

## Appendix 1. Geophysical Logs and Hydrogeologic Characteristics for Selected Wells at Aquifer Storage and Recovery Sites in Southern Florida

This appendix provides borehole data and hydrogeologic interpretation for selected aquifer storage and recovery (ASR) wells in southern Florida. Geophysical log traces, a generalized lithologic column, preferential flow zones, geologic and hydrogeologic units, constructed open-hole interval(s), and vertical changes in ambient chloride concentration, as indicated by water samples collected from known intervals, are illustrated in plots for at least one well per site. The geophysical log traces have been grouped and plotted in four tracks where available. From left to right, these borehole log curves include: track 1—gamma ray, caliper, and spontaneous potential; track 2—formation resistivity; track 3—formation porosity (sonic, neutron, and density logs) and some borehole fluid temperature; and track 4—borehole fluid (temperature, resistivity, and fluid velocity or flowmeter). A list of the geophysical logging tool devices and units used in these plots is given in table A1. Most geophysical log data can be obtained from the DBHYDRO database web site, [http://glades.sfwmd.gov/pls/dbhydro\\_pro\\_plsql/show\\_dbkey\\_info.main\\_page](http://glades.sfwmd.gov/pls/dbhydro_pro_plsql/show_dbkey_info.main_page), which was developed and operated by South Florida Water Management District (SFWMD). Hard copies of logs were digitized by the SFWMD for this study, and the data were stored in their database.

Data from monitoring wells often were used instead of injection wells because monitoring wells generally were the first (test) wells at a site and were drilled to greater depths. Where monitoring well data are used, the ASR storage open-hole interval for the injection well at the site also is shown or indicated. At one site (site 9), only a test well has been drilled

and has not yet been completed. Two of the facilities (sites 11 and 13) are at the same location, and only one plot (well L-5817, site 13) is used for both. At site 12, plots of both the ASR well and a monitoring well are included.

The geologic and hydrogeologic unit boundaries shown on the plots in this appendix are listed together with their sources of determination in tables A2 and A3. The lithologic descriptions used to illustrate lithology in the lithologic column were obtained from well completion reports written by consulting firms for the individual ASR sites or from the Florida Geological Survey (Florida Geological Survey, 2004).

Flow zones were determined primarily using the borehole fluid curves including the flowmeter, but other curves such as the caliper, resistivity, and porosity logs can provide supporting data. The sources of determination for the flow zones are given in table A4. Borehole fluid logs, however, often were not run above where the final casing was set at the top of the open interval, which sometimes was below the top of the Upper Floridan aquifer. The determination of the top of the aquifer was less certain for these cases (for example, sites 2, 3, and 4).

Wells at most sites penetrated only the Upper Floridan aquifer; at some sites, however, deep aquifers were penetrated. Both the middle Floridan aquifer and the upper part of the Lower Floridan aquifer were penetrated at five of the sites (9, 16, 21, 22, and 26), and in this appendix, a second page is included that shows these deeper aquifers. Additionally, at two other sites (25 and 28), the middle Floridan aquifer was penetrated.








**Table A1.** Geophysical logging tool devices and units used in appendix 1 plots.

[In many wells, more than one log run is shown. In most cases, these runs were spliced together at the bottom of the upper run and are labeled “(spliced)” in the heading]










Logging tools and devices		Units	
Abbreviation	Description	Abbreviation	Description
AHO10	Array induction – 1-foot resistivity A10	OHMM	Ohm-meters
AHO60	Array induction – 1-foot resistivity A60	OHMM	Ohm-meters
AHO90	Array induction – 1-foot resistivity A90	OHMM	Ohm-meters
CAL	Caliper	INCHES	Inches
DPHI	Density porosity (compensated)	PU	Porosity units as a percent
DT	Delta T – Sonic log traveltime (compensated)	USEC/FT	Microseconds per foot
DTEM	Temperature differential or gradient of borehole fluid	DEGF/FT	Degrees Fahrenheit per foot
DYND	Flowmeter (trolling down) – Pumped or flowing	CPS	Counts per second
DYND	Flowmeter (trolling down) – Pumped or flowing	RPM	Revolutions per minute
DYNU	Flowmeter (trolling up) – Pumped or flowing	CPS	Counts per second
FRES	Fluid resistivity (flow conditions unspecified)	OHMM	Ohm-meters
FSD	Flowmeter (trolling down) – static	CPS	Counts per second
GAMM	Gamma Ray	CPS	Counts per second
GR	Gamma Ray	GAPI	American Petroleum Institute standard units
ILD	Induction log deep	OHMM	Ohm-meters
ILM	Induction log medium	OHMM	Ohm-meters
LAT6	Lateral log (AO electrode spacing = 6 feet)	OHMM	Ohm-meters
LL3	Laterolog 3 (shallow focused resistivity run on induction tool)	OHMM	Ohm-meters
NEU	Neutron	CPS	Counts per second
NPFI	Neutron porosity (compensated)	PU	Porosity units as a percent
RLN	Resistivity (long normal) AM electrode spacing = 64 inches	OHMM	Ohm-meters
RSN	Resistivity (short normal) AM electrode spacing = 16 inches	OHMM	Ohm-meters
SP	Spontaneous potential	MV	Millivolts
TEMP	Temperature of borehole fluid (flow conditions unspecified)	DEGF	Degrees Fahrenheit
XCAL and YCAL	X- and Y calipers (two calipers run on same tool 90 degrees apart)	INCHES	Inches

### EXPLANATION






















#### GEOLOGIC UNITS

-  POST MIOCENE AGE ROCKS
-  HAWTHORN GROUP
-  ARCADIA FORMATION
-  SUWANNEE LIMESTONE
-  OCALA LIMESTONE
-  AVON PARK FORMATION
-  OLDSMAR FORMATION




#### HYDROGEOLOGIC UNITS

-  LOWER TAMIAMI AQUIFER
-  SURFICIAL AQUIFER SYSTEM
-  INTERMEDIATE CONFINING UNIT
-  MID-HAWTHORN AQUIFER
-  UPPER FLORIDAN AQUIFER
-  MIDDLE CONFINING UNIT
-  MIDDLE FLORIDAN AQUIFER
-  LOWER FLORIDAN AQUIFER
-  LOWER CONFINING UNIT

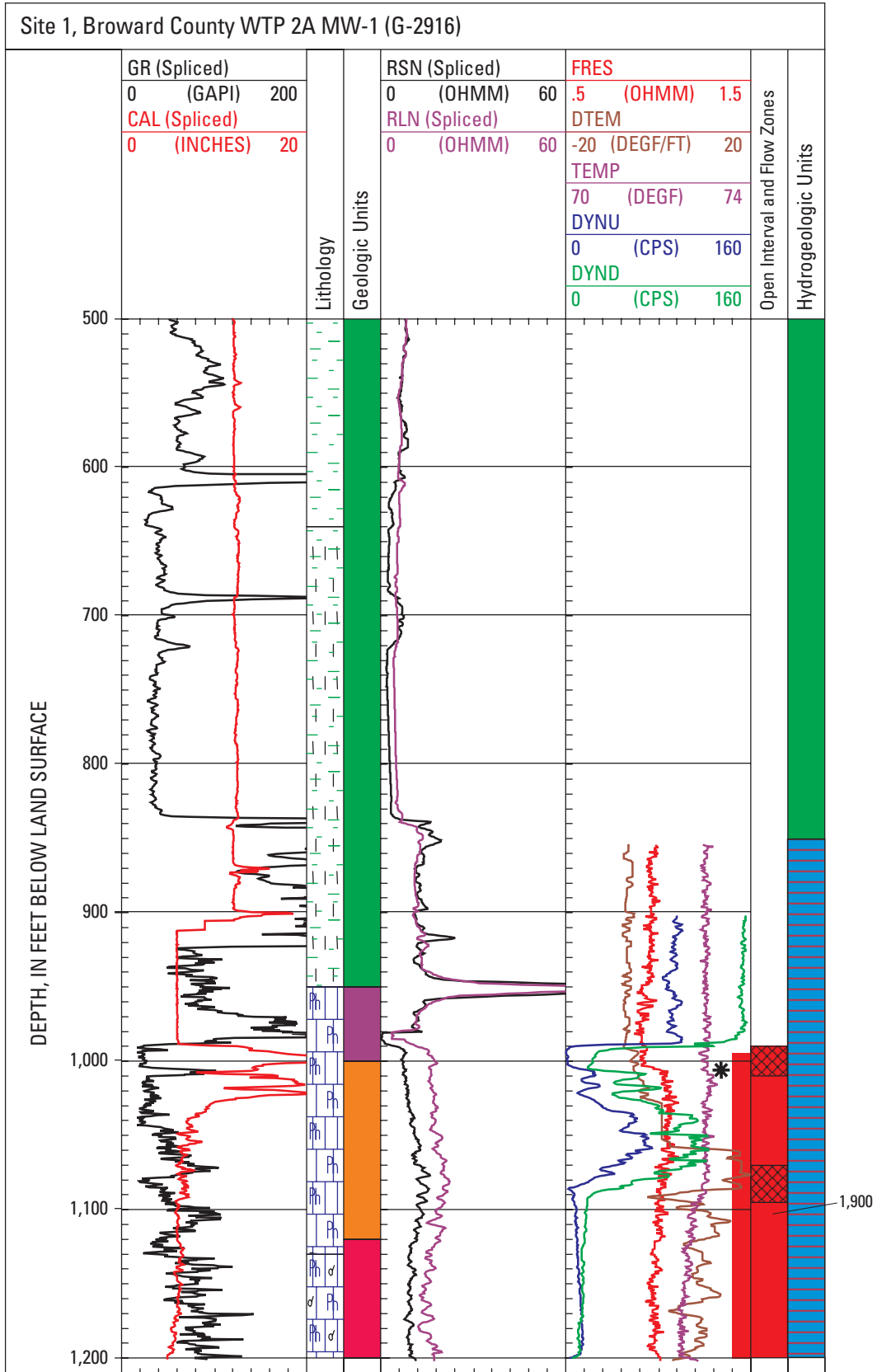
#### LITHOLOGIC SYMBOLS

- |  |   |   |
|--|---|---|
|  ANHYDRITIC     |  FOSSILIFEROUS |  SAND      |
|  CALCARENITE    |  GRAVEL        |  SANDSTONE |
|  CALCAREOUS     |  LIME MUD      |  SANDY     |
|  CHERT          |  LIMESTONE     |  SHELL BED |
|  CLAY OR CLAYEY |  NO SAMPLE     |  SILT      |
|  DOLOMITE       |  OOLITIC       |  SILTSTONE |
|  DOLOMITIC      |  PHOSPHATIC    |  SILTY     |

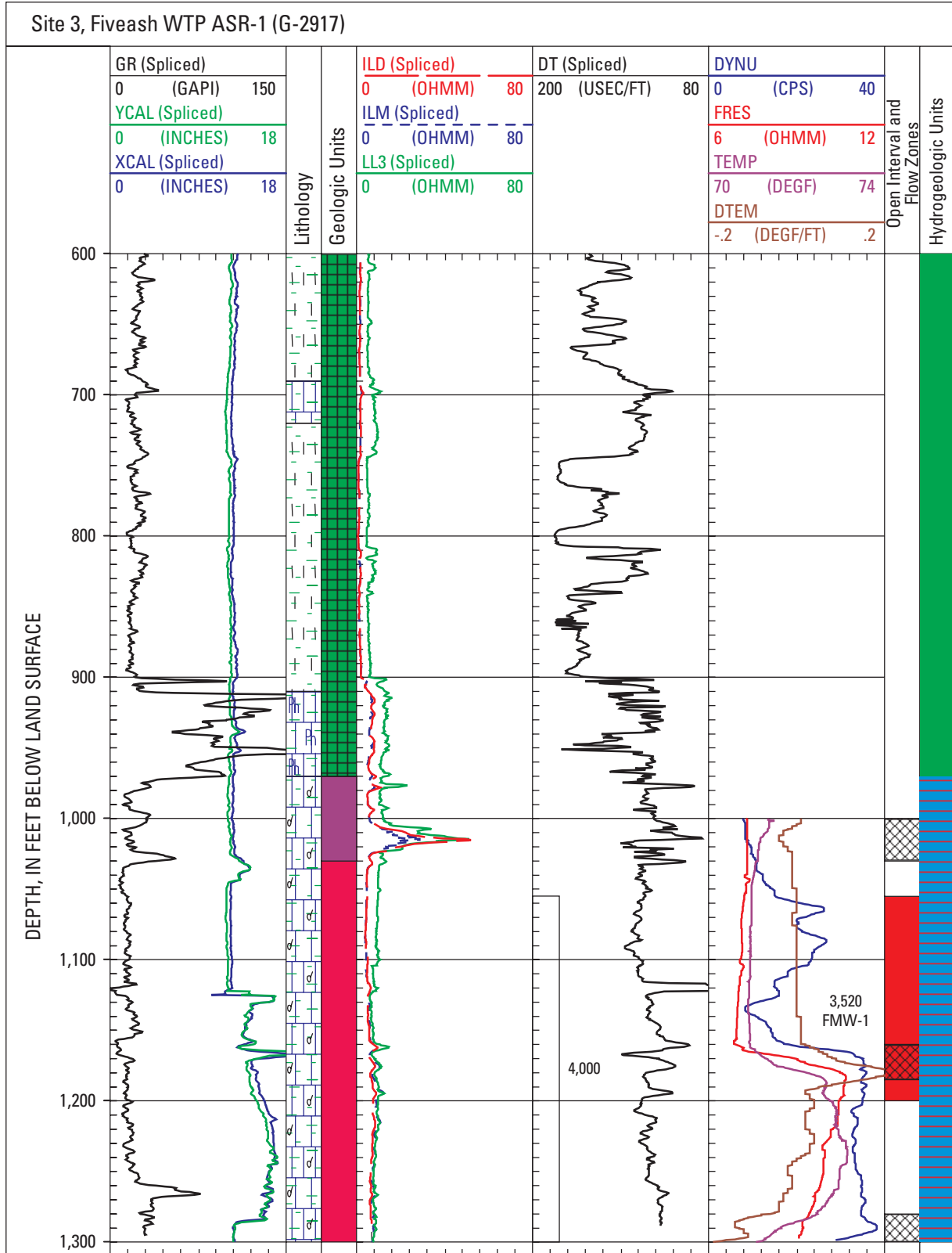
#### OTHER SYMBOLS AND WATER QUALITY DATA SYMBOLS

- |  |   |   |
|--|---|---|
| 1,900  COMPLETED OPEN-HOLE INTERVAL | 4,000  OTHER SAMPLED INTERVAL—Includes open-hole intervals, packer tests, and samples collected during reverse-air rotary drilling |  FLOW ZONE |
|--|---|---|

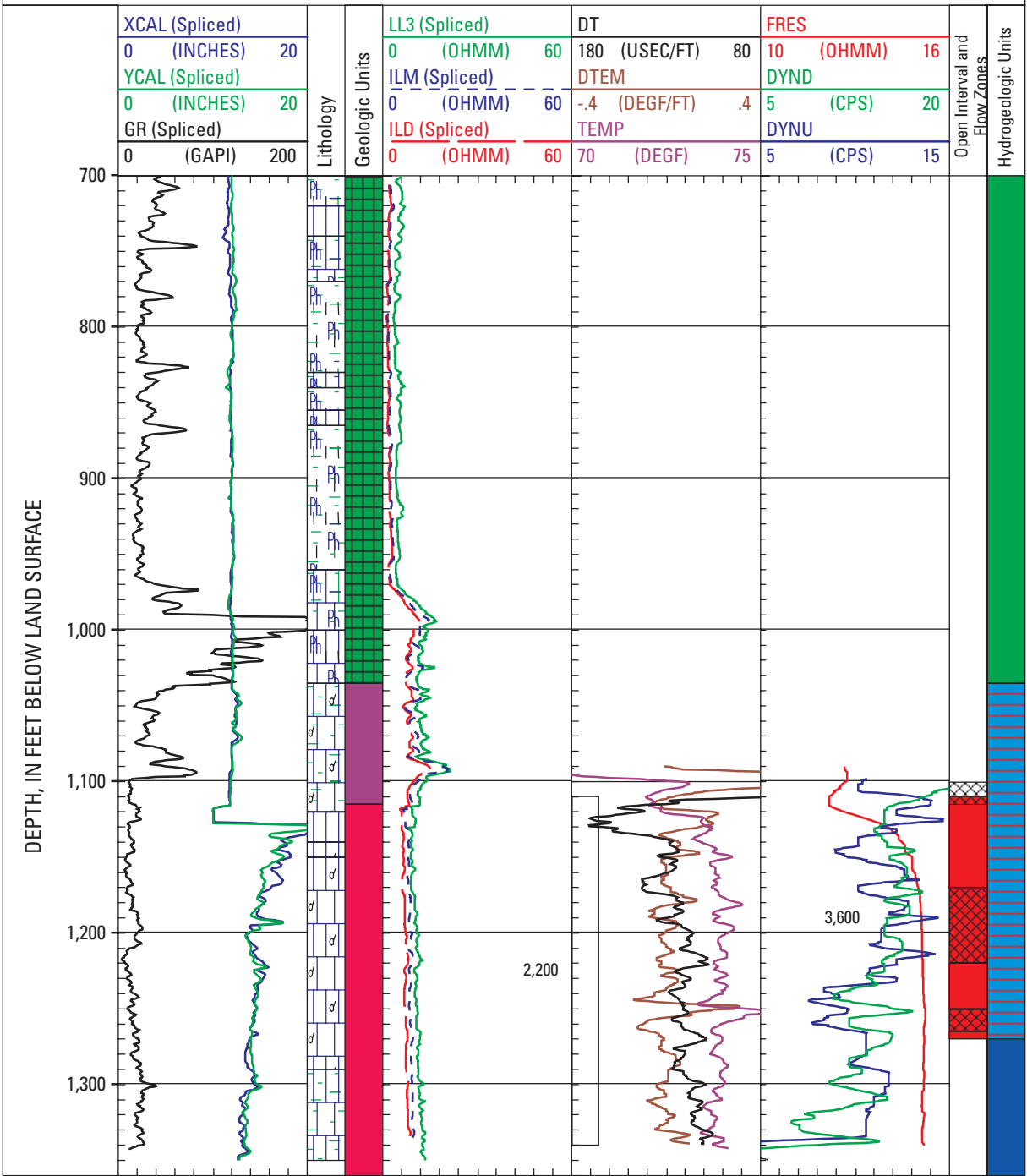
Numbers are chloride concentration in milligrams per liter in water sample obtained from delineated interval. Values are from table 4. The site name and local well number(s) at the top of each log are followed by the USGS well number in parentheses.

