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The Class V Underground Injection Control Study

Volume 1

Study Approach and General Findings

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1. EXECUTIVE SUMMARY

Class V underground injection wells are typically shallow waste disposal wells or other devices used to release fluids underground. These wells generally inject either directly into underground sources of drinking water (USDWs) or into the shallow subsurface that overlies those resources. Class V wells have a variety of designs and uses and include disposal mechanisms such as large-capacity septic systems and storm water and agricultural drainage systems.

The U.S. Environmental Protection Agency (USEPA) addresses Class V injection wells through the federal underground injection control (UIC) program under the authority of the Safe Drinking Water Act. This program includes the basic requirement that Class V injection wells cannot endanger USDWs and gives UIC program staff the authority to take whatever actions are needed to ensure that underground drinking water supplies are in fact protected. Many states have primary responsibility for implementing the program and/or control Class V wells under their own authorities.

This report presents the results of a study of 23 categories of Class V wells. The study was conducted to develop background information for USEPA to use in evaluating the risk that these wells pose to underground drinking water supplies and if additional federal regulation is warranted. Information collected on these wells included: inventory, injectate constituents, contamination incidents, and current state regulations.

USEPA estimates that more than 686,000 Class V wells within these 23 different categories currently exist in the U.S. The two largest categories by far are storm water drainage wells (approximately 248,000) and large-capacity septic systems (approximately 353,000), which together comprise almost 88 percent of the national total. In contrast, some categories are very small, including in-situ fossil fuel recovery wells, which are not presently known to exist, and spent brine return flow wells, aquaculture waste disposal wells, geothermal direct heat wells, and subsidence control wells, which have about 100 or less each. In general, there are significant uncertainties associated with these data. States maintain relatively accurate numbers for mine backfill, geothermal, aquifer recharge, aquifer storage and recovery, and aquifer remediation wells. For other well types, however, USEPA and the states suspect that their inventories underestimate the true numbers of wells.

Class V wells are located in virtually every state, especially in unsewered areas where the population is likely to depend on ground water. This is particularly true for storm water drainage wells and large-capacity septic systems, which likely exist in every state, as well as heat pump/air conditioning return flow wells which exist in 46 states and aquifer remediation wells which exist in 39 states. The following potentially exist in six or fewer states: spent brine return flow wells, aquaculture waste disposal wells, solution mining wells, geothermal power wells, salt water intrusion barrier wells, and subsidence control wells. All of the others are potentially in 10 to 32 states.

Sampling data that can be used to characterize the chemical composition of the fluids released are sparse for most well types, but the information available provides evidence that many of the wells release fluids with one or more chemicals in concentrations above drinking water maximum contaminant levels (MCLs) or health advisory levels (HALs). Nitrate along with several metals and other inorganics are particularly prevalent, with organic pollutants generally being less of a concern for most wells. Biological contaminants (coliform bacteria and other microorganisms) are also a concern for some well types, such as agricultural drainage wells, large-capacity septic systems, food processing wells, sewage treatment effluent wells if treatment systems do not function properly, possibly aquaculture waste disposal wells, and lake-level control wells (included within the storm water drainage well category).

Class V wells are typically shallow, injecting into or above USDWs, but they may also inject below USDWs. Many Class V wells release fluids into USDWs. For example, salt water intrusion barrier wells, aquifer recharge, and aquifer storage and recovery wells generally release fluids directly into USDWs for the purpose of preserving drinking water supplies, and as such, are typically held to high standards for injectate quality. Several Class V wells inject above USDWs. Large-capacity septic systems and other kinds of Class V wells that are designed as septic systems (including many food processing wells and some carwash wells and aquaculture waste disposal wells) release fluids into the shallow soil above ground water. Class V wells may also inject below the lowermost USDW, such as spent brine return flow wells.

There are no or few cases of contamination linked to most of the well types studied, although this may be due to the fact that USEPA and state UIC programs generally have limited resources to search for such cases. Wells with the most contamination cases are, predictably, the most prevalent wells, including storm water wells, large-capacity septic systems, and agricultural drainage wells. Each of these well types, plus several others, are also vulnerable to spills or illicit discharges. For example, storm water wells can be located conveniently along roads and in parking lots where spills of oil, gasoline and other contaminants can occur.

Regulatory authority over Class V wells varies widely among states. Regulatory schemes, which are very state- and well-specific, include general authority to protect USDWs using discretionary authority; permit by rule, meaning an entire class of wells is deemed permitted as long as they comply with standards and requirements found in the regulations; an identical or general permit, based on state technical regulations, is issued for each well within a given category; and authority to issue site-specific (or individual) permits, inspect, and take enforcement action. State UIC programs are generally resource-constrained. This means the states are often not able to implement UIC programs as vigorously as they would like. The lack of resources typically manifests itself in a state program that is more reactive than proactive.

An overview of the Class V injection wells discussed in this report is provided in the table below. These wells are described in detail in separate volumes that make up the body of this report, except for aquifer recharge wells and aquifer storage and recovery wells, which are covered together in Volume 21. The different well categories are extremely diverse in their purpose, their design and operation, their number and location, the nature of the fluids they inject, their potential to contaminate

USDWs, and the way they are currently regulated by the states. They include relatively simple designs that drain storm water runoff or excess water from agricultural fields, large-capacity septic systems used to dispose of sanitary sewage, wells used to dispose of wastewater from certain commercial and industrial establishments, wells used to inject water for the purpose of storage or recharging an aquifer, wells used to test new technologies, and wells used to inject fluids for the purpose of remediating a contaminated aquifer or protecting a freshwater aquifer from the intrusion of saltwater.

In addition to these 23 well categories, the study examined Class V motor vehicle waste disposal wells, large-capacity cesspools, and industrial wells. On July 29, 1998, USEPA proposed additional UIC regulations for these three well types when located in ground water- based source water protection areas being delineated by states in accordance with the 1996 Amendments to the Safe Drinking Water Act (63 FR 40586). To support decisions for the final rulemaking, USEPA collected information on motor vehicle waste disposal wells, large-capacity cesspools, and industrial wells nationwide as part of the overall Class V Study. The information compiled from this effort was placed in the public docket and announced in a notice of data availability (NODA) published in the *Federal Register* on May 21, 1999 (64 FR 27741), and is not addressed further in this report. Just as it will use the information presented in this report to support regulatory decisions for the 23 well categories covered in the table below, USEPA will use the information from the NODA to support further regulatory decisions for motor vehicle waste disposal wells, large-capacity cesspools, and industrial wells.

Overview of Class V Wells Included in This Report

Well Type	Inventory		Number of States Potentially with Wells	Injectate Constituents > MCLs or HALs	Contamination Potential	State Regulations in States With the Most Wells
	Documented	Estimated				
Agricultural Drainage Wells	>1,069	>2,842	21	Nitrate, Boron, Sulfate, Coliforms, Cyanazine, Atrazine, Alachlor, Adlicarb, Carbofuran, 1,2-Dichloropropane, Dibromochloro-propane, Chloride, and TDS	Five contamination incidents documented. Also, studies in agricultural areas have linked nitrate contamination in ground water to agricultural drainage well use. Wells may be vulnerable to spills from manure lagoons, direct discharges from septic tanks, and accidental releases of materials used in farming operations (e.g., motor oils, pesticides).	Individual permit: ID (for wells ≥18 deep) and TX Permit by rule: OH, ID (for wells <18 feet deep) IA: all wells that existed before 2/18/98 must close or get a permit by 12/31/01; new wells prohibited but may be permitted under strict conditions (unlikely to be permitted) Ban: MN (for “wells” that reach ground water)
Storm Water Drainage Wells	71,015	247,522	probably 50	Aluminum, Antimony, Arsenic, Beryllium, Cadmium, Chloride, Chromium, Color, Copper, Cyanide, Iron, Lead, Manganese, Mercury, Nickel, Nitrate, pH, Selenium, TDS, Turbidity, Zinc, Fecal Coliforms, and nine organics	Presence of these wells near highways, parking lots, and loading facilities increases likelihood/vulnerability to accidental spills and purposeful illicit discharges. Fifteen contamination incidents documented.	Permit by rule: IL, IN, MI, OH, WI (<10 ft. deep and constructed prior to 1994), MT, WY, ND, SD, UT, CO, ID (< 18 ft. deep), OR, WA, KS, TN, RI Individual permit/registration system: AZ, CA, HI, ID (> 18 ft. deep), AL, FL, TX, NH, MD, NE, NY Banned: NC, GA, WI (any new well since 1994 and wells >10 ft. deep since the 1930's), MN (for “wells” that reach ground water)

Overview of Class V Wells Included in This Report (continued)

Well Type	Inventory		Number of States Potentially with Wells	Injectate Constituents > MCLs or HALs	Contamination Potential	State Regulations in States With the Most Wells
	Documented	Estimated				
Carwash Wells	+ 4,651	+ 7,195	19	Antimony, Arsenic, Beryllium, Cadmium, Lead, Thallium, Methylene chloride, Tetrachloroethene, Aluminum, Iron, and Manganese	Possibility of contamination due to self-service nature of facilities (someone may use degreasers or other chemicals or change oil over drains). Two documented contamination incidents from unknown causes.	Permit by rule: WV Report discharge: CA Individual permit: AL, MS, NY, WA, MD, NH, and ME Ban: IA
Large-Capacity Septic Systems (LCSSs)	~43,000	~353,000 (95% prediction interval of 304,000 to 403,000)	50	Aluminum, Arsenic, Fecal Coliforms, Iron, Manganese, Nitrate (as N), Total Nitrogen Species (as N), Formaldehyde (from RV systems), Sodium	Vulnerable because any materials spilled/dumped down drains enter the well. Three documented contamination incidents with another 24 sites where contamination may have occurred.	No consistent state regulation of LCSSs. State regulations vary from stringent siting, construction, and operation requirements (e.g., MA, MN) to general construction permitting (e.g., NJ, IA)
Food Processing Wells	741	+1,468	29	Nitrate, Nitrite, Total Coliform, Ammonia, Odor, Turbidity, and Chloride	High potential for contamination due to little state oversight and type/nature of facilities. Moderate potential for receiving spills of strong cleaning chemicals due to location of floor drains and chemical storage/use practices. One documented contamination incident.	Permit by rule: AL, TN, WV, and IA Individual or general permit: AK, ME, NY, OR, and WI Varies by county/region: CA Banned: OR

Overview of Class V Wells Included in This Report (continued)

Well Type	Inventory		Number of States Potentially with Wells	Injectate Constituents > MCLs or HALs	Contamination Potential	State Regulations in States With the Most Wells
	Documented	Estimated				
Sewage Treatment Effluent Wells	1,675	>1,739	18	Fecal Coliform, Nitrate, TDS, Pesticides	Potential for impacts to ground and surface water quality from nutrients. Low vulnerability because most wells appear to have discharge limits and monitoring requirements; any injectate that does not meet the permit conditions is likely to be detected by the monitoring program. Three contamination incidents.	Permit by rule: ID, TX Aquifer Protection Program Permit: AZ Ground Water Discharge Permit: MA, NH, and WI (for discharge into a shallow subsurface absorption field located in the unsaturated zone above the water table). Individual permit: CA, FL, HI, WV, OR, WY Banned: WI (for direct discharge from a sewage treatment plant into a saturated formation)
Laundromat Wells	<700	>3,495	19	TDS and pH	Wells may be susceptible to uncontrolled laundering of contaminated articles due to unsupervised nature of coin-op laundromats. No reported contamination incidents.	Permit by rule: IA, MS, and WV Individual permit: AL and NY
Spent Brine Return Flow Wells	98	98	2	Barium, Boron, Chloride, Copper, Iron, Manganese, TDS, and pH	Unlikely to receive accidental spills or discharges. No contamination incidents reported.	Individual permit: AR, MI

Overview of Class V Wells Included in This Report (continued)

Well Type	Inventory		Number of States Potentially with Wells	Injectate Constituents > MCLs or HALs	Contamination Potential	State Regulations in States With the Most Wells
	Documented	Estimated				
Mine Backfill Wells	5,060	>7,890	22	Antimony, Arsenic, Barium, Beryllium, Boron, Cadmium, Chromium, Lead, Mercury, Molybdenum, Nickel, Selenium, Silver, Thallium, Zinc, Aluminum, Copper, Iron, Manganese, TDS, Sulfate, and pH	Contamination potential depends on site-specific conditions and practices. No contamination incidents reported that are directly attributable to Class V mine backfill wells.	Permit by rule: ID, KS, TX, IL, and ND (sometimes general or individual permits are required) General permit: WY Individual or area permit: WV, OH, IN, PA
Aquaculture Waste Disposal Wells	56	<106	6	Nitrate, Turbidity, and Chloride	Potential exists for operators to dispose of liquid wastes (e.g. waste or spent aquaculture chemicals) via aquaculture injection wells. Contamination potential depends on case-specific factors. No contamination incidents reported.	Permit by rule: ID (for wells <18 feet deep), NY Individual permit: HI, MD, ID (for wells ≥18 feet deep) General permit: WY
Solution Mining Wells	2,694	2,694	2	Sulfate, Molybdenum, Radium, Selenium, Arsenic, Lead, Uranium, TDS, Chloride, Manganese, Aluminum, Iron, and Zinc	Not likely to receive accidental spills or illicit discharges. No contamination incidents reported that are directly attributable to Class V wells.	Individual permit: AZ, NM

Overview of Class V Wells Included in This Report (continued)

Well Type	Inventory		Number of States Potentially with Wells	Injectate Constituents > MCLs or HALs	Contamination Potential	State Regulations in States With the Most Wells
	Documented	Estimated				
In-Situ Fossil Fuel Recovery Wells	0	0	0	Ammonium nitrate	Most recovery operations, in the last 20 years, seem to have caused some ground water contamination (number of cases unknown). Problems are due to recovery operations not necessarily injection. Injection wells, deemed unlikely to receive accidental spills or illicit discharges.	Individual permit: WY, CO
Special Drainage Wells	1,944	>3,750	15	Coliform, Turbidity, Nitrogen-total ammonia, Arsenic, Cadmium, Cyanide, Lead, Molybdenum, Nickel, Nitrate, Radium 226, Iron, Manganese, TDS, and Sulfate	Depends on the well type and site characteristics.	Permit by rule: ID, IN, OH Area permit: FL (single family swimming pools only) Individual permit: AK, FL, OR
Experimental Wells	396	>396	10	Chloride, Sulfides, Uranium	Experimental tracer study wells not likely to be vulnerable to spills and illicit discharges. Experimental ATES systems inject treated water, and are not very vulnerable to spills or illicit discharges. One contamination incident reported.	Permit by rule: CO, TX, ID (for wells <18 ft. deep) Individual permit: SC, NV, WA, and ID (for wells >18 ft. deep)

Overview of Class V Wells Included in This Report (continued)

Well Type	Inventory		Number of States Potentially with Wells	Injectate Constituents > MCLs or HALs	Contamination Potential	State Regulations in States With the Most Wells
	Documented	Estimated				
Aquifer Remediation Wells	10,222	10,756	39	Sometimes inject reagents at concentrations above MCLs, though no data to show levels	Not likely to be vulnerable because injectate quality controlled by the conditions of the operations being conducted. Some concern for unapproved or unsupervised voluntary cleanups. One contamination incident reported.	Permit by rule: TX Individual permit: KS, OH, SC
Geothermal Electric Power Wells	234	234	4	Aluminum, Antimony, Arsenic, Barium, Boron, Cadmium, Copper, Fluoride, Lead, Mercury, Strontium, Sulfate, Zinc, TDS, Manganese, pH, Iron, and Chloride	Generally not vulnerable to receiving accidental spills or illicit discharges, in some cases due to Best Management Practices (BMPs). No contamination incidents reported.	Individual permit: CA, HI, NV, UT
Geothermal Direct Heat Wells	31	48	10	Arsenic, Boron, Sulfate, Fluoride, Chloride, Iron, Manganese, and TDS	Unlikely to receive accidental spills or illicit discharges. No contamination incidents reported.	Permit by rule: ID (<18 ft deep) Individual permit: CA, NM, NV, UT, OR, ID (≥18 ft deep)

Overview of Class V Wells Included in This Report (continued)

Well Type	Inventory		Number of States Potentially with Wells	Injectate Constituents > MCLs or HALs	Contamination Potential	State Regulations in States With the Most Wells
	Documented	Estimated				
Heat Pump/Air Condition Return Flow Wells	27,918	>32,801 (but likely <35,000)	40	Lead, Copper, Chloride, and TDS	Low contamination potential because the wells are part of enclosed systems and are generally maintained on private property. Three contamination incidents reported.	Permit by rule: AZ, IL, KS, MI, MN, NE, ND (most wells), NY, OH, PA, SC, TN, TX, VA, WV, WY General permit: WI (for open-loop discharge to shallow subsurface soil absorption field in the unsaturated zone above the uppermost drinking water aquifer) Individual permit: DE, FL, MD (some wells), MO, NV, NC, OR (unless individually exempted), VT, WA Banned: WI (for open-loop discharge directly back into an aquifer)
Salt Water Intrusion Barrier Wells	315	>609 (but likely <700)	5	Typically meets MCLs	Unlikely to receive accidental spills or illicit discharges. No contamination incidents reported.	Permit by rule: CA Individual permit: FL, NY, and WA
Aquifer Recharge & Aquifer Storage and Recovery Wells	1,185	>1,695 (but likely <2,000)	28	A few constituents reported at levels above the MCLs (typically meets MCLs)	Unlikely to receive accidental spills or illicit discharges. No contamination incidents reported.	Permit by rule: CA, CO, ID (<18 feet deep), OK, TX Individual permit: FL, ID (≥18 feet deep), NV, OR, SC, WA
Noncontact Cooling Water Wells	<5,775	>7,780	32	Injectate expected to meet MCLs/HALs because contains no additives/not chemically altered	Low probability of pipe leaks that could result in accidental releases. No contamination incidents reported.	Permit by rule: TN, WV, OH, IA, MT, CA Individual permit: AK, WA (existing), AL, NY Ban: WA (new)

Overview of Class V Wells Included in This Report (continued)

Well Type	Inventory		Number of States Potentially with Wells	Injectate Constituents > MCLs or HALs	Contamination Potential	State Regulations in States With the Most Wells
	Documented	Estimated				
Subsidence Control Wells	28	158	5	Injectate data not available; reasonable to assume injectate in wells in NY, OR, and LA exceeds MCLs for some parameters.	Cannot be assessed due to lack of access to details on well design, construction, and operation. No contamination incidents reported.	Permit by rule: LA, OR Individual permit: NY Ban new wells: WI

2. BACKGROUND

The USEPA regulates five classes of underground injection wells, called Class I through V wells, under the authority of the Safe Drinking Water Act and through a series of UIC regulations. While implementing this program, USEPA has studied Class V injection wells and pursued new rulemaking activities and non-regulatory approaches to improve the management of Class V wells.

