4.2.3.3 Domestic Wastewater Treatment Plant Effluent Disposal Wells (5W12)

Well Purpose.

These wells should not be confused with recharge wells (5R21) and salt-water intrusion barrier wells (5B22) even though wastewater is sometimes injected into the latter. This discussion covers only domestic wastewater (sewage) treatment plant disposal (5W12) wells that are intended to dispose of the effluents from wastewater treatment plants by injecting the wastewater into or above USDW. In addition to disposal, highly treated domestic wastewater is sometimes injected between a fresh ground-water body and the leading edge of an encroaching salt water body. In such cases, the sole function of the injected water is to reverse the pressure gradient causing the landward migration of salt water. Wells injecting treated wastewater for this purpose, however, fall under the saline water intrusion barrier well category and therefore are not discussed here. Domestic wastewater injection wells also may be used to reinforce dwindling ground water resources. Where this has been done, the remoteness of domestic water supply wells, combined with the magnitude of dilution thus far has not resulted in any detectable deterioration of ground-water quality in the vicinity of the supply wells. Quite naturally, great effort has been made to select sites that are remote from points of use and to provide a very high degree of treatment -- treatment that produces an effluent meeting all currently applicable maximum concentration levels (MCL's) for drinking water. Again, however, wells injecting treated wastewater for this purpose are classified as 5R21 and will not be discussed in this section. Volumes of wastes handled vary widely, from a few thousands of gallons per day (for motels) to several millions of gallons per day (for cities).

All the facilities reviewed so far have provided at least secondary treatment, and a few could be rated as tertiary treatment plants. Secondary treatment usually involves some form of aeration (activated sludge or trickling filter or equivalent) in addition to the primary treatment (sedimentation and digestion of settleable solids). Clarification (removal of suspended solids) is always involved, and final chlorination of the plant effluent to destroy microorganisms also generally is included. Since clogging of receiving formations can become a serious obstacle in unconsolidated aquifer materials and in sandstones, special efforts to remove still more of the fine suspended solids, by filtration through sand, are likely to be necessary when injecting into such geological formations.

Inventory and Location

At this writing the inventory of type 5W12 wells is incomplete. States reporting Type 5W12 wells and their estimated numbers are shown in Table 4-37.

As seen in Table 4-37, the bulk of 5W12 wells are reported as being in the States of Florida (553 wells) and Hawaii (339 wells). The abundance of cavernous limestones in Florida, and the high permeabilities of the coralline limestones of the Florida Keys make this disposal method popular in that State. Both types of formations accept organic wastes with little tendency to plug.

Hawaii has both fractured, tunneled basalt and highly porous, ancient marine coral reefs which readily accept wastewaters. This is an economical and simple means of disposal for small towns, hotels, and institutions where there are no public sewer systems.

At first glance, the 72 wells reported for Massachusetts is surprising for a State not known for limestones or basalts. However, all 72 wells are seepage pits serving a condominium complex.

California (40 wells) and Texas (10 wells) are both in arid regions where the heavy withdrawal of ground water for irrigation

has led to some of the first serious attempts to replenish freshwater aquifers with highly treated wastewater plant effluents.

Construction, Siting, and Operation

Construction. Construction details vary widely. Some well constructions show evidence of good casing and cementing programs, good screen designs in the injection zone, and dependable flow and pressure monitoring/recording systems. Others are little more than a few feet of pipe inserted into a bore hole some 20 feet in depth. Construction details appear to be controlled more by the need to keep the wells operating than by a desire to confine the discharge to a predetermined zone.

The ability of a disposal well to inject a given discharge rate into the injection zone is primarily a function of several factors: 1) the permeability of the geological formation comprising the receiving zone, 2) the thickness of the receiving formation, 3) the design of the screen set across the receiving interval, 4) the differential pressure head that is available to force the waste water into the formation, 5) the completeness of

TABLE 4-37: SYNOPSIS OF STATE REPORTS FOR DOMESTIC WASTE WATER TREATMENT PLANT EFFLUENT DISPOSAL WELLS(5W12

REGION & STATES	EPA REGION	Confirmed Presence Of Well Type	Regulatory System	Case Studies/ Info. available	Contamination Potential Rating
Connecticut	I	NO	N/A	NO	N/A
Maine	I	NO	N/A	NO	N/A
Massachusetts	I	72 WELLS	PERMIT>15K GPD	YES	LOW
New Hampshire	I	NO	N/A	NO	N/A
Rhode Island	I	NO	N/A	NO	N/A
Vermont	I	NO	N/A	NO	N/A
New Jersey	II	NO	N/A	NO	N/A
New York	II	21 WELLS	PERMIT	NO	N/A
Puerto Rico	II	1 WELL	PERMIT	YES	HIGH
Virgin Islands	II	NO	N/A	NO	N/A
Delaware	III	NO	N/A	NO	N/A
Maryland	III	NO	N/A	NO	N/A
Pennsylvania	III	4 WELLS	N/A	NO	4TH HIGHEST/6 TYPES
Virginia	III	1 WELL	N/A	NO	N/A
West Virginia	III	NO	N/A	NO	N/A
Alabama	IV	NO	N/A	NO	N/A
Florida	IV	553 WELLS	PERMIT	YES	2ND HIGHEST/8 TYPES
Georgia	IV	NO	N/A	NO	N/A
Kentucky	IV	3 WELLS	ELIMINATE	NO	SERIOUS
Mississippi	IV	NO	N/A	NO	N/A
North Carolina	IV	NO	N/A	NO	N/A
South Carolina	IV	NO	N/A	NO	N/A
Tennessee	IV	NO	N/A	NO	N/A
Illinois	V	1 WELL	RULE	NO	N/A
Indiana	V	27 WELLS	PERMIT	NO	N/A
Michigan	V	2 WELLS	PERMIT	NO	N/A
Minnesota	V	11 WELLS	N/A	NO	N/A
Ohio	V	YES	N/A	NO	N/A
Wisconsin	V	NO	N/A	NO	N/A
Arkansas	VI	NO	N/A	NO	N/A
Louisiana	VI	NO	N/A	NO	N/A
New Mexico	VI	NO	N/A	NO	N/A
Oklahoma	VI	NO	N/A	NO	N/A
Texas	VI	NO	RULE/PERMIT	YES	N/A
Iowa	VII	NO	N/A	NO	N/A
Kansas	VII	NO	N/A	NO	N/A
Missouri	VII	NO	N/A	NO	N/A
Nebraska	VII	NO	RULE	NO	N/A
Colorado	VIII	NO	N/A	NO	N/A
Montana	VIII	NO	N/A	NO	N/A
North Dakota	VIII	NO	N/A	NO	N/A
South Dakota	VIII	NO	N/A	NO	N/A
Utah	VIII	NO	PERMIT	NO	N/A
Wyoming	VIII	YES	N/A	NO	N/A
Arizona	IX	1 WELL	PERMIT	NO	HIGH
California	IX	22 WELLS	PERMIT	NO	HIGH
Hawaii	IX	335 WELLS	PERMIT	YES	HIGH
Nevada	IX	NO	BANNED	NO	N/A
American Samoa	IX	NO	N/A	NO	N/A
Tr. Terr. of P	IX	NO	N/A	NO	N/A
Guam	IX	NO	N/A	NO	N/A
CNMI	IX	NO	N/A	NO	N/A
Alaska	X	4 WELLS	PERMIT OR RULE	NO	HIGH
Idaho	X	9 WELLS	RULE	NO	7TH HIGHEST/14 TYPES
Oregon	X	32 WELLS	N/A	NO	N/A
Washington	X	NO	RULE	NO	N/A

NOTE: SOME NUMBERS IN THIS TABLE ARE ESTIMATES.

treatment before injection, and 6) the chemical compatibility of the injectate with clays in the receiving formation.

A single term called "transmissivity" combines the first two factors mentioned above: permeability and formation thickness. The rate at which the receiving formation will accept the injected fluid is directly proportional to its transmissivity.

For injection wells in sand and gravel formations, specially designed "screens" are installed in the injection zone. These screens provide a large percentage of open area and have slot sizes that prevent movement of formation sand into the well during "development." Development is a process of agitation and removal of materials around the well intake (screen) that are fine enough to pass through the slots in the screen; it lowers the resistance to flow close to the well thereby increasing the efficiency and capacity of the well. Development is necessary before placing the well in service and is required periodically, to remove plugging materials from the face of the borehole and restore well capacity.

Frequently 18-8 stainless steel or some other suitable alloy is used as the material for the well screen; 18-8 stainless (18% minimum chromium, 8% minimum nickel, 2% maximum manganese, 0.2% maximum carbon, balance iron) is an alloy commonly used for water well screens. It is noted for its excellent resistance to corrosion by aggressive water and by harsh chemicals that sometimes must be used during redevelopment. A well screen whose length will cover a high percentage of the formation thickness is specified.

Where highly permeable formations are used for the injection zones, most disposal wells operate successfully "on gravity," that is, the pressure provided by the column of water in the well casing is sufficient to cause the wastewater to flow into the receiving formation without overflowing onto the ground surface. There are numerous examples of "gravity flow" injection wells in Florida, Kentucky, Tennessee, Hawaii, Puerto Rico and many other States where such formations exist.

Where only sand or gravel beds are available, the resistance to flow provided by the formation may require the use of pumps. In such cases, the well casing is connected directly to the pipe carrying the treatment plant effluent and the pumps maintain both the pipe and casing under pressure.

Completeness of treatment prior to injection is crucial to the successful hydraulic performance of an injection well completed in unconsolidated materials (sands and gravels). The more complete the treatment -- especially the removal of suspended solids -- the longer the well will operate at reasonable pressures before it must be shut down and rehabilitated. The plugging material may be fine sand, silt, organic matter, and microorganisms. Bacteria and certain other microorganisms find an ideal habitat within the screened portion of the injection well, where a constant supply of nutrients at nearly constant temperature is being provided by the effluent stream. Final chlorination of the effluent before injection can destroy most microorganisms and retard the growth of others within the well; unfortunately, the concentrations of chlorine necessary to be effective in water so high in organic materials also produce a wide range of chlorinated organic compounds, some of which are known to be toxic.

Siting. Injection well sites are selected for the usual considerations: economics, convenience, suitability of the target receiving formation, and, for the hydraulic effect the injection will have on the receiving formations.

The first consideration given is to drill the well as near as practical to the waste treatment facility it will serve. If the well can be constructed on land owned by the facility, additional land or rights-of-way will not have to be purchased. The closer the well is located to the point of discharge, the lower pipeline, trenching, and pumping costs will be.

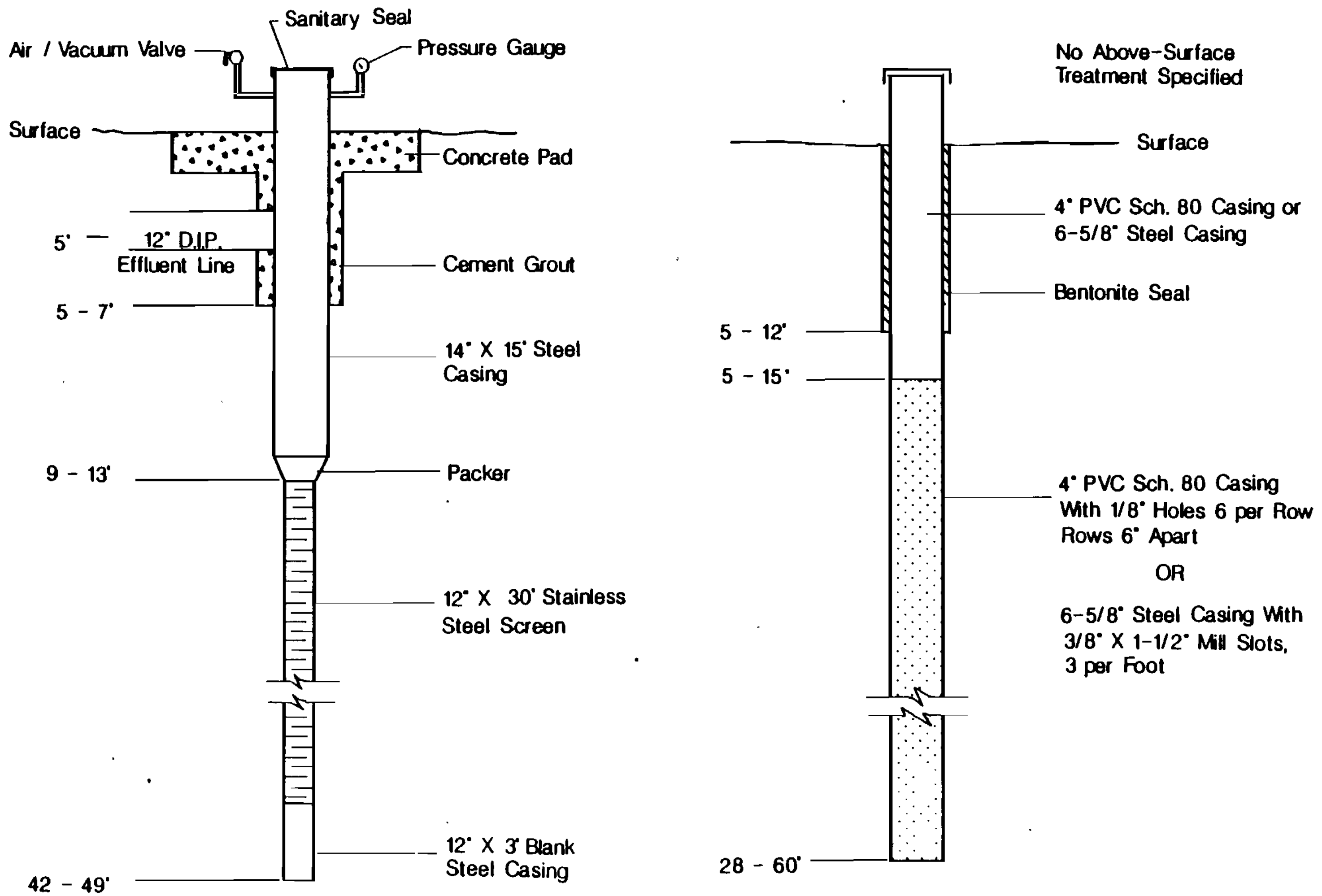
In addition, the well must be located where suitable receiving formations are available, as this will have a direct bearing on the efficiency, serviceability and dependability of the well. As in the case of water supply wells, an exploratory drilling program to locate and evaluate the injection formation may be necessary if the desired information is not already available.

Operation. Operation of injection wells for disposal of domestic treatment plant wastewater may range from very simple to relatively complex. Disposal wells in the Florida Keys, delivering effluent to shallow (25 to 30 ft.) wells completed in coralline limestones, operate by gravity flow with virtually no attention. There is no monitoring of flow or water quality, and there are no monitoring wells to track the lateral movement of the injected waters.

At the other extreme are operations such as that at Jackson Hole, Wyoming (Figures 4-27 and 4-28), where the plant effluent quality is monitored for quality and measured for volume regularly to assure that concentrations of constituents listed in the USEPA regulations never approach the MCL's for drinking water; and samples downgradient of the well are withdrawn at regular intervals to detect any significant change in ground water quality.

TYPICAL COMPLETION DIAGRAM OF RECHARGE AND MONITOR WELLS

(from Class V Injection Wells, State of Wyoming, Sept 15, 1986)

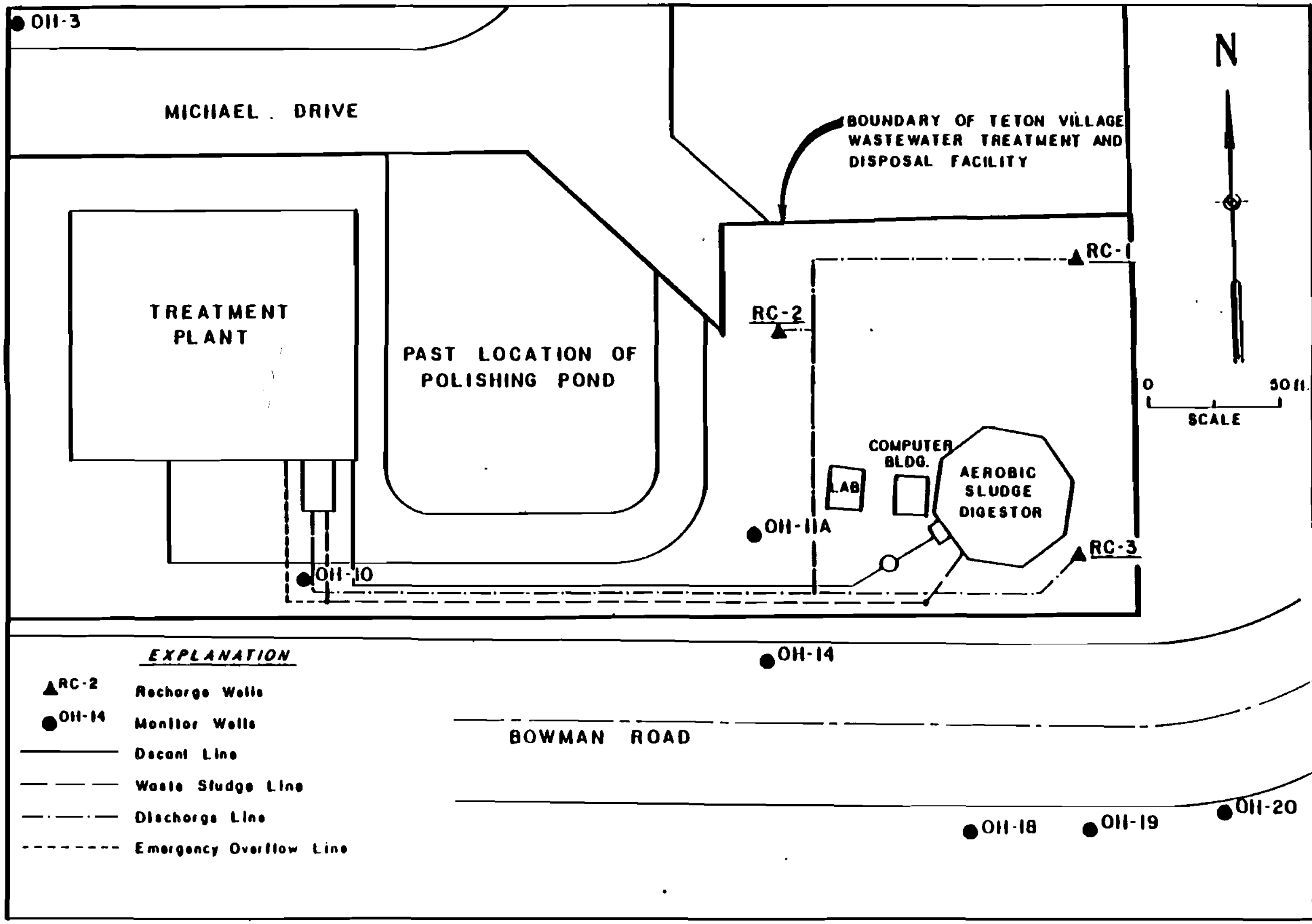


TYPICAL RECHARGE WELL

TYPICAL MONITOR WELL

Figure 4-27

5W12



5W12

Figure 4-28

TETON VILLAGE WASTEWATER TREATMENT AND DISPOSAL FACILITY, TETON COUNTY, WYOMING

(modified after Nelson Engineering and Culp Wesner Culp, 1979)

At Bay City, New York, on Long Island, an experimental domestic wastewater injection well has been operated for more than two decades by the U.S. Geological Survey and the Nassau County Department of Public Works (this experiment has been terminated and the facility is no longer operating). Water quality parameters for the injectate have been meticulously monitored throughout the period. Despite intensive treatment of the injectate, clogging has been an ever-present problem at Bay City. Bacterial contamination has been limited to a few feet radially from the injection well (Ehrlich, et al, 1979).

Both pressure and rate of injection are monitored at wells injecting into sand and gravel formations, as these values indicate when the well should be shut down for rehabilitation. Clogging elevates pumping costs and reduces the rate of injection.

Gravity flow wells injecting into highly permeable, channeled, and cavernous limestones and into basalts are not susceptible to clogging, so operation is relatively simple with no need to monitor pressures at the well head. Limestones and basalts, however, are ineffective barriers to the movement of bacteria. Wastewater treatment plant injection wells completed in such formations, therefore, are a greater threat to public health. Destruction of pathogens during treatment before injection is more critical than for wells injecting into sand formations.

Injected Fluids and Injection Zone Interactions

Numerous studies have shown that bacteria are unable to travel more than a few feet through unconsolidated sand and gravel materials. The possibility of infections from bacteria moving through such materials any appreciable distance therefore appears not to be a concern. Phosphates and nitrates, however, are present in all domestic waste treatment plant effluents, and are completely mobile. Nitrates are permitted in drinking water only in concentrations as high as 10 mg. per liter (10 parts per million) as nitrogen; when concentrations in drinking water exceed this value, they can be reduced by a process called "denitrification."

The nature of domestic wastewater (unaffected by industrial discharges) is such that, after treatment in a secondary or tertiary wastewater treatment plant, it may approach chemical compatibility with the water in the receiving formation.

There are two general categories of chemical reactions that can result when the injectate mixes with formation water. One is dissolution of aquifer rock materials; the other is the production of chemical precipitates.

If the injectate is acidic (pH less than 7.0), some of the rock matrix or minerals may be dissolved. This clearly can happen in limestones and dolomites, with no consequence unless the rocks happen to release significant amounts of undesirable minerals as they dissolve or the solution channels are increased in number or size. At Bay City, New York, the low pH of the injectate dissolved iron-bearing minerals in the sand, elevating iron concentrations in the vicinity of the injection well.

High alkalinity and higher pH (above 7.0) are more likely to cause chemical precipitation when the injectate reacts with the formation water. In this case the precipitates formed are likely to plug granular formations, especially medium to fine sands. Chemical precipates would not plug channeled formations such as limestones or basalts.

There is another type of reaction that often takes place when injectate comes in contact with native clays. Many clays are sensitive to changes in pH or the presence of certain ions -- especially sodium. A very small amount of clay dispersed within a sand aquifer can effectively block the flow of water if it swells as a result of a pH change or the presence of certain ions. These phenomena are well known to the petroleum industry, where extensive injectate water conditioning is sometimes necessary to maintain the injectivity of water flood and salt water disposal wells.

Hydrogeology and Water Use

If USDW are to be protected from possible contamination by injectates from Class V injection wells, full advantage should be taken of hydrogeological factors affecting the direction and rate of travel of injectates. The formations with the greatest permeabilities and, hence, those that accept injected water most readily are those that possess networks of interconnected channels, fractures, caverns and tunnels. Examples of these are the weathered limestones (especially the "karst" limestones) and certain types of volcanics (especially certain basalts). These types of formations also offer the additional advantage of not being vulnerable to plugging by suspended materials in the wastewater. As we shall note later, however, this inability to intercept and hold suspended materials becomes a disadvantage when public health considerations are taken into account.

Formations with low permeabilities, such as those composed of fine sand or sand with quantities of silts and clays, do not accept injectates as readily as the channeled limestones and basalts and are far more susceptible to plugging by suspended materials in the wastewater. For this reason a great deal of attention needs to be paid to carrying, to a high degree of completion, the treatment of the wastewater -- especially the removal of suspended matter. "Polishing" beds of sand, or lagoons, are sometimes placed in service (following the normal secondary treatment) to accomplish this end.

Ideally, the injection well is located so that none of the injectate would ever reach a drinking water supply source. At the very least, it should be so situated that its effect at the water supply source would be undetectable. This is not always the case, though, as can be seen from a facility in Florida.

The Florida domestic wastewater treatment plant near the town of Florida in the Arecibo District of Puerto Rico is situated in karst topography with numerous sinkholes. It was found to be operating at about double its design capacity and with the final, tertiary treatment section (sand bed filtration) out of service. The effluent, confirmed by plant operating records, was incompletely treated. It is likely that the plant effluent, some 360,000 gallons per day discharged into a sinkhole, travels downward through fissured and channeled limestone to the water table aquifer below. The same aquifer is the source of water for the town of Florida and several other nearby groups of houses.

Contamination Potential

Based on the rating system described in Section 4.1, domestic wastewater treatment plant effluent disposal wells are assessed to pose a high to low potential to contaminate USDW. These facilities typically do inject into or above Class I or Class II USDW. Well construction, operation, and maintenance may, in certain geological settings, allow fluid injection or migration into unintended zones. Injection fluids sometimes have concentrations of constituents exceeding standards set by the National Primary or Secondary Drinking Water Regulations and are of poorer quality (relative to standards of the National Primary or Secondary Drinking Water Standards or RCRA Regulations) than the fluids within any USDW in communication with the injection zone. However, fluids may be of equivalent or better quality (relative to standards of the National Primary or Secondary Drinking Water Standards and RCRA regulations) than the fluids within any USDW in connection with the injection zone. Based on injectate characteristics and possibilities for attentuation and dilution, injection sometimes occurs in sufficient volumes or at sufficient rates to cause an increase in concentration (above background levels) of the National Primary or Secondary Drinking Water Regulation parameters in ground water, or endanger human health or the environment beyond the facility perimeter.

The potential for Type 5W12 wells to contaminate USDW will vary from high to low depending on the following considerations:

1. Class V wells that inject into or above USDW are, by virtue of the location of these target injection zones alone, a threat to aquifers. Elevation alone provides the "head" or driving force necessary for the injectate to tend to move toward the USDW.

2. Where there is no geological formation providing an effective barrier separating the injectate from the USDW, as in the case of vugular limestones or basalts, bacteria may be carried by flow of the injectate to the USDW.

3. Unconsolidated sediments such as sands and fine gravels effectively filter out bacteria and other suspended solids within a few feet of the injection well.

4. When only domestic sewage is being treated, that is, no industrial wastes are present, the only soluble constituents that are fully mobile and of concern are phosphates and nitrates. Of these, only nitrates are of public health concern; they may require special treatment prior to injection.

5. Wastewater treatment plants accepting industrial wastes may present a special threat, in that many organic chemicals, as well as some "heavy" metals (frequently toxic) pass through the treatment process essentially unaffected.

6. Treatment facilities discharging into porous and channeled limestones or basalts require constant vigilance and monitoring, as these activities constitute the only barriers to potential contamination of USDW.

7. The origin of the water and the purity of the injectate require continuous vigilance by plant operators and dependability of mechanical devices.

Current Regulatory Approach

Class V domestic wastewater treatment effluent disposal wells are authorized by rule under Federally-administered UIC programs (see Section 1). Of the 19 States reporting the existence of type 5W12 wells, Florida and Hawaii have, by far, the most (80% of them).

Florida. The Florida Department of Environmental Regulation (FDER) issues construction permits for Class 5W12 wells. Permits are also required for both operation and for plugging and abandonment (P&A) of 5W12 wells. In addition, the FDER is authorized to specify monitoring requirements as a condition to operation.

The application-for-construction permit is a 3-page, rather comprehensive document that requires the presentation of information such as location and construction details of the well, the general nature and volume of the injectate, a description of the injection system, and definition of the area of review showing all water supply wells, surface water bodies, injection wells, etc. It specifies that contamination caused by the proposed well can result in revocation of the operating permit. The corresponding operating permit is non-renewable and non-expiring (except for violations of the law) and is transferable to another owner. The FDER may elaborate on specific conditions set for operation of the facility within the permit.

The FDER also requires that a permit to plug and abandon be obtained when a 5W12 well is permanently removed from service. The application requires a detailed description of the P&A plan. Upon completion of the P&A operations, the owner is required to complete a "Certification of Plugging Completion Class I, III or V Well" and record it at the FDER.

The FDER has included in its State report a draft of proposed "Revisions to the Florida UIC Class V Regulations." It deals primarily with proposed rules tightening the effluent water quality requirements and specifying the types of treatment that are expected to be used in bringing the quality up to levels safe for injection.

Hawaii. The Department of Health of the State of Hawaii issues permits for Class V wells, including the 5W12's. A single 5-page application form is required to be filled out, whether it be for an existing well, a new well, abandon and seal procedures, or other activity.

The accompanying instructions are comprehensive, calling for information on the facility such as, all wells within one-quarter mile, geology and climatology, nature and source of injectate, operating parameters, geohydrology, well logs, nature of groundwater, results of injectivity tests.

State of Hawaii statutes prohibit the operation, construction or modification of an injection well without a permit issued by the Department of Health.

California. Regional Water Quality Boards (RWQB), of which there are nine in the State, are the permitting agencies for 5W12 injection wells.

Texas. Registration is conducted by the Texas Department of Water Resources (DWR). Existing Class V wells are regulated by rule, on condition they're registered by January 6, 1983. Proposed new Class V wells must be registered with Department of Water Resources prior to construction. The Department may continue regulation by rule, or may develop "other regulating approaches for specific categories of Class V wells." The following information is required to be submitted: (1) name of facility; (2) name and address of legal contact; (3) owner; (4) nature, type and operating status of each injection well; and (5) location, depth, and construction of each well. After the Executive Director of the DWR has reviewed the proposed operation, he may require that the owner or operator apply for an injection well permit.

Oregon. Registration is with the Department of Environmental Quality (DEQ) of Oregon. The Department of Water Resources (DWR) regulates and issues permits for groundwater recharge. Individual permit drafting and source oversight are the responsibility of the five DEQ regional offices.

Alaska. Class V injection wells are under the jurisdiction of the Alaska Department of Environmental Conservation (ADEC). General permits describing the features of the facility are issued by ADEC. In addition, local regulations may control in certain areas. Currently many changes are occurring in local regulations as the need for coordination is recognized.

Idaho. All Class V wells deeper than 18 feet below land surface require permits issued by the Department of Water Resources. An application must be filed with the DWR for construction, maintenance or modification of an injection well. No well is permitted by DWR if it contaminates an USDW.

Indiana. The main State regulatory statute in Indiana for the control of pollution of both surface and groundwater is 330IAC 3-1. The Stream Pollution Control Board (SPCB) is responsible for its enforcement. All discharges from Class V wells into ground water require a permit from the SPCB <u>except</u> the following:

1. approved and/or properly operating septic tanks with less than 4,000 gallons of liquid capacity;

2. discharges composed only of storm runoff; and

3. air conditioning/cooling water return wells which do not use water additives.

The Indiana State Board of Health administers the discharge permitting program through several state sub-agencies.

Michigan. The Water Resources Commission is responsible for controlling the pollution of both surface and groundwater in the State. The Commission would require a permit be issued for any 5W12 type injection well.

Other States. Other States that indicated the existence of 5W12-type wells have not yet provided the information on permitting, or have provided information so general that its relationship to 5W12 wells is unclear. There is some evidence to suggest that several States misclassified the wells.

Recommendations

Siting. Recommendations for location of injection wells so as to protect USDW are likely to be different from those aimed at consideration of cost, land ownership and convenience. Although economics will play an important role in every case, this report will stress only those that enhance the protection of USDW.

Hydrogeologic data on the proposed injection zone and contiguous formations must be collected and interpreted in order to understand existing ground-water occurrence and movement and to predict how these likely will be affected by the injection operation (AL, WY, HI). This might include complete pumping tests (both withdrawal and injection) with sufficient observation wells available to maximize usefulness of the data.

Operation. Each injection well should be permitted to operate at a maximum predetermined injection rate and a maximum pressure, determined by site-specific hydraulic conditions -- prevailing and foreseen (WY, AL, HI).

Remedial Action. Any 5W12-type injection well injecting treatment plant effluent into an USDW and not meeting the USEPA maximum concentration levels for drinking water requires remedial actions. Specific remedy(ies) will depend on the seriousness of the threat to water supplies and the nature of the treatment process. In some cases, wells should be plugged (KY).

Alternative disposal methods and feasibility of upgrading existing plants should be evaluated (VA).

4.2.4 MINERAL AND FOSSIL FUEL RECOVERY RELATED WELLS

4.2.4.1 Mining, Sand, or Other Backfill Wells (5X13)

Well Purpose

Backfill wells are used to place hydraulic (water) or pneumatic (air) slurries of sand, gravel, cement, mill tailings/refuse, or fly ash into underground mines. Mines may be backfilled in order to:

(1) Prevent subsidence attributable to mine cave-in;
(2) Create structural stability in active mines;
(3) Dispose of mill tailings/refuse or fly ash;
(4) Control or extinguish underground mines fires; and
(5) Fill in dangerous mine openings (Texas).

This operation entails drilling wells from the surface to the roof of the mine void, casing the well, and gravity feeding or pumping a slurry down the well into the mine. In Idaho, mine tailings are mixed with water to form a slurry and are piped through existing mine tunnels into excavated portions of subsurface mines.

The term "mine backfill wells" also has been used in reference to water wells or monitor wells installed into the backfill of surface mines. The latter definition of mine backfill wells does not fit the Federal Underground Injection Control (UIC) Program regulatory definition. According to 40 CFR 146.5 (e)(8), sand backfill and other backfill wells are used to inject a mixture of water and sand, mill tailings, or other solids into mined-out portions of subsurface mines (whether what is injected is a radioactive waste or not), and are Class V injection wells.

Inventory and Location

The Federal Underground Injection Control Reporting System (FURS) database indicates an inventory of 548 mine backfill wells in 6 states while the 54 State inventory and assessment reports received at this writing indicate the existence of 6,500 wells in 16 states. The discrepancy may be attributable to the fact that many mine backfill operations are now regulated by State or Federal mine bureaus or agencies who have little contact with UIC regulators. As a result, many backfill operation regulators are not aware of FURS or the EPA UIC Program requirements. The fact that FURS does not differentiate 5X well types also may add to the inaccuracy of the FURS inventory (mine backfill wells are one of many 5X type wells).

The "State Report" inventory (Table 4-38) includes only active and temporarily abandoned mine backfill wells. There are over 20,000 permanently abandoned wells of this type in the United States. The Pennsylvania State report identified over 19,000 wells. Many backfill wells are utilized for less than 2 days, then plugged and abandoned.

Mine backfill wells are limited to the continental United States and only those States where shaft mining exists. An abundance of water for slurry transport is a significant requirement for backfill well feasibility. Therefore, mines in arid regions with low water tables are not as likely to be hydraulically backfilled as mines in the wetter regions of the country.

Construction, Siting, and Operation

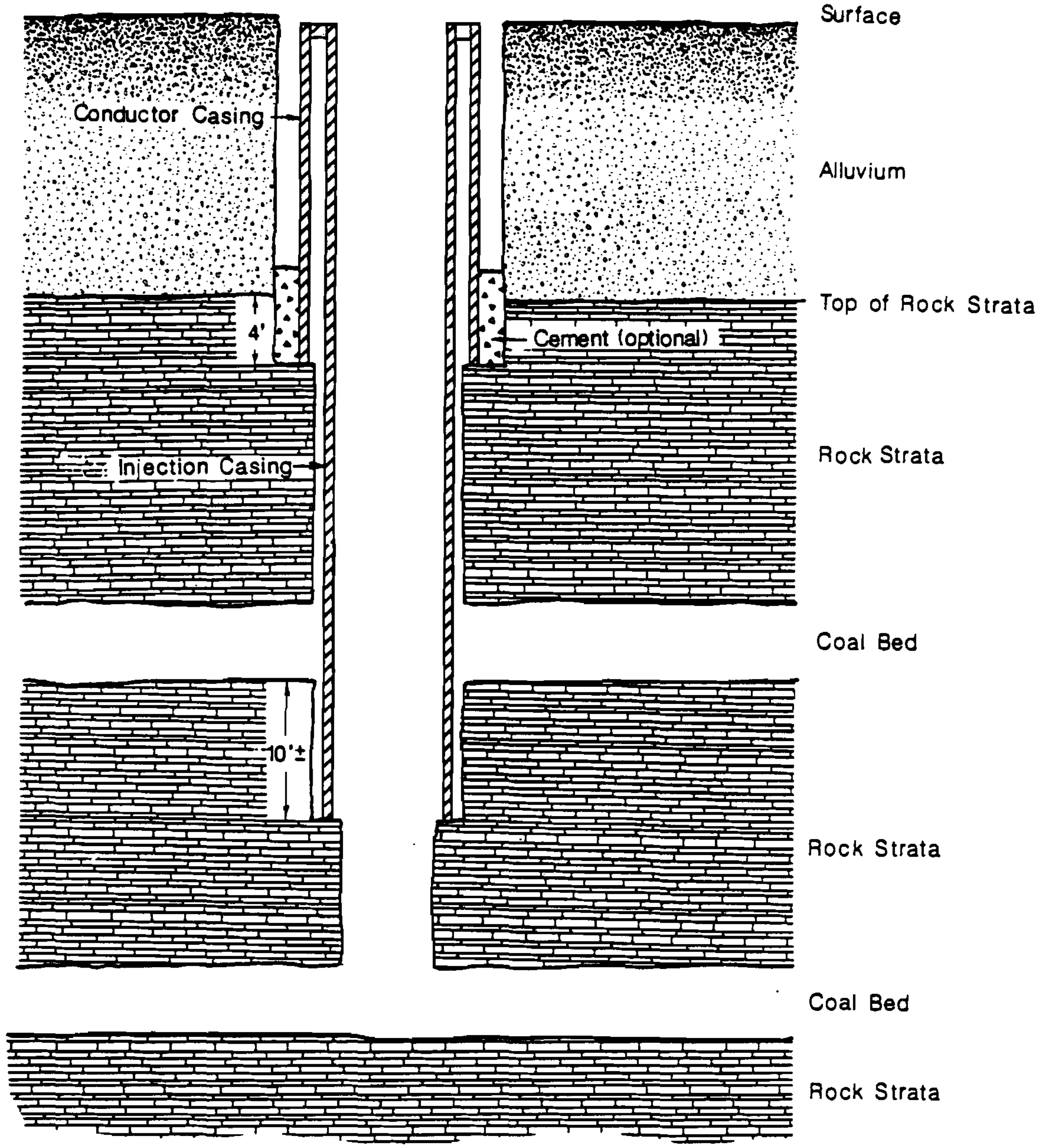
Several different types of mining-related injection wells utilize the mined-out portions of deep mines as the injection/disposal zone. Even though each well type performs a unique function, similar techniques and injected material are utilized. Operation and construction details of each mining related injection well are described below. Figures 4-29 and 4-30 present a typical mine backfill well construction and a typical subsidence control operation.

Subsidence Control. Hydraulic flushing is a technique commonly employed as a means of minimizing surface damage resulting from underground mine collapse (subsidence). It involves the use of strategically placed injection wells for the purpose of sluicing a slurry of solids into a mine void until full. Hydraulic flushing allows for substantially complete filling of all void spaces (to a predictable radius) around the well bore. Extent of fill, both laterally and vertically, is controlled by the solids concentration of the slurry and the injection rate, thus lending design flexibility dictated by mine void configuration. Bulkheads within the mine are sometimes constructed to control slurry emplacement. Hydraulic flushing for subsidence control can be applicable both above and below drainage coal seams. Economics dictate that readily available, abundant, and inexpensive fill materials be used. The fill materials commonly used are mine refuse, fly ash, cement, and crushed sandstone. Combinations of these materials are also used.

TABLE 4-38: SYNOPSIS OF STATE REPORTS FOR MINING BACKFILL WELLS(5X13)

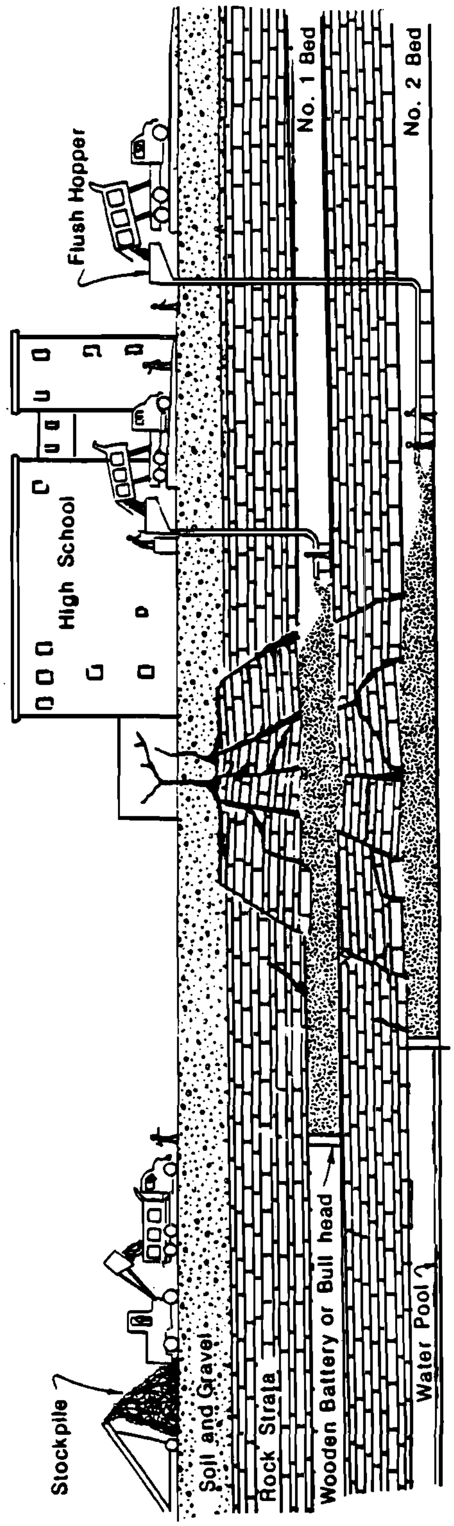
REGION & STATES	EPA REGION	Confirmed Presence Of Well Type	Regulatory System	Case Studies/ Info. available	Contamination Potential Rating
Connecticut	I	NO	N/A	NO	N/A
Maine	I	NO	N/A	NO	N/A
Massachusetts	I	NO	N/A	NO	N/A
New Hampshire	I	NO	N/A	NO	N/A
Rhode Island	I	NO	N/A	NO	N/A
Vermont	I	NO	N/A	NO	N/A
New Jersey	II	NO	N/A	NO	N/A
New York	II	NO	N/A	NO	N/A
Puerto Rico	II	NO	N/A	NO	N/A
Virgin Islands	II	NO	N/A	NO	N/A
Delaware	III	NO	N/A	NO	N/A
Maryland	III	1 WELL	PERMIT	NO	N/A
Pennsylvania	III	811 WELLS	MINE OPERATION	NO	5TH HIGHEST/6 TYPES
Virginia	III	NO	N/A	NO	N/A
West Virginia	III	258 WELLS	MINE OPERATION	NO	LOW
Alabama	IV	YES	PERMIT	NO	VARIABLE
Florida	IV	NO	N/A	NO	N/A
Georgia	IV	NO	N/A	NO	N/A
Kentucky	IV	61 WELLS	PERMIT	NO	SERIOUS
Mississippi	IV	NO	N/A	NO	N/A
North Carolina	IV	NO	N/A	NO	N/A
South Carolina	IV	NO	N/A	NO	N/A
Tennessee	IV	YES	N/A	NO	N/A
Illinois	V	5 WELLS	RULE	NO	N/A
Indiana	V	NO	N/A	NO	N/A
Michigan	V	NO	N/A	NO	N/A
Minnesota	V	NO	N/A	NO	N/A
Ohio	V	NO	N/A	NO	N/A
Wisconsin	V	NO	N/A	NO	N/A
Arkansas	VI	NO	N/A	NO	N/A
Louisiana	VI	NO	N/A	NO	N/A
New Mexico	VI	11 WELLS	N/A	YES	LOW
Oklahoma	VI	NO	N/A	NO	N/A
Texas	VI	65 WELLS	RULE	NO	LOW
Iowa	VII	NO	N/A	NO	N/A
Kansas	VII	NO	N/A	NO	N/A
Missouri	VII	4,326 WELLS(abd)	NONE	YES	LOW
Nebraska	VII	NO	RULE	NO	N/A
Colorado	VIII	2 WELLS	RULE	NO	N/A
Montana	VIII	10 WELLS	PERMIT	NO	N/A
North Dakota	VIII	300 WELLS	RULE	NO	POSITIVE
South Dakota	VIII	NO	N/A	NO	N/A
Utah	VIII	NO	RULE	NO	N/A
Wyoming	VIII	74 WELLS	PERMIT	NO	3RD-10TH HI/10 TYPES
Arizona	IX	NO	N/A	NO	N/A
California	IX	NO	N/A	NO	N/A
Hawaii	IX	NO	N/A	NO	N/A
Nevada	IX	1 WELL	N/A	NO	UNKNOWN
American Samoa	IX	NO	N/A	NO	N/A
Tr. Terr. of P	IX	NO	N/A	NO	N/A
Guam	IX	NO	N/A	NO	N/A
CNMI	IX	NO	N/A	NO	N/A
Alaska	X	NO	N/A	NO	N/A
Idaho	X	575 WELLS	RULE	NO	3RD HIGHEST/14 TYPES
Oregon	X	NO	N/A	NO	N/A
Washington	X	NO	N/A	NO	N/A

NOTE: SOME NUMBERS IN THIS TABLE ARE ESTIMATES.



TYPICAL MINE BACKFILL WELL CONSTRUCTION

Figure 4-29



TYPICAL SUSBSIDENCE CONTROL MINE
BACKFILL OPERATION

Figure 4-30

Typically, subsidence control injection wells are drilled with a rotary rig and are less than 500 feet deep. Unconsolidated surface materials are sealed off with conductor pipe. A 5- to 10-inch diameter hole then is completed into the mine void. Casing then is installed at depths to ensure delivery of the slurry materials through higher mined out or permeable zones into the mine. In most cases, neither casing is cemented during construction. The slurry material then is pumped (or gravity fed) through the borehole into the mine until the maximum radius around the well is effected and slurry refusal occurs. Upon refusal, both casing strings are removed and the well is plugged with cement from top to bottom. The delivery time required for, and total volume of, slurry emplacement is a function of mine configuration. The number of backfill injection wells necessary to complete a mine subsidence control project is contingent upon the total void volume to be filled as well as mine configuration. Delivery times range from as little as two days to a number of months. This accounts for the large number of permanently abandoned mine backfill wells.

Hydraulic flushing as a mine subsidence control technique has proven very successful in the United States and abroad. Excavations into mines which have employed this technique for coal refuse have showed that nearly total void filling had occurred and the material had drained and compacted to form competent supporting material.

Waste Disposal. Underground mining and related processes generate extremely large volumes of solid and liquid waste. Both types of waste can be generically categorized as potentially acidic and highly mineralized representing the major cause of concern for potential groundwater-quality degradation. When deep mining coal, substantial volumes of non-coal material are also extracted from the subsurface. The waste material, or mine refuse, generated is essentially sandstone, carbonaceous shale, and low grade coal. The mine refuse and coal itself are heavily concentrated with iron, manganese, and sulfide bearing minerals. These minerals, primarily pyrite, degrade the quality of the coal, and therefore it is desirable to separate the coal from the refuse and the pyrite from the coal. The refuse and the iron-sulfide precipitate (yellow-boy) formed when removing pyrite then often is injected into the mine void for disposal.

Many times the mine void is not available or is not used for mine refuse disposal and this material is deposited in "spoil" piles outside the mine portal. The pyrite and other metal-bearing minerals abundant in the spoil rapidly begin oxidizing. Water from rainfall percolates through the spoil, dissolving the oxidized material and creating a highly acidic, highly mineralized acid mine drainage. Similarly, ground water flows through abandoned deep mines becoming increasingly acidic and mineralized as it comes in contact with exposed mineral-containing rocks until it too is considered acid mine drainage. The acid mine drainage then flows by gravity down-dip to a surface discharge point, or in some instances it must be pumped from the mine for de-watering purposes to allow mining operations to continue. In either situation, the acid mine water must be treated prior to surface water discharge. Treatment consists of neutralizing the acidic nature of the mine water and aeration to allow for precipitation of metals. The sludge generated is then injected into the mine void. Also, it is not uncommon for acid water, which has been removed from an active mine, to be injected into an abandoned mine untreated. In these instances, the receiving mine is sealed to prevent gravity discharge of these acid waters.

Waste disposal well construction is typical of other mine backfill well construction. Specifically, a 5- to 10-inch diameter borehole is drilled to the mine void. Conductor pipe may or may not be used, dependent upon problems associated with unconsolidated surface material and borehole integrity. Cement is rarely used if casing is installed. The major difference between the operation of this and other backfill wells is the length of time the borehole is in service as an injection well. Waste disposal wells generally inject relatively moderate volumes of solids over extended periods of time.

A USEPA Region IV national assessment of Class V wells in the Region indicated an inventory of coal processing wastewater injection wells throughout Kentucky and Tennessee. In a number of cases a slurry is formed by consolidating wastewater from the coal washing process with coal clay and fragments of rock passed through mesh screen of No. 28 size. Chemical flocculants then are added to the mixture to facilitate settling of suspended materials. The jellied slurry, comprised of 25% to 30% firm material is injected into the mine void.

The slurry injection wells for coal processing wastewater injection in USEPA Region IV vary from 100 to 400 feet in depth. The slurry (injectate) often is transported from the processing facility to the injection well site by a pipeline and injected into the borehole which, more often than not, is without casing. In one case, the operator utilized the shaft of the mine as the injection well. Based on the USEPA Region IV study, injection rates for coal processing wastewater injection wells range from 2.7 to 350 gallons per minute, with total volume dependent upon the extent of the mine void.

Mine Fire Control. Underground mine fires, as evidenced by the number of mine fire control wells, are a significant problem in Pennsylvania. The technique found to be most effective in controlling mine fires is hydraulic flushing. Flushing is essentially flooding with a slurry of solid material as opposed to water alone. When flushing, the water portion of the slurry has sufficient heat capacity to extinguish some of the fires and dissipate heat while the solids seal the mine (see discussion of subsidence control wells), depriving the fire of oxygen and effectively putting the fire out. The solid material used to form the slurry is often mine refuse. Fly ash is another readily available waste material frequently used. Sandstone is used sometimes but is generally cost prohibitive. In some instances, only water is injected into the mine for fire control. Typically, the slurry emplacement boreholes are 8 inches in diameter and less than 100 feet deep. Eight-inch casing may be installed through any alluvial material to a maximum depth of 20 to 30 feet. This casing is never cemented. Quite often, when unconsolidated material on the surface is absent, no casing is used. On average, a well/borehole is never used for actual injection for more than a few days. The total volume of solid material injected through any one bore hole can range from 100 to more than 1,000 cubic yards. The wells are plugged immediately, from top to bottom with cement after their useful life is complete and any casing is removed.

One of the Nation's most publicized mine fires was discovered near Centralia, Colombia County, Pennsylvania in May 1962. The fire has not yet been extinguished. During the period 1962 to 1980, 1,535 boreholes were constructed for hydraulic flushing in an attempt to control the fire. Incomplete records indicate that in excess of 200,000 cubic yards of combustibly-inert solids were injected into the mine for various fire control purposes.

Injected Fluids and Injection Zones Interactions

Typical injected fluids are hydraulic or pneumatic slurries. The solid portion of the slurries may be:

1. sand;
2. gravel;
3. cement;
4. mill tailings/refuse; or
5. fly ash.

If a pneumatic slurry is emplaced in the mine, injection zone (mine shaft) interactions will be limited to oxidation if the mine itself is dry. Injection (mine shaft) interactions of hydraulic slurries range from slight water quality improvement to possible contamination from leachates or acid mine drainage. The degree and type of interaction within the mine after slurry emplacement is dependent on the source of water and type of slurry solid.

If water not affected by acid mine drainage is produced during mining and used to emplace sand, gravel, or cement slurries, no adverse interactions within the mine can be expected. In this case, mine waters are being introduced back into the mine with sand, gravel, or cement, which are essentially inert.

When slurry waters are acid mine water or ore extraction process wastewater, interactions within the mine may increase. Acid mine water will have a tendency to react with some portions of slurry solids, mine walls, or surrounding soils and mobilize potential groundwater contaminants. Process wastewaters may contain chemicals used in ore extraction that may cause interactions.

The use of mill tailings/refuse and fly ash as fill material may cause detrimental interactions. Mill tailings are low quality ore and, in the case of coal mining, are high in sulphur. Fly ash is the waste product of burned coal and has been found to contain arsenic and salts (particularly sodium sulfate). The leaching of these compounds does occur.

Mine backfill operations present special problems where, and if, ground water migrates through the backfilled mine voids and leaches high concentrations of chemical species such has heavy metals, sulfuric acid, cyanide, and other byproducts of milling processes, from the backfill material itself.

When precipitated sludge from acid mine drainage pools is emplaced in a mine containing acid mine water, the alkaline nature of the sludge may tend to neutralize the acid water and decrease the solubility of metals.

Hydrogeology and Water Usage

The mine backfill well category incorporates three operationally distinct coal mining related injection wells. Even though the wells inject for different purposes, the characteristics of the injected material are essentially the same.

Existing USDW chemical quality is critically important when assessing mine backfill wells. Mine water and interconnected groundwater is generally of moderate to poor quality with a high dissolved metals content and a potentially high pH. Therefore, the introduction of "wastes" consistent with the existing environment may not be considered degradation. An in-depth evaluation of mine backfill wells in West Virginia concludes in part that the "enhanced" pollution caused by such wells is very nearly impossible to quantify because of the low quality of receiving waters. It should be noted that mine water and aquifer quality is a function of the chemical composition of the mined out seam. Specifically, some seams have excellent water quality and, to a limited extent, serve as public drinking water supplies.

Mine backfill wells, in general, have little negative impact on ground-water quality. Short term use wells (subsidence and mine fire control) only can be considered beneficial. However, injections of acid mine drainage (AMD), AMD precipitate, and coal waste slurry are potentially detrimental, especially into mines which traverse formations serving as drinking water supplies.

It must be noted that, in many cases, surface and ground water contamination from mine waste surface piles may be more serious than contamination within a mine backfilled with that material.

Contamination Potential

Based on the rating system described in Section 4.1, mine backfill wells are assessed to pose a moderate potential to contaminate USDW. These facilities typically do inject into or above Class I or Class II USDW. In Idaho, however, this is not the case. Typical well construction, operation, and maintenance would not allow fluid injection or migration into unintended zones. Injection fluids typically have concentrations of constituents exceeding standards set by the National Primary or Secondary Drinking Water Regulations. Based on injectate characteristics and possibilities for attenuation and dilution, injection does not occur in sufficient volumes or at sufficient rates to cause an increase in concentration (above background levels) of the National Primary or Secondary Drinking Water Regulation parameters in ground water, or endanger human health or the environment beyond the facility perimeter, or in a region studied on a group/area basis.

Current Regulatory Approach

Mine backfill wells are regulated in one of three approaches:

1. By permit
2. By rule
3. As part of the overall mining operation.

The distribution of the various approaches is fairly even as evidenced by Table 4-39. The tendency, however, is to authorize these wells by rule until directives resulting from the national Class V Inventory and Assessment are issued from USEPA. Available regulatory details of each state (where mine backfilling is conducted) are included in Table 4-39.

