

Appendix F

Uncertainty Assessment Tables and Figures

Appendix F. Uncertainty Assessment Tables and Figures

As described in Section 7.3 of the main report, primary pathways (sewage versus stormwater) were estimated using the mean loading rates from each flow condition. This appendix presents the uncertainty in the primary pathway estimates based on the variability of loading rate estimates from each flow condition. Only parameters with greater than 75% frequency of detection at a given site were included. More information on this assessment can be found in Section 7.4 of the main report.

To evaluate the uncertainty in mean loading rates within the Brandon Basin, an uncertainty range of loading rates and the relative variability were established for each parameter and flow condition. Table F-1 describes the calculations used to generate these metrics. As seen in this table, the relative variability for sewage is simply the relative standard deviation, but since stormwater was not sampled directly, its relative variability is based on the standard deviation of stormflow sampling and the stormwater mean estimate. Tables F-2 through F-6 present the results of this uncertainty assessment for conventionals, metals, and organics at each location.

Table F-1. Calculations for Uncertainty Assessment of Sewage and Stormwater Loading Rates during Stormflow Conditions.

	Sewage Calculations	Stormwater Calculations
Mean Estimate	Baseflow Mean	Stormflow Mean – Baseflow Mean = Stormwater Mean
Uncertainty Range	± Baseflow Standard Deviation	± Stormflow Standard Deviation
Relative Variability	Baseflow Standard Deviation / Baseflow Mean	Stormflow Standard Deviation / Stormwater Mean

Table F-2. Uncertainty Assessment for Estimated Sewage and Stormwater Loading Rates for Conventional Parameters during Stormflow Conditions.

Analyte	Location	Sewage Loading Rate (mg/hr)			Stormwater Loading Rate (mg/hr)		
		Mean Estimate	Uncertainty Range	Relative Variability	Mean Estimate	Uncertainty Range	Relative Variability
TOC	Utah	0.145	± 0.0839	0.58	0.718	± 0.530	0.74
	East Marginal	4.20	± 1.86	0.44	7.20	± 6.90	0.96
	Brandon Regulator	4.94	± 2.92	0.59	9.34	± 9.46	1.01

Analyte	Location	Sewage Loading Rate (mg/hr)			Stormwater Loading Rate (mg/hr)		
		Mean Estimate	Uncertainty Range	Relative Variability	Mean Estimate	Uncertainty Range	Relative Variability
DOC	Utah	0.0900	± 0.0499	0.55	0.229	± 0.177	0.77
	East Marginal	3.18	± 1.81	0.57	4.05	± 6.19	1.53
	Brandon Regulator	3.33	± 1.53	0.46	4.48	± 5.65	1.26
TSS	Utah	0.232	± 0.184	0.79	3.12	± 2.21	0.71
	East Marginal	3.53	± 2.62	0.74	8.55	± 7.32	0.86
	Brandon Regulator	5.61	± 5.39	0.96	33.8	± 34.6	1.02

Table F-3. Uncertainty Assessment for Estimated Sewage and Stormwater Loading Rates for Metals during Stormflow Conditions.

Analyte	Location	Sewage Loading Rate (mg/hr)			Stormwater Loading Rate (mg/hr)		
		Mean Estimate	Uncertainty Range	Relative Variability	Mean Estimate	Uncertainty Range	Relative Variability
Total Arsenic	Utah	1.27	± 0.576	0.46	30.2	± 31.4	1.04
	East Marginal	11.8	± 5.12	0.43	73.0	± 75.6	1.04
	Brandon Regulator	790	± 2,510	3.18	-427	± 284	0.66
Dissolved Arsenic	Utah	0.981	± 0.473	0.48	13.7	± 12.6	0.92
	East Marginal	6.75	± 1.47	0.22	52.9	± 71.8	1.36
	Brandon Regulator	885	± 2,720	3.08	-699	± 140	0.20
Total Cadmium	Utah	0.294	± 0.219	0.75	6.74	± 6.49	0.96
	East Marginal	2.29	± 1.46	0.64	18.8	± 18.8	1.00
	Brandon Regulator	17.5	± 37.8	2.17	60.2	± 66.0	1.10
Dissolved Cadmium	Utah	NC	NC	NC	NC	NC	NC
	East Marginal	NC	NC	NC	NC	NC	NC
	Brandon Regulator	6.56	± 15.7	2.40	7.69	± 17.6	2.28

Analyte	Location	Sewage Loading Rate (mg/hr)			Stormwater Loading Rate (mg/hr)		
		Mean Estimate	Uncertainty Range	Relative Variability	Mean Estimate	Uncertainty Range	Relative Variability
Total Chromium	Utah	3.82	± 4.28	1.12	135	± 145	1.07
	East Marginal	35.4	± 20.3	0.57	169	± 123	0.73
	Brandon Regulator	1,500	± 4,560	3.04	65.7	± 1,370	20.8
Dissolved Chromium	Utah	1.20	± 2.47	2.06	13.1	± 16.7	1.27
	East Marginal	11.7	± 10.7	0.91	17.2	± 9.31	0.54
	Brandon Regulator	1,250	± 3,850	3.08	-1,070	± 132	0.12
Total Copper	Utah	50.3	± 32.8	0.65	794	± 715	0.90
	East Marginal	380	± 253	0.67	1,150	± 727	0.63
	Brandon Regulator	1,280	± 1,090	0.85	9,020	± 11,600	1.29
Dissolved Copper	Utah	16.0	± 9.35	0.58	170	± 163	0.96
	East Marginal	81.1	± 42.9	0.53	339	± 152	0.45
	Brandon Regulator	438	± 402	0.92	1,570	± 1,290	0.82
Total Lead	Utah	12.1	± 13.1	1.09	406	± 379	0.93
	East Marginal	84.6	± 76.4	0.90	543	± 406	0.75
	Brandon Regulator	344	± 533	1.55	3,270	± 3,290	1.01
Dissolved Lead	Utah	1.61	± 1.10	0.68	13.0	± 10.3	0.79
	East Marginal	7.41	± 3.20	0.43	44.5	± 28.5	0.64
	Brandon Regulator	50.6	± 59.6	1.18	136	± 148	1.09
Total Nickel	Utah	4.95	± 3.32	0.67	145	± 140	0.97
	East Marginal	39.4	± 19.6	0.50	166	± 105	0.63
	Brandon Regulator	1,400	± 2,740	1.95	8,490	± 21,400	2.52

Analyte	Location	Sewage Loading Rate (mg/hr)			Stormwater Loading Rate (mg/hr)		
		Mean Estimate	Uncertainty Range	Relative Variability	Mean Estimate	Uncertainty Range	Relative Variability
Dissolved Nickel	Utah	2.70	± 1.16	0.43	34.2	± 27.9	0.82
	East Marginal	23.2	± 6.20	0.27	60.6	± 28.4	0.47
	Brandon Regulator	1,320	± 2,820	2.13	6,240	± 18,400	2.95
Total Silver	Utah	0.540	± 0.911	1.69	4.34	± 5.24	1.21
	East Marginal	0.722	± 0.528	0.73	2.43	± 0.528	0.22
	Brandon Regulator	8.46	± 9.62	1.14	64.2	101	1.58
Dissolved Silver	Utah	NC	NC	NC	NC	NC	NC
	East Marginal	NC	NC	NC	NC	NC	NC
	Brandon Regulator	NC	NC	NC	NC	NC	NC
Total Vanadium	Utah	3.94	± 4.63	1.18	139	± 161	1.15
	East Marginal	31.3	± 19.9	0.64	158	± 123	0.78
	Brandon Regulator	149	± 295	1.97	867	± 829	0.96
Dissolved Vanadium	Utah	1.19	± 0.590	0.49	23.0	± 22.5	0.98
	East Marginal	8.27	± 2.47	0.30	27.5	± 18.8	0.68
	Brandon Regulator	70.7	± 117	1.65	87.3	± 109	1.25
Total Zinc	Utah	123	± 88.8	0.72	3,130	± 2,980	0.95
	East Marginal	1,310	± 1,040	0.79	5,900	± 2,820	0.48
	Brandon Regulator	2,960	± 2,920	0.99	28,000	± 26,400	0.94
Dissolved Zinc	Utah	31.2	± 21.3	0.68	877	± 879	1.00
	East Marginal	300	± 108	0.36	2,290	± 935	0.41
	Brandon Regulator	1,330	± 1,570	1.18	7,300	± 6,120	0.84

Analyte	Location	Sewage Loading Rate (mg/hr)			Stormwater Loading Rate (mg/hr)		
		Mean Estimate	Uncertainty Range	Relative Variability	Mean Estimate	Uncertainty Range	Relative Variability
Total Mercury	Utah	0.0446	± 0.0353	0.79	0.800	± 0.792	0.99
	East Marginal	0.422	± 0.248	0.59	1.34	± 1.28	0.96
	Brandon Regulator	1.16	± 1.27	1.10	18.2	± 32.5	1.78
Dissolved Mercury	Utah	NC	NC	NC	NC	NC	NC
	East Marginal	NC	NC	NC	NC	NC	NC
	Brandon Regulator	NC	NC	NC	NC	NC	NC

NC = not calculated due to < 75% FOD

Table F-4. Uncertainty Assessment for Estimated Sewage and Stormwater Loading Rates for PAHs and Phthalates during Stormflow Conditions.

Analyte	Location	Sewage Loading Rate (mg/hr)			Stormwater Loading Rate (mg/hr)		
		Mean Estimate	Uncertainty Range	Relative Variability	Mean Estimate	Uncertainty Range	Relative Variability
Phenanthrene	Utah	0.0945	± 0.0411	0.43	2.16	± 2.02	0.93
	East Marginal	NC	NC	NC	NC	NC	NC
	Brandon Regulator	1.41	± 0.771	0.55	20.6	± 18.2	0.88
Fluoranthene	Utah	0.0642	± 0.048	0.75	3.73	± 3.24	0.87
	East Marginal	NC	NC	NC	NC	NC	NC
	Brandon Regulator	1.10	± 0.732	0.66	26.6	± 22.7	0.86
Total HPAHs	Utah	0.187	± 0.176	0.94	18.7	± 18.5	0.99
	East Marginal	NC	NC	NC	NC	NC	NC
	Brandon Regulator	3.45	± 2.67	0.78	120	± 103	0.86

Analyte	Location	Sewage Loading Rate (mg/hr)			Stormwater Loading Rate (mg/hr)		
		Mean Estimate	Uncertainty Range	Relative Variability	Mean Estimate	Uncertainty Range	Relative Variability
Benzyl Butyl Phthalate	Utah	69.5	± 92.9	1.34	58.6	± 89.8	1.53
	East Marginal	3.09	± 2.35	0.76	460	± 1,160	2.52
	Brandon Regulator	102	± 95.2	0.93	475	± 777	1.64
Bis (2-ethylhexyl) phthalate	Utah	12.0	± 10.2	0.85	68.5	± 72.6	1.06
	East Marginal	26.4	± 17.2	0.65	155	± 78.1	0.50
	Brandon Regulator	96.7	± 64.0	0.66	773	± 956	1.24
Diethyl Phthalate	Utah	5.07	± 3.95	0.78	18.5	± 13.6	0.73
	East Marginal	16.8	± 8.02	0.48	16.2	± 15.9	0.98
	Brandon Regulator	49.8	± 37.3	0.75	95.5	± 99.1	1.04

NC = not calculated due to < 75% FOD.

Table F-5. Uncertainty Assessment for Estimated Sewage and Stormwater Loading Rates for Total PCBs and Dioxin/Furans during Stormflow Conditions.

Analyte	Location	Sewage Loading Rate (µg/hr)			Stormwater Loading Rate (µg/hr)		
		Mean Estimate	Uncertainty Range	Relative Variability	Mean Estimate	Uncertainty Range	Relative Variability
Total PCBs	Utah	44.2	± 47.6	1.08	1,652	± 2,180	1.32
	East Marginal	198	± 146	0.74	982	± 614	0.63
	Brandon Regulator	827	± 1,120	1.35	21,503	± 21,900	1.02
Total Dioxin/Furans	Utah	0.217	± 0.129	0.59	51.3	± 72.5	1.41
	East Marginal	2.95	± 3.57	1.21	32.1	± 18.4	0.57
	Brandon Regulator	9.59	± 14.1	1.47	323	± 239	0.74

NC = not calculated due to < 75% FOD.

Table F-6. Uncertainty Assessment for Sewage and Stormwater Loading Rates for Total Dioxin TEQs during Stormflow Conditions.