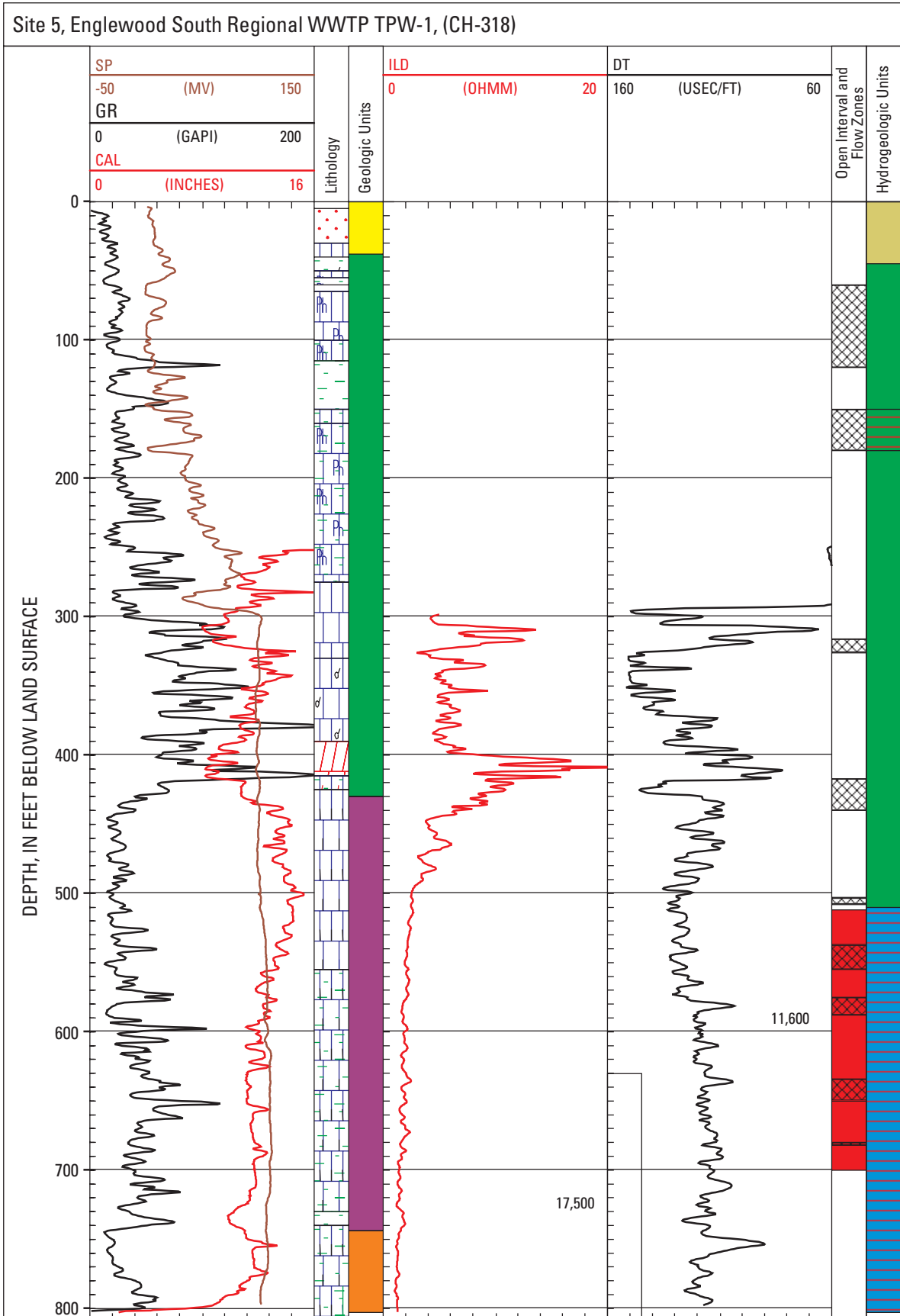




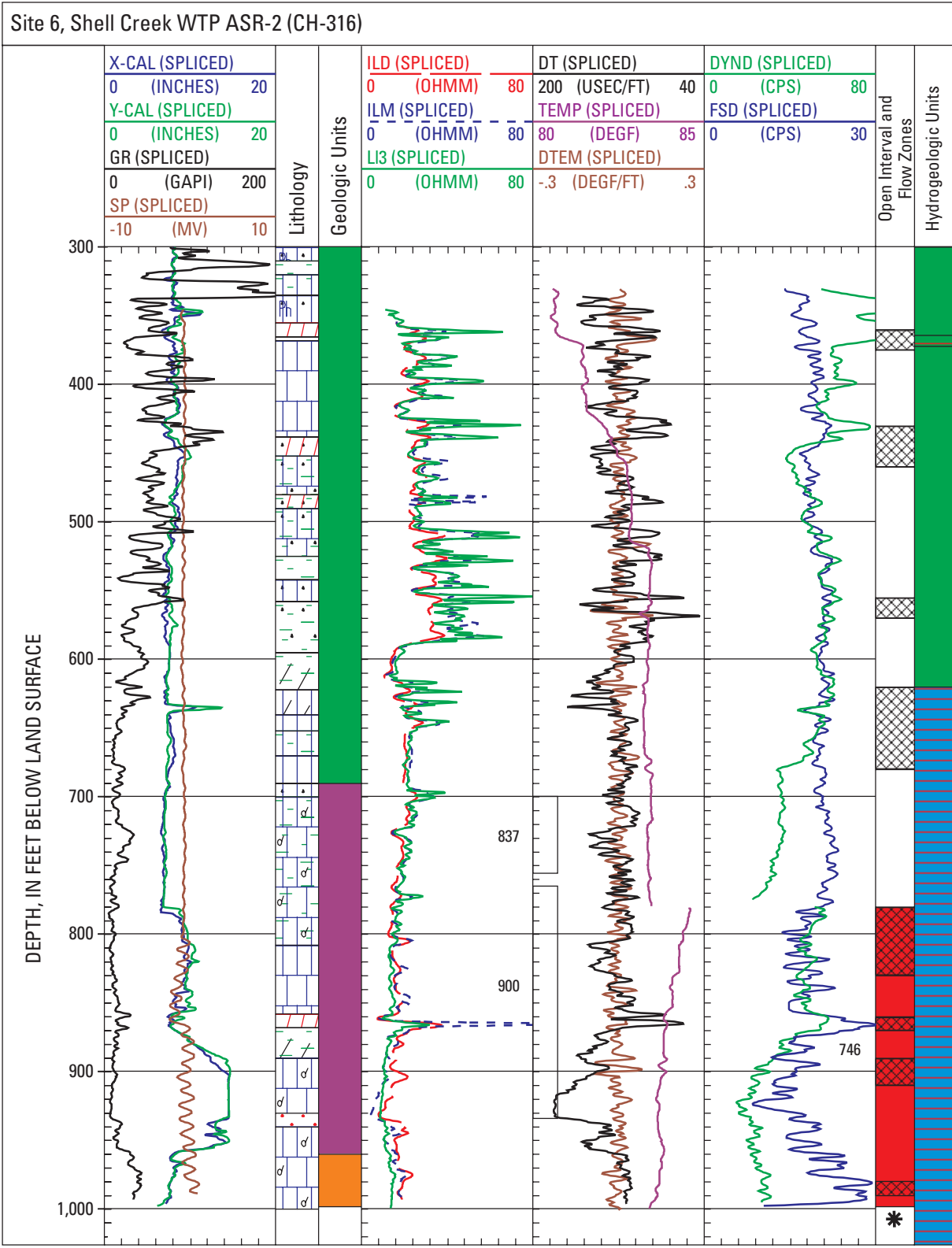


Site 4, Springtree WTP ASR-1 (G-2914)