It is believed that a significant hindrance to the FURS inventory is the fact that mining bureaus/agencies have regulatory jurisdiction in many States, and these entities are not completely familiar with the UIC program.

TABLE 4-39

REGULATORY APPROACH FOR MINE BACKFILL WELLS

STATE	REGULATORY AGENCY	PERMIT	RULE	OTHER
Alabama	State Dept. of Environmental Management	Federal UIC Regulations are utilized		
Colorado	USEPA Region VIII		Authorized by rule and inventoried. Low inventory response rate.	
Idaho	State Dept. of Water Resources		Authorized by rule until Inventory and Assessment efforts are complete. Operators must submit inventory information.	
Maryland	State Dept. of Health and Mental Hygiene	Classified as Industrial drainage and waste disposal wells. Requires groundwater discharge permit and public hearing through Waste Management Administration.		
Missouri	State Division of Geology and Land Survey			Not regulated. Expecting regulatory guidance from USEPA at completion of National Inventory and Assessment.
Montana	Bureau of Abandoned Mines	Regulated by Permit.		
North Dakota	State Department Health		Authorized by rule. Director must be notified of operations. New wells must submit drillers log and inventory information. Director may require permit.	
Pennsylvania	State Bureau of Mines and Reclamation			Regulated as part of overall mine operation.
Texas	State Water Commission		Existing well authorized by rule. Regulated through register and review process.	
West Virginia	Division of Mining			Regulated as part of overall mine operation.
Wyoming	State Dept. of Environmental	Regulated by Permit		

Recommendations

Several States provided recommendations for mining backfill operations. Some of them are summarized as follows. The siting, design, construction, and operation of mine backfill wells, when possible, should be included in overall mine operation plans and permit requirements (Illinois, Kentucky, Idaho). In many cases, this is done today, due to backfill well regulatory responsibility of State mining regulators. Contamination potential for backfill wells occurs in the mine void and not in the well-bore itself.

While injecting, slurry volumes should be monitored and compared to calculated mine volume as a check that no catastrophic failures occur (West Virginia).

Ground-water monitoring is recommended in areas that contain potable water in the stratigraphic vicinity of backfilled mine workings (Missouri). Migration of water through, or out of, backfilled mines appears to be the scenario which constitutes the primary ground-water contamination concern. Figure 4-31 presents possible ground-water contamination scenarios.

The Montana report recommended that site specific studies by conducted to determine the nature and extent of degradation due to mine backfill wells. Idaho recommends continuing authorization of mine backfill wells without permits in cases where the tailings are injected into formations that are effectively isolated from USDW.

4.2.4.2 Solution Mining Wells (5X14)

Well Purpose

In-situ or solution mining utilizes injection and recovery well techniques to bring minerals from underground deposits to the surface (Texas Department of Water Resources Report 274, 1983). Fluids designed to mobilize mineral resources are injected into an ore body, and the resulting "pregnant" solution is extracted. Minerals typically extracted by this procedure include copper, uranium, trona, borate, gold, silver, and zinc.

Solution mining falls into three general categories (Ahlness and Pojar, 1983):

1. Commercial operations with ore body preparation including such activities as blasting, block caving, and hydrofracturing, specifically to fragment the ore body;

SCENARIOS FOR POTENTIAL GROUNDWATER CONTAMINATION FOR MINE BACKFILL WELLS

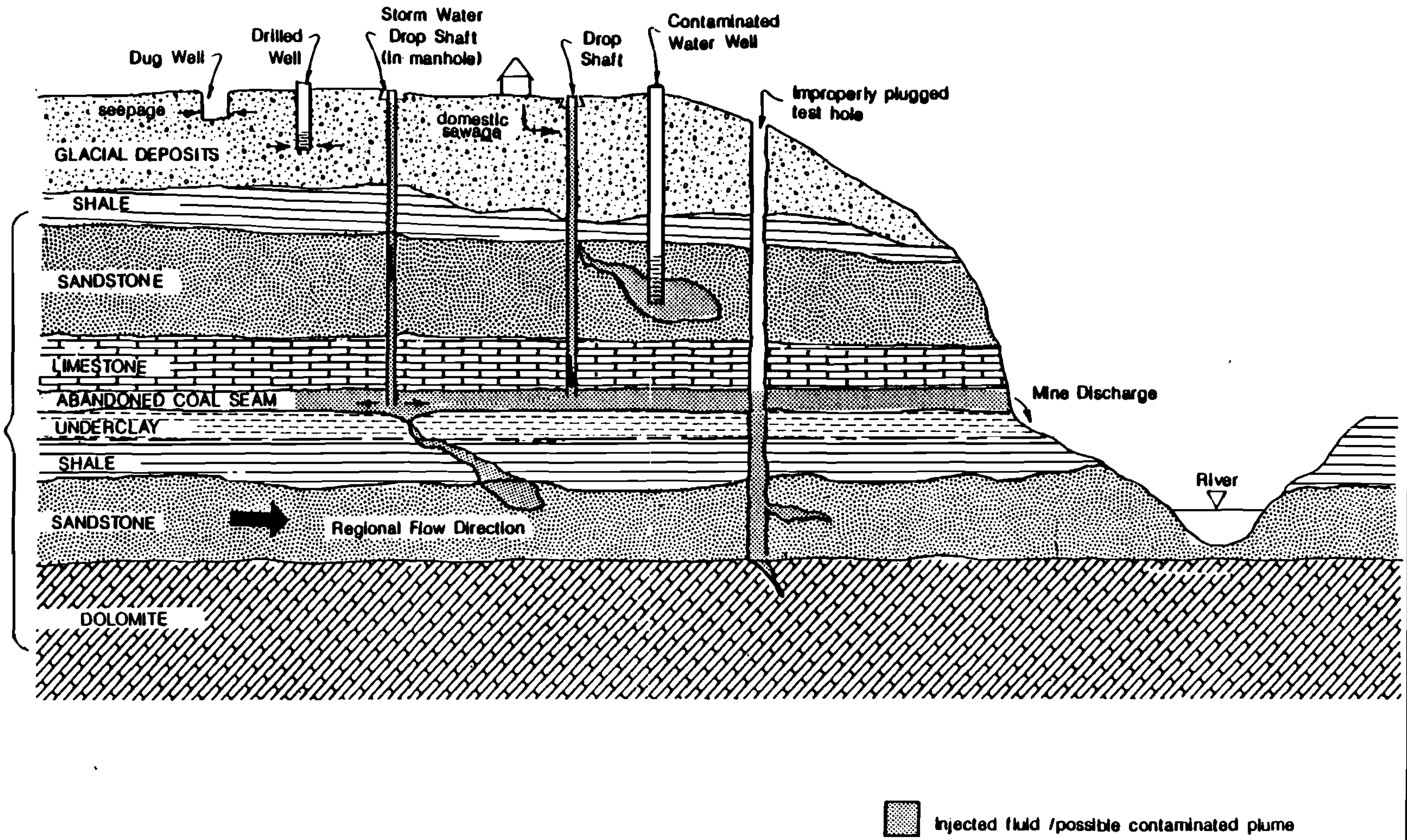


Figure 4-31

5X14

2. Commercial operations in old mine workings, including those done in open pits, worked out black caved areas, and backfilled stopes where leaching is conducted following conventional mining; and,

3. Experimental programs conducted on small scales to assess the economical and engineering feasibility of such projects.

The latter two categories are the types of programs associated with Class V injection, whereas the first category is associated with Class III injection. In-situ leaching of conventional mines is used to recover additional metals from old mine workings when conventional techniques such as open pit or tunnel recovery are economically unfeasible due to low grade ore or insufficient size of deposit. Experimental programs are typically pilot-scale feasibility studies which may or may not employ "experimental" procedures.

Inventory and Location.

Available inventory data indicate that there are presently 2,025 active and idle Class V solution mining injection wells in the United States and associated Possessions and Territories. This information has been derived from the various Class V State reports submitted. The solution mining well inventory data is presented in Table 4-40. Many more solution mining facilities actually have been reported for the United States than are indicated in the Table. These facilities are actually pilot-scale feasibility operations and are technically defined as experimental technology disposal wells (5X25). They are inventoried in the experimental technology section of this report, but their purpose and operation are consistent with injection wells used for stopes leaching solution mining.

Construction, Operation, and Siting

Specific aspects of injection wells associated with solution mining may vary from facility to facility, but construction designs generally are consistent. Plastic piping, typically PVC or CPVC, or Fiberglas pipe is used for casing, although light-weight steel casing also has been used for this purpose at certain Wyoming facilities. Casing diameters have been found to range from two to eight inches, with typical diameters of four to six inches. Depths of injection wells typically vary from about 200 ft to more than 1,000 ft and are dependent upon the depth of the ore body. The well completion may be open hole if total depth is into the ore body. If the well is seated below the ore

TABLE 4-40: SYNOPSIS OF STATE REPORTS FOR SOLUTION MINING WELLS(5X14)

REGION & STATES	EPA REGION	Confirmed Presence Of Well Type	Regulatory System	Case Studies/ Info. available	Contamination Potential Rating
Connecticut	I	NO	N/A	NO	N/A
Maine	I	NO	N/A	NO	N/A
Massachusetts	I	NO	N/A	NO	N/A
New Hampshire	I	NO	N/A	NO	N/A
Rhode Island	I	NO	N/A	NO	N/A
Vermont	I	NO	N/A	NO	N/A
New Jersey	II	NO	N/A	NO	N/A
New York	II	48 WELLS	PERMIT	NO	N/A
Puerto Rico	II	NO	N/A	NO	N/A
Virgin Islands	II	NO	N/A	NO	N/A
Delaware	III	NO	N/A	NO	N/A
Maryland	III	NO	N/A	NO	N/A
Pennsylvania	III	NO	N/A	NO	N/A
Virginia	III	NO	N/A	NO	N/A
West Virginia	III	NO	N/A	NO	N/A
Alabama	IV	NO	N/A	NO	N/A
Florida	IV	NO	N/A	NO	N/A
Georgia	IV	NO	N/A	NO	N/A
Kentucky	IV	NO	N/A	NO	N/A
Mississippi	IV	NO	N/A	NO	N/A
North Carolina	IV	NO	N/A	NO	N/A
South Carolina	IV	NO	N/A	NO	N/A
Tennessee	IV	NO	N/A	NO	N/A
Illinois	V	NO	N/A	NO	N/A
Indiana	V	NO	N/A	NO	N/A
Michigan	V	15 WELLS	N/A	NO	N/A
Minnesota	V	NO	N/A	NO	N/A
Ohio	V	NO	N/A	NO	N/A
Wisconsin	V	NO	N/A	NO	N/A
Arkansas	VI	NO	N/A	NO	N/A
Louisiana	VI	NO	N/A	NO	N/A
New Mexico	VI	1,073 WELLS	PERMIT	YES	LOW
Oklahoma	VI	NO	N/A	NO	N/A
Texas	VI	NO	N/A	NO	N/A
Iowa	VII	NO	N/A	NO	N/A
Kansas	VII	NO	N/A	NO	N/A
Missouri	VII	NO	N/A	NO	N/A
Nebraska	VII	NO	PERMIT	NO	N/A
Colorado	VIII	NO	N/A	NO	N/A
Montana	VIII	NO	N/A	NO	N/A
North Dakota	VIII	NO	N/A	NO	N/A
South Dakota	VIII	NO	N/A	NO	N/A
Utah	VIII	NO	PERMIT	NO	N/A
Wyoming	VIII	14 WELLS	PERMIT	YES	HIGHEST/10 TYPES
Arizona	IX	870 WELLS	PERMIT	YES	LOW/MODERATE
California	IX	5 WELLS	PERMIT	YES	UNKNOWN
Hawaii	IX	NO	N/A	NO	N/A
Nevada	IX	NO	N/A	NO	N/A
American Samoa	IX	NO	N/A	NO	N/A
Tr. Terr. of P	IX	NO	N/A	NO	N/A
Guam	IX	NO	N/A	NO	N/A
CNMI	IX	NO	N/A	NO	N/A
Alaska	X	NO	N/A	NO	N/A
Idaho	X	NO	N/A	NO	N/A
Oregon	X	NO	N/A	NO	N/A
Washington	X	NO	N/A	NO	N/A

NOTE: SOME NUMBERS IN THIS TABLE ARE ESTIMATES.

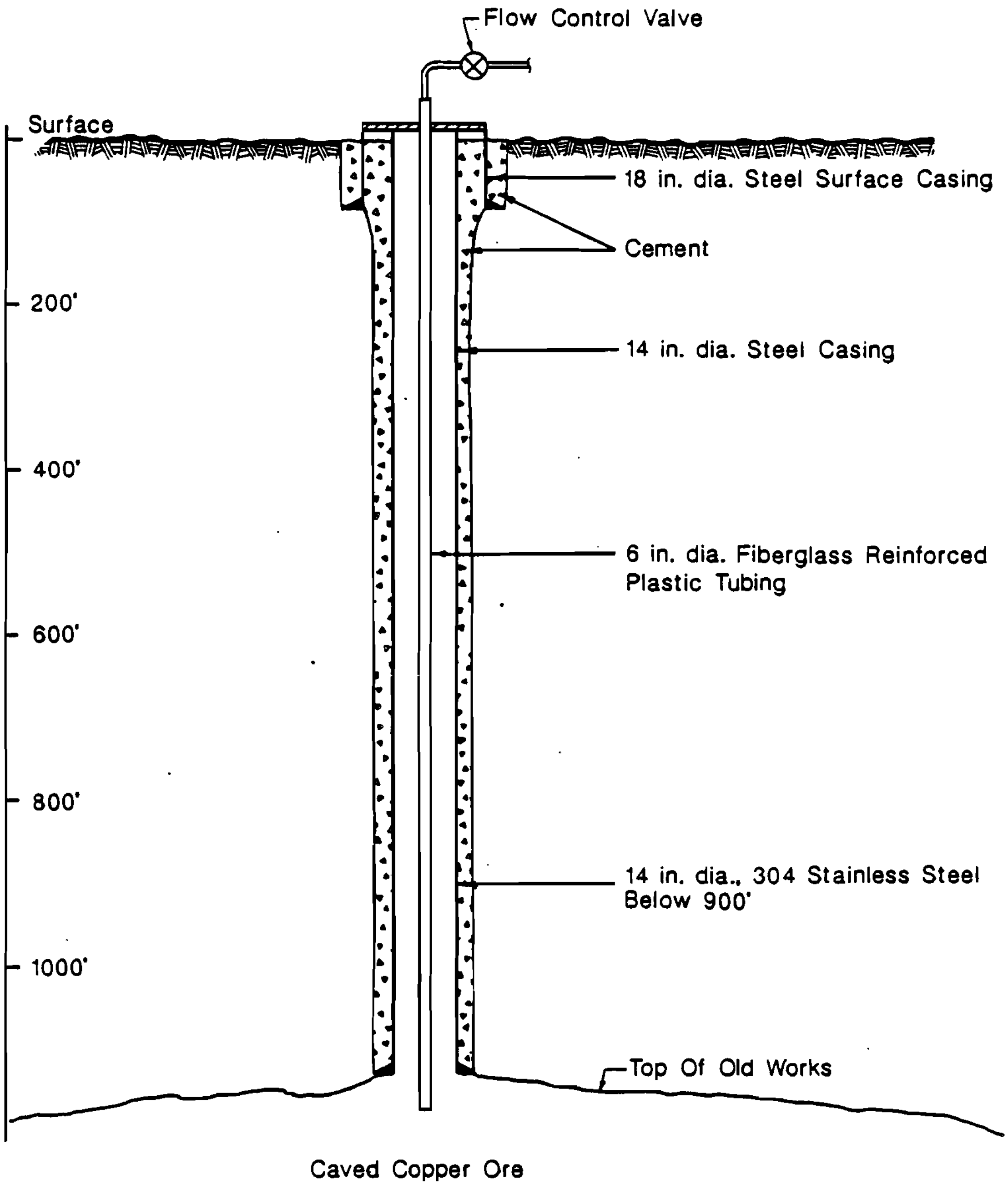
body, screened openings or perforations may be used to inject fluid into the ore body. The entire annulus between borehole and casing generally is cemented from total depth to surface. Some operators use an acid-resistant cement across the injection zone, where injectate is actually in contact with the cement job. Several centralizers may be used to assure proper positioning of casing within the wellbore. A typical construction design for solution mining injection wells is presented in Figure 4-32. In general, construction designs seem to be relatively simple and trouble free. Injection is gravity fed, and bursts in the casing due to high pressure rarely occur. However, operators do not typically conduct mechanical integrity tests. Therefore, the possibility that injection fluids unknowingly could migrate into unintended zones may exist.

In-situ leaching is the most common method used with Class V solution mining. Injection and recovery wells are constructed into an ore body that has been fragmented through blasting, block caving, or hydrofracturing. The majority of the wells inventoried in the United States are constructed in or around block caved zones. This method of in-situ solution mining involves four steps. First, a lixiviant, or "barren" solution composed of an acidic or basic oxidizing agent, is injected. This fluid will vary, depending upon the type of ore being mined. The injection of lixiviant causes mobilization of the mineral from the host ore body by creating a soluble complex salt. Third, the mineral-bearing lixiviant ("pregnant" solution) is recovered using extraction wells. Finally, the mineral is recovered from the pregnant solution at the surface using certain ion exchange techniques. One such technique is known as solvent extraction - electrowinning (SX-EW). Ideally, after solution mining activities are discontinued, a fifth step would be conducted which involves the restoration of groundwater to a prescribed post-mining quality. A schematic representation of in-situ solution mining is presented in Figure 4-33.

In-situ solution mining injection wells are sited in patterns sufficient to cover what geologic analysis has defined as the three-dimensional extent of the ore body. Spacing between wells is a function of several parameters. A primary consideration is intended injection volumes. Volumes used are directly related to the amount of fracture permeability induced by block caving. Also, capacity of the recovery system must be considered. Finally, the hydrogeologic properties of the ore body, principally porosity and permeability, must be addressed in determining adequate well spacing.

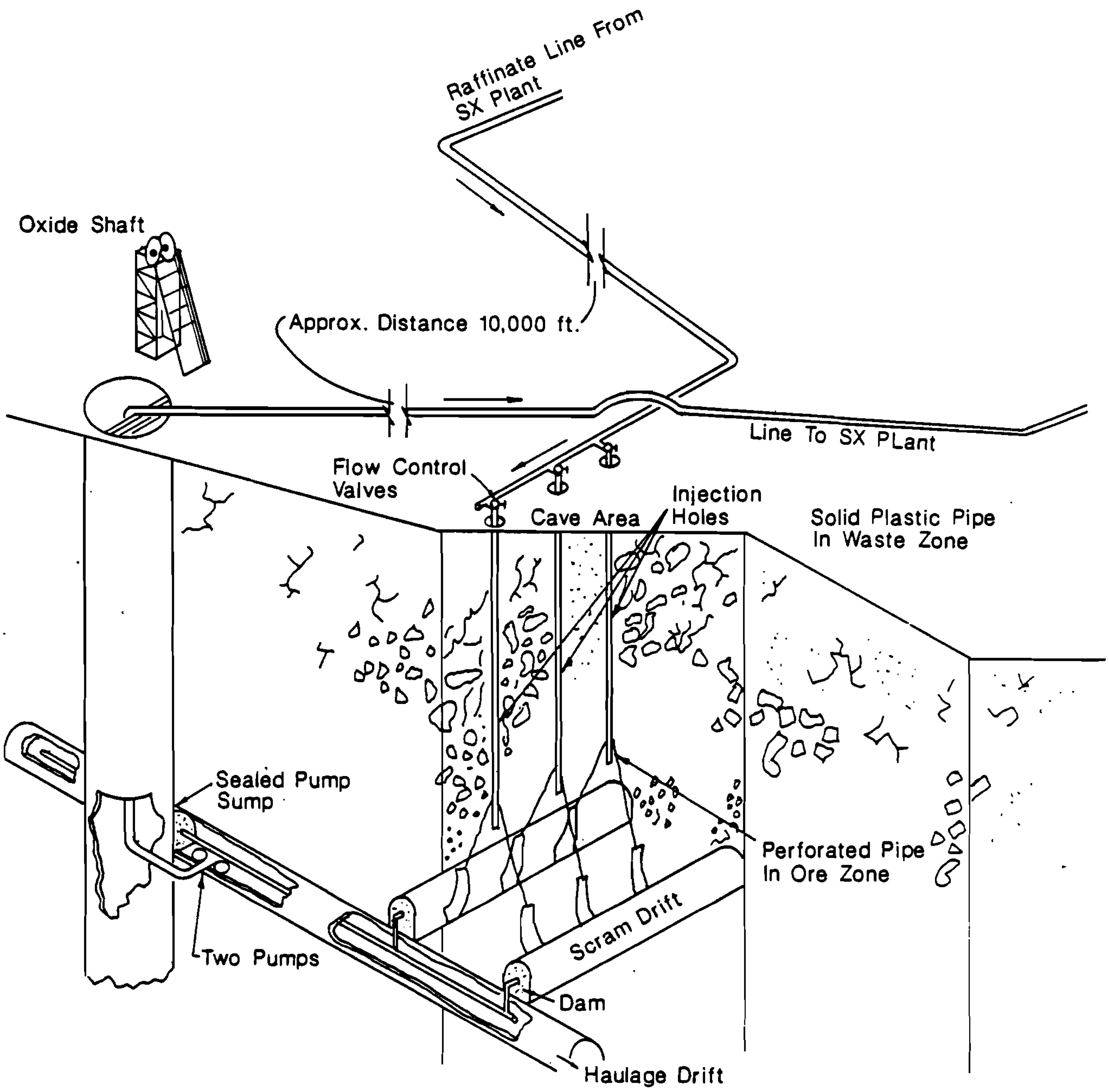
Injected Fluids and Injection Zone Interactions

Injection fluids will vary depending upon the type of mineral to be recovered. Copper and uranium are currently the



LARGE DIAMETER, HIGH VOLUME, CLASS V
SOLUTION MINING INJECTION WELLS
PROPOSED BY KOCIDE CHEMICAL CORPORATION

Figure 4-32



BLOCK DIAGRAM ILLUSTRATING APPLICATION AND COLLECTION OF LEACHING FLUID

(Courtesy: Noranda)

Figure 4-33

most widely mined minerals using in-situ procedures. Common lixiviants used for oxidizing these minerals include weak solutions (1-4%) of sulfuric or hydrochloric acid, ammonium carbonate, and sodium carbonate/bicarbonate. Ferric cyanide solutions typically are used to recovery gold, silver and other precious metals.

Operations have reported that block caved zones are actually "sumps" to ground-water flow. That is, hydraulic gradients from surrounding aquifers toward the block caved zone have been established. Because conventionally mined ore bodies usually are sulfide deposits, infiltrating ground water tends to oxidize the sulfide minerals. This process lowers the pH and increases heavy metal content within the ground water. Injection of weak acid solutions associated with solution mining only serves to enhance the natural reactivity of the sulfide minerals. Injected fluids are usually slightly more acidic than the ground water within block caved zones, as indicated by monitoring well data (Noranda Lakeshore Mines, Personal Communication, 1986).

Hydrogeology and Water Use

Ore bodies containing copper, uranium, and other precious metals are referred to as hydrothermal deposits (Tennissen, 1974). These are deposits formed in rock from hydrothermal fluids at high temperatures and pressures. Hydrothermal solutions responsible for ore deposits are of diverse origin, and sources include magmatic, meteoric, and connate waters. Ore bodies such as these are typically present within crystalline rocks of igneous or metamorphic origin that have been structurally emplaced adjacent to sedimentary rocks. Hydrothermal fluids enter the crystalline rock mass through the porous sedimentary media or fault-related fractures, or both.

Specific hydrogeologic parameters will vary among solution mining projects across the nation, but certain generalizations can be made. In mining districts of the western United States, sediments adjacent to ore bodies tend to be coarse-grained, poorly sorted alluvial valley fill. Depending upon the depth of burial, these sediments may be consolidated, semi-consolidated, or unconsolidated. Permeability within such sediments can be high, resulting in a high degree of communication between mine workings and adjacent alluvial aquifers. These aquifers may or may not be an USDW.

As discussed previously, the process of block caving creates massive void spaces in and around the ore body. Void spaces tend to establish sumps to ground-water flow, and hydraulic gradients toward the mine workings develop almost instantaneously following block caving. Volumetric data support this claim in that operators report recovery volumes as much as 20% higher than the amount of fluid injected. As long as withdrawal is approximately continual, and a positive hydraulic gradient toward the block caved zone is maintained, losses of fluid from the workings into surrounding aquifers should be minimal. If, however, an operation is left idle for a period of time sufficient to allow development of hydraulic equilibrium, migration of contaminants along natural ground-water flow gradients could occur. This may result in the degradation of USDW adjacent and downgradient to the mine workings.

In light of these hydrogeological considerations, lithologic confinement to ground-water flow is of secondary importance. As discussed, ore bodies are usually present within crystalline rocks with relatively low primary porosity and permeability. Secondary permeability, in the form of structure-related fractures is common. These fractures may have propagated into adjacent sedimentary rocks. As such, the lithologic character of "confining" units is of less concern than is the degree of fracture pervasiveness within the crystalline mass and surrounding sediments.

Contamination Potential

Based on the rating system described in Section 4.1, solution mining wells are assessed to pose a low potential to contaminate USDW. These facilities typically inject below USDW with little or no potential for migration of fluids into any USDW. Typical well construction, operation, and maintenance would not allow fluid injection or migration into unintended zones. Injection fluids typically have concentrations of constituents exceeding standards set by the National Primary or Secondary Drinking Water Regulations. Based on injectate characteristics and possibilities for attenuation and dilution, injection does not occur in sufficient volumes or at sufficient rates to cause an increase in concentration (above background levels) of the National Primary or Secondary Drinking Water Regulation parameters in ground water, or endanger human health or the environment beyond the facility perimeter.

While a variety of minerals are extracted in the United States using in-situ leaching, procedures and hydrogeologic parameters are generally very similar. Specific details regarding these considerations are not known for all solution mining facilities, but a generic assessment or contamination potential can be made using generalized, or "typical" data.

Injection of acidic or basic lixiviants used in solution mining is into block caved or hydrofractured zones generally adjacent, along at least one boundary, to consolidated or semi-consolidated sediments. These sediments are generally water-bearing, as indicated by positive flow of fluids into mine workings reported by operators. No data exist to show these ground waters are of USDW quality. With a few exceptions, such operations are in semi-remote areas away from population centers. At this time, it cannot be concluded that injection is into or above potentially useable Class IIB aquifers. Because of the general water quality conditions in alluvial aquifers of the desert Southwest, where most solution mining is occurring, it is believed that "usable" USDW are generally sparse.

As discussed, typical construction and operational aspects of solution mining are relatively simple. As such, the potential for malfunction leading to migration of fluids into USDW is considered minimal, particularly considering these mine workings are ground-water sinks. However, it must be pointed out that provisions for conducting mechanical integrity tests are not part of operational plans.

Injectate composition must be kept constant for a solution mining operation. As a result, it is easy to characterize injectate water quality. Injectates are typically acids, though weak bases are used occasionally for in-situ leaching operations for uranium. For acidic injectates, pH levels of 1-4 are typical. This clearly exceeds National Secondary Drinking Water Regulations for pH, and probably exceeds corrosivity levels as well.

Depending upon the size of the operation, injected volumes can be very large, exceeding 500,000 gallons per day. If natural ground-water flow conditions existed within and around these operations, it could be easily concluded that such volumes would cause degradation of groundwater in a large area around the facility. However, because active solution mining facilities maintain a positive flow gradient toward the mine workings, degradation beyond the facility boundary would not be anticipated.

It is hereby concluded that contamination potential attributable to in-situ solution mining is generally low. This is a generic assessment based upon the overall database for this well type. This seemingly is contradictory to the Wyoming State Report, that ranked solution mining operations as the most dangerous of the known Class V facilities within that State. However, it must be stressed that they are mining a radioactive substance (uranium) which in its own right can be considered dangerous. Secondly, there are only 199 such wells at 14 facilities in Wyoming, representing only 0.6% of the total solution mining injection wells in the United States. This percentile cannot be interpreted as "typical" for that well type.

As in other assessments for well types having limited databases, any new data acquired that supplement (or supersede) broad generalizations will be used to re-define contamination potential. Such data would include demonstration that contaminants are migrating into adjacent ground water following operation closing or that failed mechanical integrity has resulted in contamination of shallow or adjacent aquifers. Another factor would be the demonstration that an adjacent aquifer is of Class IIB quality or better. Such findings would lead to an assessment of higher contamination potential.

Current Regulatory Approach

Solution mining wells are authorized by rule under Federally-administered UIC programs (see Section 1). The best data for regulatory oversight of solution mining facilities were found in the Wyoming and Arizona State reports. It is believed that regulatory information contained therein represents typical approaches to this type of Class V injection.

Both States have established broad sweeping legislation that addresses the protection of all "waters of the State." In Arizona, enforcement of those rules is the responsibility of the Department of Health Services (ADHS). In Wyoming, the regulatory body is the Land Quality Division (LQD) of the Wyoming Department of Environmental Quality. These agencies require the submittal of applications for waste discharge permits by any operator proposing underground injection of any institutional, commercial, agricultural, or residential waste fluids. While injected fluids used for in-situ leaching operations are not technically "waste" material, operators are still bound by the terms of waste discharge permits.

Applicants for permits in the two States are required to supply detailed information about proposed injection operations. This information includes, but is not limited to, a complete description of fluids to be injected; the numbers and construction details of injection wells to be used; characteristics of the intended injection zone and all affected aquifers; all nearby ground-water users; and the materials and equipment to be used in the injection process. In some areas, a hydrogeological report and disposal impact assessment may be required. Additional conditions required with respect to permitting such wells include monitoring frequency specifications, constituents to be monitored at each monitoring well, reporting requirements, injectate quality limits, and definition of what constitutes a permit violation. An important aspect of new permit application reviews is the specification of closure plans and the restoration of the aquifer after solution mining operations have been terminated (post-closure plan). This latter aspect is a relatively new permit requirement, and several facilities exist that were permitted prior to its adoption. As such, those facilities may not be bound to any post-closure requirements at the present time.

In some States, active solution mining facilities are known to exist on Federal land or on land regulated by Federal authority, such as tribal lands. Specific management of such solution mining activities, where known, is the responsibility of the Bureau of Land Management (BLM). Initial approval of these activities on tribal lands must be granted by the tribe of concern, in conjunction with the United States Bureau of Indian Affairs (USBIA). The BLM provides technical assistance for permit approval, and requires submittal of an Environmental Assessment (EA) by the operator. Addressed specifically in the EA are the proposed solution mining plan, existing hydrogeologic conditions, and potential environmental impacts. Approval requirements include a hydrogeologic monitoring program. Leach solution applied, fresh water inflows to the facility, and amounts of leachate recovered must be specified. Moisture lost in exhaust air must be monitored as well. Finally, a ground-water monitoring network and plan is established specifying analysis requirements and reporting intervals. Closure plans discussing site reclamation, sealing of mine works, and continued hydrogeologic monitoring are not included in the EA.

Recommendations

Injection wells associated with solution mining must be sited so as to efficiently supply the necessary volumes of leachate to the disturbed ore body. While several experimental procedures for applying leachate are being tested in the United States, the best approach to large-scale operations is to site wells directly above the block caved zone and inject flood leachate by gravity flow. As such, the network of injection wells need not extend beyond the surface projection of the underground mine workings. These recommendations are contained within the Arizona report.

The preservation of mechanical integrity should be an important concern of operators. At the present time, mechanical integrity requirements are not part of permit specifications for most solution mining operations. Part of the problem is that there are not well defined procedures for determining mechanical integrity in such simple wells. The Arizona report recommends that possible types of mechanical integrity tests should be studied in the near future, and an effort to implement reliable testing should follow.

The Arizona report makes another significant recommendation. One aspect of solution mining that has the potential for broad scale contamination of ground water beyond facility boundaries concerns post-closure plans. As discussed, ground-water flow gradients toward the mine workings are anticipated while injection and recovery operations are active. However, when operations are terminated, artificial hydrogeologic conditions established during solution mining will approach equilibrium with regional hydrogeologic gradients. If proper closure and ground-water restoration are not practiced, migration of acidic ground water into adjacent alluvial aquifers would likely occur. At the present time, closure and remedial action plans are not part of permit requirements for facilities on federal lands, or lands under federal regulation. To assure this well type a future low ground-water contamination potential rating, implementation of adequate closure and remedial plans is essential.

Supporting Data

Case studies are listed in Appendix E and include Noranda's Lakeshore Mines, Pinal County, Arizona. These data are in the form of a UIC Inspection Report, dated September 9, 1986, and subsequent file review material. The inspection was conducted by representatives of Engineering Enterprises, Inc. and USEPA Region IX.

4.2.4.3 In-Situ Fossil Fuel Recovery Wells (5X15)

Well Purpose

Wells designed as In-Situ Fossil Fuel Recovery Wells are used to inject water, air, oxygen, solvents, combustibles, or explosives into underground coal or oil shale beds in order to liberate fossil fuels which can be produced to the surface by wells. To date these methods have been experimental. This is not expected to change in the near future due to the worldwide depression in oil prices. Injection wells used in in-situ processes that recover heavy oils from tar sands in the United States are part of "Enhanced Oil Recovery" methods. As such, these wells are regulated as Class II injection wells and should not be within the scope of this report. Many in-situ methods used to recover heavy oils are commercial.

Underground coal gasification (UCG) utilizes Class V injection wells to deliver air, oxygen, steam and air, or steam and oxygen mixtures into a target coal bed in order to initiate and maintain combustion of the bed and liberate a low grade gas. Target beds for underground coal gasification generally are unminable coal beds such as low grade or deep coal seams, and steeply dipping beds.

Recovery of synthetic oil "Syncrude" from oil shale usually is accomplished by burning (retorting) oil shale rubble. If it is impossible to mine and retort the oil shale at the surface, retorting is accomplished underground (in-situ). Class V injection wells are used to deliver air, oxygen, combustibles, or explosives in order to rubblize the bed, and initiate and maintain in-situ combustion. Liberated "Syncrude" is produced to the surface via production wells. "Syncrude" also can be produced by circulating hot fluids.

Inventory and Location

According to State reports, 66 in-situ fossil fuel recovery wells have been used in 5 States; Colorado, Indiana, Michigan, Texas, and Wyoming. The Federal UIC Reporting System (FURS) indicates that 38 of these wells exist in Colorado only. Wells are known, however, to have existed in Utah also. At least three of the 66 wells are known to be permanently abandoned. Due to depressed oil prices it is believed all 5X15 wells are abandoned or in the process of being abandoned. Table 4-41 indicates the well type inventories and summarize their assessment. The difference between State reports and FURS inventories may be attributable to confusion over the extent to which abandoned operations should be inventoried.

Figures 4-34, 4-35, and 4-36 indicate locations of coal fields, oil shale, and other potential synfuel resources in the United States.

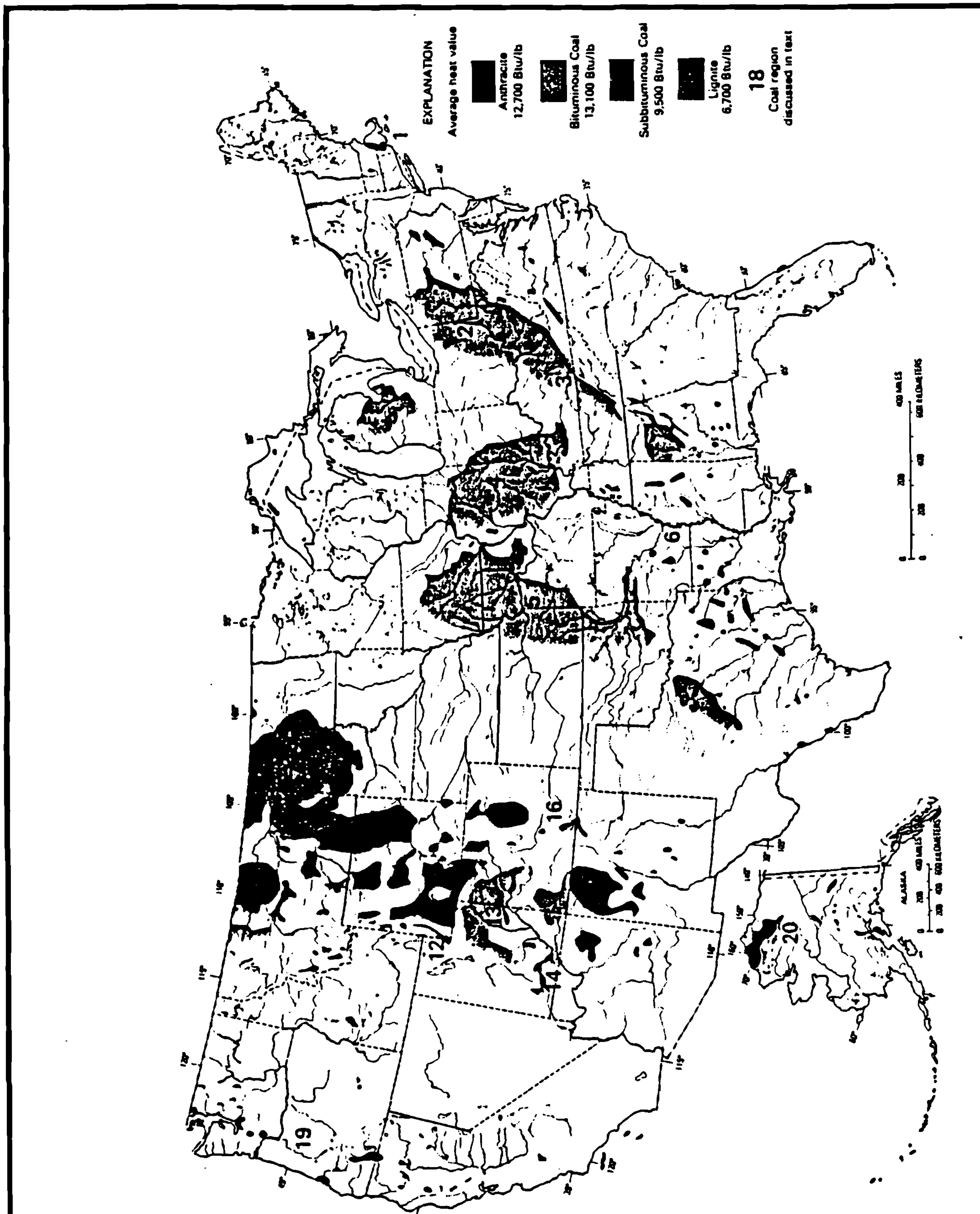
Construction, Siting, and Operation

Underground Coal Gasification. Underground coal gasification (UCG) is a process for recovering fuel from coal that is not economically or technically feasible to recover by conventional mining techniques because of its low heating value, thin seam thickness, great depth, high ash or excessive moisture content, large seam dip angle, or undesirable overburden properties. The UCG process converts coal into a useful gas product by partially combusting the coal underground in the presence of water and a limited amount of air, oxygen, steam and air, or steam and oxygen mixtures. Figure 4-37 presents a schematic cross section of the UCG process. In a simplified two-well model, an injection well and a production well are drilled into the coal deposit. The permeability of the coal seam must then be increased to permit reasonable gasification rates and prevent condensation of tars and other volatile organic matter from the produced gas as it passes through cooler parts of the coal seam. Permeability enhancement is referred to as linking (a permeable flow path is linked between the injector and producer). Linking can be accomplished by reverse combustion, directional drilling,

TABLE 4-41: SYNOPSIS OF STATE REPORTS FOR IN SITU FOSSIL FUEL RECOVERY WELLS(5X15)

REGION & STATES	EPA REGION	Confirmed Presence Of Well Type	Regulatory System	Case Studies/ Info. available	Contamination Potential Rating
Connecticut	I	NO	N/A	NO	N/A
Maine	I	NO	N/A	NO	N/A
Massachusetts	I	NO	N/A	NO	N/A
New Hampshire	I	NO	N/A	NO	N/A
Rhode Island	I	NO	N/A	NO	N/A
Vermont	I	NO	N/A	NO	N/A
New Jersey	II	NO	N/A	NO	N/A
New York	II	NO	N/A	NO	N/A
Puerto Rico	II	NO	N/A	NO	N/A
Virgin Islands	II	NO	N/A	NO	N/A
Delaware	III	NO	N/A	NO	N/A
Maryland	III	NO	N/A	NO	N/A
Pennsylvania	III	NO	N/A	NO	N/A
Virginia	III	NO	N/A	NO	N/A
West Virginia	III	NO	N/A	NO	N/A
Alabama	IV	NO	N/A	NO	N/A
Florida	IV	NO	N/A	NO	N/A
Georgia	IV	NO	N/A	NO	N/A
Kentucky	IV	NO	N/A	NO	N/A
Mississippi	IV	NO	N/A	NO	N/A
North Carolina	IV	NO	N/A	NO	N/A
South Carolina	IV	NO	N/A	NO	N/A
Tennessee	IV	NO	N/A	NO	N/A
Illinois	V	NO	N/A	NO	N/A
Indiana	V	1 WELL	N/A	NO	N/A
Michigan	V	1 WELL	N/A	NO	N/A
Minnesota	V	NO	N/A	NO	N/A
Ohio	V	NO	N/A	NO	N/A
Wisconsin	V	NO	N/A	NO	N/A
Arkansas	VI	NO	N/A	NO	N/A
Louisiana	VI	NO	N/A	NO	N/A
New Mexico	VI	NO	N/A	NO	N/A
Oklahoma	VI	NO	N/A	NO	N/A
Texas	VI	YES	PERMIT	NO	N/A
Iowa	VII	NO	N/A	NO	N/A
Kansas	VII	NO	N/A	NO	N/A
Missouri	VII	NO	N/A	NO	N/A
Nebraska	VII	NO	RULE	NO	N/A
Colorado	VIII	23 WELLS	RULE	NO	N/A
Montana	VIII	NO	N/A	NO	N/A
North Dakota	VIII	NO	N/A	NO	N/A
South Dakota	VIII	NO	N/A	NO	N/A
Utah	VIII	NO	PERMIT	NO	N/A
Wyoming	VIII	41 WELLS	PERMIT	YES	4TH-7TH HI/10 TYPES
Arizona	IX	NO	N/A	NO	N/A
California	IX	NO	N/A	NO	N/A
Hawaii	IX	NO	N/A	NO	N/A
Nevada	IX	NO	N/A	NO	N/A
American Samoa	IX	NO	N/A	NO	N/A
Tr. Terr. of P	IX	NO	N/A	NO	N/A
Guam	IX	NO	N/A	NO	N/A
CNMI	IX	NO	N/A	NO	N/A
Alaska	X	NO	N/A	NO	N/A
Idaho	X	NO	N/A	NO	N/A
Oregon	X	NO	N/A	NO	N/A
Washington	X	NO	N/A	NO	N/A

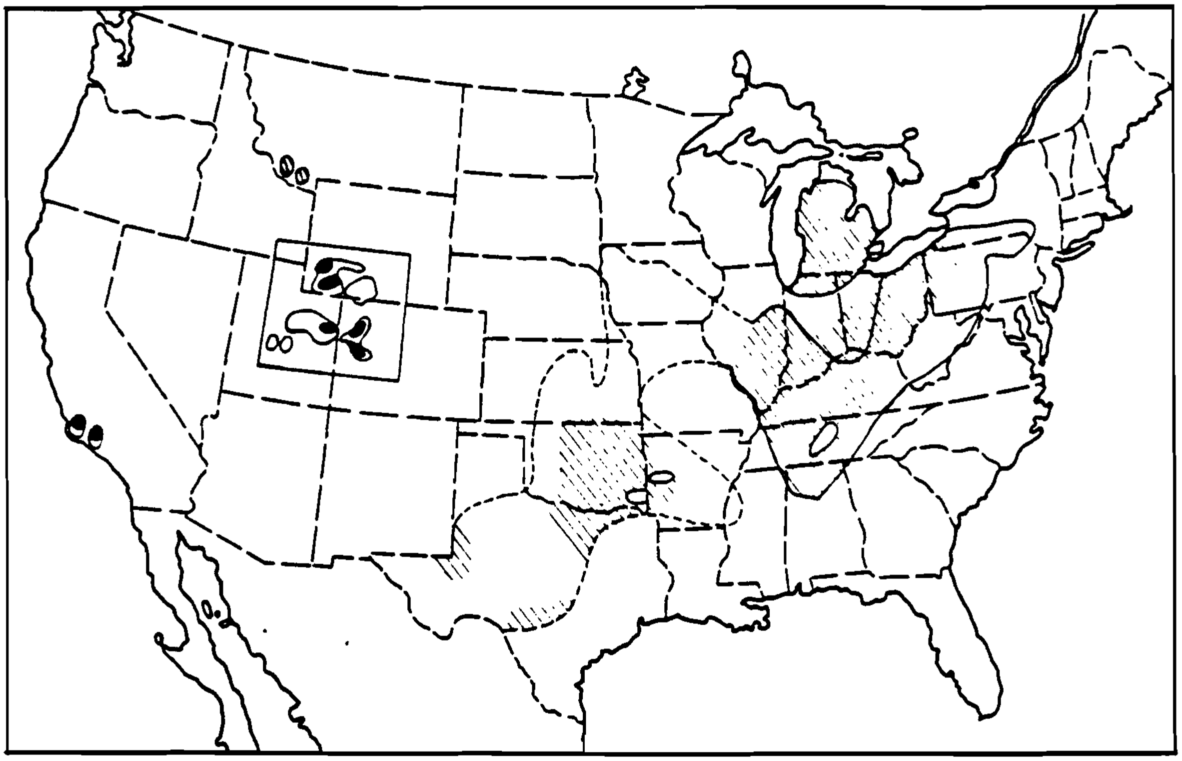
NOTE: SOME NUMBERS IN THIS TABLE ARE ESTIMATES.



COAL FIELDS OF THE UNITED STATES

(from Rickert et.al., Synthetic Fuels Development: Earth Science Considerations)

Figure 4-34



Source: Ranney, M.W., 1979, Oil Shale and Tar Sands Technology.

LEGEND

Tertiary Deposits, Green River Formation in Colorado, Utah, and Wyoming; Monterey Formation, California; Middle Tertiary Deposits in Montana. Black areas are Known High-Grade Deposits.

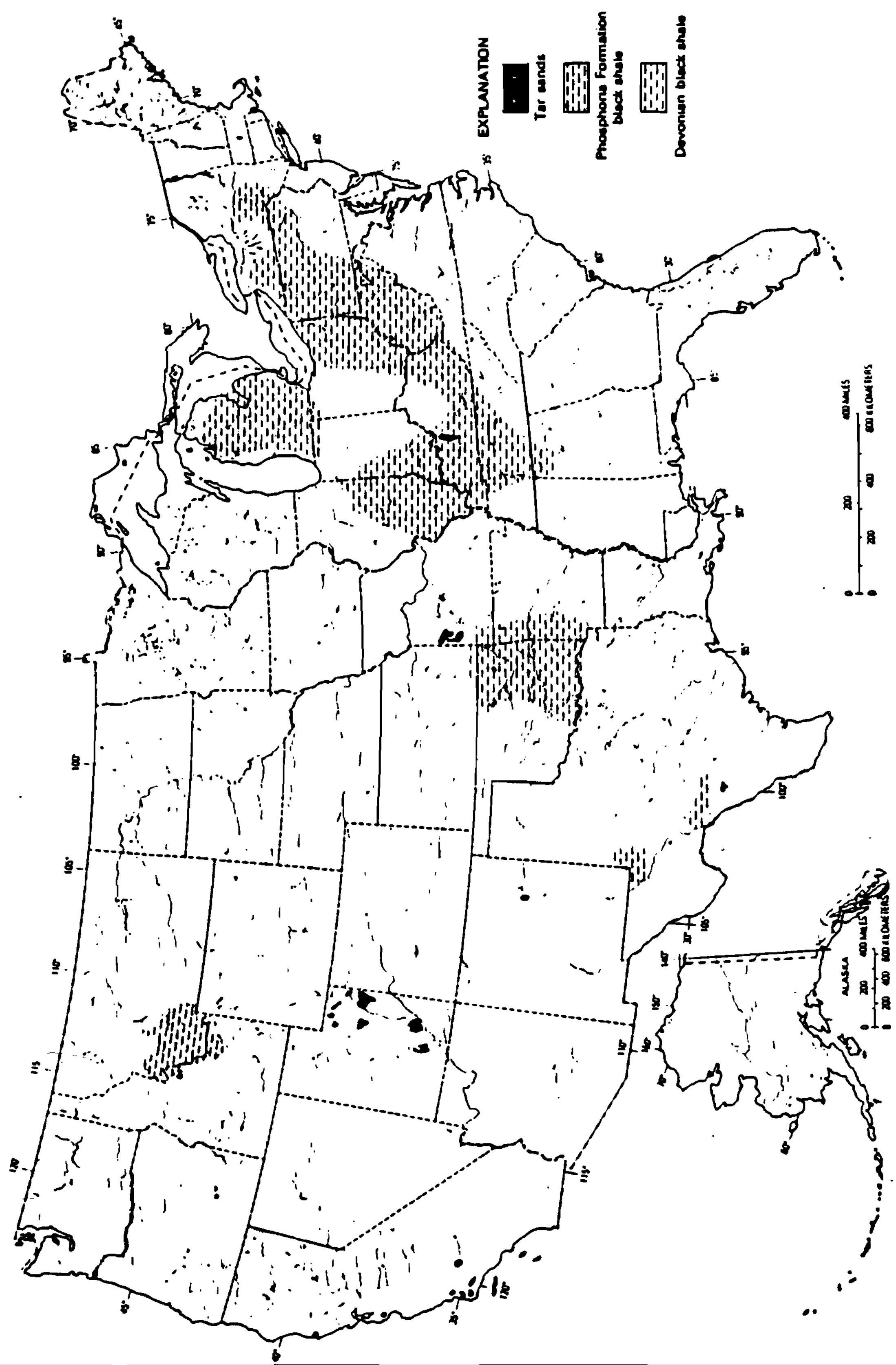
Permian Deposits, Phosphoria Formation, Montana.

Devonian and Mississippian Deposits (Resource Estimates Included for Hachured Areas Only). Boundary Dashed Where Concealed or Where Location is Uncertain.

OIL SHALE DEPOSITS OF THE UNITED STATES

(from Ranney, 1979, Oil Shale and Tar Sands Technology)

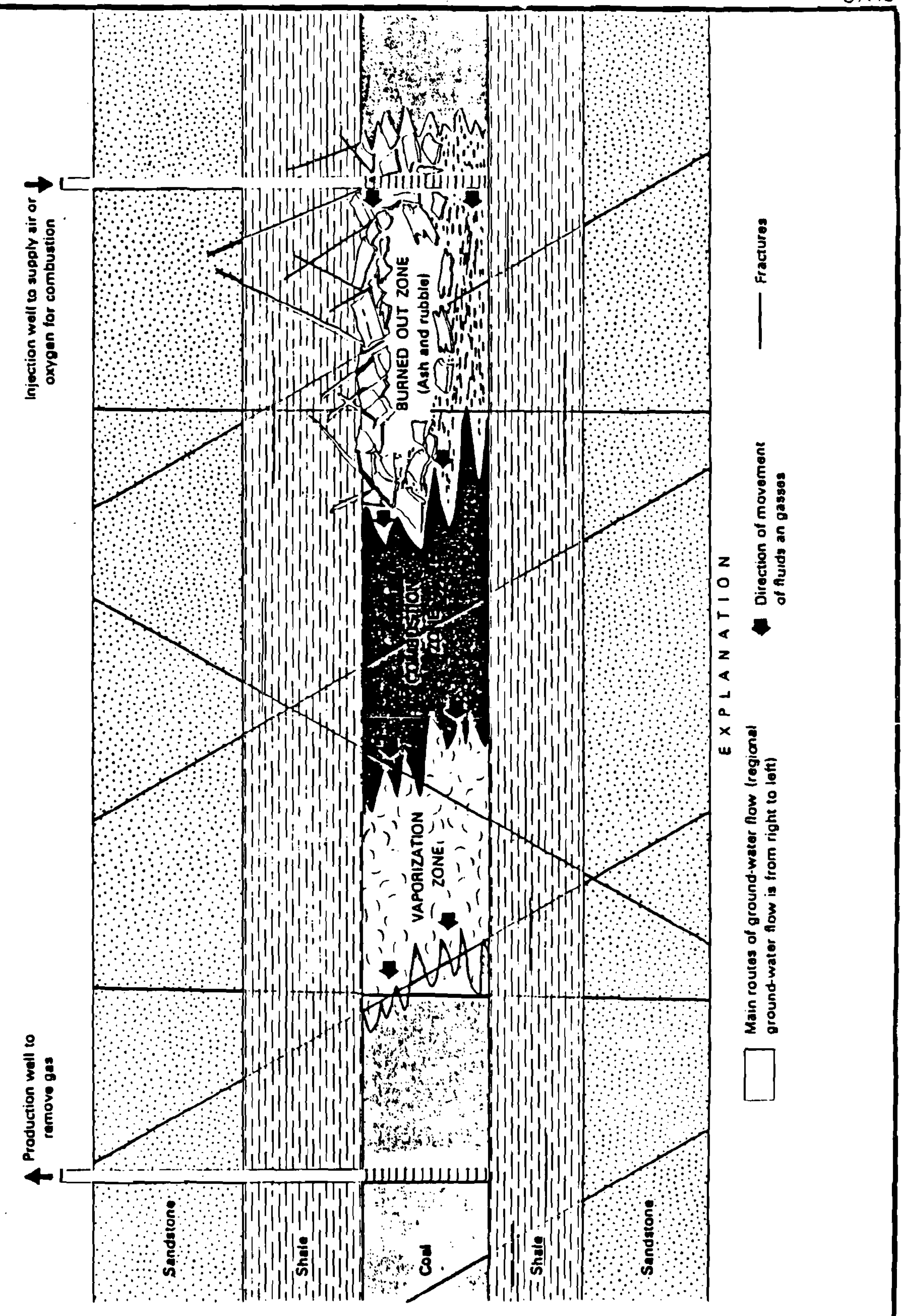
Figure 4-35



OTHER POTENTIAL SYNFUEL RESOURCES

(from Rickert et.al., Synthetic Fuels Development: Earth Science Considerations)

Figure 4-36



SCHEMATIC CROSS SECTION OF
AN IN-SITU COAL GASIFICATION PROCESS

(from Rickert et.al., Synthetic Fuels Development:
Earth Science Considerations)

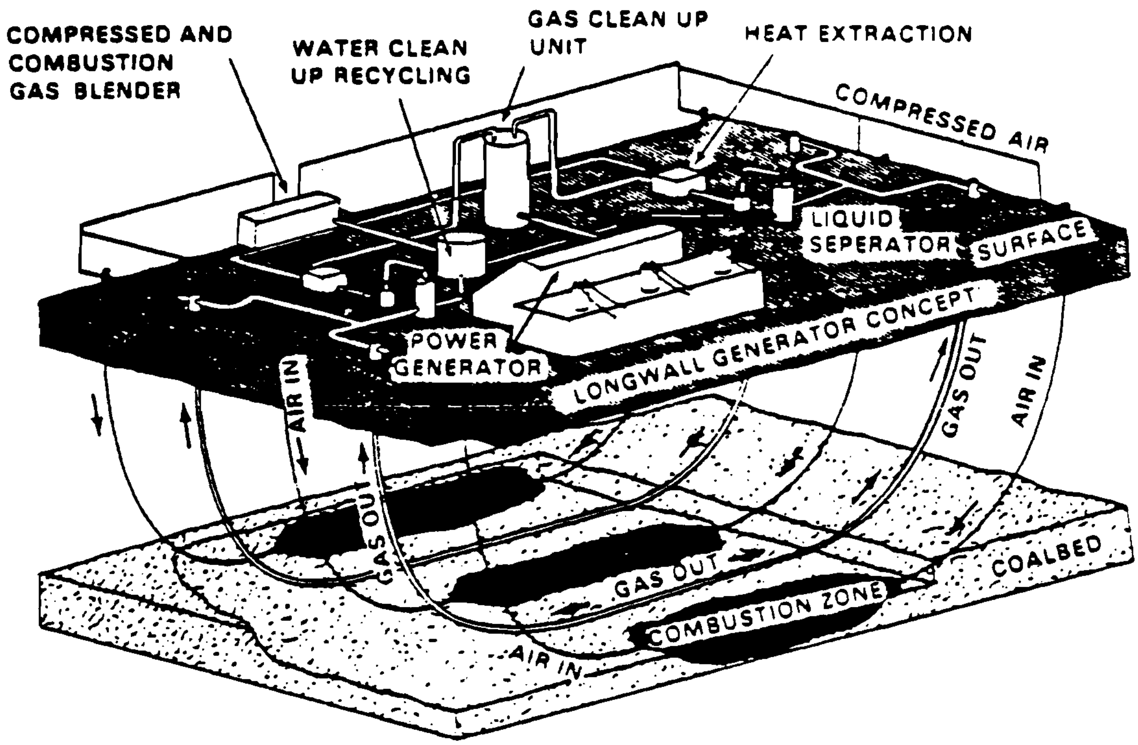
Figure 4-37

electrolinking, or hydraulic fracturing. Once linking is complete a gasifying agent, usually air or oxygen-enriched air, is injected throughout the operation to sustain combustion and effect gasification of the coal. Gases produced by the burning coal escape through the flow channel and are removed through the production well. In a commercial scale operation, several pairs of wells (or other configurations) would be simultaneously gasified.

