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Steam Electric Power Generating Point Source Category: 2007/2008 Detailed Study Report

U.S. Environmental Protection Agency
Engineering and Analysis Division
Office of Water
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Washington, D.C. 20460

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LIST OF ACRONYMS

BOD_5	Biochemical oxygen demand (5-day)
CAIR	Clean Air Interstate Rule
CAMR	Clean Air Mercury Rule
CBI	Confidential Business Information
CFR	Code of Federal Regulations
CWA	Clean Water Act
CWTS	Constructed wetland treatment system
DBA	Dibasic acid (a mixture of glutaric, succinic, and adipic acid)
DCN	Document control number
DOE	Department of Energy
DPY	Days per year
ELGs	Effluent limitations guidelines and standards
EIA	Energy Information Administration
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
ESP	Electrostatic precipitator
FGD	Flue gas desulfurization
GPD	Gallons per day
GPM	Gallons per minute
GPY	Gallons per year
HEM	Hexane extractable material
IGCC	Integrated Gasification Combined Cycle
IPM	Integrated Planning Model
MW	Megawatt
NEEDS	National Electric Energy Data System
NESCAUM	Northeast States for Coordinated Air Use Management
NETL	National Energy Technology Laboratory
NOx	Nitrogen oxides
NPDES	National Pollutant Discharge Elimination System
O&M	Operation and maintenance
PCS	Permit Compliance System
QC	Quality control
SBR	Sequencing batch reactor
SCR	Selective catalytic reduction
SGT-HEM	Silica gel treated-hexane extractable material
SNCR	Selective non-catalytic reduction
SO_2	Sulfur dioxide
TDS	Total dissolved solids
TKN	Total Kjeldahl nitrogen
TMT	Trimercapto-s-triazine
TRI	Toxics Release Inventory
TSS	Total suspended solids
UWAG	Utility Water Act Group
ZLD	Zero liquid discharge

1. INTRODUCTION AND BACKGROUND OF THE STUDY

The Steam Electric Power Generating effluent limitations guidelines and standards (ELGs) (40 CFR 423) apply to a subset of the electric power industry, namely those facilities "primarily engaged in the generation of electricity for distribution and sale which results primarily from a process utilizing fossil-type fuel (coal, oil, or gas) or nuclear fuel in conjunction with a thermal cycle employing the steam water system as the thermodynamic medium." (40 CFR 423.10) EPA's most recent revisions to the ELGs for this category were promulgated in 1982 (see November 19, 1982; 47 FR 52290). Section 304(m) of the Clean Water Act (CWA) requires EPA to develop and publish a biennial plan that establishes a schedule for the annual review and revision of national ELGs required by Section 304(b). EPA last published an Effluent Guidelines Program Plan in 2006 [71 FR 76644; December 21, 2006].

For the 2008 Effluent Guidelines Program Plan, EPA conducted a detailed study of the steam electric power generating industry to determine if the ELGs should be revised. This document describes the activities EPA undertook during the detailed study (referred to hereinafter as the "2007/2008 detailed study").

EPA has focused efforts for the 2007/2008 detailed study on certain discharges from coal-fired steam electric power plants (referred to hereinafter as "coal-fired power plants"). Specifically, the study has focused on: (1) characterizing the mass and concentrations of pollutants in wastewater discharges from coal-fired power plants; and (2) identifying the pollutants that comprise a significant portion of the category's toxic-weighted pound equivalent discharge estimate and the corresponding industrial processes responsible for the release of these pollutants. EPA's previous annual reviews have identified that the toxic-weighted loadings for this category are predominantly driven by the metals present in wastewater discharges, and that the waste streams contributing the majority of these metals are associated with ash handling and wet flue gas desulfurization (FGD) systems. Other potential sources of metals include coal pile runoff, metal/chemical cleaning wastes, coal washing, and certain low volume wastes.

The 2007/2008 detailed study was a continuation of a detailed study initiated to support the 2006 Effluent Guidelines Program Plan (i.e., the "2005/2006 detailed study"). In the 2005/2006 detailed study, EPA initially investigated whether pollutant discharges reported to the Permit Compliance System (PCS) and Toxics Release Inventory (TRI) for 2002 were accurate in reflecting that the Steam Electric Power Generating Point Source Category (40 CFR Part 423) discharges relatively high amounts of toxic-weighted pollutants, in comparison to other industry sectors. EPA also performed an in-depth analysis of the reported pollutant discharges and reviewed technology innovation and process changes. Additionally, EPA evaluated certain electric power and steam generating activities that are similar to the processes regulated for the Steam Electric Power Generating Point Source Category, but that are not currently subject to ELGs. For more information on the 2005/2006 detailed study, see *Interim Detailed Study Report for the Steam Electric Power Generating Point Source Category* (EPA-821-R-06-015; November 2006) [U.S. EPA, 2006ab].

During the 2005/2006 detailed study, EPA identified data gaps and issues that may affect the Agency's estimate of the potential hazards caused by discharges from steam electric facilities. To fill these gaps, EPA is currently collecting information on the wastewater characteristics and treatment technologies used at facilities in the Steam Electric Point Source Category. To date, EPA has collected data for the 2007/2008 detailed study through facility inspections, wastewater sampling, a data request that was sent to a limited number of companies, and various secondary data sources (see Chapter 2 for more detail on these data sources).

EPA's Office of Water is coordinating its efforts for the study with ongoing research and activities being undertaken by other EPA offices, including the Office of Research and Development, the Office of Solid Waste, and the Office of Air and Radiation (Office of Air Quality Planning and Standards and the Office of Atmospheric Programs). EPA is also coordinating certain activities with the Utility Water Act Group (UWAG), an industry trade association, and has held technical information discussions with the Electric Power Research Institute (EPRI) and treatment equipment vendors.

This report, *Steam Electric Power Generating Point Source Category: 2007/2008 Detailed Study Report* (EPA-821-R-08-011; DCN 05516), describes the status of EPA's detailed study of the steam electric industry as of June 2008. It documents the data and information that EPA used to support decisions with respect to the study and the 2008 Effluent Guidelines Program Plan.

EPA is continuing to assess available information on facilities that are not currently regulated under Part 423 but that use a steam cycle to generate electricity. EPA is also continuing to evaluate pollution prevention and water reuse opportunities in the industry; additional data that have recently been submitted by industry for review; additional questions on electric power generators using non-fossil and non-nuclear fuel; and other emerging issues such as use of Integrated Gasification Combined Cycle (IGCC) technology.

Based on the information compiled to date for the steam electric industry, EPA has determined that further review of the analytical data recently collected and the collection of additional wastewater treatment and cost data is warranted.

This report is organized into the following chapters:

- Chapter 2 discusses the data sources used in the 2007/2008 detailed study;
- Chapter 3 presents a profile of coal-fired power plants, with a focus on those operations using wet FGD systems; and
- Chapter 4 presents the references cited in this report.

2. DATA COLLECTION ACTIVITIES

As described in Chapter 1, EPA is focusing efforts for the 2007/2008 detailed study on certain discharges from coal-fired power plants, including FGD system wastes and ash handling wastes. EPA is collecting data through facility inspections, wastewater sampling, a limited survey of selected facilities, and various secondary data sources. Figure 2-1 shows the locations of coal-fired power plants at which EPA has conducted site visits, collected samples of wastewater, or obtained technical information via the data request.

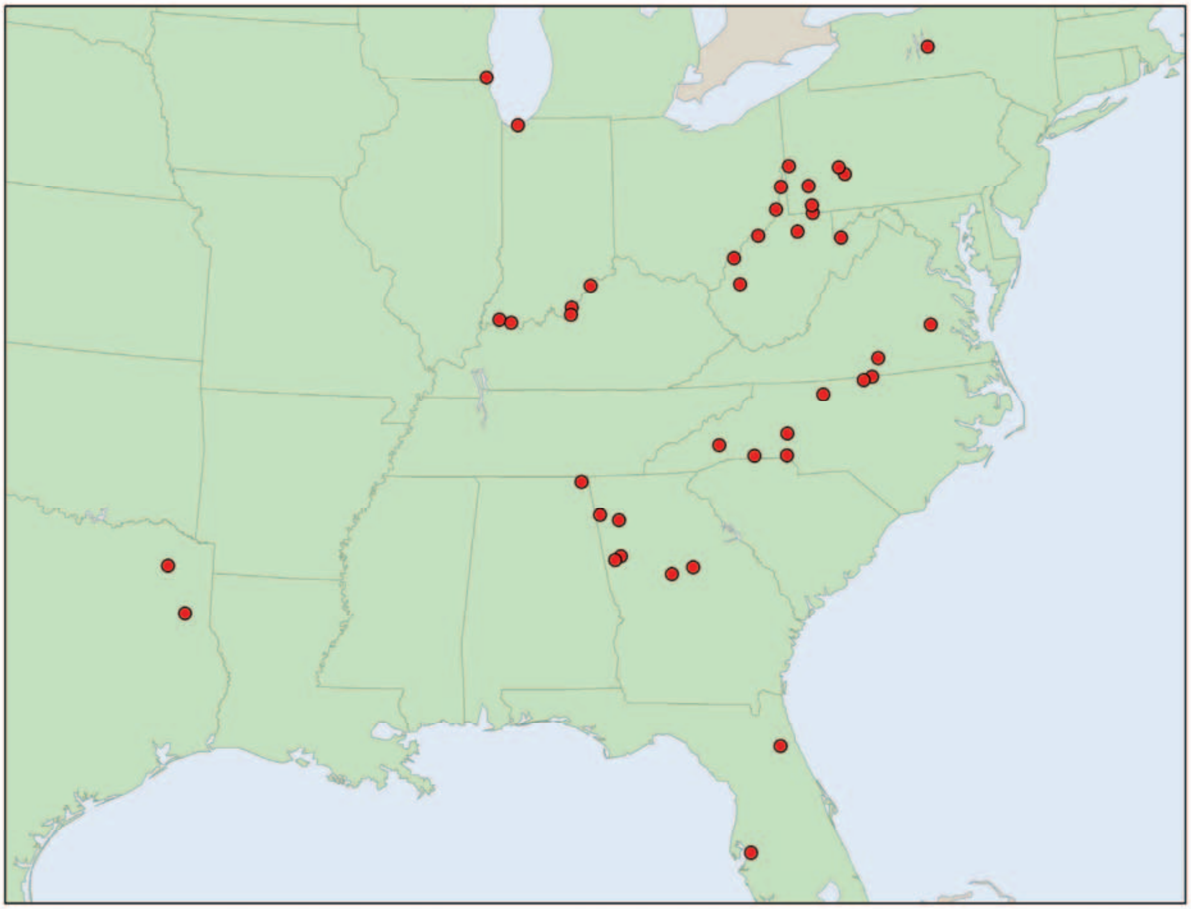

Figure 2-1. Geographic Distribution of Coal-fired Power Plants Included in EPA Data Collection Activities for 2007/2008 Detailed Study

2.1 Facility Inspections

EPA is currently conducting a site visit program to gather information on the types of wastewaters generated by coal-fired power plants, as well as the methods of managing these wastewaters to allow for recycle, reuse, or discharge. For the 2007/2008 detailed study, EPA has focused data gathering activities primarily on FGD wastewater treatment and management of ash sluice water.

In early 2007, EPA compiled a list of 96 U.S. coal-fired power plants believed to operate wet FGD systems, based on information received from EPA's Office of Air and Radiation (Hall, 2007a). EPA subsequently received and reviewed data from the Utility Water Act Group

(UWAG), an industry trade association, on 76 plants (75 of the plants operate wet FGD scrubbers), which includes two additional plants not previously identified by EPA [ERG, 2008f]. The data provided by UWAG included information on air pollution controls in place, process configurations, and other characteristics of the plants (see Section 3.2 for more information). The compiled facility data for the 75 plants operating wet FGD scrubbers are believed to represent approximately 65 percent of the total population of coal-fired power plants currently operating or planning to operate wet FGD systems.[1] EPA used the UWAG data in conjunction with information from other sources, including publicly available plant-specific information and contacts with state and regional permitting authorities, to identify potential candidate plants for site visits. EPA considered the following characteristics to select plants for site visits (not listed in any priority order):

- Coal-fired boilers;
- Wet FGD system, including:
    - Type of scrubber,
    - Sorbent used,
    - Year operation began,
    - Chemical additives used,
    - Forced oxidation process,
    - Water cycling, and
    - Solids removal process;
- Type of coal;
- Selective Catalytic Reduction (SCR) and/or Selective Non-Catalytic Reduction (SNCR) NOx controls;
- Ash handling systems;
- FGD wastewater treatment system;
- Ash treatment system; and
- Advanced mercury air controls.

Using these characteristics, EPA identified plants to contact and obtain more detailed information about the plants' operations. From the information obtained during these contacts, EPA selected 16 plants for site visits. Plant conditions, such as type of FGD system and whether target waste streams are segregated or commingled with other wastes, influenced the plant selection process. Figure 2-2 shows the geographic distribution of the plants that were visited.

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[1] As discussed in Section 3.1.2, EPA has identified 116 plants currently operating (or planning to operate) one or more wet FGD systems from all of EPA's data collection activities. See the memorandum in the docket entitled "Development of Version One of the Power Plant FGD System Data Set", dated 07/29/2008 (DCN 06128) for details on the development of this list. The total number of plants operating wet FGD systems is dynamic; additional plants have started operating FGD systems since UWAG provided information, or are currently in the process of installing FGD systems. Therefore, the data provided by UWAG are believed to represent about 65 percent of the total population of coal-fired plants currently operating wet FGD systems.

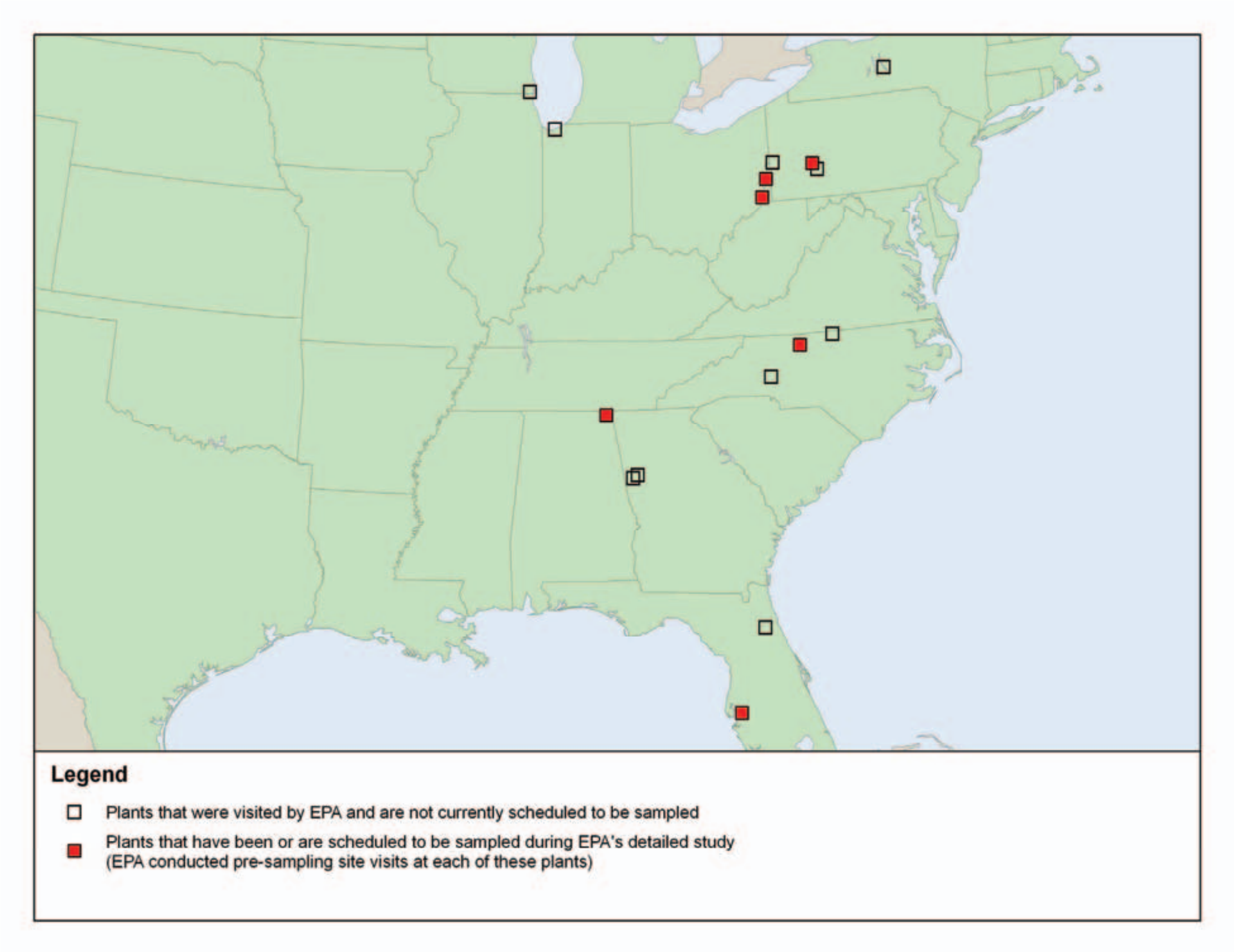

Figure 2-2. Geographic Distribution of Coal-fired Power Plants Included in EPA's Site Visit and Sampling Program for the 2007/2008 Detailed Study

During the site visits, EPA collected information on plant operations and types of wastewater management techniques. See Table 2-1 for information on the characteristics of plants visited prior to June 2008. EPA also used these visits to assess whether the site was appropriate for sampling. The objectives of these site visits were to:

- Gather general information about the plant's operations;
- Gather process-specific information;
- Gather information on pollution prevention and wastewater treatment/operations;
- Gather plant-specific information to develop sampling plans; and
- Select and evaluate potential sampling points.

From these visits, EPA selected six facilities as candidates for wastewater sampling episodes prior to December 2008. Because most of the site visits conducted thus far have focused on identifying plants for wastewater sampling, most of the site visits have been to plants with more advanced FGD wastewater treatment systems. EPA is continuing to identify potential site visit candidates to assess FGD systems using different scrubber designs or sorbents, such as magnesium-lime, and facilities operating or planning to install different types of treatment and water reuse options, including facilities achieving zero liquid discharge from their wet FGD system operations.

Table 2-1. Summary of 2007/2008 Detailed Study Site Visits

Plant Name (Reference)	Coal Type	FGD System	Year FGD Began Operation	SCR/SNCR NOx Control	Type of FGD Wastewater Treatment System	Fly Ash Handling (wet/dry)
Yates (ERG, 2007d)	Eastern Bituminous	Chiyoda jet-bubbling reactor, limestone forced oxidation, no additives (1 unit)	1992	No SCR or SNCR	Settling pond	Wet
Wansley (ERG, 2007e)	Eastern Bituminous	Currently being installed	NA	SCRs on 2 units	Currently installing a settling pond	Wet
Widows Creek (ERG, 2007g; ERG, 2007j)	Eastern Bituminous	Spray tower, limestone forced oxidation [a], no additives (2 units)	1977 and 1981	SCRs on both units with FGD	Settling pond	Wet
Conemaugh (ERG, 2007k)	Eastern Bituminous	Spray tower, limestone forced oxidation, dibasic acid additive (2 units)	1994 and 1995	No SCR or SNCR	Chemical precipitation (lime addition to pH 8.6, ferric chloride, sodium sulfide, polymer), followed by aerobic sequencing batch reactors	Dry
Homer City (ERG, 2007h; ERG, 2007i)	Eastern Bituminous	Spray tower, limestone forced oxidation, formic acid additive (1 unit)	2001	SCRs on 3 units	Chemical precipitation (lime addition to pH 8.1, ferric chloride, polymer), followed by aerobic biological reactor	Dry
Pleasant Prairie (ERG, 2007c)	Subbituminous (Powder River Basin)	Spray tower, limestone forced oxidation, no additives (2 units)	2006 and 2007	SCRs on both units with FGD	Chemical precipitation (lime addition to pH 8.9, organosulfide, ferric chloride, polymer)	Dry
Bailly (Hall, 2007b)	Bituminous (75%), Eastern Bituminous (25%)	Spray tower, limestone forced oxidation, no additives (2 units)	1992	SCR on one of the units with FGD	Polymer addition only; no pH adjustment	Dry
Seminole (Jordan, 2007)	Eastern Bituminous, also burns petroleum coke as a small percentage (up to 30%)	Spray tower, limestone forced oxidation, dibasic acid additive (2 units)	1984	No SCR or SNCR	Chemical precipitation (lime addition to pH 8, ferrous chloride, polymer)	Dry
Big Bend (ERG, 2007a; ERG, 2007f)	Eastern Bituminous, also burns petroleum coke as a small percentage (typically 1-2%; 5% maximum)	Two scrubbers for 4 units (2 units per scrubber): (1) spray tower, limestone forced oxidation, and (2) double loop spray tower, limestone forced oxidation, dibasic acid additive	1985 (double loop) and 2000 (spray tower)	SCR on one unit. Will install SCRs on the other units over the next three years.	Chemical precipitation (lime addition to pH 9.0, ferric chloride, polymer)	Dry
Cayuga (Jordan, 2008b)	Eastern Bituminous	Spray tower, limestone forced oxidation, formic acid additive (2 units)	1995	SCR on 1 unit	Chemical precipitation (lime addition to pH 10.7, ferric chloride, polymer)	Dry
Mitchell (ERG, 2007m)	Eastern Bituminous	Spray tower, limestone forced oxidation, no additives (2 units)	NA	SCRs on both units with FGD	Chemical precipitation (lime addition to pH 8.5, ferric chloride, polymer)	Wet

Table 2-1. Summary of 2007/2008 Detailed Study Site Visits

Plant Name (Reference)	Coal Type	FGD System	Year FGD Began Operation	SCR/SNCR NOx Control	Type of FGD Wastewater Treatment System	Fly Ash Handling (wet/dry)
Cardinal (ERG, 2007n)	Subbituminous	Currently being installed.	NA	SCRs on 3 units	Currently being installed	Wet
Bruce Mansfield (U.S. EPA, 2008b)	Bituminous	Venturi scrubber, magnesium-enhanced lime, inhibited oxidation (2 units). Horizontal spray scrubber, magnesium-enhanced lime, inhibited oxidation (1 unit). Additional forced oxidation as separate process for all 3 units.	1976, 1977, and 1980	SCRs on 3 units	Surface impoundment (settling)	Wet
Roxboro (Jordan, 2008a)	Eastern Bituminous	Tray tower, limestone forced oxidation, no additive (2 units operating, 2 more units planned for 2008)	2007 (and planned for 2008)	SCRs on 4 units	Settling pond followed by a anaerobic/anoxic biological treatment system for removal of metals and nutrients	Dry (but wet capability)
Belews Creek (ERG, 2008g)	Eastern Bituminous	Spray tower, limestone forced oxidation (1 unit operating, 1 more unit planned for 2008)	2008	SCRs on 2 units	Chemical precipitation followed by anaerobic/anoxic biological treatment for removal of metals and nutrients followed by a constructed wetland treatment system	Dry (but wet capability)
Marshall (ERG, 2008h)	Eastern Bituminous, additionally burns a small percentage of South American coal (2%)	Spray tower, limestone forced oxidation. (3 scrubbers for 4 units)	2006 and 2007	SNCRs on 4 units	Clarifier followed by a constructed wetland treatment system	Dry (but wet capability)

a – The FGD system is a once-through system in which the gypsum slurry in the scrubber reaction tank is not recycled back through the scrubber, but rather, is continuously discharged.

NA – Not available.

Note: The table reflects the data collected at the time of each individual site visit and does not reflect changes that have occurred since the site visits were conducted.

2.2 Wastewater Sampling

EPA is currently conducting a sampling program to characterize raw wastewaters generated by coal-fired power plants, as well as evaluate treatment technologies and best management practices used to reduce pollutant discharges. EPA developed a "generic" sampling plan [ERG, 2007b; ERG, 2007l] to provide general sampling procedures and methods EPA and its contractors will follow when conducting sampling activities. This document, in combination with plant-specific sampling plans, serves as a guide to the field sampling crew and provides procedural information for plant personnel.

EPA is in the process of collecting and analyzing samples to characterize wastewater streams generated at six coal-fired power plants. EPA conducted wastewater sampling activities at five of the plants between July and October 2007. Specifically, EPA is characterizing wastewater streams associated with wet FGD systems and ash handling operations, and evaluating the capability of various types of treatment systems to remove metals and other pollutants of concern prior to discharge. See Table 2-2 for information on the plants selected as part of the sampling program and Figure 2-2 for the geographic distribution of coal-fired power plants that were sampled or are planned to be sampled prior to December 2008.

Table 2-2. Summary of 2007/2008 Detailed Study Sampling Program

Site	Episode No.	Date of Sample Episode	Samples Planned for Collection				
			FGD			Ash Pond	
			Influent	In-Process	Effluent	Influent	Effluent
Big Bend	6547	July 2007	✓		✓		
Homer City	6548	August 2007	✓	✓	✓		✓ (bottom ash)
Widows Creek	6549	September 2007	✓		✓	✓ (fly + bottom)	✓ (fly + bottom)
Mitchell	6550	October 2007	✓	✓	✓		✓ (fly ash + other)
Cardinal	6551	October 2007				✓ (fly ash)	✓ (fly ash)
TBD	TBD	Scheduled for Fall 2008	✓	✓	✓		

The steam electric sampling and analysis program thus far has consisted of one- to two-day sampling episodes at selected plants. EPA is conducting the sampling activities primarily to characterize the FGD and ash handling wastewaters and the performance of the systems used to treat these wastes. For the five sampling episodes that EPA has already completed, EPA prepared sampling episode reports, which discuss the specific sample points, the sample collection methods used, the field quality control (QC) samples collected, and the analytical results from the wastewater samples. The reports for these five episodes are in the docket for the 2008 Effluent Guidelines Program Plan [ERG, 2008j; ERG, 2008k; ERG, 2008l; ERG, 2008m; ERG, 2008n].

Table 2-3 lists the analytes for which EPA has collected sampling data. The analytes listed reflect the current understanding of coal-fired power plant wastewaters, including contributions from coal, scrubber sorbents, treatment chemicals, and other sources. In some cases, the analytical method used (e.g., EPA Method 200.7) provides results for a range of parameters and includes certain analytes that perhaps would not have been selected individually.

Table 2-3. Analytes Included in 2007/2008 Detailed Study Sampling Program

Parameter	Method Number
Classicals	
Biochemical Oxygen Demand (5-day) (BOD_5)	SM 5210 B
Total Suspended Solids (TSS)	SM 2540 D
Total Dissolved Solids (TDS)	SM 2540 C
Sulfate	ASTM D516-90
Chloride	SM 4500–Cl–C
Ammonia as Nitrogen	SM 4500—NH3 F (18th ed.)
Nitrate/Nitrite as Nitrogen [a]	SM 4500-NO3 H
Total Kjeldahl Nitrogen (TKN)	SM 4500—N, C
Total phosphorus	EPA 365.3 (Rev 1978)
Hexane Extractable Material (HEM)	EPA 1664A
Silica Gel Treated Hexane Extractable Material (SGT-HEM)	EPA 1664A
Metals	
Total metals (27 metals: aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, selenium, silver, sodium, thallium, tin, titanium, vanadium, yttrium, and zinc)	EPA 200.7, 245.1, 245.5
Dissolved metals (27 metals)	EPA 200.7, 245.1
Low-level total metals (11 metals: antimony, arsenic cadmium, chromium, copper, lead, nickel, selenium, silver, thallium, zinc)	EPA 1638
Low-level dissolved metals (11 metals)	EPA 1638
Low-level total mercury	EPA 1631E
Low-level dissolved mercury	EPA 1631E
Hexavalent chromium	ASTM D1687-92
Low-level hexavalent chromium	EPA 1636

a – EPA method 353.2 was used for the Nitrate/Nitrite as Nitrogen analysis for Sampling Episode 6548. Standard Method 4500-NO3 H was used for Sampling Episodes 6549, 6550, and 6551. Nitrate/Nitrite as Nitrogen was not analyzed for Sampling Episode 6547.

EPA's sampling program is also collecting data on the design, operation, and performance of treatment systems at steam electric plants, specifically regarding system design and day-to-day operation. The sampling activities are focusing on influent, effluent, and in-process streams for FGD and ash handling wastewater treatment systems. During each sampling episode, EPA collects engineering information regarding the design and operation of the plant being sampled (e.g., coal usage, plant capacity, wastewater flow rates, sludge generation rates, and retention times in wastewater treatment process stages). Engineering data collection sheets were completed for each plant. This information is used to evaluate whether the specific design or operational criteria of the steam electric operations affect the wastewater characteristics.

EPA will use data from the sampling program to support the following study objectives:

- Determine the pollutants present in wastewater streams generated by or associated with air pollution controls (e.g., wet FGD systems, SCR/SNCR NOx controls, wet ash handling systems);
- Characterize the performance of steam electric wastewater treatment systems; and
- Characterize the pollutants ultimately discharged to surface water from steam electric plants.

2.3 Data Request

EPA collected information about coal-fired power plants by means of the *Data Request for the Steam Electric Power Generating Industry* ("data request"), issued under authority of Section 308 of the Clean Water Act [U.S. EPA, 2007]. The data request complements EPA's wastewater sampling effort by obtaining information about wastewater generation rates and management practices for the FGD and ash sluice waste streams, other waste streams not sampled by EPA's sampling program (e.g., coal pile runoff), and other power plant information as described below.