Analyte	Location	Sewage Loading Rate (ng TEQ/yr)			Stormwater Loading Rate (ng TEQ/yr)		
		Mean Estimate	Uncertainty Range	Relative Variability	Mean Estimate	Uncertainty Range	Relative Variability
Total Dioxin TEQs	Utah	1.45	± 1.52	1.04	262	± 329	1.26
	East Marginal	14.5	± 16.3	1.13	230	± 177	0.77
	Brandon Regulator	49.9	± 84.9	1.70	1,500	± 1,190	0.79

NC = not calculated due to < 75% FOD.

Next, relative magnitude of the pathways (sewage versus stormwater) was calculated with five different scenarios to evaluate uncertainty in the primary pathway estimates. The five scenarios were: (1) the mean estimate for both sewage and stormwater loading rates, (2) a high sewage estimate, (3) a low sewage estimate, (4) a high stormwater estimate, and (5) a low stormwater estimate. Table F-7, also provided in the main report as Table 29, explains how these were calculated.

Table F-7. Scenarios Used in the Uncertainty Assessment

Scenario	Calculated from Sampling Results		Resulting Estimates	
	Baseflow Loading Rate (= A)	Stormflow Loading Rate (= B)	Sewage Loading Rate (= A)	Stormwater Loading Rate (= B - A)
1. Mean Estimate	Mean	Mean	Mean	Mean
2. High Sewage	Mean + St Dev	Mean	High	Biased low
3. Low Sewage	Mean - St Dev	Mean	Low	Biased high
4. High Stormwater	Mean	Mean + St Dev	Mean	High
5. Low Stormwater	Mean	Mean - St Dev	Mean	Low

St Dev – Standard Deviation

Note: “Biased low” is the result of subtracting a high baseflow loading estimate from the mean stormflow loading estimate. “Biased high” is the result of subtracting a low baseflow loading estimate from the mean stormflow loading estimate.

Figures F-1 through F-32 illustrate the relative magnitude of the pathways estimated during stormflow based on the five above scenarios for all parameters with greater than 75% FOD for each sampling location. For most parameters, there was a greater range of uncertainty in relative magnitude of the pathway when stormflow loading estimates were manipulated. In the figures, sewage is abbreviated “Swg.” and stormwater is abbreviated “SW”.

These results are discussed further in the main report (Section 7.4.3). These sample specific loading rates represent loads that would be going to the West Point Treatment Plant via the Elliott Bay Interceptor.

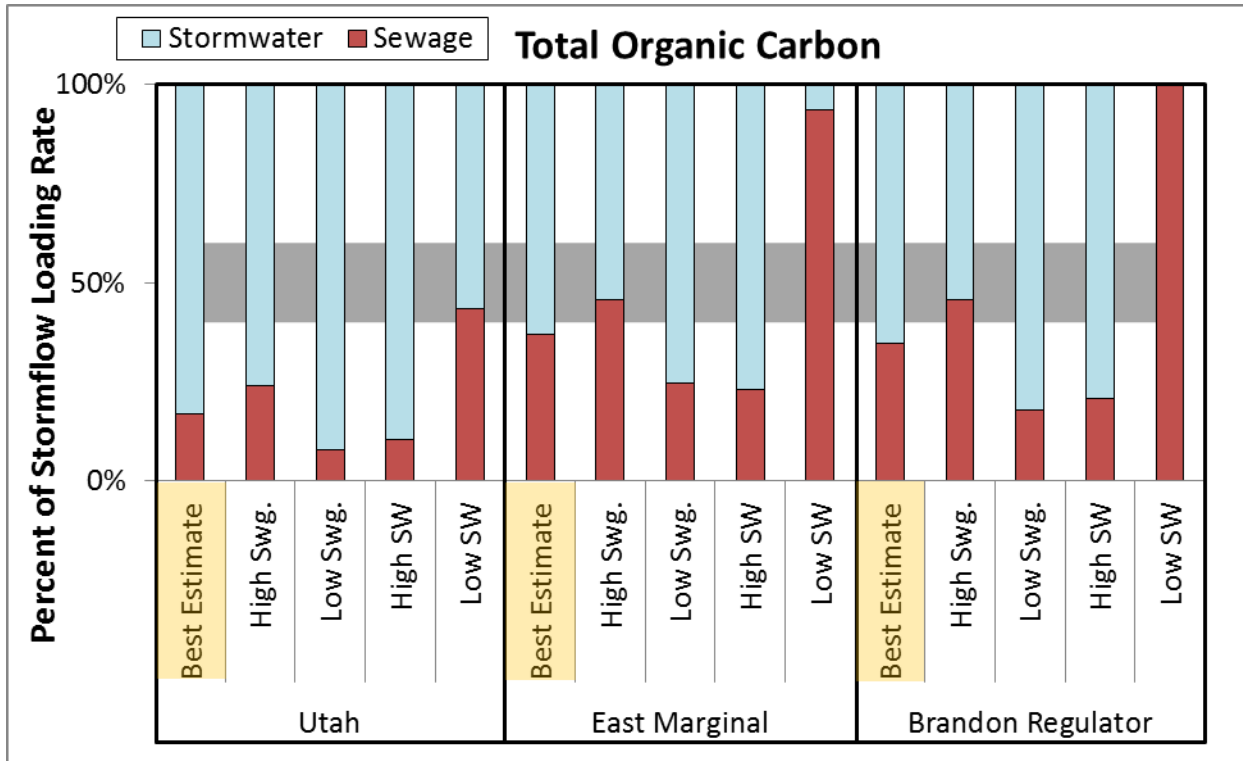


Figure F-1. Uncertainty Assessment: Relative Magnitude of Pathways During Stormflow for Total Organic Carbon Estimated Under Five Different Scenarios.

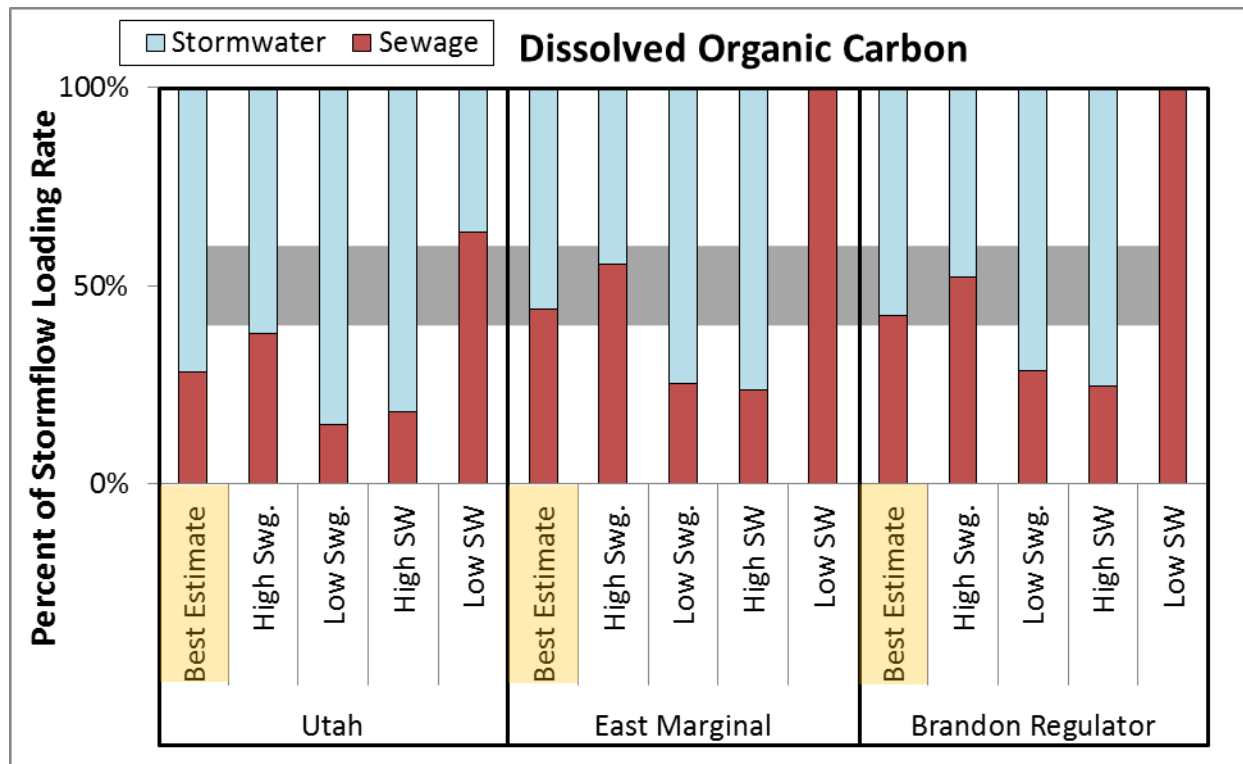


Figure F-2. Uncertainty Assessment: Relative Magnitude of Pathways During Stormflow for Dissolved Organic Carbon Estimated Under Five Different Scenarios.

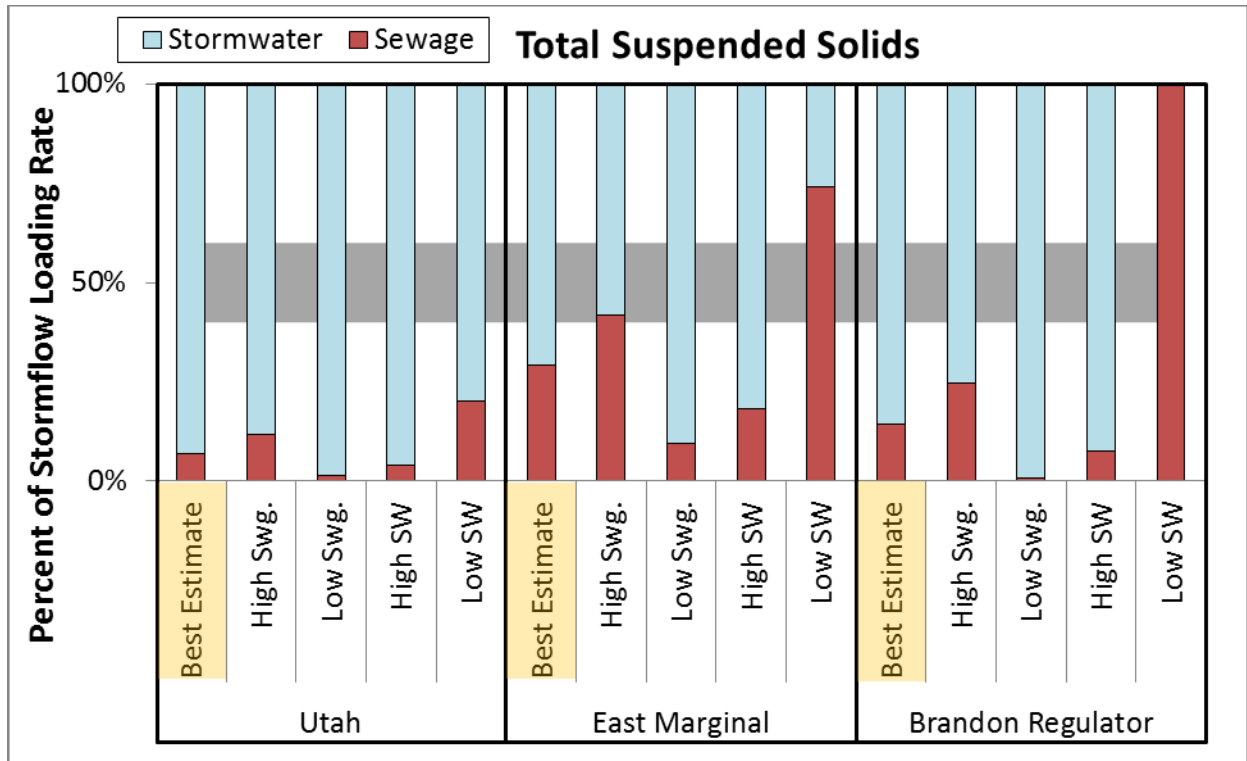


Figure F-3. Uncertainty Assessment: Relative Magnitude of Pathways During Stormflow for Total Suspended Solids Estimated Under Five Different Scenarios.