2.1 Class V Wells

As defined by USEPA, an injection well is any hole that is deeper than it is wide and is used to emplace fluids underground. This includes sophisticated designs in which holes are drilled and cased with metal or plastic pipe. However, it also includes simple designs to drain fluids to the subsurface. For example, natural surface depressions associated with a conduit to the subsurface that have been modified for the purpose of facilitating the drainage of fluids to the subsurface (called "improved sinkholes") may qualify as injection wells. Likewise, both large-capacity septic systems and those at commercial or industrial sites qualify as wells under USEPA's definitions, as do abandoned drinking water wells that have been adapted to convey fluids underground. Injection wells, however, do not include surface impoundments, ditches, or trenches that are wider than they are deep.

In order to define Class V wells, you must first define the other classes of injection wells, all of which are regulated to protect USDWs. USDWs are aquifers or portions of aquifers that currently are, or could in the future be, used as drinking water sources. Injection wells are classified based primarily on the type of fluids disposed in the well, and USEPA requirements for each well class are designed to ensure USDWs are not threatened by the well operations. Class I wells are used to inject hazardous and non-hazardous waste beneath the lowermost formation containing a USDW within one-quarter mile of the well. Class II wells are used to inject fluids associated with oil and natural gas recovery and storage of liquid hydrocarbons. Class III wells are used in connection with the solution mining of minerals. Class IV wells, which are generally prohibited, are used to inject hazardous or radioactive wastes into a formation which within one-quarter mile of a well bore contains a USDW. Class V wells are defined as any well not included in Classes I through IV.

Class V injection wells are generally shallow waste disposal wells, septic systems, storm water and agricultural drainage systems, or other devices used to release fluids either directly into USDWs or into the shallow subsurface that overlies USDWs. In order to qualify as a Class V well, the fluids released cannot be a hazardous waste as defined under the Resource Conservation and Recovery Act (RCRA). Frequently, Class V wells are designed as no more than shallow holes or septic tank and leachfield combinations intended for sanitary waste disposal. This report focuses on the following 23 categories of Class V wells:

Categories of Class V Wells

1. **Agricultural Drainage Wells** include all wells receiving agricultural runoff. This includes improved sinkholes, abandoned drinking water wells, and underground drain tiles and cisterns receiving agricultural runoff, excess irrigation water, and flood water. Those drain tiles that discharge to a ditch are exempted from UIC regulation.

2. **Storm Water Drainage Wells** are shallow injection wells designed for the disposal of rain water and melted snow. These wells typically drain paved areas such as streets and parking lots, or roofs. Improved sinkholes and abandoned drinking water wells are considered storm water drainage wells when they receive storm water runoff.

3. **Wells Used to Drain Fluids from Carwashes Where No Engine or Undercarriage Washing is Performed (called "carwash wells" in the remainder of this report)**. This includes floor drains in bays of coin-operated, manual carwashes where people use hand-held hoses to wash only the exterior of cars, trucks, and other vehicles. These kinds of carwashes are sometimes referred to as "wand washes," as opposed to "tunnel washes" or "rollover washes" where automatic washing equipment is used.

4. **Large-Capacity Septic Systems** are septic tanks and fluid distribution systems, such as leachfields or wells, used to dispose of sanitary waste only (not industrial waste, motor vehicle waste fluids, or other kinds of commercial waste that does not qualify as "sanitary waste"). These kinds of systems are typically used by multiple dwellings, business establishments, or communities for the disposal of sanitary waste. Individual or single family septic systems and non-residential systems having the capacity to serve fewer than 20 persons a day are not included.

5. **Food Processing Wells** are any type of system that accepts food processing wastewater and releases it into or above USDWs. This includes systems used to dispose of wastewaters generated from the preparing, packaging, or processing of food products (e.g., slaughterhouses, seafood or poultry processing facilities, etc.), not septic systems used solely for the disposal of sanitary waste.

6. **Sewage Treatment Effluent Wells** are used to inject treated effluent from publicly owned treatment works or treated effluent from privately owned treatment facilities receiving solely sanitary waste. A well that receives effluent from a privately owned treatment facility that receives industrial waste (as opposed to solely sanitary waste) qualifies as an industrial well, not a sewage treatment effluent well. Also, a well that injects municipal waste beneath the lowermost USDW in an area qualifies as a Class I well rather than a Class V well.

7. **Wells Used to Inject Fluids from Laundromats Where No Onsite Dry Cleaning is Performed or Where No Organic Solvents are Used for Laundering (called "laundromat wells" in the remainder of this report)**. This includes drains that lead to drywells (open holes) or septic systems at coin-operated laundromats that do not have onsite dry cleaning services.

8. **Spent Brine Return Flow Wells** are used to dispose of brines from which minerals, halogens, and other compounds have been extracted. These wells are commonly associated with manufacturing facilities that produce specialty chemicals such as boron, bromine, magnesia, or their derivatives.

9. **Mine Backfill Wells** are used to place slurries of sand, gravel, cement, mill tailings or refuse, fly ash, or other solids into underground mines. These wells can serve a variety of purposes, including subsidence prevention, filling dangerous mine openings, disposing of wastes from mine operations, and fire control.

10. **Aquaculture Waste Disposal Wells** dispose of water used for the cultivation of marine and freshwater animals and plants under controlled conditions.

11. **Solution Mining Wells** are used to extract desired minerals from mines that have already been conventionally mined. Leaching solutions (called "lixiviants") are injected through solution mining wells into an underground ore

Categories of Class V Wells (continued)

12. **In-Situ Fossil Fuel Recovery Wells** are used for recovery of lignite, coal, tar sands, and oil shale. The wells inject water, air, oxygen, solvents, combustibles, or explosives into underground or oil shale beds to liberate fossil fuels. Underground coal gasification and in-situ oil shale retorting are two processes that use in-situ fossil fuel recovery wells.

13. **Special Drainage Wells** include a variety of wells such as potable water tank overflow, construction dewatering, swimming pool drainage, and mine dewatering wells. These wells receive fluids that cannot be classified as agricultural, storm water, or industrial drainage.

14. **Experimental Wells** are used to test new technologies. Wells are not classified as experimental if the technology can be considered under an established well subclass. For example, a well used for bioremediation should be classified as an aquifer remediation well.

15. **Aquifer Remediation Wells** are used to clean up, treat, or prevent contamination of ground water. Treated ground water (from pump and treat systems), bioremediation agents, or other contaminant recovery enhancement materials may be injected into the subsurface via these wells. These wells may be associated with RCRA or Superfund cleanup projects.

16. **Geothermal Electric Power Wells** dispose of spent (meaning cooled) geothermal fluids following the extraction of heat for the production of electric power.

17. **Geothermal Direct Heat Wells** dispose of spent (cooled) geothermal fluids following the extraction of heat used directly, without conversion to electric power, to heat homes or provide heat to commercial or industrial activities.

18. **Heat Pump/Air Condition Return Flow Wells** reinject ground water that has been passed through a heat exchanger in order to heat or cool buildings. A heat pump takes thermal energy from the ground water and transfers it to the space being heated. When cooling is required, the heat pump removes heat from a building and transfers it to the ground water.

19. **Salt Water Intrusion Barrier Wells** are used to inject fluids to prevent the intrusion of salt water into an aquifer. These wells may have secondary purposes, such as to recharge an aquifer with fresh water to be used later.

20. **Aquifer Recharge Wells** are used to inject fluids to recharge an aquifer. These wells may have secondary purposes, such as salt water intrusion prevention, subsidence control, or aquifer storage and recovery.

21. **Aquifer Storage and Recovery Wells** are used to inject water for later recovery and use. These wells may have secondary purposes, such as aquifer recharge.

22. **Noncontact Cooling Water Wells**. Noncontact cooling water is water used in a cooling system designed to maintain constant separation of the water with process chemicals. Wells that inject contact cooling water or noncontact cooling water that contains additives (e.g., corrosion inhibitors, biocides) or is contaminated compared to the original source water are considered industrial wells.

23. **Subsidence Control Wells** inject fluids to control land sinking, or subsidence, caused by ground water withdrawal and other activities (but not oil and gas production).

USEPA estimates that more than 686,000 Class V wells within the above categories currently exist in the United States. These wells are located in virtually every state, especially in unsewered areas where the population is likely to depend on ground water.

In addition to these 23 well categories, there are three other types of Class V wells:

- **Motor vehicle waste disposal wells** that receive or have received fluids from vehicular repair or maintenance activities, such as an auto body repair shop, automotive repair shop, new and used car dealership, specialty repair shop, or any facility that does any vehicular repair work.

- **Cesspools** used to dispose of untreated sanitary waste, including multiple dwelling, community or regional cesspools, or other devices that have an open bottom and sometimes perforated sides. The UIC requirements do not apply to single family residential cesspools nor to non-residential cesspools that receive solely sanitary waste and have the capacity to serve fewer than 20 persons a day.

- **Industrial wells** used to inject non-hazardous industrial or commercial fluids other than those described for the other types of Class V wells listed above.

USEPA also addressed these three well types in this study. The results for these wells have already been published and placed in the public docket, as announced in a May 21, 1999 NODA (64 FR 27741). Therefore, rather than repeating the information compiled on motor vehicle waste disposal wells, large-capacity cesspools, and industrial wells, this report focuses only on the study methods and results for the other 23 well categories listed above.

2.2 Safe Drinking Water Act

The Safe Drinking Water Act (SDWA or the Act) is designed to protect the quality of drinking water in the United States. Part C of the Act specifically mandates the regulation of underground injection of fluids through wells.

Section 1421 of the Act requires USEPA to propose and promulgate regulations specifying minimum requirements for state programs to prevent underground injection that endangers drinking water sources. USEPA promulgated administrative and permitting regulations, now in 40 CFR Part 144 and 146, on May 19, 1980 (45 FR 33290), and technical requirements in 40 CFR Part 146 on June 24, 1980 (45 FR 42472). These regulations have since been amended on several occasions.

Section 1422 of the Act provides that states may apply to USEPA for primary responsibility to administer the UIC program (those states receiving such authority are referred to as "Primacy States"). Where states do not seek this responsibility or fail to demonstrate that they meet USEPA's minimum requirements, USEPA is required to prescribe, by regulation, a UIC program for such states. These direct implementation (DI) programs were established in two phases, on May 11, 1984 (49 FR 20138) and November 15, 1984 (49 FR 45308).

2.3 UIC Regulations

Under the USEPA UIC Program, Class V wells are currently authorized by rule, meaning they do not have to obtain an individual permit unless required to do so. Under 40 CFR 144.12(a), owners or operators of all injection wells are prohibited from engaging in any injection activity that allows the movement of fluids containing any contaminant into USDWs, if the presence of that contaminant may cause a violation of any primary drinking water regulation or may otherwise adversely affect human health. Sections 144.12(c) and (d) specify actions to be taken by the UIC Program Director if a well is not in compliance with section 144.12(a).

Owners or operators of Class V wells are also required to submit basic inventory information under 40 CFR 144.26. In addition, Class V wells are subject to the general program requirements of section 144.25, under which the UIC Program Director may require a permit, if necessary, to protect USDWs. Moreover, under section 144.27, USEPA may require owners or operators of any Class V well, in USEPA-administered programs, to submit additional information deemed necessary to protect USDWs. Owners or operators who fail to submit the information required under sections 144.26 and 144.27 are prohibited from using their wells.

2.4 1987 Report to Congress on Class V Wells

In accordance with the 1986 Amendments to the SDWA, USEPA summarized information on Class V wells in a Report to Congress entitled *Class V Injection Wells -- Current Inventory; Effects on Ground Water; and Technical Recommendations*, September 1987 (USEPA Document Number 570/9-87-006). That report presents a national overview of Class V injection practices and state recommendations for Class V design, construction, installation, and siting requirements. These state recommendations, however, did not give USEPA a clear mandate on what, if any, additional measures were needed to control Class V wells on the national level. For any given type of well, the recommendations varied broadly and were rarely made by more than two or three states. For example, the recommendations for large-capacity septic systems ranged from further studies (three states) to statewide ground water monitoring (one state).

2.5 Actions Since the 1987 Report to Congress

On December 30, 1993, the Sierra Club filed a complaint against USEPA in the United States District Court for the District of Columbia alleging that USEPA failed to comply with section 1421 of the SDWA regarding publication of proposed and final regulations for Class V injection wells. The complaint alleged that USEPA's current regulations regarding Class V wells do not meet the SDWA's statutory requirements to "prevent underground injection which endangers drinking water sources."

On August 31, 1994, USEPA entered into a consent decree with the Sierra Club requiring that by no later than August 15, 1995, the USEPA Administrator sign a notice to be published in the *Federal Register* proposing regulatory action that fully discharges the Administrator's rulemaking obligation under section 1421 of the SDWA with respect to Class V injection wells. The consent decree further required that a final rule on Class V wells be signed by November 15, 1996. Accordingly, on August 15, 1995, the Administrator signed a notice of proposed rulemaking intended to fulfill this obligation (60 FR 44652, August 28, 1995). In this notice, USEPA proposed not to adopt additional federal regulations for any types of Class V injection well. Instead, the Agency proposed to address the risks posed by certain wells using existing authorities and a Class V management strategy designed to (1) speed up the closure of potentially endangering wells; and (2) promote the use of best management practices to ensure that other Class V wells of concern do not endanger USDWs.

USEPA received many comments that supported the Agency's proposal to not impose more regulations for Class V wells. However, USEPA also received a number of comments that raised concerns about the proposal. In particular, several commenters questioned whether a UIC program without additional requirements for relatively high-risk well types, including Class V motor vehicle waste disposal wells, industrial waste disposal wells, and large-capacity cesspools, could prevent endangerment to drinking water sources as required by the SDWA. The Sierra Club Legal Defense Fund alleged that the proposal failed to carry out statutory requirements.

Based on these and other comments, USEPA decided to reconsider the 1995 proposed approach. Because this reconsideration would extend the time necessary to complete the rulemaking for Class V wells, USEPA and the Sierra Club Legal Defense Fund entered into a modified consent decree on January 28, 1997 that extended the dates for rulemaking that had been in the 1994 decree. The modified decree requires three actions.

- First, by no later than July 17, 1998, the USEPA Administrator was required to sign a notice to be published in the *Federal Register* proposing regulatory action that fully discharges the Administrator's rulemaking obligation under section 1421 of the SDWA with respect to those types of Class V injection wells presently determined to be high risk and for which additional information is not needed. According to the consent decree, as modified, the Administrator must sign a final rulemaking for such high-risk Class V wells by no later than October 29, 1999.

- Second, by no later than September 30, 1999, USEPA must complete a study of all Class V wells not included in the rulemaking on high-risk Class V injection wells. Based on this study, USEPA may find that some of these other types of Class V wells also pose a high risk.

- Third, by no later than April 30, 2001, the USEPA Administrator must sign a notice to be published in the *Federal Register* proposing to discharge the Administrator's rulemaking obligations under section 1421 of the SDWA with respect to all Class V injection wells not included in the first rulemaking for Class V injection wells. The Administrator must sign a final rulemaking for these remaining Class V wells by no later than May 31, 2002.

On July 29, 1998 (63 FR 40586), in response to the first action required under the modified consent decree, USEPA proposed revisions to the Class V UIC regulations that would add new requirements for the following three types of wells that, based on information available at the time, were believed to pose a high risk to USDWs: motor vehicle waste disposal wells, large-capacity cesspools, and industrial wells when located in ground water-based source water protection areas. In response to the second action required under the modified consent decree, USEPA conducted this study of the remaining 23 well categories defined above to determine whether they warrant additional UIC regulation. At the same time, the Agency collected information on motor vehicle waste disposal wells, large-capacity cesspools, and industrial wells to support rulemaking decisions for those wells. In accordance with the third action required under the modified consent decree, USEPA will use the information presented in this report for the 23 well categories, combined with the study results published previously for the three well types targeted in the July 29, 1998 proposal, to make regulatory decisions for all those well categories not addressed in the initial rulemaking on high-risk wells.