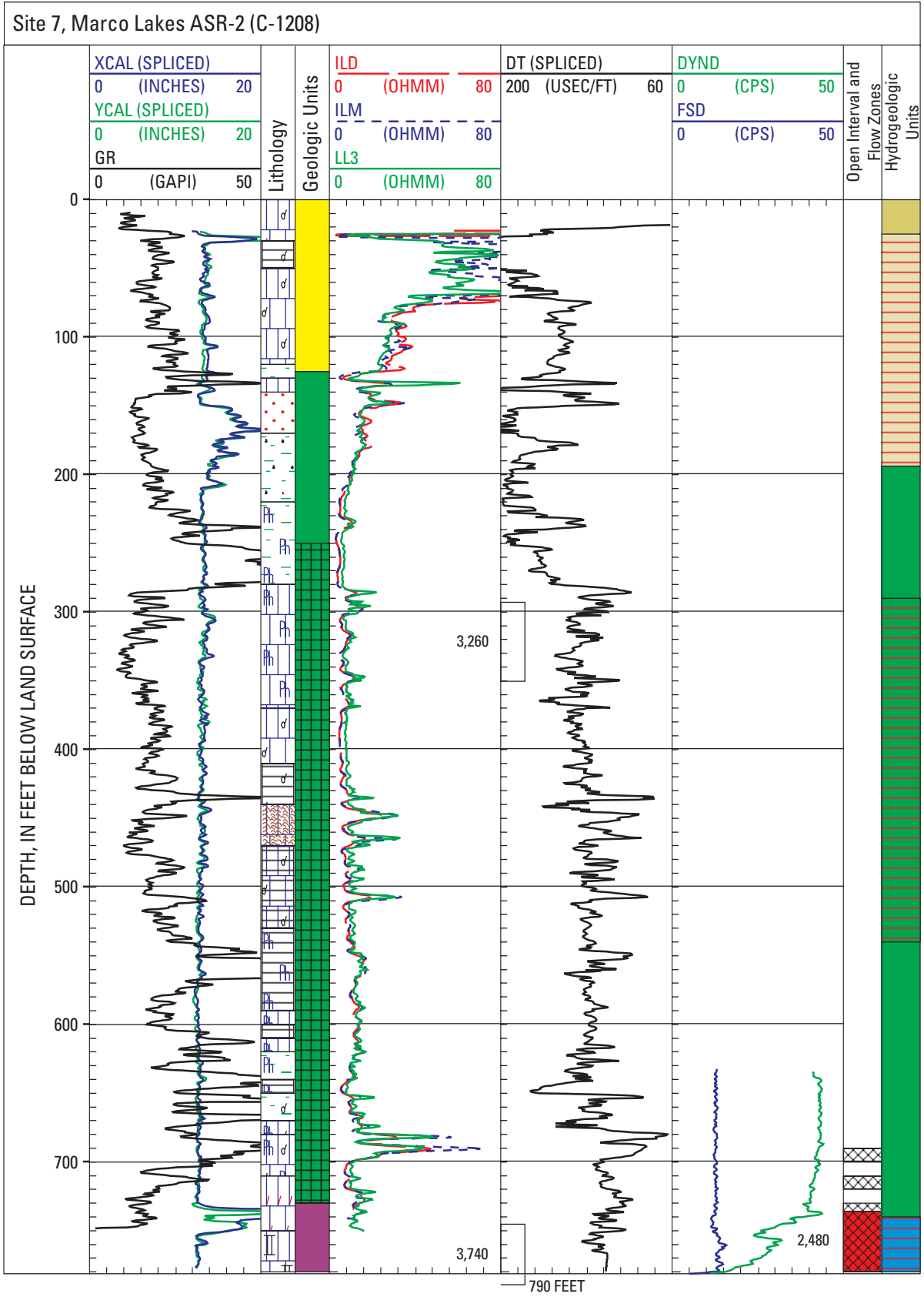


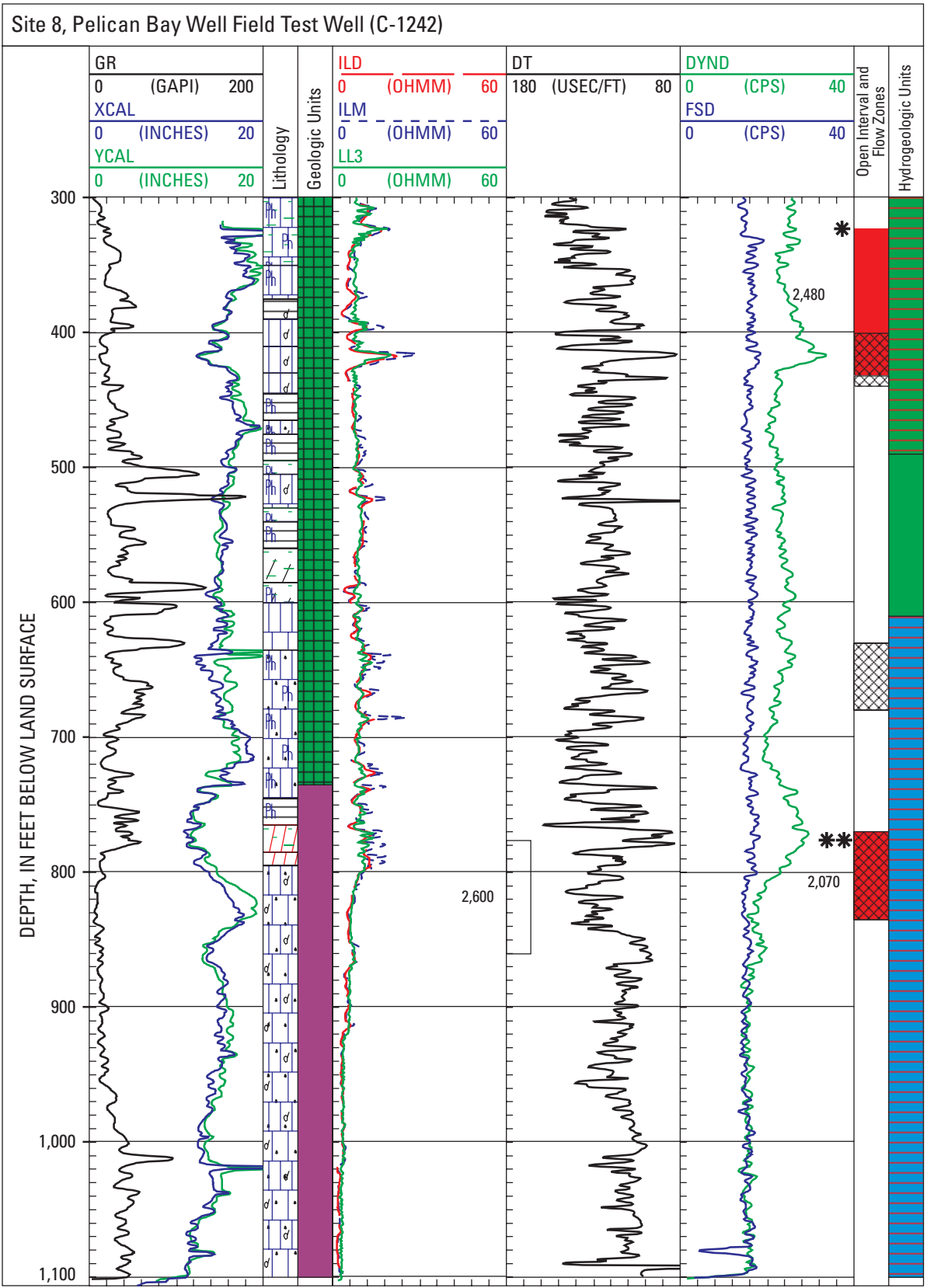


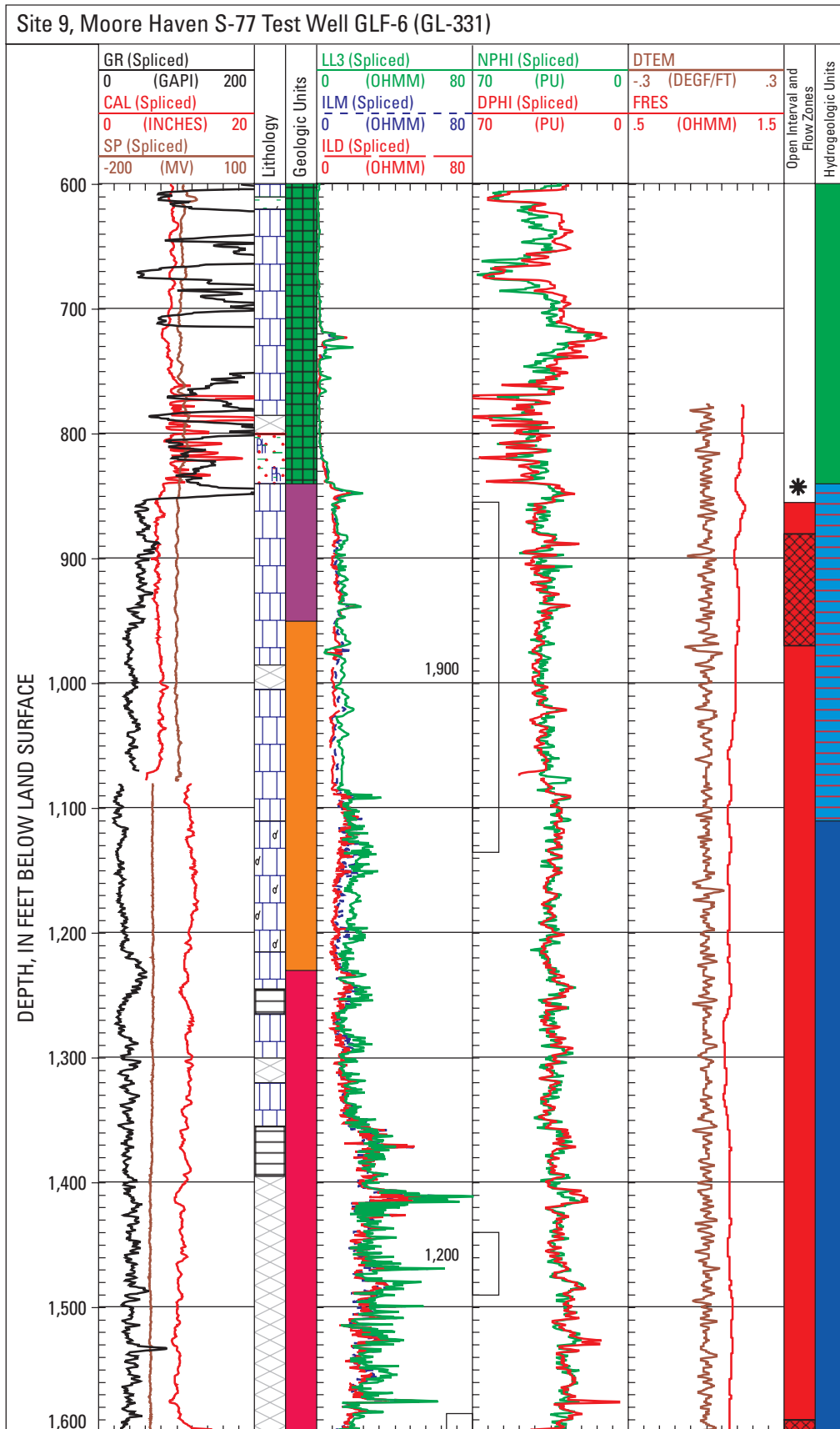




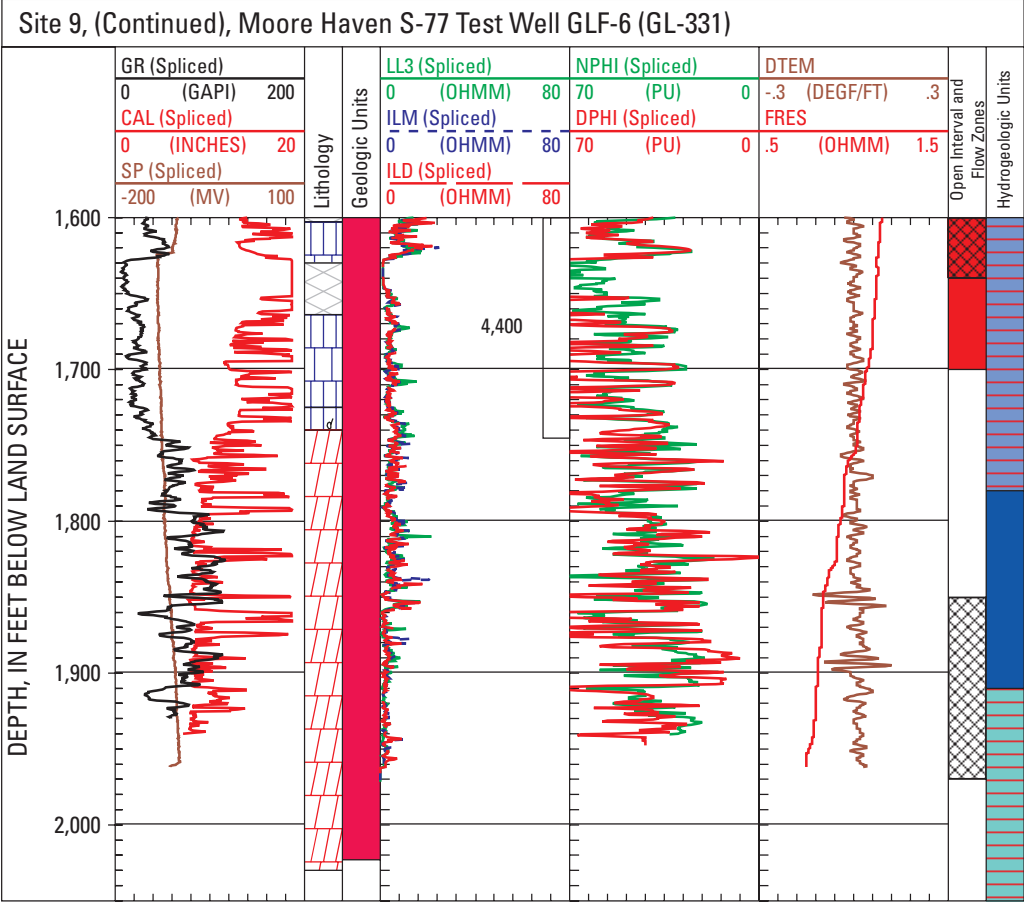
\* Bottom of storage zone in wells ASR-1, 3, and 4R is shallower, and equal to 933, 912, and 915 feet, respectively.



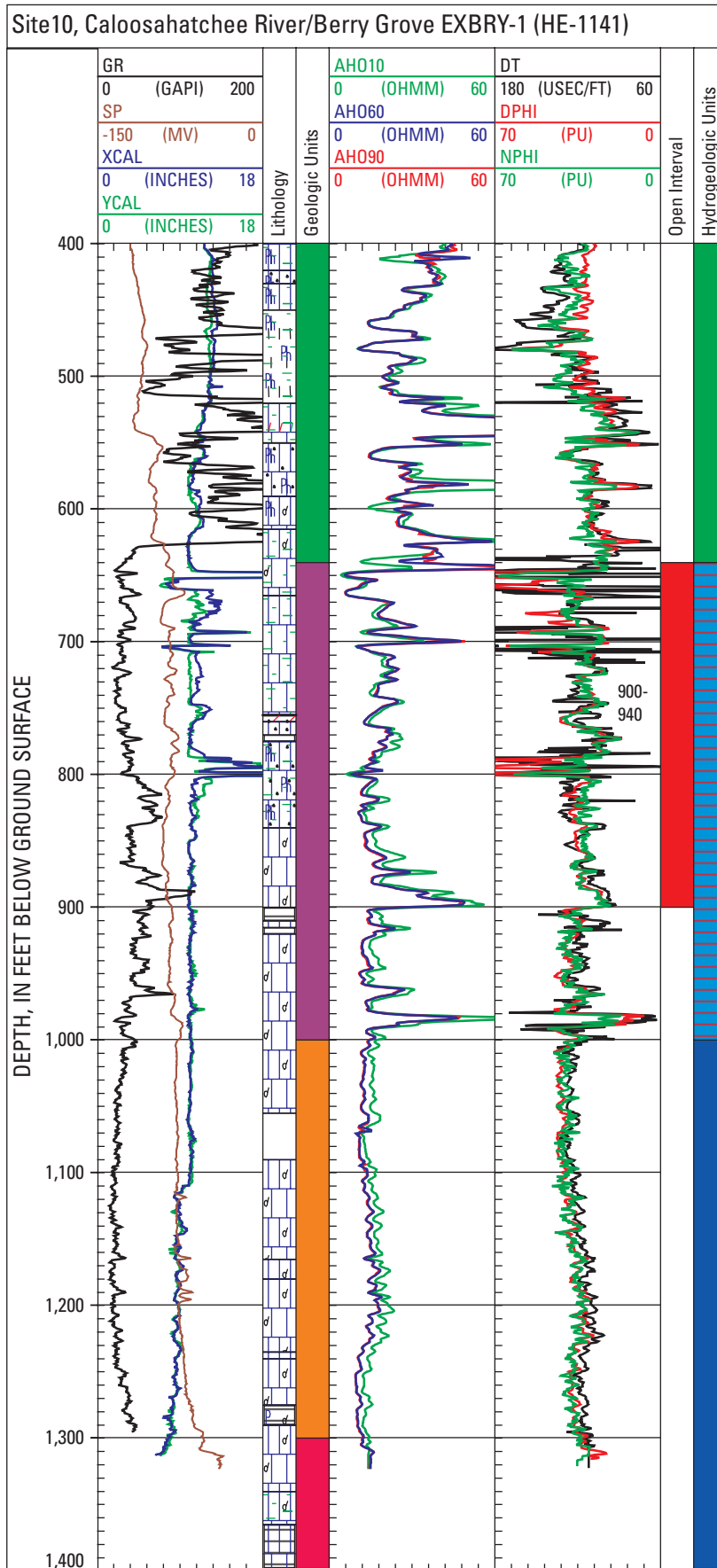


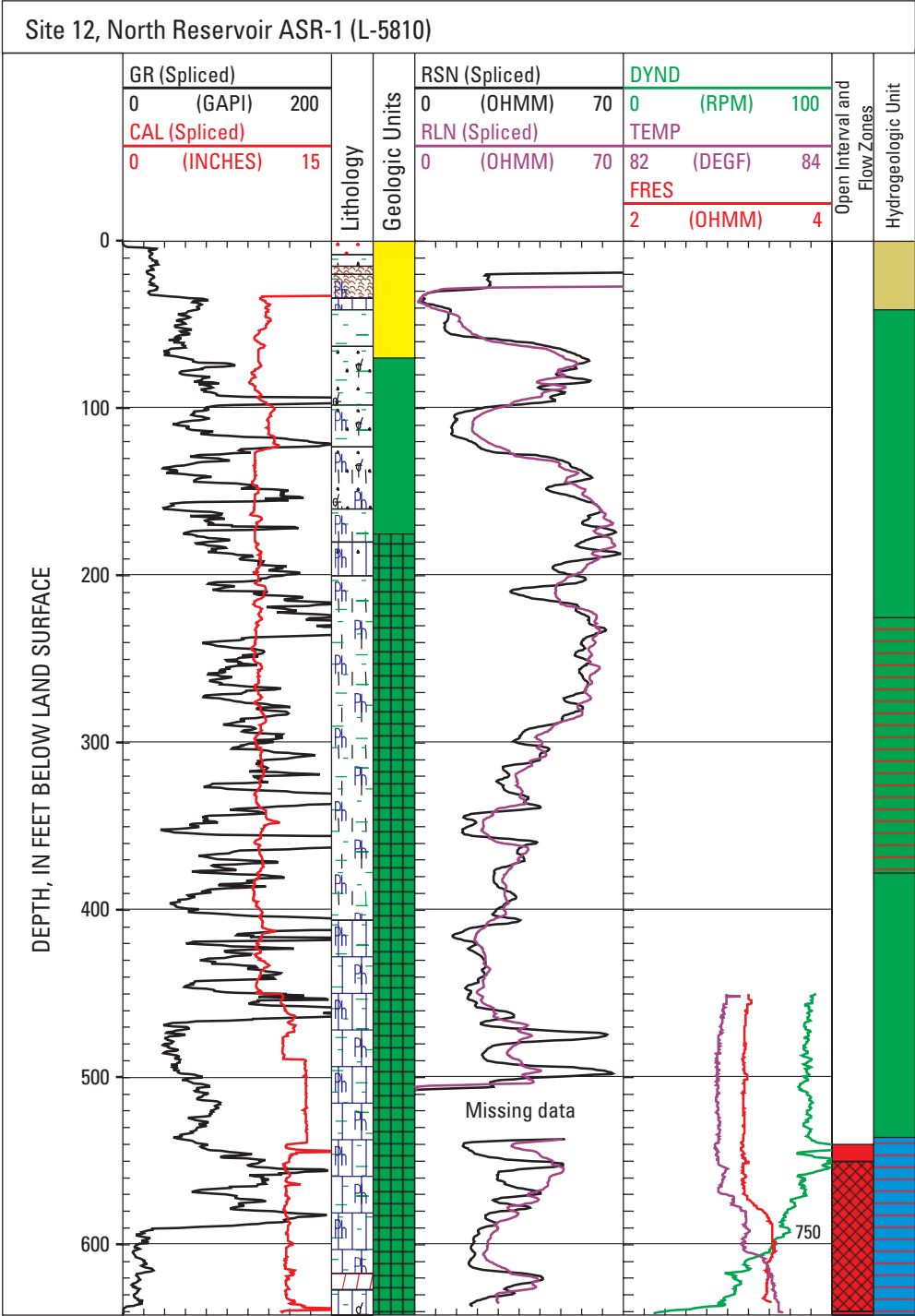


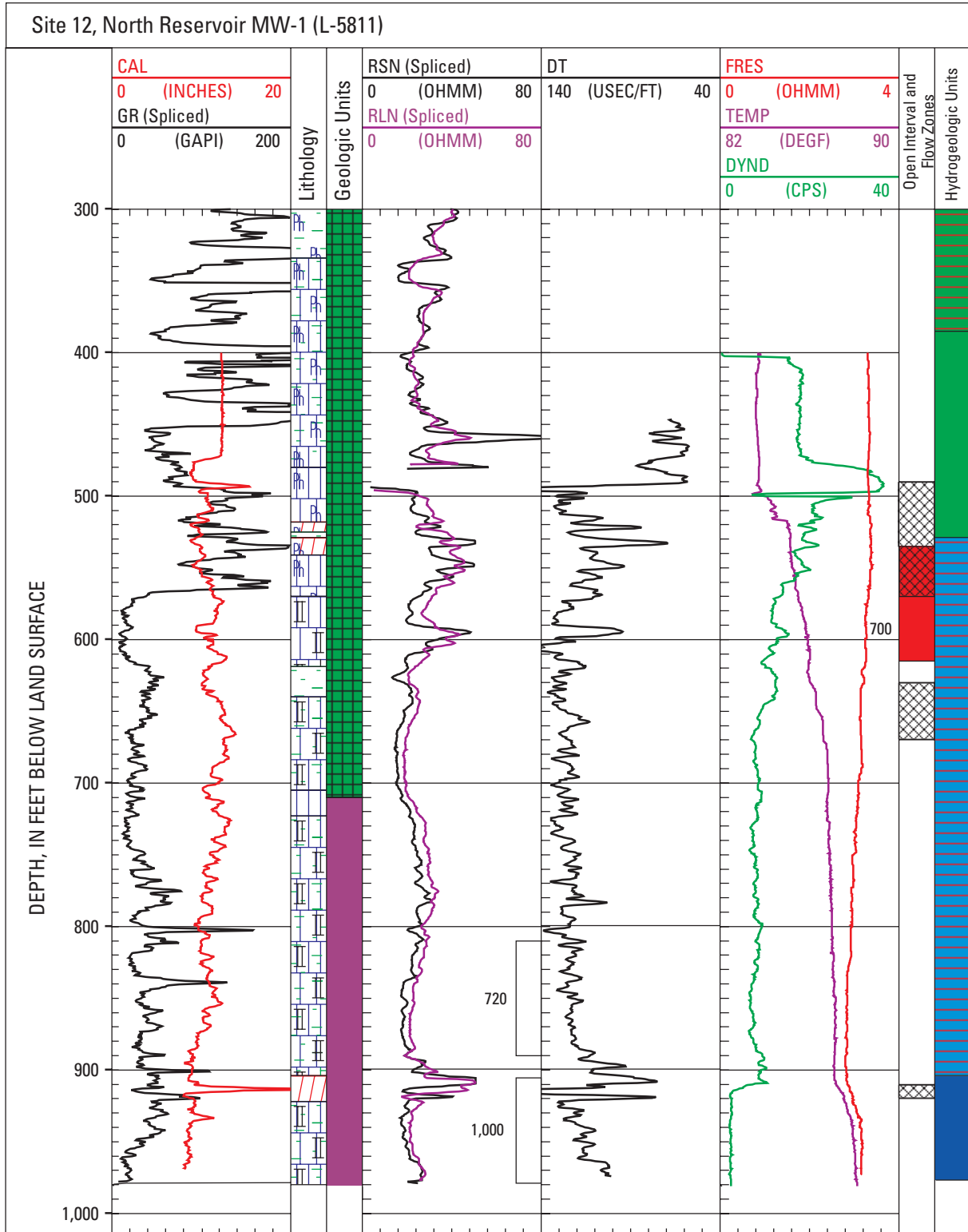
\* Well not completed. Present open interval is from 855 to 1,700 feet.