EPA selected nine power companies to receive the data request based on specific characteristics of plants they operate. Each of the companies selected operate coal-fired plants that have wet FGD systems and/or wet fly ash handling systems. Table 2-4 presents a profile of the coal-fired power plants operated by the nine selected companies (referred to hereinafter as "data request respondents"). As shown in Table 2-4, the data request respondents operate a total of 67 coal-fired power plants and provided technical information for 30 of these coal-fired power plants as instructed by Part B of the data request. These 30 coal-fired power plants (referred to hereinafter as "data request plants") either operate wet FGD systems and/or are planning to begin constructing wet FGD systems by December 31, 2010. The plants that are most likely to operate FGD systems are those that burn eastern bituminous coal, which has relatively high sulfur content, so the vast majority of the data request plants are located in the eastern United States. Figure 2-3 presents the geographic distribution of the data request plants. Chapter 3 summarizes the information collected through the data request, including the types of FGD wastewater treatment systems currently operating (as of 2006) and planned at the data request plants.

EPA distributed the data request to the nine selected power companies in May 2007 and received data request responses in August and October 2007[2]. The data requests were divided into two parts: Part A, General Power Company Information; and Part B, Power Plant Technical Information. EPA requested that each power company complete Part A of the data request and complete Part B of the data request for each coal-fired power plant they operate that meets the following criteria: was in operation in calendar year 2006; and operates at least one wet FGD system and/or is currently constructing/installing (or plans to begin constructing prior to December 31, 2010) at least one wet FGD system.

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[2] EPA received data request responses from each of the nine data request respondents in August 2007. One of the data request respondents provided a Part B response for one data request plant in October 2007.

Table 2-4. Profile of Coal-Fired Power Plants Operated by Data Request Respondents

Company Number	Coal-Fired Power Plants Operated by Data Request Respondents			Plants for which Data Request Respondents Provided Technical Information [a]		
	Total No. of Plants	Number Currently Operating Wet FGD Systems [b]	Number Not Currently Operating Wet FGD Systems, But Planning to Begin Constructing by 12/31/2010 [b]	Total No. of Plants	Number with Segregated FGD Wastewater Treatment System (Operating) [b]	Number with Wet Fly Ash Systems [c]
1	10	3	2	5	0	0
2	6	1	1	2	1	1
3	16	2	1	3	0	1
4	8	1	3	4	1	2
5	10	1	4	6	1	6
6	3	3	0	3	0	3
7	8	1	2	3	1	2
8	4	2	0	2	0	0
9	2	2	0	2	0	2
Total	**67**	**16**	**13 [d]**	**30 [d]**	**4**	**17**

Source: [U.S. EPA, 2008a]

a – Plants within the scope of Part B of the data request.

b – Based on information provided in the data request responses, as of August 2007.

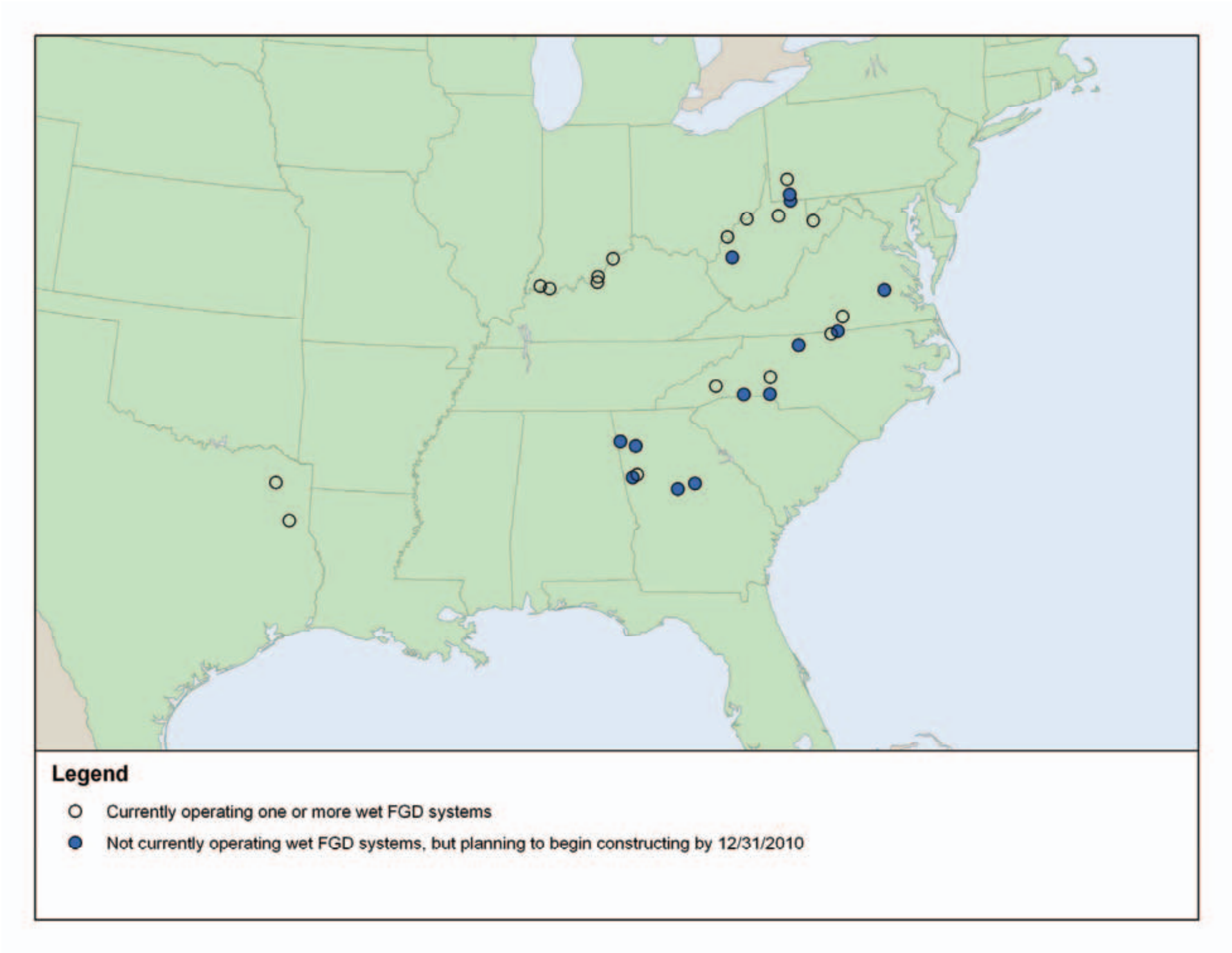
c – Prior to completing the data request, companies provided EPA with preliminary information about their coal-fired power plants. At that time, the number of plants with wet fly ash systems totaled 20. Based on information provided in response to the data request, the total number of plants with wet fly ash systems is actually 17.

d – EPA received data request technical information for 30 coal-fired power plants. One company responded to the data request with plans to install wet FGD systems at one plant by December 31, 2010; however, during follow-up communications with EPA, the company informed EPA that they have since decided not to install FGD systems as part of the company's long-term air pollution control strategies.

Part A requested the following: company contact information; corporate structure information; and profile information for the coal-fired power plants that the companies currently operate and that were in operation during 2006. Part B contained the following seven sections:

- Section 1: General Plant Information;
- Section 2: Steam Electric Power Production;
- Section 3: Fuels Used;
- Section 4: Process Wastewater Generation from Coal-fired Steam Electric Units;
- Section 5: Wastewater Discharge and Treatment Operations;
- Section 6: Wastewater Treatment Costs; and
- Section 7: Monitoring Data.

Section 1 (General Plant Information) requested plant address and contact information. Sections 2 and 3 (Steam Electric Power Production; Fuels Used) requested steam electric power production information and fuels used for each steam electric unit that the plant operated in 2006.



Source: [U.S. EPA, 2008a]
Note: Based on information provided in the data request responses, as of August 2007.

Figure 2-3. Geographic Distribution of Coal-fired Power Plants for which Data Request Respondents Provided Technical Information

Section 4 (Process Wastewater Generation from Coal-fired Steam Electric Units) requested wastewater generation information, including flow rate data, for the following wastewaters: coal pile runoff; coal pulverizer waste streams; wastewaters from ash handling and air pollution control systems (FGD, SCR/SNCR, and enhanced mercury air controls); and cooling water.

Section 5 (Wastewater Discharge and Treatment Operations) requested information on the operations of each wastewater treatment system at each plant and the associated wastewater flow rates; flow rates for untreated wastewaters; and a diagram for each plant including all coal-fired steam electric process operations, wastewater treatment systems, and treated and untreated flows. Section 6 (Wastewater Treatment Costs) requested operation and maintenance (O&M) cost data for each wastewater treatment system operated in 2006; and capital cost data for each FGD wastewater treatment system constructed between January 01, 1997, and December 31, 2006.

Section 7 (Monitoring Data) requested monitoring data for coal-fired steam electric wastewater streams that the plant collected for any reason during 2006 that meets certain sample location and analyte criteria.

In developing the data request, EPA worked with industry trade associations and other EPA program offices to develop questions that addressed the needs of the 2007/2008 detailed study while minimizing respondent burden. After distributing the data request to the nine data request respondents, EPA provided assistance and clarification regarding the data request questions directly via a help line and indirectly via UWAG.

EPA conducted a technical review of the data request responses to ensure the quality and consistency of the data. Following the technical review of each data request response, EPA communicated with the data request respondents to resolve questions and/or discrepancies found. Once resolved, EPA key-entered the revised data request responses into a database and performed a quality assurance check of the key-entered data. [ERG, 2008i]

A portion of the information provided by data request respondents was claimed as confidential business information (CBI). In these cases, EPA has provided sanitized versions of the original data request responses, documentation of follow-up communications with data request respondents, and the database of data request information in the docket for the 2008 Effluent Guidelines Program Plan.

2.4 Interactions with UWAG

UWAG is an association of over 200 individual electric utilities and four national trade associations of electric utilities: the Edison Electric Institute, the National Rural Electric Cooperative Association, the American Public Power Association, and the Nuclear Energy Institute. The individual utility companies operate power plants and other facilities that generate, transmit, and distribute electricity to residential, commercial, industrial, and institutional customers. The Edison Electric Institute is the association of U.S. shareholder-owned electric companies, international affiliates, and industry associates. The National Rural Electric Cooperative Association is the association of nonprofit electric cooperatives supplying central station service through generation, transmission, and distribution of electricity to rural areas of the United States. The American Public Power Association is the national trade association that represents publicly owned (municipal and state) electric utilities in 49 states. The Nuclear Energy Institute establishes industry policy on legislative, regulatory, operational, and technical issues affecting the nuclear energy industry on behalf of its member companies, which include the companies that own and operate commercial nuclear power plants in the United States, as well as nuclear plant designers and other organizations involved in the nuclear energy industry. UWAG's purpose is to participate on behalf of its members in EPA's rulemakings under the CWA.

UWAG commented on EPA's selection of the steam electric power generation industry for a detailed study as part of the 2006 Effluent Guidelines Program Plan and submitted comments to EPA regarding the detailed study as part of the preliminary 2008 Effluent Guidelines Program Plan. UWAG also provided data during a review of PCS and TRI data to assess national discharge loadings associated with this industry, as summarized in the *Interim Detailed Study Report for the Steam Electric Power Generating Point Source Category*

(EPA/821-R-06-015, November 2006) [U.S. EPA, 2006b]. As EPA continued with the 2007/2008 detailed study and began formulating approaches to data collection, EPA held a series of discussions with UWAG to streamline and facilitate the data collection process. Specifically, EPA communicated with UWAG to collect information on power plant characteristics to support site visit selection, discuss wastewater sampling approaches and recommendations, review the data request for clarity, and coordinate data collection for existing permit data.

2.4.1 Database of Power Plant Information

In preparing for selecting site visit candidates, EPA assembled available power plant information from the Department of Energy (DOE) and EPA's Office of Air and Radiation. Specifically, EPA was interested in coal-fired power plants that operate wet FGD systems and have wet ash handling operations. As discussed in Section 2.1, EPA provided UWAG with a list of 96 potential candidates, on which UWAG provided information. Section 3.1 summarizes the data provided by UWAG.

2.4.2 Wastewater Sampling

As discussed in Section 2.2, EPA is conducting a sampling program to characterize wastewaters generated by coal-fired power plants, and to evaluate treatment technologies and best management practices available to reduce pollutant discharges. EPA held several meetings with UWAG to discuss various approaches to the sampling program, including identifying representative sample points, providing comment on the generic sampling and analysis plan, and providing recommendations on laboratory analyses and potential interferences (particularly with handling influent samples with high concentrations of solids). UWAG participated in the facility pre-sampling site visits and provided review and comment on site-specific sampling plans. At the invitation of the plants being sampled, UWAG also collected split samples during EPA's sampling episodes. EPA held a meeting with UWAG to discuss the FGD effluent sampling results for four of the plants that have been sampled. During this meeting, EPA and UWAG compared analytical results and discussed the challenges associated with analyzing the FGD wastewaters. [ERG, 2008c]

2.4.3 Data Request

As discussed in Section 2.3, EPA developed a data request to collect information on coal-fired power plants. EPA provided UWAG an opportunity to review the data request and to recommend changes to improve the clarity of the questions involved. For example, UWAG provided input on the industry's definitions of scrubber terminology to ensure that the respondents would understand the questions that EPA included in the request. After EPA distributed the data request to the data request respondents, UWAG requested clarification regarding certain data request questions on behalf of its members. Copies of UWAG's comments and questions on the data request are included in the docket [UWAG, 2007].

2.4.4 NPDES Form 2C

UWAG and EPA coordinated efforts to create a database of selected National Pollutant Discharge Elimination System (NPDES) Form 2C data from UWAG's member companies. The NPDES Form 2C (or an equivalent form used by a state permitting authority) is an application for a permit to discharge wastewater that must be completed by existing industrial facilities (including manufacturing, commercial, mining, and silvicultural operations). This form includes facility information, data on facility outfalls, process flow diagrams, treatment information, and intake and effluent characteristics.

The NPDES Form 2C database is focused on the outfalls of coal-fired power plants that receive FGD, ash handling, or coal pile runoff waste streams. Other outfalls – such as separate outfalls for sanitary wastes, cooling water, landfill runoff, and other waste streams – were not included in the database. The database does not include Form 2C information for plants that have neither a wet FGD system nor wet fly ash handling. For example, if a plant has no wet FGD system and it is known that the only wet ash handling at the plant is for bottom ash sluicing, its information was not included in the database.

UWAG originally anticipated that these data would be available in December 2007; however, this effort was delayed and EPA received Form 2C data for 86 plants in late June 2008. [UWAG, 2008]

2.5 Interactions with EPRI

EPRI is a research-oriented trade association for the steam electric industry. EPRI conducts research funded by the steam electric industry and has extensively studied wastewater discharges from FGD systems, and provided EPA with the following reports that summarize the data collected during several of these studies:

- *Flue Gas Desulfurization (FGD) Wastewater Characterization: Screening Study* [EPRI, 2006a];
- *EPRI Technical Manual: Guidance for Assessing Wastewater Impacts of FGD Scrubbers* [EPRI, 2006b];
- *The Fate of Mercury Absorbed in Flue Gas Desulfurization (FGD) Systems* [EPRI, 2005];
- *Update on Enhanced Mercury Capture by Wet FGD: Technical Update* [EPRI, 2007b]; and
- *PISCES Water Characterization Field Study, Sites A-G* [EPRI, 1997-2001].

The EPRI reports have provided EPA with background information regarding the characteristics of FGD wastewaters and the sampling techniques used to collect the samples.

In addition, EPRI participated in meetings with EPA and provided comments on EPA’s planned data collection activities, including the data request and the sampling program. EPRI specifically commented on the sample collection techniques and considerations for laboratory analysis of FGD and ash handling wastewaters. EPRI also provided comments on EPA’s *Generic Sampling and Analysis Plan for Coal-fired Steam Electric Power Plants*. A copy of EPRI’s comments on the sampling plan is included in the docket [EPRI, 2007c].

2.6 Department of Energy (DOE)

DOE promotes scientific and technological innovation in support of its mission to advance the national, economic, and energy security of the United States. DOE's goals toward achieving this mission include applying advanced science and nuclear technology to the U.S.'s defense, promoting a diverse supply and delivery of reliable, affordable, and environmentally sound energy, advancing scientific knowledge, and providing for the permanent disposal of the U.S.'s high-level radioactive waste. In the 2007/2008 detailed study, EPA used information on electric generating facilities from DOE's Energy Information Administration (EIA) data collection forms.

EIA is a statistical agency of the DOE that collects information on existing U.S. electric generating facilities and associated equipment to evaluate the current status and potential trends in the industry. EPA used information from two of EIA's data collection forms: Form EIA-860, Annual Electric Generator Report, and Form EIA-767, Steam Electric Plant Operation and Design Report. These forms are discussed below.

2.6.1 Form EIA-860

Form EIA-860 collects information annually for all electric generating facilities that have or will have a nameplate rating[3] of one megawatt (MW) or more, and are operating or plan to be operating within five years of the filing of the Annual Electric Generator Report. The data collected in Form EIA-860 are associated only with the design and operation of the generators at facilities [U.S. DOE, 2005a].

2.6.2 Form EIA-767

Form EIA-767 collects information annually from all electric generating facilities with a total existing or planned, organic-fueled or renewable steam electric generating unit that has a nameplate rating of 10 MW or larger. The data collected in Form EIA-767 is associated with the operation and design of the entire facility. EPA used Form EIA-767 primarily for information on the facilities operating (or planning to operate) FGD systems [U.S. DOE, 2005b].

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[3] DOE defines the generator nameplate capacity as the maximum rated output of a generator under specific conditions designated by the manufacturer. Generator nameplate capacity is usually indicated in units of kilovolt-amperes (kVA) and in kilowatts (kW) on a nameplate physically attached to the generator. More generally, generator capacity is the maximum output, commonly expressed in megawatts (MW), that generating equipment can supply to system load, adjusted for ambient conditions.

3. OVERVIEW OF THE COAL-FIRED STEAM ELECTRIC INDUSTRY

As discussed in Chapter 2, EPA's 2007/2008 detailed study of the steam electric power generating industry focused on wastewater discharges from coal-fired power plants. Specifically of interest are wet FGD and ash handling wastes. As such, this chapter presents an overview of coal-fired power plants within the steam electric industry, with particular emphasis on those operating (or planning to operate) wet FGD systems. For a detailed profile of the steam electric industry in relation to the electric generating industry as a whole, see Chapter 3.0 of the *Interim Detailed Study Report for the Steam Electric Power Generating Point Source Category* (EPA-821-R-06-015; November 2006) [U.S. EPA, 2006b][4].

The wastewater information presented in this chapter is focused on FGD and ash sluice wastewater, which EPA believes to be two of the primary sources of metals discharged from coal-fired power plants. This chapter also presents available information about coal pile runoff, which can contribute a significant amount of metals to plant discharges.

As part of the collection activities for the data request, EPA collected information regarding wastewater generation flow rates for cooling water (once-through and cooling tower blowdown), pyritic mill reject sluice, air preheater washwater, and other miscellaneous low-volume wastewaters [U.S. EPA, 2008a]. The data for these waste streams are not presented in this report. For a description of other steam electric unit operations and sources of wastewater generation, see Section 3.2 of the *Interim Detailed Study Report for the Steam Electric Power Generating Point Source Category* (EPA-821-R-06-015; November 2006) [U.S. EPA, 2006b].

3.1 Flue Gas Desulfurization Systems

Power plants use FGD systems to control sulfur dioxide (SO_2) emissions from the flue gas generated in the plants' boiler. Wet FGD scrubbers are the most common type of FGD system; however, dry FGD systems also exist [U.S. EPA, 2003]. The 2007/2008 detailed study is focused on wastewaters from wet FGD systems only. There are several variations of wet FGD systems, but this section focuses on the limestone forced oxidation system and the lime or limestone non-forced oxidation system, as EPA believes these are the most common systems in the industry.

EPA has compiled information on the current or planned use of wet FGD systems at 91 plants (198 generating units), using information collected from the site visit and sampling program, the data request, and the UWAG-provided information. The wet FGD systems at 95 of the 198 generating units (48 percent) are currently or will be forced oxidation systems, and the wet scrubbers at 67 of the generating units (34 percent) are natural or inhibited oxidation systems. The remaining 36 generating units (18 percent) are currently or will be scrubbed by wet FGD systems installed after 2006. Although EPA did not collect information on the

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[4] The detailed profile of the steam electric industry presented in Section 3.0 of the *Interim Detailed Study Report for the Steam Electric Power Generating Point Source Category* [U.S.EPA, 2006a] is based on 2002 data. Although it is not as current as the data provided in this section, it does provide a picture of the coal-fired steam electric industry in relation to the entire steam electric industry, as well as a picture of the steam electric industry in relation to the entire electric generating industry. EPA has not updated the data for the entire steam electric industry or electric generating industry as the focus of the 2007/2008 Steam Electric Detailed Study is on coal-fired power plants.

oxidation process for scrubbers planned for these generating units, based on industry trends EPA expects they will be forced oxidation systems.

Limestone is by far the predominant sorbent used in wet FGD systems (74 percent of generating units), followed by lime (14 percent of generating units) and magnesium-enhanced lime (7 percent of generating units). Magnesium oxide, fly ash, and soda ash sorbents collectively are used in wet scrubbers at 5 percent of generating units.

3.1.1 Process Description and Wastewater Generation

This section describes the steam electric generating processes for wet limestone forced oxidation FGD systems and wet lime or limestone non-forced oxidation FGD systems based on data collected by EPA throughout the 2007/2008 detailed study.

3.1.1.1 Limestone Forced Oxidation FGD Scrubbers

To date, the EPA site visit and sampling program primarily focused on limestone forced oxidation systems because these types of FGD systems are the most predominant systems operating segregated wastewater treatment systems prior to discharging FGD wastewater. In addition, based on discussions with industry representatives, EPA expects that the majority of future wet FGD systems will be limestone forced oxidation. Of the 14 power plants that EPA visited between December 2006 and May 2008 that were operating an FGD system at the time of the visit, 13 were operating limestone forced oxidation FGD systems. The two plants that EPA visited that were not operating FGD systems are both in the process of installing limestone forced oxidation FGD systems.

The limestone forced oxidation FGD system works by contacting the flue gas stream with a liquid slurry stream containing a limestone ($CaCO_3$) sorbent, which effects mass transfer. Equation 3-1 shows the reaction that occurs between limestone and sulfur dioxide, producing hydrated calcium sulfite ($CaSO_3$) [EPRI, 2006a].

$$CaCO_{3\,(s)} + SO_{2\,(g)} + 1/2\ H_2O \rightarrow CaSO_3 \times 1/2\ H_2O_{\,(s)} + CO_{2\,(g)} \qquad (3\text{-}1)$$

The calcium sulfite is then oxidized to calcium sulfate (gypsum) by injecting air into the calcium sulfite slurry. Equation 3-2 shows the reaction producing gypsum ($CaSO_4 * 2H_2O$) from calcium sulfite [EPRI, 2006a].

$$CaSO_3 \times 1/2\ H_2O_{\,(s)} + ½\ O_{2\,(g)} + 3/2\ H_2O_{\,(l)} \rightarrow CaSO_4 \times 2H_2O_{\,(s)} \qquad (3\text{-}2)$$

During the site visits to power plants operating limestone forced oxidation FGD systems, EPA determined that the operation of these FGD systems varies somewhat by plant; however, most of the systems follow the same general operating procedure. Figure 3-1 presents a typical process flow diagram for a limestone forced oxidation FGD system, based on EPA's observations during the site visit and sampling program.

Most of the plants EPA visited operate a spray or tray tower FGD scrubber, in which the flue gas and the limestone slurry are configured with countercurrent flow. The flue gas enters near the bottom of the FGD scrubber and the limestone slurry and scrubber slurry recycle are pressurized and sprayed downward from several different spray levels near the top of the FGD scrubber. The spray droplets of the limestone slurry contact the flue gas and absorb the sulfur dioxide, which reacts with the limestone (see Equation 3-1). To increase the sulfur dioxide removal efficiency, some plants use additives (e.g., dibasic acid (DBA) or formic acid) in the FGD system. These additives buffer the scrubber slurry, which controls the sulfur dioxide vapor pressure in the scrubbers, thereby maximizing the sulfur dioxide absorption rate [Babcock & Wilcox, 2005]. See Section 3.1.2.1 for more information on the types of additives used by coal-fired power plants. The scrubbed flue gas then exits out the top of the FGD scrubber through a mist eliminator and then to the stack.

The spray droplets, some containing the calcium sulfite product and others with unreacted limestone, fall to the bottom of the FGD scrubber into a reaction tank. The plant injects air into the reaction tank and vigorously mixes the slurry to oxidize the calcium sulfite to gypsum (see Equation 3-2). The plant uses the scrubber recycle pumps to pressurize and pump the slurry from the reaction tank to the various spray levels within the FGD scrubber. The plant continuously recirculates the slurry in the FGD scrubber. When the percent solids or the chlorides concentration in the slurry reach a certain high set point, the plant uses the scrubber blowdown pumps to remove some of the slurry from the FGD scrubber. The plant uses this blowdown stream to reduce the levels of solids and chlorides in the scrubber slurry until a low set point is reached within the FGD scrubber. The plant then shuts off the blowdown pumps until the solids and chlorides build up again to the point of triggering a blowdown. Therefore, the scrubber blowdown is typically an intermittent transfer from the scrubber. Some plants, however, operate an FGD scrubber with a continuous blowdown, which can either be a once-through FGD system with no recycle, or an FGD system that recycles some of the slurry but is constantly blowing down slurry to keep the solids and chlorides level at a constant set point.

The parameter used to control the FGD system (i.e., percent solids or chlorides concentration) and the level at which it is controlled varies by plant. Plants control the chlorides level in the FGD system based on the metallurgy of the FGD scrubber materials of construction. Plants maintain a chlorides concentration well below that which the FGD scrubber materials of construction can withstand, normally around 12,000 – 20,000 ppm; however, some systems operate with chloride concentrations as low as 4,000 to 6,000 ppm and other plants may operate near 30,000 ppm. Plants that produce gypsum for beneficial reuse must also monitor/control the FGD system based on the percent solids because the plant must limit the amount of fines (small inert particles) in the gypsum by-product [EPRI, 2006a].

The scrubber blowdown, which is a gypsum slurry, is transferred to a dewatering process. Often, this process uses one or two sets of hydrocyclones, referred to in the industry as hydroclones.[5] The hydroclones separate the gypsum solids from the water using centrifugal force. The gypsum solids are forced outward to the walls of the hydroclones and fall downward, while the water exits the top of the hydroclones. The underflow from the first set of hydroclones, referred to as the primary hydroclones, contains the gypsum solids and is transferred to vacuum filter belts. The primary hydroclone overflow, which is mostly water and fines, is transferred to the primary hydroclone overflow head tank.

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[5] Another approach for solids removal practiced by some plants entails the use of settling ponds instead of hydroclones or other mechanical devices.

The primary hydroclone underflow sent to the vacuum filter belts is rinsed with service water to reduce the chlorides concentration if the plant intends to market the gypsum for beneficial reuse, such as for wallboard production. The vacuum filter belts then remove the water from the gypsum, drying the gypsum to its desired moisture content. At the end of the vacuum filter belts, the gypsum falls off the belts and is conveyed to a storage area until it is transported off site. Plants that do not sell the gypsum may dispose of it in an on-site landfill. Filtrate from the vacuum filter belt is recovered in a reclaim tank and either returned to the FGD scrubber or used in the limestone slurry preparation process.

The primary hydroclone overflow is often transferred from the primary hydroclone head tank to a second set of hydroclones, as shown in Figure 3-1. The second set of hydroclones is typically operated at plants treating the scrubber purge in an FGD wastewater treatment system other than a settling pond. These secondary hydroclones remove most of the remaining fines from the wastewater, which reduces the overall solids load to the FGD wastewater treatment system. The secondary hydroclones operate the same as the primary hydroclones, except that they remove far fewer solids than the primary hydroclones and the solids removed are fines; therefore, the secondary hydroclone underflow is sent to the reclaim tank and returned to the scrubber. The secondary hydroclone overflow is sent to the purge tank.

From the purge tank, the scrubber purge[6] is typically transferred to some type of FGD wastewater treatment system, which could be a settling pond or a more advanced system (see Section 3.1.4). It may also be commingled with other wastewater streams (e.g., once-through cooling water) and discharged. Because most treatment systems in use do not significantly change the chlorides concentration, the stream is not recycled back to the FGD scrubber unless the plant operates the solids removal process in a manner that purges the excess chlorides along with the solids. If the plant does not have specifications for the chlorides or fines content in the gypsum by-product, then it is possible for the plant to recycle the secondary hydroclone overflow without a purge stream because the chlorides can be removed from the FGD system by retaining the chlorides with the solids that are sent to a landfill. Most of the plants that sell the gypsum for beneficial reuse do have chloride and fines specifications, but plants that dispose of the gypsum in a landfill may not need a scrubber purge stream [Sargent & Lundy, 2007].

