Safety Performance Review - Shallow Water Flows Can Pose Significant Hazards to Deepwater Drilling

This technical discussion is intended to share information on an important safety issue. Data included in this article are current as of July 14, 2011.

Since 1984, companies operating in the Gulf of Mexico (GOM) have reported shallow water flow (SWF) events to the BOEM, a phenomenon occurring in water depths generally exceeding 600 feet. SWF events are encountered at depths between a few hundred feet to more than 4,000 feet below the mudline (BML). To date, SWF events have been reported in 157 wells (Appendix A). The average water depth and the average depth BML in which SWF events have been encountered is displayed in Figure 1.

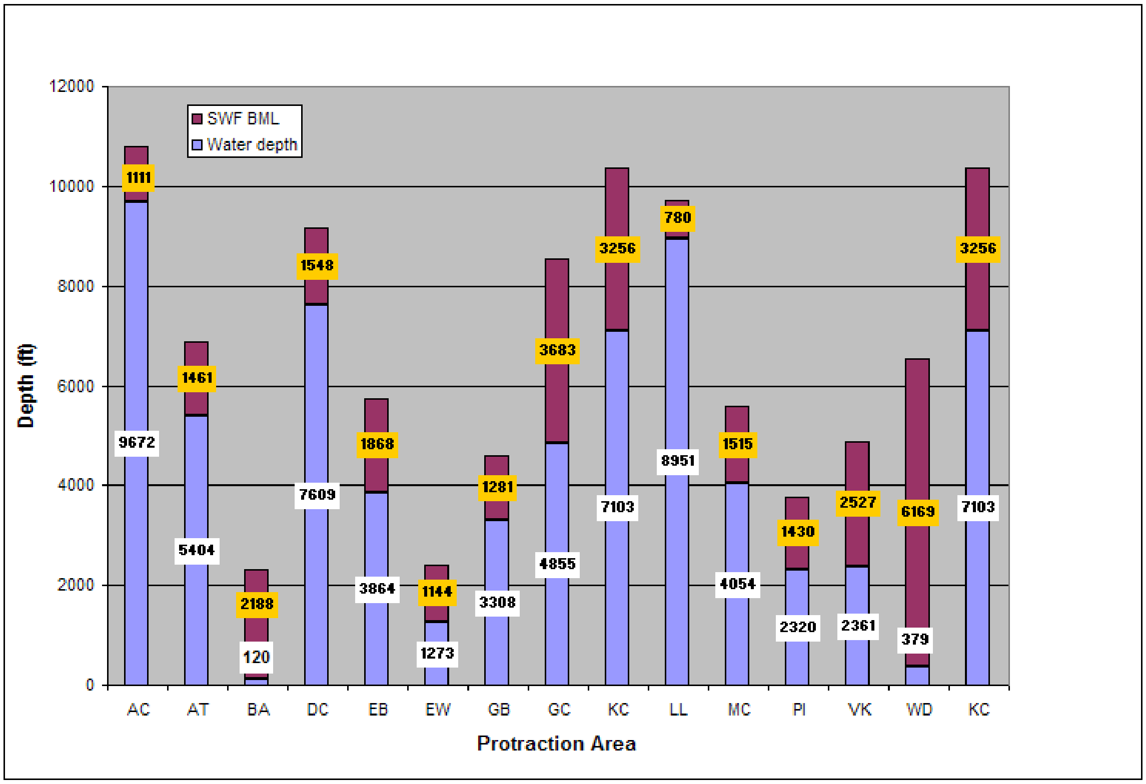

Figure1. Average water depth and average depth BML of SWF Events

Shallow water flow events occur in abnormally pressured shallow sands as a result of rapid sediment deposition, rapid slumping, rotating fault blocks, or reworked cut-and-fill channels sealed by impermeable mud or clay. Regional interpretations of depositional settings, facies, and sediment accumulation rates, allow shallow hazard reviewers to identify areas that are susceptible to SWF events (Figures 2 & 3).

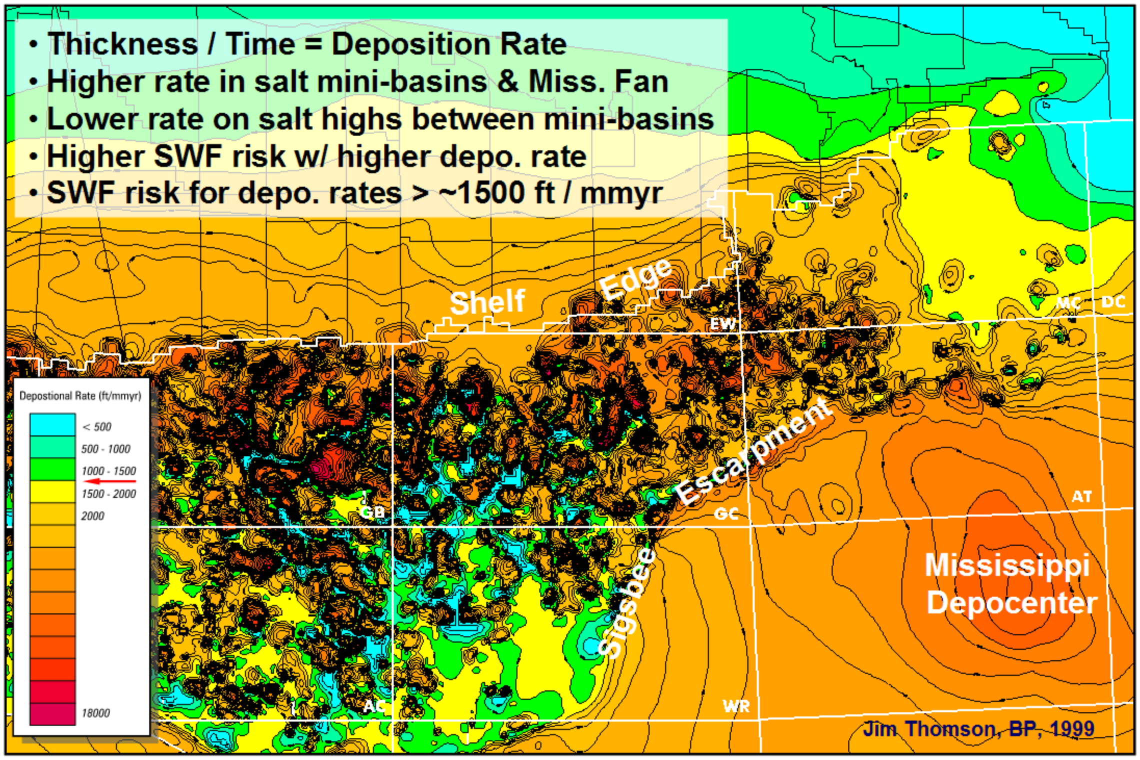

Figure 2. Average deposition rate map: Seafloor to Ps60 Reflector (0 to 1.3 Ma).

