

**SOUTH CAROLINA DNR
GROUNDWATER
MONITORING NETWORK
STATUS REPORT**

July 2009 through June 2014

**STATE OF SOUTH CAROLINA
DEPARTMENT OF NATURAL
RESOURCES**

**LAND, WATER AND
CONSERVATION DIVISION**



**WATER RESOURCES
REPORT 57
2014**

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by

Scott V. Harder, Joseph A. Gellici, and Andrew Wachob

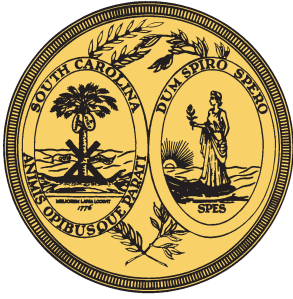
**STATE OF SOUTH CAROLINA
DEPARTMENT OF NATURAL RESOURCES**



LAND, WATER AND CONSERVATION DIVISION

WATER RESOURCES REPORT 57

2014



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PLATE

Map showing locations of DNR groundwater monitoring wells

SOUTH CAROLINA DNR GROUNDWATER MONITORING NETWORK STATUS REPORT

July 2009 through June 2014

by

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ABSTRACT

The South Carolina Department of Natural Resources (DNR) maintains a network of wells to monitor groundwater levels of the major aquifers in the State. Of the 134 wells currently monitored, 18 are located in the Piedmont and Blue Ridge Provinces, and 116 in the Coastal Plain Province. Ninety-nine wells are equipped with automated data recorders (ADRs), which measure and record water levels on the hour, and 35 are measured manually on a bimonthly basis. Data from the network are used to assess groundwater availability, monitor drought conditions, and calibrate hydrologic models. During the past five years, 27 wells were added to the network and 31 wells were equipped with recorders. This report also presents detailed descriptions of the equipment used to measure and record water levels and the data collection and processing procedures and methodologies employed by the DNR.

INTRODUCTION

The South Carolina Department of Natural Resources (DNR) routinely collects groundwater-level data for water-resource assessments and for management and planning purposes. These data are used to identify short- and long-term changes in groundwater levels and storage that occur as a result of changes in withdrawals, recharge rates, and climatic conditions; to calibrate groundwater flow models; and to determine regional hydraulic gradients and groundwater flow rates and directions of the major aquifers.

This report provides an overview of the DNR's groundwater monitoring program, documents recent additions and changes to the groundwater monitoring network, and presents near-term and long-term program goals. This report also includes a detailed description of the DNR water-level monitoring equipment and data collection and processing procedures.

PREVIOUS REPORTS

Groundwater data collected from the monitoring network are periodically summarized in data reports and utilized in the production of potentiometric maps for the major aquifers of the Coastal Plain. The most recent data report presented water-level data from 2006 through 2010 and also highlighted long-term, water-level trends (Harder and others, 2012). That report was the third in a series of reports documenting groundwater-level data collected from the DNR monitoring network. Harwell and others

(2004) documented water-level data collected from 56 wells during the period from 2000 through 2001. Ager-ton and others (2007) contains water-level data collected from 69 wells during the period from 2000 through 2005.

Other groundwater-level compilations include intermittent and periodic water-level measurements of 16 Piedmont province wells and 266 Coastal Plain province wells by Waters (2003). That report represents 282 hydrographs and is the most extensive compilation of historical South Carolina groundwater-level data to date. Hydrograph records range from 6 to 50 years, and about one-third of the record sets span periods greater than 20 years. Gellici and others (2004) published selected groundwater data illustrating the effects of the 1998–2002 drought.

Potentiometric maps for the Middendorf aquifer in 1996, 2001, 2004, 2009, and 2011 were produced by Hockensmith and Waters (1998), Hockensmith (2003a), Hockensmith (2008a), Hockensmith (2012a), and Hockensmith and others (2013a), respectively. Potentiometric maps for the Black Creek aquifer in 1995, 2001, 2004, 2009, and 2012 were produced by Hockensmith (1997), Hockensmith (2003b), Hockensmith (2008b), Hockensmith (2012b), and Hockensmith and others (2013b), respectively. Seasonal potentiometric maps for the Floridan aquifer for the period 1991–1993 are documented in Gawne (1994), and Floridan and Tertiary sand aquifer levels for 1998, 2004, 2010, and 2013 were published by Hockensmith (2001), Hockensmith (2009), Hockensmith and others (2013c), and Wachob and others (2014), respectively.

WELL IDENTIFICATION NUMBERING SYSTEM

DNR uses a well identification system that consists of a three-letter county-name abbreviation and a sequential number that is assigned by the DNR in coordination with the U.S. Geological Survey (USGS). For example, HAM-0050 represents the fiftieth well inventoried by the DNR in Hampton County. Because all the wells in the monitoring network are also included in DNR's main well inventory, the monitoring network wells are identified using this same system.

HYDROGEOLOGIC FRAMEWORK

A hydrogeologic framework describes the spatial distribution of the aquifers and confining units that control the occurrence and availability of groundwater throughout the South Carolina Coastal Plain. The hydrogeologic framework utilized in the groundwater monitoring program has historically been that of Aucott and others (1987). Aucott divided the Coastal Plain sedimentary sequence into six aquifers, which in ascending order are: Cape Fear, Mid-

dendorf, Black Creek, Tertiary sand, Floridan, and surficial. In 1995, Aadland and others presented a detailed hydrogeologic characterization of the Coastal Plain sequence at the Savannah River Site (SRS) and surrounding area that resulted in a revised hydrogeologic framework and a new hydrostratigraphic nomenclature for west-central South Carolina (Aadland and others, 1995). Aquifers and confining units were named after local geographic features near type-well localities and the previous aquifer names, which were based on geologic formations, were abandoned at SRS. This revised framework and new nomenclature were extended across the rest of the Coastal Plain in *Hydrogeologic Framework of the Atlantic Coastal Plain, North and South Carolina* (Gellici and Lautier, 2010), a chapter in the report *Groundwater Availability in the Atlantic Coastal Plain of North and South Carolina* (Campbell and Coes, 2010). For this report, the names and framework of Aucott and others (1987) continue to be used, but wells are also assigned to aquifers using the new framework and nomenclature described by Gellici and Lautier. A comparison chart between the two nomenclatures is provided in Figure 1.

Updip		Downdip		Savannah River Site		Downdip from Savannah River Site	
Tertiary sand aquifer (upper part)	Surficial aquifer	Steep Pond aquifer	Upper Three Runs aquifer	Surficial aquifer	Gordon confining unit	Surficial aquifer	Upper Florida confining unit
	Tertiary sand aquifer (lower part)			Floridan aquifer system		Upper Florida aquifer	Middle Florida confining unit
unnamed confining unit			Crouch Branch confining unit	Gordon aquifer	Gordon aquifer	Crouch Branch confining unit	Crouch Branch aquifer
Black Creek aquifer		Crouch Branch aquifer		Crouch Branch aquifer		Crouch Branch aquifer	
unnamed confining unit		McQueen Branch confining unit		McQueen Branch confining unit		McQueen Branch confining unit	
Middendorf aquifer		McQueen Branch aquifer		McQueen Branch aquifer		McQueen Branch aquifer	Charleston confining unit
unnamed confining unit		unnamed confining unit		unnamed confining unit		Gramling confining unit	Charleston aquifer
Cape Fear aquifer						Gramling aquifer	

(Aucott and others, 1987)

(Aadland and others, 1995)

(Gellici and Lautier, 2010)

Figure 1. Comparison of hydrostratigraphic nomenclature systems in South Carolina.

MONITORING WELL DISTRIBUTION

The current DNR groundwater monitoring network includes 66 monitoring sites and a total of 134 wells, of which 116 are located in the Coastal Plain province and 18 are located in the Piedmont and Blue Ridge provinces. Twenty-four locations are well cluster sites, meaning two or more wells are monitored at each of those sites. Because the Floridan, Black Creek, and Middendorf aquifers are the most heavily used aquifers in the Coastal Plain, most of the wells in the network measure these three aquifers (Figure 2). A map showing the locations of all the current monitor-

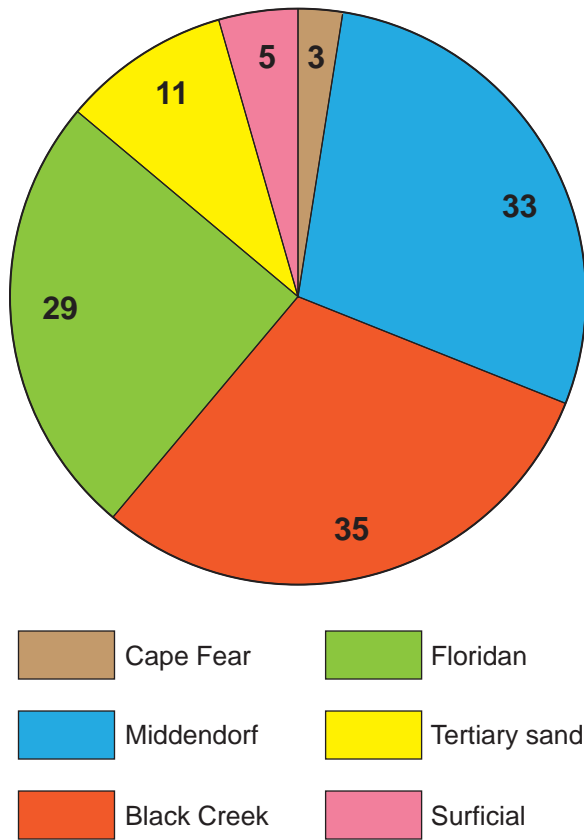


Figure 2. Distribution of monitoring wells among the Coastal Plain aquifers.

ing wells is shown in Figure 3; a larger version of this map is included as a plate at the end of this report.

Water levels in most network wells have been measured since the mid-to-late 1990s, and about one-third of the wells have water-level data going back more than 20 years, with one as far back as 1955 (Table 1). Measurements prior to the mid-1990s were made primarily by the USGS in wells that were originally maintained by that agency and which later became part of the DNR groundwater network.

Table 2 lists all current network wells, by county, and includes well locations, aquifer names, monitoring start dates, and type of monitoring site (manually or automatically measured). More details about each network well are included in Appendix A.

Table 1. Distribution of periods of record for wells in the DNR monitoring network

Period of record	Number of wells
< 5 years	22
5–10 years	15
10–20 years	51
20–30 years	38
> 30 years	8

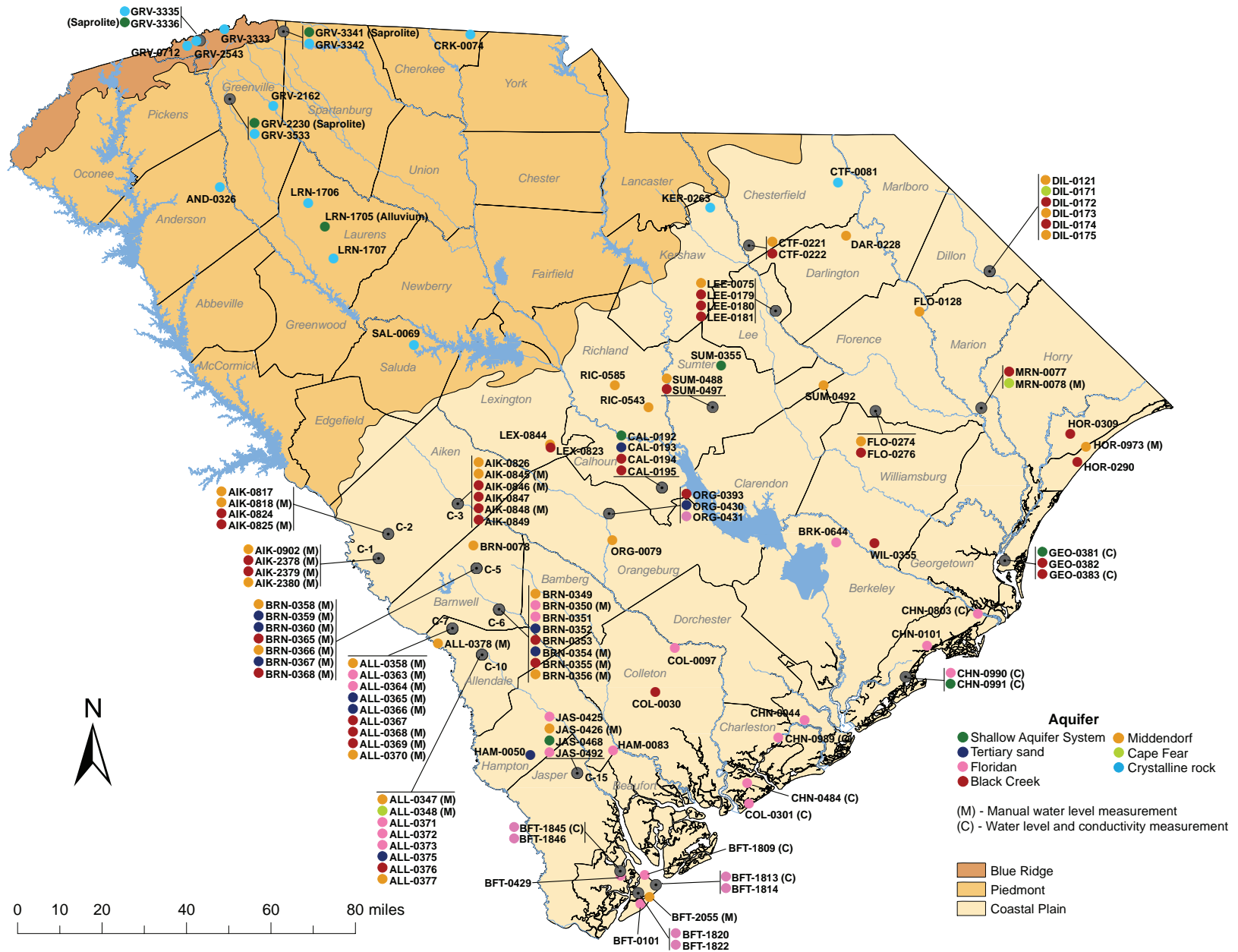


Figure 3. South Carolina DNR groundwater monitoring network (June 2014).

Table 2. DNR groundwater monitoring network wells (June 2014)

County	Well ID	Well Location	Aquifer ¹	Aquifer ²	Start Year	Type
Aiken	AIK-0817	New Ellenton, 4 miles WSW (County Road 146)	Middendorf	McQueen Branch	1988	ADR
Aiken	AIK-0818	New Ellenton, 4 miles WSW (County Road 146)	Middendorf	McQueen Branch	1988	Manual
Aiken	AIK-0824	New Ellenton, 4 miles WSW (County Road 146)	Black Creek	Crouch Branch	1991	ADR
Aiken	AIK-0825	New Ellenton, 4 miles WSW (County Road 146)	Black Creek	Crouch Branch	1989	Manual
Aiken	AIK-0826	Windsor, 4 miles NNE (Aiken State Park)	Middendorf	McQueen Branch	1989	ADR
Aiken	AIK-0845	Windsor, 4 miles NNE (Aiken State Park)	Middendorf	McQueen Branch	1993	Manual
Aiken	AIK-0846	Windsor, 4 miles NNE (Aiken State Park)	Black Creek	Crouch Branch	1993	Manual
Aiken	AIK-0847	Windsor, 4 miles NNE (Aiken State Park)	Black Creek	Crouch Branch	1993	ADR
Aiken	AIK-0848	Windsor, 4 miles NNE (Aiken State Park)	Black Creek	Crouch Branch	1993	Manual
Aiken	AIK-0849	Windsor, 4 miles NNE (Aiken State Park)	Black Creek	Crouch Branch	1993	ADR
Aiken	AIK-0902	Jackson, 1 mile NW (S.C. Highway 125)	Middendorf	McQueen Branch	2006	Manual
Aiken	AIK-2378	Jackson, 1 mile NW (S.C. Highway 125)	Black Creek	Crouch Branch	1996	Manual
Aiken	AIK-2379	Jackson, 1 mile NW (S.C. Highway 125)	Black Creek	Crouch Branch	1996	Manual
Aiken	AIK-2380	Jackson, 1 mile NW (S.C. Highway 125)	Middendorf	McQueen Branch	1995	Manual
Allendale	ALL-0347	Allendale, 3.5 miles W (County Road 52)	Middendorf	McQueen Branch	1996	Manual
Allendale	ALL-0348	Allendale, 3.5 miles W (County Road 52)	Cape Fear	Gramling confining unit	1996	Manual
Allendale	ALL-0358	Millet, 3 miles NE (County Road 24)	Middendorf	McQueen Branch	1995	Manual
Allendale	ALL-0363	Millet, 3 miles NE (County Road 24)	Floridan	Upper Three Runs	1995	Manual
Allendale	ALL-0364	Millet, 3 miles NE (County Road 24)	Floridan	Upper Three Runs	1995	Manual
Allendale	ALL-0365	Millet, 3 miles NE (County Road 24)	Tertiary sand	Gordon	2004	Manual
Allendale	ALL-0366	Millet, 3 miles NE (County Road 24)	Tertiary sand	Gordon	1997	Manual
Allendale	ALL-0367	Millet, 3 miles NE (County Road 24)	Black Creek	Crouch Branch	1995	ADR
Allendale	ALL-0368	Millet, 3 miles NE (County Road 24)	Black Creek	Crouch Branch	2006	Manual
Allendale	ALL-0369	Millet, 3 miles NE (County Road 24)	Black Creek	Crouch Branch	2006	Manual
Allendale	ALL-0370	Millet, 3 miles NE (County Road 24)	Middendorf	McQueen Branch	2006	Manual
Allendale	ALL-0371	Allendale, 3.5 miles W (County Road 52)	Floridan	Upper Floridan	1996	ADR
Allendale	ALL-0372	Allendale, 3.5 miles W (County Road 52)	Floridan	Upper Floridan	1996	ADR
Allendale	ALL-0373	Allendale, 3.5 miles W (County Road 52)	Floridan	Middle Floridan	1996	ADR
Allendale	ALL-0375	Allendale, 3.5 miles W (County Road 52)	Tertiary sand	Gordon	1996	ADR
Allendale	ALL-0376	Allendale, 3.5 miles W (County Road 52)	Black Creek	Crouch Branch	1996	ADR
Allendale	ALL-0377	Allendale, 3.5 miles W (County Road 52)	Middendorf	McQueen Branch	1996	ADR
Allendale	ALL-0378	Millet, 2.1 miles SW (Little Hell Landing)	Middendorf	McQueen Branch	2011	Manual
Anderson	AND-0326	Williamston (city water treatment plant)	Crystalline rock	Crystalline rock	1993	ADR
Beaufort	BFT-0101	Hilton Head Island (U.S. Highway 278)	Floridan	Upper Floridan	1955	ADR

Table 2. Continued

County	Well ID	Well Location	Aquifer ¹	Aquifer ²	Start Year	Type
Beaufort	BFT-0429	Bluffton, 2 miles NE	Floridan	Upper Floridan	1970	ADR
Beaufort	BFT-1809	Hilton Head Island (Hilton Head Plantation)	Floridan	Middle Floridan	1986	ADR
Beaufort	BFT-1813	Hilton Head Island (Port Royal Plantation)	Floridan	Middle Floridan	2001	ADR
Beaufort	BFT-1814	Hilton Head Island (Port Royal Plantation)	Floridan	Upper Floridan	1986	ADR
Beaufort	BFT-1820	Hilton Head Island (Indigo Run Plantation)	Floridan	Middle Floridan	2009	ADR
Beaufort	BFT-1822	Hilton Head Island (Indigo Run Plantation)	Floridan	Upper Floridan	2009	ADR
Beaufort	BFT-1845	Bluffton, 2.5 miles NE (Waddell Center)	Floridan	Middle Floridan	1993	ADR
Beaufort	BFT-1846	Bluffton, 2.5 miles NE (Waddell Center)	Floridan	Upper Floridan	1993	ADR
Beaufort	BFT-2055	Hilton Head Island (near Singleton Beach)	Middendorf	Charleston/Gramling	2003	Manual
Berkeley	BRK-0644	St. Stephen (St. Stephen Middle School)	Floridan	Gordon	2001	ADR
Barnwell	BRN-0078	Williston (West Street)	Middendorf	McQueen Branch	2014	ADR
Barnwell	BRN-0349	Barnwell, 4 miles SE (S.C. Highway 300)	Middendorf	McQueen Branch	1988	ADR
Barnwell	BRN-0350	Barnwell, 4 miles SE (S.C. Highway 300)	Floridan	Upper Three Runs	1988	Manual
Barnwell	BRN-0351	Barnwell, 4 miles SE (S.C. Highway 300)	Floridan	Upper Three Runs	1988	ADR
Barnwell	BRN-0352	Barnwell, 4 miles SE (S.C. Highway 300)	Tertiary sand	Gordon	1989	ADR
Barnwell	BRN-0353	Barnwell, 4 miles SE (S.C. Highway 300)	Black Creek	Crouch Branch	1989	ADR
Barnwell	BRN-0354	Barnwell, 4 miles SE (S.C. Highway 300)	Tertiary sand	Gordon	1989	Manual
Barnwell	BRN-0355	Barnwell, 4 miles SE (S.C. Highway 300)	Black Creek	Crouch Branch	1989	Manual
Barnwell	BRN-0356	Barnwell, 4 miles SE (S.C. Highway 300)	Middendorf	McQueen Branch	1989	Manual
Barnwell	BRN-0358	Williston, 3.5 miles S	Middendorf	McQueen Branch	1993	Manual
Barnwell	BRN-0359	Williston, 3.5 miles S	Tertiary sand	Gordon	1989	Manual
Barnwell	BRN-0360	Williston, 3.5 miles S	Tertiary sand	Upper Three Runs	1989	Manual
Barnwell	BRN-0365	Williston, 3.5 miles S	Black Creek	Crouch Branch	1993	Manual
Barnwell	BRN-0366	Williston, 3.5 miles S	Middendorf	McQueen Branch	1993	Manual
Barnwell	BRN-0367	Williston, 3.5 miles S	Tertiary sand	Upper Three Runs	1993	Manual
Barnwell	BRN-0368	Williston, 3.5 miles S	Black Creek	Crouch Branch	1993	Manual
Calhoun	CAL-0192	Creston (EMS/Fire Station)	Shallow	Surficial	2013	ADR
Calhoun	CAL-0193	Creston (EMS/Fire Station)	Tertiary Sand	Gordon	2013	ADR
Calhoun	CAL-0194	Creston (EMS/Fire Station)	Black Creek	Crouch Branch	2013	ADR
Calhoun	CAL-0195	Creston (EMS/Fire Station)	Black Creek	Crouch Branch	2013	ADR
Charleston	CHN-0044	Charleston (USDA site, U.S. Highway 17)	Floridan	Gordon	1980	ADR
Charleston	CHN-0101	Awendaw, 2.8 miles ENE (U.S. Highway 17)	Floridan	Gordon	1980	ADR
Charleston	CHN-0484	Edisto Beach, 5 miles N (Blue House Plantation)	Floridan	Gordon confining unit	2001	ADR
Charleston	CHN-0803	McClellanville, 7 miles NE (Santee Coastal Reserve)	Floridan	Gordon	2000	ADR

Table 2. Continued

County	Well ID	Well Location	Aquifer ¹	Aquifer ²	Start Year	Type
Charleston	CHN-0989	Hollywood, 2.5 miles E (Dixie Plantation)	Floridan	Gordon	2014	ADR
Charleston	CHN-0990	Awendaw, 7.1 miles SSW (Garris public boat landing)	Floridan	Gordon	2014	ADR
Charleston	CHN-0991	Awendaw, 7.1 miles SSW (Garris public boat landing)	Shallow	Surficial	2014	ADR
Colleton	COL-0030	Walterboro (Kline Street)	Black Creek	Crouch Branch	1996	ADR
Colleton	COL-0097	Walterboro, 10 miles S (S.C. Highway 61)	Floridan	Middle Floridan/Gordon	1977	ADR
Colleton	COL-0301	Edisto Beach (Edisto Beach State Park)	Floridan	Gordon confining unit	2000	ADR
Cherokee	CRK-0074	Blacksburg	Crystalline rock	Crystalline rock	1988	ADR
Chesterfield	CTF-0081	Cheraw, 2.5 miles S (Cheraw State Park)	Crystalline rock	Crystalline rock	1999	ADR
Chesterfield	CTF-0221	McBee, 3.2 miles SSW (McBee Wildlife Management Area)	Middendorf	McQueen Branch	2009	ADR
Chesterfield	CTF-0222	McBee, 3.2 miles SSW (McBee Wildlife Management Area)	Black Creek	Crouch Branch	2008	ADR
Darlington	DAR-0228	Society Hill, 3 miles SSW (Lake Darpo)	Middendorf	McQueen Branch	1999	ADR
Dillon	DIL-0121	Dillon, 6.5 miles SE (Little Pee Dee State Park)	Middendorf	McQueen Branch	1999	ADR
Dillon	DIL-0171	Dillon, 6.5 miles SE (Little Pee Dee State Park)	Cape Fear	Gramling confining unit	2014	ADR
Dillon	DIL-0172	Dillon, 6.5 miles SE (Little Pee Dee State Park)	Black Creek	McQueen Branch	2014	ADR
Dillon	DIL-0173	Dillon, 6.5 miles SE (Little Pee Dee State Park)	Middendorf	Charleston	2014	ADR
Dillon	DIL-0174	Dillon, 6.5 miles SE (Little Pee Dee State Park)	Black Creek	Crouch Branch	2014	ADR
Dillon	DIL-0175	Dillon, 6.5 miles SE (Little Pee Dee State Park)	Middendorf	McQueen Branch	2014	ADR
Florence	FLO-0128	Florence, 9.5 miles E (E.I. DuPont de Nemours)	Middendorf	McQueen Branch	1982	ADR
Florence	FLO-0274	Lake City (Lake City Airport)	Middendorf	McQueen Branch	2000	ADR
Florence	FLO-0276	Lake City (Lake City Airport)	Black Creek	Crouch Branch	2000	ADR
Georgetown	GEO-0381	Georgetown, 4.2 miles SE (Hobcaw Barony Wildlife Refuge)	Shallow	Surficial	2014	ADR
Georgetown	GEO-0382	Georgetown, 4.2 miles SE (Hobcaw Barony Wildlife Refuge)	Black Creek	McQueen Branch	2014	ADR
Georgetown	GEO-0383	Georgetown, 4.2 miles SE (Hobcaw Barony Wildlife Refuge)	Black Creek	Crouch Branch	2014	ADR
Greenville	GRV-0712	Marietta, 8 miles NW (Ceasars Head State Park)	Crystalline rock	Crystalline rock	2003	ADR
Greenville	GRV-2162	Greer (East Riverside Park)	Crystalline rock	Crystalline rock	2001	ADR
Greenville	GRV-2230	Travelers Rest, 1.5 miles S (Furman University)	Shallow	Shallow	2002	ADR
Greenville	GRV-2543	Marietta, 7 miles NNW (Jones Gap State Park)	Crystalline rock	Crystalline rock	1997	ADR
Greenville	GRV-3333	Marietta, 7.5 miles N	Crystalline rock	Crystalline rock	1997	ADR
Greenville	GRV-3335	Marietta, 7 miles NNW (Jones Gap State Park)	Crystalline rock	Crystalline rock	1999	ADR
Greenville	GRV-3336	Marietta, 7 miles NNW (Jones Gap State Park)	Shallow	Shallow	1999	ADR
Greenville	GRV-3341	Landrum, 1.5 miles WSW	Shallow	Shallow	1998	ADR
Greenville	GRV-3342	Landrum, 1.5 miles WSW	Crystalline rock	Crystalline rock	1998	ADR
Greenville	GRV-3533	Travelers Rest, 1.5 miles S (Furman University)	Crystalline rock	Crystalline rock	2002	ADR
Hampton	HAM-0050	Furman (U.S. Highway 601)	Tertiary sand	Gordon	2001	ADR

Table 2. Continued

County	Well ID	Well Location	Aquifer ¹	Aquifer ²	Start Year	Type
Hampton	HAM-0083	Yemassee	Floridan	Upper Floridan	1977	ADR
Horry	HOR-0290	Myrtle Beach (Blizzard Street & Deville Street)	Black Creek	Crouch Branch	2008	ADR
Horry	HOR-0309	Conway, 2 miles SE (U.S. Highway 501)	Black Creek	Crouch Branch	2001	ADR
Horry	HOR-0973	Myrtle Beach (surface water treatment plant)	Middendorf	Gramling	1999	Manual
Jasper	JAS-0425	Ridgeland, 9 miles NNW (U.S. Highway 278)	Floridan	Upper Floridan	2000	ADR
Jasper	JAS-0426	Ridgeland, 9 miles NNW (U.S. Highway 278)	Middendorf	Charleson	2000	Manual
Jasper	JAS-0468	Ridgeland, 9 miles NNW (U.S. Highway 278)	Shallow	Surficial	2011	ADR
Jasper	JAS-0492	Ridgeland, 9 miles NNW (U.S. Highway 278)	Floridan	Middle Floridan	2008	ADR
Kershaw	KER-0263	Bethune, 10.5 miles NW (Mt. Pisgah Elementary School)	Crystalline rock	Crystalline rock	1993	ADR
Lee	LEE-0075	Bishopville, 3.5 miles ESE (Lee State Park)	Middendorf	McQueen Branch	1999	ADR
Lee	LEE-0179	Bishopville, 3.5 miles ESE (Lee State Park)	Black Creek	Crouch Branch	2012	ADR
Lee	LEE-0180	Bishopville, 3.5 miles ESE (Lee State Park)	Black Creek	Crouch Branch	2012	ADR
Lee	LEE-0181	Bishopville, 3.5 miles ESE (Lee State Park)	Black Creek	Crouch Branch	2012	ADR
Lexington	LEX-0823	Swansea (South Spring Street)	Black Creek	Crouch Branch	2013	ADR
Lexington	LEX-0844	Swansea (Swansea High School Freshman Academy)	Middendorf	McQueen Branch	1999	ADR
Laurens	LRN-1705	Laurens (Joe R. Adair Outdoor Education Center)	Shallow	Shallow	2000	ADR
Laurens	LRN-1706	Gray Court, 2 miles S (former fire tower site)	Crystalline rock	Crystalline rock	2001	ADR
Laurens	LRN-1707	Mountville, 1 mile NW (former fire tower site)	Crystalline rock	Crystalline rock	2001	ADR
Marion	MRN-0077	Brittons Neck, 3 miles S (former fire tower site)	Black Creek	Crouch Branch	1982	ADR
Marion	MRN-0078	Brittons Neck, 3 miles S (former fire tower site)	Cape Fear	Gramling	1999	Manual
Orangeburg	ORG-0079	Rowesville, 3.1 miles NNW (Southern Patio)	Middendorf	McQueen Branch	2010	ADR
Orangeburg	ORG-0393	Orangeburg (Clark Middle School)	Black Creek	Crouch Branch	2001	ADR
Orangeburg	ORG-0430	Orangeburg (Clark Middle School)	Tertiary sand	Gordon	2001	ADR
Orangeburg	ORG-0431	Orangeburg (Clark Middle School)	Floridan	Upper Three Runs	2001	ADR
Richland	RIC-0543	Eastover (Webber Elementary School)	Middendorf	McQueen Branch	1996	ADR
Richland	RIC-0585	Columbia, 6 miles ESE (Horrel Hill Elementary School)	Middendorf	McQueen Branch	1997	ADR
Saluda	SAL-0069	Saluda, 7.5 miles NE (Hollywood Elementary School)	Crystalline rock	Crystalline rock	1993	ADR
Sumter	SUM-0355	Dalzell (Ebenezer Elementary School)	Shallow	Surficial	2003	ADR
Sumter	SUM-0488	Sumter, 3.5 miles SW (Manchester State Forest)	Middendorf	McQueen Branch	2009	ADR
Sumter	SUM-0492	Olanta, 2.5 miles WNW (Woods Bay State Park)	Middendorf	McQueen Branch	2009	ADR
Sumter	SUM-0497	Sumter, 3.5 miles SW (Manchester State Forest)	Black Creek	Crouch Branch	2009	ADR
Williamsburg	WIL-0355	Jamestown, 9.5 miles NW (Wee Tee State Forest)	Black Creek	Charleston	2012	ADR

¹ Aquifer based on hydrogeologic framework of Aucott and others (1986)

² Aquifer based on hydrogeologic framework of Gellici and Lautier (2010)

DATA COLLECTION METHODS AND INSTRUMENTATION

Introduction

Water levels are measured both manually and automatically. The majority of wells in the network (99 of 134) are equipped with automated data recorders (ADRs), which measure and record water levels every hour. Data stored in these recorders are downloaded during periodic site visits, usually once every two months, at which time manual measurements are also made to verify the accuracy of the water-level recorders. Water levels in wells not equipped with ADRs are measured manually during periodic site visits, typically on a bimonthly basis, using an electric measuring tape or pressure gage. Appendix B contains a detailed description of the different types of water-level monitoring equipment used by DNR, information about the specific instrumentation for each well in the monitoring network, and a description of data collection and processing procedures. Appendix C contains a complete description of standard field operating procedures that are followed for each site visit.

