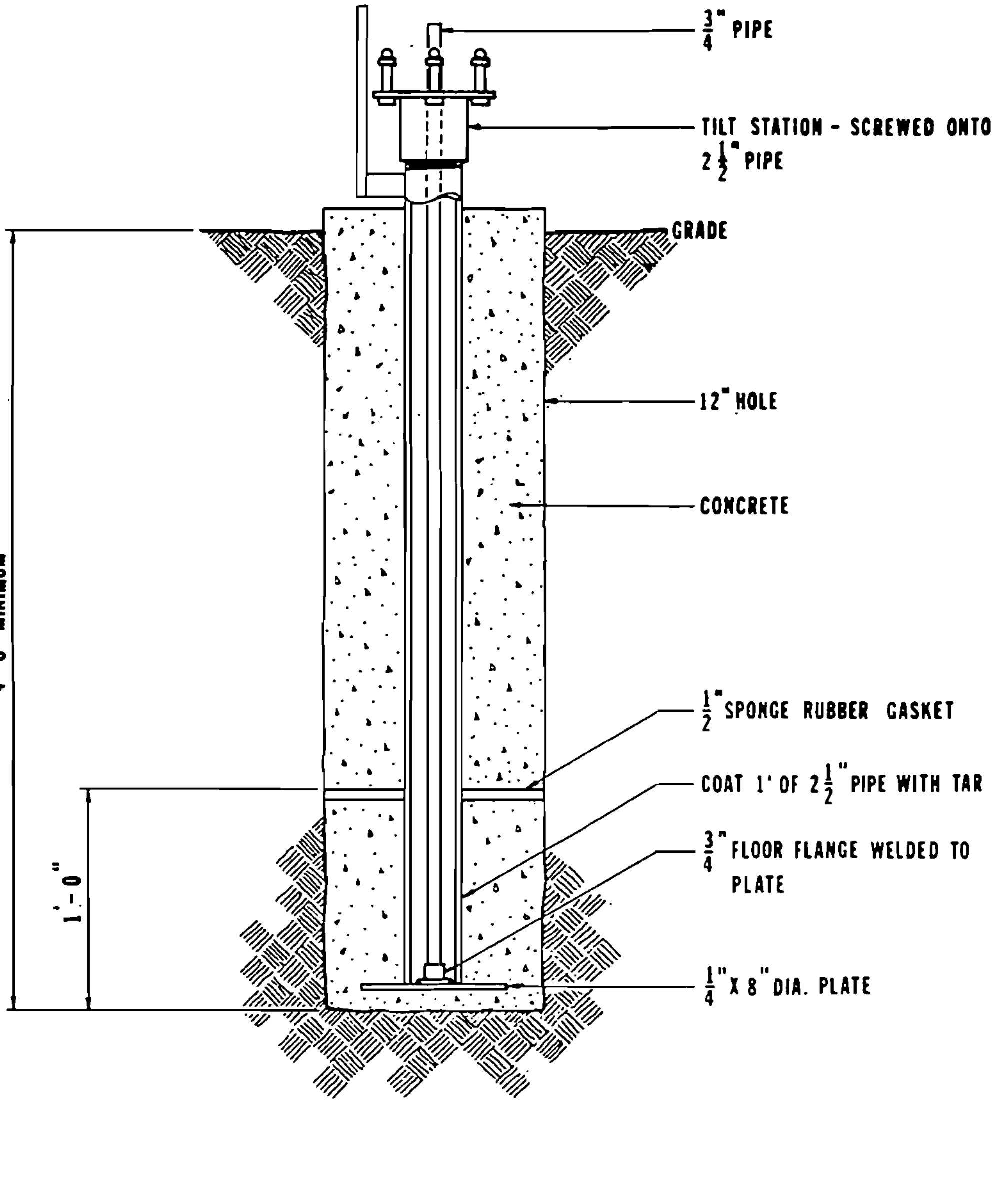


FIGURE 13.7

L. METERING OF SOLUTION MINING PRODUCTION

The metering or measurement of brine produced by solution mining and the maintenance of the records from each cavity or group of cavities is required until wells in the cavities have been abandoned and plugged [ECL 23.0305.9]. These records must be furnished to DEC upon request. The Law states that DEC cannot release these reports for publication or make them available to the general public without the consent of the producer. **These requirements of the Oil, Gas and Solution Mining Law should be specified in the regulations.**