3. STUDY APPROACH

USEPA initiated the Class V study by convening a workgroup of USEPA and state UIC representatives to help design the research effort. Workgroup members met during the spring and summer of 1997 to develop a method for collecting information. Based on these meetings, USEPA concluded that state programs have information useful to the study, but that additional information should be collected from other sources as well. USEPA also recognized that very little inventory information (i.e., data on the numbers of existing Class V wells in different locations) was available from the states for some types of wells.

As a result of this initial scoping, the final Class V study design had two components: (1) an information collection effort for the 23 Class V well categories; and (2) inventory models to estimate the number of storm water drainage wells and large-capacity septic systems, two types of wells that were believed to be quite prevalent but for which adequate inventory information was particularly lacking. These two components are described below in Sections 4 and 5, respectively. The workgroup continued to meet throughout both of these efforts to provide feedback as the study progressed.

The information developed from this research has been compiled into a 23-volume final report that consists of:

- Volume 1 (this volume), which provides general information on the study approach and results;

- Volumes 2-23, which provide a well-specific information summary for each of the 23 categories of wells that were studied (Volume 21 covers both aquifer recharge wells and aquifer storage and recovery wells); and

- Five appendices, as follows:

  - Appendix A provides the Class V Study Information Collection Request.
  - Appendix B presents the questionnaires that were used in general information collection effort.

- Appendix C outlines the methods and information used to select census tracts to visit for the purpose of developing the inventory models, presents the results from those census tract visits, and summarizes the inventory model development and results.
- Appendix D presents the drinking water standards and other criteria used in the well-specific summaries to compare to data on the quality of fluids released by the 23 well types; and
- Appendix E presents information on the ground water persistence and mobility of various chemicals possibly released by Class V wells.

4. INFORMATION COLLECTION

The information collection consisted of four activities: a literature review, state and USEPA Regional data collection, requests to the public for data, and peer review. Each of these efforts is described in turn below.

4.1 Literature Review

USEPA started the search by locating available references from the Ground Water Protection Council's (GWPC's) Injection Well Bibliography. To supplement this bibliography, USEPA used a list of key words to search the Boston Library Consortium, individual libraries, ten scientific databases, the World Wide Web, the Library of Congress, and libraries linked to the Library of Congress. USEPA also sought available information through targeted phone calls to trade associations, research institutes, universities, and other sources.

4.2 State and USEPA Regional Data Collection

4.2.1 Data Collection Methods

USEPA prepared an Information Collection Request (ICR) that outlined the methodology, identified the information to be collected, and calculated the burden associated with responding to a Class V survey. OMB approved the ICR (OMB # 240-0194) on July 31, 1998.

The first step in the collection process was to ask USEPA Regional representatives to identify the best UIC contact for each state in the Region. The scope of this search included all 50 states, the District of Columbia, Guam, the Commonwealth of Puerto Rico, the Northern Mariana Islands, the Virgin Islands, American Samoa, and the Trust Territory of the Pacific Islands. It also included Indian lands in USEPA Regions 5, 8, 9, and 10.

Next, USEPA called each contact person to explain the study, obtain some preliminary information about the data the contact had available, and describe an information request letter that the contact would soon receive. This letter requested information on the types of wells in each state and appropriate contacts for those wells.

USEPA then sent well-specific questionnaires to the contacts identified in responses to this letter. USEPA distributed nearly 700 questionnaires to USEPA Regional, state, and local respondents. Because some states were unable to complete the questionnaires due to resource constraints and other states (particularly DI states) had very limited information to share, USEPA supplemented the information from the questionnaires through follow-up telephone interviews and on-site file searches in ten primacy states (Massachusetts, Maryland, West Virginia, Florida, Illinois, Minnesota, Kansas, Wyoming, Oregon, and Washington); two DI states (California and Colorado); and two Regional Offices with DI states (Region 3: Pennsylvania, Virginia, and the District of Columbia; and Region 8: Colorado). In some cases, USEPA also completed summaries using information from other sources such as state Internet Web sites or studies and reports.

4.2.2 Information Obtained

USEPA received information on all but a few UIC programs. American Samoa was the only program to report that no Class V wells exist. Altogether, USEPA received and completed by telephone approximately 475 questionnaires, conducted scores of telephone conversations, and received a large volume of written and e-mail correspondence.

While USEPA collected a significant amount of information, the study also discovered where states are lacking data. The following sections summarize the information collected and limitations of that information in four categories: inventory data, injectate quality data, contamination incidents, and regulatory authority and implementation.

Inventory Data

Two generalizations can be made about the inventory information that was obtained:

- States generally maintain accurate inventories for mining, geothermal, aquifer recharge, aquifer storage and recovery, and aquifer remediation wells. Because these wells often require state approval before construction, states believe that they have kept accurate records of these wells.

- For other well types, states and USEPA Regions suspect that their inventories underestimate the true number of wells. For example, inventories of agricultural drainage wells may be inaccurate because of limited public records of these wells and the inability of public officials to locate these wells on rural private property without the coordination of the landowner. The survey responses indicate that agricultural drainage and storm water drainage wells are often constructed and used by individuals who may not be aware of Class V regulations and, thus, have never been reported. Furthermore, local agencies often have jurisdiction over these well types, so they may not be accounted for in a state's inventory.

In addition, there are significant uncertainties associated with the inventory data:

- In some cases, different sources provided different numbers, both for documented and estimated number of wells. In particular, documented numbers of wells reported in survey responses sometimes differed from the numbers reported in computer database printouts provided by the same state staff. These differences occasionally could not be reconciled.

- Estimated numbers were often provided as a range, or as “more than” or “less than” the documented number.

- In some state databases, different subclasses of wells could not be distinguished. For example, most states do not distinguish between carwash wells, laundromat wells, food processing wells, or non-contact cooling water wells, grouping them instead into a general industrial well category. Also, some states do not distinguish between aquifer storage and recovery wells and aquifer recharge wells in their current inventories.

- State classification of some well types differs from the classification used in this study. This was commonly the case for experimental wells. It is also possible that some states reported Class IV aquifer remediation wells as Class V aquifer remediation wells (see Section 6.15 below for the distinction between these wells).

- Although a number of studies that discuss the likely existence of agricultural drainage wells in various areas were found, USEPA was unable to get much documentation of the number or location of this type of well. State and local officials often either did not know of the existence of agricultural drainage wells or simply reported that there were none because they were banned or being phased out in the state.

- Most states use different criteria than in the federal UIC regulations for distinguishing between small and large-capacity septic systems (most states use a flow threshold rather than USEPA’s 20 persons-a-day definition).

Injectate Quality Data

The injectate quality data obtained during the study vary widely. They range from a one-time sample at one well to multiple samples at multiple wells in multiple states. The data include results from routine and special monitoring, studies, permit applications, journal articles, and reports.

There is little injectate data available for well types perceived to pose low risks to USDWs, such as heat pump/air conditioning return flow wells. State injectate sampling data for agricultural and storm water drainage wells were also difficult to find since many of these wells are located on private property. However, many studies on these well types have been conducted and USEPA more often found injectate data in the literature.

Contamination Incidents

Contamination incidents are often handled by an office other than the UIC program office, such as separate state enforcement and compliance offices. The study was less successful in tapping these other offices for information. As a separate issue, states were often reluctant to disclose contamination incidents, especially when enforcement action was pending. Furthermore, very little documentation is available that directly links contamination problems to Class V wells, although wells are often suspected of contributing to contamination.

Regulatory Authority and Implementation

Regulatory authority over Class V wells varies widely among states. Four typical regulatory schemes are as follows:

- *General authority to protect USDWs*. The State UIC Program Director has discretionary authority to take actions necessary to protect USDWs.

- *Permit by rule*. An entire class of wells is deemed permitted as long as they comply with standards and requirements found in the regulations.

- *General permit*. An identical permit, based on state technical regulations, is issued for each well in a specified class of wells.

- *Authority to issue site-specific (or individual) permits, inspect, and take enforcement action*. This authority may be linked to technical standards in the regulations and/or may give the State UIC Program Director discretion to include standards necessary to protect USDWs.

Where states have technical standards, they may contain requirements for siting or setbacks, construction, mechanical integrity testing, injection pressure or flow, injectate quality, monitoring, best management practices, reporting, financial responsibility, and closure and post-closure care.

State UIC programs are generally resource-constrained. This means the states are often not able to implement UIC programs as vigorously as they would like. This lack of resources typically manifests itself in a state program that is more reactive than proactive. For example:

- States do not make wide use of discretionary authority, except when problems are evident;

- Sampling and inspections are often problem- or complaint-driven with few states conducting routine inspections; and

- States are often unable to confirm that abandoned wells are properly plugged so that contaminants cannot enter them.

4.3 Requests to the Public for Information

USEPA sought information from the public for the Class V study. One avenue for obtaining information was the National Drinking Water Advisory Council (NDWAC). The Class V study was an agenda topic during a NDWAC workgroup meeting held on January 7-8, 1999 in Denver, Colorado (see 63 FR 66168, December 1, 1998). Issues relevant to the study also were discussed in another NDWAC workgroup meeting on March 25-26, 1999 in Washington, DC. In both of these meetings, members of the public were allowed to make statements. To obtain additional information on issues raised during these NDWAC discussions, USEPA accompanied state UIC program staff on site visits of facilities with Class V wells in New Hampshire and Maine.

USEPA also requested information through three notices in the *Federal Register*:

- 64 FR 1008, January 7, 1999, Call for Peer Reviewers and Data on Aquaculture Injection Wells, Mining Wells, Sewage Treatment Effluent Wells, and Other Class V Injection Wells Including Certain Industrial Wells; and

C 64 FR 1008, January 7, 1999, Call for Data on Class V Wells Including Agriculture and Storm Water Drainage Wells, Large-Capacity Septic Systems, and Geothermal Wells.

- 64 FR 1007, January 7, 1999, Call for Peer Reviewers and Data on Aquifer Storage and Recovery Wells, Aquifer Recharge Wells, Saline Intrusion Barrier Wells, Subsidence Control Wells, and Aquifer Remediation Injection Wells.

USEPA staff made presentations about the status of the study at semiannual meetings of the GWPC, including a March 1998 meeting in Annapolis, MD, a September 1998 meeting in Sacramento, CA, a March 1999 meeting in Washington, DC, and a September 1999 meeting in Newport, Rhode Island. During each of these presentations, the meeting participants were requested to provide available information and to identify additional information sources.

USEPA also maintained an Internet Web site for the Class V study (http://www.epa.gov/OGWDW/uic/cl5study.html). The Web site included definitions of the well types, successive drafts of well-specific information summaries, and other information about the study. It also included a form that anyone could submit on-line to provide information about Class V wells. The Web site, which was frequently visited, was advertised in the *Federal Register* notices listed above, at the GWPC meetings, and in other forums.

Finally, the July 28, 1998 proposed rule on Class V motor vehicle waste disposal wells, industrial wells, and large-capacity septic systems introduced the study and gave the pubic an opportunity to comment on the need to regulate those and all other kinds of Class V wells. Indeed, several comments were submitted providing information useful to the Class V study, including additional information on Class V food processing waste disposal wells and other types of Class V wells in Tennessee. USEPA followed up on these comments by conducting, along with state UIC Program staff, site visits to a number of food processing facilities in Tennessee that own or operate Class V wells.

4.4 Peer Review

USEPA coordinated peer reviews of draft information summaries for each of the 23 types of wells studied in order to ensure technical accuracy and completeness of the documents. These reviews ranged from a formal peer review process in which recognized technical experts for selected well types were sought, to an informal process in which drafts of the well-specific information summaries were distributed to teams of state, USEPA Regional, and USEPA Headquarters reviewers.

During these processes, reviewers were supplied with the draft information summary and a charge that asked general and specific questions to help guide the review. Some of the reviews included a conference call as an opportunity for the reviewers to discuss and share thoughts on the document. USEPA incorporated the comments received into the information summaries. Upon completion of the review process, USEPA also developed a table explaining how USEPA used the comments.

5. INVENTORY MODELS

Although the general information collection effort did include storm water drainage wells and large-capacity septic systems, the participants in the Class V study workgroup meetings told USEPA that very little inventory data on these wells were available from the states. In general, states believe that their inventories of these well types are inaccurate and would not provide a realistic national estimate. As a result, USEPA determined that it would be necessary to construct statistical inventory models to provide national estimates of the numbers of storm water drainage wells and large-capacity septic systems.

The inventory models predict the number of storm water drainage wells and large-capacity septic systems nationally based on geologic, demographic, and other characteristics. There is little theory -- and virtually no empirical research -- regarding the factors affecting the number and location of these wells. Therefore, USEPA selected and visited a sample of 99 census tracts across the nation to collect information on the numbers of wells and a variety of factors that might influence the wells' prevalence. USEPA then analyzed the data collected from these visits to develop mathematical models that can be used to estimate the numbers of storm water drainage wells and large-capacity septic systems in other locations based on certain characteristics known to exist in those areas. Appendix C describes the development and results of the inventory models in more detail.

5.1 Storm Water Drainage Wells

Storm water drainage wells were located in 22 of 99 census tracts surveyed. Such wells were primarily found along streets, but were also common in parking lots and residential areas. A few storm water drainage wells were also found in other areas, such as along bike paths or in recreational vehicle parks.

The estimate of the number of storm water drainage wells in the nation is the combination two estimates: a model estimate for wells in non-urbanized areas, and state estimates of the number of wells in urbanized areas. This approach is necessary because of the sampling strategy. Urbanized areas were excluded from the sample based on the assumption that very few storm water drainage wells would be found in urbanized areas. While a few cities make extensive use of these wells, USEPA could not adequately represent all urbanized areas in the sample to account for these wells because of the relatively small size of the sample. Therefore, USEPA relied on state and other estimates gathered as part of the general data collection effort to account for the wells in urbanized areas, and used the sample to build a model of the number of wells in non-urbanized areas.

The estimate for the total number of storm water drainage wells in the country is approximately 125,500. This represents the sum of the number of documented and estimated wells in urbanized areas (35,000 and 26,500, respectively) and the model's estimate for non-urbanized areas (64,000).

5.2 Large-Capacity Septic Systems

Large-capacity septic systems were found in sewered and unsewered areas and were used in a wide variety of circumstances. They were found in 88 out of 99 of the census tracts visited. The largest percentage of systems were located at churches, but many were also found in commercial areas, restaurants, campgrounds, public buildings, motels, residential areas, industrial areas, schools, recreational areas, and a few in other areas such as farms and ranger stations.

The model assumes that the number of large-capacity septic systems in a census tract is a linear function of the number of households on septic systems in the tract, the tract's housing density, and the percentage of soil in the tract that is poorly drained. Using an equation with these variables, the model predicts approximately 353,400 large-capacity septic systems nationwide. The 95 percent prediction interval is 304,100 to 402,600.

6. WELL-SPECIFIC SUMMARIES

This section presents information summaries for each of the 23 categories of Class V wells addressed in this report. Volumes 2 through 23 of this report provide more detail on each of these well categories in the same order in which they appear below (with Volume 21 covering both aquifer recharge and aquifer storage and recovery wells). Although each summary below is tailored to the particular issues relevant to the different wells, they all address the following basic topics in the following sequence: (1) well purpose and fluids released; (2) the extent to which the fluids released exceed drinking water standards at the point of injection; (3) generalizations about the characteristics of the underground zone receiving fluids from the wells; (4) contamination incidents or studies, if any; (5) vulnerability of the wells to spills or illicit discharges; (6) prevalence of the wells; and (7) existing state and federal controls. If any other factors are key in summarizing information on a given well type, they are woven into appropriate places within this general outline.

6.1 Agricultural Drainage Wells

Agricultural drainage wells (ADWs) are used in many places throughout the country to drain excess surface and subsurface water from agricultural fields, including irrigation tailwaters and natural drainage resulting from precipitation, snowmelt, floodwaters, etc. ADWs may also receive animal yard runoff, feedlot runoff, dairy runoff, or runoff from any other agricultural operation. In some cases, these fluids are released into ADWs in order to recharge aquifers that are used as sources of irrigation water.

The water that drains into ADWs may contain high levels of naturally occurring minerals or may be contaminated with fertilizers, pesticides, or bacteria and other microorganisms. Available sampling data show that the primary constituent in ADW injectate that is likely to exceed health-based standards is nitrate. The data also indicate that boron, sulfate, coliforms, and certain pesticides (cyanazine, atrazine, alachlor, aldicarb, carbofuran, 1,2-dichloropropane, and dibromochloropropane) in agricultural drainage have exceeded primary, or health-based, MCLs or HALs. Total dissolved solids (TDS) and chloride in some ADWs also have been measured above secondary MCLs, which are designed to protect against adverse aesthetic effects such as objectionable taste and odor.

Concerns about high concentrations of contaminants entering ADWs are compounded by the recognition that suitable subsurface geologic formations for ADWs often include areas with shallow, fractured bedrock formations, or limestone bedrock, particularly where affected by karst development that provides solution channels and sinkholes that allow rapid transmission of water. As discussed in Volume 3, some ADWs are in fact nothing more than improved sinkholes in areas with karst. Such hydrogeologic settings usually allow contaminants to migrate readily without significant attenuation.