Manual Measurements

Manual water-level measurements or “tape downs” are typically made using an electric tape, which consists of a pair of wires set inside an insulated sheath, the outside of which is marked like a measuring tape. The wires are attached to a steel probe at the bottom of the tape, but the design of the probe is such that there is a small gap between the two wires, keeping an electric circuit open. The tape is lowered into the well until the probe reaches water, which completes the electrical circuit and sounds a buzzer, indicating that the tape has reached water. The operator then reads the depth measurement on the tape, indicating depth of water from the measuring point.

At some sites, the groundwater is under enough pressure to cause the water level in a well to rise above the height of the well casing, and if the well were uncapped, water would flow freely from the well. Water levels in these flowing artesian wells cannot be measured using the typical tape-down procedure; instead, a pressure gage is attached to the well and the water pressure inside the well is measured. The water pressure is then used to calculate to what height the water would rise if the well casing were high enough to contain it.



Figure 4. Manual measurement of a water level using an electric tape.



Figure 5. Manual measurement of a water level in a flowing well using a pressure gage.

Automated Measurements

Two types of water-level sensors—shaft encoders and pressure transducers—historically have been used for automated monitoring stations whose readings are calibrated to manual measurements. By 2008, all wells in the midlands and Coastal Plain regions were instrumented with pressure transducers. Shaft encoders remained in use in several wells in the upstate; however, by the summer of 2014, all shaft encoders were removed and replaced with pressure transducers.

Shaft encoders measure depth to water and consist of a float, counterweight, cable, and pulley assembly. The float and counterweight hang freely inside the well, connected by a cable that runs over a pulley mounted near the top of the well. As the water level in the well changes, the float also moves, causing the pulley to rotate. The rotation of the pulley is measured optically or electronically, and that movement is translated into a measurement of the change in water level. Shaft encoders have a rated accuracy and resolution of 0.01 ft (feet).

Pressure transducers are installed in wells at fixed depths, below the expected range of water levels, and

provide a measurement of the height of water above the sensor. The sensor contains a semiconductor strain gage: Changes in the height of water above the sensor changes the pressure on the sensor, which deforms the crystalline lattice of the sensor's silicon diaphragm, changing the sensor's electrical resistance (piezoresistive effect) to a constant input voltage, thus changing the output voltage. Water depth is computed from the output voltage measurement.

Three brands of pressure transducers currently are utilized within the network: Schlumberger® Divers®, Solinst® Leveloggers®, and In-Situ® Trolls®. Pressure transducers are deployed in wells using direct-read cables, which allow for real-time water-level measurements to be made and also eliminates the need to remove the sensor from the well in order to download data. Most transducers in the network have a measurement range of 0–65 ft and an accuracy and resolution of less than 0.07 ft and 0.01 ft, respectively.

Most transducers are not vented to the atmosphere and thus measure the combined pressure of both the water column and the atmosphere. Because unvented transducers require barometric compensation to remove the effect of atmospheric pressure, barometric data are collected at strategic sites throughout the State (see Plate). Efforts are



Figure 6. Shaft encoder water-level monitoring system installed in a well in Greenville County.

made to ensure that a barometric monitoring site is located within 20 miles of each unvented monitoring well. Vented transducers, which have sensors open to the atmosphere via a vent tube and thus require no barometric compensation, are installed in a few wells along the coast.

Water-level and barometric transducers are synchronized with one another and record data every hour. Shaft encoders also recorded water levels every hour. Details of the specific water-level and barometric instrumentation installed at each ADR well are included in Appendix B.

Site Visits

All DNR monitoring network sites are currently visited at least six times per year. During each site visit and for every well, a manual water-level measurement is taken from the designated measuring point and recorded in a field book along with the date and time of the measurement. For wells equipped with ADRs, current or real-time readings are obtained from the ADRs (for both water-level sensors and barometric sensors, if applicable) and recorded in a field book.

Data are downloaded from the ADRs and evaluated on site to check instrument performance. For pressure transducers, the sum of the sensor's current water-level reading (height of water above probe, corrected for barometric pressure, if applicable) and corresponding manual measurement (depth to water) is calculated during each site visit. This sum, called the cable length, should be the same value for each site visit. Comparing cable length values from consecutive site visits is a means of assessing transducer performance. A minor change in cable length (0.2 ft or less for most transducers) indicates that a potential instrument fault may exist, but the ADR is not typically replaced. When cable-length tolerances are exceeded repeatedly after additional site visits, either the ADR is recalibrated, or an instrument failure is confirmed, in which case the transducer is replaced and the associated records are not added to the groundwater database. For newer transducers, the cable-length variations observed between consecutive site visits typically have been less than 0.10 ft.

Site maintenance includes replacing saturated desiccant packs at sites equipped with vented transducers; the desiccant prevents the buildup of moisture in the transducer's vent tube, which can cause faulty water-level readings and damage the equipment. Other maintenance procedures include checking for battery failure, communication errors, and spurious data spikes caused by lightning or other electromagnetic interference. Malfunctioning equipment, either ADRs or direct-read cables, are diagnosed and replaced or repaired as needed. Any issues with or changes to instrumentation are documented in a field book. A complete description of standard field operating procedures is included in Appendix C.



Figure 7. Three ADR water-level probes used in the DNR network: Schlumberger® Diver® (upper left); Solinst® Levelogger® (lower left); and In-Situ® Aqua-Troll® (right), which also measures conductivity.

DATA PROCESSING AND STORAGE

Collected data is typically processed and further reviewed for quality assurance within one to two weeks after a site visit. All data that have passed quality assurance checks are entered into an Oracle database that uses Microsoft Access as a user interface. The instrumentation history of each well is documented in the database. Documentation includes the types and models of instruments deployed, dates of operation and performance history. In addition, the original field notes are kept and maintained for each well site, and copies are periodically produced in case field books are lost or damaged. Data processing and storage for manual and automatically recorded data are as follows:

Manual Measurements

Manual measurements, along with the date and time of the measurement, are entered into the Oracle database. These measurements indicate the depth to water from a specific measuring point on the well. The measuring point height (MPH) in feet above or below land surface for each well is stored in the database. An Access query is used to subtract the MPH from the raw manual measurement to compute a water level in feet below or above land surface. Changes in the MPH height, if any, are documented within the database.

Pressure Transducers (ADR Data)

The logged hourly measurements are stored in both raw-data and processed-data files. The raw-data files contain uncorrected (uncompensated) hourly measurements and reflect the readings and the performance of various sensors as they were originally stored in data loggers. Raw data are stored mainly “as is” and are archived at the DNR for insight into hardware conditions and for quality assurance. Processed data files consist of hourly water-level data that have been corrected (compensated) for barometric pressure (vented transducers only). Computer software, specific to each brand of instrument deployed, is used to generate barometrically compensated files, which are also archived at the DNR. The software is also used to plot and review both the raw and compensated data at each ADR site as a final quality assurance check prior to entering the data in the database. When appropriate, data are winnowed of measurement anomalies and unreliable data thought to be the result of hardware failures.

The real-time ADR reading (after barometric compensation, where applicable) is entered into the database and is used along with the corresponding manual measurement to compute a cable length value. The computed cable length value is confirmed to be within the allowed tolerance before any hourly data are added to the database (typically ± 0.20 ft). A history of the cable length value for each site is

permanently stored in the database to document instrument performance.

Logged hourly water-level measurements (after compensation, where appropriate) are imported into the Oracle database. These measurements reflect the height of the water column above the sensor and are permanently stored in the database. The well’s MPH and the transducer’s cable length value are used to convert the hourly readings to water levels in feet below or above land surface, which are also permanently stored in the database.

Statistics

Daily average water levels, in feet above or below land surface, are calculated from the hourly data for those days missing 7 or fewer hourly measurements. Monthly average water levels are calculated for each month having 5 or fewer days of missing record, while monthly high and low water-level values are recorded for each month having at least one day of data. Yearly averages are computed for each calendar year having 60 or fewer missing days of record, while yearly highs and lows are recorded for each year with at least one day of data. No statistics are calculated for wells that are manually measured owing to the relatively small number of data values available for such wells. Data collected from the network are available on the DNR website at <http://www.dnr.sc.gov/water/hydro/groundwater/index.html>.

Figures 9 and 10 show illustrate hydrographs that were created using both ADR and manually collected water-level data that is available from the DNR website.



Figure 8. Pressure transducer ADR installation in a monitoring well (BRN-0078) in Williston, SC.

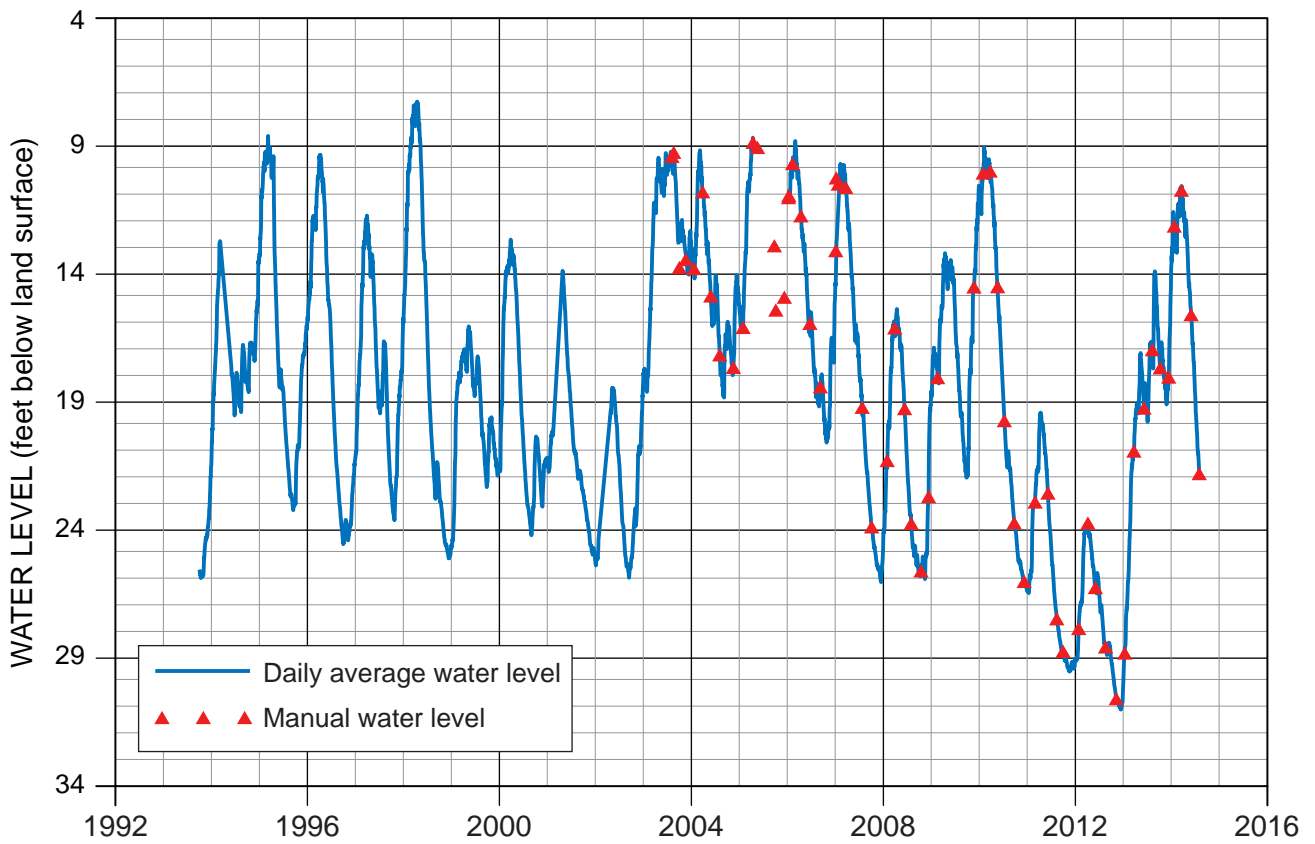


Figure 9. Daily average water levels in well SAL-0069 (Saluda County) calculated from hourly ADR data. Manual measurements made during site visits verify the accuracy of the ADR data.

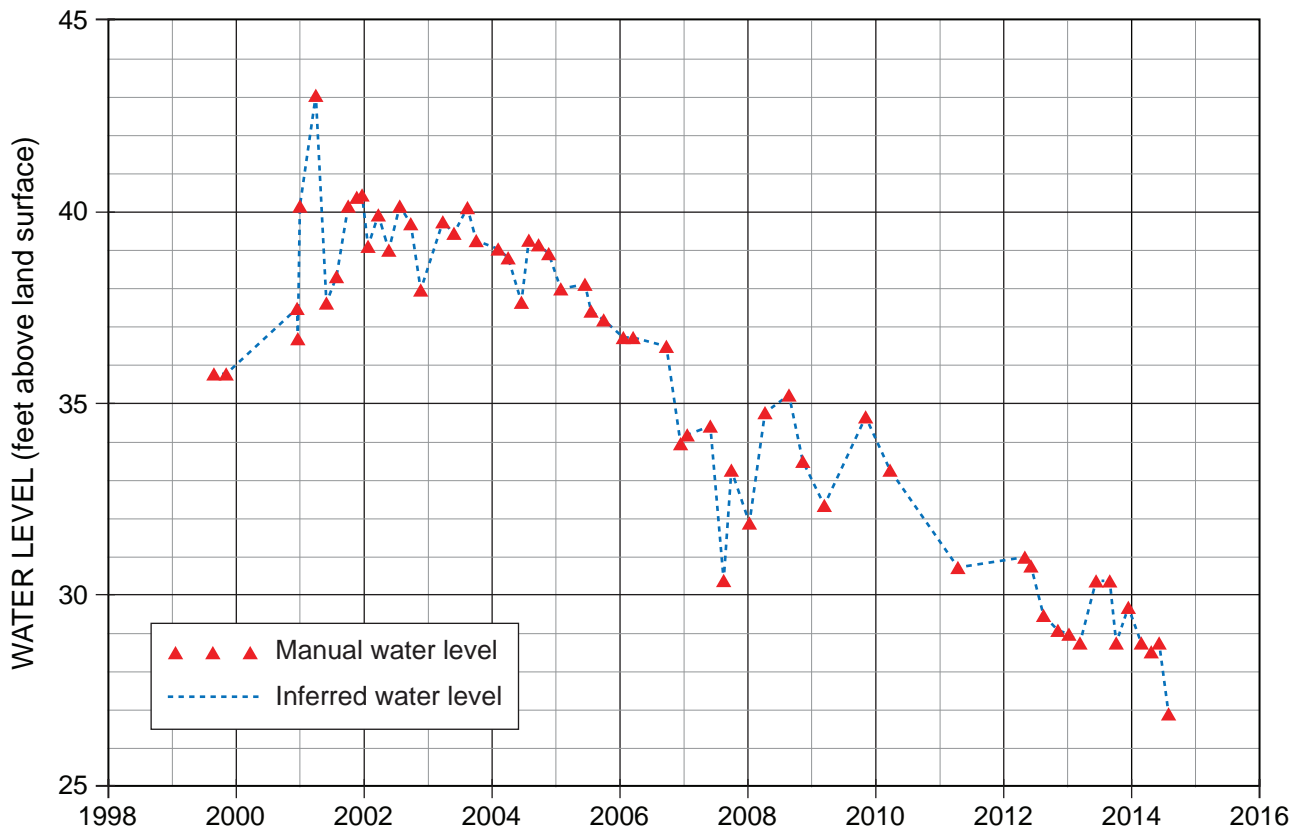


Figure 10. Manual water-level measurements made in well MRN-0078 (Marion County). Because the water level in this well is above ground, an ADR is not used, and measurements are made using a pressure gage.

RECENT CHANGES TO THE GROUNDWATER MONITORING NETWORK

Overview: July 2009 through June 2014

- Twenty-seven wells have been added to the DNR groundwater monitoring network since July 2009 (see Figure 11 and Table 3).
- Three new well-cluster sites were established—one in the Town of Creston in Calhoun County (4 new wells), one at the Hobcaw Barony Wildlife Refuge in Georgetown County (3 new wells), and one at Garris Landing (2 new wells) in northern Charleston County. Continuous cores were also drilled at the Creston and Hobcaw sites.
- Two sites that had previously been cored were revisited and completed as well-cluster sites. Three new wells were constructed at Lee State Park in Lee County, and five new wells were constructed at Little Pee Dee State Park in Dillon County. Coreholes were drilled to bedrock at both parks in the 1990s by the USGS.
- A new well was constructed in Williamsburg County at Wee Tee State Forest. The well is screened in the Black Creek aquifer and provides much needed information in an area of the Coastal Plain that lacks continuous groundwater-level data.
- An existing well at Dixie Plantation in Charleston County was rehabilitated and added to the network. This well, together with wells drilled at the Hobcaw and Garris Landing sites, will also be used to monitor saltwater intrusion.
- An existing well at Little Hell Landing in Allendale County was added to the network. Located on the floodplain of the Savannah River, the well naturally flows and is manually measured with a pressure gage.
- Three wells previously monitored by the USGS, two in Chesterfield County and one in Charleston County, were discontinued by the USGS and were added to the DNR network. DNR agreed to support the continuation of monitoring by installing and maintaining ADRs in the wells. A corehole was also drilled at the Chesterfield site to delineate the aquifers.
- A well in the Town of Gillisonville in Jasper County, which was constructed by the USGS in the surficial aquifer for a water-quality study, was added to the network.
- Other new monitoring wells include two former water-supply wells in the towns of Swansea in Lexington County and Williston in Barnwell County, as well as a former industrial well in central Orangeburg County.
- ADRs were installed in twelve existing network wells. These installations were made in two wells at the C-2 cluster site and in three wells at the C-3 cluster site, both in Aiken County; in three wells at the C-10 cluster site in Allendale County; and in one well in Chesterfield, Florence, Richland, and Sumter Counties.
- Two wells were removed from the monitoring network. Monitoring of a well in Marlboro County was discontinued owing to concerns about the influence of Lake Wallace on groundwater levels, and another well in Colleton County was abandoned by the well owner and could no longer be monitored.

Details regarding recent drilling and coring projects and other changes to the groundwater monitoring network that occurred during each of the five previous fiscal years are provided in the following sections of this report. Well construction diagrams for the 27 new wells can be found in Appendix D.

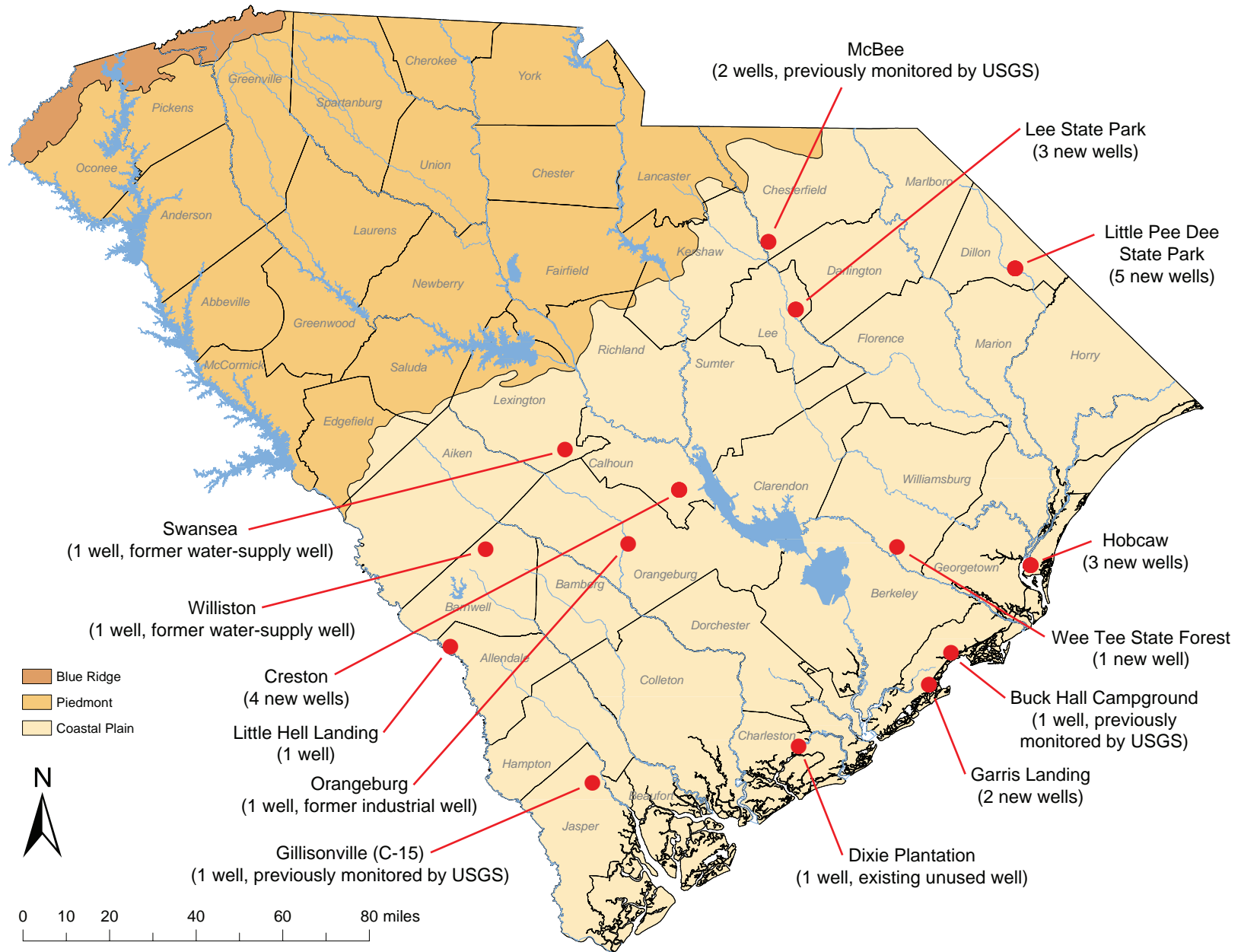


Figure 11. Sites added to the DNR groundwater monitoring network between July 2009 and June 2014.

Table 3. Wells added to the DNR groundwater monitoring network since July 2009

County	Well ID	Remarks	Screen Interval (ft)	Aquifer	Location
Allendale	ALL-0378	Existing monitoring well	845–1,055	Middendorf	Millet, 2.1 miles SW (Little Hell Landing)
Barnwell	BRN-0078	Former water supply well	568–770	Middendorf	Williston (West St.)
Calhoun	CAL-0192	New well	28–48	Shallow	Creston (EMS/Fire Station)
Calhoun	CAL-0193	New well	85–95	Tertiary Sand	Creston (EMS/Fire Station)
Calhoun	CAL-0194	New well	239–249	Black Creek	Creston (EMS/Fire Station)
Calhoun	CAL-0195	New well	345–355	Black Creek	Creston (EMS/Fire Station)
Charleston	CHN-0101	Formerly monitored by USGS	82–91	Floridan	Awendaw, 2.8 miles ENE (U.S. Highway 17)
Charleston	CHN-0989	New well	160–561*	Floridan	Hollywood, 2.5 miles E (Dixie Plantation)
Charleston	CHN-0990	New well	188–263	Floridan	Awendaw, 7.1 miles SSW (Garris public boat landing)
Charleston	CHN-0991	New well	33–43	Shallow	Awendaw, 7.1 miles SSW (Garris public boat landing)
Chesterfield	CTF-0221	Formerly monitored by USGS	235–255	Middendorf	McBee, 3.2 miles SSW (McBee Wildlife Management Area)
Chesterfield	CTF-0222	Formerly monitored by USGS	150–170	Black Creek	McBee, 3.2 miles SSW (McBee Wildlife Management Area)
Dillon	DIL-0171	New well	540–550	Cape Fear	Dillon, 6.5 miles SE (Little Pee Dee State Park)
Dillon	DIL-0172	New well	160–170	Black Creek	Dillon, 6.5 miles SE (Little Pee Dee State Park)
Dillon	DIL-0173	New well	370–375	Middendorf	Dillon, 6.5 miles SE (Little Pee Dee State Park)
Dillon	DIL-0174	New well	60–70	Black Creek	Dillon, 6.5 miles SE (Little Pee Dee State Park)
Dillon	DIL-0175	New well	315–320	Middendorf	Dillon, 6.5 miles SE (Little Pee Dee State Park)
Georgetown	GEO-0381	New well	27–47	Shallow	Georgetown, 4.2 miles SE (Hobcaw Barony Wildlife Refuge)
Georgetown	GEO-0382	New well	700–720	Black Creek	Georgetown, 4.2 miles SE (Hobcaw Barony Wildlife Refuge)
Georgetown	GEO-0383	New well	530–550	Black Creek	Georgetown, 4.2 miles SE (Hobcaw Barony Wildlife Refuge)
Jasper	JAS-0468	Formerly monitored by USGS	17–22	Shallow	Ridgeland, 9 miles NNW (U.S. Highway 278)
Lee	LEE-0179	New well	228–238	Black Creek	Bishopville, 3.5 miles ESE (Lee State Park)
Lee	LEE-0180	New well	127–197	Black Creek	Bishopville, 3.5 miles ESE (Lee State Park)
Lee	LEE-0181	New well	50–70	Black Creek	Bishopville, 3.5 miles ESE (Lee State Park)
Lexington	LEX-0823	Former water supply well	150–220	Black Creek	Swansea (S. Spring St.)
Orangeburg	ORG-0079	Former industrial well	843–974	Middendorf	Rowesville, 3.1 miles NNW (Southern Patio)
Williamsburg	WIL-0355	New well	824–864	Black Creek	Jamestown, 9.5 miles NW (Wee Tee State Forest)

* CHN-0989 is constructed as an open-hole well, without screens, and is open from 160–561 ft.

July 1, 2009–June 30, 2010 (FY09-10)

Walterboro Site, Colleton County

An unused water-supply well (COL-0016) in the Town of Walterboro (Colleton County) that had been equipped with an ADR since 1996 was abandoned and plugged with cement in February 2010 by the well owner (SCE&G) and, hence, could no longer be monitored.

Rowesville site, Orangeburg County

The Southern Patio Company in Orangeburg County gave approval to DNR to utilize a deep, unused well (ORG-0079) that was drilled on their property in the Town of Rowesville in the 1960s. The well is 995 ft deep and screened in the Middendorf aquifer (McQueen Branch) at various intervals from 843–974 ft. An ADR was installed in the well in April 2010.



Figure 12. This unused industrial well (ORG-0079) in central Orangeburg County was added to the network in 2010 to monitor the Middendorf aquifer.

July 1, 2010–June 30, 2011 (FY10-11)

No wells were added to the DNR groundwater monitoring network between July 2010 and June 2011. An ADR was installed in an existing network well (SUM-0497) at Manchester State Forest in Sumter County in April 2011.

Bennettsville Site, Marlboro County

In February 2011, the ADR was removed from one well (MLB-0112) near the Town of Bennettsville in Marlboro County owing to concerns by DNR that nearby Lake Wallace was controlling groundwater levels near the well, making water levels measured in that well somewhat meaningless.

July 1, 2011–June 30, 2012 (FY11-12)

Little Hell Landing Site, Allendale County

A deep well (ALL-0378) was constructed by Graves Well Drilling Company for DNR in 1996 in a collaborative effort with the U.S. Department of Energy and the USGS to study the direction and rate of groundwater movement underneath the Savannah River. Funding for the well was provided by the Department of Energy. The well is screened in the Middendorf aquifer (McQueen Branch) from 845–1,055 ft. Located on the Savannah River floodplain at Little Hell Landing, the well flows several hundred gallons per minute when the gate valve is opened. Sporadic measurements of the hydrostatic pressure were made dating back to 2006 using different pressure gages and transducers, but there was little consistency regarding the regularity and methodology used to obtain the measurements. In December 2011, DNR added the well to the network and now manually measures the water pressure on a bimonthly basis using a pressure gage that is calibrated once per year.

Lee State Park Site, Lee County

One of the long-term objectives of the program is to complete monitoring wells in each of the major aquifers at sites that had previously been cored. Cores provide the best-available information about the hydrostratigraphy, including the number, depths, and thicknesses of aquifers and confining units. In March 2012, it was proposed that a well-cluster be drilled at Lee State Natural Area (State Park) near the Town of Bishopville in Lee County. A corehole had been drilled to a depth of 554 ft at the park in 1996 for a joint USGS/DNR stratigraphic study. The corehole was backfilled and completed as a monitoring well (LEE-0075) in the Middendorf aquifer (McQueen Branch). An ADR was installed in the well in December 1999.

Permission was obtained from the S.C. Department of Parks, Recreation, and Tourism to drill additional wells at the park. A bid package was prepared and the drilling contract was awarded to McNeill Well Drilling, Inc. of Ridgeway, SC. In June 2012, three new wells (LEE-0179, LEE-0180, and LEE-0181) were drilled to depths of 243, 202, and 75 ft, bringing the total number of wells at the park to four. The three new wells are screened in different zones of the Black Creek aquifer (Crouch Branch). ADRs were installed in the wells and have been collecting data since July 2012 (Figure 13). Geophysical logs were also obtained from the deepest of the three holes (LEE-0179) to correlate the stratigraphy at the site of the new wells with the stratigraphy at the corehole.

Most of the wells in the current network are constructed using relatively short well screens, most commonly using 10-ft lengths. The shorter screen lengths are a good construction practice for examining hydrostatic heads to determine if different parts of a presumed aquifer are hydraulically connected. In some areas of the State, however, it is equally important to get hydraulic data for an

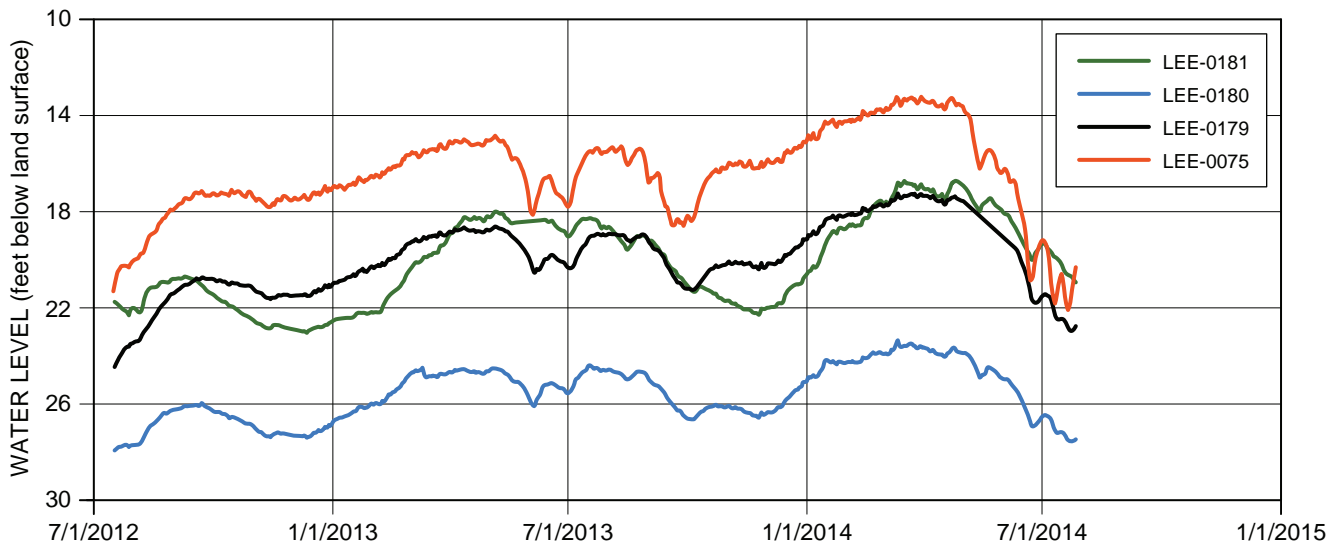


Figure 13. Daily average water levels measured in the four network wells at the Lee State Park cluster site.

aquifer, such as hydraulic conductivity and transmissivity, by means of a pumping test. In these cases, the well screen theoretically should be of such a length so that 80 percent or more of the aquifer is screened. At the Lee State Park site, well LEE-0180 was completed with 80 ft of well screen. A 24-hour pumping test was made of the well to determine the hydraulic properties of the Black Creek aquifer in the area and to determine if leakage occurs across clay beds that locally separate parts of the aquifer. Water levels were continuously measured in all four wells at the site while the well was pumped at 200 gpm (gallons per minute) for 24 hours. After pumping ceased, water levels in all wells continued to be measured for an additional 24 hours while the aquifer recovered from pumping (Figure 14). A transmissivity of 4,500 ft²/day and a hydraulic conductivity

of 45 ft/day were obtained from the test. These properties can be used to estimate water-level declines that could be expected at a given distance from the pumping well, for a given pumping rate, over a given period of time.

