with ASTM Type II cement. The fiberglass injection tubing extends to a depth of 1,025 feet, with a packer of 824 feet and stainless steel screens at 1,000 to 1,025 feet, 970 to 990 feet, 945 to 960 feet, 910 to 920 feet, and 835 to 875 feet. The open hole section in which the screens are set was underreamed to 26 inches in diameter, and gravel packed.

During an inspection of this well in 1971, a break was discovered in the 8-inch fiberglass casing, and the well was later filled with neat cement grout.

OB-4, which was used for injection beginning in June 1969, has 20-inch steel surface casing set at 85 feet, through the Pleistocene-age sands, and cemented to the surface with regular Portland cement. No intermediate casing string was set in this well. The inner casing is 6-inch fiberglass casing gravel packed from the bottom of the well up to 830 feet, and cemented from 830 feet to the surface. This well is currently used to monitor water quality in the injection zone.

OB-5 is almost identical in construction to OB-4 described above. This well was permanently plugged in October 1972 because of an apparent leak in the casing.

Injection Well I-7A is almost identical in construction to the original injection well (I-6), except that the lower 44 feet of the intermediate casing is Type 316 stainless steel, approximately the bottom 40 feet is cemented with acid-resistant resin cement and the injection tubing is 6-inch Type 316L stainless steel. Well I-7A is currently used to monitor pressure and water quality in the injection zone.

Chronology of Operational Problems. Injection Well I-6 began operation in May 1968. By June 1969, the injection pressure had exceeded the permitted 150 psi and reached 200 pounds per square inch (psi) at the design injection rate of 300,000 gallons per day (Leenheer, 1976). To maintain the required injection rate at the allowed injection pressure, Hercofina was permitted to begin injection into Observation Wells OB-4 and OB-5, respectively, located 145 feet southwest and 150 feet east of Well I-6. Injection into the 1,000-foot-zone observation wells was permitted because the waste front had reached these wells the previous September, 5 months after injection began. The injection pressure continued to increase, and, by May 1969, had exceeded the allowable 150 psi in Wells O-4 and O-5.

Partly because of the increasing pressure, the NCDEM required the owner to either repair or abandon Well I-6, or to construct a second injection well (I-7A), and expand the monitoring network by the addition of 10 wells. Attempts to rework I-6 to restore its capacity were unsuccessful (Leenheer, 1973), and the owner then elected to begin construction of I-7A as a temporary facility, to serve until surface treatment facilities become operational.

In February 1971, leakage into the Black Creek aquifer (700-foot zone) was detected at Well O-3 (Shiver, 1984) located 50 feet east of Well I-6. Based on the continuing injection pressure rise and leakage of waste into an overlying aquifer, the NCDEM determined that deep well injection is an unsuitable disposal method in this area (Shiver, 1984).

In May 1971, a break was discovered in the casing of Well I-6 at a depth of 500 feet. The damage to the casing

may have occurred during a November 1969 rework of this well (Leenheer, 1976). Also at this time, a poor bond between casing and formation was found, which provided a potential additional pathway for the leakage of waste from the injection zone. Since it was unfeasible to repair Well I-6, it was filled with cement, and Well I-7A became the primary injection well. Injection into Well O-4 resumed in October 1971 because of high injection pressure in I-7A (Leenheer, 1973).

From 1971 until December 1972, when injection was stopped, the injection pressure continued to rise. In December 1971 waste was detected in the 700-foot zone at observation Well O-9 (Leenheer, 1973). This was attributed to a leak through the annulus space of I-7A (Leenheer, 1976) although this was not confirmed. Leakage into the 700-foot zone was also suspected to be occurring through Wells OB-1, OB-2, and OB-5, and they were plugged with cement.

Post-injection monitoring now being conducted by Hercofina under a voluntary compliance agreement with NCDEM includes monthly reporting of pressure and dissolved organic carbon for Well I-7A and the 11 remaining observation wells and continuous pressure records for Wells I-7A and OB-9.

The primary causes of the operational problems at this facility were the low overall permeability of the injection zone and the chemical reactions that occurred between the waste and the aquifer and confining bed materials.

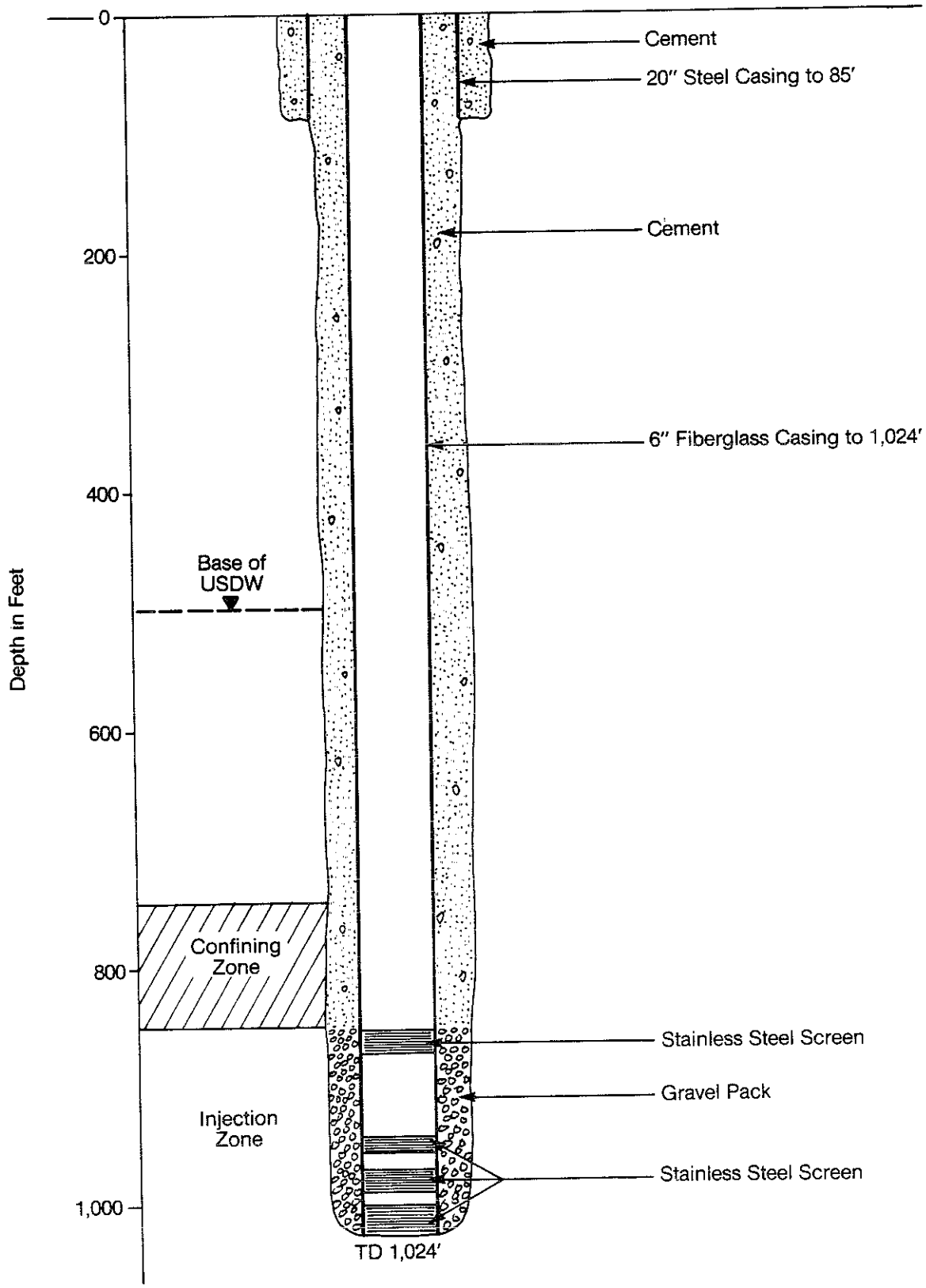
Waste-aquifer compatibility studies were not begun until January 1971 (Shiver, 1984) after injection had been underway for 2-1/2 years. These studies (Leenheer, 1973 and 1976) found that reactions between the waste and the aquifer

materials produced coatings, precipitates and gases that tended to plug the receiving zone. These studies also found that the complexing organic acids in the waste could attack the clays in the confining bed, and weaken or destroy the bonding of the cement to the well casing and formation.

Plugging of the injection zone, which already had a relatively low capacity, led to increasing injection pressures that eventually made the system inoperative within permit limitations. A break in the casing of Well I-6 at the 500-foot level is probably the major cause of waste entering the 700-foot and shallower zones. High pressure and reactions with the confining beds probably also contributed to leakage of waste out of the intended injection zone (Leenheer, 1976).

Current monitoring shows the presence of waste in the 700-foot zone, but little or no lateral spreading of the waste plume. So far as is known, the leakage of waste is confined to the 700-foot zone, which is not a USDW.

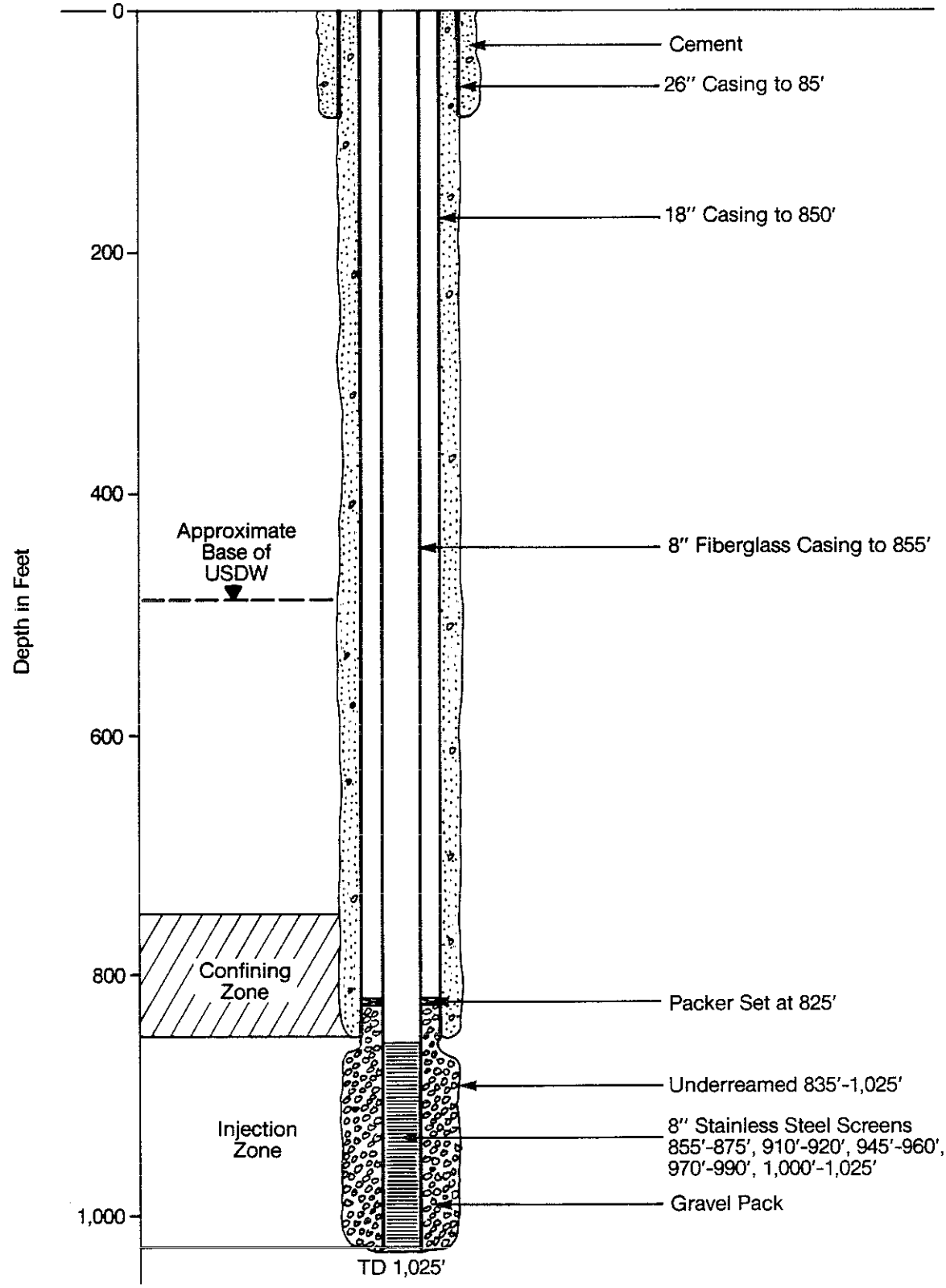
D19976.P0



HERCOFINA
Wilmington, North Carolina

OBSERVATION WELL NO. 5

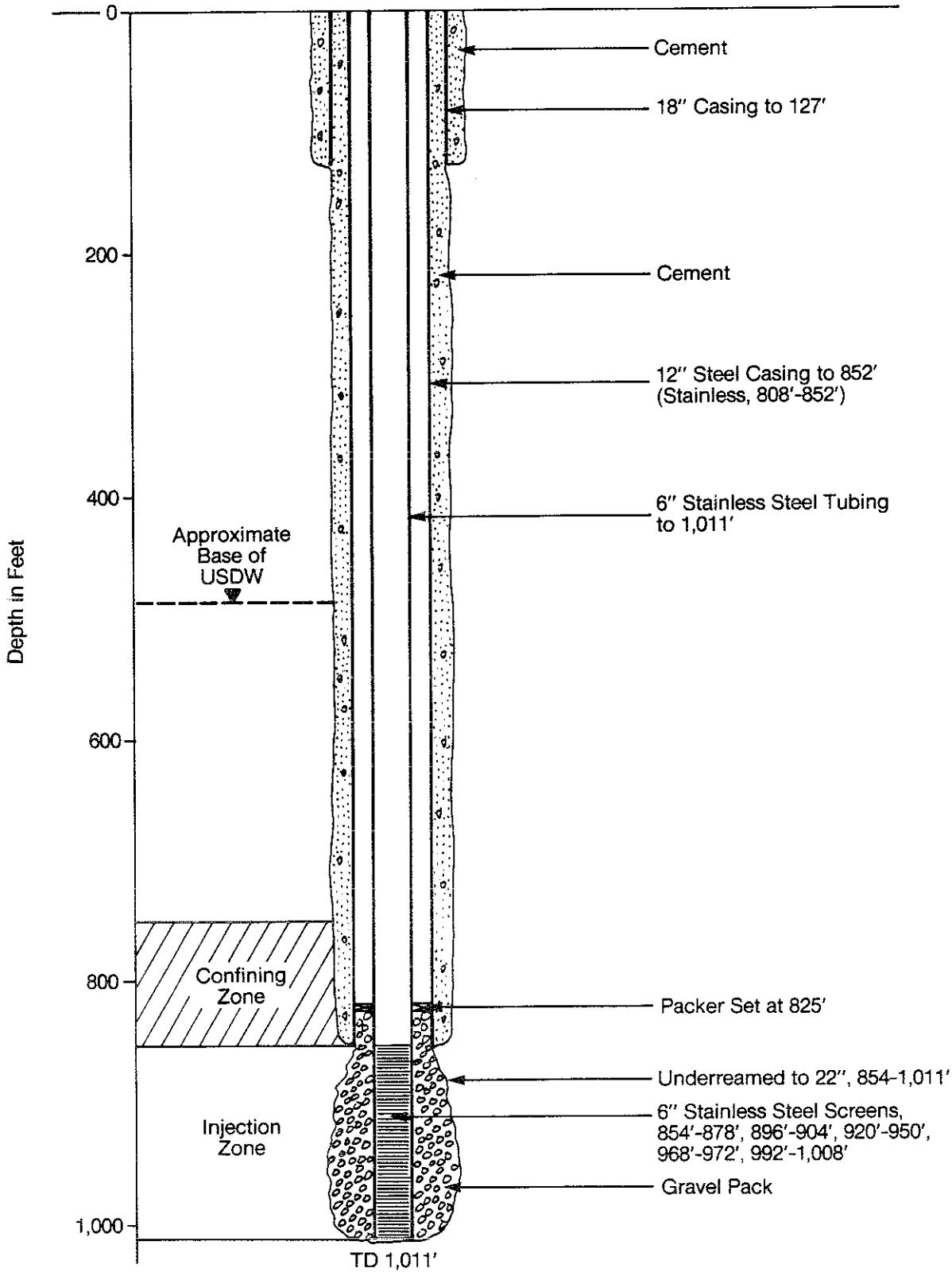
D19976.PO



HERCOFINA
Wilmington, North Carolina

INJECTION WELL I-6

D19976.P0



HERCOFINA
Wilmington, North Carolina

INJECTION WELL I-7A

CHEMICAL WASTE MANAGEMENT
OHIO LIQUID DISPOSAL, INC.
VICKERY, OHIO

Background. Ohio Liquid Disposal, Inc., a subsidiary of Chemical Waste Management, Inc., operates a commercial hazardous waste injection well facility near Vickery, Ohio. The facility has six operating injection wells and one plugged and abandoned injection well. The site is located in north-central Ohio in Sandusky County, about 70 miles west of Cleveland.

The injection wells at the Vickery site are Class I, commercial, hazardous waste injection wells. Hazardous wastes generated at numerous sources offsite are disposed of at this facility. About 70 percent of the wastes are derived from six source industries: steel manufacturing, metal treating, organic chemical manufacturing, inorganic chemical manufacturing, pollution control wastes, and the oil and gas industry. The remaining 30 percent is derived from miscellaneous sources (Texas World Operations, 1985).

Waste liquids are transported to the site by truck. After a chemical analysis, the trucks delivering aqueous wastes unload into a sump which directs the wastes through oil separators and into storage tanks. The trucks are washed and the washwater follows the same route through the facility as the original waste. The wastes are blended for neutralization and to allow for the formation of any precipitates prior to injection. After a 3-day reaction time, the aqueous fraction is filtered and pumped to the disposal wells.

The first injection well at the site was drilled in 1972 and disposal operations began in June 1976. Well 2 was drilled in 1976 and disposal began in March 1977. Wells 3 and 4

were drilled in 1976 and disposal began in August 1977. Well 1A was drilled in 1979 and injection began in January 1980. Wells 5 and 6 were drilled in 1980 and 1981, respectively, and injection began in both wells in September 1981. To date about 500 million gallons of waste have been injected at the Vickery facility. Annual injection volume for all wells should be about 147,000,000 gallons for 1985 (Texas World Operations, 1985).

All seven injection wells at this site experienced operational problems that allowed contaminants to enter a subsurface zone other than the permitted injection zone, but not into USDW's. All wells still in operation have been rebuilt and equipped with more compatible equipment and more adequate monitoring devices. Monitor wells are not required, nor have any been installed at this facility.

Site Description. The Vickery site is underlain by approximately 3,000 feet of sedimentary rocks, ranging in age from Cambrian to Pleistocene, which lie unconformably on Precambrian granitic basement rocks. Locally sediments dip slightly southeastward. The injection zone used at the site is the Mt. Simon Sandstone of Cambrian age, which lies directly above the granitic basement complex, at a depth of approximately 2,800 feet. The formation consists of approximately 110 feet of fine to coarse grained quartz sandstone. Permeability of the Mt. Simon ranges from 15 to 60 millidarcies. The Mt. Simon Formation is overlain by approximately 200 feet of low permeability, silty sandy dolomite referred to the Shady Dolomite Formation. This formation functions as the primary upper confining bed for the waste disposal activities in the Mt. Simon.

The primary aquifer beneath the site is the "Big Lime" unit, a 550-foot-thick sequence of limestone and dolomite of Mississippian and Devonian age. Most water supply wells in

the area are completed in the upper 70 to 100 feet of the Big Lime at depths of less than 200 feet. The Big Lime is overlain by 50 to 60 feet of glacial drift which is locally used as a domestic water supply. Beneath the Big Lime is about 100 feet of low permeability shales and limestones of Upper Ordovician age. The lower limit of USDW's in this area occurs within this unit at an approximate depth of 700 feet.

Well Construction Details. The seven wells at the Vickery site were completed in the Mt. Simon Formation. A 10 3/4-inch surface casing was set in each well to a depth of approximately 630 feet, to the base of the locally used USDW in the Big Lime Formation. An injection casing was set in each well to the top of the Mt. Simon at a depth of approximately 2,800 feet. Between 70 and 190 feet of open hole through the Mt. Simon and into granitic basement rocks is present in each hole below the injection casing.

The injection casing in Well 1 was constructed of carbon steel. This was the only well that did not have the lower 400 feet of the injection casing constructed of fiberglass (Wells 1A, 2, 3, and 4) or lower 60 feet constructed of Inconel 625 (Wells 5 and 6). All annular spaces between casings were cemented to the surface with Portland API Class A cement, Pozmix, or a mixture of the two cements. Wells 1, 1A, 2, 3, and 4 were constructed with fibercast injection tubing inside the injection casing. The annulus between the injection casing and tubing was filled with a diesel oil fluid seal. Wells 5 and 6 were equipped with mechanical packer seals and a pressurized annulus between the injection tubing and casing. All of the fluid seal wells were originally equipped with conductivity measuring contacts on the lower end of the injection tubing to measure the waste liquid/diesel oil interface to detect leaks in the injection

casing. Mechanical packers have now been installed in all wells and the injection tubing annulus with the injection casing is maintained at a higher pressure than the waste injection pressure.

Wellheads are equipped for continuous monitoring of injection pressure, flow rate, temperature, and annulus pressure. Access ports are provided at the wellhead for sampling the waste stream after all treatment and prior to injection.

Chronology of Operational Problems. Well 1 began experiencing increases in injection pressure to maintain flow rates almost immediately after startup in June 1976, with an increase from 590 pounds per square inch (psi) to 650 psi to inject 42 gallons per minute (gpm) during the first month of operation. Also, annular fluids were lost and required replacement almost from the beginning of operations. After the first 6 months, over 200 gallons of oil were required. Acidizing had only short-lived effects and, by August 1977, over 800 psi was required to inject 32 gpm. In May 1978, a casing inspection log revealed that the lower 35 feet of casing had suffered corrosion. This was accompanied by a gradual reduction of required injection pressure to 730 psi. In July 1979, the tubing in Well 1 was discovered to have parted at 2,240 feet and the casing was badly corroded below 1,800 feet. The well was plugged in July 1980 (Underground Resources Management, 1983).

Well 2 also experienced a general trend toward higher injection pressures and lower rates until early 1979 when flow rates increased relative to pressure. Further, an April 1978 radioactive tracer log indicated leakage outside the long string at 2,312 and 2,414 feet. A leak in the casing was discovered in September 1979 between 2,431 and 2,461. After testing, the well was returned to service but

oil had to be added to the annulus several times during the next 12 months. A caliper log in December 1980 indicated that severe corrosion was present on the liner from 2,250 to 2,370 feet; pressure tests performed at that time indicated leaks with flow rates as high as three barrels per minute. The well has not been used since December 1980. Approximately 1.5 to 4 million gallons leaked out of Well 2 (Underground Resources Management, 1983).

The injection rate at Well 1A dropped from approximately 35 to 2 gpm during the first 6 months of operation. After acid and caustic stimulation, flow was 60 gpm at 640 psi. In 15 months, flow reduced to 5 gpm and the well was again treated with caustic. A 34-gpm flow at 660 psi was obtained. Since that time, flow rate has increased while injection pressure has decreased. A leak between 2,591 and 2,606 feet was discovered during a 1983 mechanical integrity test, and it has been estimated that between 7 and 20 million gallons of waste leaked from Well 1A (Underground Resources Management, 1983).

Well 3 suffered severe losses of annular fluids and leaks in the casing were discovered in 1978; the tubing parted in 1980, allowing low-pH waste to corrode the casing below 2,340 feet; a leak was found in the casing at 2,407 to 2,467 in 1981. In November 1982, the flow rate almost doubled with no apparent injection pressure increase. A 1983 mechanical integrity test located a leak in the casing at 2,389 to 2,626 feet and casing corrosion at several places. An estimated 12 million gallons of liquid leaked from Well 3 (Underground Resources Management, 1983).

Well 4 declined from an injection rate of 50 gpm at 400 psi to 16 to 19 gpm at 580 psi in the first 2 years of operation. In 1978 the well was stimulated with explosives

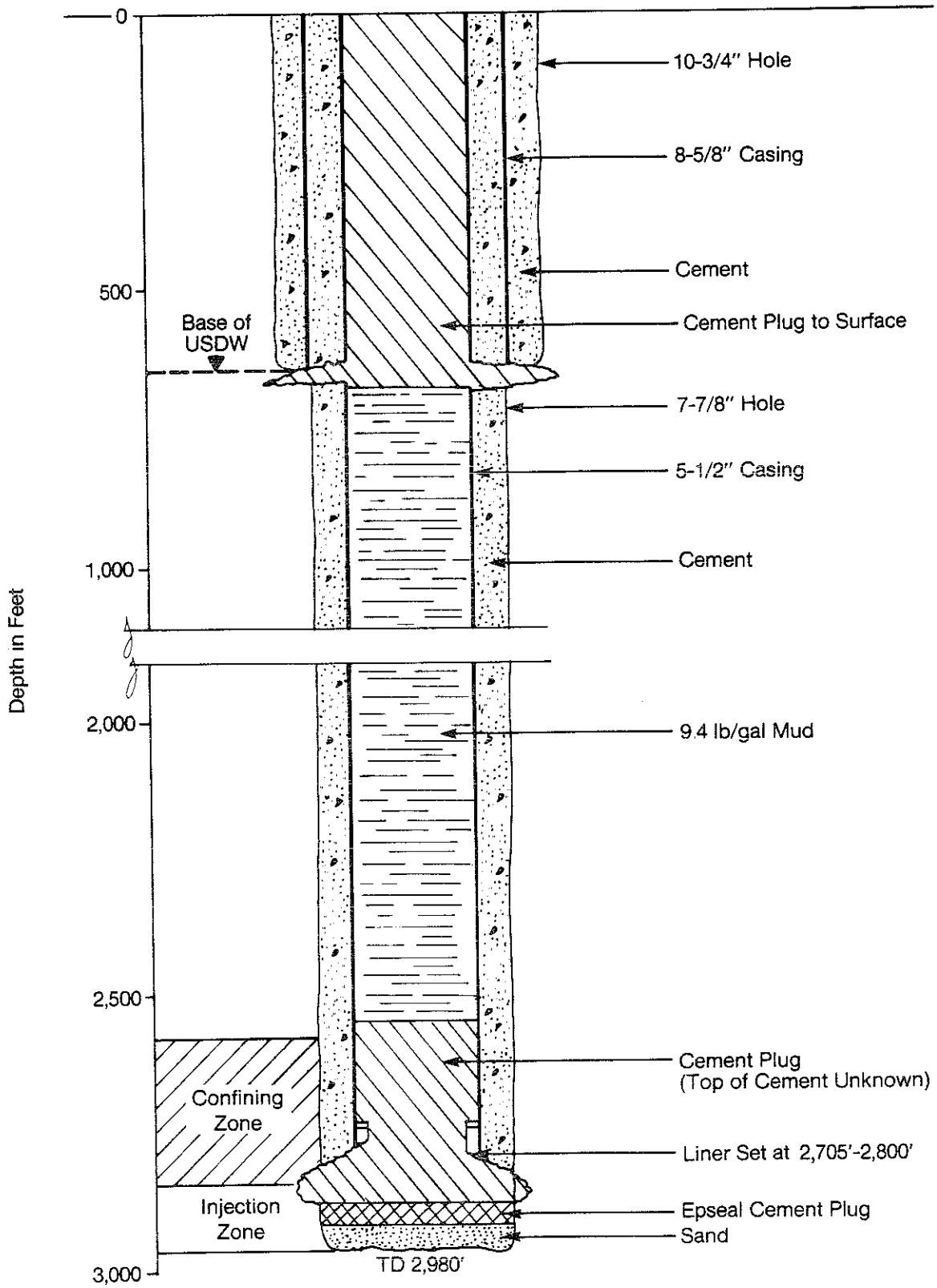
and, while personnel attempted to clean out the hole, a cable tool bit and jars were lost in the hole. Injection rates began to climb with a decrease in injection pressure until, in 1981, the well was injecting 60 gpm at 700 psi. The injection pressure declined to 400 psi in the next 8 months. A 1983 mechanical integrity test located a leak in the casing of 2,603 to 2,665 feet. An estimated 15 million gallons of fluid have leaked from Well 4 (Underground Resources Management, 1983).

Well 5 injection rates fell from 13 gpm at 840 psi to 8 gpm within the first week of operation. Acidizing the well only increased the flow to 15 gpm at 750 psi and the well was stimulated with explosives. Injection rates rose to 27 gpm at 840 psi but within two weeks fell to 9 gpm. Annulus pressures increased rapidly in August 1981 and the tubing was found to have separated. After replacing the tubing injection was resumed at 30 gpm at 780 psi. The tubing parted again in October 1981 at 1,503 feet. After replacing the tubing, injection fell to 9 gpm at 780 psi in December 1981. The well was idle until July 1982 and was worked over by scraping and resetting the packer. Injection rates in July were 10 gpm at 700 psi. In October 1982, the well was hydrofractured with a sand propant. After reassembly, the well took 67 gpm at 600 to 640 psi. A small leak in the casing was found during a 1983 mechanical integrity test between 2,768 and 1,290 feet (Underground Resources Management, 1983).

Well 6 experienced a tubing part at the wellhead in May 1981 within the first two weeks of operation and all annular fluids were apparently injected into the Mt. Simon. The well was rebuilt but the packer would not seat and pressure rose in the annulus within one week upon restart of injection. The packer was re-installed and injection begun after

2½ months but the tubing ruptured after 6 hours of injection. The well was rebuilt again and injection resumed after 3 months. Within two weeks, injection and casing annulus pressures equalized, indicating communication around the annulus. Injection proceeded until late 1983 when a mechanical integrity test was performed. The test revealed that the casing in the interval 2,682 to 2,728 feet had been corroded away. It was estimated that as much as 9 million gallons of liquid had leaked from Well 6 (Underground Resources Management, 1983).

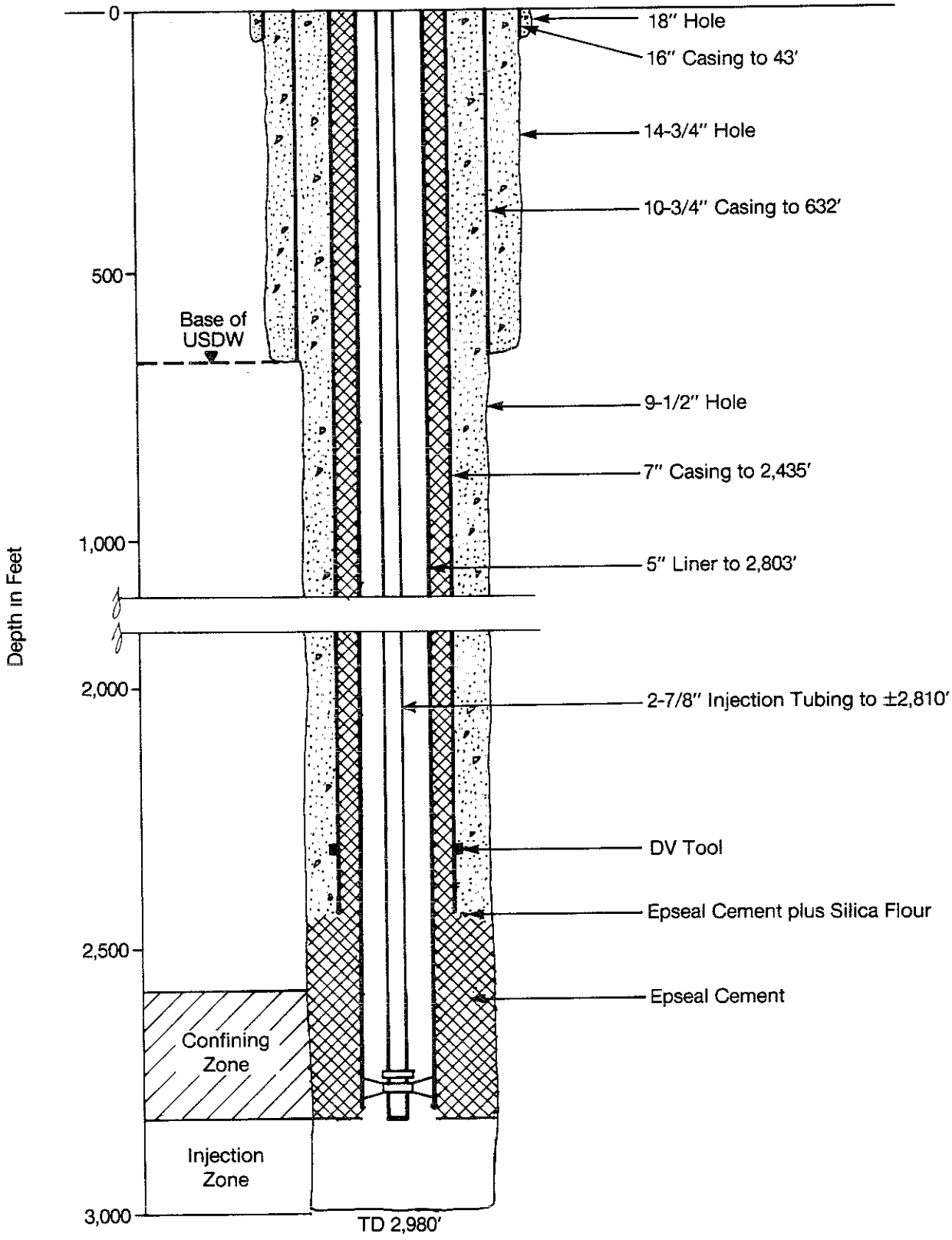
While all of the wells at the Vickery facility had experienced leakage of injection and/or annular fluids into unpermitted zones, all located leaks were well below the base of the USDW's in the area and no significant harm to human health or the environment resulted (Texas World Operations, 1985).



CHEMICAL WASTE MANAGEMENT
Vickery, Ohio

WELL NO. 1 (Plugged and Abandoned July 1980)