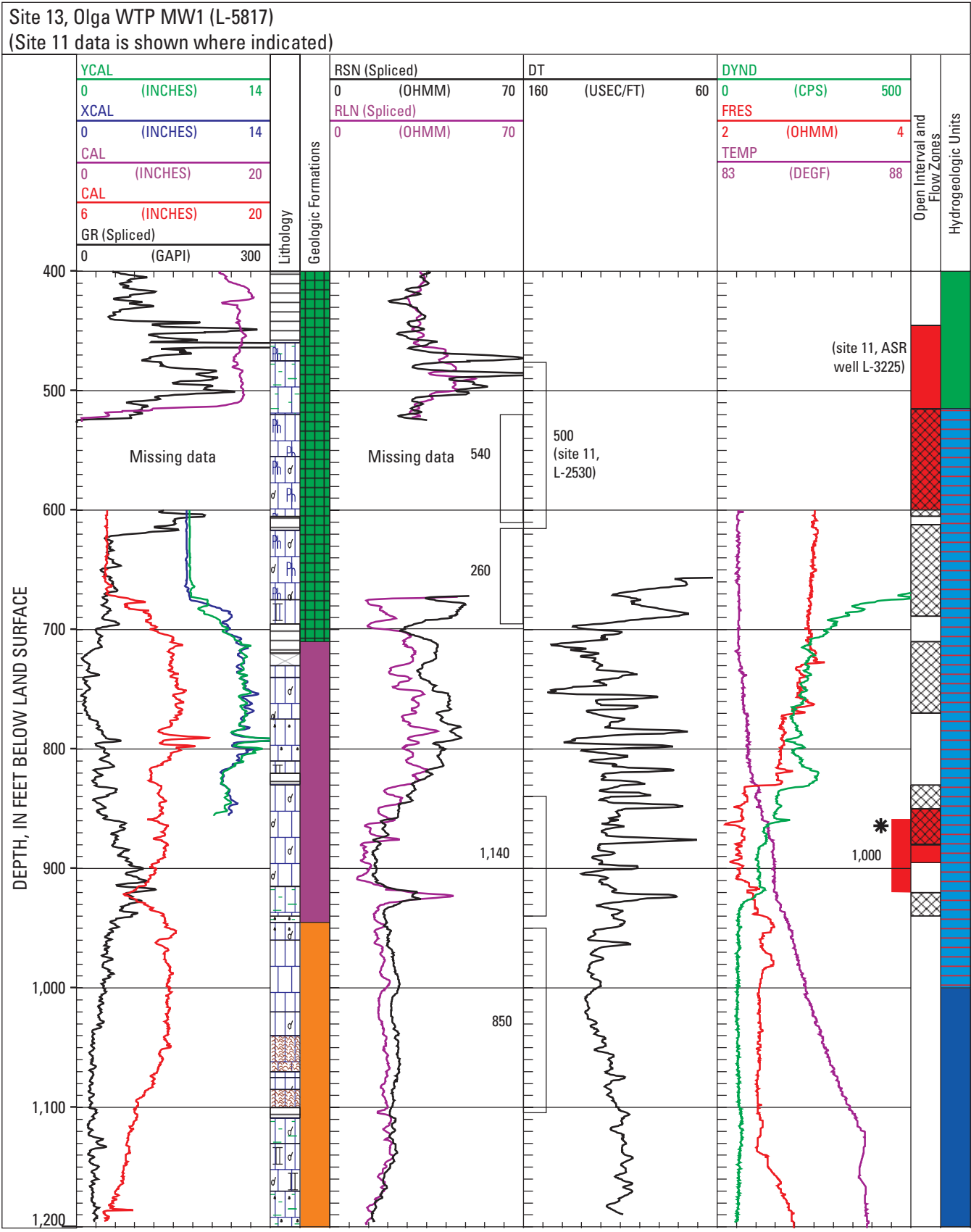
\* Well not completed. Present open interval is from 855 to 1,700 feet.



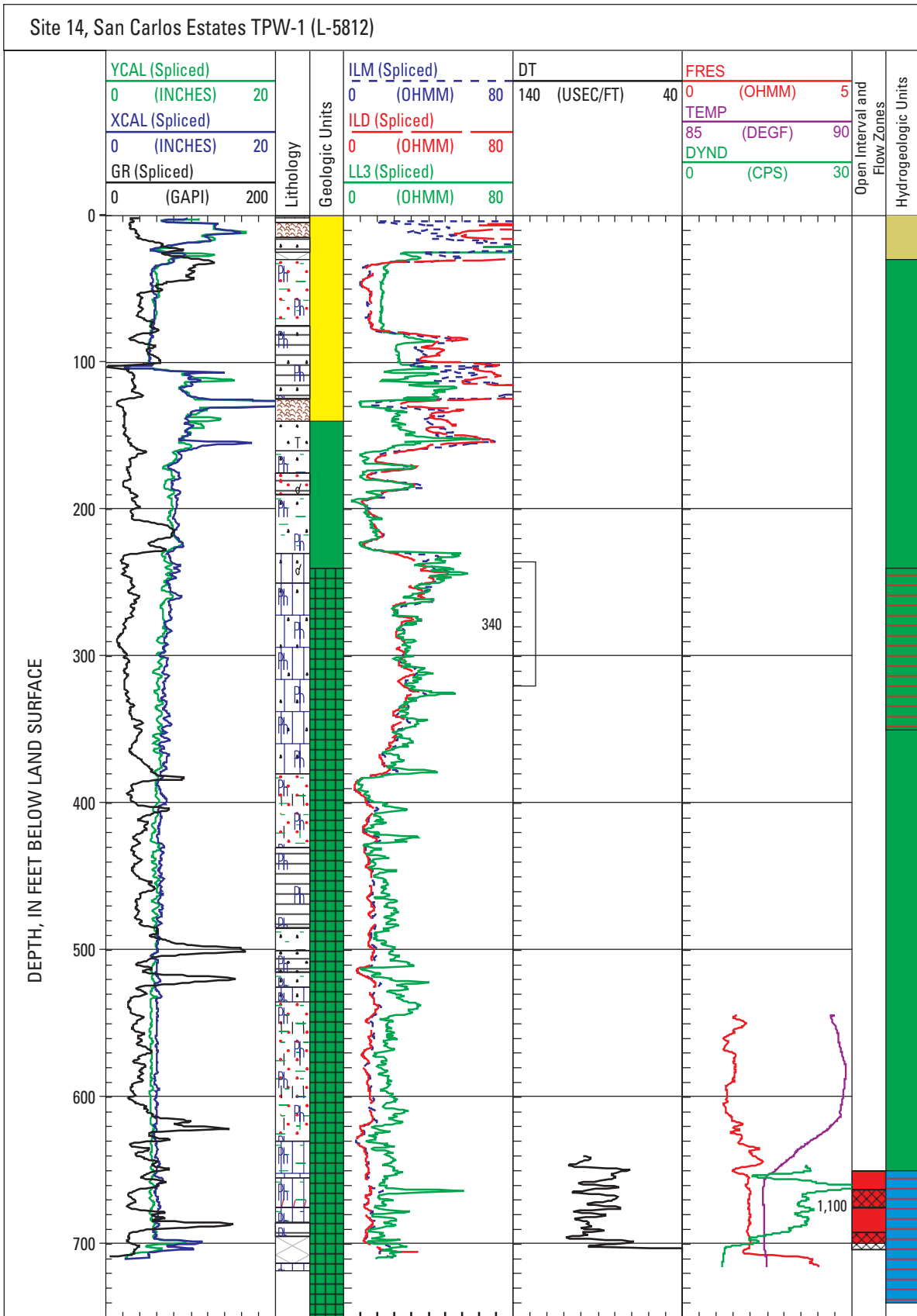




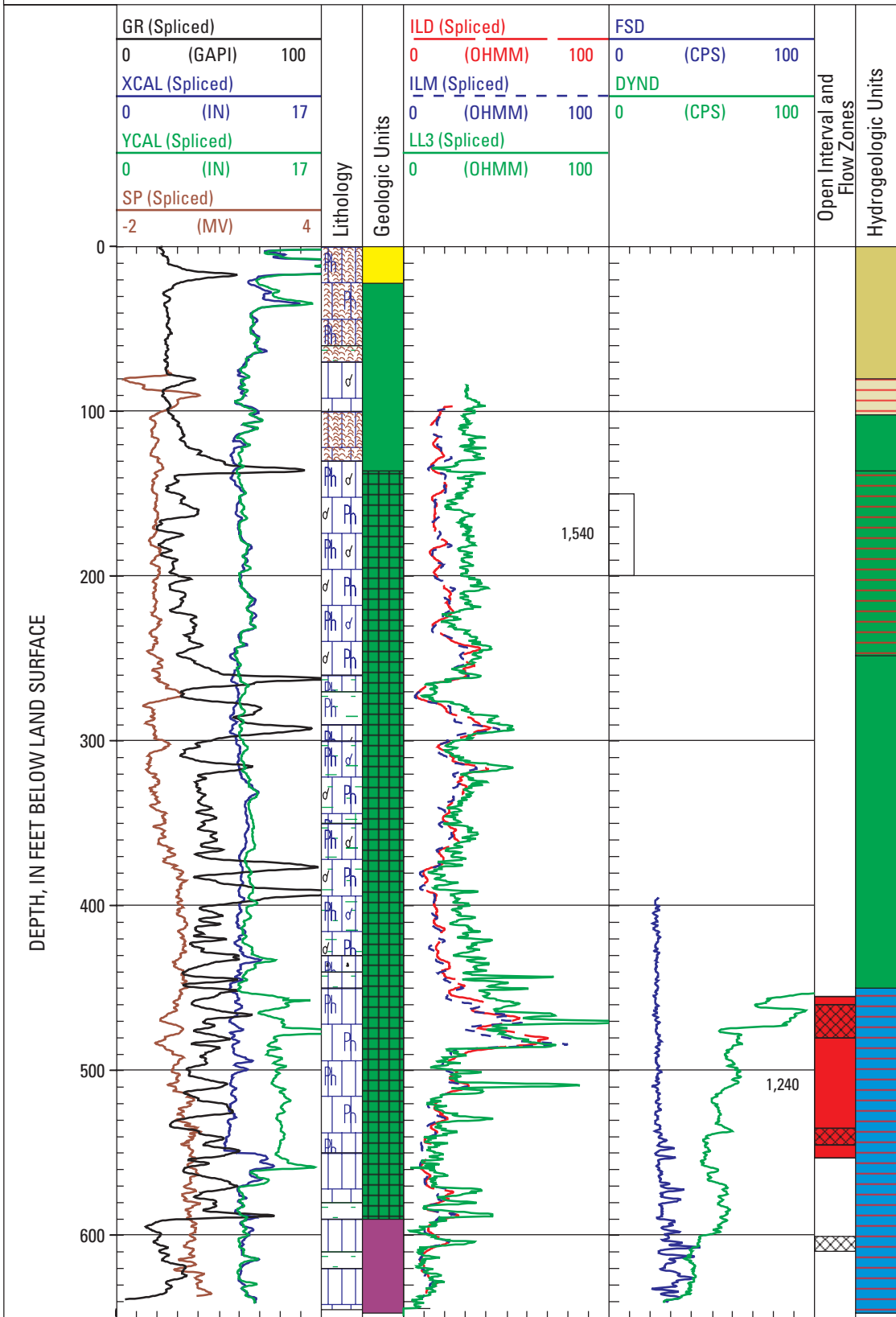


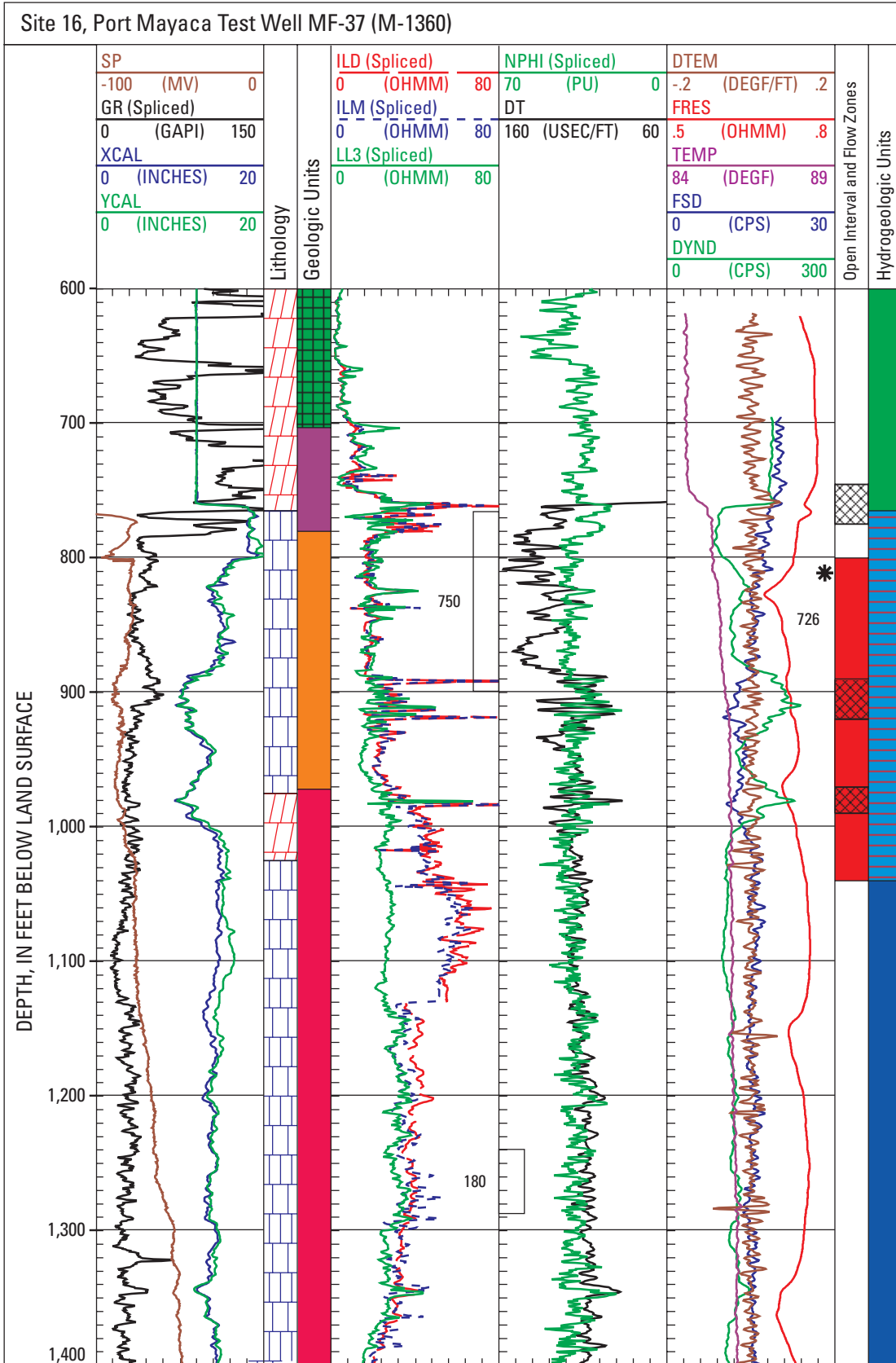


\* Open interval is for Olga WTP well ASR-1

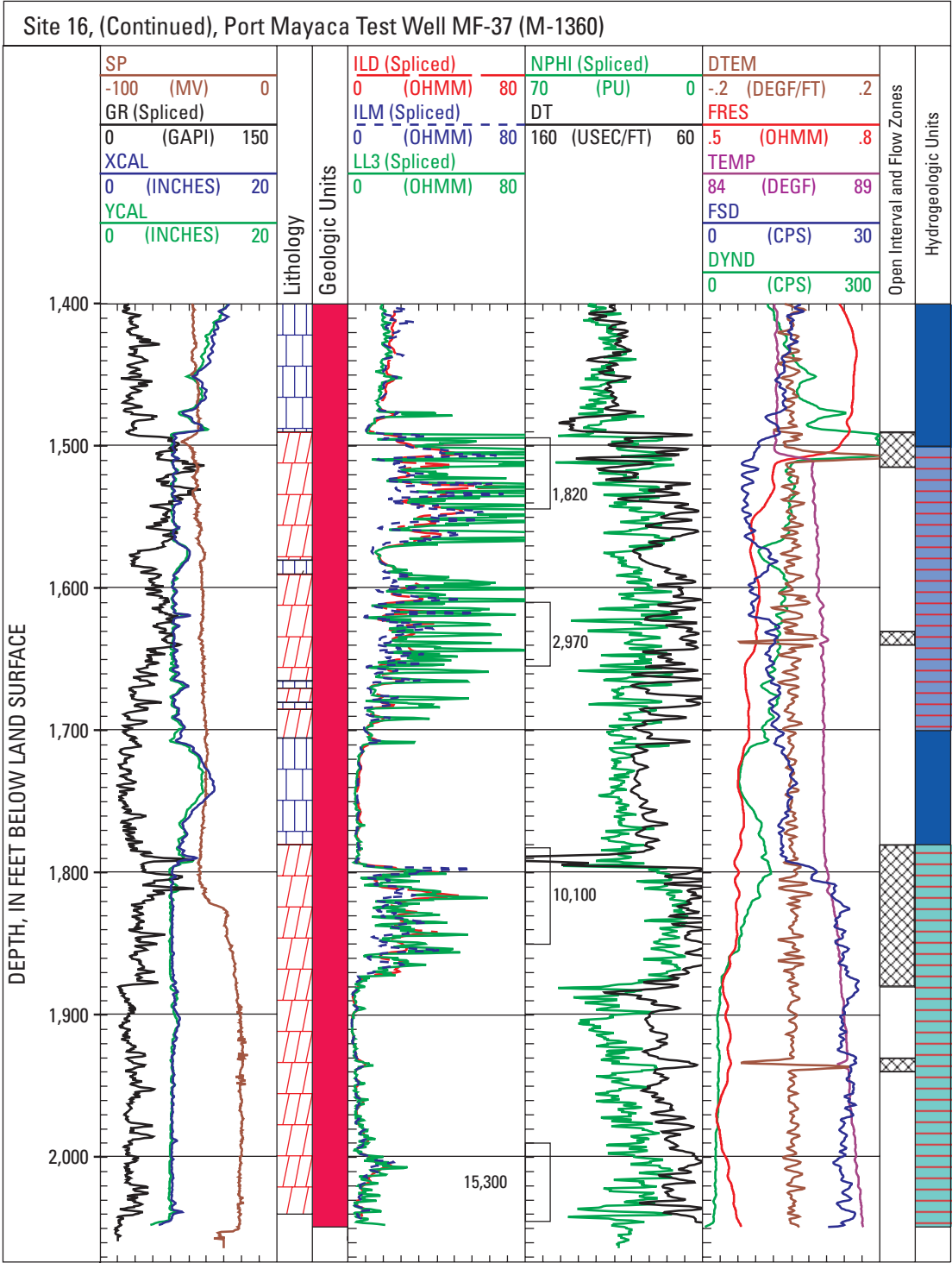


Site 15, Winkler Ave ASR-1 (L-5871)