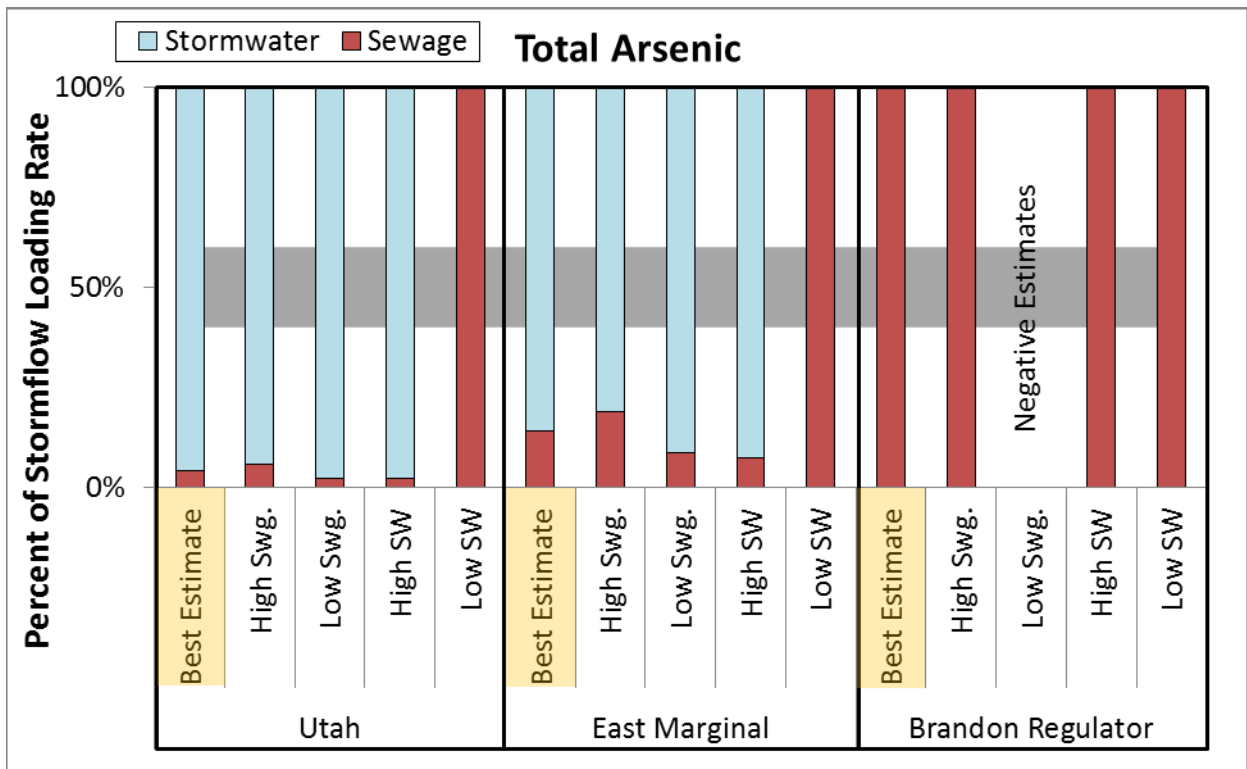


Figure F-4. Uncertainty Assessment: Relative Magnitude of Pathways During Stormflow for Total Arsenic Estimated Under Five Different Scenarios.

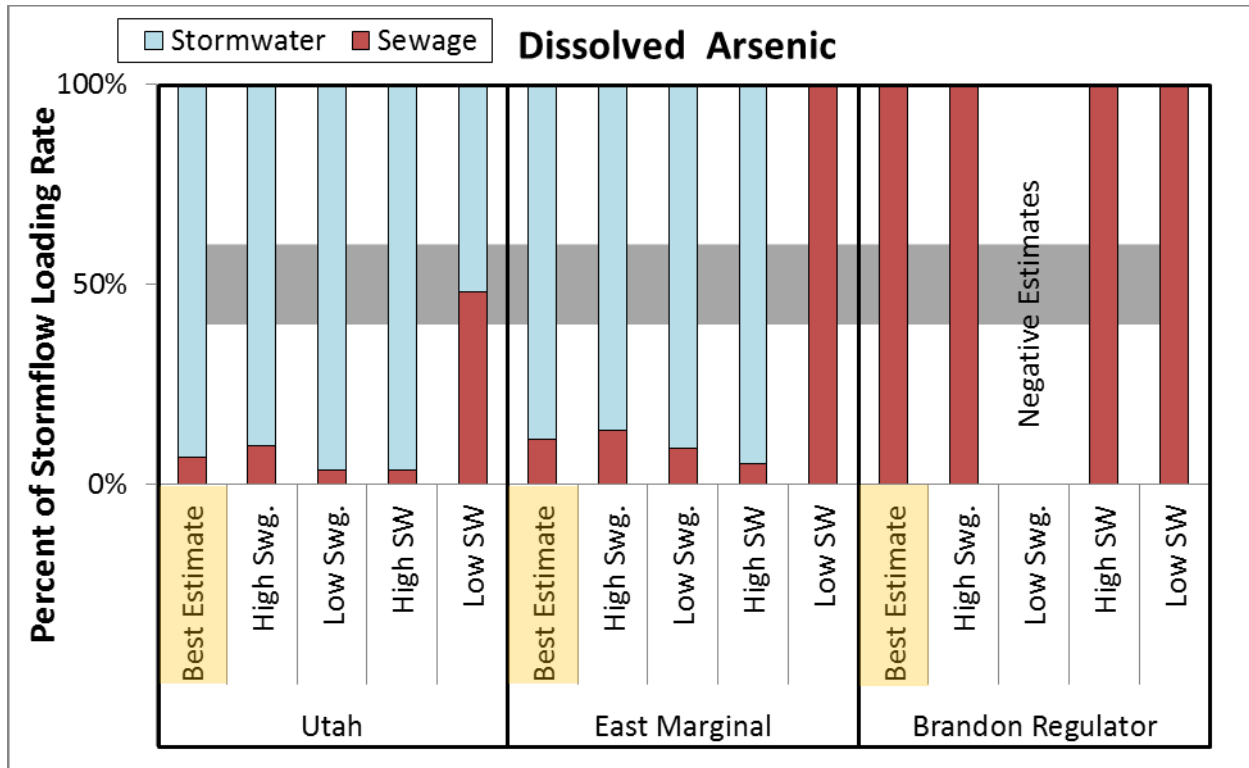


Figure F-5. Uncertainty Assessment: Relative Magnitude of Pathways During Stormflow for Dissolved Arsenic Estimated Under Five Different Scenarios.

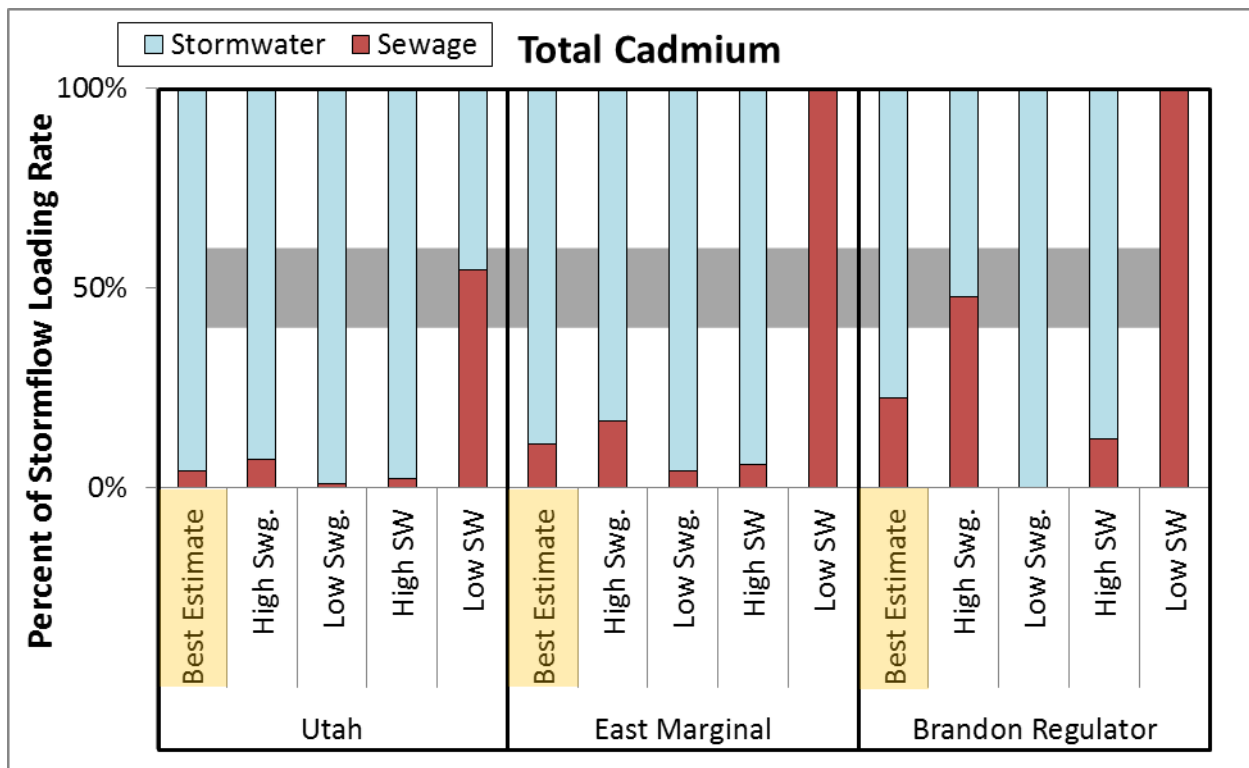


Figure F-6. Uncertainty Assessment: Relative Magnitude of Pathways During Stormflow for Total Cadmium Estimated Under Five Different Scenarios.

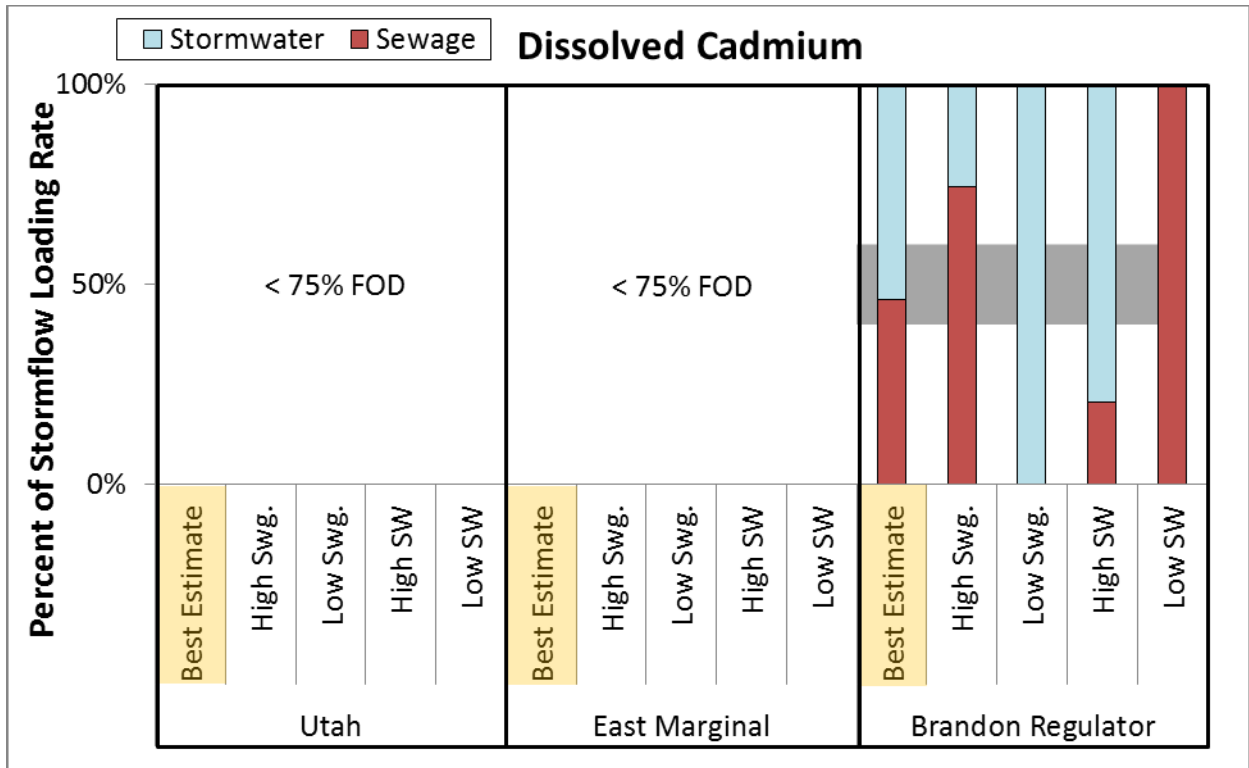


Figure F-7. Uncertainty Assessment: Relative Magnitude of Pathways During Stormflow for Dissolved Cadmium Estimated Under Five Different Scenarios.