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[6] For the purpose of this document, the scrubber blowdown refers to the slurry stream exiting the FGD scrubber which is not immediately recycled (typically transferred to a solids separation process). The scrubber purge refers to the waste stream from the FGD scrubber system (typically from a solids separation process) that is transferred to a wastewater treatment system or discharged. Both the scrubber blowdown and scrubber purge waste streams are depicted in Figure 3-1. In some instances, the scrubber blowdown and scrubber purge may be the same waste stream if the plant does not operate a solids separation process prior to wastewater treatment or discharge.

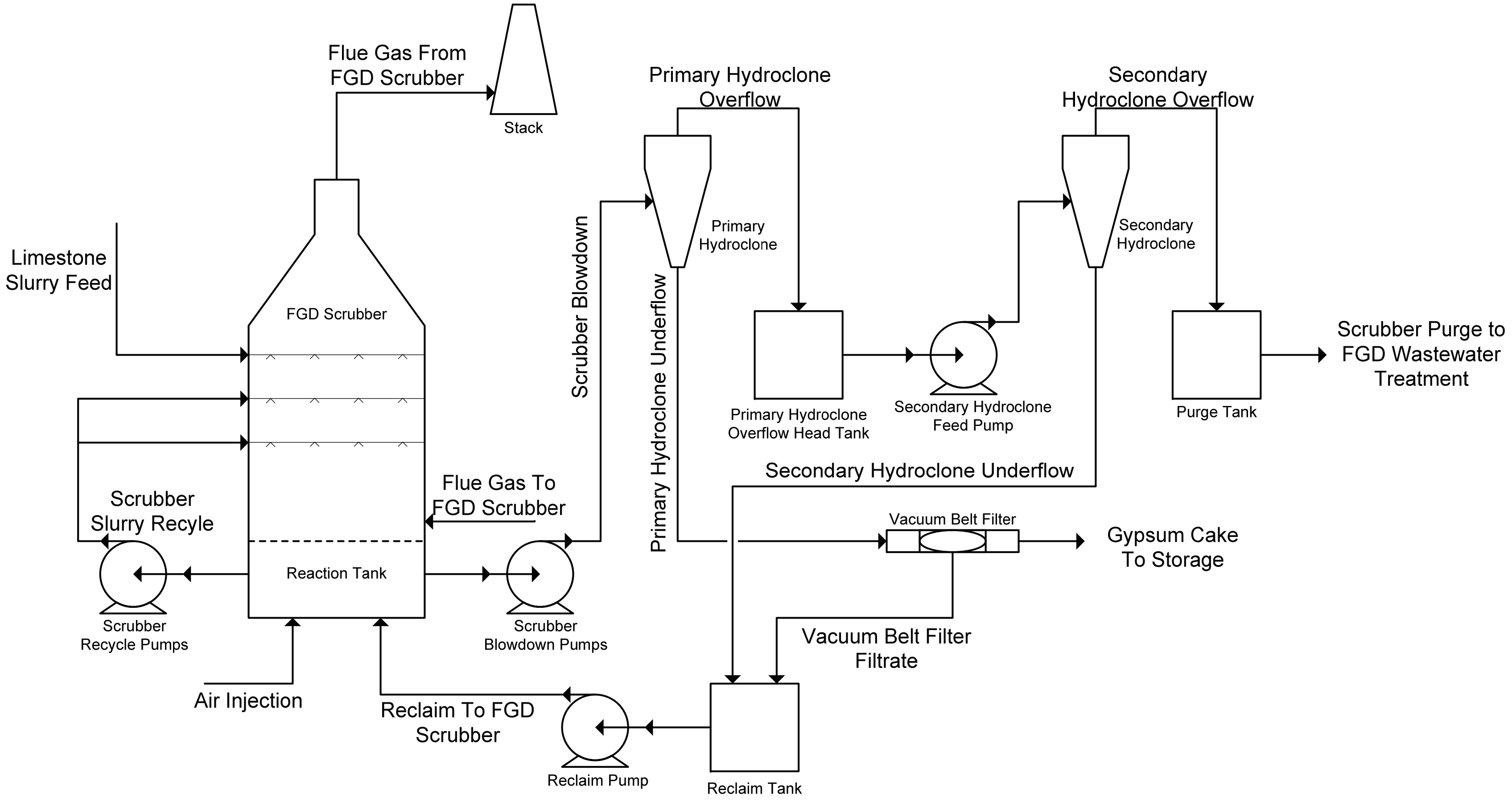

Figure 3-1. Process Flow Diagram for a Limestone Forced Oxidation FGD Scrubber System

3.1.1.2 Lime or Limestone Non-Forced Oxidation FGD Scrubbers

As described in Section 3.1.1.1, the EPA site visit and sampling program primarily focused on limestone forced oxidation FGD systems; however, lime or limestone non-forced oxidation FGD systems are also prevalent in the steam electric industry. Many of these plants do not operate wastewater treatment systems, other than settling ponds, to treat the scrubber purge. In addition, some plants are able to recycle their FGD wastewater back to the FGD system and, therefore, do not produce a scrubber purge waste stream.

The lime or limestone non-forced oxidation FGD systems work by contacting the flue gas stream with a liquid slurry stream containing a lime ($Ca(OH)_2$) or limestone ($CaCO_3$) sorbent, which effects mass transfer. Equation 3-1 shows the reaction between limestone and sulfur dioxide and Equation 3-3 shows the reaction that occurs between lime and sulfur dioxide, producing hydrated calcium sulfite ($CaSO_3$).

$$Ca(OH)_{2\,(s)} + SO_{2\,(g)} \rightarrow CaSO_3 \times \frac{1}{2} H_2O_{\,(s)} + \frac{1}{2} H_2O_{\,(l)} \qquad (3\text{-}3)$$

Figure 3-2 presents a typical process flow diagram for a lime or limestone non-forced oxidation FGD system. Most of these FGD systems are spray or tray tower FGD scrubbers, in which the flue gas and the lime or limestone slurry are configured with countercurrent flow. The flue gas enters near the bottom of the FGD scrubber, and the slurry and scrubber slurry recycle are pressurized and sprayed downward from several different spray levels near the top of the FGD scrubber. The spray droplets of the slurry contact the flue gas and absorb the sulfur dioxide, which reacts with the lime or limestone (see Equations 3-3 or 3-1, respectively). To increase the sulfur dioxide removal efficiency, some plants use additives (e.g., dibasic acid (DBA) or formic acid) in the FGD system. These additives buffer the scrubber slurry, which controls the sulfur dioxide vapor pressure in the scrubbers, thereby maximizing the sulfur dioxide absorption rate [Babcock & Wilcox, 2005]. See Section 3.1.2.1 for more information on the types of additives used by coal-fired power plants. The scrubbed flue gas then exits the top of the FGD scrubber, through a mist eliminator, and then to the stack.

The spray droplets, some containing the calcium sulfite product and others with unreacted lime or limestone, fall to the bottom of the FGD scrubber. This scrubber slurry is collected at the bottom of the FGD scrubber and the plant uses the scrubber recycle pumps to pressurize and pump the slurry from the bottom of the scrubber to the various spray levels within the FGD scrubber. The plant continuously recirculates the slurry in the FGD scrubber. When the percent solids or the chlorides concentration in the slurry reach a certain high set point, the plant uses the scrubber blowdown pumps to remove some of the slurry from the FGD scrubber system. The plant uses this blowdown stream to reduce the levels of solids and chlorides in the scrubber slurry until a low set point is reached within the FGD scrubber. The plant then shuts off the blowdown pumps until the solids and chlorides build up again to the point of triggering a blowdown. Therefore, the scrubber blowdown is typically an intermittent transfer from the scrubber. Some plants, however, operate an FGD scrubber with a continuous blowdown, which can either be a once-through FGD system with no recycle, or an FGD system that recycles some of the slurry, but is constantly blowing down slurry to keep the solids and chlorides level at a constant set-point. The parameter used to control the FGD system (i.e., percent solids or chlorides concentration) and the level at which it is controlled varies by plant.

The scrubber blowdown, which is a calcium sulfite slurry, is transferred to a dewatering process (e.g., thickener, centrifuge, settling pond, vacuum drum or belt filter). The solids from this initial dewatering step are intermittently pumped to a final dewatering process consisting of either a vacuum filter or centrifuges, although plants operating a vacuum drum filter as the first dewatering step are not likely to operate an additional vacuum filter for final dewatering. Likewise, settling pond systems typically will not operate a final mechanical dewatering process. The solid cake from the final dewatering process is sent to a landfill, either on or off site. The overflow from the thickener or vacuum drum filter is sent to a reclaim tank, from which some wastewater may be recycled back to the FGD scrubber and some may be discharged or transferred to additional treatment. The filtrate from the dewatering process is also collected in a reclaim tank and discharged or recycled back to the FGD scrubber. For a plant operating a settling pond to dewater the scrubber blowdown, the solids from the settling pond are either retained in the pond or dredged and landfilled. The overflow from the settling pond is either discharged from the plant, or recycled to the scrubber if chlorides have been sufficiently removed from the waste stream.

Plants operating non-forced oxidation FGD systems typically operate settling ponds for the treatment of the scrubber purge waste stream. Because the non-forced oxidation systems typically do not generate a sellable solid product, the solids are typically disposed of in a landfill. Like the limestone forced oxidation systems not beneficially reusing the gypsum, it may be possible for the plant to recycle the FGD wastewater without a purge stream because the chlorides can be removed from the FGD system by retaining the chlorides with the solids that are sent to the landfill [Sargent & Lundy, 2007]. Therefore, the plants operating non-forced oxidation FGD systems may not need a scrubber purge stream.

3.1.2 Coal-Fired FGD System Statistics

This section presents statistics on the number and characteristics of coal-fired power plants that have FGD systems or are planning to install them. Also included in this section are estimates of the coal-fired steam electric industry's historic, current, and projected total generating capacity and scrubbed capacity.

3.1.2.1 Current Coal-Fired FGD System Profile

This section presents a picture of the current coal-fired steam electric industry regarding number of coal-fired power plants with FGD systems, the associated scrubbed capacity, and plant characteristics. The data sources used for this profile include UWAG-provided data [ERG, 2008f], EPA's site visit and sampling data, EPA's data request information [U.S. EPA, 2008a], and the 2005 Form EIA-767 [U.S. DOE, 2005b]. See Chapter 2 for background regarding EPA's data collection activities.

Table 3-1 presents statistics on the current (as of June 2008) coal-fired steam electric power generation associated with FGD systems as compared to the broader coal-fired and fossil-fueled steam electric power generation. As shown in Table 3-1, approximately 32 percent of the coal-fired steam electric power generating capacity is currently associated with wet FGD systems. EPA expects that percentage to increase significantly in the future, as discussed in Section 3.1.2.2.

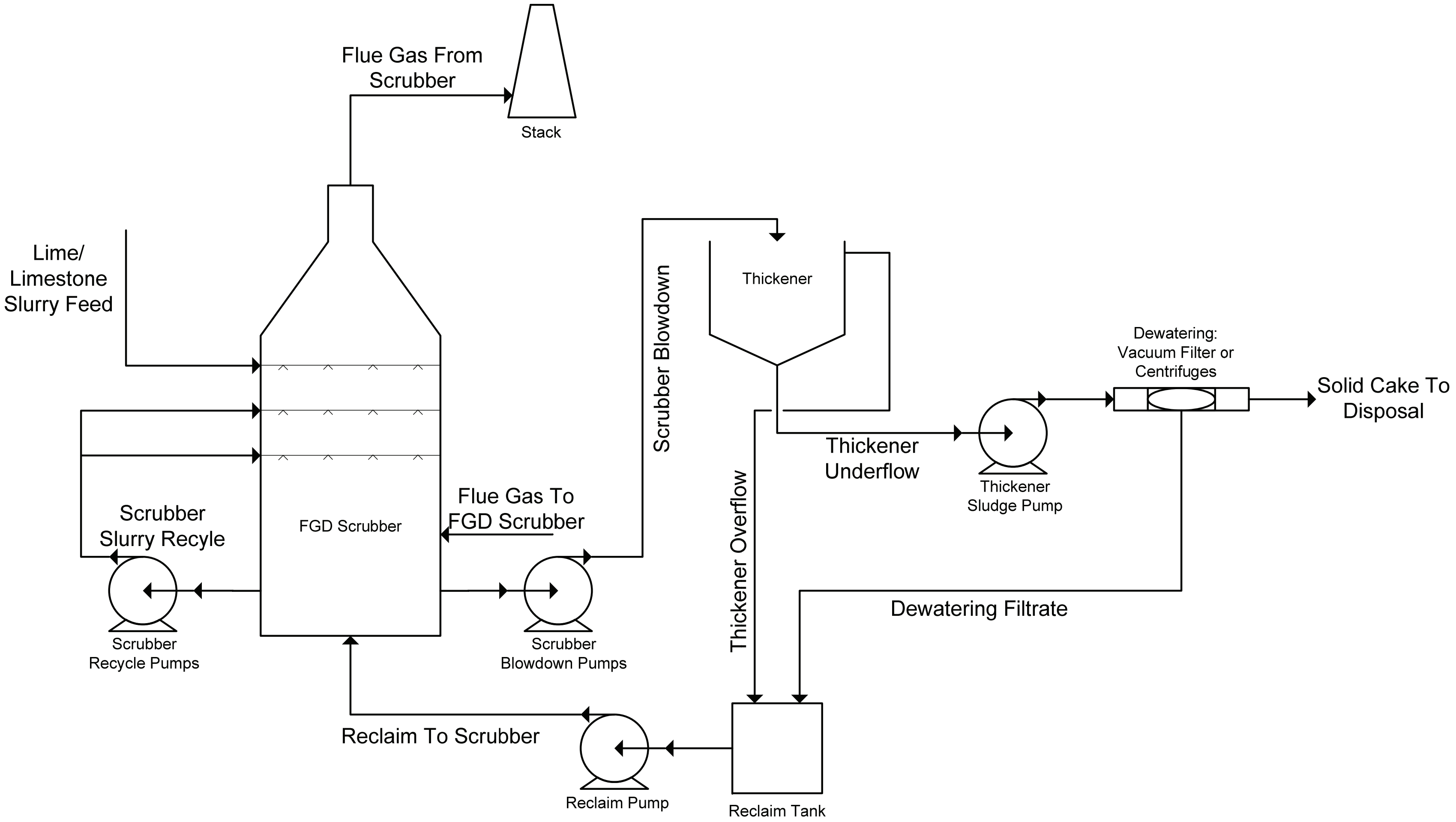

Figure 3-2. Process Flow Diagram for a Lime or Limestone Non-Forced Oxidation FGD Scrubber

Table 3-1. Scrubbed Coal-Fired Steam Electric Power Generation as of June 2008

	Fossil-Fueled Steam Electric Power Generation [a, b]	Coal-Fired Steam Electric Power Generation [a]	Coal-Fired Steam Electric Power Generation with Any FGD System (Wet or Dry) [c]	Coal-Fired Steam Electric Power Generation with a Wet FGD System [c, d]	Coal-Fired Steam Electric Power Generation with a Dry FGD System [c, d]
Number of Plants [e]	957	497	146	107	43
Number of Generating Units [e, f]	2,430	1,280	290	222	68
Capacity (MW) [e, g]	488,000	329,000	120,000 [h]	104,000 [h]	16,200 [h]

a – Source: 2005 EIA-767 [U.S. DOE, 2005b]. Includes units identified in the EIA as planned or under construction that were expected to be operating by the end of 2007.
b – Fossil-fueled generation includes coal, oil, and natural gas. It does not include nuclear generation.
c – Source: 2005 EIA-767 [U.S. DOE, 2005b] (including units associated with FGD scrubbers that were planned or under construction for 2007), UWAG-provided data [ERG, 2008f], data request information [U.S. EPA, 2008a], and site visit and sampling information.
d – The wet and dry scrubbed information is a subset of the information for “Any FGD System.” Note that several plants operate both wet and dry FGD systems. Thus, there is overlap between the number of plants with wet FGD systems and the number of plants with dry FGD systems.
e – The numbers presented have been rounded to three significant figures.
f – The number of units represents the number of generating units scrubbed and does not represent the number of FGD systems; however, the two numbers are similar, but several plants use a single FGD scrubber for more than one generating unit.
g – The capacities for the EIA-767 data represent the reported nameplate capacity. The capacities for the UWAG-provided data, data request information, and site visit and sampling information are based on information provided to EPA and may represent various capacities (e.g., nameplate capacity, net summer capacity, gross winter capacity).
h – Includes only the capacity for the scrubbed units.

EPA used the following three data sources to compile plant characteristic information for a subset of all coal-fired power plants that operate FGD systems: UWAG-provided data, EPA’s site visit and sampling data, and EPA’s data request information. The collective data from these three data sources is referred to hereinafter as the “combined data set.” The vast majority of the steam electric capacity included in these data sources is wet scrubbed, as that was the focus of EPA’s data collection effort.

Table 3-2 presents the percentage of scrubbed capacity that the combined data set represents relative to EPA’s estimate of the current and planned total scrubbed capacity. The planned units included in Table 3-2 are only for plants for which EPA collected information from the UWAG-provided data, data request, or the site visit and sampling program, and does not include many other plants and generating units that will install new FGD scrubbers over the next 10 to 15 years.

Table 3-3 summarizes plant characteristics for the wet scrubbed units included in the combined data set. EPA presents these data as a general picture of the current wet scrubbed, coal-fired steam electric industry; however, it should be noted that the combined data set also includes a relatively small number of FGD systems that are planned to begin operation over the next several years. As is the case for Table 3-2, the planned units included in Table 3-3 are only for plants for which EPA collected information during the study. Table 3-3 substantially under-represents the population of new FGD scrubbers that will be installed over the next 10 to 15 years. The UWAG-provided data mainly include information through the year 2006, with a few FGD systems coming on line through 2008. The majority of the site visit and sampling information represents conditions in place as of the date of this report, albeit with the inclusion of a few additional generating units for which the plants are planning to install wet FGD scrubbers. Most of the data request information was reported for the year 2006, but the data request also obtained information on FGD systems that were scheduled to startup or begin construction by the end of December 2010.[7]

The majority of the plants in the combined data set with FGD systems (63 percent) use eastern bituminous coal as the primary fuel source, which is to be expected considering eastern bituminous coal typically contains a higher sulfur content than other coal types. Other coals reported include subbituminous (19 percent of plants), lignite (10 percent of plants), and other bituminous coals (9 percent of plants).

Over 70 percent of the plants in the combined data set report using (or are planning to use) limestone as the FGD sorbent. Just under half of the plants use forced oxidation systems to produce gypsum, while the other half produces a calcium sulfite byproduct. Nearly half of the plants report using additives in their FGD systems. Of the additives used, DBA is the most common (18 percent of total plants), followed by emulsified sulfur (10 percent of total plants). Less commonly used additives are formic acid, adipic acid, magnesium hydroxide, and sodium formate.

More than half of the wet scrubbed units in the combined data set operate either an SCR or SNCR system for NOx control (42 percent SCR; 9 percent SNCR). Twenty-nine percent of the scrubbed units operate another form of NOx control, such as low NOx burners and over-fired air systems. Less than 15 percent of the units operate no NOx controls of any form. For details regarding the operation of NOx control systems at power plants, see Section 3.2 of the *Interim Detailed Study Report for the Steam Electric Power Generating Point Source Category* (EPA-821-R-06-015; November 2006) [U.S. EPA, 2006b].

No plants in the combined data set were identified as currently operating mercury air controls. Several plants from the data request population reported plans to install mercury air controls, such as activated carbon injection systems, between 2008 and 2010.

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[7] The data request specified that information should be provided for FGD systems planned out through December 31, 2010; however, some plants provided information associated with FGD systems planned through 2014.

Table 3-2. Scrubbed Capacity of EPA's Data Collection Sources

	Data from All Sources (Including EIA) [a]	Combined Data Set [b]	
		Number or Capacity (MW)	Percent of Data from All Sources
Wet FGD Systems			
Number of Plants with Wet FGD Systems	116	91	78%
Number of Generating Units Wet Scrubbed	254	198	78%
Wet Scrubbed Capacity (MW) [c]	123,000	103,000	84%
Dry FGD Systems			
Number of Plants with Dry FGD Systems	44	4	9%
Number of Generating Units Dry Scrubbed	69	6	9%
Dry Scrubbed Capacity (MW) [c]	17,000	3,180	19%
All FGD Systems (Wet and/or Dry)			
Number of Plants with a Wet and/or Dry FGD System	155	92	59%
Number of Generating Units Scrubbed	324	204	63%
Scrubbed Capacity (MW) [c]	140,000	106,000	75%

Note: The units associated with planned scrubbers that are included in the table are only for plants for which EPA has received additional information as part of the study; they do not represent an industry-wide compilation for all projected new FGD scrubbers.

a – Source: 2005 EIA-767 (including units associated with FGD scrubbers planned or under construction for 2007) [U.S. DOE, 2005b], UWAG-provided data (including units associated with planned FGD scrubbers) [ERG, 2008f], data request information (including units associated with planned FGD scrubbers) [U.S. EPA, 2008a], and site visit and sampling information (including units associated with planned FGD scrubbers for plants that were operating FGD systems at the time of the visit).

b – Source: UWAG-provided data (including units associated with planned FGD scrubbers) [ERG, 2008f], data request information (including units associated with planned FGD scrubbers) [U.S. EPA, 2008a], and site visit and sampling information (including units associated with planned FGD scrubbers for plants that were operating FGD systems at the time of the visit).

c – The capacities presented have been rounded to three significant figures. Due to rounding, the total capacity may not equal the sum of the individual capacities. The capacities for the EIA-767 data represent the reported nameplate capacity. The capacities for the UWAG-provided data, data request information, and site visit and sampling information are based on information provided to EPA and may represent various capacities (e.g., nameplate capacity, net summer capacity, gross winter capacity).

Table 3-3. Characteristics of Coal-Fired Power Plants with Wet Scrubbers

	Combined Data Set [a]		
	Number of Plants with Wet FGD Scrubbers	**Number of Wet Scrubbed Generating Units**	**Wet Scrubbed Capacity [b] (MW)**
Total	**91**	**198**	**103,000**
Primary Coal Type [c]			
Bituminous	65	151	76,600
Eastern Bituminous	*57*	*129*	*63,300*
Western Bituminous	*5*	*15*	*8,130*
Other Bituminous (Unknown)	*3*	*7*	*5,120*
Subbituminous	17	34	18,000
Powder River Basin	*8*	*13*	*8,080*
Other Subbituminous (unknown)	*9*	*21*	*9,930*
Lignite	9	13	8,170
Forced Oxidation			
Yes	44	95	50,400
No	38	67	32,400
No Information (Planned Units)	13	36	19,900
Sorbent			
Limestone	66	147	78,000
Lime	13	27	11,000
Magnesium Lime	8	14	9,680
Magnesium Oxide	2	3	803
Fly Ash	3	5	2,720
Soda Ash	1	2	530
Additives			
Adipic Acid	1	2	930
DBA	16	34	18,800
Formic Acid	3	4	1,530
Emulsified Sulfur	9	20	10,400
Sodium Formate	2	3	2,430
Magnesium Hydroxide	2	3	2,600
No Additives	50	95	46,100
No Information (Planned Units)	13	36	19,900

Table 3-3. Characteristics of Coal-Fired Power Plants with Wet Scrubbers

	Combined Data Set [a]		
	Number of Plants with Wet FGD Scrubbers	Number of Wet Scrubbed Generating Units	Wet Scrubbed Capacity [b] (MW)
NOx Controls			
SCR [d]	42	84	51,300
SNCR	9	18	7,100
None/Other (no SCR/SNCR)	51	96	44,400

Note: The table includes data for some plants/units that plan to install wet FGD systems in the future. The units associated with the planned wet FGD scrubbers were identified in each of the individual data sources and do not represent an industry-wide compilation of all projected new wet FGD scrubbers.

a –Source: UWAG-provided data (including units associated with planned wet FGD scrubbers) [ERG, 2008f], data request information (including units associated with planned wet FGD scrubbers) [U.S. EPA, 2008a], and site visit and sampling information (including units associated with planned wet FGD scrubbers for plants that were operating FGD systems at the time of the visit).

b – The capacities presented have been rounded to three significant figures. Due to rounding, the total capacity may not equal the sum of the individual capacities. The capacities for the EIA-767 data represent the reported nameplate capacity. The capacities for the UWAG-provided data, data request information, and site visit and sampling information are based on information provided to EPA and may represent various capacities (e.g., nameplate capacity, net summer capacity, gross winter capacity).

c – Some plants/units use a blend of more than one coal in the generating units. This table presents information for only the primary type of coal burned in the generating unit.

d – Some of the SCRs included in the table are planned/under construction.

3.1.2.2 Projected Use of FGD Systems at Coal-Fired Plants

EPA evaluated the historical increase in use of FGDs since effluent guidelines were last promulgated in 1982 and the expected trend in the amount of coal-fired capacity that would be scrubbed into the future. For this evaluation, EPA used information from the Northeastern States for Coordinated Air Use Management (NESCAUM) [NESCAUM, 2000], EIA Electric Power Annual 2001 [U.S. DOE, 2003] EIA Electric Power Annual 2006 [U.S. DOE, 2007], EPA’s National Electric Energy Data System (NEEDS) 2006 database [U.S. EPA, 2006c], and the Integrated Planning Model (IPM) [U.S. EPA, 2006a] developed by EPA’s Office of Air and Radiation.

Figure 3-3 shows how the wet scrubbed generating capacity has increased over the nearly three decades since the effluent guidelines were last promulgated, and also how the scrubbed capacity is projected to increase between now and 2025. Figure 3-4 also presents information on historical and projected scrubber use, showing the wet scrubbed capacity as a percentage of the total coal-fired generating capacity for the period 1977 to 2025. The historical capacities presented in Figures 3-3 and 3-4 are from *Environmental Regulation and Technology Innovation: Controlling Mercury Emissions from Coal-Fired Boilers* [NESCAUM, 2000], Electric Power Annual 2001 [U.S. DOE, 2003], and Electric Power Annual 2006 [U.S. DOE, 2007]. The capacities used in NESCAUM, 2000 were taken from EIA-Form 767 and could represent nameplate, summer, or winter capacities. The coal-fired generating capacities reported in the Electric Power Annual reports represent the net summer capacity; however, the U.S. DOE, 2003 and U.S. DOE, 2007 capacities for the FGD system represent the nameplate capacity. The projected capacities presented are from estimates based on the IPM model [U.S. EPA, 2006a]. The IPM model uses a variety of capacities in its estimates, but preferentially uses summer and winter capacity before nameplate capacity.

As shown in Figure 3-3, the wet scrubbed generating capacity has increased significantly since the 1982 promulgation of the current ELGs and is expected to continue to do so into the future.[8] EPA estimates that in 1977 approximately five percent of coal-fired power plant capacity was scrubbed using wet FGD systems, and by June 2008 that percentage had increased to approximately 32 percent (see Table 3-1). EPA models have predicted that by 2010, more than half of the total coal-fired power plant capacity will be wet scrubbed. The modeling also projected that over 60 percent of coal-fired capacity will be wet scrubbed by 2020, and nearly 70 percent by 2025. The upward trend in wet-scrubbed capacity is expected to continue beyond 2025. EPA predicts that the industry’s dry scrubbed capacity will increase only slightly into the future. Table 3-4 provides additional detail on estimates of future use of FGD systems, both wet and dry, as projected by the NEEDS database and IPM information [ERG, 2008d].

Based on communications with industry, EPA expects that the majority of newly installed wet FGD systems will be limestone forced oxidation systems that produce a commercial-grade gypsum by-product. All planned wet FGD systems reported in responses to the data request will use limestone as the sorbent. Additionally, EPA expects that the majority of wet scrubbed steam electric units will also include SCR systems.