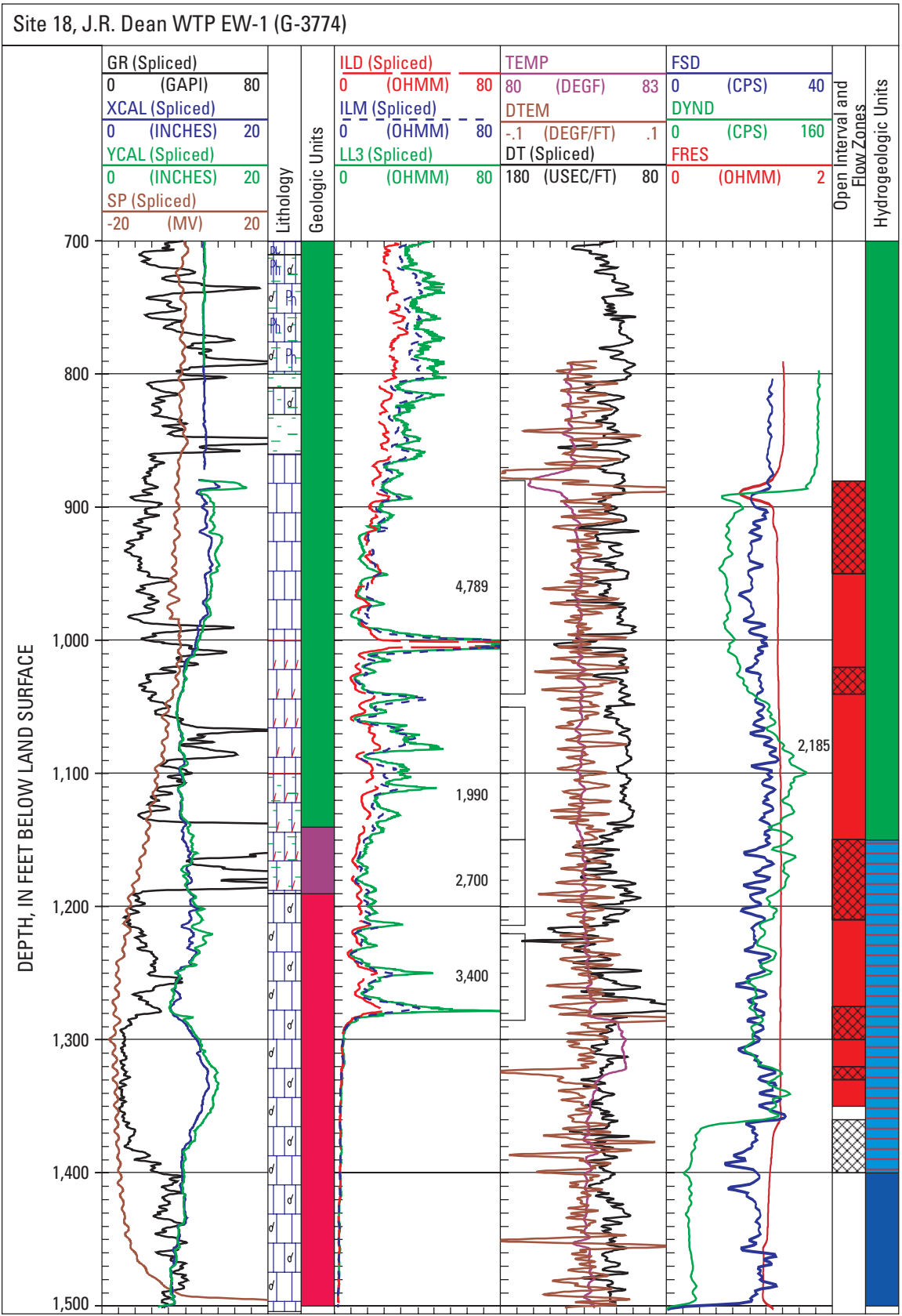




\* Open interval is for well EXPM-1 (M-1361) at the same site. Well MF-37 has not been completed, but casing was set at 765 feet.