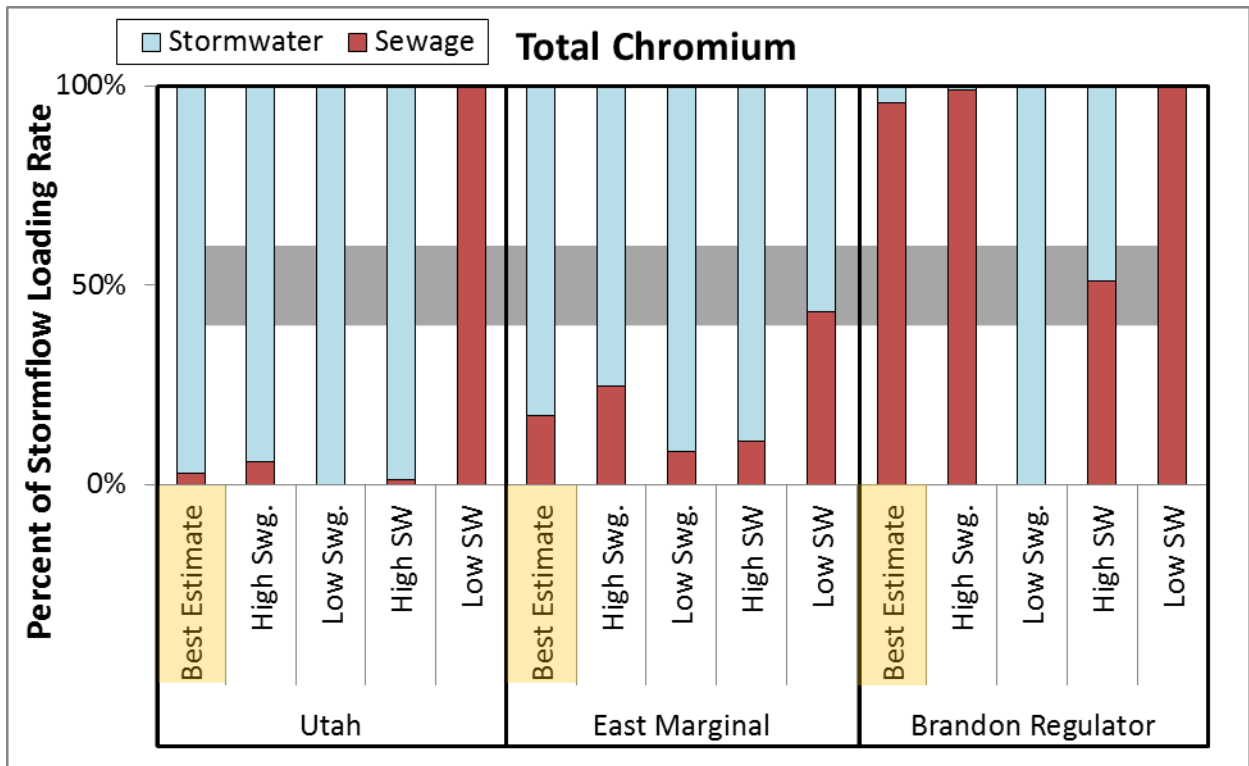


Figure F-8. Uncertainty Assessment: Relative Magnitude of Pathways During Stormflow for Total Chromium Estimated Under Five Different Scenarios.

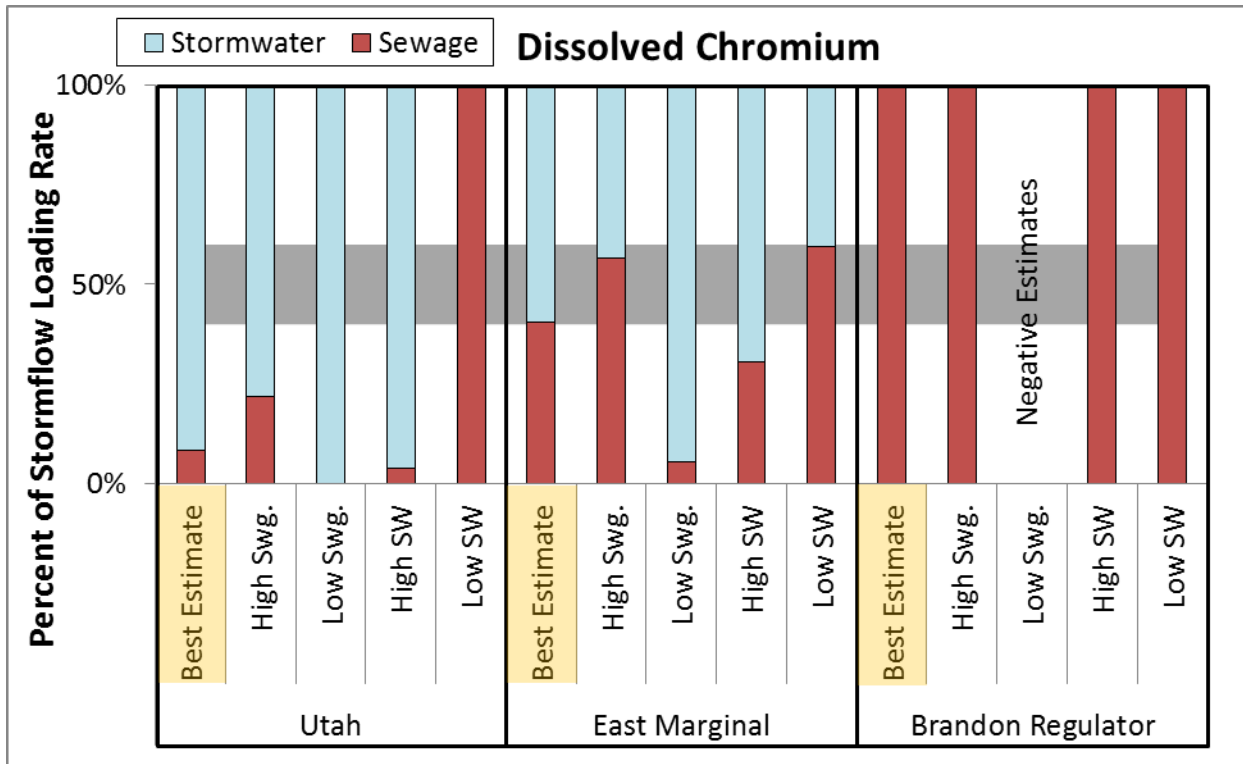


Figure F-9. Uncertainty Assessment: Relative Magnitude of Pathways During Stormflow for Dissolved Chromium Estimated Under Five Different Scenarios.

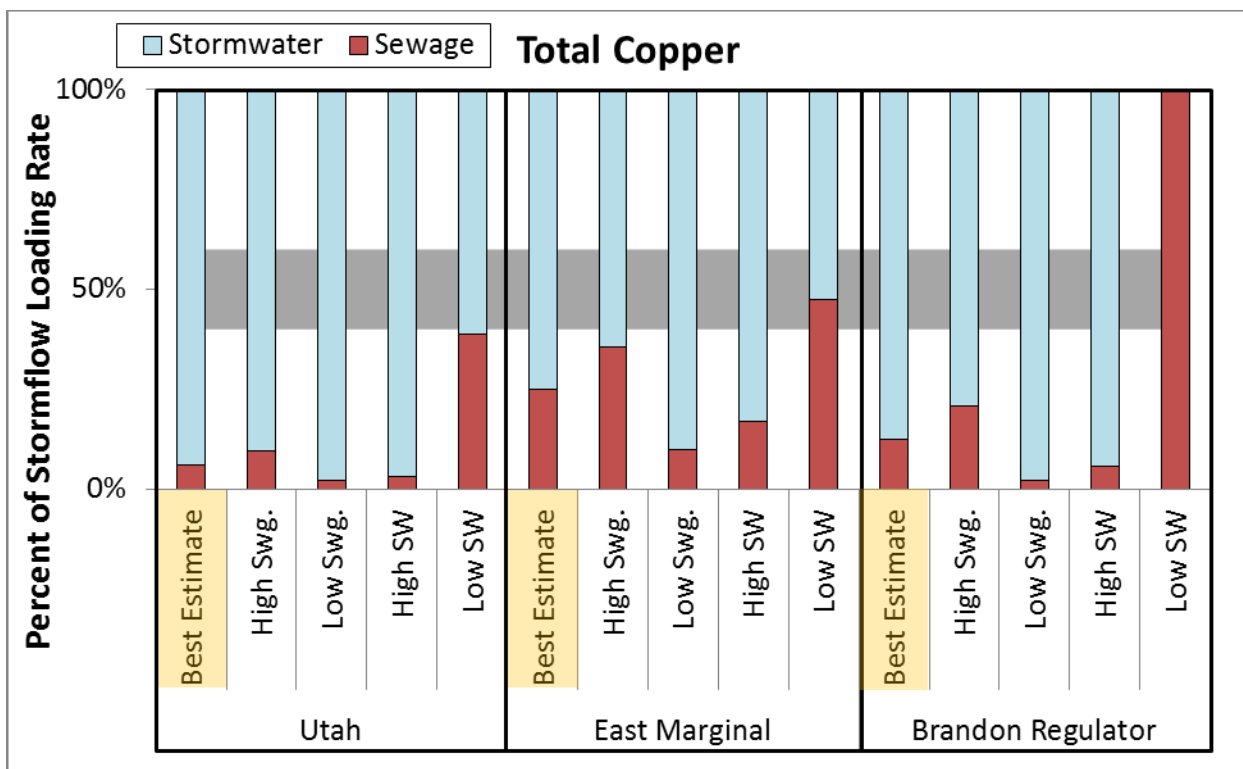


Figure F-10. Uncertainty Assessment: Relative Magnitude of Pathways During Stormflow for Total Copper Estimated Under Five Different Scenarios.

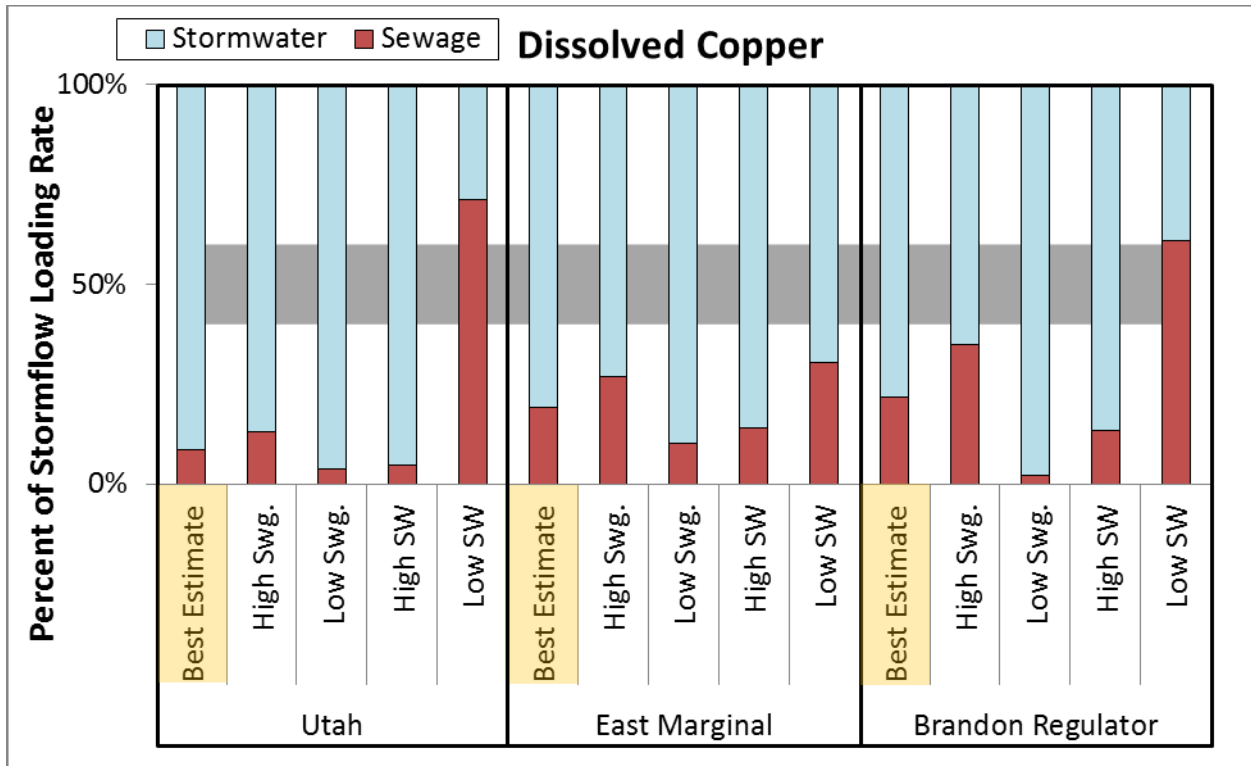


Figure F-11. Uncertainty Assessment: Relative Magnitude of Pathways During Stormflow for Dissolved Copper Estimated Under Five Different Scenarios.