A number of studies and incidents have shown that ADWs have in fact contributed to or caused ground water contamination. In particular, ten studies reviewed for this report document nitrate contamination of ground water in agricultural areas. Six of these studies clearly link the nitrate contamination to ADW use. For example, one study in north central Iowa between 1981 and 1983 found that areas with the highest density of ADWs also had the highest average concentrations of nitrate in ground water samples (37 percent of the farm wells sampled in an area with a relatively large number of ADWs had nitrate concentrations above the MCL). Four other studies, however, do not clearly distinguish nitrate contamination from ADWs versus more general sources of nonpoint source pollution associated with agriculture. In addition to these nitrate studies, there are two known contamination incidents in Iowa (in 1977 and 1997) involving direct discharges from septic tanks to ADWs. In one of these incidents, the ADW was also contaminated by runoff from the field application of hog manure. Other contamination incidents include ground water and drinking water contamination linked to 15 drainage wells in Minidoka County, Idaho in 1979, and a community supply well in Dane, Wisconsin being contaminated around 1988 by atrazine that likely drained into an improperly abandoned water well that had been illegally modified to receive surface runoff from an agricultural area.

A further concern associated with ADWs is the potential for some wells to be vulnerable to spills or illicit discharges. The close proximity of ADWs to large earthen lagoons for storing manure at large-scale confined animal feeding operations is a particular issue that has been recognized for some wells in Iowa; the growth of such operations nationwide may also make it an issue in other locations. The two cases cited above involving septic tank discharges to ADWs in Iowa may also illustrate a practice that is not uncommon in other states. Following one of those incidents, it was estimated that as many as 30 percent of the rural septic tanks in one Iowa township may be directly connected to ADWs. Separately, some ADWs may occasionally receive accidental releases of materials during farming operations, such as spills of motor oils used in equipment or bulk releases of pesticides during storage or handling. Moreover, if not carefully managed, the land application of manure in areas drained by ADWs can cause contamination, as illustrated by one of the incidents reported in Iowa.

According to the state and USEPA Regional survey conducted for this study, there are at least 1,069 documented ADWs and more than 2,842 ADWs estimated to exist in the U.S. Although believed to exist in at least 21 states, more than 95 percent of the documented wells are in just five states: Idaho (303), Iowa (290), Ohio (>200), Texas (135), and Minnesota (92). In truth, there may be thousands more ADWs than these results suggest, recognizing the significant uncertainties in the current inventory. For example, it is likely that more ADWs exist than have been counted because (1) there is often a lack of public records on such wells, (2) public officials are unable to document the locations of ADWs in remote areas on private land without the cooperation of the landowner, (3) some ADWs are hard to find or not even known to exist because they consist of tile drainage lines and cisterns entirely below ground, and (4) ADWs have been grouped with storm water drainage wells in some state inventories. Looking forward, the number of ADWs should decrease as the risk to USDWs becomes known and ADWs that cause or threaten contamination are discovered and closed. However, the known number of ADWs may actually increase as the existing wells are actively looked for and discovered.

States with the majority of known ADWs are developing and implementing regulatory programs to address these wells. Specifically:

- In Idaho, wells ≥18 feet deep are individually permitted, while shallower wells are permitted by rule.

- All ADW owners in Iowa are required to have applied for a permit by July 1, 1999. The only exception to this is ADW owners who can demonstrate that their ADW will be closed prior to December 31, 2001. New wells in Iowa are generally prohibited, although they may be permitted under very strict conditions (these conditions are so stringent that new ADWs in Iowa are unlikely to receive a permit).

- The regulations in Ohio authorize ADWs by rule as long as inventory information is submitted. All existing ADWs in the state are considered out of compliance (not rule authorized) because their owners or operators did not submit required inventory information by the applicable deadline. Any new ADWs would be examined individually by the state and subjected to conditions believed necessary to protect USDWs.

- All of the known ADWs in Texas received individual authorizations for construction of the wells. Owners or operators of any new wells would have to submit basic information to the state, which would either disapprove the well or authorize it subject to conditions deemed necessary to protect USDWs.

- Minnesota rules, which became effective on July 15, 1974, prohibit injection or disposal of any materials into a well. State staff, however, acknowledge that some ADWs continue to exist and require them to close when they are found. The prohibition relates to wells that reach ground water. Horizontal drain tiles are not included in the definition of a "well" in Minnesota.

The regulatory picture in other states with few or no ADWs in the current inventory is varied. In particular, Georgia, North Carolina, and North Dakota have banned new ADWs and require existing ADWs to close when they are found. Oregon, Washington, and Wisconsin also have a ban, but recognize that some ADWs continue to exist. Most other states authorize ADWs by rule, consistent with the existing federal UIC requirements.

These regulatory programs in the states are supplemented somewhat by non-regulatory programs and guidance at the federal level. Namely, under the authority of the Clean Water Act, the U.S. Department of Agriculture and USEPA released a draft *Unified National Strategy for Animal Feeding Operations* on September 11, 1998. Once finalized, the goal of this strategy will be for owners and operators of animal feeding operations to take actions to minimize surface and ground water pollution from confinement facilities and land application of manure. In addition, under the Coastal Zone Act Reauthorization Amendments, 29 coastal states are required to develop and implement Coastal Nonpoint Pollution Control Programs addressing nonpoint pollution from agriculture and other sources. Although these programs are aimed primarily toward surface water protection, they also will benefit ground water by emphasizing contaminant source reduction and conservation measures such as nutrient, integrated pest, and irrigation management. To support the development and implementation of these programs, USEPA issued *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters*. Much of this guidance is relevant to Class V ADWs because it presents techniques for minimizing seepage to ground water.

6.2 Storm Water Drainage Wells

Storm water drainage wells are used extensively throughout the country to remove storm water or urban runoff (e.g., precipitation and snowmelt) from impervious surfaces such as roadways, roofs, and paved surfaces to prevent flooding, infiltration into basements, etc. The primary types of storm water drainage wells are bored wells, dug wells, and improved sinkholes. In addition, "lake level control wells" are used to drain lakes to prevent overflow following heavy precipitation. Subsurface disposal of storm water is prevalent in places where there is not enough space for, or site characteristics do not allow, retention basins; where there is not a suitable surface water to receive the runoff; or where near-surface geologic conditions provide an attractive drainage zone.

The runoff that enters storm water drainage wells may be contaminated with sediments, nutrients, metals, salts, fertilizers, pesticides, and/or microorganisms. Storm water sampling data indicate that concentrations of antimony, arsenic, beryllium, cadmium, chromium, cyanide, lead, mercury, nickel, nitrate, selenium, and certain organics (e.g., benzene, benzo(a)pyrene, bis(2-ethylhexyl) phthalate, chlordane, dichloromethane, pentachlorophenol, tetrachloroethylene, and trichloroethylene) in storm water runoff have exceeded primary MCLs. Available sampling data show that concentrations of aluminum, chloride, copper, iron, manganese, TDS, zinc, and methyl tert-butyl ether have exceeded secondary MCLs or HALs. Water quality data from Florida indicate that lake level control well injectate has exceeded primary MCLs or HALs for turbidity, arsenic, pentachlorophenol, and fecal coliforms, as well as secondary MCLs for iron, manganese, pH, and color. Some of these same studies, however, report that no adverse effects on ground water were detected. In addition, some industry representatives assert that the quality of storm water drainage should be better today than reported in some of these studies, which predate the use of best management practices (BMPs) required under the National Pollutant Discharge Elimination System (NPDES) program.

In general, the point of injection for most storm water drainage wells is into sandy, porous soils, a permeable coarse-grained unit, karst, or a fractured unit because these types of formations can readily accept large volumes of fluids. Such hydrogeologic characteristics usually allow contaminants to migrate readily into ground water without significant attenuation.

Contamination related to storm water drainage wells has been reported to various degrees in Ohio, Kansas, Wisconsin, California, Washington, Arizona, Oklahoma, Tennessee, New York, Indiana, Florida, Kentucky, and Maryland. Several studies, however, do not clearly distinguish contamination from storm water drainage wells versus more general, nonpoint source pollution. The following three examples demonstrate cases in which storm water drainage wells have contributed to or caused ground water contamination.

- In 1989, a commercial petroleum facility in Fairborn, Ohio accidentally released 21,000 gallons of fuel oil that overflowed a diked area and entered two storm water drainage wells.

- In 1980, organic solvent contamination was discovered in drinking water supply wells for Lakewood, Washington following the disposal of organic waste solvents and sludge in leach pits and storm water drainage wells at McChord Air Force Base.

- In 1998, the Oak Grove, Kentucky water plant (a ground water system) was shut down due to a sharp increase in raw turbidity following a severe storm event.

Lake level control wells have been associated with two documented contamination incidents. The first occurred in 1993 when private drinking water wells in Lake Orienta, Altamonte Springs, Florida, were contaminated. In 1998, private wells in Lake Johio, Orange County, Florida, were contaminated by fluids released into lake level control wells.

As illustrated by some of these incidents, storm water drainage wells are generally vulnerable to spills or illicit discharges of hazardous substances, as they are often located in close proximity to roadways, parking lots, and commercial/industrial loading facilities where such substances are handled and potentially released. The use of a number of BMPs can reduce the likelihood of contamination, including siting, design, and operation BMPs as well as education and outreach to prevent misuse, and finally, proper closure and abandonment (see Volume 3 for a detailed discussion on these BMPs and their effectiveness). However, the frequency and pattern of BMP use varies across the country. For example, public commenters on the July 28, 1998 proposed revisions to the Class V UIC regulations cited cases in which citizens have been observed draining used motor oil into storm water drainage wells, where no measures are in place to prohibit illicit discharges. Some lakes that are drained by lake level control wells are also vulnerable to spills or illicit discharges.

Based on the state and USEPA Regional survey conducted for this study, there are approximately 71,015 documented storm water drainage wells and approximately 247,522 storm water drainage wells estimated to exist in the U.S. About 81 percent of the documented wells are in seven western states: Arizona (14,857), California (3,743), Washington (22,688), Oregon (4,148), Idaho (5,359), Montana (4,000), and Utah (2,890). Five other states contain approximately 15 percent of the total wells: Ohio (3,036), Florida (2,153), Michigan (1,301), Maryland (1,678), and Hawaii (2,622). There is considerable uncertainty regarding the exact number of storm water drainage wells for several reasons. There are approximately 200-250 lake level control wells in Florida.

In general, the installation of new storm water drainage wells is expected to increase nationwide. Many states are allowing the installation of new wells, and with the increased regulation of surface discharge under the NPDES, there may be increased use of underground injection to dispose of storm water runoff.

Some states with the majority of storm water drainage wells have developed and are implementing regulatory programs to address these wells. Examples include the following:

C In Idaho, wells #18 feet deep are authorized by rule, while deeper wells are individually permitted.

C In Arizona, California, Hawaii, Florida, and Maryland, storm water drainage wells are individually permitted.

Other states with large numbers of storm water drainage wells, however, are essentially implementing only the minimum federal UIC requirements. In particular, Washington, Oregon, Montana, Utah, Ohio, and Michigan authorize storm water drainage wells by rule.

The regulatory structure in other states with fewer or no storm water drainage wells in the current inventory is also mixed. For example, Indiana, Illinois, Wyoming, North Dakota, South Dakota, Colorado, Kansas, Tennessee, and Rhode Island also authorize storm water drainage wells by rule. Alabama, Texas, New Hampshire, and Nebraska have a permit and registration system for storm water drainage wells. Georgia and North Carolina ban new and existing wells. In Wisconsin, storm water drainage wells deeper than 10 feet have been prohibited since the 1930's. Shallow storm water drainage wells (less than 10 feet deep) in Wisconsin were authorized by rule until 1994; since 1994, construction of any storm water drainage well has been prohibited. Storm water drainage wells that meet the definition of a “well” in Minnesota are prohibited. This prohibition only applies to wells that reach ground water and not to french drains, gravel pockets, or drainfields, which normally would not meet the definition of a well in Minnesota.

These regulatory programs in the states are augmented to a degree by programs and guidance at the federal level. The Sole Source Aquifer Program has been used by some regions as a way to limit or prevent the use of storm water drainage wells by reviewing federal financially assisted construction projects in sole source aquifer areas. The Federal Highway Administration’s (FHWA’s) highway runoff water quality standards indirectly reference storm water. Although these are non-enforceable recommendations only, FHWA has issued guidance that discusses BMPs, such as wet and dry detention basins, infiltration trenches and basins, and dry wells, for controlling storm water runoff and infiltration into ground water. The Coastal Zone Management Act and Coastal Nonpoint Pollution Control Program also indirectly reference storm water in nonpoint pollution regulations; however, storm water discharges controlled under the NPDES program are exempt from the coastal nonpoint pollution control program.

6.3 Carwash Wells

Wells used to dispose of washwater that was used to wash only the exterior of vehicles (sometimes called “wand washes”) are the only carwash wells within the scope of this volume.[1] These are typically located at coin-operated, manual carwashes where people use hand-held hoses to wash vehicles. Even though the term “carwash” is used, the category includes wells that receive used washwater at facilities designed for washing all kinds of vehicles, including cars, vans, trucks, buses, boats on trailers, etc.

The cleaning solutions used at these carwashes generally consist of soap solutions, rinsewater, and wax, and are not expected to contain significant amounts of degreasing agents or solvents such as methylene chloride or trichloroethylene (because these wells, as defined, are not supposed to be receiving engine or undercarriage washwater, which is more likely to contain such substances). As a result, the spent washwater disposed in a carwash well (as defined in this report) primarily contains

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[1] Class V wells used to inject fluids from carwashes where engine or undercarriage washing is performed were classified as industrial wells and wells that receive both carwash wastewater and waste fluids from vehicle maintenance activities were classified as motor vehicle waste disposal wells in the July 29, 1998 proposed revisions to the USEPA Class V UIC regulations.

detergents, road salts, sediments, and incidental contaminants that may be washed from a vehicle's exterior, comparable to typical storm water runoff. Although there are no data on the issue, there is also concern that de-icing agents may be rinsed from cars and enter ground water. The data available on the quality of fluids entering carwash wells indicate that the concentrations of antimony, arsenic, beryllium, cadmium, lead, and thallium in the injectate typically exceed primary drinking water MCLs and HALs. Some samples show that ethylene glycol, methylene chloride, naphthalene, and tetrachloroethene also have exceeded primary MCLs or HALs, indicating that degreasers may in fact be working their way into the washwater at some facilities. The concentrations of pH, aluminum, iron, and manganese in the injectate have exceed secondary MCLs.

Two possible contamination incidents involving carwash wells were reported in Hawaii in the early 1990s. The nature and extent of contamination are unknown, but both wells were closed.

Although there are only these two reported contamination incidents associated with carwash wells, there is concern over the potential for such wells to be vulnerable to spills or illicit discharges. Because the facilities are usually unsupervised (meaning an attendant is not onsite), individuals may in fact wash their engines or undercarriages using degreasers, wash the exterior of their vehicles with chemicals other than common soap solutions, or may pour used oil, antifreeze, or other hazardous materials down these drains. No actual contamination incidents associated with this kind of illicit discharge, however, were discovered during the course of this study. Industry representatives also assert that illegal dumping of unauthorized materials into drains at self-service carwashes is less of a problem now than in the past, due to increased environmental awareness and the greater availability of hazardous material collection centers.

The inventory results for these wells are very uncertain because most responses to the state and USEPA Regional survey conducted for this study did not distinguish carwash wells from other kinds of commercial or industrial wells. These survey results suggest that there are up to 4,651 documented carwash wells and approximately 7,195 estimated carwash wells in the U.S. Although the wells are documented in 14 states, 99% of the documented wells and 98% of the estimated wells are located in nine states: Alabama, Mississippi, New York, Washington, Maryland, Iowa, West Virginia, California, and Maine. Many states estimate that more than the documented number of wells exist, although these estimates are typically based only on best professional judgment and the true number of wells is unknown. As sewer system hookups become increasingly available to carwash owners, it is expected that the number of Class V carwash wells will decrease. Many states close carwash wells when they find them.

Although West Virginia permits carwash wells by rule (in accordance with the existing federal UIC program), other states with the majority of carwash wells are developing and implementing more extensive regulatory programs to address these wells. Specifically:

- Alabama, Mississippi, New York, Washington (when the well meets BMP requirements), Maryland, and New Hampshire issue individual permits.

C Iowa bans carwash wells.

C California requires reporting of discharges from carwash wells.

C Maine issues discharge licenses for new wells and permits for existing wells.

6.4 Large-Capacity Septic Systems

Large-capacity septic systems (LCSSs) are an on-site method for partially treating and disposing of sanitary wastewater. Only those septic systems having the capacity to serve 20 or more persons-per-day are included within the scope of the UIC regulations.

LCSSs do not utilize a single design but instead are designed for each site according to the appropriate state and/or local regulations. Many conventional LCSSs consist of a gravity fed, underground septic tank or tanks, an effluent distribution system, and a soil absorption system. LCSSs may also include grease traps, several small septic tanks, a septic tank draining into a well, connections to one large soil absorption system, or a set of multiple absorption systems that can be used on a rotating basis.

LCSSs are used by a wide variety of establishments, including residential (multi-unit housing) and non-residential (commercial, institutional, and recreational) facilities. The characteristics of the sanitary wastewater from these establishments vary in terms of biological loadings and flow (e.g., daily, seasonal). Generally, the injectate from LCSSs is characterized by high biological oxygen demand and chemical oxygen demand, nitrate, trace metals and other inorganics, limited trace organics, and biological pathogens.

Even with a fully functioning system, data indicate LCSS effluent may contain arsenic, fecal coliform, nitrate (as N), total nitrogen species (as N), and formaldehyde (in septic systems serving recreational vehicles) at concentrations above primary MCLs or HALs. The concentrations of aluminum, iron, manganese, and sodium may exceed secondary MCLs.