As gasification continues, a cavity is formed in the coal seam. Its geometry continues to change as the burn proceeds. Early in the gasification process the cavity is empty. As the coal burns, the cavity roof may subside or collapse, partially filling the cavity with rubble which subsequently alters the gaseous flow patterns and burn geometry. Injection wells used to initially ignite the coal seam and maintain combustion vary widely in design although the injection fluids are similar (air, oxygen, steam, or combination). For example, in operations utilizing the reverse linking process, injection and production wells are of similar design since their respective functions are switched after initial combustion is achieved. Figures 4-38 - 4-41 show four major types of UCG processes and their respective well configurations.

Injection wells are completed in high temperature combustion zones and are exposed to subsidence. The injection well may be subjected to temperatures up to 2,735°F (1,500°C) for several hours. Special well constructions are necessary to withstand such an environment. In addition to high temperatures and possible melting, the well materials (casing, cement, wellhead, and surface valves) are subjected to sulfidation and oxidation from combustion, thermal expansion and contraction forces, and cement shrinking and parting due to overburden drying or volatilization. Subsidence of overburden materials must be accurately predicted and accounted for in the well's design and siting to avoid damage. Well completion depths generally are less than 600 ft. Wells are cased with carbon or high strength stainless steel.

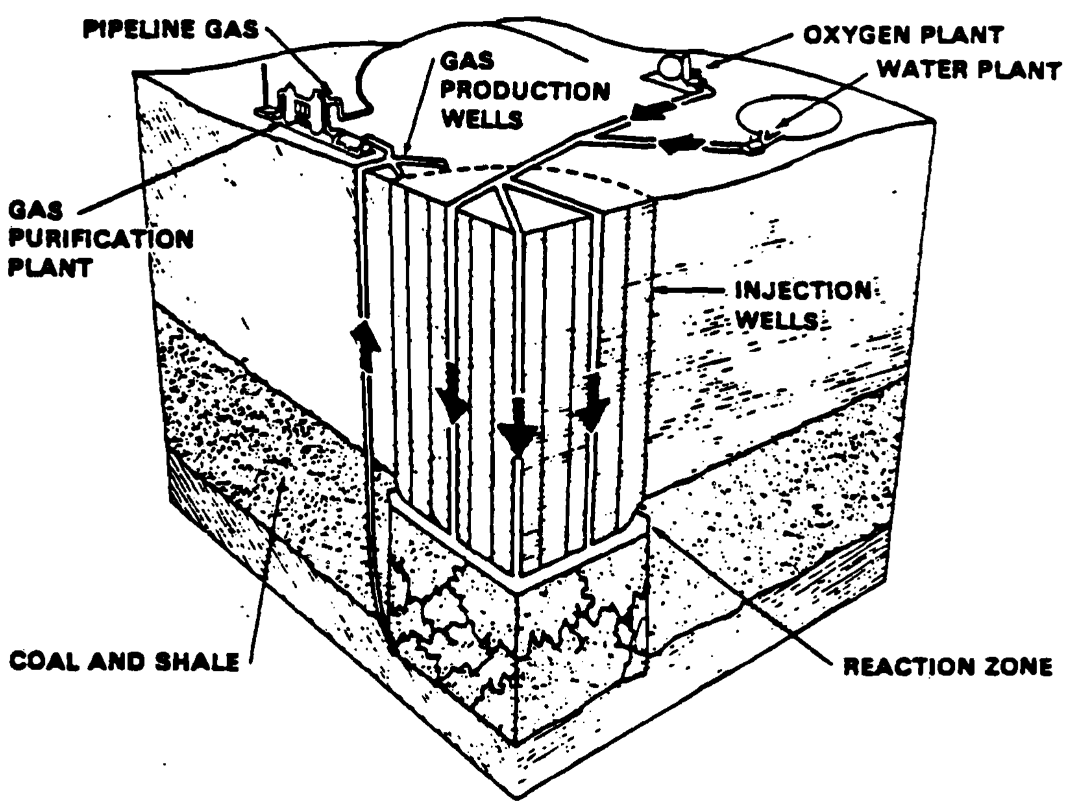
In Situ Recovery of Oil Shale. Oil shale is a fine-grained sedimentary rock that contains an oil-yielding organic material called Kerogen. Oil shale is composed of approximately 86% mineral material and 14% organic material. It is classified geologically as a marlstone because the mineral matter is primarily carbonaceous material. The organic portion is composed of 10% bitumen and 90% Kerogen. Bitumen is soluble in many organic solvents. Kerogen has a molecular weight greater than 3,000 and is insoluble in most organic solvents. Kerogen and bitumen are thermally unstable and, when heated to 480°F (250°C) or higher, thermally decompose to form gaseous and liquid products than can be refined to synthetic crude oil (Syncrude).



UNDERGROUND COAL GASIFICATION
LONGWALL GENERATOR PROCESS

(from Morgantown Energy Research Center, Proceedings; August 10-12, 1976)

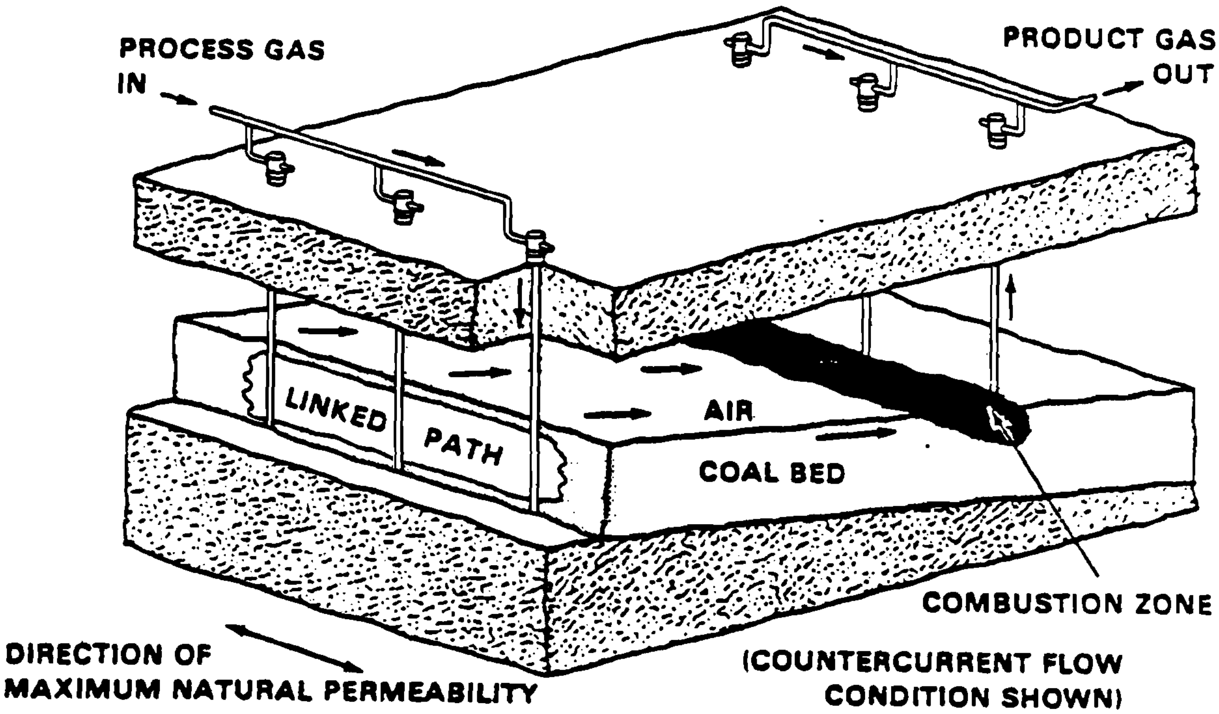
Figure 4-38



UNDERGROUND COAL GASIFICATION
PACKED BED PROCESS

(from Morgantown Energy Research Center, Proceedings; August 10-12, 1976)

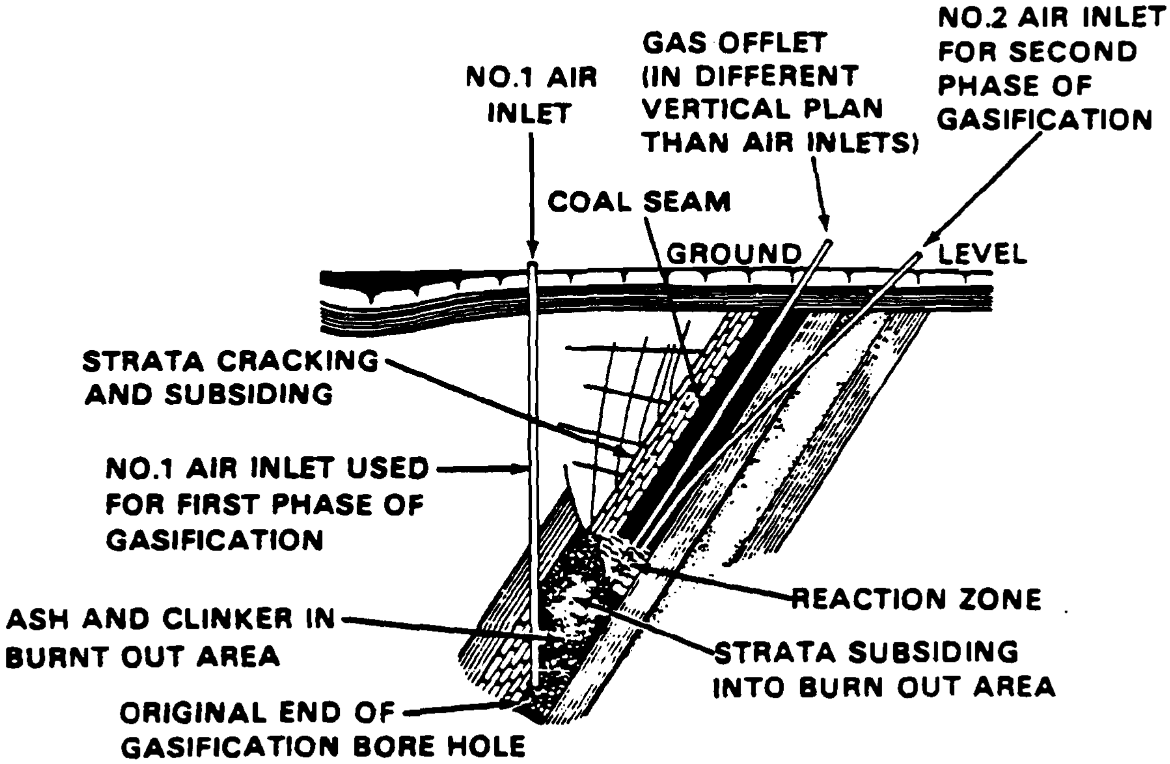
Figure 4-39



UNDERGROUND COAL GASIFICATION
LINKED VERTICAL WELLS

(from Morgantown Energy Research Center, Proceedings; August 10-12, 1976)

Figure 4-40



UNDERGROUND COAL GASIFICATION
STEEPLY DIPPING BED CONCEPT

(from Morgantown Energy Research Center, Proceedings; August 10-12, 1976)

Figure 4-41

At least three different technologies are utilized to extract petroleum products from oil shale. They are above ground retorting, in-situ, and modified in-situ (MIS). The latter two processes involve underground retorts which utilize Class V injection wells. Retorting is the process in which oil shale is heated to free the oil it contains. Above-ground retorts may be containers into which mined crushed oil shale is placed for burning. Underground retorts are simply the zones of oil shale which are to be heated. Both in-situ and MIS processes use underground retorts.

Modified in-situ processes involve partial mining of an underground retort and subsequent burning of the oil shale. Some companies have used MIS systems in which hot inert gas and air are injected by pipes into the retorts to facilitate burning. Each retort uses a number of injection conduits, the number depending on the stage of the project. This technology is usually proprietary and details of retort construction could not be obtained by States.

In the in-situ recovery process, the shale formation is initially fractured by explosives or hydraulic fracturing methods to increase permeability. A portion of the shale's organic material is then burned to obtain heat for retorting. Upon strong heating (retorting) the organic material decomposes to gas, condensable liquids, and residual carbonaceous matter which remains on the spent shale. An external fuel may be used to start and control the burning. The retorted oil shale product is extracted by pumping in a manner similar to crude oil production.

A large number of in-situ recovery techniques have been patented by various individuals and companies. However, most of these techniques are proprietary and not publicly available. A typical in-situ oil shale operation may consist of a two-well system (one injection well and one production well) or a five-spot pattern (four injection wells and one production well in the center of the pattern) completed within the oil shale bed. Injection wells are used to initially combust the oil shale and sustain the retort by continuously injection a pyrolyzing fluid. Production wells are used to recover the gaseous and liquid products which will be refined to syncrude.

Patents exist for several different in-situ oil shale production methods; each production method utilizes uniquely designed injection and production wells and varying fluids. Generally, well completion depths range from 100 to 1,000 feet below land surface. Wells are cased with carbon or higher strength stainless steel casing. Stainless steel may be used near the injection horizon. Casing is cemented to surface to keep overlying groundwater from entering the well bore using standard high temperature oil field practices.

Injected Fluids and Injection Zone Interactions

As stated previously, in-situ fossil fuel recovery injection wells may inject water, air, oxygen, solvents, combustibles, or explosives. More specifically, underground coal gasification wells may inject:

1. Air
2. Oxygen
3. Steam
4. Water
5. Igniting agents such as ammonium nitrate-fuel oil (ANFO) or propane.

In-situ oil shale retort wells may inject:

1. Air
2. Oxygen
3. Steam
4. Water
5. Sand
6. Explosives
7. Igniting agents (generally propane).

The purpose of injection in both cases is to initiate and sustain combustion in the zone.

Air, oxygen, steam, water, and sand should not damage environmental quality by themselves. The environmental impact of explosives, igniting agents, and especially combustion products on ground-water quality is the main subject of concern for this well type. Combustion products include:

1. Polynuclear aromatics
2. Cyanides
3. Nitrites
4. Phenols.

UCG Interactions. During the gasification phase, high temperature gases can migrate from the burn cavity into surrounding strata, where cooling occurs and various chemical compounds are condensed or deposited. Most of the condensed chemicals are organic compounds including light hydrocarbons, phenols, oils, and tars. The heavier organics include some polynuclear aromatic hydrocarbons and heterocyclic compounds. Other gaseous components that condense or are absorbed in surrounding ground water are ammonia, carbon dioxide, hydrogen sulfide, and methane. After gasification, an ash residue remains in the burn cavity which yields soluble inorganic components to reinvading ground water, greatly increasing the total dissolved solids content of the ground water. These soluble components include a wide array of ionic species, mostly calcium, sodium, sulfate, and bicarbonate. Additionally, many other inorganic materials are leached into the ground water in lesser quantities and include aluminum, arsenic, barium, boron, iron, zinc, cyanide, selenium, and hydroxide. (Humenick, Edgar, and Charbeneau, 1983). Table 4-42 presents water quality changes in the combustion zone after gasification.

Extensive fracturing of the surrounding rocks, and subsidence and collapse of the overburden material greatly enhance the ground-water contamination potential of UCG operations and can seriously effect the economic success of these operations. Fracturing, subsidence, and collapse occur due to the high thermal stresses of gasification and especially from the removal of coal material by gasification (ever expanding void areas are created as the coal burn progresses). Potential environmental effects include contamination of adjacent aquifers by escaping gases (fractures, voids, and damaged well bores are potential conduits) and structural disruption of overlying aquifers. Additionally, any major deformation or collapse of the overburden rock will ultimately be reflected at the surface as subsidence. Subsidence may create new pathways for surficial contaminants to enter USDW.

Oil Shale Retort Interactions. Large quantities of water are removed from oil shale during retorting (up to 1.5% of the raw shale by weight). Soluble and particulate organic matter are the components most likely to limit its environmental integrity. The pyrolytic retorting processes can produce a variety of polynuclear aromatic hydrocarbons (PAH). In addition, shale oil contains much higher concentrations of polar heterocyclic components than do crude oils. The environmental significance of the presence of large concentrations of polar and heterocyclic components in shale oil is two-fold. First, a number of organic compound types are potentially toxic and/or carcinogenic, and second, the polar characteristics increase their solubility and accommodation in water systems. Retort waste is amenable to treatment by charcoal sorption with eventual destruction of its organic compounds by heating, thus preventing adverse environmental effects.

Hydrogeology and Water Usage

In-situ fossil fuel recovery operations typically have occurred at depths less than 1,000 ft but may be technically feasible at depths up to 3,000 ft. As a result, for this well type, injection may occur above, below, or into USDW.

Water quality in coal and oil shale beds is typically poor. Even though these waters may meet USDW definition limits (TDS <

TABLE 4-42 WATER QUALITY CHANGES AFTER GASIFICATION

(Source: Humenick and Mattox, 1976)

Parameter	Before, mg l^{-1}	After, mg l^{-1}
Ca^{2+}	20	200
Mg^{2+}	5	15
Na^{+}	100	300
HCO_3	300	500
CO_3	2	0
SO_4	4	1150
H_2S	0.02	0.4
Cl^-	30	40
F^-	0.1	0.7
NO_3	--	2.0
NH_3	1.0	100
TDS	350	2300
Phenols	0.1	20
TOC	20	200
Volatile dissolved solids	--	300
CN^-	--	<0.01
CNS^-	--	<0.5
CH_4	0.42	0.16
pH	--	7.6
As	--	<0.01
Ba	--	<1
Cd	--	<0.01
Cu	--	<0.1
Cr (total)	--	<0.05
Mn	--	0.07
Hg	--	0.002
Se	--	<0.01
Ag	--	<0.05
Zn	--	<0.1
B	--	0.3

10,000 mg/l) their usefulness is questionable. The main threat to water quality is migration out of the zone during and after combustion. Zone roof collapse and resulting subsidence further adds to this concern.

If confinement within the zone can be established, several ground-water contamination concerns can be alleviated. Ground water contamination outside combustion horizons has not been substantiated. This may be due to the lack of pressure build-up and resulting flow in the combustion zone over time due to pressure release through producing wells. Water migration through the combustion zone and dispersion are the primary contaminant transport mechanisms.

Complete hydrogeologic and water usage information should be considered in any site selection process.

Contamination Potential

Based on the rating system described in Section 4.1, in-situ fossil fuel recovery wells are assessed to pose a moderate potential to contaminate USDW. These facilities typically do inject into or above Class I or Class II USDW. Typical well construction, operation, and maintenance would allow fluid injection or migration into unintended zones. Injection fluids typically have concentrations of constituents exceeding standards set by the National Primary or Secondary Drinking Water Regulations. Based on injectate characteristics and possibilities for attenuation and dilution, injection does not occur in sufficient volumes or at sufficient rates to cause an increase in concentration (above background levels) of the National Primary or Secondary Drinking Water Regulation parameters in groundwater, or endanger human health or the environment beyond the facility perimeter.

Lack of injection zone pressure build-up and resulting flow potential out of the zone precludes this well type from having a high contamination potential. Dispersion and through zone migration are the primary contaminant transport mechanisms. At present, no wells are known to operate in the United States due to economic conditions. This is not expected to change in the near future.

Current Regulatory Approach

In-situ fossil fuel recovery related wells are authorized by rule in Federally-administered UIC programs (see Section 1). This well type has only existed in Colorado, Indiana, Michigan, Utah, Texas, and Wyoming. Table 4-43 details the known responsible regulators and their approach in each State. At present none of these well types are known to be operating.

TABLE 4-43
CURRENT REGULATORY APPROACH FOR IN-SITU FOSSIL FUEL RECOVERY WELLS

STATE	REGULATORY AGENCY	PERMIT	RULE
Colorado	USEPA Region VIII	---	Regulated by rule
Texas	State Railroad Commission	Regulated by permit	
Utah	State Dept. of Health, Bureau of Water Pollution Control	In cooperation with State Dept. of Health. Dept. of Health can require a permit if deemed neces- sary	---
Wyoming	State Dept. of Environmental Quality (Land Quality Division)	Regulated by permit	---

The regulatory tendency for this well type is for State agencies to regulate by permit. Colorado is the only State where the Federal UIC program has primacy and thus regulates these wells by rule.

Recommendations

In-situ fossil fuel recovery injection wells are similar to Class I injection wells in that if wellbore integrity can be confirmed, and injection fluids or by-products are confined to the target zone, USDW protection is possible; if not, serious ground-water contamination can occur. Certainly, complete geologic and hydrogeologic investigations should be part of any operations plan (Wyoming).

Wyoming also suggests that if long term confinement of combustion zone fluids cannot be assured, remediation of zone fluids may be a way of stopping or minimizing future contamination.

Supporting Data

Supporting data (Appendix E, page 4) consists of case studies of U.S. Department of Energy projects in Wyoming.

4.2.4.4 Spent Brine Return Flow Wells (5X16)

Well Purpose

Spent brine return flow wells are used to reinject spent brine into the same formation from which it was withdrawn after the extraction of halogens or their salts. Although there are similarities between spent brine return flow wells and wells used in association with solution mining processes (Class III injection wells), the spent brine return flow wells are classified as Class V injection wells. The purpose of these wells is the re-emplacement of the spent fluids into the source formation as opposed to use as an integral part of the mining or extraction process.

Inventory and Location

Spent brine return flow wells have been reported in relatively few States. This, of course, corresponds to the location of geologic formations conducive to the extraction of halogens or salts in an economically feasible process. The largest inventory of spent brine return flow wells has been reported in Arkansas, followed by the inventory reported for Michigan. Other States reporting spent brine return flow wells include Indiana, New

York, North Dakota, Oklahoma, and West Virginia. Reported to date, the national inventory of this well type is 121 wells.

The inventory numbers reported by the States are reliable, since industries utilizing these wells are easily identifiable. Table 4-44 provides a synopsis of the inventory data from the State reports.

Well Construction, Operation, and Siting

The only information on well construction of spent brine return flow wells was received from Arkansas. Wells located in Arkansas are constructed just the same as wells used to dispose of oilfield brines (Class II injection wells). The wells have multiple strings of casing cemented in the hole, and injection is through steel tubing which generally is isolated from the casing with a packer. (See Figures 4-42 and 4-43.) The well construction reported by the State of Arkansas is compatible with the expected well usage.

The operation of spent brine return flow wells consists of injecting large volumes of fluid, typically 10,000 - 20,000 barrels of fluid per day. The injection operations are continuous, but generally injection is not at high pressures. Gravity fed wells (i.e. no applied surface pressure) are common.

The siting of any spent brine return flow well is determined by the geology of the area for the optimum production of halogen-rich brine. Siting, therefore, is limited to areas with economically recoverable brines.

Injected Fluids and Injection Zone Interactions

The injection fluids, by definition are limited to brines from which halogens or salts have been extracted. Since the brine is re-injected into the same formation from which it was produced, injection zone interactions with the injection fluid are not a problem.

However, there have been unconfirmed reports that occasionally other fluids, possibly hazardous wastes, are added to the injection stream. The effect of emplacing unknown fluids into the injection zone cannot be determined, but reports of this practice do indicate the need for strong regulation of spent brine return flow wells.

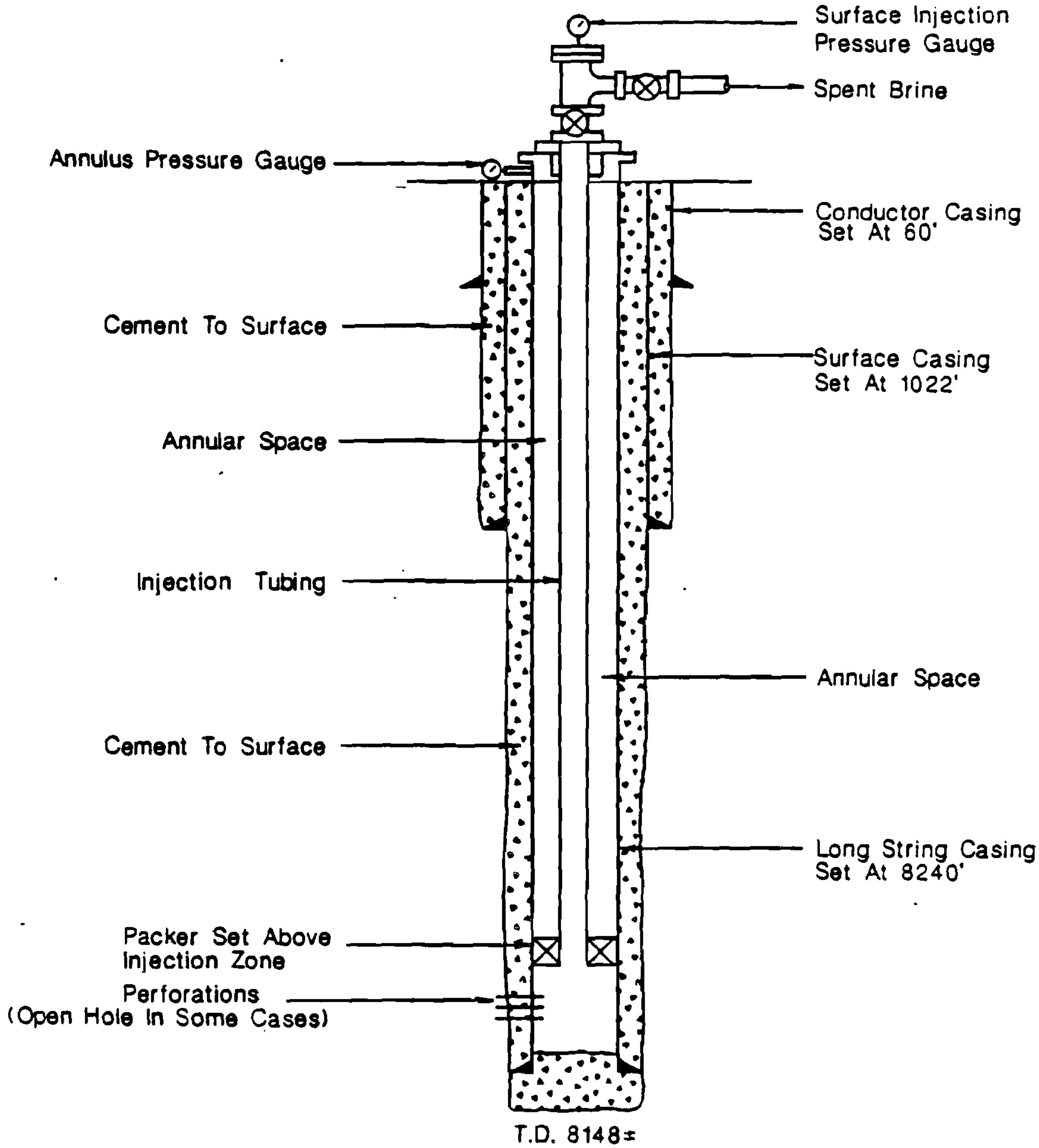
Hydrogeology and Water Usage

Spent brine return flow wells do not inject into USDW. Due to the high dissolved solids content of the brines, all reported halogen- or salt-rich brines have underlain all USDW, and are separated from fresh waters by confining layers.

TABLE 4-44: SYNOPSIS OF STATE REPORTS FOR SPENT BRINE RETURN FLOW WELLS(5X16)

REGION & STATES	EPA REGION	Confirmed Presence Of Well Type	Regulatory System	Case Studies/ Info. available	Contamination Potential Rating
Connecticut	I	NO	N/A	NO	N/A
Maine	I	NO	N/A	NO	N/A
Massachusetts	I	NO	N/A	NO	N/A
New Hampshire	I	NO	N/A	NO	N/A
Rhode Island	I	NO	N/A	NO	N/A
Vermont	I	NO	N/A	NO	N/A
New Jersey	II	NO	N/A	NO	N/A
New York	II	YES	PERMIT	NO	N/A
Puerto Rico	II	NO	N/A	NO	N/A
Virgin Islands	II	NO	N/A	NO	N/A
Delaware	III	NO	N/A	NO	N/A
Maryland	III	NO	N/A	NO	N/A
Pennsylvania	III	NO	N/A	NO	N/A
Virginia	III	NO	N/A	NO	N/A
West Virginia	III	2 WELLS	N/A	NO	N/A
Alabama	IV	NO	N/A	NO	N/A
Florida	IV	NO	N/A	NO	N/A
Georgia	IV	NO	N/A	NO	N/A
Kentucky	IV	NO	N/A	NO	N/A
Mississippi	IV	NO	N/A	NO	N/A
North Carolina	IV	NO	N/A	NO	N/A
South Carolina	IV	NO	N/A	NO	N/A
Tennessee	IV	NO	N/A	NO	N/A
Illinois	V	NO	N/A	NO	N/A
Indiana	V	8 WELLS	N/A	NO	N/A
Michigan	V	33 WELLS	N/A	NO	N/A
Minnesota	V	NO	N/A	NO	N/A
Ohio	V	NO	N/A	NO	N/A
Wisconsin	V	NO	N/A	NO	N/A
Arkansas	VI	70 WELLS	PERMIT	YES	MODERATE
Louisiana	VI	NO	N/A	NO	N/A
New Mexico	VI	NO	N/A	NO	N/A
Oklahoma	VI	7 WELLS	RULE	NO	N/A
Texas	VI	NO	N/A	NO	N/A
Iowa	VII	NO	N/A	NO	N/A
Kansas	VII	NO	N/A	NO	N/A
Missouri	VII	NO	N/A	NO	N/A
Nebraska	VII	NO	RULE	NO	N/A
Colorado	VIII	NO	N/A	NO	N/A
Montana	VIII	NO	N/A	NO	N/A
North Dakota	VIII	1 WELL	N/A	NO	N/A
South Dakota	VIII	NO	N/A	NO	N/A
Utah	VIII	NO	RULE	NO	N/A
Wyoming	VIII	NO	N/A	NO	N/A
Arizona	IX	NO	N/A	NO	N/A
California	IX	NO	N/A	NO	N/A
Hawaii	IX	NO	N/A	NO	N/A
Nevada	IX	NO	N/A	NO	N/A
American Samoa	IX	NO	N/A	NO	N/A
Tr. Terr. of P	IX	NO	N/A	NO	N/A
Guam	IX	NO	N/A	NO	N/A
CNMI	IX	NO	N/A	NO	N/A
Alaska	X	NO	N/A	NO	N/A
Idaho	X	NO	N/A	NO	N/A
Oregon	X	NO	N/A	NO	N/A
Washington	X	NO	N/A	NO	N/A

NOTE: SOME NUMBERS IN THIS TABLE ARE ESTIMATES.

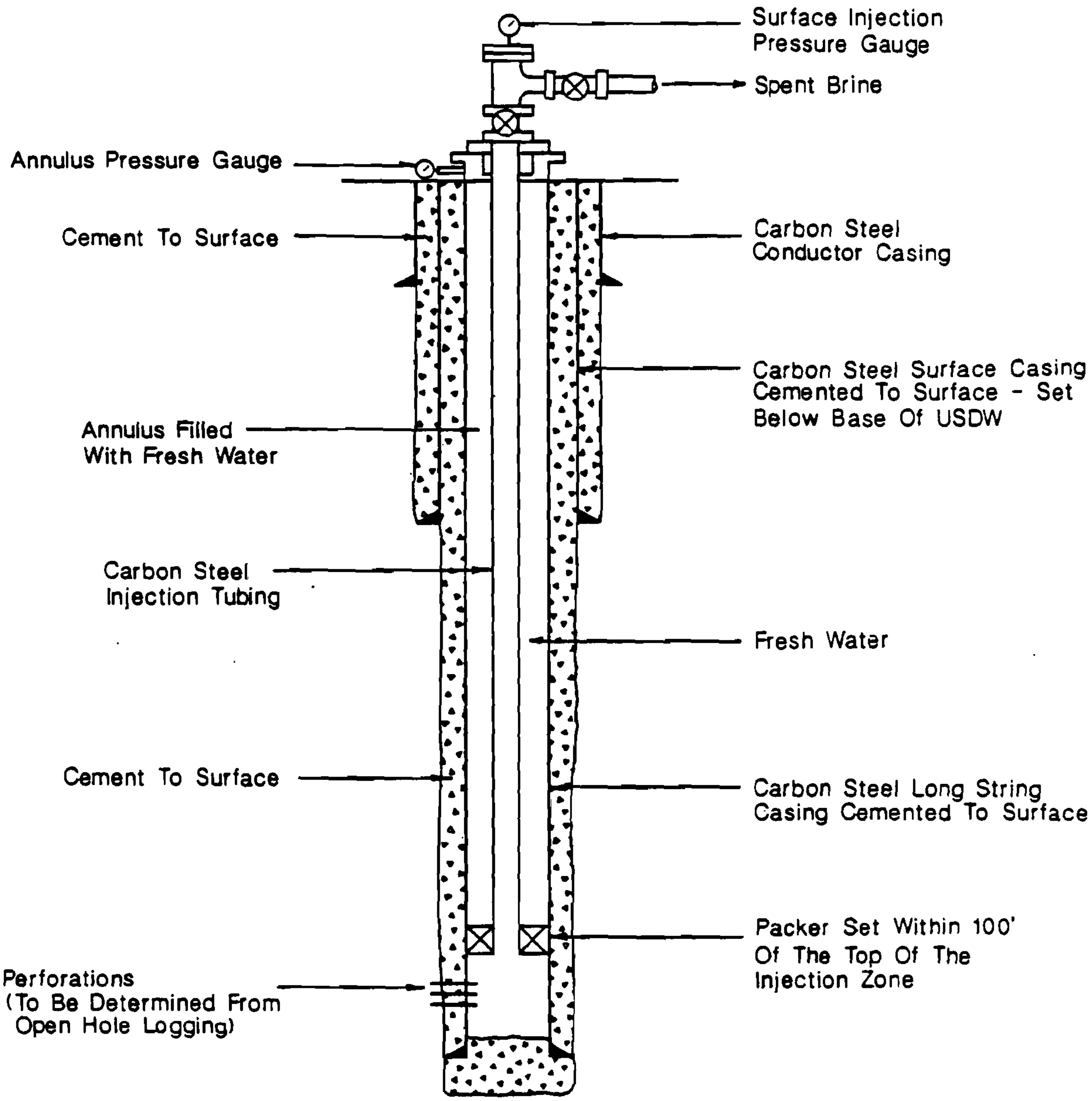


Scale: None

EXISTING CLASS V BRINE DISPOSAL INJECTION WELL
GREAT LAKES CHEMICAL CORPORATION

(Source: Arkansas, 1985)

Figure 4-42



Scale: None

CONSTRUCTION REQUIREMENTS FOR NEW CLASS V BRINE DISPOSAL INJECTION WELLS

(Source: Arkansas, 1985)

Figure 4-43

Contamination Potential

Based on the rating system described in Section 4.1, spent brine return flow wells are assessed to pose a low potential to contaminate USDW. These facilities typically inject below USDW with little or no potential for migration of fluids into any USDW. Typical well construction, operation, and maintenance would not allow fluid injection or migration into unintended zones. Injection fluids typically have concentrations of constituents exceeding standards set by the National Primary or Secondary Drinking Water Regulations. Based on injectate characteristics and possibilities for attenuation and dilution, injection does not occur in sufficient volumes or at sufficient rates to cause an increase in concentration (above background levels) of the national Primary or Secondary Drinking Water Regulation parameters in ground water, or endanger human health or the environment beyond the facility perimeter.

Since the spent brine return flow wells inject fluids through adequately constructed injection wells and into confined formations which are not USDW, the contamination potential is limited. Proper operation of the wells would ensure a low contamination potential.

Current Regulatory Approach

Spent brine return flow wells are authorized by rule under Federally-administered UIC program (See Section 1). The State of Arkansas requires a permit for spent brine return wells, while the State of Oklahoma allows injection by rule-authorization. Other agencies have not reported their regulatory approach.

The State of Arkansas appears to be effectively ensuring proper operation of the spent brine return flow wells located in the State through their permitting process. Well construction requirements must be met, and requirements for mechanical integrity verification and reporting of operating parameters are stipulated. Arkansas is implementing comprehensive sampling of the original brine and of the injection fluid as a further regulatory requirement.

Recommendations

The only significant recommendations provided came from the Arkansas state report and are summarized as follows: technical requirements for spent brine return flow wells should be similar to those for oilfield brine injection wells (Class II injection wells). Construction requirements should be developed based upon the operating parameters of the well, and mechanical integrity tests should be required. Comprehensive fluid sampling and analysis also should be done periodically. Volumes of produced and injected fluids should be compared periodically to determine if additional unlicensed wastes are being injected. The last two monitoring activities mentioned should be performed on a semi-annual or more frequent basis.

West Virginia recommends that spent brine return flow wells should be regulated in a similar manner to Class III wells.

Supporting Data

Supporting data on spent brine return flow wells have been taken in whole from the Arkansas Department of Pollution Control and Ecology Class V Report. Refer to the list in Appendix E.

4.2.5 OIL FIELD PRODUCTION WASTE DISPOSAL WELLS

4.2.5.1 Air Scrubber Waste and Water Softener Regeneration Brine Disposal Wells (5X17,5X18)

Although included in Table 1-1 as Class V injection wells, air scrubber waste and water softener regeneration brine disposal wells, types 5X17 and 5X18, are not included in the inventory and assessment portion of this report. At the time the State Class V injection well reports were written, air scrubber waste and water softener regeneration brine disposal wells were categorized as Class V injection wells. As a result, however, of a July 31, 1987, USEPA policy decision, these well types, in certain situations, may fall under the Class II category rather than Class V. This was determined to be the case with those 5X17 and 5X18 wells inventoried in the State reports.

4.2.6 INDUSTRIAL, COMMERCIAL, UTILITY DISPOSAL WELLS

4.2.6.1 Cooling Water Return Flow Wells (5A19)

Well Purpose

The low specific heat of water (the amount of energy required to raise the temperature of water by $1^{o}C$) makes water an excellent "heat sink" (readily absorbs heat). Various industries take advantage of this property of water by using it in heat exchange systems to cool processes, equipment, or products. These cooling systems often require large quantities of water to operate efficiently. Ground water is used if it is available in sufficient quantities or at low enough costs. Utilization of ground water in the cooling system most commonly entails the return of these large volumes of water to the subsurface through injection wells. Cooling water return flow wells are installed to dispose of the used cooling water, to prevent subsidence, and to avoid depletion of ground-water supplies. These wells are classified as Class V wells under 40 CFR Section 146.5 (e)(3).

Inventory and Location

The collation of an inventory of cooling water return flow wells on a national level has been complicated by: 1) State reports which contradict the Federal Underground Injection Control Reporting System (FURS) listings, 2) insufficient delineation of subclasses within FURS and State reports, and 3) the errant classification of cooling water return flow wells as heat pump/air conditioning return flow wells and vice versa.

There are 291 cooling water return flow wells inventoried to date and their distribution is presented in Table 4-45. There are some States whose FURS listing reported 5A types which were undifferentiable based on facility name. It is expected that some of these are cooling water return flow wells (5A19).

Well Construction, Operation, and Siting

Well construction varies greatly throughout the United States. Wells used to inject cooling water typically are completed at shallow depths (less than 300 feet). In some areas, due to special conditions, such as arctic provinces where permafrost occurs, wells are completed at much greater depths. Based on inventory information, the range of these cooling water return flow wells is 10 to 600 feet deep. Wells may be cased to depth, cased at the surface, or open hole for the entire depth. Due to the wide variation in construction practices, no typical well construction diagram has been included. Return flow wells are completed most commonly in the source aquifer but can be completed in another aquifer. Injection generally is achieved through gravity drainage.

There are three basic designs for the circulation of cooling waters through a cooling system. The most common design is the "closed" system which does not expose ground water to the air at any point between withdrawal and reinjection. "Open" systems, on the other hand, expose ground water to the air at some point prior to reinjection. The third system is the "contact" system which runs ground water over (in direct contact) the product to cool it. This system may be easily abused in that industrial fluids may be commingled with the cooling water.

Spent cooling fluids can be injected into several different zones. They can be returned to the source aquifer through the supply well or through another well, or they can be injected into a different aquifer. Returning spent fluids to the source aquifer is the most commonly practiced method.

Injected Fluids and Injection Zone Interactions

Injected Fluids. The nature of injected fluids depends heavily upon the type of system in place, the type of additives (if any) which are added to supply waters, and the temperature of

TABLE 4-45: SYNOPSIS OF STATE REPORTS FOR COOLING WATER RETURN FLOW WELLS(5A19)

REGION & STATES	EPA REGION	Confirmed Presence Of Well Type	Regulatory System	Case Studies/ Info. available	Contamination Potential Rating
Connecticut	I	NO	N/A	NO	N/A
Maine	I	NO	N/A	NO	N/A
Massachusetts	I	3 WELLS	PERMIT>2K GPD	YES	LOW
New Hampshire	I	3 WELLS	N/A	YES	N/A
Rhode Island	I	8 WELLS	N/A	YES	HIGH
Vermont	I	NO	N/A	NO	N/A
New Jersey	II	5 WELLS	NJPDES PERMIT	NO	N/A
New York	II	NO	N/A	NO	N/A
Puerto Rico	II	1 WELL	N/A	YES	N/A
Virgin Islands	II	NO	N/A	NO	N/A
Delaware	III	NO	N/A	NO	N/A
Maryland	III	NO	N/A	NO	N/A
Pennsylvania	III	YES	N/A	NO	N/A
Virginia	III	YES	N/A	NO	N/A
West Virginia	III	NO	N/A	NO	N/A
Alabama	IV	33 WELLS	PERMIT	NO	VARIABLE
Florida	IV	35 WELLS	PERMIT	YES	5TH HIGHEST/8 TYPES
Georgia	IV	5 WELLS	PERMIT	NO	LOW
Kentucky	IV	NO	N/A	NO	N/A
Mississippi	IV	NO	N/A	NO	N/A
North Carolina	IV	NO	N/A	NO	N/A
South Carolina	IV	2 FACILITIES	RULE	YES	2ND HIGHEST/3 TYPES
Tennessee	IV	NO	N/A	NO	N/A
Illinois	V	10 WELLS	RULE	NO	N/A
Indiana	V	22 WELLS	N/A	NO	N/A
Michigan	V	52 WELLS	N/A	NO	N/A
Minnesota	V	4 WELLS	N/A	NO	N/A
Ohio	V	YES	N/A	NO	N/A
Wisconsin	V	2 WELLS	RULE	NO	N/A
Arkansas	VI	1 WELL	NONE	NO	LOW
Louisiana	VI	NO	N/A	NO	N/A
New Mexico	VI	6 WELLS	REGISTRATION	NO	LOW
Oklahoma	VI	NO	N/A	NO	N/A
Texas	VI	NO	N/A	NO	N/A
Iowa	VII	5 WELLS	PERMIT	NO	N/A
Kansas	VII	3 WELLS	N/A	NO	POSSIBLE
Missouri	VII	NO	N/A	NO	N/A
Nebraska	VII	8 WELLS	RULE	NO	VARIABLE
Colorado	VIII	1 WELL	N/A	NO	LOW
Montana	VIII	YES	N/A	NO	LOW
North Dakota	VIII	1 WELL	N/A	NO	UNKNOWN
South Dakota	VIII	1 WELL	N/A	NO	N/A
Utah	VIII	3 WELLS	PERMIT	NO	4 (7=HIGHEST)
Wyoming	VIII	NO	N/A	NO	N/A
Arizona	IX	NO	N/A	NO	N/A
California	IX	20 WELLS	PERMIT	NO	UNKNOWN
Hawaii	IX	6 WELLS	PERMIT	YES	LOW-MODERATE
Nevada	IX	NO	N/A	NO	N/A
American Samoa	IX	NO	N/A	NO	N/A
Tr. Terr. of P	IX	NO	N/A	NO	N/A
Guam	IX	NO	N/A	NO	N/A
CNMI	IX	NO	N/A	NO	N/A
Alaska	X	2 WELLS	PERMIT	NO	MODERATE
Idaho	X	49 WELLS	PERMIT	NO	11TH HIGHEST/14TYPES
Oregon	X	NO	PERMIT>5K GPD	NO	N/A
Washington	X	YES	PERMIT	NO	N/A

NOTE: SOME NUMBERS IN THIS TABLE ARE ESTIMATES.

the water. If water runs through a closed pipe system with no additives introduced at any point, only the temperature of the water is altered. This is the most common operation in the United States. There are, however, open pipe systems which expose water to accidental introduction of surface contaminants, spills of industrial fluids, or unauthorized disposal of wastes. In addition, contact systems may alter the chemical makeup of waters by introducing contaminated fluids directly to the receiving aquifer. Contamination of the fluids may be a result of commingling of fluids or as a result of absorption or leaching of matter from products. Any additives used to improve well performance also are directly introduced to receiving aquifers.

Volumes of injected waters depend chiefly on the size of the operation. Private industries which reinject cooling water may inject only a few gallons of water per day, whereas larger industries, such as public utilities, may inject several million gallons per day.

Injection Zone Interactions. Injection of cooling water results in temperature increases within the injection zone. Effects of the temperature increase may include the dissolution of additional salts and minerals and/or the hydrolysis of certain metals within the aquifer. Injection into an aquifer other than the source aquifer can result in any number of chemical reactions, all subject to the chemical compatibilities of the different waters.

Hydrogeology and Water Use

Operators of cooling water return flow wells often inject into the shallowest aquifer which will handle the volume of water they dispose. For example, in Illinois, cooling water return flow is discharged into abandoned underground coal mines. Injection into shallow aquifers is preferred over injection into deep aquifers because of lower drilling costs. In the United States, most cooling water is injected into USDW. Wells which supply private or public waters and are located downgradient of cooling water return flow wells are threatened by thermal and/or chemical changes in the aquifer. The degree of threat to supply wells is a function of their distance from injection operations, volumes of fluid injected at those operations, hydraulics of the aquifer, the amount of water drawn in the supply wells, etc.

Contamination Potential

Based on the rating system described in Section 4.1, cooling water return flow wells are assessed to pose a moderate to low potential to contaminate USDW. These facilities typically do inject into or above Class I or Class II USDW. Since well construction, operation, and maintenance practices vary widely, injection or migration of fluids into unintended zones may occur as a result of improper construction or operation. Injection fluids may have concentrations of constituents exceeding standards set by the National Primary or Secondary Drinking Water Regulations. However, injectates from closed systems are likely to be of equivalent quality (relative to standards of the National Primary or Secondary Drinking Water Standards and RCRA regulations) to the fluids within any USDW in connection with the injection zone. Based on injectate characteristics and possibilities for attenuation and dilution, injection may occur in sufficient volumes or at sufficient rates to cause an increase in concentration (above background levels) of the National Primary or Secondary Drinking Water Regulation parameters in ground water, or endanger human health or the environment beyond the facility perimeter when contaminants are present in the injectate.

The most significant threat to USDW from cooling water injection wells results from the use of contact cooling waters and the addition of chemicals to the cooling waters. Open-pipe systems have only slightly lower contamination potential. Their contamination potential depends primarily on the steps taken to maintain the water's integrity. Any introduction of chemicals to the cooling water results in direct dispersion of chemicals into the receiving aquifer and constitutes degradation if the receiving waters are of drinking water standards. Closed-pipe systems do not chemically alter waters; therefore, their potential for contamination is limited to the chemical reactions which occur as a result of thermal alteration.

North Dakota reports that closed-loop systems generally are designed to shut down automatically in the event of pressure loss due to a below-ground pipe break. Also, most closed-loop well casings are filled with nearly impermeable grout compound which surrounds the circulation piping. This is necessary to assure proper heat conduction. Therefore, North Dakota concludes, ground-water contamination from closed loop systems is extremely low.

Thermal degradation occurs in every application of these systems. The degree to which degradation occurs, however, depends on several factors including volume of the aquifer, disparity between temperatures of injected and receiving waters, and volume of injected fluids. The chemical interaction between warm injectate water and cool water inherent to the injection zone is not well documented. Many chemical alterations are possible within an aquifer as a result of a temperature rise. Solids present in an aquifer are at equilibrium, which is to say that all those solids that will dissolve under the present conditions have done so. Changing physical conditions (such as temperature) will alter the equilibrium in the aquifer. Usually a temperature increase brings more solids into solution. This rise in total dissolved solids (TDS) constitutes degradation of the aquifer. As a result, drinking water standards may no longer be met, ground water flow may change, and biological activity may increase within the thermally altered area. Degradation may also result from the hydrolysis of certain metals in an aquifer. High levels of dissolved metals may disqualify an aquifer from drinking water classification and can cause clogging of an aquifer among other problems.

Thermal degradation and resulting chemical changes are not well documented in the United States. Much more study of the chemical alteration due to thermal degradation of aquifers is needed.

Current Regulatory Approach

Class V wells, which include cooling water return flow wells, are authorized by rule. States with primacy approach the regulation of cooling water return flow wells in many different ways, but these States have provided only minimal detail on their current regulatory programs. Some States require a permit prior to construction or operation; others authorize by rule. At least thirteen States have some type of permitting program which mandates permits for operation of cooling water return flow wells. Some of these programs are conditional and require permits for injections in excess of set volumes or for certain system designs (e.g. contact systems). In Texas, cooling water return flow wells are regulated as Class I injection wells. While regulations are diverse throughout States with primacy, most State reports recommend construction standards which may include return to the source aquifer, minimum separation between supply and injection wells, casing requirements, etc. In a few States, construction standards are included in the current regulatory programs.

Little or no information is available in State reports on local jurisdiction. Municipalities typically do not regulate cooling water return flow wells.

Recommendations

Regulation of cooling water return flow wells may best be carried out after development of specific guidelines for these wells. These guidelines should set minimum requirements for construction, siting, and monitoring. Some of the most common siting and construction standards recommended in State reports include the following:

1. Prohibition of open loop cooling water return flow wells (FL, AR, NE, UT);

2. Casing from the surface through the top of the uppermost supply and injection formation (AR);

3. Cemented casing from the top of the supply and injection formation to the land surface (AR);

4. A minimum of two wells: a supply well and a return well, maintaining proper distances between the two (AR, SC);

5. Supply and return well system construction so that spent fluids are returned to source aquifers (AR, SC);

6. Plugged cooling water return flow wells upon abandonment (by filling them with cement) (AR);

7. Restriction that nothing other than spent cooling water originating at the supply well(s) be injected (AR);

8. Various minimum locating requirements for injection wells relative to any municipal supply wells (NE, SC).

Permits to construct could be issued after submittal of an application specifically for cooling water return flow wells. According to Nebraska and Iowa, the permit application should include:

1. Detailed map showing location of injection well and all municipal, domestic, and stock wells within one mile of the well;

2. Diagram of the injection well including screen depths, casing, gravel pack, grout, etc.;

3. Diagram of the entire system; and

4. Type and volume of injected fluids (IA). This information may discuss additives, mixed waters, and other wastes which might be disposed with cooling waters.

Supporting Data

Appendix E lists abbreviated case studies from five states which were used in preparing this assessment.

4.2.6.2 Industrial Process Water and Waste Disposal Wells (5W20)
Well Purpose

Industrial process water and waste disposal wells are used to dispose of a variety of industrial wastes. Twenty-seven case studies of industrial disposal well facilities which were used in assessing this well type are listed in Appendix E and illustrate the variety of processes for which industrial disposal wells are used. Table 4-46 provides a summary of each case study. The reader will note that the case studies indicate several wells injecting wastewater which contains apparently "hazardous" materials. By definition, these may be Class IV wells. However, proving injection of "hazardous" waste as described under 40 CFR 261 Subparts C and D is very difficult. Until these facilities can be proven to inject hazardous waste or are proven to be sources of contamination or to adversely affect public health, they may be reported as Class V wells. Several types of facilities which may utilize industrial disposal wells include:

- petroleum refineries
- high-tech electric component manufacturers
- small machine manufacturers
- asphalt manufacturers
- metal plating and fabricating facilities
- reverse osmosis reject water facilities
- automobile dealers and car washes
- laundries and dry cleaners
- funeral homes and mortuaries
- chicken farmers.