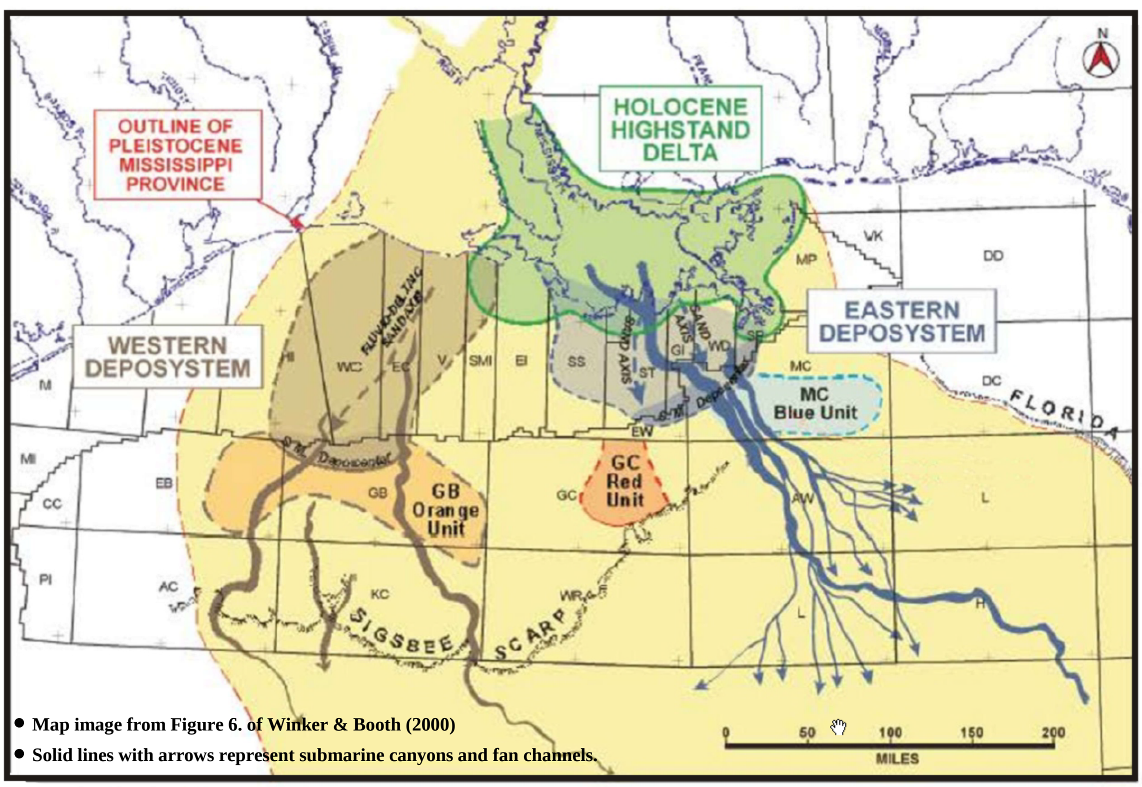

Figure 3. Map of late Pleistocene Mississippi River deposystems and SWF prone lowstand sands.

In rare cases, the disassociation of hydrates during oil production could be a source of SWF. Incidents of SWF are by far the greatest in the GC and MC protractions (Figure 4).

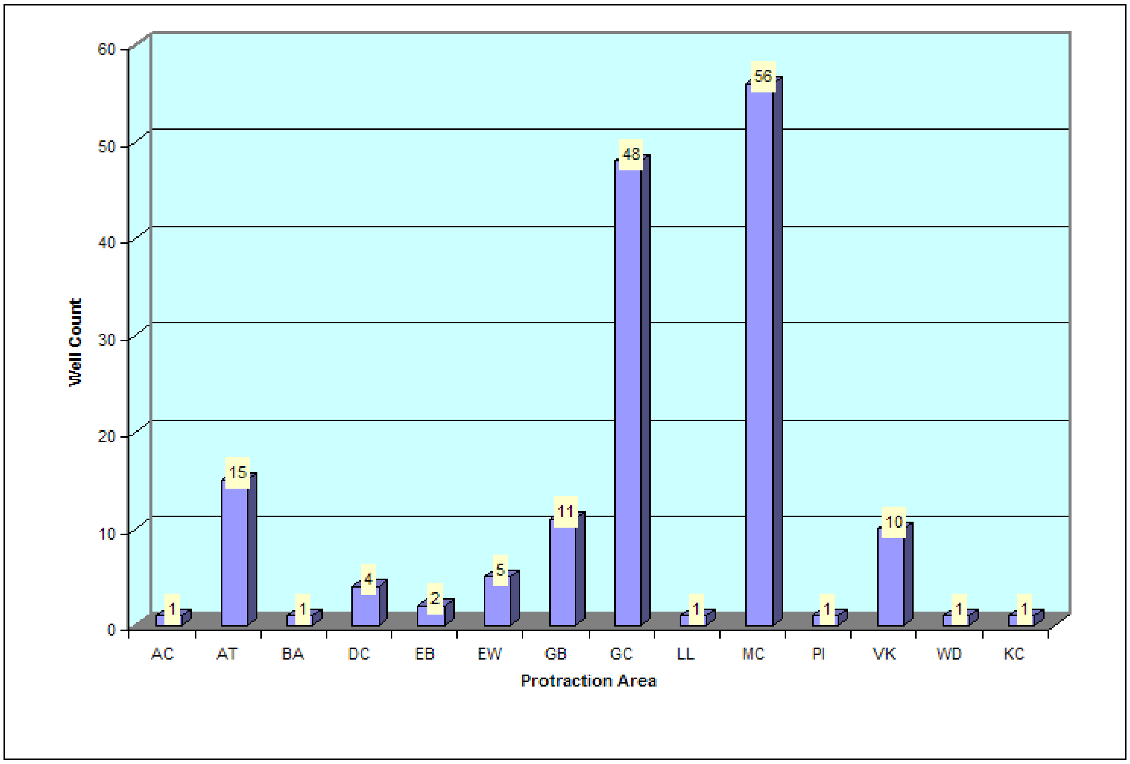

Figure 4. Shallow water flow count by area.

Shallow water flow events can threaten human safety and the environment while causing significant economic loss. Federal regulation 30 CFR 250.415 (Appendix B) requires operators to provide a statement of how they evaluated the best practices contained in API RP 65 (Appendix C) for cementing SWF zones in deep water where SWF potential is unknown or known. An example of Shell's site specific procedure for controlling SWFs is provided in Appendix D. SWF events can cost the operator additional time and money while the driller attempts to maintain control of the well and resume drilling. In some cases, the operator may have to permanently plug and abandon the well. Water flowing around the well annulus will deposit sand or silt on the seafloor within a few hundred feet of the wellhead. Although atypical, when gas is associated with a SWF, gas hydrates will form on the flat surfaces of seafloor drilling equipment. Losing time and millions of dollars encouraged the major operators to study this phenomenon. Video tapes from remotely operated vehicles (ROV) document the flow at the seafloor (Video 1). Electric logs, temperature logs, pressure logs, and geotechnical data from test wells, combined with high-resolution 3D seismic surveys, 2D high-resolution seismic surveys, or reprocessed conventional 3D surveys, are essential to properly identifying the source of the problem and refining a geologic model to determine the mechanism of SWF.

The Deep Star Consortium and Energy Research Clearing House (ERCH) previously compiled detailed information about SWFs and made some of the data available on CD. Since 2004, operators have utilized the Bureau of Safety and Environmental Enforcement's (BSEE) e-Well Permitting and Reporting System to report any significant well problems including SWF. Additionally, BOEM has contacted major oil companies in an effort to update the SWF database. The SWF map of the Gulf of Mexico (Appendix E) displays SWF blocks and wells with severity annotated by color code and depth below the mud line in feet. This classification was suggested by British Petroleum's geohazards group and adopted by the BOEM geohazard group (Figure 6).

Video 1: ROV Video, courtesy of LLOG, documenting SWF at the seafloor.