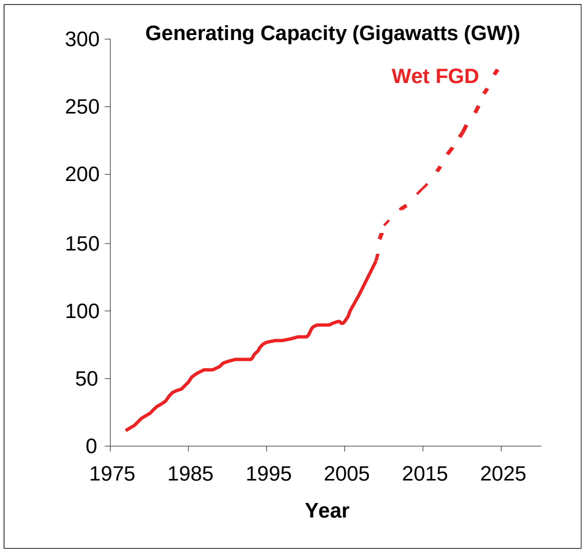

Figure 3-3. Wet Scrubbed Generating Capacity, 1977-2025

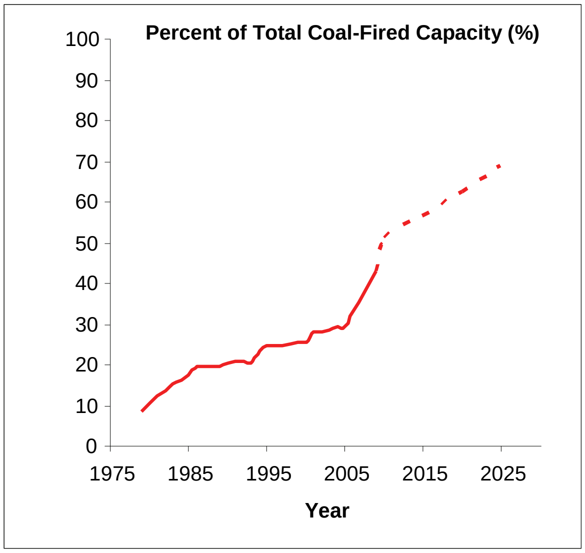

Figure 3-4. Wet Scrubbed Capacity as a Percentage of the Total Coal-Fired Generating Capacity, 1977-2025

Source: [ERG, 2008e]

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[8] EPA projected future generating capacity with FGD systems using IPM Base Case 2006 (v.3.0), which reflects the Clean Air Mercury Rule (CAMR) mercury reduction requirements and the Clean Air Interstate Rule (CAIR) NOx and SO2 emission reduction requirements for power plants. On February 8, 2008, the D.C. Circuit Court of Appeals vacated CAMR. (State of New Jersey v. EPA, 517 F.3d 574 (D.C. Cir. 2008)). The mandate effectuating the vacatur was issued on March 14, 2008. On May 21, 2008, the D.C. Circuit denied EPA's request that the full court reconsider the vacatur. The parties have until September 17, 2008, to request that the Supreme Court review the D.C. Circuit's decision. In a separate action, on July 11, 2008, the D.C. Circuit issued a decision vacating CAIR. (North Carolina v. EPA, 531 F.3d 896 (D.C. Cir. 2008)) The court's mandate in that case has not yet issued. Parties may ask the D.C. Circuit to reconsider its decision in the matter by filing petitions for rehearing no later than September 24, 2008. EPA will consider, in light of further developments in these cases, how the court decisions, as well as laws and regulations issued independently by states, may affect future installations of FGD scrubber systems as it continues reviewing the steam electric industry.

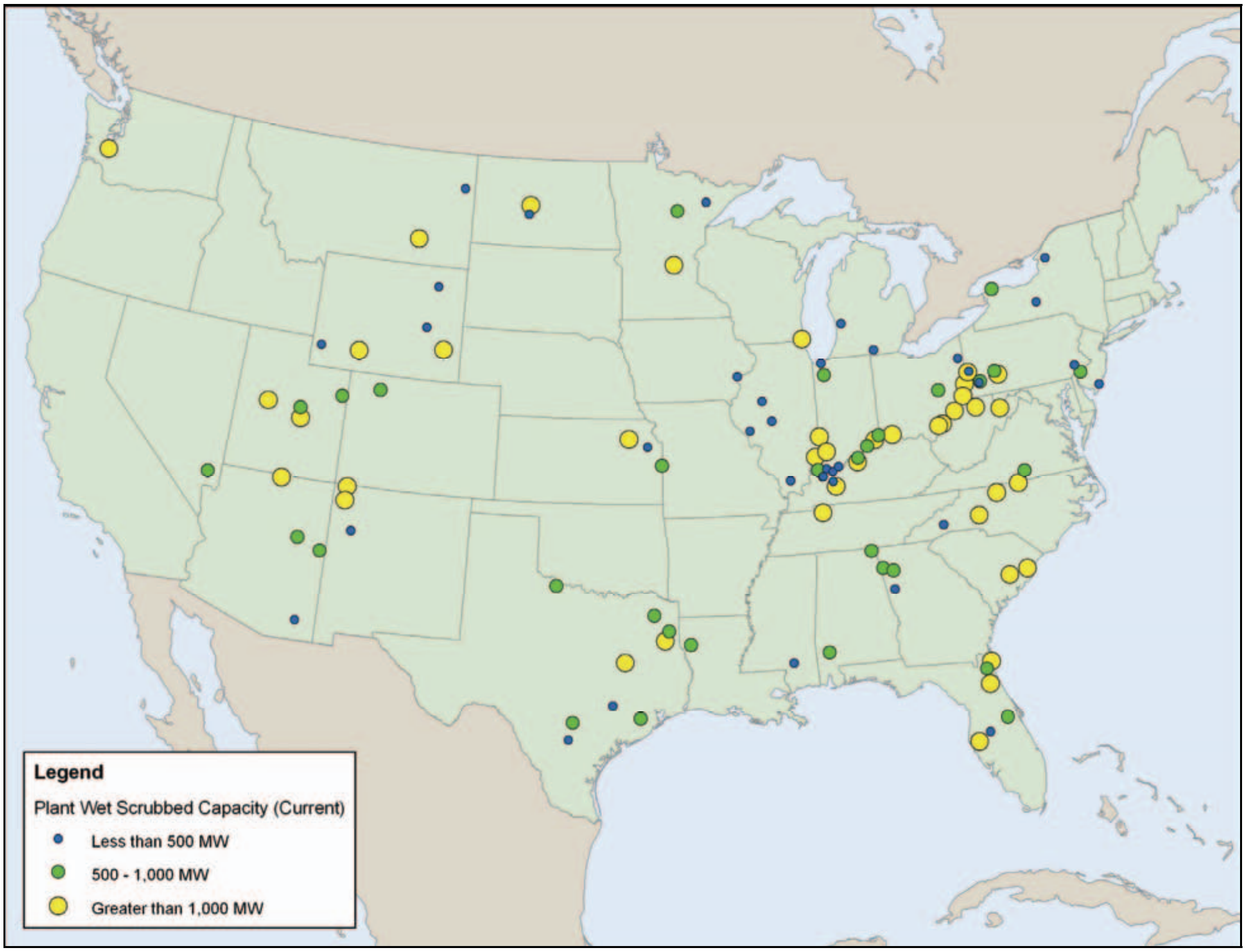
Table 3-4. Projected Future Use of FGD Systems at Coal-Fired Power Plants

	2009 Capacity (MW)	**2010 Capacity (MW)**	**2015 Capacity (MW)**	**2020 Capacity (MW)**	**2025 Capacity (MW)**
Wet Scrubbed [a]	136,000	162,000	189,000	231,000	282,000
Dry Scrubbed [a]	21,000	21,500	30,100	36,700	38,600
Total Scrubbed [a]	157,000	184,000	219,000	268,000	321,000
Total Coal-Fired Generating Capacity [a]	**316,000**	**318,000**	**333,000**	**371,000**	**409,000**
Percent Wet Scrubbed	*43%*	*51%*	*57%*	*62%*	*69%*
Percent Scrubbed	*50%*	*58%*	*66%*	*72%*	*78%*

Source: [ERG, 2008d]

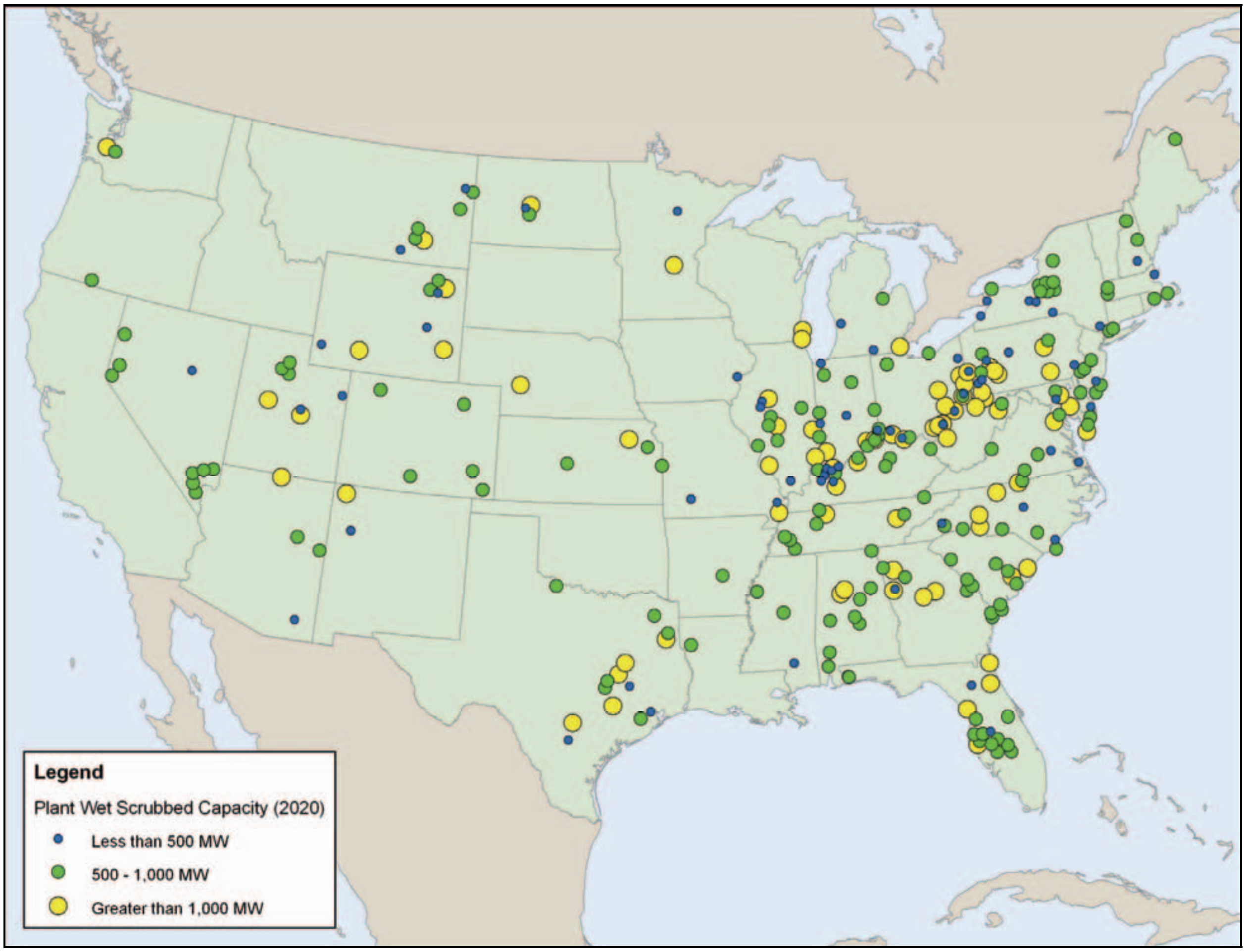
a - The capacities presented have been rounded to three significant figures. Due to rounding, the total capacity may not equal the sum of the individual capacities. The 2009 capacities are from the NEEDS 2006 database which preferentially uses summer and winter capacity before nameplate capacity. The 2010 – 2025 capacities presented in this table are from estimates based on the IPM model [U.S. EPA, 2006a], which uses the NEEDS 2006 database [U.S. EPA, 2006c] as a starting point. Because the nameplate capacities are not used in these projections, caution should be used when comparing the capacities in this table to Table 3-1.

Figure 3-5 presents the coal-fired plants currently (as of June 2008) operating wet FGD scrubber systems. Figure 3-6 present the coal-fired plants projected to be operating wet FGD scrubber systems in 2020. The capacities represented in Figures 3-5 and 3-6 are for the plant-level wet scrubbed capacity and do not represent the total coal-fired or total generating capacity at the plant. The coal-fired plants with FGD systems are heavily concentrated in the eastern United States due to use of higher sulfur coal (e.g., eastern bituminous). Figures 3-5 and 3-6, also show that the number of plants operating wet FGD scrubbers is expected to increase significantly, as is the wet scrubbed capacity.



Source: [ERG, 2008a], [ERG, 2008f]
Note: The capacities in the figure represent the plant-level wet scrubbed capacity for the entire plant; they do not represent the plant's total coal-fired or total generating capacity. The capacities for the EIA-767 data represent the reported nameplate capacity. The capacities for the UWAG-provided data, data request information, and site visit and sampling information are based on information provided to EPA and may represent various capacities (e.g., nameplate capacity, net summer capacity, gross winter capacity).

Figure 3-5. Coal-Fired Power Plants Operating Wet FGD Scrubber Systems, as of June 2008



Source: [U.S. EPA, 2008b], [ERG, 2008f]
Note: The capacities in the figure represent the plant-level wet scrubbed capacity for the entire plant; they do not represent the plant's total coal-fired or total generating capacity. The projected capacities presented are from estimates based on the IPM model. The IPM model uses a variety of capacities in its estimates, but preferentially uses summer and winter capacity before nameplate capacity.

Figure 3-6. Coal-Fired Power Plants Projected to be Operating Wet FGD Systems in 2020

3.1.3 FGD Wastewater Characteristics

This section discusses the characteristics of FGD wastewaters based on information EPA has collected thus far in the study. Section 3.1.1 describes how the FGD wastewaters are generated, while this section discusses what constituents may be present in the wastewater and flow rate information. Pollutant concentration data are presented for samples collected during the EPA wastewater sampling program, as are flow rate data from EPA's site visit and sampling program and responses to EPA's data request. See Chapter 2 for a description of EPA's data collection activities.

As described in Section 3.1.1 and Figure 3-1, the FGD scrubber blowdown (i.e., the slurry stream exiting the FGD scrubber which is not immediately recycled) is typically intermittently transferred from the FGD scrubber to the solids separation process. As a result, the FGD scrubber purge (the waste stream from the FGD scrubber system that is transferred to a wastewater treatment system or discharged) typically is also intermittent. The characteristics and flow rate of the FGD scrubber purge wastewater depend upon the type of coal, the type of scrubber, and the type of slurry dewatering process used at the plant, as well as the plant's scrubber operating practices.

Table 3-5 summarizes the FGD scrubber purge flow rates reported in the data request responses and collected during EPA's site visit and sampling program. The normalized flow rates are based on the plants' scrubbed capacity, not the plants' total coal-fired or total generating capacity. The 24 plants included in Table 3-5 operate a total of 51 wet FGD systems, which scrub the flue gas from 57 coal-fired units. The average scrubbed capacity per plant is 1,280 MW and the median scrubbed capacity per plant is 1,270 MW. The scrubber purge flow rates reported, including the normalized flow rates, vary significantly from plant to plant. Factors contributing to this variance include the type of coal burned and its characteristics (e.g., chlorine content), scrubber design, and operating practices for the FGD system, such as chlorides concentration/solids content set point and additive use. Figures 3-7 and 3-8 presents the distribution of the scrubber purge flow rates for the 24 plants included in Table 3-5. The average gallons per day (GPD)/plant and GPD/Scrubbed MW scrubber purge flow rates are similar to the FGD blowdown stream flow rates EPA observed when developing the effluent guidelines promulgated in 1982 (671,000 GPD/plant and 811 GPD/MW) [U.S. EPA, 1982].

Table 3-5. FGD Scrubber Purge Flow Rates

	Number of Plants [a]	Average Flow Rate [b]	Median Flow Rate [b]	Range of Flow Rate [b]
Flow Rate per Plant				
GPM/plant [c]	24	451	325	30.0 – 1,270
GPD/plant [d]	24	622,000	382,000	43,200 – 1,830,000
GPY/plant [d]	24	222,000,000	139,000,000	15,800,000 – 667,000,000
Normalized Flow Based on Scrubbed Capacity				
GPM/Scrubbed MW [c]	24	0.494	0.210	0.0366 – 2.16
GPD/Scrubbed MW [d]	24	681	297	52.7 – 3,100
GPY/Scrubbed MW [d]	24	238,000	108,000	19,200 – 1,130,000

Source: Data request information [U.S. EPA, 2008a], and site visit and sampling information.

a – Sixteen plants reported operating wet FGD systems in the data request and 14 of the plants visited by EPA as part of the site visit/sampling program operated wet FGD systems at the time of the visit. Two plants were included in both data sets and are only included once in Table 3-5. Two plants from the data request are not included in this summary because their wet FGD systems did not generate scrubber purge in 2006, one plant from the data request is not included because it began operation of its wet FGD system in early 2007 and therefore, did not generate scrubber purge in 2006, and one plant from the data request is not included because it only discharged scrubber purge while testing emergency transfer pumps, which is required once per month.

b – The flow rates presented have been rounded to three significant figures.

c – The GPM flow rate represents the flow rate during the actual purge.

d – Because some of the FGD scrubber purge flow rates are intermittent, GPD cannot be directly calculated from GPM. Similarly, some of the scrubber purge flows are not generated 365 days per year, so GPY cannot be directly calculated from GPD.

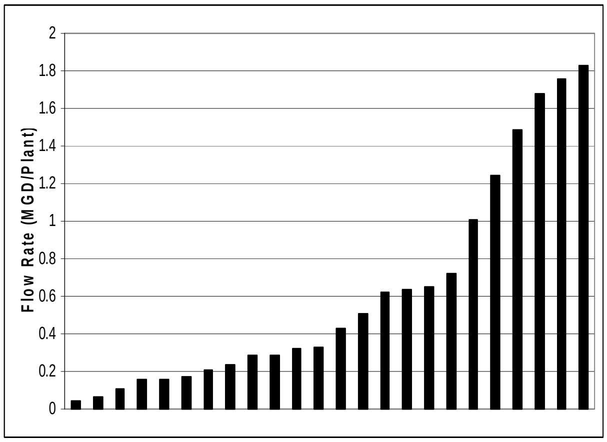


Figure 3-7. FGD Scrubber Purge Flow Rate Distributions from EPA Data Request Responses, Site Visits, and Sampling

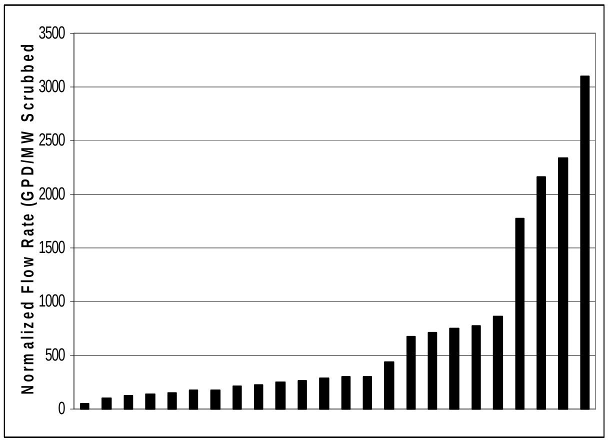


Figure 3-8. FGD Scrubber Purge Normalized Flow Rate Distributions from EPA Data Request Responses, Site Visits, and Sampling

Source: Data request information [U.S. EPA, 2008a], and site visit and sampling information.

The pollutant concentrations in FGD scrubber purge vary from plant to plant depending on the coal type, the sorbent used, the materials of construction in the FGD system, and the FGD system operation. Generally, burning a higher sulfur coal will lead to a higher flow rate for the scrubber blowdown and scrubber purge. Higher sulfur coals produce more sulfur dioxide in the combustion process, which in turn increases the amount of sulfur dioxide removed in the scrubber. As a result, more solids are generated in the reaction in the scrubber, which increases blowdown volumes.

Likewise, a high chlorine coal can increase the volume and frequency of the scrubber blowdown and scrubber purge. Many FGD systems are designed with materials resistant to corrosion for specific chloride concentrations. A generating unit burning coal with higher chlorine content will reach the maximum allowable chloride concentration in the scrubber more quickly, which will trigger the blowdown more frequently (and more importantly, the need to purge FGD wastewater to prevent chloride concentrations from exceeding allowable limits).

The wastewater treatment system treating the FGD scrubber purge may also affect the scrubber purge flow rate depending on whether it has any design constraints for particular pollutants, such as chloride concentrations for a constructed wetland treatment system.

Table 3-6 presents the pollutant concentrations representing the influent to the FGD wastewater treatment systems for the four plants that EPA sampled with FGD wastewaters.[9] The fifth plant sampled by EPA is not included in Table 3-6 because it did not have an operating FGD system at the time of sampling.

For the Big Bend sampling episode, EPA collected a grab sample of the influent to the wastewater treatment system downstream of the equalization tank feeding the treatment system. The equalization tank receives FGD scrubber purge from secondary hydroclones, off-

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[9] Note that the influent-to-treatment sample obtained for a given plant does not necessarily represent the unaltered scrubber purge, since the sample collected may include both scrubber purge and treatment system recirculation flow streams.

specification effluent, backwash from sand filters, off-specification filter press filtrate, wash water from polymer storage containers, and fume scrubber wastewater from the muriatic acid tank. During sampling, the plant transferred 154 gpm of off-specification filter press filtrate to the equalization tank, which caused the plant to divert some of the FGD scrubber purge away from the equalization tank; therefore, only 96 gpm of FGD scrubber purge was transferred to the equalization tank during the sampling episode. The total flow rate at the sampling point during the sampling episode was 250 gpm, thus scrubber purge comprised only one-third of the total influent-to-treatment flow sampled by EPA. The sampling episode report for Big Bend contains more detailed information regarding the sample collection procedures [ERG, 2008m].

For the Homer City sampling episode, EPA collected a grab sample of the influent to the wastewater treatment system downstream of the equalization tank feeding the treatment system. The equalization tank receives FGD scrubber purge from the secondary hydroclones and backwash from sand filters. During sampling, the flow rate from the equalization tank to the wastewater treatment system was 109 gpm. The sampling episode report for Homer City contains more detailed information regarding the sample collection procedures [ERG, 2008j].

Widows Creek operates once-though scrubbers (i.e., no recirculation of slurry within the absorber), with the scrubber blowdown continuously sent to settling ponds. For the Widows Creek sampling episode, EPA collected a four-hour composite sample of the influent to the FGD settling pond from a diked channel containing FGD scrubber blowdown from the two FGD scrubbers. EPA collected the samples from the diked channel at a point downstream of the influent to the channel to allow for some initial solids settling, but upstream of the inlet to the FGD settling pond. At the time of the sampling, although one of the generating units operating a FGD scrubber was shut down and therefore not sending flue gases through the scrubber, the plant continued to transfer water from the scrubber to the FGD settling pond. The flow rate entering the FGD settling pond at the time of sampling was approximately 1,170 gpm, and plant personnel estimated that approximately 390 gpm of the flow rate (one-third of the entire flow) was from the FGD scrubber of the unit that was shut down. The sampling episode report for Widows Creek contains more detailed information regarding the sample collection procedures [ERG, 2008n].

For the Mitchell sampling episode, EPA collected a grab sample of the FGD scrubber purge transfer to the FGD wastewater treatment system. The sample collected contained only FGD scrubber purge, which was transferred to the system at a flow rate of approximately 500 gpm. The sampling episode report for Mitchell contains more detailed information regarding the sample collection procedures [ERG, 2008k].

Table 3-6 shows that FGD wastewater contains significant concentrations of chloride, total dissolved solids (TDS), nutrients, and metals, including bioaccumulative metals such as arsenic, mercury, and selenium. Table 3-6 also shows that some of the pollutants are more likely to be present in the particulate phase (e.g., aluminum, chromium, mercury), whereas other pollutants are almost exclusively present in the dissolved phase (e.g., boron, magnesium, manganese). The pollutant concentrations present in the FGD wastewater are large enough that the waste stream typically requires some form of treatment prior to being discharged, at a minimum to lower the total suspended solids (TSS) concentrations to meet the 30 mg/L (30-day average) ELG limit for low-volume wastewaters (see Section 3.1.4 for more details).

Table 3-6. Influent to FGD Wastewater Treatment System Concentrations

Analyte	Method	Unit	Big Bend – Influent to FGD Wastewater Treatment [a]	Homer City – Influent to FGD Wastewater Treatment [a]	Widows Creek – FGD Scrubber Blowdown [a]	Mitchell – FGD Scrubber Purge [a]
Routine Metals - Total						
Aluminum	200.7	UG/L	31,200	289,000	234,000	17,900
Antimony	200.7	UG/L	62.5	86.4	ND (86.9)	28.7
Arsenic	200.7	UG/L	75.5	1,590	523	72.5
Barium	200.7	UG/L	1,590	11,900 R	7,200	588
Beryllium	200.7	UG/L	12.9	28.8	44.3	8.04
Boron	200.7	UG/L	626,000	224,000	28,900	229,000
Cadmium	200.7	UG/L	224	150	89.2	19.7
Calcium	200.7	UG/L	6,690,000	3,220,000	5,990,000	3,030,000
Chromium	200.7	UG/L	757	1,400	1,360	70.7
Cobalt	200.7	UG/L	172	369	ND (217)	68.0
Copper	200.7	UG/L	120	811	653	164
Iron	200.7	UG/L	23,500	824,000	299,000	60,600
Lead	200.7	UG/L	69.1	340	436	103
Magnesium	200.7	UG/L	4,830,000	2,760,000	321,000	1,470,000
Manganese	200.7	UG/L	21,900	225,000	2,780	28,800
Mercury	245.1	UG/L	ND (10.0)	243	26.5	67.5
Molybdenum	200.7	UG/L	618	375	1,340	65.0
Nickel	200.7	UG/L	2,090	2,560 R	489	554
Selenium	200.7	UG/L	4,150	4,000 R	652	2,130
Sodium	200.7	UG/L	2,530,000	1,430,000	104,000	314,000
Thallium	200.7	UG/L	ND (10.0)	Exclude	ND (43.4)	ND (10.0)
Titanium	200.7	UG/L	420	1,300 R	8,180	377
Vanadium	200.7	UG/L	724	766	1,580	203
Yttrium	200.7	UG/L	245	586	217	64.9
Zinc	200.7	UG/L	1,540	1,900	3,140	885

Table 3-6. Influent to FGD Wastewater Treatment System Concentrations

Analyte	Method	Unit	Big Bend – Influent to FGD Wastewater Treatment [a]	Homer City – Influent to FGD Wastewater Treatment [a]	Widows Creek – FGD Scrubber Blowdown [a]	Mitchell – FGD Scrubber Purge [a]
Routine Metals – Dissolved						
Aluminum	200.7	UG/L	ND (50.0)	ND (50.0)	86.6	ND (50.0)
Antimony	200.7	UG/L	33.9	ND (20.0)	ND (20.0)	ND (20.0)
Arsenic	200.7	UG/L	18.6	ND (10.0)	13.9	ND (10.0)
Barium	200.7	UG/L	1,820	149 R	257	488
Beryllium	200.7	UG/L	ND (5.00)	10.5	ND (5.00)	6.02
Boron	200.7	UG/L	618,000	254,000	24,100	232,000
Cadmium	200.7	UG/L	179	26.2	ND (5.00)	ND (5.00)
Calcium	200.7	UG/L	4,470,000	1,990,000	849,000	2,350,000
Chromium	200.7	UG/L	ND (10.0)	ND (10.0)	18.7	ND (10.0)
Hexavalent Chromium	D1687-92	UG/L	24.0	ND (2.00)	ND (2.00)	5.00
Cobalt	200.7	UG/L	ND (50.0)	201	ND (50.0)	ND (50.0)
Copper	200.7	UG/L	27.2	14.5	ND (10.0)	ND (10.0)
Iron	200.7	UG/L	ND (100)	ND (100)	ND (100)	ND (100)
Lead	200.7	UG/L	ND (50.0)	ND (50.0)	ND (50.0)	ND (50.0)
Magnesium	200.7	UG/L	4,110,000	3,100,000	176,000	1,370,000
Manganese	200.7	UG/L	9,610	173,000	583	27,900
Mercury	245.1	UG/L	ND (10.0)	ND (10.0)	ND (2.00)	ND (10.0)
Molybdenum	200.7	UG/L	581	30.6	876	22.2
Nickel	200.7	UG/L	851	1,350	ND (50.0)	355
Selenium	200.7	UG/L	3,610	656 R	366	46.9
Sodium	200.7	UG/L	1,970,000	1,440,000	76,700	324,000
Thallium	200.7	UG/L	14.3	61.2	14.3	ND (10.0)
Titanium	200.7	UG/L	12.5	ND (10.0)	ND (10.0)	ND (10.0)
Vanadium	200.7	UG/L	108	ND (20.0)	ND (20.0)	ND (20.0)
Yttrium	200.7	UG/L	ND (5.00)	6.28	ND (5.00)	ND (5.00)
Zinc	200.7	UG/L	16.8	ND (10.0)	ND (10.0)	87.8

Table 3-6. Influent to FGD Wastewater Treatment System Concentrations

Analyte	Method	Unit	Big Bend – Influent to FGD Wastewater Treatment [a]	Homer City – Influent to FGD Wastewater Treatment [a]	Widows Creek – FGD Scrubber Blowdown [a]	Mitchell – FGD Scrubber Purge [a]
Low-Level Metals – Total						
Antimony	1638	UG/L	24.9	31.1	51.8	9.23
Arsenic	1638	UG/L	165	1,220	617	59.9
Cadmium	1638	UG/L	238	52.8 R	86.0	5.28
Chromium	1638	UG/L	651 L	1,270	1,380	176 L
Copper	1638	UG/L	103	747	826	139
Lead	1638	UG/L	69.9	351	545	68.1
Mercury	1631E	UG/L	16.4	533	24.7	138
Nickel	1638	UG/L	2,570	2,840	634	650
Selenium	1638	UG/L	3,470	3,530	651	1,990
Thallium	1638	UG/L	39.8	37.3	93.8	6.33
Zinc	1638	UG/L	1,870	2,130	2,720	730
Low-Level Metals - Dissolved						
Antimony	1638	UG/L	21.9	ND (0.400)	8.90	1.97
Arsenic	1638	UG/L	137	24.2 R	18.0	20.2
Cadmium	1638	UG/L	190	24.5	3.16	ND (1.00)
Chromium	1638	UG/L	ND (160)	ND (16.0)	ND (16.0)	ND (80.0)
Copper	1638	UG/L	ND (40.0)	11.3	ND (4.00)	ND (20.0)
Lead	1638	UG/L	ND (10.0)	ND (1.00)	ND (1.00)	ND (0.500)
Mercury	1631E	UG/L	0.206	0.0809	0.0761	0.0111
Nickel	1638	UG/L	1,030	1,450	29.6	433
Selenium	1638	UG/L	3,280	584	325	443
Thallium	1638	UG/L	39.4	23.2	22.5	4.47
Zinc	1638	UG/L	ND (100)	34.7	ND (10.0)	160
Classicals						
Ammonia As Nitrogen (NH_3-N)	4500-NH_3F	MG/L	31.5	4.12	2.26	1.89
Nitrate/Nitrite (NO_3-N + NO_2-N)	353.2	MG/L	NA	54.5	1.00	20.6

Table 3-6. Influent to FGD Wastewater Treatment System Concentrations

Analyte	Method	Unit	Big Bend – Influent to FGD Wastewater Treatment [a]	Homer City – Influent to FGD Wastewater Treatment [a]	Widows Creek – FGD Scrubber Blowdown [a]	Mitchell – FGD Scrubber Purge [a]
Total Kjeldahl Nitrogen (TKN)	4500-N,C	MG/L	51.6	14.2	22.3	13.3
Biochemical Oxygen Demand (BOD)	5210B	MG/L	1,370	ND (120)	172	21.0
Chloride	4500-CL-C	MG/L	24,200	11,800	832	7,200
Hexane Extractable Material (HEM)	1664A	MG/L	ND (6.00)	ND (5.00)	22.0	11.0
Silica Gel Treated HEM (SGT-HEM)	1664A	MG/L	NA	NA	6.00 E	ND (5.00)
Sulfate	D516-90	MG/L	3,590	6,920	11,900	1,640
Total Dissolved Solids (TDS)	2540 C	MG/L	44,600	23,200	4,740	18,100
Total Phosphorus	365.3	MG/L	0.990	2.64	10.5	3.57
Total Suspended Solids (TSS)	2540 D	MG/L	4,970	13,300	25,300 E	7,320

Source: [ERG, 2008j], [ERG, 2008k], [ERG, 2008m], [ERG, 2008n]

a – The concentrations presented have been rounded to three significant figures.