Inventory and Location

Results. There are 1,938 industrial process water and waste disposal wells inventoried to date. Table 4-47 lists their numbers and distributions by State. It is likely that many more exist.

The distribution of industrial process water and waste disposal wells appears sporadic. Data may be interpreted to indicate higher numbers of wells on the coasts of the United States and lower numbers in the mid-continent. These trends may be expected due to increased industrial activity and larger populations on the coasts. However, several additional factors may affect the apparent distribution. These factors are discussed in the **Evaluation** of the inventory and include 1) difficulty identifying wells, 2) reluctancy of owners/operators to report their wells, and 3) difficulty classifying wells.

Evaluation. In general, the inventory of industrial disposal wells is believed to be poor to fair. Several factors are responsible for the lack of quality (detail) and completeness (accurate number of wells). First, the wells are difficult to locate and identify. Problems are similar to those related to

TABLE 4-46

Case Studies (5W20-Industrial Disposal Wells)

Company Name Location (Region) Nature of Business	Description
Components, Inc. **Keenebunk, ME (Reg I)** **Capacitor Manufacturer**	Used an acid solution process involving dilute solutions of nitric acid, sulfuric acid, and tantalum powder. Groundwater was determined to be locally contaminated with manganese, nitrates, and sodium. Company moved. Monitoring continues.
Southern Maine Finishing Co. **East Waterboro, ME (Reg I)** **Metal Plating and Fabricating Plant**	Operated a rudimentary wastewater treatment plant which resulted in contamination of ground and surface water. New treatment system was designed which could treat cyanide chromium acid and alkali.
York Aviation **Sanford Airport Industrial Park, ME (Reg I)** **Aircraft Maintenance**	Waste paint, spent solvents, and associated material were washed to a collection dump. After removal of solids, wastewater was disposed in a drainfield. Matter is under investigation by Maine's Department of Environmental Protection.
Eastern Air Devices **Dover, NH (Reg I)** **Electric Motor Manufacturer**	Two dry wells had been used for waste disposal. The wells were cleaned out, and fluids and solid samples were analyzed. Some organic compounds were identified (primarily tetrachloroethylene, or PCE). Hydrogeology of the area was assessed and contamination is believed to be contained.
Viscase Puerto Rico Corporation, Barceloneta, P.R. (Reg II) **Food Casing Manufacturer**	Process wastewater, ancillary cooling water, power house water, and filter backwashes were neutralized in concrete basins, filtered through anthracite filters, and then injected. Wells were plugged after approximately 10 years of use.
RCA del Caribe, Inc. **Barceloneta, P.R. (Reg II)** **Aperture Mask Manufacturer**	Wastewater contains acids, alkalis, ferric chloride, ferrous chloride, organic material, and chromium. Discharge violates several limits imposed by Environmental Quality Board. Closer monitoring is recommended.

TABLE 4-46 (Continued)

Glamourette Fashion Mills Quebradillas, P.R. (Reg II) Apparel Manufacturer - Dyeing Operations	The USEPA considers certain dyes to be hazardous. The company declined to provide information on the kinds, quantities, and concentrations of dyes in the injectate. This matter is under investigation by USEPA, Region II.
Lotus (Land Authority of Puerto Rico - Pineapple Division) Barceloneta, P.R. (Reg II) Tropical Fruit Processing and Canning	Industrial wastes come from the cooling process, pineapple washing, and pineapple extraction. The organic waste is higher than that of typical domestic sewage. Recommended limits for phenol, total dissolved solids, and surfactants are exceeded. Monitoring program is recommended.
Kendall McGraw Laboratories Sabana Grande, P.R. (Reg II) Parenteral Medical Accessories Manufacturer	Septic tank receives sanitary wastes (71%) process water (24%), and washing water (5%).
Various Automobile Dealers Long Island, NY (Reg II) Car Dealers Car Washes	The NJDEP found a Toyota dealer removing cosmolene from automobiles with formula R-E-L (87% Petroleum Hydrocarbons, 11% trichloroethane, 4% Detergents) and washing it into a dry well. Several other car dealers in New York were observed using hydrocarbons to remove cosmolene.
Permit Compliance System New York (Reg II) Permit Complaince (SPDES)	Preliminary results of an EEI investigation. Includes evaluatin of fluids injected into industrial waste disposal wells in Nassau and Suffolk Counties.
Lehigh Portland Cement Co. Woodsboro, MD (Reg III) Mining and Crushing for Cement Aggregate	Disposal well receives storm water runoff and wash water that is used to rinse rock crushing dust from the outside of trucks.
Applied Electro-Mechanics, Inc., Point of Rocks, MD (Reg III) Manufacturer of Public Address Systems	Well used for disposal of rinse water from the metal irridite and anodizing process. Drainfield used for disposal of rinsewater from the printed circuit and photographic processes. Samples showed elevated levels of copper. Facility will continue to be monitored.

TABLE 4-46 (Continued)

Hammermill Paper Co. **Erie, PA (Reg III)** **Pulp and Paper Mill**	During seven and one half years of operation, over one billion gallons of waste pulping liquors were injected. Wells were plugged when a new process for making paper was developed.
Rodale (Square D) **Emmaus Borough, PA (Reg III)** **Electrical Products Manufacturing Plant**	Approximately 3,000 gallons per day of electroplating waste containing up to 118.4 ppm cyanide were illegally dumped into 3 injection wells. Area wells (serving 10,000 people) have been sampled and no contamination found.
National Wood Preservers **Haverford Township, PA (Reg III)** **Wood Treatment and Preservation**	Pentachlorophenol (PCP) and fuel oil were discharged into disposal well. Subsequently, PCP and fuel oil migrated to the top of the water table and flowed downgradient killing or heavily depressing aquatic life for 5 1/2 miles downstream.
Highway Auto Service Station, Pittstown Township, PA (Reg III) **Auto Service Station**	Petrochemicals, cyanides, 2,2 dichlorobenzene, and a host of other known and unknown carcinogenic, teratogenic, mutagenic, and toxic chemicals were present in discharge from a mine tunnel to the Susquehanna River. Sampling analyses indicated pollution came from the station. Case study describes severe damages. Extensive clean-up and monitoring efforts continue.
Franklin A. Holland & Son **New Church, VA (Reg III)** **Chicken Farm**	Pit was constructed to dispose of fowl that die prior to being sold. Increased nitrate, organic, and bacteriological levels could be expected, but no information on nature of the liquid waste that enters the water table is available. One pit probably does not constitute high contamination potential; however, if many pits are utilized in one area, evaluation of quality and quantity of leachate may be required.
Facility Name-Not Available **Florida (Reg IV)** **Reverse Osmosis Brine**	Some Class V wells in Florida are used to dispose of reject water (brine) from water treatment plants using membrane technology (reverse osmosis) to render poor quality groundwater potable. Of particular interest are the high levels of radionuclides.

TABLE 4-46 (Continued)

American Cyanamid Company **Michigan City, IN (Reg V)** **Catalyst Manufacturers**	Injected waste generally contains high levels of total solids, Na, and SO_4. The injection zone lies between two USDW. The upper USDW is currently a source of drinking water, and the lower zone is a potential source of drinking water. It is recommended that these wells be phased out.
PureGro Co. **Bakersfield, CA (Reg IX)** **Fertilizer and Pesticide Distributor Facility**	Well used to collect rinse water runoff and spillage that occurred during material transfers. Chemicals handled on site included 1,2-dibromo-3-chloropropane (DBCP) until the State of California banned its use because of possible carcinogenic and toxic effects. Order was issued requiring subsurface investigations and soil contamination assessments. Use of this well was discontinued in 1980.
Mefford Field **Tulare, CA (Reg IX)** **Crop Dusting**	Wells were used for disposal of agricultural chemicals and hydrocarbons, wash water used to clean cropdusting planes and chemical containers, and waste petroleum products. Groundwater contamination has been documented. Additional monitoring wells should be installed.
KPF Electric Company **Stockton, CA (Reg IX)** **Manufacturing, Silver Plating, Galvanizing**	Rinse waters from silver plating contained concentrations of copper, cyanide, and silver in excess of 1 mg/l. Waste streams from galvanizing contained high concentrations of lead and zinc. Data is inadequate to delineate extent of subsurface contamination.
T.H. Agriculture and Nutrition Co. **Fresno, CA (Reg IX)** **Agricultural Chemical Formulation, Packaging, and Warehousing Plant**	Designated Superfund site. Ten areas containing industrial waste contaminants have been identified. Industrial disposal wells and an industrial leach field were responsible for soil contamination at four locations. Groundwater contamination on and downgradient from the property is well documented. Injection ceased in 1983.
Various Petroleum Refineries **California (Reg IX)** **Petroleum Marketing**	Three refinery waste injection wells at two facilities were located and investigated in California. Average injection volumes are approximately 40-50 million gallons annually. A variety of organic and inorganic constituents are found in the waste stream.

TABLE 4-46 (Continued)

UniDynamics **Goodyear, AZ (Reg IX)** **Manufacturing Plant for Defense and Aerospace Equipment**	Designated Superfund site (Phoenix Litchfield Airport). Wells and ponds were used to dispose of solvents. Groundwater contamination on site has been documented downgradient of the wells. TCE has migrated into a drinking water aquifer. The wells were closed in 1982.
Honeywell **Phoenix, AZ (Reg IX)**	Paint sludges, thinners, varnish, and solvents are disposed in two wells. Wastes generated by circuit board manufacturing processes were disposed in three wells. Given the hydrogeologic information collected to date, the threat to groundwater formerly posed by the disposal wells cannot be assessed. The wells were closed in 1982.

TABLE 4-47: SYNOPSIS OF STATE REPORTS FOR INDUSTRIAL PROCESS WATER AND WASTE DISPOSAL WELLS(5W20)

REGION & STATES	EPA REGION	Confirmed Presence Of Well Type	Regulatory System	Case Studies/ Info. available	Contamination Potential Rating
Connecticut	I	6 WELLS	PERMIT	YES	MODERATE
Maine	I	15 WELLS	N/A	YES	VARIABLE
Massachusetts	I	1 WELL	PERMIT	YES	MODERATE
New Hampshire	I	13 WELLS	N/A	YES	VARIABLE
Rhode Island	I	59 WELLS	N/A	YES	MODERATE-HIGH
Vermont	I	5 WELLS	N/A	YES	MODERATE
New Jersey	II	20 WELLS	NJPDES PERMIT	YES	VARIABLE
New York	II	350 WELLS	PERMIT	YES	SIGNIFICANT
Puerto Rico	II	28 WELLS	N/A	YES	N/A
Virgin Islands	II	3 WELLS	N/A	NO	N/A
Delaware	III	NO	N/A	NO	N/A
Maryland	III	9 WELLS	PERMIT	YES	HIGHEST/3 TYPES
Pennsylvania	III	19 WELLS	PERMIT	YES	DELETERIOUS
Virginia	III	2 WELLS	N/A	YES	VARIABLE
West Virginia	III	NO	N/A	NO	N/A
Alabama	IV	98 WELLS	PERMIT	YES	VARIABLE
Florida	IV	20 WELLS	PERMIT	YES	4TH HIGHEST/8 TYPES
Georgia	IV	NO	N/A	YES	N/A
Kentucky	IV	NO	N/A	NO	N/A
Mississippi	IV	NO	N/A	NO	N/A
North Carolina	IV	NO	N/A	NO	N/A
South Carolina	IV	200 DRAINFIELDS	PERMIT	YES	LOWEST/3 TYPES
Tennessee	IV	NO	N/A	NO	N/A
Illinois	V	16 WELLS	RULE	YES	MODERATE
Indiana	V	30 WELLS	N/A	NO	N/A
Michigan	V	9 WELLS	N/A	NO	N/A
Minnesota	V	1 WELL	N/A	NO	N/A
Ohio	V	467 WELLS	N/A	NO	HIGH
Wisconsin	V	4 WELLS	PERMIT	NO	UNKNOWN
Arkansas	VI	NO	N/A	NO	N/A
Louisiana	VI	NO	N/A	NO	N/A
New Mexico	VI	2 WELLS	N/A	YES	MODERATE
Oklahoma	VI	NO	N/A	NO	N/A
Texas	VI	2 WELLS	CLASS I	NO	N/A
Iowa	VII	NO	N/A	NO	N/A
Kansas	VII	NO	N/A	NO	N/A
Missouri	VII	NO	N/A	NO	N/A
Nebraska	VII	NO	RULE	NO	N/A
Colorado	VIII	NO	N/A	NO	N/A
Montana	VIII	NO	N/A	NO	N/A
North Dakota	VIII	NO	N/A	NO	N/A
South Dakota	VIII	NO	N/A	NO	N/A
Utah	VIII	4 WELLS	BANNED	NO	RANGE 5-7(7=HIGHEST)
Wyoming	VIII	32 WELLS	PERMIT	NO	3RD HIGHEST/10 TYPES
Arizona	IX	72 WELLS	PERMIT	YES	HIGH
California	IX	93 WELLS	PERMIT	YES	HIGH
Hawaii	IX	44 WELLS	PERMIT	YES	HIGH
Nevada	IX	NO	N/A	NO	N/A
American Samoa	IX	NO	N/A	NO	N/A
Tr. Terr. of P	IX	NO	N/A	NO	N/A
Guam	IX	NO	N/A	NO	N/A
CNMI	IX	NO	N/A	NO	N/A
Alaska	X	230 WELLS	PERMIT	NO	HIGH
Idaho	X	46 WELLS	PERMIT>18 FT	NO	10TH HIGHEST/14TYPES
Oregon	X	20 WELLS	PERMIT	YES	LOW
Washington	X	69 WELLS	N/A	NO	UNKNOWN

NOTE: SOME NUMBERS IN THIS TABLE ARE ESTIMATES.

the inventory of septic systems. Because records have not been kept on many of the wells, the inventory may never be complete. Differences in record-keeping systems among States, among agencies, and even among facilities make it difficult to use only one inventory method.

Second, owners/operators are often hesitant to report their industrial waste disposal wells. Fear of breaking the law, being shut down, and drawing bad publicity adds to their reluctance. Increased public awareness concerning the severe implications of ground-water contamination has rendered them wary.

Third, classification problems severely affect the results of inventory efforts. In some States (Texas, for example), all industrial disposal wells are regulated as Class I wells rather than Class V wells. Another problem involves the subclassification system. In some questionnaires, recipients were asked to report "dry wells used for the injection of wastes." The terminology was problematic because industrial disposal wells were consequently restricted to dry wells (a type of well construction). Therefore, septic tanks with soil absorption systems which were used to dispose industrial wastes were not identified as industrial waste facilities. Rather, they were more likely identified as septic systems and were confused with wells that receive solely sanitary wastes.

Methods. Methods used to inventory industrial disposal wells were similar to those used for other wells. In States where permits were already issued, files of those permits generally were considered the primary source of information. Where permit files were not available, information was gained from a variety of Federal, State, County, and City Agencies. County Health Departments were consistently valuable sources of information.

A variety of private industries were also contacted for information on industrial disposal wells. The list is too lengthy to print in its entirety, but examples include:

- drilling and boring contractors
- water well and oil well drillers
- civil and consulting engineers
- manufacturing and processing companies
- petroleum refineries
- laundromats and dry cleaners
- mortuaries and funeral homes
- auto dealers and car washes.

Most agencies and facilities were contacted by mail and asked to complete a questionnaire concerning well types, injected fluid characteristics, and construction features. When facilities were contacted by telephone or in person, response rates were consistently higher.

Summary. Results of the inventory effort are believed to be poor to fair. Over 1,900 industrial waste disposal wells have been inventoried to date, but it is likely that many wells have not been reported. Many States (including Puerto Rico, Indiana, Wisconsin, Arkansas, and Wyoming) have stated that inventory efforts should continue, and further efforts should be made to improve the quality and precision of the existing inventory.

Well Construction, Operation, and Siting

Industrial waste disposal wells are designed and constructed in a variety of widths, depths, and configurations. The following "wells" which formerly received industrial wastes in California demonstrate the variability of industrial disposal wells with regard to construction and design:

- a buried 55 gallon drum (flush with land surface) with no ends;
- an uncased 22 ft deep borehole backfilled with porcelain from a foundry on site;
- a 17 ft deep brick lined cistern backfilled with gravel and designed to receive septic tank effluent;
- a slotted 4-inch diameter PVC pipe leach line designed to receive septic tank effluent; and
- an abandoned cased water well penetrating deep water bearing zones.

Tables 1, 2, and 3 listed in Appendix E describe the well construction features for a wider variety of wells in California.

According to the report submitted for New York, it was discovered that the terms "dry well," "leach pit," and "cesspool" often are used interchangeably and given different meanings. For example, cesspools designed for the disposal of sanitary wastes generally are constructed of buried concrete rings stacked on top of each other. The bottoms are sand or gravel. However, cesspools with this construction often are used for the disposal of wastewaters other than sanitary waste. Furthermore, the cesspools may or may not have a manhole cover to provide access.

The New York report continues to note that "dry wells" are similar in construction to cesspools and often are considered to be cesspools. A dry well has an open bottom, according to that report, and receives only liquid wastes such as the effluent from a septic tank or series of settling ponds. The effluent percolates into the subsurface depending on the soil permeabilities. The theory behind using "dry wells" is to "filter" the effluent through earth materials in the unsaturated zone so that the liquid is relatively clear when it reaches the water table. The report further states the "practical effectiveness of this type of system depends on the attenuative characteristics of the soil and the volume and quality of wastewater."

One type of dry well that is potentially very hazardous, according to the Wyoming report, is the floor drain in a commercial or industrial facility which discharges to an open or damaged sump. These commonly are found at service stations and other facilities that perform vehicle maintenance or repair. Highly toxic compounds and heavy metals are likely to be contributed to the ground-water system. Because the usual location of such wells is in populated areas which frequently are not served by sewers or water districts, many nearby residents may obtain their water supplies from wells susceptible to contamination.

Some "injection wells" were constructed by excavating pits with a backhoe and backfilling them with gravel. No access is possible for these wells, and accurate records are not always available; thus, the dimensions of these "wells" could not always be determined.

Other types of construction also were found. Some wells were constructed of masonry. One well was found which consisted of an abandoned boxcar buried on end. Many sites were found to have leach fields and other waste disposal systems.

Industrial waste disposal wells generally do not use pressurized injection; industrial wastes are drained into these wells by gravity flow. Total depth is generally as shallow as practicable to provide discharge into a permeable zone. The injection zone is often above sensitive aquifers. The wells are typically sited in unsewered areas with commercial or industrial development. No State reports indicated injection into exempted aquifers.

Because of the nature of the siting and construction characteristics inherent to industrial disposal wells, unreported wells are likely to go unnoticed. Inspectors can easily overlook industrial disposal wells if casing does not rise above land surface.

Injected Fluids and Injection Zone Interactions

Injected Fluids. Industrial process water and waste disposal wells could potentially receive any fluid disposed by the various industries which use the wells. In New York, many industrial facilities are permitted to discharge waste to the subsurface where all underlying aquifers are classified as sole source aquifers. Periodic monitoring of injection fluids from various industrial facilities is required for compliance with State Pollutant Discharge Elimination System (SPDES) permits. Monitored parameters, including discharge rates and contaminant levels, are stored on a Permit Compliance System (PCS). The PCS data include facilities which are permitted and required to monitor specific parameters. However, some permitted facilities have not reported monitoring information.

For the purposes of this report, a copy of the PCS data, entitled, "Limits and Measurements Data for Nassau and Suffolk Facilities Discharging to Ground Water," was supplied to Engineering Enterprises, Inc. (EEI) by USEPA Region II. The data were stored in the EEI computer system in a format which allowed calculations and interpretations to be made. Calculation of "mass loading of contaminants per unit time" was one of the objectives of the study.

These PCS data included information on only those facilities which provided monitoring information. It should be noted that approximately 62 facilities are discharging wastewater from various sources including process waste, sanitary waste, non-contact cooling water, wastewater treatment plant effluent, etc.

In Nassau and Suffolk Counties, an average of 20 million gallons per day (MGD) of wastewater is injected into the subsurface by facilities listed on the PCS. Maximum volumes total nearly 21 MGD. Based on these volumes, calculations suggest that more than 190 grams of total dissolved solids (TDS) are entering the subsurface each second (190 g/sec). Converted to more familiar units, these data indicate that approximately 0.42 pounds of TDS are entering the subsurface each second, or 36 thousand pounds per day!

As illustrated in Figure 4-44, several inorganic contaminants are being injected into the subsurface. Injection rates range from 390 mg/sec of fluoride to as much as 5,900 mg/sec of nitrogen. Mass loadings per unit time for total sulfate and chloride fall in the intermediate range. It is not possible to calculate mass loadings for sulfide and sulfite due to lack of information on discharge rates.

Many EPA priority pollutants (heavy metals) and hazardous constituents identified by RCRA are being injected into the subsurface at a rate of nearly 120 mg/sec (Figures 4-45 and 4-46). Notable contaminant discharge rates include copper (125 mg/sec), iron (128 mg/sec) and nickel (151 mg/sec).

Hazardous organic constituents are injected into the subsurface at rates ranging from 4 x 10^{-6} mg/sec (xylene) to 680 mg/sec (1,1,1-Trichloroethane). (See Figure 4-47.) Discharge of additional hazardous organic elements has been permitted. Those elements include benzene, methylethyl ketone, trichloroethylene, tetrachloroethylene, trichlorofluoromethane, 1,1-dichloroethane, 1,2-transdichloroethylene, and vinyl chloride. It is not possible to calculate mass loadings per unit time for these

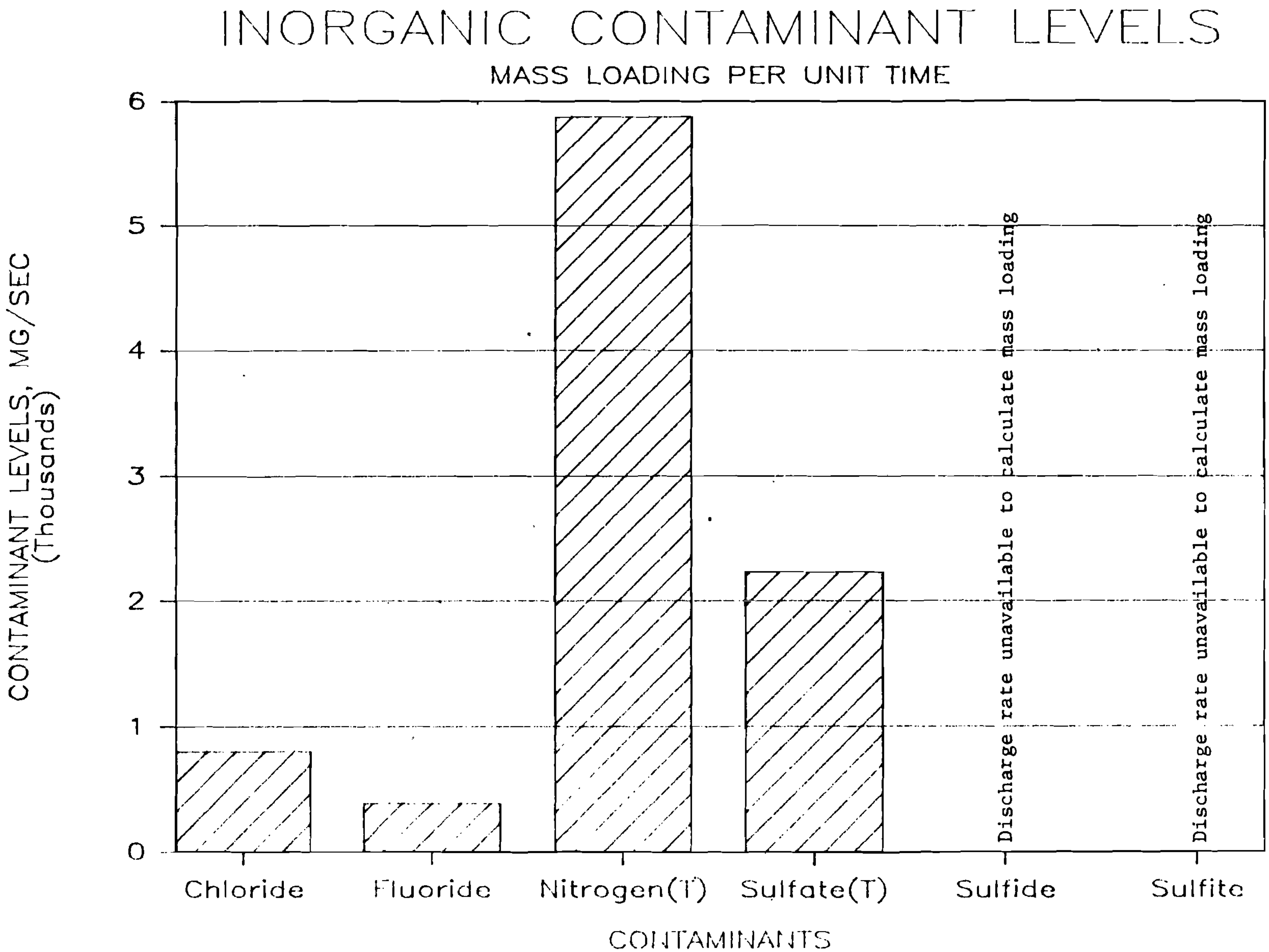


Figure 4-44. Mass loading of inorganic contaminants due to subsurface injection of industrial waste in Nassau and Suffolk Counties, New York (based on PCS data of the SPDES program).

5W20

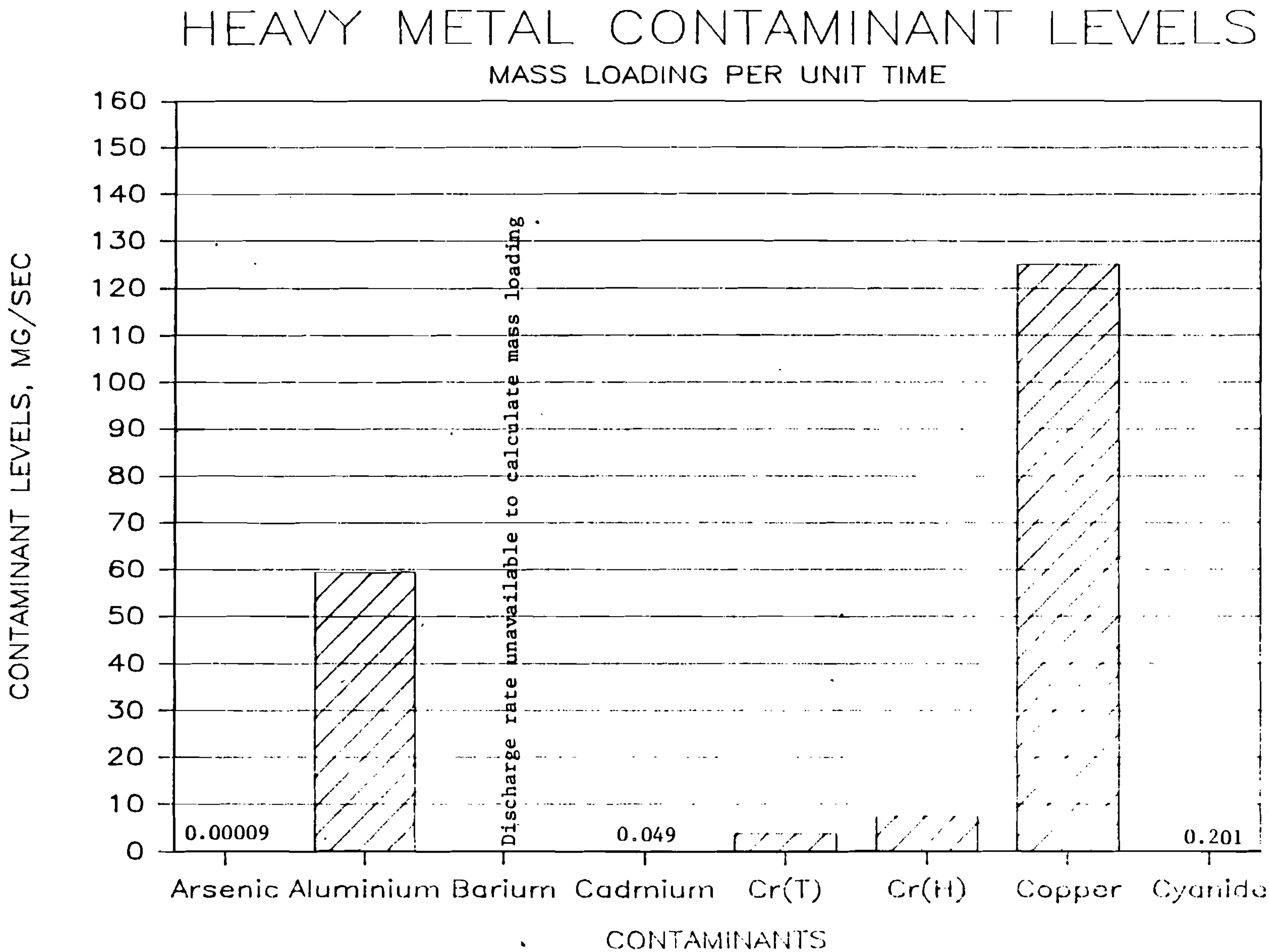


Figure 4-45. Mass loading of some heavy metal contaminants due to subsurface injection of industrial waste in Nassau and Suffolk Counties, New York (based on PCS data of the SPDES Program).

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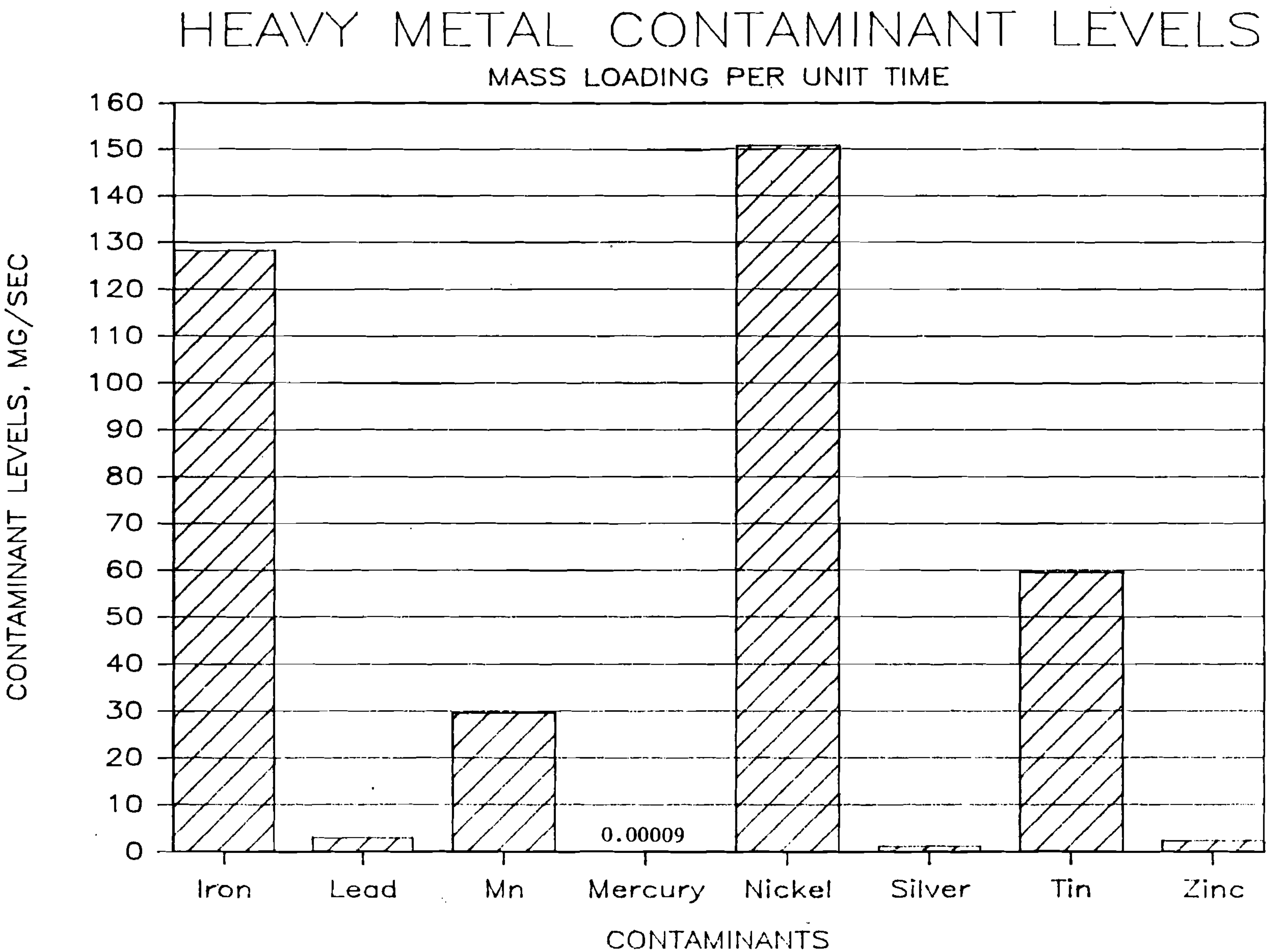

Figure 4-46 . Mass loading of additional heavy metals contaminants due to subsurface injection of industrial waste in Nassau and Suffolk Counties, New York (based on PCS data of the SPDES Program).

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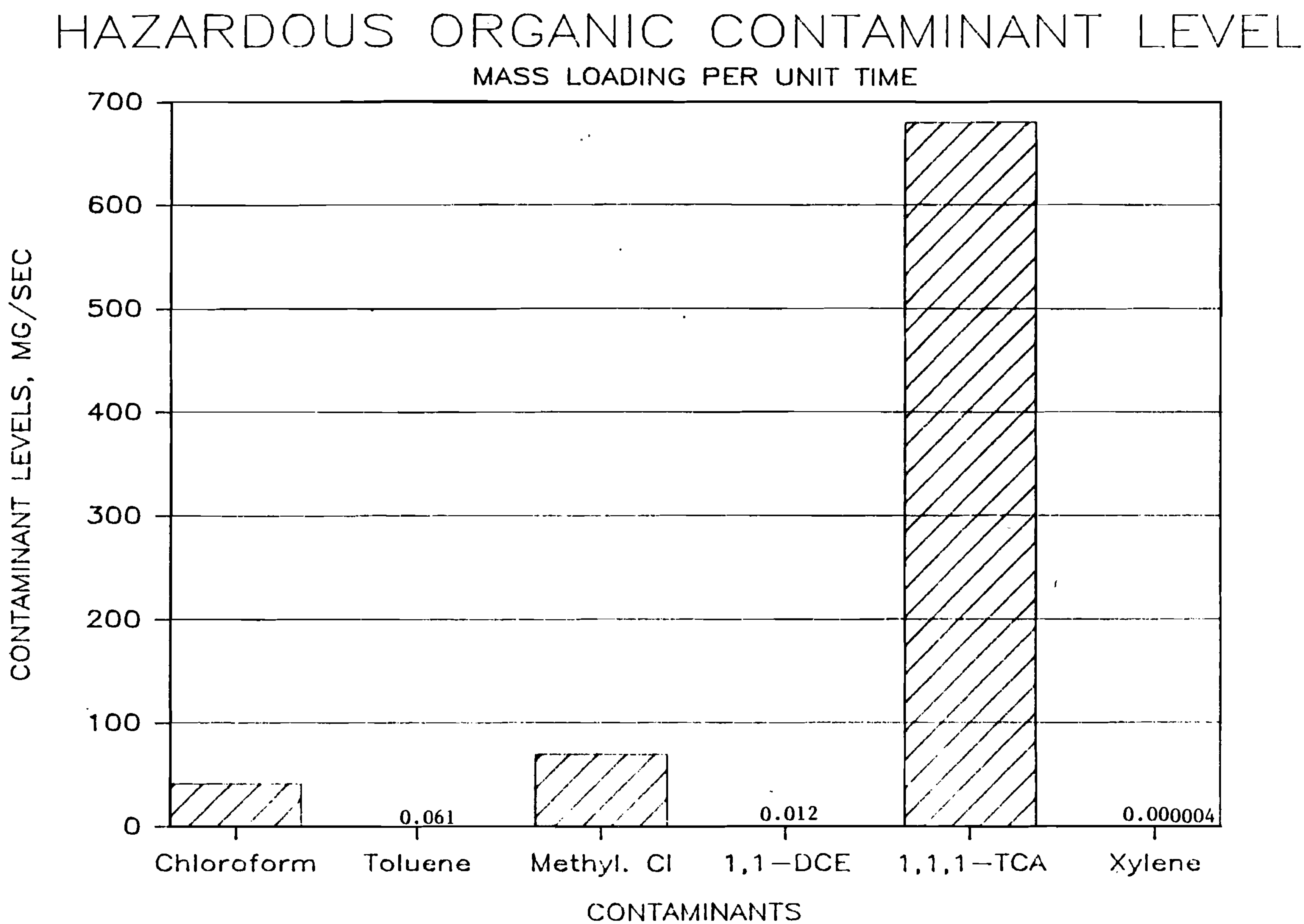


Figure 4-47. Mass loading of hazardous organic contaminants due to subsurface injection of industrial waste in Nassau and Suffolk Counties, New York (based on PCS data of the SPDES program).

5W20

contaminants because the permitted facilities did not provide discharge rates.

Some acids and related contaminants are discharged at a rate slightly below 22 mg/sec, as illustrated in Figure 4-48. Figure 4-49 indicates that other organic constituents are injected at rates ranging from 0.3 mg/sec to just under 200 mg/sec. Other biological and microbiological indicators, including carbonaceous biological oxygen demand (BOD(c)), chemical oxygen demand (COD), and carbonaceous oxygen demand (OD(c)), are injected at rates below 1,200 mg/sec. Coliform is injected at 130,000 #/sec (Figure 4-50).

In conclusion, many facilities in Nassau and Suffolk Counties are permitted to discharge as many as 65 organic and inorganic constituents to the subsurface. In some cases, fluids containing contaminant levels which exceed drinking water standards are injected. In other cases, fluids containing contaminant levels which are below drinking water standards are injected in excessive volumes (average 20 million gallons per day). These fluids typically percolate through the vadose zone to the water table. Some contaminants in the waste fluids may be attenuated by the vadose zone due to various physical, chemical, and biological processes. Nevertheless, contaminants have the potential to degrade ground water-quality. Contamination potential depends on volume, persistence, mobility, and toxicity of the injected constituents.

Although the information provided by New York was the most specific with respect to injectate quality, several other States provided general information on the composition of injected waste streams. For example, the California report identified waste streams which included waste laboratory chemicals, petroleum products, pesticides, pesticide and defoliant rinse waters, degreasing solvents, and industrial process chemicals. These wastes typically contain one or more of the compounds listed under 40 CFR Part 261 Subpart D (RCRA regulations). Further investigations should be conducted to determine whether these are Class IV facilities.

Alabama also provided data on the constituents of waste streams from various facilities. Tables 4-48 through 4-50 list a few of the substances identified.

It should be noted here that some wells which are classified as industrial disposal wells also may contain sanitary wastes which vary greatly depending on their origin. As discussed earlier, many facilities utilize septic systems to dispose of their industrial wastes. Sanitary wastes from those facilities are likely to be mixed in the waste stream. Section 4.2.3.2 discusses the characteristics of injected fluids discharged to septic systems.

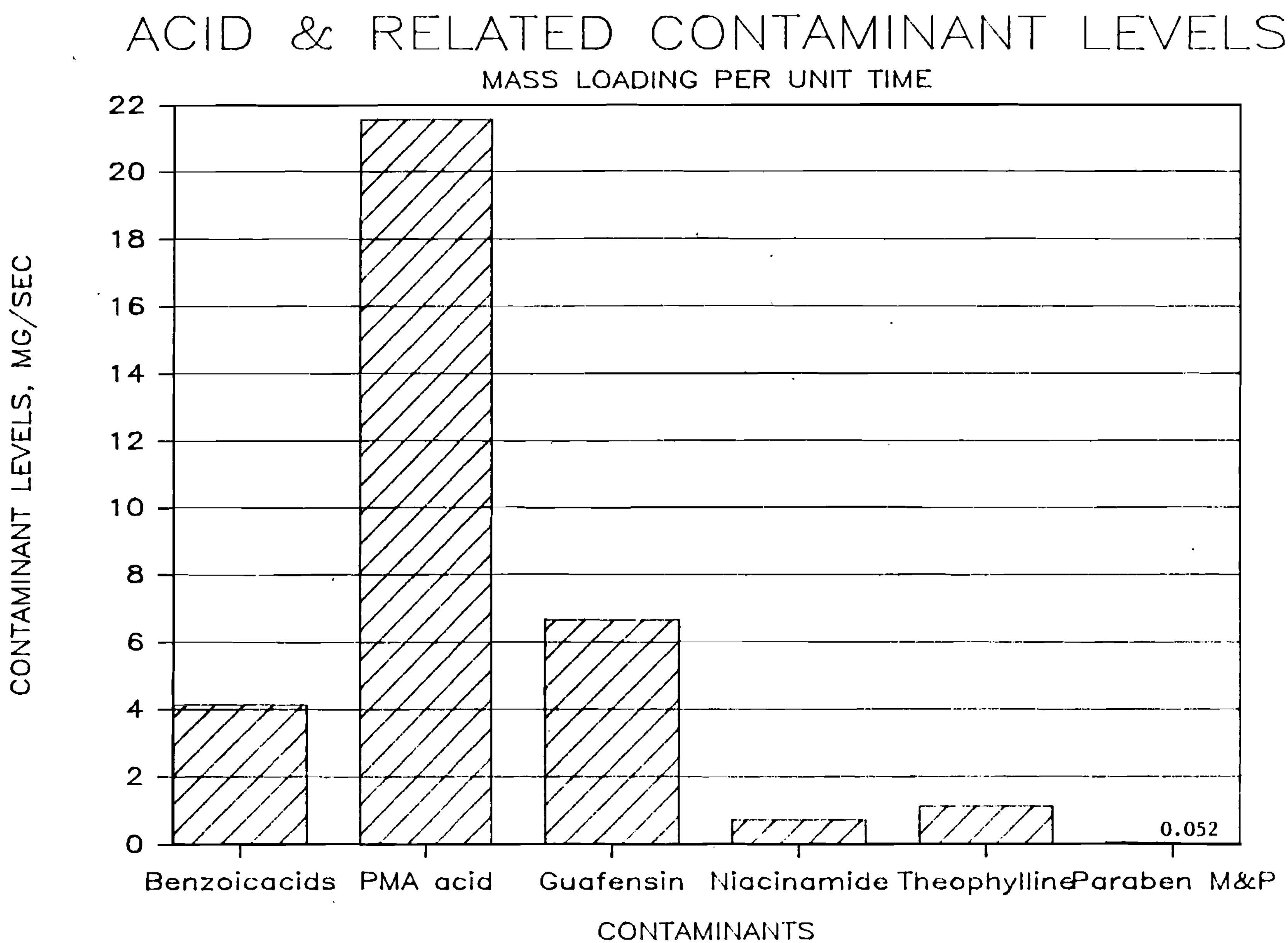


Figure 4-48. Mass loading of acid and related contaminants due to subsurface injection of industrial waste in Nassau and Suffolk Counties, New York (based on PCS data of the SPDES Program).

5W20

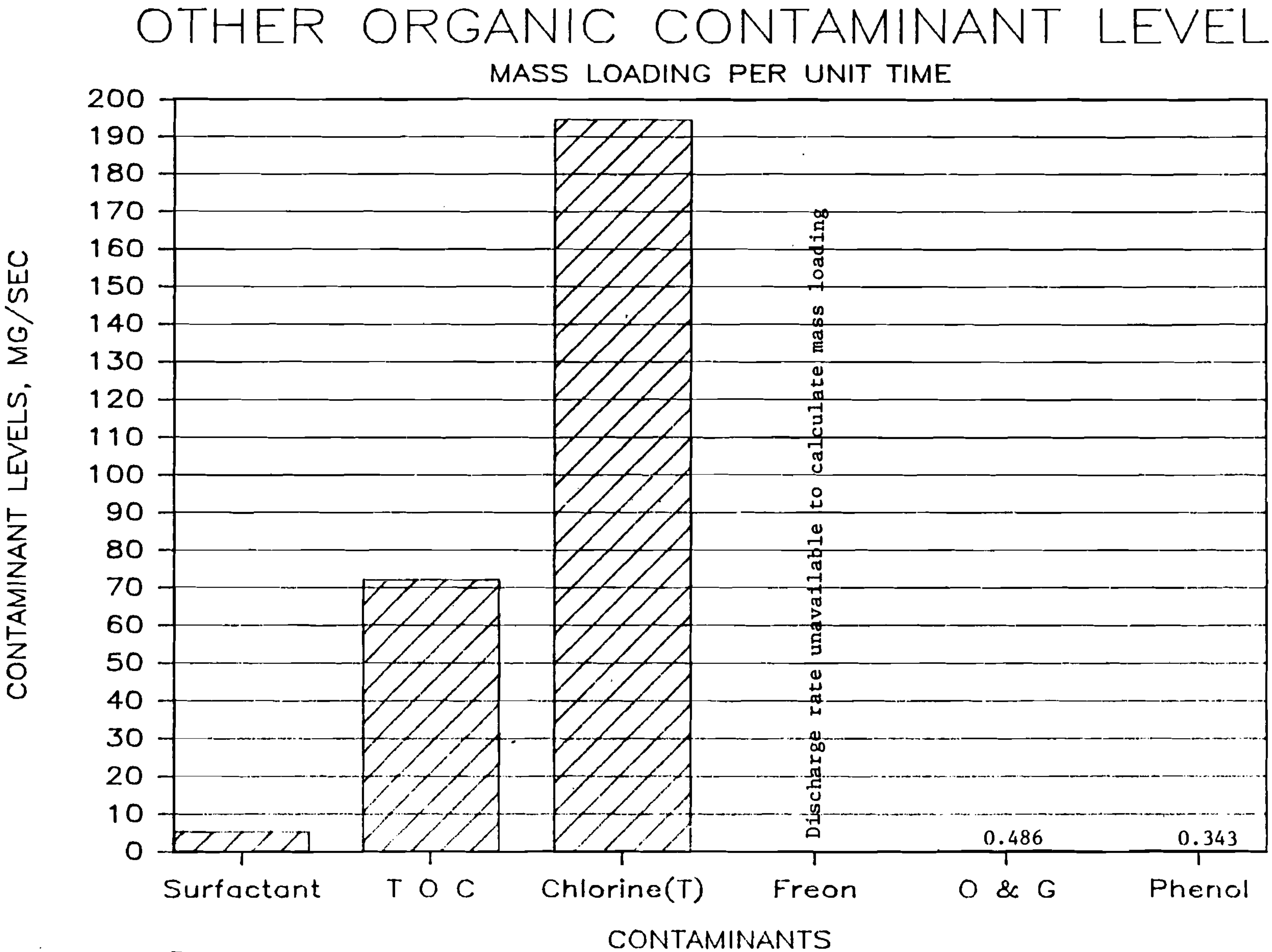


Figure 4-49. Mass loading of other organic contaminants due to subsurface injection of industrial waste in Nassau and Suffolk Counties, New York (based on PCS data of the SPDES Program).

5W20

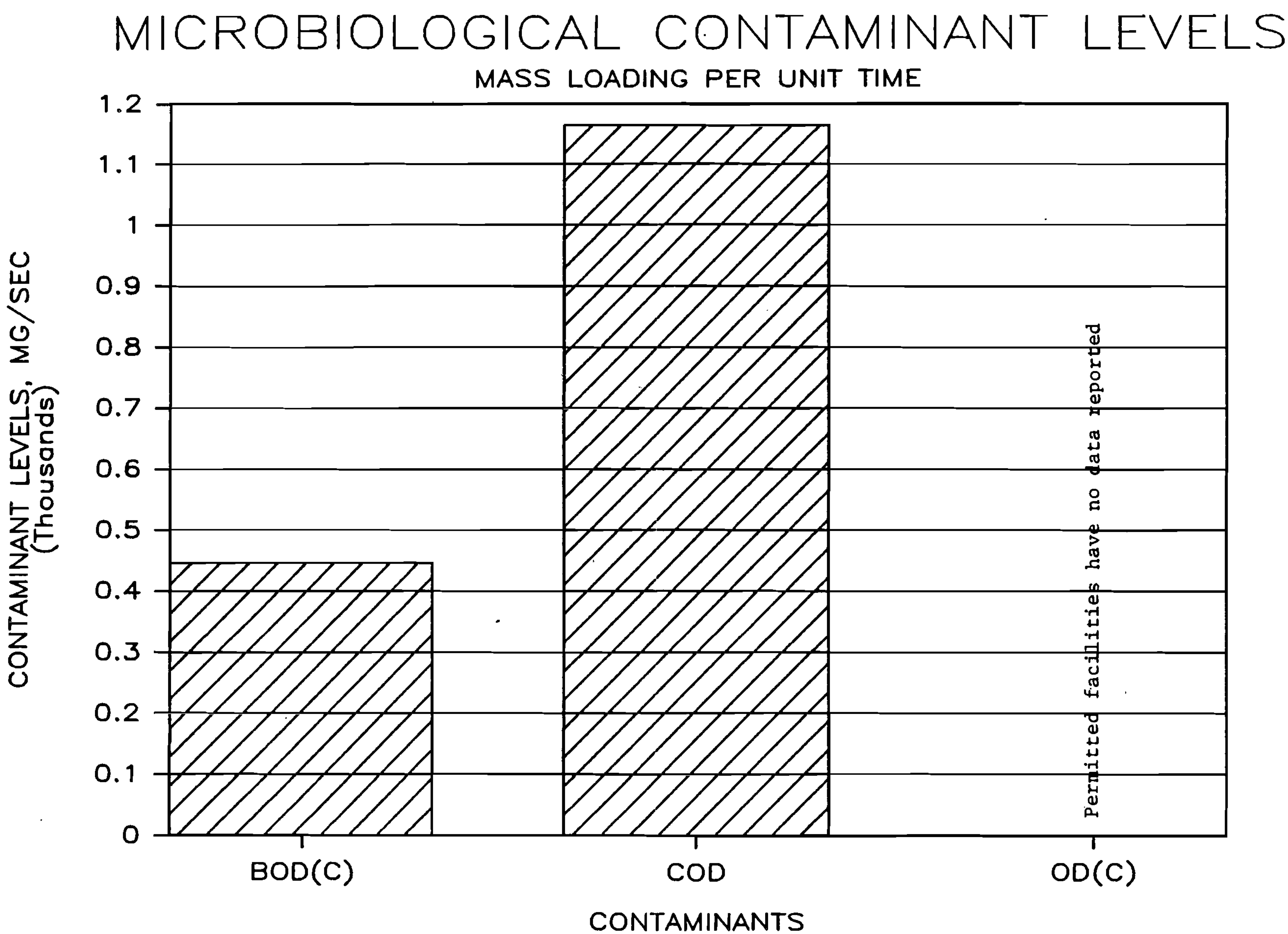


Figure 4-50 . Mass loading of microbiological contaminants due to subsurface injection of industrial waste in Nassau and Suffolk Counties, New York (based on PCS data of the SPDES Program).

5W20

TABLE 4-48

FORMALDEHYDE DATA

Embalming Process Sample	
Lavender Funeral Home	195 mg/l
Rocko Funeral Home	750 mg/l
Septic Tank Sample	
O'Bryant Chapel	< .1 mg/l
Williams Funeral Home	.15 mg/l
Nichols Funeral Home	2.4 mg/l

TABLE 4-49

TYPICAL LAUNDERETTE WASTE

Substance	**Range (mg/l)**		
	Minimum	**Average**	**Maximum**
ABS	3.0	44.0	126.0
Suspended Solids	15.0	173.0	784.0
Dissolved Solids	104.0	812.0	2,064.0
COD	65.0	447.0	1,405.0
Alkalinity	61.0	182.0	398.0
Chlorides	52.0	57.0	185.0
Phosphates	1.4	148.0	430.0
pH	5.1	-	10.0
Nitrates	-	< 1.0	-
Free Ammonia	-	3.0	-
Sulfates	-	200.0	-

TABLE 4-50

TYPICAL POLLUTANT CONCENTRATIONS IN WASTEWATER FROM SELF-SERVICE AUTO WASHES (10 MONTH PERIOD)

Substance	**Range (mg/l)**		
	Minimum	**Average**	**Maximum**
Total Solids	729	2,006	3,334
Total Volatile Solids	207	456	871
Suspended Solids	95	386	840
Volatile Suspended Solids	25	72	116
BOD (5)	15	57	166
Oil and Grease	38	86	200

As stated previously, it is difficult to generalize about the quality of fluids injected into an industrial process water and waste disposal well. Fluid qualities vary with industrial processes. It is important to emphasize, however, that industrial wastes may contain "hazardous" constituents.

Injection Zone Interactions. Limited data are available concerning the interaction between industrial waste effluent and injection zones. More research is needed to determine the effects of the waste stream, particularly on the unsaturated zone. A study by Wilson (1983) indicated that very little attenuation of common organics and heavy metals occurs in the vadose zone during lateral migration. Due to design limitations, little data on attenuation during vertical migration were obtained during Wilson's study. It should be noted that the Wilson study dealt with concentrations expected in urban storm water runoff and not those expected from disposal of industrial wastes. Some of the constituents which made up the waste streams, however, were similar to those identified in several industrial facilities.

On a positive note, according to Wyoming, removal of contaminants may occur as a result of settling of solids, filtration, dilution, and chemical reactions in the saturated zone. However, if a perched water table is created, lateral flow of contaminants may increase. Metals and organics appear to be attenuated less by saturated lateral flow, the report notes, than do microorganisms.

In summary, interactions between injection zones and industrial waste effluent probably result from processes similar to those which occur in other well types. Chemical incompatibility between injected fluids and fluids inherent to the injection zones are likely to result in precipitation or dissolution of various minerals based on characteristics such as temperature, pressure, and pH. Injection of low quality fluids with respect to quality of the ground water may result in degradation of the ground water depending on volumes, rates, and constituents of the injected fluids.

Hydrogeology and Water Usage

Site specific hydrogeologic factors strongly influence the contamination potential posed to USDW by industrial waste disposal practices. Industrial disposal wells typically inject wastes above or into USDW. Hydrogeologic factors which significantly influence the contamination potential of industrial disposal wells include:

1. thickness of the vadose zone below the injection well;

2. physical and chemical properties of vadose zone sediments below the injection well; and

3. presence/absence of confining layers (aquicludes).