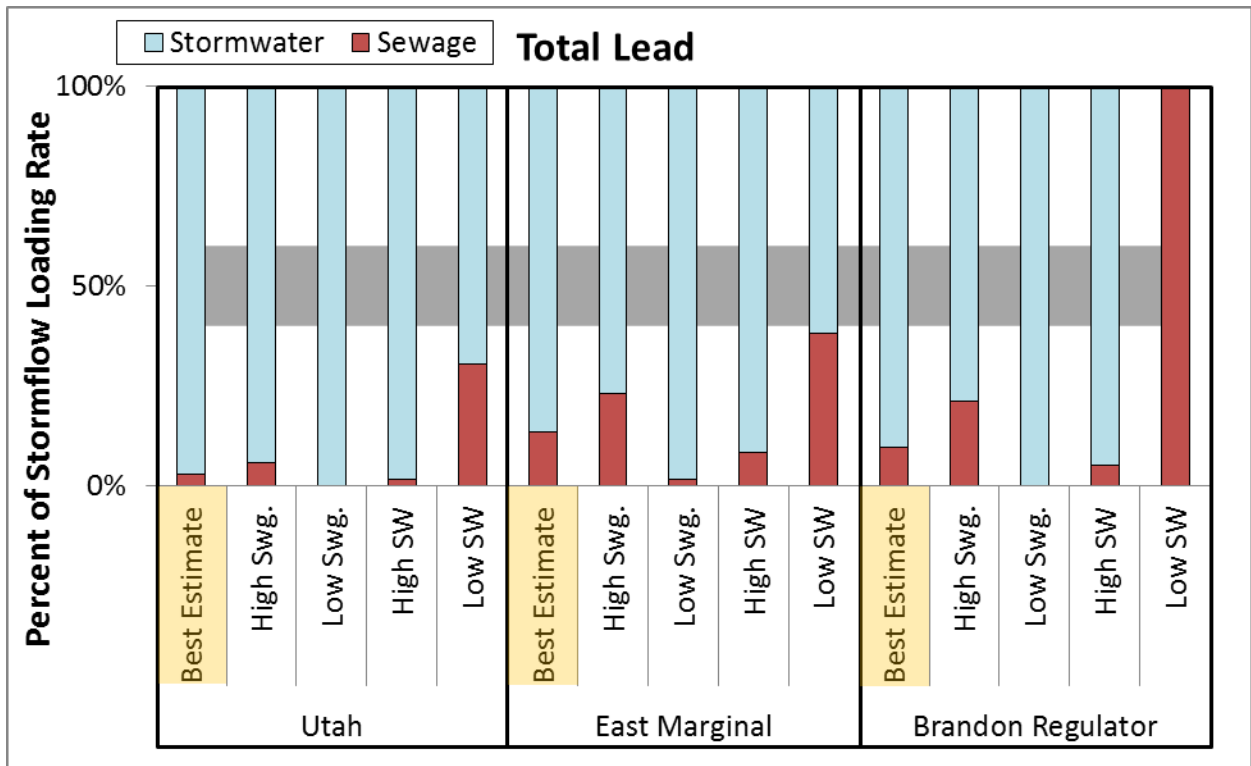


Figure F-12. Uncertainty Assessment: Relative Magnitude of Pathways During Stormflow for Total Lead Estimated Under Five Different Scenarios.

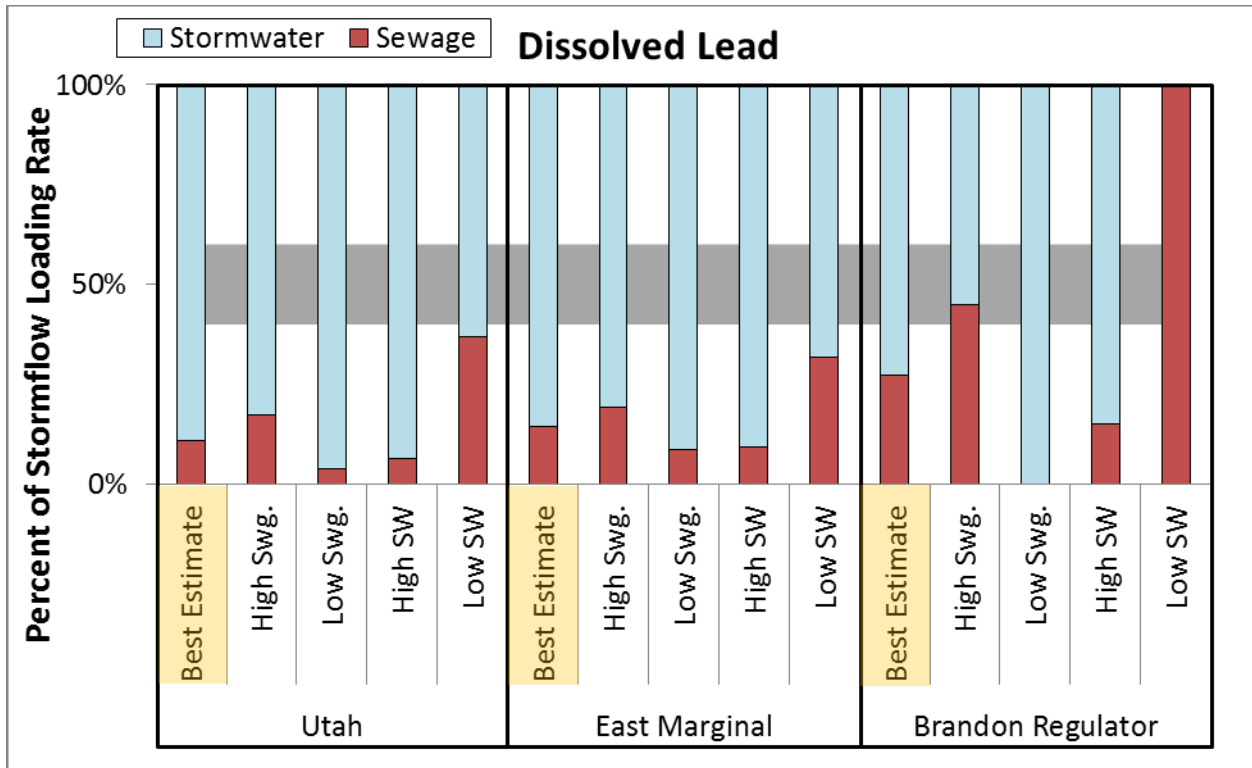


Figure F-13. Uncertainty Assessment: Relative Magnitude of Pathways During Stormflow for Dissolved Lead Estimated Under Five Different Scenarios.

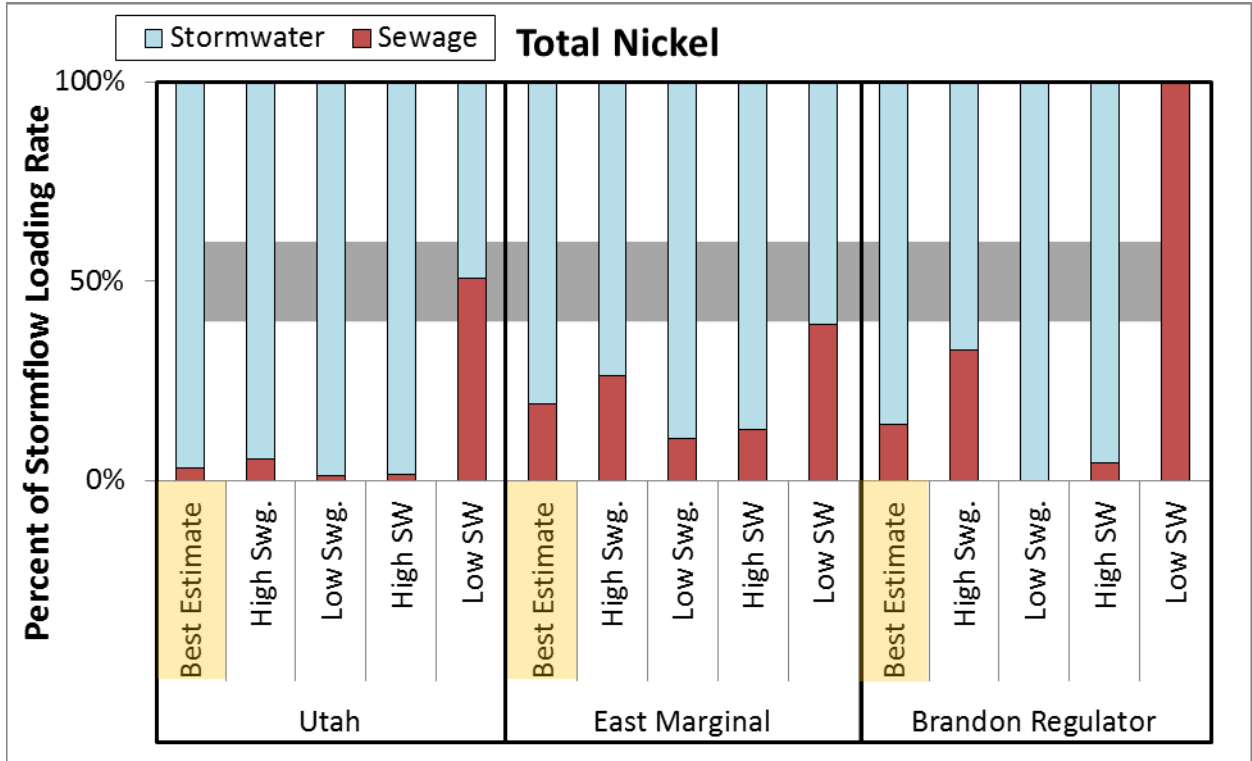


Figure F-14. Uncertainty Assessment: Relative Magnitude of Pathways During Stormflow for Total Nickel Estimated Under Five Different Scenarios.

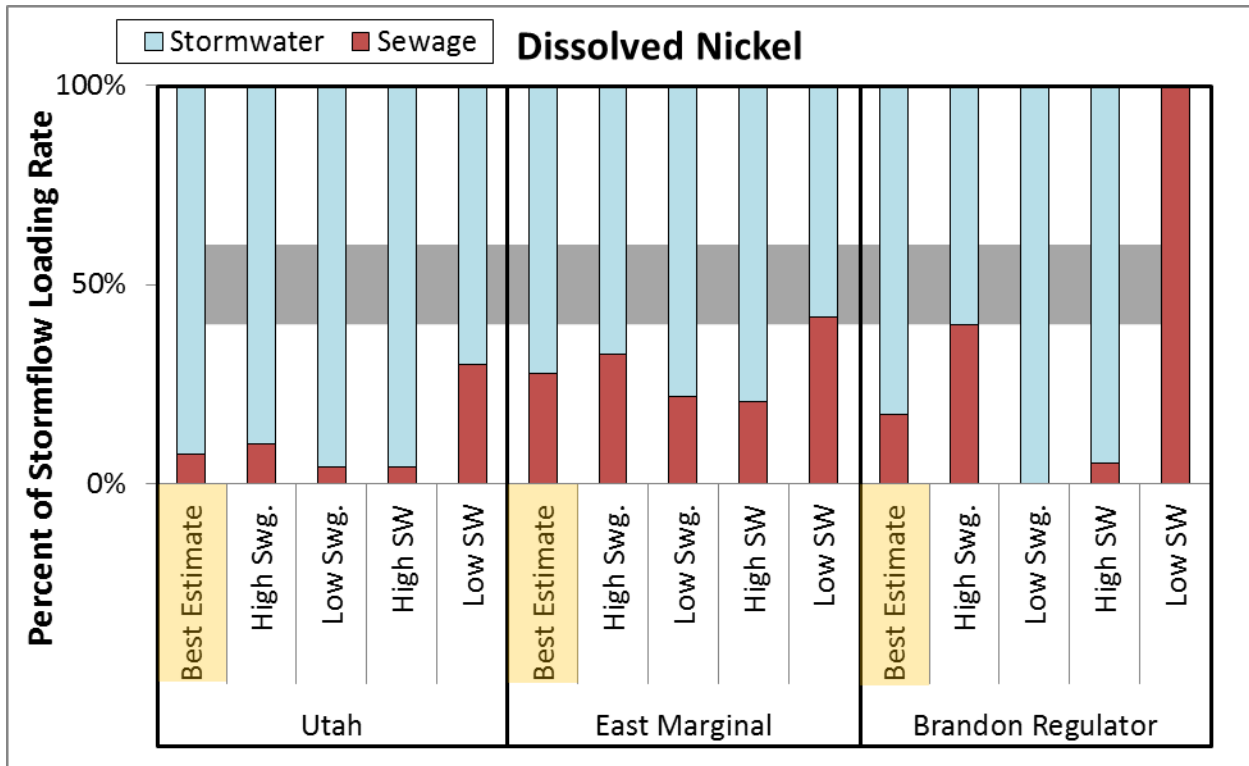


Figure F-15. Uncertainty Assessment: Relative Magnitude of Pathways During Stormflow for Dissolved Nickel Estimated Under Five Different Scenarios.