Information derived from pumping tests also aids in the delineation of aquifers by observing how pumping from one zone affects water levels in adjacent zones. For example, water levels in LEE-0179, screened in a zone below LEE-0180, showed a slight water-level decline during the 24 hours of pumping, and a corresponding water-level recovery when the pumping ceased. This indicates that minor leakage occurs across several clay beds that separate the zones, suggesting some degree of hydraulic connection between the aquifer zones.

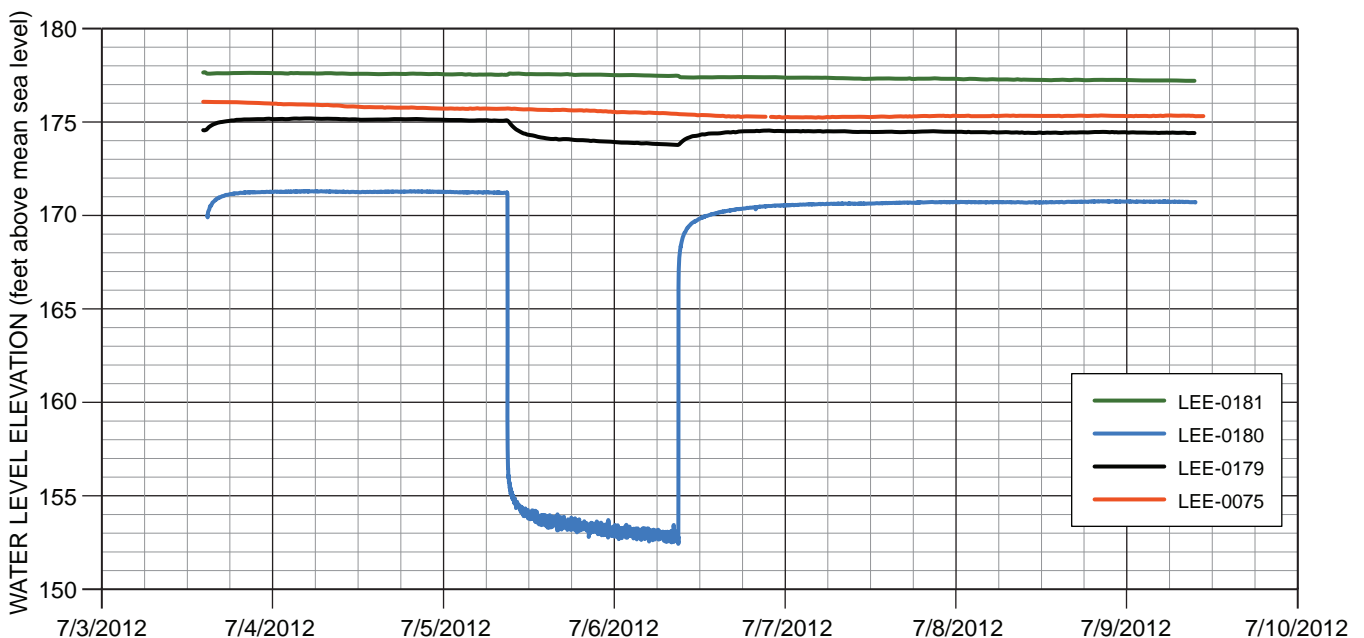


Figure 14. Water levels measured during the pumping test of LEE-0180 at the Lee State Park.

July 1, 2012–June 30, 2013 (FY12-13)



Figure 15. Drilling of the new wells at the Lee State Park cluster site in June 2012.

Awendaw Site, Charleston County

Owing to reduced funding, the USGS discontinued monitoring a Floridan-aquifer well (CHN-0101) at Buck Hall Campground near the Town of Awendaw in Charleston County that had been monitored since 1980. DNR added the well to its network and installed an ADR in this well in May 2012.



Figure 16. Modern transducers (visible on top of the steel plate, which is covering the well) fit easily inside the metal housing that was constructed to accommodate much bulkier shaft-encoder equipment that was previously used to record water levels in this well (CHN-0101) near Awendaw in Charleston County. DNR took over monitoring of this well in 2012 from the USGS, which had monitored the well since 1980.

Wee Tee State Forest Site, Williamsburg County

A major data gap in the monitoring network exists in Williamsburg County, where very few wells are available for monitoring purposes. In 2012, the DNR received permission from the S.C. Forestry Commission to drill a well at Wee Tee State Forest in southwest Williamsburg County. A bid package was prepared and a contract was awarded to A.C. Schultes of Carolina, Inc. The contract called for a 6-inch test hole to be drilled to bedrock (approximately 1,900 ft) prior to completing a well in the Black Creek aquifer. Drilling began in June 2012. Early in the drilling operation, however, a lost-circulation zone in a shallow limestone unit was encountered, and repeated efforts to re-establish circulation of the drilling fluids failed. To prevent the likelihood of hole collapse, it was decided by DNR and the contractor that the hole should be plugged with cement. A new hole was drilled about 50 ft from the original hole using surface casing to prevent the loss of drilling fluids into the shallow limestone. The test hole was drilled to 1,515 ft and geophysical logs were obtained by the contractor.

In July 2012, a monitoring well (WIL-0355) was constructed in the borehole. This well, screened from 824–864 ft in the Black Creek aquifer (Charleston), is the first DNR monitoring well in Williamsburg County. A 24-hour pumping test was conducted in late July 2012, and an ADR was installed in the well in February 2014.



Figure 17. Drilling of the new monitoring well at Wee Tee State Forest in Williamsburg County (WIL-0355). The pipes seen in the foreground are sections of 6-inch and 4-inch diameter casing that were used to construct the 869-foot deep well.

Gillisonville Site, Jasper County

In August 2012, a shallow well in the Town of Gillisonville in Jasper County (JAS-0468) was equipped with an ADR and added to the DNR network. The well was completed in the surficial aquifer system by the USGS in 2005 for a water-quality study.

Installation of ADRs in existing wells

ADRs were installed in ten existing network wells that previously were measured manually. These installations were made in two wells at the C-2 cluster site in Aiken County (AIK-0817 and AIK-0824), in two wells at the C-3 cluster site in Aiken County (AIK-0826 and AIK-0847), in three wells at the C-10 cluster site in Allendale County (ALL-0371, ALL-0375, and ALL-0376), and in wells in Chesterfield (CTF-0081), Florence (FLO-0276), and Richland Counties (RIC-0585).

July 1, 2013–June 30, 2014 (FY13-14)

Swansea Site, Lexington County

In October 2012, the Town of Swansea in Lexington County indicated that it was planning on permanently abandoning one of its public-supply wells (LEX-0823). Years earlier, the Town began purchasing water from West Columbia and no longer needed its wells. In August 2013, an agreement was reached between the Town, DNR, and DHEC that would allow the Town to transfer responsibility of the well to DNR for monitoring purposes. The well is screened in the Black Creek aquifer (Crouch Branch). An ADR was installed in the well in August 2013.

Creston Site, Calhoun County

One objective of the DNR groundwater monitoring program is to establish monitoring wells in those areas of the State where increased groundwater usage may be having an adverse effect on the resource. In the summer of 2012, DNR hydrologists were contacted by citizen groups in Calhoun County who were concerned about the increased number of high-production irrigation wells that were being drilled in the County. Several citizens claimed that the increased pumping had lowered water levels in their domestic wells to the point where their submersible pumps had to be lowered. Up until that time, no permanent monitoring wells were available in the County that could be used to assess the situation and no coreholes had been drilled.

In the spring of 2013, funding became available to drill a corehole in the County and to install monitoring wells in each aquifer. Permission was obtained from the Calhoun County Council to drill behind the newly constructed EMS/fire station in the Town of Creston, which is located in the southern regions of the County. In July 2013, the USGS (Reston, Va.) was hired to do the coring. Using a wireline coring system, a core was collected from land surface to 1,058 ft. Core samples were boxed, labeled, photographed, and described and are currently stored in the rock/sediment repository at the S.C. Geological Survey in Columbia. Upon completion of the coring operation, geophysical logs were made of the borehole, after which the borehole was backfilled with neat cement.

The core and geophysical logs revealed that the area is underlain by the shallow aquifer system, Tertiary sand



Figure 18. The USGS coring operation behind the Creston EMS/fire station in Calhoun County in July 2013.

aquifer (Gordon), two zones of the Black Creek aquifer (Crouch Branch), and the Middendorf aquifer (McQueen Branch). The USGS returned to the drill site in August 2013 to auger the upper 50 ft for a paleoclimatology study that was being made in the area. Upon completion of the drilling, the auger hole was completed as a well (CAL-0192) in the shallow aquifer system to a depth of 49 ft. An ADR was installed in the well in August 2013.

A bid package was prepared to drill additional wells at the site and in September 2013 a contract was awarded to McNeill Well Drilling, Inc. of Ridgeway, SC. In September and October 2013, three new wells were drilled to depths of 100, 254, and 360 ft. Two of the three wells (CAL-0194 and CAL-0195) are screened in the Black Creek aquifer (Crouch Branch) and one (CAL-0193) is screened in the Tertiary sand aquifer (Gordon). ADRs were installed in the three wells in October 2013. Hydrographs of all four wells are shown in Figure 23.



Figure 19. USGS drillers collecting core samples from the Creston site in Calhoun County in July 2013.



Figure 20. Two boxes of core samples from the Creston site. The box above contains sands collected from 22–29 ft; the box below contains clays recovered from 409–419 ft.



Figure 21. A box of core at the Creston site, cleaned and ready for on-site description.



Figure 22. The four monitoring wells that make up the Creston cluster site in Calhoun County in were completed in October 2013.

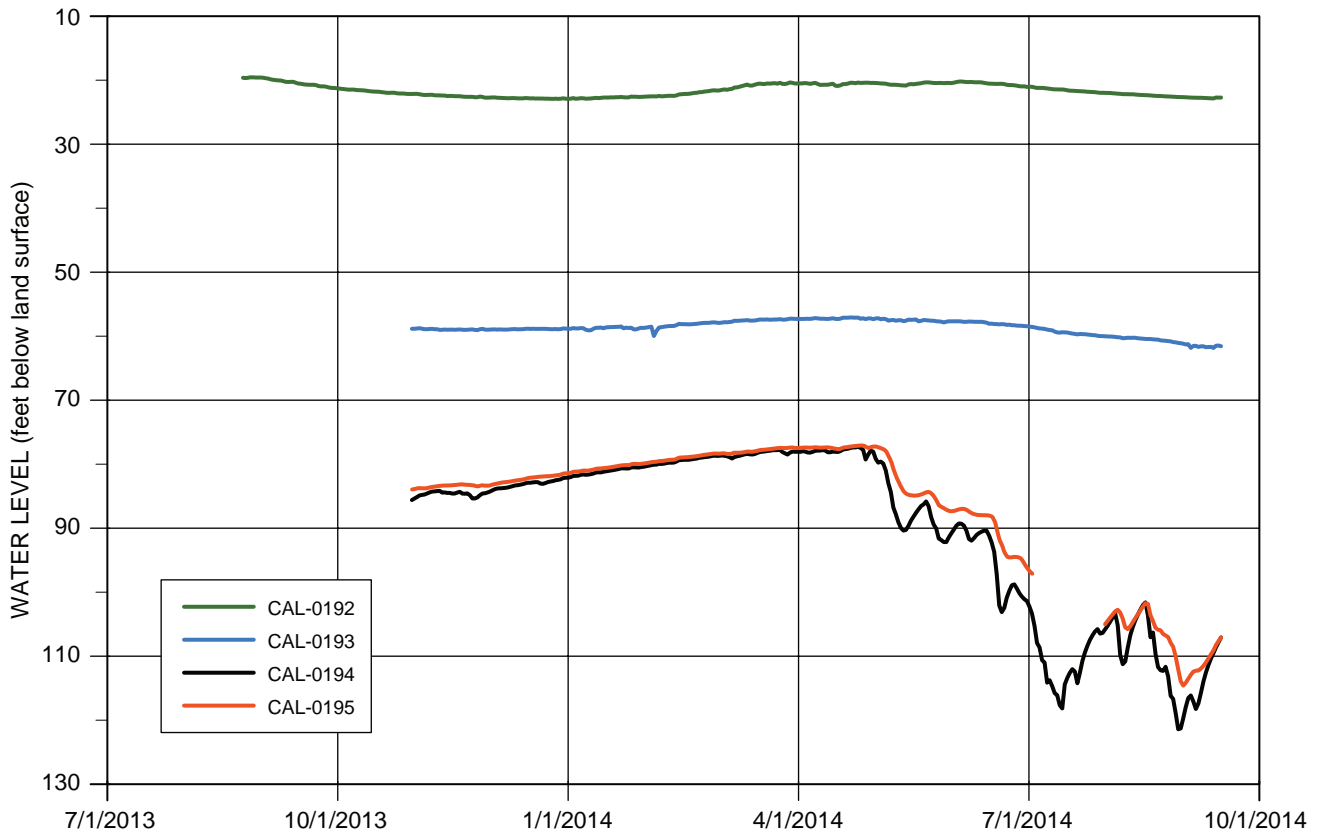


Figure 23. Daily average water levels measured in the four network wells at the Creston cluster site in Calhoun County. The water level decline observed in wells CAL-0194 and CAL-0195 during the summer of 2014 is the result of local groundwater pumping for agricultural irrigation.

Williston Site, Barnwell County

In 2013, the Town of Williston in Barnwell County indicated that it was planning on permanently abandoning one of its public-supply wells (BRN-0078) because of elevated levels of iron in the water. In February 2014, an agreement was reached between the Town, DNR, and DHEC that allowed the Town to transfer responsibility of the well to DNR for monitoring purposes. A caliper log was made by DNR to determine the depth of the well and to ensure that the well was open and accessible (Figure 24). Differences between the original reported depth (775 ft) and the logged depth (745 ft) suggested that the well may have backfilled by about 30 ft. Reported screen locations, however, matched screen locations identified on the caliper log, with the exception of the deepest screen (760–770 ft). The remaining screens in the well are staggered at depths from 568–578, 599–604, 638–658, 702–712, and 734–744 ft, all within the Middendorf aquifer (McQueen Branch). A new wellhead was constructed and the well was fenced in for security purposes. An ADR was installed in May 2014.



Figure 24. Preparing to run a caliper log of the Williston well (BRN-0078). The logging tool is seen here, out of the well, with its arms fully extended. Inside the well, the arms measure the diameter of the well as the tool is brought up from the bottom of the well.



Figure 25. The Williston well (BRN-0078) site, after the new wellhead and fence were constructed.

Garris Landing Site, Charleston County

In 1995, the USGS drilled a continuous core from land surface to 320 ft at Moore’s Landing in Charleston County. (The landing has since been renamed Garris Landing.) The core was drilled as a stratigraphic test hole and in support of an aquifer-storage-and-recovery study that was being made in the area. An open-hole well was constructed from the original corehole (CHN-0802) but has since been found to be unsuitable for monitoring purposes. Efforts to rehabilitate the well in 2013 with compressed air resulted in a partial collapse and filling of the well.

In the spring of 2014, permission was obtained from the U.S. Fish and Wildlife Service, who own and maintain the landing, to construct two new wells at the landing—one (CHN-0991) in the shallow aquifer system and one (CHN-0990) in the Floridan aquifer (Gordon). Well construction was contracted out to Edge Solutions, Inc. of Ravenel, SC and the wells were constructed in April 2014. Geophysical logs, including temperature, fluid conductivity, and gamma-ray, were made of each well. ADRs for water-level and conductivity were installed in August 2014.



Figure 26. Drilling the two new wells at Garris Landing in Charleston County.

Little Pee Dee State Park Site, Dillon County

As mentioned above, one of the long-term objectives of the groundwater monitoring program is to return to sites that previously had been cored to complete monitoring wells in each of the major aquifers. In March 2014, it was proposed that a well-cluster be drilled at Little Pee Dee State Park in Dillon County. A corehole was drilled at the park in 1996 to a depth of 646 ft in a joint USGS/DNR project to obtain stratigraphic information. The corehole was backfilled to 294 ft and completed as a monitoring well (DIL-0121) in the Middendorf aquifer (McQueen Branch). An ADR was installed in the well in 1999.

In May 2014, permission was obtained from the S.C. Department of Parks, Recreation, and Tourism to drill additional wells at the park. A bid package was prepared and a contract was awarded to AAA Well Drilling, Inc. of Lexington, SC. Owing to space limitations at the site of the original corehole, the site selected for the new wells was approximately 3,200 ft from the corehole. For this reason, a deep borehole to 555 ft was initially drilled to obtain geophysical logs that could be compared to logs obtained from the corehole. Drilling commenced in May and was completed in June. Five new wells were drilled—



Figure 27. The five new monitoring wells constructed at Little Pee Dee State Park in June 2014.

two (DIL-0172 and DIL-0174) in the Black Creek aquifer (Crouch Branch and McQueen Branch), two (DIL-0173 and DIL-0175) in the Middendorf aquifer (Charleston and McQueen Branch), and one (DIL-0171) in the Cape Fear aquifer (Gramling). The wells were drilled to depths of 75, 175, 325, 380, and 555 ft. ADRs were installed in each well in early July 2014.

Dixie Plantation Site, Charleston County

An existing, unused well (CHN-0989) at Dixie Plantation in Charleston County (property owned and managed by the College of Charleston) was added to the network to monitor water level and conductivity. Very little construction or historic information was available for this well, which was slated for abandonment. The College of Charleston donated the well to DNR for monitoring purposes. DNR staff dismantled the cinder-block structure that housed the well to provide greater access for geophysical logging and maintenance. Geophysical logs were made to determine the depth, construction and overall condition of the well. The logs showed that the well was constructed as an open hole in the Floridan aquifer (Gordon) to a depth of 531 ft with 8-inch steel casing extending from land surface to 160 ft.

An analysis of the logs and the manner in which the logging tools softly sank into sediments at the bottom of the well suggested that sediment may have collapsed into the open hole and settled to the bottom of the well. It could not, however, be determined from the logs or logging operation how much sediment had accumulated. Because the well was going to be used to monitor conductivity, it was decided that the well should be pumped to clear out any loose sediment from the bottom of the well and to flush stagnant water out of the well.

Edge Solutions, Inc. was contracted to pump the well. Edge developed a unique “skirt” that slipped around the outside and past the bottom of a submersible pump that would be used to direct sediment from the bottom of the well to the pump intake and ultimately out of the well through the drop pipe. Two pumps were used—one with a two-horsepower motor and another with a five-horsepower motor. Some sediment was pumped from the well, but not a significant amount. Rehabilitation of the well ended April 15, 2014 after two days of pumping. A caliper log made on April 17 showed that no significant changes to the diameter of the borehole occurred as a result of the pumping. It was deduced from the way that the tool touched bottom that the well was relatively free of sediment. Edge Solutions, Inc. was also contracted to repair and upgrade the wellhead structure to secure the well and make it suitable for instrumentation.

On April 17, temperature and fluid-conductivity logs were made of the well. A second set of logs were made on June 4. ADRs for water level and conductivity were installed in August 2014.



Figure 28. A view of the Dixie Plantation well (CHN-0989) in August 2013, before the old pump was removed and the well rehabilitated.



Figure 30. Before installing ADR equipment into the Dixie Plantation well, the well was pumped to flush out stagnate water and sediment that may have accumulated in the well during the years since it had been used.



Figure 29. Preparing to run geophysical logs of the Dixie Plantation well. The logging tool is hanging in the well, about to be lowered to the bottom of the well.



Figure 31. The new steel housing and concrete pad constructed for the Dixie Plantation well (CHN-0989).

McBee Corehole Site, Chesterfield County

In recent years, citizens near the Town of McBee in Chesterfield County have expressed concerns about the impact that increased groundwater withdrawals might be having on local aquifers. In 2008, about 2 MGD (million gallons per day) were being pumped from wells completed mainly in the Middendorf aquifer, which occurs in the interval from about 250–350 ft. (As of 2014, about 4 MGD is being pumped.) To address these concerns, the USGS was hired by Alligator Rural Water & Sewer Company, Inc., the main purveyor of water in the County, to develop a groundwater flow model to evaluate the effects of pumping.

To support the USGS flow model and to better understand the impact of this pumping, DNR contracted with Austin Well Drilling, Co. of West Columbia for the installation of two monitoring wells at the McBee Wildlife Management Area in southwest Chesterfield County in 2008. One well (CTF-0221) was completed in the Middendorf aquifer (McQueen Branch) to a depth of 260 ft, and the other (CTF-0222) in the Black Creek aquifer (Crouch Branch) to a depth of 175 ft. A head difference of about 13 ft is observed across clay beds that separate the aquifers, indicating some degree of hydraulic separation between the aquifers. ADRs were installed in both wells and were funded and maintained by the USGS from 2008 until 2013, when the groundwater project concluded. DNR installed ADRs in both wells in January 2014 and continues to maintain them. ADR data indicate that water levels in both aquifers have declined slightly over the past six years (Figure 32).

Owing to budgetary constraints, a corehole had not been drilled in 2008 prior to the installation of the monitoring wells, as is normally done. To gain insight into the composition and hydraulic properties of the aquifers at the

site, and to support regional subsurface mapping efforts, a corehole was drilled in June 2014. The USGS (Reston, Va.) was hired to do the coring. A wireline coring system was used to collect core from land surface to bedrock (400 ft). Core samples were boxed, labeled, photographed, and described, and are currently stored at the rock/sediment repository at the S.C. Geological Survey in Columbia. Upon completion of the coring operation, geophysical logs were made of the borehole, after which the borehole was back-filled with neat cement.



Figure 33. USGS and DNR personnel collecting core samples at the McBee cluster site in June 2014.

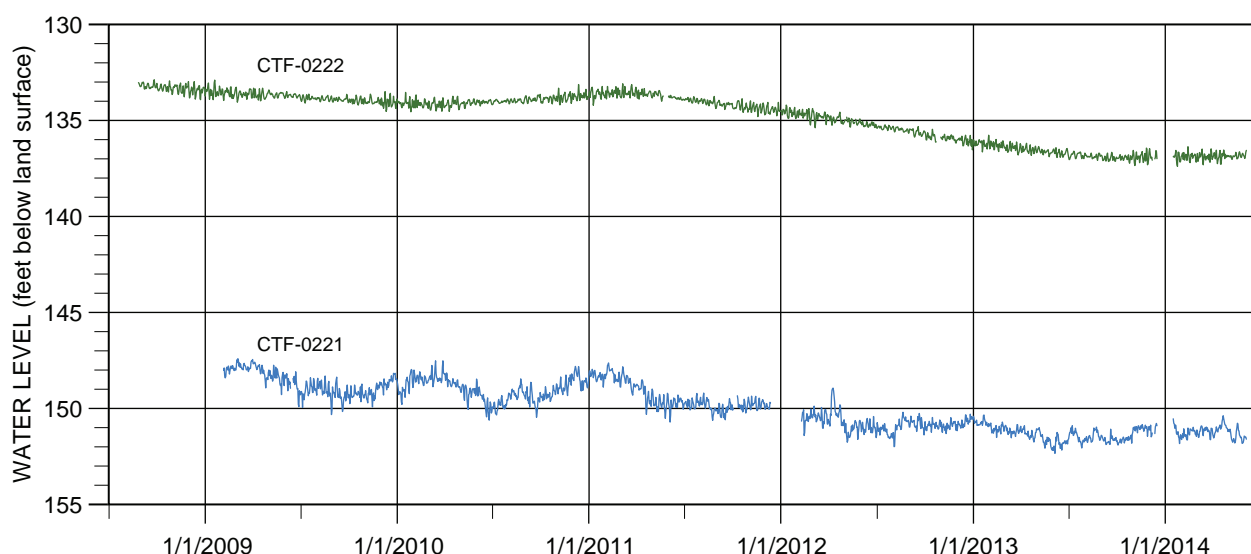


Figure 32. Water levels measured in the Middendorf (CTF-0221) and Black Creek (CTF-0222) aquifers near McBee in Chesterfield County. Water-level data were collected by the USGS from 2008 through 2013; DNR took over monitoring these wells in January 2014.

Hobcaw Site, Georgetown County

In FY13-14, the DNR established a long-term groundwater monitoring site at Hobcaw Barony Wildlife Refuge in Georgetown County to monitor groundwater levels and conductivity. Water-level declines of over 100 ft have been noted in several deep wells in the area and there is growing concern about the potential for saltwater intrusion into the aquifer. The first phase of project involved coring a borehole to delineate the aquifers and confining units of the area. The USGS (Reston, Va.) was hired to perform the coring operation. A continuous core from land surface to 830 ft was obtained in March and April 2014 using a wireline coring system. Cores were boxed, labeled, photographed, and described by hydrologists and geologists with DNR and are currently store in the rock/sediment repository at the S.C. Geological Survey in Columbia. Upon completion of the coring operation, geophysical logs were made of the borehole (Figure 35) and the borehole was later backfilled with neat cement.

The second phase of the project involved the construction of monitoring wells. A shallow sand zone from land surface to 23 ft is the water-table aquifer. A well (GEO-0381) was completed at the base of this aquifer by the USGS during the coring operation and was equipped with an ADR in August 2014. Three deeper water-bearing zones were delineated from the core and geophysical logs at depths of 500–560 ft, 585–645 ft, and 670–735 ft. The upper two zones are in the Black Creek aquifer (Crouch Branch) and the lower zone is in the Black Creek aquifer (McQueen Branch). AAA Well Drilling, Inc. of Lexing-



Figure 34. A view of the 2-inch diameter core barrel before it is lowered into the corehole at the Hobcaw site.

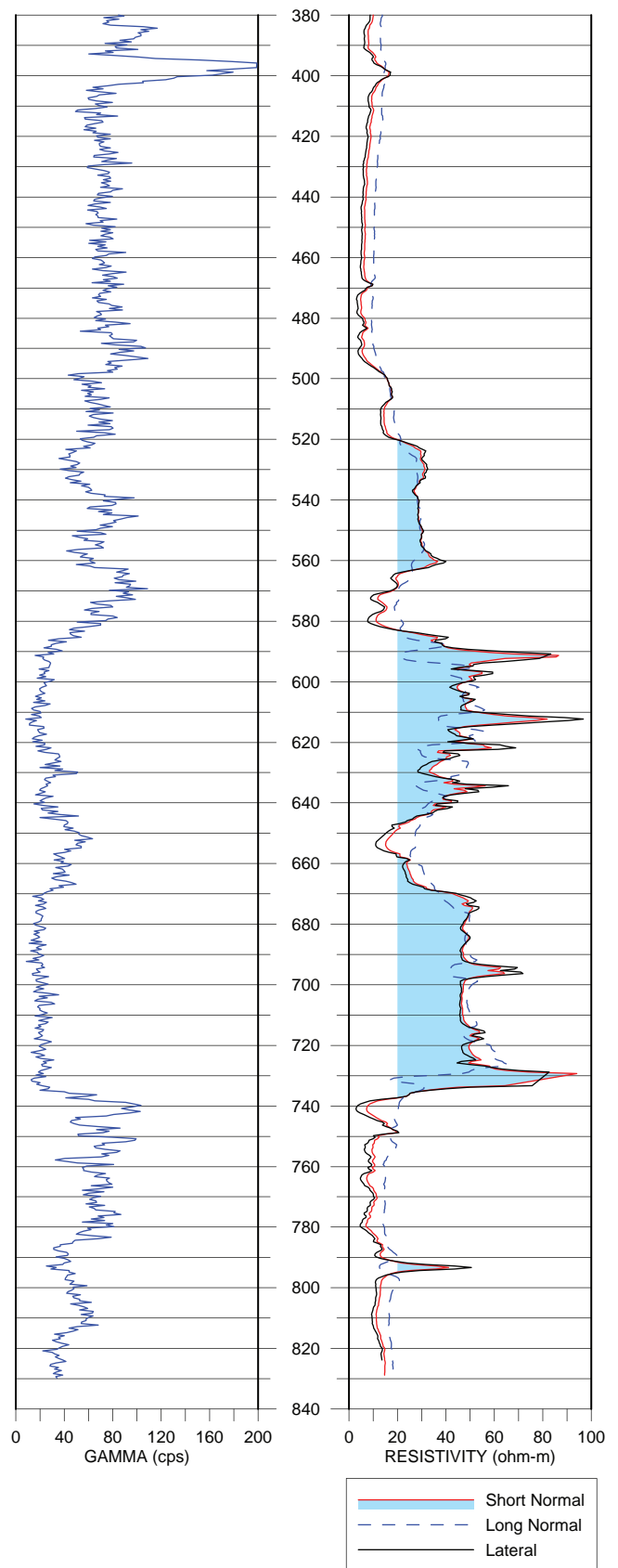


Figure 35. A section of the geophysical logs made in the Hobcaw corehole (GEO-0380). The shaded area on the resistivity log indicates a water-bearing zone.

ton, SC was hired to construct two monitoring wells, one screened from 530–550 ft (GEO-0383) and one from 700–720 ft (GEO-0382). ADRs for water level were installed in August 2014. A conductivity probe was also installed in GEO-0381 in August 2014, and a conductivity probe is expected to be installed in GEO-0383 in September 2014

Installation of ADR in existing well

An ADR was installed in an existing network well (AIK-0849) at the C-3 cluster site in Aiken County in February 2014.



Figure 36. Core samples recovered from the Hobcaw site. The sample from a depth of 790 ft is an unconsolidated sand; the sample from 792 ft is a shelly sand that has been cemented with calcium carbonate.



Figure 37. The entire core from the Hobcaw site is on display for public viewing during a “media day” event held on March 31, 2014, the last day of coring work.



Figure 38. The three completed wells at the Hobcaw site in Georgetown County. In the background is a weather station operated by Clemson University.

GOALS OF THE DNR GROUNDWATER MONITORING PROGRAM

Increase the number of groundwater-level monitoring wells

An overall goal of the program is to have an adequate number of wells in the network to generate accurate, statewide potentiometric maps of each aquifer. Because there are currently not enough wells in the existing network, the development of potentiometric maps is dependent upon water-level data collected from wells that are owned by outside entities, such as municipalities, industries, and private citizens. These additional wells are not always available to be measured and can be permanently lost to abandonment over time. It is expected to take many years to accomplish this goal. Currently, about 135 wells are used to make a potentiometric map of the Middendorf aquifer, 100 to make a Black Creek map, and 200 to make a Floridan map.

A shorter-term goal is to establish at least one complete well-cluster site in each of the 28 Coastal Plain counties. A complete cluster site is one that has a core, preferably to bedrock, and nearby wells screened in each of the major aquifers. A partial cluster site is one that has a core but does not have wells completed in each aquifer, or a site that has several wells but no corehole (Table 4; Figure 39). Several counties—Clarendon, Hampton, Kershaw, Marlboro, and Williamsburg—have neither a corehole nor a site containing several wells completed in different aquifers.

Develop a network of drought-assessment monitoring wells

Another long-term goal is to have a statewide, real-time drought-assessment network composed of relatively shallow monitoring wells that are linked to the office via telemetry systems. These wells should preferably be screened in the shallow (water-table) aquifer system, be located on higher ground between streams where groundwater levels are less directly influenced by surface water, and be located away from major pumping centers. A telemetry system has been purchased by DNR and will be deployed in the near future at a pilot study site in Orangeburg County. The purpose of this network would be to provide near real-time groundwater levels to water managers, drought committee members, and the State Drought Coordinator before, during, and after droughts. Such information will be used, along with other hydrologic and meteorological data, to assess the severity of droughts.

Develop a network of saltwater-intrusion monitoring wells

Another long-term goal is to develop a saltwater-intrusion network composed of monitoring wells located along the coast that are equipped with conductivity probes. Water samples will be collected periodically to ground-truth the conductivity data, and fluid conductivity and temperature geophysical logs will be obtained annually or biennially from the wells. Initially, the goal will be to develop a network of wells that are completed in the shallow aquifer system and in the uppermost confined aquifer in the area. The uppermost confined aquifer is the Floridan aquifer in Jasper and Beaufort Counties (Upper and Middle Floridan aquifers), the lower part of the Tertiary sand aquifer in Colleton and Charleston Counties (Gordon aquifer), and the Black Creek aquifer in Georgetown and Horry Counties (Crouch Branch aquifer). Over time, wells from deeper aquifers and wells farther inland will be added to the network. This network will provide information to water managers and planners about the occurrence and movement of saltwater into freshwater aquifers along the coast.