E – Sample analyzed outside holding time.

L – Sample result between 5x and 10x blank result.

R – MS/MSD % Recovery outside method acceptance criteria.

Exclude – Results were excluded because the MS/MSD samples had a zero percent recovery.

NA – Not analyzed.

ND – Not detected (number in parenthesis is the report limit). The sampling episode reports for each of the individual plants contains additional sampling information, including analytical results for analytes measured above the detection limit, but below the reporting limit (i.e., J-values).

Table 3-7 presents the pollutant concentrations representing the effluent from the FGD wastewater treatment systems for the four plants that EPA sampled with FGD wastewater treatment systems. The fifth plant sampled by EPA is not included in Table 3-7 because it did not have an operating FGD system at the time of sampling.

The Big Bend FGD wastewater treatment system consists of an equalization tank followed by a chemical precipitation system to reduce dissolved metals using lime for hydroxide precipitation and ferric chloride for iron co-precipitation. The plant then adds a flocculating polymer to the wastewater and transfers it to a clarifier to remove the solids. The overflow from the clarifiers is filtered using sand gravity filters, transferred to a final holding tank, and then discharged. EPA collected a grab sample of the effluent from the FGD wastewater treatment system after the final holding tank. The average flow rate of the effluent from the FGD wastewater treatment system during the sampling episode was 104 gpm. The sampling episode report for Big Bend contains more detailed information regarding the sample collection procedures [ERG, 2008m].

The Homer City FGD wastewater treatment system consists of an equalization tank followed by a chemical precipitation system to reduce dissolved metals using lime for hydroxide precipitation, ferric chloride for iron co-precipitation, and a clarifier for solids removal. The FGD wastewater is sent through a first stage of lime and ferric chloride precipitation followed by a clarifier, and the wastewater is then treated in a second stage of lime and ferric chloride precipitation followed by a clarifier. After the second clarifier, the wastewater is transferred to an aerobic biological treatment system designed for the removal of BOD. After the biological system, the wastewater is filtered, transferred to a final holding tank, and discharged. EPA collected a grab sample of the effluent from the FGD wastewater treatment system directly from the final holding tank. The average flow rate of the effluent from the final holding tank during the sampling episode was approximately 107 gpm. The sampling episode report for Homer City contains more detailed information regarding the sample collection procedures [ERG, 2008j].

The Widows Creek FGD wastewater treatment system is a pond system that consisted of three settling ponds at the time of sampling; however, during the two site visits prior to the sampling episode, the plant was operating four settling ponds. The FGD scrubber blowdown is pumped to the inlet channels of the pond system which direct the wastewater to the first FGD settling pond. The overflow from the first FGD settling pond is transferred to a second FGD settling pond and then to a final FGD settling pond. The overflow from the final settling pond is then discharged from the plant. EPA collected a grab sample of the effluent from the FGD wastewater treatment system from the FGD wastewater discharge stream of the third settling pond. EPA estimated that the effluent flow rate from the treatment system was equal to the influent to the treatment system, which was estimated to be 1,170 gpm. The sampling episode report for Widows Creek contains more detailed information regarding the sample collection procedures [ERG, 2008n].

The Mitchell FGD wastewater treatment system consists of a chemical precipitation system to reduce dissolved metals using lime for hydroxide precipitation followed by a clarifier for solids removal. The overflow from the clarifier is transferred to an equalization tank, where treated effluent is recycled by the plant when the system is not discharging. After the equalization tank, the plant uses ferric chloride for iron co-precipitation and then adds an anionic polymer and transfers the wastewater to a second clarifier. The overflow from the second

Table 3-7. Effluent from FGD Wastewater Treatment Systems Concentration

Analyte	Method	Unit	Big Bend – Effluent from FGD Wastewater Treatment [a, b]	Homer City – Effluent from FGD Wastewater Treatment [a, b]	Widows Creek – Effluent from FGD Pond System [a, b]	Mitchell – Effluent from FGD Wastewater Treatment [a, b]
Routine Metals - Total						
Aluminum	200.7	UG/L	ND (50.0)	ND (50.0)	111	ND (50.0)
Antimony	200.7	UG/L	22.1 R	<20.8	ND (20.0)	ND (20.0)
Arsenic	200.7	UG/L	ND (10.0)	ND (10.0)	49.5	<10.3
Barium	200.7	UG/L	1,490	71.3 R	179	433
Beryllium	200.7	UG/L	ND (5.00)	7.68	ND (5.00)	ND (5.00)
Boron	200.7	UG/L	369,000	191,000	31,500	208,000
Cadmium	200.7	UG/L	24.9	ND (5.00)	ND (5.00)	ND (5.00)
Calcium	200.7	UG/L	4,420,000	2,000,000	987,000	2,380,000
Chromium	200.7	UG/L	ND (10.0)	ND (10.0)	ND (10.0)	ND (10.0)
Cobalt	200.7	UG/L	ND (50.0)	ND (50.0)	ND (50.0)	ND (50.0)
Copper	200.7	UG/L	<10.3	12.5	ND (10.0)	16.2
Iron	200.7	UG/L	ND (100)	<117	ND (100)	318
Lead	200.7	UG/L	ND (50.0)	ND (50.0)	ND (50.0)	ND (50.0)
Magnesium	200.7	UG/L	2,510,000	2,610,000	189,000	1,280,000
Manganese	200.7	UG/L	60.1	30,100	623	4,440
Mercury	245.1	UG/L	ND (10.0)	ND (10.0)	ND (2.00)	ND (10.0)
Molybdenum	200.7	UG/L	450 R	37.6	1,500	22.9
Nickel	200.7	UG/L	221	ND (50.0)	ND (50.0)	ND (50.0)
Selenium	200.7	UG/L	2,910 R	771	236	83.6 R
Sodium	200.7	UG/L	1,590,000	1,280,000	69,500	305,000
Thallium	200.7	UG/L	16.8	ND (10.0)	ND (10.0)	ND (10.0)
Titanium	200.7	UG/L	13.5	ND (10.0)	ND (10.0)	<10.1
Vanadium	200.7	UG/L	ND (20.0)	ND (20.0)	42.1	ND (20.0)
Yttrium	200.7	UG/L	ND (5.00)	ND (5.00)	ND (5.00)	ND (5.00)
Zinc	200.7	UG/L	ND (10.0)	ND (10.0)	ND (10.0)	25.4

Table 3-7. Effluent from FGD Wastewater Treatment Systems Concentration

Analyte	Method	Unit	Big Bend – Effluent from FGD Wastewater Treatment [a, b]	Homer City – Effluent from FGD Wastewater Treatment [a, b]	Widows Creek – Effluent from FGD Pond System [a, b]	Mitchell – Effluent from FGD Wastewater Treatment [a, b]
Routine Metals - Dissolved						
Aluminum	200.7	UG/L	ND (50.0)	ND (50.0)	ND (50.0)	ND (50.0)
Antimony	200.7	UG/L	20.8 T	ND (20.0)	ND (20.0)	ND (20.0)
Arsenic	200.7	UG/L	10.8 R,T	ND (10.0)	46.7	ND (10.0)
Barium	200.7	UG/L	1,410	70.6 R,T	191	389
Beryllium	200.7	UG/L	ND (5.00)	7.71	ND (5.00)	ND (5.00)
Boron	200.7	UG/L	397,000	184,000	29,200	199,000
Cadmium	200.7	UG/L	19.3	ND (5.00)	ND (5.00)	ND (5.00)
Calcium	200.7	UG/L	5,210,000	1,930,000	932,000	2,270,000
Chromium	200.7	UG/L	ND (10.0)	ND (10.0)	ND (10.0)	ND (10.0)
Hexavalent Chromium	D1687-92	UG/L	ND (2.00)	ND (2.00)	ND (2.00)	11.0
Cobalt	200.7	UG/L	ND (50.0)	ND (50.0)	ND (50.0)	ND (50.0)
Copper	200.7	UG/L	ND (10.0)	11.8	ND (10.0)	14.1
Iron	200.7	UG/L	ND (100)	166 R	ND (100)	ND (100)
Lead	200.7	UG/L	ND (50.0)	ND (50.0)	ND (50.0)	ND (50.0)
Magnesium	200.7	UG/L	2,930,000	2,510,000	184,000	1,220,000
Manganese	200.7	UG/L	55.6	29,100	543 R	4,120
Mercury	245.1	UG/L	ND (10.0)	ND (10.0)	ND (2.00)	ND (10.0)
Molybdenum	200.7	UG/L	430 T	35.8	1,470	21.4
Nickel	200.7	UG/L	210	ND (50.0)	ND (50.0)	ND (50.0)
Selenium	200.7	UG/L	2,860 R	741 R	226	71.7
Sodium	200.7	UG/L	1,880,000	1,230,000	66,200	300,000
Thallium	200.7	UG/L	12.5	ND (10.0)	ND (10.0)	ND (10.0)
Titanium	200.7	UG/L	13.7	ND (10.0)	ND (10.0)	ND (10.0)
Vanadium	200.7	UG/L	ND (20.0)	ND (20.0)	40.0	ND (20.0)
Yttrium	200.7	UG/L	ND (5.00)	ND (5.00)	ND (5.00)	ND (5.00)

Table 3-7. Effluent from FGD Wastewater Treatment Systems Concentration

Analyte	Method	Unit	Big Bend – Effluent from FGD Wastewater Treatment [a, b]	Homer City – Effluent from FGD Wastewater Treatment [a, b]	Widows Creek – Effluent from FGD Pond System [a, b]	Mitchell – Effluent from FGD Wastewater Treatment [a, b]
Zinc	200.7	UG/L	ND (10.0)	ND (10.0)	ND (10.0)	ND (10.0)
Low-Level Metals - Total						
Antimony	1638	UG/L	14.2	ND (0.400)	11.8	<1.37
Arsenic	1638	UG/L	68.0	23.0	47.6	<25.2
Cadmium	1638	UG/L	25.8	ND (2.00)	3.73	ND (3.00)
Chromium	1638	UG/L	ND (80.0)	ND (16.0)	ND (16.0)	ND (120)
Copper	1638	UG/L	ND (20.0)	9.67	ND (4.00)	ND (30.0)
Lead	1638	UG/L	ND (5.00)	ND (1.00)	ND (1.00)	ND (1.50)
Mercury	1631E	UG/L	0.156	0.117	0.0438	0.788
Nickel	1638	UG/L	381	92.1	36.2	<155
Selenium	1638	UG/L	2,500	613	208	431 T
Thallium	1638	UG/L	31.1	16.0	11.1	3.96
Zinc	1638	UG/L	ND (50.0)	15.2	ND (10.0)	<83.5
Low-Level Metals - Dissolved						
Antimony	1638	UG/L	13.7	ND (0.400)	11.9	1.64
Arsenic	1638	UG/L	72.4	22.5	46.5	20.9 T
Cadmium	1638	UG/L	22.2	ND (2.00)	3.74	ND (1.00)
Chromium	1638	UG/L	ND (80.0)	ND (16.0)	ND (16.0)	ND (80.0)
Hexavalent Chromium	1636	UG/L	ND (5.00)	ND (2.50)	3.20	ND (2.50)
Copper	1638	UG/L	ND (20.0)	9.39	ND (4.00)	ND (20.0)
Lead	1638	UG/L	ND (5.00)	ND (1.00)	ND (1.00)	ND (0.500)
Mercury	1631E	UG/L	0.0688	0.0542	0.0107	0.159
Nickel	1638	UG/L	396	93.5	33.3 L	102
Selenium	1638	UG/L	2,560	620	293	407
Thallium	1638	UG/L	31.5	15.8	11.0	3.99
Zinc	1638	UG/L	ND (50.0)	15.7	ND (10.0)	ND (50.0)

Table 3-7. Effluent from FGD Wastewater Treatment Systems Concentration

Analyte	**Method**	**Unit**	**Big Bend – Effluent from FGD Wastewater Treatment** [a, b]	**Homer City – Effluent from FGD Wastewater Treatment** [a, b]	**Widows Creek – Effluent from FGD Pond System** [a, b]	**Mitchell – Effluent from FGD Wastewater Treatment** [a, b]
Classicals						
Ammonia As Nitrogen (NH_3-N)	4500-NH3F	MG/L	24.1	0.295	0.220	3.49
Nitrate/Nitrite (NO_3-N + NO_2-N)	353.2	MG/L	NA	36.5 R	0.0945	25.4
Total Kjeldahl Nitrogen (TKN)	4500-N,C	MG/L	98.7	3.04	2.51	9.74
Biochemical Oxygen Demand (BOD)	5210B	MG/L	>1,720	ND (120)	<10.0	<7.50
Chloride	4500-CL-C	MG/L	22,500	11,800	1,120	6,700
Hexane Extractable Material (HEM)	1664A	MG/L	6.00	ND (5.00)	ND (5.00)	5.00
Silica Gel Treated HEM (SGT-HEM)	1664A	MG/L	ND (6.00)	NA	NA	ND (4.00)
Sulfate	D516-90	MG/L	1,920	2,790	2,060	1,770
Total Dissolved Solids (TDS)	2540 C	MG/L	40,600	22,600	5,830	17,700
Total Phosphorus	365.3	MG/L	0.355	0.520	0.0115 E	0.0745
Total Suspended Solids (TSS)	2540 D	MG/L	31.5	<5.50	8.00 E	17.5

Source: [ERG, 2008j], [ERG, 2008k], [ERG, 2008m], [ERG, 2008n]

a – The FGD effluent results represent the average of the FGD effluent and the duplicate of the FGD effluent analytical measurements.

b – The concentrations presented have been rounded to three significant figures.

< – Average result includes at least one non-detect value. (Calculation uses the report limit for non-detected results).

> – Result above measurement range.

E – Sample analyzed outside holding time.

L – Sample result between 5x and 10x blank result.

R – MS/MSD % Recovery outside method acceptance criteria.

T – MS/MSD RPD outside method acceptance criteria.

NA – Not analyzed.

ND – Not detected (number in parenthesis is the report limit). The sampling episode reports for each of the individual plants contains additional sampling information, including analytical results for analytes measured above the detection limit, but below the reporting limit (i.e., J-values).

clarifier is transferred to a final holding tank and either transferred to the bottom ash pond and eventually discharged or recycled back to the equalization tank. EPA collected a grab sample of the effluent from the FGD wastewater treatment system from the discharge line of the final holding tank. The average flow rate from the effluent of the FGD wastewater treatment system during the sampling episode was 541 gpm. The sampling episode report for Mitchell contains more detailed information regarding the sample collection procedures [ERG, 2008k].

Table 3-7 shows that treated FGD wastewater from these systems contains significant concentrations of chlorides, TDS, and some metals, including selenium (a bioaccumulative metal). Most metals still present in the treated FGD wastewater are predominantly in the dissolved phase.

3.1.4 FGD Wastewater Treatment

EPA's 2007/2008 detailed study has largely centered on FGD wastewater generated at coal-fired power plants. Sections 3.1.1 and 3.1.3 describe the generation and characteristics of FGD wastewater. This section discusses the various treatment systems available to treat FGD wastewater, as well as treatment technologies that are currently under investigation. The treatment systems and technologies that EPA has identified during this detailed study include the following:

- Settling ponds;
- Chemical precipitation (using hydroxide and/or sulfide);
- Biological treatment;
- Constructed wetlands;
- Zero-liquid discharge; and
- Other technologies under investigation.

Based on information EPA collected throughout the detailed study, most of the plants discharging FGD wastewater use pond-based approaches; however, there are indications that the use of more advanced wastewater treatment systems is increasing.

Table 3-8 presents information on the FGD wastewater treatment systems currently operating at plants included in EPA's data set. Information is provided for 82 out of the 107 plants (77 percent) operating wet FGD scrubber systems as of June 2008, representing 166 out of the 222 wet-scrubbed coal-fired generating units (75 percent). Of these 82 plants, 30 plants (37 percent) do not discharge any FGD wastewater, and another plant achieves zero discharge of the FGD wastewater from several of its wet scrubbers. These plants are able to achieve "zero discharge" by either recycling all FGD wastewater back to the scrubber (27 plants), using evaporation ponds (3 plants), or mixing the FGD wastewater with dry fly ash (one plant).

Fifty-two of the 82 plants currently operating wet FGD scrubbers discharge the FGD wastewater. Of these 52 plants, 31 plants (38 percent of the total; 60 percent of the discharging plants) treat the wastewater using a settling pond, 15 plants (18 percent of the total; 29 percent of the discharging plants) rely on more advanced treatment such as chemical precipitation or biological treatment, two plants use constructed wetlands treatment systems as the primary treatment mechanism, and four plants commingle the FGD wastewater with other waste streams

Table 3-8. FGD Wastewater Treatment Systems Identified During EPA's Detailed Study

	Wet FGD Systems in the Combined Data Set Currently Operating as of June 2008 [a]			**Wet FGD Systems in the Combined Data Set Expected to Begin Operating After June 2008 [b]**		
	Number of Plants with FGD Wastewater Treatment Systems	**Number of Generating Units Serviced by FGD Wastewater Treatment Systems**	**Wet Scrubbed Capacity [c] (MW)**	**Number of Additional Plants Expected to Install FGD Wastewater Treatment Systems [c]**	**Number of Additional Generating Units Expected to be Serviced by FGD Wastewater Treatment Systems [c]**	**Wet Scrubbed Capacity [d] (MW)**
Total	**82**	**166**	**84,100**	**9**	**32**	**18,700**
Settling Ponds	**31**	**64**	**26,700**	**2**	**12**	**8,810**
Combined FGD and Ash Ponds (FGD solids removal prior) [e, f]	19	43	15,000	0	1	750
Combined FGD and Ash Ponds (No FGD solids removal prior) [e, g]	2	3	1,070	—	—	—
FGD Ponds (FGD solids removal prior) [f, h]	4	8	3,540	1	5	4,040
FGD Ponds (No FGD solids removal prior) [g, h]	6	10	7,110	1	6	4,020
Chemical Precipitation ("Chem Precip")	**11**	**20**	**10,400**	**5**	**13**	**7,580**
Chem Precip (type unknown)	—	—	—	1	1	562
Hydroxide Chem Precip	8	15	8,330	2	7	4,200
Hydroxide and Sulfide Chem Precip	1	2	1,230	2	5	2,820
Combination Settling Pond and Chem Precip	2	3	803	—	—	—
Tank-Based Biological	**1**	**3**	**2,150**	**1**	**2**	**1,150**
Anoxic/Anaerobic Biological (designed for metals & nitrogen removal)	1	3	2,150	1	2	1,150

Table 3-8. FGD Wastewater Treatment Systems Identified During EPA's Detailed Study

	Wet FGD Systems in the Combined Data Set Currently Operating as of June 2008 [a]			**Wet FGD Systems in the Combined Data Set Expected to Begin Operating After June 2008 [b]**		
	Number of Plants with FGD Wastewater Treatment Systems	**Number of Generating Units Serviced by FGD Wastewater Treatment Systems**	**Wet Scrubbed Capacity [c] (MW)**	**Number of Additional Plants Expected to Install FGD Wastewater Treatment Systems [c]**	**Number of Additional Generating Units Expected to be Serviced by FGD Wastewater Treatment Systems [c]**	**Wet Scrubbed Capacity [d] (MW)**
Combination Chem Precip and Tank-Based Biological	**3**	**5**	**4,800**	**1**	**5**	**1,140**
Chem Precip and Anoxic/Anaerobic Biological (designed for metals & nitrogen removal)	—	—	—	1	5	1,140
Chem Precip and Aerobic Biological (designed for BOD_5 removal)	2	3	2,400	—	—	—
Chem Precip, Anoxic/Anaerobic Biological (designed for metals & nitrogen removal), and CWTS	1	2	2,400	—	—	—
Zero Discharge	**31**	**60**	**34,600**	**—**	**—**	**—**
Zero Discharge: Recycle All FGD Water	27	55	32,100	—	—	—
Zero Discharge: Evaporation Pond	3	4	1,880	—	—	—
Zero Discharge: Conditioning Dry Fly Ash	1	1	600	—	—	—

Table 3-8. FGD Wastewater Treatment Systems Identified During EPA's Detailed Study

	Wet FGD Systems in the Combined Data Set Currently Operating as of June 2008 [a]			**Wet FGD Systems in the Combined Data Set Expected to Begin Operating After June 2008 [b]**		
	Number of Plants with FGD Wastewater Treatment Systems	**Number of Generating Units Serviced by FGD Wastewater Treatment Systems**	**Wet Scrubbed Capacity [c] (MW)**	**Number of Additional Plants Expected to Install FGD Wastewater Treatment Systems [c]**	**Number of Additional Generating Units Expected to be Serviced by FGD Wastewater Treatment Systems [c]**	**Wet Scrubbed Capacity [d] (MW)**
Other Handling	**6**	**14**	**5,410**	**—**	**—**	**—**
CWTS	2	6	2,480	—	—	—
Commingled with other Wastewater	4	8	2,920	—	—	—

a – Source: UWAG-provided data [ERG, 2008f], data request information [U.S. EPA, 2008a], and site visit and sampling information. Includes treatment systems servicing units identified in the "combined data set" with wet FGD systems operating as of June 2008, and systems in the "combined data set" that will startup after June 2008. Units from the "combined data set" that were identified solely from the EIA-767 data are not included in the table because the FGD wastewater treatment system information for those units is unavailable. The data set shown in this table represents 82 of the 107 plants (77 percent), 166 of the 222 generating units (75 percent), and 81 percent of the wet scrubbed capacity for currently operating wet FGD systems (as of June 2008). The 9 plants that will install new FGD wastewater treatment systems after June 2008 represent only a fraction of future wet FGD installations.

b – Source: Data request information [U.S. EPA, 2008a] and site visit and sampling information. Includes only treatment systems servicing units identified in the "combined data set" with planned wet FGD systems expected to begin operating after June 2008. It does not represent all wet FGD systems that will begin operating after June 2008.

c – 25 of the 32 additional generating units will be serviced by new FGD wastewater treatment systems that will be installed at 9 plants. The remaining 7 of the 32 additional generating units will be serviced by existing FGD wastewater treatment systems; therefore, the plant is not included in the count of "Additional Plants Expected to Install FGD Wastewater Treatment Systems."

d – The capacities presented have been rounded to three significant figures. Due to rounding, the total capacity may not equal the sum of the individual capacities. The capacities for the UWAG-provided data, data request information, and site visit and sampling information are based on information provided to EPA and may represent various capacities (e.g., nameplate capacity, net summer capacity, gross winter capacity). In addition, for some facilities included in the data request, the capacities reported in the UWAG-provided data differed from the capacities reported in the data request.

e – The combined FGD and ash pond system refers to a settling pond that handles untreated FGD scrubber purge and ash wastewaters (either bottom ash or fly ash sluice). Some plants transferred treated FGD wastewaters to the ash pond for dilution prior to discharge, but these systems are not reflected in this table.

f – "FGD Solids removal prior" means that gypsum or calcium sulfite sludge was removed prior to treatment.

g – "No FGD Solids removal prior" means that gypsum or calcium sulfite sludge was sent to the settling pond.

h – The FGD pond system refers to settling ponds that handle untreated FGD scrubber purge, but do not handle ash wastewaters. The FGD pond may handle other wastewaters along with the FGD scrubber purge, such as low-volume wastes, but the pond cannot receive ash wastewaters to be considered an FGD pond.

(other than ash sluice water). Note that many plants commingle the FGD waste stream with other wastewater streams following the management practice shown in Table 3-8.

Table 3-8 also presents information for the type of treatment systems that will be used treat wastewater from new FGD scrubbers that will begin operating in the next few years, using information reported by the companies responding to EPA's data request. Data are provided for nine plants that do not currently operate FGD wastewater treatment systems, and thus will be installing new treatment systems as scrubbers are installed. Despite recent interest in the use of more advanced wastewater treatment systems, the data indicate that the use of pond systems may continue to be significant, particularly at the plants that have pre-existing ponds.

EPA investigated whether there is a relationship between FGD system age and the type of treatment system used. Wastewater from FGD systems that came online in the 1970s, 1980s, and early 1990s is typically treated in pond systems or recycled. In a couple of cases, wastewater from FGD systems that came on line in the mid-1980s is treated with hydroxide chemical precipitation systems. Most of the more advanced wastewater treatment systems are associated with plants that installed FGD scrubbers in the last decade. However, the move toward advanced treatment systems is not universal and some plants have reported that they intend to use existing or new settling ponds to treat the wastewater from new scrubbers.

The following sections discuss individual FGD wastewater treatment systems and technologies. For some of the technologies that are under investigation, such as those discussed in Section 3.1.4.6, EPA has only limited information at this time.

3.1.4.1 Settling Ponds

Settling ponds are designed to remove particulates from wastewater by means of gravity. To accomplish this, the wastewater must reside in the pond long enough for removal of the desired particle size. The size and configuration of settling ponds vary by plant; some settling ponds operate as a system of several ponds, while others consist of one large pond. The ponds are generally sized to provide a certain residence time to reduce the TSS levels in the wastewater and to allow for a certain life-span of the pond based on the rate of solids buildup within the pond. Coal-fired power plants do not typically add treatment chemicals to settling ponds, other than to adjust the pH of the wastewater before it exits the pond to bring it into compliance with NPDES permit limits.

Settling ponds can effectively reduce the amount of TSS in wastewater, as well as specific pollutants that are in particulate form, provided that the settling pond has a sufficiently long residence time; however, settling ponds are not designed to reduce the amount of dissolved metals. Table 3-6, in Section 3.1.3, shows that the FGD wastewater entering a treatment system contains significant concentrations of several pollutants in the dissolved phase of the wastewater, including boron, manganese, and selenium. Therefore, these dissolved metals are likely discharged if FGD wastewater is treated in settling ponds. Additionally, EPRI has reported that adding FGD wastewater to ash ponds may reduce the settling efficiency in the ash ponds, due to gypsum particle dissolution, thus increasing the effluent TSS concentration [EPRI, 2006b].

The pond systems used by power plants for treating FGD wastewater have the potential to undergo seasonal turnover effects, similar to other ponds and lakes that become thermally stratified as a result of seasonal conditions. During the summer, some temperate lakes may become thermally stratified. When this occurs, the top layer of the lake is warmer and contains higher levels of dissolved oxygen, whereas the bottom layer of the lake is colder and has significantly lower levels of oxygen, often being anoxic. Typically during fall, as the air temperature decreases, the upper layer of the pond becomes cooler and more dense, then sinks and causes the entire volume of the lake to circulate. Solids that have settled at the bottom of the pond could potentially become resuspended due to the mixing, leading to increased concentrations of pollutants being discharged during the turnover period. In addition, EPA believes that anaerobic conditions at the bottom of the pond may promote the formation of methylmercury, which could then be present in the discharge. Seasonal turnover effects are largely dependent on the size and configuration of the pond or lake, and some ponds likely do not experience turnover because they are too small and shallow; however, some of the power plant settling ponds are large and deep (e.g., 340 acres, greater than 10 meters deep). EPA will continue to investigate this phenomenon as it relates to pollutant discharges from coal-fired power plants.