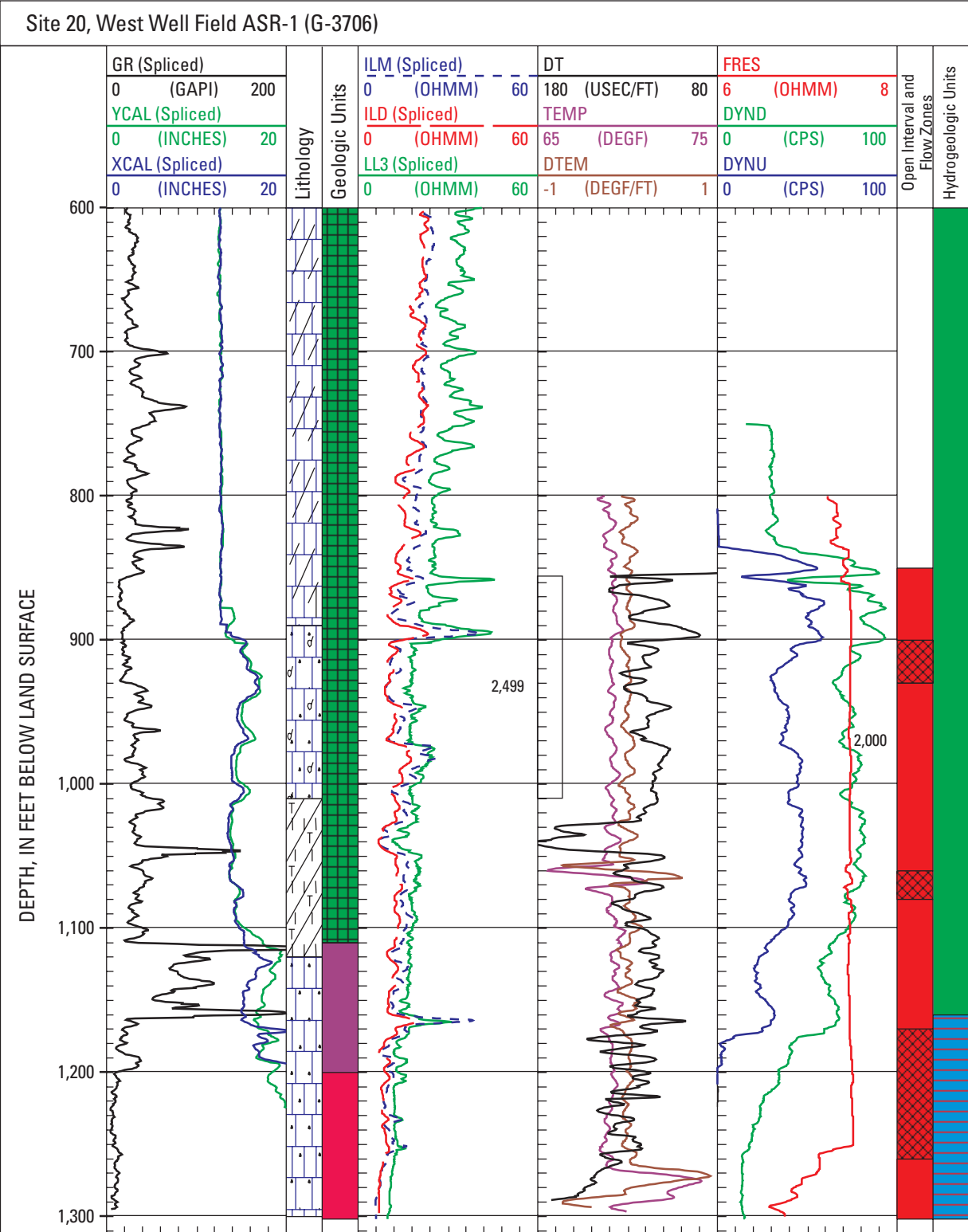


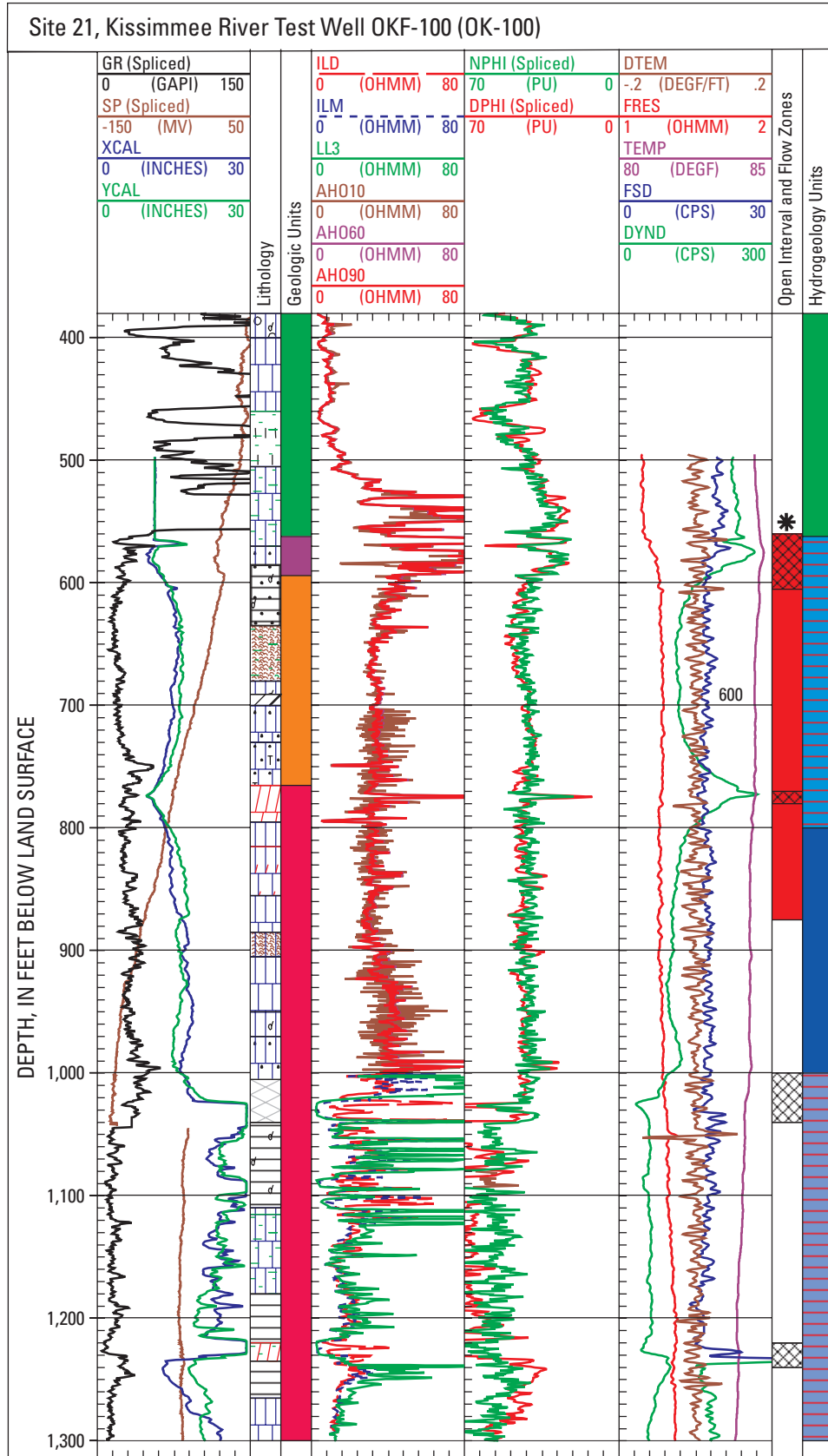


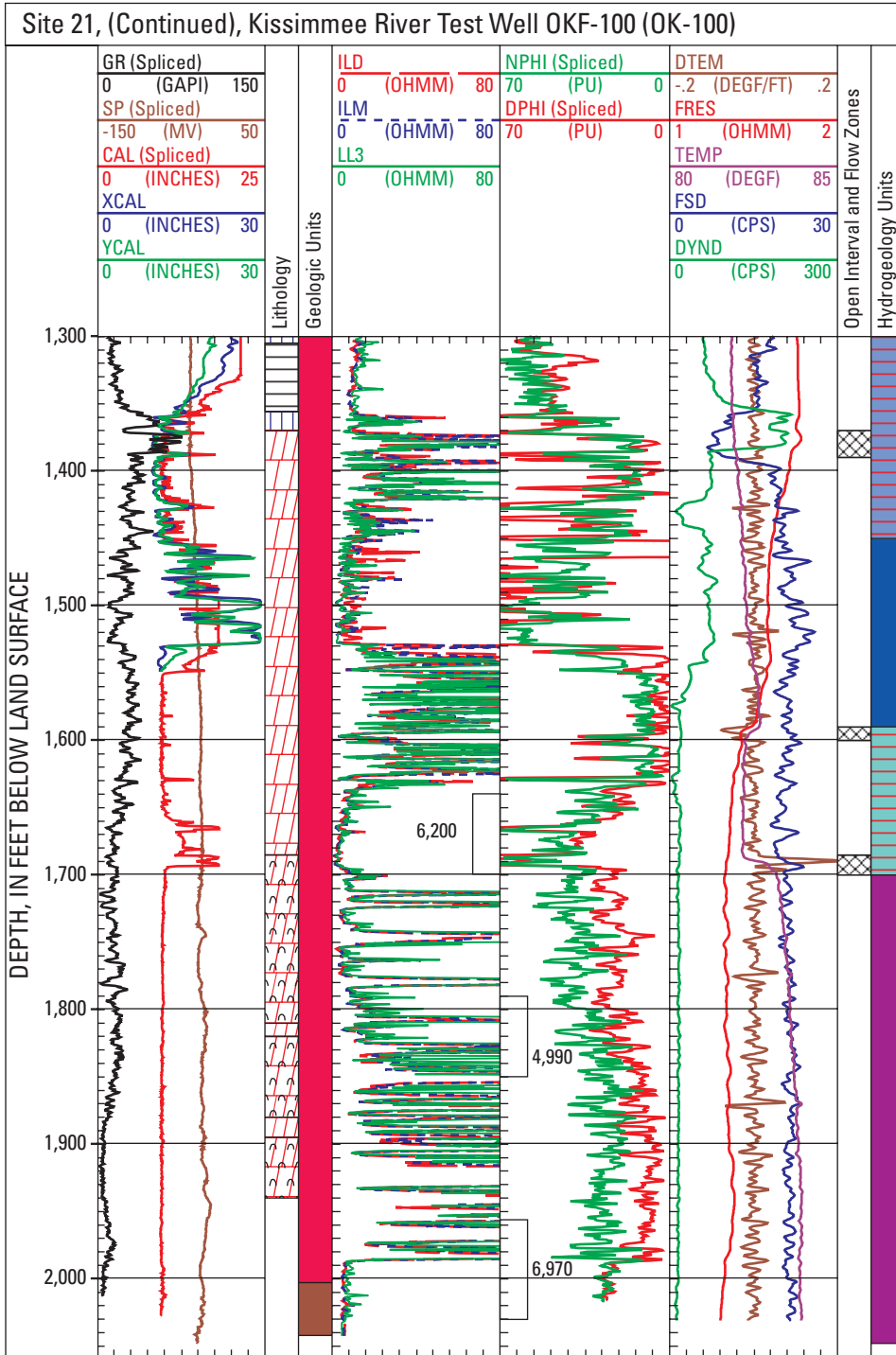


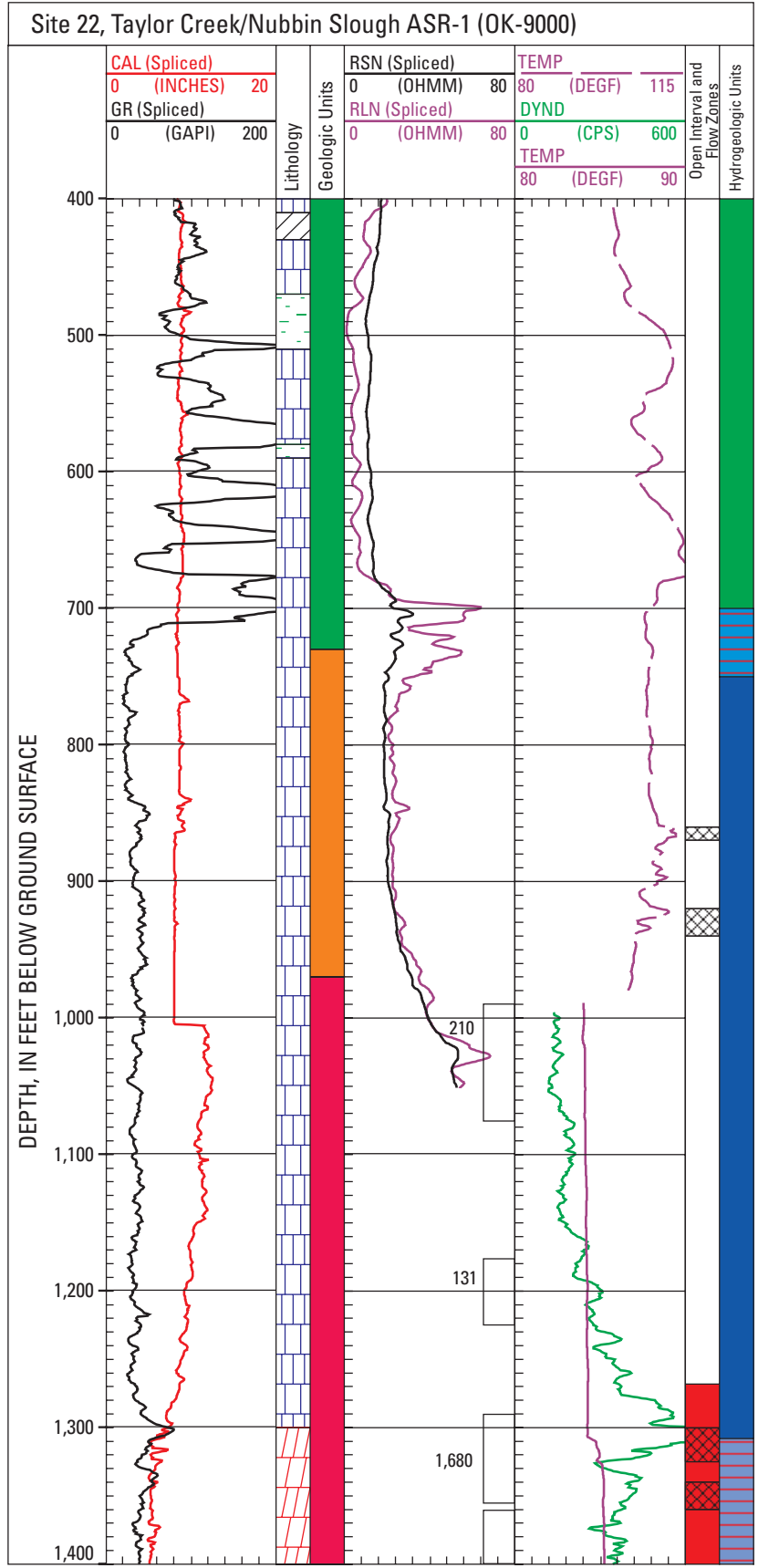


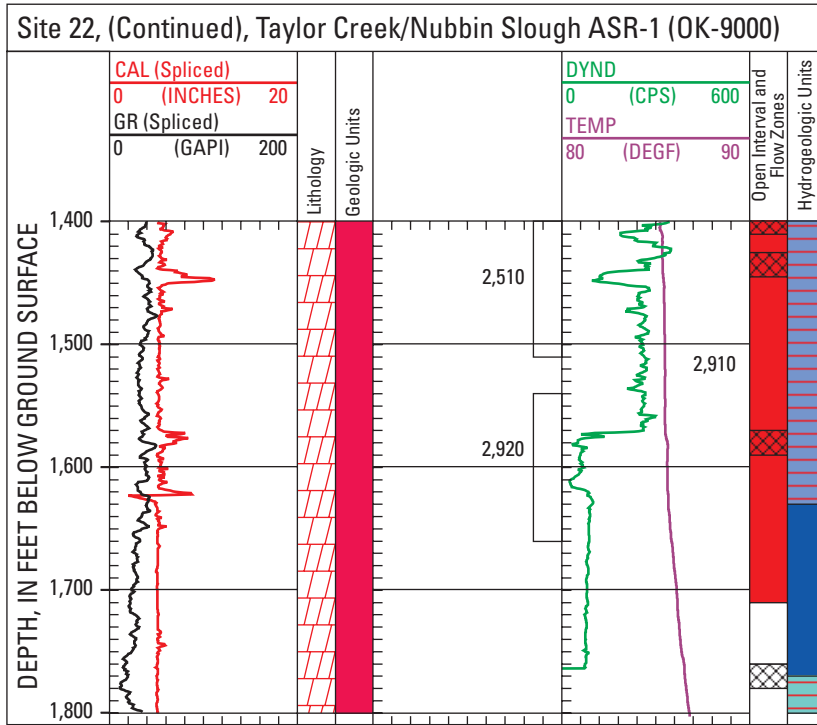


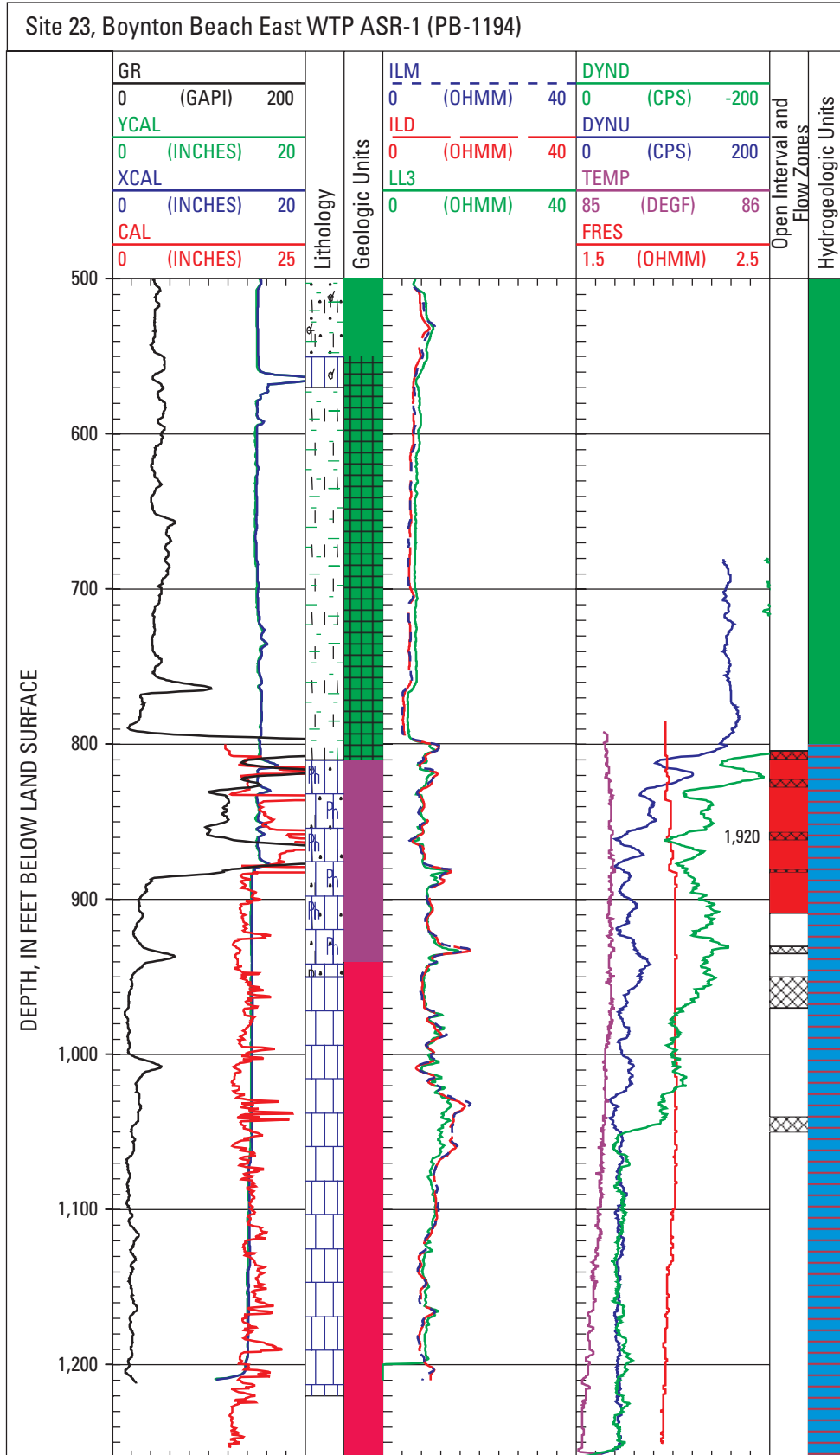




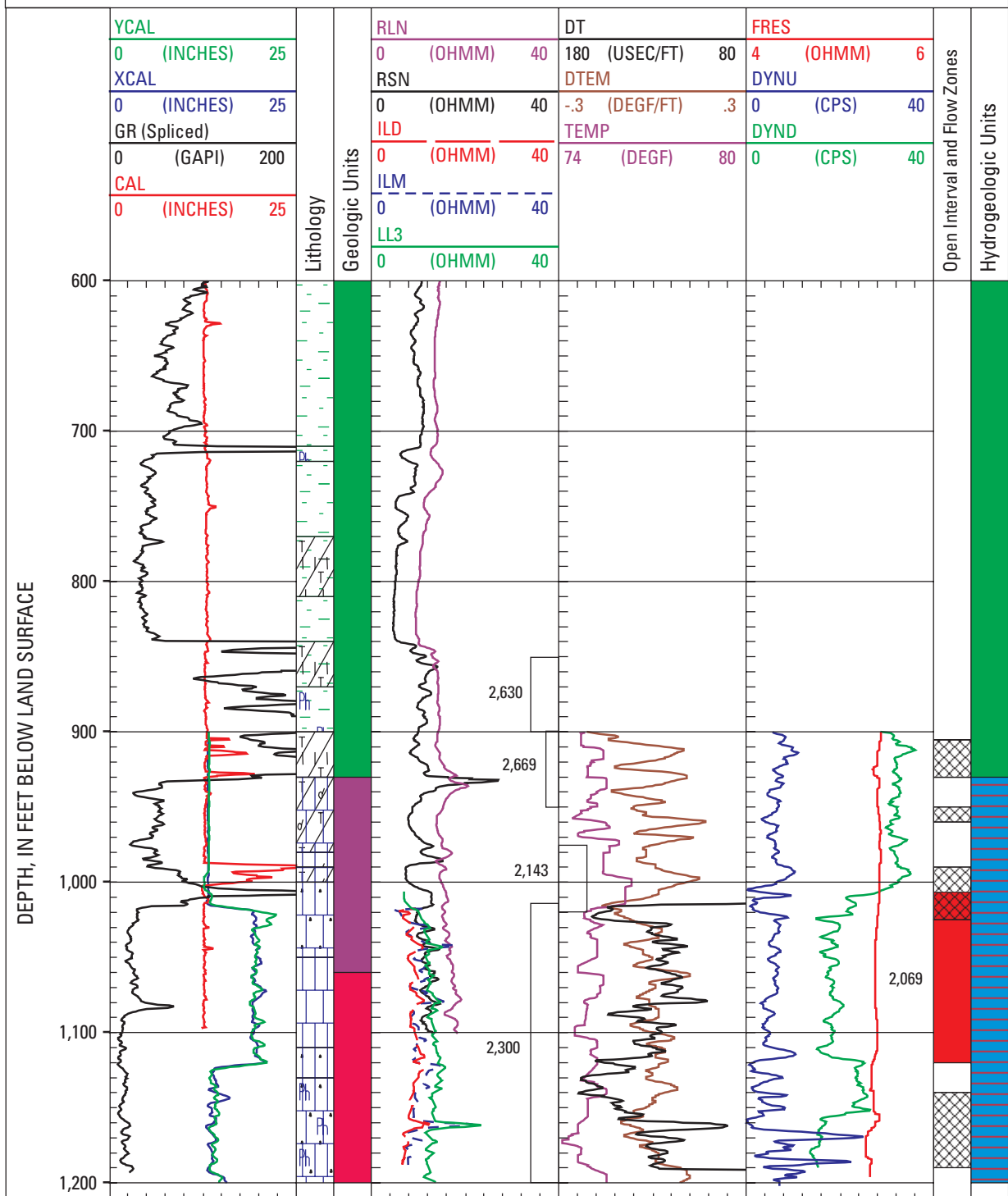


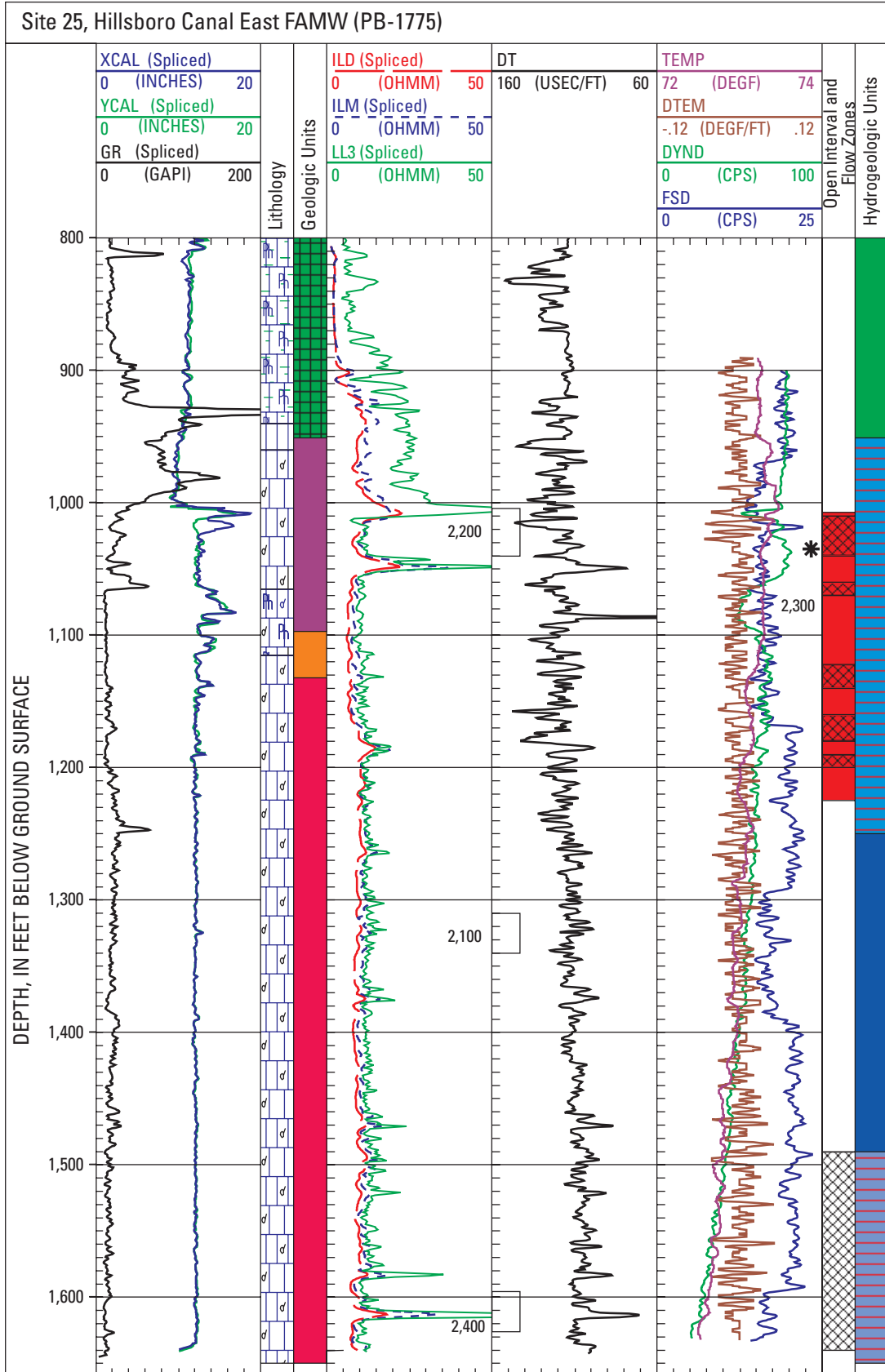






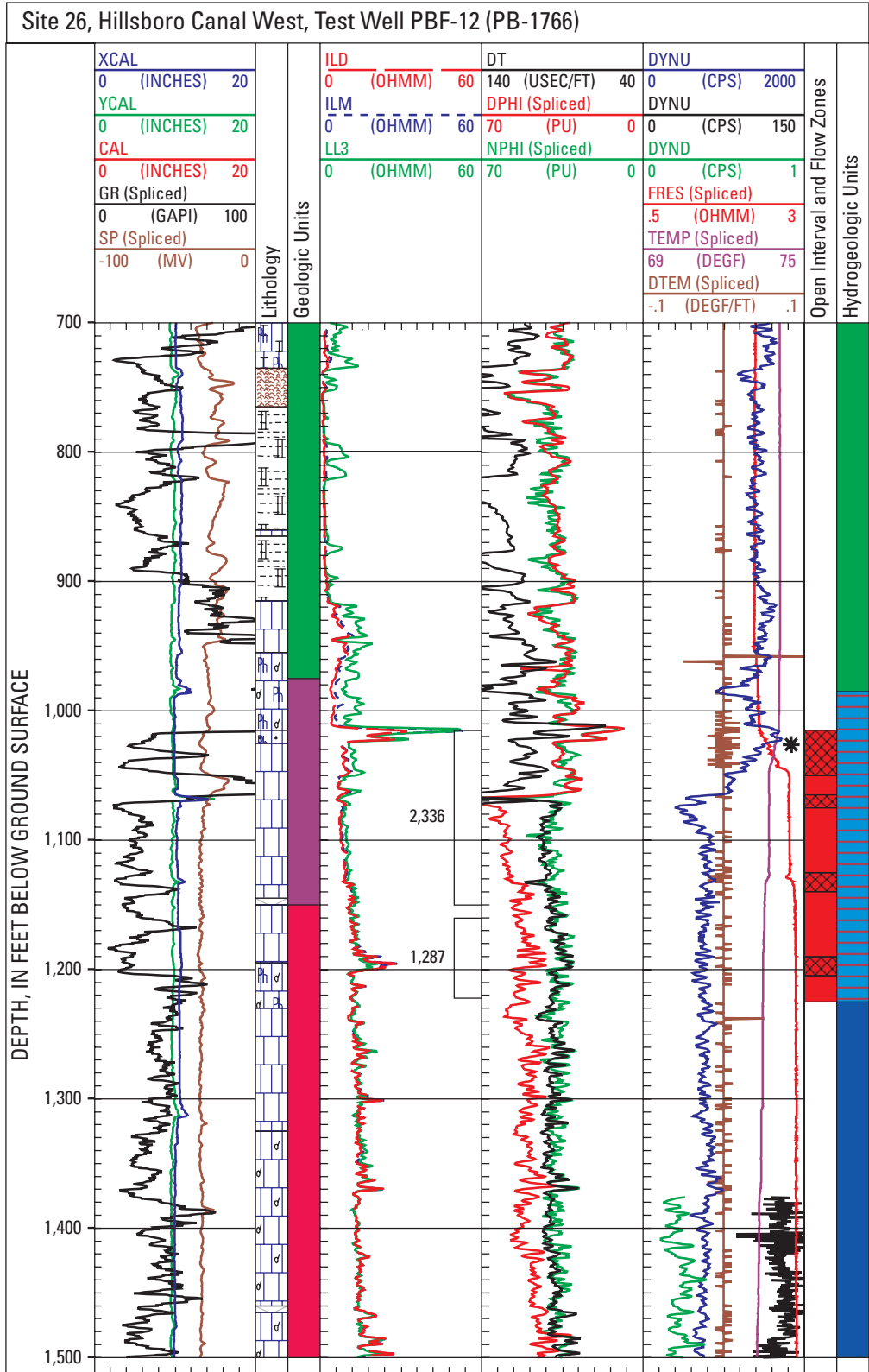
Site 24, Delray Beach North Storage Reservoir ASR-1 (PB-1702)