The effect of these constituents on USDWs depends in part on the characteristics of the injection zone. It is difficult to generalize about the injection zone for LCSSs because these systems have been constructed nationwide. Typically, LCSSs are located in well-drained soils; however, LCSSs have been located in areas with karst or fractured bedrock. The injectate from LCSSs receives partial treatment within the system (i.e., settling and biodegradation in the septic tank). However, attenuation occurs as the septic tank effluent travels through the soil media below the fluid distribution system, which is most commonly a leachfield. Dissolved organic matter, pathogens, and some inorganic constituents can be attenuated in unsaturated soils below the soil absorption system.

The likelihood of ground water contamination resulting from LCSSs may be minimized by following BMPs relating to siting, design, construction and installation, and operation and maintenance. Careful siting and design of the LCSS are important because understanding site limitations can prevent future system failure. The construction and installation of the septic system is best left to professionals, so that the underlying soils are not damaged through compaction and systems are not constructed during periods of high moisture, both of which are likely to contribute to early system failure. Further, it is recommended that LCSSs be properly operated and maintained by conducting inspections and performing maintenance as appropriate, "resting" the soil absorption field, pumping the septic tank to remove solids as necessary, and limiting system loading (e.g., water conservation, reducing chemical use or addition). Owners or operators of LCSSs who follow such BMPs are likely to maximize the life of their system and lower the likelihood that their system would contaminate a USDW.

Nevertheless, contamination incidents caused by LCSSs have occurred. For example, in Racine, MO during 1992, two drinking water wells at a nearby church and school were contaminated by sewage, causing 28 cases of Hepatitis A. In Coconino County, AZ during 1989, failure of the leaching field (due to excessive flow) at a resort area resulted in approximately 900 cases of gastroenteritis. In Richmond Heights, FL during 1974, a drinking water well was contaminated by sewage from a nursery school, and resulted in approximately 1,200 cases of gastrointestinal distress. In addition, 24 other instances have been identified where LCSS failure and ground water contamination may have resulted. While there are surely other examples of LCSS failure across the U.S. beyond these known incidents, the prevalence of contamination cases appears low relative to the prevalence of these systems.

LCSSs are vulnerable to spills because any materials spilled or dumped down sinks, toilets, or floor drains connected to the sanitary waste system can enter the septic tank. Examples of the materials that may enter LCSSs include household cleaning products and wastes (e.g., cleaning solvents and spent solutions) that were either intentionally or accidentally spilled as well as chemicals dumped illicitly (e.g., waste oil). Once in the LCSS, these materials are not necessarily treated by the system and may be released to ground waters that may serve as USDWs. USDWs may also be vulnerable due to the large numbers of LCSSs operating nationwide. While the incremental effect associated with spills at each LCSS may be small, aggregating each of these spills may provide evidence of a broader contamination problem for USDWs.

According to anecdotal evidence, the LCSS is believed to be a frequently used onsite wastewater disposal option. Yet, until this study constructed the inventory model to estimate total numbers of LCSSs nationwide, no quantitative information on system prevalence was available. As discussed in Section 5.2, the inventory model estimated 353,400 LCSS in the nation; with a 95 percent prediction interval, the range is 304,100 to 402,600. In comparison, the survey responses documented about 43,000 systems and estimated approximately 132,000 systems.

In the future, the total number of systems is expected to increase as the population increases. USEPA found that construction and use of LCSSs will continue in areas where geological conditions are favorable and sewerage is not readily available or economically feasible. In addition, these systems will continue to be constructed because using LCSSs is an accepted and economically attractive practice. While some states are now encouraging owners of large systems to connect to municipal sewers (when such connections become available), there do not seem to be any states planning to ban LCSSs entirely.

USEPA also found that there are no consistent state definitions or regulations of LCSSs. While the 20 persons-per-day criterion is used to define systems subject to federal UIC regulation, states generally characterize large systems using flow definitions that range from 2,000 to 20,000 gallons per day (gpd). Regulation of LCSSs is also highly variable across states. Some states have stringent requirements for large systems. For example, Massachusetts and Minnesota both use 10,000 gpd as the cutoff for large systems and have strict requirements for siting, construction, and operation. Other states only require general construction permitting. For example, New Jersey and Iowa both use a 2,000 gpd threshold for large systems but only require that such systems meet specific construction standards. In addition, LCSSs may be regulated by local regulations that focus on enforcing state and/or county building and health ordinances.

6.5 Food Processing Wells

Food processing wells are essentially commercial septic systems used to dispose of food preparation-related wastewater and equipment or facility wash down water. This group of wells also includes food processing wastewater drywells, which allow wastewater to enter the soil untreated. Both kinds of systems usually inject process wastewater that may contain high levels of organic substances (e.g., food waste), cleaning compound residues, and various inert substances. These wells are typically found at small facilities that usually have less than ten full time employees and are located in unsewered, rural areas.

Food processing wells are similar to domestic septic systems, but instead of receiving toilet and shower water, they receive larger quantities of equipment washdown and process wastewater. The wastewater entering the soil via these wells can contain high biochemical oxygen demand (BOD) levels due to the organic fluids (e.g., blood from animal slaughtering facilities) and some food residues (e.g., shellfish meat from shellfish processing facilities) entering the wastewater stream. In addition, the injectate may contain high levels of nitrate, nitrite, total coliform, ammonia, turbidity and chlorides. No injectate sampling has been performed, so it is difficult to ascertain what constituents typically exceed MCLs or HALs. However, based on observations during site visits and assumptions described in studies of similar wastewater treatment systems, it appears likely that the concentrations of nitrate, nitrite, total coliform, and ammonia may exceed primary MCLs or HALs. It is also possible that due to the high organic content of the injectate, the secondary MCLs for turbidity and chloride may be exceeded.

Food processing wells typically inject above USDWs and into a variety of different geological formations, terrains, and soils. However, one recently closed food processing well at a fruit processing facility in Hawaii was injecting directly into a USDW. As with sanitary septic systems, for food processing wells to work properly it is necessary that the injection zone consist of moderately permeable soils. Site visits in Tennessee revealed that some food processing facilities inject slaughterhouse wastewater, via septic systems, into fractured geologic units and karst terrains that apparently had very little top soil.

Only one USDW contamination incident has been identified that is clearly linked to a food processing well. In Maine, in 1998, a lobster processing/holding facility discharged large volumes of seawater into its combined food processing well and sanitary septic system. As a result, the chloride concentration in a nearby private drinking water well exceeded the secondary MCL.

Food processing wells may be vulnerable to receiving spills that occur at the facility. Some food processing facilities use strong cleaning compounds to clean or disinfect equipment and, based on observations from site visits, some facilities may not always be storing these chemicals in storage areas away from floor drains that are connected to food processing wells. Therefore, spills may result in the release of cleaning/disinfecting chemicals into the injection zone.

According to the state and USEPA Regional survey conducted for this study, there are at least 741 documented food processing wells and more than 1,468 estimated to exist in the U.S. Of the 741 documented wells 43% are found in Maine and New York and 52% are found Alabama and West Virginia. The remaining few are found in Alaska, Wisconsin, Hawaii and a few other states. Tennessee also has a significant number of food processing wells but the inventory has not been finalized. These well totals are considered very uncertain because they are often based on professional judgment only and because many states do not distinguish between food processing wells and other kinds of commercial/industrial wells in many state inventories. Overall, it seems that the number of active food processing wells throughout the country is decreasing because many UIC program staff are actively encouraging individuals not to install injection wells for this purpose and because the areas served by sewers are expanding. Additionally, there are some states that are closing all food processing wells as they are found.

States such as Maine, Alabama and New York, which have significant numbers of food processing wells, require individual permits or waste discharge licenses prior to construction and operation. However, in Maine if the food processing well meets local plumbing codes, no discharge license is required. West Virginia and Tennessee, on the other hand, authorize these wells by rule but may require more extensive permitting or closure efforts if it appears that operations may result in USDW endangerment. All food processing wells in Wisconsin are permitted individually through the Wisconsin Pollutant Discharge Elimination System (WPDES). Oregon covers these wells under a state general permit. Hawaii, with only a few wells, prohibits injection into a USDW unless an individual site-specific permit is issued. Depending on the type of food being processed, food processing facilities must comply with food handling and preparation regulations put forth by counties and states, as well as requirements from the federal government under the Federal Meat Inspection Act, the Federal Poultry Inspection Act, or the Federal Drug and Cosmetic Act.

6.6 Sewage Treatment Effluent Wells

Class V sewage treatment effluent wells are used in many places throughout the country for the shallow disposal of treated sanitary waste from publicly owned treatment works or treated effluent from a privately owned treatment facility that receives only sanitary waste. For the purpose of this study, injection wells that are used to dispose of industrial waste (not sanitary waste) from industrial wastewater treatment facilities (not publicly owned treatment works) are not sewage treatment effluent wells, but rather are industrial wells. In addition to being used for the purpose of wastewater disposal, sewage treatment effluent wells are commonly used where injection will aid in aquifer recharge or subsidence control, or to prevent salt water intrusion.

The effluent that is injected into sewage treatment effluent wells is generally subjected to secondary or tertiary treatment in a municipal wastewater treatment plant or a privately owned wastewater treatment plant. However, one facility identified in the study discharges effluent that is subject to only primary treatment to subsurface disposal units. Secondary treated effluent may contain fecal coliform and nitrates at concentrations above primary MCLs, and either secondary or tertiary treated effluent also may exceed secondary MCLs for chloride, sulfates, or TDS. Available injectate quality data for sewage treatment effluent wells indicate that injectate samples have exceeded MCLs for fecal coliform, nitrates, TDS, and pesticides at at least one facility; however, many of these reported exceedances are represented by only one or two injectate samples, and data are not available to indicate whether these exceedances are one-time events or routine occurrences. Also, available information indicates that at least one facility is permitted to discharge injectate that exceeds the secondary MCL for chloride.

Approximately 42 percent of the documented sewage treatment effluent wells are located in Florida, and approximately 700 of these wells (35 percent of the total documented inventory) are located in the Florida Keys and inject into shallow (<50 feet) aquifers that are of extremely poor quality and that are not likely to be used as sources of drinking water. Approximately 26 percent of the total documented well inventory are located in California. Other sewage treatment wells in Florida, Arizona, and other states, are used to inject treated wastewater effluent for aquifer recharge, and may be injecting into aquifers of drinking water quality. Nearly 19 percent of the documented wells are located in Hawaii. Hawaii UIC regulations do not allow operation of sewage treatment effluent wells within one quarter mile of a drinking water source, and it is anticipated that many of these wells inject into aquifers that are not of drinking water quality. No data were provided by survey respondents concerning the characteristics of injection zones for other states where sewage treatment effluent wells are currently operated.

Several studies and incidents have shown that sewage treatment effluent wells may have contributed to or caused ground water or surface water contamination. One study showed nitrate contamination of onsite ground water at a sewage treatment effluent site in New Hampshire where both primary treated effluent and septage were released into a leach field. Two sewage treatment effluent wells on the Island of Maui, Hawaii were thought to be causing surface water contamination through migration of nitrates in the injectate to surface water bodies. One of these wells has been shut down and the other is the subject of an ongoing enforcement action by USEPA. The U.S. Geological Survey is conducting a long-term study of the operation of sewage treatment effluent wells in the Florida Keys to assess whether migration of nitrates from injectate is contributing to surface water contamination.

Sewage treatment effluent wells are not vulnerable to spills or illicit discharges. The injectate is treated wastewater, and the wastewater treatment plants that generate the injectate are generally subject to effluent quality standards and monitoring, reporting, and record keeping requirements. Incidents where injectate failed to meet injectate quality standards would generally be detected, and corrective action would be taken by the wastewater treatment plant operator. Moreover, sewage treatment effluent injectate is piped to the well from the wastewater treatment plant, so contamination in route is unlikely, and the types and quantities of hazardous materials that would be present at a wastewater treatment plants is limited. Spills of hazardous materials (e.g., chlorine) into the wastewater treatment plant system are unlikely and would also generally be detected by the wastewater treatment plant effluent monitoring system.

According to the state and USEPA regional survey conducted for this study, there are 1,675 documented sewage treatment wells, and more than 1,739 wells are estimated to exist in the U.S. More than 95 percent of the documented wells are located in five states: Arizona (79); California (205); Florida (830); Hawaii (378); and Massachusetts (105). New York did not report any documented sewage treatment effluent wells in the state, but reported that there may be less than 50 undocumented wells.

Considering that sewage treatment effluent wells are associated with either publicly or privately owned wastewater treatment plants that are generally required to have operating permits, the inventory of sewage treatment effluent wells is considered to be relatively accurate compared with other injection well categories for which wells do not always receive permits. Nevertheless, there may be a somewhat larger or smaller number of sewage treatment effluent wells than these results suggest. For example, New Hampshire did not report any sewage treatment effluent wells in the state in its survey response; however, two facilities that inject treated effluent into subsurface disposal units, classified as injection wells for the purpose of this report, were identified through field visits. Conversely, Maine initially identified 168 sewage treatment effluent wells in its survey response; however, further investigation revealed that these facilities are discharging untreated wastewater effluent to subsurface disposal units that are classified as large-capacity septic systems and not as sewage treatment effluent wells. Although no state UIC programs other than Maine and New Hampshire are known to have miscategorized sewage treatment effluent wells, if other states have done so, the reported inventory may either overestimate or underestimate the true number of sewage treatment effluent wells in the U.S.

States with the majority of sewage treatment effluent wells have developed and implemented a variety of programs to address these wells. Specifically:

C In Florida, sewage treatment effluent wells are required to have individual permits and meet MCLs.

- In Hawaii, regulations have established ground water protection zones where the construction of sewage treatment effluent wells is prohibited. Wells outside of these zones are required to obtain individual permits.

- Arizona requires sewage treatment effluent wells to obtain ground water protection permits, and requires the well operators to demonstrate that MCLs will not be exceeded at the facility property boundary. Arizona also has published BMPs for the operation of wastewater treatment plants (and their associated sewage treatment effluent wells).

- California requires sewage treatment effluent wells to obtain individual permits.

- Massachusetts requires sewage treatment effluent wells to obtain ground water discharge permits.

The regulatory picture in other states with few sewage treatment effluent wells in the current inventory is also mixed. States either permit sewage treatment effluent wells by rule (e.g., Texas, Idaho), require them to obtain ground water protection permits (e.g., New Hampshire), or require them to obtain individual permits (e.g., West Virginia). Some states (e.g., New Hampshire) establish ground water compliance zones (generally at the site boundary) while others (e.g., Idaho) require injectate to meet MCLs at the point of injection. In Wisconsin, the operator of a facility that discharges sewage treatment effluent into a subsurface soil absorption system that is constructed in the unsaturated zone above the water table is required to obtain a WPDES permit. Direct discharges into a saturated formation is prohibited in Wisconsin.

These regulatory programs in the states are supplemented by regulatory standards and guidelines that apply to the operation of municipal wastewater treatment plants under the authority of the Clean Water Act and associated state regulations. BMPs for wastewater treatment plants have also been established by USEPA under the Clean Water Act. These BMPs are equally appropriate for treatment plants that discharge to surface water and those that discharge (inject) into ground water.

6.7 Laundromat Wells

Wells used to inject fluids from laundromats where no onsite dry cleaning is performed or where no organic solvents are used for laundering are classified as “laundromat wells” for the purpose of this study. These wells are located throughout the U.S. and can be found at coin-operated laundromats.

The characteristics of the fluids drained into these wells are similar to those of greywater from household washing machines. The limited data that are available from coin-operated washers indicate that none of the primary drinking water MCLs or HALs are exceeded by laundromat washwater. However, the injectate has exceeded the secondary MCLs for pH and TDS.

It is not a typical practice to locate laundromat wells in injection zones with specific geologic characteristics (laundromat wells do not tend to be located in areas with karst, fractured bedrock, or any other particular kind of subsurface feature).

Although there are no reported contamination incidents associated with laundromat wells, some wells may to be vulnerable to spills or illicit discharges. For instance, the unsupervised nature of coin-operated laundromats may make Class V wells at those facilities susceptible to contamination due to laundering of contaminated articles. For instance, an individual may wash highly contaminated articles, such as solvent-soaked or oily rags, that may result in increased contaminant concentrations in the wash water. As another example, it is reasonable to expect that any sinks or floor drains at the facility, which also may receive minor spills, would be hooked into the same plumbing system that collects and transfers wash water to the injection well. No actual contamination incidents associated with these kinds of discharges, however, were discovered during the course of this study.

The inventory results for laundromat wells are very uncertain because most responses to the state and USEPA Regional survey conducted for this study did not distinguish laundromat wells from other kinds of commercial or industrial wells. These results suggest that there are less than 700 documented laundromat wells in the U.S. The wells are documented in 12 states, with Alabama, West Virginia, New York, Mississippi, and Iowa providing the highest estimates (Collectively, these five states account for more than 90 percent of the estimated national inventory). Although many states estimate numbers of wells much higher than the numbers documented, most are unsure of the exact number of wells.

States with the majority of documented or estimated laundromat wells are implementing various kinds of regulatory programs to address these wells. Alabama and New York issue individual permits. Individual permits are also sometimes required in West Virginia. However, in Iowa, Mississippi, and West Virginia, the wells are permitted by rule; that is, as long as owners and operators meet certain requirements, they are allowed to operate a laundromat well.