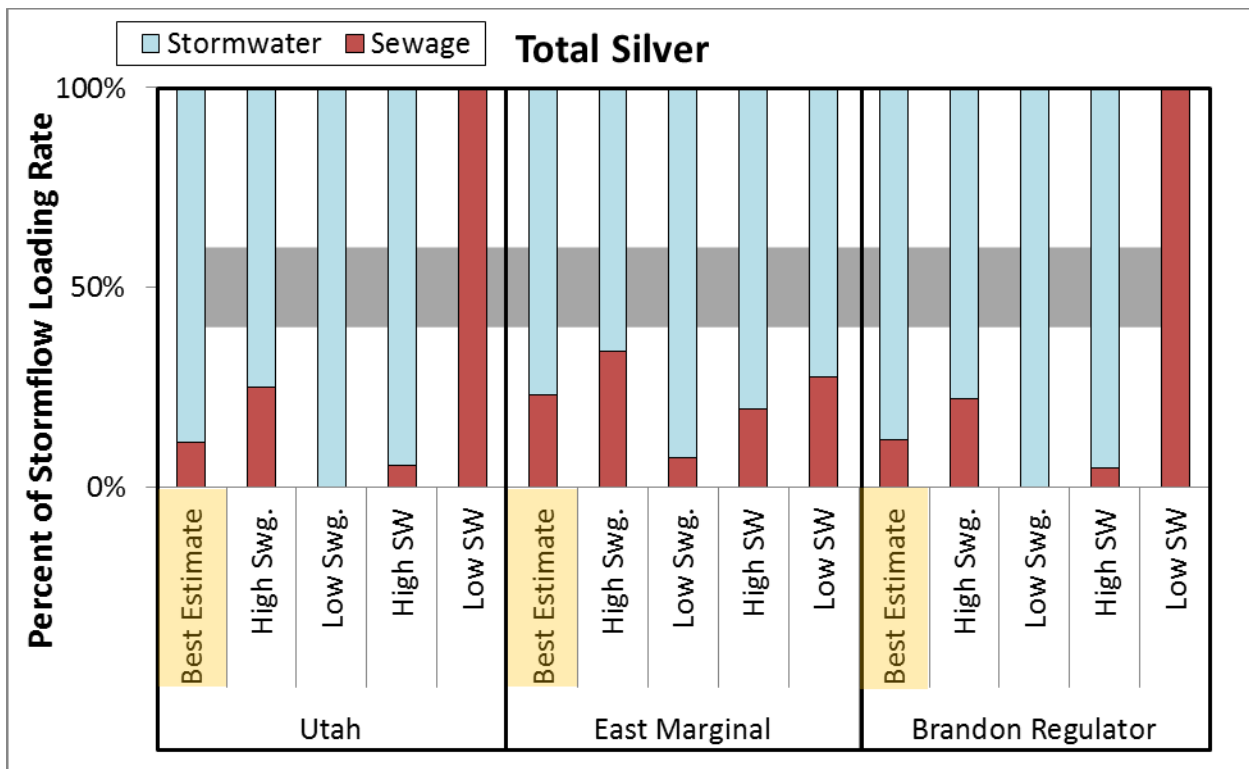


Figure F-16. Uncertainty Assessment: Relative Magnitude of Pathways During Stormflow for Total Silver Estimated Under Five Different Scenarios.

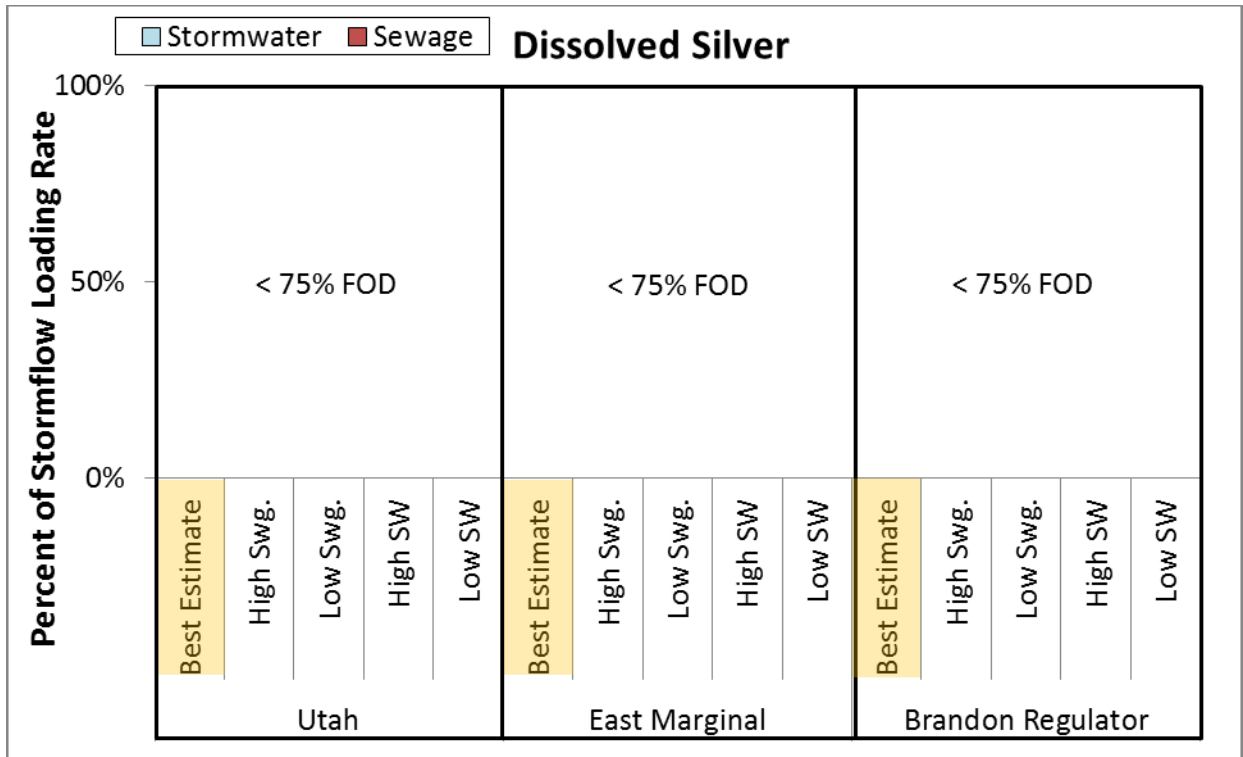


Figure F-17. Uncertainty Assessment: Relative Magnitude of Pathways During Stormflow for Dissolved Silver Estimated Under Five Different Scenarios.

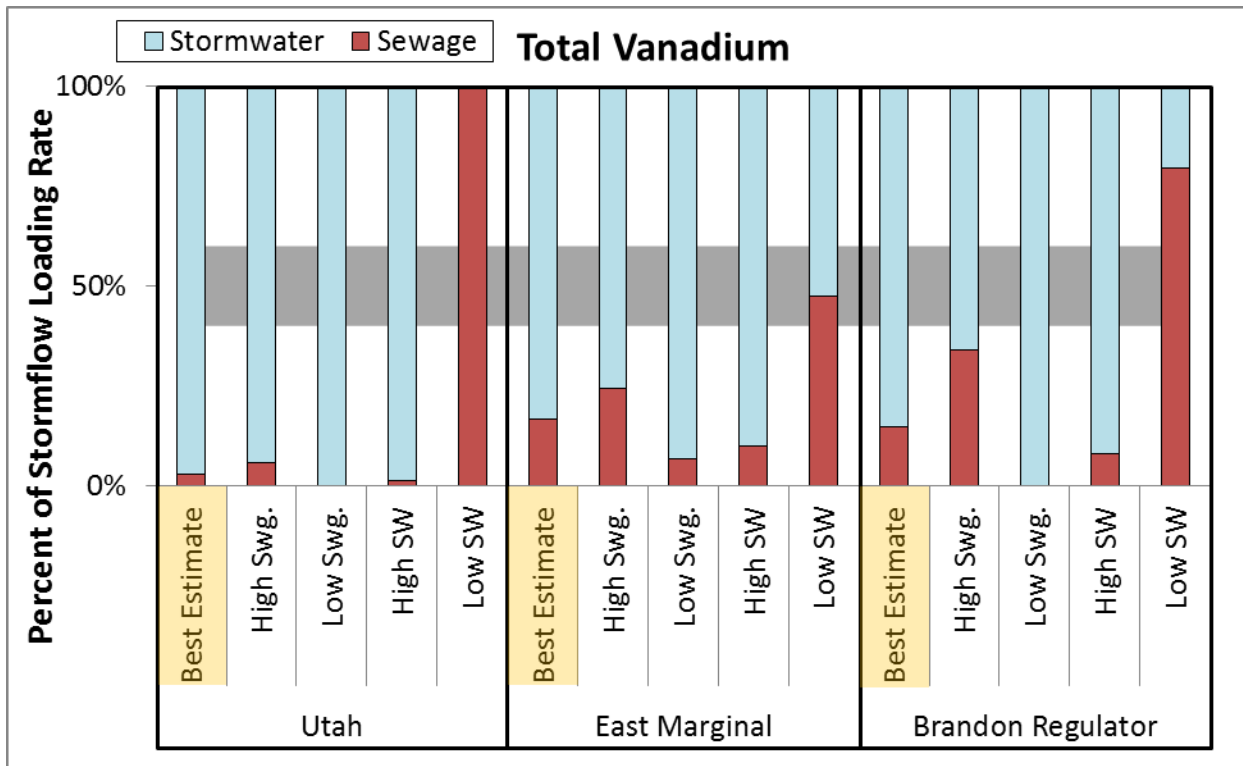


Figure F-18. Uncertainty Assessment: Relative Magnitude of Pathways During Stormflow for Total Vanadium Estimated Under Five Different Scenarios.