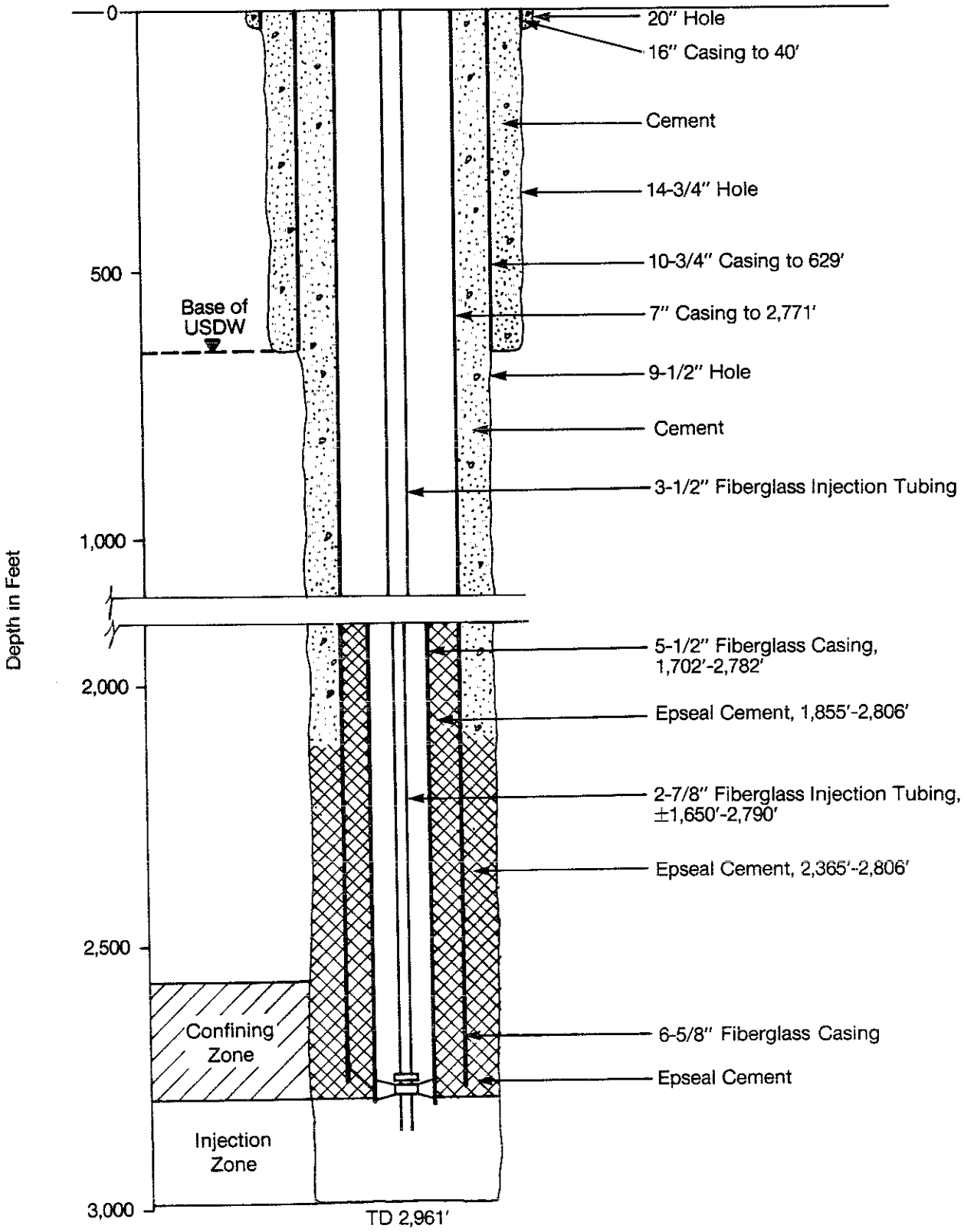
D19976.P0



CHEMICAL WASTE MANAGEMENT
Vickery, Ohio

WELL NO. 1A

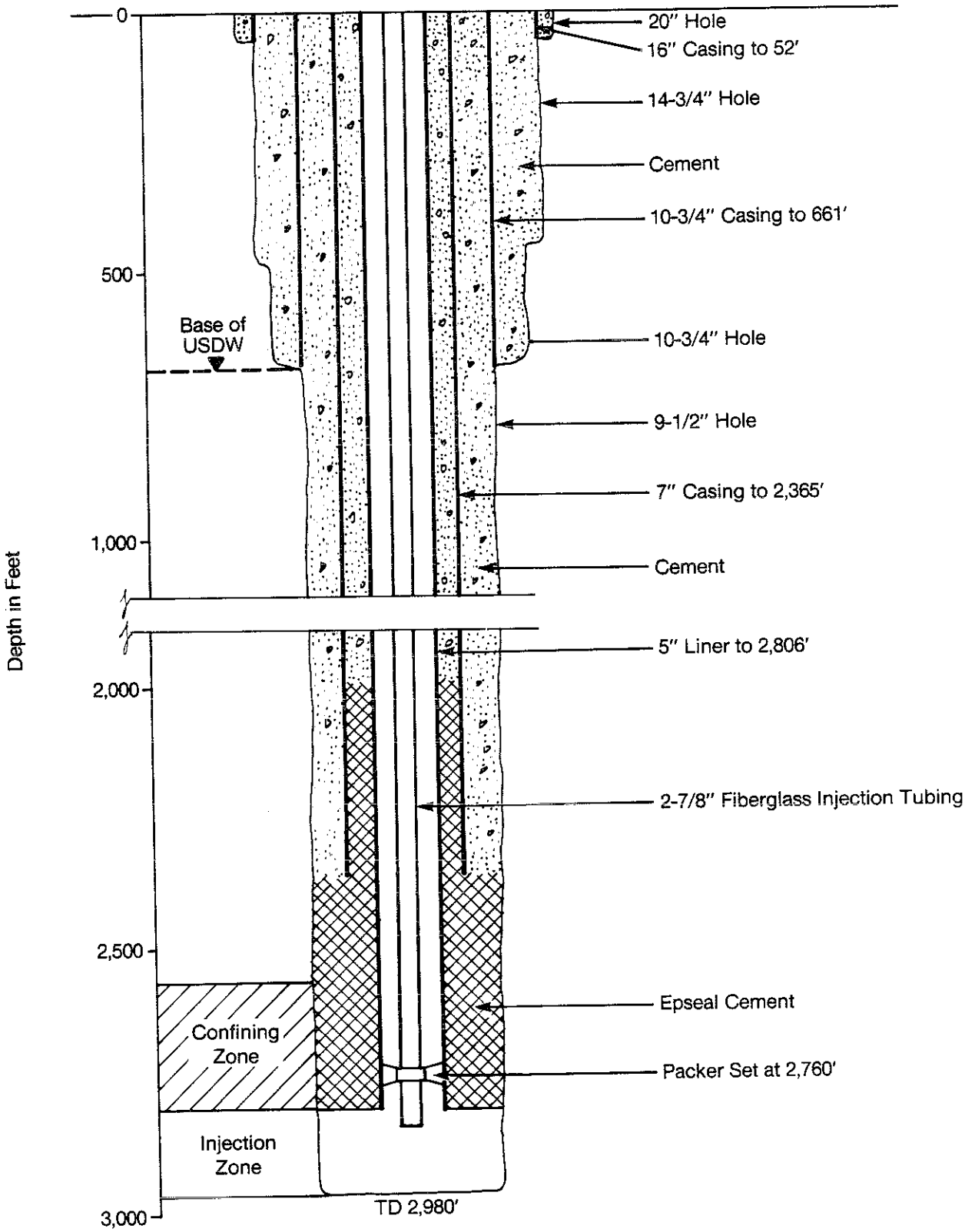
D19976.P0



CHEMICAL WASTE MANAGEMENT
Vickery, Ohio

WELL NO. 2

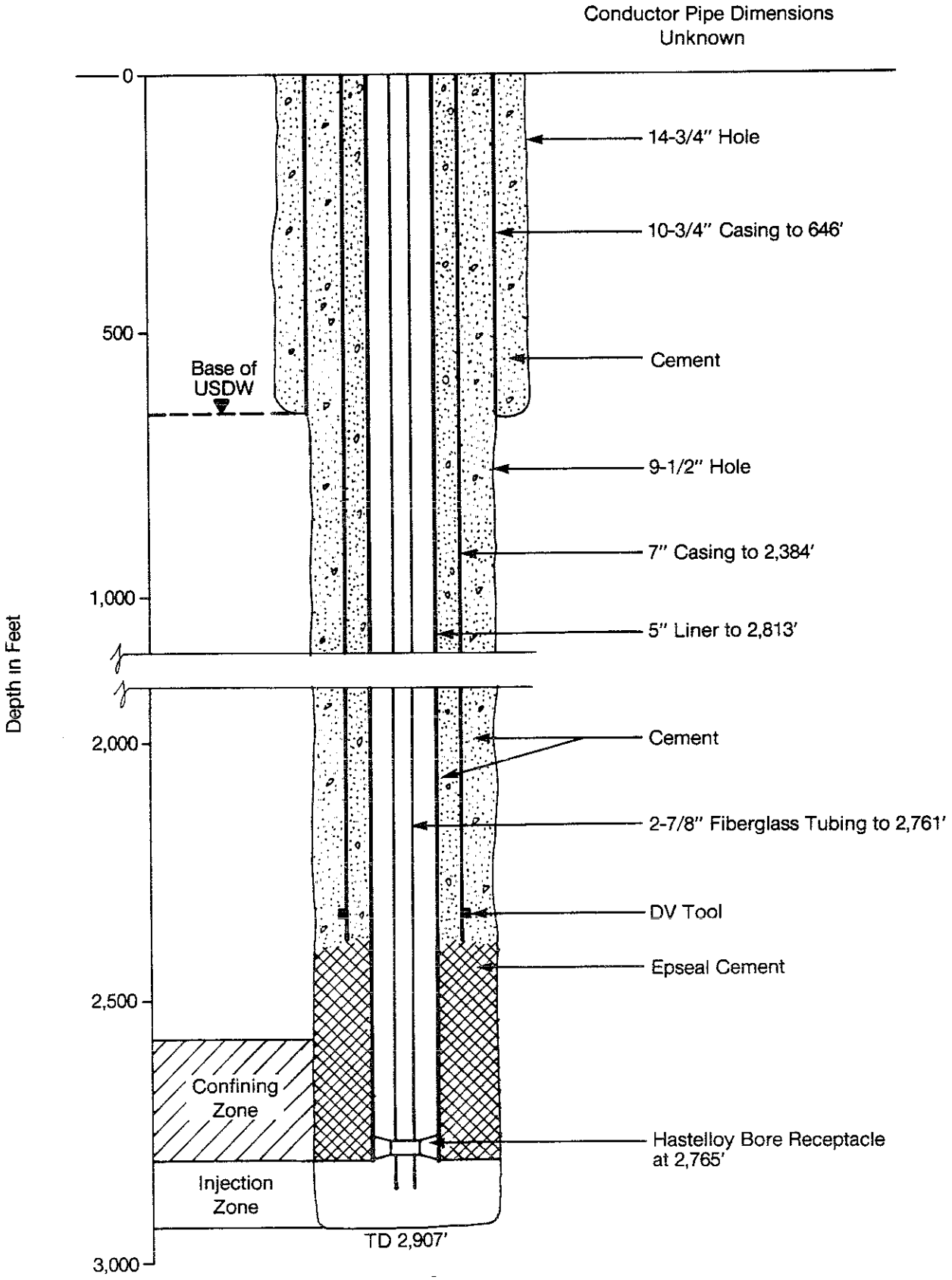
D19976.P0



CHEMICAL WASTE MANAGEMENT
Vickery, Ohio

WELL NO. 3

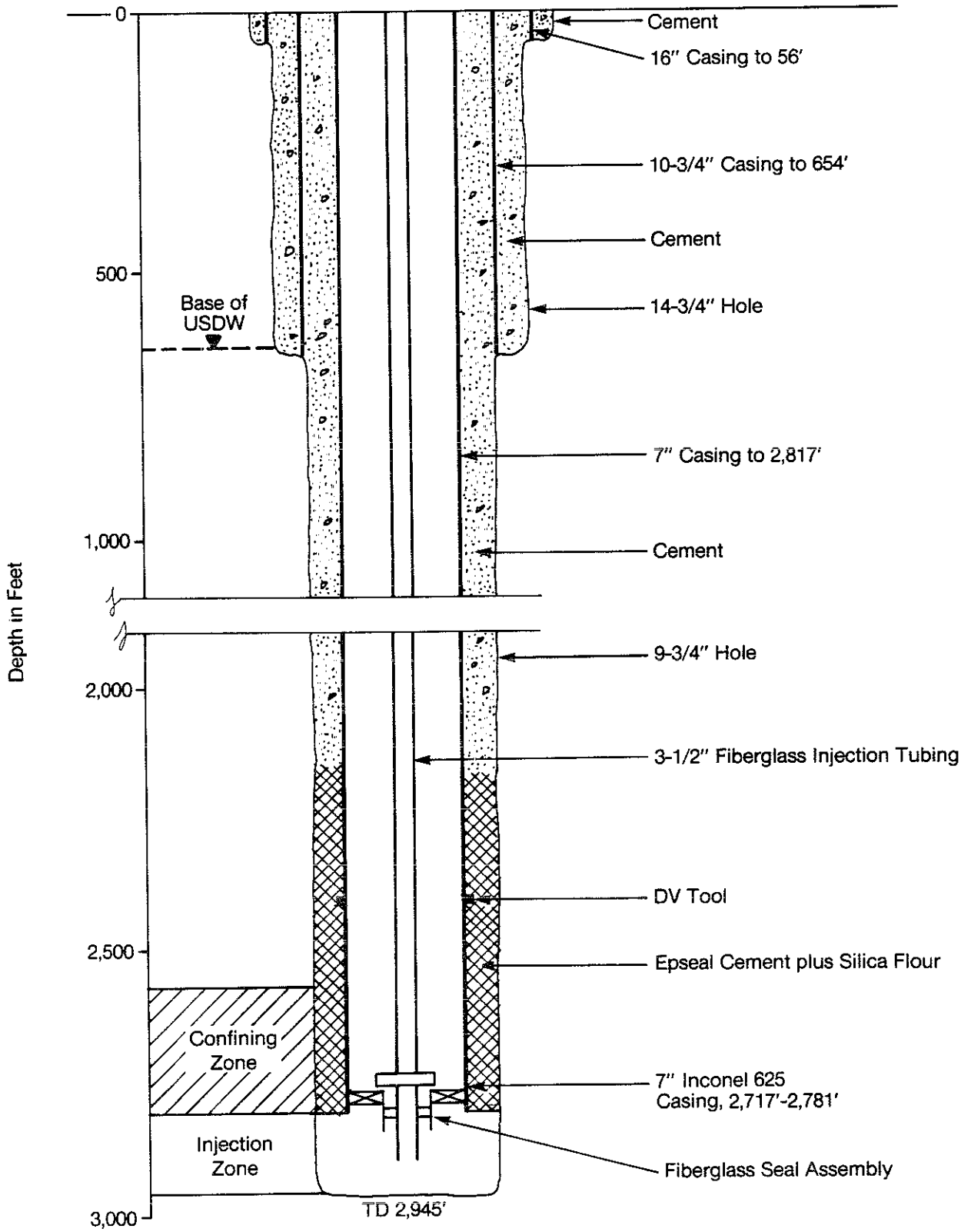
D19976.P0



CHEMICAL WASTE MANAGEMENT
Vickery, Ohio

WELL NO. 4

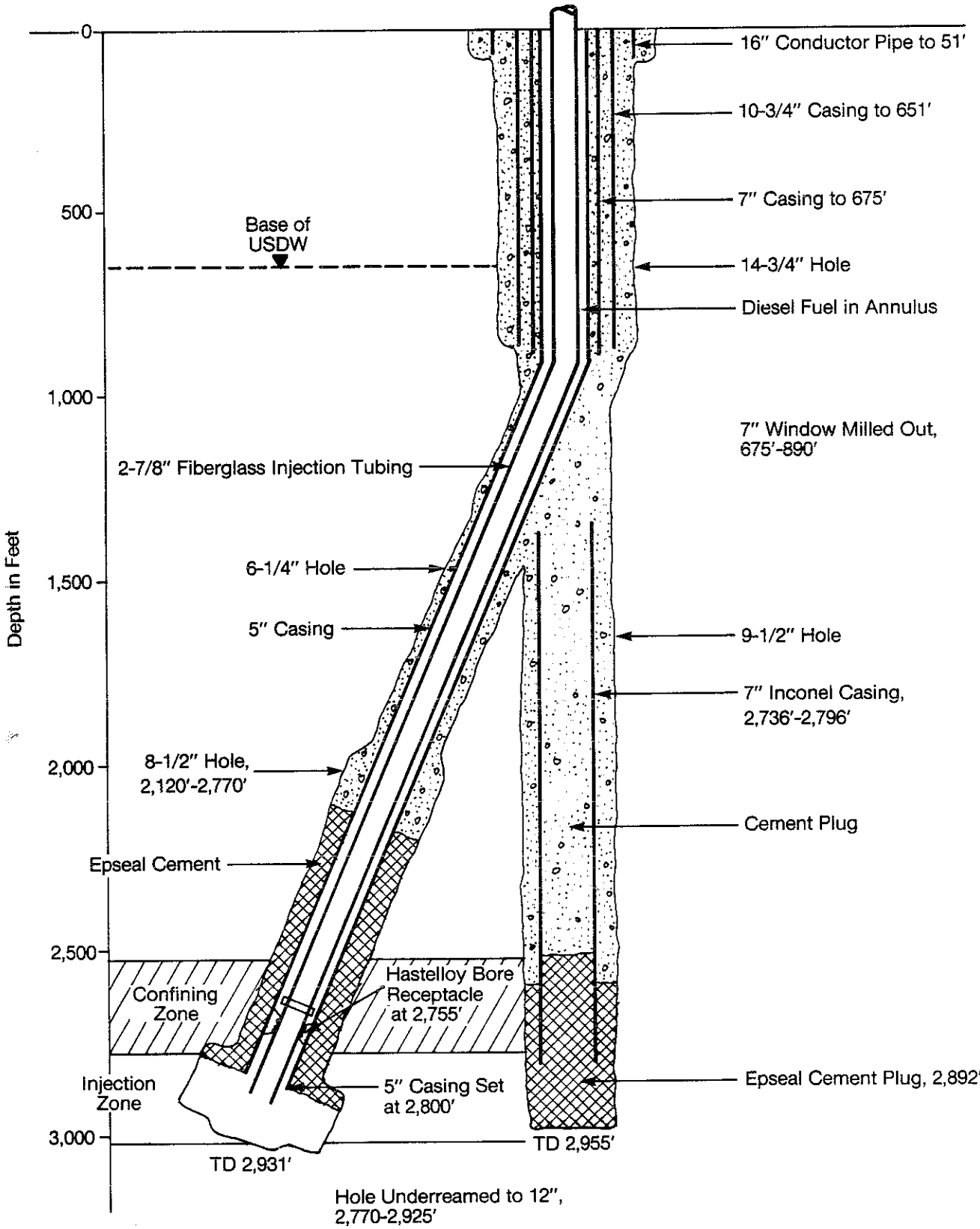
D19976.P0



CHEMICAL WASTE MANAGEMENT
Vickery, Ohio

WELL NO. 5

D19976.P0



CHEMICAL WASTE MANAGEMENT
Vickery, Ohio

WELL NO. 6

EMPIRE REEVES STEEL
MANSFIELD, OHIO

Background. Empire Reeves Steel, Division of Cyclops Corporation, constructed and operated the first waste disposal well in Ohio (Empire Reeves Steel Division, November 1968). The well was located at the Empire Reeves Steel Mill, north of the city limits of Mansfield in Richland County.

From the mill operations, a waste sulfuric acid pickle liquor is produced daily in amounts up to 50,000 gallons (Hoagland, 1966). The waste is 5 to 10 percent H_2SO_4. The waste stream was first filtered, passed through a surge tank, and then pumped down the well under pressure.

The injection system was designed for surface pressures up to 3,000 pounds per square inch (psi) with flow rates of 72 gallons per minute (gpm). However, while the well was in operation the surface pressures averaged 300 psi to 1,500 psi with flow rates averaging 18 gpm (Empire Reeves Injection Well File). Over 10 million gallons of pickle liquor was disposed of during the life of this well.

The well was plugged in 1971 because of severe corrosion of the tubing and casing.

Site Description. The injection well disposes of waste into the Mount Simon Sandstone. This is the basal sand overlying the Precambrian basement surface in Ohio and occurs in the area from approximately 4,750 feet to 4,870 feet.

Overlying the Mount Simon is the Eau Clair Formation. The Eau Clair is reported as low permeability dolomite with interbedded shales and is approximately 150 feet thick. The base of fresh water is reported to be approximately 500 feet.

Well Construction Details. The Empire Reeves disposal well was constructed by setting 10-3/4-inch casing at 674 feet and cementing it to the surface. A 7-inch casing was then set at 4,975 feet and cemented to the surface. An open hole exists from 4,975 feet to 5,085 feet. A 3-1/2-inch plastic-lined steel injection tubing was set in a packer at 4,974 feet.

After a packer leak was detected, the packer was moved up to 4,743 feet and 210 feet of fiberglass tubing was installed beneath it.

Chronology of Operational Problems. The Empire Reeves disposal well begin injecting spent pickle liquor on November 11, 1968. Injection continued without interruption until April 1969 when the annulus monitor system detected a tubing or packer leak. To address this problem, the annular pressure was kept higher than the injection pressure during injection by injecting inhibited water down the annulus.

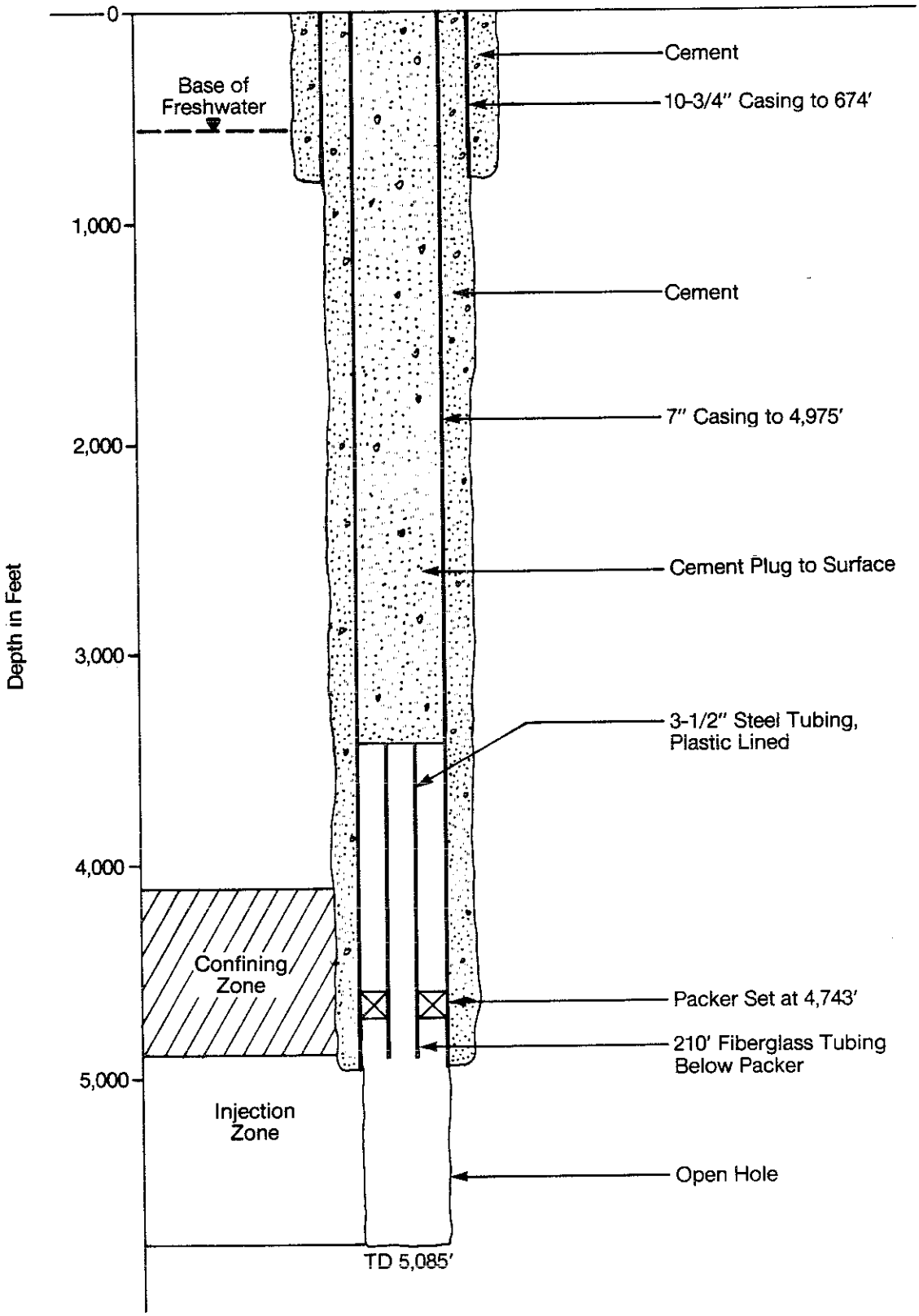
In June 1969, the well was inspected and a packer leak resulting from corroded casing was found. The packer was moved up from 4,974 feet to 4,743 feet and 210 feet of fiberglass tubing was installed beneath the packer (Deep Well Pollution Control Corp., 1969).

In August 1969, another packer failure was discovered. Fresh water was again continuously pumped down the annulus during waste injection (Haddad and Brooks, 1970). Empire Reeves was instructed by the Department of Natural Resources to repair the well by December 1969. In December 1969, March 1970, and again in May 1970, Empire Reeves requested an extension of the deadline for repairing the well. The well was kept in service during this time (Empire Reeves Steel, December 1969, March 1970, and May 1970).

In June 1970, repair work on the well began. The tubing was found parted and badly corroded. Only approximately 3,400 feet could be fished out in 6 days. The 7-inch casing was also found to be badly corroded. Danger of its collapse was partly the reason for not fishing out all the tubing. A caliper survey indicated extreme corrosion of the 7-inch casing from the blockage at 3,388 feet to 2,950 feet and from 1,870 feet to 2,220 feet (Empire Reeves Steel Division, June-July 1970).

In February 1971, the injection well was permanently plugged with cement (Williams, 1971).

D19976.PO



EMPIRE--REEVES STEEL DIVISION
OF CYCLOPS CORPORATION
Mansfield, Ohio

AMERICAN AIRLINES, INC.
TULSA, OKLAHOMA

Background. American Airlines, Inc., uses deep injection wells at their Tulsa, Oklahoma, facility to dispose of wastewater generated during aircraft maintenance operations. The American Airlines Maintenance and Engineering Center is located in Tulsa County. The total area of the facility is about 270 acres.

Waste injected into the deep wells is mainly water containing various solvents, cleaners, and acids used during maintenance work on aircraft exteriors, interiors, and engines. The present annual injection volume is about 108 million gallons per year (Oklahoma State Department of Health (OSDH) Fact Sheet, 1985).

Injection at this facility began in February 1960, into a single 3,060-foot well. The original well (Well No. 1) is still in use. A second well (Well No. 2), 3,100 feet in depth, has been completed, but has not, as of October 1985, been placed in service. Other surface facilities include two large concrete equalization tanks in which waste streams are collected before injection, and a pump station housing three positive displacement pumps having a combined capacity of 435 gallons per minute (gpm).

Monitoring facilities include eight shallow wells situated around the equalization tanks, and two 250-foot wells onsite monitoring the first USDW above the disposal zone. Injection pressure and rate, and annulus pressure are continuously recorded and reported monthly. One deep monitoring well (MW-2) is sampled monthly, and the samples are analyzed for parameters specified in the operating permit.

Water levels are measured and samples taken quarterly from the eight shallow wells around the equalization tanks.

Although Well No. 1 appears to be operating normally, the well bore is obstructed at a depth of 1,825 feet. Also, the annulus between the injection tubing and casing is filled with solids of unknown composition, up to a depth of approximately 1,510 feet. The fill in the annulus prevents removing the tubing for mechanical integrity inspections and a workover to remove the observation in the well bore. Because of OSDH concerns about the mechanical integrity of Well No. 1, American Airlines consented to the construction of Well No. 2 to provide for wastewater disposal in case Well No. 1 becomes unusable. An operation permit for Well No. 2 is pending. American Airlines is currently evaluating alternatives for reworking or plugging Well No. 1.

Site Description. The American Airlines Maintenance and Engineering Center is located at an airport industrial complex north of the City of Tulsa, Oklahoma. The facility encompasses about 270 acres. The injection wells and related surface facilities are situated in a 2-acre compound in the north-central part of the facility.

Sources of potable groundwater are limited at the site. Practically all potable water is obtained from surface sources. At depths greater than 250 feet, groundwater in the area contains more than 10,000 mg/L total dissolved solids (TDS). Potential aquifers containing less than 10,000 mg/L TDS include the alluvium, to a maximum depth of approximately 60 feet, and the Oologah Formation to a maximum depth of approximately 250 feet (Williams Brothers, 1982).

The disposal zone is the Arbuckle Group of the Ordovician and Cambrian systems (Williams Brothers, 1982). The zone

includes the Arbuckle Dolomite, the Reagan Sandstone and the underlying "granite wash." The total thickness of the zone is slightly over 1,300 feet. Consultant reports indicate that there is about 90 feet of permeable strata within this zone in Well No. 1. The top of the zone (the Arbuckle Dolomite) occurs in well No. 1 at a depth of 1,729 feet. The thickness of the disposal zone is variable, and is controlled largely by the topography of the underlying bedrock (Precambrian) surface. Regionally, the Arbuckle Group sediments dip toward the southwest at approximately 45 feet per mile.

The primary confining bed is the Woodford Shale with a thickness of approximately 40 feet. The Tyner Shale, below the Woodford, and the Mississippian limestone, overlying the Woodford, also act as confining beds. The aggregate thickness of these confining beds is about 500 feet.

Well Construction Details. Well No. 1 as completed in October 1959, had two steel casings and 5-1/2-inch steel injection tubing set with a packer. The well was completed open-hole through the Arbuckle Group, and penetrates a few feet into the underlying granite.

The surface casing is 10-3/4-inch OD, steel set at a depth of 416 feet and cemented to the surface with Portland cement. The long casing string is 7-inch OD, steel casing set at a depth of 1,807 feet and cemented to the surface with pozzolan cement. The injection tubing is 5-1/2-inch OD steel and extends to a depth of 1,755 feet. The injection packer assembly consists of a Baker Sliding Sleeve, Arrow casing packer, and seating nipple.

The first workover of this well referred to in agency files occurred in December 1971. No specific details of this

operation are available. Records indicate that casing inspection and electronic casing caliper logs were run at that time, and showed the casing and tubing to be in good condition.

A workover planned for December 1982 was suspended because the packer would not release to allow removal of the injection tubing. The tubing was subsequently found to be stuck below 1,510 feet, presumably because of fill in the annulus. The well bore is obstructed at a depth of 1,825 feet, about 18 feet below the packer. The well is being operated in this configuration.

Well No. 2, completed in November 1984, is 3,110 feet deep. The surface casing is 13-3/8-inch OD steel, set to a depth of 471 feet and cemented to the surface. The long casing string is 9-5/8-inch OD steel, set to a depth of 1,791 feet and cemented to the surface. The bottom 30 feet of the 9-5/8-inch casing is Type 316 stainless steel. The injection tubing is 5-1/2-inch steel, set with a packer to a depth of 1,771 feet. The well is completed open hole in the Arbuckle Group.

The deep monitoring wells at this facility are constructed with 4-inch PVC pipe and slotted screen gravel packed in a 7-7/8-inch hole. The annulus above the gravel pack is sealed with bentonite and cement.

Chronology of Operational Problems. The only operational problem reported from the time of the initial operation in 1959 until the discovery in December 1984 that the well bore was obstructed has to do with the recording and reporting of injection flow rates. Rules of the ODSH require the continuous recording of injection rate; since the American Airlines facility uses positive displacement pumps, the

operator reported "pump-on" and "pump-off" times, and calculated the corresponding injection rates. Several non-compliance notices were sent regarding the issue, which appears to have been resolved by requiring continuous recording of the operating period for each injection pump.

The reason for the workover performed on Well No. 1 in 1971 is not known. Records of the mechanical integrity logs suggest that no major work was done. The planned 1982 workover was in response to OSDH concerns over the mechanical integrity of the well.

In November 1982, American Airlines initiated a mechanical integrity testing program in Well No. 1. During this testing, the borehole was found to be obstructed at a depth of 1,825 feet. The workover contractor then attempted to remove the 5-1/2-inch injection tubing in preparation for cleaning out the well bore to its original depth.

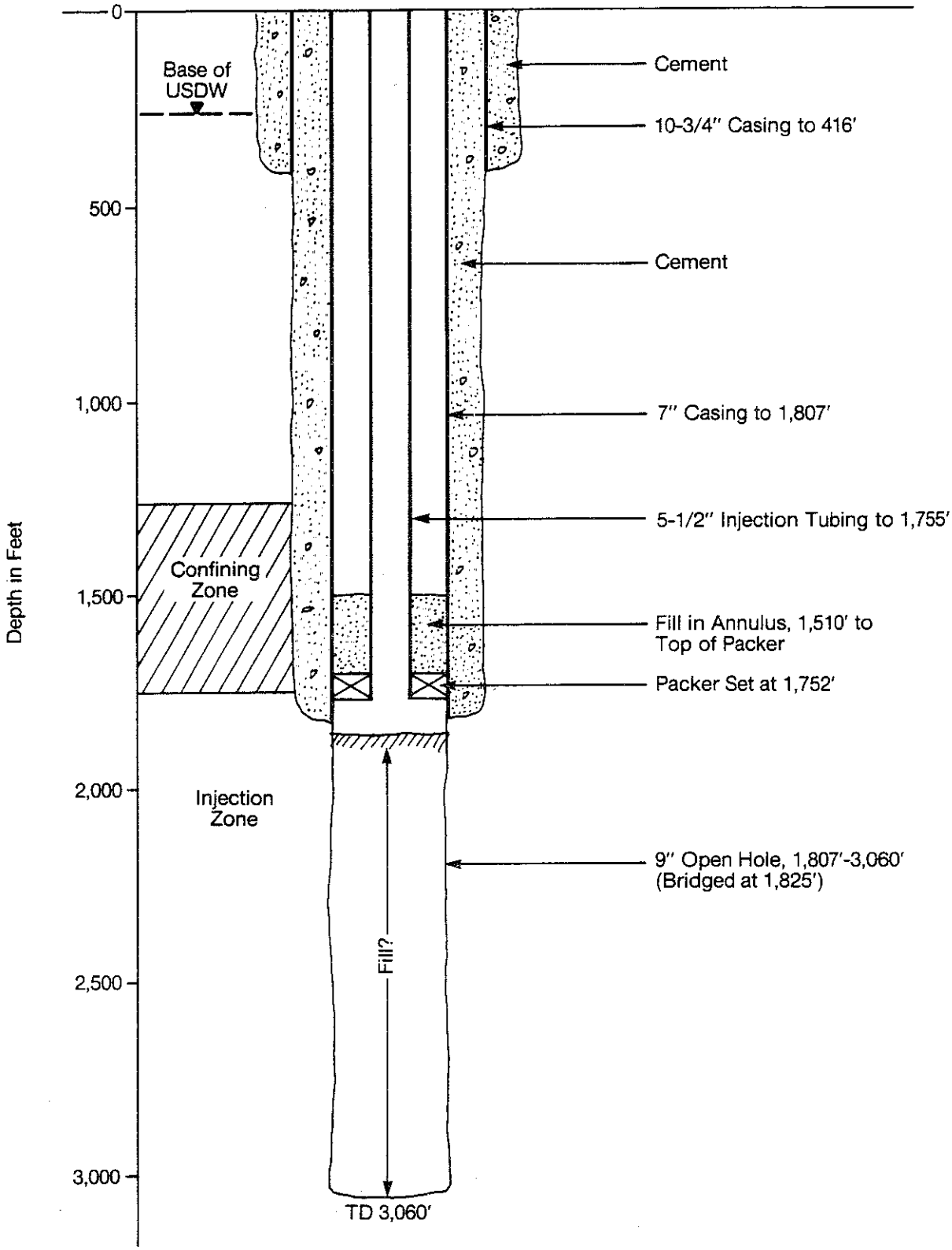
Attempts to remove the tubing were unsuccessful because the packer would not release. A free point indicator survey determined that the tubing was stuck in the annulus at 1,510 feet (Williams Brothers, 1982). The stuck tubing was attributed to a buildup of sludge in the annulus above the packer (OSDH, 1983). The presumed sludge buildup was considered to be highly suggestive of a casing or tubing leak, although a May 1983 radioactive tracer survey showed no leakage.

Confirmation of mechanical integrity would require that the well be out of service for a substantial length of time, which was not acceptable to American Airlines. To resolve this issue, American Airlines agreed to construct a second well (Well No. 2), and that well No. 1 would remain in service until an operation permit was issued for Well No. 2.

A consent agreement was entered on December 27, 1983, between American Airlines and OSDH regarding replacement or repair of the injection well, and establishing a schedule for compliance.

Well No. 2 was completed in November 1984, but has not yet been issued an operation permit. Well No. 1 remains in use pending issuance of the permit.

D19976.P0



AMERICAN AIRLINES, INC.
Tulsa, Oklahoma

DISPOSAL WELL NO. 1

AGRICO CHEMICAL COMPANY
VERDIGRIS PLANT
ROGERS COUNTY, OKLAHOMA

Background. The Agrico Verdigris Plant is located near the town of Catoosa in northeastern Oklahoma, about 20 miles northeast of Tulsa. The plant site occupies about 620 acres, part of which is within the flood plain of the Verdigris River. The plant manufactures chemical fertilizer.

The process generates 600 to 800 gpm of rinsewater, process wastewater, and cooling tower blowdown. The waste stream contains chromium nitrates, ammonia, caustic brine, and spent cleaning and water treatment chemicals. Prior to December 1977, the wastewater was discharged to onsite lagoons for disposal. Since that date, the waste has been injected into the brine-bearing Arbuckle Limestone via a 2,733-foot deep well. Injection pressure ranges from 240 to 310 psi. Permitted maximum injection pressure at the surface is 320 psi. Surface facilities include a lined equalization pond to allow blending and cooling of wastes prior to injection and a 21,000-gallon capacity surge tank. A deep monitoring well open to the base of the USDW and four shallow wells in the USDW are provided. Monitoring parameters include injection pressure, rate, and temperature; annulus pressure; and water quality in the deep monitoring well. Data are submitted monthly to Oklahoma State Department of Health (OSDH).

Three malfunctions have been reported since the well was placed in service in late 1977. In each case, fluctuations in annulus pressure indicated a tubing or packer leak and, upon inspection, the indicated leak was found at the packer. The packer was repaired or replaced as needed, and the leakages ceased. Reported groundwater contamination of the

uppermost aquifer in the vicinity was found upon inspection to be associated with a leaking surface impoundment.

Site Description. Agrico Chemical Plant area consists of 620 acres in Rogers County, Oklahoma. The site is located in the Central Lowland physiographic region, west of the Ozark Plateau. Near-surface rock formations of Pennsylvanian age dip toward the west or northwest, forming steep eastward facing escarpments. The topography of the region consists of a succession of gently rolling hills and broad river valleys that follow the strike of the underlying rocks (Woodruff, 1928). At the Agrico site, which is located in the flood plain of the Verdigris River, the topography is flat and lies at an elevation of 574 feet above mean sea level. A 50- to 200-foot thick veneer of alluvial sands and gravels overlie Pennsylvanian-age bedrock of limestone, shale and evaporites.

Beneath the Pennsylvanian formations lie limestones, sandstones, and shale of Mississipian age. These deposits overlie the Arbuckle Limestone of early Ordovician age which in turn overlies Precambrian granite.

The formations underlying the site are not favorable for development of groundwater supplies (Marcher, 1971). Wells yield only a few gallons per minute when completed in the shales, siltstones, sandstones, and limestones of Pennsylvanian and Mississippian age. Locally, along the Verdigris River, wells tapping the alluvial deposits of sand and gravel in the upper 50 feet of the soil profile may yield from 10 to 30 gpm. However, no aquifers containing a significant source of drinking water are present (Schoft, 1955).

The principal sources of oil and gas in the area are the Bartlesville and Burgess sands encountered at the site between depths of approximately 700 to 1,000 feet. Possible oil and gas yields may be found in the Mississippi Lime, a principal producing horizon in the Catoosa field. No producing oil or gas wells are known within a 2-mile radius of the Agrico site. Records show four wells, all plugged and abandoned, that penetrated the Arbuckle Lime within the area of review.

The primary injection zone is the Arbuckle Limestone and the Reagan Sand between the depths of 1,382 and 2,715 feet. These formations contain saltwater and total dissolved solids above 100,000 mg/L (Godsey-Erlougher, 1979).

The primary confining zone is the Woodford Shale and the Tyner Formation between 1,284 and 1,380 feet in depth.

Well Construction Details. The injection well is constructed with a 20-inch surface casing to a depth of 40 feet, a 13-3/8-inch middle casing to 200 feet and a 9-5/8-inch production casing set to a depth of 1,506 feet. All casings are completely cemented to land surface. Installed inside the production casing is 1,427 feet of 7-inch OD, 7.9 lb/ft, 0.45-inch wall glass Texas Fiberglass Products tubing. This liner is sealed to the production casing by a permanently installed packer set at 1,454 feet. The well is completed with open hole from 1,506 feet to a total depth of 2,733 feet below the ground surface (elevation--2,159 feet below mean sea level). The principal geologic formation of the injection zone is the Arbuckle Limestone, present between depths of 1,382 and 2,656 feet.

A spinner flowmeter survey conducted while injecting indicates by the upper portion of the Arbuckle above 2,260 feet

receives little fluid and therefore may have some confining characteristics.

The deep monitoring well is located about 100 feet west of the injection well, toward the Verdigris River. This well was initially constructed using a 5-1/2-inch outside diameter (O.D.) steel casing pipe that was perforated between depths of 180 to 190 feet, 136 to 146 feet, and 90 to 100 feet, and would yield only about one quart per hour of salty water. A plug was then set in the well at a depth of 120 feet, and the casing perforated at 68 to 88 feet. As completed, the well yields about one gallon per hour of brackish water.

Chronology of Operational Problems. On April 3, 1980, Agrico personnel notified OSDH that the well had been shut down because of a suspected communication between the annulus and injection tubing (Agrico, 1980). The tubing was removed from the well for inspection, and found to be in good condition. However, the tubing was replaced with 7-inch O.D. fiberglass tubing manufactured by Texas Fiberglass Products. A new packer was also installed, leaving the original packer in place to provide a "double packer" configuration. A pressure test confirmed that the leak had been repaired (OSDH, 1980).

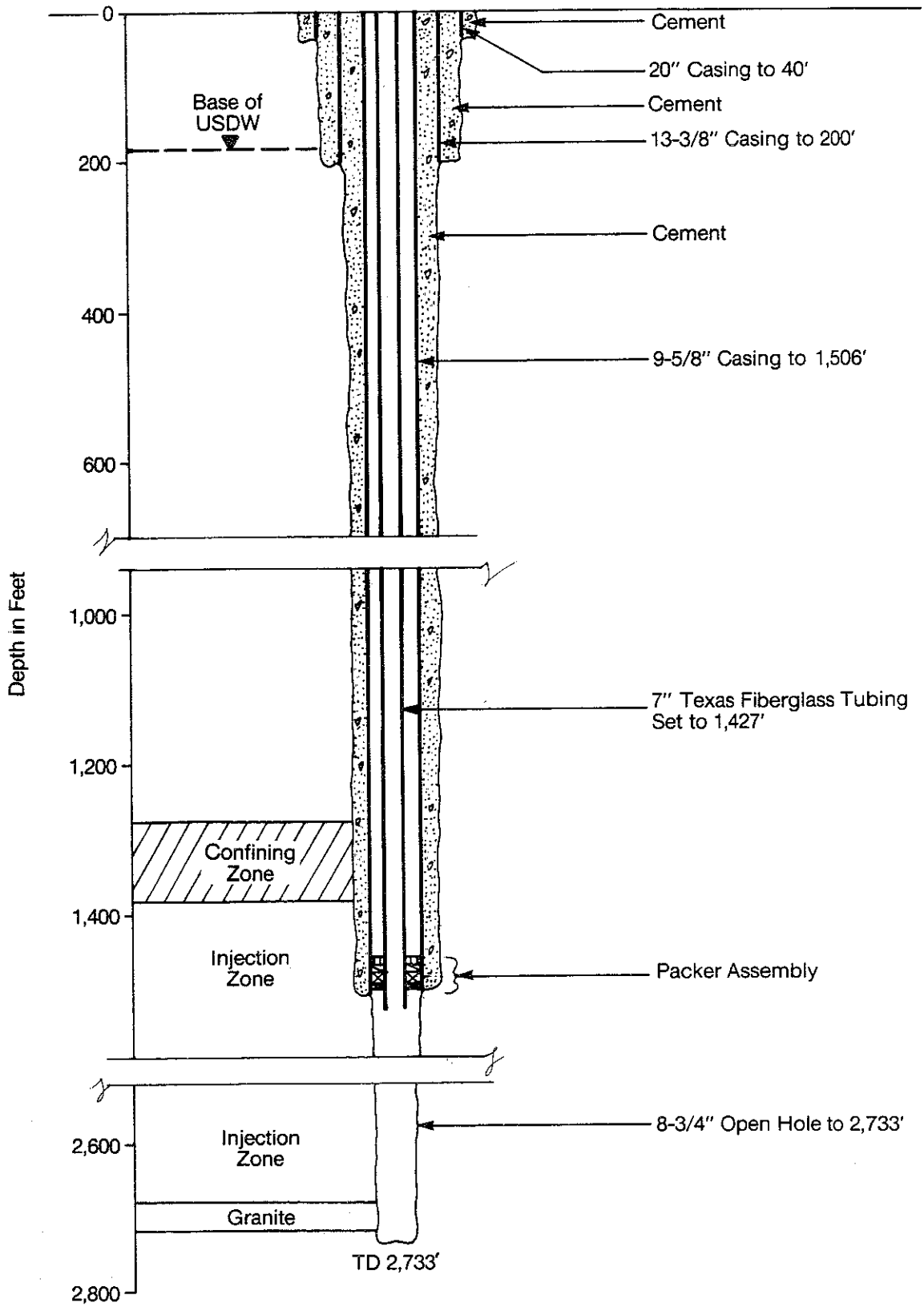
Suspected communication between tubing and annulus was again reported in June 1982, and the tubing was removed for inspection. The workover report (Williams Brothers, 1982) indicates that the cause of the leak was a 2-inch hole in the packer assembly. The packer was again replaced and the well returned to service. During the June 1982 workover to replace the packer, geophysical surveys including a casing inspection log, a cement bond log, an audio leak detector survey, and a differential temperature log, were run. These logs and surveys confirmed the mechanical integrity of the 9.625-inch casing (Williams Brothers, 1982).

In March 1983, an increase in annulus pressure was reported (Williams Brothers, 1983) indicating a possible leak. Again, the liner was removed for inspection and packer replacement.

None of the incidents described above allowed the escape of wastewater into a USDW or an unpermitted disposal zone. Each incident seems to have been detected and corrected quickly, before the main structure of the well was damaged.

Incidents of groundwater contamination in the vicinity of the Agrico plant in 1980 (iron and manganese in a private well) and 1982 (high nitrates in shallow monitoring wells) were reported by the company to be related to natural conditions and a leaking surface impoundment, respectively.

D19976.P0



AGRICO CHEMICAL COMPANY
Verdigris Plant, Rogers County, Oklahoma

DISPOSAL WELL NO. 1

CHEMICAL RESOURCES, INC.
TULSA, OKLAHOMA

Background. Chemical Resources, Inc. (CRI), operates a commercial waste disposal facility located in an industrial complex near Tulsa, Oklahoma. Waste is injected into a single 3,364-foot disposal well at the facility. The only liquid wastes not accepted are PCB's, chlorinated organics, hydrofluoric acid, radioactive wastes, and wastes containing more than 3 percent cyanide. Wastes are delivered primarily by tank truck and rail. Depending on the operation schedules at the facility and the waste composition, individual batches of waste could be pumped directly to the well or stored in onsite holding tanks for treatment or blending.

The injection well was drilled in 1973. A permit was issued for operation as an industrial waste disposal facility in March 1974. The initial use of the well was disposal of spent acid wastes from neighboring metal plating and galvanizing plants. In September 1975, the facility began accepting wastes from other industries.

The injection system consists of one 3,364-foot deep well, one 90-foot monitoring well completed into the Cleveland Sand (lowest USDW), several waste storage tanks, a surface impoundment, a positive displacement injection pump, and associated piping and monitoring equipment. Seven shallow groundwater monitoring wells at the site are used primarily for monitoring shallow groundwater near the surface facilities.

Leaks in the injection tubing and casing in 1983 allowed injection into a zone overlying the permitted injection zone (William Brothers, 1984). Remedial cementing of the casing, installation of a liner, and replacement of the injection

tubing and packer corrected the malfunction. Most of the actions and complaints relate to surface handling of wastes and are not considered relevant to the operation of the injection well.

Site Description. The site is located on the flood plain of the Arkansas River, near Tulsa, Oklahoma. It is in an industrial complex and occupies about four acres. A concrete dike surrounds the site to capture spilled waste liquids and to protect the site from flooding at the 100-year flood elevation.

The only potential drinking water aquifers in the area are the Checkerboard Limestone and the upper part of the Cleveland Sand. The 10,000-mg/L total dissolved solids (TDS) isopleth occurs within the Cleveland Sand at a depth of 100 feet or less.

The injection well is 3,364 feet deep, and is completed open hole from 2,093 feet to 3,364 feet. The injection intervals are the Arbuckle Lime between 2,093 and 3,285 feet, and the Cambrian-age sandstone from 3,285 to the top of the granite at 3,360 feet. The Simpson Group sandstones that overlie the Arbuckle are hydraulically contiguous with the Arbuckle, and function as a part of the disposal zone. The TDS content of the injection zone ranges from 167,000 to 170,000 mg/L.

The primary confining unit is the Woodford Shale and shale in the basal unit of the Mississippian limestone. The aggregate thickness of shale is about 50 feet.

The effective permeability of the injection zone was initially estimated by CRI to be approximately 200 millidarcies.

Injection pressures range between 400 and 600 psi (well-head), depending on the specific gravity of the waste being injected. Pressures up to 1,000 psi were experienced prior to cleaning and acidizing the well in March 1985. The injection rate is approximately 90 gpm.

Some waste invaded the overlying Mississippian Lime and Burgess Sand through holes in the well casing prior to 1983. The Burgess Sand is capped by a 340-foot thickness of shale. Thus, no upward migration of waste from the invaded zone is expected.

Well Construction Details. As originally completed, the well had two steel casings, and a 2-7/8-inch fiber-reinforced plastic injection tubing set with a packer. The 8-5/8-inch surface casing was set at a depth of 127 feet, and cemented with 100 sacks of Class A neat cement, circulated to the surface. The 5-1/2-inch, 15-lb/ft, long casing string was set at a depth of 2,093 feet, and cemented with 300 sacks of Class H cement, circulated to the surface. The injection tubing was set on a packer at a depth of approximately 1,990 feet.

A major workover of the well was completed in March 1983, with the installation of a liner and new injection tubing. During this workover, leaks in the existing 5-1/2-inch casing were repaired by squeezing with Class H cement. A 4-1/2-inch liner was installed inside the 5-1/2-inch casing to a depth of 2,071 feet, and cemented with 75 sacks of Class H cement, followed by 55 sacks of acid-resistant latex cement. The cement top between the 5-1/2-inch casing and 4-1/2-inch liner is 900 feet below the surface. A new injection tubing consisting of 2,130 feet of 3-1/2-inch OD Type 316L stainless steel tubing was installed with an Arrow Type H stainless steel packer set at 2,050 feet. Tubing extends about 90 feet below the packer.

Another rework was completed in March 1985 for the purpose of cleaning and acidizing the well, and determining its mechanical integrity. The well was cleaned out to total depth, and the tubing and packer were reinstalled as described above.

A total of eight monitoring wells have been installed at the site. Seven of these are completed with screens in the surficial aquifer at depths of 18 to 25 feet. The deep monitor well is completed in the Cleveland Sand between 36 and 91 feet in depth, and monitors at the base of the USDW. The wells are sampled quarterly and analyzed for pH, specific conductance, TOC, and TOH.

Other monitoring equipment includes a strip chart recorder for annulus pressure, injection pressure, temperature, well operating time, and the specific gravity of the fluid being injected.

Chronology of Operational Problems. No reports of non-compliance were found in agency files relating to injection at this facility from 1975 until November 1982. A workover of the well occurred in May 1981, but descriptions of the purpose and outcome were not found in Oklahoma State Department of Health files.

In November 1982, an inspection of the facility by Oklahoma State Department of Health staff revealed that the pressure in the well annulus was tracking the injection pressure (Oklahoma State Department of Health, 1983). No mechanical integrity test had been performed (or at least none were reported) since the well was placed in service in 1974.

In January 1983, the company was directed to run tests to determine the mechanical integrity of the well, and an

agreement to accomplish this work was signed March 5, 1983 (Oklahoma State Department of Health, January 1983).

In early March 1983, the 2-7/8-inch tubing was pulled and found to be leaking. The packer itself was in very poor condition. A tracer survey indicated 10 areas of casing damage between the depths of 1,337 and 1,618 feet. Other areas of damage were revealed by a casing caliper log and casing inspection log to a depth of 1,992 feet. Within the damaged interval, at least 18 holes were detected in the 5-1/2-inch casing. The casing was essentially disintegrated from 1,992 feet to the casing shoe at 2,093 feet (Oklahoma State Department of Health, March 1983). Most of the holes are reported to have been opposite impermeable strata, so that no waste could have escaped through them.

However, waste did escape through holes opposite the Burgess Sand and Mississippian Lime. Waste also escaped into the Simpson sands through the disintegrated casing, but this was considered of minor significance because this stratum is hydraulically contiguous with the injection zone. Neither of the zones invaded by wastes are USDW's. By late March 1983, the well workover had been completed, and the well returned to service on April 1, 1983.

Under the terms of the March 5 agreement, the operator had 30 days after April 1 to enter into a consent agreement providing for a mechanical integrity testing program, construction of a monitoring well to the lowest USDW and two shallow monitoring wells, installation of equipment for continuous recording of agreed monitoring parameters, and specific improvements to surface facilities.