20 **Table 4. Coreholes and associated monitoring cluster sites in the Coastal Plain (as of June 2014)**

County	Site name	Corehole ID	Location	Number of wells	Complete (C) or Incomplete (I) cluster site	Depth of core (ft)	Cored to bedrock?
Aiken	C-1	AIK-0902	Jackson, 1 mile NW (S.C. Highway 125)	4	C	574	Yes
	C-2	AIK-0817	New Ellenton, 4 miles WSW (County Road 146)	5	C	561	Yes
	C-3	AIK-0826	Windsor, 4 miles NNE (Aiken State Park)	6	C	526	Yes
Allendale	C-7	ALL-0358	Millet, 3 miles NE (County Road 24)	9	C	1,416	Yes
	C-10	ALL-0348	Allendale, 3.5 miles W (County Road 52)	9	C	1,734	Yes
Bamberg	River's Bridge State Park	BAM-0068	Ehrhardt, 5.7 miles SW (River's Bridge State Park)	0	I	415	No
Barnwell	C-5	BRN-0358	Williston, 3.5 miles S	7	C	1,084	Yes
	C-6	BRN-0349	Barnwell, 4 miles SE (S.C. Highway 300)	8	C	1,385	Yes
Beaufort	Hilton Head	BFT-2055	Hilton Head Island (near Singleton Beach)	1	I	3,833*	Yes
Berkeley	St. Stephen	BRK-0644	St. Stephen (St. Stephen Middle School)	1	I	1,826	Yes
Calhoun	Creston	CAL-0190	Creston (EMS/Fire Station)	4	I	1,058	Yes
Charleston	Cannon Park	CHN-0800	Charleston (downtown at Cannon Park)	0	I	1,012	No
	Garris Landing	CHN-0802	Awendaw, 7.1 miles SSW (public boat landing)	2	I	369	No
	Santee Coastal Reserve	CHN-0803 CHN-0820	McClellanville, 7 miles NE (Santee Coastal Reserve)	1	I	1,539	No
Chesterfield	McBee WMA	CTF-0321	McBee, 3.2 miles SSW (McBee Wildlife Management Area)	2	I	400	Yes
	Cheraw State Park	CTF-0081	Cheraw, 2.5 miles S (Cheraw State Park)	1	I	245	Yes
Clarendon	---						
Colleton	Edisto Beach	COL-0364	Edisto Beach (Edisto Beach State Park)	0	I	977	No
Darlington	Lake Darpo	DAR-0228	Society Hill, 3 miles SSW (Lake Darpo)	1	I	447	Yes
Dillon	Little Pee Dee State Park	DIL-0121	Dillon, 6.5 miles SE (Little Pee Dee State Park)	6	C	647	Yes

* Side-wall cores approximately every 10 ft.

Table 4. Continued

County	Site name	Corehole ID	Location	Number of wells	Complete (C) or Incomplete (I) cluster site	Depth of core (ft)	Cored to bedrock?
Dorchester	St. George #1	DOR-0211	St. George, 3.0 miles SE (U.S. Highway 78)	0	I	2,063	Yes
	Clubhouse Cross-roads #1	DOR-0037	Cottageville, 7.8 miles SE (County Road 163)	0	I	2,599	Yes
Florence	Florence	FLO-0268	Florence (downtown)	0	I	716	Yes
	Lake City	FLO-0274	Lake City (Lake City Airport)	2	I	1,090	Yes
Georgetown	Hobcaw Barony	GEO-0380	Georgetown, 4.2 miles SE (Hobcaw Barony Wildlife Refuge)	3	I	830	No
Hampton	---						
Horry	Myrtle Beach	HOR-0973 HOR-1165	Myrtle Beach (surface water treatment plant)	1	I	1,427	Yes
Jasper	C-15	JAS-0426	Ridgeland, 9 miles NNW (U.S. Highway 278)	4	I	2,900*	Yes
Kershaw	---						
Lee	Lee State Park	LEE-0075	Bishopville, 3.5 miles ESE (Lee State Park)	4	C	554	Yes
Lexington	Swansea	LEX-0844	Swansea (Swansea High School Freshman Academy)	1	I	548	Yes
Marion	Brittons Neck	MRN-0078	Brittons Neck, 3 miles S (former fire tower site)	2	I	1,230	Yes
Marlboro	---						
Orangeburg	Clark Middle School	ORG-0393	Orangeburg (Clark Middle School)	3	I	1,138	Yes
Richland	Eastover	RIC-0543	Eastover (Webber Elementary School)	1	I	557	Yes
	Horrel Hill	RIC-0585	Columbia, 6 miles ESE (Horrel Hill Elementary School)	1	I	469	Yes
Sumter	MAN-1A	SUM-0296	Rimini, 3.4 miles NW (Manchester State Forest)	0	I	725	No
	Sumter Airport	SUM-0340	Sumter, 5.0 miles NNW (Sumter Airport)	0	I	690	Yes
Williamsburg	---						

* Side-wall cores approximately every 10 ft.

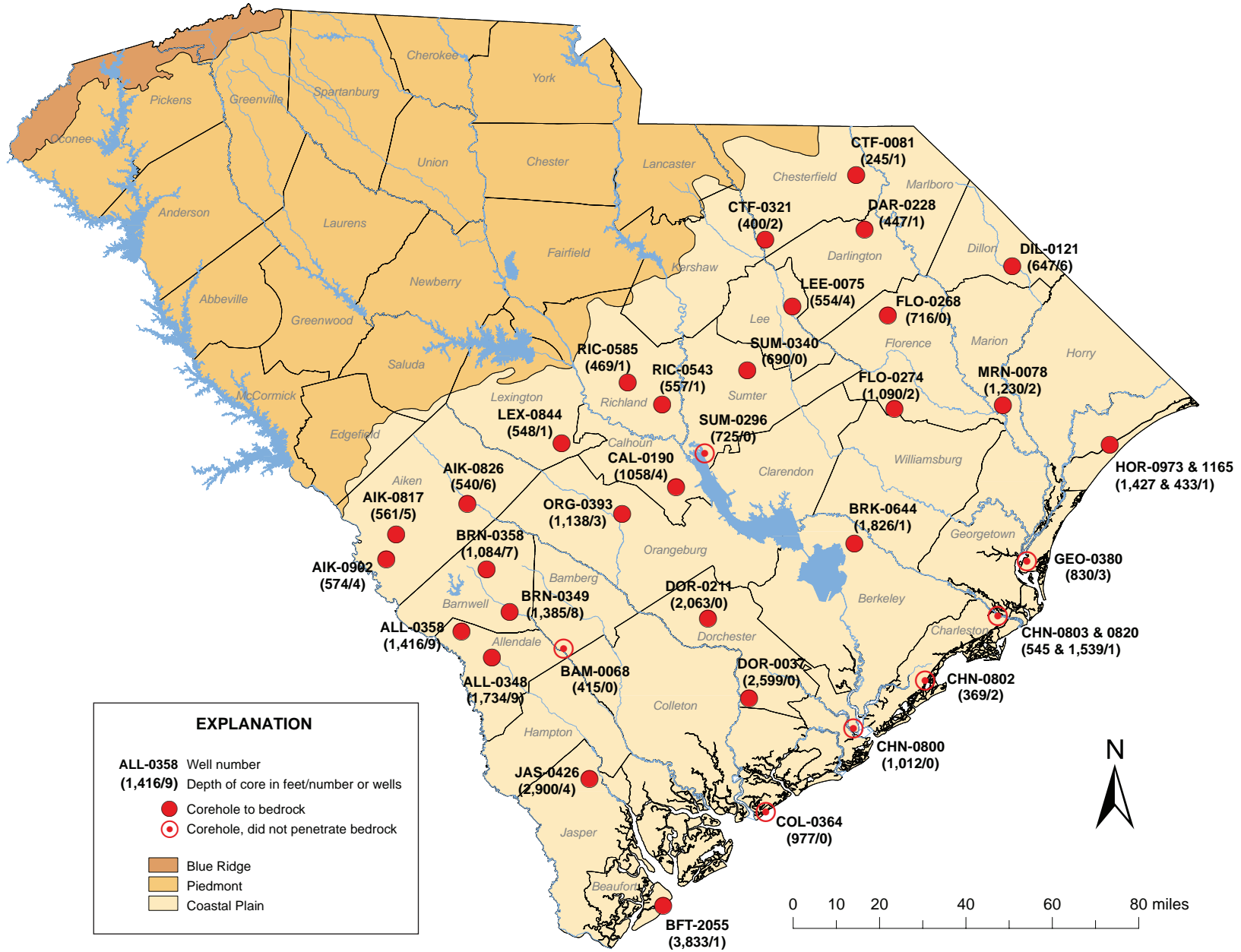


Figure 39. Locations of coreholes that have been drilled for the DNR groundwater monitoring network.

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APPENDIX A

DNR Groundwater Monitoring Network Wells

Table A1. DNR groundwater monitoring network wells (as of June 2014)

Well ID	DNR grid number	Measuring point description	Measuring point height (ft)	Latitude / Longitude (Dec. Deg.)	Land surface elevation (ft)	Elevation method	Well depth (ft)	Screen or open-hole interval (ft)	Aquifer ¹	Aquifer ²
AIK-0817	40V-s2	Top of sanitary seal	2.94	33.437847 81.770372	418.2	Survey	535	520–530	Middendorf	McQueen Branch
AIK-0818	40V-s3	Top of sanitary seal	3.06	33.437831 81.770256	417.5	Survey	425	410–420	Middendorf	McQueen Branch
AIK-0824	40V-s5	Top of sanitary seal	2.6	33.437794 81.770361	417.8	Survey	365	350–360	Black Creek	Crouch Branch
AIK-0825	40V-s6	Top of sanitary seal	1.66	33.437767 81.770275	418.0	Survey	231	216–226	Black Creek	Crouch Branch
AIK-0826	36U-o1	Top of sanitary seal	2.1	33.542411 81.485739	294.0	Survey	500	485–495	Middendorf	McQueen Branch
AIK-0845	36U-o2	Top of sanitary seal	2.88	33.542519 81.485675	296.0	Survey	356	341–351	Middendorf	McQueen Branch
AIK-0846	36U-o3	Top of sanitary seal	3.02	33.542339 81.485586	296.9	Survey	255	240–250	Black Creek	Crouch Branch
AIK-0847	36U-o4	Top of sanitary seal	2.79	33.542464 81.485544	298.1	Survey	193	178–188	Black Creek	Crouch Branch
AIK-0848	36U-o5	Top of sanitary seal	3.05	33.542303 81.485414	298.8	Survey	131	116–126	Black Creek	Crouch Branch
AIK-0849	36U-o6	Top of sanitary seal	3.05	33.542375 81.485403	300.7	Survey	97	82–92	Black Creek	Crouch Branch
AIK-0902	40W-q1	Top of sanitary seal	2.7	33.353522 81.808803	231.1	Survey	511	496–506	Middendorf	McQueen Branch
AIK-2378	40W-q2	Top of sanitary seal	1.54	33.353286 81.809017	219.5	Survey	185	170–180	Black Creek	Crouch Branch
AIK-2379	40W-q3	Top of sanitary seal	2.43	33.353386 81.808953	222.9	Survey	266	251–261	Black Creek	Crouch Branch
AIK-2380	40W-q4	Top of sanitary seal	2.29	33.353433 81.808900	227.5	Survey	385	370–380	Middendorf	McQueen Branch
ALL-0347	35AA-q2	Top of sanitary seal	2.25	33.024733 81.384250	280.8	Survey	1,423	1,408–1,418	Middendorf	McQueen Branch
ALL-0348	35AA-q3	Top of sanitary seal	2.8	33.024994 81.384753	279.6	Survey	1,605	1,575–1,600	Cape Fear	Gramling confining unit
ALL-0358	37Z-t3	Top of sanitary seal	2.27	33.113283 81.506128	242.2	Survey	1,123	1,108–1,118	Middendorf	McQueen Branch

Table A1. Continued

Well ID	DNR grid number	Measuring point description	Measuring point height (ft)	Latitude / Longitude (Dec. Deg.)	Land surface elevation (ft)	Elevation method	Well depth (ft)	Screen or open-hole interval (ft)	Aquifer ¹	Aquifer ²
ALL-0363	37Z-t4	Top of sanitary seal	2.96	33.113761 81.506194	245.2	Survey	105	90–100	Floridan	Upper Three Runs
ALL-0364	37Z-t5	Top of sanitary seal	2.82	33.113633 81.506153	244.3	Survey	225	210–220	Floridan	Upper Three Runs
ALL-0365	37Z-t6	Top of sanitary seal	3.19	33.113536 81.506142	243.4	Survey	333	318–328	Tertiary Sand	Gordon
ALL-0366	37Z-t7	Top of sanitary seal	2.76	33.113392 81.506150	242.6	Survey	400	385–395	Tertiary Sand	Gordon
ALL-0367	37Z-t8	Top of sanitary seal	3.04	33.113419 81.505969	244.9	Survey	566	551–561	Black Creek	Crouch Branch
ALL-0368	37Z-t9	Top of sanitary seal	2.98	33.113528 81.506011	245.7	Survey	691	676–686	Black Creek	Crouch Branch
ALL-0369	37Z-t10	Top of sanitary seal	2.82	33.113156 81.506094	241.2	Survey	800	785–795	Black Creek	Crouch Branch
ALL-0370	37Z-t11	Top of sanitary seal	2.72	33.113300 81.505958	244.2	Survey	975	960–970	Middendorf	McQueen Branch
ALL-0371	35AA-q4	Top of sanitary seal	3.00	33.024839 81.384689	281.4	Survey	217	192–212	Floridan	Upper Floridan
ALL-0372	35AA-q5	Top of sanitary seal	2.96	33.024822 81.384561	281.2	Survey	155	140–150	Floridan	Upper Floridan
ALL-0373	35AA-q6	Top of sanitary seal	2.74	33.024850 81.384250	278.8	Survey	372	327–367	Floridan	Middle Floridan
ALL-0375	35AA-q8	Top of sanitary seal	3.46	33.024903 81.384925	282.0	Survey	583	453–578	Tertiary Sand	Gordon
ALL-0376	35AA-q9	Top of sanitary seal	3.33	33.024875 81.384808	281.4	Survey	994	784–989	Black Creek	Crouch Branch
ALL-0377	35AA-q10	Top of sanitary seal	3.52	33.024778 81.384389	280.7	Survey	1,199	1,174–1,194	Middendorf	McQueen Branch
ALL-0378	37AA-g2	Top of outer metal enclosure	4.75	33.062028 81.564194	84	LIDAR	1,060	845–1,055	Middendorf	McQueen Branch
AND-0326	48H-n2	Top of casing	1.1	34.622668 82.481881	788	LIDAR	398	75–398	Crystalline Rock	Crystalline rock
BFT-0101	27KK-y1	Bottom surface of instrument housing	3.39	32.168778 80.740644	13.4	Survey	442	129–442	Floridan	Upper Floridan

Table A1. Continued

Well ID	DNR grid number	Measuring point description	Measuring point height (ft)	Latitude / Longitude (Dec. Deg.)	Land surface elevation (ft)	Elevation method	Well depth (ft)	Screen or open-hole interval (ft)	Aquifer ¹	Aquifer ²
BFT-0429	28JJ-y1	Top of polyboard support platform	1.85	32.264056 80.819639	20.6	Survey	300	119–300*	Floridan	Upper Floridan
BFT-1809	27JJ-q2	Bottom surface of instrument housing	1.2	32.267138 80.722771	10.8	Survey	903	227–890*	Floridan	Middle Floridan
BFT-1813	27KK-j05	Top of casing	0.6	32.233104 80.677023	10.5	Survey	600	276–600*	Floridan	Middle Floridan
BFT-1814	27KK-j6	Top of sanitary seal	0.72	32.233131 80.677028	11	LIDAR	210	120–210	Floridan	Upper Floridan
BFT-1820	27KK-o10	Top of PVC insert	0.82	32.203956 80.749583	8.9	Survey	600	316–600*	Floridan	Middle Floridan
BFT-1822	27kk-o11	Top of PVC insert	0.61	32.203944 80.749419	8.7	Survey	260	091–260*	Floridan	Upper Floridan
BFT-1845	28JJ-p5	Top of PVC insert	2.86	32.280425 80.821561	11.3	Survey	600	255–600	Floridan	Middle Floridan
BFT-1846	28JJ-p6	Top of PVC insert	3.1	32.280500 80.821528	11.3	Survey	180	85–180*	Floridan	Upper Floridan
BFT-2025	27KK-r14	valve nearest quick connect	2.82	32.191380 80.703849	11.2	Survey	3,708	2,782–3,688	Middendorf	Charleston/ Gramling
BRK-0644	18W-b2	Top of aluminum collar	3.0	33.404313 79.933885	72	LIDAR	93	53–93	Floridan	Gordon
BRN-0078	36W-j1	Top of sanitary seal	3.63	33.399878 81.421874	337	LIDAR	775	568–770	Middendorf	McQueen Branch
BRN-0349	34Y-x1	Top of sanitary seal	3.33	33.178678 81.314481	207.7	Survey	1,045	1,030–1,040	Middendorf	McQueen Branch
BRN-0350	34Y-x2	Top of sanitary seal	2.74	33.179167 81.314169	206.5	Survey	170	155–165	Floridan	Upper Three Runs
BRN-0351	34Y-x3	Top of sanitary seal	2.75	33.179103 81.314053	206.4	Survey	95	80–90	Floridan	Upper Three Runs
BRN-0352	34Y-x4	Top of sanitary seal	2.49	33.178994 81.314147	206.3	Survey	293	278–288	Tertiary Sand	Gordon
BRN-0353	34Y-x5	Top of sanitary seal	2.61	33.178886 81.314286	206.8	Survey	588	573–583	Black Creek	Crouch Branch
BRN-0354	34Y-x6	Top of sanitary seal	2.85	33.179086 81.314278	206.7	Survey	411	396–406	Tertiary Sand	Gordon

Table A1. Continued

Well ID	DNR grid number	Measuring point description	Measuring point height (ft)	Latitude / Longitude (Dec. Deg.)	Land surface elevation (ft)	Elevation method	Well depth (ft)	Screen or open-hole interval (ft)	Aquifer ¹	Aquifer ²
BRN-0355	34Y-x7	Top of sanitary seal	2.59	33.178994 81.314394	207.1	Survey	701	686–696	Black Creek	Crouch Branch
BRN-0356	34Y-x8	Top of sanitary seal	2.47	33.178886 81.314481	207.7	Survey	929	914–924	Middendorf	McQueen Branch
BRN-0358	35X-e2	Top of sanitary seal	2.0	33.321342 81.407067	264.7	Survey	847	832–842	Middendorf	McQueen Branch
BRN-0359	35X-e3	Top of sanitary seal	2.12	33.321819 81.406575	264.6	Survey	214	199–209	Tertiary Sand	Gordon
BRN-0360	35X-e4	Top of sanitary seal	2.06	33.321703 81.406714	263.4	Survey	140	125–134	Tertiary Sand	Upper Three Runs
BRN-0365	35X-e5	Top of sanitary seal	3.0	33.321603 81.406800	262.6	Survey	539	524–534	Black Creek	Crouch Branch
BRN-0366	35X-e6	Top of sanitary seal	3.0	33.321358 81.406906	265.8	Survey	715	700–710	Middendorf	McQueen Branch
BRN-0367	35X-e7	Top of sanitary seal	3.0	33.321503 81.406917	262.9	Survey	285	270–280	Tertiary Sand	Upper Three Runs
BRN-0368	35X-e8	Top of sanitary seal	3.05	33.321450 81.406797	264.2	Survey	443	428–438	Black Creek	Crouch Branch
CAL-0192	26T-x4	Top of PVC instrument support	3.39	33.598500 80.647750	190.1	Survey	49	28–48	Shallow Aquifer System	Surficial
CAL-0193	26T-x5	Top of PVC instrument support	3.52	33.598639 80.647889	190.5	Survey	100	85–95	Tertiary Sand	Gordon
CAL-0194	26T-x6	Top of PVC instrument support	3.08	33.598583 80.647861	189.9	Survey	254	239–249	Black Creek	Crouch Branch
CAL-0195	26T-x7	Top of PVC instrument support	3.03	33.598583 80.647861	189.6	Survey	360	345–355	Black Creek	Crouch Branch
CHN-0044	19DD-o1	Top of polyboard support platform	0.65	32.796615 80.070112	8.4	Survey	434	180–425	Floridan	Gordon
CHN-0101	13AA-n2	Top of polyboard support platform	0.46	33.046038 79.566737	22	TOPO	91	82–91	Floridan	Gordon
CHN-0484	22GG-d1	Bottom surface of instrument housing	1.7	32.581328 80.305468	13.5	Survey	560	280–548*	Floridan	Gordon confining unit
CHN-0803	11Z-b1	Top of casing	2.46	33.155777 79.363864	9.9	Survey	113	48–113	Floridan	Gordon

Table A1. Continued

Well ID	DNR grid number	Measuring point description	Measuring point height (ft)	Latitude / Longitude (Dec. Deg.)	Land surface elevation (ft)	Elevation method	Well depth (ft)	Screen or open-hole interval (ft)	Aquifer ¹	Aquifer ²
CHN-0989	21EE-a2	Top of sanitary seal	3.02	32.737332 80.177658	15	TOPO	531	160–561*	Floridan	Gordon
CHN-0990	14BB-p4	Top of sanitary seal	2.88	32.940688 79.656869	5	TOPO	268	188–263	Floridan	Gordon
CHN-0991	14BB-p5	Top of sanitary seal	2.97	32.940649 79.656894	5	TOPO	48	33–43	Shallow	Surficial
COL-0030	27CC-j1	Top of sanitary seal	0.3	32.895883 80.677858	60.4	Survey	1,340		Black Creek	Crouch Branch
COL-0097	26AA-k1	Top of sanitary seal	1.78	33.047717 80.597583	80	LIDAR	342	134–342*	Floridan	Middle Floridan/ Gordon
COL-0301	22GG-w4	Bottom surface of instrument housing	2.65	32.511619 80.299245	9.0	Survey	545	516–545	Floridan	Gordon confining unit
CRK-0074	36B-b16	Top of casing	1.3	35.155294 81.442778	821	LIDAR	265	99–265	Crystalline Rock	Crystalline rock
CTF-0081	17H-f1	Bottom surface of instrument housing	1.8	34.643167 79.911564	193	LIDAR	244	231–244	Crystalline Rock	Crystalline rock
CTF-0221	22J-v1	Top of instrument housing	3.69	34.428750 80.282806	409.1	Survey	260	235–255	Middendorf	McQueen Branch
CTF-0222	22J-v2	Top of instrument housing	4.25	34.422872 80.282806	409.1	Survey	175	150–170	Black Creek	Crouch Branch
DAR-0228	17J-m1	Bottom surface of instrument housing	1.7	34.458903 79.879917	168	LIDAR	186	175–185	Middendorf	McQueen Branch
DIL-0121	10L-b1	Bottom surface of instrument housing	2.98	34.328553 79.283008	99	LIDAR	294	269–284	Middendorf	McQueen Branch
DIL-0171	10L-c2	Top of PVC instrument support	3.0	34.330271 79.286919	82	LIDAR	555	540–550	Cape Fear	Gramling confining unit
DIL-0172	10L-c3	Top of PVC instrument support	2.94	34.330283 79.286972	82	LIDAR	175	160–170	Black Creek	McQueen Branch
DIL-0173	10L-c4	Top of PVC instrument support	2.96	34.330286 79.286983	82	LIDAR	380	370–375	Middendorf	Charleston
DIL-0174	10L-c5	Top of PVC instrument support	2.9	34.330301 79.287013	82	LIDAR	75	60–70	Black Creek	Crouch Branch
DIL-0175	10L-c6	Top of PVC instrument support	2.94	34.330315 79.287024	82	LIDAR	325	315–320	Middendorf	McQueen Branch

Table A1. Continued

Well ID	DNR grid number	Measuring point description	Measuring point height (ft)	Latitude / Longitude (Dec. Deg.)	Land surface elevation (ft)	Elevation method	Well depth (ft)	Screen or open-hole interval (ft)	Aquifer ¹	Aquifer ²
FLO-0128	13M-p3	Top of sanitary seal	2.75	34.195667 79.580372	94	LIDAR	695	265–690	Middendorf	McQueen Branch
FLO-0274	16Q-s1	Bottom surface of instrument housing	1.34	33.855853 79.766617	77.6	Survey	560	540–560	Middendorf	McQueen Branch
FLO-0276	16Q-s2	Bottom surface of instrument housing	1.31	33.855833 79.766622	78.0	Survey	250	230–250	Black Creek	Crouch Branch
GEO-0381	9W-y3	Top of PVC instrument support	3.15	33.335815 79.244638	10	Topo	47	27–47	Shallow Aquifer System	Surficial
GEO-0382	9W-y4	Top of sanitary seal	3.09	33.335813 79.244599	10	Topo	730	700–720	Black Creek	McQueen Branch
GEO-0383	9W-y5	Top of sanitary seal	2.90	33.335814 79.244558	10	Topo	560	530–550	Black Creek	Crouch Branch
GRV-0712	50B-r1	Top of sanitary seal	0.6	35.106546 82.626367	3,179	LIDAR	450	28–450	Crystalline Rock	Crystalline rock
GRV-2162	46E-a2	Lower shelf in instrument housing	1.53	34.904605 82.263341	872	LIDAR	281	83–289	Crystalline Rock	Crystalline rock
GRV-2230	48D-v2	Bottom surface of instrument housing	2.4	34.924401 82.444599	982	LIDAR	20	4–20	Shallow Aquifer System	Shallow
GRV-2543	49B-o2	Bottom surface of instrument housing	1.46	35.126334 82.571352	1,328.6	Survey	50	0–50	Crystalline Rock	Crystalline rock
GRV-3333	48B-d3	Top of sanitary seal	1.24	35.166123 82.471393	1,872.7	Survey	264	58–264*	Crystalline Rock	Crystalline rock
GRV-3335	49B-o4	Top of sanitary seal	1.06	35.124998 82.573712	1,353.4	Survey	110	62–110*	Crystalline Rock	Crystalline rock
GRV-3336	49B-o5	Top of sanitary seal	2.08	35.124998 82.573712	1,353.2	Survey	20	14–20*	Shallow Aquifer System	Shallow
GRV-3341	45B-d1	Top of sanitary seal	2.58	35.160745 82.224687	1,030.4	Survey	80	70–80*	Shallow Aquifer System	Shallow
GRV-3342	45B-d2	Top of PVC instrument support	1.09	35.160745 82.224687	1,030.4	Survey	334	132–334*	Crystalline Rock	Crystalline rock
GRV-3533	48D-v9	Bottom surface of instrument housing	2.23	34.924401 82.444599	982	LIDAR	243	45–243	Crystalline Rock	Crystalline rock
HAM-0050	33EE-v1	Top of white PVC instrument support fitting	2.25	32.679794 81.187117	114	LIDAR	968	Open hole?	Tertiary Sand	Gordon

Table A1. Continued

Well ID	DNR grid number	Measuring point description	Measuring point height (ft)	Latitude / Longitude (Dec. Deg.)	Land surface elevation (ft)	Elevation method	Well depth (ft)	Screen or open-hole interval (ft)	Aquifer ¹	Aquifer ²
HAM-0083	29EE-s1	Top of plywood support platform	2.05	32.697664 80.850811	30	LIDAR	113	85–113*	Floridan	Upper Floridan
HOR-0290	6S-v2	Top of of PVC insert	0.0	33.670796 78.939180	21	LIDAR	459		Black Creek	Crouch Branch
HOR-0309	6R-r1	Top of white PVC instrument support fitting	3.74	33.767615 78.966320	41.8	Survey	375	360–375	Black Creek	Crouch Branch
HOR-0973	5S-f1	Top of well head blind flange	3.37	33.722647 78.903051	15	LIDAR	1331	1,012–1,328	Middendorf	Gramling
JAS-0425	30FF-o1	Bottom surface of instrument housing	1.97	32.618014 80.995339	64.1	Survey	225	150–225*	Floridan	Upper Floridan
JAS-0426	30FF-o2	Top of well head blind flange	2.74	32.618200 80.995389	62.3	Survey	1994	1,949–1,994	Middendorf	Charleston
JAS-0468	30FF-o4	Top of white PVC instrument support fitting	2.97	32.617778 80.995833	64.1	Survey	23.7	17-22	Shallow Aquifer System	Surficial
JAS-0492	30FF-o3	Top of PVC insert	2.66	32.618094 80.995278	65	LIDAR	600	300–600*	Floridan	Middle Floridan
KER-0263	24I-i1	Top of sanitary seal	1.45	34.558931 80.445233	470	LIDAR	455	103–455*	Crystalline Rock	Crystalline rock
LEE-0075	21M-k1	Bottom surface of instrument housing	3.55	34.202390 80.175006	196	LIDAR	356	306–356	Middendorf	McQueen Branch
LEE-0179	21M-k2	Top of sanitary seal	2.97	34.202251 80.174364	196	LIDAR	243	228–238	Black Creek	Crouch Branch
LEE-0180	21M-k3	Top of sanitary seal	3.0	34.202209 80.174480	197	LIDAR	202	127–197	Black Creek	Crouch Branch
LEE-0181	21M-k4	Top of sanitary seal	2.78	34.202219 80.174513	197	LIDAR	75	50–70	Black Creek	Crouch Branch
LEX-0823	32S-b2	Top of sanitary seal	3.11	33.735778 81.105389	305	LIDAR	225	150–220	Black Creek	Crouch Branch
LEX-0844	32S-b4	Bottom surface of instrument housing	3.35	33.746031 81.107575	366	LIDAR	522	392–502	Middendorf	McQueen Branch
LRN-1705	43J-c2	Bottom surface of instrument housing	2.82	34.490742 82.042902	638.3	Survey	39	29–39*	Shallow Aquifer System	Shallow
LRN-1706	44I-b1	Top of sanitary seal	0.0	34.570851 82.113771	847	LIDAR	168	Open hole	Crystalline Rock	Crystalline rock

Table A1. Continued

Well ID	DNR grid number	Measuring point description	Measuring point height (ft)	Latitude / Longitude (Dec. Deg.)	Land surface elevation (ft)	Elevation method	Well depth (ft)	Screen or open-hole interval (ft)	Aquifer ¹	Aquifer ²
LRN-1707	43K-k1	Bottom surface of instrument housing	0.75	34.381281 82.006283	660	LIDAR	223	Open hole	Crystalline Rock	Crystalline rock
MRN-0077	10Q-p1	Top of white PVC instrument support fitting	1.7	33.861750 79.330625	34.7	Survey	356	325–355	Black Creek	Crouch Branch
MRN-0078	10Q-p2	Top of well head blind flange	2.86	33.861781 79.330303	33.6	Survey	1,038	1,008–1,028	Cape Fear	Gramling
ORG-0079	29V-v1	Top of outer casing	0.67	33.413189 80.847567	184	LIDAR	995	843–974	Middendorf	McQueen Branch
ORG-0393	29U-v1	Bottom surface of instrument housing	3.51	33.508258 80.864939	257	LIDAR	463	423–463	Black Creek	Crouch Branch
ORG-0430	29U-v2	Bottom surface of instrument housing	3.25	33.508267 80.864917	257	LIDAR	275	205–265	Tertiary Sand	Gordon
ORG-0431	29U-v3	Bottom surface of instrument housing	3.13	33.508267 80.864925	257	LIDAR	93	83–88	Floridan	Upper Three Runs
RIC-0543	27Q-m1	Bottom surface of instrument housing	3.44	33.875017 80.702433	184.8	Survey	420	370–410	Middendorf	McQueen Branch
RIC-0585	29P-t4	Top of 2 inch casing	4.2	33.948939 80.840953	327.0	Survey	403	363–393	Middendorf	McQueen Branch
SAL-0069	39N-u3	Top of sanitary seal	2.3	34.087861 81.669919	453.1	LIDAR	480	92–480*	Crystalline Rock	Crystalline rock
SUM-0355	23O-y3	Top of sanitary seal	1.25	34.016525 80.402206	199	LIDAR	47		Shallow Aquifer System	Surficial
SUM-0488	24Q-l1	Top of sanitary seal	2.0	33.874289 80.437892	178	LIDAR	546	511–541	Middendorf	McQueen Branch
SUM-0492	19P-q3	Top of sanitary seal	2.1	33.945669 79.979736	121	LIDAR	522	502–517	Middendorf	McQueen Branch
SUM-0497	24Q-l2	Bottom surface of instrument housing	3.27	33.874167 80.437767	178	LIDAR	100	70–100	Black Creek	Crouch Branch
WIL-0355	16W-b2	Bottom surface of instrument housing	3.9	33.402523 79.778185	54	LIDAR	869	824–854	Black Creek	Charleston

* open-hole interval

1 Aquifer based on hydrogeologic framework of Aucott and others (1986)

2 Aquifer based on hydrogeologic framework of Gellici and Lautier (2010)

APPENDIX B

Data Collection Methods and Instrumentation

DATA COLLECTION METHODS AND INSTRUMENTATION

Well Location and Land Surface Elevation Data

The locations of all monitoring wells have been determined with the Global Positioning System (GPS) using the North American Datum of 1983 (NAD83).