Thick vadose zones provide an increased sorptive surface area for dissolved industrial waste contaminants. As noted before, little research has been performed to determine the extent of adsorption/absorption processes which actually occur between wastewater contaminants and vadose zone sediments.

The permeability of vadose zone sediments is a second significant hydrogeologic determinant. Laterally continuous, low permeability silt or clay layers generally act as confining beds. Such strata existing above or below the injection zone can effectively restrict the migration of waste effluent to other zones which may contain drinking water.

Hydrogeologic factors contributed considerably to ground-water contamination at two facilities (reviewed for this report) where contamination was caused, in part, by industrial waste disposal wells. Industrial disposal wells at the Thompson Hayward Agricultural and Nutrition Company (THAN) in Bakersfield, California and at Mefford Field in Tulare, California were completed above shallow ground-water tables. Piezometric elevations reported at each site were less than 25 feet below land surface. Silty to coarse alluvium sands also were reported to comprise the vadose zones below each facility.

Industrial disposal wells described within each of the industrial disposal well case studies (Appendix E) injected waste waters above or into USDW. In two site studies, domestic water wells were located within 1/2 mile of the disposal wells. Domestic water wells downgradient of the THAN site in Fresno, California have been contaminated from disposal well operations at the facility (Kleinfelder and Associates, 1983). Water wells also have been contaminated from past operations of industrial disposal wells (septic tanks with wells) located in the eastern half of the San Fernando Valley (L.A. Department of Water and Power, 1983).

Industrial disposal wells in Arizona at both UniDynamics and Motorola Inc., 52nd Street Facility, were completed above shallow ground-water tables. Piezometric elevations at both sites were less than 100 feet below land surface. Permeable alluvial sands also were reported to comprise the vadose zones below each facility. (Ecology and Environment Inc., 1986; Guiterrez-Palmenberg, Inc., 1983). Groundwater contamination on-site has been documented downgradient of the wells at Unidynamics.

Some active industrial disposal wells reported in Arizona overlie the Salt River Valley. Aquifers in the valley are used for irrigation and public water supply (USGS, 1983). Waters tapped by municipal water purveyors are generally greater than 300 feet below land surface.

As illustrated by the case studies previously described, the usual location of industrial waste disposal wells is in populated areas which are frequently not served by sewers or local water districts. Many nearby residents may obtain their water supplies from shallow wells completed in aquifers which produce ground water that is susceptible to contamination.

Contamination Potential

Based on the rating system described in Section 4.1, industrial process water and waste disposal wells are assessed to pose a high potential to contaminate USDW. These wells typically do inject into or above Class I or Class II USDW. Typical well construction, operation, and maintenance would allow fluid injection or migration into unintended zones. Injection fluids typically have concentrations of constituents exceeding standards set by the National Primary or Secondary Drinking Water Regulations. Fluids may exhibit characteristics or contain constituents listed as hazardous as stated in the RCRA Regulations. Based on injectate characteristics and possibilities for attenuation and dilution, injection does occur in sufficient volumes or at sufficient rates to cause an increase in concentration (above background levels) of the Primary or Secondary Drinking Water Regulation parameters in ground water, or endanger human health or the environment beyond the facility perimeter or in a region studied on a group/area basis.

It is difficult to define "typical" scenarios for the criteria listed in the rating system because the industrial disposal well category is so diverse. In order to fairly assess the wells, they must be judged on a site specific basis. However, for the purposes of this study, the interest of groundwater protection mandates that worst-case scenarios are more heavily weighted.

As stated earlier, industrial disposal wells are likely to be located in populated areas which are frequently not served by sewer systems or water districts. Therefore, nearby residents may obtain their water supplies from wells. It is presumed that these wells produce water which meets drinking water quality standards. In other words, the ground water inherent to the injection zone is likely to belong to Class I or Class II of the Groundwater Classification System.

It is difficult to identify "typical" construction, operation, and maintenance features; therefore, worst-case scenarios will be applied to this section of the rating system. In many cases previously described, wells showed no signs of casing, cement, tubing, packers, or wellhead assemblies. Furthermore, injection pressures, rates, and volumes "typically" are not monitored. The injected fluids are likely not to be analyzed, and many facilities are believed to be operating without permits. Under present operational procedures, there is a great potential for abuse, as illustrated by the case studies from Pennsylvania (Appendix E). Programs established to conduct mechanical integrity tests and to properly plug and abandon wells are rare. Based on these criteria, it is reasonable to assume that typical well construction, operation, and maintenance practices will allow injection or fluid migration into USDW.

Contaminants identified in wastewaters discharged to industrial disposal wells are numerous and site specific. Nevertheless, many waste streams may contain contaminants which are defined as "hazardous" per 40 CFR Part 261, Subparts C and D. Detailed investigation is needed to determine whether these wastes actually meet the "hazardous" criteria. Contaminants detected in some waste streams include TCE, xylene, benzene, and various pesticides, to name just a few.

Identifying injection volumes and rates is probably the most difficult parameter for which to determine a "typical" scenario. The reader is referred to the case studies (list provided in Appendix E) for evidence that injection of industrial wastes frequently occurs in sufficient volume or at a sufficient rate to cause an increase in concentration (above background levels) of the National Primarey or Secondary Drinking Water Regulation parameters in groundwater, or endanger human health or the environment either (a) beyond a facility's perimeter, or (b) in a region studied on a group/area basis.

Current Regulatory Approach

Industrial waste disposal wells are authorized by rule under Federally-administered UIC programs. Several available case studies suggest that 40 CFR 144.12 is possibly being violated. These requirements state:

> No owner or operator shall construct, maintain, convert, plug, abandon, or conduct any other injection activity in a manner that allows the movement of fluid containing any contaminant into underground sources of drinking water, if the presence of that contaminant may cause a violation of any primary drinking water regulation under 40 CFR Part 142 or may otherwise adversely affect the health of persons.

Unfortunately, many agenices with the authority to regulate these systems are under-staffed and are not able to inspect all systems, according to Utah. Limited State and local government resources make it easy for an operator to modify portions of his wastewater system (without being detected) to discharge to dry wells instead of to a municipal sewer. In States where well manufacturers and installers currently are unregulated and have no obligation to report their installations to local and State authorities, primary construction of facilities with industrial disposal wells may go unnoticed.

Furthermore, proving that injected waste is "hazardous" as described in 40 CFR 261 Subparts C and D is very difficult. Until these facilities can be proven to inject "hazardous" waste or are proven to be sources of contamination or to adversely affect public health, they may be classified as Class V wells.

Some questions have been raised concerning whether the RCRA program or the UIC program maintains jurisdiction over certain Class V wells when potentially "hazardous" wastes are involved. This problem is prevalent in regulating septic systems that receive industrial waste or toxic household waste. The following paragraphs summarize the RCRA regulations regarding household wastes and conditionally exempt small quantity generator (SQG) wastes. The information is excerpted from personal correspondence with the USEPA and indicates that the UIC program clearly maintains control over authorization of this type of injection well.

> Household wastes are defined in 40 CFR Part 261.4(b)(1) as "any material (including garbage, trash and sanitary wastes in septic tanks) derived from households (including single and multiple residences, hotels and motels, bunkhouses, ranger stations, crew quarters, campgrounds, picnic grounds, and day use recreation areas). It is conceivable that household wastes could contain toxic chemicals. Yet, under Part 261.4(b), these wastes are not considered RCRA hazardous wastes. Therefore, wells injecting household wastes for disposal purposes would fall under the Class V category rather than the Class IV category, even though these wastes may contain toxic chemicals.
>
> Small quantity generators of less than 100 kilograms per month are exempt from full RCRA regulations, under Part 261.5(g), provided that certain conditions are met. If the generator does meet the conditions, hazardous wastes may either be treated or disposed of in an on-site facility or an off-site storage, treatment, or disposal facility which is either:

1. permitted under Part 270; or

2. in interim status under Parts 270 and 265; or

3. authorized to manage hazardous waste by a State with a hazardous waste management program approved under Part 271; or

4. permitted, licensed, or registered by a State to manage municipal or industrial solid waste; or

5. a recycling or reclamation facility.

Thus, a Class V well that has been permitted, licensed, or registered as a facility by a State may inject RCRA hazardous wastes produced by conditionally exempt small quantity generators of less than 100 kilograms per month. In situations where this occurs, the well must be reclassified as Class IV. Since Class IV wells are prohibited, under 40 CFR 144.13, the well then must be properly plugged and abandoned in accordance with the requirements of Parts 144.14 and 144.23.

Several States implement stringent requirements for industrial process water and waste disposal wells. Table 4-47 indicates the regulatory systems described in each State report. Unfortunately, specific regulatory information provided in the State reports usually was very general or non-existent.

States with primacy approach the regulation of industrial waste disposal wells in many different ways. Some States require a permit prior to construction or operation while others authorize by rule. At least sixteen States have some type of permitting program in place which mandates a permit for the operation of industrial disposal wells. Some of these programs are conditional and require permits for injections in excess of set volumes or for certain system designs. Texas regulates industrial disposal wells as Class I injection wells. While regulations are diverse throughout States with primacy, most State reports recommend permitting systems which set minimum construction standards and monitoring requirements. In a few States, permitting systems and monitoring programs are part of the current regulatory program.

Several States quote applicable State regulations which, summarized, prohibit the injection of wastes which will degrade ground water. Examples include Indiana and North Carolina. Some States require general permits for operation of any type of injection well. Because the waste streams often contain potentially hazardous constituents, however, the trend in many States seems to be moving toward individually permitting industrial disposal wells. States with individual permitting programs include New Jersey, Wisconsin, Alabama, Maryland, and Oregon. The regulatory systems of New Jersey, New York, and California are described in greater detail in the following paragraphs. These three systems were used as examples because information concerning the systems was readily available.

New Jersey. The following information is a direct excerpt from the New Jersey State Pollution Discharge Elimination System (NJSPDES) permit application package.

ADDITIONAL GENERAL CONDITIONS FOR INDUSTRIAL/COMMERCIAL DISCHARGES BY SUBSURFACE DISPOSAL

A. Monitoring Requirements

1. Flow measuring device(s) shall be installed in the waste stream(s) prior to discharge to the subsurface system such that the total daily flow can be measured on a continuous basis.

2. Flow shall be recorded and reported to the Department as required in the discharge monitoring requirements of this permit.

B. Maintenance Requirements

1. Septic Tanks

Septic tanks, if utilized, shall be inspected on at least a semi-annual basis to determine the level of sludge that has accumulated. When the level of the sludge reaches one-quarter (1/4) of the capacity of any septic tank within a single system, all tanks within that system shall be pumped.

The permittee shall also conduct an inspection of the following appurtenances on at least an annual basis:

Appurtenance	Inspection
Septic Tanks	Leaks, Baffle Corrosion
Conveyance Piping*	Leaks, Solids Accumulation Grade
Distribution Box	Leaks, Solids Accumulation Elevation

*Internal inspection to be performed only if readily accessable: otherwise inspection only for surface evidence of system failure.

The permittee shall maintain a record of all inspections performed and shall make the record of the inspections available to the Department upon request.

Prior to pumping any septic tank, the permittee shall arrange at his/her own expense for an EP Toxicity Test (or other such test as the Department may currently require to be performed on the sludge content. The results of the EP Toxicity Test (or other such test as the Department may currently require) shall be forwarded to the Bureau of Hazardous Waste Manifest and Classification of the Division of Waste Management for classification.

a. If the classification of the sludge is other than I.D. 73, appropriate disposal and any necessary manifesting and all applicable Waste Flow Rules shall be followed pursuant to the rules, regulations and requirements of the Division of Waste Management.

b. If the classification of the sludge is I.D. 73, the septic tank pumpings shall be disposed of pursuant to Section 18 (Residuals Management) of the General Conditions for all NJPDES Permits unless adopted Waste Flow Rules require otherwise.

2. Subsurface Disposal Area

a. The immediate and surrounding area of the subsurface disposal area shall be inspected on at least a monthly basis for evidence of malfunctioning. Said evidence shall include, but shall not be limited to breakout, ponding, wet areas, odors and an overabundance or loss of vegetative cover. A record of these inspections shall be maintained by the permittee and shall be made available to the Department upon request.

b. At the first indication of malfunctioning, the owner shall notify the Department pursuant to Section 14 (Reporting Noncompliance) in the General Conditions for All NJPDES Discharge Permits.

C. Operation Restrictions

1. The permittee shall comply with all provisions of Section 5.9, Additional Conditions Applicable to all UIC Permits, of the NJPDES regulations. N.J.A.C. 7:14A-1 et seo.

2. The operation of a subsurface disposal system shall at no time create an unpermitted discharge to any surface water of the State or a persistent standing, ponded, or flowing fluid condition.

3. When the Department has reason to believe that contamination of the ground waters is being caused by this facility, remedial measures shall be required to determine the extent of the suspected contamination and/or to correct the contaminated conditions. The remedial measures shall include, but shall not be restricted to, the installation of ground water monitoring wells, modification(s) of the treatment system (if any), installation of a treatment system and/or reduction of cessation or the discharge.

New York. In New York, the Department of Environmental Conservation (NYDEC) regulates the discharge of pollutants to both surface water and ground water under the State Pollutants Discharge Elimination System (SPDES) program. The SPDES program is operated based on the provision under Article 12 of NYDEC and the authority of the Federal Water Pollution Control Act. All facilities that discharge more than 1,000 gallons per day of wastewater to the subsurface are permitted through this program. The following discussion of the program concerns discharge to both the surface and subsurface.

The NYDEC has nine regional headquarters and several suboffices. The Division of Water at the Central office of the NYDEC in Albany, NY, coordinates all efforts through the regional headquarters. The regional headquarters, in turn, delegate responsibilities to respective suboffices and counties on a regional basis. The Division of Water of the central office issues Technical and Operational Guidance Service (TOGS) to establish priorities and procedures for the SPDES program.

According to TOGS (1985), the SPDES permitting is divided into two classes: Significant Permit Classes, and Non-Significant Classes.

Significant permit classes consist of all USEPA designated major* permits (NPDES Program?), plus the following non-major permits:

1. Municipal

2. Toxic Industrial

3. Non-Toxic Industrial

4. Private, Commercial and Institutional (PCI) (Regional Concern)

Non-Significant Classes consist of non-major PCI and other industrial permits less those designated for inclusion in the significant class under subpart 2, 3, and 4 above.

* (Most USEPA major permits in Long Island discharge to surface water.)

The regional offices have the authority to process all first time applications and issue permits complete with expiration date regardless of class. The permits are then classified as significant or non-significant based on certain guidelines. The potential for the discharge to create serious nuisance conditions, impact on water supply or bathing areas, and intense public concern are some items considered in this evaluation.

The Bureau of Wastewater Facilities Design (BWFD) sends renewal notices to dischargers in the significant class. The regional permit administrator, in turn, processes the applications and reissues permits as applicable. The BWFD sends renewal notices, also, to dischargers in the non-significant classes. However, the Bureau extends such permits indefinitely under the provision of the state administrative procedures. In any case, the permitees in the non-significant classes are required to monitor discharges as necessary and retain the analytical results for inspection by the Department or its designated agent.

The overall goal of the SPDES is to reduce severe contamination potential by closely monitoring all significant discharges while ensuring compliance of all nonsignificant permits by spot inspections. All monitoring data for significant classes are stored in the NYDEC's Permit Compliance System (PCS) data storage. Appropriate actions are taken on those facilities that discharge wastewater in excess of the water quality regulations as specified in Title 6, Chapter X, Parts 700 - 705 of the New York State Codes, Rules and Regulations, (NYDEC, 1986). Most of the above discussion is based on TOGS (1985) reporting by the Division of Water of the NYDEC.

It is not clear whether other States have State regulatory systems similar to those of New York and New Jersey, but programs such as these are beneficial to the protection of ground water.

California. Little or no information is available in most State reports on local jurisdiction. The following excerpt is from the California report and illustrates how local agencies may be responsible for regulating industrial disposal wells.

> Class V industrial waste disposal wells (5W20) operating in California are regulated under the California State Health and Safety Code and the California State Water Code. Each code grants specific enforcement powers and responsibilities to two environmental regulatory branches:
>
> - the Department of Health Services
> - the State Water Resources Control Board and its nine Regional Water Quality Control Boards.
>
> The Department of Health Services (DOHS) and a California Regional Water Quality Control Board often coordinate actions at sites where regulatory jurisdictions overlap. This, however, is not true in all cases.
>
> Class V industrial waste disposal wells are regulated differently according to the type of wastes they dispose. Wells found to dispose of waste waters containing hazardous wastes (as defined in the State of California Health and Safety Code Chapter 6) are subject to stricter regulations recently passed under California Assembly Bill No. 2058. (The California Health and Safety Code was amended to contain the provisions of this bill in 1985.)
>
> Provisions under the bill prohibit:
>
>> any person on or after January 1, 1986, from discharging hazardous waste into an injection well which commenced operation on or after January 1, 1986, and prohibits such a discharge after January 1, 1988, into an injection well which commenced operation before January 1, 1986, unless the person has received a hazardous waste facilities permit for the well, the well is not within 1/2 mile of drinking water, and the injection well

> does not discharge hazardous waste into or above a specified formation, unless granted an exemption by the department (DOHS) pursuant to a specified procedure. (California AB 2058, 1985)

The bill also prohibits the DOHS from issuing a hazardous waste facilities permit unless a hydrogeologic assessment report for the industrial waste disposal well is reviewed and approved. Groundwater monitoring and injection zone requirements must also be stipulated by the DOHS before issuing a hazardous waste discharge permit. The bill further requires Regional Water Quality Boards to base waste discharge requirements which they issue for hazardous waste injection wells on hydrogeologic assessment reports. Hydrogeologic assessment reports (HAR) are carefully reviewed by Regional Water Quality Control Boards and the DOHS. Industrial disposal well owners are often required to submit extensive site specific hydrogeologic data within their HAR. (See "Industrial Disposal Well case Study, Kearney-KPF", Appendix E for an example of information required by state agencies within a HAR). In response to orders received from the DOHS and the Regional Water Quality Control Boards, a number of facilities are currently conducting hydrogeologic site investigations.

Class V wells not identified to discharge hazardous waste (as designated by the State) are regulated by the State and Regional Water Quality Control Boards. These Boards are empowered by the California State Water Code to require...

> any person ...who is discharging, or who proposes to discharge, wastes or fluid into an injection well, to furnish the State or Regional Board with a complete report on the condition and operation of the facility or injection well, or any other information that may be reasonable required to determine whether the injection well threatens to pollute the waters of the state. (Porter Cologne Water Quality Code, Sect. 13263.5a, 1985).

'When a report filed by any person pursuant to this section (California State Water Code, Section 132601e) is not adequate in the judgement of the regional board, the board may require the person to supply the additional information which it deems necessary' (California State Water Code, Section 13260(e) as amended by AB 2058). Waste discharge requirements for industrial disposal wells are set by the Regional Board on a case by case basis. These requirements can specify the design, location and type of construction among other requirements which must be complied with by the injection well owner in a lawful manner. Shallow industrial waste disposal wells discovered by the Regional Boards to have operated without waste discharge permits have been closed by the Boards in most cases. These wells can reopen if, after reviewing the waste discharge report, a Regional Board judges that the shallow industrial disposal well will not threaten regional groundwaters.

Based on information provided in State reports, it is likely that the local regulatory system utilized by California is more stringent than systems in other States.

Recommendations

Recommendations provided by State reports are summarized on the State Report Summaries in Appendix A. While some States provided only general recommendations for continuation of the UIC program as a whole, other States provided recommendations for specific well types. The following list of recommendations includes most of the topics addressed in the State reports. State reports which contain specific recommendations are identified in parentheses.

Inventory.

1. Inventory efforts should be continued with a high priority given to identifying industrial disposal facilities (PR, IN, WI, AK, WY).

2. Assume that all industrial waste disposal practices have deleterious effects on USDW, thus warranting immediate attention. Then conduct site investigations to assess the true contamination potential (PA).

3. The NPDES program could be more effective in helping the UIC program by requiring sewer improvement districts to inventory all industrial users of their systems and to review details of each user's waste streams(s) (NY).

4. The issue of the reluctance of operators to report their wells can be overcome by presenting a coordinated program (about waste streams that are allowed) through a multi-media approach. The

multi-media approach should encourage public participation at the State and local levels (States in Region V).

Hydrogeological Evaluations.

1. "Extensive groundwater evaluation studies should be completed in order to identify areas which would be vulnerable to contamination due to industrial waste disposal. Standard criteria should be developed to define in precise terms the criteria that constitute vulnerability," (PR, AS).

2. "Drainage areas surrounding industrial facilities should be studied and all possible pollution sources noted," (KS).

Permits.

1. "Industrial disposal wells should be permitted only when the injectate contains less than 10,000 mg/l TDS," (FL).

2. These wells can be detected and managed by local building code, environmental, or sewage protection programs (UT).

Inspections.

1. Inspection of industrial waste disposal facilities should be continued (PR).

2. "Inspection teams should be reinforced by chemical or industrial engineers whose familiarity with the industrial processes would render a more objective assessment of the impact industry might have on the environment," (PR).

3. Inspection of well construction practices should be mandatory along with annual inspections to ensure adherence to appropriate regulations (MD, KS).

Monitoring.

1. "Request all industries to conduct monitoring programs," (PR).

2. "Tighten up sampling requirements to assure their being representative of material reaching the injection well," (PR).

3. "If USDW is/are present above the injection zone, monitoring should be required which is capable of detecting the migration of effluent in the direction of the USDW," (FL).

4. Ground-water monitoring should be conducted using a minimum of one upgradient and two downgradient wells, (AZ).

5. Existing State regulations should be reviewed and revised to provide more prudent control of injection and monitoring requirements (HI).

6. All nonhazardous industrial process water and waste disposal wells shown to have a high contamination potential should be phased out. These wells should be required to inject below USDW as Class I wells in the future. Other 5W20 wells should be periodically checked for injection rate and fluid quality (States in Region V).

Alternative Methods.

1. The practice of injecting industrial process water and waste should be discouraged, and wastes should be routed to on-site treatment facilities or municipal sanitary sewer systems where possible, (FL, UT).

2. "Discharge of industrial process wastes to septic systems should be discouraged due to the fact that septic tank systems are not designed to adequately treat this waste type," (NE).

3. "Septic tanks were designed to treat domestic (kitchen and toilet) wastes only. The septic tank really has no place in industry except to treat wastes generated exclusively by a mess hall (cafeteria) and sanitary facilities. Even very small amounts of some industrial wastes can render a tank useless for the stabilization of domestic waste," (PR).

4. Alternative methods for disposal of industrial process water and waste should be considered (MD).

5. The policy of prohibiting the installation of septic tank/drainfields for treating embalming fluids (current practice requires holding facilities and periodic removal and proper disposal) should be continued (SC).

6. Until additional data is at hand to define the fate of industrial wastes in the saturated zone, it is prudent to take extraordinary precautions to minimize the potential for aquifer degradation via injection of highly toxic substances (WA).

7. Alternatives to land disposal such as recycling or resource recovery, reduction of wastes generated through process modification, and improved methods of hazardous waste neutralization should be actively pursued (WA).

Supporting Data

Appendix E lists 27 case studies of industrial process water and waste disposal facilities used in preparing this assessment. Also listed in Appendix E are three tables which illustrate varying construction features and injectate constituents of several industrial disposal wells in California.

4.2.6.3 Automobile Service Station Disposal Wells (5X28)

Well Purpose

Wastewater comprised of waste antifreeze fluids, waste petroleum products (oil, grease, etc.), floor washings (including detergents, sediments, etc.), and miscellaneous wastes originates from service bays at gas stations and auto dealerships. This type of wastewater will be called Service Bay Wastewater (SBW) in the following discussion. SBW typically is disposed of by three general methods: discharge to sanitary sewers, discharge to the subsurface by injection, and riddance by other methods such as storage or hauling of waste to an off-site disposal or recycling facility. (See Figure 4-51.)

Of particular concern is the injection of wastes to the subsurface brought about through one or a combination of methods. One method of waste injection involves discharge of wastewater through disposal wells or dry wells which exclusively receive wastewater from service bay drains. For the purpose of identification in the following sections, these wells will be called single purpose wells. The other method of injection involves discharge of SBW through cesspools, septic tank systems, or storm water drainage wells. These discharge systems will be called multi-purpose disposal systems as they receive wastes both from service bay drains and sewage or storm water runoff. In the event that the SBW is disposed through septic tank systems, the waste may be finally discharged to the subsurface through cesspools, dry or disposal wells, drainfields or other disposal methods. Hence, SBW may be injected to the subsurface through any of the above mentioned disposal methods, all of which are regulated under the UIC regulations.

Inventory and Location

Some States like Connecticut, Idaho, Illinois, Indiana, Michigan, New Jersey, New York, and Utah have conducted site-specific investigations to identify and assess the impact of SBW

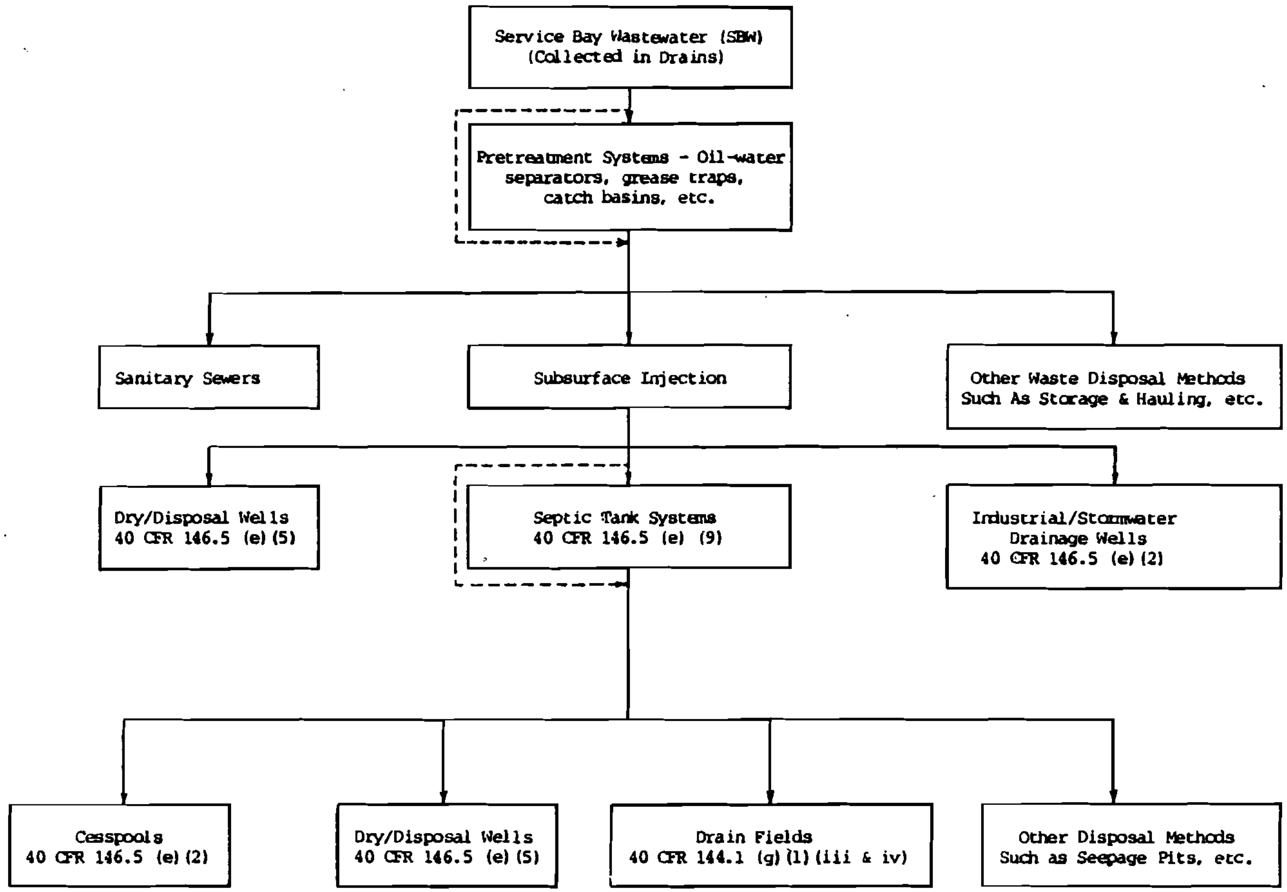


Figure 4-51
Typical disposal methods employed by gasoline service stations and car dealerships that discharge service bay wastewater (SBW)

5X28

injection to the subsurface. Appropriate corrective actions are now being implemented based on the findings of these investigations.

A nationwide inventory has not been conducted for gasoline station service bay disposal wells. By and large, such an inventory has not been conducted because most States are not aware of such injection practices. Meanwhile, those States that are aware sometimes misinterpret the Class V definition and identify certain disposal techniques as septic tank systems or storm water drainage wells.

The USEPA Region II conducted several field trips in New York and New Jersey and identified some automobile service stations that were suspected of injecting service bay wastewater to the subsurface. (Engineering Enterprises, Inc. (EEI) was contracted to sample and analyze some of these injection wells in Long Island, New York. The preliminary investigation in Long Island, New York, revealed that three out of eight gasoline service stations investigated discharge SBW to the subsurface through single purpose and multipurpose wells. It was not possible to identify the disposal method at the rest of the sites. Missing plumbing records and site plans, modifications to old plumbing, and lack of information exchange during transfer of ownerships were some of the many elements that affected proper identification of a disposal method at these five sites.

In Connecticut, an inventory has not been completed because SBW disposal methods are identified and regulated only on a case-by-case basis as they are reported or identified during routine inspection. In New Jersey, the New Jersey Department of Environmental Protection (NJDEP) reported 18 service station disposal wells of which 11 non-filer facilities are undergoing enforcement actions, one facility is closed, and the others are either permitted or under investigation. In other words, there is no extensive program setup to inventory or regulate such disposal methods.

Under all of these circumstances it was not possible to obtain a complete inventory either on a State level or national level. Table 4-51 is a synopsis of the inventory data given by the states.

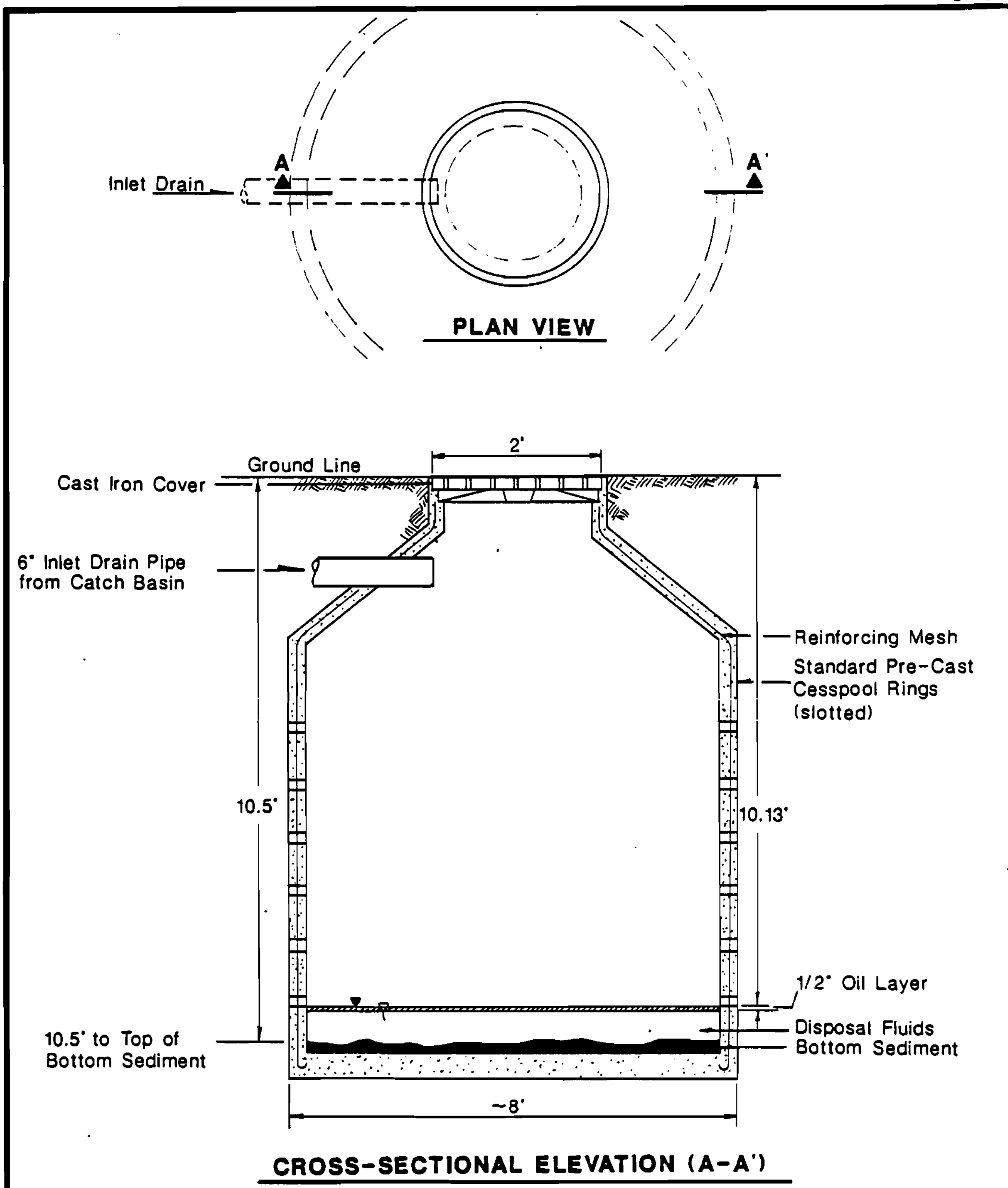
Well Construction, Operation, and Siting

As discussed before, wastewater from service bays may be discharged through single purpose or multipurpose wells. Construction of multipurpose wells is similar to constructions discussed under septic tank systems or storm water drainage wells. Single purpose wells designed to discharge only service bay wastewater are typically completed at shallow depths using standard precast cesspool rings as illustrated in Figure 4-52. At some sites, depending on the volume of waste discharged and

TABLE 4-51: SYNOPSIS OF STATE REPORTS FOR AUTOMOBILE SERVICE STATION WASTE DISPOSAL WELLS(5X28)

REGION & STATES	EPA REGION	Confirmed Presence Of Well Type	Regulatory System	Case Studies/ Info. available	Contamination Potential Rating
Connecticut	I	1 WELL	PERMIT	YES	HIGH
Maine	I	NO	N/A	NO	N/A
Massachusetts	I	NO	N/A	NO	N/A
New Hampshire	I	NO	N/A	NO	N/A
Rhode Island	I	3 WELLS	N/A	YES	LOW
Vermont	I	10 WELLS	N/A	YES	MODERATE/HIGH
New Jersey	II	18 WELLS	NJPDES PERMIT	YES	N/A
New York	II	3 WELLS	PERMIT	YES	HIGH
Puerto Rico	II	NO	N/A	NO	N/A
Virgin Islands	II	NO	N/A	NO	N/A
Delaware	III	NO	N/A	NO	N/A
Maryland	III	NO	N/A	NO	N/A
Pennsylvania	III	NO	N/A	NO	N/A
Virginia	III	1 WELL	N/A	NO	N/A
West Virginia	III	NO	N/A	NO	N/A
Alabama	IV	NO	N/A	NO	N/A
Florida	IV	YES	PERMIT	NO	N/A
Georgia	IV	NO	N/A	NO	N/A
Kentucky	IV	NO	N/A	NO	N/A
Mississippi	IV	NO	N/A	NO	N/A
North Carolina	IV	NO	N/A	NO	N/A
South Carolina	IV	NO	N/A	NO	N/A
Tennessee	IV	NO	N/A	NO	N/A
Illinois	V	5 WELLS	RULE	NO	N/A
Indiana	V	2 WELLS	N/A	NO	N/A
Michigan	V	27 WELLS	N/A	NO	N/A
Minnesota	V	NO	N/A	NO	N/A
Ohio	V	NO	N/A	NO	N/A
Wisconsin	V	NO	N/A	NO	N/A
Arkansas	VI	NO	N/A	NO	N/A
Louisiana	VI	NO	N/A	NO	N/A
New Mexico	VI	YES	N/A	NO	N/A
Oklahoma	VI	NO	N/A	NO	N/A
Texas	VI	NO	N/A	NO	N/A
Iowa	VII	1 WELL	N/A	NO	HIGH
Kansas	VII	NO	N/A	NO	N/A
Missouri	VII	5 WELLS	N/A	NO	UNKNOWN
Nebraska	VII	NO	RULE	NO	N/A
Colorado	VIII	NO	N/A	NO	N/A
Montana	VIII	NO	N/A	NO	N/A
North Dakota	VIII	NO	N/A	NO	N/A
South Dakota	VIII	NO	N/A	NO	N/A
Utah	VIII	2 WELLS	BANNED	NO	6 (7=HIGHEST)
Wyoming	VIII	NO	N/A	NO	N/A
Arizona	IX	NO	N/A	NO	N/A
California	IX	NO	N/A	NO	N/A
Hawaii	IX	NO	N/A	NO	N/A
Nevada	IX	YES	N/A	NO	HIGH
American Samoa	IX	NO	N/A	NO	N/A
Tr. Terr. of P	IX	NO	N/A	NO	N/A
Guam	IX	NO	N/A	NO	N/A
CNMI	IX	NO	N/A	NO	N/A
Alaska	X	NO	N/A	NO	N/A
Idaho	X	21 WELLS	RULE	NO	4TH HIGHEST/14 TYPES
Oregon	X	NO	N/A	NO	N/A
Washington	X	NO	N/A	NO	N/A

NOTE: SOME NUMBERS IN THIS TABLE ARE ESTIMATES.



DETAIL OF A DRY/DISPOSAL WELL
SAMPLED AT A GASOLINE SERVICE STATION
LONG ISLAND, NEW YORK

Figure 4-52

the geology, a series of standby wells may also be constructed as the situation warrants.

Wastewater effluent originating from service bays may pass through a pretreatment system before being discharged into a disposal well. Such pretreatment systems include grease pits, oil water separators, or catch basins. Figure 4-53 is an illustration of a catch basin sampled in New York. Injection takes place by simple gravity flow from the pretreatment system to the subsurface disposal facility.

Injected Fluids and Injection Zone Interactions

Typically, wastewater from service bay drains may include waste oil, antifreeze, floor washings (including detergents, organics, and inorganic sediment), and other petroleum products. Hence, wastewater of this nature may contain highly toxic organics and heavy metal priority pollutants along with other organic and inorganic compounds that may eventually migrate to the ground water. Many of these contaminants may be absorbed or adsorbed to the organic and inorganic suspended sediments and settleable sediments.

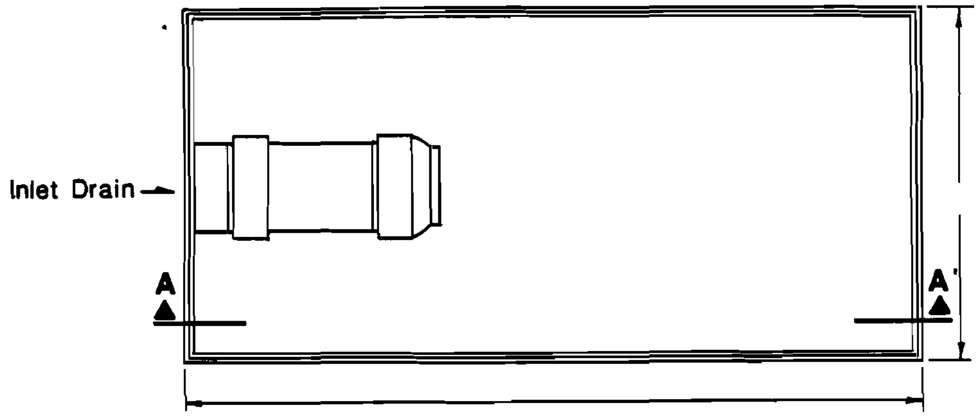
Samples obtained at some gas stations during the preliminary investigations in Long Island, New York showed contaminant levels highly in excess of drinking water standards. High levels of heavy metals (total), ethylene glycol, and volatile organics were detected in the wastewater samples collected in the investigation.

During the investigation in New York and a separate investigation in Utah, it was estimated that some wells had up to two feet of oily residue in the wells, and the entire inside of the wells was coated with black oily films. Case studies are listed in Appendix E.

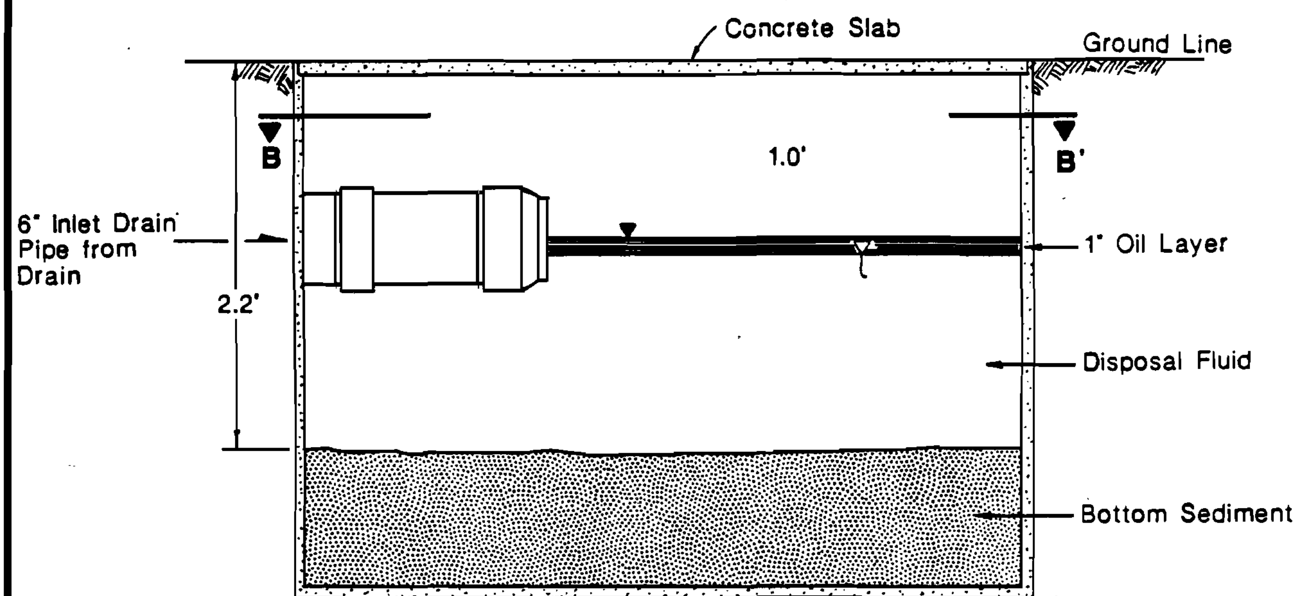
At most sites, waste fluids enter the unsaturated subsurface zone by gravity flow, seeping through slots and openings of the disposal well. Waste fluids migrate vertically downward in the unsaturated (vadose) zone by force of gravity. In this process, the fluids may leave behind residual contamination in the wells and in the flow path through the vadose zone, due to adsorption or absorption. The residue potentially may leach or desorb contaminants to the subsurface for long periods of time.

Hydrogeology and Water Use

Wastewater from service bays typically is injected into the shallow subsurface (within 20 to 30 feet of land surface). Consequently, at many sites, shallow aquifers may be in or near such discharge zones. Shallow aquifers are highly vulnerable to contamination regardless of their location with respect to injec-



PLAN VIEW (B-B')



CROSS-SECTIONAL VIEW (A-A')

DETAIL OF A CATCH BASIN
SAMPLED AT A GASOLINE SERVICE STATION
LONG ISLAND, NEW YORK

Figure 4-53

tion zones since contaminants in SBW may eventually reach the aquifer.. Incidentally, most gas station service bays are located in populated areas that may have many additional sources of pollution (See Figure 4-54). Some residents in the area may obtain their drinking water from wells completed in shallow aquifers in the general area. Contaminants entering the shallow aquifers may migrate through the ground water and, eventually, contaminate drinking water wells in the vicinity.

In some areas where shallow aquifers are non-potable, water wells may be completed in deeper aquifers. Contaminants from SBW disposal wells may still migrate down to the deeper aquifer, depending on the hydrogeological connection between the upper shallow aquifer and the deeper aquifer. Improperly abandoned or poorly constructed and maintained water wells may also contribute to connectivity of shallow and deep aquifers.

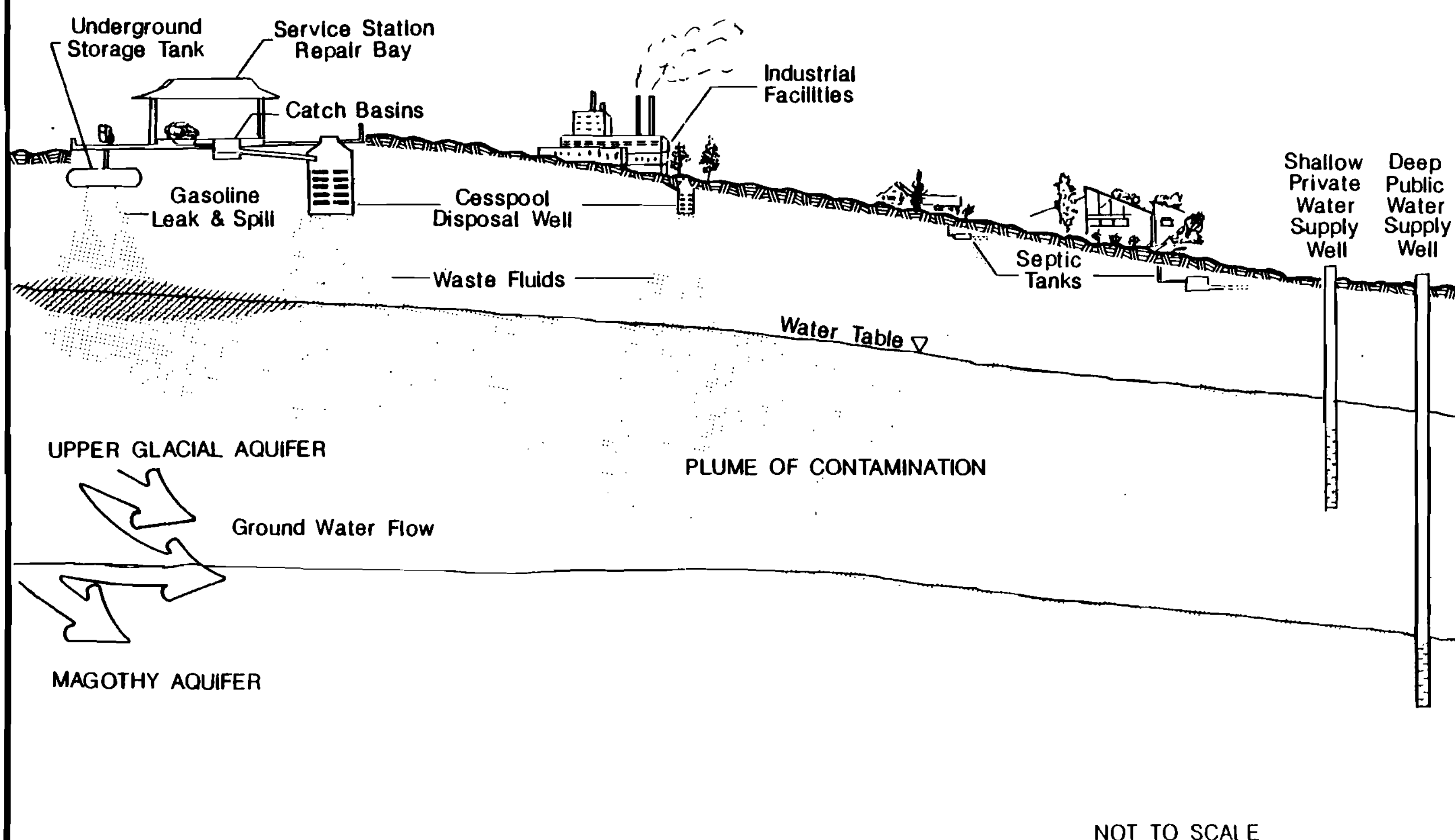
Contamination Potential

Based on the rating system described in Section 4.1, automobile service station waste disposal wells are assessed to pose a high potential to contaminate USDW. These wells typically do inject into or above Class I or Class II USDW. Typical well construction, operation, and maintenance would allow fluid injection or migration into unintended zones. Injection fluids typically have concentrations of constituents exceeding standards set by the National Primary or Secondary Drinking Water Regulations. Furthermore, many of the fluids are likely to exhibit characteristics or contain constituents listed as hazardous as stated in the RCRA Regulations. Based on injectate characteristics and possibilities for attenuation and dilution, injection does occur in sufficient volumes or at sufficient rates to cause an increase in concentration (above background levels) of the National Primary or Secondary Drinking Water Regulation parameters in groundwater, or endanger human health or the environment beyond the facility perimeter or in a region studied on a group/area basis.

When SBW is disposed by subsurface injection, it usually is discharged to a shallow zone. The waste is injected into the subsurface in populated areas that depend, in many instances, on ground water as a source of drinking water. Hence, in most cases, the injection zones are underlain by USDW. Also, the construction, operation, and maintenance of many subsurface injection methods allow contaminants to migrate into unintended zones in the subsurface. The injection fluids commonly contain toxic organics and heavy metal priority pollutants in excess of drinking water standards. Finally, injected fluids are very likely to cause degradation of ground-water quality beyond the facility perimeter. Based on the above findings and the rating systems developed and discussed at the beginning of Section Four, it can be concluded that subsurface discharge of SBW presents a high potential to contaminate USDW in the vicinity. This

Figure 4-54

HYPOTHETICAL VIEW OF VARIOUS SOURCES OF CONTAMINATION AND TRANSPORT OF TOXICS IN THE SUBSURFACE (EEI, 1986)



5X28

conclusion is reaffirmed by some state reports, including New York, Utah, and Iowa, that rate these disposal methods as those that pose a high contamination potential.

As discussed above, discharge of such contaminants to the subsurface has an immediate or potential impact on the ground-water quality and, thereby, poses a threat to human health and the environment. The impact ground-water quality is influenced by the transport and fate of the injected fluids in the subsurface.

As mentioned by Keeley, Piwoni, and Wilson (1986), there are many natural processes that affect the transport and fate of pollutants (Table 4-52). They are divided into physical, chemical, and biological processes. These processes may, in many instances, reduce the contamination potential. Nevertheless, these contaminants have the ability to eventually degrade the ground-water quality depending on the volume, persistence, mobility, and toxicity of the injected fluid. Investigations that study the transport and fate of contaminants can be both costly and time consuming but are essential. Such investigations become more complicated (especially in densely populated residential and industrial areas as in the case of the Long Island, New York study) as different sources of contamination contribute to the gross contamination plume.

A thorough investigation of the various factors mentioned above is necessary to understand the full impact and contamination potential of service bay waste water injection on USDW.

Current Regulatory Approach

Automobile service station waste disposal wells are authorized by rule under Federally-administered UIC progrmas (see Section 1). Currently, gasoline station disposal wells are not actively regulated by the USEPA or by many State systems. One reason is that some States do not believe that such disposal practices exist. Also, many other States are confused and misled, believing that multipurpose wells like septic tank systems and storm water/industrial drainage wells (that also discharge waste from service bays) do not meet the definition (in UIC Regulations) of "Automobile Service Station Disposal Wells."

Some States, however, are beginning to recognize the impact of these injection practices. For instance, according to Patton (1987), Connecticut has barred any discharge of wastewater to the subsurface from gasoline station service bays. All facilities, old and new, are now required to dispose of such wastewater only through the sewer system or other means where the waste is removed from the area. Operators are required to obtain necessary permits in this regard. Facilities that do not follow these requirements have been asked to immediately seal off such drains.

TABLE 4-52
NATURAL PROCESSES THAT AFFECT SUBSURFACE CONTAMINANT TRANSPORT. (KELLEY, PIWONI AND WILSON, 1986)

Physical processes
Advection (porous media velocity)
Hydrodynamic dispersion
Molecular diffusion
Density stratification
Immiscible phase flow
Fractured media flow
Chemical processes
Oxidation-reduction reactions
Radionuclide decay
Ion-exchange
Complexation
Co-solvation
Immiscible phase partitioning
Sorption
Biological processes
Microbial population dynamics
Substrate utilization
Biotransformation
Adaptation
Co-metabolism

Other States, including Wyoming, Wisconsin, New Jersey, and New York, are taking effective steps to mitigate these injection practices. Some States, like Texas, are now requiring permits for these discharges, and have classified the wells as Class I wells (Musick, 1986).

The USEPA Region II recently sampled catch basins and disposal wells at eight gas stations in Long Island, New York. Results (though inconclusive) show that many USEPA priority pollutants and other toxic compounds in the injection fluid may be highly in excess of the drinking water standards. USEPA Region II is currently sending out Class V well inventory/investigation forms to new car dealers in New York.

Another type of facility that discharges service bay wastewater is car dealerships which maintain service bays. A USEPA investigation in New Jersey revealed that a foreign car dealer was operating a Class IV well and injecting hazardous waste that contained trichloroethane (used for degreasing). Effective actions were taken and, consequently, the Director of the New York Class V UIC program sent nearly 1,400 permit applications to new car dealers (since the probability of injection practices similar to New Jersey were anticipated to be occurring in New York). Based on the monitoring information required for permit compliance, the State Director hopes to determine whether there is current injection of potentially hazardous or otherwise toxic wastes. Local governments do not regulate subsurface discharge of service bay wastewater at the present time.

Recommendations

As discussed previously, subsurface injection or discharge of potentially hazardous and toxic fluids from service bays at gasoline stations and car dealerships is a threat to human health and the environment.

An inventory of SBW disposal systems on a state level and, eventually, on a national basis is vital (New York, Puerto Rico, Idaho). This information can be employed in making an assessment of the contaminant mass loading and detrimental effects on the subsurface water quality. Unsewered areas, such as in some areas of Long Island, New York, may have large concentrations of SBW subsurface disposal facilities. Therefore, it may be appropriate to begin inventories in these unsewered areas and gradually work outward.

Iowa suggests requiring a permit to operate which includes information on construction features, a plan to utilize separators and holding tanks, and a plan to sample and analyze the injected fluids.