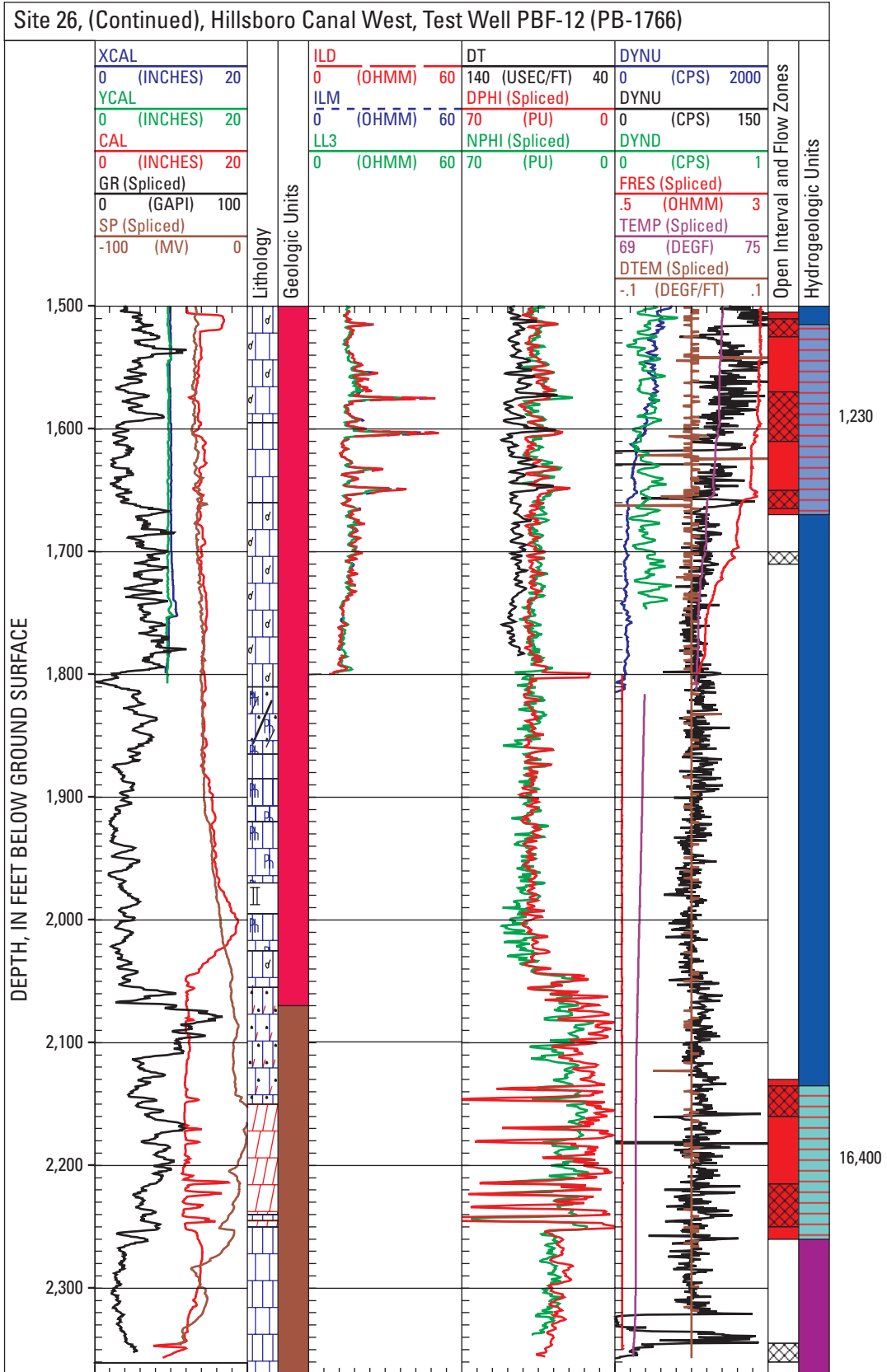


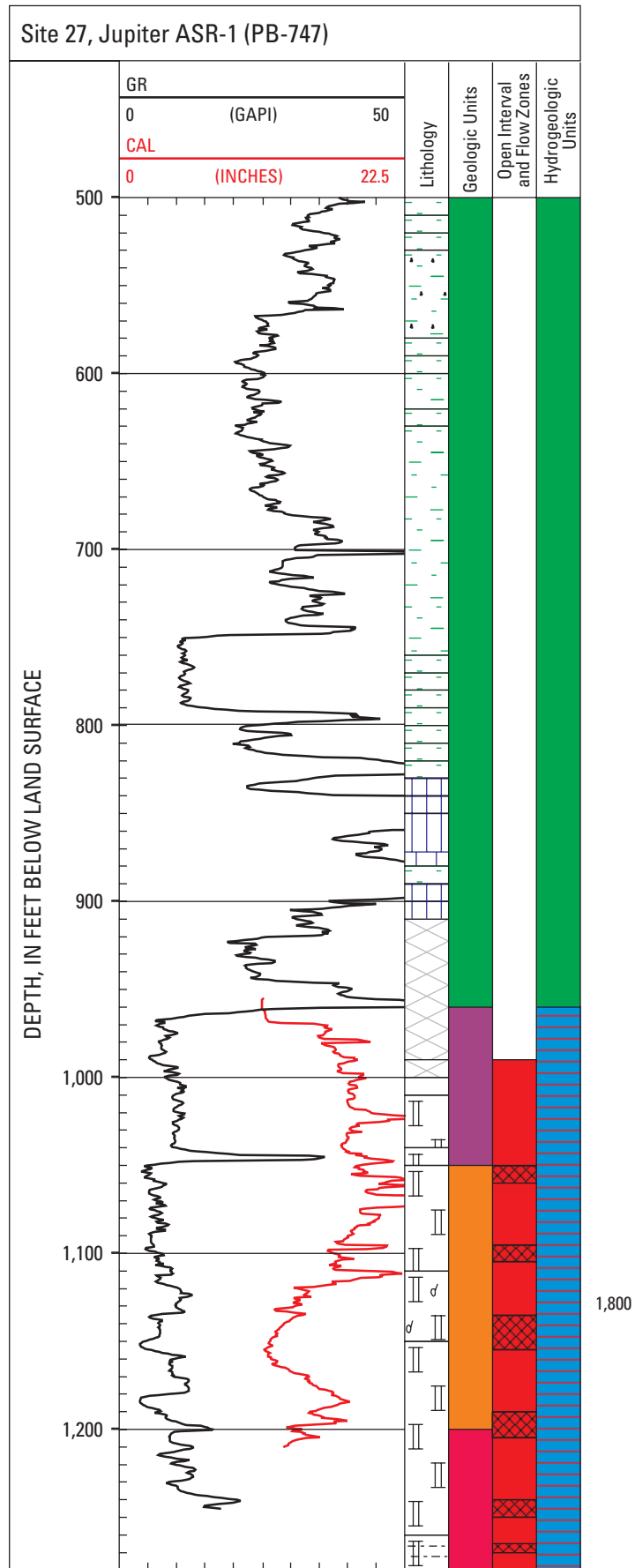


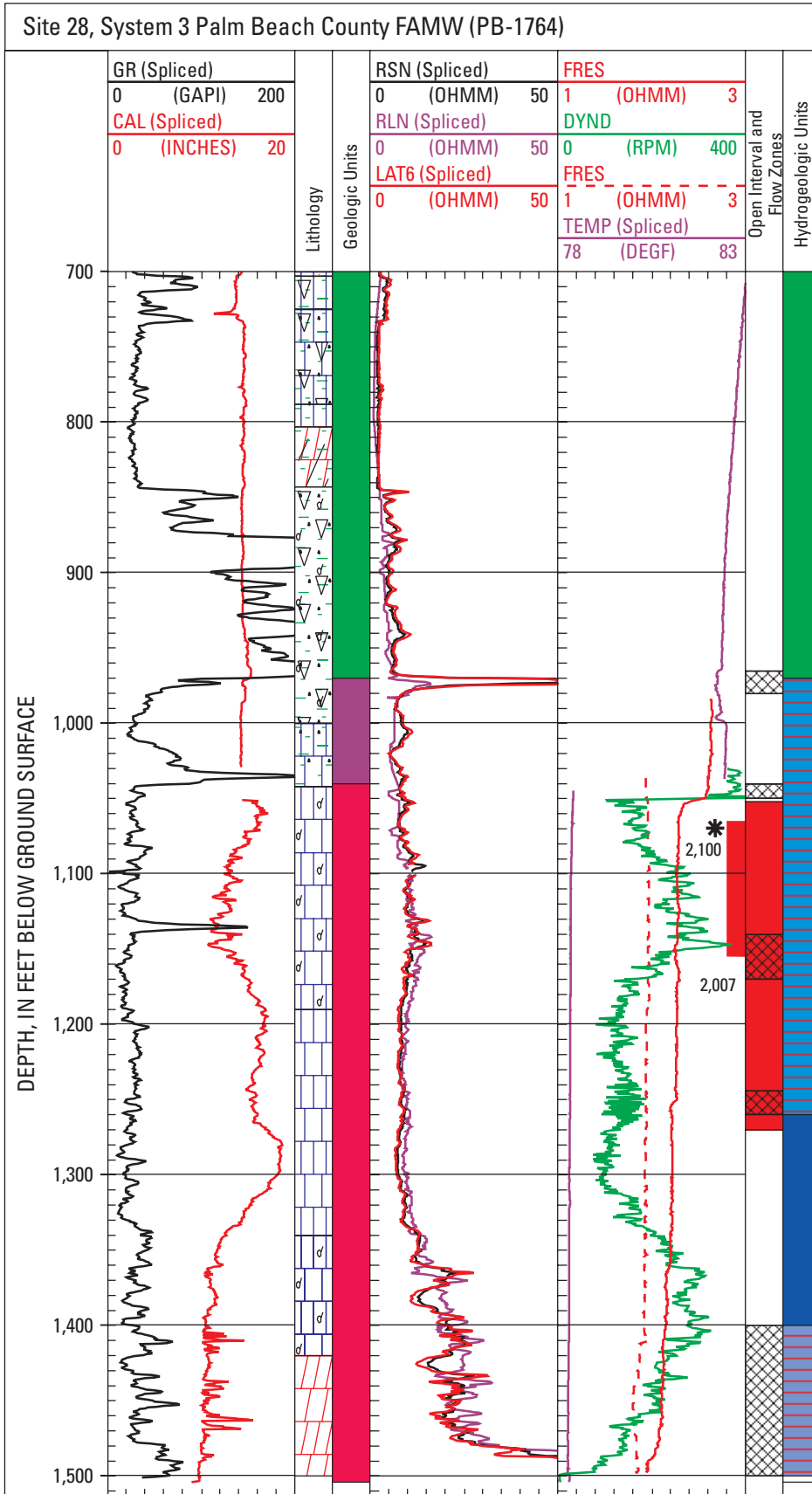
\* Well ASR-1 at this site has an open interval of from 1,010 to 1,225 feet

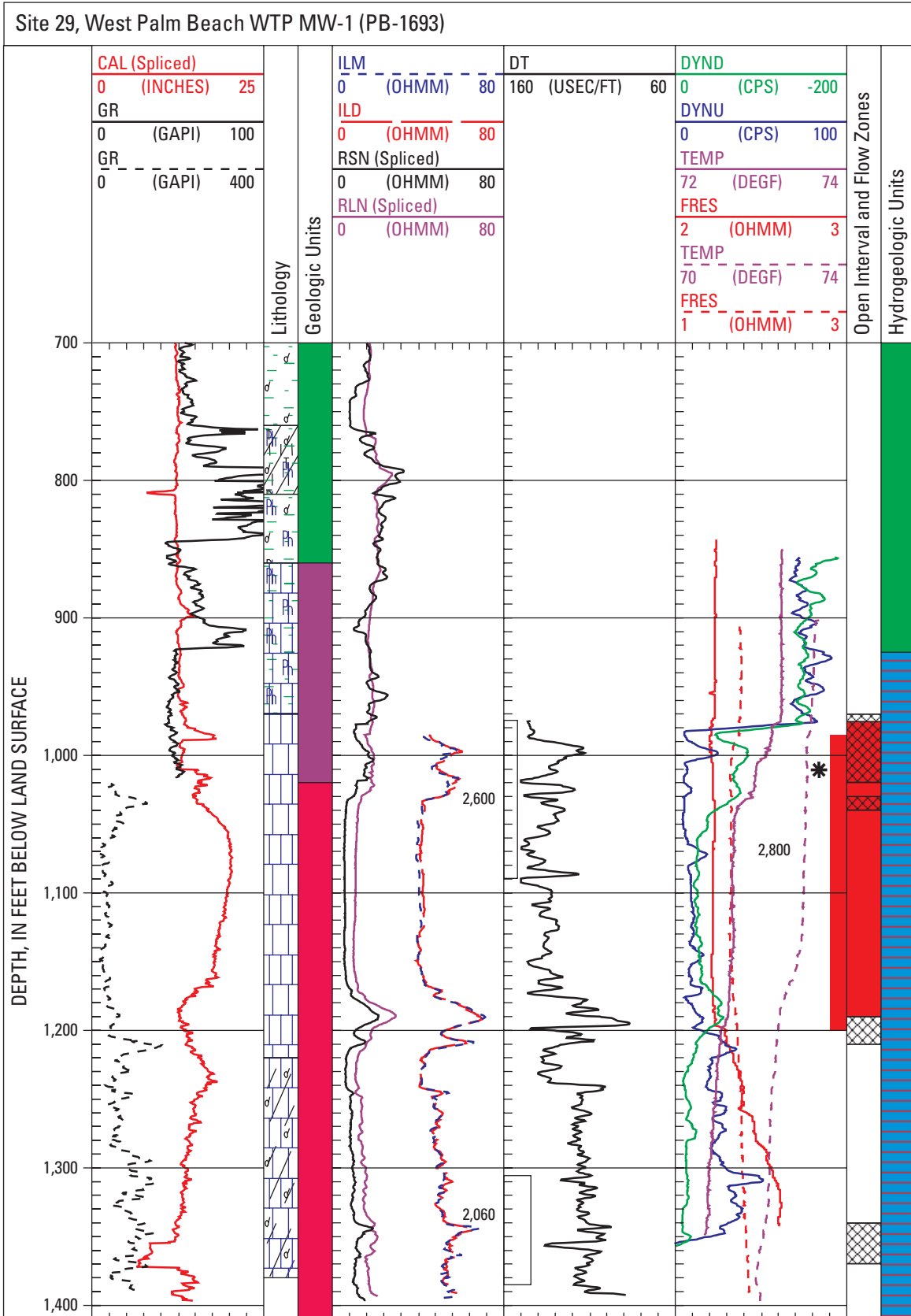






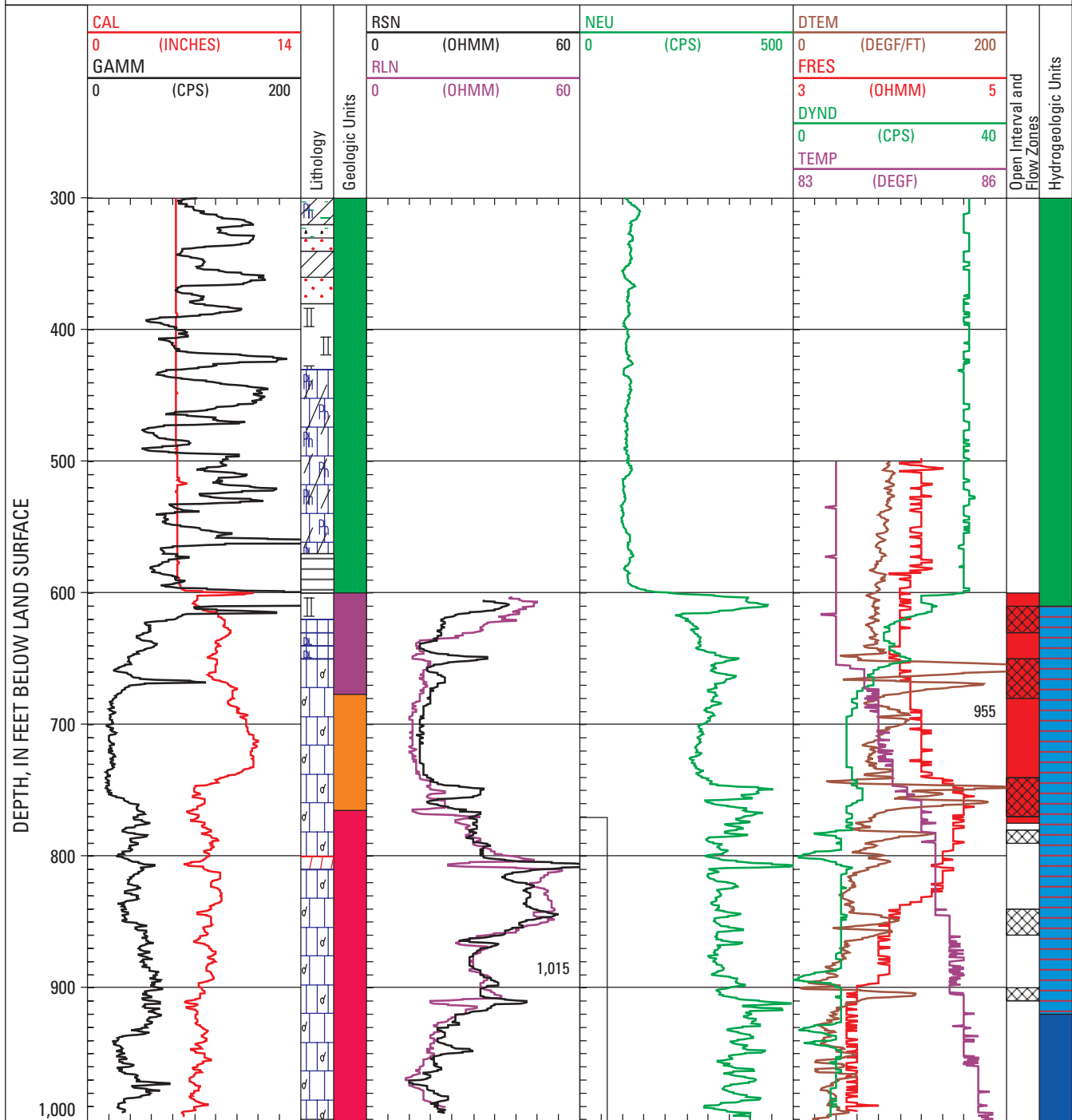






\* Open interval in well ASR-1 at same site

Site 30, St. Lucie County ASR-1, SLF-50 (STL-356)