A number of the network's land-surface and measuring-point elevations were surveyed from USGS or South Carolina Geodetic Survey benchmarks and are reported to the nearest tenth or hundredth of a foot using the North American Vertical Datum of 1988 (NAVD88). Elevations not determined from existing benchmarks are estimated from LIDAR data and reported to the nearest foot. Owing to the lack of current LIDAR data in Georgetown County and portions of Charleston County, elevations for 7 wells were taken from USGS topographic maps and estimated to the nearest foot, and are considered accurate to one-half the map contour interval.

Manual Measurements

Manual measurements or tape downs are typically made with electric tapes, which are capable of an accuracy of 0.01 ft (feet). However, visibility, thermal expansion and contraction, and tape sinuosity diminish measurement accuracy in field conditions, and accuracies, therefore, are assumed to be no better than 0.05 ft in practice. Less accuracy is likely where depth to water is greater than 100 ft.

Flowing artesian wells are manually measured with 0–30, 0–60, or 0–100 psi (pounds per square inch) range Bourdon-type test gages. The gages are calibrated once a year at a commercial testing laboratory and are rated to 0.25 percent of their respective measurement ranges. In practice, accuracy will be diminished by errors from gage-zero adjustment, parallax, readings near the extremes of gage range, and mechanical degradation subsequent to calibration. Table B1 summarizes the manufacturer-rated accuracies and the authors' assumptions for measurement.

Automated Measurements

Water-level sensors used for automated monitoring stations have historically included pressure transducers and shaft encoders whose readings are calibrated to manual measurements. By 2008, all wells in the midlands and Coastal Plain regions were instrumented with pressure transducers. Shaft encoders continued to be used in a series of wells in the upstate; however, by the summer of 2014, all shaft encoders were removed and replaced with pressure transducers.

Pressure transducers measure the height of water above a semiconductor strain gage: electrical resistance to an input voltage and, therefore, voltage output changes as varying water pressure deforms the crystalline lattice of the gage's silicon diaphragm (piezoresistive effect). There is a near-linear correlation between the sensor's pressure range and output-voltage range, and water depth is computed from the voltage measurement. There are three brands of pressure transducers currently utilized within the network: Schlumberger® Divers®, Solinst® Leveloggers®, and In-Situ® Trolls®. Pressure transducers are deployed in wells using direct read cables, which allows for real-time water level measurements to be determined and also eliminates the need to remove the sensor from the well.

Table B2 lists specifications for the various types of transducers utilized in the network. Most transducers in the network have a pressure range from 0–65 ft (0–20 meters) and accuracies and resolutions of less than 0.07 ft and 0.01 ft, respectively. Nearly all of these transducers are not vented to the atmosphere and measure total pressure, which includes pressure from both the water column and the atmosphere. Unvented transducers require barometric compensation to determine water level, and hence, barometric data are collected at strategic sites for correction purposes (see Plate). Efforts are made to ensure that a barometric monitoring site is located within 20 miles of each monitoring well.

Vented transducers, which have sensors open to the atmosphere via a vent tube, are installed in a few sites

Table B1. Ranges and accuracies of 0.25-percent precision test gages used by DNR

Gage range (psi)	Rated gage accuracy (psi)	Rated gage accuracy (ft)	Measurement accuracy (ft)
0 – 30	0.075	0.17	0.4
0 – 60	0.150	0.34	0.5
0 – 100	0.250	0.57	0.8

along the coast and require no barometric compensation. In addition, a few transducers (Aqua TROLL 200s) along the coast have a pressure range of 0–692 ft (0–210 meters), are vented to the atmosphere, and have accuracies and resolutions of 0.70 ft and 0.03 ft, respectively. These probes also measure conductivity and are part of a DNR’s saltwater intrusion monitoring program. Recently, Aqua TROLL 200s at several sites were replaced by separate water level probes (Solinst Leveloggers or Schlumberger Divers with a 20 meter pressure range) and conductivity probes in order to improve the accuracy of the water level measurements at these sites. Transducers with ceramic and titanium hous-

ings are typically used along the coast to provide protection from the potential corrosive effects of saltwater.

Shaft encoders were made by Unidata (models 6540, 6550). Shaft encoders measure depth to water and consist of a pulley whose movement is optically or electronically measured, and a cable, float, and counterweight assembly. They have a rated accuracy and resolution of 0.01 ft.

Water level and barometric transducers are synchronized with one another and record data every hour. Shaft encoders also recorded water levels every hour. Table B3 lists the 99 ADR sites in the network along with the instrumentation currently associated with each site.

Table B2. Specifications of ADR equipment currently installed in monitoring network

Brand	Model	Pressure Range	Variables	Housing Material
In-Situ	Aqua TROLL 200	0–692 ft (0–210 m)	water level, conductivity, temperature	titanium
In-Situ	Level TROLL 500	0–69 ft (0–21 m)	water level, temperature	titanium
Schlumberger	DI501, Baro Diver	0–5 ft (0–1.5 m)	barometric pressure	stainless steel
Schlumberger	DI502, Mini Diver	0–65 ft (0–20 m)	water level, temperature	stainless steel
Schlumberger	DI602, Micro Diver	0–65 ft (0–20 m)	water level, temperature	stainless steel
Schlumberger	DI702, Cera Diver	0–65 ft (0–20 m)	water level, temperature	ceramic
Schlumberger	DI273, CTD Diver	0–328 ft (0–100 m)	water level, conductivity, temperature	ceramic
Solinst	3001, Barologger Edge	0–3 ft (0–1 m)	barometric pressure	stainless steel / titanium coating
Solinst	3001, Levelogger Edge	0–65 ft (0–20 m)	water level, temperature	stainless steel / titanium coating
Solinst	3001, Barologger Gold	0–3 ft (0–1 m)	barometric pressure	stainless steel / zirconium
Solinst	3001, Levelogger Gold	0–65 ft (0–20 m)	water level, temperature	stainless steel / zirconium

Table B3. ADR equipment currently installed in each ADR well

Well ID	Brand	Water-level Model	Barometer Model
AIK-0817	Solinst	3001 Levelogger Edge	DI501, Baro Diver
AIK-0824	Solinst	3001 Levelogger Edge	
AIK-0826	Solinst	3001 Levelogger Edge	
AIK-0847	Solinst	3001 Levelogger Edge	
AIK-0849	Solinst	3001 Levelogger Edge	3001, Barologger Edge
ALL-0367	Solinst	3001 Levelogger Edge	
ALL-0371	Solinst	3001 Levelogger Edge	
ALL-0372	Solinst	3001 Levelogger Edge	
ALL-0373	Solinst	3001 Levelogger Gold	3001, Barologger Gold
ALL-0375	Solinst	3001 Levelogger Edge	
ALL-0376	Solinst	3001 Levelogger Edge	
ALL-0377	Solinst	3001 Levelogger Gold	
AND-0326	Schlumberger	DI502, Mini Diver	DI501, Baro Diver
BFT-0101	Solinst	3001 Levelogger Edge	
BFT-0429	In-Situ	Level TROLL 500	
BFT-1809	Schlumberger	DI702, Cera Diver	
BFT-1813	In-Situ	Aqua TROLL 200	
BFT-1814	Schlumberger	DI702, Cera Diver	
BFT-1820	Schlumberger	DI502, Mini Diver	DI501, Baro Diver
BFT-1822	Solinst	3001 Levelogger Edge	3001, Barologger Edge
BFT-1845	In-Situ	Aqua TROLL 200	
BFT-1846	In-Situ	Level TROLL 500	
BRK-0644	Schlumberger	DI602, Micro Diver	
BRN-0078	Solinst	3001 Levelogger Edge	
BRN-0349	Solinst	3001 Levelogger Edge	
BRN-0351	Solinst	3001 Levelogger Edge	
BRN-0352	Solinst	3001 Levelogger Gold	
BRN-0353	Solinst	3001 Levelogger Edge	
CAL-0192	Solinst	3001 Levelogger Edge	
CAL-0193	Solinst	3001 Levelogger Edge	3001, Barologger Edge
CAL-0194	Solinst	3001 Levelogger Edge	
CAL-0195	Solinst	3001 Levelogger Edge	
CHN-0044	Schlumberger	DI602, Micro Diver	DI501, Baro Diver
CHN-0101	Schlumberger	DI602, Micro Diver	
CHN-0484	Schlumberger	DI702, Cera Diver	
CHN-0803	Solinst	3001 Levelogger Edge	3001, Barologger Edge
CHN-0989	Solinst	3001 Levelogger Edge	
CHN-0990	Schlumberger	DI273, CTD Diver	DI501, Baro Diver
CHN-0991	Schlumberger	DI602, Micro Diver	
COL-0030	Solinst	3001 Levelogger Edge	
COL-0097	Solinst	3001 Levelogger Edge	3001, Barologger Edge
COL-0301	In-Situ	Aqua TROLL 200	
CRK-0074	Solinst	3001 Levelogger Gold	3001, Barologger Gold
CTF-0081	Solinst	3001 Levelogger Edge	3001, Barologger Edge

Table B3. Continued

Well ID	Brand	Water-level Model	Barometer Model
CTF-0221	Solinst	3001 Levelogger Edge	3001, Barologger Edge
CTF-0222	Solinst	3001 Levelogger Edge	
DAR-0228	Solinst	3001 Levelogger Edge	3001, Barologger Edge
DIL-0121	Solinst	3001 Levelogger Edge	3001, Barologger Edge
DIL-0171	Solinst	3001 Levelogger Edge	
DIL-0172	Solinst	3001 Levelogger Edge	
DIL-0173	Solinst	3001 Levelogger Edge	
DIL-0174	Solinst	3001 Levelogger Edge	
DIL-0175	Solinst	3001 Levelogger Edge	
FLO-0128	Schlumberger	DI602, Micro Diver	DI501, Baro Diver
FLO-0274	Schlumberger	DI602, Micro Diver	DI501, Baro Diver
FLO-0276	Schlumberger	DI602, Micro Diver	
GEO-0381	Solinst	3001 Levelogger Edge	
GEO-0382	Solinst	3001 Levelogger Edge	3001, Barologger Edge
GEO-0383	Solinst	3001 Levelogger Edge	
GRV-0712	Solinst	3001 Levelogger Gold	3001, Barologger Gold
GRV-2162	Solinst	3001 Levelogger Gold	3001, Barologger Gold
GRV-2230	Solinst	3001 Levelogger Gold	3001, Barologger Gold
GRV-2543	Solinst	3001 Levelogger Gold	
GRV-3333	Solinst	3001 Levelogger Gold	3001, Barologger Gold
GRV-3335	Solinst	3001 Levelogger Gold	3001, Barologger Gold
GRV-3336	Solinst	3001 Levelogger Gold	
GRV-3341	Solinst	3001 Levelogger Gold	3001, Barologger Gold
GRV-3342	Solinst	3001 Levelogger Gold	
GRV-3533	Solinst	3001 Levelogger Gold	
HAM-0050	Solinst	3001 Levelogger Edge	
HAM-0083	Solinst	3001 Levelogger Edge	
HOR-0290	Schlumberger	DI502, Mini Diver	
HOR-0309	Schlumberger	DI602, Micro Diver	DI501, Baro Diver
JAS-0425	Solinst	3001 Levelogger Edge	3001, Barologger Edge
JAS-0468	Solinst	3001 Levelogger Edge	
JAS-0492	Solinst	3001 Levelogger Edge	
KER-0263	Schlumberger	DI502, Mini Diver	DI501, Baro Diver
LEE-0075	Solinst	3001 Levelogger Edge	
LEE-0179	Solinst	3001 Levelogger Edge	3001, Barologger Edge
LEE-0180	Solinst	3001 Levelogger Edge	
LEE-0181	Solinst	3001 Levelogger Edge	
LEX-0823	Solinst	3001 Levelogger Edge	3001, Barologger Edge
LEX-0844	Solinst	3001 Levelogger Edge	
LRN-1705	Schlumberger	DI502, Mini Diver	DI501, Baro Diver
LRN-1706	Solinst	3001 Levelogger Edge	3001, Barologger Edge
LRN-1707	Solinst	3001 Levelogger Edge	3001, Barologger Edge
MRN-0077	Schlumberger	DI502, Mini Diver	DI501, Baro Diver
ORG-0079	Solinst	3001 Levelogger Edge	

Table B3. Continued

Well ID	Brand	Water-level Model	Barometer Model
ORG-0393	Solinst	3001 Levellogger Edge	
ORG-0430	Solinst	3001 Levellogger Edge	
ORG-0431	Solinst	3001 Levellogger Edge	3001, Barologger Edge
RIC-0543	Schlumberger	DI602, Micro Diver	DI501, Baro Diver
RIC-0585	Schlumberger	DI602, Micro Diver	
SAL-0069	Schlumberger	DI602, Micro Diver	DI501, Baro Diver
SUM-0355	Solinst	3001 Levellogger Edge	
SUM-0488	Schlumberger	DI602, Micro Diver	
SUM-0492	Schlumberger	DI602, Micro Diver	
SUM-0497	Schlumberger	DI602, Micro Diver	
WIL-0355	Schlumberger	DI502, Mini Diver	DI501, Baro Diver

Site Visits

Site visits are currently made a minimum of 6 times per year. A manual measurement is taken from the appropriate measuring point during each site visit and recorded in a field book along with the date and time of the measurement. For automated sites, current or real-time readings are obtained from the ADRs (for both water level sensors and barometric sensors, if applicable) and recorded in a field book. Measurements and sensor settings are made relative to a specified measurement point, and the methods used generally follow those of U.S. Geological Survey (USGS) Stand Alone Procedure Documents (Table B4).

Data are downloaded from the ADRs and evaluated for quality control and instrument performance. For pressure transducers, the sum of the sensor's current water level reading (depth above probe corrected for barometric pressure, if applicable) and corresponding manual measurement (depth to water) is determined during each site visit and is compared to previous sums to determine transducer performance. The sum of the sensor's water-level reading and manual measurement is called the cable length. Where the cable length is found to differ by 0.2 ft from previous measurements (for probes having a 0–65 ft pressure range), a

potential instrument fault may exist, but the ADRs are not typically replaced. Where the specifications are exceeded repeatedly after additional site visits, either instruments are recalibrated or instrument failure is confirmed. If failure is confirmed, the transducer is replaced and the associated records are not added to the groundwater database. Although cable length variations of ± 0.2 ft are tolerated, variations for new transducers over the past 5 years typically have been within ± 0.10 ft.

Transducers with a 0–692 ft pressure range are replaced if the differences in the cable length values determined for each site visit are consistently greater than 0.7 ft. Where the specifications are exceeded repeatedly, instruments are recalibrated or instrument failure is confirmed. Transducers are replaced and records are excluded from the database if instrument failure is confirmed.

For shaft encoders, the sensor reading was set in reference to a manual tape measurement; however, well plumb, casing joints, and cable disturbances can affect subsequent readings. Measurements within 0.10 ft of a concurrent manual measurement are accepted, along with the corresponding records. The records were excluded if successive sensor and manual measurements differed by more than 0.10 ft and if there was no clear means to adjust the record for

Table B4. USGS Stand Alone Procedure Documents applied to the DNR monitoring program

Document number	Title
GWPD-1	Water-level measurement using graduated steel tape
GWPD-3	Establishing a permanent measuring point
GWPD-4	Water-level measurement using an electric tape
GWPD-5	Locating a well
GWPD-12	Water-level measurement in a flowing well

cable slip, float snags, or other error.

Equipment maintenance includes replacing saturated desiccant packs at sites with vented transducers. The desiccant prevents the buildup of moisture in the transducer's vent tube, which can cause faulty water level readings and damage the equipment. Other instrumentation issues include battery failure, communication errors and spurious spikes caused by lightning or other electromagnetic interference. Malfunctioning equipment, either ADRs or direct-read cables, are diagnosed and replaced or repaired as needed. Any issues or changes to instrumentation are documented in a field book. A complete description of standard field operating procedures (SOPs) is located in Appendix C.

Data Processing and Storage

Collected data is typically processed and further reviewed for quality assurance within two weeks after a site visit. All data that have passed quality assurance checks are entered into an Oracle database that uses Microsoft Access as a user interface. The instrumentation history of each well is documented in the database. Documentation includes the types and models of instruments deployed, dates of operation and performance history. In addition, the original field notes are kept and maintained for each well site, and copies are periodically produced in case field books are lost or damaged. Data processing and storage for manual and automated data are as follows:

Manual Measurements

Manual measurements, along with the date and time of the measurement, are entered into the Oracle database. These measurements indicate the depth to water from a specific measuring point on the well. The measuring point height (MPH) in feet above or below land surface for each well is stored in the database. An Access query is used to subtract the MPH from the raw manual measurement to compute a water level in feet below or above land surface. Changes in the MPH height, if any, are documented within the database.

Pressure Transducers

The logged hourly measurements are stored in both raw-data (uncompensated) and processed-data files (compensated, unvented transducers only). The raw-data files contain uncorrected hourly measurements and reflect the readings and the performance of various sensors as they were originally stored in data loggers. Raw data are stored mainly "as is" and are archived at the DNR for insight into hardware conditions and for quality assurance. Processed data files consist of hourly water-level data that have been corrected for barometric pressure. Computer software, specific to each brand of instrument deployed, is used to generate barometrically compensated files, which are also archived at the DNR. The software is also used to plot and review both the raw and compensated data at each ADR site

as a final quality assurance check prior to entering the data in the database. When appropriate, data are winnowed of anomalous measurements and unreliable data thought to be the result of hardware failures.

The real-time ADR reading (after barometric compensation where applicable) is entered into the database and is used along with the corresponding manual measurement to compute a cable length value. The computed cable length value is confirmed to be within the allowed tolerance before any hourly data are added to the database (typically ± 0.20 ft). A history of the cable length value for each site is permanently stored in the database to document instrument performance.

Logged hourly water-level measurements (after compensation, where appropriate) are imported into the Oracle database. These measurements reflect the height of the water column above the sensor and are permanently stored in the database. An Access query, which uses a well's MPH and a designated cable length value, converts the hourly readings to water levels in feet below or above land surface. These hourly water levels are also permanently stored in the database.

Shaft Encoders

Raw-data files containing the logged hourly measurements from well sites with shaft encoders are stored "as is". The raw-data files reflect depths to water from each well's specified measuring point. An encoder's real-time ADR reading is entered into the database and compared directly to the corresponding manual measurement to evaluate instrument performance. For each encoder, the real-time readings are confirmed to be within the allowable tolerance prior to adding the hourly data to the database (± 0.10 ft). The raw data are imported to the Oracle database and permanently stored. Using each well's MPH, an Access query is used to convert the raw hourly data to water levels referenced to land surface. The adjusted hourly water level data are permanently stored in the database.

Statistics

An Access query computes daily average water levels, in feet above or below land surface, from the hourly data for those days missing 7 or fewer hourly measurements. Monthly average water levels are calculated for each month having 5 or fewer days of missing record, while monthly high and low water-level values are recorded for each month having at least one day of data. Yearly averages are computed for each calendar year having 60 or fewer missing days of record, while yearly highs and lows are recorded for each year with at least one day of data. No statistics are calculated for wells that are manually measured owing to the relatively small number of data values available for such wells. Data collected from the network are available on the DNR website at <http://www.dnr.sc.gov/water/hydro/groundwater/index.html>.

APPENDIX C

DNR Standard Operating Procedures for ADR Water Level Network Wells

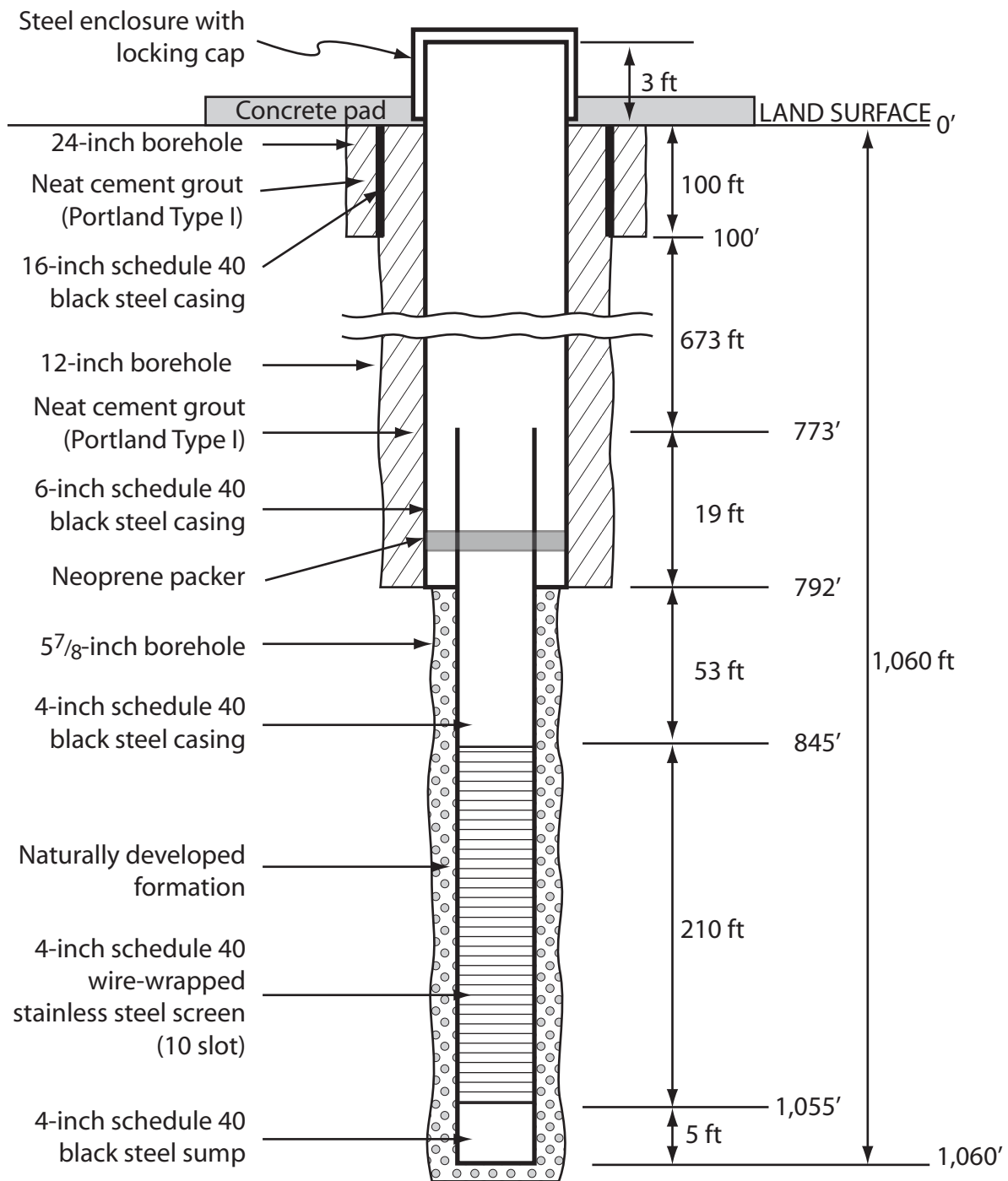
DNR STANDARD OPERATING PROCEDURES FOR ADR WATER LEVEL NETWORK WELLS

1. Site visits should be made a minimum of 6 times per year, approximately once every two months. Additional site visits may be necessary to repair/replace malfunctioning equipment or do perform additional site maintenance.
2. Appropriate quality control and quality assurance measures should be implemented during each site visit:
 - a. For sites with pressure transducers, cable length values should be determined during the time of visit and compared to previous cable length estimates to evaluate the sensor's performance. The cable length value is the sum of 1) the depth of water above probe as measured by the transducer and 2) the depth to water from the measuring point (manual measurement).
 - b. For sites with unvented pressure transducers and no barometric instrument installed on site, a measurement must be taken from a spare barometric instrument that is transported from site to site. This measurement will allow an estimate of the depth of water above probe, and thus, an estimate of the cable length value during each site visit.
 - c. For transducers with pressure ranges rated at 65 feet (20 meters) or less, ADRs should be replaced if cable length values deviate by more than ± 0.20 ft for two consecutive downloads.
 - d. For transducers with pressure ranges rated at 210 meters, ADRs should be replaced if cable length values deviate by more than ± 0.70 ft. for two consecutive downloads.
 - e. Clock accuracy should be checked during each site visit for each ADR instrument. In most cases, a one or two minute error is acceptable. Clocks off by more than a few minutes should be reset.
 - f. For wells that are tidally influenced, the manual measurement and the real-time ADR reading must be collected simultaneously in order to compute accurate cable length values.
3. Model numbers and serial numbers should be documented for all installed ADRs and associated equipment (direct read cables, for example). Any changes to instrumentation must be clearly documented (date and time of change, model and serial numbers of any instrumentation removed along with model and serial numbers of any instrumentation added).
4. Efforts should be made to ensure that enough inventory is immediately available to replace faulty ADR equipment in the field to avoid the additional loss of data.
5. Under normal circumstances, data collected during a site visit should be checked for quality control and quality assurance or sent to the Columbia office for review within two weeks of the site visit.
6. If ADR instrumentation at a given site is determined to be malfunctioning while reviewing data in the office, efforts should be made to replace or repair the ADR instruments as soon as possible. This may require additional site visits.
7. Clocks for all instrumentation will be programmed in Eastern Standard Time. Do not correct for Daylight Savings.
8. For sites with unvented pressure transducers, desiccant packs must be replaced once every 6–8 weeks to prevent moisture from accumulating in the transducer's vent tube. Excess moisture can cause faulty ADR readings and can potentially damage the transducer.
9. Site maintenance, such as clearing vegetation and ensuring site security, should be performed as necessary during each visit.

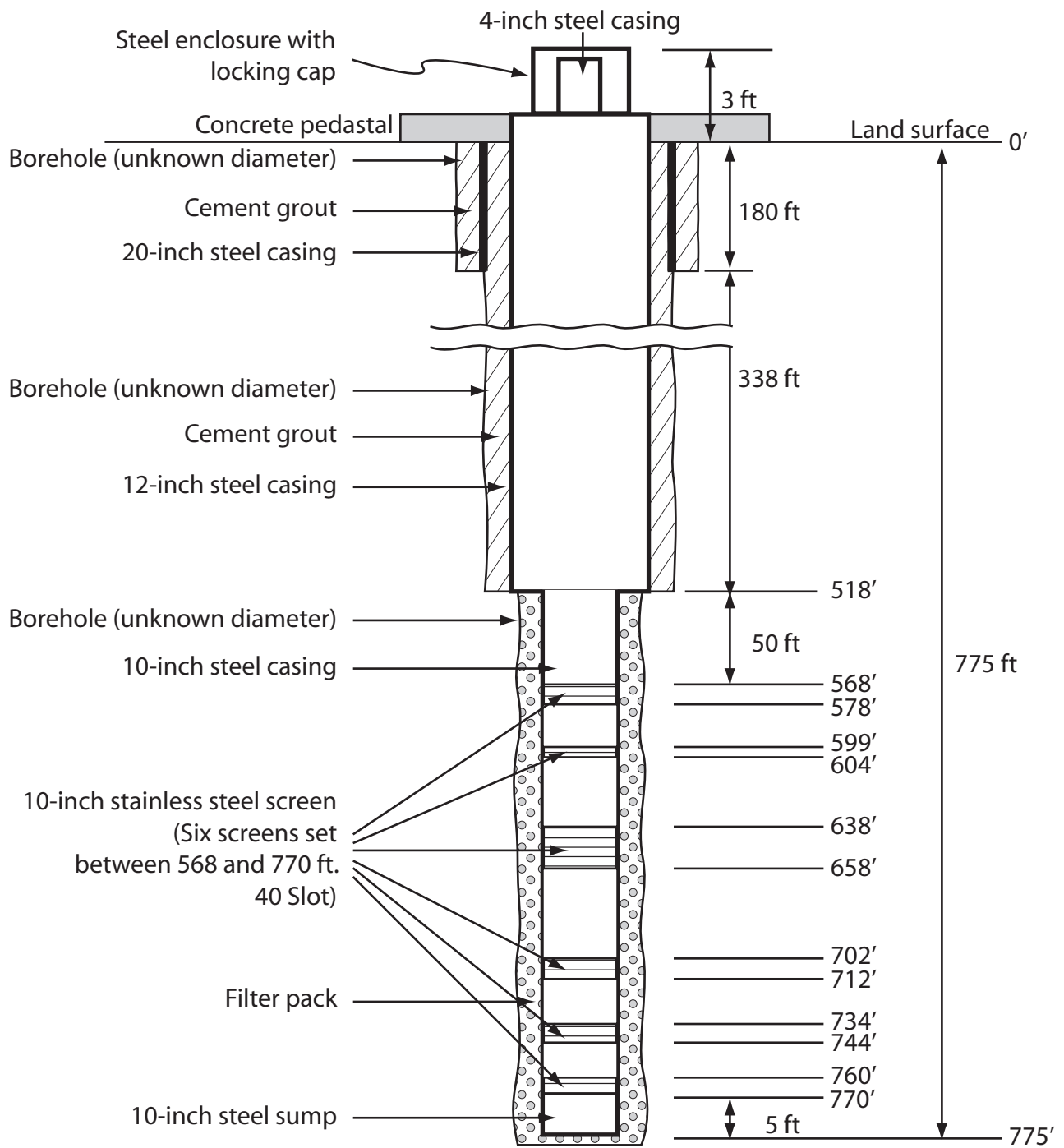
APPENDIX D

Well Construction Diagrams for wells added to the DNR Groundwater Monitoring Network since 2009