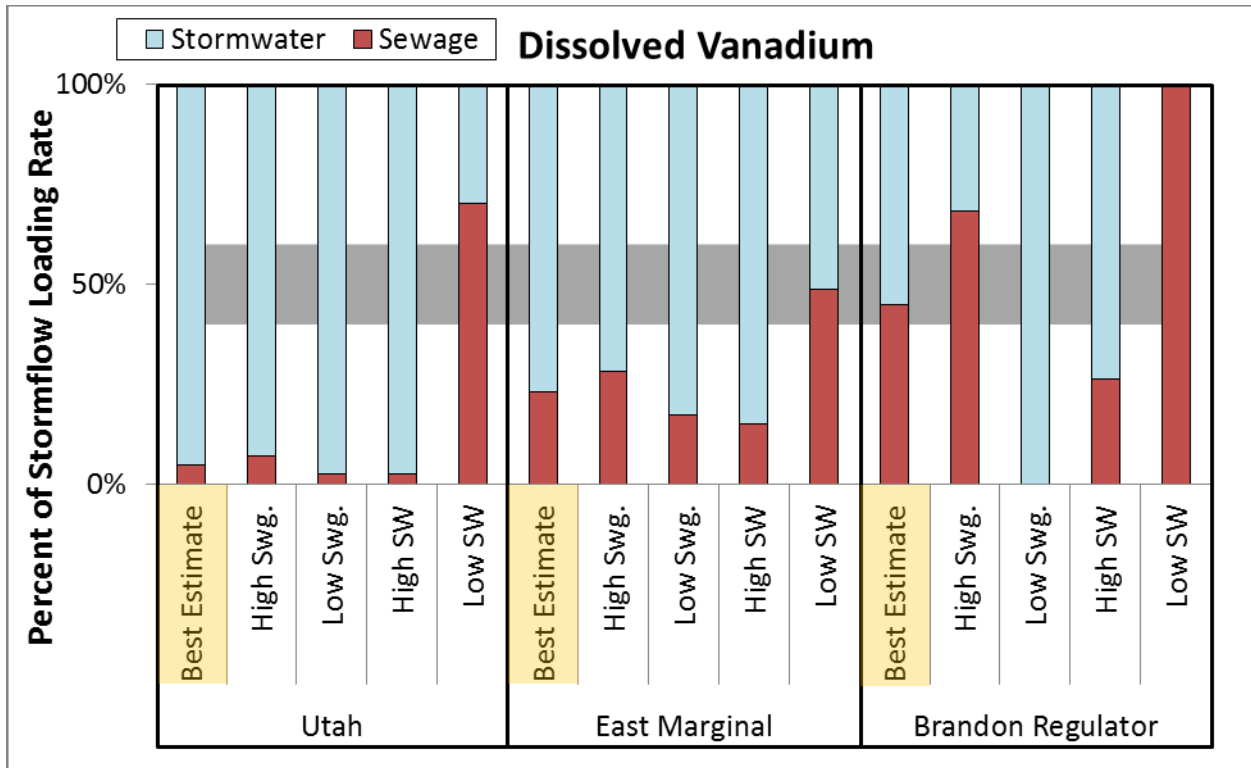


Figure F-19. Uncertainty Assessment: Relative Magnitude of Pathways During Stormflow for Dissolved Vanadium Estimated Under Five Different Scenarios.

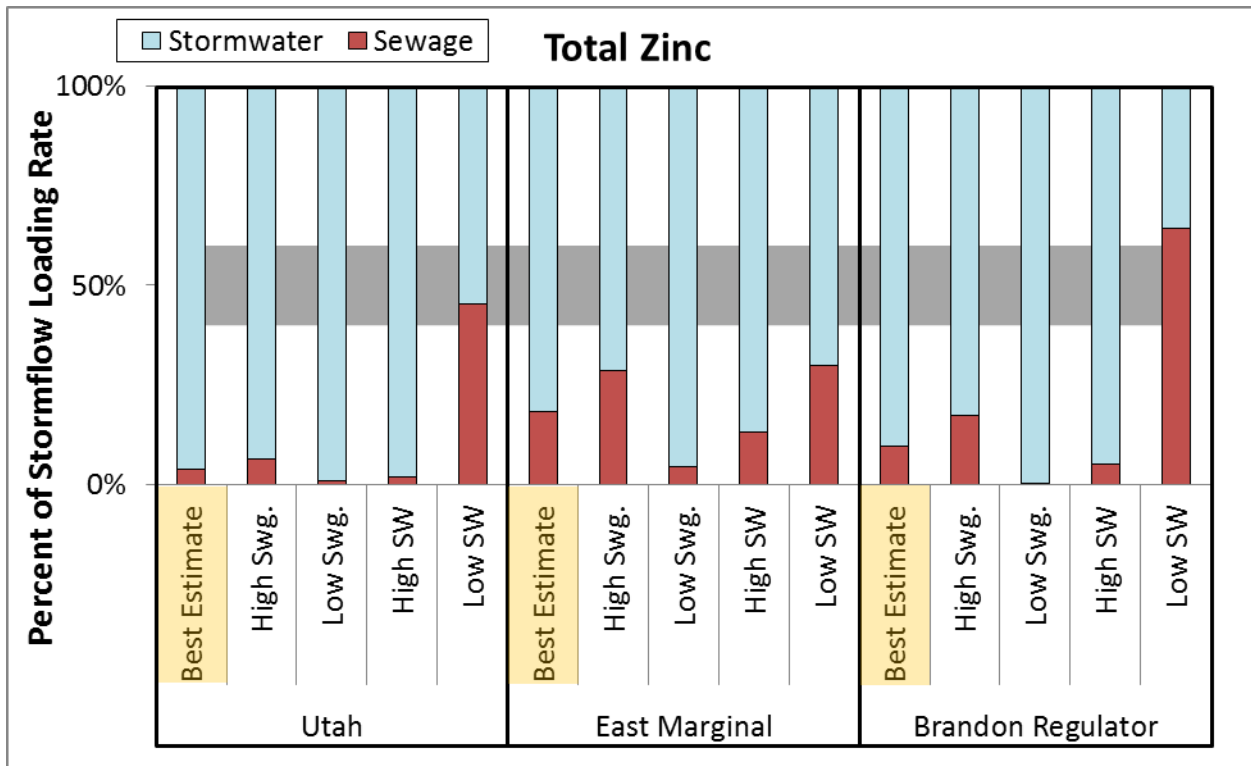


Figure F-20. Uncertainty Assessment: Relative Magnitude of Pathways During Stormflow for Total Zinc Estimated Under Five Different Scenarios.

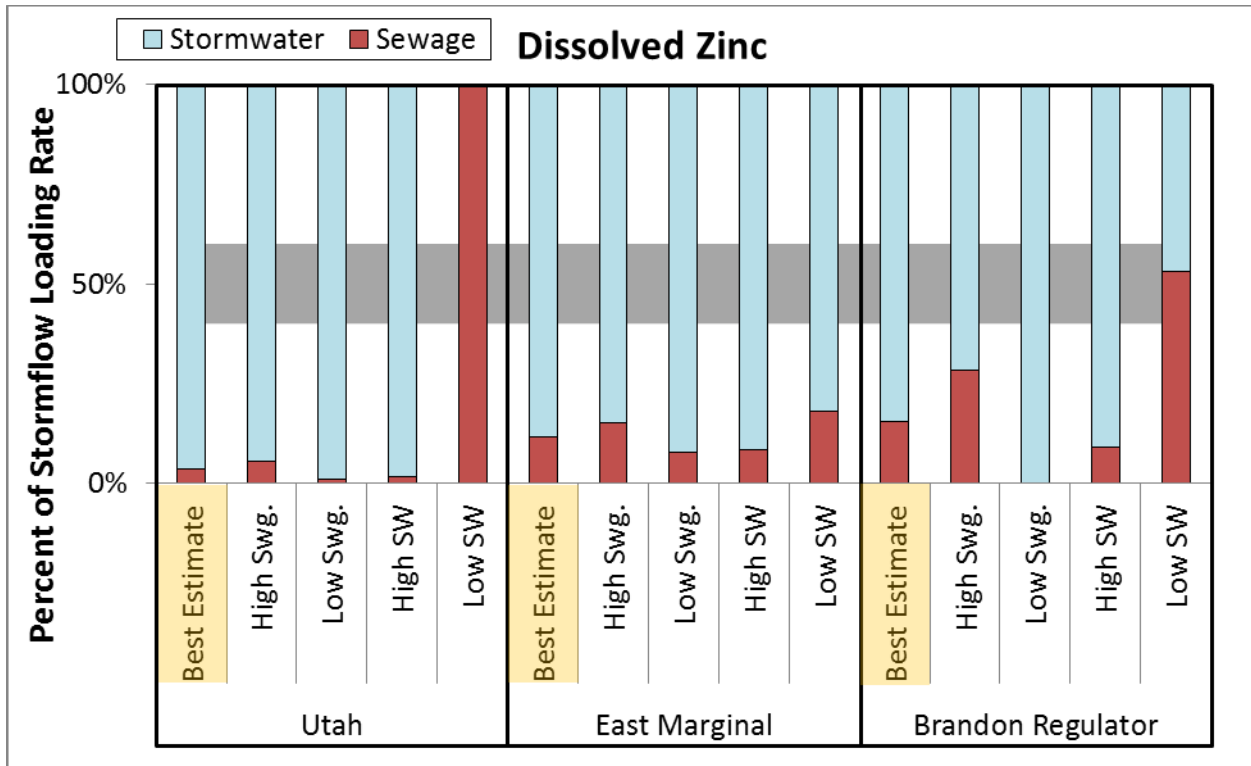


Figure F-21. Uncertainty Assessment: Relative Magnitude of Pathways During Stormflow for Dissolved Zinc Estimated Under Five Different Scenarios.

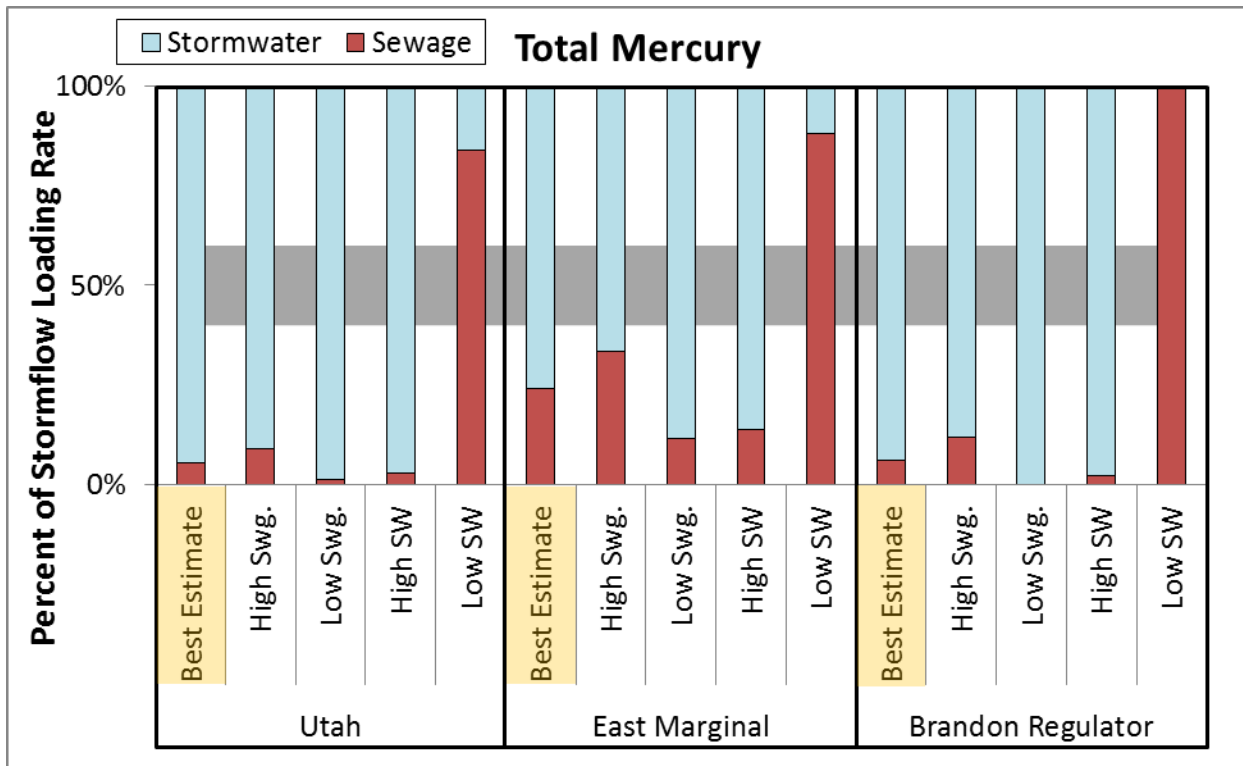


Figure F-22. Uncertainty Assessment: Relative Magnitude of Pathways During Stormflow for Total Mercury Estimated Under Five Different Scenarios.