As shown in Table 3-8, settling ponds are the most commonly used systems for managing FGD wastewater within EPA's combined data set. Sixty percent of the plants discharging FGD wastewater use settling ponds (31 of 52 plants), and most of those plants transfer FGD scrubber purge wastewater (or FGD scrubber blowdown) directly to a settling pond that also treats other waste streams, specifically fly ash sluice and/or bottom ash sluice. Ten of the 31 plants transfer the FGD scrubber purge wastewater (or FGD scrubber blowdown) to a settling pond specifically designated for the treatment of FGD wastewater. In these cases, the FGD wastewater pond effluent is either discharged directly to surface waters or transferred to a commingled settling pond for further settling and dilution.

EPA has also identified two plants (one currently operating FGD system and one planned) that transfer the FGD scrubber purge to a settling pond for initial solids removal and then transfer the wastewater to a biological treatment system for further treatment.

Most settling pond systems within EPA's combined data set are associated with wet FGD systems that were installed prior to 2000. More advanced treatment systems have received increased attention in recent years; however, information compiled by EPA indicate that the use of pond systems may continue to be significant in the future, with some plants currently without scrubbers announcing that they will rely on settling ponds to treat FGD wastewater. Settling ponds are also expected to be the treatment system of choice for wastewater from scrubbers that will be installed at plants already operating at least one wet FGD system.

3.1.4.2 Chemical Precipitation

In a chemical precipitation wastewater treatment system, chemicals are added to the wastewater to alter the physical state of dissolved and suspended solids to facilitate settling and removal of the solids. The specific chemical(s) used depends upon the type of pollutant requiring removal. In the case of metals removal, lime (calcium hydroxide) is often added to elevate the pH of the wastewater and facilitate the precipitation of metals into insoluble hydroxides. The calcium carbonate formed from the precipitation reaction acts as a coagulant for the metal hydroxides. A significant amount of lime is required for metals precipitation/coagulation if it used alone, whereas less lime is required if used together with an iron salt such as ferric chloride. The ferric chloride acts as a coagulant, forming a dense floc that enhances settling of the metals precipitate in downstream clarification stages. Additionally, ferric chloride may coprecipitate some metals and organic matter.

In chemical precipitation systems designed to treat FGD wastewater, sulfide chemicals (e.g., trimercapto-s-triazine (TMT), Nalmet®, sodium sulfide) may be added to enhance the precipitation and removal of heavy metals, such as mercury. While precipitation due to hydroxide addition can remove some heavy metals, precipitation due to sulfide addition can remove additional heavy metals because metal sulfides have lower solubilities than metal hydroxides. FGD wastewater chemical precipitation systems may include various configurations of lime, ferric chloride, and sulfide addition stages, as well as clarification stages.

The EPA site visit and sampling program has focused on chemical precipitation systems currently in place to treat FGD wastewater. Of the 14 coal-fired power plants that EPA visited that were operating FGD systems at the time of the visit, nine of the plants operate a chemical precipitation system (either hydroxide or both hydroxide and sulfide) to treat the FGD wastewater. Figure 3-9 presents a process flow diagram of a typical precipitation system (hydroxide and sulfide addition) based on information EPA collected during site visits. Note that a chemical precipitation system that does not include sulfide precipitation is similar to the system shown in Figure 3-9, except that it would not include reaction tank 2, where the sulfide is added.

In the chemical precipitation system shown in Figure 3-9, the FGD scrubber purge wastewater from the plant’s hydroclones is transferred to an equalization tank, where the intermittent flows from the hydroclones are equalized, allowing the plant to pump a constant flow rate of FGD scrubber purge through the treatment system. The equalization tank also receives wastewater from a filtrate sump, which includes water from the gravity filter backwash and filter press filtrate.

The FGD scrubber purge is transferred at a continuous flow from the equalization tank to reaction tank 1, where the plant adds hydrated lime to raise the pH of the wastewater from between 5.5 – 6.0 to between 8.0 – 10.5 to precipitate the soluble metals as insoluble hydroxides and oxyhydroxides. The reaction tank also desaturates the remaining gypsum in the wastewater, which prevents gypsum scale formation in the downstream wastewater treatment equipment.

From reaction tank 1, the wastewater flows to reaction tank 2, where organosulfide (most commonly TMT) is added. Plants either operate the organosulfide precipitation step after the hydroxide precipitation step, as shown in Figure 3-9, or before the hydroxide precipitation step. Additionally, some plants may operate a clarification step between the two precipitation steps.

From reaction tank 2, the wastewater flows to reaction tank 3, where ferric chloride is added to the wastewater for coagulation. The effluent from reaction tank 3 flows to the flash mix tank, where polymer is added to the wastewater, prior to be being transferred to the clarifier. Alternatively, the polymer can be added directly to the waste stream as it enters the clarifier. The polymer is used to flocculate fine suspended particles in the wastewater.

The clarifier settles the solids that were initially present in the FGD scrubber purge stream as well as the additional solids (precipitate) that were formed during the chemical precipitation steps. The overflow from the clarifier may be acidified with hydrochloric acid to

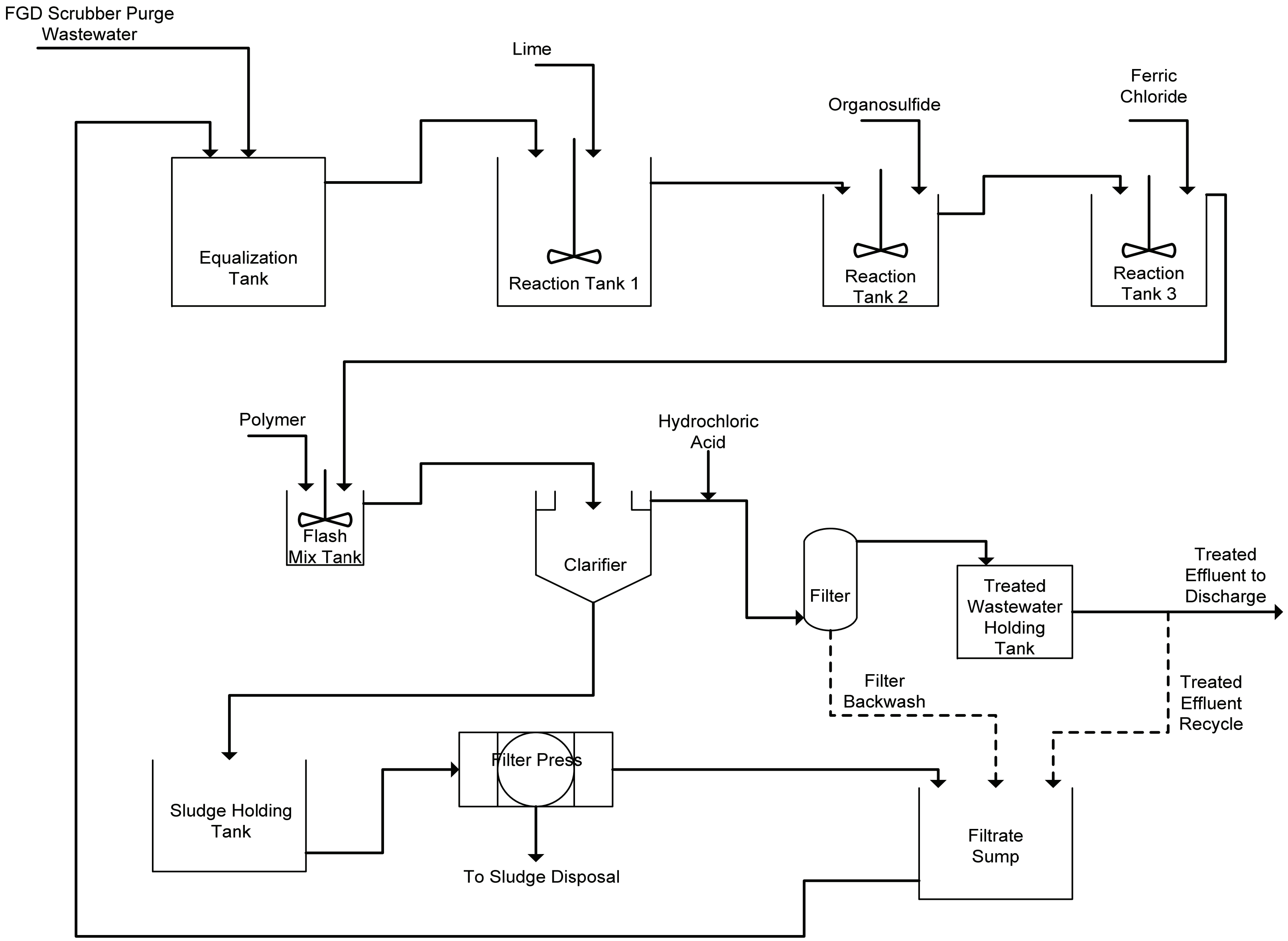

Figure 3-9. Process Flow Diagram for a Hydroxide and Sulfide Chemical Precipitation System

readjust the pH value to meet effluent limits. After acidification, the wastewater may flow through a sand filter. The backwash from the sand filters is transferred to a filtrate sump and recycled back to the equalization tank at the beginning of the treatment system.

The treated FGD wastewater is collected in a wastewater holding tank and either discharged directly to surface waters or, more commonly, commingled with other waste streams prior to discharge. As described in Section 3.1.1, plants do not normally recycle this treated FGD wastewater within the FGD scrubber system because of the chlorides level.

The sludge from the clarifier is transferred to the sludge holding tanks using transfer pumps. The sludge is then dewatered using a filter press. The cake generated from the filter press is typically sent to an on-site landfill for disposal. The filter press filtrate is transferred to a filtrate sump and recycled back to the equalization tank at the beginning of the treatment system.

As shown in Table 3-8, 14 of the 52 currently discharging plants in EPA's combined data set (27 percent) are operating a chemical precipitation system to treat FGD scrubber purge wastewater. Three of these 14 plants operate chemical precipitation systems that include a sulfide precipitation step. The majority of the chemical precipitation systems were installed after 1995.

3.1.4.3 Biological Treatment

Biological wastewater treatment systems use microorganisms to consume biodegradable soluble organic contaminants and bind much of the less soluble fractions into floc. Pollutants may be reduced aerobically, anaerobically, and/or with the use of anoxic zones. Based on the information EPA has collected during the 2007/2008 detailed study, two main types of biological treatment systems are currently used (or planned) to treat FGD wastewater: aerobic systems for BOD5 removal; and anoxic/anaerobic systems for metals and nutrient removal. These systems can use fixed film or suspended growth bioreactors, and operate as conventional flow-through or as sequencing batch reactors (SBR). The subsections below discuss the wastewater treatment processes for each of these biological treatment systems. EPA has compiled information on two aerobic systems and two anoxic/anaerobic systems operating as of June 2008, and five more anoxic/anaerobic systems scheduled to begin operating over the next year. Indications are that additional plants are considering installing biological treatment systems.

Aerobic Biological Treatment

An aerobic biological treatment system can effectively reduce BOD_5 from wastewaters. In a conventional flow-through design, the wastewater is continuously fed to the aerated bioreactor. The microorganisms in the reactor use the dissolved oxygen from the aeration to digest the organic matter in the wastewater, thus reducing the BOD_5. The digestion of the organic matter produces sludge, and may be treated with a vacuum filter to better manage its ultimate disposal. The treated wastewater from the system overflows out of the reactor.

An SBR is a type of activated sludge treatment system that can reduce BOD_5 and, when operated to create anoxic zones under certain operating conditions, it can also achieve nitrification and denitrification. Plants often operate at least two identical reactors that are operated sequentially in batch mode. The treatment in each SBR consists of a four stage process:

fill, aeration and reaction, settling, and decant. While one of the SBRs is settling and decanting, the other SBR is filling, aerating, and reacting.

When operated as an aerobic system, the SBR operates as follows. The filling stage of the SBR consists of transferring the FGD wastewater into the SBR that contains some activated sludge from the previous reaction batch. During the aeration and reaction stage, the reactor is aerated and the BOD_5 is reduced as the microorganisms digest the organic matter in the wastewater. During the settling phase, the air is turned off, and the solids in the SBR are allowed to settle to the bottom. The wastewater is then decanted off the top of the SBR and either transferred to surface water for discharge or transferred for additional treatment. Additionally, some of the solids from the bottom of the SBR are removed and transferred for processing, but some of the solids are retained in the SBR, leaving the microorganisms in the system.

EPA has collected information from two coal-fired power plants operating an aerobic biological reactor as part of the FGD wastewater treatment system. In each case the biological step follow chemical precipitation processes. One plant uses a conventional aerobic biological system while the other operates as an aerobic SBR. Both of these plants use additives in their FGD scrubbers (DBA or formic acid), which increases the BOD_5 concentration in the scrubber purge wastewater. These aerobic biological treatment systems were installed for the purpose of reducing the BOD_5 in the wastewater.

Anoxic/Anaerobic Biological Treatment

Some coal-fired power plants are moving towards the use of anoxic/anaerobic biological systems to achieve better reductions of certain pollutants (e.g., selenium, mercury, nitrates) than has been possible with other treatment processes employed at power plants.

EPA has collected information on two plants currently operating fixed-film anoxic/anaerobic bioreactors and two additional plants that plan to operate similar fixed-film bioreactors in the near future. These plants are each operating (or planning to operate) some form of pre-treatment upstream of the bioreactors, either chemical precipitation or settling ponds, to reduce the wastewater TSS concentration entering the bioreactor.

The fixed-film bioreactor consists of an activated carbon bed that is inoculated with microorganisms, which are tailored on a site-specific basis to reduce selenium and other metals. Growth of the microorganisms within the activated carbon bed creates a fixed-film that retains the microorganisms and precipitated solids within the bioreactor. A molasses-based feed is added to the wastewater prior to entering the bioreactor as a feed source for the microorganisms. [Pickett, 2006]

The bioreactor is designed for plug flow, containing different zones within the reactor that have differing oxidation potential. The top part of the bioreactor is more aerobic and allows for nitrification and organic carbon oxidation. As the wastewater moves down through the bioreactor, it enters an anoxic zone where denitrification occurs as well as reduction of both selenate and selenite. [Pickett, 2006]

As selenate and selenite are reduced within the bioreactor, elemental selenium forms nanospheres that adhere to the cell walls of the microorganisms. Because the microorganisms are retained within the bioreactor by the activated carbon bed, the elemental selenium is essentially fixed to activated carbon until it is removed from the system. The bioreactor can also reduce other metals within the system, including arsenic, cadmium, and mercury. [Pickett, 2006]

Periodically, the bioreactor must be flushed to remove the solids and inorganic materials that have accumulated within the bioreactor. The flushing process involves fluidizing the bioreactor by flowing water upward through the system, which dislodges the particles fixed within the activated carbon. The water and solids overflow from the top of the bioreactor and are removed from the system. This flush water must be treated prior to being discharged because of the elevated levels of solids and selenium. [Pickett, 2006]

Another system developed by a treatment system vendor is based on anoxic/anaerobic biological treatment, but relies on the use of suspended growth flow-through bioreactors instead of fixed film bioreactors. Nevertheless, both designs share the fundamental processes that lead to denitrification and reduction of metals in anoxic and anaerobic environments. This suspended growth bioreactor system is currently undergoing long-term pilot testing.

The anoxic/anaerobic conditions described for the flow-through systems can also be achieved using SBRs. The SBR operation would be similar to that described above for the aerobic biological treatment system; however, to create anoxic conditions the aeration stage would be followed by a period of air on, air off, which creates aerobic zones for nitrification and anoxic zones for denitrification, removing the nitrogen present in the wastewater. EPA has collected information on three coal-fired power plants that are planning to operate anoxic/anaerobic biological SBRs, with startup scheduled to occur by 2010. The SBR systems at these plants are expected to be operated in combination with chemical precipitation systems, with the overall systems designed to optimize reductions of metals and nitrogen compounds.

3.1.4.4 Constructed Wetlands

A constructed wetland treatment system is an engineered system that uses natural biological processes involving wetland vegetation, soils, and microbial activity to reduce the concentrations of metals, nutrients, and TSS in wastewater. A constructed wetland typically consists of several cells that contain bacteria and vegetation (e.g., bulrush, cattails), which are selected based on the specific pollutants targeted for removal. The vegetation completely fills each cell and produces organic matter (i.e., carbon) used by the bacteria. The bacteria reduce metals that are present in the aqueous phase of the wastewater, such as mercury and selenium, to their elemental state. The targeted metals are partitioned into the sediment and taken up by the vegetation in the wetland cells. The wetland cells are contained above a nonpermeable liner. [EPRI, 2006b; Rodgers, 2005]

Constructed wetlands performance can be adversely affected by high temperature, COD, nitrates, sulfates, boron, and chlorides in wastewater. Coal-fired power plants dilute FGD wastewater with service water before it enters a constructed wetland to reduce the chlorides concentration and temperature, which can damage the vegetation in the treatment cells. Chlorides in a constructed wetlands treatment system typically must be maintained below 4,000 mg/L. Most plants operate the FGD scrubber system to maintain chloride levels within in range 12,000-20,000 ppm. As a result, plants operating constructed wetlands treatment systems will need to dilute the FGD wastewater prior to transferring it to the wetland. EPA has observed that plants operating the wetlands tend to operate the FGD system at the lower end of the chloride range. To accomplish this, the plants purge FGD wastewater from the system at a higher flow rate than they otherwise would do if operating the FGD scrubber at a higher chloride level.

Three coal-fired power plants currently operate a constructed wetland for treatment of FGD wastewater. Two of these plants use the constructed wetlands as the main treatment system for the targeted pollutants (i.e., mercury, selenium, nutrients, and TSS). These plants operate a solids removal system (i.e., clarifier) upstream of the CWTS. The third plant operates a hydroxide and sulfide chemical precipitation system followed by a biological treatment system upstream of the CWTS. In this case, the CWTS is used as a polishing step for metals removal.

3.1.4.5 Zero Liquid Discharge

Zero liquid discharge (ZLD) systems are systems that do not generate a waste stream that is discharged from the plant. Based on information EPA has collected during the 2007/2008 detailed study, five main types of ZLD systems are available to treat FGD wastewater: evaporation with distillate recovery, complete recycle, evaporation ponds, conditioning dry fly ash, and underground injection. The subsections below discuss the wastewater treatment processes for each of these ZLD systems.

There is one coal-fired power plant in the U.S. that is currently installing an evaporator to treat FGD scrubber purge resulting in a zero liquid discharge [Water Online, 2007b]. In addition, there are six coal-fired power plants in Italy that are operating or in the process of installing evaporators to treat FGD scrubber purge [Industrial Water World, 2006; Water Online, 2007a]. EPA has identified 27 coal-fired plants that are operating their FGD systems with complete recycle of the scrubber purge. Additionally, EPA has identified two plants that prevent discharging FGD wastewater by using evaporation ponds, and another plant that uses the FGD wastewater to condition the dry fly ash generated. Underground injection is currently being used to dispose of FGD wastewater at one coal-fired power plant, with another plant slated to do so starting next year.

Evaporation with Distillate Recovery

Evaporators in combination with a final drying process can eliminate the discharge of certain wastewater streams at various types of industrial plants, including power plants, oil refineries, and chemical plants. The evaporation ZLD system uses a falling-film evaporator (also referred to as a brine concentrator) to produce a concentrated wastewater stream and a reusable distillate stream. The concentrated wastewater stream may be further processed in a crystallizer or spray dryer, in which the remaining water is evaporated, eliminating the wastewater stream. When used in conjunction with a crystallizer or spray dryer, this process eliminates the liquid discharge stream by generating clean distillate and a solid by-product that can then be disposed of in a landfill.

At power plants, evaporators are most often used to treat waste streams such as cooling tower blowdown and demineralizer waste, but coal-fired power plants have recently begun to consider, install, and operate evaporator systems for the treatment of FGD wastewater as well. In Italy, two coal-fired power plants have recently begun treating FGD wastewater with evaporator systems, and several other plants are installing evaporator systems for the treatment of FGD wastewater. In the United States, there are currently no evaporator systems treating FGD wastewater, but there is at least one plant installing an evaporator system for the treatment of FGD wastewater.

In an evaporator system used to treat FGD wastewater, the first step is to adjust the pH of the FGD scrubber purge to approximately 6.5. After the pH adjustment, the scrubber purge is sent through a heat exchanger to bring the waste stream to its boiling point. The waste stream continues to a deaerator where the noncondensable materials such as carbon dioxide and oxygen are vented to the atmosphere. [Aquatech, 2006]

From the deaerator, the waste stream enters the sump of the brine concentrator. Brine from the sump is pumped to the top of the brine concentrator and enters the heat transfer tubes. While falling down the heat transfer tubes, part of the solution is vaporized and then compressed and introduced to the shell side of the brine concentrator. The temperature difference between the vapor and the brine solution causes the vapor to transfer heat to the brine solution, thereby condensing the compressed vapor as distilled water and vaporizing some of the brine solution. The condensed vapor (distillate water) is recycled within the plant, typically as boiler make-up water. [Aquatech, 2006]

To prevent scaling within the brine concentrator as a result of the gypsum present in the FGD scrubber purge, the brine concentrator is seeded with calcium sulfate. The calcium salts preferentially precipitate onto the seed crystals instead of the tube surfaces of the brine concentrator. [Shaw, 2008]

The concentrated brine slurry from the brine concentrator tubes falls into the sump and is recycled with the feed back to the top of the brine concentrator for additional processing, while a small amount is continuously withdrawn from the sump and transferred for additional processing. The brine concentrator can typically concentrate the FGD scrubber purge five to ten times, which reduces the inlet FGD scrubber purge water volume by 80 or 90 percent. [Shaw, 2008]

Three options are typically considered to be available for eliminating the brine concentrate: (1) final evaporation in a brine crystallizer; (2) evaporation in a spray dryer; or (3) using the brine to condition dry fly ash or other solids and disposal of the mixture in a landfill.

There are a large number of plants currently using brine concentrators to treat a waste stream other than FGD scrubber purge (e.g., cooling tower blowdown). For these non-FGD systems, the concentrated brine withdrawn from the sump would typically be sent to a forced-circulation crystallizer to evaporate the remaining water from the concentrate and generate a solid product for disposal. However, the calcium and magnesium salts present in the scrubber purge can pose difficulties for the forced-circulation crystallizer. To prevent this, the FGD scrubber purge can be pretreated using a lime-softening process (i.e., chemical precipitation) upstream of the brine concentrator. With water softening, the magnesium and calcium ions precipitate out of the purge water and are replaced with sodium ions, producing an aqueous solution of sodium chloride that can be more effectively treated with a forced-circulation crystallizer. [Shaw, 2008]

Coal-fired power plants can avoid having to operate the chemical precipitation pretreatment process by using a spray dryer to evaporate the residual waste stream from the brine concentrator. This approach will create a solid product that can be landfilled. Another alternative to the brine crystallization process is to blend the concentrated brine waste stream with dry fly ash or other solids, and dispose of the resulting mixture in a landfill.

Complete Recycle

As discussed in Section 3.1.1, plants that are not producing a reusable solid product from the FGD system (e.g., wallboard-grade gypsum), may be capable of operating the system without producing a scrubber purge waste stream. Because the solids are being landfilled, the plant will not have a chloride specification for the solids; therefore, the plant will not need to rinse the solids to remove the chlorides before the solids are dewatered. If the plant is able to balance the chlorides generated in the FGD scrubber system with the chlorides retained in the solids that are sent to the landfill, then the plant may be able to operate without a scrubber purge [Sargent & Lundy, 2007].

The other parameter that must be controlled to achieve complete recycle of the FGD wastewater is a negative water balance for the system. Without a negative water balance, some of the FGD wastewater would have to be discharged, or recycled elsewhere within the plant, to prevent the build up of water in the system. Most of the water entering the FGD system is from the sorbent (e.g., lime or limestone) preparation which feeds the sorbent slurry to the FGD scrubber. Additional water is used for washing the mist eliminators, water seal for the vacuum filter seal pumps, and other various equipment washings [Babcock & Wilcox, 2005]. Most of the water entering the system is evaporated as the flue gas is quenched in the FGD scrubber. In addition, water exits the system in the solids disposal, and if necessary, in a scrubber purge stream [Babcock &Wilcox, 2005]. Therefore, if enough chlorides are retained in the calcium sulfite or gypsum solids that are sent to the landfill, then the plant can operate without a scrubber purge.

Evaporation Ponds

Some power plants located in the southwestern United States use evaporation ponds to achieve zero liquid discharge. Because of the warm, dry climate in this region, the plants can send the FGD wastewater to one or more ponds where the water is allowed to evaporate. At these plants, the evaporation rate achieved by the pond is greater than or equal to the flow rate of the FGD wastewater to the pond and no water is discharged from the evaporation pond.

Conditioning Dry Fly Ash

Many plants that operate dry fly ash handling systems need to condition the dry fly ash with water to prevent the fly ash from blowing away while it is being trucked to the landfill or other disposal. EPA has identified one plant that uses FGD wastewater to condition its dry fly ash. In addition, there is another plant that will use an evaporation system in combination with conditioning dry fly ash to achieve zero liquid discharge [Water Online, 2007b]. The plant will use the evaporation system to reduce the volume of the FGD scrubber purge waste stream, and the effluent from the brine concentrator will be mixed with dry fly ash and disposed of in a landfill.

Underground Injection

Underground injection is a technique used to dispose of wastes by injecting them into an underground well. This technique is an alternative to discharging wastewater to surface waters. High pressure pumps are used to inject the wastewater into the concrete-lined wells. The bottom of the well is located between impermeable rock surfaces, which prevent the waste from reaching potable water aquifers. One plant is currently using underground injection for the disposal of FGD scrubber purge and a second plant is expected to begin injecting its scrubber purge for disposal in 2009. Underground injection has its own permitting and regulations, which are not covered under the NPDES program.

3.1.4.6 Other Technologies under Investigation

EPRI is currently conducting studies to evaluate and demonstrate technologies that have the potential to remove trace metals, specifically mercury and selenium, from FGD wastewater. Some of the technologies being studied are already being used to treat FGD wastewater. EPRI is conducting pilot- and full-scale optimization field studies of these developed technologies, including chemical precipitation (organosulfide and iron coprecipitation), constructed wetlands, and an anoxic/anaerobic biological treatment system. Other technologies being studied have been demonstrated on other industrial wastewaters, but have not been tested on FGD wastewaters. [EPRI, 2008a]

Iron Cementation

EPRI has conducted laboratory feasibility studies of the metallic iron cementation treatment technology as a method for removing all species of selenium from FGD wastewater. The iron cementation process consists of contacting the FGD wastewater with an iron powder, which reduces the selenium to its elemental form (cementation). The pH of the wastewater is raised to form hydroxides and the slurry is filtered to remove the precipitates from the wastewater. The iron powder used in the process is separated from the wastewater and recycled back to the cementation step. From the initial studies, EPRI concluded that the metallic iron cementation approach is promising for treating FGD wastewater for multiple species of selenium, including selenite, selenate, and other unknown selenium compounds. EPRI is planning to continue conducting laboratory- and pilot-scale feasibility studies of the technology to evaluate selenium and mercury removal performance. [EPRI, 2008b]

Reverse Osmosis

Reverse osmosis systems are currently in use at power plants, usually for the treatment of cooling tower blowdown wastewaters to achieve a zero liquid discharge. EPRI has identified a high efficiency reverse osmosis (HERO™) process that allows the reverse osmosis system to operate at a high pH, which allows the system to treat high silica wastewaters because silica is more soluble at higher pHs. The wastewater undergoes a water softening process to raise the pH of the wastewater before the HERO™ system.

Although the HERO™ system has been demonstrated for use with power plant cooling tower blowdown wastewater, the system has potentially limited use for FGD wastewater due to the osmotic pressure of the FGD wastewater resulting from the high chloride and TDS concentrations. If the osmotic pressure of the FGD wastewater exceeds the pressure capacity of the membrane, then the reverse osmosis system cannot be used. [EPRI, 2007a]

The use of the HERO™ system for the treatment of FGD wastewater may not be possible at many power plants; however, some plants with lower TDS and chloride concentrations may be able to operate these systems. The HERO™ system is of particular interest for the treatment of boron from FGD wastewaters because boron becomes ionized at an elevated pH and therefore, could be removed using a reverse osmosis system. [EPRI, 2007a]

Sorption Media

Sorption media has been used by the drinking water industry to remove arsenic from the drinking water. These sorption processes are designed to adsorb pollutants onto the media's surface area using physical and chemical reactions. The designs most commonly used in the drinking water industry use metal-based adsorbents, typically granular ferric oxide, granular ferric hydroxide, or titanium based oxides. The sorption media is usually a single use application which can typically be disposed of in a non-hazardous landfill after its use. In addition, the single use design prevents the plant from needing any further treatment of the residuals. According to EPRI, these sorption media have shown removals for the common forms of arsenic and selenium from drinking water. [EPRI, 2007a]

Ion Exchange

Ion exchange systems are currently in use at power plants for the pretreatment of boiler make up water. Ion exchange systems are designed to remove specific constituents from wastewater; therefore, specific metals can be targeted by the system. The ion exchange process does not generate any residual sludge; however, is does generate a regenerant stream which contains the metals stripped from the wastewater. EPA has compiled information on a plant that is pilot testing two ion exchange resins this year. [EPRI, 2007a]

Electro-Coagulation

Electro-coagulation is a technology that uses an electrode to introduce an electric charge to the wastewater, which neutralizes the electrically charged colloidal particles. These systems typically use aluminum or iron electrodes, which are dissolved into the waste stream during the process. The dissolved metallic ions precipitate with the other pollutants present in the wastewater and form insoluble metal hydroxides. According to EPRI, additional polymer or supplemental coagulants may need to be added to the wastewater depending on the specific characteristics. These systems are typically used to treat small waste streams, ranging from 10 to 25 gpm; however, systems up to 50 or 100 gpm may be reasonable. [EPRI, 2007a]

Other Technologies

Other technologies under laboratory-scale study include polymeric chelates, taconite tailings, and nano-scale iron reagents. In addition, EPRI is investigating various physical treatment technologies, primarily for mercury removal, including filtration. [EPRI, 2008a]

3.2 Ash Handling Operations

Combusting coal in steam electric boilers generates solid, noncombustible constituents of the coal, referred to as ash. The heavier ash particles collect on the bottom of the boiler and are referred to as bottom ash. The finer ash particles are light enough to be transferred out of the boiler with the flue gas exhaust and are referred to as fly ash. The characteristics of the ash depend on the type of fuel combusted, how it is prepared prior to combustion, and the operating conditions of the boiler. This section discusses the operations for handling these ash particles and the wastewater generated from the ash handling operations.