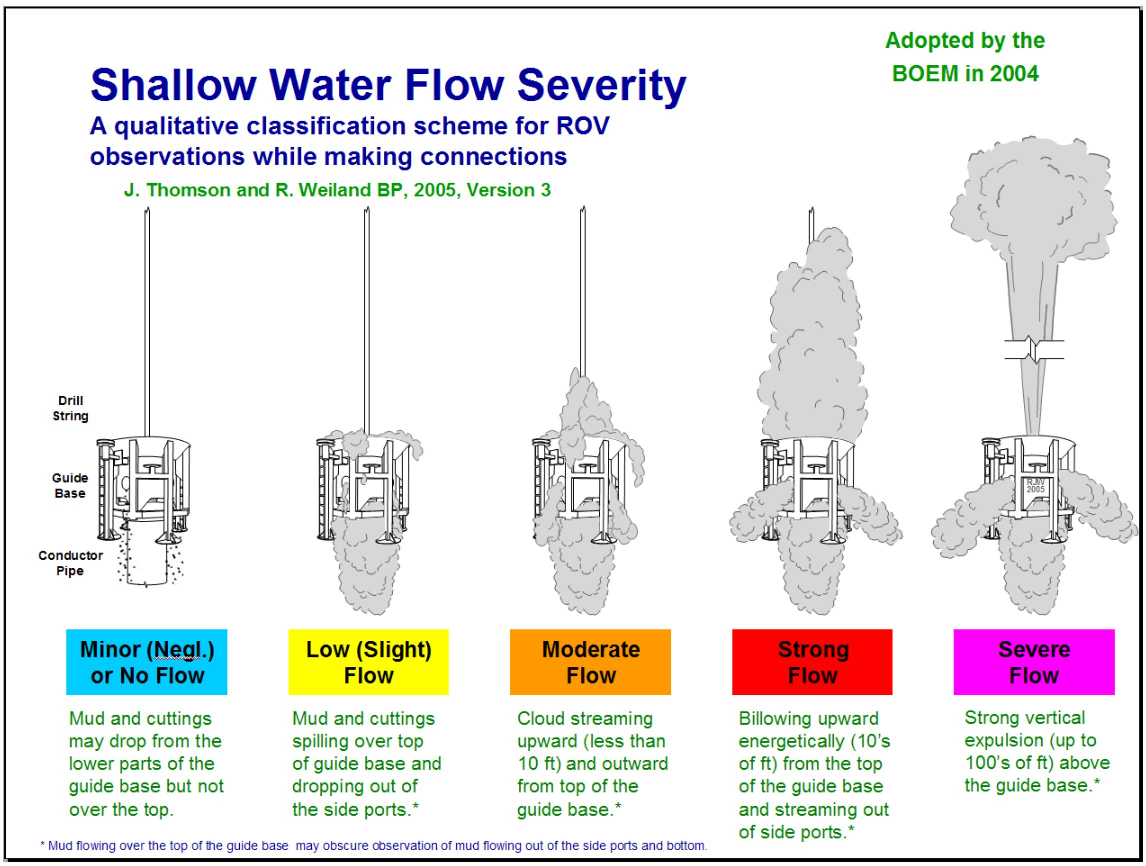

Figure 6. SWF Severity classification.

The classification is based on the height of the uncontrolled SWF flow above the wellhead monitored by ROV. Severity varies from minor to severe. The relationship between SWF count, average severity, and number of wells lost to SWF for each GOM area is displayed in Figure 7.

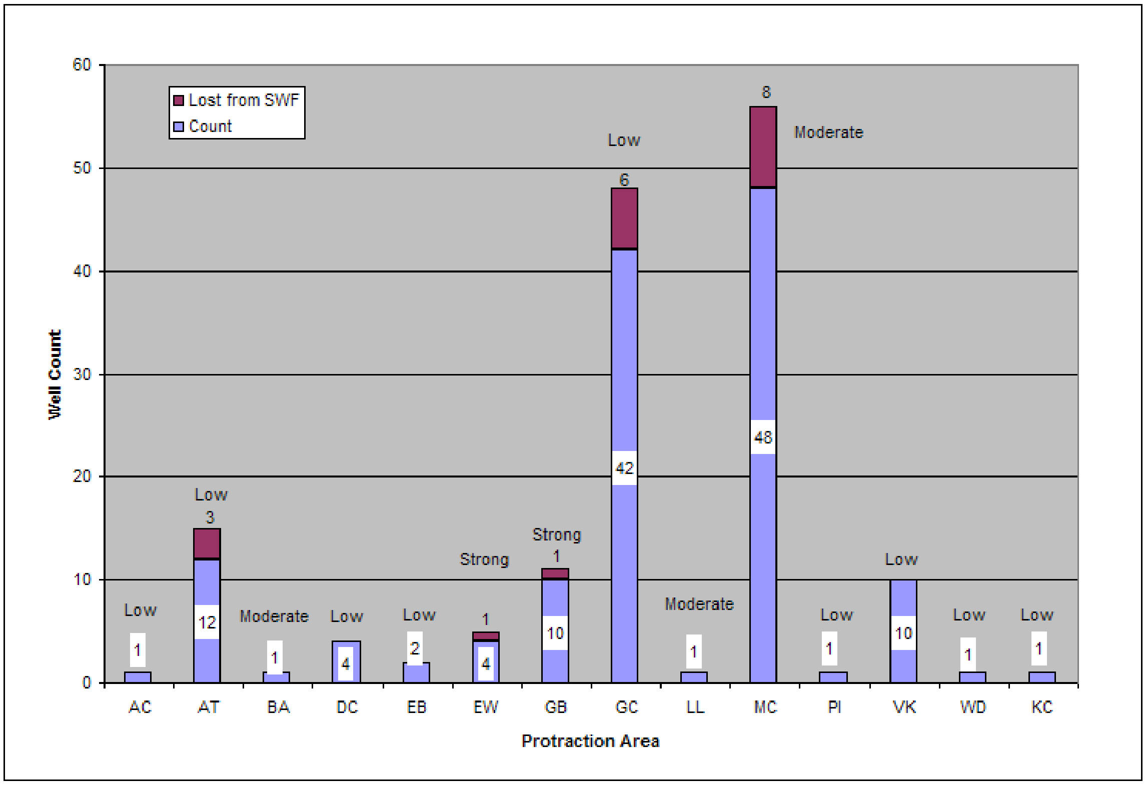

Figure 7. SWF count, average severity, and number of wells lost to SWF.

When the severity of the SWF was not reported, it was classified as Low. These maps and files will be updated annually to assist operators in identifying potentially hazardous areas, so that they may take the appropriate drilling precautions.

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References

Winker, C.D., and Booth, J.R., 2000. Sedimentary dynamics of the salt-dominated continental slope, Gulf of Mexico: integration of observations from the seafloor, near-surface, and deep subsurface. *Deep-Water Reservoirs of the World: Proc. GCSSEPM 20th Annual. Res. Conf.,* 1059–1086.

Appendix A.