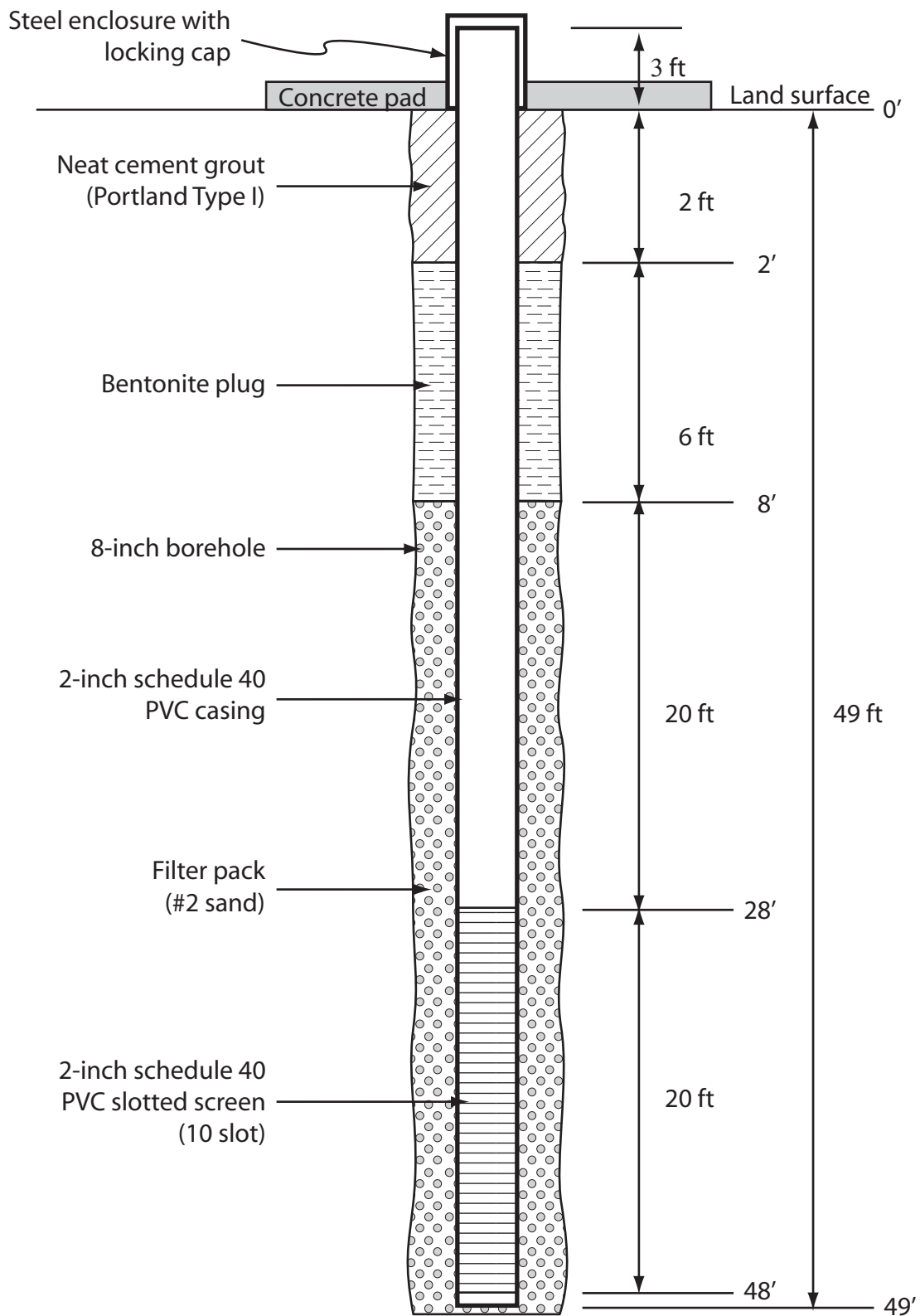
Well	Page
ALL-0378	60
BRN-0078	61
CAL-0192	62
CAL-0193	63
CAL-0194	64
CAL-0195	65
CHN-0101	66
CHN-0989	67
CHN-0990	68
CHN-0991	69
CTF-0221	70
CTF-0222	71
DIL-0171	72
DIL-0172	73
DIL-0173	74
DIL-0174	75
DIL-0175	76
GEO-0381	77
GEO-0382	78
GEO-0383	79
JAS-0468	80
LEE-0179	81
LEE-0180	82
LEE-0181	83
LEX-0823	84
ORG-0079	85
WIL-0355	86



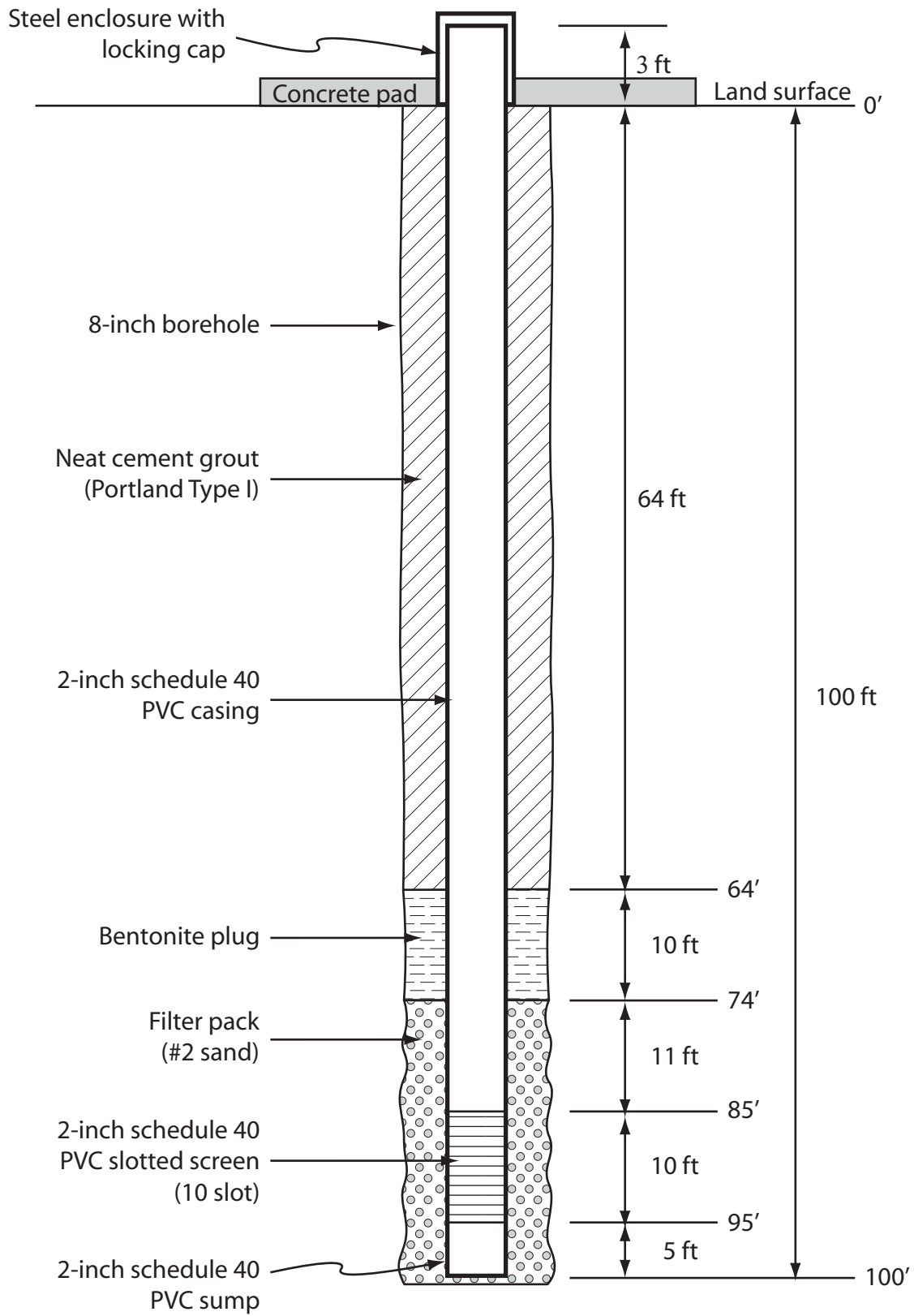
ALL-0378 well construction diagram.



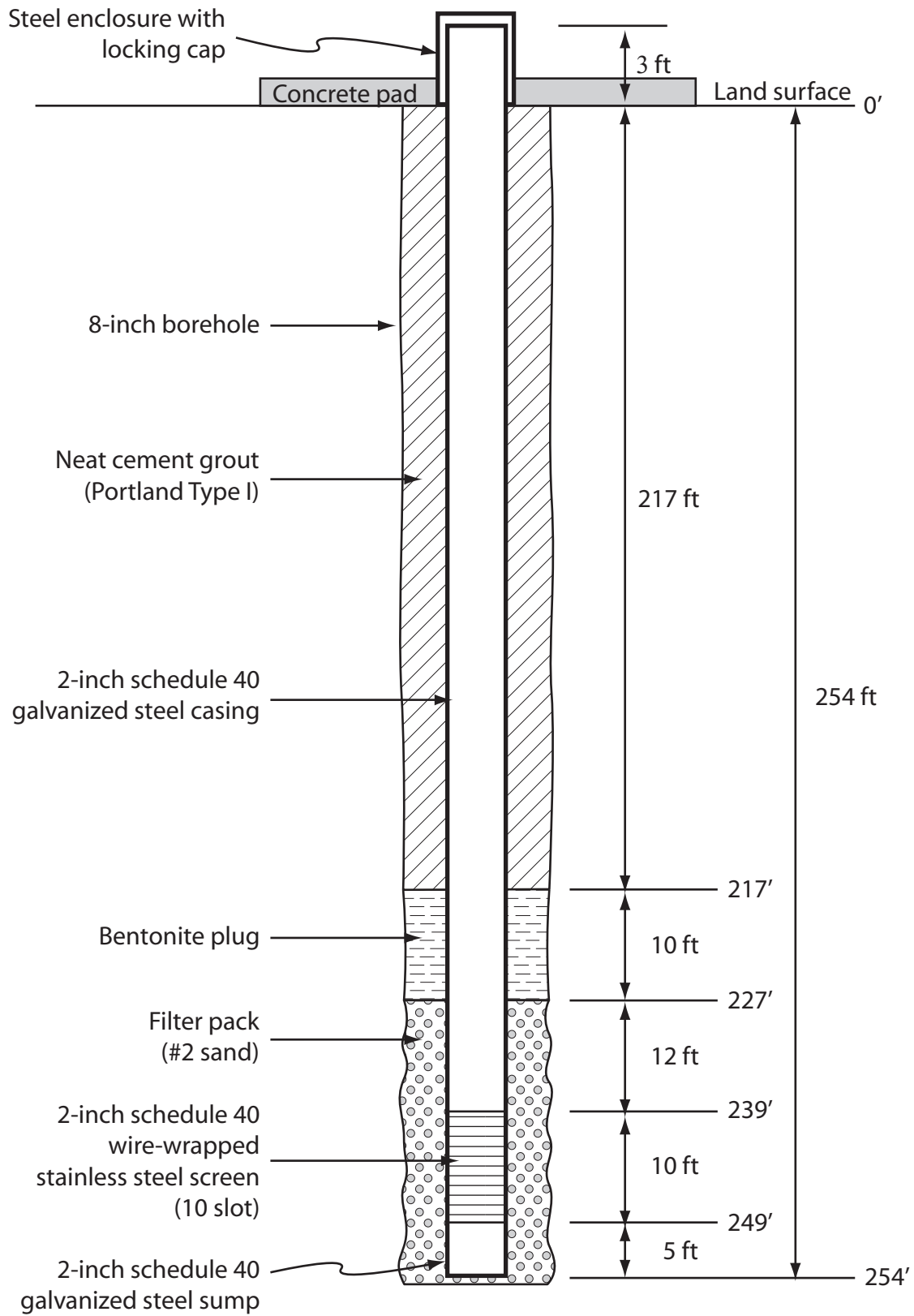
BRN-0078 well construction diagram.



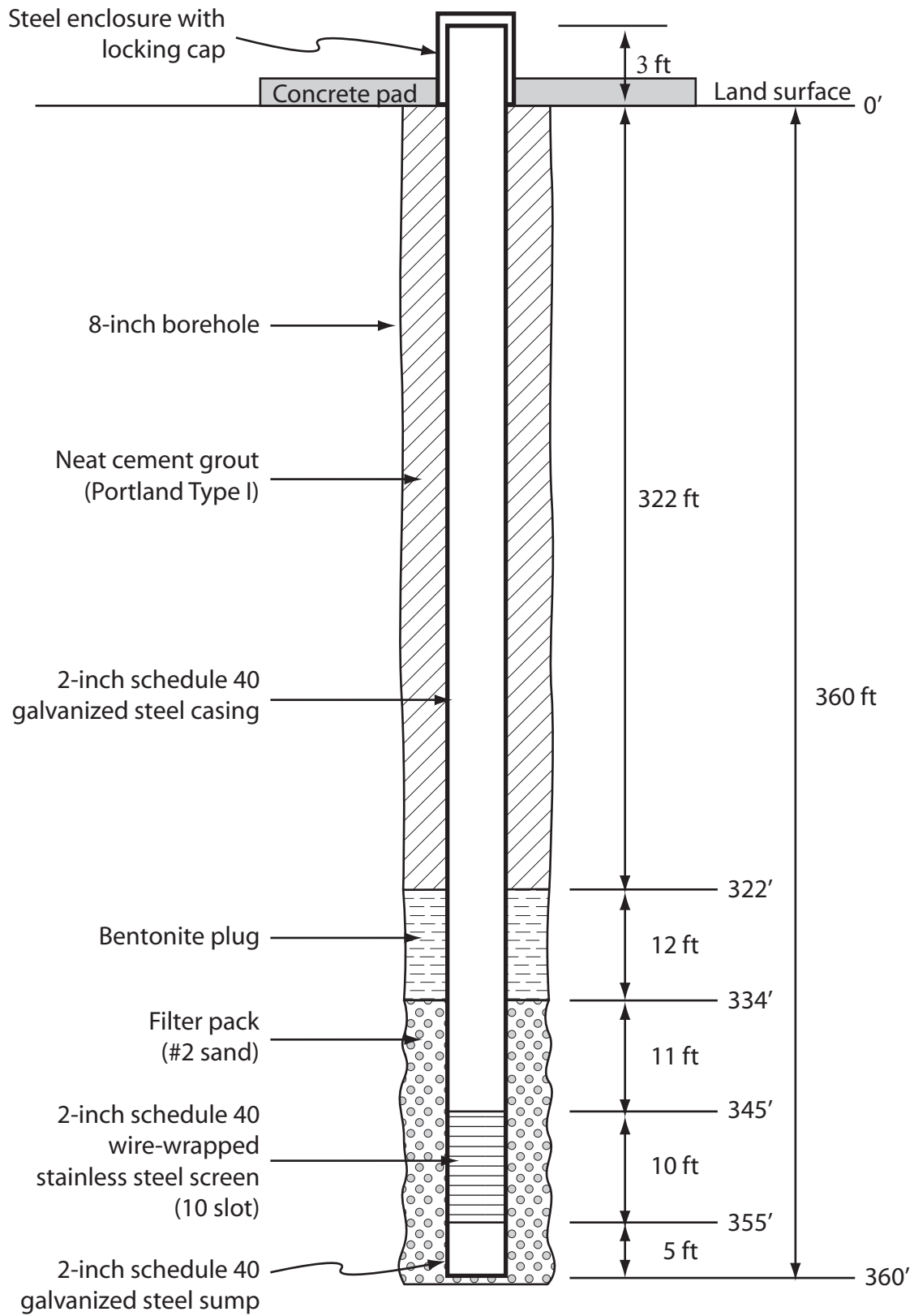
CAL-0192 well construction diagram.



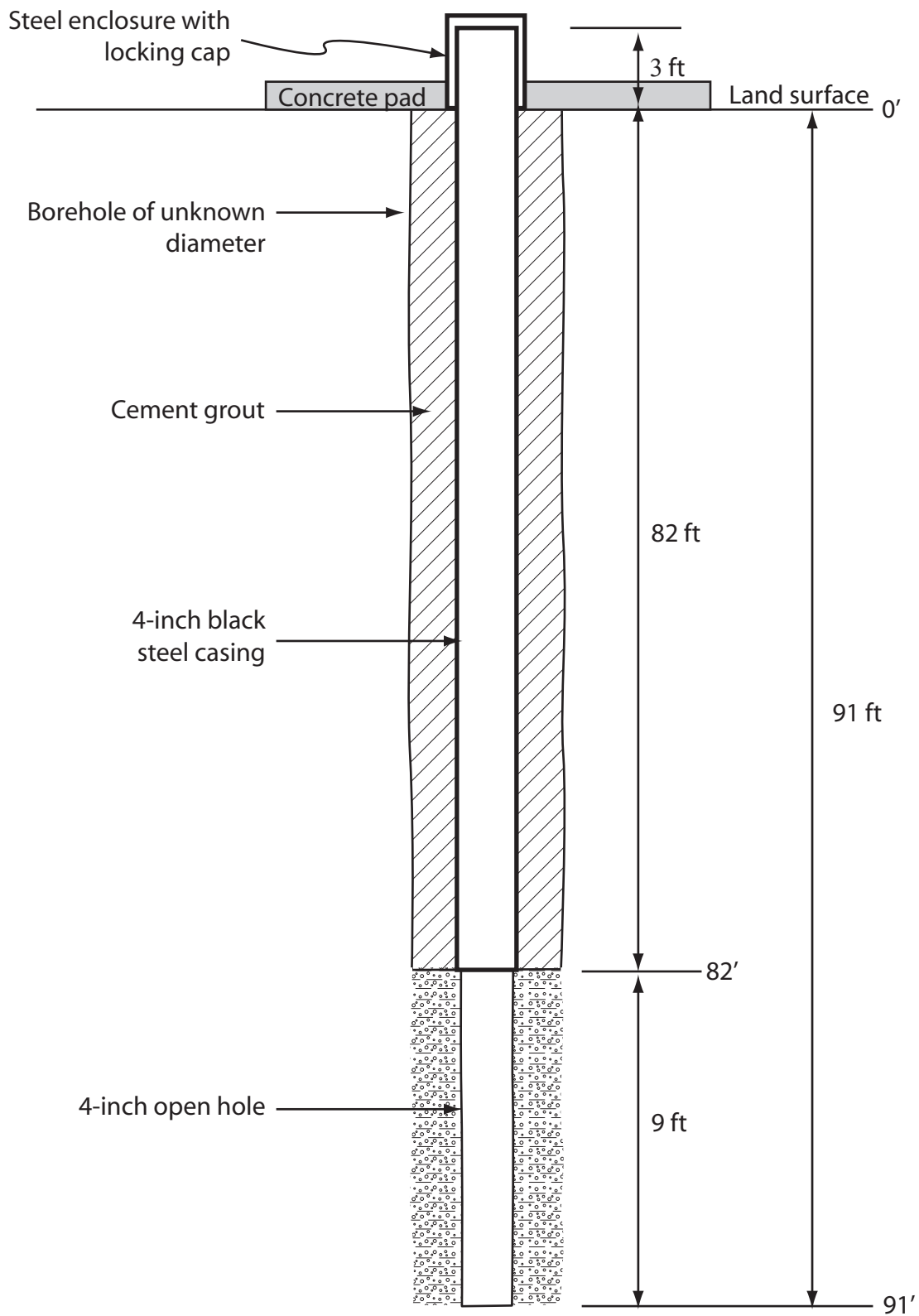
CAL-0193 well construction diagram.



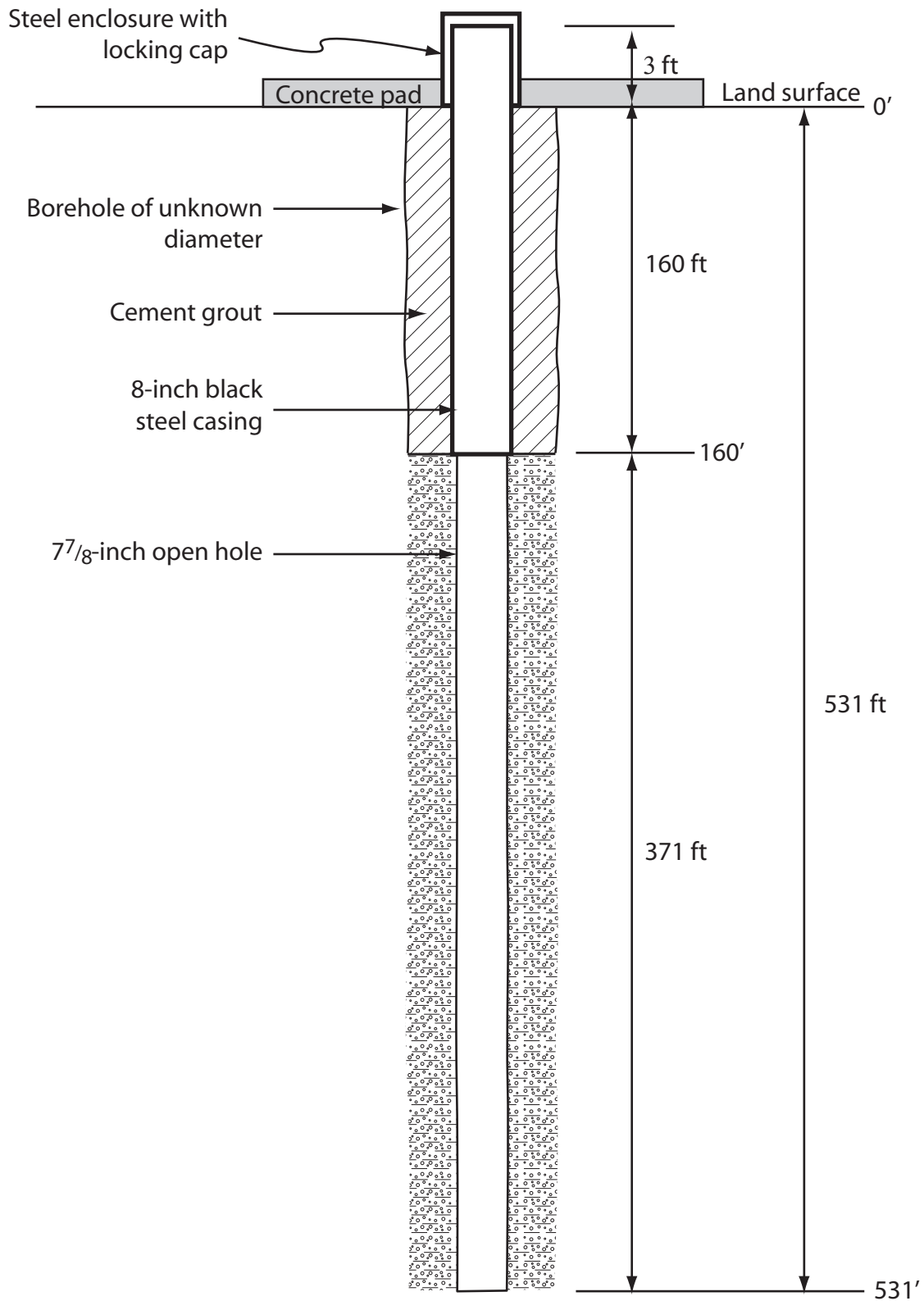
CAL-0194 well construction diagram.



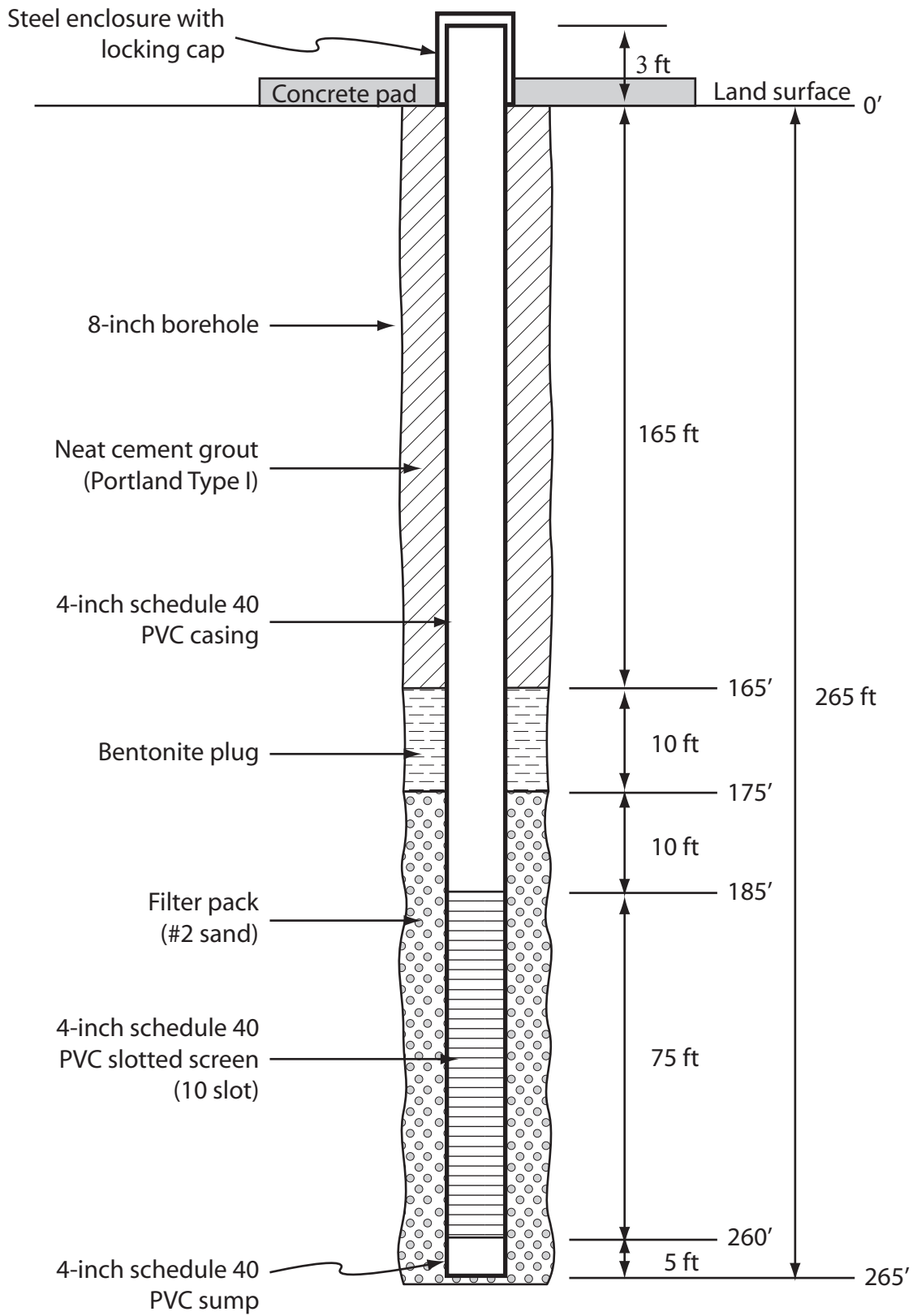
CAL-0195 well construction diagram.



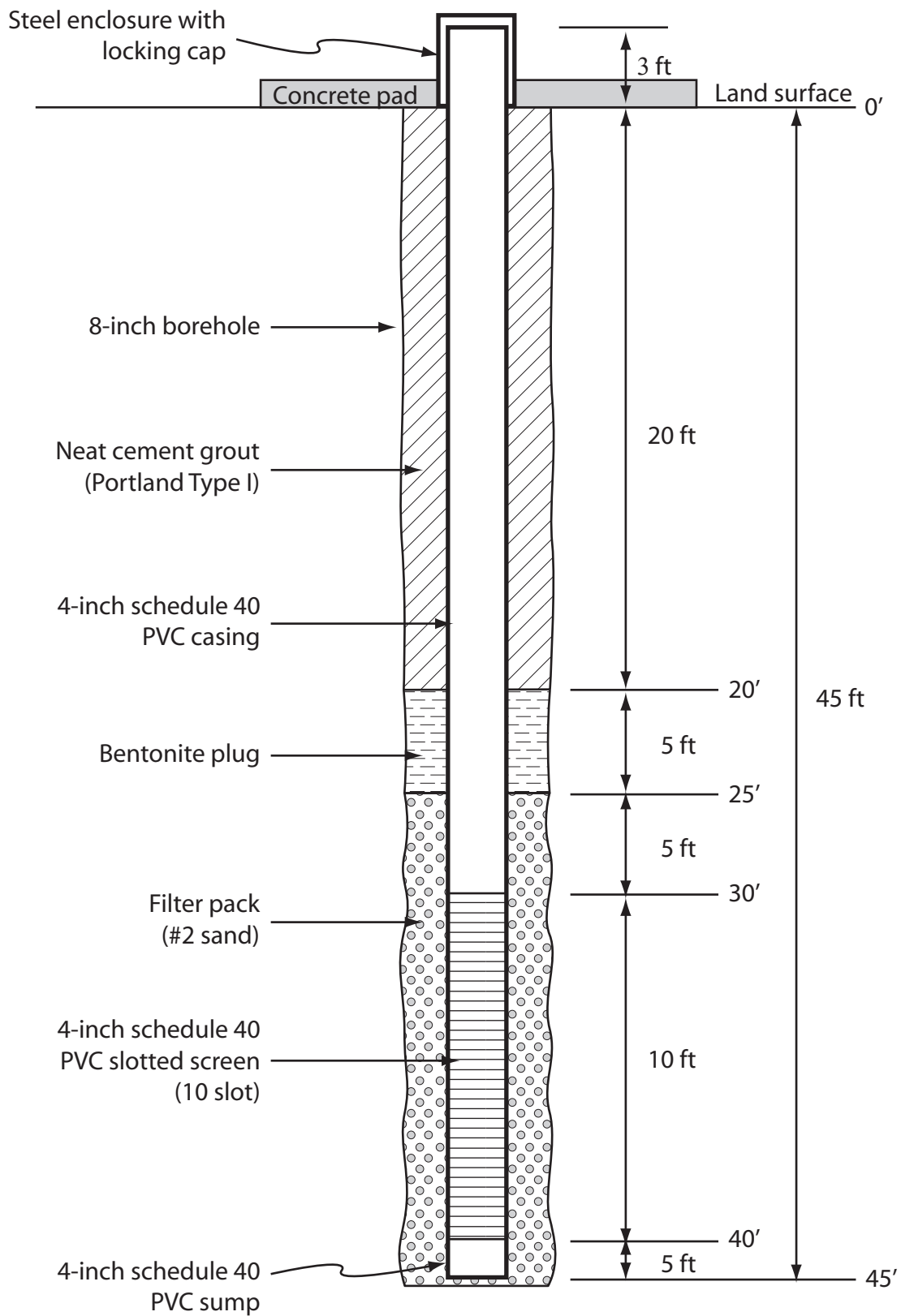
CHN-0101 well construction diagram.



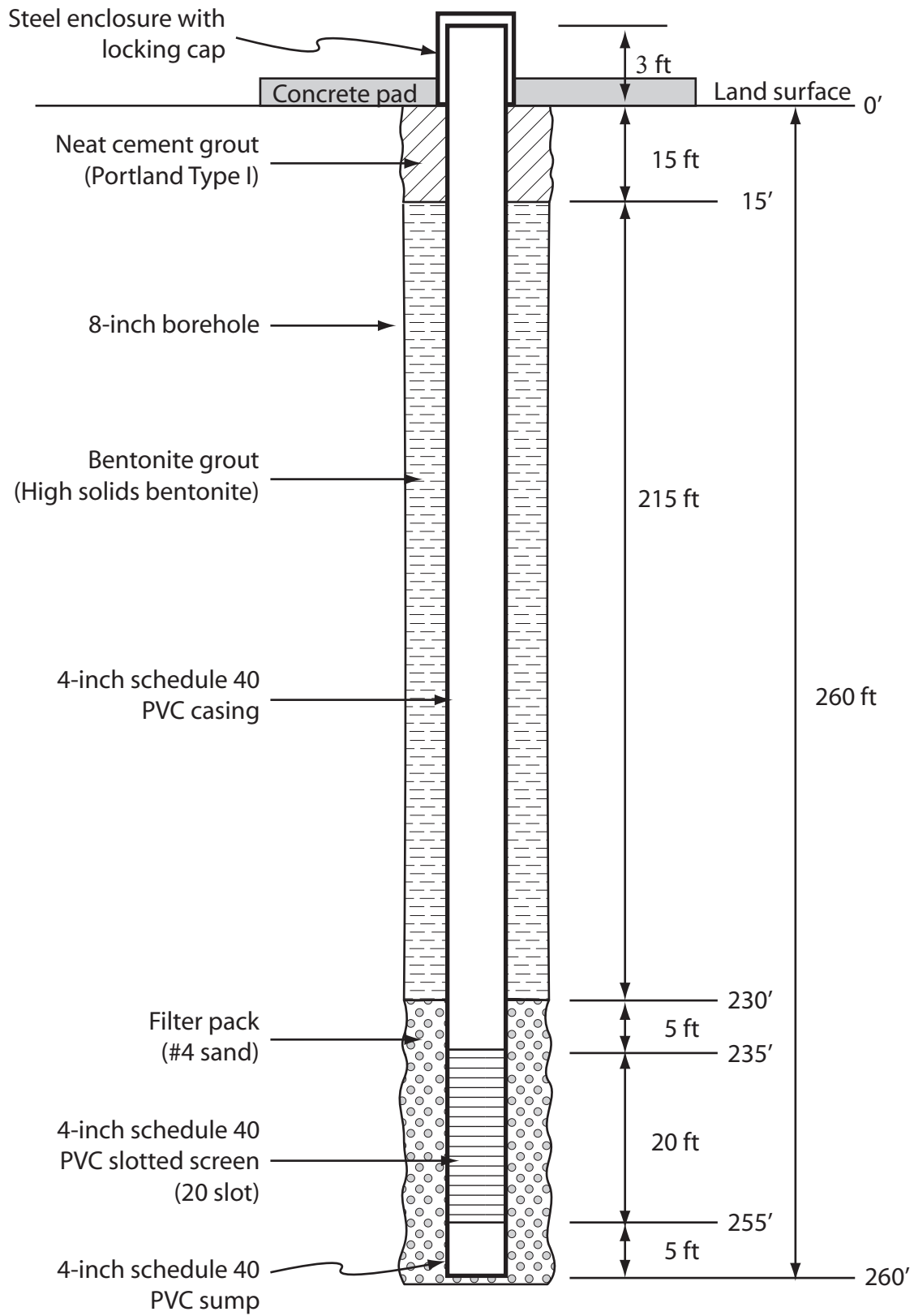
CHN-0989 well construction diagram.