M. METHANE GAS

Bedded salt in New York generally contains little gas, although, methane gas has been encountered in the solution mining process by at least one operator in New York (Griffin, 1984, personal communication #30). Accidents have occurred when explosive concentrations of this gas have built up in the sheds protecting the wellhead and pump. **These sheds should be vented to help protect against methane build up in areas where it is known to occur.**

N. BRINE DISPOSAL

The existing oil, gas and solution mining program contains provisions for the proper disposal of production brines. These provisions have more relevance to the oil and gas program than to solution mining.

There is little or no waste generated from the solution mining process itself. Additives are not usually mixed in the fresh water used for solution mining and the salt obtained from New York's salt beds is often 99 percent pure. However, the processes associated with extracting the salt from the brine or the use of the brine for chemical manufacturing produces some waste products. After freshwater has been cycled several times through the solutioning process, some salt impurities such as calcium, magnesium, chlorides and sulfates will accumulate. A SPDES permit must be obtained from the Department to discharge this effluent into surface waters and/or groundwaters so that safe levels of discharge are maintained. The DEC Division of Water issues these SPDES permits. Solution mining operators in New York must also receive approval from the Department and EPA to dispose of salt impurities (mainly chlorides and sulfates) into inactive solution mining cavities or into a porous formation. The Marcellus Shale can be used as a disposal zone where natural fracturing has created porosity and permeability.

Cargill Salt Company is currently operating one active disposal well for recycled wastewater which is injected into an old salt gallery with the overflow going into the Marcellus formation (see Figure 13.8) (Sevenker, 1984). No sulfate precipitation problems have occurred as yet in the Marcellus formation. The disposal rate is 30 gpm which equates to 43,200 gallons per day or 1,028 barrels a day.

An application for the disposal of brine by subsurface injection must be approved by the Department [6NYCRR 556.5(b)(2)] and EPA. At the same time the application is submitted, the operators of all leases or units offsetting the lease or unit on which the input well is or will be located must also be notified [6NYCRR Part 556.5(b)(2)]. The Department will hold the application for ten days. If neither the Department nor any of offsetting operators express concerns then the application will be approved. If there are concerns, then a public hearing is scheduled [6NYCRR Part 556.5(b)(2)]. **It is suggested that the ten day waiting period specified in the regulation be extended to 15 days.**

O. MONITORING WELLS

Monitoring wells, which are wells drilled into freshwater aquifers solely for observation, may be used to check for the movement of brine from a salt cavity into drinking water supplies. For the most part, monitoring wells have not been required in New York because the existing solution mining