API #	SPUD DATE	WELL	S. LEASE	S. AREA	BLK #	SEVERITY	SWFT SS (ft)	WD (ft)	SWFT BML (ft)	OPERATOR	WELL INTEGRITY
608054002100	17-Sep-02	1	G20882	AC	947	LOW	10783	9672	1111	UNION OIL COMPANY OF CALIFORNIA	yes
608184005000	06-Jan-05	1	G18537	AT	267	MINOR	4275	3341	934	SHELL OFFSHORE INC	yes
608184000300	13-Mar-92	1	G12270	AT	222	LOW	4374	3170	1204	BP EXPLORATION & OIL INC	yes
608184005700	18-Jun-05	1	G16910	AT	398	MINOR	4473	3619	854	BP EXPLORATION & PRODUCTION INC	yes
608184004200	07-Apr-03	1	G23021	AT	182	not reported	5432	3710	1722	CHEVRON USA INC	yes
608184002700	21-Feb-02	2	G13198	AT	63	LOW	6469	4457	2012	ATP OIL & GAS CORPORATION	no
608184002300	23-Aug-01	1	G16874	AT	194	MODERATE	6704	4572	2132	CHEVRON USA INC	no
608184001100	08-Jul-99	1	G13197	AT	26	LOW	7048	6505	543	BP EXPLORATION & OIL INC	yes
608184004600	19-Feb-04	1	G08038	AT	618	LOW	7202	6257	945	BHP BILLITON PETROLEUM (GOM) INC	no
608184006000	16-Jun-06	SA001	G08037	AT	617	MODERATE	7211	6171	1040	BHP BILLITON PETROLEUM (GOM) INC	yes
608184000500	26-Mar-95	1	G08036	AT	575	not reported	7470	6220	1250	BHP BILLITON PETROLEUM (GOM) INC	yes
608184000700	11-Jul-97	1	G08918	AT	378	LOW	7758	5843	1915	CHEVRON USA INC	yes
608184004400	02-Jul-03	2	G08035	AT	574	MINOR	8236	6215	2021	BHP BILLITON PETROLEUM (GOM) INC	yes
608184000800	21-Jul-97	1	G08035	AT	574	not reported	8496	6133	2363	BHP BILLITON PETROLEUM (GOM) INC	yes
608184007200	06-Jan-10	2	G28129	AT	428	LOW	8679	7142	1537	ENI US OPERATING CO INC	yes
608184001000	12-Aug-98	1	G10006	AT	119	MINOR	9171	7716	1455	CHEVRON USA INC	yes
427044011600	08-May-83	4	G04558	BA	A 7	MODERATE	2308	120	2188	PIONEER NATURAL RESOURCES USA INC	yes
608234000300	22-Feb-97	1	G10445	DC	177	LOW	8655	6740	1915	ATP OIL & GAS CORPORATION	yes
608234001000	03-Apr-04	SS001	G23526	DC	618	LOW	8900	7823	1077	ENI US OPERATING CO INC	yes
608234001200	19-Sep-04	SS002	G23526	DC	618	MODERATE	9427	7787	1640	ENI US OPERATING CO INC	yes
608234001300	11-May-05	SS002	G23529	DC	621	LOW	9647	8087	1560	ANADARKO PETROLEUM CORPORATION	yes
608044020000	08-Jan-01	SS001	G17255	EB	421	not reported	4090	2740	1350	NOBLE ENERGY INC	yes
608044023600	22-Oct-02	1	G22293	EB	645	not reported	4548	3789	759	MAXUS US EXPLORATION COMPANY	yes
608104009900	11-Aug-96	1	G13087	EW	986	STRONG	1028	528	500	UNION OIL COMPANY OF CALIFORNIA	no
608104005300	18-Aug-86	2	G05803	EW	947	not reported	1456	496	960	MCMORAN OIL & GAS LLC	yes
608105004000	18-Sep-93	1	G10968	EW	1006	STRONG	2379	1879	500	MARATHON OIL COMPANY	no
608105003800	03-Mar-92	1	G10967	EW	1005	not reported	3456	1681	1775	MARATHON OIL COMPANY	yes
608104006300	28-Nov-87	1	G05820	EW	1006	not reported	3768	1783	1985	MOBIL OIL EXPLORATION & PRODUC	yes
608074008600	27-Aug-91	1	G07492	GB	425	not reported	2967	2217	750	EXXON MOBIL CORPORATION	yes
608074006500	08-Feb-90	1	G11548	GB	594	MODERATE	3535	2560	975	SHELL OFFSHORE INC	yes
608074004500	23-Feb-87	1	G07498	GB	471	LOW	4250	2873	1377	SHELL OFFSHORE INC	yes
608074020900	13-Jul-99	SE001	G08252	GB	516	LOW	4348	3380	968	SHELL OFFSHORE INC	yes
608074023300	07-Aug-01	2	G20792	GB	515	MINOR	4390	3290	1100	MARATHON OIL COMPANY	no
608074014400	25-Sep-95	A002	G11553	GB	602	LOW	4674	3693	981	SHELL OFFSHORE INC	yes
608074014200	13-Sep-95	1	G11553	GB	602	SEVERE	4768	3708	1060	SHELL OFFSHORE INC	no
608074030400	07-Sep-09	LL003	G17358	GB	385	LOW	5056	2514	2542	SHELL GULF OF MEXICO INC	yes
608074022900	22-Mar-01	A003	G11573	GB	783	LOW	5424	4674	750	CONOCOPHILLIPS COMPANY	yes
608074018000	17-Dec-97	1	G09240	GB	785	LOW	5500	4640	860	CONOCO INC	yes
608074003700	21-Jul-88	1	G08241	GB	426	MODERATE	5563	2837	2726	SHELL OFFSHORE INC	yes
608115012100	08-Aug-97	1	G15546	GC	113	LOW	2220	2045	175	MARUBENI OIL & GAS USA INC	yes
608114042200	13-Feb-05	SS001	G21785	GC	141	MODERATE	2308	1041	1267	LLOG EXPLORATION OFFSHORE LLC	yes
608114024700	17-Apr-99	3	G15563	GC	237	LOW	2705	1985	720	BHP BILLITON PETROLEUM (GOM) INC	yes
608114047500	04-Apr-06	2	G26292	GC	82	STRONG	3200	2435	765	W & T OFFSHORE INC	no
608114002900	24-Aug-84	2	G06994	GC	31	not reported	3329	2090	1239	EP OPERATING LIMITED PARTNER	no
608114007800	14-Aug-87	1	G06995	GC	32	LOW	3401	2269	1132	BP AMERICA PRODUCTION COMPANY	no
608115008800	04-Dec-94	3	G05911	GC	205	LOW	3448	2600	848	CHEVRON USA INC	yes
608114020300	16-Mar-95	2	G12205	GC	180	LOW	3554	2200	1354	BP AMERICA PRODUCTION COMPANY	yes
608114023200	19-Jul-98	1	G18344	GC	212	MODERATE	3630	2585	1045	TOTAL E&P USA INC	yes
608115007800	09-Jul-91	2	G05911	GC	205	MODERATE	3683	2700	983	CHEVRON USA INC	yes