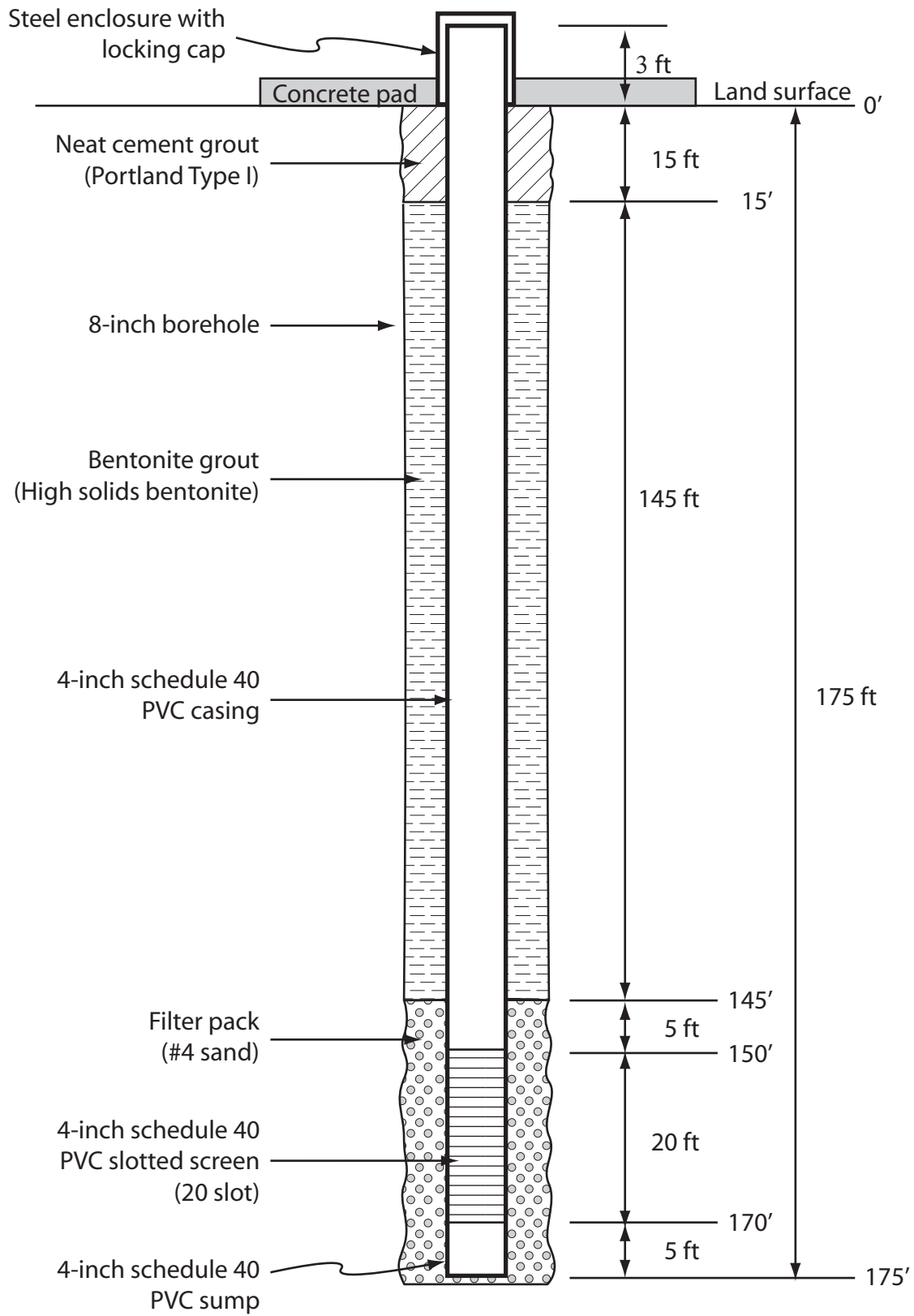
CHN-0990 well construction diagram.



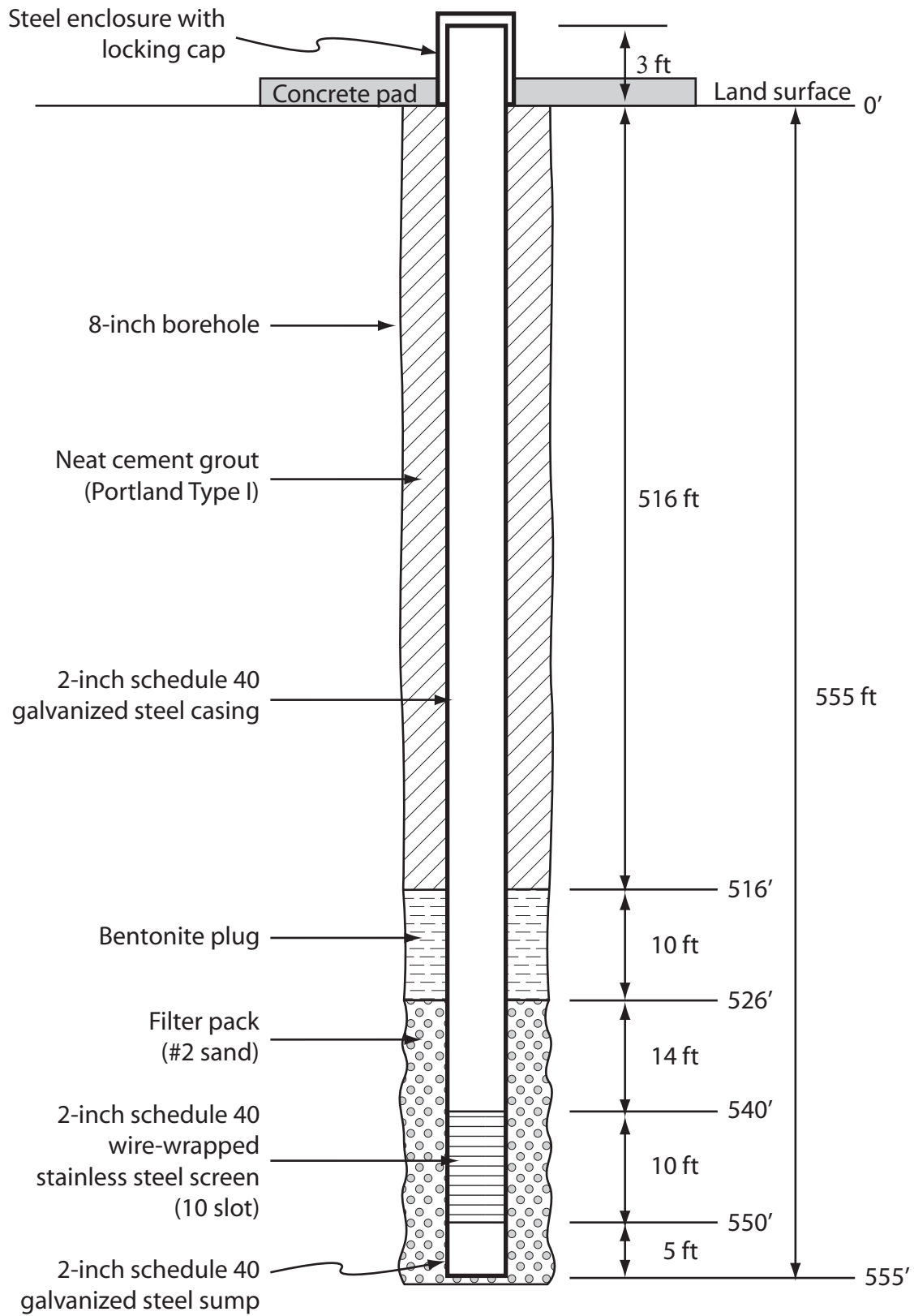
CHN-0991 well construction diagram.



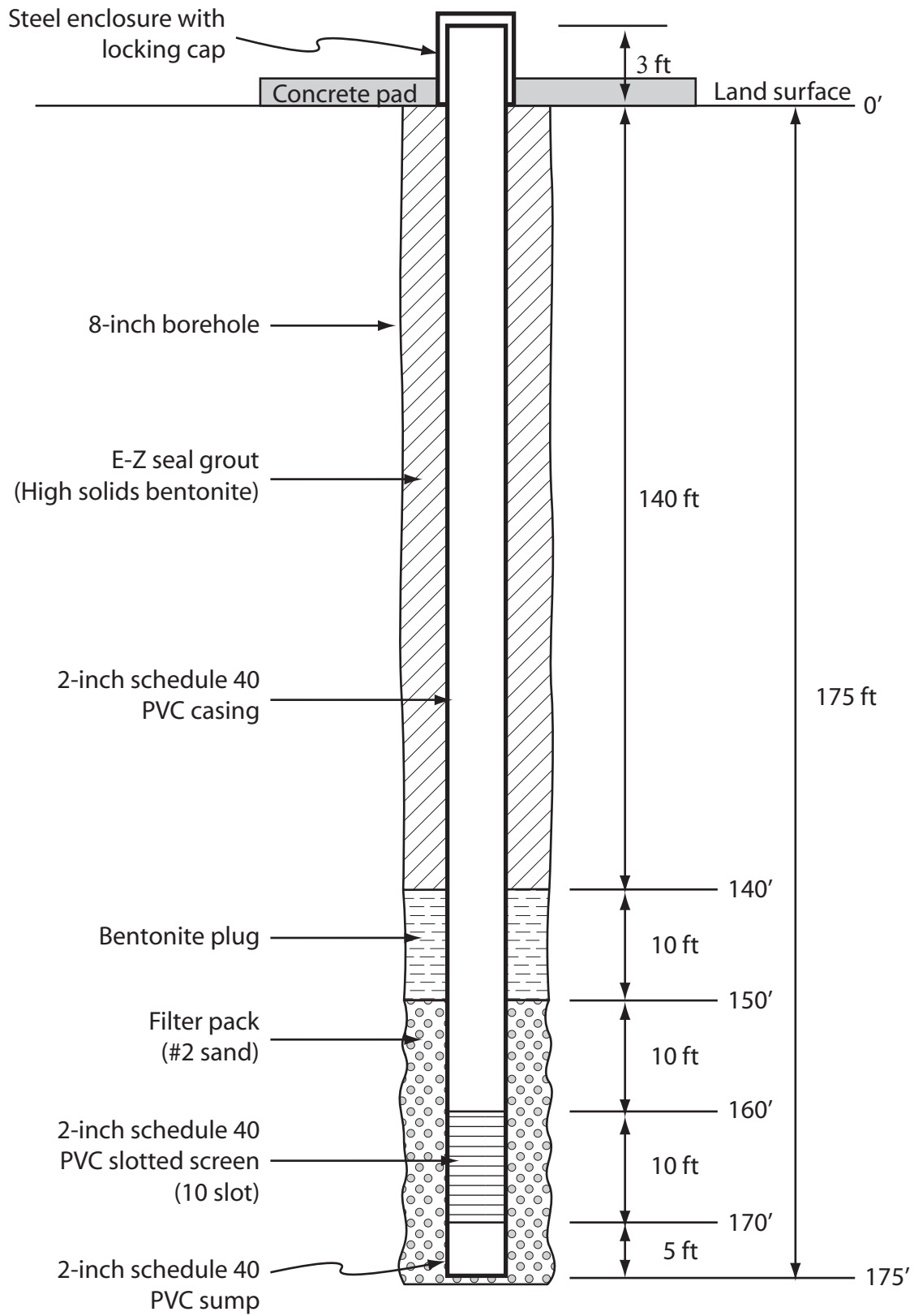
CTF-0221 well construction diagram.



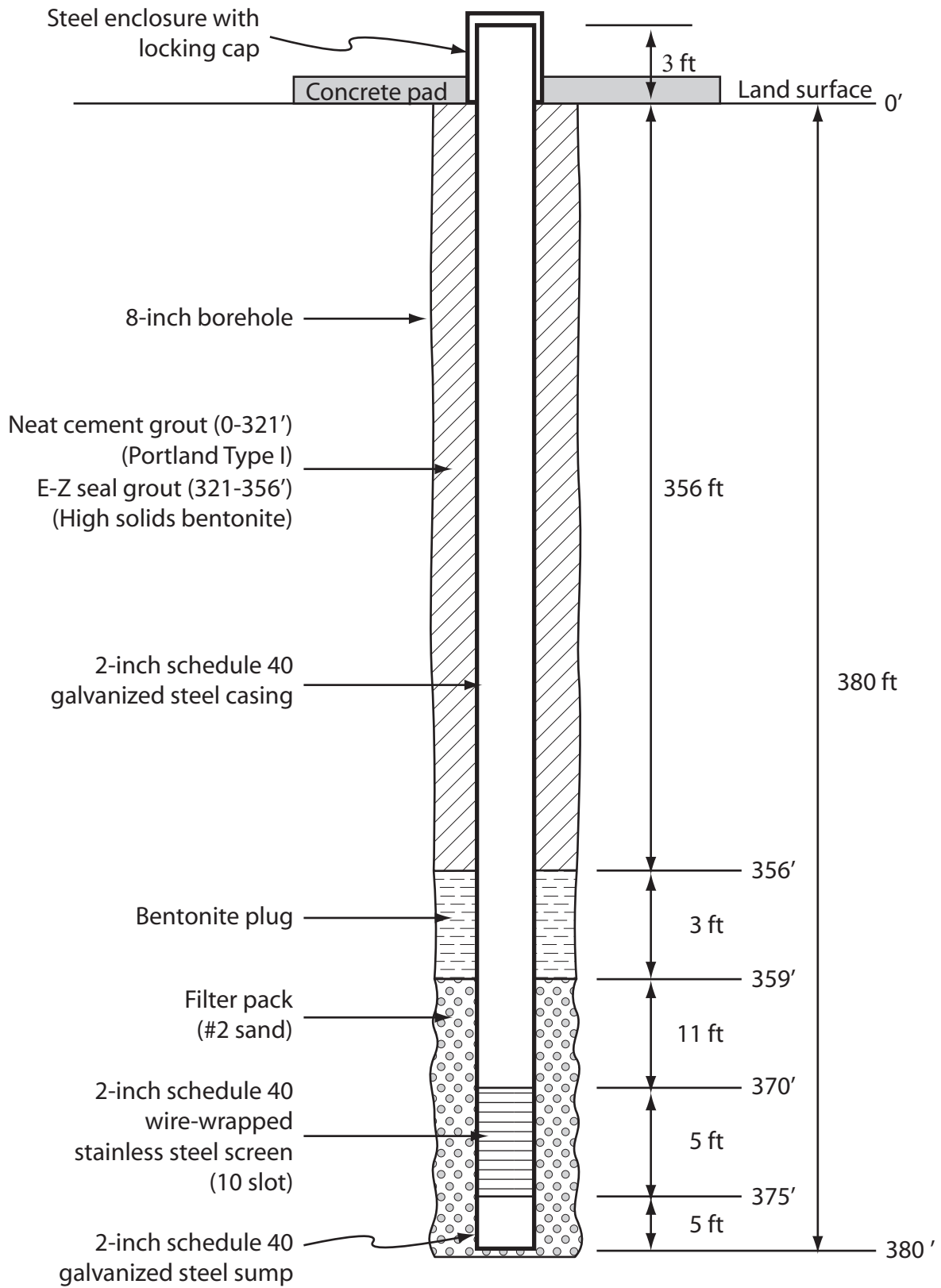
CTF-0222 well construction diagram.



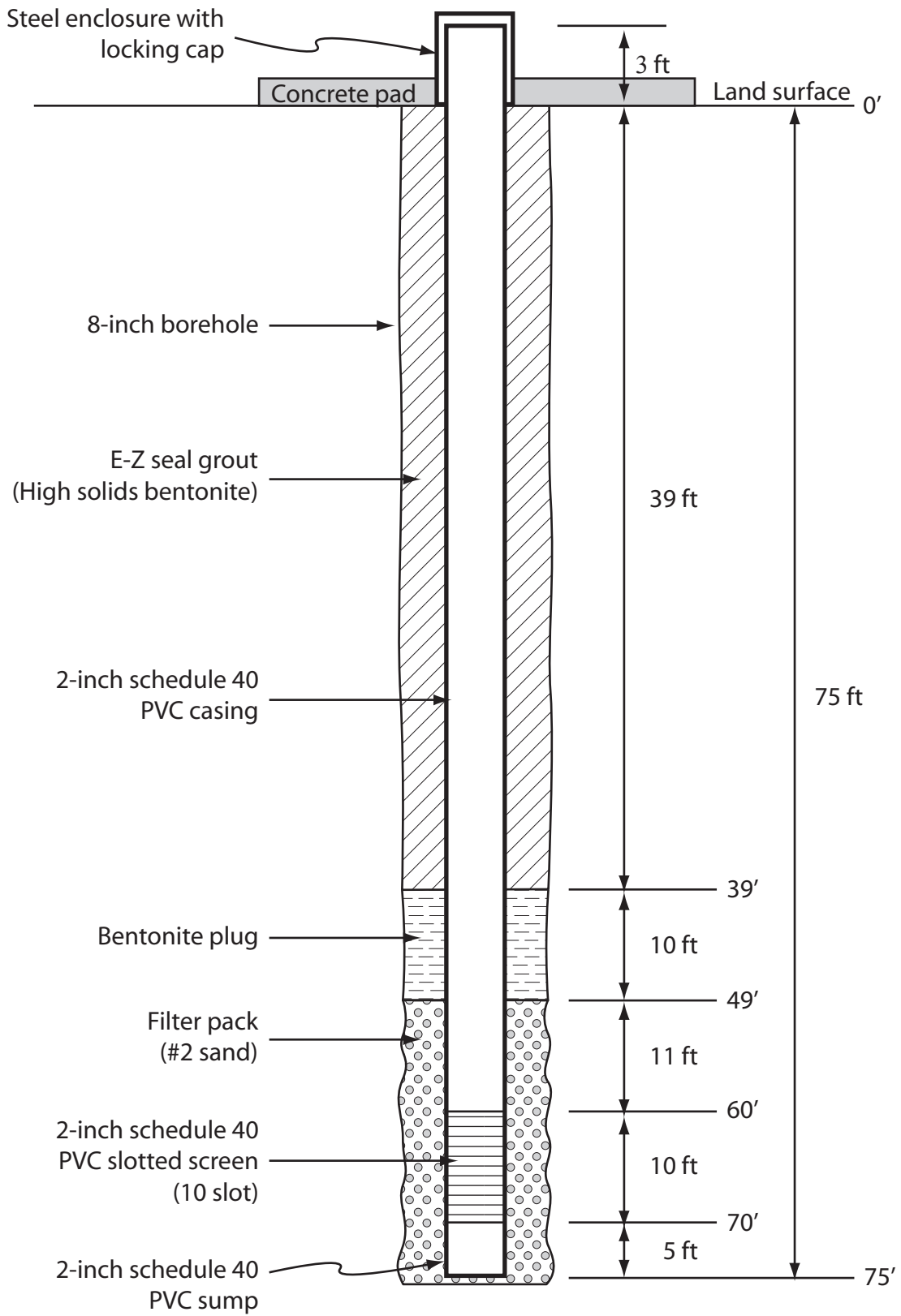
DIL-0171 well construction diagram.



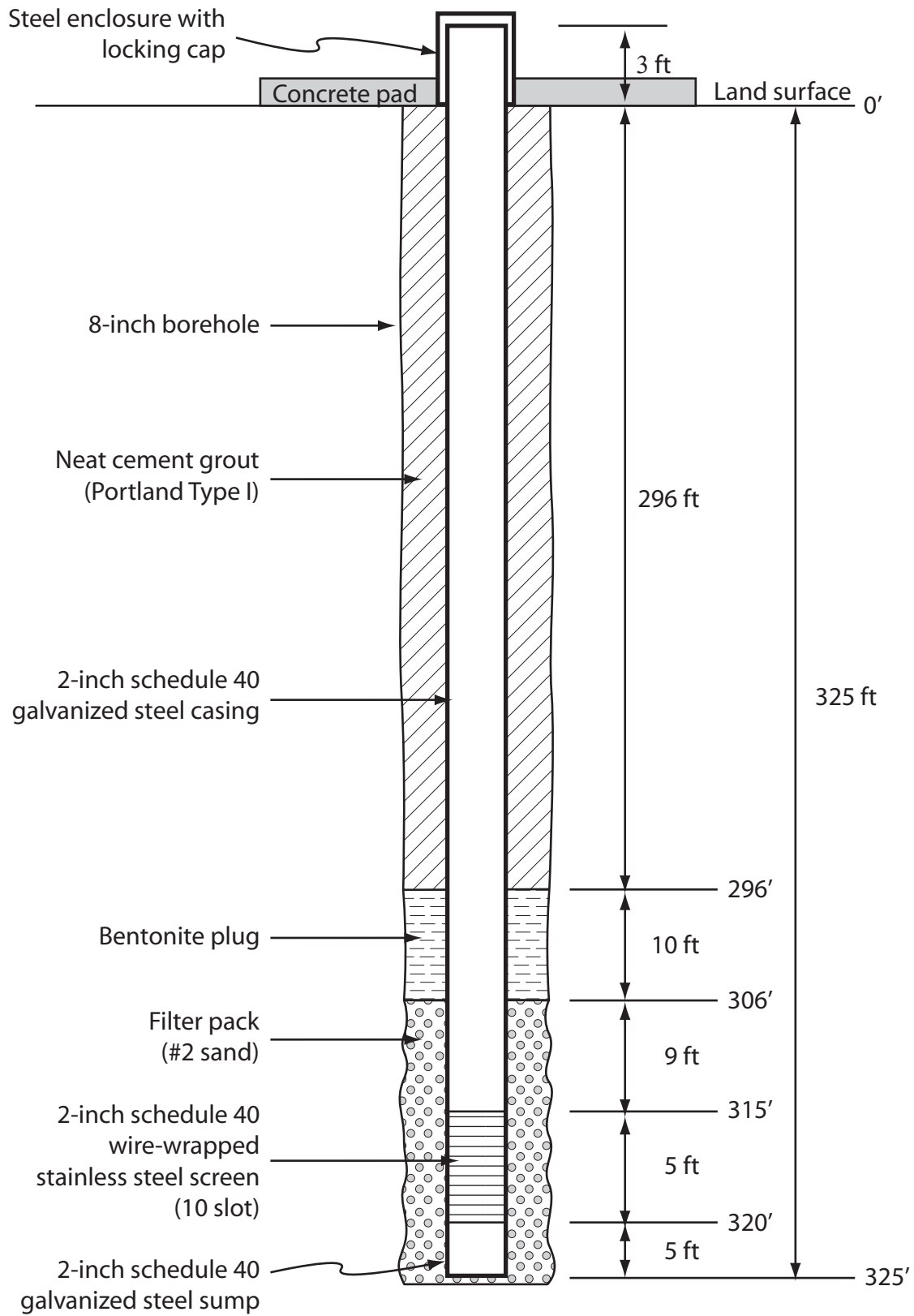
DIL-0172 well construction diagram.



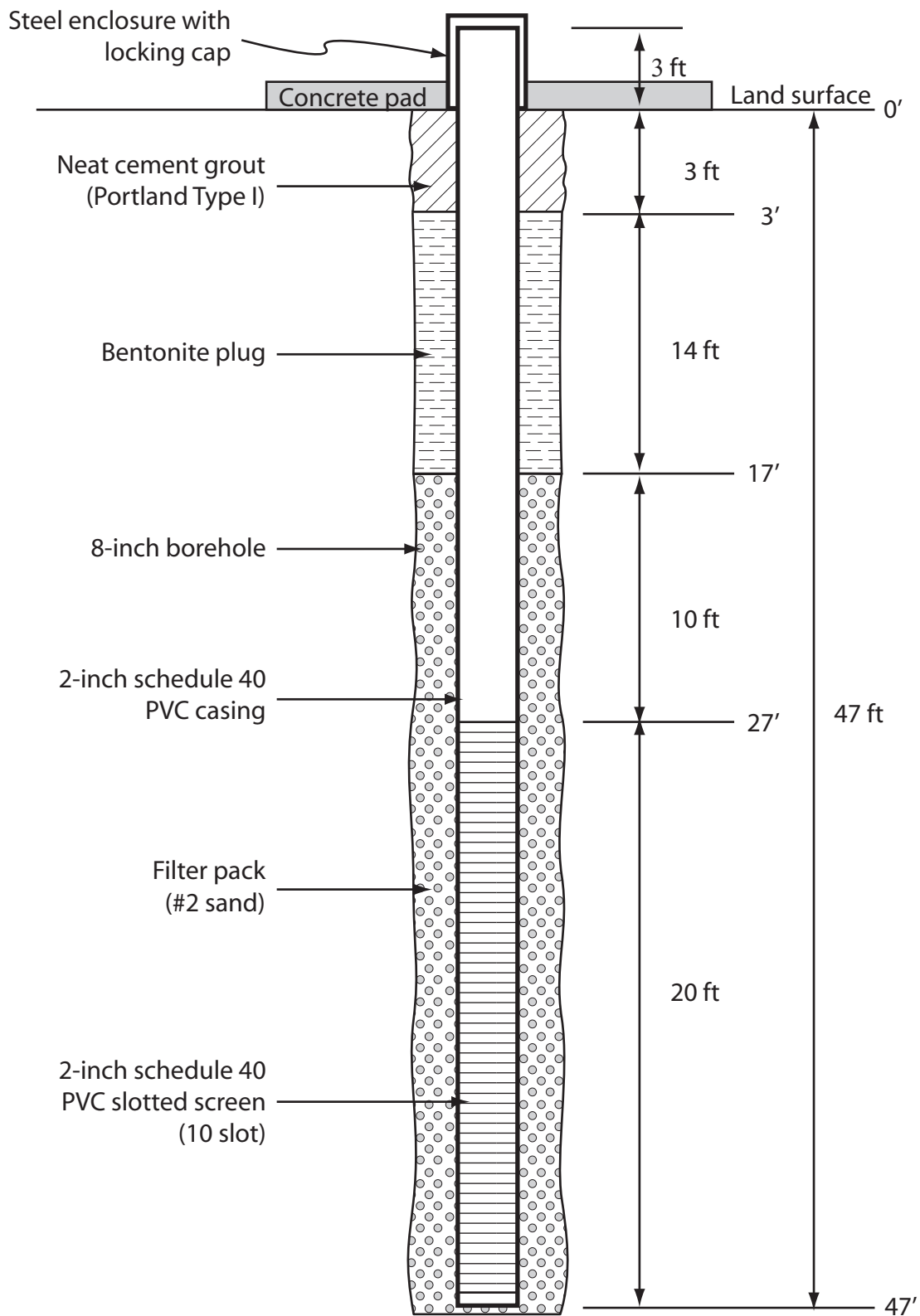
DIL-0173 well construction diagram.



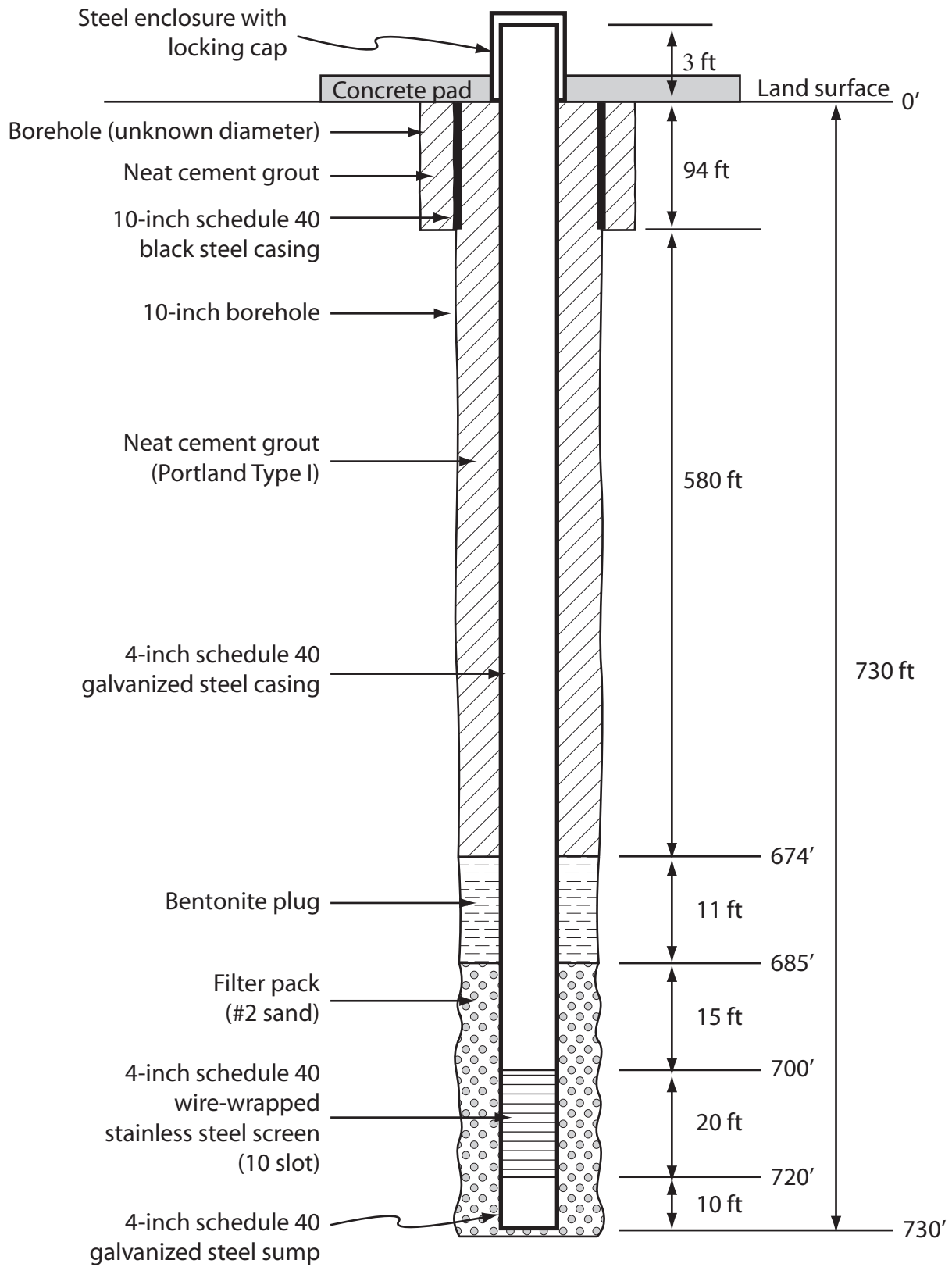
DIL-0174 well construction diagram.