The consent order had not been executed by May 1 (the target date) and the operator was directed to cease operations of

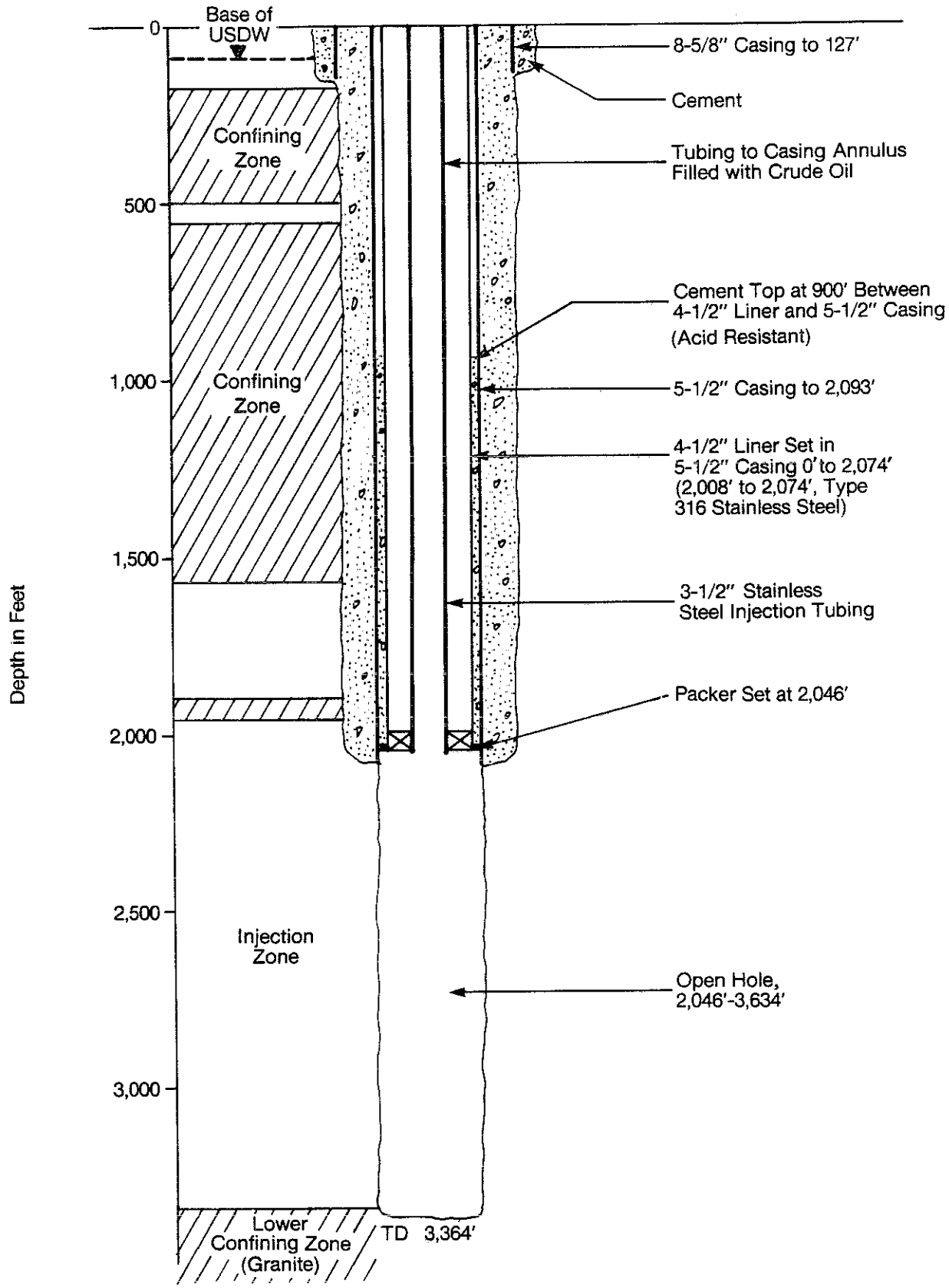
the well (OSDH, May 1983). On May 6, the consent order was signed, and an implementation schedule agreed upon.

Remedial actions under the consent order were substantially completed by July 24, 1983. Issues remaining unresolved at that time were resolution of permitted injection pressure, and the extent to which waste had invaded the Burgess and Mississippian formations as a result of the 1981-82 tubing and casing leaks. The latter issue was addressed in a waste invasion study submitted to OSDH in September 1984 (Williams Brothers, 1984).

In March 1985, the operator voluntarily implemented a well workover to meet injection pressure limitations proposed by OSDH. Based on tests performed during the workover, the operator requested OSDH approval of a higher operating injection pressure limit than that permitted by the state. At this writing, the request for a higher operating injection pressure limit is under review by the Oklahoma Industrial Waste Council.

The well now appears to be operating in compliance with current regulations except for the injection pressure issue.

D19976.P0



CHEMICAL RESOURCES, INC.
(After 1985 Workover)
Tulsa, Oklahoma

HAMMERMILL PAPER COMPANY
ERIE, PENNSYLVANIA

Background. The Hammermill Paper Company is located in Erie, Pennsylvania, on the shores of Lake Erie. The facility contained three onsite injection wells, classified as Class I non-hazardous, which handled waste from the Neutracel® pulping process (Brown and Spalding, December 1966). The pulp liquor wastes were piped to the surface treatment facility for disposal in the wells. Prior to treatment, the raw waste contained chlorides, sulfates, formates, acetate, and heavy metals. However, the waste characteristics would not now meet the minimum RCRA requirements for a hazardous waste classification.

In September 1961, the Sanitary Water Board of Pennsylvania decided to prohibit Hammermill's previously approved waste disposal to Lake Erie (Brown and Spalding, December 1966). The order was made effective in 1965, thereby encouraging Hammermill's investigation into alternative treatment and disposal methods.

The disposal well method was deemed feasible providing the pulp liquor characteristics were modified and the fluids filtered prior to injection (Brown and Spalding, December 1966). This form of treatment would remove particles or chemical precipitates that would plug the formation and cause increased injection pressures.

The wells operated at approximately 700 gallons per minute (gpm) with injection pressures ranging from 1,300 to 1,700 pounds per square inch gauge (psig) (Brown and Spalding, December 1966). There was no continuous monitoring indicated for the injection well operations. The total volume of liquor injected into the three wells was over one billion gallons.

All wells were plugged and abandoned in September 1972, as a result of casing corrosion in Well Nos. 1 and 2 (D'Appolonia, 1983). Well No. 1 was the only well that directly discharged wastewater to Lake Erie as a result of a casing leak (Brown and Spalding, 1966). However, the continued operation of the well system is alleged to have caused upward migration of wastewater and natural brines through an improperly abandoned gas well.

Site Description. The Hammermill facility is located on the shores of Lake Erie at a surface elevation of approximately 650 feet. The subsurface geology was based primarily on exploratory oil wells within the area. Dow Industrial Services Feasibility Report indicated that the information was poor, especially from wells drilled prior to 1950. Well log data indicate that the subsurface formations dip to the south and east at 75 feet to 150 feet per mile. The formations with suitable disposal characteristics were sandstones and limestones.

The Silurian Bass Island Formation is the principal injection zone and is present at a depth of nearly 1,600 feet with a thickness of approximately 100 feet. The overall thickness of the unit increases to the southeast. In western Pennsylvania, the unit is reported as a brown or gray-tan, dense, finely crystalline, porous limestone with some sand and chert. In southeastern Ontario the Bass Island consists primarily of dolomite. The Bass Island is extensive yet variable in thickness and lithology (D'Appolonia, 1983).

The injected fluid would be restricted from migrating vertically into a USDW by the dense limestones, interbedded sandstone and shale, and chert lenses. No evidence of faulting within the area was reported by Dow Industries.

The zone containing 10,000 mg/L total dissolved solids (TDS) is estimated to be at a depth of 900 feet. Water supply wells within the area reach a maximum depth of nearly 400 feet. Most water wells are completed into the unconsolidated glacial sediments at depths near 100 feet.

Well Construction Details. Hammermill Injection Well No. 1 was constructed from January 24, 1963, to March 15, 1963. This well was the initial test well which was converted into an injection well (D'Appolonia, March 1983).

The well was constructed by driving a 13-3/8-inch surface casing to 40 feet to isolate the unconsolidated sediments. A 9-5/8-inch casing was set to 1,359 feet and cemented to the surface to isolate the shallow aquifers. The 7-inch injection casing was set to 2,106 feet with an open hole extending to 2,115 feet. The 7-inch casing was cemented up to 880 feet, forming an open annulus between the 9-5/8-inch and 7-inch casings (D'Appolonia, March 1983).

This design permitted leak detection above the cement top at 880 feet. A 4½-inch injection tubing was hung in the 7-inch casing to a depth of 1,650 feet. No packer was installed at the bottom end of the tubing to form an open annular monitoring system. The 7-inch casing was perforated between the depths of 1,620 and 1,670 feet in the Bass Island Formation. A cast iron bridge plug was set at 1,710 feet, isolating the open hole test zone (D'Appolonia, March 1983).

Initial injection testing was performed on March 5, 1964, using water. Bacterial growth in the water plugged the formation, causing increasing injection pressures. Subsequently, biocide was added to the injected water to prevent bacterial growth. On April 24, 1964, the first spent pulping liquor was injected into the well. Initial

injection pressures were 1,120 psig at 194 gpm and 1,170 psig at 388 gpm. During the first 15 million gallons injected, the pressure at both flows increased steadily and then leveled off at 1,220 psig at 194 gpm and 1,330 psig at 388 gpm (Brown and Spalding, 1983).

Drilling began on the second injection well (Hammermill No. 2) on July 26, 1964. The well was constructed by setting and cementing a 13-5/8-inch casing to 79 feet. A 9-5/8-inch casing was set to 2,538 and cemented to surface. The 7-inch injection casing was installed to 5,100 feet to test deeper injection zones and cemented up to 700 feet. The original well completion used a slotted 5-inch liner from 5,100 to 5,975 feet. As a result of excessive injection pressures at this depth, the well was recompleted by perforating between 1,620 feet and 1,670 feet and installing a bridge plug at 2,038 feet. The 7- and 9-5/8-inch casings and cement sheaths were perforated using two hundred seventy 5-1/2-inch selecto-jets. The well was put into operation in September 1965 (Brown and Spalding, 1983). Additional filtration and a separate pump station were constructed for the operation of Well No. 2.

Hammermill No. 3 was constructed similarly to the first two wells with the injection interval in the Bass Island Formation. A 13-3/8-inch casing was set and cemented to 58 feet. The 9-5/8-inch casing was set and cemented to 1,405 feet. The 7-inch injection casing was set and cemented to 2,181 feet. The well was completed as an open hole from 2,181 to 2,354 feet and the 7-inch casing was perforated from 1,620 to 1,718 feet. Both zones appeared to receive the injected fluid. A 4-1/2-inch fiberglass tubing was installed to 1,610 feet inside the 7-inch casing. No available information suggests that a packer or cement were in place around the injection tubing (D'Appolonia, 1983).

Hammermill No. 3 well was completed and put into service in May 1968. Using the existing surface facilities, this well was constructed to increase the disposal capacity of the plant, and reduce the chance of discharging effluent to Lake Erie if one of the wells became temporarily inoperable.

Chronology of Operational Problems. The 7-inch casing burst at Hammermill No. 1 on April 14, 1968. The spent pulping liquor from the well backflowed to the land surface, entering Lake Erie. Nearly three weeks were required to shut in the well so repair efforts could proceed (Brown and Spalding, 1966). The discharge to the lake was monitored and it was determined that no serious damage would result to the lake from the discharge. The burst casing resulted from corrosion to the injection casing in the uncemented open annular interval. The corrosive nature of the pulping liquor itself was not anticipated to create this blowout (Brown and Spalding, 1966).

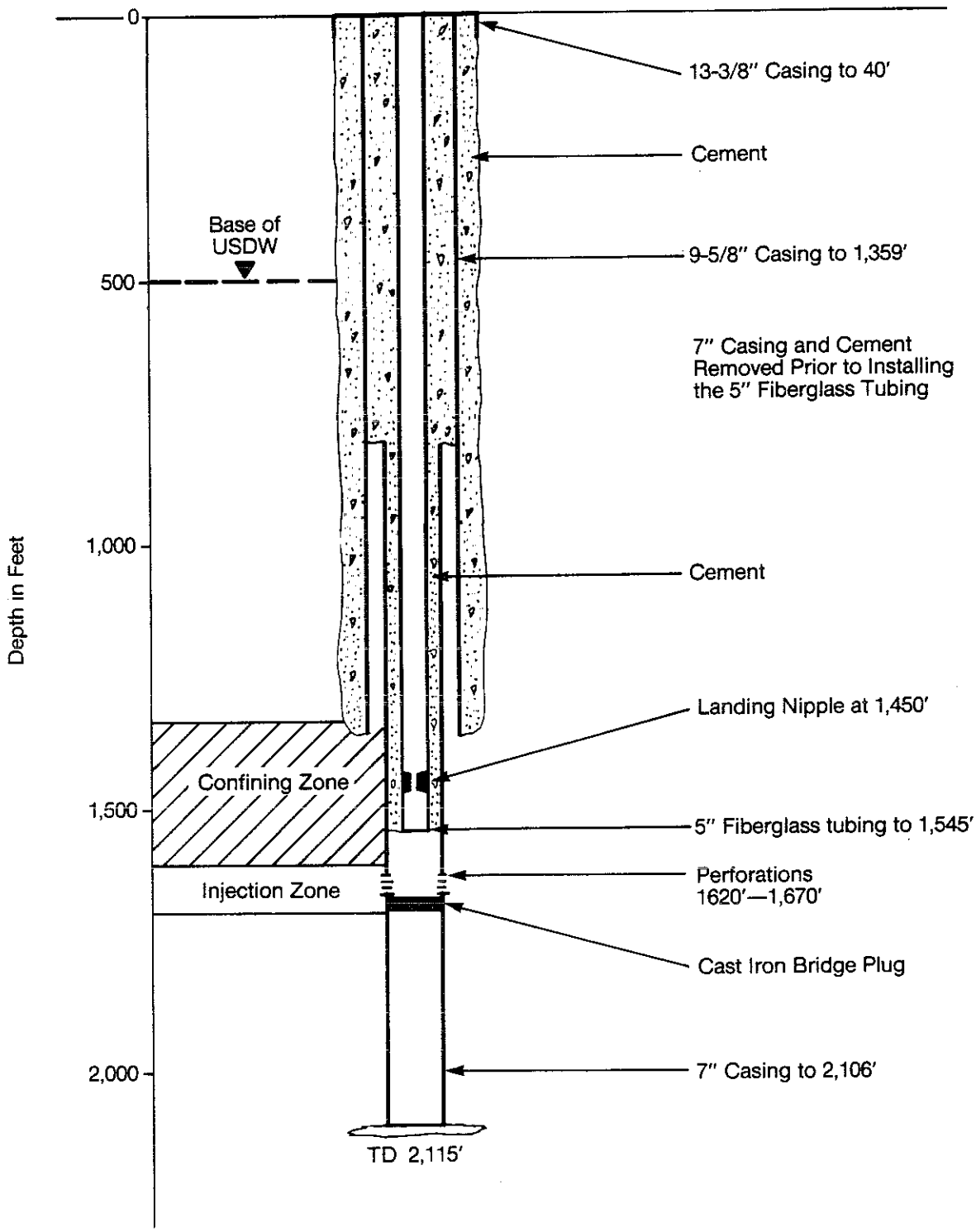
The 7-inch casing above 880 feet was removed from the well and milled, leaving the casing below 880 feet in place. A 5-inch fiberglass tubing was installed and cemented to the surface, eliminating any form of annular monitoring (Brown and Spalding, 1966).

A similar corrosion problem in which the injection casing collapsed occurred in Well No. 2. The casing collapse was verified during a workover prompted by an increase in injection pressure (Brown and Spalding, 1966). This well was taken out of service without endangering a USDW or potable surface waters.

The most prominent environmental problem alleged to have been caused by the Hammermill injection well system was the occurrence of flowing black water at an abandoned gas well.

The abandoned gas well (Erie No. 1) on Beach No. 7 of Presque Isle State Park was drilled in 1910. The well was improperly abandoned, providing a path of vertical migration of fluids from the Bass Island Formation to the surface. This abandoned gas well was nearly 4-1/2 miles from the Hammermill site. Within the operating time frame, the Hammermill effluent front should not have migrated radially away from the injection wells to this distance (D'Appolonia, 1983). So far, no data have shown the injection wells to be the direct cause of this event.

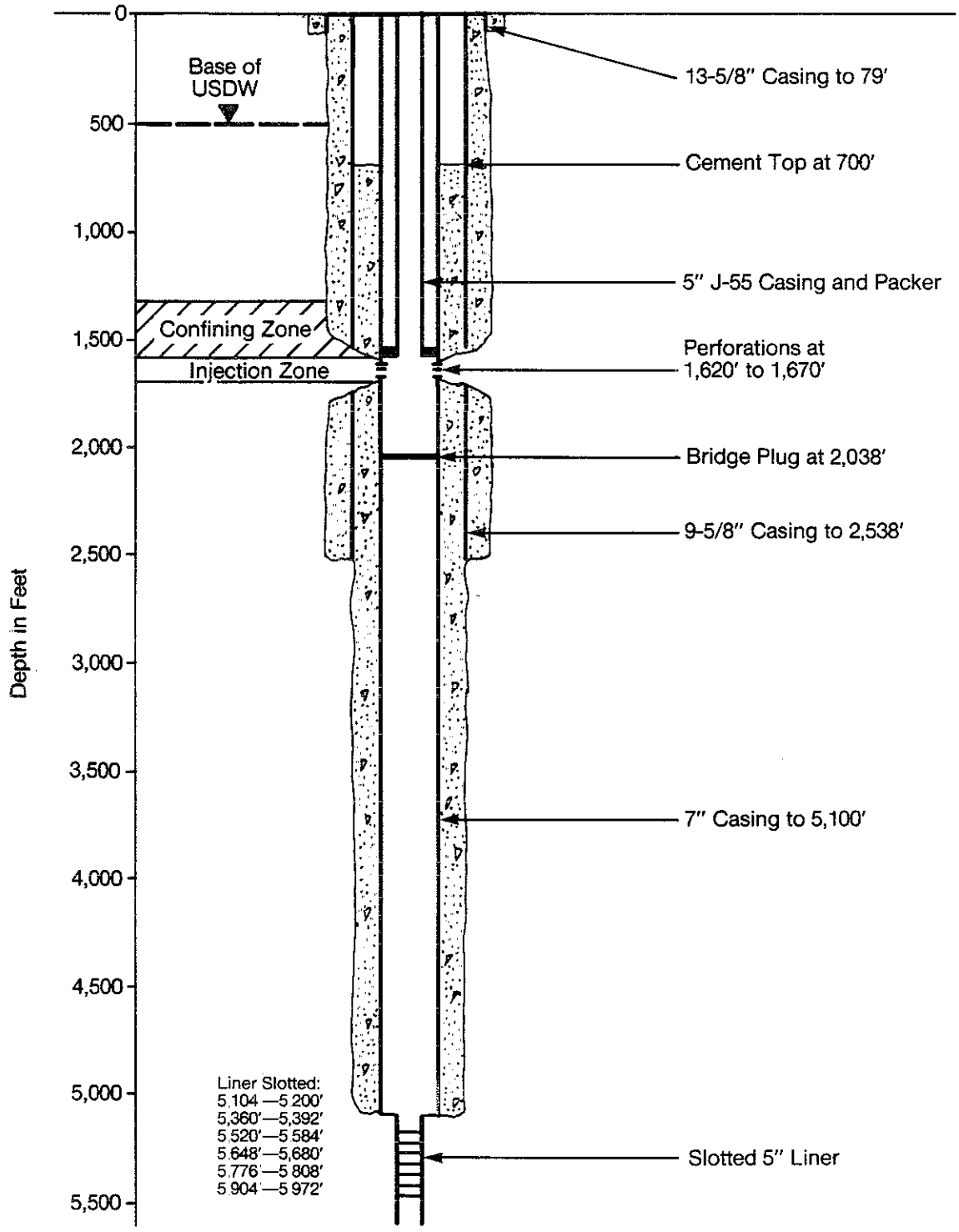
D19976.P0



HAMMERMILL PAPER COMPANY
Erie, Pennsylvania

INJECTION WELL NO. 1 AFTER RECOMPLETION (5-23-68)
(Permanently Plugged and Abandoned with Cement September 1972)

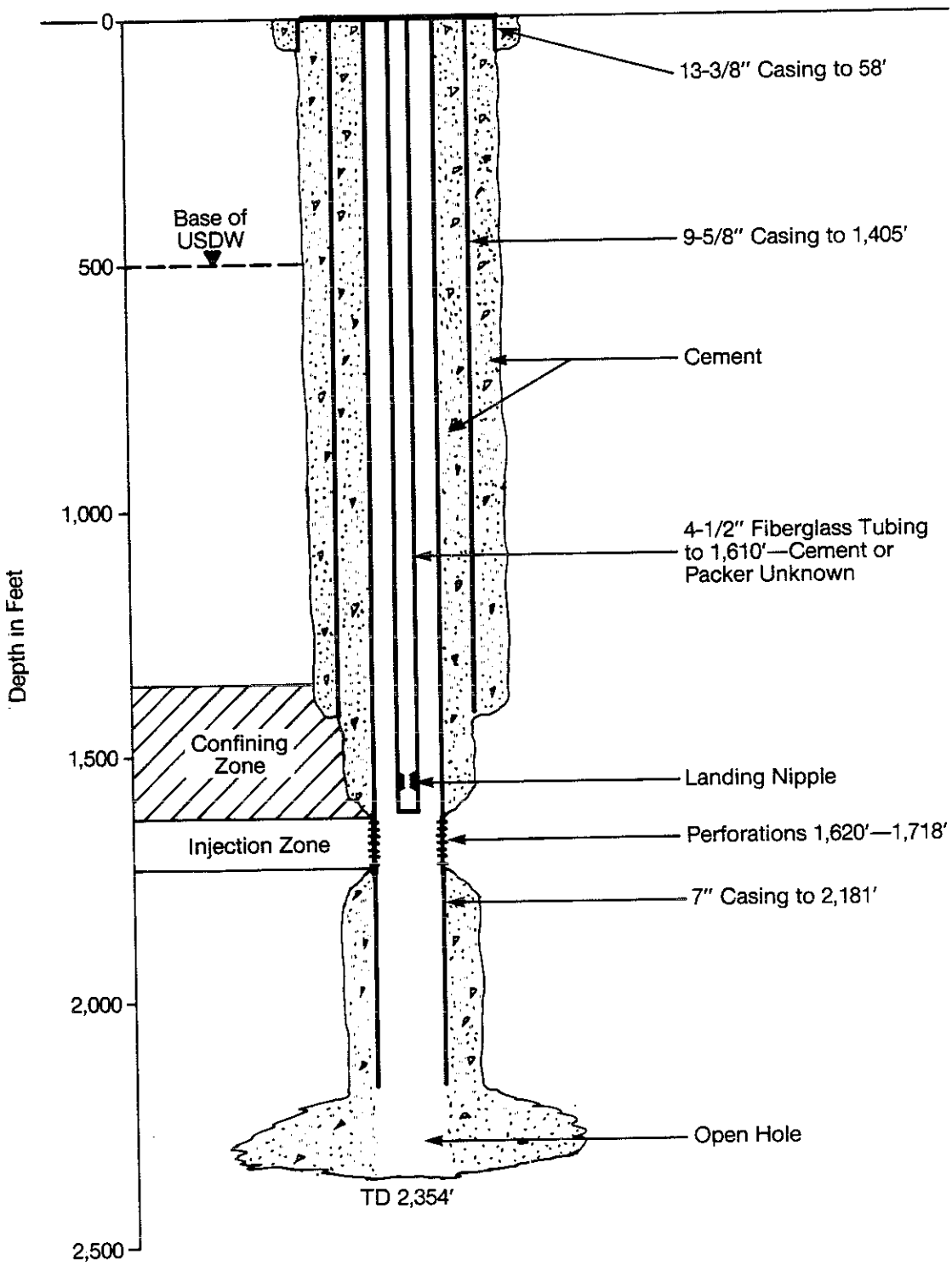
D19976.PO



HAMMERMILL PAPER COMPANY
Erie, Pennsylvania

INJECTION WELL NO. 2 ORIGINAL COMPLETION (8-29-64)
(Permanently Plugged and Abandoned with Cement September 1972)

D199976.PO



HAMMERMILL PAPER COMPANY
Erie, Pennsylvania

INJECTION WELL NO. 3 ORIGINAL COMPLETION
(Permanently Plugged and Abandoned with Cement September 1972)

JONES AND LAUGHLIN STEEL CORPORATION
ALIQUIPPA WORKS
ALIQUIPPA, PENNSYLVANIA

Background. Jones and Laughlin Steel Corporation operated an injection well at their Aliquippa, Pennsylvania, steel mill for disposing of waste pickle liquor from 1961 to 1972. The Aliquippa plant is located in northwestern Pennsylvania, about 40 miles north of Pittsburgh.

The injection well was designed to inject low pH, acidic wastes from onsite sources at an average rate of 100 gallons per minute (gpm). One 5,445-foot-deep injection well was used. No groundwater monitor wells were required by regulatory agencies, nor were any installed on the site.

During the 11 years the injection well was used at the plant, surface injection pressures ranged from 2,800 pounds per square inch gauge (psig) to 4,200 psig. These injection pressures yielded bottom hole pressures of 4,954 to 6,673 psi, respectively (Westlund, 1971). The well was plugged and abandoned in 1972.

Site Description. Potable water is obtained from the sand and gravel beds in the Quarternary system which underlies the site to a depth of 92 feet. The depth to the base of the USDW is unknown.

The injection well was completed to inject wastes into limestone and chert of the Onondaga Group and sandstone of the Oriskany Group. The Onondaga was encountered in the injection well from a depth of 5225 to 5388 feet and the Oriskany from 5388 to 5425 feet. The confining strata were reported as being composed of 2,000 feet of impermeable shales, siltstones, and sandstones (Stewart, 1968).

Well Construction Details. The Jones and Laughlin injection well was constructed with 20-inch diameter conductor pipe driven 73 feet; 13-3/8-inch surface casing set and cemented to 211 feet; 9-5/8-inch intermediate casing set and cemented to 2,406; and 7-inch injection casing set to 5,252 and cemented from 2,600 to 5,252 feet. The annulus outside the 7-inch casing was not cemented above 2,600 feet, being open to the upper Devonian subsurface interval from 2,406 to 2,600 feet to serve as a source for deep groundwater quality monitoring. Fibercast injection tubing, 3½ inches in diameter, was set almost to the bottom of the 7-inch casing. The well was originally completed as open hole from 5,252 to 5,445 feet. The recompletion in 1968 allowed injection into zones as shallow as 4,585 feet but did not seal off lower zones and the injection zone was redefined as everything below 4,585 feet. In 1969, the fibercast injection tubing was replaced with Penton-lined steel tubing (Jones and Laughlin Steel Corporation, 1968).

During the entire life of the well, injection occurred through both the injection tubing and the annulus between the 7-inch casing and the 3½-inch injection tubing. Approximately 25 gpm of water was injected down the annulus while approximately 75 gpm of waste was injected down the tubing.

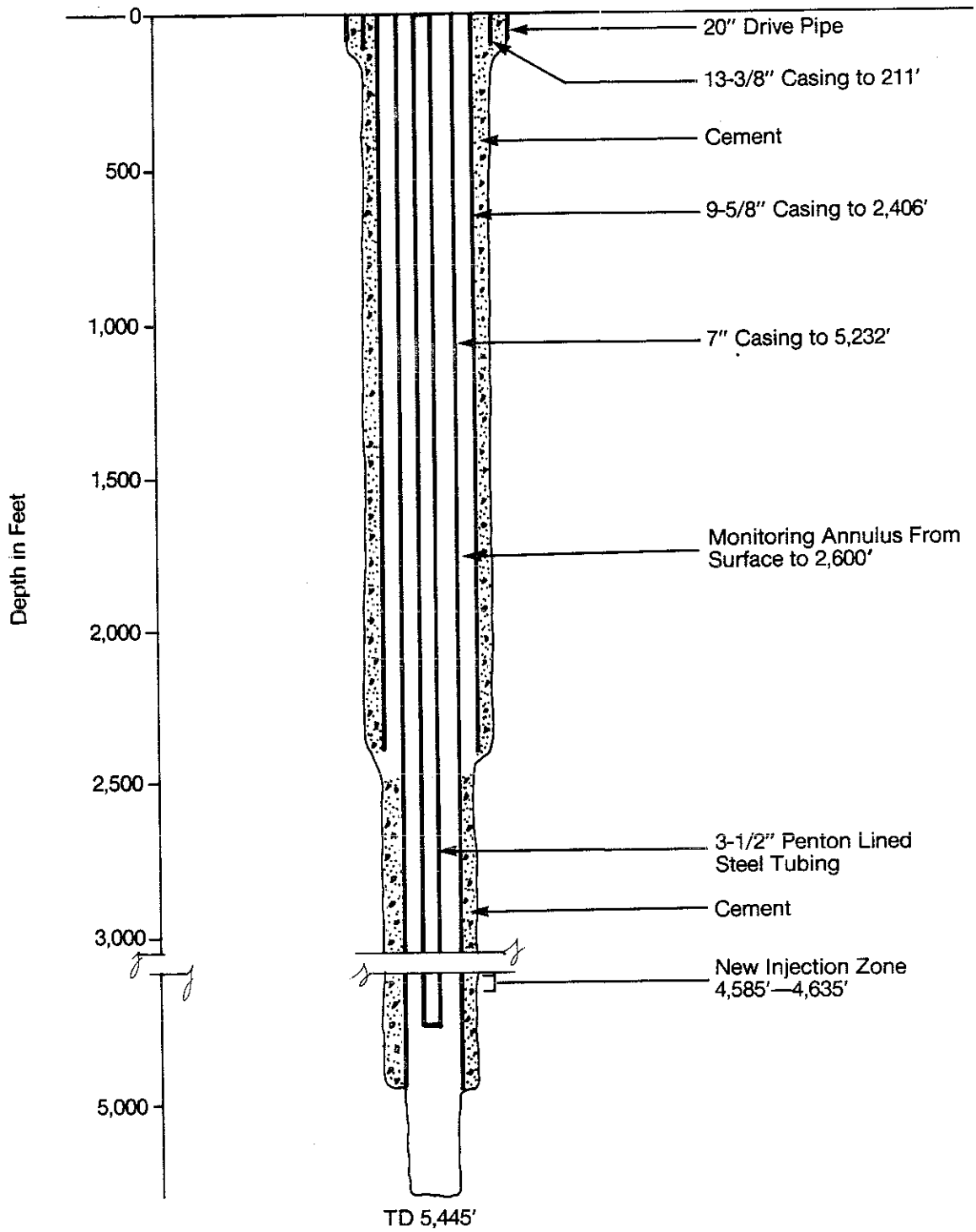
The decision to replace the fibercast tubing was predicated on several occurrences of cracks and coupling breaks in the tubing; in one instance, several hundred feet of the tubing broke off, fell to the bottom of the borehole, and interfered with injection into the lowermost zones (Emrich, 1969).

Chronology of Operational Problems. Between 1961 when injection began and 1968 when efforts were made to obtain State permission to recomplete the well and redefine the injection zone, nothing is known about the well operation

from available state agency files except for a note in Westlund's (1971) chronology which states "...August 19, 1968--letter from R. A. Landon to Dr. Jukkala, Oriskany sandstone and basal chert of Onondaga were lost to injection due to pressure buildup and corrosion of injection tubing." Also, a letter report by W. H. Jukkola (1969) of Jones and Laughlin Steel states that the most recent problems with the well were marked changes in injection pressure and that the well was shut down to determine why the changes occurred. Upon investigation, casing damage was found as shallow as 4,585 feet, well below usable water zones. No pressure or water quality problems had been detected by the annulus monitoring system at 2,600 feet and wastes were not threatening the environment.

The reason(s) for plugging and abandoning the injection well in 1972 are not known from available state agency files.

D19976.P0



JONES & LAUGHLIN STEEL CORP.
Aliquippa, Pennsylvania

Injection Well (Prior to Plugging in 1972)

AMERICAN MAGNESIUM COMPANY
SNYDER, TEXAS

Background. The American Magnesium Company operated a magnesium mining and recovery plant about nine miles west southwest of Snyder, Texas, within the Diamond M oil field. The operation consisted of recovery wells to extract magnesium-rich brines from the Permian Yates Sand in Borden County Texas, concentration of the brine in solar evaporation ponds, and 26-mile pipeline transport to the extraction plant and disposal well in Scurry County, Texas. The produced brine contained 11.5 percent magnesium chloride ($MgCl_2$), which was concentrated to a 25 percent $MgCl_2$ solution by the solar evaporation ponds. The concentrated magnesium brines were dehydrated further at the extraction plant, and the chloride salts were separated electrochemically into magnesium metal and chlorine gas. The chlorine gas was recovered and transported to a chlorine plant. Magnesium is used primarily as an aluminum alloy.

The waste brine resulting from this process consisted of 14,820 mg/L Ca; 28,440 mg/L Mg; 31,180 mg/L Na; 126,600 mg/L Cl; and 206,410 mg/L TDS, with a pH of 7.17 (Ed L. Reed, 1976). A limitation of 7.34 million gallons total volume injected per month existed on the operation. Some stormwater from settling and storage ponds at the site was also injected.

One injection well (to a recompleted depth of 2,730 feet) was used for waste brine disposal. No monitoring wells were at the site although an attempt was made to recomplete an oil well as a monitor well. Pretreatment of the neutral brine solution consisted of filtration prior to injection. Surface facilities at the Scurry County site consisted of storage ponds for the raw brine solution, and three process

wastewater retention and evaporation ponds. The latter ponds were also used to retain contaminated stormwater runoff. Three pumps were used for injection, which was on an intermittent schedule of two to three days per week. The maximum permitted injection rate was 170 gallons per minute (gpm) at a maximum surface injection pressure of 1,000 pounds per square inch (psi) (Texas Department of Water Resources, (TDWR) 1985a).

No oil production occurs in the injection zone (Ed L. Reed, 1976), but secondary oil production from deeper zones occurs in the adjacent Kelly-Snyder Field.

During three permitting public hearings, operators in that field charged that the American Magnesium waste was causing a higher than average incidence of casing leaks in adjacent producing and injection wells, thus endangering oil production through premature abandonment of those wells.

The American Magnesium Company declared bankruptcy in December 1980, and shut the well in on December 12, 1980. The MPLC North American Magnesium Company purchased the plant in 1982, but decided to move its operation to Canada in 1983 and abandon the Scurry County site. The well was permanently plugged and abandoned on November 23, 1983.

Site Description. The Snyder Plant is situated in a valley and ridge topography, within the Bluff Creek drainage basin, a tributary of the Colorado River. Land use in the surrounding area is predominantly ranching and oil production.

Potable groundwater occurs at the site in the Pliocene Ogallala Formation, which consists of approximately 15 feet of sandy, limy gravels, and caliche. The major aquifer is in red and gray sands of the Dockum Group of Triassic age at depths of 100 to 200 feet. Potable water does not exist

below an approximate depth of 350 feet (Ed L. Reed, 1976). The Santa Rosa aquifer of Triassic age occurs at a depth of 375 to 580 feet, and contains total dissolved solids of approximately 50,000 mg/L at the site.

Injection is into the Permian Clearfork Formation, a light olive-gray dolomitic limestone occurring in the interval 2,600 to 2,700 feet. The actual injection interval is from 2,662 to 2,698 feet. Porosities range from 7 to 12 percent and the permeability is 8 millidarcies. Confinement is provided by the San Andres carbonates in the interval 1,725 to 2,480 feet.

Well Construction Details. The well was originally drilled by the Lion Oil Company in 1949, as the No. 33 McLaughlin, with an initial potential of 317 barrels per day. A 12-1/4-inch hole was drilled to 1,769 feet, and a 9-5/8-inch casing was set and cemented to the surface. A 5-1/2-inch casing string was set to 6,859 feet in an 8-3/4-inch hole, and cemented back to an estimated 5,691 feet. Total well depth was 6,871 feet. The well was abandoned in August 1968 with bridge plugs at 6,182 and 6,159 feet. In 1969, the well was converted for disposal. A cement plug was set between 2,730 and 2,860 feet, and the intervals between 2,678 to 2,698 feet were perforated. A 2-7/8-inch fiberglass tubing was set with production packers at 2,652 and 2,660 feet. The annulus was filled with produced brine water. In February 1976, the zone between 2,662 to 2,672 feet was also perforated (Ed L. Reed, 1976).

Chronology of Operational Problems. The Texas Railroad Commission issued the original waste disposal permit in June 1968, and the well operated intermittently until 1971, when fire destroyed the plant. Production resumed in mid-1973, and injection continued sporadically. Detailed operating

records are not available for September 1969 through January 1976, but no instances of groundwater contamination are known to have occurred from this well (TDWR, 1985a). The tubing and packers were repaired in December 1974 (Ed L. Reed, 1976). Increasing injection pressures during 1975 reached a peak of an average maximum injection pressure of 1,437 psi between January 19, 1976, to February 3, 1976. Consequently, an additional zone between 2,662 to 2,672 feet was perforated in February 1976, and the well was acidized at the same time. The pressure dropped to 780 psi, but began to gradually increase until it exceeded the permitted maximum of 1,000 psi. After several cycles of acidization followed by decreased pressures that gradually increased, a workover was performed in June 1976. Between January 19, 1976, and June 20, 1976, the maximum injection pressure was exceeded 48 days, which violated conditions of the permit (TDWR, 1985). The well was cleaned out, the zone between 2,660 to 2,680 feet was reperforated, and the tubing and packer were replaced. As a result of the workover, no pressure buildup occurred through December 1976. On November 4, 1976, a suspected leak in the injection tubing caused plant waste to leak into the annulus (TDWR, 1985a).

The injection tubing and casing were tested in May 1977, and as a result of the testing, a small leak into the annulus through either the tubing or packer was discovered. The TDWR required American Magnesium to fill the annulus with corrosion inhibiting fluid and to maintain a net positive pressure of 1,000 to 1,050 psi on the annulus by adding corrosion inhibitor as needed. This was accomplished in August 1977, along with the installation of injection and annulus pressure, flow measurement, and pH measurement instrumentation.

Satisfactory yearly inspections occurred in 1978 and 1979, but an annulus pressure problem was identified in the February 1980 inspection. A leak in the injection tubing was suspected (TDWR, 1985a). The well was shut in on December 12, 1980, and the company filed for bankruptcy on January 14, 1981.

The site has a long history of permit applications, temporary permits, and requests for permit or application extensions. This resulted, in part, from changing jurisdiction from the Texas Railroad Commission in 1968 to the Texas Water Quality Board (TWQB) in 1975 to the TDWR in 1977. Other reasons include an anticipated six-fold plant expansion by 1979, and development of an alternative disposal method. Beginning in 1977, the company conducted feasibility studies on constructing a closed system of brine production from the Yates Sand in Borden County, which involved construction of a return line into Borden County for reinjection of the waste stream into the Yates aquifer for repressurization. American Magnesium had also obtained a permit to recomplete an old Monsanto well with an injection zone at 8,500 feet, and to construct a new well in that interval. Although permits were granted for these wells, bankruptcy was declared before any work began.

Adjacent land owners and the regulatory agency began expressing concern about the American Magnesium injection operation in 1975 and 1976, respectively. Chevron, U.S.A. formally objected to various permit renewals at public hearings in 1975, 1977, and 1979, on the grounds that injection represented a predictable hazard to producing wells in the area. Although the Texas Railroad Commission stated in 1976 that American Magnesium's injection did not threaten oil and gas resources in the area, the TWQB staff

was concerned that the operation was a potential hazard to usable groundwater and oil and gas production in the area (TDWR, 1985a).

Approximately 50 wells are producing within a one mile radius of the injection well, from the San Andres and Glorieta Sands above the injection zone, and from the Lower Clearfork and Canyon Reef formations below the injection zone (Ed L. Reed, 1976). Chevron USA operates a secondary recovery project for oil recovery from the Canyon Reef Formation of the Kelly-Snyder Oil Field adjacent to the American Magnesium operation. Most of the producing wells penetrating the Clearfork Formation (American Magnesium's injection zone) and completed in the Canyon Reef Formation were not cemented through that zone. Chevron maintained that brine injection into the Clearfork Formation was a contributing factor in the accelerated casing leak problems noted in Chevron wells adjacent to the injection well. Chevron expressed concern at a 1979 public hearing that early abandonment with loss of oil production would result, and recommended permit denial on the grounds that American Magnesium had adequate time to develop alternative disposal methods or that American Magnesium deepen their injection interval. Chevron stated that, within a 2-mile radius of the injection well, 39.5 percent of all Chevron's producing wells have had leaks, whereas outside the 2-mile radius, the percent of wells in which leaks have occurred was 21.7 (Chevron, 1979). Average cost to repair these leaks was $20,000 (TDWR, 1985a).

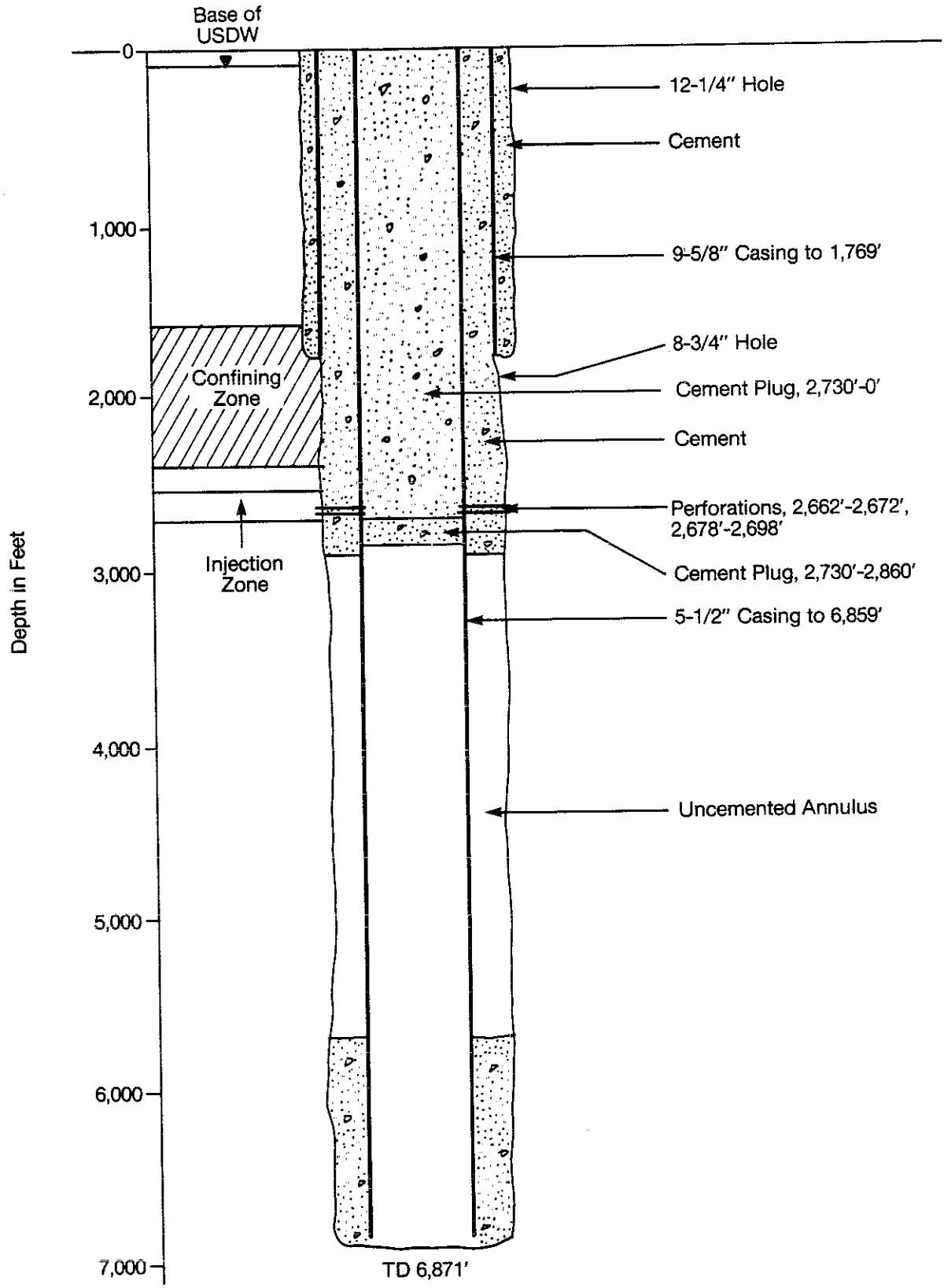
The TWQB was concerned that if sufficient pressures built up in the injection zone, this would cause movement of native brines or injected fluids around the uncemented long string casings, resulting in increased corrosion and creating a potential hazard to the oil and gas producing wells and to

groundwater quality. Consequently, when the TWQB issued Temporary Order 76-52E in September 1976, a proviso in that permit was that American Magnesium must recomplete the Monsanto McLaughlin Well No. 34, located 1,320 feet south of the injection well, as a pressure monitor well. If pressures in the monitor well were sufficient to flow native or injection fluids to the surface, American Magnesium would have to cease injection.