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API #	SPUD DATE	WELL	S. LEASE	S. AREA	BLK #	SEVERITY	SWFT SS (ft)	WD (ft)	SWFT BML (ft)	OPERATOR	WELL INTEGRITY
608115007600	28-Aug-90	1	G05909	GC	161	MODERATE	3717	2575	1142	CHEVRON USA INC	yes
608114005400	12-Nov-85	1	G05896	GC	72	not reported	3762	1980	1782	SHELL OFFSHORE INC	no
608115008400	07-Mar-94	1	G07057	GC	296	MODERATE	3928	3290	638	SHELL OFFSHORE INC	yes
608114020501	28-Mar-98	TA005	G12209	GC	200	LOW	3936	2670	1266	SHELL OFFSHORE INC	yes
608114028700	30-Aug-00	2	G15555	GC	165	LOW	3979	2780	1199	BP EXPLORATION & PRODUCTION INC	yes
608114019700	14-Feb-94	1	G12209	GC	200	LOW	4027	2761	1266	SHELL OFFSHORE INC	yes
608114027606	27-May-02	SS001	G20051	GC	243	not reported	4080	3065	1015	NEXEN PETROLEUM USA INC	yes
608115012600	21-Feb-98	1	G11054	GC	338	LOW	4162	3244	918	SHELL DEEPWATER DEVELOPMENT INC	yes
608114034000	19-Jun-02	SS002	G20051	GC	243	not reported	4171	3048	1123	NEXEN PETROLEUM USA INC	yes
608114018300	09-Apr-91	1	G07053	GC	286	not reported	4266	3124	1142	EXXON MOBIL CORPORATION	yes
608115006600	08-Dec-88	1	G05097	GC	472	LOW	4317	3778	539	ENI US OPERATING CO INC	yes
608115012900	12-Mar-98	1	G13171	GC	341	not reported	4457	3394	1063	NEWFIELD EXPLORATION GULF COAST LLC	yes
608114023300	29-Aug-98	1	G11066	GC	463	LOW	4488	4032	456	BP EXPLORATION & OIL INC	yes
608114050400	19-Dec-07	1	G28077	GC	448	LOW	4496	3266	1230	DEEP GULF ENERGY LP	yes
608114030800	17-Aug-01	1	G16727	GC	282	MODERATE	4507	2386	2121	BHP BILLITON PETROLEUM (GOM) INC	yes
608114027800	17-May-00	1	G15555	GC	165	LOW	4564	2705	1859	BP EXPLORATION & PRODUCTION INC	yes
608115008200	04-Jan-94	1	G07069	GC	429	not reported	4612	3690	922	EXXON MOBIL CORPORATION	yes
608114003803	26-Apr-85	1	G07049	GC	254	not reported	4792	3135	1657	ENI US OPERATING CO INC	yes
608114020200	13-Nov-94	1	G08880	GC	506	LOW	4863	4243	620	TEXACO EXPLORATION AND PROD	yes
608114023000	07-Jun-98	1	G11064	GC	461	LOW	4893	4229	664	BP EXPLORATION & OIL INC	yes
608114023500	20-Dec-98	1	G11080	GC	644	MINOR	4930	4292	638	BP EXPLORATION & PRODUCTION INC	yes
608115006400	25-Mar-89	1	G07995	GC	158	LOW	5006	2950	2056	SHELL OFFSHORE INC	yes
608114037500	13-Jul-03	1	G18387	GC	435	MODERATE	5215	3815	1400	CONOCOPHILLIPS COMPANY	no
608114028500	06-Sep-00	1	G15611	GC	783	LOW	5591	4317	1274	BP EXPLORATION & PRODUCTION INC	yes
608114024600	17-May-99	SS001	G11075	GC	562	not reported	5689	3979	1710	ANADARKO PETROLEUM CORPORATION	yes
608114038400	11-Aug-03	1	G16808	GC	823	LOW	5844	4129	1715	BP EXPLORATION & PRODUCTION INC	yes
608114027300	27-Feb-00	2	G05922	GC	473	not reported	5888	3833	2055	ENI US OPERATING CO INC	yes
608114052000	02-Aug-08	3	G16765	GC	610	LOW	6340	4389	1951	BHP BILLITON PETROLEUM (GOM) INC	yes
608114038900	30-Jan-04	2	G09982	GC	826	LOW	6855	5062	1793	BP EXPLORATION & PRODUCTION INC	yes
608114048500	02-Oct-06	1	G16716	GC	246	not reported	7000	3271	3729	WOODSIDE ENERGY USA INC	yes
608114029800	08-May-01	2	G15607	GC	743	LOW	7190	6587	603	BP EXPLORATION & PRODUCTION INC	yes
608114040400	30-Apr-04	DC122	G15607	GC	743	MODERATE	7343	6822	521	BP EXPLORATION & PRODUCTION INC	yes
608114041100	14-Apr-04	DC142	G15607	GC	743	MODERATE	7607	6825	782	BP EXPLORATION & PRODUCTION INC	yes
608114040600	19-Apr-04	DC131	G15607	GC	743	MODERATE	7607	6824	783	BP EXPLORATION & PRODUCTION INC	yes
608114040700	10-May-04	DC132	G15607	GC	743	LOW	7619	6820	799	BP EXPLORATION & PRODUCTION INC	yes
608114034800	12-Aug-02	4	G15607	GC	743	LOW	8350	6896	1454	BP EXPLORATION & PRODUCTION INC	yes
608114034900	07-Nov-02	5	G15607	GC	743	LOW	8525	5405	3120	BP EXPLORATION & PRODUCTION INC	yes
608114057000	25-Apr-10	BA003	G09981	GC	825	LOW	10748	5221	5527	BP EXPLORATION & PRODUCTION INC	no
608084002000	15-Oct-09	1	G21444	KC	875	LOW	10359	7103	3256	ANADARKO PETROLEUM CORPORATION	yes
608244000300	22-May-04	1	G23480	LL	399	MODERATE	9731	8951	780	ANADARKO PETROLEUM CORPORATION	yes
608174037700	16-Mar-90	2	G07963	MC	807	LOW	3282	2927	355	SHELL OFFSHORE INC	yes
608174084000	24-Jan-99	3	G14016	MC	711	not reported	3400	2950	450	ATP OIL & GAS CORPORATION	no
608174102500	09-Nov-03	3	G07952	MC	718	LOW	3410	2920	490	BP EXPLORATION & PRODUCTION INC	yes
608174102800	06-Dec-03	2	G07957	MC	762	MODERATE	3412	3147	265	SHELL OFFSHORE INC	no
608174114200	15-Nov-09	1	G26265	MC	540	STRONG	3530	2036	1494	STATOIL USA E&P INC.	yes
608174113100	02-Nov-07	SS001	G27277	MC	503	MODERATE	3929	3099	830	LLOG EXPLORATION OFFSHORE LLC	yes
608174060000	03-Mar-98	1	G14013	MC	667	not reported	3930	2902	1028	ANADARKO E&P COMPANY LF	yes
608174112501	23-Jun-07	SS001	G18245	MC	460	MODERATE	3983	2823	1160	ENI US OPERATING CO INC	yes
608174033700	06-Aug-88	2	G08852	MC	764	not reported	4030	3252	778	SHELL OFFSHORE INC	yes
608174051000	03-Jun-95	1	G07952	MC	718	not reported	4039	2828	1211	MARINER ENERGY INC	yes

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608174038800	11-Mar-91	4	G07963	MC	807	MODERATE	4043	2956	1087	SHELL OFFSHORE INC	yes
608174046000	17-Oct-93	A001	G07963	MC	807	LOW	4121	2945	1176	SHELL OFFSHORE INC	yes
608174084200	20-Feb-99	1	G19931	MC	243	LOW	4184	2805	1379	W & T ENERGY VI LLC	yes
608174081000	02-May-98	2	G25098	MC	546	not reported	4220	2508	1712	ENI US OPERATING CO INC	yes
608174094500	30-Aug-01	2	G14005	MC	496	not reported	4308	1637	2671	MARUBENI OIL & GAS USA INC	yes
608174040200	24-Jul-91	5	G07963	MC	807	LOW	4330	2937	1393	SHELL OFFSHORE INC	yes
608174094900	24-Sep-01	1	G16625	MC	587	LOW	4430	2338	2092	BP EXPLORATION & PRODUCTION INC	yes
608174039400	06-Mar-91	2	G09896	MC	899	LOW	4568	4340	228	SHELL OFFSHORE INC	no
608174045500	11-Dec-93	1	G05868	MC	809	MODERATE	4632	3762	870	SHELL OFFSHORE INC	yes
608174114100	04-Feb-08	2	G24104	MC	754	STRONG	4700	2696	2004	ATP OIL & GAS CORPORATION	no
608174038500	17-Aug-90	2	G09883	MC	854	LOW	4723	4020	703	SHELL OFFSHORE INC	yes
608174118200	07-Jan-10	SS001	G32301	MC	199	LOW	4727	2465	2262	LLOG EXPLORATION OFFSHORE LLC	yes
608174033600	23-Jul-88	1	G08852	MC	764	not reported	4775	3252	1523	SHELL OFFSHORE INC	no
608174097900	14-Feb-02	1	G21188	MC	849	SEVERE	4819	3599	1220	NOBLE ENERGY INC	yes
608174058400	19-Nov-97	3	G08852	MC	764	MODERATE	4916	3263	1653	SHELL OFFSHORE INC	no
608174082000	27-Jul-98	1	G16661	MC	941	LOW	4918	3927	991	ATP OIL & GAS CORPORATION	yes
608174114000	28-Jan-08	1	G28025	MC	761	LOW	4950	3031	1919	LLOG EXPLORATION OFFSHORE LLC	no
608174039500	09-Mar-91	3	G09896	MC	899	LOW	5056	4340	716	SHELL OFFSHORE INC	no
608174036200	01-Nov-89	1	G07963	MC	807	LOW	5062	3013	2049	SHELL OFFSHORE INC	yes
608174050900	07-May-95	1	G08806	MC	292	LOW	5189	3405	1784	NOBLE ENERGY INC	yes
608174050300	22-Dec-94	2	G07976	MC	935	LOW	5270	3859	1411	SHELL OFFSHORE INC	yes
608174053700	04-Jul-96	4	G09873	MC	810	MODERATE	5348	3907	1441	SHELL OFFSHORE INC	no
608174100900	25-Mar-03	1	G22898	MC	725	LOW	5436	4334	1102	HESS CORPORATION	yes
608174047000	14-Apr-94	1	G07976	MC	935	LOW	5626	3918	1708	SHELL OFFSHORE INC	yes
608174035100	05-Apr-89	1	G07958	MC	763	MODERATE	5764	3170	2594	SHELL OFFSHORE INC	yes
608174038300	11-Jul-90	1	G09883	MC	854	LOW	5989	4020	1969	SHELL OFFSHORE INC	no
608174058000	06-Oct-97	5	G09896	MC	899	LOW	6216	4394	1822	SHELL OFFSHORE INC	yes
608174038000	05-Jul-90	3	G07963	MC	807	MODERATE	6222	2930	3292	SHELL OFFSHORE INC	yes
608174086400	17-Nov-99	A002	G19996	MC	773	MODERATE	6534	5610	924	ENI US OPERATING CO INC	yes
608174089400	21-Aug-00	1	G13145	MC	727	SEVERE	6547	4891	1656	CHEVRON USA INC	yes
608174112800	21-Jul-07	3	G18301	MC	860	LOW	6548	5667	881	CHEVRON USA INC	yes
608174105400	18-Oct-04	1	G16659	MC	937	STRONG	6605	4181	2424	BHP BILLITON PETROLEUM (GOM) INC	no
608174028900	20-Nov-86	1	G07955	MC	731	LOW	7022	5400	1622	SHELL OFFSHORE INC	yes
608174114800	19-May-08	1	G28030	MC	948	MODERATE	7025	6090	935	NOBLE ENERGY INC	no
608174039200	25-Jan-91	1	G09896	MC	899	MODERATE	7052	4340	2712	SHELL OFFSHORE INC	no
608174058500	27-Nov-97	1	G09813	MC	476	LOW	7075	6627	448	BP AMERICA PRODUCTION COMPANY	yes
608174033000	11-Jun-88	1	G07954	MC	730	MODERATE	7170	5328	1842	SHELL OFFSHORE INC	yes
608174112100	19-Apr-07	1	G19997	MC	775	MODERATE	7560	5673	1887	BP EXPLORATION & PRODUCTION INC	no
608174057800	20-Sep-97	1	G09837	MC	607	LOW	7836	6590	1246	BP EXPLORATION & PRODUCTION INC	yes
608174091300	23-Jan-01	1	G15519	MC	864	MODERATE	7858	6265	1593	CHEVRON USA INC	yes
608174051300	10-Nov-95	A001	G07944	MC	429	LOW	7978	6240	1738	BP EXPLORATION & PRODUCTION INC	yes
608174103100	16-Mar-04	13	G09868	MC	778	LOW	8408	6034	2374	BP EXPLORATION & PRODUCTION INC	yes
608174085700	05-Oct-99	1	G16670	MC	1002	MINOR	8436	7416	1020	CHEVRON USA INC	yes
608174039600	11-Mar-91	4	G09896	MC	899	LOW	8730	4340	4390	SHELL OFFSHORE INC	yes
608174091100	17-Jan-01	1	G16641	MC	696	LOW	8912	6941	1971	CHEVRON USA INC	yes
608174054600	30-Oct-96	H001	G09821	MC	520	LOW	9109	6738	2371	BP EXPLORATION & PRODUCTION INC	yes
608024000200	15-Dec-96	1	G13395	PI	654	LOW	3750	2320	1430	SHELL DEEPWATER DEVELOPMENT INC	yes
608164009400	03-Aug-85	2	G06886	VK	783	LOW	2258	1151	1107	W & T ENERGY VI LLC	yes
608164018100	13-Apr-93	A001	G06894	VK	915	MODERATE	4004	3236	768	BP AMERICA PRODUCTION COMPANY	yes
608164013000	26-May-88	1	G05784	VK	869	not reported	4164	1918	2246	EXXON MOBIL CORPORATION	yes