The following three recommendations are excerpts from Utah's report on Class V injection wells (1987):

A. These wells can be corrected by providing underground holding tanks (total containment) for the waste oils/fluids. These tanks would require regular off-loading to waste oil reclaimers. In Utah, there is economic incentive for a service station to sell waste oil to a reclaimer. The management of these wells would be accomplished at the local government level because they already enforce their building and sewer ordinances. Any inspections by state or federal staff would be a duplication of effort.

B. Communities with a water reclamation system commonly prohibit oil and grease discharges to their sewer. Consequently, some operators opt to discharge to dry wells as a "loophole" to the environmental regulations. Local building code and sewer pretreatment inspection should be able to locate and manage these wells.

C. The UIC program has not been effective in controlling this problem, but local government has. The UIC program can be more effective by educating those local government staff who conduct building and environmental inspections. This training will help locate these violators and hopefully solve the problem.

4.2.7 RECHARGE WELLS

4.2.7.1 Aquifer Recharge Wells (5R21)

Well Purpose

Artificial recharge is used primarily as a water resource management tool. The main objective of artificial recharge is to increase the amount of water entering an aquifer, thereby allowing a greater rate of ground-water withdrawal. This may be conducted during periods of excess surface water during rainy seasons, or it may involve importation of water from nearby areas.

During natural recharge through stratified soils, water collects or perches on less permeable subsurface layers. If recharge continues over a long period of time over a large area, perched water may approach the land surface and cause ponding. Under these conditions, recharge wells are very effective because they bypass the impermeable sublayer restrictions to vertical flow (Bianchi, et al., 1978) and inject directly into USDW.

In addition to water storage, artificial recharge through wells may be used for other reasons. Other applications include prevention of salt water intrusion into fresh water aquifers

(Section 4.2.7.2), disposal of wastewater treatment effluent (4.2.3.3), subsidence control (4.2.7.3), disposal of urban and agricultural runoff (4.2.1.2, 4.2.1.1), and aquifer remediation (4.2.8.3). This section will cover recharge wells which have been reported to serve the primary purpose of augmenting underground water supplies.

Inventory and Location

The inventory data collected by each State, Territory, and Possession account for a total of approximately 3,558 aquifer recharge wells (See Table 4-53). The wells included in this category have been limited to those which have been reported as recharge wells. New York has reported 3,000 recharge basins which have been included in the inventory as requested by the State of New York; however, it is unlikely that these would qualify as Class V facilities unless wells were installed to enhance basin drainage. The distinction between recharge well types and drainage well types is oftentimes difficult. Recharge wells may serve secondary purposes, such as drainage. Likewise, a secondary purpose of drainage wells may be aquifer recharge. This sometimes leads to a conflict of interest which, in turn, may increase contamination potential to some underground sources of drinking water.

Inventory information from other sources has been compiled by the Environmental and Ground Water Institute at the University of Oklahoma (O'Hare et al., 1986). Figures 4-55 and 4-56 reflect information from this source. See Appendix E for the reference to a list of facilities represented on Figure 4-56.

Many other recharge projects probably exist throughout the United States, its territories, and possessions. One would expect to find recharge wells in areas where populations are heavily dependent upon ground-water supplies for irrigation and domestic use, where evapotranspiration and extraction of water exceeds recharge, and in areas with restrictive subsurface layers which impede natural recharge.

Construction, Siting, and Operation

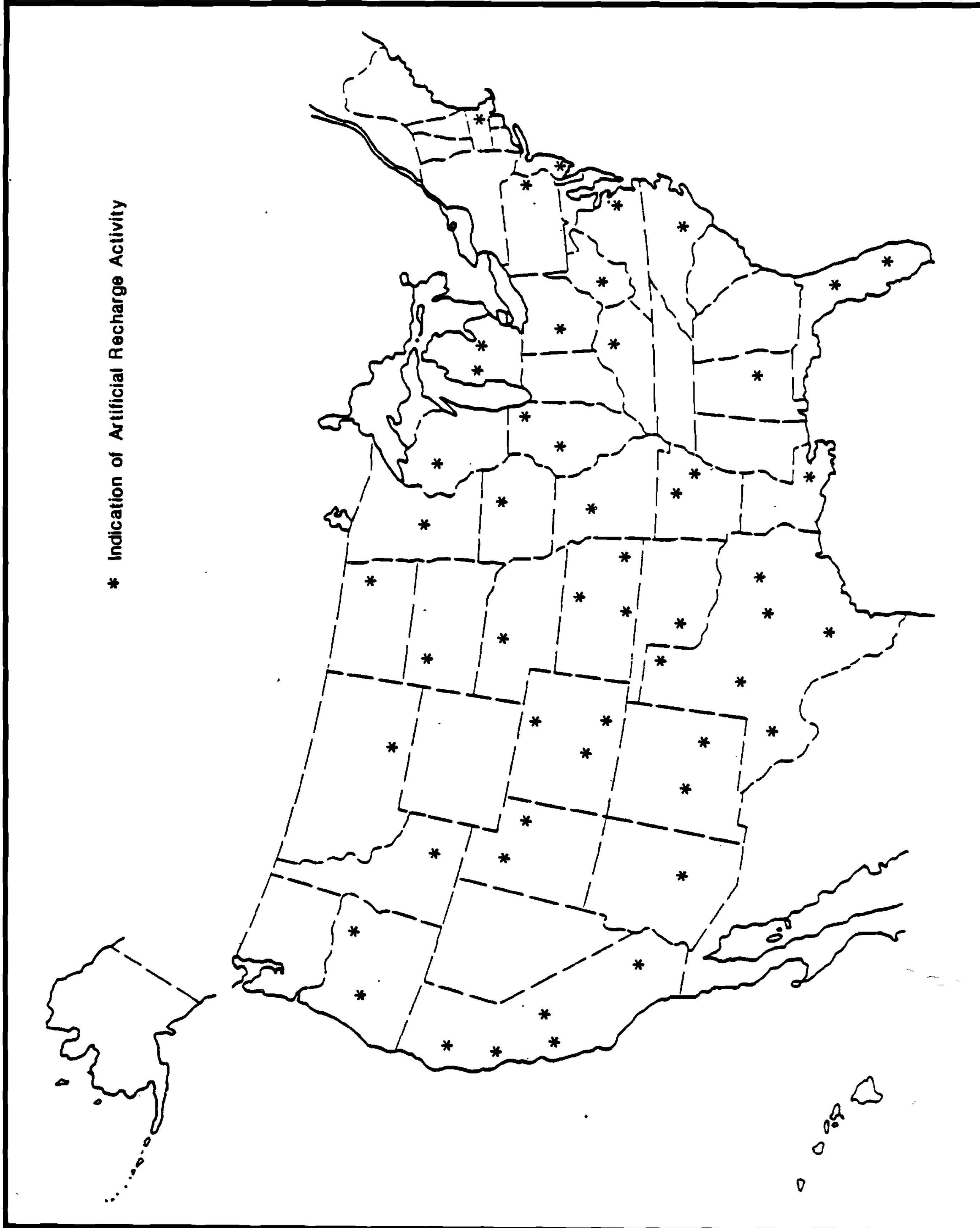
There are several methods of artificial recharge in widespread use. These include surface spreading, infiltration pits and basins, and wells or shafts. Surface spreading and infiltration basins recharge through surface seepage. Wells may be utilized in areas where existence of impermeable strata between the surface and the aquifer makes recharge by surface infiltration impractical. Wells are also used in urban areas where sufficient land for surface spreading is not available.

Construction, siting, and operation of recharge wells will depend on whether the well serves a secondary purpose. Aquifer recharge wells inventoried include some wells that also serve as

TABLE 4-53: SYNOPSIS OF STATE REPORTS FOR AQUIFER RECHARGE WELLS(5R21)

REGION & STATES	EPA REGION	Confirmed Presence Of Well Type	Regulatory System	Case Studies/ Info. available	Contamination Potential Rating
Connecticut	I	NO	N/A	NO	N/A
Maine	I	NO	N/A	NO	N/A
Massachusetts	I	NO	N/A	NO	N/A
New Hampshire	I	1 WELL	N/A	YES	LOW
Rhode Island	I	NO	N/A	NO	N/A
Vermont	I	NO	N/A	NO	N/A
New Jersey	II	NO	RULE/PERMIT	NO	N/A
New York	II	3000 BASINS	N/A	NO	N/A
Puerto Rico	II	NO	N/A	NO	N/A
Virgin Islands	II	NO	N/A	NO	N/A
Delaware	III	NO	N/A	NO	N/A
Maryland	III	NO	N/A	NO	N/A
Pennsylvania	III	NO	N/A	NO	N/A
Virginia	III	NO	N/A	NO	N/A
West Virginia	III	NO	N/A	NO	N/A
Alabama	IV	NO	N/A	NO	N/A
Florida	IV	349 WELLS	PERMIT	YES	3RD HIGHEST/8 TYPES
Georgia	IV	NO	N/A	NO	N/A
Kentucky	IV	NO	N/A	NO	N/A
Mississippi	IV	NO	N/A	NO	N/A
North Carolina	IV	NO	N/A	NO	N/A
South Carolina	IV	NO	N/A	NO	N/A
Tennessee	IV	NO	N/A	NO	N/A
Illinois	V	1 WELL	RULE	NO	N/A
Indiana	V	NO	N/A	NO	N/A
Michigan	V	NO	N/A	NO	N/A
Minnesota	V	1 WELL	N/A	NO	N/A
Ohio	V	NO	N/A	NO	N/A
Wisconsin	V	NO	N/A	NO	N/A
Arkansas	VI	NO	N/A	NO	N/A
Louisiana	VI	NO	N/A	NO	N/A
New Mexico	VI	30 WELLS	REGISTRATION	NO	LOW
Oklahoma	VI	NO	N/A	NO	N/A
Texas	VI	44 WELLS	PERMIT +	YES	V LOW X
Iowa	VII	NO	N/A	NO	N/A
Kansas	VII	4 WELLS	N/A	NO	POSSIBLE
Missouri	VII	NO	N/A	NO	N/A
Nebraska	VII	4 WELLS	RULE	NO	VARIABLE
Colorado	VIII	NO	N/A	NO	N/A
Montana	VIII	NO	N/A	NO	N/A
North Dakota	VIII	NO	N/A	NO	N/A
South Dakota	VIII	NO	N/A	NO	N/A
Utah	VIII	NO	RULE/PERMIT	NO	N/A
Wyoming	VIII	7 WELLS	PERMIT	YES	6TH HIGHEST/10 TYPES
Arizona	IX	51 WELLS	PERMIT	YES	LOW *
California	IX	52 WELLS	PERMIT	YES	UNKNOWN
Hawaii	IX	NO	N/A	NO	N/A
Nevada	IX	NO	N/A	NO	N/A
American Samoa	IX	NO	N/A	NO	N/A
Tr. Terr. of P	IX	NO	N/A	NO	N/A
Guam	IX	NO	N/A	NO	N/A
CNMI	IX	NO	N/A	NO	N/A
Alaska	X	NO	N/A	NO	N/A
Idaho	X	7 WELLS	PERMIT>18 FT	YES	7TH HIGHEST/14 TYPES
Oregon	X	NO	N/A	NO	N/A
Washington	X	7 WELLS	N/A	NO	N/A

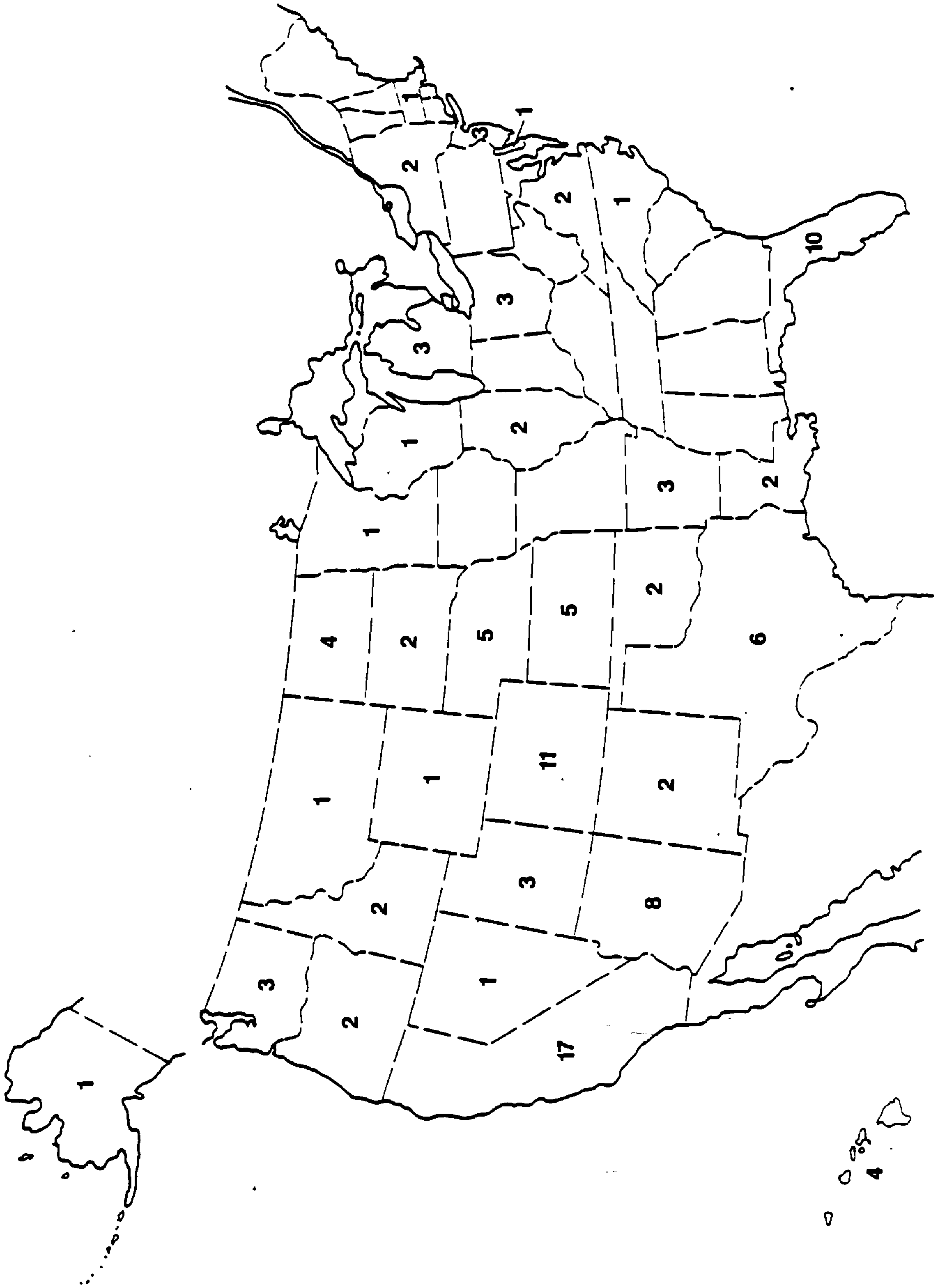
NOTE: SOME NUMBERS IN THIS TABLE ARE ESTIMATES.
+ WHERE UNDERGROUND WATER DISTRICTS HAVE BEEN ESTABLISHED
X PROVIDED POLLUTANTS ARE KEPT OUT OF RECHARGE WATER
* PROVIDED PROPER DESIGN, CONSTRUCTION AND OPERATION



INDICATION OF ARTIFICIAL RECHARGE ACTIVITY FROM LITERATURE AND/OR VERBAL COMMUNICATION WITH VARIOUS AGENCIES

(from O'Hare et al, 1986)

Figure 4-55



NATIONAL ARTIFICIAL RECHARGE ACTIVITY
PAST AND PRESENT PROJECTS, DEMONSTRATIONS, PILOT PROJECTS, EXPERIMENTS, AND STUDIES

(after O'Hare et al, 1986)

Figure 4-56

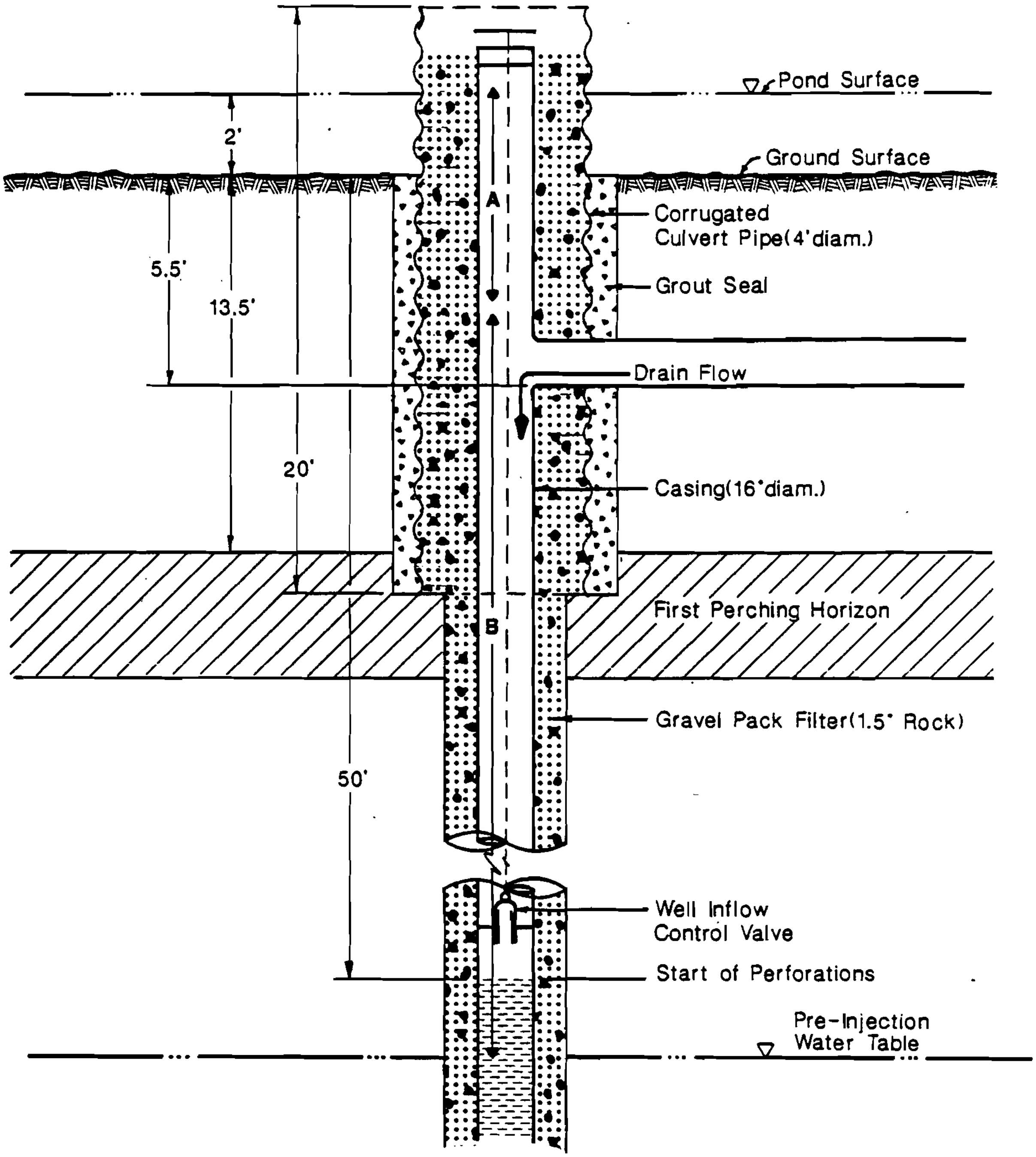
drainage and disposal wells. This can often pose a potential threat to the receiving aquifer, especially when the injection zone is a drinking water supply aquifer.

The subsurface drain collector - deep well recharge system known as Leaky Acres Recharge Project in Fresno, California illustrates construction specifics of a recharge well used exclusively for the purpose of aquifer recharge. The well was constructed using a reverse rotary rig to bore a 34-inch diameter hole. The injection casing is 16 inches in diameter. A 4-foot diameter corrugated culvert was used as conductor pipe to isolate the upper drain collector zone of the soil profile from the deeper aquifers. The conductor was grouted from ground surface to a depth of 20 feet into the first horizon perching zone. The casing perforations start at a depth of 50 feet and extend to full depth of the 250 foot borehole (Figure 4-57). The recharge well is located at the center of a 10-acre ponding basin. Injected water is diverted from an areal canal, filtered through surface soils, and collected through a subsurface tile drain system for injection.

Many of the reported recharge wells from Florida are actually "connector" wells which are also used to dewater phosphate mining areas. These wells are constructed through an impermeable perching layer of strata close to the surface, thereby draining the perched water to a deeper water supply aquifer. This results in recharge of the deep aquifer through the constructed well, which "connects" the deep aquifer to the shallow perched aquifer. These wells are typically 12 inches or greater in diameter and approximately 200-300 feet deep. Wells are usually cased with PVC pipe from the surface to the injection zone. The PVC pipe is slotted and screened at the "intake" zone within the surficial aquifer. Water in this zone drains into the slotted casing and cascades through the pipe into the deeper injection zone.

Many of the reported recharge wells from Texas are "dual purpose" wells which alternately produce ground water for irrigation and inject agricultural surface runoff into the supply aquifer. Texas also reports recharge wells northeast of El Paso, sited at a domestic wastewater treatment plant. The El Paso area wells serve the secondary purpose of treated waste disposal for the treatment plant. Plant recharge/disposal wells are constructed to a depth of approximately 800 feet (See Figure 4-58.) The Teton Village Wastewater Treatment Plant in Wyoming also utilizes injection wells for recharge and waste disposal. Construction, siting, and operation variations exist throughout the United States. The variables are determined by local hydrogeologic conditions and any secondary purposes of wells. The above examples provide a representative sampling of wells which illustrate the diversity of aquifer recharge application.

One of the major operational problems with recharge injection wells is clogging. During extended periods of injection, some clogging generally occurs near the borehole due to accumula-

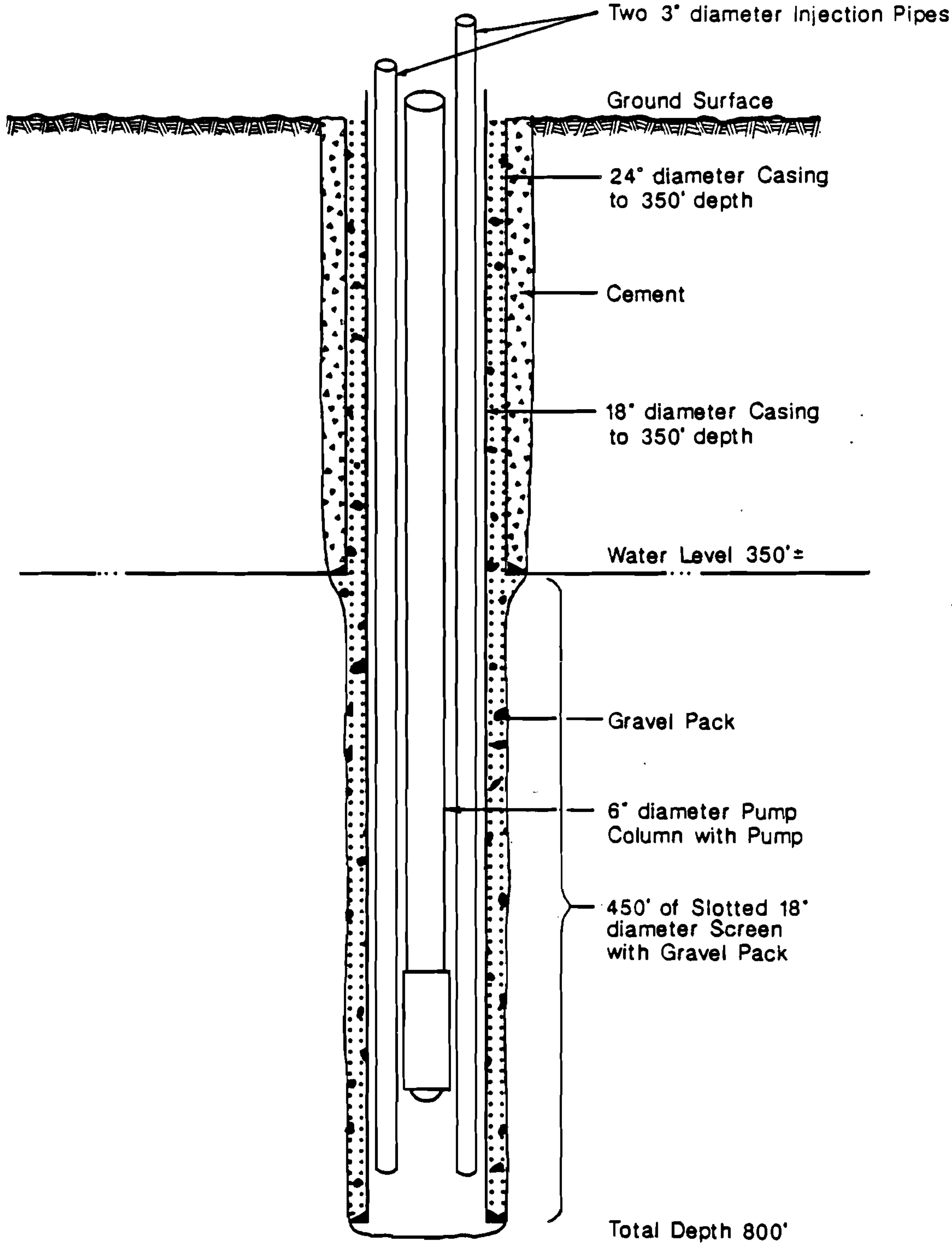


A Collection Head
B Maximum Injection Head

SCHEMATIC OF FRESNO
RECHARGE WELL CONSTRUCTION

(from W.C. Bianchi, et al, 1978)

Figure 4-57



Scale: None

DIAGRAM OF RECHARGE/DOMESTIC WASTE DISPOSAL WELL IN EL PASO, TEXAS

(after Texas DWR, 1986)

Figure 4-58

tion of suspended solids. Design of a recharge well to allow redevelopment or removal of the clogged aquifer interface near the borehole is possible. Redevelopment procedures for wells at the Leaky Acres Project in Fresno, California involve shifting of a coarse, well-rounded gravel pack at the injection zone. This movement dislodges the sand and clogging fines from the aquifer, thus creating a clean injection face. Dislodged material is pumped out of the well during redevelopment procedures.

Other redevelopment practices include cleaning of the injection zone through methods such as flush pumping, surging, and jetting. The injection wells at El Paso utilize a downhole pump (Figure 4-58) to redevelop the well by surging and pumping. This is a common redevelopment procedure. Clogging may also result from biological activity, chemical incompatibility, and entrained air. Injection zone interactions will be discussed further in the following section.

Injected Fluids and Injection Zone Interactions

Injection fluid characteristics will vary depending on the source of injection waters. Water quality transformations that might occur during passage of injected water through an aquifer include adsorption, ion exchange, precipitation and dissolution, chemical oxidation, biological nitrification and denitrification, aerobic or anaerobic degradation of organic substrates, mechanical dispersion, and filtration.

Field experience has shown that recharge wells lose capacity with time, even with refined surface water pretreatment, because of gradual penetration of clogging materials. Pretreatment methods include the use of settling basins and soil filtration before injection. These procedures are effective in removing much of the clogging material. Attempts have been made to chemically disperse deeply-trapped sediment and move it more deeply into the aquifer, but concern about effects of this approach on water quality and producing wells in the area has limited this technique. Sodium Hexametaphosphate is one chemical that is sometimes added for clay particle dispersal. Periodic cleaning of the well will also decrease clogging caused by suspended solids.

In addition to suspended solids, clogging may result from the presence of air bubbles in recharge water, bacteria growth, and chemical reactions between the receiving aquifer water and injection water. These problems can be remedied by injecting chemically and thermally compatible, well filtered water, and preventing turbulence from cascading water during injection.

Mechanical jamming from rearrangement of grains in the aquifer reduces pore volume and may result from alternatively pumping and injecting fluids through the same well. This is generally not a major problem with properly designed and constructed wells.

Some types of recharge wells inject into the vadose or unsaturated zone above the aquifer. These wells allow the injectate to bypass a significant portion of materials between the surface and the injection zone, but injected fluids must pass through some material before reaching the saturated zone. Passage through part of the unsaturated zone will allow attenuation of some constituents before water reaches an aquifer.

The major advantages of direct aquifer injection through wells are the immediate response of aquifer water levels and a relatively high rate of recharge. Disadvantages of direct aquifer injection include: 1) direct introduction of water and any chemical or biological contaminants that may be present in the recharge water, 2) recharge using pressurized injection could result in extensive formation fracturing, and 3) introduction of suspended solids may cause local clogging of the aquifer and contamination due to adsorption and transportation of pollutants. The solids of greatest concern are the colloidal clays, because they resist most forms of settling and filtration and are, therefore, difficult to remove from waters prior to injection (Dvoracek, 1971).

Hydrogeology and Water Use

A thorough and detailed knowledge of hydrogeologic features is necessary for adequately selecting a recharge site. Some parameters to be considered include geologic and hydraulic boundaries, tectonic boundaries, inflow and outflow of water, porosity, hydraulic conductivity, transmissivity, storage capacity, water resources available for recharge, natural recharge, water balance, lithology, and depth of the aquifer. Special attention is required for karstic regions, where injected water may rapidly discharge to the surface through underground caverns. In some areas, injection below karstic discharge outlets can minimize volume of discharge after recharge (U.N., D.E.S.A., 1975).

Populations in arid climates are generally more dependent upon ground water, as surface water is usually not readily available. Heavy ground-water demands in these areas may cause depletion in the supply aquifer. Irrigated agricultural areas of California and Arizona are prime examples of depletion resulting from heavy ground-water demand.

Contamination Potential

Based on the rating system described in Section 4.1, aquifer recharge wells are assessed to pose a high to low potential to contaminate USDW. These facilities typically do inject into or above Class I or Class II USDW. Typical well construction, operation, and maintenance vary considerably but ideally would not allow fluid injection or migration into unintended zones. Injection fluids should be of equivalent or better quality (relative to standards of the National Primary or Secondary Drinking Water Standards and RCRA regulations) than the fluids within any USDW in connnection with the injection zone. However, some case studies revealed that injection fluids are of poorer quality (relative to standards of the National Primary or Secondary Drinking Water Standards) than the fluids within any USDW in communication with the injection zone. Based on injectate characteristics and possibilities for attenuation and dilution, injection does occur in sufficient volumes or at sufficient rates to cause an increase in concentration (above background levels) of the National Primary or Secondary Drinking Water Regulation parameters in ground water, or endanger human health or the environment beyond the facility perimeter when contaminants are present in the recharge water.

Ground-water quality may be adversely affected by injection recharge practices if the quality of the injection water is not closely monitored. Serious consequences may result if low quality water is injected directly into utilized underground sources of drinking water. Recharge wells may introduce contaminants to supply aquifers from shallower perched water zones if wells are not properly designed and constructed to prevent communication between zones.

Florida's "connector" wells are specifically designed to allow communication between the surficial perched aquifer and the deeper supply aquifer. A case study on these aquifer connector wells was carried out by the Florida Department of Environmental Regulation, Bureau of Groundwater Protection. This study concluded that 10-20% of the connector wells inject water that greatly exceeds primary drinking water standards for gross alpha radiation, and another 30-40% inject water that slightly exceeds that standard. The concentration of combined radium 226/228 exceeds primary drinking water standards in about 10% of these wells. Injectate consistently exceeds secondary drinking water standards for iron.

Additionally, some of these wells may be located in close proximity to phosphate chemical plant waste disposal areas. These wells may provide a conduit to the water supply aquifer for possible toxic waste plumes originating at chemical plant waste disposal sites. Ground-water samples from the surficial aquifer have been obtained within a contaminant plume from a waste disposal area. Samples taken revealed possibilities of extreme contamination. Records show some cases of sulfate and fluoride concentrations in excess of 5,000 mg/l, sodium concentrations in excess of 2,000 mg/l, chromium concentrations of 2.0 mg/l (forty times the primary drinking water standard), and extremely acidic pH values below 2. Injectate volumes and concentrations will vary according to precipitation amounts and drainage patterns.

Florida receives approximately 53 in/yr precipitation of which approximately 14 in/yr comprises runoff (Pettyjohn, et al., 1979). The case study carried out by the FDER Bureau of Groundwater Protection is listed in Appendix E of this report.

Many inventoried recharge wells in Texas are "dual purpose" irrigation supply/injection wells located on the High Plains. Farmers have been practicing this recharge method for 20-30 years. Recharge wells are also sited in playa lakes in the area. These lakes develop impermeable clay layers along their bottoms from settling solids. Wells are constructed to drain the land and recharge the aquifer. Water injected into "dual purpose" wells and playa lake recharge wells is agricultural runoff. The injection zone is the Ogallala aquifer. Ten wells were inventoried in the High Plains area, and two of these were sampled by the Texas Department of Water Resources for injectate quality. (See Appendix E.) Sampling results indicated that injectate water quality was of higher standards than aquifer water quality at the time the sample was taken (March-April, 1982). This sampling episode may not be representative of typical conditions throughout the year. Nitrate levels in the aquifer water sampled ranged from 8.4 mg/l to 43 mg/l in the two wells (the primary drinking water standard for nitrate is 45 mg/l). This variation raises questions about the origin of nitrate concentrations in the second well. Injectate waters, when sampled and analyzed for nitrate, measured only .04 mg/l. Common chemical contaminants associated with agricultural runoff include nitrates, phosphorus, pesticides, herbicides, pathogens, metals, and total dissolved solids.

Domestic wastewater may contain nitrogen, bacteria, viruses, and organic or inorganic pollutants. Effluent is more susceptible to toxic chemical contaminants if it serves an industrial sector. Refer to Section 4.2.3.3 for more in depth information on domestic wastewater disposal wells.

In summary, the contamination potential of properly designed, constructed, and operated recharge wells is low (proper operation would include careful injectate monitoring to prevent introduction of poor quality fluids). However, many inventoried wells may be improperly designed, constructed, and/or operated and, therefore, must be assessed as a moderate (Texas dual purpose wells) to high (Florida connector wells) contamination threat. Contamination potential is directly dependent upon injectate quality in a properly designed and constructed well.

Current Regulatory Approach

Aquifer recharge wells are authorized by rule under Federally administered UIC programs (see Section 1). State reports were generally not specific with regard to regulatory jurisdiction; however, information from the following States is pertinent. Injection wells in Florida are currently permitted through the Florida Department of Environmental Regulation. Recharge wells on the High Plains of Texas are permitted by the High Plains Underground Water Conservation Districts in areas where underground water districts have been established. The only permit requirement for these wells is that no pollutants enter the fresh water aquifer through them. A well completion report must also be furnished to the local district by the well owner (Texas DWR, 1986). Arizona has passed regulations for ground-water quality protection and has established an aquifer protection permit program under the Environmental Quality Act of 1986. Arizona House Bill 2209 deals specifically with regulation of aquifer recharge and underground storage projects.

Recommendations

The Florida and Nebraska state reports indicate that major concerns for aquifer recharge injection wells include injectate water quality monitoring, and proper design, construction, and operation of wells. Nebraska recommends that injectate water quality generally be of equivalent or better quality than water contained in the receiving aquifer.

The Arizona report suggests that regulatory personnel should set standards for aquifers on a case by case basis to determine aquifer water quality and allowable quality parameters for injectate waters. For example, if the aquifer serves as a drinking water source, water quality standards should not exceed drinking water standards. Local hydrogeologic information is necessary to adequately assess each site and recharge situation.

Supporting Data

Referenced supporting data for Aquifer Recharge Wells is listed in Appendix E of the report.

4.2.7.2 Salt Water Intrusion Barrier Wells (5B22)

Well Purpose

Artificial recharge is used in many coastal areas to control the intrusion of salt water into fresh water aquifers. Intrusion of salt water is predominantly due to reversal of the ground-water gradient caused by pumping. Over-pumping of fresh water in coastal areas allows salt water to flow inland and contaminate fresh ground water. Since as little as two percent sea water in fresh water can render it unpotable, controlling intrusion has received considerable attention.

Several methods have been proposed to control salt water intrusion. These include: (1) control of pumping patterns; (2) construction of an impermeable subsurface barrier using materials such as sheet piling, puddled clay, emulsified asphalt, cement grout, bentonite, silica gel, calcium acrylate, or plastics; (3) formation of an extraction barrier whereby a continuous pumping trough is formed by a line of wells adjacent to the ocean, (4) use of combination injection - extraction barriers utilizing injection and extraction wells; (5) direct artificial recharge to raise groundwater levels; and (6) maintenance of fresh water ridge along the coast utilizing artificial recharge (D.K. Todd, 1974). Saline water may also intrude fresh water aquifers in inland areas where fresh and saline waters are in contact. The most usual cause of this problem is overpumping of the fresh water aquifer. This allows upconing of saline water to the pumping well.

Inventory and Location

The inventory data collected by the States, Territories, and Possessions account for a total of 164 saline water intrusion barrier wells. Of this total, 155 wells are located in the state of California. Washington reported a total of 7, and Florida reported 2. Table 4-54 provides a synopsis of information from the State reports.

The West Coast Basin Barrier Project in Los Angeles County, is the first and largest intrusion barrier project in the State of California. This project utilizes 106 injection wells and stretches approximately 10 miles along the coast.

It is certain that uninventoried wells exist. One operation of significance which was not included in inventory numbers is the Palo Alto Intrusion Barrier Project in Santa Clara County, California. This operation is located adjacent to the southern tip of San Francisco Bay. Treated sewage is being injected and extracted at this location to form a fresh water ridge barrier against intruding saline bay waters (see list of applicable Case Studies, Appendix E).

Construction, Siting, and Operation

Utilizing injection wells to control sea water intrusion may be accomplished by utilizing direct recharge, whereby groundwater levels are raised and maintained through injection of high quality water; or by maintaining a fresh water ridge, whereby water is injected through a line of wells near the coast. The most complex method of maintaining a fresh water ridge is an injection-extraction system whereby a ridge and pumping trough is formed (Todd, 1974). This method requires a smaller volume of fresh water for injection than does the system used to maintain a fresh water ridge. However, it also requires twice as many wells.

Wells may be utilized in a variety of ways to form a fresh water barrier against salt water intrusion. Injection or

TABLE 4-54: SYNOPSIS OF STATE REPORTS FOR SALINE WATER INTRUSION BARRIER WELLS(5B22)

REGION & STATES	EPA REGION	Confirmed Presence Of Well Type	Regulatory System	Case Studies/ Info. available	Contamination Potential Rating
Connecticut	I	NO	N/A	NO	N/A
Maine	I	NO	N/A	NO	N/A
Massachusetts	I	NO	N/A	NO	N/A
New Hampshire	I	NO	N/A	NO	N/A
Rhode Island	I	NO	N/A	NO	N/A
Vermont	I	NO	N/A	NO	N/A
New Jersey	II	NO	RULE/PERMIT	NO	N/A
New York	II	NO	N/A	NO	N/A
Puerto Rico	II	NO	N/A	NO	N/A
Virgin Islands	II	NO	N/A	NO	N/A
Delaware	III	NO	N/A	NO	N/A
Maryland	III	NO	N/A	NO	N/A
Pennsylvania	III	NO	N/A	NO	N/A
Virginia	III	NO	N/A	NO	N/A
West Virginia	III	NO	N/A	NO	N/A
Alabama	IV	NO	N/A	NO	N/A
Florida	IV	2 WELLS	PERMIT	NO	N/A
Georgia	IV	NO	N/A	NO	N/A
Kentucky	IV	NO	N/A	NO	N/A
Mississippi	IV	NO	N/A	NO	N/A
North Carolina	IV	NO	N/A	NO	N/A
South Carolina	IV	NO	N/A	NO	N/A
Tennessee	IV	NO	N/A	NO	N/A
Illinois	V	NO	N/A	NO	N/A
Indiana	V	NO	N/A	NO	N/A
Michigan	V	NO	N/A	NO	N/A
Minnesota	V	NO	N/A	NO	N/A
Ohio	V	NO	N/A	NO	N/A
Wisconsin	V	NO	N/A	NO	N/A
Arkansas	VI	NO	N/A	NO	N/A
Louisiana	VI	NO	N/A	NO	N/A
New Mexico	VI	NO	N/A	NO	N/A
Oklahoma	VI	NO	N/A	NO	N/A
Texas	VI	NO	N/A	NO	N/A
Iowa	VII	NO	N/A	NO	N/A
Kansas	VII	NO	N/A	NO	N/A
Missouri	VII	NO	N/A	NO	N/A
Nebraska	VII	NO	RULE	NO	N/A
Colorado	VIII	NO	N/A	NO	N/A
Montana	VIII	NO	N/A	NO	N/A
North Dakota	VIII	NO	N/A	NO	N/A
South Dakota	VIII	NO	N/A	NO	N/A
Utah	VIII	NO	RULE/PERMIT	NO	N/A
Wyoming	VIII	NO	N/A	NO	N/A
Arizona	IX	NO	N/A	NO	N/A
California	IX	155 WELLS	PERMIT	YES	LOW +
Hawaii	IX	NO	N/A	NO	N/A
Nevada	IX	NO	N/A	NO	N/A
American Samoa	IX	NO	N/A	NO	N/A
Tr. Terr. of P	IX	NO	N/A	NO	N/A
Guam	IX	NO	N/A	NO	N/A
CNMI	IX	NO	N/A	NO	N/A
Alaska	X	NO	N/A	NO	N/A
Idaho	X	NO	N/A	NO	N/A
Oregon	X	NO	N/A	NO	N/A
Washington	X	7 WELLS	PERMIT	NO	LOW

extraction wells may be separately, or a combination injection-extraction system may be employed.

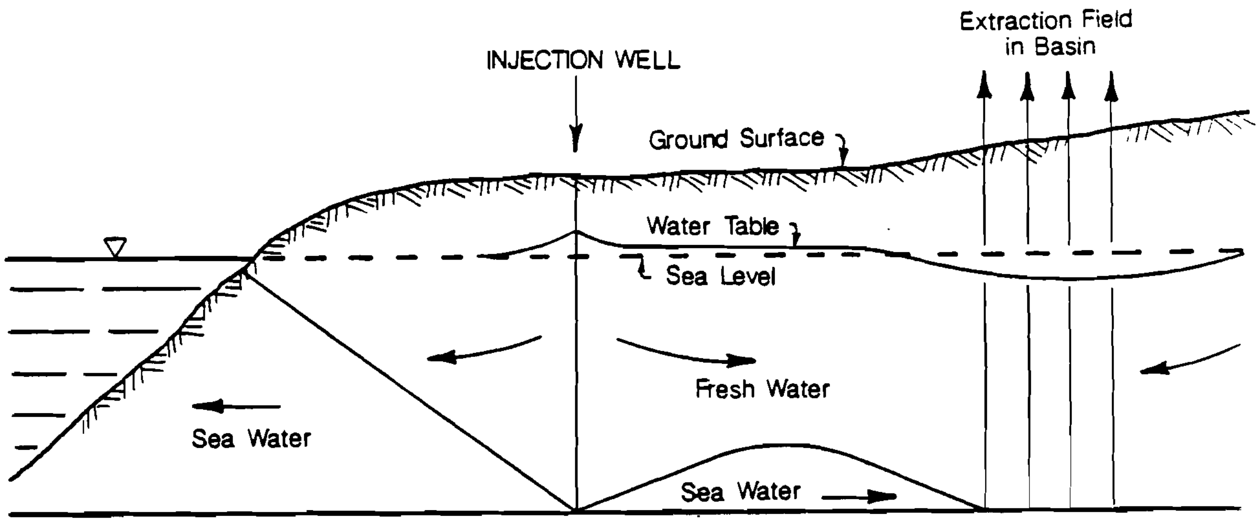
If injection wells alone are utilized, these wells will be sited along the coast, and fresh water will be injected to form a fresh water barrier (see Figure 4-59). If extraction wells alone are utilized, they will be sited along the coast to extract salt water so that it does not further intrude into fresh water aquifers. A combination injection-extraction system may be utlized to extract salt water along the coast when some intrusion has taken place, while simultaneously injecting fresh water further inland (see Figure 4-60). An injection-extraction system may also be utilized to inject water along the coast to form a fresh water ridge, while simultaneously extracting this water further inland. This may prevent aquifer contamination when injectate water quality is low relative to that found within the aquifer. An example of this system exists at Palo Alto, California, and will be discussed further in this report.

Figure 4-61 illustrates construction features of salt water intrusion barrier injection wells used at the Alamitos Project in Los Angeles. These wells utilize 12-inch diameter stainless steel casing and are approximately 300 feet deep. Injection wells for sea water intrusion barriers commonly have injection capacities of 0.5-1.5 cubic feet per second (cfs). Attempts to increase capacities by using high injection pressures may result in problems such as formation fracturing. Cases exist in which the ground surface near the well settled, the well casing buckled, the gravel pack was plugged, and hydraulic communication between aquifers was established due to overpressuring the aquifer (Toups, 1974).

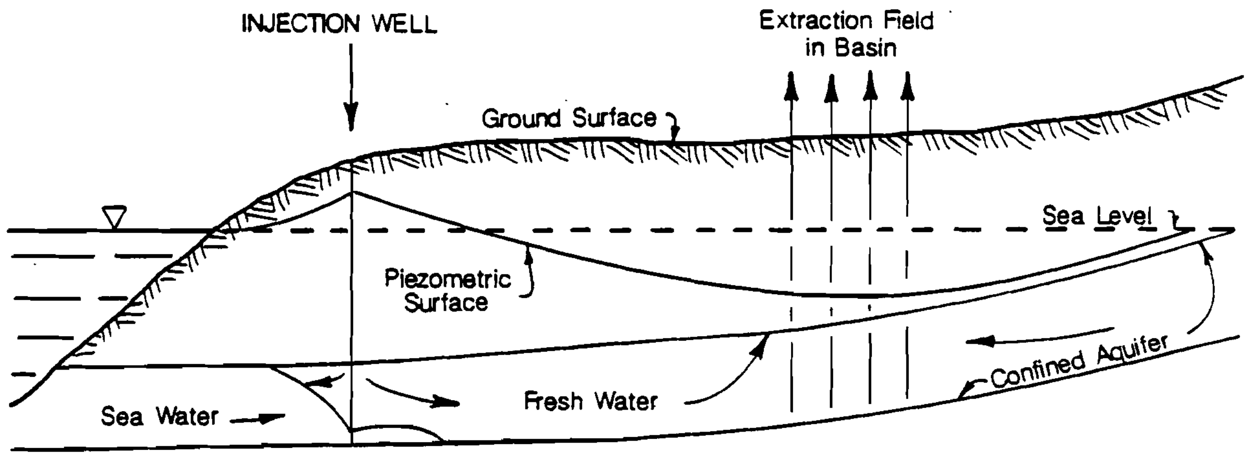
Injected Fluids and Injection Zone Interactions

Characteristics of injection fluids will vary depending upon the source. An intrusion barrier system has been implemented in Palo Alto, California which injects effluent from an advanced sewage treatment plant as fresh water in the injection-extraction system. The effluent is injected along the coast and is later extracted by wells farther inland to prevent contamination of the drinking water supply. After extraction, the diluted effluent is made available for industrial and agricultural purposes (Sheahan, 1977). Examples of other injection fluid sources include surface runoff, which may be comprised of urban and agricultural runoff, and imported surface waters from canals, rivers, and lakes.

Since injected fresh water is less dense than intruding salt water it will overlie the intruded fluid, and a transition zone will exist between fresh and saline waters. The purpose of injected fluid is to keep the transitional and saline waters from intruding into fresh water zones.



IN AN UNCONFINED GROUNDWATER BASIN

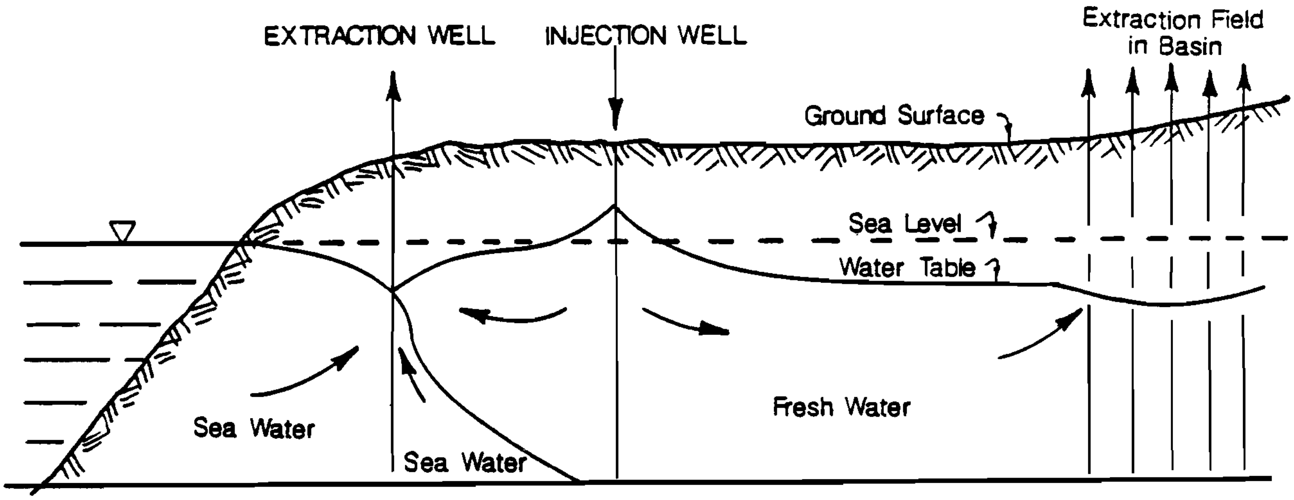


IN A CONFINED GROUNDWATER BASIN

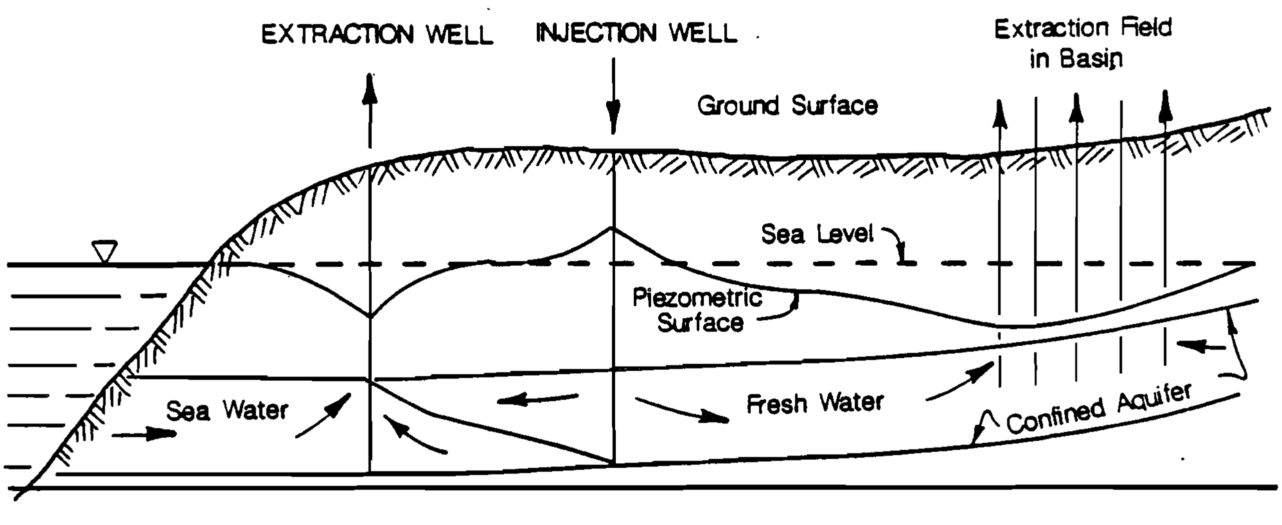
HYDROLOGIC CONDITIONS WITH A
FRESH WATER RIDGE ACTING AS
A SEA WATER BARRIER

(after Todd, D.K., 1974)

Figure 4-59



IN AN UNCONFINED GROUNDWATER BASIN

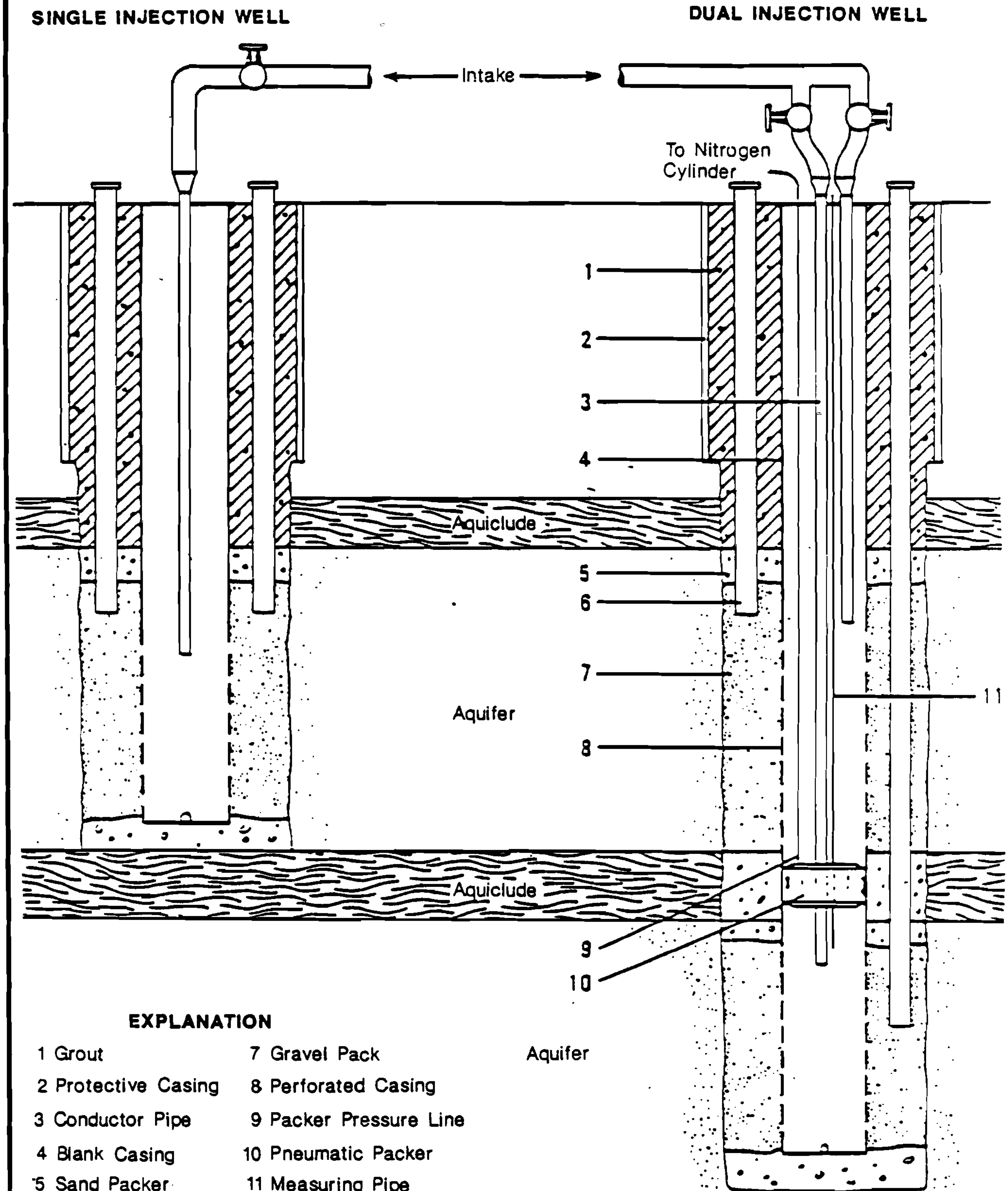


IN A CONFINED GROUNDWATER BASIN

HYDROLOGIC CONDITIONS WITH A COMBINATION INJECTION-EXTRACTION SEA WATER BARRIER

(after Todd, D.K., 1974)

Figure 4-60



EXPLANATION

1 Grout
2 Protective Casing
3 Conductor Pipe
4 Blank Casing
5 Sand Packer
6 Tremie Pipe
7 Gravel Pack
8 Perforated Casing
9 Packer Pressure Line
10 Pneumatic Packer
11 Measuring Pipe

Aquifer

SALT WATER INTRUSION BARRIER WELLS
LOS ANGELES, CALIFORNIA

(from Texas DWR, 1984)

Figure 4-61

Two major problems can occur within the injection zone as a result of this type of injection, both dependent upon the nature of the injected fluid. The first is that chemical or biological contaminants, associated with agricultural or urban runoff and treated sewage, can be introduced into the injection zone with the recharge water. Second, suspended solids can be introduced with the injected fluid, causing local clogging within the injection zone and contamination due to adsorption and transportation of pollutants. Clogging solids of greatest concern in are colloidal clays. Colloids resist most forms of settling and filtration and are, therefore, difficult to remove from waters prior to injection (Dvoracek, 1971).