The company made several unsuccessful attempts to recomplete the Monsanto well as a monitor well before it ran out of funds. A formation water sample was taken during recompletion efforts, and the magnesium concentration (97 mg/L) indicated the waste front had not yet reached the monitor well (TDWR, 1985a).

The TWQB found no conclusive evidence that the American Magnesium Company injection operation caused groundwater contamination (TWQB, 1976b), but recommended that injection into the Clearfork Formation be stopped as soon as an alternative disposal method was approved. Efforts to develop and construct an alternative disposal method ceased when the company declared bankruptcy, and, the well was permanently plugged and abandoned with cement from the bottom to the surface.

D19976.P0



AMERICAN MAGNESIUM COMPANY
Snyder Plant, Scurry County, Texas

WASTE DISPOSAL WELL 133 (Plugged November 1983)

CECOS INTERNATIONAL
ODESSA, TEXAS

Background. CECOS International, Inc., operates a commercial hazardous waste disposal site approximately 3/4 of a mile east of Odessa, in Ector County, Texas. The original owners, Chaparral Disposal Company, obtained surface and disposal leases to use the O.W. Pool Well No. 1 for injection, and applied for an injection well permit in 1977. No commercial disposal sites existed in West Texas at that time to accommodate small industries or small quantity generators that could not afford surface treatment facilities at each site. Wastes were also accepted from throughout Texas and from other states such as New Jersey and West Virginia.

Wastes are received from the following types of operations: microcircuitry manufacturing, gasoline treating, pharmaceutical and chemical manufacturing, semi-conductors, mercaptan manufacturing, plating and metal etching, machine shops, drum yards, pesticide formulation, styrene scrubbers, ink roller manufacturing, and propane scrubbers. Wastes from site cleanup operations in New Jersey are also received. Types of wastes permitted include acidic alkaline solutions; cleaning solutions; chlorinated and non-chlorinated solvents; waste and oil coolants; pesticides and herbicides; resins, polymers and brines; plating solutions; ammonia and nitrate solutions, and non-biodegradable organics (Texas Water Commission, 1978). Wastes with a pH below 5.0 cannot be injected without neutralization. Waste is injected by batch disposal, at a permitted rate of 180 gpm or up to 7.77 million gallons per month (Texas Water Commission, 1980).

One injection well exists at the site. At one time, an adjacent Gulf Oil well was being considered for conversion

to a pressure monitor well, but this has not been accomplished. Wastes with a pH greater than 5.0 are not usually pretreated. Customers must prefilter the waste before bringing it to the site. Produced brine is injected as a buffer between incompatible wastes.

Surface facilities consists of an off-loading area for the trucks, two 6,000-gallon freshwater storage tanks, a 20,000-gallon brine storage tank, a 6,000-gallon polypropolin emergency storage tank, 100-mesh screen basket filters followed by two 25-micron and two 5-micron pod filters in series and a positive displacement pump (Texas Department of Water Resources (TDWR), 1985c). Wastes are delivered to the site by tank truck and usually pumped directly from the truck through the filters to the well. A concrete sump at the foot of the loading pad is used to contain spills during off-loading. The sump is periodically pumped out and the waste fluid is injected. Contaminated soil, sludges, filter cartridges, and other solids are drummed or placed in a closed skid-type dumpster and periodically removed to the CECOS Lake Charles, Louisiana, landfill. All solid waste generated at the site is handled in this manner.

The permitted monthly injection rate as amended in May 1980 is 180 gpm, with total monthly volume injected reduced to 7.74 million gallons. The maximum permitted surface injection pressure is related to the waste fluid density. For fluids ranging in density from 7-13 lb/gal, the maximum injection pressure ranges from 2,210 to 530 psi, respectively (Texas Water Commission, 1980). Prior to permit issuance, the Department was concerned about the elevated pressures in the injection zone and the effect these pressures may have on any nearby wells that have been improperly abandoned. Because of high reservoir pressures and plugging of the well bore, CECOS has, on occasion,

exceeded its permitted surface injection pressures. These occurrences were due to the well operator failing to monitor well operations properly.

Site Description. The well is situated in the O.W. Pool lease on the eastern flank of the Central Basin Platform of west Texas. The "red beds," which are surface and shallow alluvial deposits, are approximately 125 feet thick at the site, and are hydraulically connected with the underlying basal sands and limestones of Cretaceous age. Municipal, industrial, irrigation, and domestic supplies are obtained from these formations. In the Pool lease area, many shallow water supply wells have been abandoned after encroachment of naturally mineralized groundwater. Depth to usable water at the site is 1,350 feet. The City of Odessa municipal well field is approximately 6-1/2 miles northwest of the site (Texas Water Quality Board (TWQB), 1977).

The Santa Rosa Sandstone supplies poor-quality water suitable for industrial uses and for secondary recovery projects, with total dissolved solids (TDS) ranging from 2,600 to 3,000 mg/L.

The injection zone is in the Permian San Andres Formation, which occurs at the site in the interval 4,900 to 5,900 feet. The San Andres is a limestone interbedded with anhydrite, which grades from a dolomitic to sandy to dense limestone. The interval between 4,900 to 5,600 feet consists of fossiliferous and dolomitic limestones, while the lower 300 feet is a dense limestone not suitable for injection (TWQB, 1977). Porosities in the injection zone are approximately 12 percent, while permeability ranges from 7 to 32 millidarcies. Confinement is provided by the overlying Grayburg Limestone of Permian age.

No oil is produced from the injection zone. Within a 2-1/2-mile radius of the injection well, however, 65 oil and gas wells penetrate the injection zone. Most of these wells are still active, and are completed at depths ranging from 10,000 to 12,000 feet. Typical construction of these oil and gas wells consists of a surface casing set and cemented to approximately 300 feet, an intermediate casing set through the San Andres and cemented to surface, and a long string. Only three wells within the 2-1/2-mile radius do not have intermediate casing set through the San Andres (TDWR, 1978).

Well Construction Details. Gulf Oil Company originally drilled the well in 1956, and abandoned it in 1967. During abandonment, 7,752 feet of the 5-1/2-inch casing were cut and recovered. Cement plugs were set at 8,817 to 9,040 and 5,750 to 5,850 feet. The current configuration consists of a 13-3/8-inch casing set and cemented to 407 feet, a 9-5/8-inch casing to 5,798 feet and cemented to the surface, and a 7-inch casing to 4,808 feet, 67 feet above the San Andres. A 2-7/8-inch internally plastic coated tubing to 4,805 feet is set with a packer at 4,787 feet. The casing-tubing annulus is filled with corrosion inhibiting fluid. The 9-5/8-inch casing is perforated over the interval 4,900 to 5,605 feet.

Chronology of Operational Problems. The Chaparral Disposal Company, Inc., first applied for an injection well permit in 1977, with a maximum proposed injection rate of 260 gallons per minute (gpm) and a maximum surface injection pressure of 1,750 psi. The original permit issued in May 1978 authorized a 260-gpm injection rate and an operating surface injection pressure of 800 psi, and total volume injected per month of 11.2 million gallons (Texas Water Commission, 1978). Injection for testing began on November 9, 1978, and full scale injection began on January 15, 1979.

During permit application review, the TDWR recognized that the proposed injection zone was not an ideal injection zone, because of the relatively low permeability and porosities in that zone. Potential problems from anticipated high injection pressures and pressure buildup in the injection zone included potential fracturing of overlying beds, leakage across confining beds, and a greater potential for migration of fluids through three improperly cemented wells identified in the 2-1/2-mile area of review. Pressure limitations and annual reservoir pressure measurements were proposed means to alleviate these potential problems (TDWR, 1985c).

After the June 1979 inspection, the TDWR issued a citation to the owners for noncompliance with the permit (TDWR, 1979). Leakage from the packing gland of the injection pump and from the spent filters and filter pump was noted. The site was also out of compliance for failure to install pressure gauges and a continuous recording pH meter, to maintain the continuous recording pressure meter and flow meter, to submit the well completion report, and to maintain proper records. The leaking pump seals were repaired on July 3, 1979, and the monitoring instruments were installed or overhauled in July.

An operational incident that contributed to increasing injection pressures occurred in October 1979. On October 26, 1979, a truckload of oily waste was injected before operators realized that the oil and brine had separated. Approximately 3,200 to 4,000 gallons of oil were injected, causing some formation plugging. The following day, 4,800 gallons were backflowed from the well into vacuum tank trucks. The well was shut in to assess the damage. A spinner flow meter and temperature survey were run, which indicated that perforations between 5,540 to 5,560 feet were

covered with fines and oil, perforations between 5,510 and 5,530 feet were partially covered, perforations from 5,165 to 5,255 feet were taking 25 percent of the flow, and the remaining perforated interval was taking the rest of the flow (TDWR, 1985c). The well was acidized, which reduced the surface injection pressure from 1,080 pounds per square inch gauge (psig) to a range of 960 to 1,025 psig.

However, continuing high injection pressures at low flow rates resulted in another acid stimulation on November 30, 1979. No improvement in the operating surface pressures resulted from this acid job. Most of the bottom hole pressure buildup in late 1979 can be attributed to the operational error of injecting incompatible wastes.

During the first six months of 1980, the surface injection pressure exceeded the permit limits, and several bottom hole pressure surveys were conducted. A bottom hole pressure recorder was lost down the well during one of these tests. On September 26, 1980, a water soluble waste stream consisting mainly of rainwater mixed with downhole treatment chemicals was injected, resulting in an injection pressure increase from 1,300 to 1,700 pounds per square inch (psi). The following day 1,100 gallons were backflowed and a subsequent waste stream was injected at normal pressures. Over 30,000 gallons of the first waste had been injected previously with no problems.

After a successful inspection in April 1981, between May 29-31, 1981, wellhead pressures jumped to 1,650 psi. The suspected cause was solids in the injection tubing. After backflushing into a tanker, the pressure dropped approximately 150 psi. The waste receipts increased from 250,000 gallons in May to 530,000 gallons in July, with a decline in waste densities from 9.5 to 8.8 pounds/gallon.

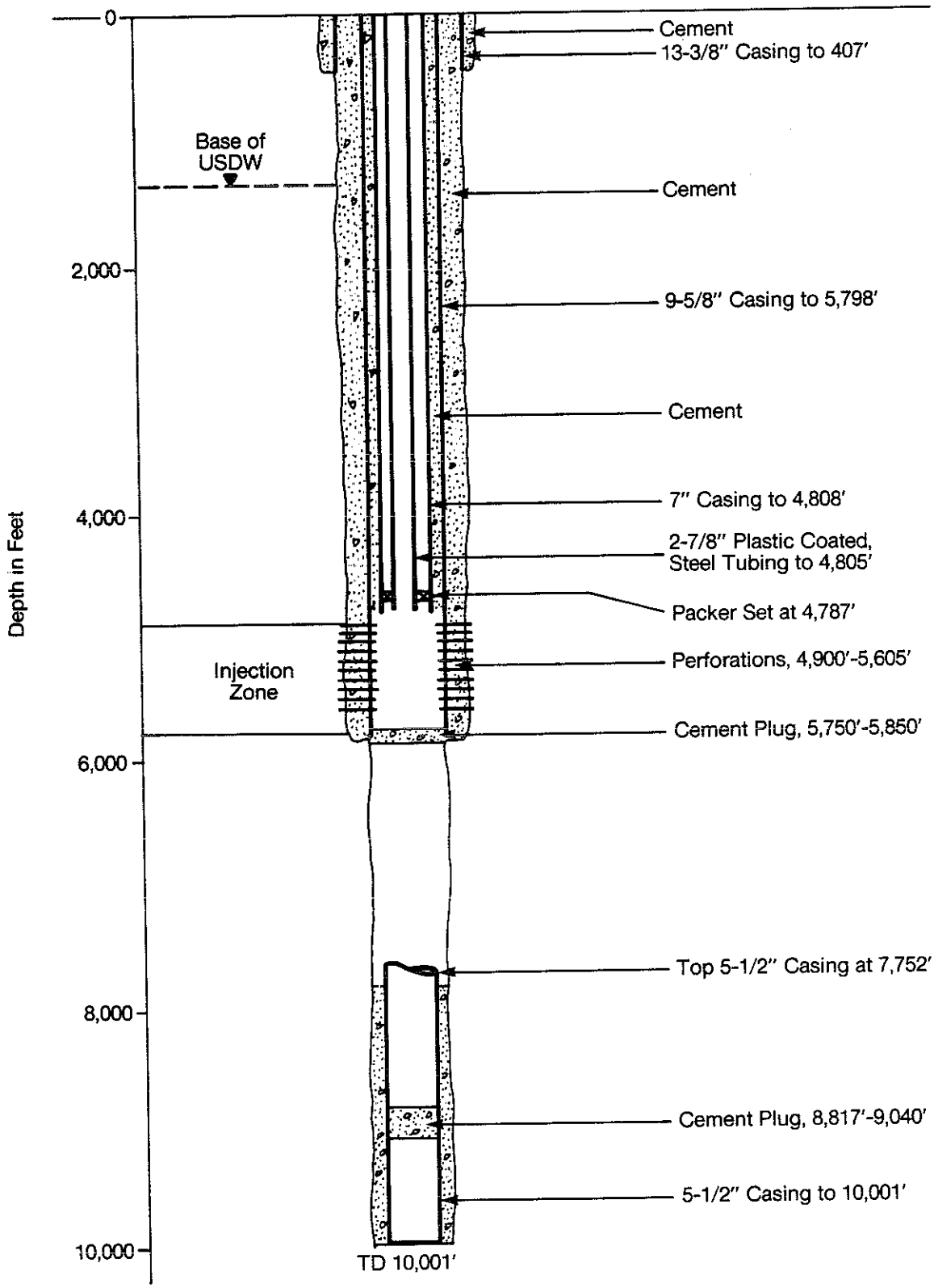
During July 22-24, 1981, maximum surface injection pressures were exceeded when wastes of 9-10 lb/gallon densities were injected. Backflowing failed to reduce pressures. The well was acidized on January 22, 1982, with only moderate success. Pressures continued to increase in 1982 until a workover was performed in September. Additional perforated zones between 4,950 to 4,980 feet and 5,340 to 5,360 feet resulted.

After continued operating pressures that were at the permit limit throughout 1982, the TDWR stated that elevated injection zone pressures had reached the point where no further increases in operating pressures could be authorized in the San Andres without a detailed study of artificial penetrations within the area of review. The TDWR was concerned that elevated injection zone pressures were sufficiently high that upward migration in improperly abandoned oil wells in the area of review may occur.

Through June 1983, TDWR inspection reports indicate that the maximum permitted surface injection pressure was exceeded on several occasions. The 1984 and 1985 inspections were satisfactory.

Prior to any injection at this site, the TDWR and the owners were aware that use of the proposed injection zone would have some restrictions. The Department has followed a course of limiting surface injection pressures, and currently will not allow any additional pressure increases until all artificial penetrations within a 2-1/2-mile radius are reviewed and any appropriate corrective action is taken.

D19976.P0



CECOS INTERNATIONAL, INC.
Odessa, Texas

WASTE DISPOSAL WELL 146

CHEMICAL WASTE MANAGEMENT
CORPUS CHRISTI, TEXAS

Background. Chemical Waste Management (CWM) operates a waste disposal facility near Corpus Christi, Texas, which handles a variety of offsite commercial and industrial wastes. The wastewaters are general process waters, some of which may be either acidic or caustic. A landfill was also operated onsite for solids disposal and was closed in 1983.

The waste disposal facility was originally owned and operated by International Pollution Control, Inc. (IPCI). The waste disposal permit for Well WDW-70 was transferred to CWM in February 1980.

In addition to the well, IPCI used numerous earthen pits for waste oil/water separation. As a result of the surface facilities and waste handling procedures, IPCI received numerous enforcement actions. Minor permit violations pertaining to the injection well were indicated on the Texas Water Quality Board Inspection (TWQB) Reports. However, the well violations did not cause environmental damage or contamination of usable groundwater. Following the purchase of the site, CWM proceeded with a major cleanup and closeout of waste ponds.

The CWM site uses steel tanks for receiving liquid waste. Earthen pits that were used for oil/water separation and solids settlement were required to be closed by the Texas Department of Water Resources (TDWR) in 1980.

Wastewater received for injection disposal undergoes equalization, oil skimming, and cartridge filtration prior to injection. The wastewaters are then contained above ground in storage tanks in accordance with the TDWR permit application.

Site Description. The shallow surface materials are primarily clay and sand. The Pleistocene Beaumont Formation, a clay unit, extends to a depth of nearly 400 feet within the review area. The general inclination of the subsurface strata is to the east at 20 to 30 feet per mile. The injection zone is into the Harrington Sand of the Basal Catahoula Formation (Miocene Sands) at a depth of 9,540 to 4,715 feet. Marine shales above the injection zone prevent upward migration of wastes from the disposal zone (TDWR, n.d.).

Groundwater at the site is generally of poor quality. Total dissolved solids (TDS) concentration increases with depth within the near-surface Beaumont Clay and approaches 3,300 mg/L TDS. The injection zone contains waters with greater than 100,000 mg/L TDS, and there is no usable amount of hydrocarbons present (TDWR, n.d.).

Well Construction. The injection well is constructed with a 20-inch casing driven to 30 feet to isolate the loose surficial sediments. A 10-3/4-inch surface casing is set at 586 feet and cemented to the surface, isolating the potentially usable groundwaters. A 7-inch injection casing is set at 4,770 feet and cemented to the surface. The bottom 400 feet of the 7-inch casing was cemented with resin cement to protect it from corrosion. The casing is perforated between 4,540 and 4,715 feet. A 2-7/8-inch vinyl ester resin fiberglass tubing and packer assembly were set at 4,585 feet. The fiberglass tubing was eventually replaced by a 3-1/2-inch steel tubing set at 4,380 feet (TDWR, n.d.).

The well design and reservoir pressure buildup modeling allowed for a maximum injection rate of 150 gallons per minute (gpm) at 750 pounds per square inch gauge (psig) surface injection pressure as permitted by the Texas Department of Water Resources. The well operates with few

problems. Workovers are required occasionally to clean out the well bottom when sand enters the perforations or when the tubing and packer assembly need maintenance.

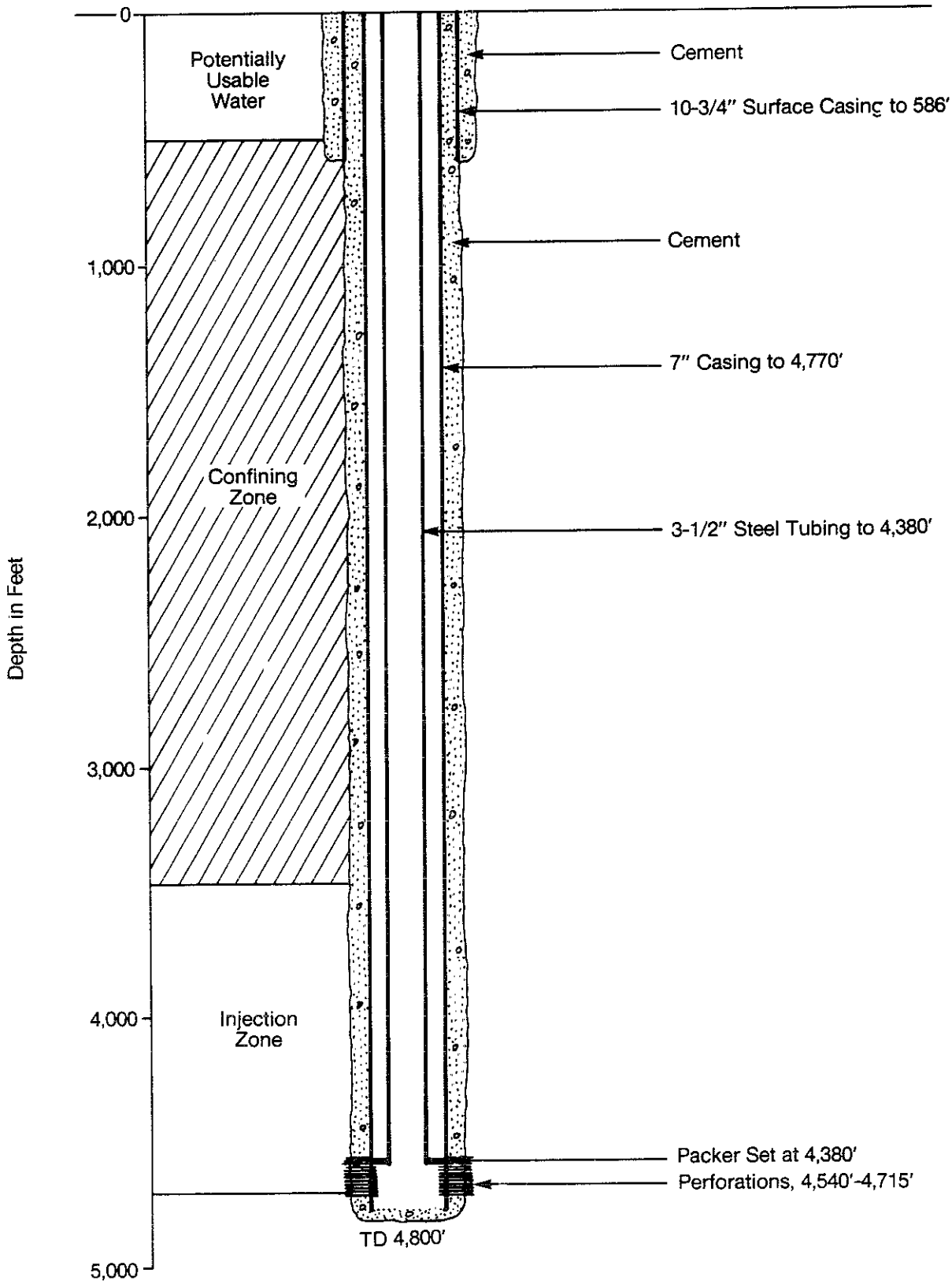
Chronology of Operational Problems. The TDWR file contains numerous citations and enforcement actions recorded from October 1973 through September 1979. During this interval, the disposal facility was operated by IPCI. Violations were associated with the waste handling and storage prior to injection disposal. Violations included unpermitted discharge from retention ponds to public waters, spills of oily wastes, overflowing ponds, seepage of wastes off plant property, and buried waste oil emerging from the ground surface from improperly covered pits. On May 3, 1979, the injection well instrumentation was found to be not operating satisfactorily.

The primary cause of these violations was inadequate and insufficient capacity for treatment and disposal of industrial wastes in the surface facilities. As a result, solid and liquid wastes were buried in numerous unplotted shallow trenches around the site. The ground in the process area was saturated from previous waste spills, and the rainfall runoff controls were inadequate. Buried drums of waste were located in unplotted burial sites where waste was seeping to the surface (TDWR Inspection Reports).

In 1980, after the permit was transferred to CWM, the TDWR and CWM entered into an enforcement compliance directive, which required the assessment and closure of the disposal pits on site and improvement of the surface facilities. One of these old pits had penetrated permeable sands, making it necessary to conduct an assessment of the areal extent of subsurface contamination at the site. The pits were then closed in accordance with the Board's requirements.

The injection well itself is recorded as having workovers to replace tubing and packer assemblies or to clean out sand that entered the casing perforations. No records indicate the need for major workovers, nor do they indicate the contamination of usable groundwater through the direct use of the well.

D19976.P0



CHEMICAL WASTE MANAGEMENT
Corpus Christi, Texas

WASTE DISPOSAL WELL 070

CITIES SERVICE FRACTIONATORS, INC.
MONT BELVIEU, TEXAS

Background. Cities Service Fractionators, Inc., operates a plant to fractionate raw hydrocarbons near Mont Belvieu, Texas. The plant and injection well are located approximately one mile west of Mont Belvieu, on a 40-year leased tract in Chambers County. The plant fractionates isobutane, butane, propane, ethane, and gasoline from raw hydrocarbon liquids. An oily dipropyl and dibutyl disulfide waste stream is produced during the proprietary Merox process, which removes mercaptans from the feedstock. The waste stream consists of 50 percent sulfur by weight, 50 percent ethyl, propyl, and butyl groups by weight, and some mercaptans that give the waste a disagreeable odor. Less than 3,000 gallons per day of waste are produced (Texas Water Quality Board (TWQB), 1970).

The waste stream is insoluble in water and difficult to treat. Waste disposal was complicated by the lack of a market for the disulfide compounds, small volumes produced, and presence of odorants in the waste stream. Several other disposal and recycling options were investigated before injection was determined to be the most satisfactory option (Texas Department of Water Resources (TDWR), 1985b).

One injection well was constructed to a total depth of 2,203 feet when the plant was constructed in early 1971. No pretreatment is provided prior to injection, but the waste is essentially free of suspended solids. Surface facilities consist of a closed system that includes an 8,000-gallon surge tank, a pressure recorder, and a small positive displacement pump if gravity flow is insufficient. Injection is by batch disposal. Average injection rate is 2 gallons per minute (gpm), with a maximum injection rate of 5 gpm. Maximum permitted surface injection pressure shall not exceed 800 pounds per square inch (psi), and the maximum

monthly volume of injected fluid shall not exceed 90,000 gallons. No separate monitoring wells are proposed.

The injection well was placed in service on March 1, 1971. On February 28, 1985, the permit was cancelled and transferred to the Texas Railroad Commission.

Site Description. The injection well is situated on the northwest flank of the Barbers Hill Salt Dome, 40 feet below the topographic high, and surrounded by numerous producing wells in the Barbers Hill Field. The oil wells were drilled from the 1930's to 1965, and produce from sands in the 5,000- to 6,000-foot interval. No oil has been produced from the injection zone, a sand interval between 2,000-2,200 feet.

Base of the freshwater-bearing sands is 1,450 feet, with brackish water occurring in the interval of 1,450 to 1,900 feet. Saltwater sands occur beneath 1,900 feet. There are no water wells on the site, but a municipal water supply well for the City of Mont Belvieu is located 4,300 feet north of the injection well (TWQB, 1970).

Interbedded sands and clays of the Beaumont Clay and Lissie formations of Pleistocene age overlie the Barbers Hill Salt Dome. The Willis and Goliad formations of Pliocene age have been penetrated by the salt dome, and pinch out against the salt dome. These formations are composed of interbedded sand, sandstone, gravel, silt, and clay.

The injection zone is a massive sand unit of Pliocene age that occurs at an approximate depth of 2,030 to 2,140 feet, and pinches out against the salt dome about 250 to 300 feet east of the injection well. Net sand thickness in the injection zone is approximately 100 feet, with porosities

ranging from 20 to 30 percent. Confinement is provided by approximately 550 feet of sand and clay between the top of the injection zone and the base of the freshwater-bearing sands. Clay and shale strata comprise 272 feet of the 550-foot separation.

The waste has a lower specific gravity and is immiscible with the formation fluids. The disulfide waste should slowly, gravimetrically segregate to the top of the disposal zone. Since the injection zone dips away from the salt dome, the waste will reportedly migrate updip until it collects against the salt dome (TDWR, 1985b). Further upward migration into the overlying clay confining beds will not occur because the surface tension of the interstitial water in the clay exceeds that of the disulfide.

Well Construction Details. The well was originally completed in 1971. The tubing and packer were pulled for mechanical integrity testing in 1984, and the packer was replaced with a different model. The current configuration of the well includes an 8-5/8-inch surface casing set in a 12-1/4-inch hole to 134 feet and cemented back to surface. A 5-1/2-inch steel casing is set in a 7-7/8-inch hole to a total depth of 2,203 feet, and cemented back to the surface. The plugged back depth is 2,178 feet, with sand fill to 2,118 feet and perforations in the 5-1/2-inch casing between 2,104-2,112 and 2,115-2,120 feet.

A 2-3/8-inch, internally plastic coated tubing is set with a packer at 2,046 feet. The casing-tubing annulus is pressurized at approximately 60 psi. (JAVA Petroleum Consultants, 1984).

Chronology of Operational Problems. From startup in March 1971 until August 1975, the well operated without incident

and well below the permit limitations of 800 pounds per square inch gauge (psig) maximum surface injection pressure and of 90,000 gallons total volume injected per month. In July 1975, Cities Service lost a disposal contract and consequently requested that their permit be amended to include an additional 21,000 gallons per month of spent caustic, water, amine, and glycol.

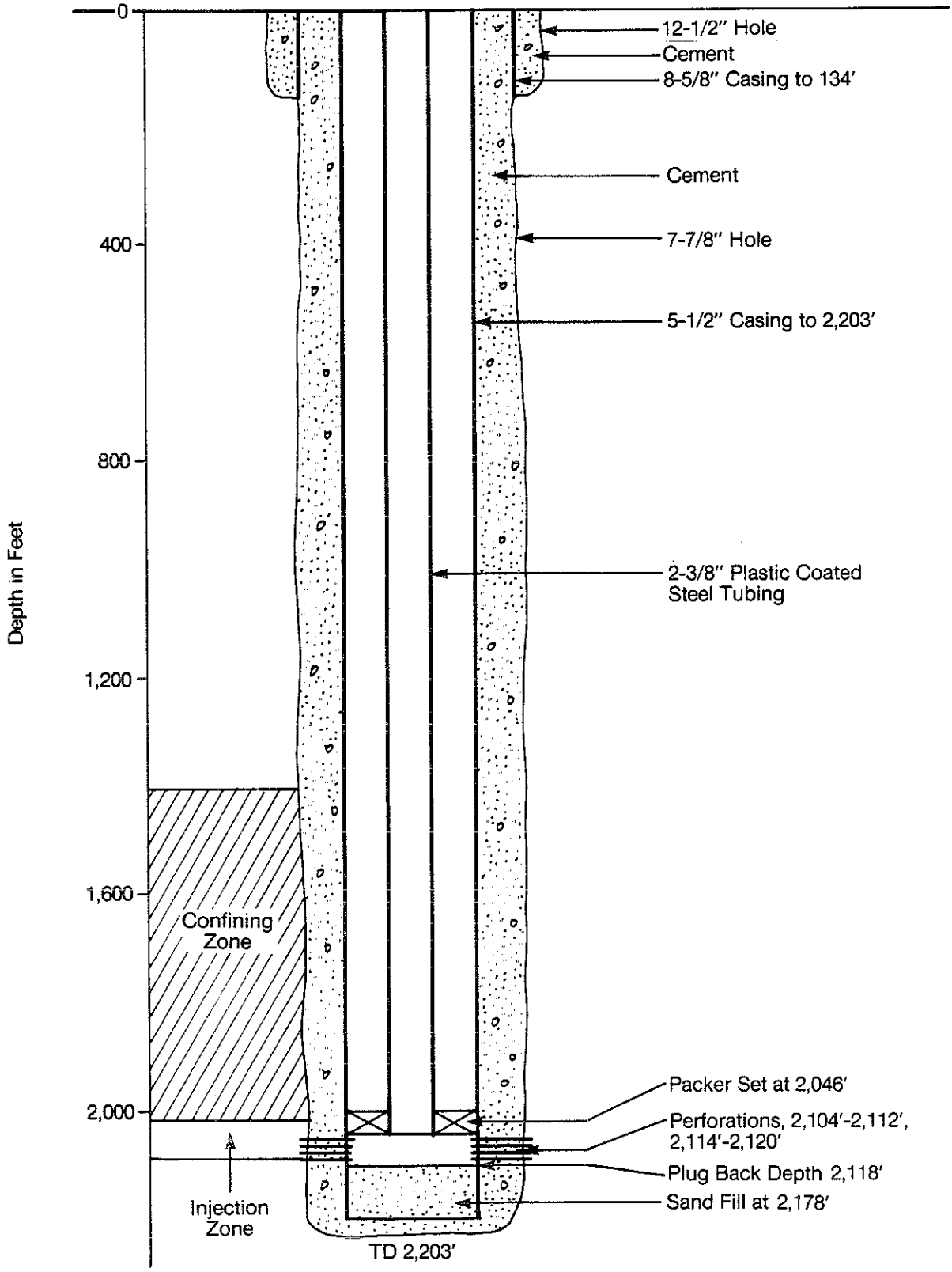
A public hearing for the proposed permit amendment was announced, and the City Council of Mont Belvieu formally objected on the grounds that their water supply may be endangered (TWQB, 1976a).

A public hearing was held October 20, 1975. Two objections to the proposed amendments were received. A nearby landowner complained that his water well, completed into the 300-foot sands, was contaminated. Representatives from the TWQB and the Texas Railroad Commission conducted an investigation and determined that possible pollution and degradation of the well (sulfide content of 0.61 ppm) may be a natural geologic phenomenon but was not caused by the Cities Services well (Paine, 1976). The City of Mont Belvieu's concern about possible endangerment to their water supply was also discounted after a study of the pressure increase and waste fluid movement was conducted (Paine, 1976). The permit amendment was granted in September 1976, with provisions for upgraded monitoring. The additional monitoring included installing pressure gauges on the injection tubing and tubing-long string casing annulus, filling the annulus with corrosion-inhibiting fluids and maintaining a positive pressure on the annulus, and installing continuous recording devices for injection tubing pressures, flow rates, and tubing-long string casing annulus pressures (TWQB, 1976a).

Yearly inspection reports from 1978-1982 indicated no operational problems, and that the well was meeting the conditions of the permit (TDWR, 1985b). In 1983, Cities Service applied to the Texas Railroad Commission to inject oil and gas waste into a porous formation not productive of oil and gas. The hearing was held May 10, 1983, and September 23, 1983.

In January 1984, the tubing was pulled, visually inspected, and found to be in good condition with no indication of corrosion. Mechanical integrity testing was then performed, consisting of a casing-tubing annulus pressure test (to 1,000 psi) and a radioactive tracer survey. No leaks in the casing-tubing annulus were detected, and no evidence of upward migration outside the well casing was found. On February 28, 1985, the TDWR permit was cancelled because the well was reclassified as a Class II well, and the well was transferred to the Texas Railroad Commission's jurisdiction. The current Texas Railroad Commission permit has more restrictive pressure and volume requirements than the cancelled TDWR permit.

D19976.P0



CITIES SERVICE FRACTIONATORS
Mont Belvieu, Texas

WASTE DISPOSAL WELL 092

UIPC

DSI TRANSPORTS, INC.
DEER PARK, TEXAS

Background. DSI Transports, Inc., operates a Class I commercial, hazardous waste disposal well in Deer Park, Texas. The company provides services for tractor-trailer transport vehicles in the form of cleaning and maintenance. The services performed on company-owned and subcontracted chemical transports and trailers result in a highly variable wastewater. In addition to wastewater generated onsite from the above operations, DSI accepts offsite wastewater from nearby industries.

The wastewater is separated into treatable and nontreatable wastewater. The nontreatable wastewater is disposed of via the injection well. Before being injected, the wastewater passes through a coagulant tank, a settling tank, and a filter system. The DSI waste disposal well (WDW), 169, is currently permitted to dispose of waste within the interval of 5,545 to 7,300 feet. The maximum injection rate permitted is 260 gallons per minute (gpm) at a surface pressure not to exceed 1,300 pounds per square inch gauge (psig).

Site Description. The DSI plant site is located in Harris County Texas, on the Gulf Coast basin. This geosynclinal basin is reported to contain 36,000 feet of Cenozoic strata.

The disposal zone is into the Frio Sands which occur from approximately 5,400 to 7,500 feet. The Basal Frio is predominantly sand interbedded with shales and extends from approximately 6,800 to 7,500 feet. The upper Frio consists of alternating layers of sands and shales. A northeast to southwest fault cuts the disposal zone 3,500 feet north of the well. There is no reported influence on the fault from the waste disposal operations.

The Frio is underlain by the Vicksburg Group which consists primarily of shale with some sandstone lens. The Vicksburg occurs at approximately 7,500 feet and is reported to be over 1,000 feet thick in the area.

Overlying the Frio is the Marine Anahuac Formation. This formation is predominantly shale with small amounts of sandstones. This formation acts as confining bed and is reported to be approximately 600 feet thick.

The base of freshwater in the area is approximately 2,750 feet. Freshwater is defined here as having a resistivity of greater than 20 ohm-meters. The lower Chicot and Evangeline aquifers produce most of the groundwater in the area from 300 to 600 feet. These aquifers are comprised mostly of sands, gravels, and clays.

Well Construction Details. WDW 169 was constructed by setting and cementing 9-5/8-inch casing to 2,827 feet. The 5-1/2-inch long string casing was set and cemented to 7,103 feet. This 5-1/2-inch casing consisted of steel casing to 6,754 feet and 5-1/2-inch fiberglass from 6,754 to 7,100 feet. The cement collar and casing shoe complete the long string to a depth of 7,103 feet. A 2-7/8-inch stainless steel screen and telltale section was gravel packed and set from 7,050 to 7,330 feet. The packer was set at 7,010 feet with 2-7/8-inch fiberglass tubing set into the packer.

The long string casing was later perforated from 6,974 to 7,042 feet when sand was found in the bottom of the well. The packer was moved up and set at 6,764 feet.

Chronology of Operational Problems. WDW 169 was completed in March 1981. The well was placed in service December 1981.

In March 1982, WDW 169 experienced a loss of annulus pressure and the well was shut down. When the tubing was pulled, it parted and fell into the well. The fallen tubing was successfully fished out of the well. The well was found filled with sand below 7,016 feet. The casing was perforated from 6,974 to 7,042 feet, and the packer and tubing were reset at 6,764 feet. The well was acidized and returned to service (Golden Strata, April 1982).

The tubing was pulled in November 1982 in response to a loss of annulus pressure. A caliper log indicated the casing was in good condition. The tubing was inspected and returned to the well (Davis, 1983).

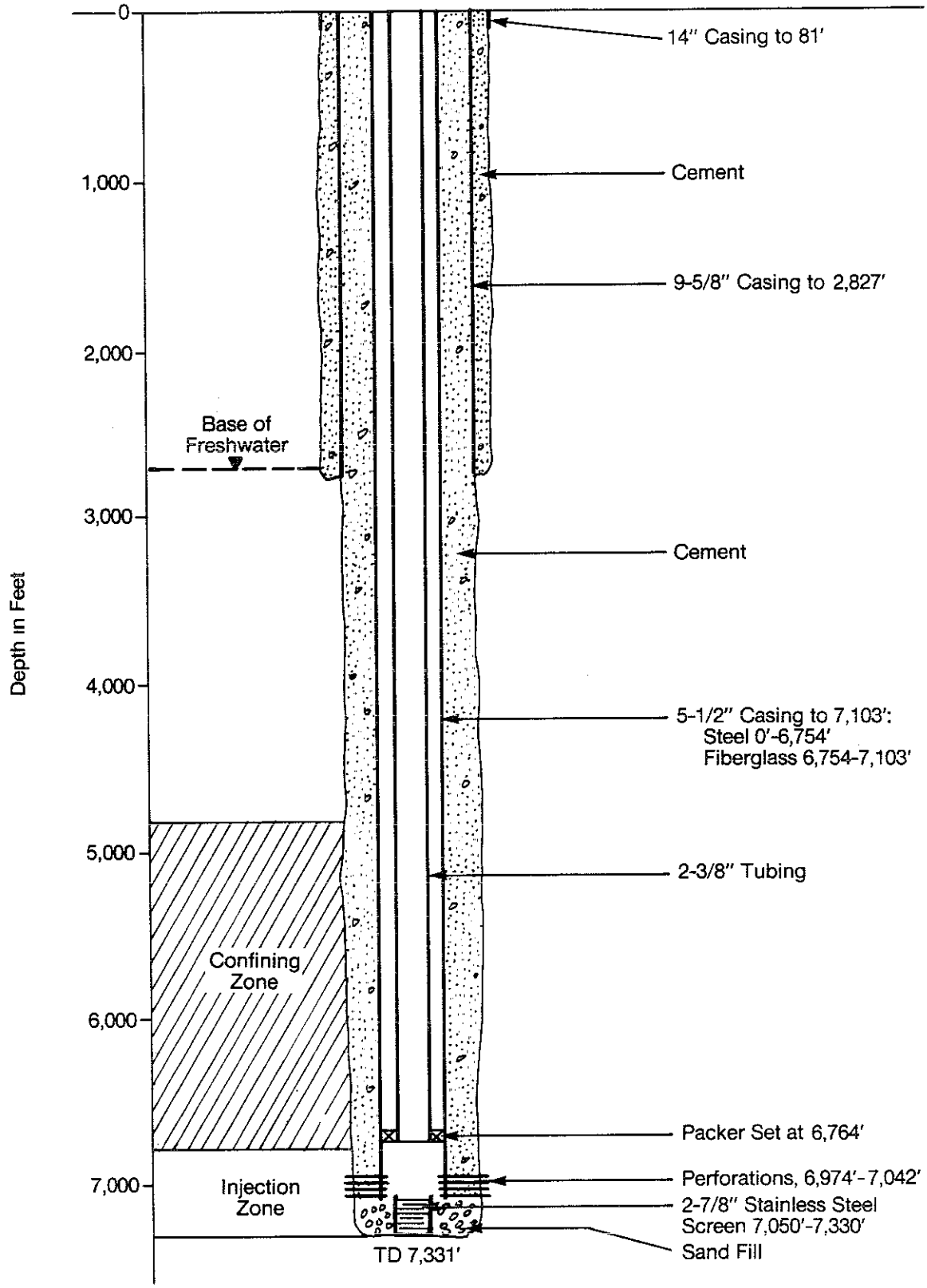
The required UIC mechanical integrity tests were performed in December 1983. The well met all UIC requirements for mechanical integrity.

The well was perforated again in February 1984 from 6,950 to 6,970 feet. Some of the tubing joints were found defective and were replaced.

In early April 1984, a workover was performed to determine the cause of a potential annulus/injection tubing communication. The tubing was found parted at 1,067 feet. Steel tubing was installed in the well because of continued problems with fiberglass tubing. The steel tubing began to leak in late April, when it was removed and replaced with new fiberglass tubing set so that less tension was exerted on the tubing than previously.

In December 1984, communication was observed between the tubing and annulus after a temporary increase and decrease in injection pressure. The packer was found to have a leak and a new packer was installed on top of the old packer. The tubing was replaced and the well was returned to service.

D19976.P0



DISPOSAL SYSTEMS, INC.
Deer Park, Texas

WASTE DISPOSAL WELL 169

E.I. DUPONT DE NEMOURS & CO., INC.
CORPUS CHRISTI PLANT
INGLESIDE, TEXAS

Background. DuPont's Corpus Christi plant is located in San Patricio County on the north shore of Corpus Christi Bay adjacent to the La Quinta ship channel. The plant site is on Highway 361 about one mile west of Ingelside, Texas. Three injection wells have been used at the plant for disposal of hazardous wastes from manufacturing carbon tetrachloride, tetrachloroetheylene, and Freon® 113 and 114. Of the three wells, Waste Disposal Well (WDW) 79 was plugged and abandoned in October 1983, and WDW 109 and WDW 121 are currently active. This case history addresses WDW 121, which is used currently for disposal of Freon® alkaline wastes.

WDW 121 has accepted two different waste streams. The original permit in 1974 allowed for disposal of a 30 percent aqueous HCl solution with a pH less than one. In 1980, DuPont applied for an amendment to their permit to dispose of Freon® waste instead of the aqueous HCl. The Freon® waste was described as an alkaline solution of sodium hydroxide containing soluble fluoride and chloride salts and trace quantities of arsenic and sodium hypochlorite or hydrogen peroxide. The waste stream is filtered before being pumped down the well. Two 60,000-gallon fiberglass reinforced plastic storage tanks are used for surface storage of this waste.

This well was reportedly found in 1978 to have casing leaks because of corrosion from the hydrochloric acid waste stream. An extensive reworking was conducted and the well brought back into service in October 1980. The well was re-permitted under UIC in 1983 and is currently active.

Site Description. The plant is situated in the coastal bend region of the West Gulf Coastal Plain. The upper 3,050 feet of sediments consist of interbedded sands, clays, and shales. Geologically, Pleistocene-Holocene sediments occur from the surface to approximately 1,100 feet, and Upper Miocene-Pliocene sediments from 1,100 feet to approximately 3,050 feet.

The confining unit for the injection wells is the Lagarto formation. This 1,000-foot-thick shale occurs in the approximate subsurface interval from 3,050 feet to 4,050 feet.

Underlying the Lagarto is the Oakville Formation. The Oakville consists of seven or eight distinct sand bodies separated by shales. The Oakville occurs from approximately 4,050 feet to 5,050 feet in the injection well area.

Underlying the Oakville is the Catahoula Formation, consisting of poorly sorted, fluvial-deltaic sands, with interbedded shales and clays. The upper Catahoula Sands, which occur from 5,050 feet to 5,450 feet, serve as the injection zone.

Underlying the Catahoula is the Anahuac Formation, which is a marine shale in the approximate interval from 5,900 feet to 6,300 feet. This formation serves as the lower confining zone for the injection well.

The principal freshwater aquifer in the area is the Beaumont Formation. This formation consists of fine to very fine sand, silt, and clay at depths ranging to 400 feet. The total dissolved solids concentration in the Ingleside area is approximately 2,000 mg/L at 150 feet. In the area of the injection well, the Beaumont is not known to yield freshwater.