Appendix A.

API #	SPUD DATE	WELL	S. LEASE	S. AREA	BLK #	SEVERITY	SWFT SS (ft)	WD (ft)	SWFT BML (ft)	OPERATOR	WELL INTEGRITY
608164013800	06-Apr-89	2	G05784	VK	869	not reported	4450	2050	2400	EXXON MOBIL CORPORATION	yes
608164012400	21-Feb-88	1	G08471	VK	873	LOW	5014	3810	1204	SHELL OFFSHORE INC	yes
608164009000	01-Mar-85	1	G06893	VK	912	LOW	5020	2441	2579	SHELL OFFSHORE INC	yes
608164009800	16-Nov-85	1	G06896	VK	956	MINOR	5068	3112	1956	SHELL OFFSHORE INC	yes
608164010200	23-Jun-86	3	G06893	VK	912	LOW	5897	2952	2945	SHELL OFFSHORE INC	yes
608164008800	02-Nov-84	1	G06886	VK	783	LOW	5954	1450	4504	W & T ENERGY VI LLC	yes
608164013400	22-Nov-88	4	G06886	VK	783	LOW	7060	1494	5566	W & T ENERGY VI LLC	yes

Appendix B.

(i) Projected plans for well testing (refer to § 250.460 for safety requirements).

[68 FR 8423, Feb. 20, 2003]

§ 250.415 What must my casing and cementing programs include?

Your casing and cementing programs must include:

(a) Hole sizes and casing sizes, including: weights; grades; collapse, and burst values; types of connection; and setting depths (measured and true vertical depth (TVD));

(b) Casing design safety factors for tension, collapse, and burst with the assumptions made to arrive at these values;

(c) Type and amount of cement (in cubic feet) planned for each casing string; and

(d) In areas containing permafrost, setting depths for conductor and surface casing based on the anticipated depth of the permafrost. Your program must provide protection from thaw subsidence and freezeback effect, proper anchorage, and well control.

(e) A statement of how you evaluated the best practices included in API RP 65, Recommended Practice for Cementing Shallow Water Flow Zones in Deep Water Wells (incorporated by reference as specified in § 250.198), if you drill a well in water depths greater than 500 feet and are in either of the following two areas:

(1) An ''area with an unknown shallow water flow potential'' is a zone or geologic formation where neither the presence nor absence of potential for a shallow water flow has been confirmed.

(2) An ''area known to contain a shallow water flow hazard'' is a zone or geologic formation for which drilling has confirmed the presence of shallow water flow.

[68 FR 8423, Feb. 20, 2003, as amended at 72 FR 8903, Feb. 28, 2007]

§ 250.416 What must I include in the diverter and BOP descriptions?

You must include in the diverter and BOP descriptions:

(a) A description of the diverter system and its operating procedures;

(b) A schematic drawing of the diverter system (plan and elevation views) that shows:

(1) The size of the annular BOP installed in the diverter housing;

(2) Spool outlet internal diameter(s);

(3) Diverter-line lengths and diameters; burst strengths and radius of curvature at each turn; and

(4) Valve type, size, working pressure rating, and location;

(c) A description of the BOP system and system components, including pressure ratings of BOP equipment and proposed BOP test pressures;

(d) A schematic drawing of the BOP system that shows the inside diameter of the BOP stack, number and type of preventers, location of choke and kill lines, and associated valves; and

(e) Information that shows the blind-shear rams installed in the BOP stack (both surface and subsea stacks) are capable of shearing the drill pipe in the hole under maximum anticipated surface pressures.

[68 FR 8423, Feb. 20, 2003]

§ 250.417 What must I provide if I plan to use a mobile offshore drilling unit (MODU)?

If you plan to use a MODU, you must provide:

(a) *Fitness requirements.* You must provide information and data to demonstrate the drilling unit's capability to perform at the proposed drilling location. This information must include the maximum environmental and operational conditions that the unit is designed to withstand, including the minimum air gap necessary for both hurricane and non-hurricane seasons. If sufficient environmental information and data are not available at the time you submit your APD, the District Manager may approve your APD but require you to collect and report this information during operations. Under this circumstance, the District Manager has the right to revoke the approval of the APD if information collected during operations show that the drilling unit is not capable of performing at the proposed location.

(b) *Foundation requirements.* You must provide information to show that site-specific soil and oceanographic conditions are capable of supporting the proposed drilling unit. If you provided sufficient site-specific information in

Appendix C.

API RP 65: Cementing Shallow Water Flow Zones in Deep Water Wells

Publication Date: Sep 1, 2002
SDO: API: American Petroleum Institute
☐ DOD Adopted ☐ ANSI Approved

FLOWS

This document is the compilation of technology and practices used by many operators drilling wells in deep water. In a number of cases, there is not a single way of performing a specific operation. In some cases, several options may be listed, but in others there may be practices which are successful, but which are not listed in this document. This document is not meant to limit innovation.

In wells drilled in deep ocean waters, water flows from shallow formations can compromise the hydraulic integrity of the tophole section. Modes of failure include: (1) poor isolation by cement resulting in casing buckling/shear; (2) pressure communication to other shallow formations, causing them to be overpressured; and (3) disturbance of the seafloor due to breakthrough of the shallow flow to the mudline. Such damage can and has resulted in the complete loss of drilling templates containing previously cased wells. Additionally, such shallow flow can result in changes in the state of stress in the tophole section, possibly resulting to damage to existing casings in the present or adjacent wells later in the life of the well.