6.8 Spent Brine Return Flow Wells

Naturally occurring surface and underground brines are used as the source for commercial production of a variety of mineral commodities, including common salt, calcium chloride, sodium sulfate, and/or magnesium, iodide, or bromide compounds. When underground brines serve as the raw material for production of mineral commodities, the brine is extracted from the subsurface through production wells, the target compounds or elements are extracted, and the resulting “spent brine” is normally[2] returned to the subsurface through spent brine return flow (injection) wells.

The chemical characteristics of the injected spent brine are determined primarily by the characteristics of the brine that is withdrawn for processing and the nature of the extraction and

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[2] At least one facility disposes of spent brines from extraction of minerals from brine withdrawn from underground sources by surface discharge (to a playa lake bed) instead of by injection.

production processes used. As a result, spent brine characteristics can vary substantially from facility to facility, although in some cases the brine characteristics are similar when several facilities withdraw brine from a common formation, as is the case in Arkansas. In Arkansas, available data indicate that concentrations of barium and boron in spent brine routinely exceed primary MCLs or HALs. Data available for Michigan facilities indicate that chloride, copper, iron, manganese, TDS, and pH levels frequently exceed secondary MCLs. Data are not available to determine whether concentrations of some other constituents, including some heavy metals, are present at concentrations above health-based levels.

Spent brine return flow wells inject spent brine into the same formation from which it was withdrawn, which in all current cases is below the lowermost USDW. (In fact, most spent brine return flow wells were initially drilled as production wells and subsequently converted to injection wells.) The chemical composition of the spent brine is generally similar to that of the produced brine except that the concentration of target elements (e.g., magnesium) has been reduced and the concentration of other elements (e.g., calcium) may have been increased through substitution. Thus, the MCL exceedances observed for the spent brine are also typical for the produced brine and the receiving formation.

No incidents of USDW contamination by spent brine return flow wells were identified during preparation of this report. In addition, spent brine return flow wells are not likely to receive accidental spills or illicit discharges. Corrosion of some well materials by the brine is a common problem, however. Therefore, injection is through corrosion-resistant tubing and well integrity is monitored on an ongoing basis.

According to the state and USEPA Regional survey conducted for this study, there are 98 documented spent brine return flow wells that are regulated as Class V injection wells in Arkansas (74) and Michigan (24). Several other states, including New York, Tennessee, California, and Oklahoma, indicate that spent brine wells exist, but they are regulated as Class II or III wells.

The specific features of well construction and operation may vary somewhat with the location and timing of construction of the well, but in general, all the wells are built according to regulatory or permit requirements that have many features in common with Class I and Class II injection wells. Arkansas has placed jurisdiction over spent brine return flow wells in its Oil and Gas Commission, which applies Class II UIC permitting requirements as well as a special set of construction and operating standards. For wells in Michigan, individual UIC permits are issued by USEPA Region 5.

6.9 Mine Backfill Wells

Mine backfill wells are used in many mining regions throughout the country to inject a mixture of water and sand, mill tailings, or other materials (e.g., coal combustion ash, coal cleaning wastes, acid mine drainage treatment sludge, flue gas desulfurization sludge) into mined out portions of underground mines. On occasion, injection (in low porosity grout form) also occurs into the rubble disposal areas at surface mining sites. Mine shafts and pipelines in an underground mine, as well as more “conventional” drilled wells, used to place slurries and solids in underground mines are considered mine backfill wells.

Such wells may be used to provide subsidence control (the most common purpose), enhanced ventilation control, fire control, reduced surface disposal of mine waste, enhanced recovery of minerals, mitigation of acid mine drainage, and improved safety.

The physical characteristics and chemical composition of the materials that are injected into backfill wells vary widely depending on the source of the backfill material, the method of injection, and any additives (e.g., cement) that may be included. Data from leaching tests (e.g., USEPA Method 1311--TCLP) of backfill materials indicate that concentrations of antimony, arsenic, barium, beryllium, boron, cadmium, chromium, lead, mercury, molybdenum, nickel, selenium, thallium, sulfate, and zinc frequently exceed primary MCLs or HALs. Concentrations of aluminum, copper, iron, manganese, TDS, sulfate, and pH frequently exceed secondary MCLs.

At sites where water is present in the injection zone (the previously mined ore body), the mine water may already exceed MCLs or HALs prior to injection either as a result of mining activity or natural conditions. At such sites, one objective of injection often is to improve the already poor quality of the mine water by reducing the availability of oxygen in the mine workings and/or neutralizing acid mine drainage. In other areas, water from coal beds may be used to supply domestic wells.

No incidents of contamination of a USDW have been identified that are directly attributable to injection into mine backfill wells. Although ground water contamination is not uncommon at mining sites, it is generally difficult to identify the specific causes. The chance that backfill injection will contribute to ground water contamination is highly dependent on site conditions, including mine mineralogy, site hydrogeology, backfill characteristics, and injection practices. Some studies of the effects of backfill injection on mine water quality show that concentrations of some cations and anions can increase in mine water following injection, whereas concentrations of trace metals generally are relatively unaffected or decline over time. Other studies (at other sites) show an increase in selected metal concentrations.

The vulnerability of mine backfill wells to receiving spills or illicit discharges also depends on site-specific conditions and practices. For example, if coal ash is hauled to a mine site, slurried with water, and then injected, the likelihood of contamination of the injected material resulting from a spill or illicit discharge is relatively low. On the other hand, if mill tailings are collected in a tailings pond along with site runoff and other facility wastes prior to injection, then the likelihood of contamination of the backfill material by spills would be higher.

According to the state and USEPA Regional survey conducted for this study, there are approximately 5,000 documented mine backfill wells and more than 7,800 wells estimated to exist in the United States. A total of 17 states report having mine backfill wells. More than 90 percent of the documented wells reported are in four states: West Virginia (401), Ohio (3,570), North Dakota (200), and Idaho (575). In truth, there may be more due to the broad scope of this well type and the fact that some state inventories may count these wells as subsidence control wells while others did not. Also, the number of active wells at any given time varies widely due to their generally short life span, most often a few days or less. The number of mine backfill wells has the potential to grow in the future due to the growing movement to decrease surface disposal and control ground subsidence.

State regulations pertaining to mine backfill wells vary significantly in their scope and stringency. Some states impose few specific restrictions while others require permitting, or impose requirements by contract rather than regulation. Some of these approaches include permit by rule (e.g., Idaho, Kansas, Texas, Illinois, North Dakota), general or area permits (e.g., Wyoming), and individual permits (e.g., Ohio, West Virginia, Indiana, Pennsylvania). In addition, federal requirements for planning and approval of mining activities include mine backfill activities. These requirements apply in states that have not obtained primacy under the Surface Mining Control and Reclamation Act and to activities on federal and Native American tribal lands.

6.10 Aquaculture Waste Disposal Wells

Methods employed for the controlled cultivation of aquatic organisms can vary substantially. Some aquaculture facilities use pens suspended in open water bodies, while others use systems that circulate water through tanks. Many aquaculture operations accumulate wastewater and sludge that requires removal. At dozens of such facilities in Hawaii and in several other states, this effluent is disposed via underground injection.

Injected aquaculture effluent includes fecal and other excretory wastes and uneaten aquaculture food. The primary chemical and physical constituents of these wastewaters are therefore nitrogen- and phosphorus-based nutrients and suspended and dissolved solids. The effluent may also contain bacteria pathogenic to humans and chemicals, pesticides, and/or aquaculture additives. However, the incidence and concentrations of human pathogenic bacteria, chemicals, pesticides, and additives in injectate is unknown. Information on aquaculture wastewater quality industry-wide is very limited, and wastewater properties are believed to vary greatly among different aquaculture operations. Available analytical data for aquaculture injectate and aquaculture effluent suggest that the concentrations of most parameters are generally below applicable standards. Contaminants that may exceed the standards under some circumstances include turbidity and possibly nitrite and nitrate. The secondary MCL for chloride is also exceeded in the wastewater from some seawater-based operations, but as long as these wastes are injected to saline aquifers, they pose no threat to USDWs.

The injection zone for aquaculture wastewater is characterized by relatively high porosity, as aquaculture wastewaters typically have significant suspended solids content. Seawater-based aquaculture operations in Hawaii inject wastewater into brackish or saline aquifers that flow seaward. Little information is available regarding other aquifers receiving aquaculture injectate.

No contamination incidents related to aquaculture wastewater disposal have been reported. Information about the threat of contamination posed by these wells is also inconclusive. For example, in Idaho, an aquaculture well is known to inject wastewater directly into an aquifer, but the quality of the aquifer, its status as a USDW, and the resulting impacts, are unknown. The subsurface disposal system (i.e., a leaching field) known to be in use by an aquaculture operation in Maryland is situated above a Type 1 (high quality) aquifer, but no impacts have been observed.

Aquaculture wells generally are not vulnerable to spills or illicit discharges. Most are located within private facilities and are not accessible to the public for unsupervised waste disposal. However, the potential exists for operators to dispose of harmful liquid wastes (e.g., waste aquaculture chemicals, or spent tank water with higher concentrations of chemicals used for temporary treatment of cultivated organisms) via aquaculture injection wells. No such cases have been reported.

According to the state and USEPA Regional survey conducted for this study, a total of 56 documented Class V aquaculture waste disposal wells exist in the U.S. The great majority occur in Hawaii (51 wells, or 93 percent). The remaining documented wells are in Wyoming (2 wells), Idaho (1 well), New York (1 well), and Maryland (1 well). In addition to these documented wells, as many as 50 additional wells are estimated to exist in California. Thus, the true number of aquaculture waste disposal wells in the U.S. is likely to approach 100. Given that the value of U.S. aquaculture production has grown by 5 to 10 percent per year over the past decade, and that the aquaculture industry remains the fastest growing segment of U.S. agriculture, there is some possibility that the number of Class V aquaculture waste disposal wells will increase.

Programs to manage Class V aquaculture waste disposal wells vary between the states with such wells:

- In Hawaii, aquaculture injection wells are authorized by individual permit. Class V wells are grouped for purposes of permitting into six subclasses. Aquaculture wells may fall into two of the subclasses, depending on the character of the injectate and the water in the receiving formation.

- In Wyoming, aquaculture wells are covered under a general permit. The permit specifies certain construction and operating requirements (e.g., pretreatment of wastewater).

- In Idaho, wells greater than 18 feet deep are individually permitted, while shallower wells are authorized by rule.

- In New York, the Class V UIC program is directly implemented by USEPA Region 2. Beyond the federal UIC requirements, state regulations require permits for all point-source discharges into ground water.

- In Maryland, individual permits are required for any discharge of pollutants to ground water, for any industrial discharge of wastewater to a well or septic system, for any septic system with 5,000 gpd or greater capacity, or for any well that injects fluid directly into a USDW.

- In California, regional authorities issue permits for all Class V wells but the stringency of these authorities varies across the state. Aquaculture facilities thought to operate injection wells may not be required to obtain permits for these wells.

6.11 Solution Mining Wells

Solution mining wells are used to inject a fluid (lixiviant) into underground mines to dissolve mineral values from the ore. The resulting “pregnant” solution is then brought to the surface, through separate wells, for subsequent recovery of the dissolved mineral being produced. Solution mining wells that are currently regulated under the federal definition of Class V injection wells are used in the recovery of copper, uranium, and potentially other minerals, from mines that have already been conventionally mined, through the injection of solutions of sodium bicarbonate or sulfuric acid in ground water or recirculated mine water. When solution mining techniques are used to extract minerals from ore bodies that have not been conventionally mined, the injection wells are classified as Class III injection wells under USEPA regulations.

The characteristics of the injected solution are highly dependent on those of the ore body being mined because a variety of metals present in the ore body are incorporated into the solution as it goes through repeated cycles of injection, extraction, and reinjection. Data on the composition of solution mining fluids indicate that the concentrations of sulfate, molybdenum, radium, selenium, arsenic, lead, and uranium exceed primary drinking water MCLs or HALs. Concentrations of TDS, chloride, manganese, aluminum, iron, sulfate, and zinc have been measured above the secondary MCLs. Site-specific factors determine which constituents exceed one or more of the standards.

In many cases, the hydrogeology of the injection zone, or mined ore body, has already been altered by ground water pumping as well as previous mining. In uranium mining, for example, the formation is a water-bearing sandstone. As part of solution mining operations, ground water flow is normally modified to create a drawdown, or zone of depression, so that the injected lixiviant is retained in the leaching zone for subsequent recovery.

No ground water contamination incidents have been identified that are directly attributable to Class V solution mining injection wells. However, the fluids injected into these wells inherently contain a variety of metals at concentrations above MCLs or HALs, and contamination resulting from a combination of mining-related activities has been reported at several sites. Elevated concentrations of metals have been observed in ground water in the vicinity of solution mining operations, but complex hydrogeology and other mining and mining-related activities make it difficult to attribute the cause to a specific activity, such as solution mining injection wells. At sites where solution mining injection wells are used, the likelihood that ground water contamination will result is dependent primarily on overall mining operations rather than the specific construction and operational practices of the injection wells. Specifically, the chance of migration of the solubilized metals from the injection zone depends on the effectiveness of measures like ground water pumping and monitoring that are used to ensure that the leaching solution is contained within the *in situ* leaching zone.

No information was collected that indicates these wells are vulnerable to receive spills or illicit discharges.

The state and USEPA Regional survey results indicate that there are 2,694 documented solution mining wells in the U.S. (no more were estimated, indicating that there is substantial confidence in this documented number). Eight of these wells are associated with a uranium mine in New Mexico; the remaining wells occur at two copper mines in Arizona. Wells at one solution mining operation in Potash, Utah that meet the federal Class V definition are not included in this report because they are regulated by the state as Class III wells. Another solution mining well in Colorado that was initially permitted as an experimental Class V well is considered a Class III well. The prevalence of Class V solution mining wells in the future depends on a wide range of factors such as commodity prices and the development of lower cost mining and beneficiation processes.

Both Arizona and New Mexico control solution mining through the use of individual permits, although in Arizona, where the UIC program is implemented by USEPA Region 9, the state uses an Aquifer Protection Permit rather than a UIC permit. Both states have operating and monitoring requirements. Arizona also places requirements on construction and maintenance practices, and financial assurance must be demonstrated.

6.12 In-Situ Fossil Fuel Recovery Wells

In-situ fossil fuel recovery wells are used to facilitate in-situ conversion of a hydrocarbon resource into a gaseous or liquid form that can be extracted through production wells. Specifically, in-situ fossil fuel recovery wells are used to initiate and then to maintain and control combustion through injection of air, oxygen, steam, carbon dioxide, or ignition agents. There are three types of processes that may use in-situ fossil fuel recovery wells: in-situ combustion of tar sand deposits, underground coal gasification (UCG), and in-situ oil shale retorting. In-situ combustion of tar sand deposits has not been employed in the U.S.

Most of the injected materials are gases (e.g., air, oxygen) that are not likely to show exceedances of MCLs or HALs. When ignition agents such as ammonium nitrate are injected, exceedances of MCLs or HALs would be expected, but has not been documented.

In-situ fossil fuel recovery wells inject into a hydrocarbon-containing unit, which is often a steeply inclined coal seam or oil shale deposit that is not practical to mine with conventional methods. Although injected gases generally do not introduce contaminants into the subsurface, injection may alter the characteristics of a USDW, if the gases are allowed to contact a USDW, by changing the USDW's temperature or increasing the level of gas saturation.

Contamination of ground water resulting from in-situ fossil fuel recovery operations is well documented, to the extent that most, if not all, in-situ fossil fuel recovery operations initiated in the last 20 years appear to have caused some ground water contamination. The ground water is not contaminated with the injected materials, however. Rather, it is contaminated with combustion byproducts, such as benzene. At some sites, water containing benzene and other combustion byproducts, such as phenols, has migrated via fractures or other means from the reaction zone into nearby ground water.

The in-situ fossil fuel operations conducted in the U.S. have all operated on a trial, rather than full-scale basis. The scale of the reaction zone in these cases led to lower temperatures than would be expected in full-scale operation. At these lower temperatures, pyrolysis can dominate the process, resulting in greater generation of products of incomplete combustion than would be expected in a full-scale operation. In addition, full-scale operation would create a larger combustion cavity, resulting in a stronger and more extensive ground water depression zone. Such a depression zone would be expected to cause ground water to flow to, rather than away from, the combustion zone, thus reducing the migration of contaminants outside the combustion zone.

The observed contamination problems are associated with in-situ fossil fuel recovery operations, rather than rare spills or accidents. Overall, in-situ fossil fuel recovery wells are not likely to receive spills or illicit discharges.

According to the state and USEPA Regional survey conducted for this study, there are neither documented nor estimated active in-situ fossil fuel recovery wells in the U.S. The Agency is not aware of plans to construct any new wells.

State UIC regulations in Wyoming and state mining regulations in both Wyoming and Colorado establish permitting and operating requirements for in-situ fossil fuel recovery wells. In both states, mining plans are required that must address siting, construction, operation, monitoring, and closure of production and injection wells. Colorado's mining regulations do not include specific requirements for mechanical integrity testing, plugging and abandonment, or financial assurance. Requirements in Wyoming are both extensive and more specific.

6.13 Special Drainage Wells

Special drainage wells are used throughout the country to inject drainage fluids from sources other than direct precipitation. This is a "catch-all" category, including all drainage wells that are not agricultural, industrial, or storm water drainage wells. The specific types of wells that fit into this category are:

- Pump control valve discharge and potable water tank overflow discharge wells;

- Landslide control wells;

- Swimming pool drainage wells; and

- Dewatering wells.