Well Construction Details. WDW 121 was completed in 1975 with 13-3/8-inch surface casing set and cemented to 1,018 feet. A 9-5/8-inch, long-string steel casing was set and cemented to 5,141 feet. A 7-1/4-inch fiberglass liner and steel hanger was cemented to the 9-5/8-inch-long string casing from 4,177 feet to 5,147 feet with Epseal, an acid-proof epoxy cement. A 3-1/2-inch fiberglass screen was set from 5,081 feet to 5,242 feet, and a 4-1/2-inch fiberglass tubing set to 4,992 feet.

In 1980, the well was recompleted by removing the old fiberglass 7-1/4-inch liner and steel hanger and 3-1/2-inch fiberglass screen. The 9-5/8-inch steel long string casing was also removed below 5,055 feet. A 7-1/4-inch fiberglass liner was cemented in place from 4,104 feet to 5,143 feet. The open hole beneath the liner was under-reamed to 15 inches. A 3-1/2-inch screen was set and gravel packed from 5,040 feet to 5,242 feet. New fiberglass tubing was set in the well.

Chronology of Operational Problems. Drilling began in November 1974 for WDW 121. The well was to be a replacement well for WDW 79. Construction was completed in November 1975 and injection began in March 1976. The well was operated with a packerless fluid flush hydraulic seal. Fresh water is continuously pumped down the annulus during injection.

Early in 1978, an increase in annulus pressure initiated a workover. The tubing was pulled and found to be parted at the thirty-third joint (E.I. DuPont, October 1978). The lower portion had fallen into the well screen. The tubing was removed and the casing was logged and pressure tested. A leak of approximately 125 gpm was found between 5,020 feet and 5,050 feet. Small leaks were found between 4,178 feet and 5,020 feet. The well was temporarily abandoned.

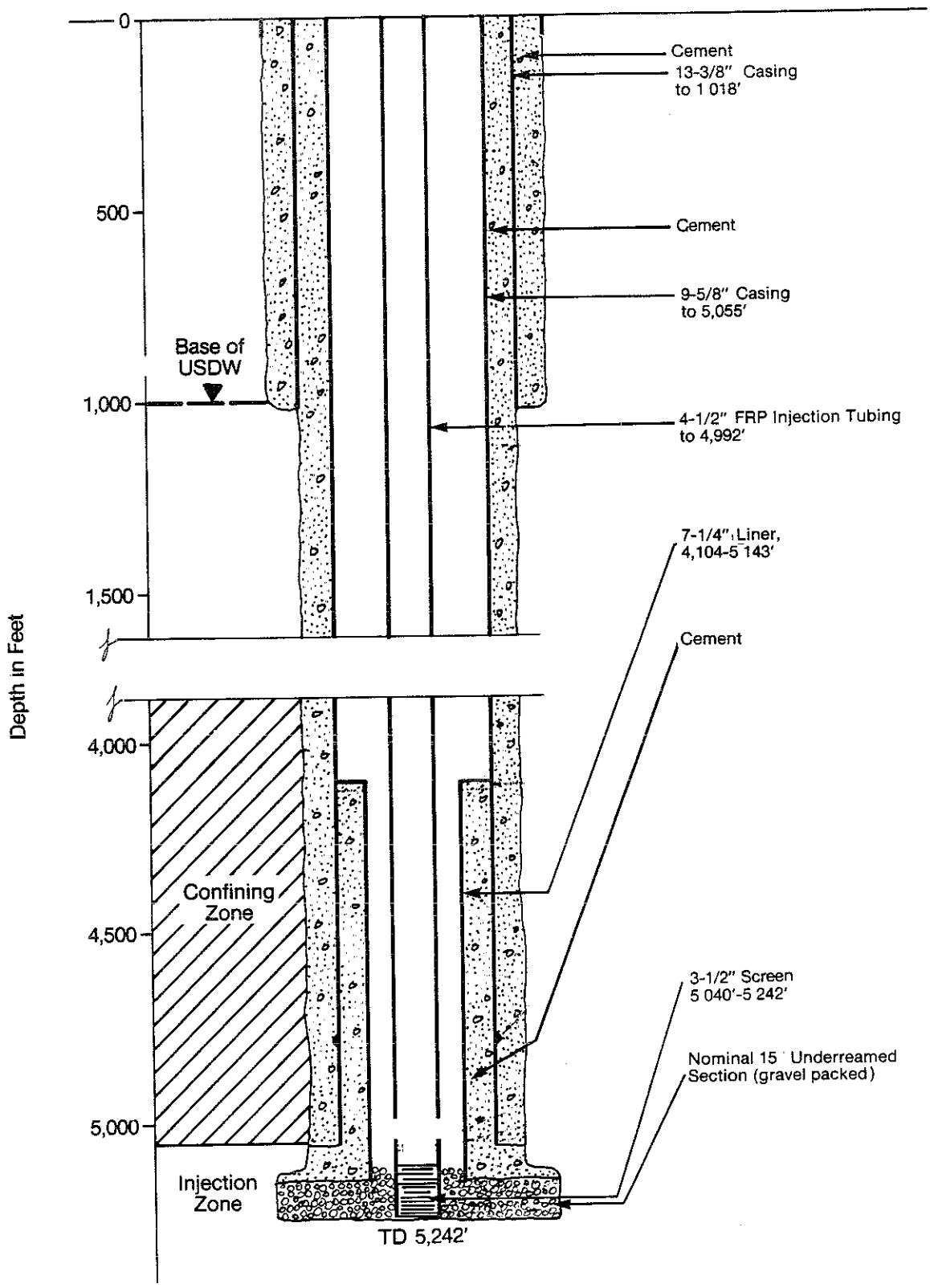
In January 1980, DuPont proposed to rework WDW 121 for the injection of Freon® alkaline waste. This work was performed between April and June 1980. The damaged portion of the casing was removed and the well was relined. A new screen section and gravel pack were installed. The well was returned to service in October 1980.

In December 1981, injectivity of the well declined. The screen was found filled with formation sand (E.I. DuPont, December 1981 and November 1982). The well was cleaned out and returned to service.

In March 1983, the mechanical integrity test required for the UIC permitting process was performed. Fluid was detected exiting the 7-1/4-inch fiberglass casing at approximately 5,070 feet. A cool plume of fluid was detected with a temperature log above the permitted zone at 4,957 feet (E.I. DuPont, March 1983).

The well was placed back in service with the mechanical integrity approval put on hold (Texas Department of Water Resources (TDWR), March 1983). The possible leak was into the lower Oakville formation, which is an acceptable injection zone although such a discharge from WDW 121 was unpermitted at the time. The UIC re-permit now includes the lower Oakville as an injection zone. In June 1984, the mechanical integrity test was approved (TDWR, June 1984).

D19976.P0



E.I. DUPONT de NEMOURS & CO., INC.
Corpus Christi Plant

WASTE DISPOSAL WELL 121

E.I. DUPONT DE NEMOURS & CO., INC.
SABINE RIVER WORKS
ORANGE, TEXAS

Background. DuPont operates seven Class I injection wells at the Sabine River Works in Orange, Texas. The plant is located in Orange County, two miles south of the City of Orange on a 1,450-acre tract owned by Dupont.

The wastewater disposed of consists of three waste streams generated from two different processes. An adiponitrile plant on the property generates three waste streams: an organic waste, an aqueous acidic waste, and an alkaline waste. An adipic acid plant on the property generates another aqueous acidic waste. Each area has several wells for waste disposal: a primary well for each waste stream and a backup well. Wastes are traditionally segregated by composition and characteristics, thus necessitating multiple wells.

Typically, the wastewater is pumped to surge tanks where it is held prior to injection. Then the waste is pumped through pressure filters before being disposed of via the injection wells. The waste is currently injected at rates up to a maximum of approximately 800 gallons per minute (gpm). Injection pressure also varies and will occasionally rise above 1,000 pounds per square inch (psi), the maximum permitted pressure is currently 1,500 psi.

The wells at the Sabine River Works have experienced problems with plugging and the pressure rise associated with the decreased injectivity. The main causes of the plugging appear to be the unconsolidated sand used for the injection zone. The sand has filled the screen or perforated zone in the wells many times, resulting in a decrease in injectivity.

Site Description. The Sabine River Works is located on the coastal plain. The topography of the area is essentially flat. The principal drainage in the area is the Sabine River, located adjacent to the southeast side of the property, and the Adams Bayou on the east side of the site.

The injection zone consists of Miocene-age sediments of clean, fine-grained sand. The undifferentiated Miocene sediments are reported to be up to 7,000 feet thick in the area.

Fresh water with a total dissolved solid concentration of 1,000 ppm or less is reported to occur at an average depth of 720 feet in the area. Water with a total dissolved solids (TDS) of 1,000 to 3,000 ppm is reported to occur at a depth of 950 feet.

The zone between the base of the freshwater and the top of the uppermost injection zone, which occurs at 2,550 feet in Waste Disposal Well (WDW) 12, contains twelve confining shale strata with a total thickness of 725 feet. Additional confining shale strata in the 2,500- to 4,100-foot interval total approximately 1,150 feet.

Well Construction Details. WDW 12 was constructed by first setting a 20-inch casing to 80 feet. A 15-inch hole was drilled through the casing to 1,650 feet. A 9-5/8-inch casing was set in the hole and cemented to 1,650 feet. A 5-9/16-inch stainless steel casing was set and cemented in a 8-3/4-inch hole to 5,250 feet. After the cementing, the casing was found parted and out of line at approximately 2,944 feet. A 3-1/2-inch stainless steel liner was set from 2,730 to 2,944 feet and the well filled with cement below 2,944 feet. The casing was initially perforated from 2,648 to 2,920 feet. The casing was later perforated from 2,550 to 2,580 feet. Completed in 1965, the well was operated without a packer or tubing.

WDW 23 was constructed with 1,631 feet of 9-5/8-inch casing. The casing was set in a 15-inch hole and cemented to the surface. A 5-1/2-inch stainless steel casing was set in a 8-3/4-inch hole to 5,204 feet and cemented to the surface. The casing was perforated from 4,780 to 5,110 feet with 1/2-inch diameter holes. The well was operated without a packer or tubing.

A bridge plug was later set at 4,930 feet and additional perforations made up to 4,066 feet. Another bridge plug was set at 4,020 feet and the well was progressively perforated up to 3,700 feet. The well was plugged with cement in 1973.

WDW 54 was constructed by driving 20-inch casing to 80 feet. A 13-3/8-inch casing was set and cemented to 1,640 feet. A 9-5/8-inch casing was set and cemented to 4,873 feet. A 16-inch hole was underreamed from 4,900 to 4,989 feet and a 5-5/8-inch slotted liner set and gravel-packed in the underreamed hole. The liner was 161 feet long and the bottom 82 feet was slotted. A 5-1/2-inch stainless steel tubing was set in a packer at 4,820 feet.

WDW 54 was later sidetracked and completed in the 4,921- to 5,006-foot interval. A 3-1/2-inch stainless steel screen and liner were gravel packed in the underreamed hole. The 5-1/2-inch stainless steel tubing was set in a packer at 4,270 feet.

WDW 56 was constructed by driving 16-inch casing to 80 feet. A 9-5/8-inch casing was set to 1,638 feet and cemented to the surface. A 5-1/2-inch casing was set to 4,620 feet and cemented to the surface. The bottom portion of the 5-1/2-inch casing was set in resin cement. A 9-3/4-inch underreamed hole was cut from 4,622 to 4,658 feet and a

2-3/8-inch slotted liner, 89 feet long, was gravel packed in the hole. The slotted section was 17 feet long. A 2-3/8-inch injection tubing was run to a packer at 4,448 feet. The well was later recompleted in the interval from 4,527 to 4,553 feet. A bridge plug was set at 4,560 feet and a 2-7/8-inch screen and liner was gravel packed in the well. The 2-3/8-inch injection tubing was replaced with 3-1/2-inch tubing.

WDW 55 was constructed by driving 20-inch casing to 80 feet. A 13-3/8-inch casing was set to 1,616 feet and cemented to the surface. A 9-5/8-inch casing was set to 4,877 feet and cemented to the surface. Fifty sacks of resin cement were placed at the bottom of the 9-5/8-inch casing. The well was drilled out to 5,020 feet and a section underreamed from 4,894 to 4,978 feet. A 5-5/8-inch liner was gravel packed in the underreamed hole consisting of 71 feet of slotted and 90 feet of blank section. A 5-1/2-inch stainless steel injection tubing was installed and set in a packer at 4,814 feet. WDW 55 was later recompleted by installing a 6-5/8-inch stainless steel liner from 4,468 to 4,619 feet. The liner was cemented in place with Epseal cement. A bridge plug was installed at 4,774 feet and the well was perforated from 4,618 to 4,726 feet. A 3-1/2-inch stainless steel screen was gravel packed in the interval 4,501 to 4,730 feet.

WDW 57 was constructed by driving 16-inch casing to 75 feet. A 9-5/8-inch casing was set to 1,638 feet and cemented to the surface. A 5-1/2-inch casing was set to 4,628 feet and cemented to the surface. The bottom of the 5-1/2-inch casing was cemented with 30 sacks of resin cement. A 9-inch underreamed hole was cut from 4,628 to 4,662 feet. A 2-3/8-inch liner was gravel packed in the underreamed section of the well. The liner was 89 feet long with

17 feet slotted at the bottom. A 2-3/8-inch tubing was run to the packer set at 4,572 feet.

WDW 57 was later recompleted into a higher zone. The casing was perforated from 4,519 to 4,553 feet. The packer was reset at 4,498 feet with 2-7/8-inch stainless steel tubing set into it.

WDW 104 was constructed by setting a 13-3/8-inch casing to 1,407 feet and cemented it to the surface. A 8-5/8-inch casing was set and cemented to 4,935 feet. A stainless steel section was included in the 8-5/8-inch casing in the interval 2,355 to 2,865 feet and in the bottom 479 feet. The upper stainless steel section was installed to protect the casing from past acidic waste injected into WDW 12. Epseal cement was used to seal the bottom portion of the 8-5/8-inch casing. The well was underreamed and a slotted liner was gravel-packed in the interval from 4,940 to 4,996 feet. A 5-1/2-inch stainless steel tubing was set in a packer at 4,900 feet. The gravel packed zone was later moved up to 4,744 to 4,763 feet. The well was later plugged with cement.

Chronology of Operational Problems. WDW 12 was constructed and permitted to inject adipic acid process wastewaters in early 1965. Construction problems prevented this well from being completed to its drilled depth of 5,250 feet, and a shallower depth of 2,550 feet was permitted. During the cementing operation on the 5-9/16-inch stainless steel casing, the casing reportedly shifted upwards about 2 feet and dropped back down. It was reported the cementing operation required a much higher pressure to continue after the casing shift. Cement was returned to the surface. An impression block ran down the hole found the casing had parted and was out of line at approximately 2,944 feet (E.I. DuPont, February 1965). A 230-foot-long, 3-1/2-inch

stainless steel liner was set and cemented above the separation to seal leaks in the casing collars. The well was filled with cement below 2,944 feet.

Because of the presence of old oil and gas wells in the vicinity with no records of abandonment, WDW 12 was allowed to operate at its shallow depth on an emergency basis only. Operation was to be allowed only until a replacement well could be constructed (Texas Water Quality Board (TWQB), September 1965). Injection of waste into this well began in August 1965. The well was used intermittently on an emergency basis from June 1966 until August 1971, with a total of 350 million gallons of waste disposed of during that time. The well was then plugged with cement after a reported casing collapse (Texas Water Quality Board, August 1971).

WDW 23 was constructed as a replacement for WDW 12 in 1966. Once this well was completed, WDW 12 served as the emergency backup to WDW 23 until WDW 12 was plugged in 1971. Continuous injection of waste into WDW 23 began in June 1966. By August 1966, the well had sanded up. The sand was removed and the formation reportedly gravel-packed.

In October 1966, the well had again filled with sand with a corresponding increase in injection pressure. A bridge plug was set at 4,930 feet and the casing perforated from 4,710 to 4,550 feet.

Between October 1966 and March 1971, WDW 23 was perforated and cement squeezed, moving up the hole to 4,066 feet. Because of the assumed unplugged oil and gas wells in the vicinity, the use of an injection interval above 4,000 feet required permission from the Texas Railroad Commission. This usage was granted for emergency use only in April 1971.

In 1972, WDW 104 was drilled to serve as a primary well for the adipic waste stream. WDW 23 was operated as the standby well for WDW 104. WDW 23 was perforated as high as 3,700 feet before being completely plugged with cement in November 1972 as a result of recurrent sand problems (TWQB, April 1973).

WDW 104 began injection of waste in July 1972. In October 1972, a malfunction in the waste filter system resulted in the need to scrape and flush the injection tubing and acidize the injection zone (E.I. DuPont, October 1972).

High injection pressure in March 1973 was observed at the well head. The well was removed from service and the tubing was pulled. The injection zone was underreamed again with a new slotted screen and gravel pack installed. The injection string was reinstalled and full injectivity was regained.

In January 1974, sand fill was found in the well after shutting down because of high injection pressure. The well was acidized, hydrojetted, and returned to service only to pressure up again. In March 1974, the well was shut down for a complete workover (E.I. DuPont, August 1974). A workover was performed, replacing the slotted screen and gravel pack. During the workover, a radioactive tracer was run and resulted in a cement squeeze at 4,910 feet. A final tracer survey indicated no fluid was migrating above 4,880 feet. The tubing was repaired, with some joints replaced, and the well was placed back in service in June 1974.

In December 1975, high injection pressure was again observed at WDW 104. The well was acidized and the screen was hydrojetted. The well was placed back in service until January 1976. When high injection pressures again were

observed a major workover moved the injection zone up to 4,744 to 4,763 feet. Nineteen feet of the casing was milled out. The area was underreamed and a 4-1/2-inch slotted screen was gravel packed in place (DuPont, May 1975). The well was placed back in service in May 1976.

WDW 104 was temporarily abandoned in January 1977 after a reported annulus leak repair. The casing at 4,300 feet was repaired but after the well was put back on line high injection pressures caused the well to be taken out of service. In February 1978, WDW 104 was plugged with cement (DuPont, February 1978).

WDW 54 was placed in service in June 1971. The well was operated until August 1972 when the packer was discovered to be leaking. The packer was reseated 18 feet lower in the well by the addition of tubing. During this workover, the well was cleaned by hydrojetting and acidization and the tubing was scraped. The well was then placed back in service.

In November 1972, the annulus lost pressure again. Six more inches were added to the tubing and the packer was reseated. The well was returned to service.

The well's injectivity decreased in January 1973, resulting in a complete reworking of the well. The tubing, gravel pack, and slotted liner were removed. The injection zone was re-underreamed and a new slotted liner, gravel pack and packer were installed. The tubing was reworked with defective sections replaced (E.I. DuPont, May 1973). The well was placed back in service in March 1973.

In May 1973, the permits for WDW 54 and 55 were amended to allow these two wells to handle adipic acidic wastes as well

as adiponitrile acidic wastes. These two wells were used as backups to WDW 104 after 1973.

A decreased injectivity in WDW 54 resulted in acidization with hydrojetting to clean the screen in October 1973 and August 1976. Sand and brown solid material was washed out of the screen during these operations.

In July 1981, the wells injectivity again decreased. The screen was found collapsed and full of sand. During an attempted cleaning shale, which was thought to be from the confining bed, circulated out of the hole (E.I. DuPont, August 1981). The well was perforated and squeezed at 4,750 feet. A 6-5/8-inch liner was epoxy cemented in from 4,470 to 4,620 feet. The casing was then perforated from 4,620 to 4,720 feet and a screen gravel-packed in the perforated casing.

The screen and gravel pack were replaced when the well injectivity decreased again in May 1982. New stainless steel injection tubing was installed.

In November 1982, an annulus leak was reported. Six gallons per hour were reported to be lost from the annulus (Texas Department of Water Resources (TWDR), November 1982). This leak was variable, and was finally traced to the packer unseating. This was corrected in 1983 after close monitoring and monthly reports to the Texas Water Commission.

In December 1983, pressure filter instrumentation was lost after 75 hours of subfreezing weather. As a result, some high differential pressures were allowed across the filter.

The well was acidized and hydrojetted to clean the screen in July and December 1983 and in January 1984. The January 1984 acidization did not restore an acceptable injectivity. The well was worked over and the screen and gravel pack were replaced.

In May 1984, the well was sidetracked because of decreased injectivity. The well was recompleted with an underreamed zone from 4,921 to 5,006 feet with screen and gravel pack installed. The polished bore receptacle packer was set at 4,271 and 5-1/2-inch stainless steel tubing was installed.

WDW 55 was completed in July 1971. The well was operated until December 1972 when the tubing was scraped and the screen was hydrojetted and acidized. The work was necessitated by a filter malfunction.

The well was hydrojetted and acidized in November 1983, March 1984, and June 1984. The work was performed when injectivity decreased because of sand in the screen.

The injectivity decreased again in July 1984 and acidization and hydrojetting failed to restore the wells previous injectivity. The well was taken off line and a workover was scheduled for January 1985.

WDW 56 was completed in June 1971. The well operated until January 1973 when it was removed from service because of a decrease in injectivity resulting in high injection pressure (E.I. DuPont, July 1973). The screen was found plugged with formation sand. The well was re-underreamed and a new screen and gravel pack installed. The tubing was in good condition and was reinstalled. The well was returned to service in March 1973.

In September 1973, the annulus pressure in WDW 56 was lost because of a leaking packer. The packer was repaired and the well hydrojetted and acidized. The well was returned to service in October 1973.

In October 1975 and in October 1976, the wells injectivity decreased. The well was cleaned by hydrojetting and acidization and returned to service.

In July and August 1980, WDW 56 was recompleted in a higher zone to overcome decreased injectivity. A 2-7/8-inch screen and liner were gravel packed in the well with the slotted interval from 4,526 to 4,553 feet. A bridge plug was set at 4,560 feet (E.I. DuPont, August 1980). The well was placed back in service as a primary well for a new alkaline waste stream.

WDW 57 was completed in August 1971. The well operated until April 1975 when it was shut down when injection pressures increased (E.I. DuPont, July 1975). The tubing, packer, and liner were removed and the well re-underreamed. A new slotted and blank liner was installed and gravel packed in the hole. The tubing and packer were replaced and the well placed in a standby condition until August 1975.

After WDW 57 was placed back in service in August 1975, the injection pressure steadily rose. By September 1975 it reached 1,500 psi, which was the maximum permitted. The well was cleaned out by hydrojetting and acidization. Precipitation and viscosity changes in the injected organic waste was cited as the cause of the decreased injectivity (E.I. DuPont, December 1975).

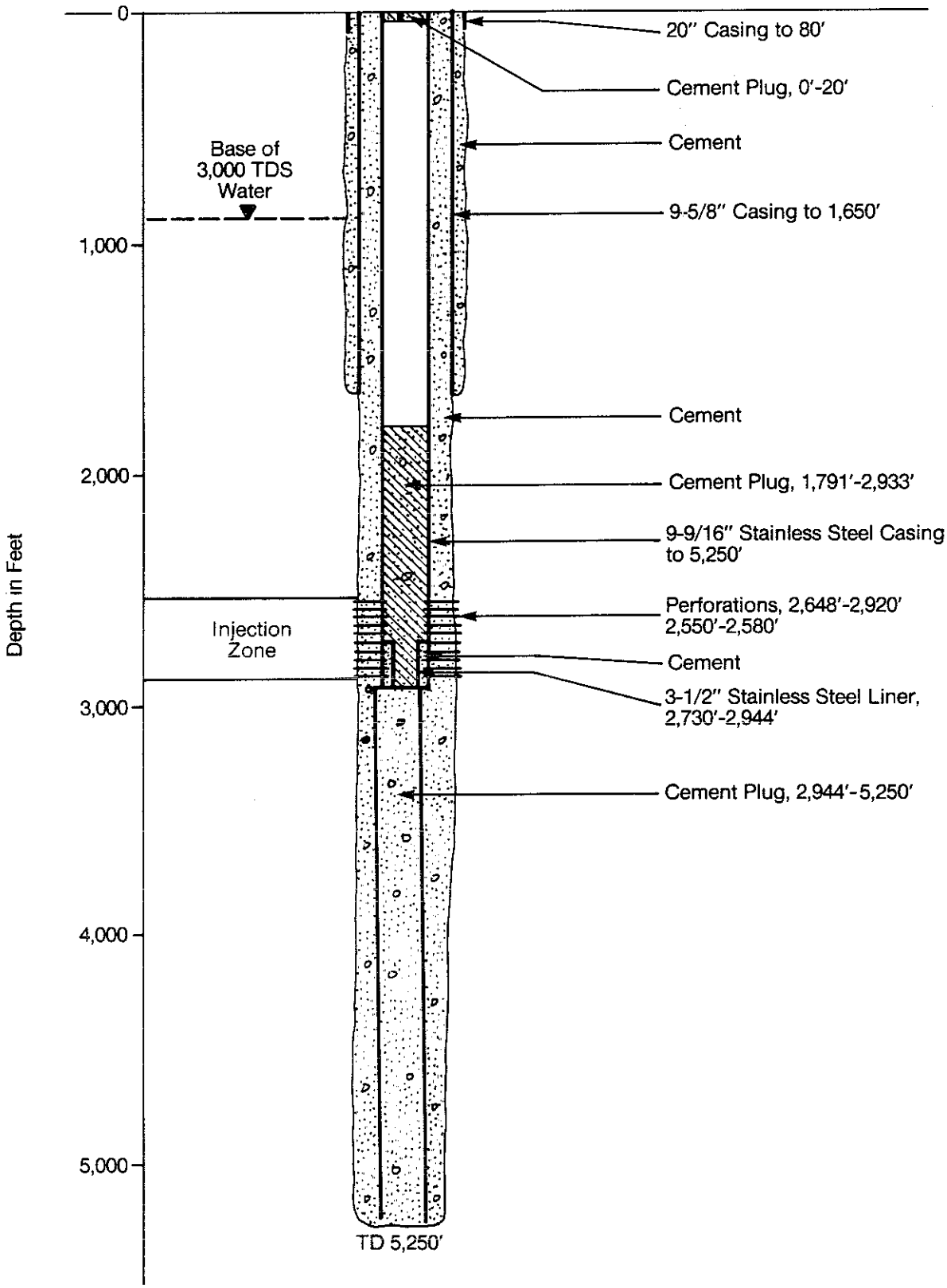
In April 1977, the well was cleaned out by hydrojetting and acidization. The well was then returned to service.

By July 1977, the injectivity decreased again causing the injection zone to be abandoned. The well was recompleted between 4,514 and 4,554 feet by perforating the casing. A 2-7/8-inch slotted screen was gravel packed into the interval. The well was returned to service in December 1977.

An increase in injection pressure caused WDW 57 to be worked over in May 1979. The screen, gravel pack, and liner were removed and the well cleaned out. A new packer was set at 4,498 feet and injection was made directly into the perforations with no screen or gravel pack installed.

In October 1983, a small corrosion hole was found in the injection tubing in WDW 57. The tubing was replaced, a chloride annulus fluid was substituted for the sodium nitrite used earlier, and the packer was redressed and reinstalled. The well was then returned to service.

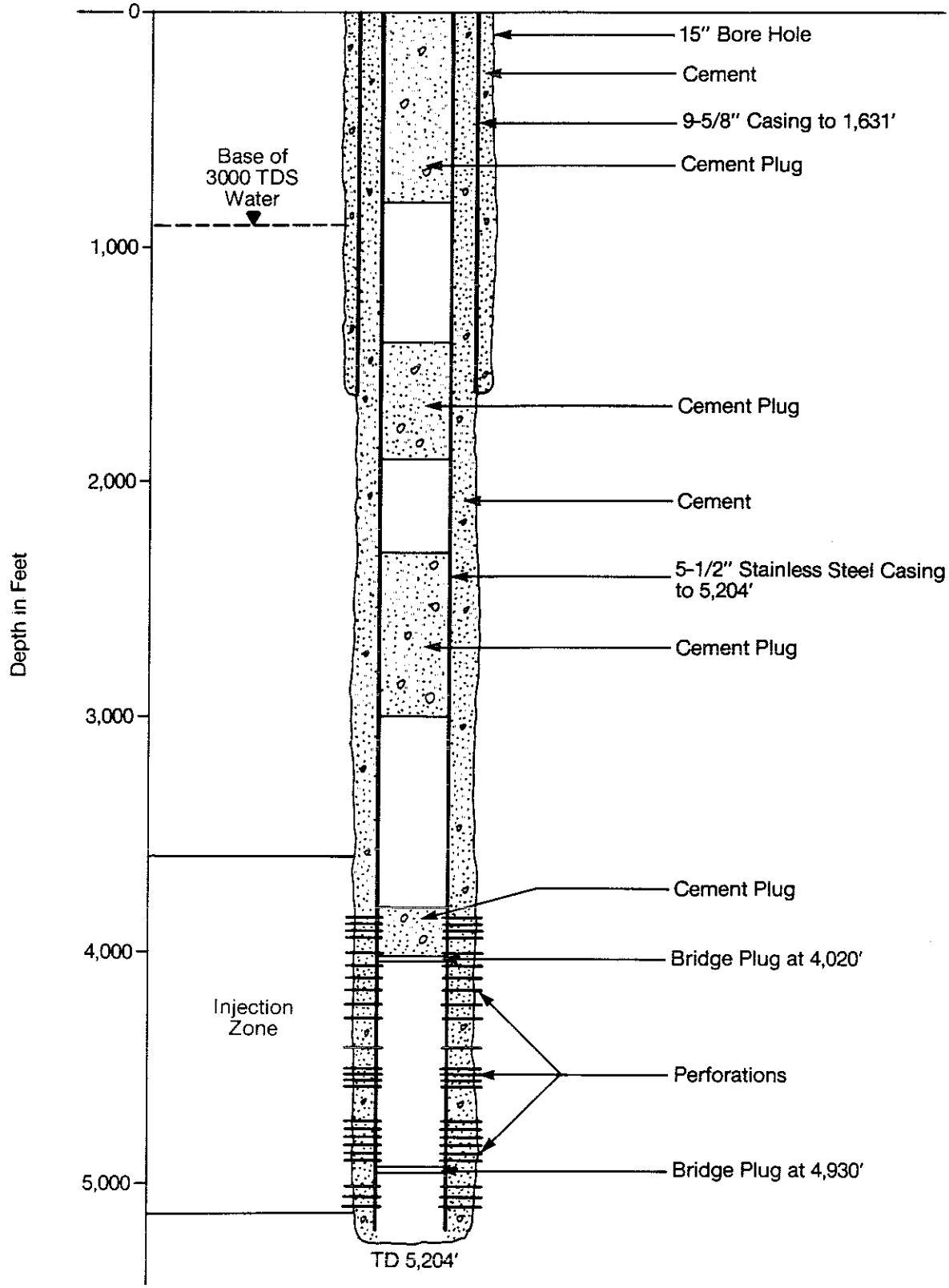
D19976.P0



E.I. DU PONT DE NEMOURS & COMPANY, INC.
Sabine River Works, Orange, Texas

WASTE DISPOSAL WELL 012 (Plugged 8/71)

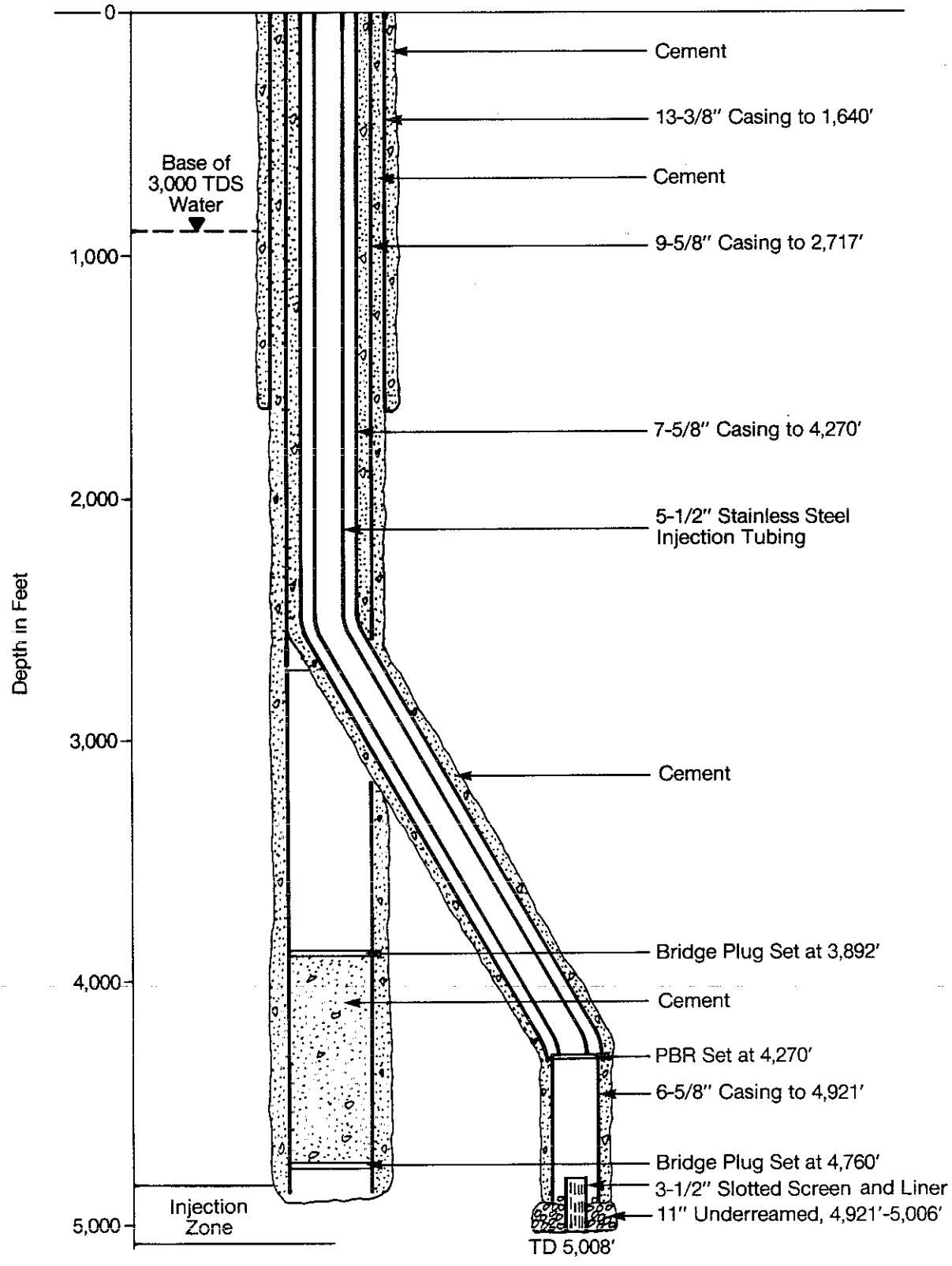
D19976.P0



E.I. DU PONT DE NEMOURS & COMPANY, INC.
Sabine River Works, Orange, Texas

WASTE DISPOSAL WELL 023 (Plugged 11/72)

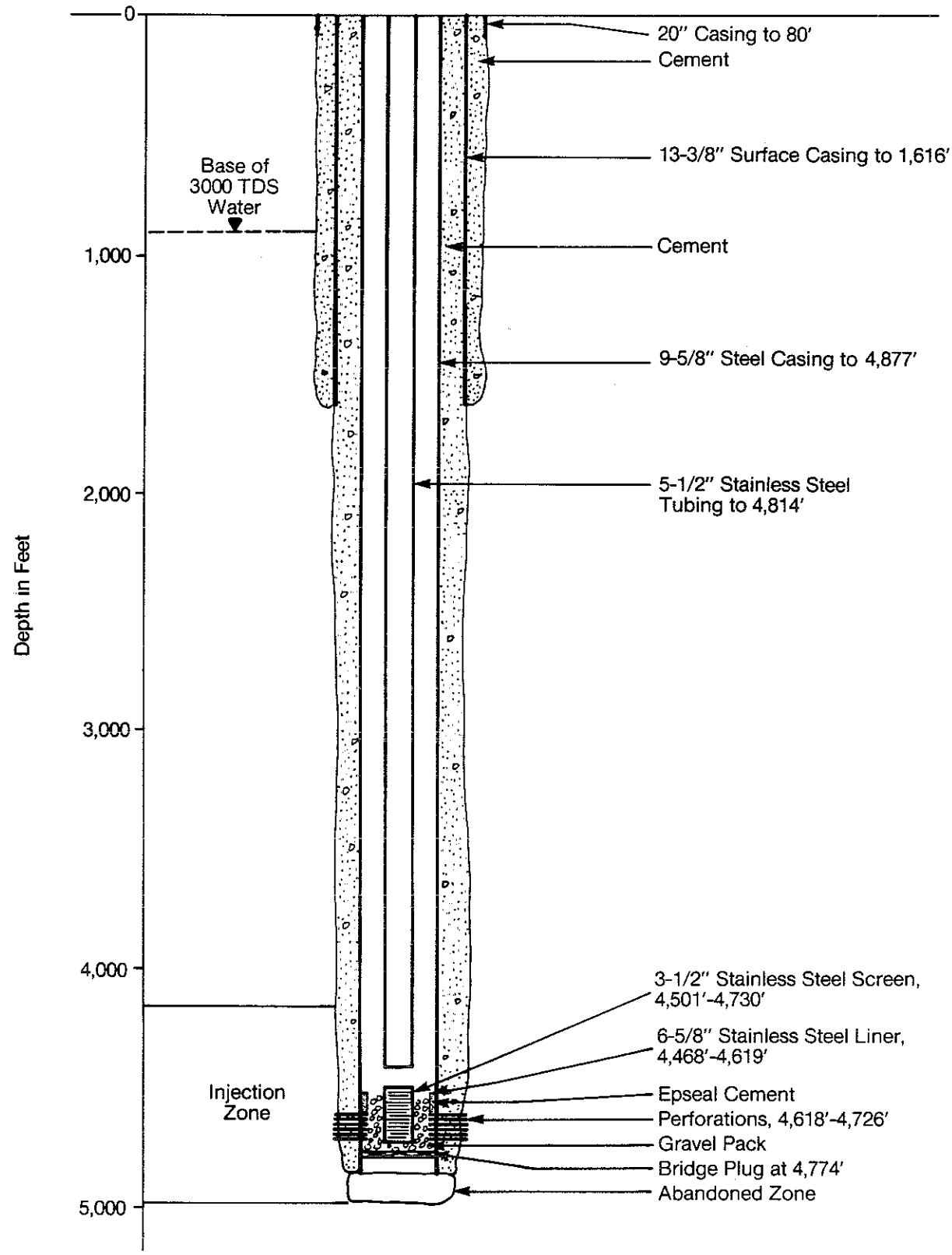
D19976.P0



E. I. DU PONT DE NEMOURS & COMPANY, INC.
Sabine River Works, Orange, Texas

WASTE DISPOSAL WELL 054

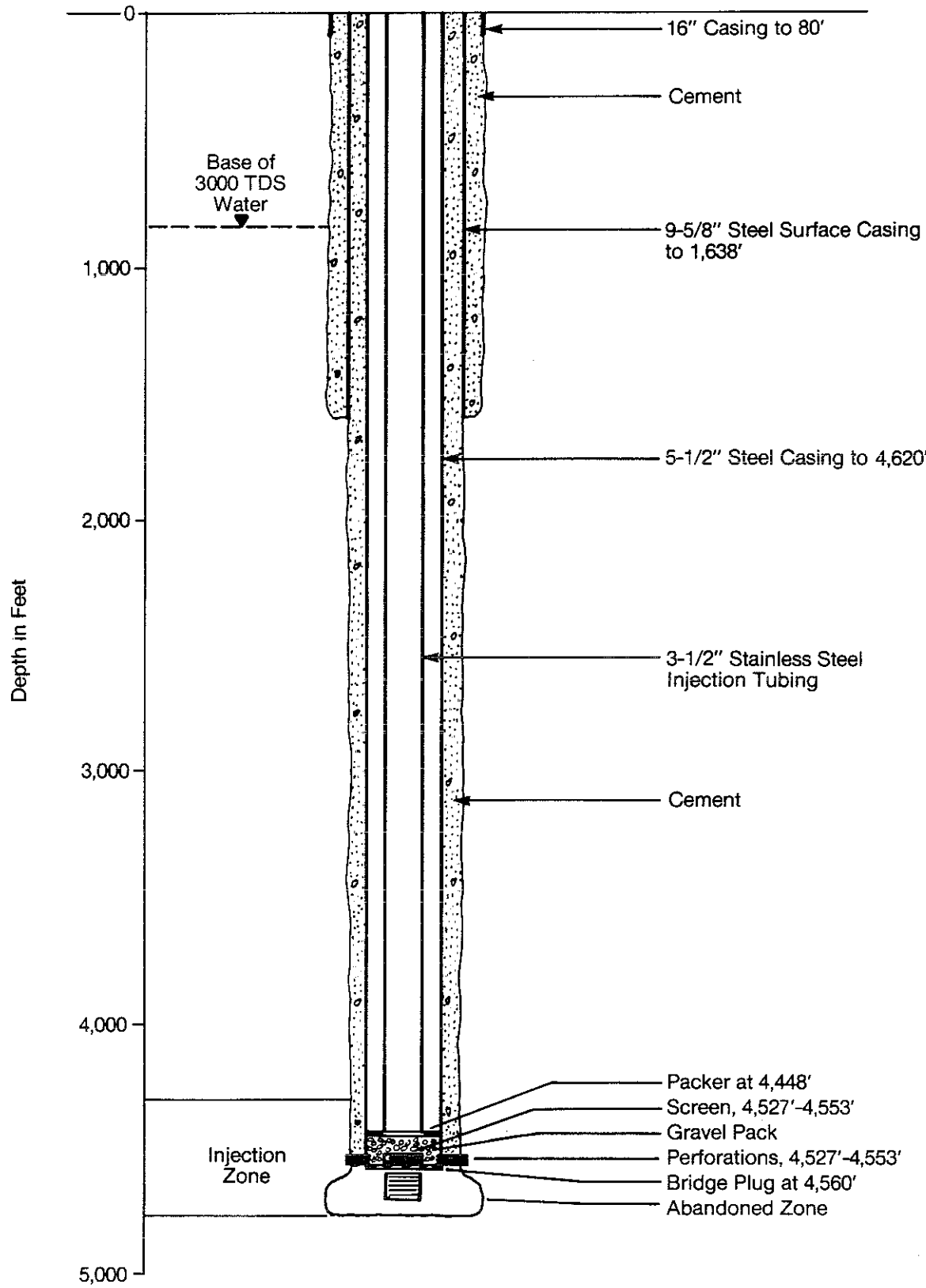
D19976.P0



E. I. DU PONT DE NEMOURS & COMPANY, INC.
Sabine River Works, Orange, Texas

WASTE DISPOSAL WELL 055

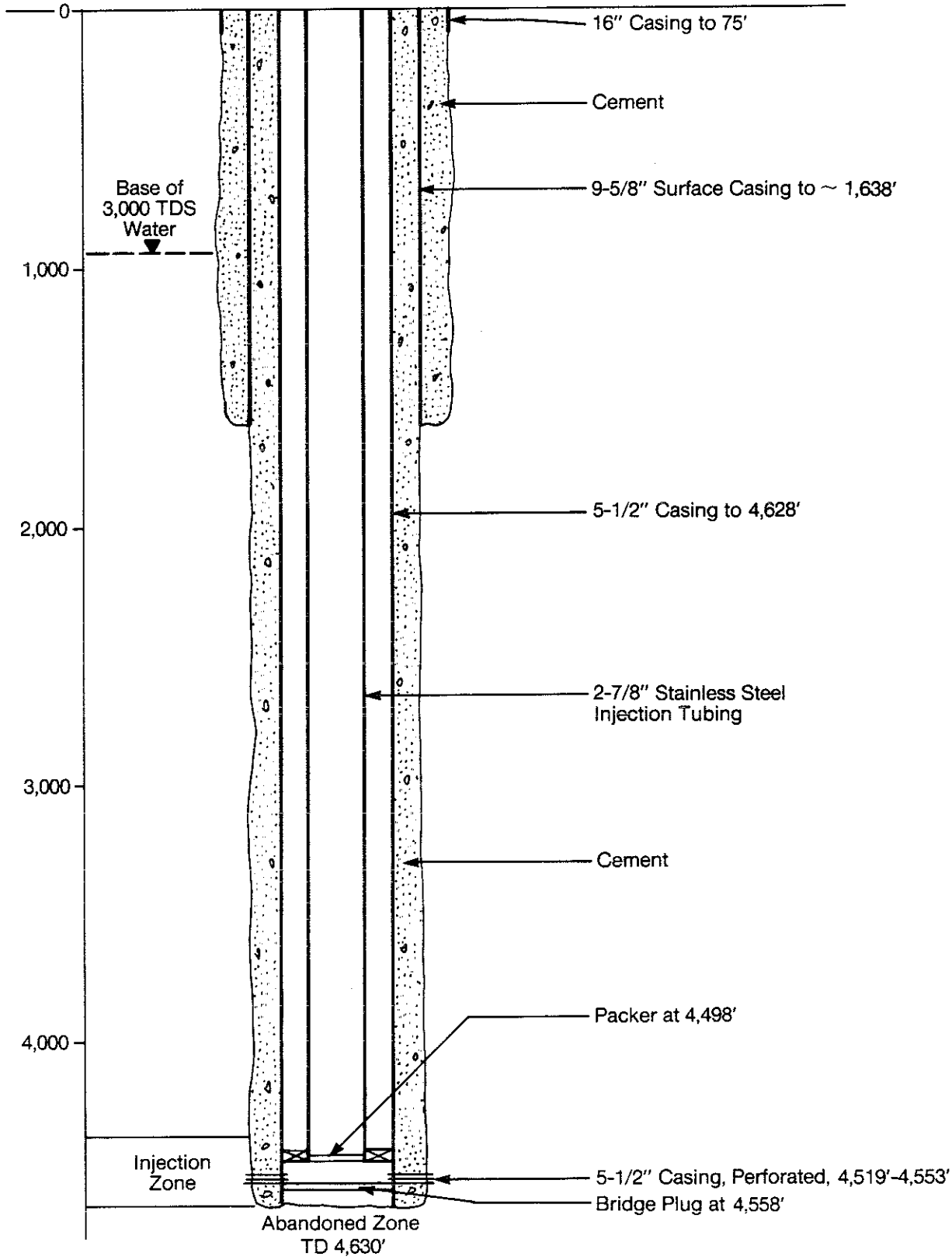
D19976.P0



E. I. DU PONT DE NEMOURS & COMPANY, INC.
Sabine River Works, Orange, Texas

WASTE DISPOSAL WELL 056

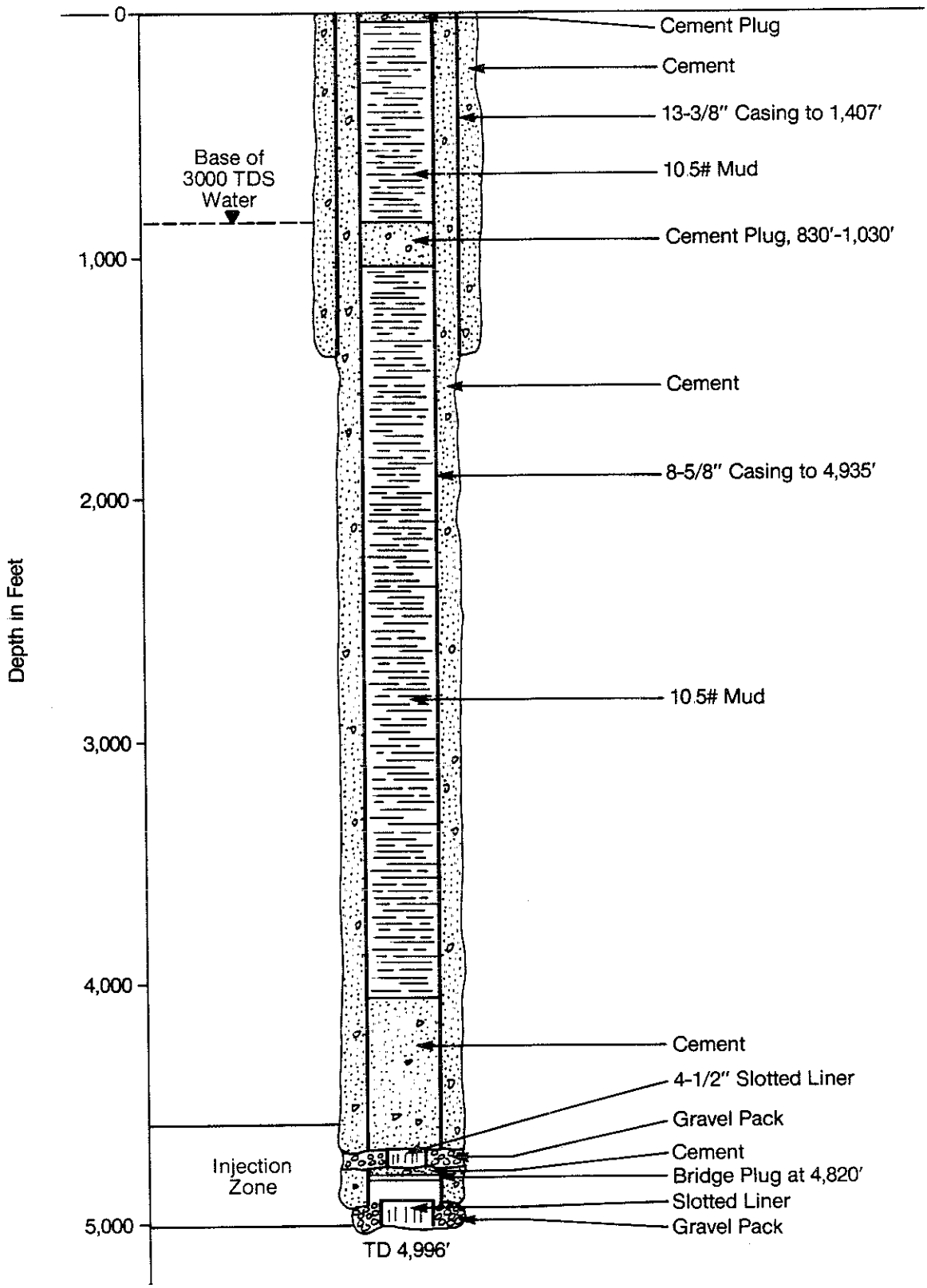
D19976.P0



E. I. DU PONT DE NEMOURS & COMPANY, INC.
Sabine River Works, Orange, Texas

WASTE DISPOSAL WELL 057 (Recompleted Dec. 1977)

D19976.P0



E.I. DU PONT DE NEMOURS & COMPANY, INC.
Sabine River Works, Orange, Texas

WASTE DISPOSAL WELL 104 (Plugged 2/78)

EMPAK, INC.
DEER PARK, TEXAS

Background. Empak, Inc., a subsidiary of Geo-Ject, Inc., operates a commercial hazardous waste injection well in Deer Park, Texas. The well is operated under Texas Permit WDW 157. The plant is located in eastern Harris County, adjacent to the Houston ship channel.