Flows from these shallow formations are frequently a result of abnormally high pore pressure resulting from under-compacted and over-pressured sands caused by rapid deposition. Not all flows are the result of these naturally developed formation geo-pressures. Hydraulic communication with deeper, higher pressure formations is another cause for abnormal shallow pressures. Some of the observed shallow flow problems have been due to destabilization of gas hydrates or induced storage during drilling and casing and cementing operations. Although minor compared to geo-pressured sands, flows due to induced storage may still cause damage from sediment erosion or mining, breakthrough to adjacent wells and damage to the cement before it sets. These problems can worsen with each additional well when batch setting shallow casings. Although most of the discussion in this text is focused on shallow water flow (SWF), shallow flows can be mixtures of water, gas and formation fines. In most cases the concepts are similar and can be employed with minor modifications, depending on the type of flow.

Flows allow production of sand and sediments resulting in hole enlargement which can increase the flow potential and make it more difficult to control. The enlargement may also cause caving of formations above the flow interval. The flow of water and formation material from these zones can result in damage to the wells including foundation failure, formation compaction, damaged casing (wear and buckling), reentry and control problems and sea floor craters, mounds and crevasses (OTC 11972, IADC/SPE 52780).

HAZARDS

The Gulf of Mexico has been divided into areas by the severity of the hazard based on data from geotechnical wells (SPE/IADC 67772). The Minerals Management Service (MMS) also maintains a map showing the location of flow incidents on a web site at http://www.gomr.mms.gov/homepg/offshore/safety/wtrflow.html.

Appendix C.

The following factors make drilling in deep water with SWF potential unique:

a. Temperatures at the mud line and through the shallow sediments are quite low and may approach 40°F.

b. Pore and fracturing pressures are very close, making the drilling window very narrow.

c. The hole is drilled riserless, with returns taken to the sea floor.

d. Seawater is used for drilling.

e. There is no means to control flow at the wellhead.

f. Returns and flows are observed only remotely through video from a remotely operated vehicle (ROV).

g. In development projects, conductor and surface casing are batch set.

The shallow water flow conditions described in this document exist in wells drilled in water depths greater than about 500 ft and more commonly at water depths greater than 1000 ft. These wells are commonly drilled from floating drilling rigs such as drill ships, semi-submersibles, spars and tension leg platforms.

Shallow water flow sands are typically encountered at depths of 600 ft - 2500 ft below mud line (BML). The conditions favoring the formation of shallow water flow sands include:

a. High rate of deposition (> 1500 ft/million years) sedimentary basins of current or ancestral river complexes, such as the Mississippi River depocenter.

b. Areas with substantial regional uplift, in which once deeply buried sediments are encountered at shallow depths - North Sea, Norwegian Sea.

c. Continental slope regions subject to large scale subsea slides - Storegga Slide area, Norwegian North Sea.

Abnormal pressures may be present in the tophole section of a deepwater well. Abnormal pressure can be trapped below the impermeable layers found above the SWF sands, or may begin at or near the mud line and increase more-or-less linearly with depth. In general, the degree of over-pressurization is consistent with the rate of deposition. Pore pressures equating to 8.6 lbm/gal to 9.5 lbm/gal equivalent mud weight (EMW) may be encountered in the SWF zones. When abnormal pressures are trapped below impermeable barriers, the pore pressure can be very close to the fracture gradient of the sediment. This results in a very narrow pressure margin within which drilling operations must be conducted to maintain well control and prevent induced fracturing of formations. (See SPE/IADC 67772.) The margin between pore pressure and fracture gradient becomes more narrow as water depth increases.

Temperatures at the mud line of a deepwater wellbore are quite low, in the range of 35°F - 55°F depending on water depth, latitude, and presence of warm/cold ocean currents. The low temperatures result in slow hydration of the cement making special slurries and/or additives necessary. The geothermal gradients found in deepwater areas may be sequestered as a result of the water depth effect and may suppress wellbore temperatures throughout the entire stratigraphic column. In other areas the geothermal gradient may rise quickly to normal values as depth increases.

Appendix C.

BEST PRACTICES

Because of such problems and to form an effective seal while preventing flow, careful attention must be paid to the cementation of wells having the potential for shallow flow. This document addresses the drilling and cementing process and makes recommendations for such wells. Appendix F gives a matrix for this process with values for each step. The resultant score provides the user with a factor of the relative chance of success of the cementation process. This process and matrix are based on known industry practices and are meant to be used to apply the process within the constraints of the well conditions with the greatest degree of risk minimization.

The process includes:

a. Site selection.

b. Drilling.

c. Fluid properties.

d. Wellbore preparation and conditioning.

e. Operational procedures and good cementing practices.

f. Mud removal and placement technique.

g. Cement slurry design.

h. Pre-job preparation.

i. Cement job execution.

j. Additional considerations.

k. Post cementing operations.

l. Remediation of flows.

A number of "best practices" have been developed for drilling and cementing in the deepwater, shallow water flow environment. Generally, these have been developed from lessons learned while drilling deepwater wells. These practices are applied to minimize the risk of shallow water flow and to aid in successfully drilling and cementing the casing through the SWF zones. These practices include the following, which are discussed in more detail throughout the document.

a. Site selection to minimize the risk for and severity of shallow water flow.

b. Use of pressure while drilling and resistivity tools to identify permeable sands and flow events.

c. Use of ROV to check for flow with each connection.

d. Rapid action to contain flows.

Appendix C.

e. Switching to mud to control flow as soon as it is encountered.

f. Selection of casing seats/casing program to facilitate control and to reach the well objectives.

g. Low fluid loss and gel strengths of pad mud spotted in the hole just prior to running casing.

h. Use of foamed cement and/or special slurries to maintain control across the SWF zones.

i. Batch setting conductor and surface casings.

A list of "lessons learned" in successfully isolating the top hole section in the presence of SWF include the following:

a. The pore pressure of SWF sand(s) must be hydrostatically contained at the first indication of flow.

b. SWF zones that are drilled underbalanced while flowing will not likely be isolated with cement.

c. Flows that are not contained soon after beginning can jeopardize the success of the project.

d. Wells in which the SWF sands have been hydrostatically controlled must still be cemented with flow mitigating cement systems.

e. Mechanical isolation devices, when used without flow mitigating cement systems, may not provide zonal isolation over the life of the well.

Note that this document is not meant to be a training manual. Although fairly comprehensive, there are still many details which are not discussed and which must be addressed when drilling and cementing wells in deep water. It is meant to highlight key parameters for increasing the chance of successfully drilling and cementing casings where there is a risk of shallow water flow and to discuss options that are available. Many more details can be gleaned from the references listed in the Bibliography. Most of the information in this document is from U.S. Gulf of Mexico experience. The concepts can be applied in other deep water environments with appropriate modifications. The user should consult experts within the industry for specific details of the cementing process relating to the technology being employed by a specific company for a specific scenario. The construction of the casings through the SWF zones must be a team effort to be successful. All parties involved must participate in the planning and execution of all phases of the process to ensure successful construction of the conductor and surface casings.

Appendix D.

The following procedures relate to a specific operation to address shallow water flow based on a particular set of circumstances. The following procedures are provided as an example only, and are not intended to represent appropriate procedures for all circumstances and situations. Each operator should develop, in accordance with BOEM & BSEE rules and regulations, procedures appropriate for its operations to control shallow water flow in deepwater operations.

Site Specific procedure to control SWF in deep water

Cementing Summary

Include data per 30 CFR 250.415 (e). Discuss how API RP 65 was used in planning the cementing program to prevent Shallow Water Flow.