Pump control valve discharges and potable water tank overflows may be drained to the subsurface on occasion, usually when an emergency overflow or bypass procedure takes place. Landslide control wells are used to dewater the subsurface in landslide-prone areas. Removing ground water from sediments decreases the weight of the sediments and increases the resistance to shearing in the area. Swimming pool drainage wells are used to drain swimming pool water to the subsurface for seasonal maintenance or special repairs. Dewatering wells are used at construction sites to lower the water table and keep foundation excavation pits dry. Dewatering wells may also be used at mining sites, where they are known as "connector wells," to drain water from an upper aquifer into a lower one to facilitate mining activities.

In addition to these four types of wells, USEPA Region 5 reports the existence of steam trap wells, which inject steam condensate collected from a system of pipelines at one industrial facility in East Chicago, Indiana. Although classified as special drainage wells for the purpose of this study, these steam trap wells are not considered in detail because they only exist at one facility and no specific information about them is available.

Injectate characteristics vary among the types of special drainage wells. The injectate from pump control valve discharge and potable water tank overflows is expected to meet all drinking water standards due to the potable nature of the water. The quality of injectate in landslide control wells depends on the quality of the ground water that is being drained to a deeper level in the subsurface. The limited amount of available data indicates that swimming pool drainage well injectate contains coliforms. In addition, the recommended chemical composition of swimming pool water includes TDS levels above the secondary MCL for drinking water. Data show that dewatering well injectate typically contains the following constituents above primary MCLs or HALs: turbidity, nitrogen-total ammonia, arsenic, cadmium, cyanide, lead, molybdenum, nickel, nitrate, and radium 226. Additionally, the following constituents in dewatering well injectate are typically detected above secondary MCLs: iron, manganese, TDS, and sulfate. Measured pH levels are also below the lower end of the secondary MCL range.

Because special drainage wells do not tend to be located in areas with specific geologic characteristics (they are typically located wherever the need for a certain type of drainage exists), generalizations about the injection zone characteristics are very limited. In Florida, where swimming pool drainage wells and mine dewatering wells are prevalent, the injection zone is typically karst. Swimming pool water is often injected into aquifers from which the pool water was initially withdrawn, and the injected water quality is usually not significantly degraded from that in the receiving aquifer. In some cases, swimming pool drainage wells inject into saline aquifers. Landslide control wells and dewatering wells inject into deeper aquifers that can accept large volumes of fluid from upper aquifers.

No contamination incidents have been reported for pump control valve discharge and potable water tank overflow discharge wells, landslide control wells, or swimming pool drainage wells. A 1984 study expressed concern over water quality received by the Floridan aquifer when dewatering wells were operated at several phosphate mining sites. However, no contamination incidents caused by the use of dewatering wells have been reported.

In general, special drainage wells are not highly vulnerable to spills or illicit discharges. The extent of any potential contamination caused by dewatering or landslide control wells is highly dependent upon the characteristics of the construction or mining site or potential landslide location that is being dewatered. Pump control valves and potable water tanks and swimming pools are not especially vulnerable to spills or illicit discharges.

According to the state and USEPA Regional survey conducted for this study, there are approximately 1,944 documented special drainage wells and more than 3,750 special drainage wells estimated to exist in the U.S. The wells are documented in 13 states, although 97 percent are located in Florida (782) and Indiana (1,102). The trends in constructing and operating special drainage wells indicate that these numbers are likely to decrease in the future. An alternative type of landslide control well may replace the type that injects water deeper into the subsurface. This alternative moves water to the ground surface or to surface water bodies. Swimming pool drainage wells, which are mainly located in Florida, are associated with older pools and are generally no longer constructed. Many of the mine dewatering wells associated with phosphate mining in Florida have been closed.

Special drainage wells are rule authorized in Idaho, Indiana, and Ohio. However, the other states with the majority of special drainage wells are implementing more specific regulatory programs to address these wells. Specifically, individual permits are issued in Alaska, Florida, and Oregon, and general permits for single family swimming pools are issued in Florida. A *de facto* ban on connector wells exists in Florida because old wells are terminated and plugged as they are discovered, and new connector wells are not permitted.

6.14 Experimental Wells

Experimental technology injection wells have been reported in seven states and are used to test new or unproven technologies. Experimental "tracer study" wells, which inject chemicals to evaluate hydrogeological parameters, comprise the vast majority of wells classified as experimental wells for the purpose of this study. Experimental technologies also have been recently applied in Class V wells associated with Aquifer Thermal Energy Storage (ATES) systems, which store thermal energy by injecting heated and/or cooled water into an aquifer. The existence of experimental wells varies widely from state to state because, in some instances, different definitions of "experimental well" are used by different states. The definitions used by the states may not necessarily correspond to the USEPA definition included in the Class V Study questionnaire.

Experimental Tracer Study Wells

Many different types of substances are injected into experimental tracer study wells. Examples of these substances include organic dyes, inert gases, short half-life radionuclides, rare earth metals, and inorganic or organic compounds. Only one experimental well was reported for which injectate did not meet the primary MCLs, secondary MCLs, and HALs, this being a tracer study well at a site in Naturita, Colorado. The injectate for this tracer well exceeded MCLs for sulfates and chloride, and contained arsenic and molybdenum at levels greater than HALs.

The injection zone characteristics for experimental technology injection wells vary widely depending upon the purpose of the well. Wells used for tracer studies may inject into contaminated aquifers, sometimes including aquifers that serve as drinking water supplies.

No contamination incidents were reported for experimental tracer study wells. In addition, these wells are not vulnerable to spills or illicit discharges because injectate quality is controlled by the conditions of the experiment being conducted. Tracer study wells generally release tracers in small quantities.

According to the state and USEPA Regional survey conducted for this study, six states have a total of 396 documented experimental tracer study wells: South Carolina, Colorado, Nevada, Idaho, Texas, and Washington. More than 97 percent of the documented tracer study wells exist in South Carolina (207 wells or 52%) and Nevada (179 wells or 45%, although some of these wells are reportedly now plugged and abandoned). Most of the tracer study wells in South Carolina and Nevada are being operated at U.S. Department of Energy facilities. The States of Massachusetts, Florida, and Mississippi indicated that they may have experimental wells, but that they could not provide an estimate of how many wells actually exist. The Texas and Washington UIC programs identified five and two experimental wells operating in their states, respectively, but did not provide any information concerning the types of wells (they may in fact be something other than tracer study wells). The Illinois UIC program reported two experimental wells that are most likely no longer operating. Survey responses from the other states indicated that they had no experimental wells as defined in the survey questionnaire.

The experimental technology wells in South Carolina, Nevada, and Washington are individually permitted by the state. The wells in Colorado and Texas are permitted by rule, although the wells in Colorado must have a construction permit. In Idaho, wells less than 18 feet deep are permitted by rule and wells greater than 18 feet deep are individually permitted. Although Wisconsin did not report the existence of any experimental tracer study wells, Wisconsin's administrative rules require that an approval be obtained for any future wells. Any approval in Wisconsin would be based on the condition that the approved experimental injection practice may not exceed the state's numerical ground water quality enforcement standards. Similarly, even though no active ATES systems or experimental tracer study wells are reported in Minnesota, that state has issued variances for experimental ATES systems and tracer studies in the past.

ATES System Wells

Heated or cooled process water, which may originate from native ground water, surface water, or potable water, are injected into ATES systems. Experimental ATES wells inject water into the same formation from which it was withdrawn. While no contamination incidents were reported for ATES system wells, several reports mentioned that the concentration of constituents in ground water receiving fluids from some ATES wells were higher than background levels. The wells are not vulnerable to spills or illicit discharges because injectate quality is controlled by the conditions of the process operation. In particular, experimental ATES systems inject treated water for which injectate quality must be controlled. No UIC programs reported any operating ATES system wells in the survey responses. ATES systems, however, were recently operated in Minnesota and New York, and are in operation in several European countries.

6.15 Aquifer Remediation Wells

Aquifer remediation wells (ARWs) are widely used around the country for beneficial uses associated with the control of ground water contamination. These wells may be used for different specific purposes, including to: (1) introduce remediation agents (i.e., chemicals or microorganisms) into contaminated aquifers to neutralize the contamination; (2) increase ground water flow through the contaminant zone in an aquifer to aid in contaminant removal; (3) form hydraulic barriers to contain contaminant plumes; and (4) re-inject treated ground water for aquifer recharge after an onsite pump-and-treat system.

Class V aquifer remediation wells are distinguished from Class IV wells, which dispose of hazardous or radioactive waste into or above a formation which contains a USDW within one-quarter mile (see 40 CFR §144.6(d)). Although Class IV wells are generally prohibited, they are allowed if they are used to inject treated contaminated ground water that qualifies as hazardous or radioactive waste and is being reinjected into the same formation from which it was drawn, if approved by USEPA pursuant to the provisions for cleanup of releases under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or the Resource Conservation and Recovery Act (RCRA) (see 40 CFR §144.13(c)). A well that meets this definition is a Class IV well, not a Class V aquifer remediation well.

For many reagents and nutrients injected into ARWs, the concentration in the injectate likely exceeds MCLs or HALs because higher concentrations of such reagents and nutrients are needed for them to serve their intended purposes. The data available about these wells are insufficient to establish meaningful comparisons between concentrations of injected reagents or nutrients in ground water monitoring wells, located downgradient from the ARW where they were injected, and the corresponding MCLs or HALs. Based on the information reviewed, it appears that ground water monitoring activities associated with remediation projects typically focus on the contaminants of concern for remediation, rather than on the reagents, nutrients, or other substances injected into the affected aquifer as part of the remedial activity.

The injectate in ARWs is typically (i.e., in the case of the first three purposes mentioned above) directed into a contaminated aquifer where constituents of concern exceed MCLs. On the other hand, re-injection of treated ground water from an onsite pump-and-treat system may occur into a different formation than that which is being remediated, with the objective of recharging the aquifer. In this last case, the receiving formation may be a USDW and the injectate is monitored to ensure that constituents of concern present in the injectate do not exceed MCLs.

One contamination incident associated with an ARW was reported in the state and USEPA regional survey conducted for this study. The incident occurred at the Hassayampa Landfill Superfund

Site in Arizona in 1998. A failure in an automatic cut-off valve in a pump-and-treat system, concurrent with a failure in the treatment unit, resulted in the accidental injection of untreated ground water into a clean USDW. The extent of the impact on the USDW or to drinking water wells was not reported.

A majority of ARWs appear to be covered under CERCLA cleanups, RCRA corrective actions, or Underground Storage Tank (UST) cleanup actions. As with any remedial measure, they usually require the approval of the appropriate state and/or federal regulatory agencies. There is some concern for voluntary cleanups that are not approved or completed according to standards typical of cleanups overseen by a state or federal agency. Limited information from the survey suggests that voluntary cleanups do occur, but little is known about them based on the information available. Nevertheless, in some USEPA regions, voluntary cleanups are periodically the subject of inspections by state or federal regulatory agencies and in Ohio, one of the states with the highest number of ARWs, no contamination is known to have occurred as a result of the operation of an ARW.

The survey results indicated that there are 10,222 documented ARWs located in 39 states and territories. A significant fraction (65 percent) of the total is concentrated in South Carolina (3,409), Texas (1,177), Ohio (1,170), and Kansas (936). As part of this survey, state and USEPA regional officials estimated that a slightly higher number of wells, 10,756, actually exists. Taking into consideration the fact that a significant number of additional wells were reported as "under construction" at the time of survey (e.g., 2,170 wells in South Carolina alone), the actual total number of wells could be between 12,000 and 14,000. This also suggests a potential future increase in the number of ARWs.

Based on a review of relevant regulations for the states where ARWs are most prevalent and for a limited set of additional states that constitute a broad geographical sample, it was established that individual permits are required for these wells in at least Arizona, California, Kansas, Nevada, Ohio (required for those wells expected to exceed MCLs), and South Carolina, which collectively have approximately one-half of the documented wells. ARWs may be authorized by rule in New Hampshire and Texas. At the federal level, ARWs are subject to the federal UIC standards, and, as indicated, may be additionally regulated under CERCLA cleanups, RCRA corrective actions, and the UST Program.

6.16 Geothermal Electric Power Wells

Several dozen power plants located in four western states use geothermal energy to produce electricity. At these power plants, hot (>100°C (212°F)) geothermal fluids produced from subsurface hydrothermal systems serve as the energy source. Following the recovery of heat energy from the produced fluids, the liquid fraction (if any) is reinjected into the same hydrothermal system through one or more electric power geothermal injection wells.

The temperature and chemical characteristics of geothermal fluids vary substantially. For example, TDS concentrations are about 1,000 mg/l at The Geysers (in northern California) but about 250,000 mg/l at the Salton Sea geothermal field (in southern California). Despite these variations, however, concentrations of some metals (e.g., antimony, arsenic, cadmium, lead, mercury, strontium, zinc) and other constituents in the produced and injected geothermal fluids routinely exceed primary MCLs or HALs at one or more geothermal fields. The specific constituents that exceed the standards and the magnitude of the exceedences varies from site to site, with substantial variations observed within some fields. Sulfate, chloride, manganese, iron, pH, and TDS also frequently exceed secondary MCLs.

At some geothermal power plants, other fluids associated with power plant operation, such as condensate and cooling tower blowdown, are injected along with the geothermal fluids. In a few situations, supplemental water from additional sources, such as surface waters, storm waters, ground water, and wastewater treatment effluent, is also injected. Concentrations of metals and other constituents in these supplemental water sources are typically lower than in the geothermal fluids. An exception is biological constituents (e.g., coliforms) that are sometimes present in injected surface water and treated wastewater at concentrations above drinking water standards. The Geysers geothermal field in California is the principle example of injection of surface waters and treatment plant effluent along with geothermal fluids. Ground water is injected (in addition to geothermal fluids) to replace mass lost through condensate evaporation at the Dixie Valley geothermal field in Nevada.

Geothermal fluids used for electric power generation are normally injected into the same subsurface hydrothermal system from which they were produced. In fact, a majority of geothermal injection wells were drilled as production wells and subsequently converted to injection wells. Both production and injection wells are carefully engineered because power production depends on the wells and drilling costs are substantial, frequently exceeding $1 million per well.

Despite this care, well failures have occurred during both drilling and operation, due to the high pressures and temperatures encountered, exposure of well equipment to the corrosive geothermal fluids, and seismic activity that sometimes bends or breaks well casings. In some cases, well failures have occurred at sites where no USDW is present. At a geothermal power plant site in Hawaii, however, ground water monitoring data indicate that temperature, chloride concentrations, and chloride/magnesium ratios increased following a blowout[3] during drilling of an injection well.

In general, electric power geothermal injection wells are not vulnerable to receiving spills or illicit discharges because geothermal fluids are handled in closed piping systems that are managed as an integral part of the power plant system. At some facilities, contaminants could be added to the injectate as a result of leaks or spills of lubricants, fuels, or chemicals at the power plant site. For example, at sites that collect and inject storm water, such as the power plants at The Geysers, injectate could include fuel, transformer oil, lubricants, or chemicals that leak or spill on the site. To help prevent injectate contamination from such sources, potential sources of leaks and spills are covered and/or are bermed separately from other parts of the facility. In addition, oil/water separators are provided for some plant areas (e.g., the electric switch yard) to provide further assurance that leaked or spilled oil is not injected.

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[3] Uncontrolled release of gas and/or fluids from a well.

According to the state and USEPA Regional survey conducted for this study, four states -- California, Utah, Hawaii, and Nevada -- have a total of 234 electric power geothermal injection wells, with most of the wells reported in California (174, or 74 percent) and Nevada (53, or 23 percent). The number of geothermal power injection wells is not expected to increase substantially in the foreseeable future because gas-fired power plants can generally produce power at a lower cost than geothermal plants. However, if marketing of geothermal power as a "green" energy source is successful as the utility industry is deregulated, a modest increase in the number of geothermal power plants and associated injection wells may occur. Additional geothermal power plants are currently being considered in California and have been proposed previously in Oregon. Seven additional injection wells have recently been permitted in Hawaii.

Individual permits are required for electric power geothermal injection wells in all four states that have this type of Class V injection well. The permits are issued by state agencies, U.S. Bureau of Land Management (BLM), and/or the USEPA Regional Office, depending on the state and whether the well is located on state, federal, or private land. In general, the permits are similar to those issued for Class II injection wells. They establish requirements and oversight for design and construction, operating conditions, monitoring and mechanical integrity testing, financial responsibility, and plugging and abandonment.

6.17 Geothermal Direct Heat Wells

Geothermal fluids are used to heat individual homes and/or communities or to provide heat to greenhouses, aquaculture, and other commercial and industrial processes in several (primarily western) states. Following use of geothermal fluids for such heating application, some facilities use geothermal direct heat return flow wells to return these geothermal fluids to the subsurface.

The temperature and chemical characteristics of geothermal fluids used for heating vary substantially from site to site. At some sites, the geothermal fluids are of drinking water quality and, in fact, are used as drinking water and not reinjected. More commonly, concentrations of some constituents exceed MCLs or HALs. Available data indicate that arsenic, boron, sulfate, and fluoride exceed primary MCLs or HALs and that TDS, chloride, iron, manganese, and sulfate exceed secondary MCLs. TDS concentrations are generally <10,000 ppm except in the comparatively rare situations where high temperature geothermal fluids used for power production are also used for heating.

When geothermal fluids used for heating are reinjected into the subsurface following use (rather than discharged to surface water or used for drinking, irrigation, or livestock watering), they typically are reinjected into the same hydrothermal formation from which they were produced. In addition, the composition of the geothermal fluids normally does not change appreciably as a result of use for heating, although traces of pump lubricating oil may be added in some cases.