At this commercial facility, waste streams from a variety of industries are injected. Empak has identified the categories of wastes for injection that include pesticides, caustics, metallics, organics, spent acids, and waste oils. The original permit allowed for an injection rate of 300 gallons per minute (gpm) with a well head pressure of 600 pounds per square inch (psi). In July 1981, Empak's permit was amended to allow a surface pressure of 1,500 pounds per square inch gauge (psig).

Continuous monitoring devices record the surface injection pressure, volume injected and annulus pressure of the well. The well operator is required to maintain monthly reports, submitted to the Texas Department of Water Resources (TDWR) on a quarterly basis (TDWR, 1978-1983).

One enforcement action was taken against Empak for exceeding its maximum injection pressure (TDWR, April 1981). The case resulted in formal enforcement action and payment of assessed penalties. WDW 157 is currently permitted and is active.

Site Description. WDW 157 is located in the Gulf Coast Geosyncline. There are approximately 36,000 feet of Cenozoic sediments in the area. A northeast-southwest fault bisects the injection zone in southeast Harris County.

There is no reported influence on the well from the fault (TDWR, June 1980).

The injection zone is into the lower portion of the Basal Frio Sands Formation, which occurs from approximately 5,400 feet to 7,500. The Basal Frio consists of primarily sand, interbedded with shales, and is approximately 700 feet thick. The upper portion of the Frio consists of sands and shales.

Underlying the Frio is the Vicksburg Formation. The Vicksburg consists of a thick shale sequence. In the area, the Vicksburg occurs at approximately 7,500 feet and is over 1,000 feet thick.

Overlying the Frio is the Marine Anahauc Formation. This formation is a shale with small amounts of sandstone. The Anahauc is approximately 600 feet thick in the area.

The major aquifers in the area are the upper and lower Chicot and the Evangeline. The upper Chicot exists at a depth of 150 feet and has an average total dissovled solids (TDS) value of 1,700 mg/L. The lower Chicot exists at a depth of 500 feet and has a reported TDS concentration of 550 mg/L. The Evangeline exists at a depth of 2,650 feet and has a TDS concentration of 1,500 mg/L. Beneath the Evangeline is the Jasper aquifer. This aquifer occurs at a depth of 3,250 feet and has a TDS concentration of 7,500 mg/L (U.S. EPA, 1985c).

Well Construction Details. WDW 157 was constructed by driving a 16-inch casing to 81 feet. A 10-3/4-inch casing was set and cemented in a 14-3/4-inch hole to 2,843 feet. Cement was returned to the surface. A 7-inch casing was set and cemented in a 9-7/8-inch borehole to 7,518 feet. The

7-inch casing was cemented to the ground surface. Perforations were made in the 7-inch casing from 7,280 to 7,330 feet. Steel 3-1/2-inch injection tubing was set to 6,781 feet on a Baker Model AL-2 retrievable packer. The annulus was filled with brine.

Chronology of Operational Problems. WDW 157 began injecting waste in November 1980. A leak in the well annulus was detected shortly after startup. The well was shut down and the packer replaced. The well was returned to service.

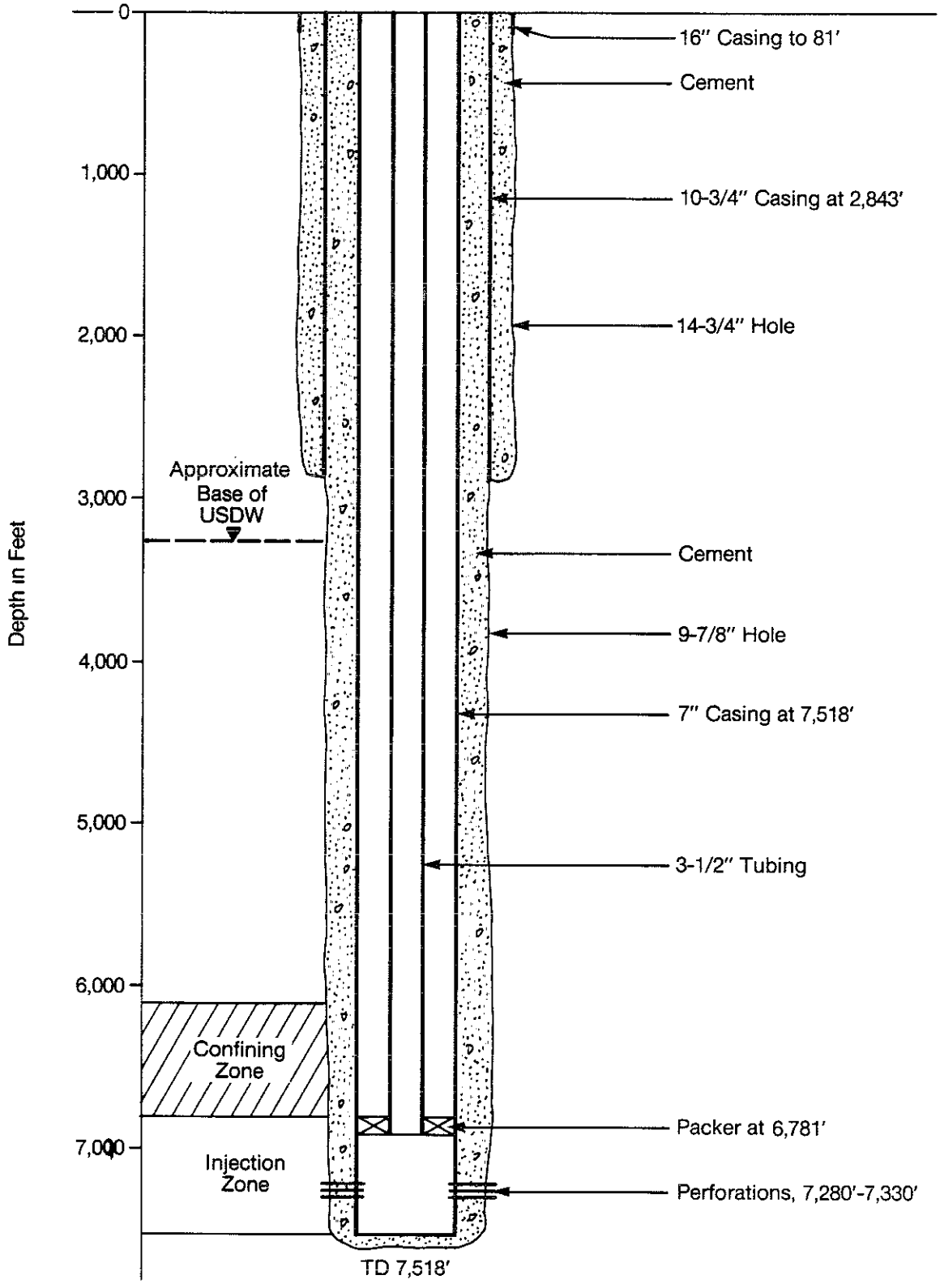
In May 1981, a leak in the disposal well system was suspected. The tubing and packer were removed. The 7-inch casing was scraped, a temporary packer was set at 6,290 feet, and the casing pressure tested at 1,600 psi. The test indicated no leakage from the casing. Fill was found in the well to 7,269 feet. The well was washed out to 7,312 feet and the tubing and packer reinstalled. Fill was tagged again at 7,274 feet before the well was returned to service (Ken E. Davis and Associates, January 1981).

In 1981, Empak increased its injection pressure without approval of TDWR. A TDWR staff inspection noted the violations, and corrective changes were requested of Empak. Formal enforcement resulted in a fine against Empak.

In July 1983, an annulus leak was suspected in WDW 157. A leak was located in the tubing at 3,025 feet. A tubing patch was installed from 3,013 to 3,035 feet. The patch was pressure tested and the well returned to service.

In September 1983, a workover was performed to correct a leaking annulus. The tubing and packer were pulled and the tubing was replaced. The injection string was run back into the well and the well returned to service (Ken E. Davis and Associates, August 1983).

In October 1983, an annulus leak was again detected and a hole in the tubing discovered. New carbon steel tubing was installed in the well and the well returned to service.



EMPAK, INC.
Deer Park Plant, Texas

WASTE DISPOSAL WELL 157 (As of 1/19/80)

MALONE SERVICES COMPANY
TEXAS CITY, TEXAS

Background. The Malone Service Company is a commercial hydrocarbon recovery and waste disposal well operation. The facility is located approximately 2-1/2 miles south of Texas City, Texas, in Galveston County. The site is bounded by the Gulf Coast Waste Disposal Authority landfill, landfarm, and sludge holding area, the Texas City Municipal Landfill, and the Monsanto Chemical Company pits.

The Malone Service Company has used an earthen retention basin as a wastewater receiving and settling basin since 1964. In October 1970, the first disposal well, WDW 73, began injection of wastewater from their oil reclamation and commercial disposal service. A second well, WDW 138, was put into service in November 1979. WDW 138 injects wastewater from nearby petrochemical plants and serves as a backup injection system for WDW 73.

The disposal wells handle many industrial liquid wastes from more than 300 generators. The wastewaters contain both organic and inorganic components which are classified as hazardous and nonhazardous. Examples of typical offsite wastes include waste diesel fuel, phenolic resin water, waste paint sludge, waste dinitrophenol solution, chromic acid solution, waste sodium hydroxide, and others.

Both wells have functioned properly, requiring only general maintenance and occasional workovers. No contamination of potable waters or endangerment of the environment has resulted from the use of the injection wells.

Leachate from the retention pond seeped into a buried sand channel that passes beneath the Malone site. Groundwater monitoring has indicated that the contamination has migrated

only a few hundred feet down gradient and is laterally confined to the channel by adjacent clay deposits. The pond has been closed and replaced by a concrete API separator.

Site Description. The Malone facility is located on the coastal plain of eastern Texas near Galveston Bay. The topography of the area is essentially flat with an elevation of three to ten feet. Near the surface, sediments consist of the Pleistocene Series, Beaumont Clay. The unit is composed of 400 to 1,100 feet of clays and marls interbedded with sand. At a depth of approximately 500 feet, the formation contains nearly 300 feet of sand, identified as the Alto Loma Sand, which serves as the principal fresh water aquifer for the area. Total dissolved solids (TDS) concentration for the Alto Loma Sand is approximately 750 ppm (Golden Strata Services, August 1977).

The Pleistocene Series Lissie Formation underlies the Beaumont. It consists of 1,200 to 1,400 feet of alternating clay, shale, and lenticular fine to coarse grained sand.

Below the Lissie is 5,000 to 7,000 feet of Miocene sediments consisting of alternating massive sand and shale formations. The injection zones lie in these undifferentiated deposits. The shale units below approximately 2,000 feet provide confinement from water bearing formations with less than 10,000 mg/L TDS. The 10,000-mg/L TDS interface occurs near 1,800 feet.

Well Construction. WDW 73 is constructed with 10-3/4-inch surface casing set and cemented at a depth of 1,184 feet. The 7-inch steel long string was set and cemented at 5,118 feet. The long string is perforated from 4,912 to 4,995 feet in undifferentiated Miocene Sand. A 3-1/2-inch steel tubing is installed and isolated by packer at 4,878 feet, creating a monitoring annulus (Davis, 1969).

WDW 138 is constructed with a 16-inch steel conductor casing driven to 120 feet. A 10-3/4-inch steel casing was set and cemented at 1,202 feet. The 7-inch steel long string is set and cemented at 4,458 feet. The long string is perforated from 4,162 to 4,323 feet in a Miocene sand unit above and isolated from the WDW 73 injection zone. A 3-1/2-inch steel injection tubing is installed and isolated by a packer at 3,908 feet (Golden Strata Services, May 1978).

Both well installations contain continuous monitoring instrumentation for injection pressure, and annulus pressure. The annulus remains at a positive pressure. Injection rate and effluent pH are also monitored.

Pre-injection treatment of effluent includes the separation of settleable solids and free/emulsified oils in the receiving API separator. The effluent is then equalized, filtered, and stored in an intermediate tank. The tank fluid is finally polished through sand filters then injected. This process produces solid free effluent with a pH range of 4 to 6.

Chronology of Operational Problems. Malone Service Company has used WDW 73 and WDW 138 in a safe and environmentally sound manner. Maintenance activities and workovers have occurred on both wells, which have allowed for their successful operation.

WDW 73 was placed in service in 1970, and required only two episodes of acidization during the first 5 years of operation. In March 1977, the tubing and packer were replaced as preventive maintenance. TDWR inspections in 1978 noted only minor problems such as monitoring gauges and chart recorders in need of calibration.

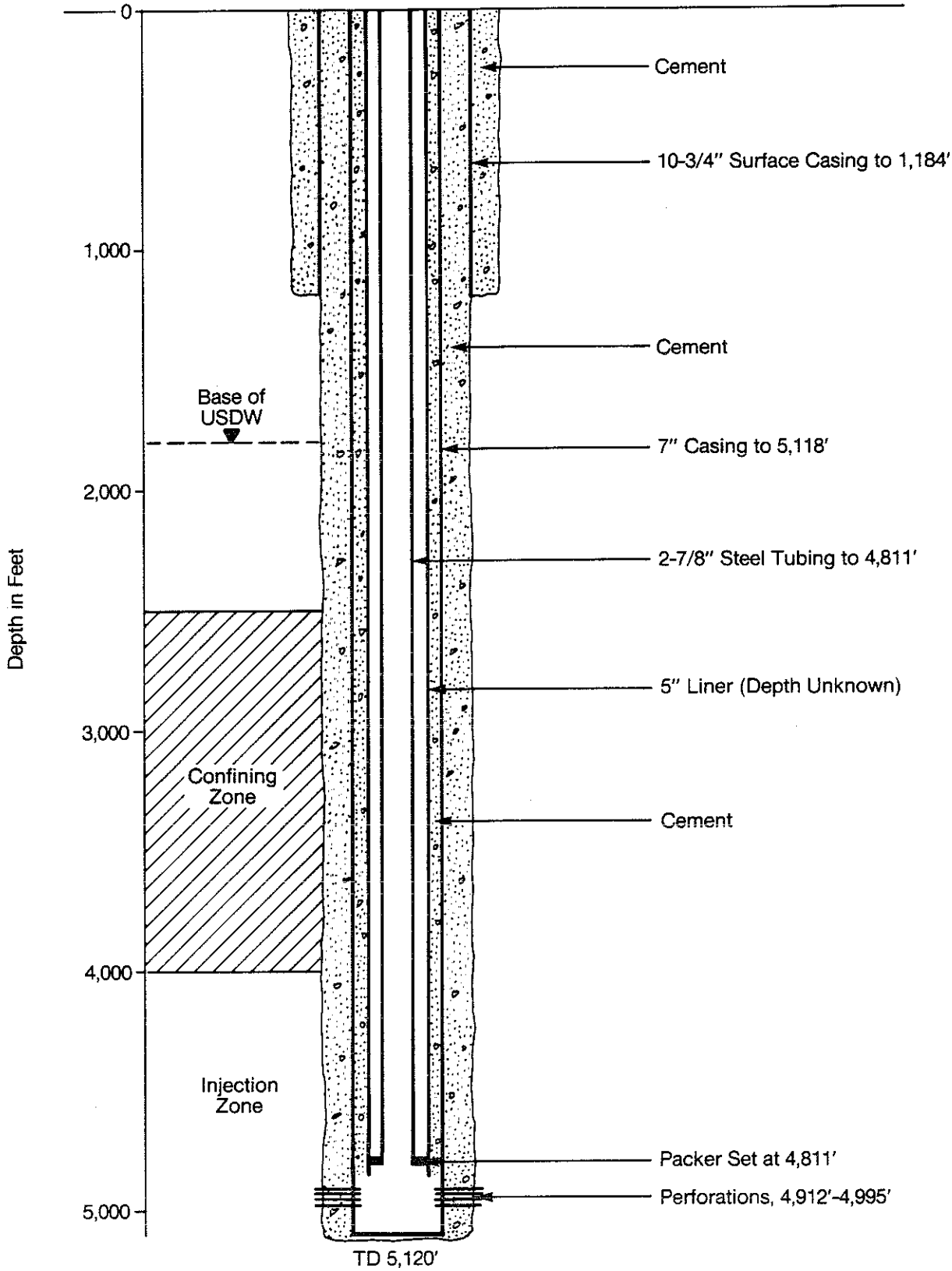
In January 1980, WDW 73 was shut in because of an increase in annular pressure. The tubing was pulled and approximately 25 joints of tubing with one or more holes were noted. The uppermost hole in the tubing was located at 2,396 feet, and the lowermost hole was located at 4,496 feet. A caliper log run from 4,900 to 5,000 feet indicated numerous possible holes in the casing from 2,370 to 4,318 feet. A subsequent casing pressure test located at least one perforated interval between 4,158 and 4,189 feet. A well workover was performed to set and cement a 5-inch liner to the surface, and to install a new 2-7/8-inch tubing with a packer set at 4,850 feet. The well was successfully pressure tested and returned to service.

In June 1981, WDW 73 was flushed out because of increasing injection pressure resulting from sand in the well. WDW 138 had two incidences of communication between the tubing and annulus on April 24, 1981, and in July 1982. These incidences resulted in the removal and repair of the injection tubing. On January 12, 1984, a radioactive tracer survey determined the presence of a hole in the long string below the packer but above the perforated interval. Waste fluids discharged into the permitted injection interval above the known perforated zone. It was not determined what caused the hole other than corrosion or an accidental discharge of the perforating gun. During the survey, all but the upper perforations were observed to be filled with sand. No workover information is available.

The retention pond at the Malone facility has had problems resulting in the contamination of groundwater onsite. The TDWR required groundwater studies be conducted to assess the extent of the contamination. The results indicated that a buried sand channel running beneath the site had been contaminated from the pond leachate. The contamination was determined to be confined to the sand channel.

As a result of the problems arising from the use of the retention pond, the TDWR required the closure of the pond and the installation of groundwater recovery wells. The retention pond was replaced by a concrete API separator.

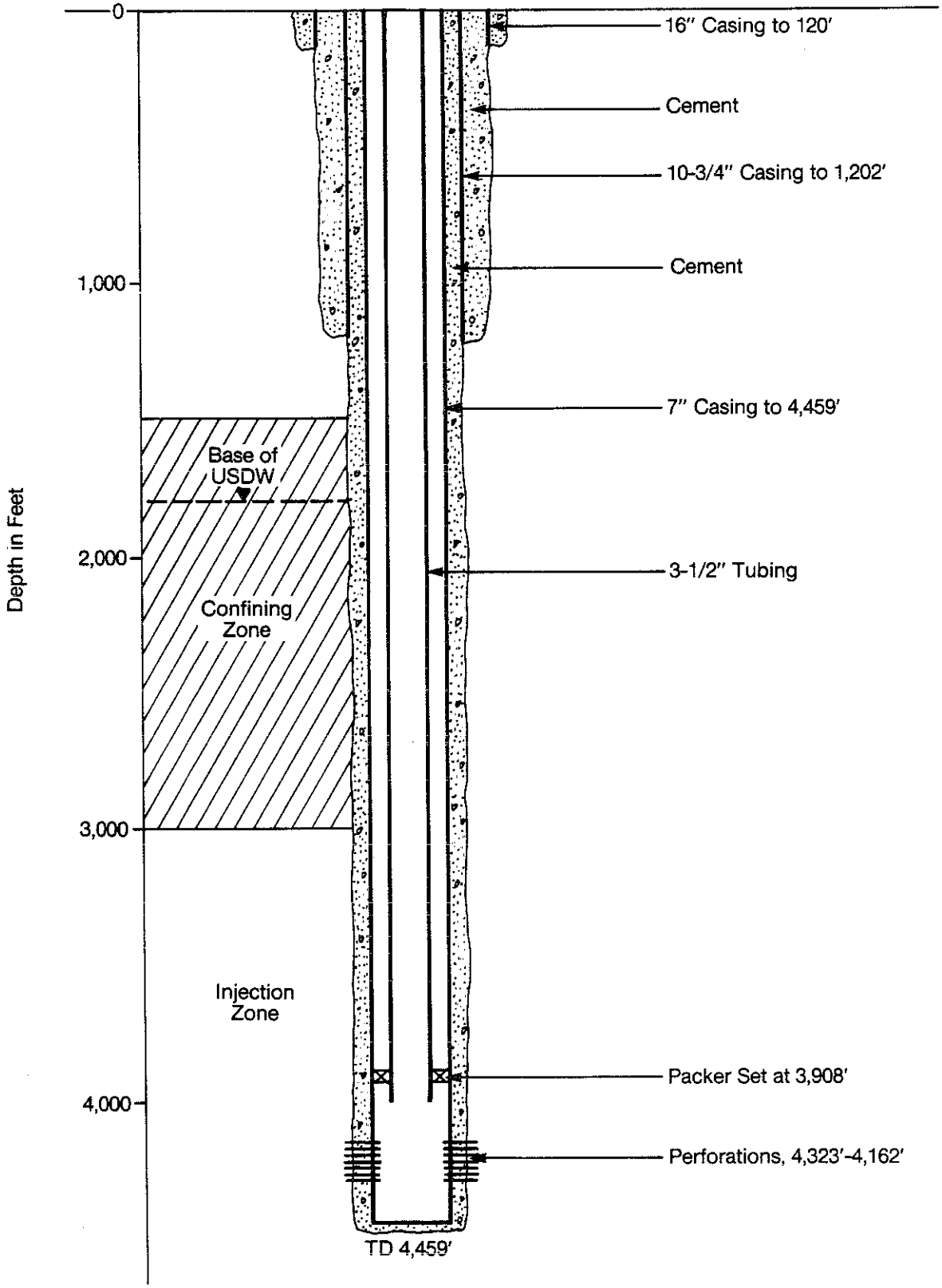
D19976.P0



MALONE SERVICE COMPANY
Swan Lake Plant, Texas City, Texas

WASTE DISPOSAL WELL 073

D19976.P0



MALONE SERVICE COMPANY
Swan Lake Plant, Texas City, Texas

WASTE DISPOSAL WELL 138

UIPC

POTASH COMPANY OF AMERICA
DUMAS, TEXAS

Background. Potash Company of America operates a Class I injection well near Dumas, Texas. The well is located on the plant site, approximately five miles north of Dumas, in Moore County.

The plant operation converts potassium chloride to potassium sulphate. The injected waste is excess hydrochloric acid which is produced during the plant process. The concentration of the hydrochloric acid solution is greater than 30 percent.

The Potash plant operates only one well which is approximately 1,250 feet deep. The waste is piped directly to the well head from the plant storage. The well is operated intermittently and at gravity flow conditions with flow rates that range from 30 to 40 gpm.

Site Description. The topography of the Potash plant is relatively flat with the maximum elevation difference around 10 feet. Waste disposal is into the Glorieta Formation, consisting of predominantly shale and sandstone with some fine crystalline dolomite.

Freshwater in the area is obtained from the Ogallala Formation which is found from 310 to 515 feet. The base of fresh water is reported to be at approximately 460 feet.

Well Construction Details. Waste Disposal Well (WDW) 003 was constructed by setting a 8-5/8-inch casing to 1,088 feet and cementing to the surface. A 3-1/2-inch fibercast tubing was installed to 1,250 feet with the bottom 100 feet being fibercast screen. The interval from 1,135 to 1,265 feet was

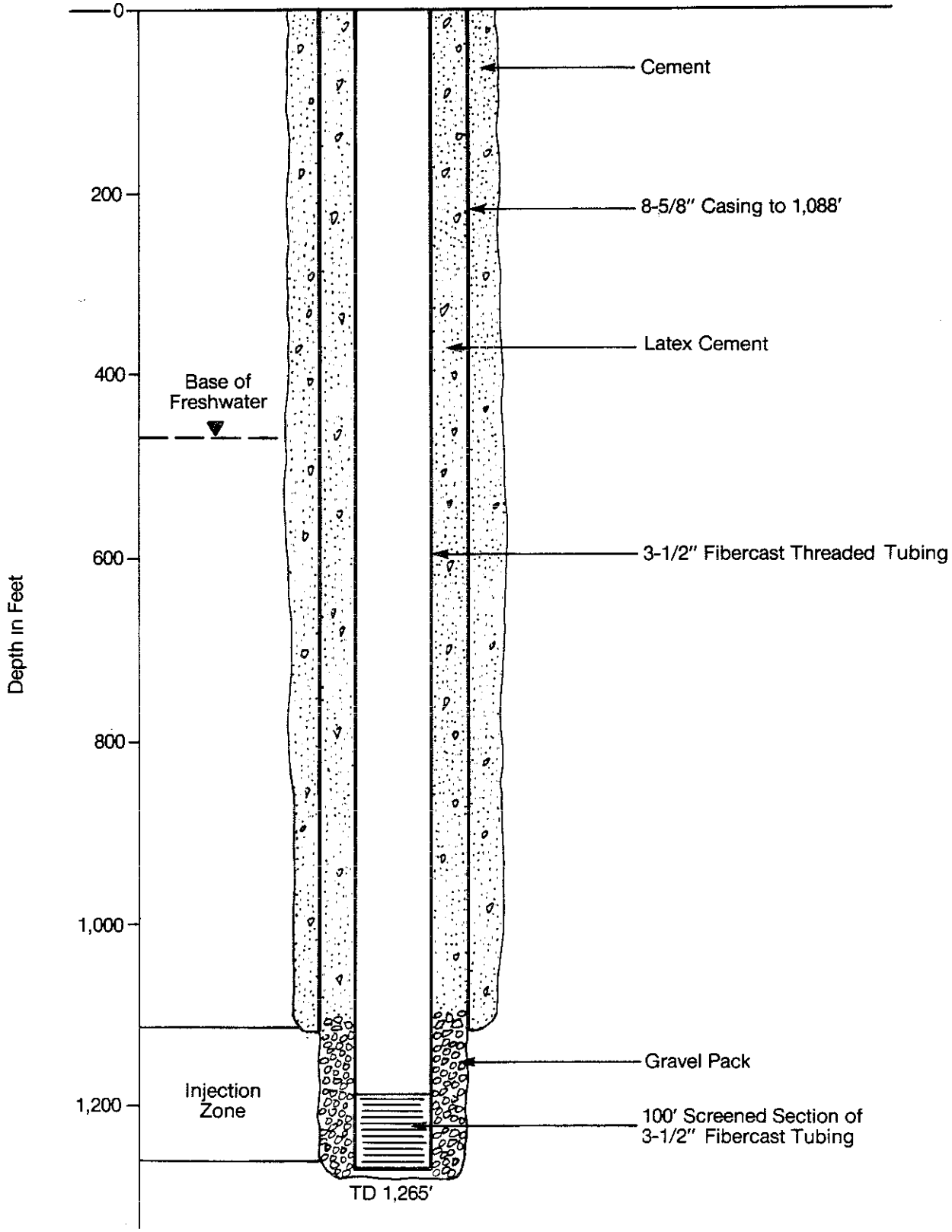
gravel-packed. Acid resistant cement was placed in the annulus from the top of the gravel to 1,013 feet. The well was certified as properly constructed on November 21, 1962. The annulus between the tubing and casing was later filled with latex cement.

Chronology of Operational Problems. WDW 003 was placed in service in March 1962. The well was operated until July 1972 when acid was detected in the annulus. The annulus was flushed out with a soda ash solution to neutralize the acid and then filled with cement. The well was placed back in service (Texas Water Quality Board, July 1976).

In June 1973, the well was pressure tested. A pressure of 250 psi was maintained on the well for 2 hours with less than 10 percent deviation.

The most current information collected for WDW 003 indicates Potash is attempting to repermit the well under the UIC guidelines.

D19976.P0



POTASH COMPANY OF AMERICA
Dumas, Texas

WASTE DISPOSAL WELL 003

SONICS INTERNATIONAL, INC.
DALLAS, TEXAS

Background. Sonics International, Inc., operated two Class I injection wells in Eastland County, two miles west of Ranger, Texas, from early February 1974 until their abandonment in late March 1982.

The wells were used as commercial disposal facilities and received both hazardous and non-hazardous liquid wastes from various offsite customers. Sonics operated a fleet of diesel transports to pick up liquid wastes at a rail site facility 2 miles from the wells or directly from the customer's location. Sonics' initial permit approved the disposal of spent acids, cleaning solutions, chlorinated and nonchlorinated solvents, waste oil, and coolants (Texas Water Quality Board (TWQB), December 1973). In June 1975, Sonics' permit was amended to include the disposal of alkaline solutions, pesticides, herbicides, resins, polymers, brine solutions, plating solutions, ammonia and nitrate solutions, and non-biodegradable organics. There was no onsite pretreatment of the waste.

In February 1974, Sonics began injection of liquid wastes into Waste Disposal Well (WDW) 116. This former water production well was drilled in 1968. Recompletion of the well consisted of cementing the open annulus from 2,300 feet to the surface and perforating the injection zone (TWQB, February 1974). In 1978, WDW 137 was added to the operation as a backup well. This former oil well was recompleted by setting a 4½-inch liner to the packer setting depth (Sonics International, February 1978). Soon after WDW 137 was put on line, contamination was discovered in a nearby oil well, NASH #2 (Sonics International, May 1978). Late in 1979, 2,800 cubic yards of earth, contaminated from leaks and well

blowouts was removed in a site cleanup effort. In 1980, problems with downhole equipment resulted in Sonics ceasing operations. Both Sonics wells were abandoned during March and April 1982.

Site Description. The Sonics injection well site is located on an outcrop of the Canyon Formation of Pennsylvanian age. The topography of the area is that of gently rolling hills dipping generally to the northwest.

The injection zone is the Chappel Reef of Mississippian age. This bioherm has a maximum thickness in the area of 370 feet. The approximate area the elongated, dome-shaped bioherm occupies is more than 136 acres. The porosity has been calculated at 5.4 percent and the effective permeability has been determined to be 525.5 millidarcies.

Sediments overlying and surrounding the bioherm consist of shales of the Barnett Formation which range from 15 to 100 feet in thickness. Overlying the Barnett Formation is the Bend Series, which generally consists of shales and limestones. Within the Bend Series is the Ranger Sand, a 30- to 50-foot sand which is the major producing horizon of the Ranger field. The Bend Series is 850 to 1,200 feet thick.

Underlying the Chappel is the Ellenburger Limestone of Ordovician age. The Ellenburger is a grey dolomite series approximately 1,000 feet thick.

Usable groundwater in the area occurs in thin outliers of the Antlers Sand that is normally found on topographically high areas in the region. Some shallow sands also contain groundwater and occur erratically within 250 feet of the surface.

Well Construction Details. WDW 116 was originally drilled in 1968 as Layne No. 3. It was constructed by setting 10-3/4-inch surface casing to 306 feet. Cement was circulated to the surface. Seven-inch steel casing was set to 3,604 feet and cemented with Incor Pozmix cement. The cement was originally circulated from the casing shoe to 2,300 feet below the surface.

In January 1974, the well was recompleted as an injection well by perforating the 7-inch casing at approximately 2,235 feet and circulating cement to the surface. A Johnson 101 packer was set on 3,600 feet of 2-3/8-inch tubing.

WDW 137 was originally drilled in 1968 as oil producing well Layne No. 4. The well was completed with 10-3/4-inch surface casing set at 305 feet. Seven-inch, long-string casing was set at 3,936 feet. The top of the cement was calculated to be at 1,300 feet; however, at abandonment, cement was determined to be at the surface. The well was perforated from 3,620 feet to 3,744 feet and from 3,810 feet to 3,844 feet. Layne No. 4 was plugged in 1974 as a permit requirement for WDW 116.

In early 1978, Layne No. 4 was recompleted as WDW 137. The plugs placed in the well in 1974 were first drilled out. The well bottom was tagged at 3,848 feet. A 4½-inch liner was run from the surface to 3,592 feet, and was cemented in place. A cement bond log located the top of cement at approximately 1,200 feet. A Gibson KV-30 packer was set near the bottom of the 4½-inch liner on 2-3/8-inch tubing.

Chronology of Operational Problems. Injection began in WDW 116 in February 1974. The well was operated at gravity flow with a permitted volume limit of 0.280 million gallons per month.

In June 1975, Sonics' permit was amended to allow a maximum monthly injection volume of 2.0 million gallons, and a maximum wellhead pressure of 190 pounds per square inch gauge (psig). Additional categories of waste were also added.

Because pressure could not be maintained on the annulus of WDW 116 in November 1975, a new packer and tubing were installed with the packer set at 3,522 feet. A 30-foot joint of tubing was also installed below the packer, and the well was returned to service in December 1976.

During the week of February 3, 1976, the packer and tubing in WDW 116 were pulled and inspected. A few bad joints in the tubing were replaced and the well was acidized. The tubing and packer were returned to the well. This workover was in preparation for a large volume contract to begin sometime in February 1976.

During the week of February 13, 1976, a workover was performed on WDW 116 to restore annulus pressure. Three joints of tubing were replaced because of holes. The packer was reset and the well returned to service.

During the week of February 23, 1976, WDW 116 was again worked over. A 60- to 70-foot accumulation in the well bottom was removed, new tubing and the old packer were installed, and the well was returned to service.

In May 1976, a leaking packer initiated a workover that included solvent treatment of Well WDW 116 and acidization. The packer was replaced and the well returned to service.

WDW 116 was acidized again in October 1976. In June 1977, Sonics was cited for faulty recording devices.

In March 1978, WDW 137 began injecting wastewater. The following month Sonics requested an increase in wellhead pressure from 190 psig to 1,000 psig for both wells. In May 1978, NASH No. 2, a nearby oil well, was producing oil contaminated with chlorinated organics at levels higher than 4,000 ppm.

Between June 1978 and October 1978, WDW 137 was worked over to repair a leaking casing. The well was determined to have flow behind the casing from 3,592 feet to 3,660 feet. To remedy the situation, a squeeze cement job was performed. Logs run after the cementing indicated that the job was successful in stopping the leak. The contaminants that invaded the oil zone were pumped out with the oil until they were no longer detectable in the oil produced.

In November 1978, the packer was replaced in WDW 137. In January 1979, higher pressures based on the waste stream density were allowed. In February 1979, communication between the tubing and annulus was discovered and the packer was replaced.

WDW 137 operated until late August 1979. The packer was replaced in July 1979 and again in September 1979. During the workover in early September 1979, a new packer failed to seat, and the well was killed with mud and capped.

The tubing and packer on WDW 116 were serviced in October 1977 because the annulus was not able to hold pressure. In April 1978, an odor complaint was filed against Sonics. In October 1978, the pressure recorders on WDW 116 were found to be operating incorrectly. In July 1979, a packer failure was not reported and a citation was issued.

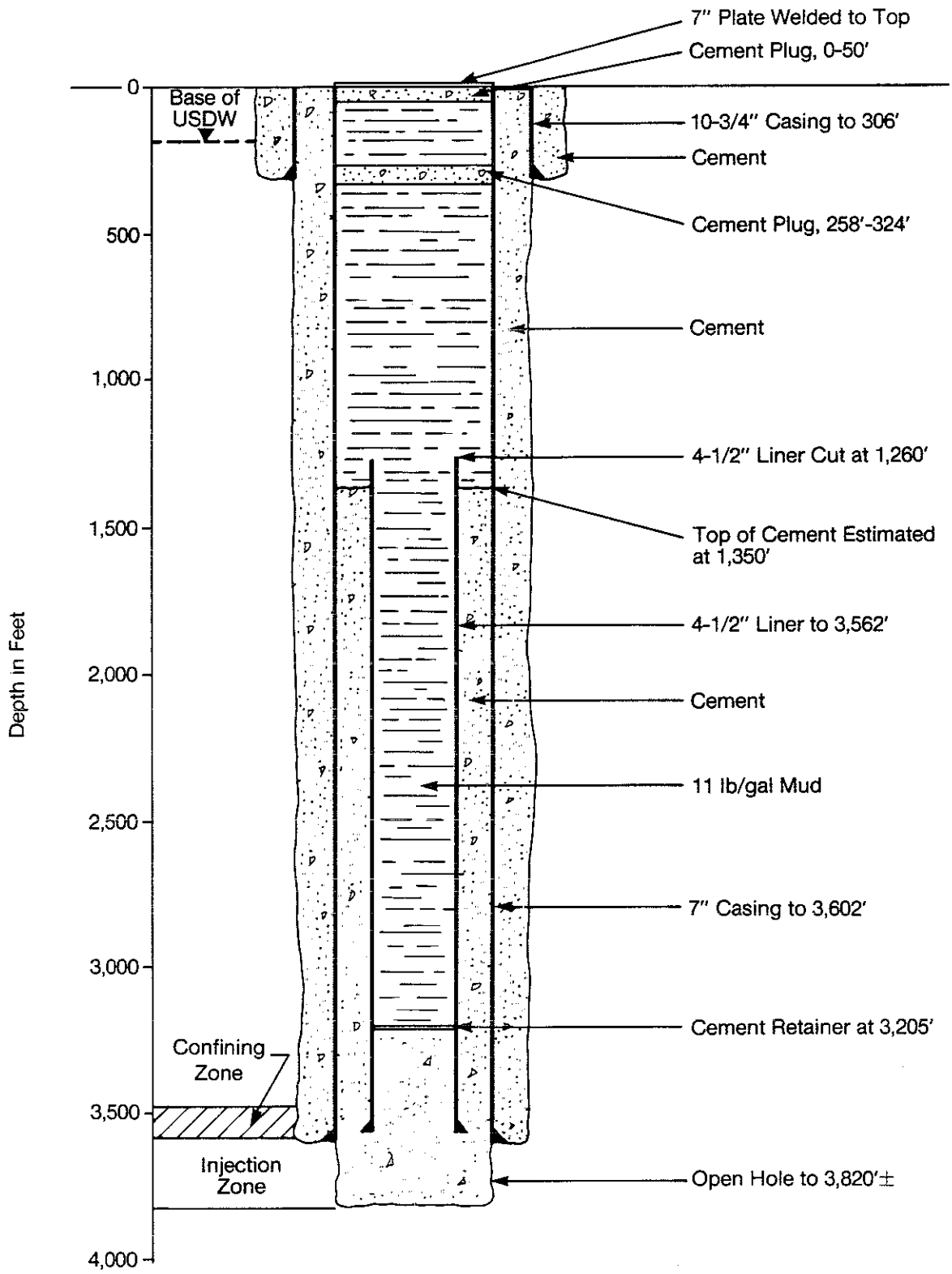
A major workover was performed on WDW 116 in August 1979. Leaks in the tubing and casing were discovered. During the workover, several well blowouts occurred. Blowouts were reportedly caused by carbon dioxide generated by the injection of acid wastes. A 4½-inch liner was set and cemented in WDW 116 during this workover. In October 1979, communication between the tubing and annulus was discovered. The tubing and packer were replaced.