Major items that go into the planning of the cementing of the open water strings of casing (32", 28", and 22") are:

- Use a specialized Shallow Water Flow Team – if available - whose primary focus is identifying drilling locations that minimize as many sub-surface shallow hazards as possible. This includes identifying potential water flow sands, hydrate bearing strata, shallow faults, shallow gas sands and seabed slopes.
- The manifold location for the development should consider all of the above. In addition, the manifold location should be selected in close proximity to wells which successfully drilled and secured the shallow water flow section of the well.

In addition to picking a location which avoids / minimizes risks in the shallow portion of the well, the following practices will be implemented:

- Lead cement will be designed as foam cement.
- Bottom portion (shoe joints) of the casing will be centralized.
- Minimum cement volumes will be based on a minimum of 100% open and cased hole volume.
- A shallow water flow annular shut off device will be deployed with the HP wellhead.
- Valves will be run on the 28" casing X 32" casing annulus which will be shut after cementing to isolate this annulus.
- Cement weights will be designed to provide higher hydrostatic pressure than the pad mud left in the well prior to cementing.
- The well will not be flowing prior to the trip out of the well to run casing and when cementing operations commence.
- The job will be pumped thru an inner string.
- Minimum of 2 times the hole volume of kill mud will be on location at all times while drilling the 32", 28" and 22" casing hole section.
- The hole interval for the 28" casing and 22" casing will be drilled with mud.
- Any flows identified on connections or with the PWD will be killed immediately.

- Displacement rates will be designed to minimize the chances for loss circulation due to equivalent circulating densities.
- The cement will be tested according to API Specs and the tests appropriately reviewed.
- The well will be conditioned and fresh kill / pad mud with the lowest practical gel strengths / yield point will be spotted prior to tripping out of the well to run casing.
- The well will be monitored on final trip out to ensure there is no flow.
- The 32", 28", and 22" casing strings will be run and hung off on a casing cart prior to drilling the interval to minimize the time the hole is static without pipe (drill pipe or casing) being on bottom.

Discuss drilling precautions taken to prevent possible Shallow Water Flow Zones.

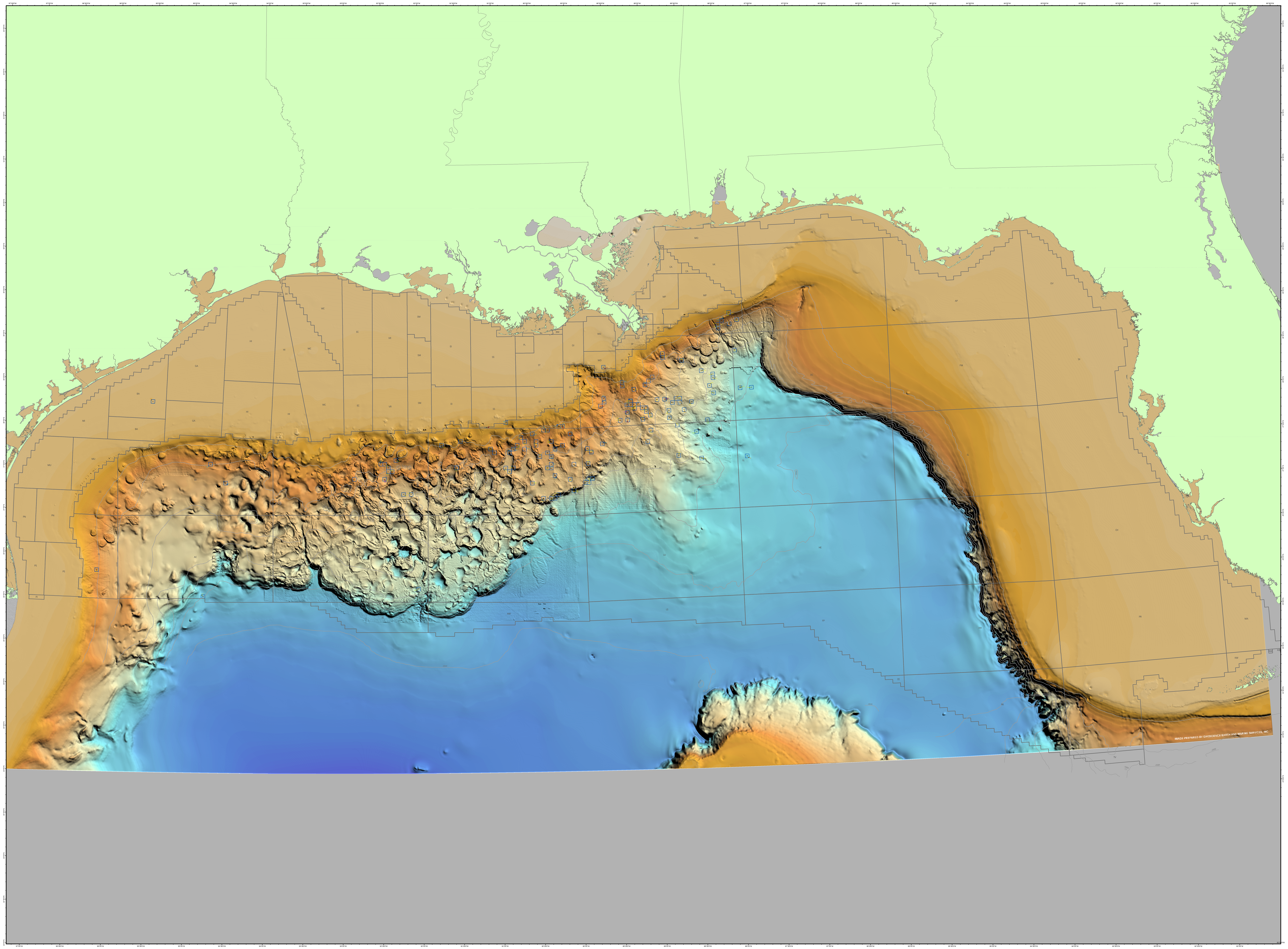
- 5,000 bbls of 16.0 ppg mud will be available at the rig for drilling to the 32" casing point at 4,300' (~880' of hole below the 38" jet pipe). The bottom 200' to 500' of hole will be drilled with 11.0 ppg mud.
- 15,000 bbls of 16.0 ppg mud will be available for drilling to the 28" casing point. The entire interval will be drilled with 12.0 ppg mud. A conditioning trip will be made and 12.3 ppg pad mud will be spotted prior to tripping out of the hole to run 28" casing.
- 45,000 bbls of 16.0 ppg mud will be available for drilling to the 22" casing point. The entire interval will be drilled with 13.2 ppg mud. A conditioning trip will be made and 13.5 ppg pad mud will be spotted prior to tripping out of the hole to run 22" casing.
- 28" casing will be set prior to drilling into the interval with the highest likelihood of encountering shallow water flow sands. This will provide the highest fracture gradient possible for handling an unlikely flow from this interval.
- The rig will have a backup ROV. Drilling operations will stop if an ROV is unable to be on bottom monitoring the wellhead 100% of the time.
- The PWD will be monitored continuously on the rig as well as office based Real Time Monitoring for changes. Anytime the slope of the PWD curve changes radically, drilling will stop, the pumps will be turned off, and the well will be checked for flow with the ROV. If the well is flowing, the mud weight will be increased until the flow stops.
- All connections will be monitored for flow with the ROV. If the well is flowing on connections the mud weight will be increased until the flow stops.
- ROV feed will be made available for monitoring by the office based Real Time Monitoring Team (24/7) and the SWF Team if they are available, as well as the sub surface geologists, onshore drilling engineers, and superintendents.

Appendix D.

- Mud weights for drilling the riserless section are based on both what was successful at near-by Wells, and a shallow pore pressure / fracture gradient prediction (plot) for the interval
- 22” casing point was based on stopping above potential sands below 5,850’.

Appendix E

Shallow Water Flow Map



LEGEND

- Unknown Flow
- Strong Flow
- Severe Flow
- Moderate Flow
- Minor flow
- Low Flow
- Shallow Water Flow Blocks
- GOM Blocks
- Bathymetry Contours

ci = 500 meters

1470 Depth Below the Mud Line of the Shallow Water Flow

Bathymetric map courtesy of Texas A&M University & Geosciences Earth and Marine Services

Bureau of Ocean Energy Management