Clogging problems may also be caused by recharge with water that is not chemically compatible with receiving water or aquifer material. These problems include precipitation of solids and the swelling of clay particles present in the aquifer. For example, if the water used for recharge has a higher sodium-calcium ratio than the receiving water, and clay particles are present in the formation, swelling can occur. Ion exchange occurs between calcium and sodium ions adsorbed onto clay minerals. The sodium ions hydrate more than the calcium ions which causes the clay particles to swell, resulting in decreased aquifer pore space and permeability. These types of reactions can be prevented by choosing an alternate recharge water or by treating the recharge water prior to injection to bring it into equilibrium with the aquifer system.

There are a variety of reactions that may occur during injection into an aquifer. Among the most notable are adsorption, ion exchange, precipitation and dissolution, oxidation, biological nitrification and denitrification, aerobic and anaerobic degradation of organic substrates, mechanical dispersion, and filtration. The relative influence of reactions such as these must be addressed on a site-specific basis, and will be dependent upon the chemical nature of the fluids involved.

Hydrogeology and Water Use

Studies by the US Geological Survey of saline ground water (1965) indicate that approximately two thirds of the U.S. is underlain by ground water containing more than 1,000 mg/l of dissolved solids. Coastal intrusion has been recognized to occur in almost all of the states bordering the sea. Most serious are those sections where coastal urban areas have led to exploitation of local ground-water resources. The states of California, Texas, Florida, New York (Long Island), and Hawaii have been affected to the largest extent. The problem is also known internationally (Todd, 1974).

The most significant hydrogeologic parameters to address in assessing this well type are the rate at which intrusion is occurring and the nature of the chemical interactions between sea water and the injection fluid. Increases in intrusion rates are due to decreased hydraulic head resulting from water extraction via wells tapping the fresh water aquifer. Intrusion is also controlled largely by lithologic and structural features within the area and their influence on hydraulic gradients and transmissivities.

Contamination Potential

Based on the rating system described in Section 4.1, salt water intrusion barrier wells are assessed to pose a low potential to contaminate USDW. These wells typically do inject into or above Class I or Class II USDW. Typical well construction, operation, and maintenance would not allow fluid injection or migration into unintended zones. Injection fluids should be of equivalent or better quality (relative to standards of the National Primary or Secondary Drinking Water Standards and RCRA regulations) than the fluids within any USDW in connection with the injection zone. Based on injectate characteristics and possibilities for attenuation and dilution, injection does not occur in sufficient volumes or at sufficient rates to cause an increase in concentration (above background levels) of the National Primary or Secondary Drinking Water Regulation parameters in groundwater, or endanger human health or the environment in a region studied on a group/area basis.

The contamination potential posed by wells of this type depends heavily upon the type of injectate used and treatment provided. Significant variation in sources for injectate water exists. Effluent from advanced sewage treatment plants, surface runoff, and imported surface waters are the most notable sources of injectate. Water from these sources may contain constituents at levels in excess of National Primary and Secondary Drinking Water Standards, especially if injectate is not sufficiently treated. In addition, constituent levels set forth in 40 CFR, Part 261, Subparts C and D may be exceeded owing to the influence of pesticides, agricultural nutrients, and urban chemicals. At the present time, no data exist to substantiate this.

This sort of injection generally occurs within currently or potentially useable drinking water aquifers. Support for this statement stems from an indication that sea water intrusion is most prominent in regions drawing heavily from wells for agricultural and domestic purposes. If contaminants associated with improperly treated domestic wastes or agricultural and urban runoff are injected directly into presently used drinking water supplies, serious health and safety problems could develop. Injectate quality is especially important since salt water intrusion barrier projects inject large volumes of water. Degradation of USDW on a local or regional scale could occur if injectate water quality is poor.

The contamination potential for saline water intrusion barrier wells is considered low, provided the wells are properly designed, constructed, and operated, and injectate quality is adequately monitored. These wells are designed specifically to remediate contamination problems associated with intrusion.

Current Regulatory Approach

Salt water intrusion barrier wells are authorized by rule under Federally-administered UIC programs (see Section 1). The California Regional Water Quality Control Boards regulate saline water intrusion barrier wells in California. A waste discharge permit is required statewide for salt water intrusion barrier wells injecting waste-water, such as sewage effluent. Injection wells in the State of Washington are currently regulated under the nondegradation provisions of the Water Pollution Control Act and the Water Resources Act. Other Washington State laws applicable to Class V wells include Chapter 90 of the Regulation of Public Groundwaters, the Pollution Disclosure Act, and the Planning Enabling Act. The Florida Department of Environmental REgulation permits Class V wells in Florida. Inspection and surveillance of Class V wells is under the jurisdiction of FDER District offices.

Recommendations

The following recommendations regarding saline water intrusion barrier wells appear in the California report. Proper design, construction, and operation is required to prevent possible contamination resulting from communication with surface waters and other penetrated zones. Wells must be properly cased, cemented, and operated to prevent this problem.

Processes and fluids involved with salt water intrusion barrier projects are variable and often site specific. Lithologic and hydrogeologic parameters that influence salt water intrusion in coastal areas should be defined, and coastal USDW should be defined and characterized with regard to water quality in areas experiencing saline water intrusion problems. Interactions of injected fluids with formation fluids also should be characterized for operating barrier projects. If it can be shown that potentially usable USDW are being degraded by this injection, immediate steps toward corrective action should be initiated.

Because these projects are typically of a broad scope, inventory maintenance and update should not be difficult. A regularly updated inventory is fundamental to maintaining proper regulatory authority.

Supporting Data

The referenced supporting data for Saline Water Intrusion Barrier Wells is listed in Appendix E of the report.

4.2.7.3 Subsidence Control Wells (5S23)

Well Purpose

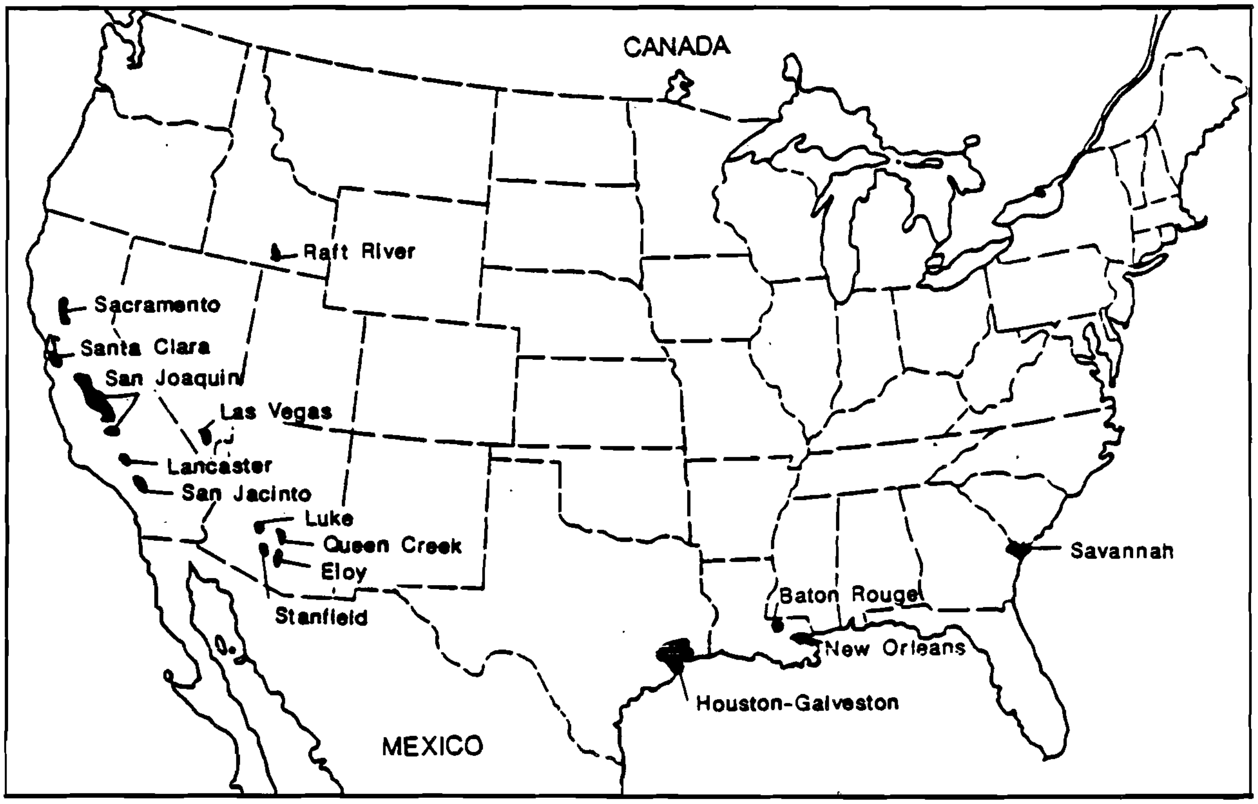
Subsidence control wells are recharge wells employed for the primary purpose of controlling land subsidence. Subsidence is the sudden sinking or gradual downward settling of the earth's surface with little or no horizontal motion. Subsidence may result from a variety of natural geologic or man-induced processes. For purposes of this report and the UIC program, we will limit our discussion to subsidence resulting from excessive ground-water withdrawal.

Problems associated with subsidence include: (1) differential changes in elevation and gradient of stream channels, drainage, and water transport structures, (2) failure of water casings due to compressive stresses generated by compaction of the aquifer system(s), (3) tidal encroachment in lowland coastal areas, and (4) damage to engineering structures (Poland et. al., 1984).

Inventory and Location

The inventory data collected by each State and United States territories and possessions accounts for a total of only 4 wells at one location in Wisconsin. These 4 wells are associated with a construction project. However, problems with subsidence are prevalent in southwestern states, most notably in California, Texas, and Arizona. The Houston-Galveston area of Texas has experienced subsidence which has led to catastrophic flooding along Galveston Bay. Thousands of sinkholes exist in karstic regions from Florida to Pennsylvania. These sinkholes are most often the result of ground-water withdrawal. Some areas of land subsidence resulting from ground-water withdrawal in the United States are depicted in Figure 4-62. Case studies of subsidence problems in Alabama, Texas, and California are listed in Appendix E. Subsidence control wells may be used now or in the future to control problems in these areas. Table 4-55 presents the inventory data from the State reports.

A recharge injection project has been carried out in Long Beach, California for purposes of subsidence control and oil recovery. It is true that this represents a Class II rather than a Class V injection well; however, the same principles would apply for subsidence control purposes.



SOME AREAS OF LAND SUBSIDENCE
RESULTING FROM GROUNDWATER WITHDRAWAL

(after Poland et al, 1984)

Figure 4-62

TABLE 4-55: SYNOPSIS OF STATE REPORTS FOR SUBSIDENCE CONTROL WELLS(5S23)

REGION & STATES	EPA REGION	Confirmed Presence Of Well Type	Regulatory System	Case Studies/ Info. available	Contamination Potential Rating
Connecticut	I	NO	N/A	NO	N/A
Maine	I	NO	N/A	NO	N/A
Massachusetts	I	NO	N/A	NO	N/A
New Hampshire	I	NO	N/A	NO	N/A
Rhode Island	I	NO	N/A	NO	N/A
Vermont	I	NO	N/A	NO	N/A
New Jersey	II	NO	N/A	NO	N/A
New York	II	YES	N/A	NO	N/A
Puerto Rico	II	NO	N/A	NO	N/A
Virgin Islands	II	NO	N/A	NO	N/A
Delaware	III	NO	N/A	NO	N/A
Maryland	III	NO	N/A	NO	N/A
Pennsylvania	III	NO	N/A	NO	N/A
Virginia	III	NO	N/A	NO	N/A
West Virginia	III	NO	N/A	NO	N/A
Alabama	IV	NO	N/A	NO	N/A
Florida	IV	NO	N/A	NO	N/A
Georgia	IV	NO	N/A	NO	N/A
Kentucky	IV	NO	N/A	NO	N/A
Mississippi	IV	NO	N/A	NO	N/A
North Carolina	IV	NO	N/A	NO	N/A
South Carolina	IV	NO	N/A	NO	N/A
Tennessee	IV	NO	N/A	NO	N/A
Illinois	V	NO	N/A	NO	N/A
Indiana	V	NO	N/A	NO	N/A
Michigan	V	NO	N/A	NO	N/A
Minnesota	V	NO	N/A	NO	N/A
Ohio	V	NO	N/A	NO	N/A
Wisconsin	V	4 WELLS	PERMIT	NO	LOW
Arkansas	VI	NO	N/A	NO	N/A
Louisiana	VI	NO	N/A	NO	N/A
New Mexico	VI	NO	N/A	NO	N/A
Oklahoma	VI	NO	N/A	NO	N/A
Texas	VI	NO	N/A	NO	N/A
Iowa	VII	NO	N/A.	NO	N/A
Kansas	VII	NO	N/A	NO	N/A
Missouri	VII	NO	N/A	NO	N/A
Nebraska	VII	NO	RULE	NO	N/A
Colorado	VIII	NO	N/A	NO	N/A
Montana	VIII	NO	N/A	NO	N/A
North Dakota	VIII	NO	N/A	NO	N/A
South Dakota	VIII	NO	N/A	NO	N/A
Utah	VIII	NO	RULE/PERMIT	NO	N/A
Wyoming	VIII	NO	N/A	NO	N/A
Arizona	IX	NO	N/A	NO	N/A
California	IX	NO	N/A	NO	N/A
Hawaii	IX	NO	N/A	NO	N/A
Nevada	IX	NO	N/A	NO	N/A
American Samoa	IX	NO	N/A	NO	N/A
Tr. Terr. of P	IX	NO	N/A	NO	N/A
Guam	IX	NO	N/A	NO	N/A
CNMI	IX	NO	N/A	NO	N/A
Alaska	X	NO	N/A	NO	N/A
Idaho	X	NO	N/A	NO	N/A
Oregon	X	NO	N/A	NO	N/A
Washington	X	NO	N/A	NO	N/A

NOTE: SOME NUMBERS IN THIS TABLE ARE ESTIMATES.

Construction, Siting, and Operation

Although the injection wells used in the Wilmington Oil Field subsidence control/enhanced recovery project are not Class V wells, they are illustrative of construction, siting, and operation of subsidence control injection wells (See Figure 4-63). In this particular case, oil production resulted in decreased fluid pressures in the oil saturated sand zone underlying an impermeable shale layer. This shale layer acts as a trapping mechanism, preventing further upward migration of petroleum. As fluid pressures decreased with oil production, water contained in the shale zone was squeezed out by weight of overburden into the zone of lowered pressure. This resulted in compaction of the shale layer, which caused subsidence at the surface.

The water injection well was sited down structural dip to oil production. This allows injection into the water saturated zone of the reservoir rock. Since oil is less dense, injected water acts to push the oil upward toward the producing well, and also to increase reservoir pressures. Increasing reservoir pressures in this case resulted in abatement of the previously described shale dewatering and compaction. This project resulted in reduction of the subsiding area and local land surface rebound of as much as 1 foot (Mayuga and Allen, 1969).

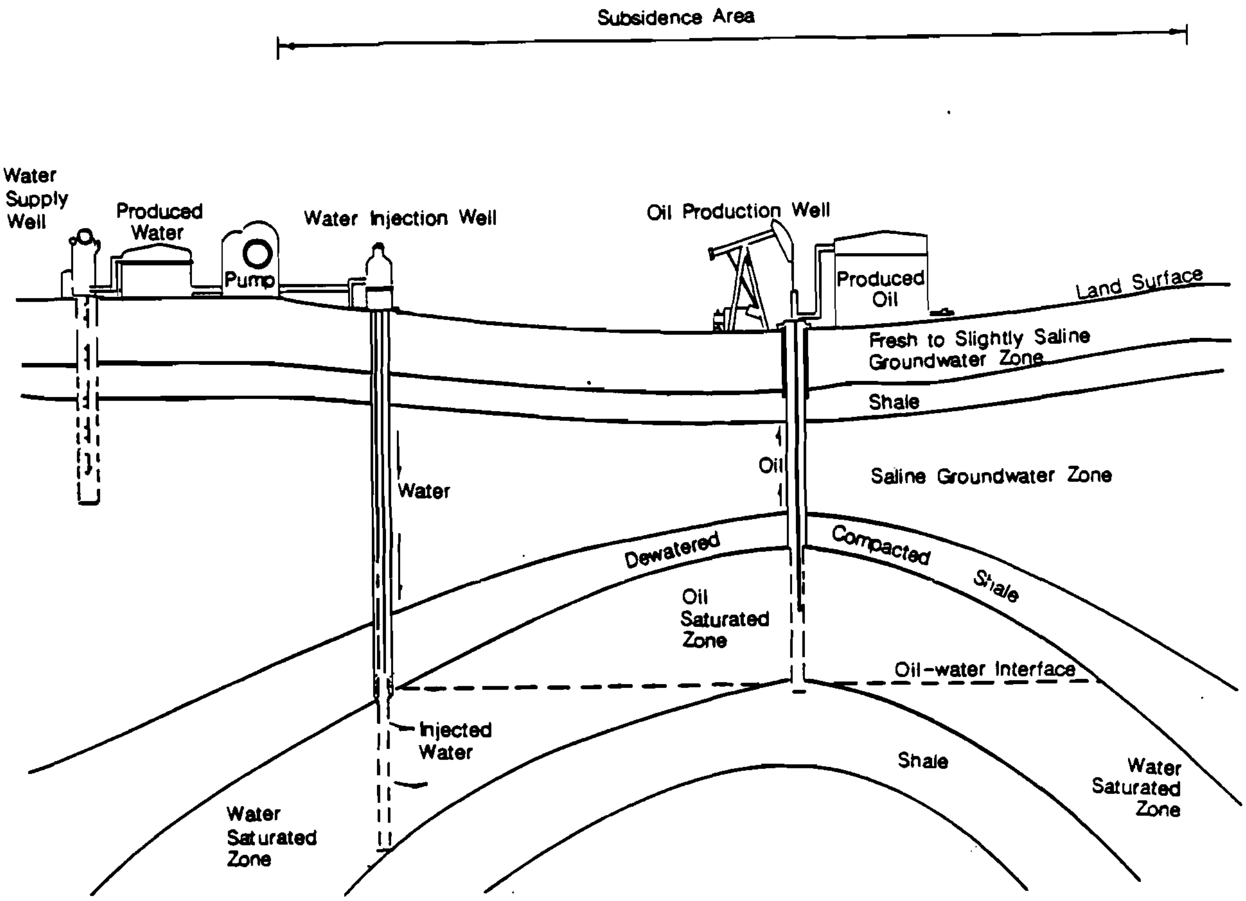
The inventoried wells in Wisconsin are temporary and have been constructed for the purpose of restoring piezometric levels during tunnel construction procedures. This is necessary to minimize damage from settlement during construction of the Milwaukee Tunnel project (Wisconsin DNR, 1986). Construction, siting, and operation practices will vary according to hydrogeologic conditions.

Injected Fluids and Injection Zone Interactions

Injection fluid characteristics and injection zone interactions are discussed in depth under Section 4.2.7.1 (Aquifer Recharge Wells) of the report. The following discussion deals with some physical properties and characteristics of the injection zone with regard to compaction and response to injection.

Water level fluctuations change effective stresses in the following 2 ways (Poland et. al., 1984):

1. A rise in the water table provides buoyant support for the grains within the zone of change while water decline removes buoyant support in this zone. These changes in gravitational stress are transmitted downward to all underlying deposits.



SCHEMATIC DIAGRAM OF SUBSIDENCE CONTROL
(Water Injection) WELL AND OIL WELL
Wilmington Oil Field, Long Beach, CA
(after Texas DWR, 1986)

Figure 4-63

2. A change in position of the water table or potentiometric surface of the confined aquifer system may induce vertical hydraulic gradients across confining or semiconfining beds and thereby produce a seepage stress. If preexisting seepage stresses are altered in direction or magnitude, a change in effective stress will result.

Since aquitards (composed of clay or shale) are highly compressible in comparison to aquifers (granular porous and permeable media), they may determine by number and thickness the system's susceptibility to compaction. Aquifers themselves are relatively incompressible at low pressures, however compression due to rearrangement of grains will occur at higher pressures (at the effective stress point). Compression may be permanent (inelastic) or recoverable (elastic). If geologic conditions are favorable, injection wells may aid in recovery of compacted strata.

Hydrogeology and Water Use

Subsidence due to ground-water withdrawal develops principally under two contrasting environments and mechanics (Poland et. al., 1984). One environment is that of karst areas where ground water flows through underground cavernous openings. The ground-water body provides buoyant support to overlying material in these areas. When ground-water levels drop, the buoyant support is removed and the hydraulic gradient is increased. This may result in erosion of unconsolidated material overlying the karst material, and also further dissolution of the karst material itself. This process may result in catastrophic collapse of roof material, forming sinkholes.

The second and more prevalent environment of occurrence is that of young unconsolidated, or semiconsolidated elastic sediments of high porosity which were deposited in shallow marine, alluvial, or lacustrine environments. This environment consists of aquifer systems containing aquifers of sand and/or gravel of high permeability and low compressibility, which are interbedded with clayey aquitards of low vertical permeability and high compressibility (Poland et. al., 1984). These aquifer systems compact in response to increased overburden stress. This is caused by decreased fluid pressures in the coarse-grained aquifers resulting from excessive extraction of water from this zone. Clay zones are thus dewatered and compacted as fluids move into the zone of lowered pressure. If overburden pressures continue to increase, aquifers may also compact due to grain rearrangement.

Principle clay minerals of which aquitards are composed belong to the montmorillonite, illite, or kaolin groups. Montmorillonite clays are the most compressible, and are the most predominant clays in the compacting aquifer systems of the southwestern United States.

Populations in arid climates are generally more dependent upon ground water, as surface water is not readily available in many of these areas. Heavy ground-water demands may cause severe depletion leading to subsidence. High ground-water demand in irrigated agricultural areas of the southwestern United States has caused widespread subsidence problems. Subsidence in Arizona has led to the formation of earth fissures.

Contamination Potential

Based on the rating system described in Section 4.1, subsidence control wells are assessed to pose a low potential to contaminate USDW. These wells typically do inject into or above Class I or Class II USDW. Typical well construction, operation, and maintenance would not allow fluid injection or migration into unintended zones. Injection fluids should be of equivalent or better quality (relative to standards of the National Primary or Secondary Drinking Water Standards and RCRA regulations) than the fluids within any USDW in connection with the injection zone. Based on injectate characteristics and possibilities for attenuation and dilution, injection does not occur in sufficient volumes or at sufficient rates to cause an increase in concentration (above background levels) of the National Primary or Secondary Drinking Water Regulation parameters in ground water, or endanger human health or the environment in a region studied on a group/area basis.

Subsidence control injection wells discharge directly into or above USDW. If subsidence control wells are not properly designed, constructed, and operated contamination may result. Wells must be properly sealed to prevent cross contamination and surface inflow. Special design, construction, and operation problems may arise in subsiding areas, as wells may be subject to casing or seal failures resulting from compressive stresses. Ground-water quality may be adversely affected by subsidence control recharge practices if injectate water quality is not closely monitored. Serious aquifer degradation may result if low quality water is injected directly into drinking water supply aquifers since injected volumes are quite large. Contamination potential for subsidence control wells is considered to be low providing they are properly designed, constructed, and operated. Serious problems may arise with improper practices which may lead to a high contamination potential. Refer to Section 4.2.7.1 for more information on the contamination potential of recharge wells.

Severe land subsidence itself may threaten water quality in some instances. Underground structures such as water and sewer systems, pipelines, and storage tanks may be damaged by land subsidence and earth fissures. There have been some cases in Arizona of people dumping refuse into open fissures. Earth fissures and sinkholes may extend to depths of regional supply aquifers and could provide a conduit for surface pollutants to enter drinking water supply aquifers.

Current Regulatory Approach

Subsidence control wells are authorized by rule under Federally administered UIC programs (see Section 1). The inventoried wells in Wisconsin have been permitted by the Wisconsin Department of Natural Resources (WDNR). These wells will be used temporarily during a construction project and will be properly plugged after the project is completed. The WDNR approved these wells under certain conditions, which include proper construction, operating, and abandonment procedures. The injectate source will be public supply drinking water. The project proposal was found by the WDNR to be consistent with the USEPA UIC regulations and local state regulations.

The Harris-Galveston Coastal Subsidence District was created in May 1975 to provide for the regulation of ground-water withdrawal within district boundaries for the purpose of ending subsidence. In 1978 (Smith-Southwest Industries, Inc. vs. Friendswood Development Company) the Texas Supreme Court ruled that ground-water users were not liable for subsidence damage caused by past actions, but could be held liable for damages due to future negligent or malicious ground-water pumpage (Poland, et. al., 1984).

In 1958 the United States sued oil and gas producers in the previously mentioned Wilmington oil field for damages to the U.S. Naval Base on Terminal Island, and other properties, resulting from subsidence. This was the largest damage suit in United States history for subsidence caused by the pumping of underground fluids. This case was settled out of court and the Anti-Subsidence Act of 1958 compelled Wilmington oil field producers to unitize and repressure the depleted reservoir (Poland, el. al., 1984).

Recommendations

Recommendations for subsidence control wells are similar to those for recharge wells (See Section 4.2.7.1). Injectate quality should be monitored, and proper well design, construction, and operation are most important. Injectate quality should be of equivalent or better quality than fluids in the receiving aquifer. Standards should be set on a case by case basis.

Supporting Data

Referenced supporting data for Subsidence Control Wells is listed in Appendix E of the report.

4.2.8 MISCELLANEOUS WELLS

4.2.8.1 Radioactive Waste Disposal Wells (5N24)

Well Purpose

The purpose of radioactive waste disposal wells is to dispose of wastes containing radioactive materials, in concentrations exceeding those listed in 10 CFR Part 20, Appendix B, Table 2, Column 2, into subsurface formations. These wastes are low level radioactive wastes. This subcategory includes wells that inject heat exchange and cooling water process equipment waste condensate from facilities managing radioactive materials. In addition, non-radioactive wastes from laboratory drains also may be injected into these wells.

Inventory and Location

The inventory data collected by each State, Territory, and Possession, account for a total of approximately 122 radioactive waste disposal wells. There tends to be a hesitancy by the operators of possible radioactive waste disposal wells to identify themselves. However, when this report was coordinated with the Department of Energy, staff at all levels were cooperative and offered full and complete data for this report. It is very possible that the current inventory of known radioactive waste disposal wells constitutes only a percentage of those actually in existence. Table 4-56 indicates where inventoried Class V radioactive waste disposal wells are located.

A major problem in the inventory of radioactive waste disposal wells is determining which wells are Class V injection wells and which wells would meet the criteria for Class IV injection wells, which are banned. Also, wells which have not disposed of radioactive wastes since the inception of the UIC program would not fall under the jurisdiction of the UIC regulations; however, mention of these facilities is included in this inventory for completeness.

The Nuclear Regulatory Commission (NRC) under the Energy Reorganization Act of 1974, licenses and regulates the following facilities according to Section 202:

1. Demonstration Liquid Metal Fast Breeder reactors when operated as part of the power generation facilities of an electric utility system, or when operated in any other manner for the purpose of demonstrating the suitability for commercial application of such a reactor.

TABLE 4-56: SYNOPSIS OF STATE REPORTS FOR RADIOACTIVE WASTE DISPOSAL WELLS(5N24)

REGION & STATES	EPA REGION	Confirmed Presence Of Well Type	Regulatory System	Case Studies/ Info. available	Contamination Potential Rating
Connecticut	I	NO	N/A	NO	N/A
Maine	I	NO	N/A	NO	N/A
Massachusetts	I	NO	N/A	NO	N/A
New Hampshire	I	NO	N/A	NO	N/A
Rhode Island	I	NO	N/A	NO	N/A
Vermont	I	NO	N/A	NO	N/A
New Jersey	II	NO	N/A	NO	N/A
New York	II	NO	N/A	NO	N/A
Puerto Rico	II	NO	N/A	NO	N/A
Virgin Islands	II	NO	N/A	NO	N/A
Delaware	III	NO	N/A	NO	N/A
Maryland	III	NO	N/A	NO	N/A
Pennsylvania	III	NO	N/A	NO	N/A
Virginia	III	NO	N/A	NO	N/A
West Virginia	III	NO	N/A	NO	N/A
Alabama	IV	NO	N/A	NO	N/A
Florida	IV	NO	N/A	NO	N/A
Georgia	IV	NO	N/A	NO	N/A
Kentucky	IV	NO	N/A	NO	N/A
Mississippi	IV	NO	N/A	NO	N/A
North Carolina	IV	NO	N/A	NO	N/A
South Carolina	IV	NO	N/A	NO	N/A
Tennessee	IV	1 WELL(ABD)	N/A	NO	N/A
Illinois	V	1 WELL	RULE	NO	N/A
Indiana	V	NO	N/A	NO	N/A
Michigan	V	NO	N/A	NO	N/A
Minnesota	V	NO	N/A	NO	N/A
Ohio	V	NO	N/A	NO	N/A
Wisconsin	V	NO	N/A	NO	N/A
Arkansas	VI	NO	N/A	NO	N/A
Louisiana	VI	NO	N/A	NO	N/A
New Mexico	VI	1 WELL(ABD)	ILLEGAL	YES	LOW
Oklahoma	VI	1 WELL(ABD)	RULE	NO	N/A
Texas	VI	NO	N/A	NO	N/A
Iowa	VII	NO	N/A	NO	N/A
Kansas	VII	NO	N/A	NO	N/A
Missouri	VII	NO	N/A	NO	N/A
Nebraska	VII	NO	RULE	NO	N/A
Colorado	VIII	NO	N/A	NO	N/A
Montana	VIII	NO	N/A	NO	N/A
North Dakota	VIII	NO	N/A	NO	N/A
South Dakota	VIII	NO	N/A	NO	N/A
Utah	VIII	NO	RULE/PERMIT	NO	N/A
Wyoming	VIII	NO	N/A	NO	N/A
Arizona	IX	NO	N/A	NO	N/A
California	IX	NO	N/A	NO	N/A
Hawaii	IX	NO	N/A	NO	N/A
Nevada	IX	NO	N/A	NO	N/A
American Samoa	IX	NO	N/A	NO	N/A
Tr. Terr. of P	IX	NO	N/A	NO	N/A
Guam	IX	NO	N/A	NO	N/A
CNMI	IX	NO	N/A	NO	N/A
Alaska	X	NO	N/A	NO	N/A
Idaho	X	4 WELLS	PERMIT>18 FT	YES	7TH HIGHEST/14 TYPES
Oregon	X	NO	N/A	NO	N/A
Washington	X	116 WELLS	PERMIT	YES	HIGH

NOTE: SOME NUMBERS IN THIS TABLE ARE ESTIMATES.

2. Other demonstration nuclear reactors when operated as part of the power generation facilities of an electric utility system, or when operated in any other manner for the purpose of demonstrating the suitability for commercial application of such a reactor.

3. Facilities used primarily for the receipt and storage of high-level radioactive wastes resulting from activities licensed under such Act.

The Kerr-McGee facility in Oklahoma falls under the jurisdiction of the NRC. The State of Oklahoma reports a permit request from the Kerr-McGee Corporation for disposal of "very low-level radioactive wastes." Oklahoma reports that these wastes were below the level designated as nuclear waste and, therefore, did not permit the well as a radioactive waste disposal well. The well was plugged in December 1985. Applications for radioactive waste injection at NRC licensed facilities are evaluated on a case-by-case basis and in accordance to EPA regulations.

The Department of Energy (DOE) under the Atomic Energy Act of 1954 regulates the remaining facilities included in the current inventory. At the Hanford Atomic Operations in Richland, Washington, information has been documented concerning the disposal of radioactive wastes; however, available information indicates that the injection wells have not been used to inject fluids containing radioactive materials since the 1950's. Another facility which has injected radioactive wastes, in the form of cement grout, in the past is the Oak Ridge National Laboratory in Oak Ridge, Tennessee. According to State officials, radioactive wastes are no longer injected into those wells, and there are no plans to resume this type of injection due to the difficulties in obtaining a UIC permit. The last reported injection activity there occurred in 1984.

In the State of Idaho, DOE maintains one low-level radioactive waste disposal well at the DOE Idaho Chemical Processing Plant (ICPP) on the Idaho National Engineering laboratory reservation. According to an Idaho assessment of Class V injection wells, this well is maintained as an emergency disposal method to the facility's ongoing waste percolation pond disposal system.

A tile field cooling water disposal system has been reported by the State of Illinois at the Fermi National Accelerator Laboratory in Batavia, Illinois. The radioactive wastes are composed of cooling water with low levels of Beryllium 7, which has an affinity for adhesion to the clay into which disposal occurs. Under current DOE policy, no injection wells are being used to dispose of radioactive materials.

Construction, Siting, and Operation

Construction and operation of radioactive waste disposal wells varies greatly. At Oak Ridge National Laboratory, radioactive wastes were blended with cement to form a slurry which was pumped under pressure through a cased well into subsurface strata.

At the Hanford Facility in Washington, injection has occurred through three distinct methods. The methods include: reverse wells, french drains, and cribs. According to the State of Washington Department of Ecology, the Hanford facility has operated 13 reverse wells, 32 french drains, and 70 cribs since the early 1940's. There is some uncertainty as to which of these disposal methods would fall under jurisdiction of the UIC program. The "reverse wells" undeniably are subject to UIC regulation. Reverse wells are cased wells with a perforated bottom section for disposal of the radioactive materials. A french drain consists of a rock-filled cell with an open bottom that allows liquids to seep into the ground. A crib is an underground structure which consists of a settling tank, diversion box, distribution line, and a perforated drain pipe which allow fluids to seep into the subsurface. The cribs at the Hanford facility, however, did not include a settling tank.

The ICPP low-level radioactive waste disposal well in Idaho is constructed of 12-inch diameter casing which extends from 15 feet below ground surface (base of well pit) to 588 feet, the total depth of the borehole. The borehole encountered approximately 40 feet of unconsolidated materials and penetrated approximately 548 feet of interlayered basalt and sedimentary strata. The lowermost 138 feet of casing (from 450 feet to 588 feet) is perforated. Ground water is encountered in the ICPP emergency injection well at a depth of 440 feet. In 1983, the well was lined with 10-inch diameter PVC casing and back-filled to a depth of 520 feet. No explanation for the casing and backfilling effort was presented in the Idaho report. However, DOE has informed EPA that the PVC casing and backfilling were standard techniques to correct well collapse.

Injected Fluids and Injection Zone Interactions

A variety of radioactive materials reportedly have been injected into radioactive waste disposal wells. Reported wastes include Beryllium 7, Tritium, Strontium 90, Cesium 137, Potassium 40, Cobalt 60, Plutonium, Americium, Uranium, and other Radionuclides.

At the Idaho DOE facility, the ICPP emergency injection well is not utilized for routine injection. The injectate, as demonstrated from fluids disposed in the facility's routine disposal system, would include: heat exchange condensate and cooling water, boiler blowdown, deionizer regeneration solutions, chemical makeup solutions, process equipment waste condensate, nonradioactive wastes from laboratory drains, and fluids from pilot plant drains.

According to the 1985 records, approximately 136,000 gallons of injectate were disposed through the ICPP emergency injection well. According to the Idaho report, only one injection episode occurred from January 1, 1986 through October 1, 1986. During this injection episode, approximately 850 gallons of injectate were disposed through the ICPP injection well.

Based on water quality data, injectate of the ICPP injection well is not considered hazardous in accordance with the definition of RCRA listed and characteristic hazarous waste under 40 CFR Part 261. In addition, the injectate is in accordance with the Idaho Department of Health and Welfare, Radiation Control Regulation for release to an uncontrolled area. However, the concentrations of radiochemical constituents, as well as nitrates and mercury, have exceeded the USEPA Primary Drinking Water Standards (40 CFR, Part 142). They also exceeded the discharge quality standards of the Idaho Injection Well Regulations.

According to the Washington Department of Ecology report on the Hanford facility, injection fluids originated from a variety of sources which include laboratories and processing areas. The fluids may contain condensates and laboratory wastes.

Hydrogeology and Water Use

Inventoried injection facilities inject wastes which are reported to be confined within the perimeters of the site. There is no expected water usage on these sites; however, the potential transport of these materials off-site needs further evaluation. Since injection occurs at very shallow depths, there still remains the potential for contaminating USDW if transport of these radioactive material occurs. Investigations should be conducted to determine whether these wells are Class V or Class IV injection wells, based on location of USDW with respect to injection zones.

Contamination Potential

With the data available from the State reports, the contamination potential cannot be adequately determined.

Current Regulatory Approach

Radioactive waste disposal wells are authorized by rule under Federally-administered UIC programs (see Section 1). See Table 4-56 for a synopsis of regulatory systems by State.

Recommendations

Washington provided the following recommendations for its Class V program:

1. The Department proposes to use the provision of [the state waste discharge permit program (Chapter 173-216 WAC)] to authorize and take enforcement actions for discharges which do not satisfy the standard of all known available reasonable methods of treatment and control.

2. The disposal standard for cribs and french drains will be to treat the waste before discharge and not to rely soley on evaporation, the soil, and dilution to treat the wastes.

3. The number of permits issued and permit compliance and enforcement actions will be negotiated annually with Environmental Protection Agency through the State/EPA Agreement program planning process.

4.2.8.2 Experimental Technology Wells (5X25)

Well Purpose

These wells are used in experimental or unproven technology. Studies are generally conducted on a pilot scale to assess the economic and technological feasibility of applying such procedures. Most wells of this type have been used in technologies associated with recovering fossil fuels and other minerals. Examples of these technologies include underground coal gasification, in situ oil shale retorting, in situ solution mining, tracer studies, aquifer remediation, and secondary water recovery projects. While underground coal gasification and in situ oil shale retorting are regarded as experimental technologies, projects of this kind have been operated on large scales and associated injection wells are classified as a specific type of Class V well. These technologies are discussed thoroughly in a previous section of this report (See Section 4.2.4.3). In situ solution mining, primarily for uranium and copper recovery, is a specific type of Class V injection and also is discussed in a previous section (See Section 4.2.4.2). Certain of these solution mining facilities are operating at pilot scales and are technically defined as an experimental technology, though little to no difference in procedures exists.

Inventory and Location

Inventory updates, through State reports and other database additions, result in an inventory of 225 experimental technology wells, located in 17 States. A summary of available inventory, regulatory systems, contamination potential ratings and known case studies is presented in Table 4-57.

Referring to Table 4-57, it will be noted that over half the reported experimental technology wells are located in Wyoming (135). The Wyoming State report indicates that this number represents three well types: underground coal gasification, in situ oil shale retorting, and in situ uranium solution mining. At the present time, none of these facilities is believed to be active, presumably due to economic difficulties plaguing those industries. In addition, the two known experimental technology wells in California, associated with a refinery clean-up project are presently inactive. The Alabama report describes a well used in an "experimental" capacity to dispose of treated domestic wastewater. Another well in that State is used to dispose of wastewater generated by the recovery and treatment of contaminated ground water. The report indicates that both projects are short-term and do not appear to be feasible for continued use. The implication of these reports is that there are actually very few active experimental technology injection operations in the United States at the present time.

Construction, Siting, and Operation

Because of the diverse nature of experimental well types, aspects of construction, siting, and operation will also be diverse. The specific examples provided in State reports are discussed in the following paragraphs. For a description of construction, siting, and operation typical of in situ solution mining, underground coal gasification, and in situ oil shale retorting, see the appropriate sections of this report.

The facility in Alabama disposing of treated domestic wastewater uses an injection well approximately 65 feet deep. Six-inch diameter PVC slotted screen is used for casing and is gravel packed at the borehole annulus for the entire depth of the well. Monitoring is conducted at five wells for total suspended solids, fecal coliform, ammonia, BOD (5-day), and pH. Flow rate averages 43 gallons per minute, and maximum daily volume is 36,000 gallons.

The other experimental facility in Alabama is used to inject wastewater generated by the recovery and treatment of contaminated ground water. Wells are 80 feet deep and screened over the bottom 25 feet. Ten-inch diameter steel casing is secured in the 16-inch borehole with cement grout. Adjacent to the 10-inch diameter wire-wound, stainless steel screen is a gravel pack capped with fine sand. Fluid injected must meet criteria for COD and nitrated organics (100 mg/l and 0.5 mg/l, respectively). Maximum flow rate is 100 gallons per minute.

TABLE 4-57: SYNOPSIS OF STATE REPORTS FOR EXPERIMENTAL TECHNOLOGY INJECTION WELLS(5X25)

REGION & STATES	EPA REGION	Confirmed Presence Of Well Type	Regulatory System	Case Studies/ Info. available	Contamination Potential Rating
Connecticut	I	NO	N/A	NO	N/A
Maine	I	NO	N/A	NO	N/A
Massachusetts	I	NO	N/A	NO	N/A
New Hampshire	I	NO	N/A	NO	N/A
Rhode Island	I	NO	N/A	NO	N/A
Vermont	I	NO	N/A	NO	N/A
New Jersey	II	NO	N/A	NO	N/A
New York	II	NO	N/A	NO	N/A
Puerto Rico	II	NO	N/A	NO	N/A
Virgin Islands	II	NO	N/A	NO	N/A
Delaware	III	NO	N/A	NO	N/A
Maryland	III	NO	N/A	NO	N/A
Pennsylvania	III	NO	N/A	NO	N/A
Virginia	III	NO	N/A	NO	N/A
West Virginia	III	NO	N/A	NO	N/A
Alabama	IV	2 WELLS	PERMIT	YES	MODERATE
Florida	IV	3 WELLS	PERMIT	NO	N/A
Georgia	IV	NO	N/A	NO	N/A
Kentucky	IV	NO	N/A	NO	N/A
Mississippi	IV	5 WELLS	RULE	NO	N/A
North Carolina	IV	8 WELLS	PERMIT	NO	N/A
South Carolina	IV	NO	N/A	NO	N/A
Tennessee	IV	NO	N/A	NO	N/A
Illinois	V	2 WELLS	RULE	NO	N/A
Indiana	V	NO	N/A	NO	N/A
Michigan	V	4 WELLS	N/A	NO	N/A
Minnesota	V	2 WELLS	N/A	NO	N/A
Ohio	V	NO	N/A	NO	N/A
Wisconsin	V	NO	N/A	NO	N/A
Arkansas	VI	NO	N/A	NO	N/A
Louisiana	VI	NO	N/A	NO	N/A
New Mexico	VI	6 WELLS	PERMIT	YES	LOW-
Oklahoma	VI	NO	N/A	NO	N/A
Texas	VI	6 WELLS	N/A	NO	LOW
Iowa	VII	NO	N/A	NO	N/A
Kansas	VII	NO	N/A	NO	N/A
Missouri	VII	NO	N/A	NO	N/A
Nebraska	VII	2 WELLS	RULE	NO	N/A
Colorado	VIII	2 WELLS	N/A	NO	LOW
Montana	VIII	NO	N/A	NO	N/A
North Dakota	VIII	NO	N/A	NO	N/A
South Dakota	VIII	NO	N/A	NO	N/A
Utah	VIII	NO	RULE/PERMIT	NO	N/A
Wyoming	VIII	135 WELLS	PERMIT	YES	LOW-HIGH
Arizona	IX	32 WELLS	PERMIT	YES	LOW-MODERATE
California	IX	2 WELLS	PERMIT	NO	UNKNOWN
Hawaii	IX	6 WELLS	PERMIT	NO	LOW-MODERATE
Nevada	IX	5 WELLS	PERMIT	NO	UNKNOWN
American Samoa	IX	NO	N/A	NO	N/A
Tr. Terr. of P	IX	NO	N/A	NO	N/A
Guam	IX	NO	N/A	NO	N/A
CNMI	IX	NO	N/A	NO	N/A
Alaska	X	NO	N/A	NO	N/A
Idaho	X	NO	N/A	NO	N/A
Oregon	X	NO	N/A	NO	N/A
Washington	X	3 WELLS	N/A	NO	N/A

NOTE: SOME NUMBERS IN THIS TABLE ARE ESTIMATES.

Air injection tests have been conducted in Texas as a mode of secondary water recovery. This experimental method is used to determine whether air pressure will force capillary water within the unsaturated zone of the aquifer to migrate down to the saturated zone. A six-inch diameter injection well was completed to 116 feet. Steel casing is seated in or below an impermeable stratum and cemented to surface. Slotted steel tubing is seated to total depth, below the impermeable stratum. A packer isolates the injection zone. The injection well is surrounded in a radial pattern by five monitoring wells. An estimated 12 million cubic feet of air was injected during a 217-hour test.

An experimental procedure tested at the University of Minnesota attempted storing heated ground-water in a confined aquifer. The goal was to recover energy, via heat, from the injected fluid. Four short-term cycles were studied. Wells were constructed of stainless steel casing, screened across permeable intervals of the confined aquifer. This screened casing (6-inch diameter) extended down from 13-3/8-inch steel casing. The lower casing was surrounded by a gravel pack designed to accommodate thermal expansion of the casing. The injection zone was isolated by a packer. Constant speed turbine pumps were seated at about 450 feet. Hot fluid was injected and stored for various lengths of time, then recovered to test the heat content of the fluid. A fixed-bed precipitator using high-purity limestone was used to treat injected fluid to prevent scaling. Similarly, hardness was removed before heating the ground-water using an ion-exchange water softener.

Injected Fluids and Injection Zone Interactions

Each type of experimental injection operation makes use of a different type of injectate. A variety of acidic and basic compounds can be used for in situ solution mining operations. These fluids and their potential interactions with the injection zone are discussed in Section 4.2.4.2. Similarly, fluids used for underground coal gasification and in situ oil shale retorting are reported, along with injection zone interactions, in Section 4.2.4.3.

The Alabama facility injecting treated domestic wastewater has been monitored for total suspended solids, fecal coliform, ammonia, BOD, and pH. The Alabama report stated that there were no permit limitations for those parameters. The permit was for one year, and injectate volumes of 36,000 gallons per day would result in a maximum of over 13 million gallons injected at that facility. No information on the injection aquifer was presented by the Alabama facility.

The other Alabama facility, injecting wastewater associated with treatment of contaminated ground water, was reported to inject up to 100 gallons per minute. On an annual basis, this would result in a maximum of over 50 million gallons injected.

This injected fluid was subject to contaminant limits per the operating permit. Again, no information with respect to the injection zone was presented by the facility.

For the secondary water recovery operation in Texas, it was stated that air was injected under pressure to affect movement of capillary water toward the water table. It is believed that this activity results in very little interaction at a molecular level between injected air and formation water. Data regarding hydrogeological character of the injection zone were not reported by the Texas facility.

Finally, the experimental procedure applied in Minnesota for storing injected hot water made use of ground water extracted from the intended injection zone. Before heating, the water was softened by ion exchange. A fixed-bed reactor is part of the injection system and is used to precipitate calcium carbonate, thus preventing scaling within the injection wells. The conclusion is that the injectate was actually of better quality than injection zone water with respect to hardness and total dissolved solids (TDS). The influence of temperature differentials between injectate and injection zone fluids upon lithological parameters was not determined by the facility.

The previous discussions, though not exhaustive, exemplify that no singular or typical description of injection fluids or injection zone interactions can be made. Characterization of these parameters must be conducted on a site-specific basis. Each known facility studied should place emphasis the following parameters:

1. Goal of the operation;
2. Nature and volume of injected fluids;
3. Site hydrogeology; and
4. Construction, operation, and maintenance features.

Hydrogeology and Water Use

It is difficult to make broad hydrogeological generalizations with respect to these wells. Experimental procedures involving injection can vary greatly as can the goals of these projects. Again, it should be emphasized that experimental procedures for in situ solution mining, underground coal gasification, and in situ shale retorting are discussed with respect to hydrogeologic parameters in previous sections.

In general, experimental injection operations reported within the United States are characterized by injection into confined aquifers. Exceptions to this may be the two experimental facilities reported by Alabama where injection wells reach a maximum depth of only 80 feet. Though specific details for these aquifers are not known, the well depths are indicative of unconfined or semi-confined aquifer conditions.

The Wolfforth Air-Injection test, a 1984 experimental secondary water recovery test, was conducted in two unsaturated zones separated by a "bed of hard rock" (High Plains Underground Water Conservation District No. 1, July, 1985). The depth of this well (110 feet) is such that the aquifer beneath the hard rock unit was probably confined, and the zone above this layer was unconfined or semi-confined. Two tests were conducted at the Wolfforth site. The first test was designed to inject air under low pressure (8 psi) at low volumes (300 cubic feet/minute) into the unsaturated zone above the confining layer. Two key results were noted. First, moisture content within the unsaturated zone decreased within a 300-foot radius of the injection well, indicative that the procedure actually could move capillary water. Second, injection actually increased the moisture content within the confined aquifer below the hard rock layer.

A second test conducted at Wolfforth was designed to inject air at low pressures and volumes into the confined zone below the hard rock layer. Results similar to the initial test occurred, namely a decrease in moisture content around the injection well and increased yields within a two-mile radius in irrigation wells during and after the test. Additionally, researchers were able to observe the influence of lateral variations in aquifer characteristics upon capillary water movement induced by air injection. Results of these injection tests conclusively demonstrated that water levels could be significantly raised in radii of several tens of miles using air injection. Other important findings were 1) up to 30 percent of the capillary water in storage can be released under relatively low air pressures and volumes using this procedure, and 2) post capillary water drainage can occur for several months or years after short-term injection.

Another experimental injection operation for which relatively full documentation exists is the aquifer thermal energy storage (ATES) project. These experiments were conducted at the University of Minnesota. The procedure made use of a combination extraction-injection system whereby ground water is heated and injected into a confined aquifer for storage. Results showed that energy recovery via this process was 62 percent of the energy added to the injected ground-water for long-term cycles. Energy recoveries varied from 46-62 percent for the four short-term experiments conducted.

Wells used in this procedure were completed in a highly variable sequence of late Cambrian marine sediments (Franconia-Ironton-Galesville sequence). This is a highly stratified, confined aquifer, present at a depth of about 590 feet. It is approximately 200 feet thick and is under a static head of about 400 feet (Hoyer and Walton, 1984). The aquifer is composed of sandstone interbedded with shale, siltstone, and dolomite. Ground water is calcium-magnesium bicarbonate and is extracted from and injected into the same zones. The upper zone, part of the Upper Franconia, is a fine- to medium-grained sandstone demonstrating varying concentrations of glauconite. It is confined above and below by relatively impermeable silty dolomites and siltstones, respectively. The lower injection zone is the entire section of Ironton and Galesville rocks. These formations are a sequence of medium quartzose sandstones and fine feldspathic sandstones with shale laminations. Similar to the upper zone, the Ironton-Galesville sequence is a highly permeable aquifer bounded above and below by relatively impermeable silts, fine sands, and silty dolomites.

The foregoing site-specific information on experimental injection operations has been presented to demonstrate parameters important to such operations. Ground-water remediation and recovery, thermal energy storage, and fossil fuel and mineral recovery are known to be major objectives of experimental strategies. Other important aspects of experimental injection include 1) lithologic character of the injection zone (mineralogy, permeability, vertical confinement, and lateral variation), 2) nature of injected fluid, 3) ground-water quality, and 4) injection system design. Each of these aspects will vary, and their influence upon system performance and environmental impact should be evaluated on a site-specific basis.

Contamination Potential

Based on the rating system described in Section 4.1, experimental technology wells inventoried to date are assessed to pose a moderate to low potential to contaminate USDW, but each operation must be assessed individually. These facilities typically do inject into or above some USDW. Typical well construction, operation, and maintenance would not allow fluid injection or migration into unintended zones. Injection fluids typically have concentrations of constituents exceeding standards set by the National Primary or Secondary Drinking Water Regulations. Based on injectate characteristics and possibilities for attenuation and dilution, injection may or may not occur in sufficient volumes or at sufficient rates to cause an increase in concentration (above background levels) of the National Primary or Secondary Drinking Water Regulation parameters in ground water, or endanger human health or the environment beyond the facility perimeter.

Because of the variability exhibited in experimental technologies associated with Class V injection, it is not possible to assign a singular contamination potential. In previous sections, it has been stated that contamination potential attributable to in situ solution mining is generally low and that contamination potential from underground coal gasification and in situ shale retorting is moderate. These results indicate that meaningful assessment of experimental technologies for contamination potential must be system-specific. The following paragraphs contain assessments for the types of experimental injection operations inventoried to date.