From September 1979 to December 1979, problems with odors were again reported. The problem was found to be contaminated fluids in the sumps next to the wells. The sumps were cleaned, and approximately 2,800 cubic yards of contaminated soil was removed from the Sonics site.

In March 1980, a site visit to investigate another odor complaint uncovered an unreported spill, indicating that Sonics was again in violation of their permit. During this site visit, low levels of contamination were still present in the NASH No. 2 oil production well. By June 1980, WDW 116 was shut in, pending a test program. Sonics had financial difficulty arranging for the required testing and, in March 1982, plugged and abandoned both wells.

WDW 116 experienced several blowouts during its operation which were partially responsible for surface contamination of the Sonics site. WDW 137 is believed to be responsible for the direct contamination of oil production well NASH No. 2 with chlorinated organics. The Sonics wells have a history of malfunctions, non-compliances, surface leaks, tubing and packer leaks, odor complaints, and blowouts. All of these were recurring; many were detected only by site visits.

D19976.PD

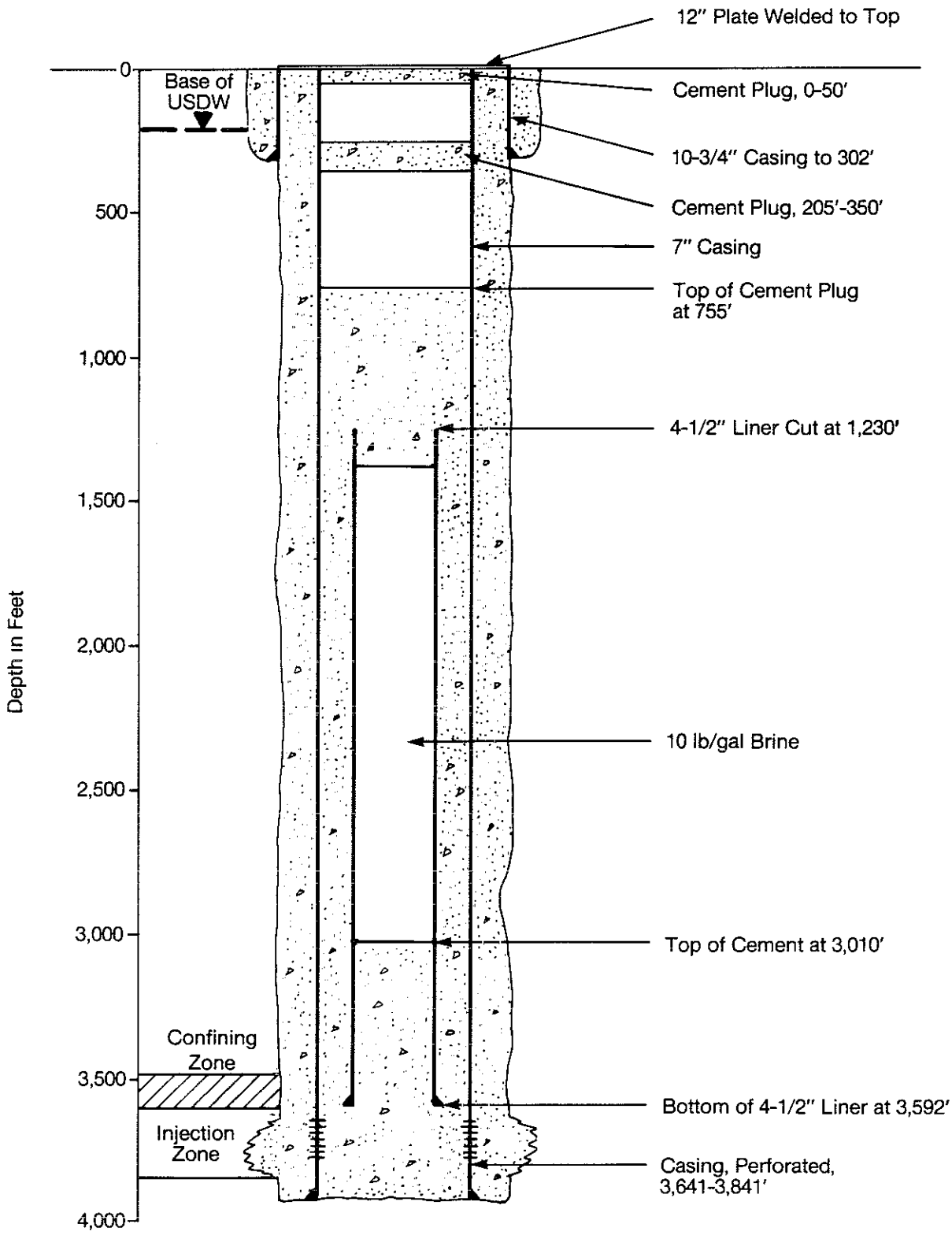


SONICS INTERNATIONAL
Ranger, Texas

WASTE DISPOSAL WELL 116 (Plugged April 1982)

UIPC

D19976.PO



SONICS INTERNATIONAL
Ranger, Texas

WASTE DISPOSAL WELL 137 (Plugged April 1982)

VELSICOL CHEMICAL CORPORATION
JEFFERSON COUNTY, TEXAS

Background. Velsicol Chemical Corporation Injection Well WDW 118 is located on the west side of West Port Arthur Road, approximately five miles southeast of Loop 251, southeast of the City of Beaumont in Jefferson County, Texas.

Velsicol acquired two injection wells from Mobil Corporation in October 1973. The wells had been used since 1965 for treatment plant wastewater from the processing of raw Neches River water used in Mobil's acid manufacturing plant (Texas Water Quality Board (TWQB), 1971). Mobil Injection Wells WDW 31 and WDW 47 were re-permitted to Velsicol Wells WDW 118 and WDW 119. Velsicol began using the wells in 1974 to dispose of wastewater resulting from the production of Banvel, a selective herbicide. Early in 1975, Velsicol's permit was amended to include disposal of wastewater resulting from the production of benzoic acid. The waste is pretreated by adjusting the pH, settling, and filtering.

During a workover to investigate erratic injection pressures and a suspected leak in June 1975, a leak in the WDW 118 injection casing was discovered near the 600-foot depth. The injection well was operating without injection tubing and contaminated a USDW. The well was abandoned and two monitoring wells were drilled in an effort to clean up the site.

Site Description. The wells are located on the north flank of the Gulf Coast Geosyncline. Sediments in this portion of the geosyncline generally dip to the southeast. A major structural feature, the Spindletop Salt Dome, is located 3 miles north of the site.

The stratigraphy in the injection well area consists of sediments of Recent age through the Miocene of the Tertiary system. The Miocene and younger formations are undifferentiated and contain approximately 6,000 feet of sands interbedded with dark marine shales (TWQB, December 21, 1973).

The disposal zone consists of medium to fine grained Micoene sands. Between 5,640 and 5,656 feet, the average permeability is 3,190 md with an average porosity of 33.6 percent. The formation fluid is a brine with a total dissolved solids (TDS) concentration of 125,077 mg/L (TWQB, December 21, 1973). Usable quality water occurs in the area to a subsurface depth of approximately 1,000 feet (TWQB, December 21, 1973).

Well Construction Details. Injection Well 118 was constructed with 8-5/8-inch steel, 24-lb/ft steel surface casing set and cemented to 2,521 feet. A 5-1/2-inch, 17 lb/ft, Type 304, stainless steel long string was set at 6,000 feet and cemented with densified Incor. The cement was returned to the surface. The well was perforated from 5,932 to 5,978 feet and later perforated again from 5,932 to 5,967 feet. The well was operated without injection tubing.

Chronology of Operational Problems. On January 14, 1974, Velsicol Chemical Corporation was issued permit No. WDW 118 and WDW 119 to operate two industrial waste disposal wells. The permit for WDW 118 was conditional upon proving the integrity of the 5-1/2-inch O.D. casing, as this well was designed without a tubing. This testing was done in early 1974 and consisted of a pressure test of the casing.

Disposal records for January through June 1974 indicate that monthly volumes ranged from 1,634,560 to 3,352,320 gallons at surface pressures from 600 to 900 pounds per square inch (psi).

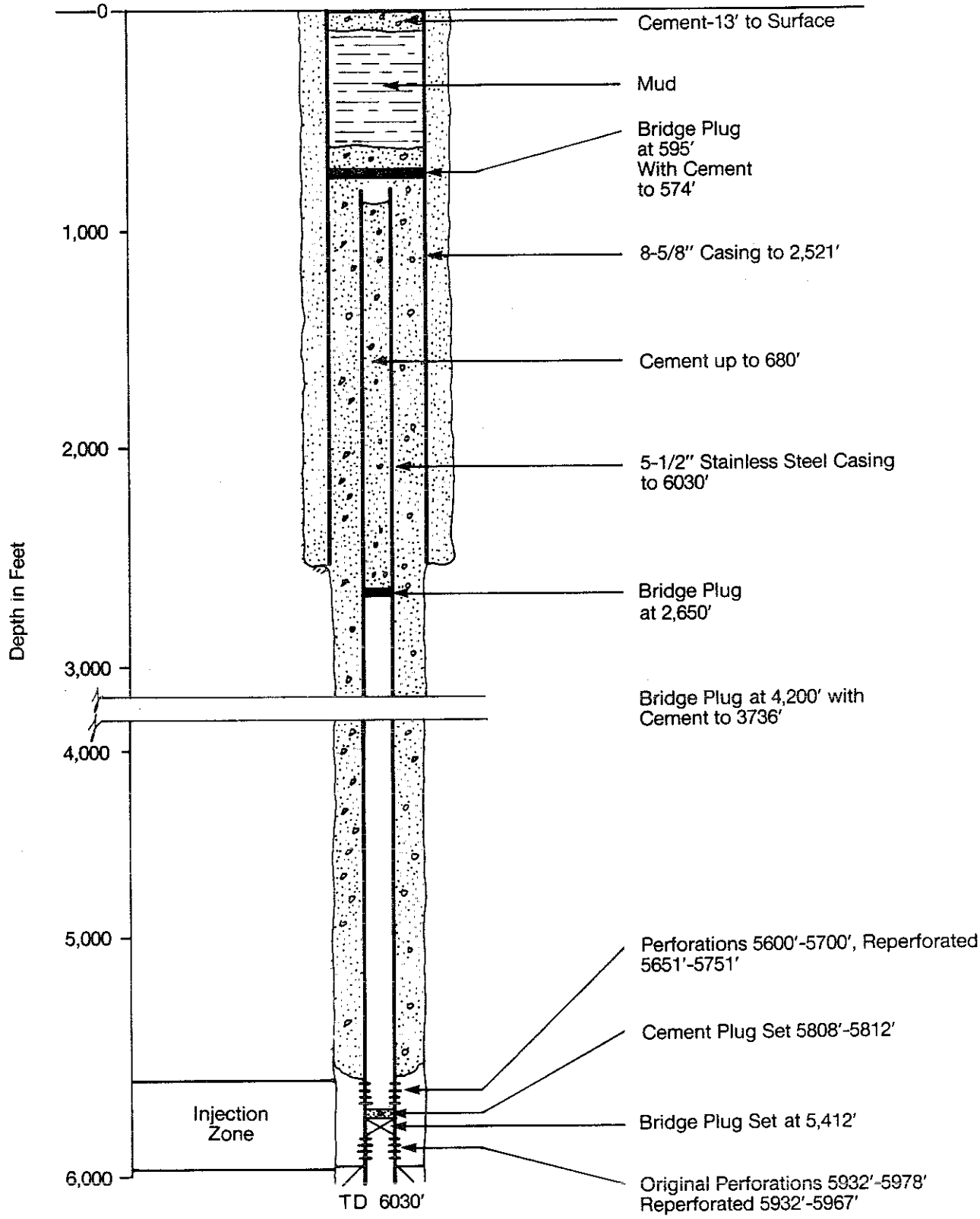
The semi-annual report for the period July through December 1974 indicated lower than normal injection pressures. The average surface injection pressure in July 1974 was 746 pounds per square inch gauage (psig). The pressure declined continuously and, in December 1974, was 97 psig. The injection rate did not decrease during this time nor did Velsicol report any problems with the injection zone. The decreased pressures continued until May 1975 when the well was shut down to determine the reason for the decreased injection pressure. An inspection and pressure test indicated numerous leaks in the 5-1/2-inch casing, some as shallow as 600 feet, where both the long string and surface casing were penetrated (Subsurface, Inc., 1975 and TWQB, August 1976).

Velsicol decided to plug the well and drill a replacement. The abandonment plan included a determination of possible contamination of usable quality water. These tests ultimately resulted in the drilling of two monitor wells and various testing of WDW 118. It was determined that wastewater escaped into the lower Chicot aquifer. The water in the area of contamination has a background quality of approximately 4,000 mg/L TDS (TWQB, December 2, 1976).

Wastewater was found in the No. 1 monitor well, located adjacent to WDW 118, in low levels. Monitor Well No. 1 was pumped for approximately 90 days in which time the wastewater contamination levels decreased and the TWQB felt little additional wastewater could be recovered (TWQB, December 2, 1976).

WDW 118 was plugged in January 1977. After the plugging, the second monitor well was drilled 50 feet southeast of Monitor Well No. 1, and showed no contamination.

D19976.P0



VELSICOL CHEMICAL CORP.
New Acres, Texas

WASTE DISPOSAL WELL 118

NORTHWEST PETROCHEMICAL CORPORATION
ANACORTES, WASHINGTON

Background. Northwest Petrochemical Corporation operated an injection well from 1960 to May 1985 to dispose of wastes generated onsite at their facility in Anacortes, Washington. The facility injected wastewaters produced during the manufacture of cresylic acid and turpentines.

After production, the cresylic acid was fractionally distilled onsite to produce phenolic compounds for sale. Wastewater with high levels of phenolic contaminants was washed with a solvent to remove the majority of the contamination, and recycled to feedstocks. The turpentine production resulted in very little wastewater. Discharge to the injection well consisted of cooling tower and boiler blowdown which were mixed with plant site runoff (stormwater). The combined discharge was treated by means of solvent extraction to remove phenolic substances. Typically, the injected wastes had a pH of 7.7; total phenols, 0.7 mg/L; and total oils, <1 mg/L.

Pretreatment prior to injection consisted of pH adjustment, solvent extraction to reduce the concentration of phenolics to compliance levels, and filtration. The volume injected averaged 10,000 gallons per day (gpd) and the maximum was 20,000 gpd. The company operated one injection well and had one groundwater monitor well.

Monitoring parameters from the monitor well were checked weekly and reported monthly and included pH, total phenols and total oils. Permitted limits for phenols were a daily average of 1.0 mg/L and for oils were a daily average of 10.0 mg/L and a maximum of 15.0 mg/L.

In 1984, a near surface casing break was repaired and a new inductor tube was grouted in place within the casing. This repair was successful and the well was placed back in service until May 1985.

Site Description. Anacortes is located on Fidalgo Island, a land mass in the northern part of Puget Sound, about 50 miles north of Seattle, Washington. The land surface at the injection well is elevated about 50 feet above sea level.

The base of the USDW beneath the site reportedly occurs at a depth of 254 feet. Usable aquifers occur at depths of 50 to 60 feet and 130 to 150 feet and consist of sand and gravel. The total dissolved solids (TDS) content of the 130 to 150 feet deep aquifer is 150 mg/L (Northwest Petrochemical, 1960). The onsite monitor well monitors waters less than 130 feet deep.

The injection zone used at this site was a fine to very fine sand, 20 feet thick, encountered at a depth of 330 feet. The original TDS content of the injection zone was 15,000 mg/L. The unit was described as "moderately permeable." Confining beds 15 feet thick are present immediately above the injection zone, and were described as "highly confining" (Northwest Petrochemicals, 1960). Another unit, described as "semi-confining," occurs at a depth of 250 to 305 feet (Northwest Petrochemicals, 1960).

Well Construction Details. The well was constructed with steel casing, using welded joints. The well was completed to inject into a sand formation at a depth of 330 to 350 feet. No other construction information concerning this well exists.

Chronology of Operational and Regulatory Problems. In 1978, the State of Washington Department of Ecology requested that Northwest Petrochemical install a flow meter on the injection well to monitor the volume of fluid injected, which was accomplished.

The Department of Ecology issued a 5-year State Waste Discharge Permit in May 1980. The state UIC regulations banning all Class I wells went into effect on February 29, 1984. Therefore, when Northwest Petrochemical's permit was due for renewal in May 1985, the state indicated that they could no longer use the well. Wastewater is currently disposed of offsite, and Northwest Petrochemical is in the process of plugging and abandoning the well.

Section 4
SURVEY METHODOLOGY

Section 4
SURVEY METHODOLOGY

SOURCES OF DATA

The primary sources of information on Class I wells were the state or federal agency with primacy for the Class I well UIC program in each state. The Federal Register (40 CFR Part 147, Volume 49, No. 93, May 11, 1984) was used to identify the primacy states and those states in which EPA is directly implementing the Class I well program. The June 1985 copy of the EPA Office of Drinking Water Class I Well Inventory became the master working list from which visits to various state and federal offices were planned.

As a preliminary screening process, the directors of the UIC program for each state were asked to respond to a questionnaire (see Appendix A) concerning the organization of their files and to identify Class I wells in their state that had allegedly experienced some type of operational problem. UIPC Executive Board members also provided lists and information on well operational problems of which they were aware. Published accounts from sources such as professional journals and newspaper articles also provided names of sites that may have had problems. From these sources, 42 sites were identified for this survey. Three additional sites were added during the initial data collection activities. The location of case history sites is shown in Figure 4-1.

Agency files and records were used extensively during data collection efforts. The UIC program directors' and staffs' knowledge of the operational histories at the well sites was used throughout this study. The most accurate and current well data were obtained from the questionnaire, phone conversations, and personal interviews.

D19976.S0

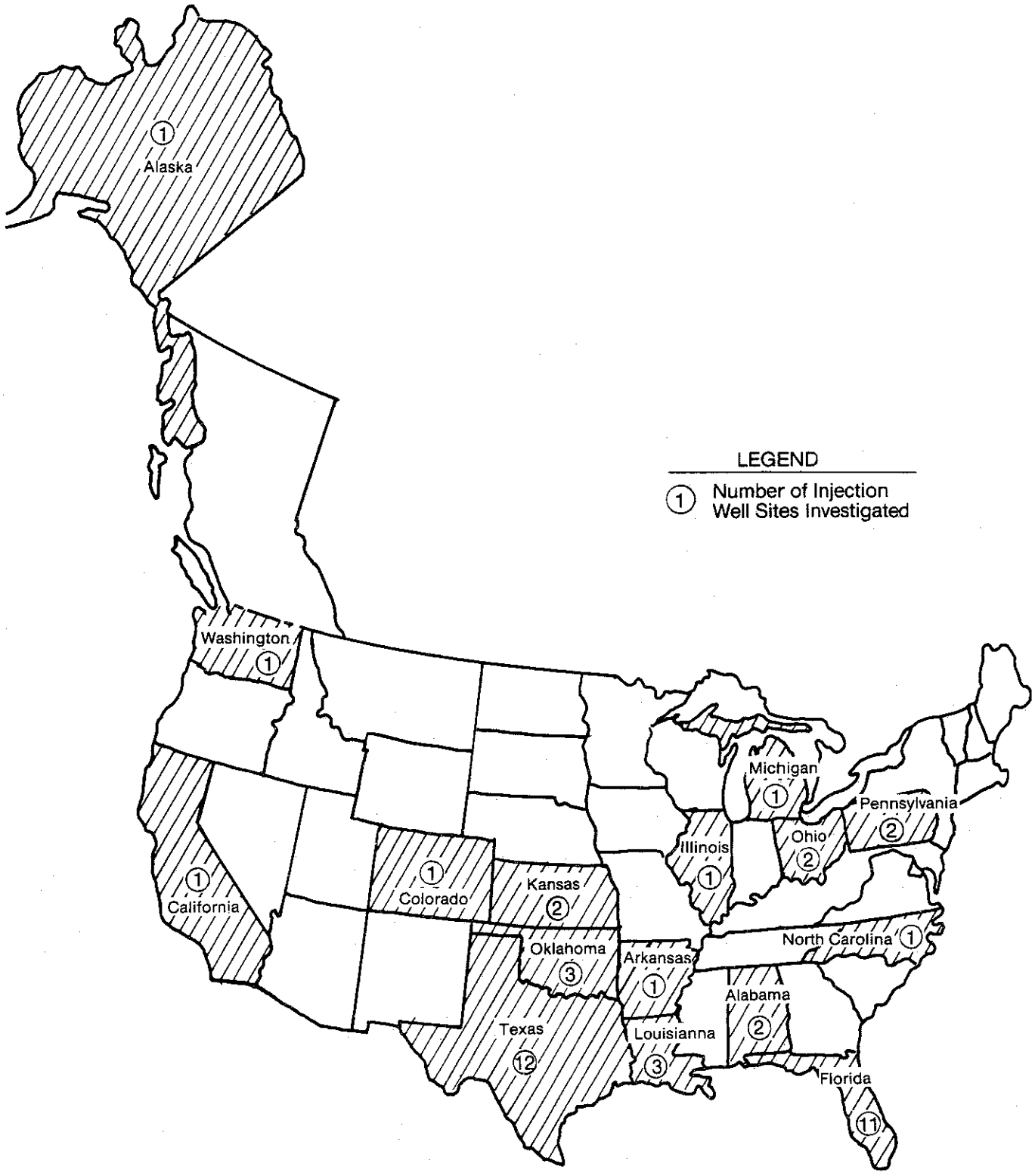


FIGURE 4-1.
CASE HISTORY SITE LOCATIONS

The EPA Report to Congress on Injection of Hazardous Wastes and the accompanying data base were used to supplement information from the primacy agency files. Information in the EPA's Site Visit Report was also used in the preparation of several of the case histories in this report.

DATA COLLECTION

UPIC approved the worksheet that was developed to ensure uniform data collection (see Appendix B). Topics of information include current operating status, waste characteristics, permit conditions, well design and above-ground equipment, hydrogeologic information, monitoring, current operating conditions, operating history, and well plugging.

During the data collection effort, the status of some of the wells had to be evaluated. The current well classification was used to determine if the well was included in the Phase I well study. In one case, wells at a site included in the initial 45 were reclassified as Class V wells, and, consequently, were only briefly summarized.

The state and federal agency offices from which Class I well data were obtained are shown in Table 4-1. Preliminary interviews with the program directors and their staffs were conducted upon arrival at each agency to determine the location and organization of their files.

In states that have been granted UIC primacy, operational injection well facilities are required to obtain a state operating permit. The repermit applications and accompanying engineering reports were a source of recent and generally reliable information on well construction and operation. Construction and operating permits provided

Table 4-1
STATE AND FEDERAL AGENCY OFFICES FROM WHICH
CLASS I WELL DATA WERE OBTAINED

State	Agency
Alabama	Alabama Department of Environmental Management
Alaska	U.S. Environmental Protection Agency Region X
Arkansas	Arkansas Department of Pollution Control and Ecology
California	U.S. Environmental Protection Agency Region IX
Colorado	U.S. Environmental Protection Agency Region VIII
	U.S. Department of the Army Rocky Mountain Arsenal Information Center
Florida	Department of Environmental Regulation
Illinois	Illinois Environmental Protection Agency Division of Land Pollution Control
	Illinois State Geological Survey Groundwater Section
Indiana	U.S. Environmental Protection Agency Region V
Kansas	Department of Health & Environment Bureau of Oil Fields
Kentucky	U.S. Environmental Protection Agency Region IV
Louisiana	Department of Natural Resources Office of Conservation
Michigan	U.S. Environmental Protection Agency Region V
Mississippi	Department of Natural Resources Bureau of Pollution Control
New York	U.S. Environmental Protection Agency Region II
North Carolina	North Carolina Department of Natural Resources & Community Development Groundwater Section--Division of Environmental Management
North Dakota	State Department of Health Water Supply and Pollution Control
Oklahoma	Oklahoma State Department of Health Industrial and Solid Waste Services
Ohio	Ohio Environmental Protection Agency Division of Solid and Hazardous Wastes
Pennsylvania	U.S. Environmental Protection Agency Region III
	Commonwealth of Pennsylvania Department of Environmental Resources
Tennessee	U.S. Environmental Protection Agency Region IV
Texas	Texas Water Commission Underground Injection Section
Washington	Washington Department of Ecology
West Virginia	Department of Natural Resources Division of Water Resources
Wyoming	Wyoming Environmental Quality

information on operating restrictions and monitoring requirements. Monthly operating reports were used to obtain data on maximum and average injection pressure and injection flow rate.

Inspection report files on each facility were a reliable source of information on mechanical integrity testing, non-compliance incidents, and operational problems. Operational reports submitted by the facility operators on a monthly or quarterly basis, were used to obtain the current operating data and indications of operational problems during that period. Quarterly non-compliance reports required by EPA were reviewed to determine well operational problems and other problems occurring at the facility. Correspondence files were used to establish the current status of the well(s) and to reconstruct the chronology of operational events at that site.

REVIEW PROCEDURES

Preparation of a case history for an injection well site with a long or complicated operational life occasionally required some interpretation of existing records. A review procedure was used in the preparation of this report to assure that objectivity and accuracy were maintained.

Part of the review process included three progress meetings with the UIPC Executive Director and the UIPC Committee Chairpersons. The first meeting was conducted to evaluate the initial data collection effort and modify the approach as needed. The second meeting was held to review the first 15 case histories and collected data. The third meeting was to review the draft final report. Other review procedures included internal senior level staff review, and final review and approval from the UIPC Executive Board, thus assuring that the project objectives were met.

Upon completion of the draft case histories, the UIPC mailed copies to the well owners and the respective UIC directors for review. Each party was requested to comment on the case history, thus providing verification of the reported events. Of the 45 sites, comments from UIC directors were received for 21 sites, and owner comments were received on 20 sites. Comments ranged from minor corrections of quantities and sequence of events to significant disagreement with the events reported in the draft case histories. However, with the exception of one or two responses, the comments generally concurred with the case histories.

The mechanism for incorporating comments varied with the site and the type of comments received. Many of the comments concerned minor depth or construction detail changes, and were routinely made. In other cases, discussions with UIC directors and owners were held to resolve differences. All comments received from owners and UIC directors are available in a separate appendix upon request.

BIBLIOGRAPHY

BIBLIOGRAPHY

Agrico Chemical Company. Letter to D.A. Hesch, Oklahoma State Department of Health (OSDH files). April 4, 1980.

Alabama Department of Environmental Management. 10,000 TDS Horizon Mapping Project. Alabama Geological Survey. Open File Report. 1981.

ARCO, Alaska, Inc. Permit Application for Class I Hazardous Waste Injection. Application Submitted to U.S. Environmental Protection Agency. 1984.

Athans, Julie. Personal Communication. ARCO Alaska, Inc. 1985.

Barraclough, J.T. Waste Injection into a Deep Limestone in Northwestern Florida. Groundwater. Volume 4, No. 1, pp. 22-24. 1966.

BC&E/CH2M HILL. A Comprehensive Report on Drilling and Testing of the Monitoring and Injection Wells at the Southwest Wastewater Treatment Plant for the City of St. Petersburg, Florida. Gainesville, Florida. Project No. 412-73-01-J. 1978.

Black, Crow & Eidsness, Inc. Deep Well Disposal at the Belle Glade Mill of the Sugar Cane Growers Cooperative of Florida: Summary of Operational History and Future Expansion. Gainesville, Florida. Engineering Report 386-74-50. September 1974.

Black, Crow & Eidsness, Inc. Drilling and Testing of Deep Disposal and Monitoring Wells. Engineering Report Prepared for the City of Stuart, Martin County, Florida. January 1975.

Black, Crow & Eidsness, Inc. Drilling and Testing of Waste Disposal Well No. 1 Furfural Plant. Sugar Cane Growers Cooperation of Florida. Engineering Report 386-65-R. Gainesville, Florida. December 1965.

Black, Crow & Eidsness, Inc. Drilling and Testing of the Second Deep Injection Well for General Waterworks Corporation at the Kendale Lakes Wastewater Treatment Plant, Dade County, Florida. Gainesville, Florida. July 1972.

Black, Crow & Eidsness, Inc. Engineering Report on Drilling and Testing of Deep Well for Peninsula Utilities Corporation Coral Gables, Florida. Gainesville, Florida. February 1972.

Black, Crow & Eidsness, Inc. Engineering Report on Drilling and Testing of Deep Well for Peninsula Utilities Corporation Coral Gables, Florida. Gainesville, Florida. 1970.

Black, Crow & Eidsness, Inc. Modifications to Deep Well Injection System. Engineering Report 386-71-01. Gainesville, Florida. March 1972.

Black, Crow & Eidsness, Inc. Results of Drilling and Testing of Monitoring and Disposal Wells at Margate, Florida. Gainesville, Florida. March 1974.

Black, Crow & Eidsness, Inc. Report on the Drilling and Testing of the Second Deep Injection Well for General Waterworks Corporation of Kendale Lakes WWTP Dade County, Florida. 1972.

Black, Crow & Eidsness, Inc. Wastewater Studies on Deep Well Injection. Engineering Report 386-68-51. April 1969.

Braunstein, J., editor. Proceedings of the Second International Symposium on Underground Waste Management and Artificial Recharge. New Orleans, Louisiana. September 26-30, 1973. Volume 1 and 2, 1973.

Brown, R.W. and C.W. Spalding. Deep-Well Disposal of Spent Hardwood Pulping Liquors. Journal of the Water Pollution Control Federation. December 1966.

California Department of Health Services. Determination of Imminent and Substantial Endangerment and Remedial Action Order. Docket No. HSA 84/85-002. Rio Bravo Disposal Facility. Bakersfield, California. 1985.

California Public Works Department. Official Notice to Comply. Issued to Rio Bravo Disposal Facility, a California Limited Partnership. Bakersfield, California. November 1984.

California Regional Water Quality Control Board, Central Valley Region. Water Discharge Requirements for Rio Bravo Refining Company. Order No. 83-078. 1983.

CH2M HILL. Deep Injection System Monitoring Data Review: December 1982 through April 1984. Prepared for the City of Stuart, Florida. May 1984.

CH2M HILL. Drilling and Testing of the Deep Injection and Monitoring Wells at the City of Margate Wastewater Treatment Plant. Deerfield Beach, Florida. December 1984.

CH2M HILL. Engineering Report on the 3-Year Injection Well Testing and Monitoring Program. June 1980 to June 1983. City of St. Petersburg Northeast Wastewater Treatment Plant. 1983.

CH2M HILL. Engineering Report on the 32-Month Injection Well Testing and Monitoring Program. City of St. Petersburg Southwest Wastewater Treatment Plant. 1982.

CH2M HILL. Engineering Report on the Rehabilitation of the Deep Injection and Monitoring Wells at the Stuart Wastewater Treatment Plant. April 1982.

CH2M HILL, Inc. Interim 90-day Injection Test Report on the 3-Year Testing Program at the St. Petersburg Northeast Wastewater Treatment Plant (Injection Period June 9, 1980 through September 10, 1980). 1980.

CH2M HILL. Investigation, Testing and Repair of Deep Injection Well IW-1 at the City of Margate Wastewater Treatment Plant. Deerfield Beach, Florida. June 1985.

CH2M HILL. Mechanical Integrity Inspection of Well IW-3. Engineering Report. Prepared for QO Chemicals, Inc. Belle Glade, Florida. September 1985.

CH2M HILL. Plugging of Wells IW-1, IW-2 and SMW-1. Letter Report Prepared for QO Chemicals, Inc. Belle Glade, Florida. August 1981.

Chevron USA, Inc. Statement Chevron U.S.A., Inc. Exhibit No. 1, Public Hearing in Snyder, Texas, Concerning Waste Disposal Well Renewal Application by American Magnesium Company. November 6, 1979.

Conger, Robert M. The Geohydrology, Subsurface Geology, and Reservoir Engineering as Related to the CECOS International Commercial Class I Injection Well at the Willow Springs Site. Department of Natural Resources. Office of Conservation, Injection and Mining Division. Calcasieu Parish, Louisiana. October 17, 1985.

D'Appolonia. Interim Report Presque Isle State Park Gas Well Investigation. Hammermill Paper Company. Erie, Pennsylvania. Project No. X83-1039-DW. March 1983.

Davis, L.W. Preliminary Report: Deep Well Disposal of Industrial Wastes. Malone Services Company, Inc. Texas City, Texas. November 1969.

Deep Well Pollution Control Corporation. Industrial Waste Disposal with a Deep Well at the Empire Reeves Steel Division of the Cyclops Corporation Mill at Mansfield, Ohio. 1966.

Dean, B.T. The Design and Operation of a Deep-Well Disposal System. Journal of the Water Pollution Control Federation (37)2:245-254. 1964.

Deep Well Pollution Control Corporation. Letter to Wayne Connor, Ohio Division of Oil and Gas, from R.E. Decker. Empire Reeves Well No. 1. Mansfield, Ohio. September 23, 1969.

Dildine, Jack. Environmental Assessment of a Proposed Action to Plug and Abandon the Deep Injection Well and Associated Surface Facilities. Rocky Mountain Arsenal Report. Denver, Colorado. June 1984.

Disposal Systems, Incorporated. Disposal Well No. 1 (WDW 169), Completion Report. Subsurface Disposal Corporation. Deer Park Terminal, Harris County, Texas. 1981.

E.A. Polumbus, Jr. and Associates, Inc. Final Report on Drilling of Pressure Injection Disposal Well, Rocky Mountain Arsenal, Denver, Colorado. November 30, 1961.

E.I. DuPont de Nemours and Co., Inc., Corpus Christi Plant. WDW 121 (Well No. 3), Chronology of Well Repair. Texas Department of Water Resources Well File. October 3, 1978.

E.I. DuPont de Nemours and Co., Inc. Final Report for the Mechanical Integrity Testing of Waste Disposal Well No. 3 (WDW 121) at Corpus Christi. Ingelside, Texas. June 20, 1983.

E.I. DuPont de Nemours and Co., Inc. Inspection/Screen Cleanout, WDW 121. Report to Texas Department of Water Resources. November 15, 1982.

E.I. DuPont de Nemours and Co., Inc. Letter to Gerald Millican, Director, Solid Waste and Underground Injection, Texas Department of Water Resources from Charles A. Evans, Staff Engineer, Environmental Department, Corpus Christi Plant. June 19, 1978.

E.I. DuPont de Nemours and Co., Inc. Letter to Bill Klempt, Texas Department of Water Resources, from L.B. Ramke Regarding WDW 54. Orange, Texas. August 25, 1981.

E.I. DuPont de Nemours and Co., Inc. Letter to Gerald Mullican, Texas Department of Water Resources, from L.B. Tamke. Plugging of WDW 104. Orange, Texas. February 27, 1978.

E.I. DuPont de Nemours and Co., Inc. Letter to Gerald Mullican, Texas Water Quality Board, from T.R. Landon. Cleaning of Well No. 7. Orange, Texas. October 30, 1972.

E.I. DuPont de Nemours and Co., Inc. Letter to Harvey B. Davis, Executive Director, Texas Department of Water Resources, from Charles A. Evans, Coordinator of Environmental Affairs, DuPont Corpus Christi Plant. December 30, 1981.

E.I. DuPont de Nemours and Co., Inc. Letter to Seth Burnitt, Texas Water Commission, from I.M. Williamson. Waste Disposal Well No. WDW 12. Orange, Texas. February 26, 1965.

E.I. DuPont de Nemours and Co., Inc. Letter Report to Gerald Mullican, Texas Water Quality Board, from L.B. Ramke. Cleaning of WDW 57. Orange, Texas. December 10, 1975.

E.I. DuPont de Nemours and Co., Inc. Letter Report to Gerald Mullican, Texas Water Quality Board, from L.B. Ramke. Rework of WDW 57. Orange, Texas. July 3, 1975.

E.I. DuPont de Nemours and Co., Inc. Letter Report to Robert Hill, Texas Water Quality Board, from L.B. Ramke. Rework of WDW 54. Orange, Texas. May 22, 1973.

E.I. DuPont de Nemours and Co., Inc. Letter Report to Robert Hill, Texas Water Quality Board, from L.B. Ramke. Rework of WDW 56. Orange, Texas. July 9, 1973.

E.I. DuPont de Nemours and Co., Inc. Letter Report to Robert Hill, Texas Water Quality Board, from L.B. Ramke regarding WDW 104. Orange, Texas. August 2, 1974.

E.I. DuPont de Nemours and Co., Inc. Letter Report to Robert Kent, Texas Water Quality Board, from L.B. Ramke. Rework of WDW 104. Orange, Texas. May 12, 1975.

E.I. DuPont de Nemours and Co., Inc. Letter Report to Sam Pole, Texas Department of Water Resources. Rework of WDW 56. Orange, Texas. August 26, 1980.

E.I. DuPont de Nemours and Co., Inc. Staff Report on Application for Subsurface Waste Disposal Permit for WDW 104. Sabine River Works, Orange County, Texas. January 14, 1972.

E.I. DuPont de Nemours and Co., Inc. Telephone Memo from J. Creach to Ben Knape, Texas Department of Water Resources. Corpus Christi Plant. Ingelside, Texas. March 16, 1983.

Ed L. Reed & Association. Engineering Report: Application for the Extension of the Temporary Deep Disposal Well Permit. American Magnesium Company. Scurry County, Texas. n.d.

Environmental Action Foundation. Fact Packet, Deep Well Injection. 1984.

Empire Reeves Steel Division. Deep Well Acid Disposal System. Mansfield, Ohio. November 22, 1968.

Empire Reeves Steel Division. Letter to Wayne Connor, Ohio Division of Oil and Gas, from A. Reynolds. Mansfield, Ohio. December 18, 1969.

Empire Reeves Steel Division. Letter to Wayne Connor, Ohio Division of Oil and Gas, from A. Reynolds. Mansfield, Ohio. March 30, 1970.

Empire Reeves Steel Division. Letter to Wayne Connor, Ohio Division of Oil and Gas, from A. Reynolds, Mansfield, Ohio. May 27, 1970.

Empire Reeves Steel Division. Work Log on DW No. 1. Mansfield, Ohio. June 24-July 2, 1970.

Emrich, G.H. Failure of Jones and Laughlin Steel Corporation Deep Disposal Well. Memo to W.A. Lyon, Pennsylvania Bureau of Sanitary Engineering. Pittsburg, Pennsylvania. 1969.

Evans, David M. The Denver Area Earthquakes and the Rocky Mountain Arsenal Disposal Well. The Mountain Geologist. Volume 3, No. 1. 1966.

Fair, Doyle F. Letter to Dave Noller, Vulcan Materials Co. Well No. 6. February 14, 1980.

Faulkner, G.L., and C.A. Pascale. Monitoring Regional Effects of High Pressure Injection of Industrial Wastewater in a Limestone Aquifer. Groundwater. Volume 13, No. 2. 1975.

Florida Department of Environmental Regulation. Application to Abandon Class I, III, or V Injection Well Systems. City of St. Petersburg, Florida. St. Petersburg Northeast. Permit Files. 1985.

Florida Department of Environmental Regulation. Application to Construct/Operate Domestic Wastewater Treatment and Disposal Systems. DER Form 17-1.205(1). McKay Creek Pollution Control Facility. Largo, Florida. November 1985a.

Florida Department of Environmental Regulation. Correspondence, Inspection, Permit, and Enforcement Records. Tallahassee, Florida. 1985b.

Florida Department of Environmental Regulation. Florida Class I and Major Class V Injection Well Data Sheets. 1985c.

Florida Department of Environmental Regulation. Florida Underground Injection Control 1984 Compliance Inspection Report. 1985d.

Florida Department of Environmental Regulation. Florida Underground Injection Control Quarterly Permitting and Noncompliance Report, October-December 1984. 1985e.

Florida Department of Environmental Regulation. Florida Underground Injection Control Quarterly Permitting and Noncompliance Report. April-June 1985f.

Florida Department of Environmental Regulation. Kaiser Aluminum Correspondence Files. Tallahassee, Florida.

Florida Department of Environmental Regulation. Permit Number UD52-64919. Prepared for the Southwest Wastewater Treatment Plant. St. Petersburg, Florida. Issued June 6, 1983.

Florida Department of Environmental Regulation. Permit to Operate a Liquid Industrial Waste Treatment and Disposal System at the QO Chemical Belle Glade Plant. Permit No. I050-76412. April 1984.

Florida Department of Environmental Regulation. St. Petersburg Southwest Wastewater Treatment Correspondence Files. 1985g.

Florida Department of Environmental Regulation. Technical Advisory Committee July 14, 1982, Meeting Summary. Kendale Lakes Wastewater Treatment Plant. Miami, Florida. July 20, 1982.

Frontier Chemical Company. Plant Site Disposal Well No. 2. July 1961.

Godsey-Earlougher, Inc.. Drilling and Completion of a Deep Disposal Well, Verdigris Plant. Tulsa, Oklahoma. March 1979.

Golden Strata Services, Inc. Completion Report for Tenneco Oil Company Waste Disposal Well No. 5. Serial No. 971325 St. Bernard Parish, Chalmette, Louisiana. November 1984a.

Golden Strata Services, Inc. Completion Report for Tenneco Oil Company Waste Disposal Well No. 6. Serial No. 971326 St. Bernard Parish, Chalmette, Louisiana. November 1984b.

Golden Strata Services, Inc. Malone Services Company Application for Permit of Subsurface Injection of Industrial Waste. Texas City, Texas. August 1977.

Golden Strata Services, Inc. Malone Services Company Drilling and Completion Report. WDW 138 Galveston Co. Texas. May 1978.

Golden Strata Services, Inc. Plugging and Abandonment Report for Tenneco's Class I Waste Disposal Well No. 2. Tenneco Oil Company Chalmette, Louisiana. 1984c.

Golden Strata Services, Inc. Rollins Environmental Services of Louisiana Workover Report. Workover Starting February 18, 1982. GSS Job #502. Iberville, Louisiana. 1982.

Golden Strata Services, Inc. Rollins Environmental Services of Louisiana Workover Report. Workover Starting March 3, 1982. GSS Job #505. Iberville, Louisiana. 1982.

Golden Strata Services, Inc. Repermit Application for Ethyl Corporation Disposal Wells. Magnolia, Arkansas. September 1983.

Golden Strata Services, Inc. Repermit Application for Rollins Environmental Services Iberville Plant Disposal Well No. 1. Iberville, Louisiana. n.d.

Golden Strata Services, Inc. Workover Report Tenneco Oil Company Chalmette Refinery Waste Disposal Well No. 4. St. Bernard Parish, Louisiana. 1984d.

Golden Strata Services, Inc. Workover Report WDW 169. Disposal Systems, Incorporated. Deer Park, Texas. March 6 through April 2, 1982.

Golden Strata Services, Inc. Workover Summary of Rollins Environmental Services. Iberville, Louisiana. 1981.

Goolsby, D.A. Geochemical Effects and Movement of Injected Industrial Waste in a Limestone Aquifer. Underground Waste Management and Environmental Implications Memoir. American Association of Petroleum Geologists. No. 18. 1972.

Goolsby, D.A. Hydrochemical Effects of Injecting Wastes into a Limestone Aquifer Near Pensacola, Florida. Groundwater Journal of the Technical Division, National Water Well Association. Volume 1, pp. 13-19. 1971.

Gordon, W. and J. Bloom. Deeper Problems: Limits to Underground Injection as a Hazardous Waste Disposal Method. Natural Resources Defense Council, Inc. n.d.

Greenleaf/Telesca Planners Engineers Architects, Inc. Construction of Test Wells South Cross Bayou Pollution Control Facility Supplement No. 1. Engineering Report. Job No. 1528.89. Pinellas County, Florida. 1977.

Ground Water and Wells. Johnson Division, Universal Oil Products Co. St. Paul, Minnesota. 1972.

Haddad and Brooks. Report to Wayne Connor, Ohio Division of Oil and Gas, from R.E. Williams. Cyclops Corporation Industrial Disposal Well No. 4. Mansfield, Ohio. November 10, 1970.

Healey, H.B. Potentiometric Surface and Areas of Artesian Flow of the Floridan Aquifer in Florida, May 1974. Bureau of Geology Map Series 73. 1975.

Hickey, J.J. Hydrogeologic Data for the South Cross Bayou Subsurface--Injection Test Site Pinellas County, Florida. U.S. Geological Survey Open File Report 78-575. 1979.

Hickey, John J. Hydrogeology and Results of Injection Tests at Waste-Injection Test Sites in Pinellas County, Florida. U.S. Geological Survey Water Supply Paper 2183. 1982.

Hickey, John J. Hydrogeology, Estimated Impact, and Regional Well Monitoring of Effects of Subsurface Wastewater Injection, Tampa Bay Area, Florida. U.S. Geological Survey Water-Resources Investigations. 80-118. 1981.