3.2.1 Process Description and Wastewater Generation

This section describes the steam electric generating processes for fly ash and bottom ash based on data collected by EPA throughout the 2007/2008 detailed study.

3.2.1.1 Fly Ash Handling Operations

To remove the fly ash particles from the flue gas at coal-fired power plants, most plants operate electrostatic precipitators (ESPs). The ESPs use high voltage to generate an electric charge on the particles contained in the flue gas. The charged particles then collect on a metal plate with an opposite electric charge. As the particles begin to layer on the metal plates, the plates are tapped/rapped to loosen the particles, which fall into collection hoppers. Each unit has multiple hoppers that collect ash from different locations within the ESP. The hoppers located closer to the inlet of the ESP collect the larger fly ash particles that are removed more easily, and the hoppers located closer to the outlet of the ESP collect the finer fly ash particles that are more difficult to remove. In addition, the hoppers at the inlet collect more fly ash than the hoppers at the outlet of the ESP.

Once the fly ash is collected in the hoppers, the plant can either handle the fly ash in a dry or wet fashion. Plants that operate a dry fly ash handling system pneumatically transfer the fly ash from the hoppers to fly ash storage silos. From the silos, the fly ash is loaded into trucks and either hauled to a landfill for disposal or hauled off site for beneficial reuse, such as cement manufacturing.

Plants that operate a wet fly ash handling system use a wastewater stream (e.g., service water) to sluice the fly ash out of the hoppers. The water stream used to sluice the fly ash from the hoppers does not flow through the hoppers, but instead flows through piping connected to the hoppers. The flowing stream creates a vacuum that pulls the fly ash out of the hoppers. Plants usually have a sluice stream for each individual ESP, which operates continuously. Because each ESP has more than one hopper, the plant is continuously cycling through each of the hoppers based on which hopper contains the most fly ash at a given time. The inlet hoppers are sluiced more frequently or for longer periods because they collect more fly ash than the outlet hoppers. This fly ash sluice is most commonly sent to a wet impoundment, referred to as an ash pond.

3.2.1.2 Bottom Ash Handling Operations

Most coal-fired boilers currently in operation in the United States operate dry-bottom boilers as opposed to wet-bottom boilers [Babcock &Wilcox, 2005]. The primary difference between these two types of boilers is that bottom ash is intentionally maintained in a molten, fluid state in the lower portion of a wet-bottom boiler, whereas the bottom ash in a dry-bottom boiler is solidified in the lower portion of the boiler [Babcock &Wilcox, 2005]. The remainder of this discussion focuses on the bottom ash handling operations for a dry-bottom boiler.

In a typical dry-bottom boiler, the lower portion of the boiler slopes inward from the front and rear walls of the boiler, leaving a three- to four-foot opening that runs the width of the bottom of the boiler. These sloped walls and opening allow the bottom ash to feed by gravity to the bottom ash hoppers that are positioned below the boiler. The bottom ash hoppers are connected directly to the boiler bottom to prevent any boiler gases from leaving the boiler. The hoppers have sloped side walls as well, except the hoppers' left and right walls slope downward, which allows the hoppers to have a single exit point. Depending on the size of the boiler, there may be more than one bottom ash hopper running along the opening of the bottom of the boiler. The bottom ash hoppers are filled with water to quench the hot bottom ash as it enters the hopper. [Babcock & Wilcox, 2005]

Once the bottom ash hoppers have filled with bottom ash, a gate at the bottom of the hopper opens and the ash is directed to grinders to grind the bottom ash into smaller pieces [Babcock & Wilcox, 2005]. After the bottom ash hoppers below the boiler have been emptied, the gate at the bottom of the hoppers close and the hoppers again fill with water. The bottom ash hoppers are typically sized to accommodate approximately 8 hours worth of bottom ash generation [Babcock & Wilcox, 2005]; therefore, the bottom ash is sluiced about two to four times a day. The frequency of bottom ash sluicing depends upon the hopper size and the operation of the boiler. The duration of the bottom ash sluice depends upon the number and size of hoppers and the bottom ash sluice flow rate. From EPA's site visit experiences, the bottom ash sluice duration was generally between 30 minutes to one hour for each unit.

After the bottom ash has been ground, the ash is sluiced with water and pumped either to a pond or a dewatering hydrobin[10]. Because the bottom ash particles are heavier than the fly ash particles, they are more easily separated from the sluice water than the fly ash particles. In addition, if the bottom ash sluice water is treated in an ash pond or in a hydrobin system, then the overflow from these systems can be recycled elsewhere within the plant. During the site visit program, EPA visited two plants with segregated bottom ash handling systems and these plants reused the bottom ash overflow to sluice more bottom ash. These plants only discharged the bottom ash overflow if the water began accumulating in the system and needed to be discharged for volume control.

3.2.2 Ash Sluice Water Characteristics

This section discusses the wastewater characteristics of fly ash and bottom ash wastewaters based on information EPA has collected thus far in the study. Section 3.2.1 discusses how these wastewaters are generated, while this section discusses what constituents

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[10] Some plants operate dry bottom ash handling systems. Ash handled in a dry fashion is typically transferred to landfills.

may be present in the wastewater as well as the flow rates reported. In addition, this section presents concentration data (as available) for pollutants present in the waste stream samples that were collected during the EPA wastewater sampling program, as well as flow rate data from responses to EPA's data request. See Chapter 2 for background regarding EPA's data collection activities.

As described in Section 3.2.1.1, the fly ash sluice waste stream is usually a continuous stream from each of the coal-fired units. Fly ash sluice is one of the larger volume flows for coal-fired power plants. Table 3-9 presents the fly ash sluice flow rates reported in the data request responses. The flow rates that are normalized on a MW basis are based on the plants' total coal-fired capacity. The average coal-fired capacity per plant is 1,210 MW and the median coal-fired capacity per plant is 1,140 MW.

Sluice flow rates are not the same as pond overflow rates. In addition to the sluice flow, ash ponds typically receive other waste streams. Factors acting to reduce the pond overflow rate include pond losses from infiltration and evaporation, and whether the water held in the ash pond is recycled back to the plant for reuse. The average fly ash pond overflow flow rates collected during the development of the 1982 effluent guidelines are 2,610,000 GPD/plant and 3,810 GPD/MW. [U.S. EPA, 1982].

Table 3-9. Fly Ash Sluice Flow Rates

	Number of Plants	Average Flow Rate [a]	Median Flow Rate [a]	Range of Flow Rate [a]
Flow Rate per Plant				
GPM/plant [b]	17	5,890	3,000	188 - 27,500
GPD/plant [d]	17	7,640,000	4,030,000	270,000 - 39,600,000
GPY/plant [d]	17	2,710,000,000	1,470,000,000	6,480,000 - 14,500,000,000
Normalized Flow Rate based on Total Coal-Fired Capacity				
GPM/Coal-Fired MW [b, c]	17	4.59	4.08	0.291 - 9.38
GPD/Coal-Fired MW [c, d]	17	5,830	5,140	419 - 11,900
GPY/Coal-Fired MW [c, d]	17	2,090,000	1,870,000	2,050 - 4,350,000

Source: [U.S. EPA, 2008a]

a – The flow rates presented have been rounded to three significant figures.

b – The GPM flow rate represents the flow rate during the actual sluice.

c – For this analysis, EPA assumed that the total capacity for each coal-fired steam electric unit is associated with coal use. Non-coal-fired units are not included in the capacity calculations.

d – Because the fly ash sluice flow rate is not always continuous, the GPD cannot be directly calculated from the GPM. Similarly, some of the fly ash sluice flows are not generated 365 days per year, so GPY cannot be directly calculated from GPD.

As described in Section 3.2.1.2, bottom ash sluice is an intermittent stream from each of the coal-fired units. The bottom ash sluice flow rates are typically not as large as the fly ash sluice flow rates, as typically more fly ash than bottom ash is generated in coal-fired boilers, but bottom ash sluice is still one of the larger volume flows for steam electric plants.

Table 3-10 presents the bottom ash sluice flow rates reported in the data request responses. The flow rates that are normalized on a MW basis are based on the plants' total coal-fired capacity. The average coal-fired capacity per plant is 1,570 MW and the median coal-fired capacity per plant is 1,560 MW.

As was noted above, sluice flow rates are not the same as pond overflow rates. The average bottom ash pond overflow flow rates collected during the development of the 1982 effluent guidelines are 2,600,000 GPD/plant and 3,880 GPD/MW. [U.S. EPA, 1982].

Table 3-10. Bottom Ash Sluice Flow Rates from EPA Data Request Responses

	Number of Plants [a]	Average Flow Rate [b]	Median Flow Rate [b]	Range of Flow Rate [b]
Flow Rate per Plant				
GPM/plant [c]	27	3,370	1,740	358 - 12,600
GPD/plant [e]	27	3,290,000	2,380,000	253,000 - 18,100,000
GPY/plant [e]	27	1,190,000,000	810,000,000	92,400,000 - 6,600,000,000
Normalized Flow Rate Based on Total Coal-Fired Capacity				
GPM/Coal-Fired MW [c, d]	27	2.21	1.18	0.479 - 9.38
GPD/Coal-Fired MW [d, e]	27	1,940	1,600	222 - 7,070
GPY/Coal-Fired MW [d, e]	27	701,000	585,000	81,100 - 2,580,000

Source: [U.S. EPA, 2008a]

a – 29 of the 30 data request plants reported generating bottom ash sluice; however, two plants are excluded from this summary because they were unable to reasonably estimate the bottom ash sluice flow rates.

b – The flow rates presented have been rounded to three significant figures.

c – The GPM flow rate represents the flow rate during the actual sluice.

d – For this summary, EPA assumed that the total capacity for each coal-fired steam electric unit is associated with coal use. Non-coal-fired units are not included in the capacity calculations.

e – Because the bottom ash sluice flow rate is not always continuous, the GPD cannot be directly calculated using only the GPM. Similarly, some of the bottom ash sluice flows are not generated 365 days per year, so GPY cannot be directly calculated from GPD.

The pollutant concentrations in ash sluice wastewater vary from plant to plant depending on the coal used, the type of boiler, and the particulate control system used by the plant. In addition, the waste stream characteristics also vary in a cyclical fashion during the discharges. For example, the fly ash sluice characteristics vary depending on which of the ash hoppers is being sluiced and the bottom ash sluice characteristics at the beginning of the intermittent sluicing period are likely to be different than the characteristics at the end of the sluice period. Table 3-11 presents the pollutant concentrations representing the influent to the ash pond systems.

Table 3-11. Ash Pond Influent Concentrations

Analyte	Method	Unit	Widows Creek – Diked Channel Influent to Combined Ash Pond [a, b]	Cardinal – Influent to Fly Ash Pond [a]
Routine Metals - Total				
Aluminum	200.7	UG/L	94,800	320,000
Antimony	200.7	UG/L	ND (38.0)	ND (81.2)
Arsenic	200.7	UG/L	131	1,520
Barium	200.7	UG/L	6,080	5,060
Beryllium	200.7	UG/L	11.3	71.5
Boron	200.7	UG/L	4,330	2,790
Cadmium	200.7	UG/L	ND (9.50)	39.6
Calcium	200.7	UG/L	103,000	204,000
Chromium	200.7	UG/L	107	1,300
Cobalt	200.7	UG/L	ND (95.0)	381
Copper	200.7	UG/L	188	964
Iron	200.7	UG/L	80,700	298,000
Lead	200.7	UG/L	208	786
Magnesium	200.7	UG/L	25,700	35,100
Manganese	200.7	UG/L	337	1,120
Mercury	245.1	UG/L	2.66	2.31
Molybdenum	200.7	UG/L	65.5	333
Nickel	200.7	UG/L	ND (95.0)	739
Selenium	200.7	UG/L	27.5	ND (20.3)
Sodium	200.7	UG/L	31,200	69,900
Thallium	200.7	UG/L	ND (19.0)	ND (40.6)
Titanium	200.7	UG/L	7,150	24,900
Vanadium	200.7	UG/L	346	2,340
Yttrium	200.7	UG/L	133	521
Zinc	200.7	UG/L	785	1,220
Routine Metals - Dissolved				
Aluminum	200.7	UG/L	663	283
Antimony	200.7	UG/L	ND (20.0)	ND (20.0)
Arsenic	200.7	UG/L	46.0	86.8
Barium	200.7	UG/L	178	164
Beryllium	200.7	UG/L	ND (5.00)	ND (5.00)
Boron	200.7	UG/L	2,150	1,380
Cadmium	200.7	UG/L	ND (5.00)	ND (5.00)
Calcium	200.7	UG/L	40,300	94,800
Chromium	200.7	UG/L	ND (10.0)	ND (10.0)
Hexavalent Chromium	D1687-92	UG/L	ND (2.00)	5.00
Cobalt	200.7	UG/L	ND (50.0)	ND (50.0)
Copper	200.7	UG/L	ND (10.0)	ND (10.0)

Table 3-11. Ash Pond Influent Concentrations

Analyte	Method	Unit	Widows Creek – Diked Channel Influent to Combined Ash Pond [a, b]	Cardinal – Influent to Fly Ash Pond [a]
Iron	200.7	UG/L	ND (100)	ND (100)
Lead	200.7	UG/L	ND (50.0)	ND (50.0)
Magnesium	200.7	UG/L	7,110	15,200
Manganese	200.7	UG/L	ND (15.0)	40.3
Mercury	245.1	UG/L	ND (0.200)	ND (0.200)
Molybdenum	200.7	UG/L	50.1	243
Nickel	200.7	UG/L	ND (50.0)	ND (50.0)
Selenium	200.7	UG/L	26.8	16.6
Sodium	200.7	UG/L	13,400	64,400
Thallium	200.7	UG/L	ND (10.0)	ND (10.0)
Titanium	200.7	UG/L	ND (10.0)	ND (10.0)
Vanadium	200.7	UG/L	66.8	70.7
Yttrium	200.7	UG/L	ND (5.00)	ND (5.00)
Zinc	200.7	UG/L	ND (10.0)	ND (10.0)
Low-Level Metals - Total				
Antimony	1638	UG/L	13.1 L	33.1
Arsenic	1638	UG/L	88.9	519
Cadmium	1638	UG/L	ND (20.0)	9.51
Chromium	1638	UG/L	ND (160)	569
Copper	1638	UG/L	114	719
Lead	1638	UG/L	104	260
Mercury	1631E	UG/L	1.02	1.16
Nickel	1638	UG/L	ND (200)	291
Selenium	1638	UG/L	ND (200)	ND (200)
Thallium	1638	UG/L	ND (4.00)	43.6
Zinc	1638	UG/L	198	720
Low-Level Metals - Dissolved				
Antimony	1638	UG/L	8.54	17.4
Arsenic	1638	UG/L	49.5	80.7
Cadmium	1638	UG/L	ND (2.00)	ND (1.00)
Chromium	1638	UG/L	ND (16.0)	ND (80.0)
Hexavalent Chromium	1636	UG/L	NA	NA
Copper	1638	UG/L	ND (4.00)	ND (20.0)
Lead	1638	UG/L	ND (1.00)	ND (0.500)
Mercury	1631E	UG/L	ND (0.000500)	0.000550
Nickel	1638	UG/L	ND (20.0)	ND (100)
Selenium	1638	UG/L	ND (100)	21.2
Thallium	1638	UG/L	ND (0.400)	3.10
Zinc	1638	UG/L	ND (10.0)	ND (50.0)

Table 3-11. Ash Pond Influent Concentrations

Analyte	Method	Unit	Widows Creek – Diked Channel Influent to Combined Ash Pond [a, b]		Cardinal – Influent to Fly Ash Pond [a]
Classicals					
Ammonia As Nitrogen (NH_3-N)	4500-NH3F	MG/L	0.400		0.170
Nitrate/Nitrite (NO_3-N + NO_2-N)	353.2	MG/L	0.360		2.65
Total Kjeldahl Nitrogen (TKN)	4500-N,C	MG/L	7.41		1.01
Biochemical Oxygen Demand (BOD)	5210B	MG/L	53.0		ND (2.00)
Chloride	4500-CL-C	MG/L	21.4		56.8
Hexane Extractable Material (HEM)	1664A	MG/L	ND (5.00)		7.00
Silica Gel Treated HEM (SGT-HEM)	1664A	MG/L	NA		6.00
Sulfate	D516-90	MG/L	58.1		1,110
Total Dissolved Solids (TDS)	2540 C	MG/L	224		662
Total Phosphorus	365.3	MG/L	16.6		4.03
Total Suspended Solids (TSS)	2540 D	MG/L	9,190	E	23,400

Source: [ERG, 2008l], [ERG, 2008n]
a – The concentrations presented have been rounded to three significant figures.
b – The sample collected from the diked channel influent to the combined ash pond represents only the wastewaters associated with six of the eight generating units. The wastewaters for the other two units enter the combined ash pond at a different point.
E – Sample analyzed outside holding time.
L – Sample result between 5x and 10x blank result.
NA – Not analyzed.
ND – Not detected (number in parenthesis is the report limit). The sampling episode reports for each of the individual plants contains additional sampling information, including analytical results for analytes measured above the detection limit, but below the reporting limit (i.e., J-values).

For the Widows Creek sampling episode, EPA collected a 12-hour composite sample of the influent to the ash pond from a diked channel containing fly ash sluice, bottom ash sluice, and several low-volume wastewaters, including coal pile runoff overflow, boiler blowdown, nonchemical metal cleaning wastewater, roof and switchyard drainage, flow wash water, and miscellaneous cooling water. EPA collected the samples from the diked channel at a point downstream of the influent to the channel to allow for some initial solids settling, but upstream of the open water area of the ash pond. The wastewater contained within the diked channel represents the wastewater generated from six of the eight units at the plant, which represents approximately 42 percent of the plant's generating capacity. The other two units also generate wastewaters that enter the ash pond; however, the wastewaters enter the pond at a different location. Plant personnel estimated that the flow rate entering the ash pond at the time of sampling for the six units was approximately 12.1 mgd. The sampling episode report for Widows Creek contains more detailed information regarding the sample collection procedures [ERG, 2008n].

For the Cardinal sampling episode, EPA collected a three-hour composite sample of the influent to the fly ash pond. The influent to the fly ash pond consisted of fly ash sluice water and some dilution water (approximately one-third of the total influent flow). The fly ash is collected by ESPs at the plant and sluiced to the fly ash pond. During the sampling episode, the plant personnel estimated the influent flow rate to the fly ash pond was 6,330 gpm. The sampling episode report for Cardinal contains more detailed information regarding the sample collection procedures [ERG, 2008l].

Table 3-11 shows that the ash sluice waste streams contain significant concentrations of TSS and metals. The ash sluice metals concentrations are typically lower than those of the FGD wastewater (see Table 3-6), but the TSS concentration is higher. Many of the metals in the ash sluice stream are primarily present in the particulate phase. The TSS and metals concentrations present in the ash sluice water are large enough that the waste stream typically requires some form of treatment prior to being discharged, at a minimum to lower the TSS concentrations to meet the 30 mg/L (30-day average) ELG limit for fly ash and bottom ash transport water (see Section 3.2.3 for more details).

Table 3-12 presents the pollutant concentrations representing the effluent from ash ponds. Each of these pond systems treats different types of wastewater; therefore, the various effluents cannot be directly compared with each other. In addition, the influent concentrations presented in Table 3-11 for Widows Creek should not be directly compared with the effluent concentrations in Table 3-12 because the influent only represents a portion of the waste streams entering the pond system.

Homer City operates a dry fly ash handling system and a wet bottom ash handling system. The bottom ash sluice water from Homer City is first transferred to hydrobins, which remove approximately 90 to 95 percent of the solids from the wastewater. The overflow from the hydrobins is transferred to the two bottom ash ponds operating in parallel. The overflow from the bottom ash ponds is transferred to a clearwell and then discharged or reused to sluice more bottom ash. EPA collected a grab sample of the effluent from the bottom ash treatment system at Plant E directly from the clearwell. The average flow rate discharged from the clearwell during the sampling episode was 314.5 gpm. The sampling episode report for Homer City contains more detailed information regarding the sample collection procedures [ERG, 2008j].

Widows Creek operates a combined fly ash and bottom ash pond system. The fly ash from seven of the eight units (one unit uses the FGD system for particulate control) and bottom ash from all eight units, as well as several other low-volume wastewaters enter the combined ash pond. The wastewater entering the ponds is first collected in two different sumps; from each sump the wastewater flows by gravity through diked channels made of ash until it reaches the main pond. The overflow from the main ash pond flows to a second pond where the plant injects carbon dioxide, if needed, to decrease the pH of the wastewater to within the range of 6.0 to 9.0. The overflow from the second pond enters the pumping basin, where the treated wastewater is pumped to a canal where the plant draws intake water from the river. Alternatively, if the pumping basin begins to overflow, then the plant has an emergency overflow discharge directly to surface water. EPA collected a grab sample of the effluent from the combined ash pond directly from the pumping basin. EPA estimated that the average flow rate discharged from the pumping basin during the sampling episode was 29.9 mgd. The sampling episode report for

Widows Creek contains more detailed information regarding the sample collection procedures [ERG, 2008n].

Mitchell operates a fly ash pond treatment system. The fly ash pond receives the fly ash sluice water from Mitchell, fly ash sluice from a neighboring power plant, wastewater from a coal washing preparation plant, treated acid mine drainage wastewater, and stormwater runoff. The waste streams enter the fly ash pond at various locations within the pond and flow to the dam located at the end of the pond. The dam controls the flow from the pond into a channel that discharges to surface water. EPA collected a grab sample of the effluent from the fly ash pond from the channel discharging to the surface water. The average flow rate discharged from the fly ash pond during the sampling episode was 5,400 gpm. The sampling episode report for Mitchell contains more detailed information regarding the sample collection procedures [ERG, 2008k].

Cardinal operates a fly ash pond treatment system. The fly ash pond receives fly ash sluice water and occasionally some dilution water. The ash sluice water and dilution water enter at the same point in the pond and flow to the dam located at the opposite end of the pond. The dam controls the flow from the pond into a channel that discharges to surface water. EPA collected a grab sample of the effluent from the fly ash pond from the channel discharging to the surface water. The average flow rate discharged from the fly ash pond during the sampling episode was 5,416 gpm. The sampling episode report for Cardinal contains more detailed information regarding the sample collection procedures [ERG, 2008l].

Table 3-12 shows that the treated ash pond effluent wastewaters contain low concentrations of TSS and most nutrients; however, metals are still present in the wastewater. Table 3-12 also shows that most of the metals present in the treated ash pond wastewater are predominantly in the dissolved phase.

Table 3-12. Ash Pond Effluent Concentrations

Analyte	Method	Unit	Homer City – Effluent from Bottom Ash Pond [a]	Widows Creek – Effluent from Combined Ash Pond [a]	Mitchell – Effluent from Fly Ash Pond [a]	Cardinal – Effluent from Fly Ash Pond [a, b]
Routine Metals - Total						
Aluminum	200.7	UG/L	323	1,070	404	344
Antimony	200.7	UG/L	ND (20.0)	ND (20.0)	24.6	21.2
Arsenic	200.7	UG/L	ND (10.0)	38.2	150	77.6
Barium	200.7	UG/L	101	227	133	165
Beryllium	200.7	UG/L	ND (5.00)	ND (5.00)	ND (5.00)	ND (5.00)
Boron	200.7	UG/L	396	2,210	2,350	1,100
Cadmium	200.7	UG/L	ND (5.00)	ND (5.00)	ND (5.00)	ND (5.00)
Calcium	200.7	UG/L	186,000	58,500	115,000	88,400
Chromium	200.7	UG/L	ND (10.0)	13.5	15.9	ND (10.0)
Cobalt	200.7	UG/L	ND (50.0)	ND (50.0)	ND (50.0)	ND (50.0)
Copper	200.7	UG/L	ND (10.0)	ND (10.0)	ND (10.0)	ND (10.0)
Iron	200.7	UG/L	355	144	ND (100)	ND (100)
Lead	200.7	UG/L	ND (50.0)	ND (50.0)	ND (50.0)	ND (50.0)
Magnesium	200.7	UG/L	31,800	6,680	21,000	17,900
Manganese	200.7	UG/L	128	ND (15.0)	ND (15.0)	64.7
Mercury	245.1	UG/L	ND (0.200)	ND (0.200)	ND (0.200)	ND (0.200)
Molybdenum	200.7	UG/L	19.7	143	359	361
Nickel	200.7	UG/L	ND (50.0)	ND (50.0)	ND (50.0)	ND (50.0)
Selenium	200.7	UG/L	6.02	16.2	177	44.5
Sodium	200.7	UG/L	106,000	21,300	526,000	70,800
Thallium	200.7	UG/L	ND (10.0)	ND (10.0)	ND (10.0)	ND (10.0)
Titanium	200.7	UG/L	ND (10.0)	14.5	ND (10.0)	12.6
Vanadium	200.7	UG/L	ND (20.0)	68.5	110	104
Yttrium	200.7	UG/L	ND (5.00)	ND (5.00)	ND (5.00)	ND (5.00)
Zinc	200.7	UG/L	21.6	ND (10.0)	ND (10.0)	ND (10.0)

Table 3-12. Ash Pond Effluent Concentrations

Analyte	Method	Unit	Homer City – Effluent from Bottom Ash Pond [a]	Widows Creek – Effluent from Combined Ash Pond [a]	Mitchell – Effluent from Fly Ash Pond [a]	Cardinal – Effluent from Fly Ash Pond [a, b]
Routine Metals - Dissolved						
Aluminum	200.7	UG/L	231	357	241	130 L
Antimony	200.7	UG/L	ND (20.0)	ND (20.0)	23.9	20.9
Arsenic	200.7	UG/L	ND (10.0)	30.1	138	74.6
Barium	200.7	UG/L	106	206	128	157
Beryllium	200.7	UG/L	ND (5.00)	ND (5.00)	ND (5.00)	ND (5.00)
Boron	200.7	UG/L	397	2,200	2,290	1,090
Cadmium	200.7	UG/L	ND (5.00)	ND (5.00)	ND (5.00)	ND (5.00)
Calcium	200.7	UG/L	192,000	55,400	113,000	87,200
Chromium	200.7	UG/L	ND (10.0)	11.9	14.1	ND (10.0)
Hexavalent Chromium	D1687-92	UG/L	ND (2.00)	12.0	7.00	<3.50
Cobalt	200.7	UG/L	ND (50.0)	ND (50.0)	ND (50.0)	ND (50.0)
Copper	200.7	UG/L	ND (10.0)	ND (10.0)	ND (10.0)	ND (10.0)
Iron	200.7	UG/L	106	ND (100)	ND (100)	ND (100)
Lead	200.7	UG/L	ND (50.0)	ND (50.0)	ND (50.0)	ND (50.0)
Magnesium	200.7	UG/L	32,600	6,430	20,300	17,700
Manganese	200.7	UG/L	129	ND (15.0)	ND (15.0)	42.9
Mercury	245.1	UG/L	ND (0.200)	ND (0.200)	ND (0.200)	ND (0.200)
Molybdenum	200.7	UG/L	20.2	136	330	352
Nickel	200.7	UG/L	ND (50.0)	ND (50.0)	ND (50.0)	ND (50.0)
Selenium	200.7	UG/L	6.10 L	15.3	162	43.8
Sodium	200.7	UG/L	106,000	20,000	514,000	70,300
Thallium	200.7	UG/L	ND (10.0)	ND (10.0)	ND (10.0)	ND (10.0)
Titanium	200.7	UG/L	ND (10.0)	ND (10.0)	ND (10.0)	ND (10.0)
Vanadium	200.7	UG/L	ND (20.0)	64.7	108	99.9
Yttrium	200.7	UG/L	ND (5.00)	ND (5.00)	ND (5.00)	ND (5.00)
Zinc	200.7	UG/L	35.2	ND (10.0)	ND (10.0)	ND (10.0)

Table 3-12. Ash Pond Effluent Concentrations

Analyte	Method	Unit	Homer City – Effluent from Bottom Ash Pond [a]	Widows Creek – Effluent from Combined Ash Pond [a]	Mitchell – Effluent from Fly Ash Pond [a]	Cardinal – Effluent from Fly Ash Pond [a, b]
Low-Level Metals - Total						
Antimony	1638	UG/L	1.09	4.39	25.8	21.9
Arsenic	1638	UG/L	6.52	34.9	142	69.8
Cadmium	1638	UG/L	ND (0.500)	ND (0.500)	1.32	1.14
Chromium	1638	UG/L	ND (4.00)	13.5 L	20.4	4.64 L
Copper	1638	UG/L	2.37	1.49	5.47	2.98
Lead	1638	UG/L	ND (0.250)	0.490	0.580	0.420
Mercury	1631E	UG/L	0.00511	0.00157	0.00212	0.00125
Nickel	1638	UG/L	10.7	ND (5.00)	11.0	10.7
Selenium	1638	UG/L	5.74	17.1	191	45.8
Thallium	1638	UG/L	1.32	1.46	1.72	2.84
Zinc	1638	UG/L	24.2	ND (2.50)	10.1	5.98
Low-Level Metals - Dissolved						
Antimony	1638	UG/L	0.990	4.45	22.5	22.4
Arsenic	1638	UG/L	5.00	29.0	131	68.9
Cadmium	1638	UG/L	ND (0.500)	ND (0.500)	1.17	1.11
Chromium	1638	UG/L	ND (4.00)	12.6 L	16.0	4.49 L
Hexavalent Chromium	1636	UG/L	3.01	14.7	17.4	3.96
Copper	1638	UG/L	2.08	ND (1.00)	4.54	2.27
Lead	1638	UG/L	ND (0.250)	ND (0.250)	ND (0.250)	ND (0.250)
Mercury	1631E	UG/L	0.00141	ND (0.000500)	ND (0.000500)	ND (0.000500)
Nickel	1638	UG/L	10.4	ND (5.00)	9.57	10.6
Selenium	1638	UG/L	5.16	15.6	161	45.0
Thallium	1638	UG/L	1.31	1.49	1.42	2.87
Zinc	1638	UG/L	15.0	ND (2.50)	9.51	4.15

Table 3-12. Ash Pond Effluent Concentrations

Analyte	Method	Unit	Homer City – Effluent from Bottom Ash Pond [a]	Widows Creek – Effluent from Combined Ash Pond [a]	Mitchell – Effluent from Fly Ash Pond [a]	Cardinal – Effluent from Fly Ash Pond [a, b]
Classicals						
Ammonia As Nitrogen (NH_3-N)	4500-NH_3F	MG/L	0.340	0.160	0.150	0.205
Nitrate/Nitrite (NO_3-N + NO_2-N)	353.2	MG/L	37.0	0.230	0.730	4.73 E
Total Kjeldahl Nitrogen (TKN)	4500-N,C	MG/L	1.36	3.39	ND (0.100)	<0.785 L
Biochemical Oxygen Demand (BOD)	5210B	MG/L	ND (2.00)	4.00	2.00	ND (2.00)
Chloride	4500-CL-C	MG/L	90.0	20.0	240	60.0
Hexane Extractable Material (HEM)	1664A	MG/L	ND (5.00)	6.00	ND (5.00)	10.0
Silica Gel Treated HEM (SGT-HEM)	1664A	MG/L	NA	ND (5.00)	NA	ND (4.00)
Sulfate	D516-90	MG/L	1,290	80.7	1,110	494
Total Dissolved Solids (TDS)	2540 C	MG/L	1,250	281	2,050	673
Total Phosphorus	365.3	MG/L	1.09	0.250 E	0.200	0.0870
Total Suspended Solids (TSS)	2540 D	MG/L	5.00	12.0 E	15.0	6.00

Source: [ERG, 2008bj], [ERG, 2008k], [ERG, 2008l], [ERG, 2008n]

a – The concentrations presented have been rounded to three significant figures.

b – The ash pond effluent results represent the average of the ash pond effluent and the duplicate of the ash pond effluent analytical measurements.