FIGURE 13.8 CARGILL SALT BRINE WASTEWATER DISPOSAL WELLS

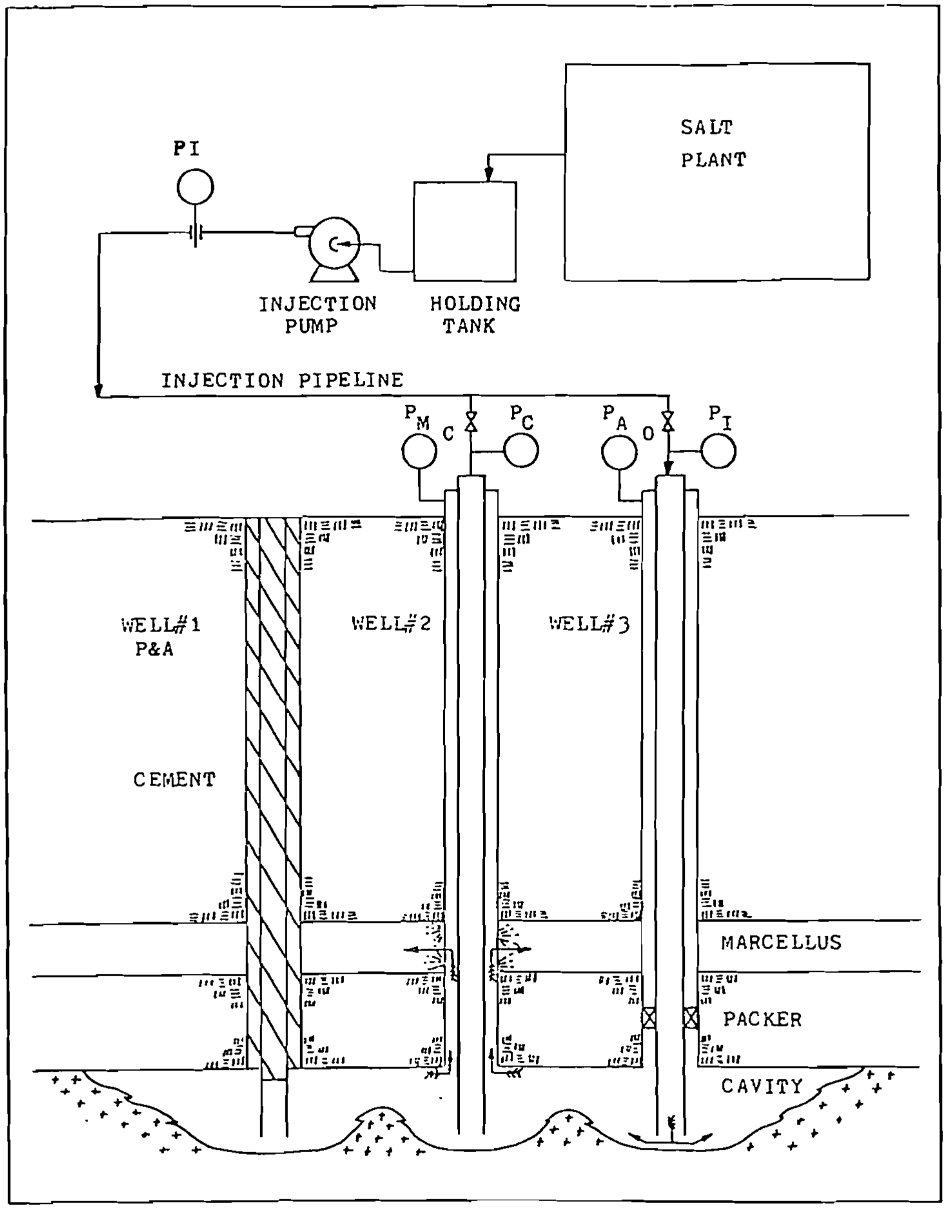


FIGURE 13.8

operations are not located near any primary or principal aquifers. In addition, monitoring wells generate the same plugging and abandonment concerns as production wells. However, it might be necessary to require monitoring wells in areas with freshwater or subject to subsidence or catastrophic collapse. **The regulations should be revised to specifically state that DEC may require monitoring wells when solution mining operations are adjacent to high yield freshwater aquifers.**

P. EARTHQUAKES

There has been some research conducted on the possibility of injection from nearby salt mining operations increasing subsurface pore pressures and causing a reactivation of existing faults. The research conducted to date is not altogether conclusive but suggests that zones astride known faults which have been associated with seismic activity in the past should be identified. According to a January 1984 report of the Northeastern U.S. Seismic Network Bulletin No. 30 of Seismicity of the Northeastern United States, there were no earthquake epicenters detected during the period October 1975 to March 1983 in New York's solution mining areas.

Q. TEMPORARY ABANDONMENTS AND SHUT-INS

When a solution mining well is no longer utilized, it must be permanently plugged and abandoned. There are certain exceptions built into the existing regulations for temporary abandonment or shut-in of oil and gas wells. The existing regulations specify time periods for allowable temporary abandonment and shut-in and procedures to extend these allowable periods should it be necessary. **It is recommended that these regulations be revised to include a specific citation to solution mining wells.** The oil and gas drilling section has more information about these procedures.