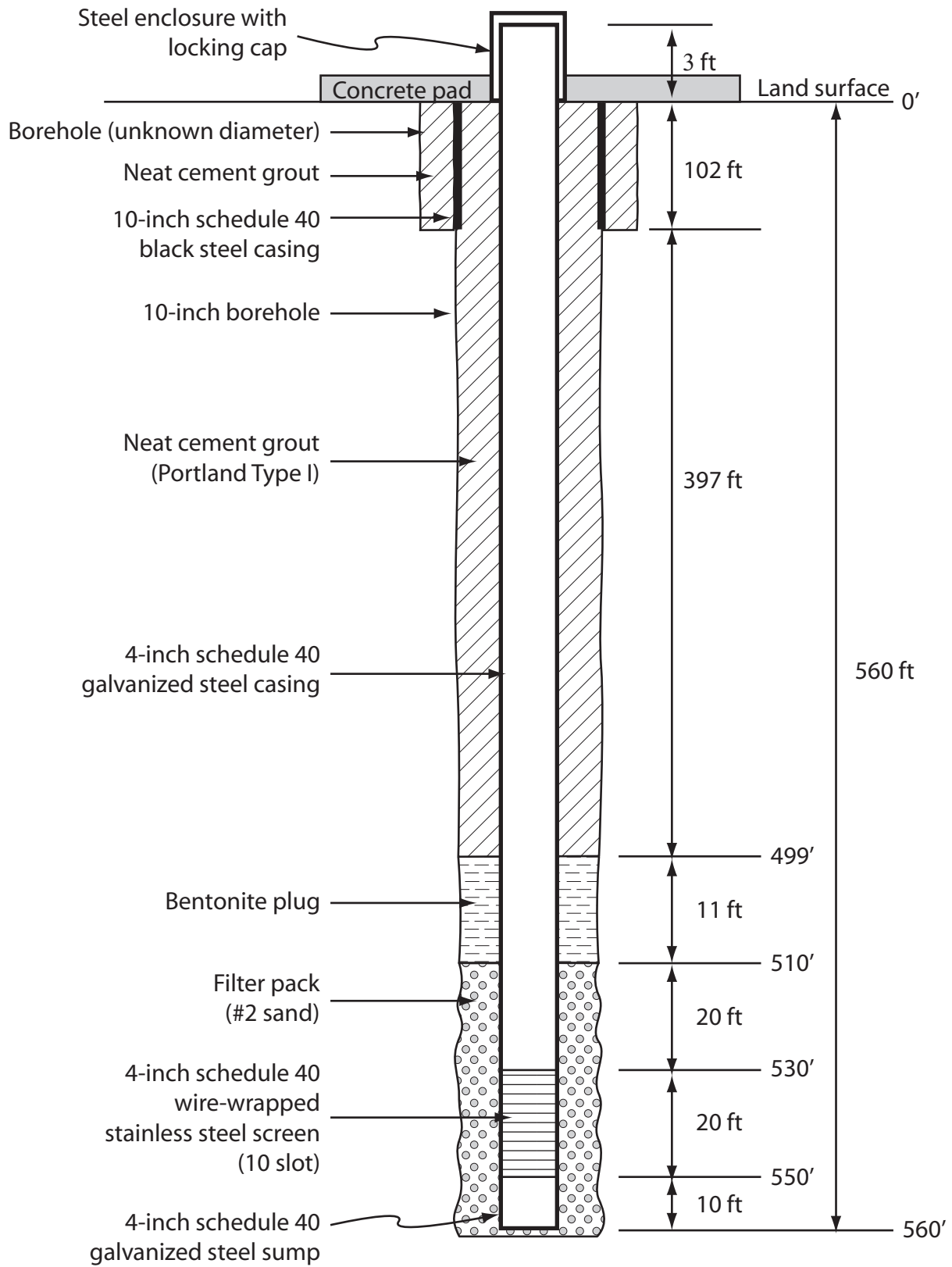
DIL-0175 well construction diagram.



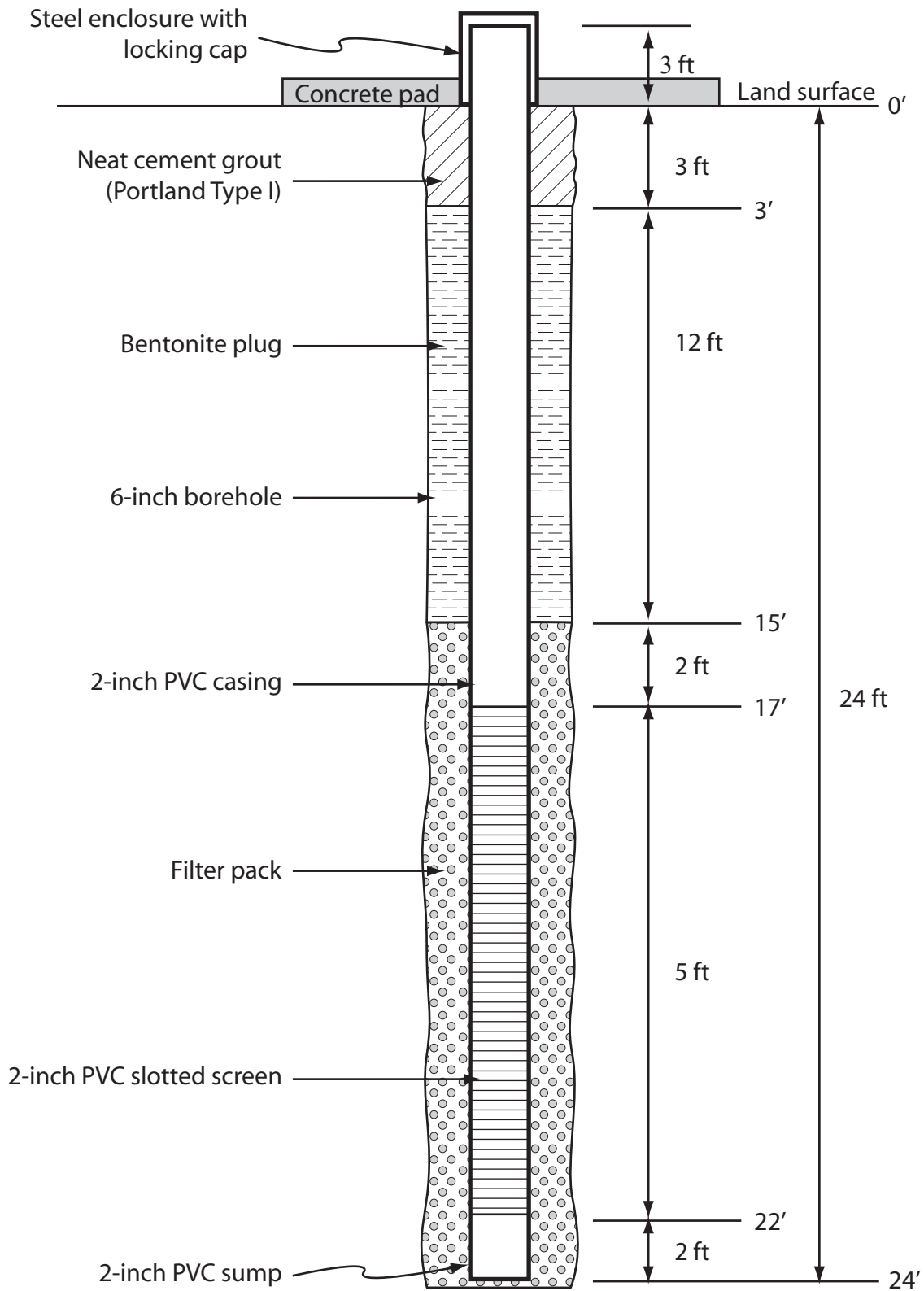
GEO-0381 well construction diagram.



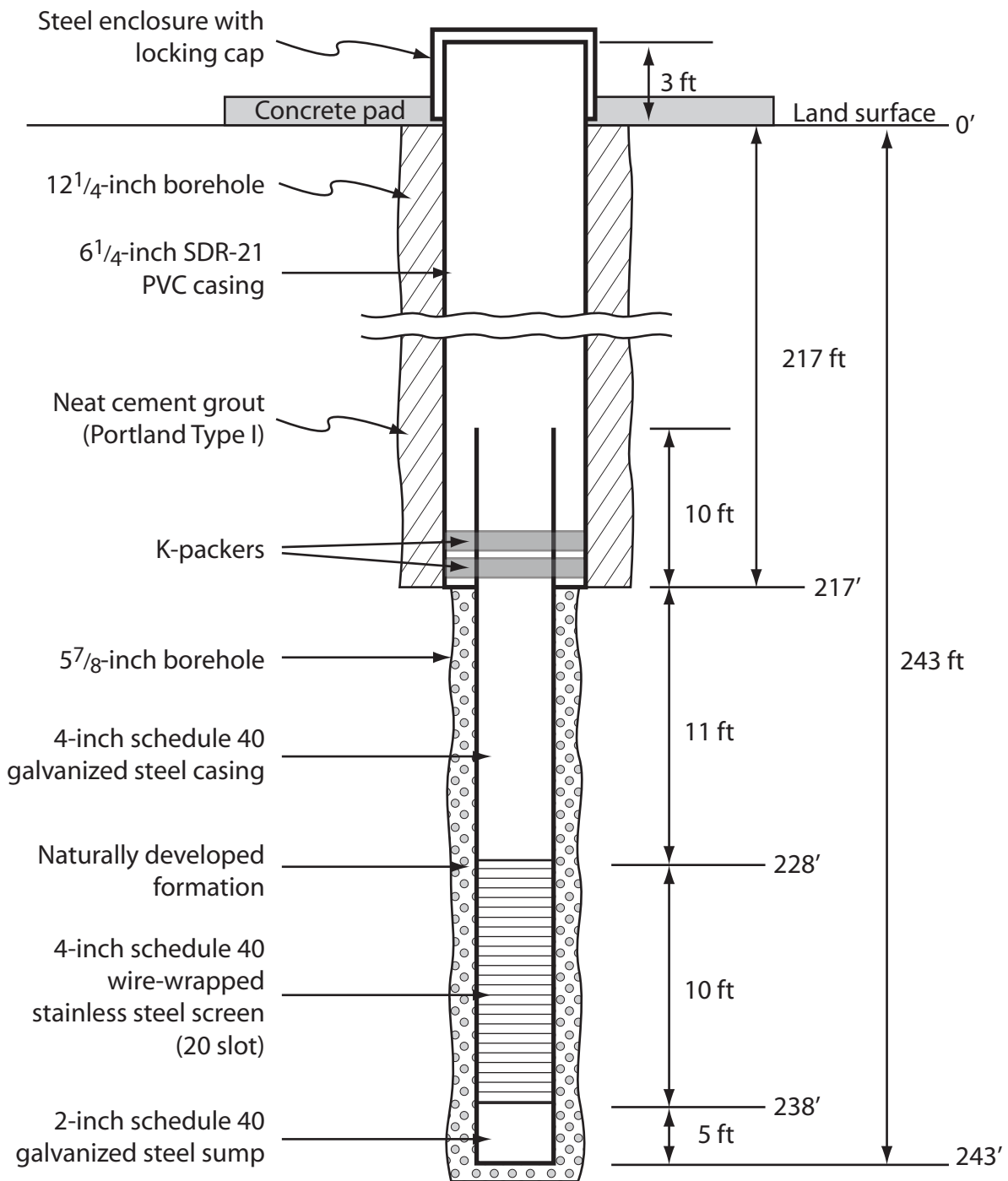
GEO-0382 well construction diagram.



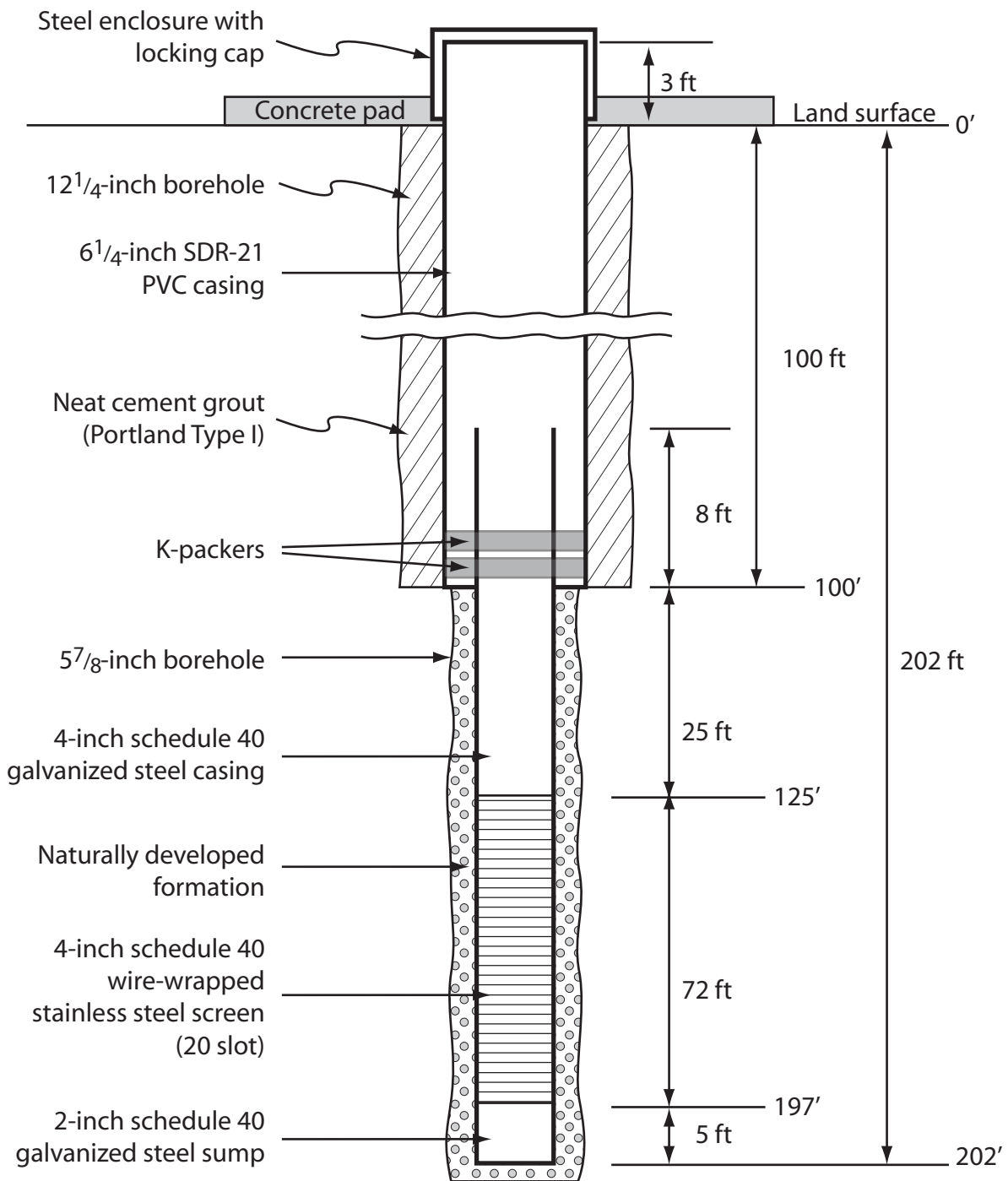
GEO-0383 well construction diagram.



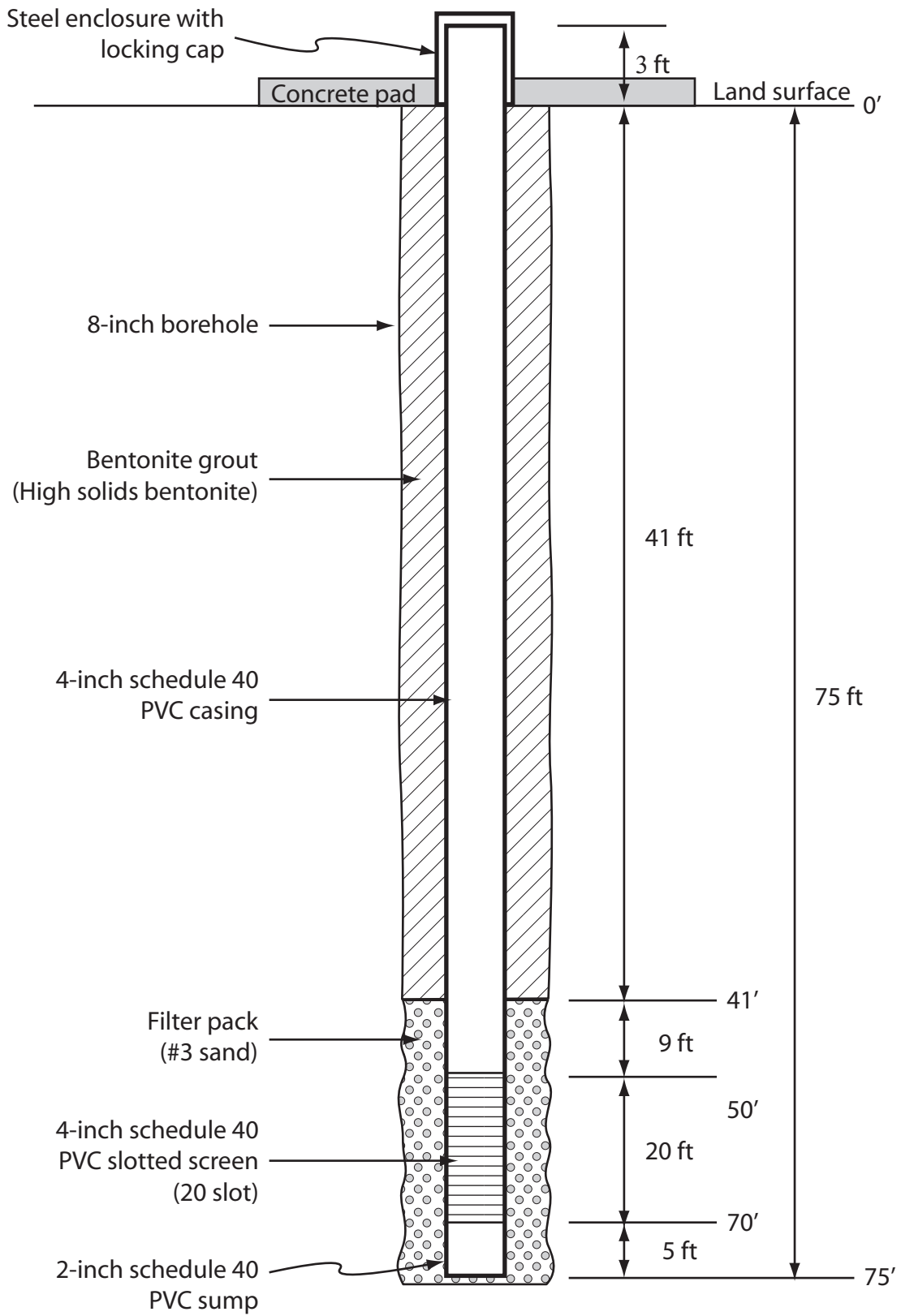
JAS-0468 well construction diagram.



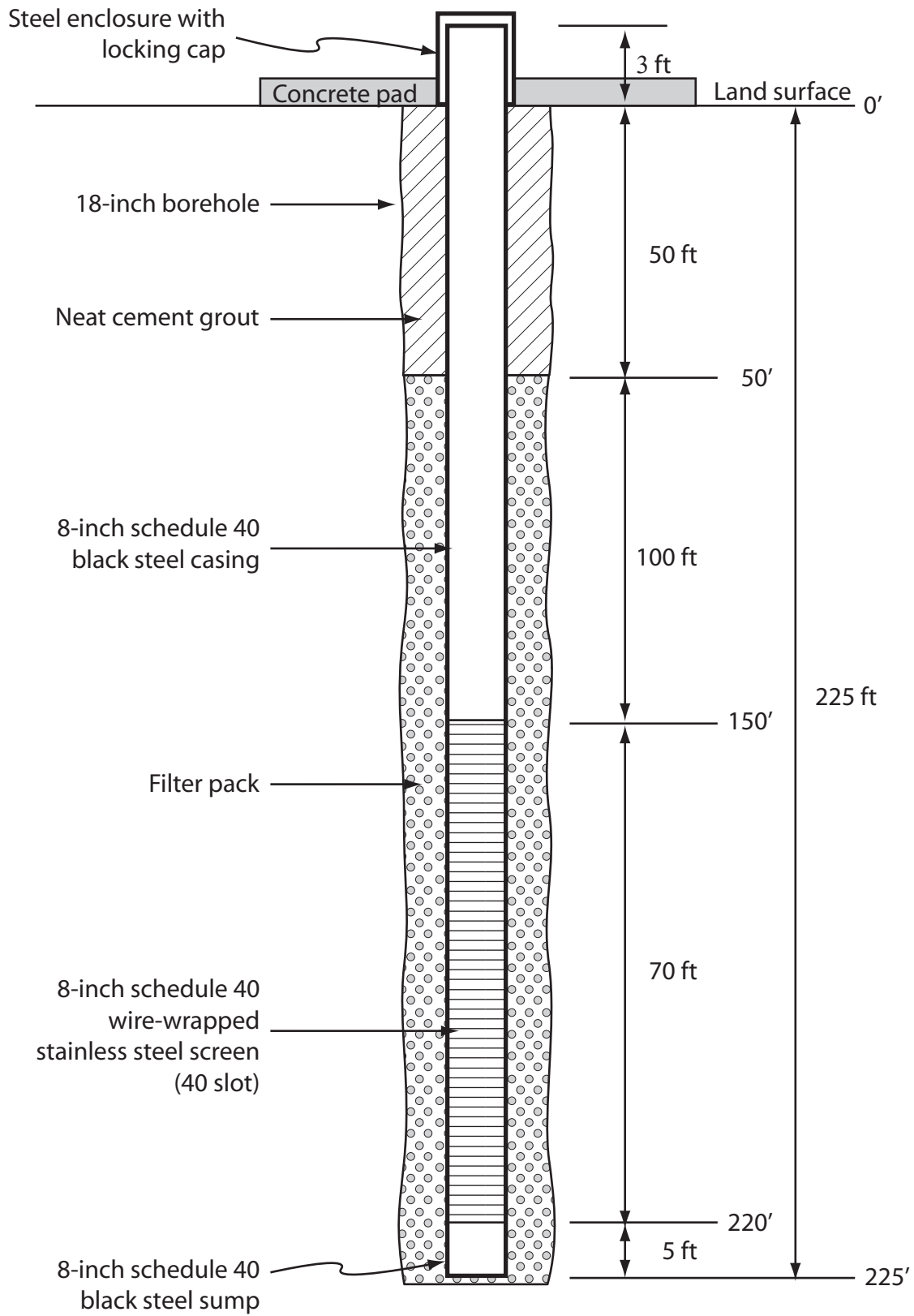
LEE-0179 well construction diagram.



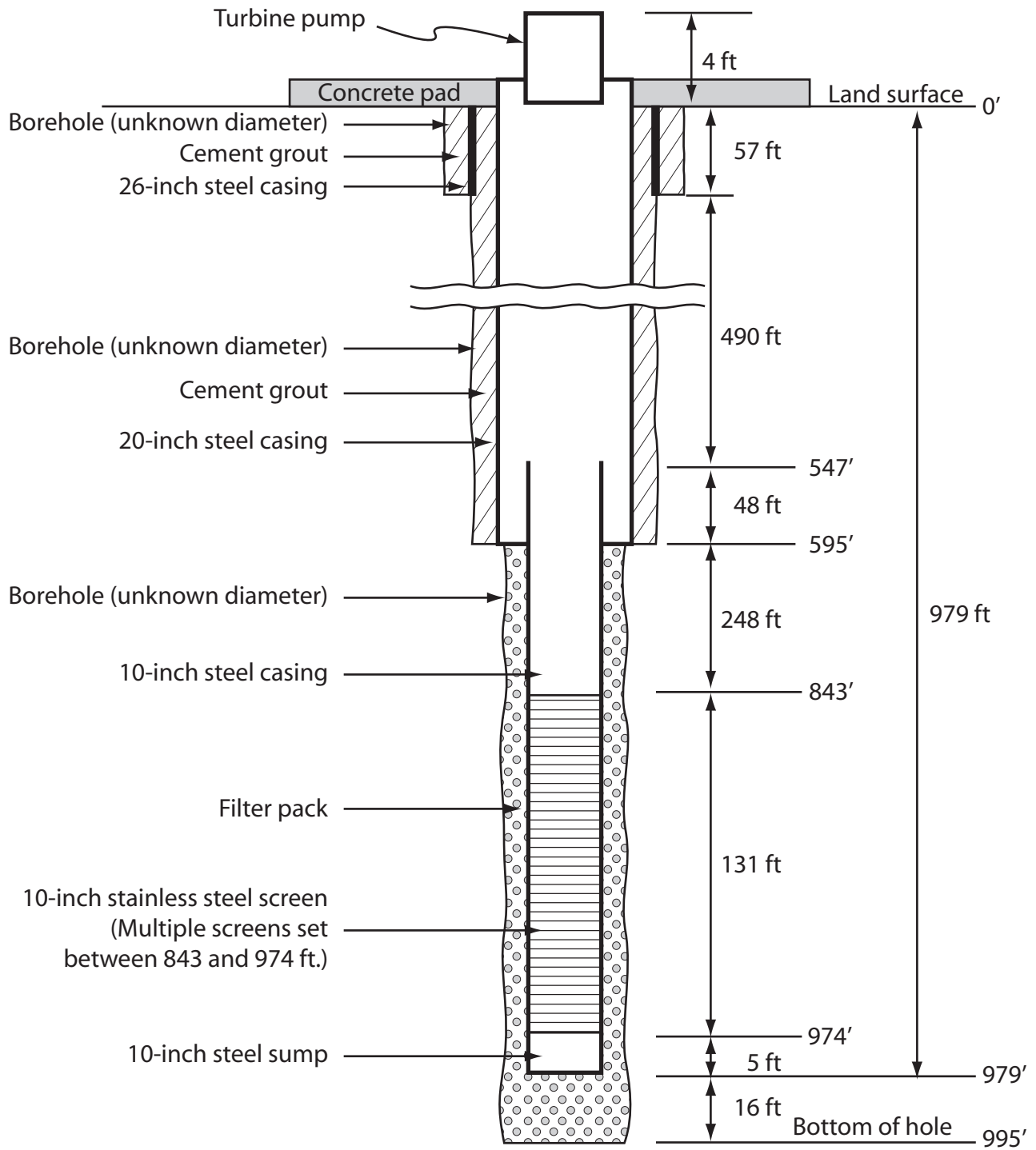
LEE-0180 well construction diagram.



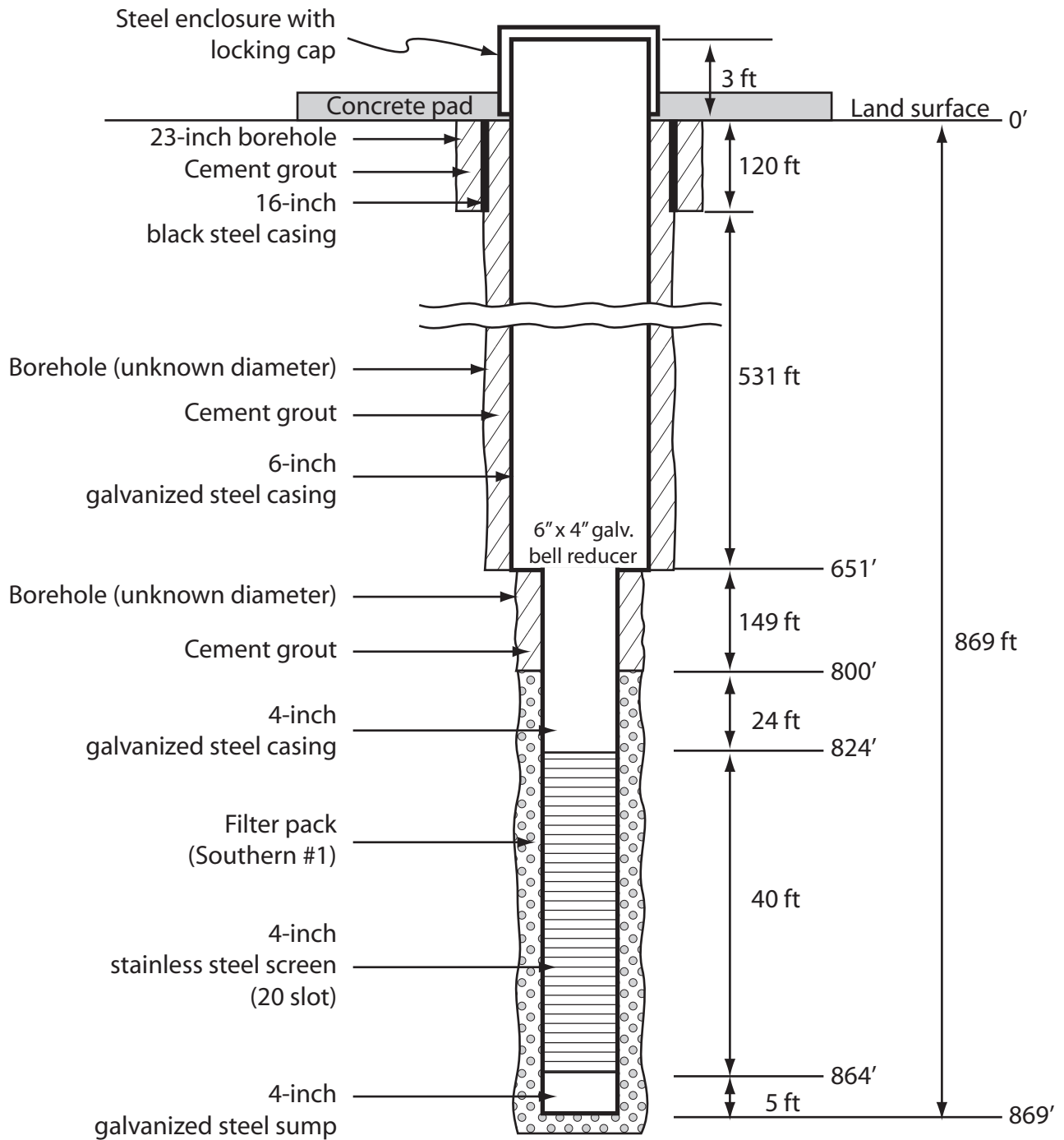
LEE-0181 well construction diagram.



LEX-0823 well construction diagram.

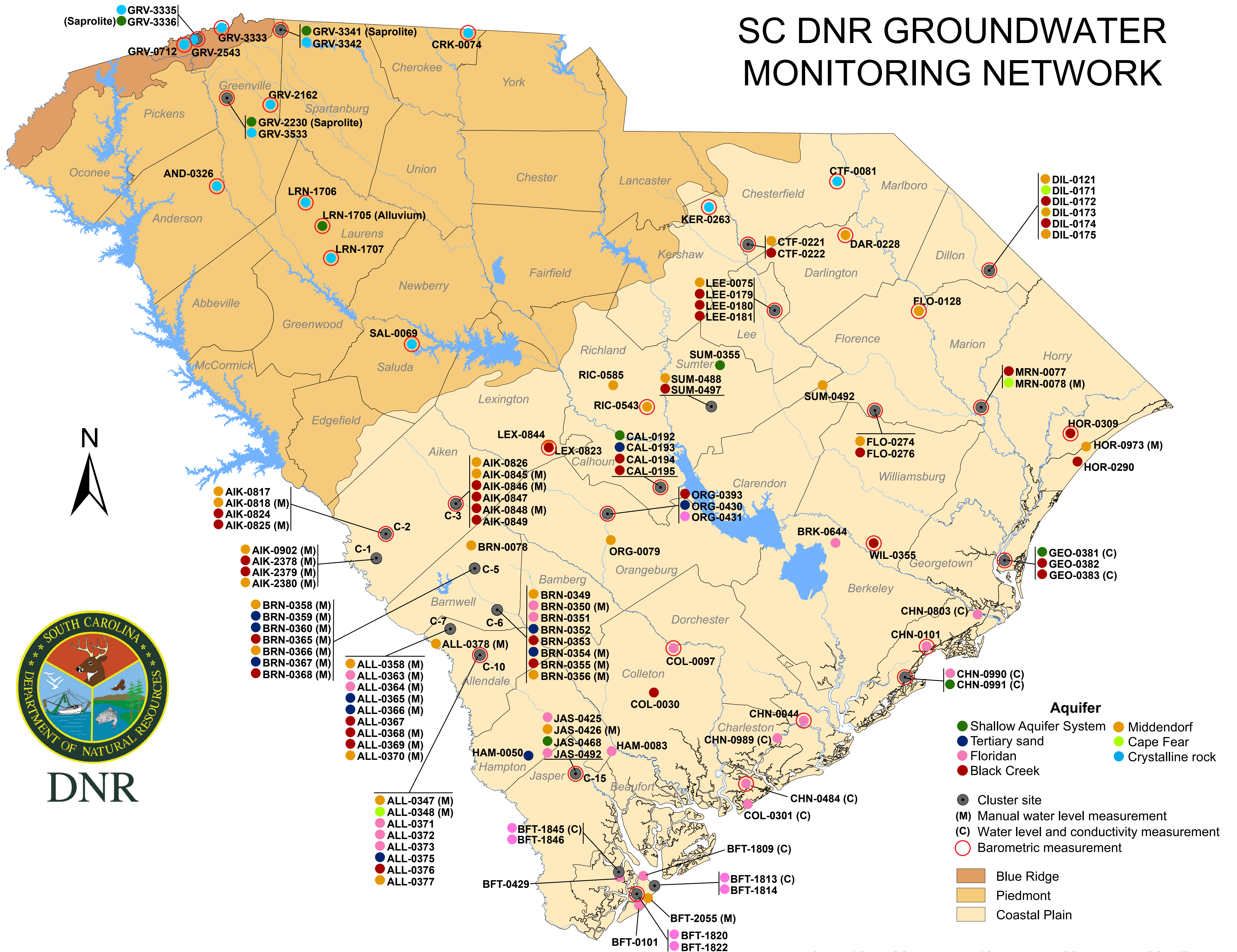


ORG-0079 well construction diagram.



WIL-0355 well construction diagram.

SC DNR GROUNDWATER MONITORING NETWORK



DNR

Map prepared by the Land, Water & Conservation Division of the South Carolina Department of Natural Resources, September 2014.