< – Average result includes at least one non-detect value. (Calculation uses the report limit for non-detected results).

E – Sample analyzed outside holding time.

L – Sample result between 5x and 10x blank result.

NA – Not analyzed.

ND – Not detected (number in parenthesis is the report limit). The sampling episode reports for each of the individual plants contains additional sampling information, including analytical results for analytes measured above the detection limit, but below the reporting limit (i.e., J-values).

3.2.3 Ash Sluice Treatment Systems

Fly ash sluice and bottom ash sluice are typically treated in large settling pond systems. For plants with wet fly ash handling and wet bottom ash handling, the two sluice streams are often commingled within the same settling pond system along with other waste streams. For plants with only one wet ash handling system (e.g., fly or bottom ash, but typically wet bottom ash), the ash sluice may be treated in an ash pond; however, these pond systems typically include other plant wastewaters. The design and operation of ash settling ponds is comparable to that of FGD settling ponds, which is described in Section 3.1.4.1. Settling ponds can be an effective means of removing TSS from ash sluice water, particularly from bottom ash sluice water, which contains relatively dense ash particles. Settling ponds may also be an effective means of removing some metals from fly ash sluice water when these metals are present in particulate form (see Section 3.2.2). Similar to the FGD settling pond systems, EPA believes that the ash pond systems are likely to undergo seasonal turnover effects, as described in Section 3.1.4.1. Seasonal turnover of the ash pond has the potential to increase the concentration of pollutants in the discharge during the turnover period.

EPA compiled information regarding management techniques for fly ash and wastewater treatment systems for fly ash sluice. Table 3-13 presents fly ash handling practices at plants included in EPA's combined data set, which includes UWAG-provided data, site visits and sampling data, and data request information. As shown in Table 3-13, approximately one-third of these plants handle the majority of their fly ash wet. Table 3-14 shows that 95 percent of the plants that handle any amount of fly ash wet send the fly ash sluice to settling ponds. Ninety-one percent of the fly ash ponds from the combined data set receive both fly ash and bottom ash. Only one of the fly ash ponds included in the combined data set is completely segregated (i.e., it receives only fly ash wastewater).

More plants in the combined data set operate wet bottom ash handling systems than wet fly ash handling systems. Twelve percent of the plants in the combined data set operate all or a portion of their bottom ash dry (11 plants; 20 units; 9,269 MW). Fewer wet fly ash systems are expected because the New Source Performance Standards promulgated in 1982 prohibit the discharge of wastewater pollutants from fly ash transport water. Not surprisingly, EPA has found that the steam electric units generating wet fly ash sluice tend to be older units, while dry ash handling systems tend to be operated on newer units.

The plants within EPA's combined data set that operate wet bottom ash handling systems send their bottom ash sluice to hydrobins, settling ponds, or both (see Section 3.2.1.2 for discussion of these systems). EPA has observed that most bottom ash settling ponds also receive other plant wastewaters. In response to the data request, no plants reported operating segregated bottom ash ponds.

For all of the fly and bottom ash ponds reported in response to the data request, waste streams other than ash sluice ranged from 3 to 93 percent of the total pond influent flow (in 2006). The major types of influent, other than ash sluice, were various types of low-volume wastes, cooling tower blowdown, and FGD wastewater. [U.S. EPA, 2008a]

Table 3-13. Fly Ash Handling Practices at Plants Included in EPA's Combined Data Set

Fly Ash Handling	Number of Plants [a]	Number of Generating Units	Capacity [b]
Wet-Sluiced [c]	32 (34%)	79 (37%)	30,500 (28%)
Handled Dry or Removed in Scrubber [d]	61 (65%)	120 (55%)	69,100 (64%)
Other – Most Ash Handled Dry or Unknown [e]	8 (9%)	18 (8%)	8,110 (8%)
Total	**94**	**217**	**108,000**

Source: UWAG-provided data (including planned units) [ERG, 2008f], data request information (including planned units) [U.S. EPA, 2008a], and site visit and sampling information (including planned units). EPA's combined data set contains information on 116 out of approximately 500 coal-fired power plants, and represents about 20% of the total coal-fired industry. Note that all data request units (those with and without FGD systems) are included in this data set; however, the data set presented in Table 3-3 includes only data request units associated with FGD systems.
a – Number of plants is not additive because some plants operate units with different types of fly ash handling practices.
b – The capacities presented have been rounded to three significant figures. Due to rounding, the total capacity may not equal the sum of the individual capacities. The capacities for the UWAG-provided data, data request information, and site visit and sampling information are based on information provided to EPA and may represent various capacities (e.g., nameplate capacity, net summer capacity, gross winter capacity, etc.).
c – Represents plants/units that handle all or almost all of their fly ash wet.
d – Represents plants/units in which ash is either handled dry (and sold or landfilled) or removed in a scrubber.
e – Represents plants/units that either handle a relatively small amount of their fly ash wet and the rest dry, or for which the information received on fly ash handling was unclear.

Table 3-14. Fly Ash Sluice Wastewater Treatment Systems at Plants Included in EPA's Combined Data Set

Type of Fly Ash Wastewater Treatment System	Number of Plants	Number of Generating Units	Capacity (MW) [a]	Number of Treatment Systems That Also Receive FGD Wastewater
Settling pond, commingled with bottom ash	21 (57%)	64 (66%)	22,200 (58%)	4
Settling pond, NOT commingled with bottom ash	3 (8%)	6 (6%)	5,360 (14%)	1
Settling pond, not known if commingled with bottom ash	11 (30%)	25 (26%)	10,200 (26%)	2
Other (trucked away, no wastewater)	2 (5%)	2 (2%)	747 (2%)	0
Total	**37**	**97**	**38,600**	**7**

Source: UWAG-provided data (including planned units) [ERG, 2008f], data request information (including planned units) [U.S. EPA, 2008a], and site visit and sampling information (including planned units). EPA's combined data set contains information on 116 out of approximately 500 coal-fired power plants, and represents about 20% of the total coal-fired industry. Note that this table represents the plants/units from Table 3-13 that handle any amount of fly ash wet (i.e., the "Wet-sluiced" and "Most Ash Handled Dry" plants/units).
a – The capacities presented have been rounded to three significant figures. Due to rounding, the total capacity may not equal the sum of the individual capacities. The capacities for the UWAG-provided data, data request information, and site visit and sampling information are based on information provided to EPA and may represent various capacities (e.g., nameplate capacity, net summer capacity, gross winter capacity).

3.3 Coal Piles

Coal-fired power plants typically receive the coal via train or barge; however, depending on the location of the mine, trucks could also transport the coal to the plant. The coal is unloaded in a designated area and conveyed to an outdoor storage pile, known as a coal pile. Power plants generally store between 25 and 35 days worth of coal in the coal pile, but this varies by plant. Some coal-fired plants may operate more than one coal pile depending on the location of the boilers and whether different types of coal are used or blended.

3.3.1 Coal Pile Runoff Generation

Rainwater contacting the coal pile generates a waste stream that contains pollutants associated with the coal, referred to as coal pile runoff. The quantity of runoff depends upon the amount of rainfall, the physical location and layout of the pile, and the absorption of water under the pile. The amount of contaminants generated depends upon the coal characteristics and the residence time of water within the coal pile.

3.3.2 Coal Pile Runoff Characteristics

As described in Section 3.3.1, the quantity of coal pile runoff generated depends upon the size, location, and layout of the coal pile, the absorption of water under the pile, and the amount of rainfall at the plant. Coal pile runoff is intermittently transferred to a coal pile runoff pond (only during or immediately after times of rainfall). Table 3-15 presents the estimated coal pile runoff flow rates reported in the data request responses. Most of the flow rates in Table 3-15 were estimated by the plants based on the amount of rainfall at the plant, the size of the coal pile, and a runoff coefficient (based on plant experiences). The flow rates that are normalized on a MW basis are based on the plants' total coal-fired capacity. The average coal-fired capacity per plant is 1,490 MW and the median coal-fired capacity per plant is 1,300 MW.

Table 3-15. Coal Pile Runoff Generation from EPA Data Request Responses

	Number of Plants	Average [a]	Median [a]	Range [a]
DPY/plant [b]	30	133	124	40 - 365
Flow Rate per Plant				
GPY/plant	30	31,100,000	17,600,000	2,070,000 - 364,000,000
Flow Rate Normalized by Coal-Fired Capacity				
GPY/MW [c]	30	19,300	12,600	2,650 - 109,000
Flow Rate Normalized by Tons of Coal Burned				
GPY/Ton of Coal	30	6.61	5.20	1.25 – 26.2

Source: [U.S. EPA, 2008a]

Note: The coal pile runoff flow rate is dependent on the geographic location of the plant (determines the amount of rainfall), the capacity of the plant, and the amount of coal reserve at the plant (determines the size of the pile).

a – The flow rates presented have been rounded to three significant figures.

b – Estimated number of days coal pile runoff wastewater was generated in 2006.

c – For this summary, EPA assumed that the total capacity for each coal-fired steam electric unit is associated with coal use. Non-coal-fired units are not included in the capacity calculations.

The rainfall generating the coal pile runoff can dissolve inorganic salts or cause chemical reactions in the coal piles, which will be carried away in the runoff. Coal pile runoff may contain high concentrations of copper, iron, aluminum, nickel, and other constituents present in coal [U.S. EPA, 1982]. Plants typically direct coal pile runoff wastewaters to a holding pond along with stormwater runoff from other areas near the coal pile. This section does not present pollutant concentration data for coal pile runoff because EPA has not sampled a coal pile runoff waste stream.

3.3.3 Coal Pile Runoff Treatment Systems

Coal pile runoff is typically treated in settling ponds, as mentioned in Section 3.3.2. Based on information received in response to the data request, coal pile runoff ponds are more likely to be segregated than ash ponds. Of the 15 coal pile runoff ponds reported in the data request responses (categorized as coal pile runoff ponds because they do not receive any ash sluice), all but two ponds receive only (or essentially only) coal pile runoff. As is the case for ash settling ponds, coal pile runoff ponds are typically designed for TSS removal. Each of the 15 data request coal pile runoff ponds was reported to be designed for TSS removal. In addition, some plants reported that the ponds were also designed to meet pH targets and three were reported to be designed for metals removal; however, the plants do not appear to be performing any specific treatment for metals removal (i.e., none of the plants reported any chemical addition to the ponds).

During EPA’s site visits and sampling program, EPA determined that many of the plants operating segregated coal pile runoff ponds collect and store the runoff in ponds until the pond is at a level that could overflow. At that point, the plant either discharges the coal pile runoff to surface waters or commingles the coal pile runoff with other wastewater (e.g., transferred to ash pond system) prior to discharge.

4. REFERENCES

Aquatech. 2006. Telephone conversation with Manoj Sharma of Aquatech and T.J. Finseth of Eastern Research Group, Inc. "Aquatech Boron Mitigation System." (11 April). DCN 03639.

Babcock & Wilcox Company. 2005. *Steam: Its Generation and Use*. 41st edition. Edited by J.B. Kitto and S.C. Stultz. Barberton, Ohio. DCN 05759.

Eastern Research Group, Inc. (ERG). 2007a. Memorandum to Ron Jordan, US EPA. "Notes from Site Visit at Tampa Electric Company's Big Bend Station on April 27, 2007." (24 May). DCN 04728.

Eastern Research Group, Inc (ERG). 2007b. Final Generic Sampling and Analysis Plan for Coal-Fired Steam Electric Power Plants . (1 June). DCN 04296.

Eastern Research Group, Inc (ERG). 2007c. Sampling Plan, Wisconsin Electric Power Company's Pleasant Prairie Power Plant. (14 June). DCN 04298.

Eastern Research Group, Inc (ERG). 2007d. Final Engineering Site Visit Report for Georgia Power's Plant Yates. (27 June). DCN 04301.

Eastern Research Group, Inc (ERG). 2007e. Final Engineering Site Visit Report for Georgia Power's Plant Wansley. (27 June). DCN 04302.

Eastern Research Group, Inc (ERG). 2007f. Sampling Plan, Tampa Electric Company's Big Bend Station. (10 July). DCN 04815A1.

Eastern Research Group, Inc (ERG). 2007g. Final Engineering Site Visit Report for Tennessee Valley Authority's Widows Creek Fossil Plant. (18 July). DCN 04714.

Eastern Research Group, Inc (ERG). 2007h. Engineering Site Visit Report for EME Homer City Generation L.P.'s Homer City Power Plant. (09 August). DCN 04718.

Eastern Research Group, Inc (ERG). 2007i. Sampling Plan, EME Homer City Generation L.P.'s Homer City Power Plant. (17 August). DCN 04860A1.

Eastern Research Group, Inc (ERG). 2007j. Sampling Plan, Tennessee Valley Authority's Widows Creek Fossil Plant. (04 September). DCN 04840A1.

Eastern Research Group, Inc (ERG). 2007k. Final Engineering Site Visit Report for Reliant Energy's Conemaugh Power Plant. (17 September). DCN 04717.

Eastern Research Group, Inc (ERG). 2007l. Memorandum to Ron Jordan: Addendum to the Generic Sampling and Analysis Plan for Coal-Fired Steam Electric Power Plants (27 September). DCN 04296A1.

Eastern Research Group, Inc (ERG). 2007m. Sampling Plan, Ohio Power Company's Mitchell Plant. (09 October). DCN 05912A1.

Eastern Research Group, Inc (ERG). 2007n. Sampling Plan, Buckeye Power Company's Cardinal Power Plant. (09 October). DCN 05917A1.

Eastern Research Group, Inc (ERG). 2008a. Coal-Fired Power Plants Operating Wet FGD Scrubber Systems As of June 2008. (14 July). DCN 06167.

Eastern Research Group, Inc (ERG). 2008b. Coal-Fired Power Plants Expected to be Operating Wet FGD Scrubber Systems by 2020. (14 July). DCN 06168.

Eastern Research Group, Inc (ERG). 2008c. Memorandum to Ron Jordan, EPA. "Meeting Between EPA and UWAG on April 10, 2008: Draft Summary of Discussion." (24 July). DCN 05847.

Eastern Research Group, Inc (ERG). 2008d. Memorandum to Ron Jordan, EPA. "Model Plant Size Distributions and IPM Future Scrubbed Capacity Projections. (25 July). DCN 05850.

Eastern Research Group, Inc. (ERG). 2008e. Memorandum to Public Record for the Effluent Guidelines Program Plan 2007/2008, EPA Docket Number OW-2006-0771. "Documentation for the Historical and Projected Capacities for Coal-Fired and Wet FGD Plants." (25 July). DCN 05853.

Eastern Research Group, Inc. (ERG). 2008f. Memorandum to Public Record for the Effluent Guidelines Program Plan 2007/2008, EPA Docket Number OW-2006-0771. "Development of Version One of the Power Plant FGD System Data Set." (29 July). DCN 06128.

Eastern Research Group, Inc. (ERG). 2008g. Final Site Visit Notes for Duke Energy Carolina's Belews Creek Steam Station (Non-CBI). (19 August). DCN 06145.

Eastern Research Group, Inc. (ERG). 2008h. Final Site Visit Notes for Duke Energy Carolina's Marshall Steam Station. (19 August). DCN 06143.

Eastern Research Group, Inc. (ERG). 2008i. Memorandum to Ron Jordan and Ahmar Siddiqui, US EPA. "Quality Assurance Procedures Used for the Steam Electric Data Request Responses." (20 August). DCN 06172.

Eastern Research Group, Inc (ERG). 2008j. Final Sampling Episode Report, EME Homer City Generation L.P.'s Homer City Power Plant. (August). DCN 05823.

Eastern Research Group, Inc (ERG). 2008k. *Final Sampling Episode Report, Ohio Power Company's Mitchell Plant*. (August). DCN 05834.

Eastern Research Group, Inc (ERG). 2008l. Final Sampling Episode Report, Buckeye Power Company's Cardinal Power Plant. (August). DCN 05836.

Eastern Research Group, Inc (ERG). 2008m. Final Sampling Episode Report, Tampa Electric Company's Big Bend Station. (August). DCN 05816.

Eastern Research Group, Inc (ERG). 2008n. Final Sampling Episode Report, Tennessee Valley Authority's Widows Creek Fossil Plant. (August). DCN 05844.

Electric Power Research Institute (EPRI). 1997 - 2001. *PISCES Water Characterization Field Study, Sites A-G*. Palo Alto, CA. DCNs 05060-05065.

Electric Power Research Institute (EPRI). 2005. *The Fate of Mercury Absorbed in Flue Gas Desulfurization (FGD) Systems.* 1009955. Palo Alto, CA. (March) DCN 04538.

Electric Power Research Institute (EPRI). 2006a. *Flue Gas Desulfurization (FGD) Wastewater Characterization: Screening Study.* 1010162. Palo Alto, CA. (March). DCN 04539.

Electric Power Research Institute (EPRI). 2006b. *EPRI Technical Manual: Guidance for Assessing Wastewater Impacts of FGD Scrubbers.* 1013313. Palo Alto, CA. (December). Available online at: http://www.epriweb.com/public/000000000001013313.pdf. Date accessed: 16 May 2008. DCN 04537.

Electric Power Research Institute (EPRI). 2007a. *Treatment Technology Summary for Critical Pollutants of Concern in Power Plant Wastewaters*. 1012549. Palo Alto, CA. (January). Available online at: http://www.epriweb.com/public/000000000001012549.pdf. Date accessed: 26 June 2008. DCN 05794.

Electric Power Research Institute (EPRI). 2007b. *Update on Enhanced Mercury Capture by Wet FGD: Technical Update.* 1012673. Palo Alto, CA. (March). DCN 04536.

Electric Power Research Institute (EPRI). 2007c. Memorandum to Ron Jordan, US EPA. "EPRI Comments on EPA Draft Sampling and Analytical Plan of March 31, 2007." (16 April). DCN 04829.

Electric Power Research Institute (EPRI). 2008a. Environment Quick News: A Monthly Report from EPRI's Environment Sector. Program 56: Effluent Guidelines and Water Quality Management. Available online at: http://mydocs.epri.com/docs/CorporateDocuments/Newsletters/ENV/QN-2008-02/ENV-QN-2008-02.pdf. Date accessed: 16 May 2008. DCN 05793.

Electric Power Research Institute (EPRI). 2008b. Program on Technology Innovation: Selenium Removal from FGD Wastewaters Using Metallic Iron Cementation. Available online at: http://my.epri.com/portal/server.pt?Abstract_id=000000000001016191. Date accessed: 16 May 2008. DCN 05692.

Hall, Josh. 2007a. List of Facilities Operating FGD Systems and Requested Information – Final. (February 23). DCN 04801A1.

Hall, Josh. 2007b. Letter to Dean McDevitt. "Notes from Site Visit at Northern Indiana Public Service Company's Bailly Generating Station on April 19, 2007." (02 August). DCN 05701.

Hjeresen, Dennis. 2001. "Green Chemistry and the Global Water Crisis." Pure and Applied Chemistry. Vol. 73, Issue 8, p. 1237 - 1241. (August). Available online at: http://old.iupac.org/publications/pac/2001/pdf/7308x1237.pdf. Date accessed: May 13, 2008. DCN 05693.

Industrial Water World. 2006. Water Briefs: Aquatech Awarded EPC Contract for FGD Wastewater ZLD System in Italy. (6 July). Available online at: http://ww.pennnet.com/display_article/259531/41/ARCHI/none/INDUS/1/WaterBriefs:-Aquatech-awarded-EPC-contract-for-FGD-wastewater-ZLD-system-in-Italy/. Date accessed: August 21, 2008. DCN 06175.

Jordan, Ron. 2007. Notes from EPA Site Visit at Seminole Electric Cooperative's Seminole Power Plant on April 26, 2007. (05 July). DCN 04731.

Jordan, Ron. 2008a. Site Visit Notes: Progress Energy Carolinas' Roxboro Steam Electric Plant (March 11, 2008). (07 July). DCN 05789.

Jordan, Ron. 2008b. Notes from Site Visit at the AES Cayuga Generation Plant on May 21, 2007." (14 July). DCN 05791.

Northeastern States for Coordinated Air Use Management (NESCAUM). 2000. *Environmental Regulation and Technology Innovation: Controlling Mercury Emissions from Coal-Fired Boilers*. Boston, MA. (September). Available online at: http://www.nescaum.org/documents/rpt000906mercury_innovative-technology.pdf/. DCN 05691.

Pickett, Tim, et al. 2006. "Using Biology to Treat Selenium." Power Engineering. (November). Available online at: http://pepei.pennnet.com/display_article/278443/6/ARTCL/none/none/Using-Biology-to-Treat-Selenium/. Date accessed: May 16, 2008. DCN 05689.

Rodgers, J. H., et al. 2005. Clemson University. *Specifically Designed Constructed Wetlands: A Novel Treatment Approach for Scrubber Wastewater*. Available online at: http://www.netl.doe.gov/technologies/coalpower/ewr/water/pp-mgmt/pubs/42178%20final%20report%200905.pdf. Date accessed: 5 September 2007. DCN 04979.

Sargent & Lundy, L.L.C. 2007. *Flue Gas Desulfurization Technology Evaluation: Dry Lime vs. Wet Limestone FGD*. 11311-001. Chicago, IL. (March). Available online at: http://www.lime.org/FGD/FGDTechEvalDryLimevWetLimestoneFGD11311001.pdf. Date accessed: June 12, 2008. DCN 05792.

Shaw, William A. 2008. "Benefits of Evaporating FGD Purge Water." Power. (March). 59-63. Available online at: http://www.powermag.com/powerweb/archive_article.asp?a=60-F_WM&y=2008&m=march. Date accessed: March 14, 2008. DCN 05907.

U.S. DOE. 2003. U.S. Department of Energy. Electric Power Annual 2001. DOE/EIA-0348(2001). Energy Information Administration (EIA). Available online at: http://tonto.eia.doe.gov/ftproot/electricity/034801.pdf. (March). DCN 05786.

U.S. DOE. 2005a. U.S. Department of Energy. *Annual Electric Generator Report* (collected via Form EIA-860). Energy Information Administration (EIA). The data files are available online at: http://www.eia.doe.gov/cneaf/electricity/page/eia860.html. DCN 05705.

U.S. DOE. 2005b. U.S. Department of Energy. *Annual Steam-Electric Plant Operation and Design Data* (collected via Form EIA-767). Energy Information Administration (EIA). The data files are available online at: http://www.eia.doe.gov/cneaf/electricity/page/eia767.html. DCN 05705.

U.S. DOE. 2007. U.S. Department of Energy. *Electric Power Annual 2006*. DOE/EIA-0348(2006). Energy Information Administration (EIA). Available online at: http://www.eia.doe.gov/cneaf/electricity/epa/epa_sum.html. (November). DCN 05690.

U.S. EPA. 1982. Development Document for Effluent Limitations Guidelines and Standards and Pretreatment Standards for the Steam Electric Point Source Category. EPA-440-1-82-029. Washington, DC. (November). DCN 03589.

U.S. EPA. 2003. *Air Pollution Control Technology Fact Sheet.* EPA-452/F-03-034. Available online at: http://www.epa.gov/ttn/catc/dir1/ffdg.pdf. DCN 03777.

U.S. EPA. 2005. *Preliminary Engineering Report: Steam Electric Detailed Study*. EPA 821-B-05-005. Washington, DC. (August). Available online at: http://www.epa.gov/waterscience/guide/304m/report_steam_electric.pdf. DCN 02176.

U.S. EPA. 2006a. *Integrated Planning Model (IPM)*. “EPA Base Case 2006 (v.3.0).” (28 March). Available online at: http://www.epa.gov/airmarkt/progsregs/epa-ipm/index.html. DCN 05775.

U.S. EPA. 2006b. *Interim Detailed Study Report for the Steam Electric Power Generating Point Source Category*. EPA 821-R-06-015. Washington, DC. (November). Available online at: http://www.epa.gov/guide/304m/steam-interim.pdf. DCN 03401.

U.S. EPA. 2006c. *National Electric Energy Data System (NEEDS) 2006*. “2006 NEEDS Database”. Available online at: http://www.epa.gov/airmarkt/progsregs/epa-ipm/index.html. DCN 04924.

U.S. EPA. 2007. Data Request for the Steam Electric Power Generating Industry. (07 May). DCN 04322.

U.S. EPA. 2008a. Non-CBI Steam Electric Data Request Database. (June 12). DCN 05754

U.S. EPA. 2008b. Final Engineering Site Visit Report for First Energy Generation Corp’s Bruce Mansfield Power Plant. (21 August). DCN 06147.

Utility Water Act Group (UWAG). 2007. “Comments of the Utility Water Act Group on EPA’s Draft Data Request for the Steam Electric Generating Industry.” (23 March). DCN 04998.

Utility Water Act Group (UWAG). 2008. Form 2C Effluent Guidelines Database. (30 June). DCNs 05856 and 05861.

Water Online. 2007a. HPD Awarded Flue Gas Desulfurization (FGD) Effluent Treatment for Monfalcone Coal-Fired Generating Station. (31 January). Available online at: http://www.wateronline.com/article.mvc/HPD-Awarded-Flue-Gas-Desulfurization-FGD-Effl-0001. Date accessed: August 21, 2008. DCN 06174.

Water Online. 2007b. Aquatech International Corporation Awarded Contract by KCPL. (31 May). Available online at: http://www.wateronline.com/article.mvc/Aquatech-International-Corporation-Awarded-Co-0001. Date accessed: August 21, 2008. DCN 06176.