No documented cases of USDW contamination by geothermal direct heat return flow wells have been reported. In addition, the wells typically are not vulnerable to receiving accidental spills or other illicit discharges, because the geothermal fluids are handled in closed piping systems. Typically, the geothermal fluids are produced from a well, passed through a heat exchanger, and injected down another well.

The survey results indicate that there are 31 documented geothermal direct heat return flow wells and another 17 more wells estimated to exist. Although these wells exist in as many as 11 states, more than 80 percent of the documented wells are in only five states: Oregon (8), Nevada (7), Utah (4), New Mexico (4) and Idaho (3). All of the 17 estimated wells are in Oregon, but Alaska also indicated the potential presence of these wells without providing an estimated number.

Individual permits are required for geothermal direct heat return flow wells in all five of the states that have most of these wells. In Idaho, an individual permit is not required if the well is <18 feet deep, but all of the geothermal direct heat return flow wells are substantially deeper than 18 feet. Individual permit requirements, which also apply in California, are similar in many respects to those for Class II wells. Further, for wells located on federal land, BLM approval of well drilling, testing, and abandonment is also required by regulations promulgated under the Geothermal Steam Act of 1970.

6.18 Heat Pump/Air Condition Return Flow Wells

Ground-source heat pump/air condition (HAC) systems heat or cool buildings by taking advantage of the relatively constant temperature of underground hydrogeologic formations. They extract heat energy from ground water for use in heating buildings, and use ground water as a heat sink when cooling buildings. Two types of ground-source HAC systems are generally used: closed-loop systems and open-loop systems. Closed-loop systems circulate water entirely within a system of closed pipes, involve no subsurface injection of wastewater, and are therefore not subject to oversight and regulation by the UIC program. Open-loop HAC systems withdraw ground water from a source well, pass it through the HAC heat exchanger, and then discharge the water. Many open-loop HACs return used ground water to the subsurface via injection wells. These “return flow wells” are classified as Class V wells under the UIC program, and are covered in this study.

Because water is not consumed by HAC systems, the quantity of return flow water (injectate) is generally the same as that withdrawn. The quality of HAC injectate also usually reflects the characteristics of the source ground water. However, HAC injectate may differ from source water in several ways. HAC injectate is generally 4 to 10 degrees Fahrenheit cooler or warmer than the source water (depending on whether the HAC is in heating or cooling mode). In some cases, the temperature drop can cause salts and other dissolved solids to precipitate into suspension, or the temperature increase can cause suspended solids to dissolve into solution. HAC injectate can also contain: metals leached from the pipes and pumps; bacteria (where oxygen, nutrients, and a source of bacteria are present); precipitated ferric iron solids (where dissolved iron is present in source water, and the HAC system introduces oxygen); and chemical additives (sometimes used for disinfection or corrosion prevention). Very little data on injectate properties were available for this study. However, the available data indicate that HAC injectate has in some cases exceeded the primary drinking water MCLs for lead and copper and the secondary MCLs for chloride and TDS.

HAC systems most commonly re-inject ground water into the same formation from which it is withdrawn. The aquifer used is relatively porous in order to provide adequate ground water flow to source wells and from return wells. Dual-aquifer systems may be feasible where another formation (a different formation from which source water is withdrawn) is more readily accessible for return flow discharge, and is capable of handling HAC return flow. Dual-aquifer systems that withdraw from contaminated aquifers and re-inject into USDWs can contaminate the receiving USDWs. As a result, several states prohibit dual-aquifer HAC systems, or require that HAC source aquifers be of higher quality than return aquifers.

A few USDW contamination incidents have been reported for HAC return flow wells. In 1996, a well in New York was found to have contaminated a USDW with chloride and TDS above the secondary MCLs. The incident was attributed to leaking well casings and inter-aquifer contamination. In Minnesota, a water sample from a well in 1984 indicated high levels of lead, while another sample taken from a different well in 1985 showed high levels of lead and copper (all above the primary standards). This was attributed to leaching of metals from the HAC system pipes and pumps. In North Carolina, well samples have been reported to contain high levels of iron and coliform, attributed to poor HAC well construction and operation allowing introduction of oxygen and contaminants. As the quality of HAC injectate industry-wide is unknown, it is not clear whether these known contamination cases are isolated cases, or indicative of a wider problem with this type of well.

HAC return flow wells are generally part of systems that are completely closed above ground, and are generally located on private property. Therefore, the likelihood of USDW contamination by spills or illicit discharges at HAC return flow wells is very low.

According to the state and USEPA Regional survey conducted for this study, there are 27,921 documented HAC return flow wells in 34 states.[4] The estimated number of wells existing in the U.S. is more than 32,804 wells (but probably not more than 35,000), in over 40 states. Approximately 88 percent of all documented wells are in four states: Texas (12,828 wells, or 46 percent), Virginia (7,769, or 28 percent), Florida (3,101, or 11 percent), and Tennessee (1,000, or 4 percent). Another 30 states collectively account for the remaining 11 percent of the total documented U.S. inventory, with each state having less than 3 percent of the total. However, many states do not have accurate well counts and the definitions of closed-loop and open-loop wells used by some states differ from the USEPA definitions.

Nearly all of the states with HAC return flow wells have statutory and regulatory requirements at the state level, some of which regulate the size, design, and/or additives used in these systems. Of the states in which the largest numbers of HAC wells are found, USEPA directly implements the UIC

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[4] This number includes some closed-loop systems, as not all states use the same definitions as USEPA for "open-loop" and "closed-loop" systems.

program for all Class V injection wells (including HAC return flow wells) in Arizona, Michigan, Minnesota, New York, Pennsylvania, Tennessee, and Virginia. The other states with many HAC return flow wells are UIC Primacy States for Class V wells, and authorize the wells by rule (Illinois, Kansas, Nebraska, North Dakota, Ohio, South Carolina, Texas, West Virginia, and Wyoming) or issue individual permits (Delaware, Florida, Maryland, Missouri, Nevada, North Carolina, Oregon, Vermont, and Washington). In Wisconsin, which is also a Primacy State for Class V wells, discharge to a shallow absorption system located in unsaturated soils is allowed under a general permit, but discharge directly into a saturated soil or aquifer is prohibited.

A number of relatively straight-forward best management practices are available that can virtually ensure that HAC wells do not contaminate USDWs. Judging by the very low incidence of recorded USDW contamination (relative to the number of wells), it appears that HAC owners and operators are aware of and generally apply best management practices.

6.19 Salt Water Intrusion Barrier Wells

Salt water intrusion barrier wells are used to inject water into a fresh water aquifer to prevent the intrusion of salt water. Control of salt water intrusion through the use of these wells may be achieved by creating and maintaining a "fresh water ridge." This fresh water ridge may be achieved with a line of injection wells paralleling the coast. Another method used to control salt water intrusion is through the use of an injection-extraction system. Such a system may be used to inject fresh water inland, while salt water intruded into the aquifer is being extracted along the coast.

Waters of varying qualities are injected to create salt water intrusion barriers, including untreated surface water, treated drinking water, and mixtures of treated municipal wastewater and ground or surface water. Injectate typically meets primary and secondary drinking water standards. Ground water monitoring and toxicological, chemical, and epidemiological studies have found no measurable adverse effects on either ground water quality or the health of the population ingesting the water, when the injectate was treated wastewater effluent.

Salt water intrusion barrier wells are drilled to various depths depending on the depth of the aquifer being protected. They inject into fresh ground water aquifers used as drinking water supplies that are in hydraulic connection with an extensive salt water body, such as a sea, a salt lake, or an ocean.

No contamination incidents associated with the operation of salt water intrusion barrier wells have been reported.

Because protection of drinking water supplies is the major goal of a salt water intrusion barrier well and the injectate typically meets drinking water standards, salt water intrusion barrier wells are unlikely to receive spills or illicit discharges of potentially harmful substances.

According to the state and USEPA Regional survey conducted for this study, there are 315 salt water intrusion barrier wells documented in the United States. The number of salt water intrusion barrier wells in the nation is estimated to be greater than 609, but unlikely to be higher than 700. All documented salt water intrusion barrier wells are located in California (308), Florida (1), and Washington (6). In addition, as many as 200 salt water intrusion barrier wells are believed to exist in New York. There also may be some wells in New Jersey, which indicated in its survey response that it has salt water intrusion barrier wells but did not provide any numbers.

The statutory and regulatory requirements differ significantly among California, Florida, Washington, and New York. In California and New York, USEPA Regions 9 and 2, respectively, directly implement the UIC program for Class V injection wells. However, both states have additional jurisdiction over salt water intrusion barrier wells through state regional water quality control boards in California and state pollutant discharge elimination system permits in New York. In contrast, Florida and Washington are UIC Primacy States for Class V wells. Both of these states require individual permits for the operation of salt water intrusion barrier wells.

6.20 Aquifer Recharge Wells and Aquifer Storage and Recovery Wells

Aquifer recharge and aquifer storage and recovery (ASR) wells are used to replenish water in an aquifer for subsequent use. While an aquifer recharge well is used only to replenish the water in an aquifer, ASR wells are used to achieve two objectives: (1) storing water in the ground; and (2) recovering the stored water (from the same well) for a beneficial use. Both of these types of wells, however, may have secondary objectives, such as subsidence control and prevention of salt water intrusion into fresh water aquifers. Aquifer recharge and ASR wells are found in areas of the U.S. that have high population density and proximity to intensive agriculture; dependence and increasing demand on ground water for drinking water and agriculture; and/or limited ground or surface water availability. ASR wells are also found in areas that have no freshwater drinking water supplies, or in coastal areas where salt water intrusion into freshwater aquifers is an issue.

Aquifer recharge and ASR well injectate consists of potable drinking water (from a drinking water plant), ground water (treated or untreated), and surface water (treated or untreated).[5] Water injected into aquifer recharge and ASR wells is typically treated to meet primary and secondary drinking water standards. This is done to protect the host aquifer and to ensure that the quality of the ground water to be recovered is adequate for subsequent use. In addition, most state and local regulatory agencies require the injectate in aquifer recharge and ASR wells to meet drinking water standards in order to prevent degradation of ambient ground water quality. However, it should be noted that, in some instances, constituents have been measured at concentrations slightly above drinking water standards.

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[5] Aquifer recharge and ASR well injecting wastewater are addressed separately in the sewage treatment effluent well summary, which is Volume 7 of this report.

Aquifer recharge and ASR wells are drilled to various depths depending on the depth of the receiving aquifer. They may inject into confined, semi-confined, or unconfined aquifers, although most of these wells inject into semi-confined aquifers that have been partially dewatered due to overpumping.

No contamination incidents associated with the operation of aquifer recharge or ASR wells have been reported.

Because the major goal of aquifer recharge and ASR wells is to replenish water in aquifers for subsequent use and its injectate typically meets drinking water standards, aquifer recharge and ASR wells are unlikely to receive spills or illicit discharges.

According to the state and USEPA Regional survey conducted for this study, there are approximately 1,185 aquifer recharge and ASR wells documented in the U.S. This total includes 807 aquifer recharge wells, 130 ASR wells, and 248 wells (in California and Idaho) that cannot be distinguished among aquifer recharge and ASR wells in the available inventory. The estimated number of aquifer recharge and ASR wells in the nation is greater than 1,695, but unlikely to be higher than 2,000. This estimate does not include 200 wells proposed to be built in Florida as part of the "Everglades Restoration Project." Approximately 89 percent of the documented aquifer recharge and ASR wells are located in ten states: California (200), Colorado (9), Florida (<488), Idaho (48), Nevada (110), Oklahoma (44), Oregon (16), South Carolina (55), Texas (67), and Washington (12). Wisconsin has conditionally approved one aquifer storage and recovery well as part of a pilot study at a municipal water system in Oak Creek, and a second pilot project in Green Bay, Wisconsin is under development. The project in Green Bay is expected to be operational within the next year.

The statutory and regulatory requirements differ significantly among the ten states where the majority of the aquifer recharge and ASR wells are believed to exist. In California and Colorado, USEPA Regions 9 and 8, respectively, directly implement the UIC program for Class V injection wells. However, both states have additional jurisdiction over aquifer recharge and ASR wells through state regional water quality control boards in California and permitting of extraction and use of waters artificially recharged in Colorado. The remaining eight states are UIC Primacy States for Class V wells. Oklahoma and Texas authorize aquifer recharge and ASR wells by rule. Florida, Nevada, Oregon, South Carolina, and Washington require individual permits for the operation of aquifer recharge and ASR wells. In Idaho, construction and operation of shallow injection wells (<18 feet) is authorized by rule; construction and use of a deep injection well ($18 feet) requires an individual permit.

6.21 Noncontact Cooling Water Wells

For the purpose of this study, “noncontact cooling water wells” are limited only to wells used to inject noncontact cooling water that contains no additives and has not been chemically altered. Wells that inject contact cooling water or noncontact cooling water that contains additives (e.g., corrosion inhibitors, biocides) or is contaminated compared to the original source water are considered “industrial wells.”

USEPA defines noncontact cooling water (in 40 CFR §418.21 governing fertilizer manufacturing) as "water which is used in a cooling system designed so as to maintain constant separation of the cooling medium from all contact with process chemicals...provided, that all reasonable measures have been taken to prevent, reduce, eliminate and control to the maximum extent feasible...contamination...." No sampling data were obtained during the course of this study that can be used to characterize the quality of fluids injected into noncontact cooling water wells. However, given the very narrow way that such wells and noncontact cooling water are defined, it is reasonable to expect that the quality of the fluids will not threaten USDWs.

Available information suggests that these wells are commonly used in situations in which cooling water is withdrawn from an aquifer and then injected back into the same formation (so-called "cooling water return flow wells" as defined in 40 CFR §146.5(e)(3)). In these situations, the quality of the fluids injected will be the same as the quality of the fluids in the receiving formation, except for a change in temperature.

No contamination incidents associated with noncontact cooling water wells, as defined for the purpose of this study, have been reported. The only scenario in which noncontact cooling water wells could be contaminated would involve pipe leaks that allow process chemicals or other contaminants to commingle with the cooling water. Illicit discharges into these wells appear extremely unlikely, since noncontact cooling water systems are operated as closed systems that are virtually inaccessible for "midnight dumping." No incidents of this or any other kind were uncovered during the course of this study.

As for some of the other well categories addressed in this study, the inventory results for noncontact cooling water wells are very uncertain because most responses to the state and USEPA Regional survey did not distinguish these wells from other kinds of commercial or industrial wells. The survey results suggest that there are more than 7,780 noncontact cooling water wells in the nation, but this number includes some carwash wells, laundromat wells, and food processing waste disposal wells. The survey results also indicate that noncontact cooling water wells may exist in as many as 22 states, although most appear to be concentrated in Alaska (212), Washington (3,900), and Tennessee (1,000). Ninety-eight percent of the documented and estimated noncontact cooling water wells in the U.S. are found in ten states: Ohio, New York, West Virginia, Alabama, Tennessee, Iowa, Montana, California, Alaska, and Washington.

Of the three states that have the vast majority of noncontact cooling water wells, Alaska and Washington require the wells to be individually permitted. Tennessee currently permits them by rule, following a program like the minimum federal requirements established in USEPA's existing UIC regulations.

6.22 Subsidence Control Wells

Subsidence control wells are injection wells whose primary objective is to reduce or eliminate the loss of land surface elevation due to removal of ground water providing subsurface support. These wells also may be used to control land subsidence caused by man-induced activities other than ground water withdrawal (e.g., construction). Land subsidence control is achieved by injecting water into an underground formation to maintain fluid pressure and avoid compaction.

Sources of injectate in subsidence control wells include untreated surface water, untreated ground water, saline water, and surface water treated to drinking water standards. No data on injectate constituents or concentrations associated with subsidence control wells are available. However, it is reasonable to assume that injectate in some subsidence control wells exceeds drinking water standards for some parameters.

None of the known, active subsidence control wells inject into USDWs. Some wells are being used to inject beneath construction zones to minimize damage from settlement caused by construction, and other wells inject into a salt dome cavity that is used for the storage of oil at the Strategic Petroleum Reserve Weeks Island site in Louisiana.

No contamination incidents associated with the operation of subsidence control wells have been reported.

Details on the design, construction, and operation of subsidence control wells are not available. Thus, it is not possible to determine if subsidence control wells are vulnerable to receiving spills or illicit discharges.

According to the state and USEPA Regional survey conducted for this study, there are 28 subsidence control wells documented in the United States. All documented subsidence control wells are located in Louisiana (8), Oregon (14), and Wisconsin (6). The estimated number of subsidence control wells in the nation is approximately 158. Of these, as many as 50 wells may be located in New York. The documented and estimated numbers of subsidence control wells in the United States do not include any wells in Alaska. However, officials responsible for the UIC Program in that state did not rule out the possibility that some exist.

The statutory and regulatory requirements differ significantly among the four states where subsidence control wells are believed to exist. Louisiana, a UIC Primacy state for Class V wells, authorizes subsidence control wells by rule. In New York, USEPA Region 2 directly implements the UIC program for Class V injection wells. However, New York has additional jurisdiction over Class V wells through state pollutant discharge elimination system permits. Oregon, a UIC Primacy state for Class V wells, authorizes subsidence control wells by rule. The six wells in Wisconsin were individually permitted by the Department of Natural Resources. All six of these wells have either been abandoned or are in the process of being abandoned. New subsidence control wells in Wisconsin are now prohibited.