R. PERMANENT PLUGGING AND ABANDONMENT

All wells must be permanently plugged and abandoned and have proper surface restoration once they are no longer being used for production or injection and the allowable time periods for a temporary abandonment or shut-in have expired. Proper plugging and abandonment of wells is an important step for complete protection of the environment. As with oil and gas wells, plugging responsibilities must be undertaken before a lease is abandoned. **It is recommended that it be stated in regulation as it is in the Law that plugging responsibilities for solution mining wells cannot be transferred without the agreement of parties involved and the approval of DEC.**

The potential environmental impacts of improperly plugging and abandoning solution mining wells are similar to those for oil and gas wells. However, the absence of oil and gas and the existence of a large subsurface void generate concerns different than those created by unplugged oil and gas wells. Continued entry of freshwater from rain or other forms of precipitation into an unplugged salt cavity could cause further salt dissolution leading to uncontrolled cavity growth. Subsidence and possible groundwater contamination may result, depending on the natural direction of fluid movement and the location of surface recharge areas. Plugging solution mining wells is extremely important in order to halt continued subsurface deterioration. In the extreme case, unplugged wells could make the land unfit for a variety of purposes because of instability and render surface and groundwater supplies unsuitable for drinking, agricultural, recreation, and other uses due to salt contamination.

A large percentage of the solution salt wells developed over the past 100 years have not been properly plugged and abandoned causing serious environmental concerns. In addition, there are approximately ten solution salt wells which cease production annually. These wells must be properly plugged and abandoned. **The Department will agressively pursue operators of these wells to ensure that the wells are properly plugged and abandoned.**

Portions of the Department's well plugging and surface restoration requirements are applicable to solution mining. These include the depth of cement around various formations in the wellbore, the location of cement plugs, the treatment of the intervals between cement plugs and materials to replace any casing drawn from a well. Surface restoration requirements contained in the current regulations for oil and gas wells are also used for solution mining wells. These regulations require the owner to fill any pit or other excavation which has been created to facilitate drilling or production of a well. The oil and gas regulations also require operators to make a reasonable effort to smooth the surface adjacent to the well and restore the vegetation so as to place the surface in a condition similar to the adjacent terrain. Surface restoration requirements can be waived if it can be demonstrated that no hazard will result and the landowner has signed the appropriate release. The oil and gas well plugging and abandonment section discusses all of these requirements. **It is recommended that the regulations be revised so that the application of these surface restoration requirements to solution mining is cited.**

Operators in New York often plug solution salt wells by first placing a bridge plug near the bottom of the wellbore although the current regulations allow a brush bridge plug to still be used. Some sections of the casing may be perforated and squeezed with extra cement as needed. Other operators may only perforate and cement squeeze the casing near the base of the wellbore, around the Marcellus and Oriskany or other similar formations, and from 200' to the surface. The casing is usually cut below plow depth. **It is recommended that the plugging requirements proposed for oil and gas wells be applied to solution mining with some modifications to reflect special**

conditions presented by solution mining wells such as specifying a cast iron bridge plug or supporting bridge of other approved material be set in the wellbore above the solution cavity prior to plugging the well.

Before plugging operations can begin, operators must first notify DEC and obtain a plugging permit. Under extreme circumstances, an agreement regarding plugging operations may be obtained before an operator plugs a well, followed by required paperwork. A Department representative makes every attempt to attend the plugging operations and/or inspect the plugging job when completed, as for oil and gas wells. **It is recommended that the standard notification and plugging permit requirements be incorporated in regulation by a citation to solution mining wells.**

Non-routine incidents that may occur during the plugging operations that might affect the health, safety, welfare or property of any person must be reported to DEC in the same fashion as that required for oil and gas wells. **It is recommended that the non-routine incident reporting requirement be included in the regulations for solution mining operations.**

Within 30 calendar days after the plugging of any well, the owner must file with the Department a plugging report on the form prescribed. This form and the procedures for filing the report are the same as those for oil and gas wells. **It is recommended that the regulatory program require operators of solution mining wells who cease operations, submit with their final abandonment report a map of the location and extent of the salt cavities developed. In addition, the location of any subsidence bowls, sink-holes, mud boils or other phenomena created or suspected to have been created as a result of the solution mining operation should be detailed on this map.** It is extremely important that this information be detailed so that future uses of the land can be appropriately accommodated.