Due to the limited data presented for the experimental systems in Alabama, these two facilities are assessed together, using certain broad generalizations. One operation disposes of treated domestic wastewater, and the other injects wastewater produced due to the recovery and treatment of contaminated ground water. Injection at both facilities is relatively shallow, and both injection zones may be USDW. However, from the limited description presented, it cannot be concluded these aquifers are Class IIB quality or better.

Construction designs for the Alabama facilities provide for specific injection intervals. Screened openings are employed, and the up-hole portions of wells at both facilities are cemented and grouted. However, the reported well depths are shallow enough to imply that the injection zones are actually semi- to unconsolidated and are probably not totally confined. As such, it is likely that injection fluids have migrated vertically into other zones.

At the facility disposing of treated wastewater, injectate is monitored for total suspended solids, fecal coliform, ammonia, BOD, and pH, yet no permit limitations exist for these parameters. At the other facility, limitations for chemical oxygen demand (COD) and nitrated organics have been established, but other constituents present within contaminated ground water are not addressed. The conclusion is that there is a strong likelihood that some constituents are present within these waste streams that exceed certain Primary and/or Secondary Drinking Water Regulations.

Finally, injection volumes must be addressed. Maximum injection volumes for these facilities can be several tens of millions of gallons annually. Though specific hydrogeologic conditions for each site have not been ascertained, these volumes could result in contamination of ground water beyond facility boundaries.

In summary, it cannot be concluded that injection at the two Alabama facilities is into Class IIB aquifers. However, construction and operation of the wells is probably resulting in migration of injection fluids into unintended zones. In addition, the possibility exists that certain drinking water regulations are being exceeded for injection fluids and that injection volumes are sufficient to cause increases in these constituents within ground water beyond facility boundaries. It is hereby concluded that injection conducted at these two facilities poses moderate threat of contamination to local USDW. This assessment could be amended to high contamination potential, should further data about USDW in the area become available.

In Texas, the air injection operation for secondary water recovery was into an aquifer used extensively as an irrigation water aquifer. That aquifer's potential useability as a drinking water supply has not been demonstrated. Injection of air into the unconfined zone actually resulted in changes in moisture content within the confined aquifer. With respect to injectate quality, only compressed air was injected. The composition of air would not be such that any Primary or Secondary Drinking Water Regulations would be exceeded, nor would it cause increases in those constituents within ground-water beyond facility boundaries. Therefore, this particular injection operation poses a low ground-water contamination potential.

At the University of Minnesota facility, injection fluid was merely heated ground water which was returned to the same zones it was extracted from. It could not be determined if the extraction-injection aquifer was of Class IIB quality. Well construction was found to be relatively simple, and the potential for migration of fluids into unintended zones may be considered to exist. Because the same fluid is extracted, heated and injected, increases in constituents of Primary and Secondary Drinking Water Standards may or may not occurr beyond facility boundaries. Therefore, this particular injection operation has presented low potential for contamination to USDW.

To summarize what has been demonstrated in the previous discussion, contamination potentials ranging from low to moderate are possible for experimental injection operations as presently understood. Future data regarding known operations or new inventory information may result in a higher contamination assessment. It will be necessary to evaluate each facility individually.

Current Regulatory Approach

Experimental technology wells are authorized by rule under Federally-administered UIC programs (see Section 1). Review of the various types of experimental injection operations has indicated that in situ solution mining, underground coal gasification, and in situ shale retorting are the most thoroughly regulated. Aspects of regulatory jurisdiction over these well types are discussed in earlier sections of this report.

Data regarding regulatory authority over other representative well types is largely absent. The Alabama facility injecting wastewater generated by recovery and treatment of contaminated ground water operates under concentration limitations for COD and nitrated organics. It is presumed these restrictions are part of waste discharge permit requirements, but the issues of such permits remain in question. Some inventoried facilities may not operate under permit programs at the present time. Refer to Table 4-57 for a synopsis of State regulatory systems.

Recommendations

Experimental technologies involving injection vary greatly. As such, recommendations addressing siting, construction, and operation must be broad and general in nature. Siting injection wells associated with precious metal or fossil fuel recovery will, of course, be dependent upon the location and dimensions of the mineral deposit. The California report recommends that injection wells for other technologies, not location dependent, should not be sited where poor quality fluid injection into a Class IIB aquifer could occur. The report further suggests that detailed ground-water studies should be conducted for any potential injection site. Points to be addressed in such studies might include general ground-water quality, aquifer dimensions, and present ground-water uses, as well as potential for further use.

Additional recommendations from the California report include chemical analysis of the waste stream at regular intervals. Frequency for such analyses will be dictated by the general nature of the waste stream with respect to potentially hazardous or toxic materials, and volumes of injection. Establishment of mechanical integrity at regular intervals should be part of every operational plan, according to both the Arizona and California reports. The type of tests employed will be dependent upon the materials used for casing, and the type of completion (perforations, screened openings, or open hole).

Most of the experimental injection facilities discussed in this report are inactive or have been abandoned. Facilities known to still be active are certain solution mining operations in the southwestern United States. No evidence for USDW contamination exists at the present time. As a result, no recommendations for remedial or corrective action were proposed in the State reports except to continue to identify USDW in areas where experimental injection is occurring. These data could be used to better assess, on a site-specific basis, potential contamination to USDW from this kind of Class V injection.

Supporting Data

Two case studies are listed in Appendix E for Experimental Technology Injection wells. The first is a study of aquifer thermal energy storage conducted on the University of Minnesota campus by the Minnesota Geological Survey. The second case study represents an air-injection test conducted in Texas to attempt enhancement of secondary fresh water recovery. The test was conducted jointly by the Texas Department of Water Resources, the High Plains Underground Water Conservation District Number 1, and the City of Wolfforth, Texas.

4.2.8.3 Aquifer Remediation Related Wells (5X26)

Well Purpose

Aquifer remediation can be defined as the implementation of remedial measures to correct deficiencies, improve selected parameters (such as quality or flow), or to prevent anticipated or possible problems in permeable materials which contain or are capable of containing ground water. The implementation of these programs historically has been in response to problems which have already occurred and, to a much lesser extent in recent years, as a preventive practice.

Recent years have seen the incidence, or at least the recognition, of ground-water contamination on the increase. In light of this, the public awareness and concern have demanded correction of these problems. Remediation programs implemented throughout the United States have many widely varying arrays which normally are a function of several parameters including type and quantity of pollutants, area of contaminated water, hydrogeologic regimens, and others. While aquifer remediation programs are implemented through the use of different tactics, they have certain goals which are common throughout. These goals include, first and foremost, the abatement of contamination, second, the containment of the area of contamination, and last, the restoration of the aquifer. Injection wells quite often are used in these programs for a variety of purposes. They are implemented to achieve one or more of these goals. They can be used to introduce chemicals or microorganisms designed to neutralize the contamination, or they may be used to transport clean waters to the contaminated zones for the purpose of diluting tainted waters and forming hydraulic barriers, or they may be used to return treated waters to the aquifer. Many people refer to wells utilized to return treated water to the aquifer as "recharge wells," or simply "injection wells." Returning treated waters to the aquifer and setting up hydraulic barriers to contain contamination plumes are the most common uses for injection wells in aquifer remediation strategies.

The use of injection wells in some portion of the remedial strategy is almost an absolute. Most of the programs implemented in the past have included the removal of contaminated waters, above ground treatment, and subsequent return of these waters to the production zone. With technological advancements made in recent years, this is not always necessary. In-situ treatment is rapidly becoming a popular and relatively inexpensive remedial tactic. This requires the introduction of some agent or agents which will counteract and eliminate the contaminated waters without removing them from the aquifer. Each of these schemes, in-situ treatment and recovery and treatment, require some sort of injection program. It is these injection wells which are assessed in the following sections.

A specialized type of aquifer remediation related wells, known as hydrocarbon recovery "recharge" wells, is addressed separately in the following section, 4.2.8.4.

Inventory and Location

To date, the inventory of aquifer remediation wells in the United States includes 353 injection wells distributed throughout fifteen States as shown in Table 4-58. Since an abatement and restoration program may require several injection wells at a single contamination site, these wells often are clustered. The 257 injection wells accounted for in the USEPA Underground Injection Control database (known as FURS) are distributed throughout ten States with the majority of these injection wells located in three of those states (81 in Colorado, 59 in Michigan, and 60 in Oklahoma). This clustering is accounted for by concentrations of certain industrial practices which are prevalent in those States such as petroleum refining in oil-rich Oklahoma (refer to Section 4.2.8.4) and the manufacturing of industrial chemicals at a site in Colorado. This is demonstrated by the fact that all 60 injection wells located in Oklahoma are located at various petroleum refineries, and all 81 injection wells in Colorado are at the Rocky Mountain Arsenal which was used by the government during the Second World War for the manufacturing of chemicals used in warfare and later leased by private industry for chemical manufacturing. It should be noted that these wells serve the secondary purpose of aquifer recharge.

Construction, Siting, and Operation

The construction of injection wells used in aquifer remediation programs varies widely throughout the United States. The depths to which these wells are installed is based on the location of the contaminated aquifer. Since most contamination occurs as a result of surface or near surface spills, the depths of injection wells used in aquifer remediation are generally quite shallow. Over 50% of these wells are installed to depths of less than 100 feet (based on available inventory information). Diameters range from 1 to 12 inches for those wells (50%) identified above but also vary widely according to the amount of fluids they must deliver to the subsurface.

Remediation injection wells are screened when completed in sands and gravels. This eliminates or reduces incrustation and facilitates water movement (the latter being of primary concern in aquifer remediation). Furthermore, injection wells used for aquifer remediation are almost always cased, the only exception to this being the "wells" which return fluids through surface introduction (percolation). Casing is constructed of PVC piping and generally is installed from the surface through the top of the injection zone. The casing aids in supporting the walls of the well, helps keep out possible surface contaminants, and

TABLE 4-5B: SYNOPSIS OF STATE REPORTS FOR AQUIFER REMEDIATION(5X26)

REGION & STATES	EPA REGION	Confirmed Presence Of Well Type	Regulatory System	Case Studies/ Info. available	Contamination Potential Rating
Connecticut	I	NO	N/A	NO	N/A
Maine	I	NO	N/A	NO	N/A
Massachusetts	I	NO	N/A	NO	N/A
New Hampshire	I	NO	N/A	NO	N/A
Rhode Island	I	2 WELLS	N/A	NO	HIGH
Vermont	I	NO	N/A	NO	N/A
New Jersey	II	9 WELLS	NJPDES PERMIT	NO	N/A
New York	II	NO	N/A	NO	N/A
Puerto Rico	II	1 WELL	N/A	YES	N/A
Virgin Islands	II	NO	N/A	NO	N/A
Delaware	III	NO	N/A	NO	N/A
Maryland	III	NO	N/A	NO	N/A
Pennsylvania	III	NO	N/A	NO	N/A
Virginia	III	NO	N/A	NO	N/A
West Virginia	III	NO	N/A	NO	N/A
Alabama	IV	1 WELL	PERMIT	NO	VARIABLE
Florida	IV	NO	N/A	NO	N/A
Georgia	IV	NO	N/A	NO	N/A
Kentucky	IV	NO	N/A	NO	N/A
Mississippi	IV	NO	N/A	NO	N/A
North Carolina	IV	12 WELLS	PERMIT	NO	N/A
South Carolina	IV	NO	N/A	NO	N/A
Tennessee	IV	NO	N/A	NO	N/A
Illinois	V	NO	N/A	NO	N/A
Indiana	V	4 WELLS	N/A	NO	N/A
Michigan	V	59 WELLS	N/A	NO	N/A
Minnesota	V	7 WELLS	N/A	NO	N/A
Ohio	V	NO	N/A	NO	N/A
Wisconsin	V	17 WELLS	RULE	NO	LOW
Arkansas	VI	NO	N/A	NO	N/A
Louisiana	VI	NO	N/A	NO	N/A
New Mexico	VI	50 WELLS	N/A	NO	MOD-LOW
Oklahoma	VI	60 WELLS	RULE	NO	N/A
Texas	VI	37 WELLS	N/A	NO	N/A
Iowa	VII	NO	N/A	NO	N/A
Kansas	VII	15 WELLS	N/A	NO	LOW
Missouri	VII	YES	N/A	NO	N/A
Nebraska	VII	YES	PERMIT	NO	N/A
Colorado	VIII	81 WELLS **	N/A	NO	LOW
Montana	VIII	NO	N/A	NO	N/A
North Dakota	VIII	NO	N/A	NO	N/A
South Dakota	VIII	NO	N/A	NO	N/A
Utah	VIII	NO	RULE/PERMIT	NO	N/A
Wyoming	VIII	NO	N/A	NO	N/A
Arizona	IX	NO	N/A	NO	N/A
California	IX	NO	PERMIT	NO	LOW *
Hawaii	IX	NO	N/A	NO	N/A
Nevada	IX	NO	N/A	NO	N/A
American Samoa	IX	NO	N/A	NO	N/A
Tr. Terr. of P	IX	NO	N/A	NO	N/A
Guam	IX	NO	N/A	NO	N/A
CNMI	IX	NO	N/A	NO	N/A
Alaska	X	NO	N/A	NO	N/A
Idaho	X	NO	N/A	NO	N/A
Oregon	X	NO	N/A	NO	N/A
Washington	X	NO	N/A	NO	N/A

NOTE: SOME NUMBERS IN THIS TABLE ARE ESTIMATES.
* PROVIDED PROPER DESIGN, CONSTRUCTION AND OPERATION
** THESE WELLS SERVE THE SECONDARY PURPOSE OF AQUIFER RECHARGE

maintains the proper integrity between the injected fluids and the contaminated zones. The typical construction of injection wells used in aquifer remediation programs is shown in Figure 4-64.

Siting is a key factor in aquifer remediation strategies. In almost all cases injection wells are located upgradient from any discharge wells and contamination plumes. This facilitates the proper migration of injection fluids with respect to remediation objectives. Different remedial tactics require different arrays of injection wells.

Injection wells used to control hydraulic flow require different orientations in relation to contamination plumes than those injection wells returning treated waters to an aquifer. For instance, some injection strategies utilize two injection wells, a "double-cell containment" array, to contain and facilitate the proper movement of a contamination plume (Figure 4-65). A different strategy might be to utilize a single injection well to facilitate the proper movement and containment of plumes (Figure 4-65).

Isolating contaminants in an aquifer by using these hydraulic "barriers" requires much more precision in the siting of injection wells than does the return of treated waters. Typically, injection wells used to return treated waters simply are located upgradient of any recovery wells in the aquifer.

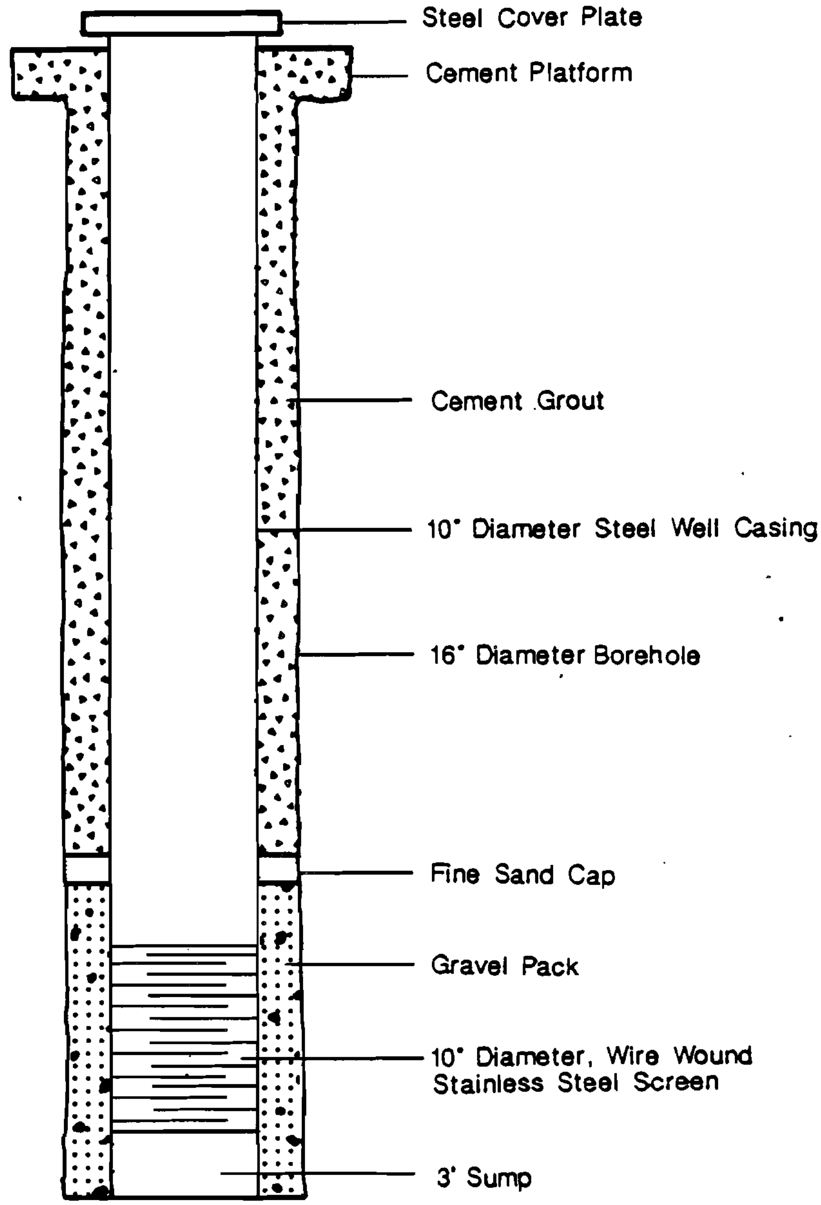
The operation of almost all of the injection wells used for aquifer remediation is by simple gravity flow. To date, there is no inventory information available indicating the use of pressurized injection.

Injected Fluids and Injection Zone Interactions

The primary forms of aquifer contamination which have been addressed in remediation programs are contamination through the introduction of organic compounds (chiefly hydrocarbons), industrial chemicals, and inorganic compounds. Because most contamination occurs as a result of surface or near surface spills, the nature and volume of injected fluids is a function of the hydrogeologic regime, the parameters of the contamination plume, and the design of the remediation program.

Hydrocarbon recovery largely depends on the types of hydrocarbons involved and on the recovery system being used. Recharge rates range from a few gallons per minute (gpm) to 100 gpm (refer to Section 4.2.8.4 for more detail). The constituents in the injected stream generally consist of some hydrocarbons recirculated back to the contaminated aquifer.

There is a facility in Alabama currently using two injection wells to recover and treat contaminated ground water. Standards

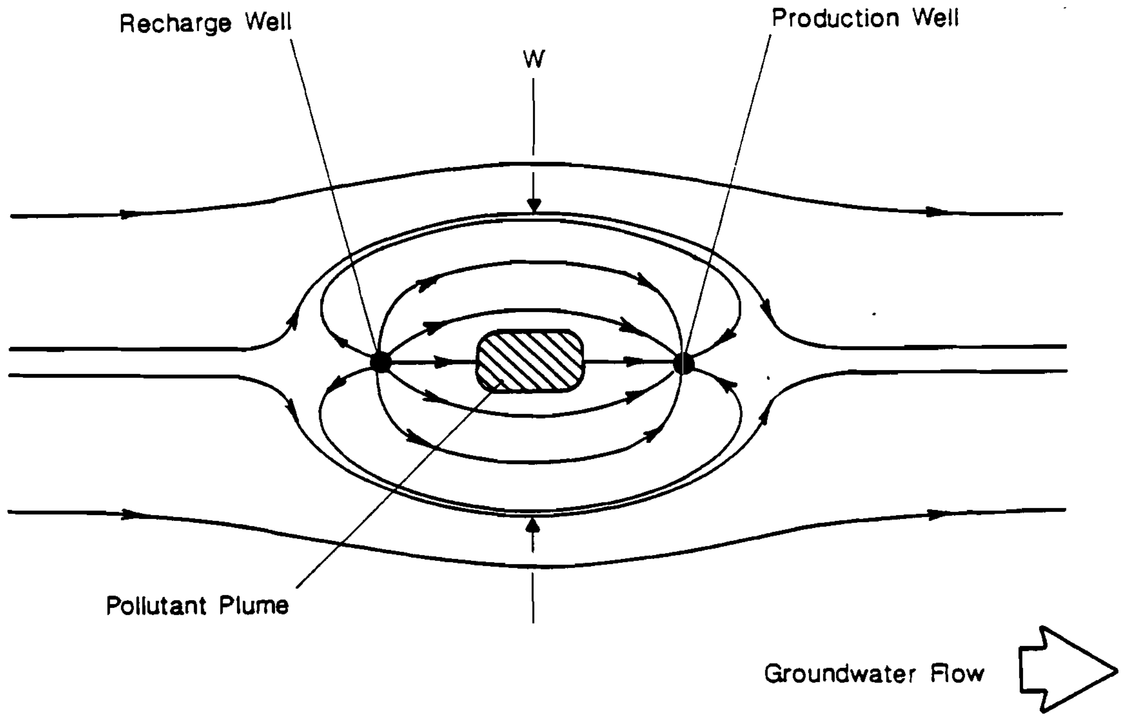


Not To Scale

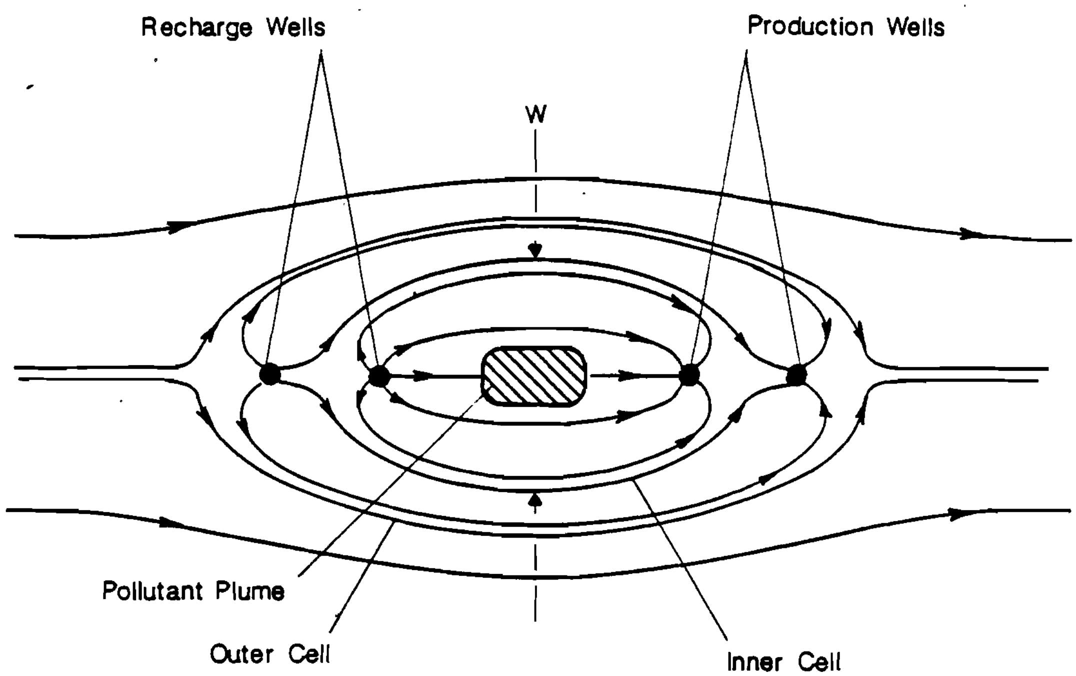
UNIROYAL CHEMICAL INJECTION WELL
USED FOR AQUIFER REMEDIATION

(from Alabama, 1986)

Figure 4-64



A. SINGLE-CELL



B. DOUBLE-CELL

SINGLE CELL AND DOUBLE CELL
HYDRAULIC CONTAINMENT SHOWING FLOW LINES

(from Wilson, 1984)

Figure 4-65

have been set for these injection fluids which must be met. These consist of no more than 100 mg/l COD and no more than 0.5 mg/l of nitrated organics.

Remediation programs for recovery and treatment of ground water contaminated with industrial chemicals most often utilize recovery wells to extract contaminated ground water. The tainted water undergoes above-ground filtering prior to reinjection. In Colorado, the remediation program at the Rocky Mountain Arsenal utilizes injection wells to return water that has been extracted from the contaminated zone and purified by carbon filtering. This method is used to aid in removing industrial chemicals and wastes.

Inorganic chemicals are also often present in unacceptable quantities in many aquifers. New techniques are being developed to treat these waters in situ and include a method called Vyredox which is being used in pilot programs in some areas of the United States to remove iron and manganese. Vyredox treatments involve the injection of degreased, highly oxygenated waters which precipitate out iron and manganese, thus improving water quality.

Hydrogeology and Water Use

Injection wells used in aquifer remediation programs seldom inject fluids into USDW. Their purpose is to restore contaminated aquifers to a condition in which they can provide usable waters. The degree of restoration may differ based on the projected use of the water. Because these remediation programs are generally expensive, aquifers that are easily replaced are seldom restored. This means that, in general, the aquifer might have to be the primary source of water for a variety of users to mandate remediation. The expense of remediation might be undertaken voluntarily by an industry if it can recover significant amounts of leaked product (enough to make it profitable), or it might be mandated by governmental or public demand in an area where users are not able to utilize low quality water.

Contamination Potential

Contamination potential for these wells must be assessed on a site specific basis rather than as a group. Since the goal of aquifer remediation is to increase the quality of an aquifer as a unit, one might jump to the conclusion that as Class V wells they possess a low potential for contamination. This, however, is not always the case. There are injection wells used in aquifer remediation programs which may place uncontaminated zones or other aquifers in the vicinity in jeopardy due to the nature of injected constituents or the hydrogeologic strata. This, however, varies widely from application to application. In accordance with the rating system previously outlined, we can only say that these wells possess (as a group) an unknown potential for contamination. It is possible to assess any of these wells on a site specific basis with the proper information, and efforts should be made in future work to do so. However, the varying hydrogeology, injection fluid nature, water use, and remediation techniques result in different potentials for contamination at different sites.

Current Regulatory Approach

Aquifer remediation wells are authorized by rule under Federally administered UIC programs (see Section 1). State and local authorities have little to do with the regulation of aquifer remediation. They may require the reporting of these wells for inventory efforts (per USEPA mandates) but seldom monitor these wells. Aquifer remediation programs are generally subject to widespread media attention which may aid State and local governments in monitoring these programs.

Recommendations

The Kansas State report suggests that implementation of a registration and monitoring program is in order. This would allow for site specific evaluations and the subsequent setting, on a site specific basis, of operating conditions which will aid restoration activities and restrict or eliminate any contamination potential. The Oklahoma State report recommends that these wells be constructed to the same set of standards by which discharge wells are constructed to insure the injection wells' integrity and to maintain remediation program standards. At a minimum, injection wells used in remedial programs should be cased from the surface through the top of the injection zone and screened in sands and gravels, and the annulus should be grouted. It is recommended in the Florida State report that injected fluid quality should be required to be better than the quality of the fluid inherent to the injection zone but not necessarily required to meet drinking water standards.

4.2.8.4 Hydrocarbon Recovery Injection Wells (5X26)

Well Purpose

Hydrocarbon recovery injection (recharge) wells are used to return the coproduced water pumped from hydrocarbon recovery wells back into the aquifer. These wells are a specialized type of aquifer remediation related wells (Section 4.2.8.3). The hydrocarbons and water are separated either by the pumping system in the recovery wells or by surface separators.

Hydrocarbons such as gasoline, diesel, fuel oil, and other refined petroleum products may leak into the subsurface from tanks and pipelines and migrate downward. Most such hydrocarbons are lighter than water and accumulate as a discrete layer of free hydrocarbons floating on the water table. If this hydrocarbon layer is not removed from the water table it will migrate downgradient into streams or move under adjoining properties. In areas where the water table is very shallow (less than about 20 feet) fire and other hazards from fumes are possible in addition to ground-water pollution.

Removal of the free hydrocarbon layer (contamination source) may be accomplished by a variety of remedial methods of which pumping is the most common. In many instances a two-pump system is used. The bottom pump in the recovery well creates a cone of depression in the water table and pumps only water. The hydrocarbon flows down the cone of depression into the well and is pumped out by the upper pump which pumps only hydrocarbons. In other situations, both water and hydrocarbons are pumped from the well by a single pump, and the oil and water are then separated at the surface.

With either rehabilitation system water must be removed from the aquifer in order to remove the hydrocarbons. In many cases the most feasible and environmentally sound method of disposing of the water is to discharge the water back into the aquifer through injection wells.

Inventory and Location

Large-scale hydrocarbon recovery is currently underway at many active and abandoned refineries, tank farms, and terminals across the United States. Such remedial action will become more widely practiced as more of these facilities are investigated. There are approximately 350 active and inactive refinery sites in the United States, and as yet an undetermined number of tank farms and terminals - probably on the order of 1,000 to 5,000. Although no inventory has been made, it is estimated that cleanup of free hydrocarbons may be required at 30 to 50 percent of these sites. Water reinjection wells may be used at approximately 25 percent of the sites anticipated to require remedial action.

Small-scale hydrocarbon recovery will be required at approximately 270,000 underground storage tanks that are estimated to have leaked. However, injection of the water produced in the remedial actions is anticipated at only a small fraction of these sites.

Construction, Siting, and Operation

The design and construction of water injection wells used in hydrocarbon recovery is not sophisticated. These wells are commonly only 20 to 100 feet deep and are constructed with plastic (PVC) casing 2 to 6 inches in diameter. Such wells are not operated under pressure and the surface seal around the outside of the casing is used only to prevent surface fluids from migrating down the annulus. Figure 4-66 is a typical hydrocarbon recovery injection well schematic. Figure 4-67 is a typical hydrocarbon recovery well. The water produced by the recovery well is piped to the injection well. Maintenance of these water injection wells is limited to periodic well rehabilitation to remove plugging caused by the high iron content commonly associated with hydrocarbon pools.

Injected Fluids and Injection Zone Interactions

No data have been submitted by the States, but it is known that in some instances the injected water contains water soluble fractions from the hydrocarbons such as benzene, toluene, and xylene, commonly referred to as BTX. The BTX content of the injected water may, in some instances, exceed currently recommended drinking water standards. The Oklahoma Water Resources Board (OWRB) put together a list of constituent concentrations both "realistic and representative" for typical injection streams located in remediation areas at certain refineries in Oklahoma. This list is given in Table 4-59.

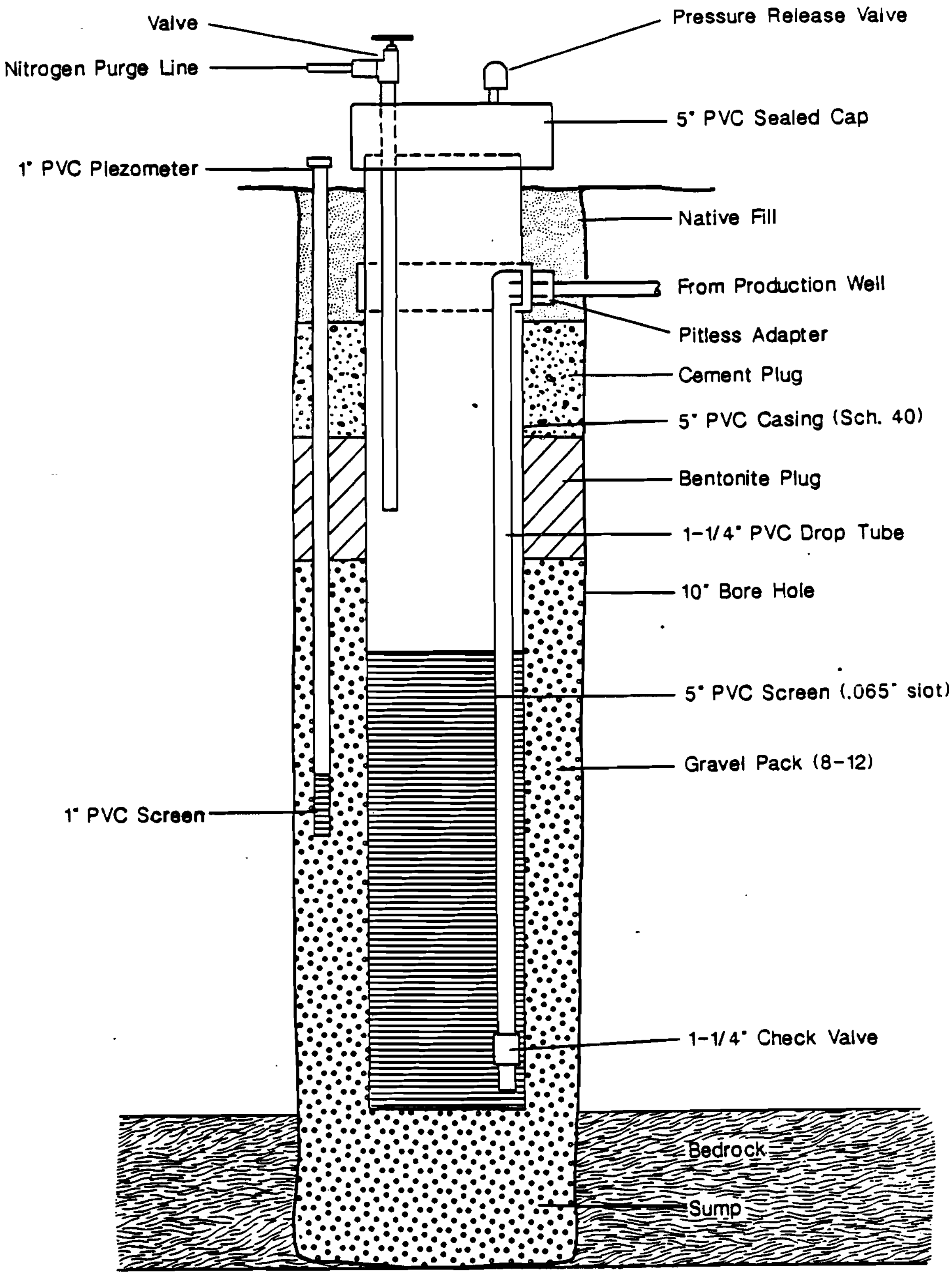
TABLE 4-59

OWRB LIST OF CONSTITUENT CONCENTRATIONS FOR HYDROCARBON RECOVERY INJECTION WELL FLUIDS

Oil/Grease	4.80	mg/l	Lead	0.02	mg/l
Phenols	3.00	mg/l	Iron	8.40	mg/l
Toluene	12.80	mg/l	Total Hardness	86.80	mg/l
Benzene	7.90	mg/l	pH	7.10	
			COD	229.00	mg/l

Normally, water containing BTX would be treated before injection back into the aquifer; however, in many cases involving hydrocarbon recovery, such treatment would be pointless unless the soil is also cleaned or removed. Only 40 to 60 percent of the total amount of hydrocarbons floating on the water table can be recovered. The unrecoverable fraction remains in the soil above the water table and continues to provide a source of BTX into the underlying ground water. Therefore, removing the BTX from the water being pumped from the aquifer and reinjected is useless unless all of the hydrocarbons are removed from the soil or the contaminated soil is excavated.

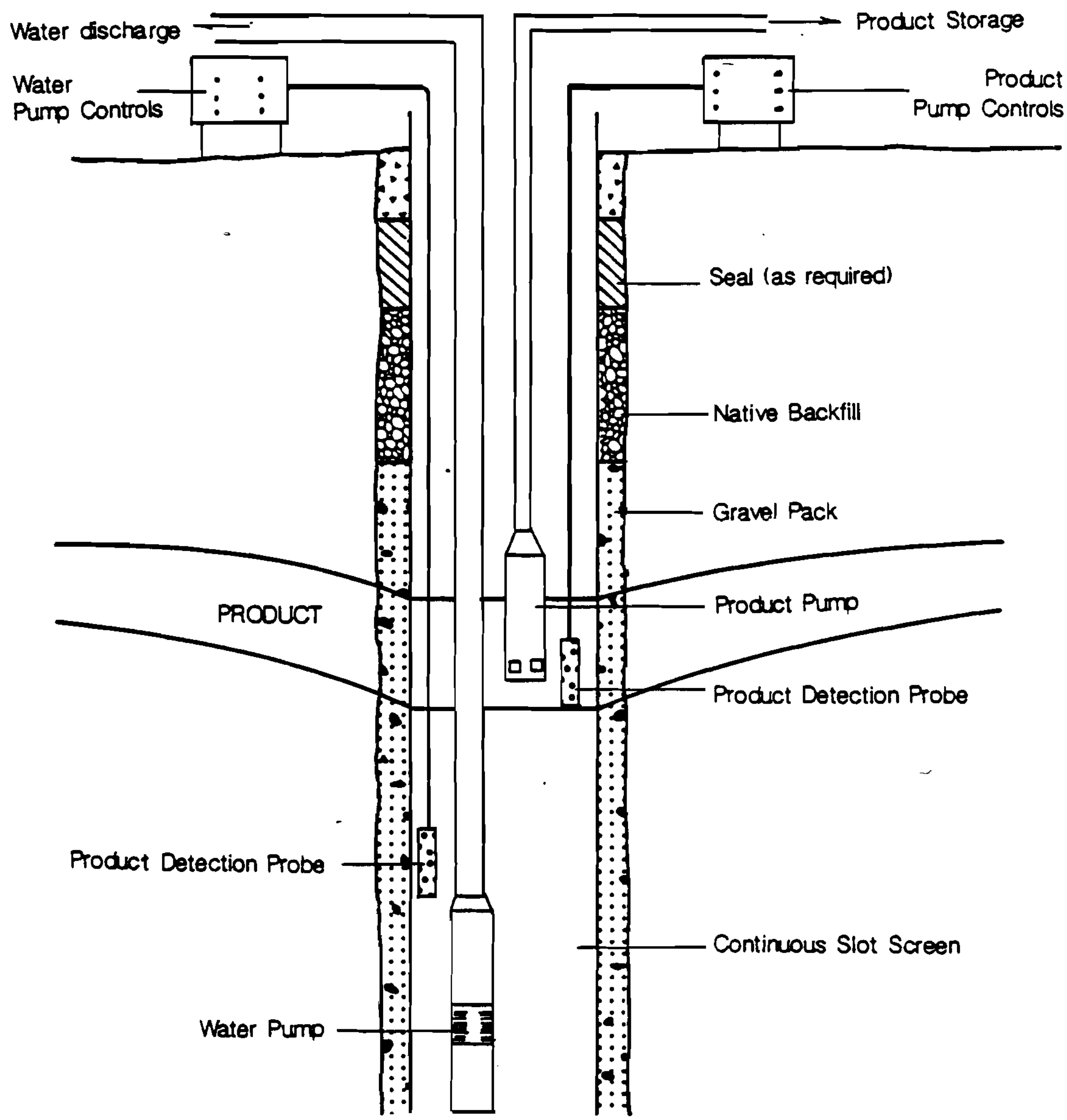
In large-scale hydrocarbon recovery projects, the amount of water injected back into the aquifer may total up to 1,000 gpm. Handling of such volumes by existing on-site treatment is usually not feasible; furthermore, injection of the water can accelerate the cleanup of the free hydrocarbons.



TYPICAL CLOSED RECHARGE WELL COMPLETION
AQUIFER REMEDIATION

(Source: Oklahoma, 1985)

Figure 4-66



SCHEMATIC OF TWO-PUMP SYSTEM UTILIZING
ONE RECOVERY WELL FOR AQUIFER REMEDIATION

(from Oklahoma, 1985)

Figure 4-67

In small-scale rehabilitation efforts, where less than 50 gpm water is produced, alternatives other than injection are more feasible, hence injection is rarely needed.

In all cases, the quality of the water being injected is the same as the quality of the water already in the aquifer, providing, of course, the water is injected into the same geologic horizon and area from which it was originally pumped.

Hydrogeology and Water Use

Hydrocarbon recovery as a form of aquifer remediation may be required in a wide variety of hydrogeological settings. It is considered probable at this time that only a small minority of the large-scale hydrocarbon recovery operations requiring the use of injection wells would be located over an aquifer being used as a water supply. Most refineries and major tank farms are believed to be located on bedrock or over very shallow alluvial geologic environments not being used for water supply.

Contamination Potential

The overall contamination potential of hydrocarbon recovery injection wells is unknown; contamination potential must be assessed on a case by case basis. Recharging water being pumped by a hydrocarbon recovery operation back into the same geologic environment from which the water was originally pumped does not contribute to the contamination of the water already there. In many instances removal of the free hydrocarbons alone accomplishes the objective of the rehabilitation action, i.e. where drinking water supplies are not threatened by the continued presence of BTX.

In those instances where the water in the aquifer contains BTX or other contaminants exceeding drinking water standards and where drinking water supplies are threatened, treatment of the water prior to injection should be accomplished. It must be stressed, however, that cleanup of the water underlying a hydrocarbon pool must be accompanied by complete cleanup of the hydrocarbons remaining in the soil above the water table in order to prevent the water from becoming recontaminated.

Recommendations

No recommendations concerning this type of remediation well were provided in State reports.

4.2.8.5 Abandoned Drinking Water/Waste Disposal Wells (5X29)

Well Purpose

Intentionally or unintentionally, unplugged or improperly abandoned water wells can become receptacles for the disposal of waste. Intentional misuse may involve disposal of hazardous wastes, sewage, or simply household garbage. Improperly abandoned wells can become the conduit by which unintentional disposal occurs. Surface runoff draining into a well and the establishment of a hydraulic connection between aquifers of different water quality are two examples of unintentional misuse.

An important consideration is that surface or near-surface contamination may be transferred to potable aquifers without the benefit of natural clean-up processes. Ground water usually travels very slowly, a few to tens of feet per year, and during that downward movement through unsaturated soils, natural purification occurs. Purification involves filtering, biological, and other chemical changes. Rainfall runoff or spills entering improperly abandoned wells around industrial sites, construction sites, animal feedlots, etc. will be injected directly into an aquifer, circumventing the purification process.

Inventory and Location

A total of 3,050 abandoned drinking water wells have been reported. There is also one such well on the FURS inventory. Documented cases of abandoned drinking water wells used for waste disposal were rarely found in the State reports. Much of the reported inventory represents estimates of improperly abandoned water wells from a few States. Most States reported no such wells exist. This is understandable since most States do not make an effort to check the status of the thousands of private drinking water wells on a periodic basis.

The distribution of reported wells is shown on Table 4-60. In all likelihood there are probably several hundred to many thousands of 5X29 wells in every State. Because of a lack of understanding among the general public as to the nature and occurrence of ground water and its sensitivity to contamination, most disposal is probably unintentional. Eventually some of these wells are discovered after a complaint about poor water quality from a well owner prompts an investigation.

Construction, Siting, and Operation

A vast array of well designs is possible for this well type. Local hydrogeologic conditions, preferences on materials, and construction methods are the sources of variability. Most of these wells are probably shallow wells dug, bored, or drilled for livestock and domestic uses. A lack of understanding, finances,

TABLE 4-60 SYNOPSIS OF STATE REPORTS FOR ABANDONED DRINKING WATER WELLS/WASTE DISPOSAL (5X29)

REGION & STATES	EPA REGION	Confirmed Presence Of Well Type	Regulatory System	Case Studies/ Info. available	Contamination Potential Rating
Connecticut	I	NO	NO	NO	N/A
Maine	I	NO	NO	NO	N/A
Massachusetts	I	NO	NO	NO	N/A
New Hampshire	I	NO	NO	NO	N/A
Rhode Island	I	NO	P&A RULES	NO	N/A
Vermont	I	NO	NO	NO	N/A
New Jersey	II	NO	P&A RULES	NO	N/A
New York	II	NO	NO	NO	N/A
Puerto Rico	II	NO	P&A RULES	NO	N/A
Virgin Islands	II	NO	NO	NO	N/A
Delaware	III	NO	P&A RULES	NO	N/A
Maryland	III	NO	P&A RULES	NO	N/A
Pennsylvania	III	NO	P&A RULES	NO	N/A
Virginia	III	NO	P&A RULES	NO	N/A
West Virginia	III	NO	P&A RULES	NO	N/A
Alabama	IV	NO	P&A RULES	NO	N/A
Florida	IV	YES	P&A RULES	NO	N/A
Georgia	IV	NO	P&A RULES	NO	N/A
Kentucky	IV	NO	NO	NO	N/A
Mississippi	IV	NO	NO	NO	N/A
North Carolina	IV	NO	P&A RULES	NO	N/A
South Carolina	IV	NO	NO	NO	N/A
Tennessee	IV	NO	P&A RULES	NO	N/A
Illinois	V	NO	P&A RULES	NO	N/A
Indiana	V	156 WELLS	NO	NO	N/A
Michigan	V	630 WELLS	P&A RULES	YES	N/A
Minnesota	V	1,309 WELLS	P&A RULES	YES	N/A
Ohio	V	YES	P&A RULES	NO	N/A
Wisconsin	V	NO	P&A RULES	NO	N/A
Arkansas	VI	NO	P&A RULES	NO	N/A
Louisiana	VI	NO	P&A RULES	NO	N/A
New Mexico	VI	NO	NO	NO	N/A
Oklahoma	VI	NO	P&A RULES	NO	N/A
Texas	VI	945 WELLS	P&A RULES	NO	N/A
Iowa	VII	NO	NO	NO	N/A
Kansas	VII	NO	P&A RULES	NO	N/A
Missouri	VII	NO	P&A RULES	NO	N/A
Nebraska	VII	YES	P&A RULES	NO	N/A
Colorado	VIII	YES	P&A RULES	NO	HIGH
Montana	VIII	NO	NO	NO	N/A
North Dakota	VIII	NO	P&A RULES	NO	N/A
South Dakota	VIII	NO	P&A RULES	NO	N/A
Utah	VIII	7 WELLS	BANNED	NO	RANGE 2-7(7=HIGHEST)
Wyoming	VIII	NO	P&A RULES	NO	N/A
Arizona	IX	NO	P&A RULES	NO	N/A
California	IX	NO	P&A RULES	NO	N/A
Hawaii	IX	NO	NO	NO	N/A
Nevada	IX	NO	P&A RULES	NO	N/A
American Samoa	IX	NO	NO	NO	N/A
Tr. Terr. of P	IX	NO	NO	NO	N/A
Guam	IX	NO	NO	NO	NO
CNMI	IX	NO	NO	NO	NO
Alaska	X	3 WELLS	P&A RULES	NO	HIGH
Idaho	X	NO	P&A RULES	NO	N/A
Oregon	X	NO	P&A RULES	NO	N/A
Washington	X	NO	P&A RULES	NO	NO

NOTE: SOME NUMBERS IN THIS TABLE ARE ESTIMATES.

and regulatory oversight contribute to these wells' potential to degrade ground water.

Private, domestic wells are most likely to be found in rural areas. Therefore, chances of locating improperly abandoned drinking water wells are probably highest in rural areas where there is a heavy reliance on ground water. Though fewer in number, such wells located in suburban or urban areas could have a greater adverse impact on ground-water resources. A municipal well field contaminated by such wells would be costly indeed.

Injected Fluids and Injection Zone Interactions

Potentially, a spectrum of contaminants including hazardous chemicals, sewage, and saline water could enter and degrade USDW through these wells. Dilution or other attenuation mechanisms may reduce contaminant levels as the injectate moves away from the well. The areal distribution of contamination is very much case specific. Variables such as the nature of the contaminant (i.e. salt, metals, petroleum products, bacteria), injection rates and volumes, volume of water in the USDW, natural recharge rate, the USDW rock type, background water quality in the USDW, and hydraulic conductivity of the USDW will determine the impact of contamination.

Ground-water contamination caused by faulty well construction has been documented in an 1,100 square mile area of Southeast Nebraska by Exner and Spalding (1985). Nitrate-nitrogen (NO_3 - as N) and coliform contamination were most prevalent in dug (47%) or augered (80%) wells with open-jointed casing. Farms in this rural area are cash grain-livestock operations, and nitrogen fertilizer use is low. Surface and shallow subsurface leakage into improperly constructed wells from barnyards and corrals was primarily responsible for the contamination. Rural water districts have been formed due to the private well contamination problems. Wells abandoned in favor of a public supply add to the problem because they are not being properly abandoned.

The Minnesota State report describes an on-going practice of domestic sewage disposal by 75 homes via old water wells. In this case the area was connected to a city water supply and the private well owners chose not to plug their wells or maintain them as reserve water supplies. Contamination would be in the form of NO_3 and fecal coliform. Other contaminants might be household cleaning agents, paint, and solvents.

Cases of herbicides or pesticides entering USDW through improperly constructed or abandoned water wells are also known. Improperly constructed farmstead water supply wells acting as conduits for herbicide or pesticide contamination are discussed by Jones (1973), and Exner and Spalding (1985).

Hydrogeology and Water Use

Shallow aquifers utilized for private domestic and/or livestock water supplies are probably most affected by these wells. Historically, these aquifers have had some of the best quality ground water available.

In 1980, 97 percent of rural domestic water supplies in the United States was obtained from ground-water sources (USGS, 1985). The word "rural" carries false connotations of "uninhabited". Actually, about 42 million people were served by their own supply of domestic well water in 1975 (Pettyjohn, et. al., 1979).

Problems with the sanitary condition of private domestic wells have been recognized for years. Studies on the condition of individual water supplies provided by wells were conducted in several states including Wyoming, Ohio, Iowa, Georgia, Kentucky, and Tennessee, during the early 1970's. At that time it was estimated that 40 percent of the supplies were polluted by nitrates or coliform bacteria (Whitsell and Hutchinson, 1973). The studies concluded that faulty and inadequate well construction was primarily responsible for the situation (Whitsell and Hutchinson, 1973).

Contamination Potential

Based on the rating system described in Section 4.1, abandoned drinking water/waste disposal wells are assessed to pose a moderate potential to contaminate USDW. These facilities typically do inject into or above Class I or Class II USDW. Typical well construction, operation, and maintenance would allow fluid injection or migration into unintended zones. Injection fluids may or may not have concentrations of constituents exceeding standards set by the National Primary or Secondary Drinking Water Regulations. Based on injectate characteristics and possibilities for attenuation and dilution, injection may or may not occur in sufficient volumes or at sufficient rates to cause an increase in concentration (above background levels) of the National Primary or Secondary Drinking Water Regulation parameters in groundwater, or endanger human health or the environment in a region studied on a group/area basis.

Confirmed incidents of intentional waste disposal via abandoned water wells seem rare. A literature search of two electronic ground-water and environmental databases, Enviroline and Water Resources Abstracts, did not result in a single case study. Such activities were alluded to in a few State reports, but only Minnesota and Michigan had documented occurrences.

The major contamination problem seems to be the unintentional injection caused by faulty or inadequate well construction and abandonment. The evidence points to a broad scale problem, especially in rural areas. The most significant contaminants are nitrates and coliform bacteria, both health hazards.

This well type is rated as a moderate contamination potential according to the rating scheme. Yes answers can be given to the first three questions under high contamination potential. The fourth question, concerning injection volumes, cannot be answered affirmatively. Exner and Spalding (1985) found that NO_3 contamination varied widely in their study area, indicative of point-source contamination. Contaminant plumes from such wells may have crossed property lines but had not spread to affect all water supplies in the 1,100 square mile study area.

Current Regulatory Approach

Abandoned drinking water wells used for injection are authorized by rule under Federally-administered UIC programs (see Section 1). According to State reports received, the direct implementation States have not issued UIC permits for this injection practice.

According to Gass and others (1977), most States have some regulations dealing with abandonment of water wells. At the time of their investigation, many of the State programs were inadequate. Some of the major reforms suggested in the Minnesota report included:

1. procedures for well abandonment need to be described in detail for each different subsurface environment;

2. provisions need to be made for enforcement of abandonment regulations; and

3. requirements need to be made for permanent plugging and abandonment procedures to be done by licensed water well drillers.

Recommended plugging and abandonment procedures from two organizations, USEPA, and the American Water Works Association are referenced in Appendix E. States having some kind of regulation are indicated on Table 4-63. The regulatory status of fifteen states, the District of Columbia, American Samoa, Guam, the Trust Territories of the Pacific Islands and the Commonwealth of the Mariana Islands is unknown.

Recommendations

Utilization of former water wells for intentional waste disposal requires regulatory oversight. Such wells would be injecting directly into USDW. Years of neglect or inadequate construction standards could result in a well becoming a hydraulic connection between aquifers of varying water quality. Limitations on injectate quality and quantity must be imposed to protect USDW if these wells are allowed to operate.

The USEPA Region V DI program stresses that the issue of abandoned drinking water wells should be seriously considered. Abandoned drinking water wells are a prime suspect for surface runoff which is an uncontrolled source of contaminants. Any uncontrolled source of contaminants poses a high potential for contamination of USDW. These wells are completed in zones that are currently being used for drinking water or may be used sometime in the future.

Unintentional injection through improperly plugged and abandoned water supply wells is a widespread problem. Most States already have regulations concerning abandonment, but due to the large numbers of private wells in existence, inspection and enforcement is not feasible. In some cases the plugging and abandonment procedures are not described in sufficient detail in the State regulations to protect USDW. The danger of inadequate plugging and abandonment is also present in several States where persons performing such work do not have to be licensed water well drillers. The USEPA may be able to bring a more standardized approach to plugging and abandoning water wells among the States, Territories, and Possessions.

The problem of locating these improperly plugged and abandoned wells and the question of who will pay to permanently seal the wells will be difficult to resolve. Well owners may not call attention to their abandoned wells because they do not want to pay the $500 - $1,500 fee to plug and abandon the average 4-inch diameter domestic well (Minnesota, 1986). Without well owners' help, State and local officials do not have the personnel, time, or money to perform inspections to locate the wells.

The answer seems to lie in federal support of approved State programs to locate and properly plug and abandon these wells. Puerto Rico, Indiana, Michigan, and Minnesota recommend that better inventories be established. The Minnesota Department of Health has undertaken such a program, although costs are the responsibility of the well owner. The Minnesota program deserves study because (1) it tries to establish the scope of the problem, (2) areas of the State have been prioritized for action, and (3) procedures for plugging and abandonment are described. The USEPA would have to produce a similar guidance document to the States should this approach be taken nationally. The Minnesota Department of Health program is included in the list of supporting data in Appendix E.

Utah suggests that the only corrective alternative for these wells is closure and that this practice must be halted to prevent aquifer contamination. Utah also suggests that sanitary sewer hook-up should be required for domestic waste disposal and disposal of industrial wastes which have received necessary pretreatment. Hazardous waste should be handled in accordance with RCRA regulations. It appears that the most practical way these wells can be located and closed is to educate the public and personnel in other government programs (i.e., RCRA, NPDES, local environmental and planning/building programs) in how to locate these wells, what they consist of, and the damage they can do to ground water.