Hickey, John J. Subsurface Injection of Treated Sewage into a Saline-Water Aquifer at St. Petersburg, Florida--Aquifer Pressure Buildup. Groundwater. Volume 22, No. 1. 1984.

Hickey, John J. and W.E. Wilson. Results of Deep-Well Injection Testing at Mulberry, Florida. U.S. Geological Survey, Water-Resources Investigations 81-75. 1982.

Hoagland Drilling Company, Inc. Industrial Waste Disposal with a Deep Well on the Empire Reeves Steel Mill Site. Preliminary Report. Mansfield, Ohio. 1966.

Illinois Environmental Protection Agency. Field trip memo and agency files. Velsicol Chemical Corporation. Marshall, Illinois. February 16, 1977.

Illinois Environmental Protection Agency. Letter to J. Brown (Velsicol Chemical Corporation, Marshall, Illinois), from L. Eastep, IEPA. July 2, 1985.

Illinois Environmental Protection Agency. Meeting notes and agency files. Velsicol Chemical Corporation. Marshall, Illinois. February 2, 1977.

Illinois Environmental Protection Agency. Meeting notes and agency files. Velsicol Chemical Corporation. Marshall, Illinois. April 19, 1977.

JAVA Petroleum Consultants. Mechanical Integrity Test and Injection Survey Performed for Cities Service Fractionators, Inc. Mont Belvieu, Texas. January 1984.

Jones and Laughlin Steel Corporation. Revised Subsurface Disposal Well. Drawing Submitted to Pennsylvania Department of Health. 1968.

Jukkola, W.H. Letter to T. Vayansky, Pennsylvania Department of Health. Jones and Laughlin Steel Corporation. Aliquippa Works Deep Disposal Well. 1969.

Kansas Corporation Commission, State of. Vulcan Materials Company Well Plugging Records. Well No. 2. Wichita, Kansas. January 1973.

Kansas Department of Health and the Environment. Correspondence File, Vulcan Wells. 1985.

Kansas Department of Health and the Environment. Permit Application for Vulcan's Class I Injection Wells. Wichita, Kansas. Revised April 29, 1985.

Kansas State Department of Health. Oil Field and Subsurface Disposal. Vulcan Materials Company. Well No. 1 Information Questionnaire. 1972.

Ken E. Davis Associates. Application to Repermit Waste Disposal Well No. 1 Browning Ferris Industries. CECOS International, Inc. Lake Charles, Louisiana. KEDA Project No. 82-0205. November 1982.

Ken E. Davis Associates. Application to Repermit Waste Disposal Well No. 1, Revision 1. CECOS International, Inc. Lake Charles, Louisiana. KEDA Project No. 20-0467. December 1984.

Ken E. Davis Associates. Conservation Monitoring Plan Report on Monitor Well Installation and Sample Analyses, CECOS International, Inc., Willow Springs Facility, Calcasieu Parish, Louisiana. DNR Office of Conservation Compliance Order No. UIC-85027. KEDA Project No. 20-0557. May 1985.

Ken E. Davis Associates. Drilling and Completion of Empak, Inc. Disposal Well No. 1. Deer Park, Texas. June 10, 1980.

Ken E. Davis Associates. Mechanical Integrity Testing, Phase I, Mary Anderson Well No. 1 Rio Bravo Disposal Facility. Kern County, California, KEDA Project No. 20-513. 1985.

Ken E. Davis Associates. Operations and Maintenance Manual, Browning-Ferris Industries, Inc. CECOS International, Inc. Lake Charles, Louisiana. KEDA Job No. 80-0094 and 82-0218. October 1982.

Ken E. Davis Associates. Proposed Closure Plan for Hazardous Waste Disposal Facilities at the Rocky Mountain Arsenal. Denver, Colorado. March 1984.

Ken E. Davis Associates. Proposed Conservation Monitoring Plan. Compliance Order No. UIC-85027. KEDA Project No. 20-536. CECOS International, Inc. Lake Charles, Louisiana. April 1985.

Ken E. Davis Associates. Report on Loss of Mechanical Integrity in Well No. 3. Prepared for Tenneco Oil Company. Chalmette, Louisiana. Project No. 20-505. 1985.

Ken E. Davis Associates. Rework Report, Disposal Well No. 3, Tenneco Oil Company. Chalmette, Louisiana. April 1985.

Ken E. Davis Associates. Workover and Plug Back of Well No. 1. Browning-Ferris Industries Willow Springs Facility. CECOS International, Inc. Lake Charles, Louisiana. KEDA Project No. 84-0392. July 1984.

Ken E. Davis Associates. Workover No. 3, Waste Disposal Well No. 1 WDW 157. Prepared for Empak, Inc., Deer Park, Texas. August 10, 1983.

Ken E. Davis Associates. Workover of Empak, Inc. Disposal Wellk No. 1 (WDW 157). Deer Park Plan, Harris County, Texas. January 15, 1981.

Ken E. Davis Associates. Workover Report, Disposal Well No. 1. KEDA Project No. 83-0321. CECOS International, Inc. Lake Charles, Louisiana. October 1983.

Ken E. Davis Associates. Workover Report. Waste Disposal Well No. 169. Prepared for DSI Transports, Inc. Deer Park, Texas. 1983.

Kennedy, Mike. Personal Communication Regarding Monsanto Textiles Company. Florida Department of Environmental Regulation. 1985.

Kidd, J.T. and S.W. Shannon, eds. Stratigraphy and Structure of the Birmingham area, Jefferson County, Alabama. Guidebook, 16th Annual Field Trip, Alabama Geological Society. 1978.

Kleeman, C. U.S. EPA Region III Letter to Edward Shoener, Remedial On-Scene Coordinator, Superfund Remedial Section. Hammermill Paper Company. Erie, Pennsylvania. May 26, 1983.

Leenheer, J.A., and R.L. Malcolm. Case History of Subsurface Waste Injection of an Industrial Organic Waste. In: J. Braunstein, ed. Underground Waste Management and Artificial Recharge. September 1973.

Leenheer, J.A., R.L. Malcolm, and W.R. White. Physical Chemical and Biological Aspects of Subsurface Organic Waste Injection Near Wilmington, North Carolina. U.S. Geological Survey Professional Paper 987. 1976.

Louis R. Reeder and Associates. Review and Assessment of Deep-Well Injection of Hazardous Waste. Volume III, Appendix D. Prepared for Municipal Environmental Research Laboratory, Solid and Hazardous Waste Research Division. Cincinnati, Ohio. National Technical Information Service. U.S. Department of Commerce. PB-269003. June 1977.

Louisiana Department of Environmental Quality, Environmental Control Commission Findings of Fact Compliance Order and Schedule. February 29, 1984.

Louisiana Geological Survey. A Study of the Subsurface Geology at the Browning-Ferris Industries Facility Willow Springs, Louisiana. 1983.

Louisiana Geological Survey. A Study of the Subsurface Geology at the Rollins Environmental Services Facility Bayou Sorrel, Louisiana. Iberville, Louisiana. (Cover memo from B.C. Hanson, LGS). 1983.

Louisiana Office of Conservation. Application of CECOS International, Incorporated, Formerly BFI. Report of Hearing Held at Lake Charles, Louisiana. Docket No. UIC 85-1. XV Volumes. January 23, 1985.

Louisiana Office of Conservation. Compliance Order No. UIC-85027. April 1, 1985.

Louisiana Office of Conservation. Letter from A.P. Caldwell, Tenneco Oil to Firtz Spencer, UIC Administrator. State Files. Chalmette, Louisiana. 1982.

Louisiana Office of Conservation. Letter from E.F. Lekouge, Tenneco Oil to Steve Culpepper, Office of Conservation. State Files. Chalmette, Louisiana. 1985.

Louisiana Office of Conservation. Order No. WD 85-10. Baton Rouge, Louisiana. October 24, 1985.

Louisiana Office of Conservation. Plug and Abandon Report. Tenneco Oil Company Well No. 2 Chalmette, Louisiana. Serial No. 970942. 1984.

Louisiana Office of Conservation. Report of Hearing Held at Baton Rouge, Louisiana. Application of Rollins Environmental Services of Louisiana, Inc. Docket No. UIC 83-23. Volumes I, II, and III. October 28, 1983.

Louisiana Office of Conservation. Report of Hearing Held at Plaquemine, Louisiana. Application of Rollins Environmental Services, Inc. Waste Disposal Well Iberville Parish. Docket No. WD78-3. November 29, 1978.

Louisiana Office of Conservation. Rollins Correspondence File. Iberville, Louisiana. 1976-1985.

Louisiana Office of Conservation. Well History and Work Resume Report. Tenneco Oil Company. Well No. 3. Chalmette, Louisiana. Serial No. 970960. 1985.

Lovette, S. Personal Communication Regarding Dow Chemical, Midland, Michigan. U.S. Environmental Protection Agency, Region V. Chicago, Illinois. October 17, 1985.

Marcher, Melvin V., and R.H. Bingham. Reconnaisance of the Groundwater Resources of the Tulsa Quadrangle, Northeastern Oklahoma. Oklahoma Geological Survey Map HA-2. 1971.

Mechem, Russell. Personal Communication Regarding Rio Bravo Disposal Facility, Bakersfield, California. U.S. EPA, San Francisco, California. 1985.

Merritt, M.L. Digital Simulation of the Regional Effects of Subsurface Injection of Liquid Waste Near Pensacola, Florida. USGS Water Resources Investigations Report 84-4042. Monsanto Textiles Company. 1984.

Metzger, D.P. Memo to D.K. Noller. No. 4 Deep Well Repairs of July 1982. Vulcan Chemicals. Wichita, Kansas. July 23, 1982.

Moore, D. and F. Hinkle. Monitoring Report on Waste Disposal Well Operations at the United States Steel Fairfield (Alabama) Plant. Alabama Geological Survey Open File Report. 1979.

Noller, D.K. Letter to W.R. Bryson, Vulcan Chemical Company. Deep Well No. 3. April 1, 1977.

Noller, D.K. Letter to W.R. Bryson, Vulcan Chemical Company. Deep Well No. 3. May 18, 1977.

Noller, D.K. Letter to W.R. Bryson, Vulcan Chemical Company. Well No. 6. November 25, 1981.

Northwest Petrochemicals. Geology and Hydrology of Anacortes Plant Site. Independent Consulting Geologist Report. 1960.

Ohio Department of Natural Resources, Division of Oil and Gas. Empire Reeves Steel Injection Well File. Mansfield, Ohio.

Oklahoma State Department of Health Services. Memo to File from Tim Baker. Agrico Chemical Company, Verdigris Plant. Catoosa, Oklahoma. July 1980.

Oklahoma State Department of Health Services, Industrial Waste Division. Letter to D.G. Davidson, American Airlines from D.S. Hensch, OSDH. August 19, 1983.

Oklahoma State Department of Heath, Industrial Waste Division. Letter to W.J. Lamberton, Chemical Resources, Inc., from J.K. Leavitt, OSDH, Agency Files. May 4, 1983.

Oklahoma State Department of Health, Industrial Waste Division. Letter to W.J. Lamberton, Chemical Resources, Inc., from D.A. Hensch, OSDH, from Agency Files. January 13, 1983.

Oklahoma State Department of Health, Industrial Waste Division. Memo to D.A. Hensch Regarding CRI Well. Agency Files. December 21, 1982.

Oklahoma State Department of Health, Industrial Waste Division. Memo to file from D.A. Hensch Regarding CRI Well. Agency files. March 3, 1983.

Oklahoma State Department of Health, Industrial Waste Division. Memo to R. Kellog Regarding CRI Well. Agency Files. November 20, 1981.

Oklahoma State Department of Health, Waste Management Service. Fact Sheet for Draft Operations Permit. American Airlines, Inc. Tulsa, Oklahoma. February 19, 1985.

Paine, Phillip J. Hearing Commission Report to be Presented to the Executive Director of the Texas Water Quality Board Concerning the Application for an Amendment to Subsurface Disposal Permit No. WDW-92. Cities Service Fractionators, Inc. Mont Belvieu, Texas. 1976.

Parker, G.G. Water Resources of Southeastern Florida. U.S. Geological Survey Water Supply Paper 1255. 1955.

Pinellas County Sewer System. Background and Preliminary Injection Monitoring Data for Deep Well Injection Program at McKay Creek Wastewater Treatment Facility. Largo, Florida. 1985.

QO Chemicals, Inc. Application for Operation Permit Renewal, Volume 1. Belle Glade, Florida. August 1983.

Rima, D.R., E.B. Chase, and B.M Myers. Subsurface Waste Disposal by Means of Wells--A Selective Annotated Bibliography. U.S. Geological Survey Water-Supply Paper 2020. 1971.

Rio Bravo Disposal Facility. Incident Report on November 9, 1984, Spill. Bakersfield, California. Submitted to U.S. EPA January 21, 1985.

Rollins Environmental Services. Application for Class I Waste Disposal Well Permit. Serial No. 142165. Iberville, Louisiana. November 1982.

Rosenshein, J.S. and J.J. Hickey. Storage of Treated Sewage Effluent and Stormwater in a Saline Aquifer, Pinellas Peninsula, Florida. Groundwater. Vol. 15, No. 4, pp. 284-293. 1977.

Schoft, Stuart F. Map Showing Groundwater Reservoirs in Oklahoma. Oklahoma Geological Survey Map 72-2, 1955.

Scott, Harold. Personal Communication Regarding ARCO Alaska. U.S. Environmental Protection Agency. 1985.

Seaburn and Robertson, Inc. Deep Well Injection Monitoring Program for McKay Creek Pollution Control Facility. Pinellas County Sewer System, Pinellas County, Florida. 1983.

Seaburn and Robertson, Inc. Program to Investigate Pressure Buildup and Apparent Leakage at South Cross Bayou Injection Facility. Pinellas County, Florida. 1985.

Seaburn and Robertson, Inc. Report of Sidewall Coring Results from South Cross Bayou and McKay Creek. Pinellas County, Florida. 1985.

Seaburn and Robertson, Inc. Results of Recent Hydrologic testing Required by SWFWMD Order 77-44 at South Cross Bayou Pollution Control Facility. Pinellas County, Florida. 1978.

Seaburn and Robertson, Inc. Summary and Evaluation of the Hydrogeological Testing Program at the South Cross Bayou Pollution Control Facility. Pinellas County, Florida. 1979.

Shiver, Richard. A Status Report on the Temporarily Abandoned Class II Injection System of Hercofina, Wilmington, New Hanover County, North Carolina. North Carolina Department of Environmental Management Class I Hazardous Waste Injection Facility Report. 1984.

Socolow, A.A. Letter to Carlyle W. Westlund, Division of Water Quality, Bureau of Water Quality Management. Hammermill Paper Company. Erie, Pennsylvania. December 18, 1980.

Sonics International, Inc. Letter to David Jeffries, Texas Department of Water Resources, from W.K. Brewster. Dallas, Texas. May 22, 1978.

Sonics International, Inc. Workover of WDW 137. Dallas, Texas. February 14, 1978.

Southwest Florida Water Management District. Memorandum: South Cross Bayou Injection Facility Well Construction Permit Application Nos. 76I-001, 76I-002, and 76I-003 in Pinellas County, Florida. Order No. 76-109. 1976.

Southwest Florida Water Management District. Order No. 77-1. City of St. Petersburg's Southwest Injection Facility. Well Construction Permit Applications 76-I-004, 76-I-005, and 76-I-006. Pinellas County, Florida. 1977.

Southwest Florida Water Management District. Order No. 77-44. 1977.

Southwest Research Institute. Metallurgical Examination of Failed Disposal Well Liner. Final Report. Prepared for QO Chemicals, Inc., Belle Glade, Florida. February 1974.

Stauffer Chemical Company. Permit Application, Injection Well 3. Cold Creek Plant. Bucks, Alabama. October 1981.

Stewart, R.S. Letter to W. Lytle, Pennsylvania Geological Survey. Recompletion of Jones and Laughlin Steel Injection Well. 1968.

Subsurface Disposal Corporation. Tenneco Oil Company Disposal Well No. 3 (HWDW-95) Chalmette, St. Bernard Parish, Louisiana. Drilling of Disposal Well No. 3 (HWDW-95) 5 December 1980 through 11 January 1981. Job No. TC-01-LA-0. 1981.

Subsurface, Inc. Application to Office of Conservation State of Louisiana for Two Deep Injection, Industrial Waste Disposal Wells. Tenneco Oil Company. Chalmette, Louisiana. Project No. 79-045. October 1979.

Subsurface, Inc. Browning-Ferris Industries--Chemical Services, Inc. Disposal Well No. 1 (Recompletion of the WWF Gas and Edna Anderson. April 5, 7, and 21, 1976; May 18, 1976; June 1, 8, and 9, 1976; and June 14-August 5, 1976. Report Prepared by Tom W. Ball. CECOS International, Inc. Lake Charles, Louisiana. 1976.

Subsurface, Inc. Workover Report, Well No. 2. Velsicol Chemical Corporation. Job No. 750527. Bellaire, Texas. May 30-June 10, 1975.

Tenneco Oil Company. Letter to Michel J. Paque, Executive Director of the Underground Injection Practices Council, from A.P. Caldwell, Processing and Marketing Refinery General Manager. Chalmette, Louisiana. December 6, 1985.

Tetra Oil Company. Underground Injection Control Program for Rio Bravo Disposal Facility. Engineering Report Accompanying UIC Permit Application. Bakersfield, California. 1984.

Texas Department of Water Resources. Citation No. 3467. CECOS International, Inc. Odessa, Texas. 1979.

Texas Department of Water Resources. Correspondence File. Waste Disposal Well 003. Potash Company of America, Inc., Dumas Plant. Austin, Texas.

Texas Department of Water Resources. Correspondence and Permit File Empak Waste Disposal Well 157. 1978-1983.

Texas Department of Water Resources. Correspondence File. Waste Disposal Well 169. DSI Transports, Inc. Deer Park, Texas.

Texas Department of Water Resources. Disposal Well Inspection Report. Empak Waste Disposal Well 157. April 29, 1981.

Texas Department of Water Resources. Disposal Well Permit Application Waste Disposal Well 70. Chemical Waste Management. Corpus Christi, Texas, n.d.

Texas Department of Water Resources. Investigation Report. Chemical Waste Management Permit No. 01337, Corpus Christi.

Texas Department of Water Resources. Letter to John Harris, DuPont, from Harry D. Pruett, P.E., TDWR, Regarding Waste Disposal Well 121. June 14, 1984.

Texas Department of Water Resources. Permit File on Waste Disposal Well 133. American Magnesium Company. Snyder, Texas. 1985a.

Texas Department of Water Resources. Permit File on Waste Disposal Well 92. Cities Service Fractionators, Inc. Mont Belvieu, Texas. 1985b.

Texas Department of Water Resources. Permit Files for Waste Disposal Well 146. CECOS International. Odessa, Texas. 1985c.

Texas Department of Water Resources. State Permit Subsystem Long Listing. August 13, 1985.

Texas Department of Water Resources. Technical Report on Application for an Industrial Waste Disposal Well Permit. Empak, Inc., File. Deer Park, Texas. June 1980.

Texas Department of Water Resources. Technical Report on Application for Subsurface Waste Disposal Permit. CECOS International, Inc. Odessa, Texas. 1978.

Texas Department of Water Resources. Telephone Memorandum to File No. WDW 55/WDW 54 from Rhonda MacKinnon. Orange, Texas. November 4, 1982.

Texas Department of Water Resources. Telephone Memo to J. Harris, DuPont, from B. Knape, TDWR. Corpus Christi Plant, Waste Disposal Well 121. Ingleside, Texas. March 17, 1983.

Texas Department of Water Resources. Temporary Order No. 76-52E issued by Texas Water Quality Board. American Magnesium Company. Snyder, Texas. 1985.

Texas Water Commission. Application for Waste Disposal Well 24. Interoffice Memo to Commission from Groundwater Division. E.I. DuPont de Nemours and Co., Inc. Orange, Texas. August 6, 1985.

Texas Water Commission. Permit to Conduct Underground Injection Under Provisions of Chapter 27, Texas Water Code. Waste Disposal Well 146. CECOS International, Inc. Odessa, Texas. 1978.

Texas Water Commission. Permit to Conduct Underground Injection Under Provisions of Chapter 27, Texas Water Code. Waste Disposal Well 146. CECOS International, Inc. Odessa, Texas. 1980.

Texas Water Development Board. Application for Two Industrial Waste Injection Well Permits, DuPont Wells 3 and 4. Memo to File from Groundwater Division. Orange, Texas. July 23, 1969.

Texas Water Quality Board. Application for Permit for Subsurface Injection of Industrial Waste. CECOS International, Inc. Odessa, Texas. 1977.

Texas Water Quality Board. Application for Permit for Subsurface Injection of Industrial Waste. Texas Department of Water Resources Permit Files. Cities Service Fractionators, Inc. Mont Belvieu, Texas. File WDW-92. 1970.

Texas Water Quality Board. Application for Subsurface Waste Disposal Permit. Velsicol Chemical Corporation. December 21, 1973.

Texas Water Quality Board. Hearing Commissions Report. Sonics International. Dallas, Texas. June 6, 1975.

Texas Water Quality Board. Inspection Reports Prepared by CECOS International, Inc. Odessa, Texas. August 1, 1975; September 16, 1974; August 27, 1975; June 13, 1976; May 1981; August 1981; October 1982; May 1983.

Texas Water Quality Board. Interoffice Memo to File from Bob Hill Regarding Witnessing the Plugging of Injection Well WDW 12. Orange, Texas. August 27, 1971.

Texas Water Quality Board. Interoffice Memo to File from J.W. Blackwell. Cancellation of Disposal Well Permit WDW 23. Orange, Texas. April 30, 1973.

Texas Water Quality Board. Interoffice Memo to File Regarding Certification of TWC Permit WDW 12, Orange, Texas. September 23, 1965.

Texas Water Quality Board. Interoffice Memo to File WDW 118 from Bob Kent. Velsicol Chemical Corporation. July 29, 1976.

Texas Water Quality Board. Interoffice Memo to File WDW 118 from Jim Bain Regarding Velsicol Chemical Corporation. August 10, 1976.

Texas Water Quality Board. Interoffice Memo to File WDW 118 from Jim Bain Regarding Velsicol Chemical Corporation. February 15, 1974.

Texas Water Quality Board. Interoffice Memo to Gerald W. Mullican, Chief, Geological Services from Geological Services Staff Regarding Velsicol Chemical Corporation File WDW 118. December 2, 1976.

Texas Water Quality Board. Interoffice Memo to WDW 116 File from Bob Hill Regarding Witnessing the Cementing of the Long String Casing. February 14, 1974.

Texas Water Quality Board. Permit to Mobil Corporation No. 01169. Velsicol Chemical Corporation, WDW 118. January 29, 1971.

Texas Water Quality Board. Staff Report on Amendment to WDW-92, Cities Service Fractionators, Chambers County. Mont Belvieu, Texas. 1976a.

Texas Water Quality Board. Staff Report on Application for Subsurface Waste Disposal Permit. WDW 116. Sonics International. Dallas, Texas. December 18, 1973.

Texas Water Quality Board. Summary Data for Industrial and Municipal Injection Wells. Potash Company of America. WDW 003. July 30, 1976.

Texas Water Quality Board. Technical Report on Application for Subsurface Waste Disposal Permit. American Magnesium Company. Snyder, Texas. 1976b.

Texas World Operations, Inc. Application for UIC Permits for Chemical Waste Management, Inc. Vickery, Ohio. July 1985.

Thomas, David and Ray Quick. Personal Communication concerning Ethyl Corporation. Arkansas Department of Pollution Control and Ecology. Magnolia, Arkansas. 1985.

Trautmann, William L. Memorandum for Record. Fact Sheet on Deep Injection Well at Rocky Mountain Arsenal, Rocky Mountain Arsenal Information Center. Denver, Colorado. August 6, 1982.

Tucker, W.E. and R.E. Kidd. Deep-Well Disposal in Alabama. Alabama Geological Survey Bulletin 104. 1973.

Underground Resources Management, Inc. Technical Report in Support of Permit Applications for Waste Injection Wells. Volumes 1 and 2. Tenneco Oil Company. Chalmette, Louisiana. 1983.

Underground Resource Management, Inc. Evaluation of a Subsurface Waste injection System Near Vickery, Ohio. Prepared for the Ohio Environmental Protection Agency. Austin, Texas. March 1984.

Underground Resources Management, Inc. Summary of Groundwater Investigations of the "700-foot" Sand. Austin, Texas. Tenneco Oil Company. Chalmette, Louisiana. February 1985.

United States Army. Disposal Well Pumping Records. Rocky Mountain Arsenal. Denver, Colorado. January 1962-April 1966.

United States Army Environmental Hygiene Agency. Rocky Mountain Arsenal. Report of Industrial Waste Survey. Denver, Colorado. February 9-21, 1965.

United States Department of Commerce, National Technical Information Service. Citations From the Selected Water Resources Abstracts Database. Deep Well Disposal (1977 - April 1983). PB83-864058. 1983.

United States Department of Commerce. National Technical Information Service. Citations from the U.S. Department of Energy (EDB) Database Deep Well Disposal (1976-October 1984) PB84-877042. 1984.

United States Environmental Protection Agency. An Introduction to the Technology of Subsurface Wastewater Injection. Environmental Research Laboratory, Office of Research and Development. EPA-600/2-77-240. Ada, Oklahoma. December 1977.

United States Environmental Protection Agency. 40 CFR Parts 122 and 146. Rules and Regulations. Federal Register. Volume 45, Number 123. June 24, 1980. Page 42472.

United States Environmental Protection Agency. Federal Underground Injection Control Reporting System. Comprehensive Report. June 24, 1985a.

United States Environmental Protection Agency. Groundwater Investigation. Westlake-Willow Springs Area, Calcasieu Parish, Louisiana. CECOS International, Inc. Region VI. September 1978.

United States Environmental Protection Agency. Report to Congress on Injection of Hazardous Waste. Office of Drinking Water. EPA 570/9-85-003. 1985b.

United States Environmental Protection Agency. Site Visit Report. (Facilities visited as part of the data gathering effort for the preparation of the Report to Congress on the Injection of Hazardous Waste). EPA 570/9-85-003. Office of Drinking Water. 1985c.

United States Environmental Protection Agency. Underground Injection Control Permit Files. 1985d.

United States Environmental Protection Agency. Undergroud Injection Control Section. Permit Files on Rio Bravo Disposal Facility, Mary Anderson #1. Bakersfield, California. 1985e.

Vecchioli, J., and D.I. McKenzie, C.A. Pascall, and W.E. Wilson. Active Waste-Injection Systems in Florida, 1976. U.S. Geological Survey, Open-File Report 79-1296. pp. 14-16. 1979.

Velsicol Chemical Corporation. Letter to R. Piskin, IEPA Agency Files, from L. Nelson, Velsicol. Marshall, Illinois. February 22, 1977.

Velsicol Chemical Corporation. Letter to R. Piskin, IEPA Agency Files from L. Nelson, Velsicol. Marshall, Illinois. April 26, 1977.

Vulcan Materials Company. Information Questionnaire. Underground Industrial Waste Disposal System Well #1. Wichita, Kansas. 1972.

Vulcan Materials Company. Well Plugging Application Form. Well No. 2. Wichita, Kansas. 1972.

Warner, D.L., and J.H. Lehnr. An Introduction to the Technology of Subsurface Wastewater Injection. U.S. Environmental Protection Agency. Robert S. Kerr Environmental Research Laboratory. EPA-600/2-77-240. 1977.

Warner, Don L. Survey of Industrial Waste Injection Wells. Volume 1. Prepared for Geological Survey, Advanced Research Projects Agency. National Technical Information Service. U.S. Department of Commerce. AD-756 641. Springfield, Virginia. June 1972.

Westlund, C.W. Jones and Laughlin Steel Corporation Aliquippa Deep Disposal Well Chronology. Aliquippa, Pennsylvania. Memorandum Report. 1971.

Williams Brothers Engineering Company. American Airlines Geologic/Hydrologic Study of Maintenance and Engineering Center Injection Well No. 1. Tulsa, Oklahoma. December 1982.

Williams Brothers Engineering. Chronological Workover Report, Agrico Chemical Company Disposal Well No. 1. Catoosa, Oklahoma. 1982.

Williams Brothers Engineering. Investigation of Waste Invasion of Burgess and Mississippian Formations. Engineering Report for Chemical Resources, Inc. Tulsa, Oklahoma February 22, 1984.

Williams Brothers Engineering. Workover of Disposal Well No. 1 April 11-16, 1983. Letter Report. Agrico Chemical Company, Verdigris Plant. Catoosa, Oklahoma. April 1983.

Wilson, W.E., D.C. Parsons, and R.M. Spechler. Hydrologic Data for a Subsurface Waste-Injection Site at Mulberry, Florida, 1972-1977. U.S. Geological Survey, Open-File Report 79-683. 1979.

Wilson, W.E., J.S. Rosenshein, and J.D. Hunn. Hydrologic Evaluation of Industrial-Waste Injection at Mulberry, Florida: Underground Waste Management and Artificial Recharge. Volume 1, pp. 552-564. 1973.

Woodruff, E.G. and C.L. Cooper. Geology of Rogers County, Oklahoma. Oklahoma Geological Survey Bulletin 40-U. 1928.

Appendix A
UIC PROGRAM DIRECTORS' QUESTIONNAIRES

CLASS I WELL FAILURE AND PERFORMANCE EVALUATION QUESTIONNAIRE

Do you maintain a state injection well inventory that is more detailed or current than the EPA Federal Underground Reporting System (FURS)?

Are copies of the annual and quarterly non-compliance reports that are submitted to EPA available in your office?

Does any other agency have jurisdiction over Class I wells in your state?

What wells do you know of that have histories of well failures or malfunctions? Please list, or give a rough estimate of the percentage of the total wells in your state that have had failures or malfunctions.

Have there been any enforcement cases on any Class I wells in your state?

Are the permitting and enforcement files available in your office? Is monitoring data available?

What is required to obtain access to these files?

Specific Questions for Enforcement Divisions:

a. Have you had any enforcement cases concerning Class I wells?

b. Are the files available and accessible?

c. List known cases.

Appendix B
CH2M HILL DATA COLLECTION WORKSHEET

Entry Date of Data _____/_____/_____
day mo yr

GENERAL INFORMATION:

Facility Name: _____

Facility ID No. _____ State _____ Federal _____

Owner/Address: _____
(Owner's Representative: plant manager, etc.)

Phone: _____ SIC Code: _____ Well ID No.: _____

Facility Address: _____

_____

County _____ State _____

Lat. _____ Long. _____

CURRENT STATUS:

Under construction__ Active__ Temporarily abandoned__ Permanently abandoned__

Drilled never used__ Permitted not drilled__ Permit cancelled never drilled__

Other _____

WASTE CHARACTERISTICS:

__Class I Municipal __ Class I Nonhazardous Industrial __ Class I Hazardous:

RCRA Code ____ Class I Other: _____

Physical/Chemical Description: _____

_____

_____

Were Compatibility Tests Performed on Waste Stream Prior to Injection _____

Results: _____

pH:_____ Specific Gravity:_____ Temp:_____ Total Dissolved Solids,

mg/L:_____

Pretreatment:

___Solids Removal ___pH Adjustment ___Biological Treatment ___Chemical

Treatment ___None ___Other (explain)_____

PERMIT CONDITIONS:

Is well under current UIC Permit? ___yes ___no Permit No. _____

State or Federal _____

Applying for UIC Permit: ___yes ___no ___ status unknown

Type of UIC Permit: ___Area ___Construction ___Operating __ Plugging &

Abandonment

Maximum injection rate on permit: _____

Maximum surface injection pressure on permit: _____

Limitations on total volume of injected waste (give amounts):

____Monthly ____Yearly ___None _____Other (explain)_____

gnPR17/26

Other Restrictions on Operating Procedures: _____

_____

Area of Review: _____ miles Comments: _____

_____

WELL DESIGN AND SURFACE EQUIPMENT:

	Casing and Tubing Information			
	Dia.	Hole Dia.	Casing, Tubing, Wt. & Grade	Setting Depth
Surface:				
Intermediate 1:				
Intermediate 2:				
Injection:				
Liner:				
Tubing:				

Type of Seal: _____

Completion Method (type and depth): _____

_____

Subsurface Equipment (packers, etc.): _____

_____

Surface Equipment:	Yes	No	Comments
Holding Tanks:			
Surge Protection System:			
Filters:			
Pumps:			

GEOHYDROLOGIC INFORMATION:

Geologic Description of Injection and Confining Zones

	Injection Unit(s)	Confining Unit(s)
Name		
Lithology		
Age of Unit		
Depth, ft.		
Thickness, ft.		
Injection Interval, ft.		
Porosity, %		
Permeability, millidarcies		

Depth to USDW interface: _____

Total Dissolved Solids of Injection Zone (initial): _____ mg/L

Underground Sources of Drinking Water:

Aquifer Name	Depth	Thickness	Lithology	TDS (mg/L)

MONITORING:

Are monitoring wells required: __yes __ No Number Installed: _____

Location	Well #	Well #	Well #
Type:			
Depth(s) Monitored:			
Aquifer Monitored:			
Parameters:			

Have monitor wells detected upward fluid migration? _____ yes _____ no

Into USDW? _____ yes _____ no Describe:_____

Frequency of Mechanical Integrity Testing Required in Permit:_____

Type of Mechanical Integrity Testing Approved in Permit:_____

Frequency of Annular Pressure Testing Required in Permit:_____

Frequency of Reporting:_____

Other Monitoring Requirements:_____

_____

CURRENT OPERATING CONDITIONS:

Injection Rate gpm

1984	Average	_____	Maximum	_____
1983		_____		_____
1982		_____		_____

Injection Pressure, psi (well head_____ bottom hole_____ other_____)

1984	Average	_____	Maximum	_____
1983		_____		_____
1982		_____		_____

Annual Volume Injected, 1984 _____ 1983 _____ 1982 _____, million gallons

Date Injection Began_____ Date Injection Ceased_____

OPERATING HISTORY:

Results of All Mechanical Integrity Tests (include dates):_____

_____

_____

Repairs, Workovers, or Remedial Actions Required During Life of Well:_____

Incidences of Noncompliance with Permit (List violations type: administrative versus operational, and resolution)

		Date
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		

WELL PLUGGING RECORD:

Date Well Plugged: _____

Plugging Method: _____

Plugging Materials: _____

ADDITIONAL NOTES:

NOTE: Attach well diagram as it exist today.

APPENDIX C
GLOSSARY

Appendix C
GLOSSARY

Abandoned well--a well whose use has been discontinued because it cannot be used for its intended purpose.

Acidizing--the process of treating a formation with acid, usually hydrochloric, for the purpose of effecting an increase of permeability and porosity by dissolving the acid-soluble portion of the rock constituents.

Annulus--the space between adjacent well casings, between the inner casing and tubing, or between a well casing and an open borehole. Annuli between casings and between a well casing and open borehole are typically filled with cement. The annulus between the inner casing and tubing is filled with fluid.

Aquifer--a formation, group of formations, or part of a formation that contains sufficient saturated permeable and porous material to yield significant quantities of water to wells and springs.

Area of review--that radial distance from an injection well within which records of other active or abandoned wells must be checked to determine whether the proposed injection has a potential for contaminating overlying or underlying aquifers by fluid migration through the existing wells. The Area of Review must also be checked for faults that penetrate the confining zone and may provide a pathway for fluid migration.

Artesian--an adjective referring to groundwater confined under sufficient hydrostatic pressure to cause the water to rise above the upper surface of the aquifer. Groundwater under artesian conditions may or may not flow at land surface.

Capping--the process by which a well is sealed.

Casing--pipe lowered into a borehole during construction to support the sides of the hole and thus prevent the walls from caving, to prevent loss of drilling mud into porous ground, or to prevent water, gas, or other fluid from entering or leaving the hole. The number, thickness, type of materials, and length of casing must be designed for the life of the well and to protect underground sources of drinking water.

Cement circulation--the operation whereby a cement slurry is pumped into a drill hole or through and up the casing with cement returning to the ground surface or designated point.

Conductor casing--casing to be installed in the well to isolate loose surficial materials and stabilize drill rig foundation.

Confined groundwater--water that is under pressure significantly greater than atmospheric whose upper limit is the bottom of a bed of distinctly lower conductivity than that of the material in which the water occurs.

Confining zone--a geological formation, group of formations, or part of a formation that limits fluid movement into or out of adjacent aquifers. Synonymous with confining bed.

Contaminant--any undesirable physical, chemical, biological, or radiological substance or matter in water.

Core--a cylindrical sample of rock or soil material. Cores are often taking during drilling through the confining zone, so that tests can be performed on the rock material to demonstrate its confining characteristics.

Disposal or injection casing--the deepest casing set in a well which isolates the injection zone from overlying aquifers, and provides well control in the event of a tubing or packer leak and protected access to the disposal zone. Synonymous with long string casing.

Disposal well--a well used for the disposal of liquid waste into a subsurface stratum.

Drilling fluid--a fluid circulated in the borehole during construction of a well, used to lubricate bit and bearings, remove cuttings, support the borehole walls, and control subsurface pressure by transporting weighting material.

Fault--a surface or zone of rock fracture along which there has been displacement. If a fault penetrates the confining zone within the Area of Review, a potential pathway for fluid migration may exist.

Fish--an obstruction in a well bore, usually a part of the drilling tools or other construction equipment lost in a well during construction. Fishing--the process of removing or attempting to remove such an obstruction.

Flow rate--the volume per unit time of fluid substances which flow through a conduit, orifice, pipe, pump, turbine, or channel. Injection wells are designed to accommodate maximum flow rate, and injection well permits usually contain flow rate restrictions.

Formation--a body of rock characterized by a degree of lithologic homogeneity; it is prevailingly, but not necessarily, tabular and can be mapped on the earth's surface or traceable in the subsurface.

Formation water--water present in a water-bearing formation under natural conditions as opposed to introduced fluids, such as drilling mud. Formation waters are displaced by injected fluids.

Geophysical log--the record of depth versus some parameter obtained from a variety of recording devices which measure the physical properties of formations penetrated and their contained fluids. These properties include electrical conductivity and resistivity, the ability to transmit and reflect sonic energy, natural radioactivity, hydrogen ion content, and temperature, among others. These physical properties are then interpreted in terms of lithology, porosity, fluid content and chemistry.

Groundwater--water below the land surface in a saturated zone. Synonymous with formation water.

Grout--a slurry, usually of portland cement, water, and other additives, that are placed and allowed to set in the annular space between two casings, or between the outside casing and the drilled hole, to prevent the circulation of fluids within the annular space to stabilize the pipe and to protect the casing from corrosion. Synonymous with cement.

Hazardous waste--any waste, as defined in 40 CFR 261 Subpart A, "which may (a) cause or significantly contribute to an increase in mortality or an increase in serious irreversible or incapacitating reversible illness or (b) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed."

Injection well--a well into which fluids are injected; used to provide access to the injection zone. Synonymous with disposal well.

Injection zone--a geological formation, group of formations, or part of a formation receiving fluids through a well. The injection zone must be of sufficient thickness and areal extent and composed of rock material suitable for receiving injected fluids without undue pressure buildup.

Intermediate casing--a casing which can be set to protect against drill hole sloughing, to isolate the borehole during deeper drilling, to control artesian flow, to protect brackish-water zones, and to facilitate the installation of deeper casing strings.

Killing a well--the process of stopping the flow from a well under naturally or artificially induced artesian conditions by adding fluids with densities greater than the fluid being produced from the well, and providing a head pressure greater than the formation source.

Liner--a string of casing installed inside the production casing, usually for the purpose of repairing or extending the production casing. Liners may or may not extend to the surface.

Lithology--the physical characteristics of a rock or sediment.

Long string--See Disposal casing.

Mechanical integrity test--any test performed on an injection well for the purpose of confirming that there is no subsurface leakage of waste through or around any part of the well structure. Mechanical integrity testing is performed at a minimum of every five years, but is often required at more frequent intervals.

Microannulus--a minute opening that may exist between a well casing and a surrounding grout sheath that is in contact with but is not bonded to the casing.

Mud--see Drilling fluid.

Mud circulation--the process of pumping drilling fluid down the drill pipe and up the well bore during drilling. Circulation may be normal (down the drill pipe) or reverse.

NGVD--acronym for National Geodetic Vertical Datum, a reference elevation.

Packer--a device lowered into a wellbore or well casing that can be expanded by manipulation from the surface to produce a fluid-tight seal between the sides of the borehole or the casing and the tubing.

Permeability--the capacity of a porous rock, sediment, or soil to transmit a fluid without altering the structure of the medium; a measure of the relative ease of fluid flow. Confining beds must be relatively impermeable to keep injected fluids in the injection zone.

Plugging--1. the act or process of sealing an abandoned well by partially or completely filling the borehole, casing, and annulus with cement or other impervious material so as to prevent the flow of fluids from the well or between formations within the well. 2. the lodging of solid particles or gas bubbles in the pores of a permeable zone, leading to a reduction in its permeability.

Plugging record--a systematic listing of the materials and procedures employed in the permanent or temporary abandonment of water, oil, gas, test, exploration and injection wells.

Porosity--The property of a rock, soil, or other material containing interstices. It is commonly expressed as a percentage of the bulk volume of material occupied by interstices, whether isolated or connected.

Radioactive tracer survey--a test in which a short half-life radioactive material is pumped into a well and followed through the wellbore with a gamma ray sensing device to determine the path of fluid flow within the well and adjacent formations. The radioactive tracer survey is used in mechanical integrity testing to verify competence and performance of the confining layer, and is often used as one means of demonstrating mechanical integrity.

Shut-in (well)--the process of isolating the well from the production or injection facilities and piping by closing the wellhead valves, sealing the well by closing the blowout preventer (BOP), or killing the well and installing a valve or cap that will not permit flow from or into the well.

Shut-in tubing (pressure)--the static pressure in a well, usually measured downhole.

Sidetrack--the process of directionally drilling (deviating) holes that bypass blockages or otherwise damaged portions of the boreholes or well casing, or to reach a target zone objective.

Squeeze--a cementing process that involves applying hydraulic pressure to a cement slurry in contact with a formation through open perforations in the well casing or open wellbore, in which the cement material is forced into the perforations or loss zone and allowed to set, effecting a repair.

Stratum (plural: strata)--a sedimentary bed or layer, egardless of thickness, that consists of generally the same kind of rock material.

Subsidence--the lowering of a natural land surface in response to earth movements; removal of underlying supporting material by mining or solution of solids, either artificially or from natural causes; compaction due to wetting (Hydrocompaction); oxidation of organic matter in soils; or added load on the land surface.

Surface casing--a string of casing set to protect freshwater zones and support deeper casing strings, and to which well head connections are made.

Transmissivity--the rate at which a fluid in an aquifer is transmitted through a unit width under a unit hydraulic gradient. The injection zone must have sufficient transmissivity to receive the proposed volume of injected fluid without undue pressure buildup.

Temporarily abandoned well--a well that is taken out of service with the intent of future use after its repair or when the use of the well becomes economically feasible. See Shut-in well.

Total dissolved solids ("TDS")--the concentration of dissolved material in water.

UIC--acronym referring to the Underground Injection Control program under Part C of the Safe Drinking Water Act.

Unconfined groundwater--water in an aquifer that has no upper confinement; thus, the surface forms a water table, and is at atmospheric pressure.

USDW--an acronym for Underground Source of Drinking Water, referring to an aquifer or portion of an aquifer that contains less than 10,000 mg/L TDS, and which may be or potentially may be used as a source of drinking water (40 CFR Part 146.03).

Well--a bored, drilled, or driven shaft, or a dug hole, whose depth is greater than the largest surface dimension.

Well head--a device which supports valves and piping attached at the top of the well for the purpose of directing fluid to or from the well, providing for logging access and mounting of pressure gauges and other devices.

Well log--a chart of a parameter versus depth which provides a record of some physical property that may be interpreted in terms of the characteristics of the rocks, the fluids contained in the rocks, and the construction of the well. A log obtained from a well may, for example, show such information as resistivity, radioactivity, spontaneous potential, and acoustic velocity of the rocks penetrated as a function of depth.

Well monitoring--the measurement by onsite instruments, readings, samples, or laboratory methods of the pressure, water quality, or water level in a well.

Well plug--a watertight seal installed in a borehole or well to prevent movement of fluids. The plug can be cement inside the casing, or a manufactured packer or bridge.

Well stimulation--several processes used to clean the well bore, enlarge channels, and increase permeability in the interval to be injected thus making it possible for wastewater to move more readily into the formation. These processes include surging, jetting, blasting, acidizing, and hydraulic fracturing.

Well workover--a remedial action that requires the well to be taken out of service for cleaning, repairs, or modifications; usually requires the services of a workover rig.