**Table A2.** Geologic unit boundaries and sources of determination.

[Depths are in feet below land surface. If more than one top for a formation is given, the top determined for this study was used for the appendix 1 plots. USGS, U.S. Geological Survey; NP, not present; PBCWUD, Palm Beach County Water Utilities Department; --, not determined or not penetrated]

Site number	USGS local well identifier	Site name abbreviation and other well identifier	Depth to top of Hawthorn Group	Depth to top of Arcadia Formaton	Depth to top of Suwannee Limestone	Depth to top of Ocala Limestone	Depth to top of Avon Park Formation	Depth to top of Oldsmar Formation	Reference
1	G-2916	BC MW-1	380	--	850	1,000	1,120	--	CH2M HILL (1997)
			--	--	950	NP	--	--	This study
2	G-2887	DFB ASR-1	520		NP	NP	990	--	Florida Geological Survey (2004)
3	G-2917	FA ASR-1	270	555	970	1,030	--	--	Montgomery Watson (1998c)
			--	--	--	NP	1,030	--	This study
4	G-2914	ST ASR-1	190	510	1,035	1,115	--	--	Montgomery Watson (1998a)
			--	--	--	NP	1,115	--	This study
5	CH-318	EW ASR-1	38	--	430	744	--	--	This study
6	CH-316	SC ASR-2	118	--	690	960	--	--	Montgomery Watson Harza (2002b)
7	C-1208	ML ASR-2	125	250	730	--	--	--	Water Resources Solutions, Inc. (2000c)
8	C-1242	PBW EW-1	125	250	735	--	--	--	Water Resources Solutions, Inc. (2002d)
9	GL-331	MH GLF-6	155	530	840	950	1,230	--	Florida Geological Survey (2004)
10	HE-1141	CR EXBRY-1	210	--	640	1,000	1,330	--	This study
12	L-5810	NR ASR-1	70	175	710	1,140	--	--	Water Resources Solutions, Inc. (1999b)
	L-5811	NR MW-1	70	175	710	1,140	--	--	Water Resources Solutions, Inc. (1999b)
13	L-5817	OL MW-1	7	237	710	945	--	--	Water Resources Solutions, Inc. (2000a)
14	L-5812	SCE TPW-1	140	240	750	--	--	--	CH2M HILL (1999b)
15	L-5871	WA ASR-1	22	136	590	--	--	--	CH2M HILL (2000c)
16	M-1360	PM MF-37	146	435	703	780	972	--	Florida Geological Survey (2004)
17	G-3061	HI ASR-1	--	--	957	NP	1,038	--	Florida Geological Survey (2004)
18	G-3774	JRD EW-1	130	--	870	NP	1,190	--	CH2M HILL (2003)
			--	--	1,140	NP	--	--	This study
19	G-3768	SWF ASR-1	155	460	1,030	NP	1,130	--	CH2M HILL (2001b)
20	G-3706	WWF ASR-1	160	490	940	NP	1,150	--	CH2M HILL (1998b)
			--	--	1,110	NP	1,200	--	This study
21	OK-100	KR OKF-100	145	325	562	594	765	2,003	Florida Geological Survey (2004)
22	OK-9000	LO ASR-1	200		NP	730	970	--	Florida Geological Survey (2004)
23	PB-1194	BB ASR-1	370	550	810	NP	890	--	CH2M HILL (1993)
			--	--	--	NP	940	--	This study
24	PB-1702	DRB ASR-1	390	--	930	NP	1,060	--	CH2M HILL (1998c)
25	PB-1775	HCE FAMW	262	493	951	1,097	1,132	--	PBCWUD (2003a)
26	PB-1766	HCW PBF-10	205	--	975	NP	1,150	2,070	Florida Geological Survey (2004)
27	PB-747	JU ASR-1	250	--	960	1,050	1,200	--	Reese (2004)
28	PB-1764	SY3 FAMW	330	--	1,030	1,110	1,340	--	PBCWUD (2003b)
			--	--	970	NP	1,040	--	This study
29	PB-1693	WPB MW-1	120	--	970	NP	1,060	--	CH2M HILL (1998a)
			--	--	860	NP	1,020	--	This study
30	STL-356	SL ASR-1	130	--	600	677	765	--	Reese (2004)

**Table A3.** Hydrogeologic unit boundaries and sources of determination.

[Depths are in feet below land surface. If more than one boundary for an aquifer is given, the boundary determined for the present study was used for the appendix 1 plots. USGS, U.S. Geological Survey; WRS, Water Resources Solutions, Inc.; PBCWUD, Palm Beach County Water Utilities Department; SFWMD, South Florida Water Management District; --, not present, not determined, or not penetrated]

Site number	USGS local well identifier	Site name abbreviation and other well identifier	Depth to top of lower Tamiami aquifer		Depth to base of surficial aquifer system	Mid-Hawthorn aquifer		Upper Floridan aquifer		Middle Floridan aquifer		Lower Floridan aquifer		Reference
			Depth to top	Depth to base		Depth to top	Depth to base	Depth to top	Depth to base	Depth to top	Depth to base	Depth to top	Depth to base	
1	G-2916	BC MW-1	--	--	380	--	--	850	--	--	--	--	--	CH2M HILL (1997)
2	G-2887	DFB ASR-1	--	--	175	--	--	--	--	--	--	--	--	CH2M HILL (1996) This study
3	G-2917	FA ASR-1	--	--	270	--	--	970	--	--	--	--	--	Montgomery Watson (1998c)
4	G-2914	ST ASR-1	--	--	190	--	--	1,035	--	--	--	--	--	Montgomery Watson (1998a)
5	CH-318	EW ASR-1	--	--	45	150	180	510	--	--	--	--	--	PBS&J and CH2M HILL (2000)
6	CH-316	SC ASR-2	--	--	118	364	372	690	1,026	--	--	--	--	Montgomery Watson Harza (2002b)
7	C-1208	ML ASR-2	25	194	160	290	540	740	--	--	--	--	--	WRS (2000c)
8	C-1242	PBW EW-1	55	160	160	250	490	610	--	--	--	--	--	WRS (2002d)
9	GL-331	MH GLF-6	--	160	160	--	--	840	1,110	1,600	1,780	1,910	2,030	Mike Bennett (SFWMD, written commun., 2002; 2003)
10	HE-1141	CR EXBRY-1	--	210	210	--	--	640	1,000	--	--	--	--	This study
12	L-5810	NR ASR-1	--	41	41	225	378	536	--	--	--	--	--	WRS (1999b)
	L-5811	NR MW-1	--	40	40	230	385	529	904	--	--	--	--	WRS (1999a)
13	L-5817	OL MW-1	--	7	7	237	395	515	--	--	--	--	--	WRS (2000a)
			--	--	--	--	--	--	1,000	--	--	--	--	This study
14	L-5812	SCE TPW-1	--	30	30	240	350	650	--	--	--	--	--	CH2M HILL (1999b)
15	L-5871	WA ASR-1	80	102	102	136	248	450	--	--	--	--	--	CH2M HILL (2000c)
16	M-1360	PM MF-37	--	170	170	--	--	765	1,040	1,500	1,700	1,780	2,050	This study
17	G-3061	HI ASR-1	--	178	178	--	--	975	--	--	--	--	--	Merritt (1997)
18	G-3774	JRD EW-1	--	130	130	--	--	870	--	--	--	--	--	CH2M HILL (2003)
			--	--	--	--	--	1,150	1,400	--	--	--	--	This study
19	G-3768	SWF ASR-1	--	155	155	--	--	1,040	--	--	--	--	--	This study
20	G-3706	WWF ASR-1	--	160	160	--	--	940	--	--	--	--	--	CH2M HILL (1998b)
			--	--	--	--	--	1,160	--	--	--	--	--	This study
21	OK-100	KR OKF-100	--	145	145	--	--	562	800	1,000	1,450	1,590	1,700	This study
22	OK-9000	LO ASR-1	150	--	--	--	--	700	750	1,308	1,630	1,770	--	This study
			--	280	280	--	--	--	--	--	--	--	--	CH2M HILL (1989)
23	PB-1194	BB ASR-1	--	350	350	--	--	810	--	--	--	--	--	CH2M HILL (1993)
24	PB-1702	DRB ASR-1	--	390	390	--	--	930	--	--	--	--	--	CH2M HILL (1998c)



**Table A3.** Hydrogeologic unit boundaries and sources of determination.—Continued

Site number	USGS local well identifier	Site name abbreviation and other well identifier	Depth to top of lower Tamiami aquifer	Depth to base of surficial aquifer system	Mid-Hawthorn aquifer		Upper Floridan aquifer		Middle Floridan aquifer		Lower Floridan aquifer		Reference
					Depth to top	Depth to base	Depth to top	Depth to base	Depth to top	Depth to base	Depth to top	Depth to base	
25	PB-1775	HCE FAMW	--	210	--	--	951	--	--	--	--	--	PBCWUD (2003a) This study
26	PB-1766	HCW PBF-12	--	205	--	--	985	1,225	1,515	1,670	2,135	2,260	Bennett and others (2001)
27	PB-747	JU ASR-1	--	250	--	--	960	--	--	--	--	--	This study
28	PB-1764	SY3 FAMW	--	330	--	--	1,030	1,500	--	--	--	--	PBCWUD (2003b) This study
29	PB-1693	WPB MW-1	--	120	--	--	925	--	--	--	--	--	This study CH2M HILL (1998a)
30	STL-356	SL ASR-1	--	130	--	--	610	920	--	--	--	--	This study

**Table A4.** Flow zone sources of determination.

[Flow zone depths are shown in the appendix 1 plots. WTP, water treatment plant; WWTP, wastewater treatment plant; WRS, Water Resources Solutions, Inc.]

Site number	USGS local well identifier	Site name and other well identifier	Reference
1	G-2916	Broward County WTP 2A—MW-1	This study
2	G-2887	Deerfield Beach West WTP—ASR-1	This study
3	G-2917	Fiveash WTP—ASR-1	This study
4	G-2914	Springtree WTP—ASR-1	This study
5	CH-318	Englewood South Regional WWTP—ASR-1	PBS&J and CH2M HILL (2000)
6	CH-316	Shell Creek WTP—ASR-2	This study
7	C-1208	Marco Lakes—ASR-2	This study
8	C-1242	Pelican Bay Well Field—EW-1	This study
9	GL-331	Moore Haven S-77—GLF-6	This study
10	HE-1141	Caloosahatchee River/Berry Grove—EX-BRY-1	This study
12	L-5810 L-5811	North Reservoir—ASR-1 North Reservoir—MW-1	This study This study
13	L-5817	Olga WTP—MW-1	WRS (2000a) for top two zones. This study for bottom 3 zones
14	L-5812	San Carlos Estates—TPW-1	This study
15	L-5871	Winkler Avenue—ASR-1	This study
16	M-1360	Port Mayaca S-153—MF-37	This study
17	G-3061	Hialeah—ASR-1	Merritt (1997)
18	G-3774	J.R. Dean WTP—EW-1	This study
19	G-3768	Southwest Well Field—ASR-1	This study
20	G-3706	West Well Field—ASR-1	This study
21	OK-100	Kissimmee River—OKF-100	This study
22	OK-9000	Taylor Creek/Nubbin Slough (Lake Okeechobee)—ASR-1	This study
23	PB-1194	Boynton Beach East WTP—ASR-1	This study
24	PB-1702	Delray Beach North Storage Reservoir—ASR-1	This study
25	PB-1775	Hillsboro Canal East—FAMW	This study
26	PB-1766	Hillsboro Canal West, site 1—PBF-10	This study
27	PB-747	Jupiter—ASR-1	This study
28	PB-1764	System 3 Palm Beach County—FAMW	This study
29	PB-1693	West Palm Beach WTP—MW-1	This study
30	STL-356	St. Lucie County—ASR-1	This study

## Appendix 2. Sources of Literature for the Aquifer Storage and Recovery Sites in Southern Florida

[Site numbers refer only to this report. FDEP, Florida Department of Environmental Protection; WTP, water treatment plant; WWTP, wastewater treatment plant]

Site number (fig. 1)	Site name and abbreviation	References
1	Broward County WTP 2A (BC)	CH2M HILL (1997; 1999a); Hazen and Sawyer, P.C. (2002)
2	Deerfield Beach West WTP (DFB)	Camp, Dresser, and McKee, Inc. (1993)
3	Fiveash WTP (FA)	Hazen and Sawyer, P.C. (2003; 2004); Montgomery Watson (1998c)
4	Springtree WTP (ST)	Montgomery Watson (1998a; 2000b); Montgomery Watson Harza (2002a)
5	Englewood South Regional WWTP (EW)	PBS&J and CH2M HILL (2000); CH2M HILL (2004a)
6	Shell Creek WTP (SC)	Montgomery Watson (1998b; 2000a); Montgomery Watson Harza (2002b); Water Resources Solutions, Inc. (2002e; 2003d)
7	Marco Lakes (ML)	Viro Group Inc. (1998); Water Resources Solutions, Inc. (1999c; 2000c,d; 2002a; 2003c; 2004a,b)
8	Pelican Bay Well Field (PBW)	Water Resources Solutions, Inc. (2002d)
9	Moore Haven S-77 (MH)	Weekly drilling and construction reports submitted to FDEP
10	Caloosahatchee River/Berry Grove (CR)	Weekly drilling and construction reports submitted to FDEP
11	Lee County WTP (LC)	Fitzpatrick (1986)
12	North Reservoir (NR)	Water Resources Solutions, Inc. (1999a,b; 2002b, 2003a)
13	Olga WTP (OL)	Water Resources Solutions, Inc. (2000a,b; 2002c; 2003b)
14	San Carlos Estates (SCE)	CH2M HILL (1999b; 2000a,b; 2001b)
15	Winkler Avenue (WA)	CH2M HILL (2000c; 2002b)
16	Port Mayaca S-153 (PM)	Bennett and others (2004)
17	Hialeah (HI)	Merritt (1997)
18	J.R. Dean WTP (JRD)	CH2M HILL (2003)
19	Southwest Well Field (SWF)	CH2M HILL (2001a); Miami-Dade Water and Sewer Dept. (2003)
20	West Well Field (WWF)	CH2M HILL (1998b)
21	Kissimmee River (KR)	CH2M HILL (2004b)
22	Taylor Creek/Nubbin Slough—Lake Okeechobee (LO)	CH2M HILL (1989); Quiñones-Aponte and others (1996)
23	Boynton Beach East WTP (BB)	CH2M HILL (1993)
24	Delray Beach North Storage Reservoir (DRB)	CH2M HILL (1998c; 2002a)
25	Hillsboro Canal, East (HCE)	Palm Beach County Water Utilities Department (2003a)
26	Hillsboro Canal, West, Site 1 (HCW)	Bennett and others (2001).
27	Jupiter (JU)	J.J. Plappert, Florida Department of Environmental Protection (written commun., 1977)
28	System 3 Palm Beach County (SY3)	Palm Beach County Water Utilities Department (2003b)
29	West Palm Beach WTP (WPB)	CH2M HILL (1998a)
30	St. Lucie County (SL)	Wedderburn and Knapp (1983)