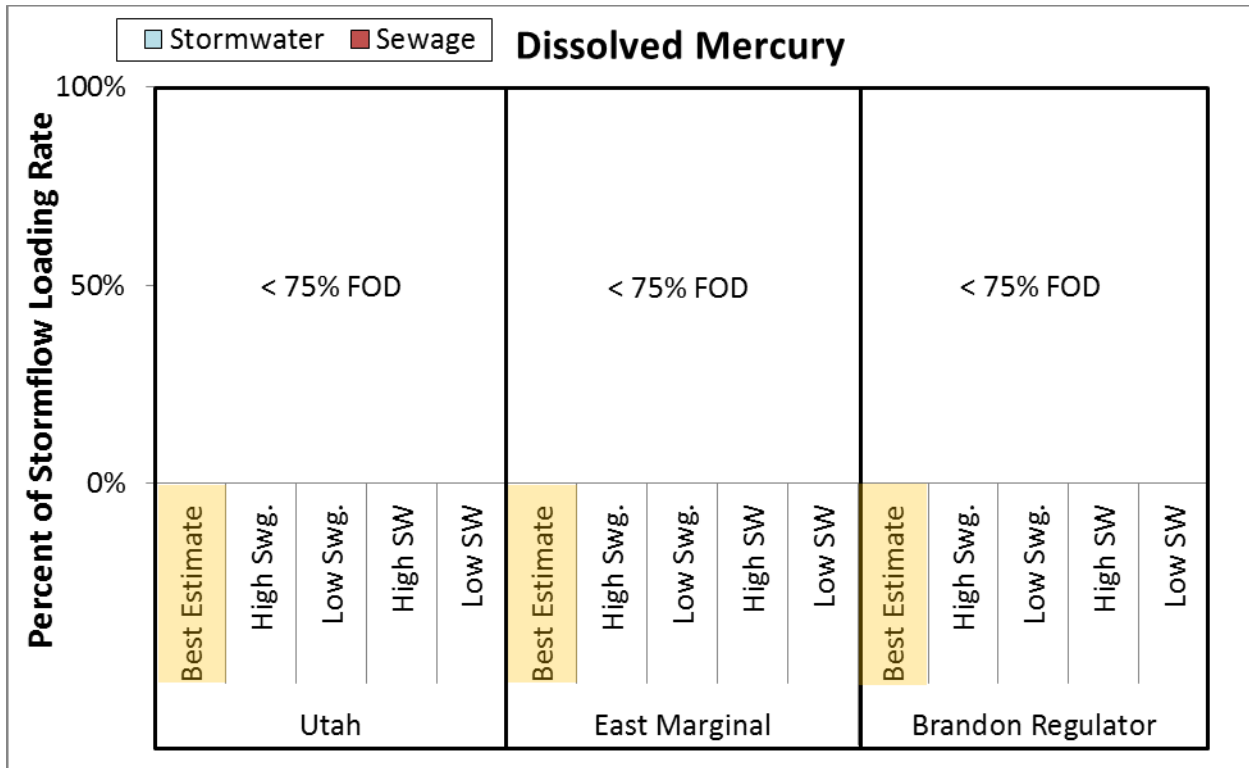


Figure F-23. Uncertainty Assessment: Relative Magnitude of Pathways During Stormflow for Dissolved Mercury Estimated Under Five Different Scenarios.

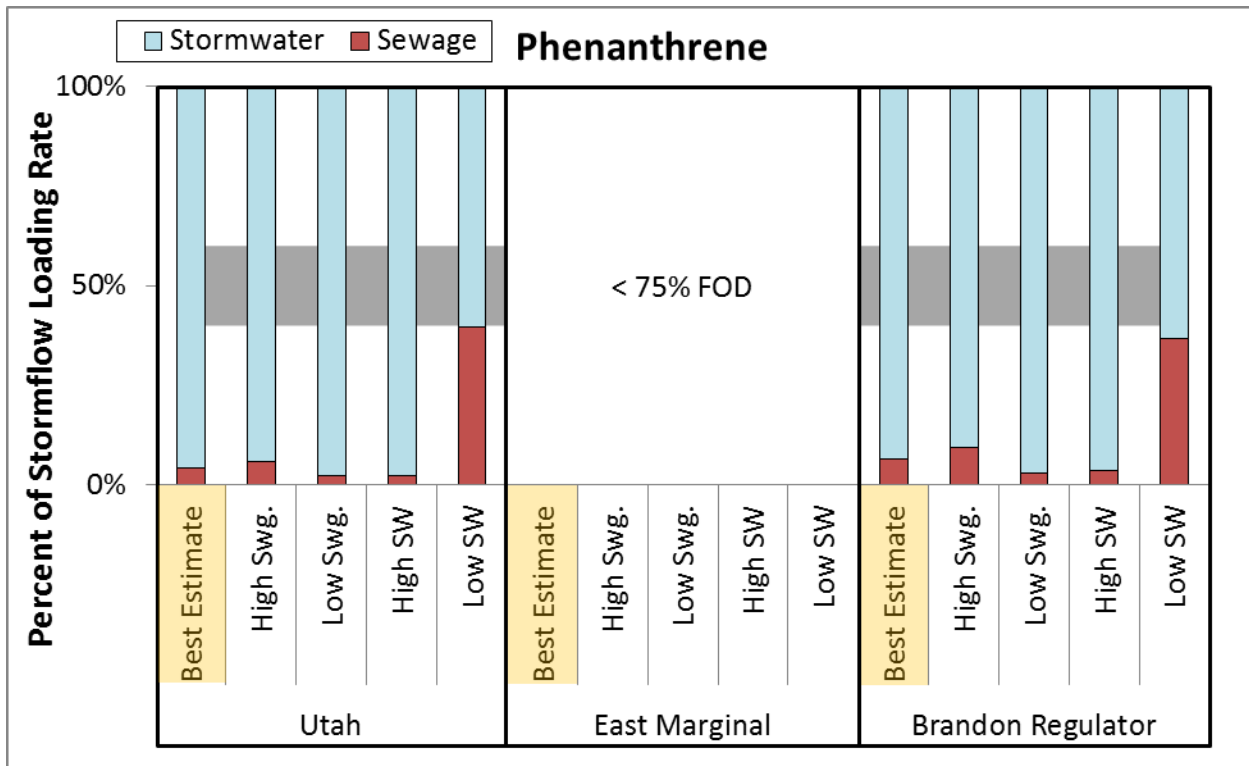


Figure F-24. Uncertainty Assessment: Relative Magnitude of Pathways During Stormflow for Phenanthrene Estimated Under Five Different Scenarios.

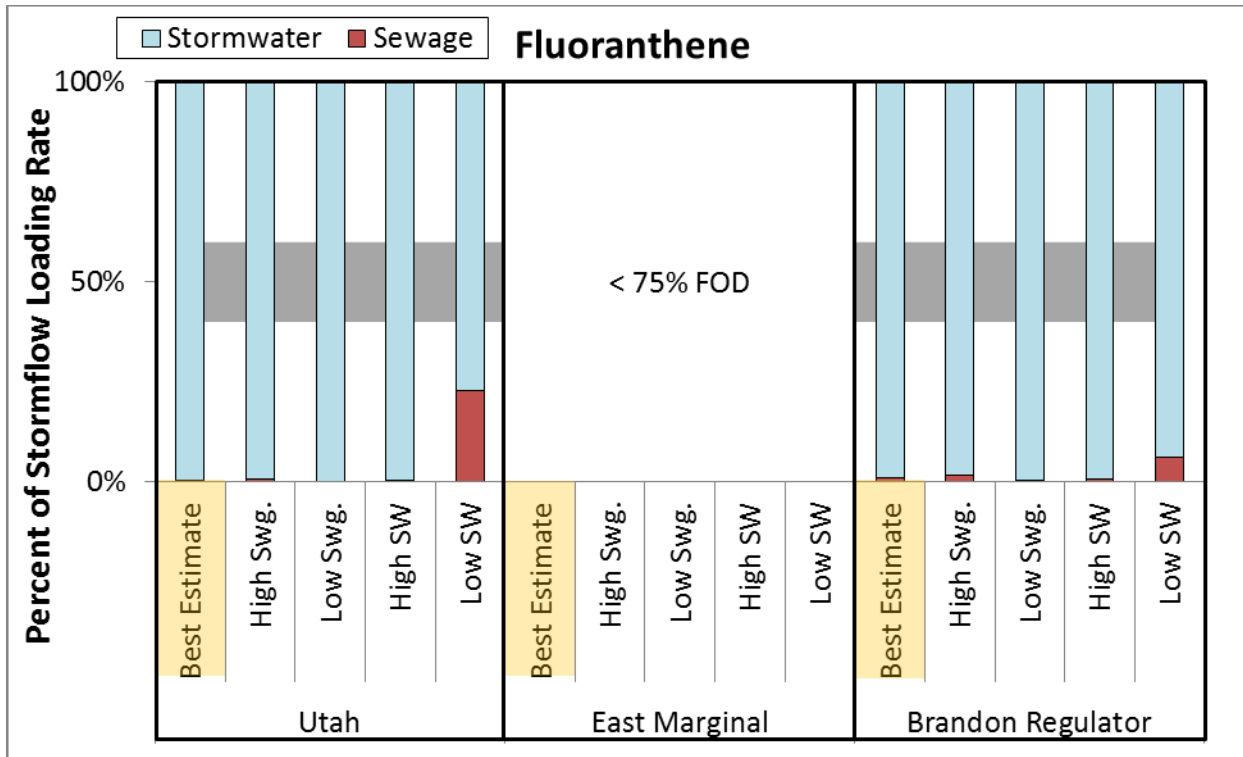


Figure F-25. Uncertainty Assessment: Relative Magnitude of Pathways During Stormflow for Fluoranthene Estimated Under Five Different Scenarios.

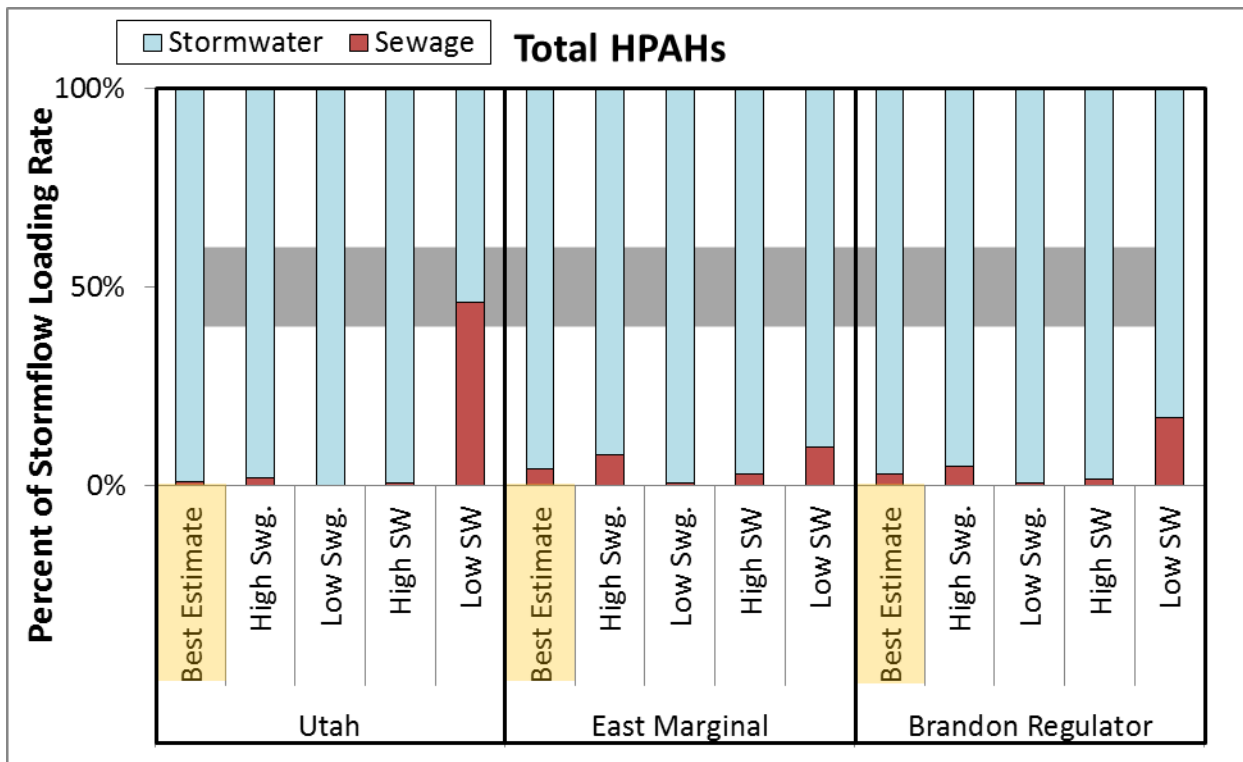


Figure F-26. Uncertainty Assessment: Relative Magnitude of Pathways During Stormflow for Total HPAHs Estimated Under Five Different Scenarios.

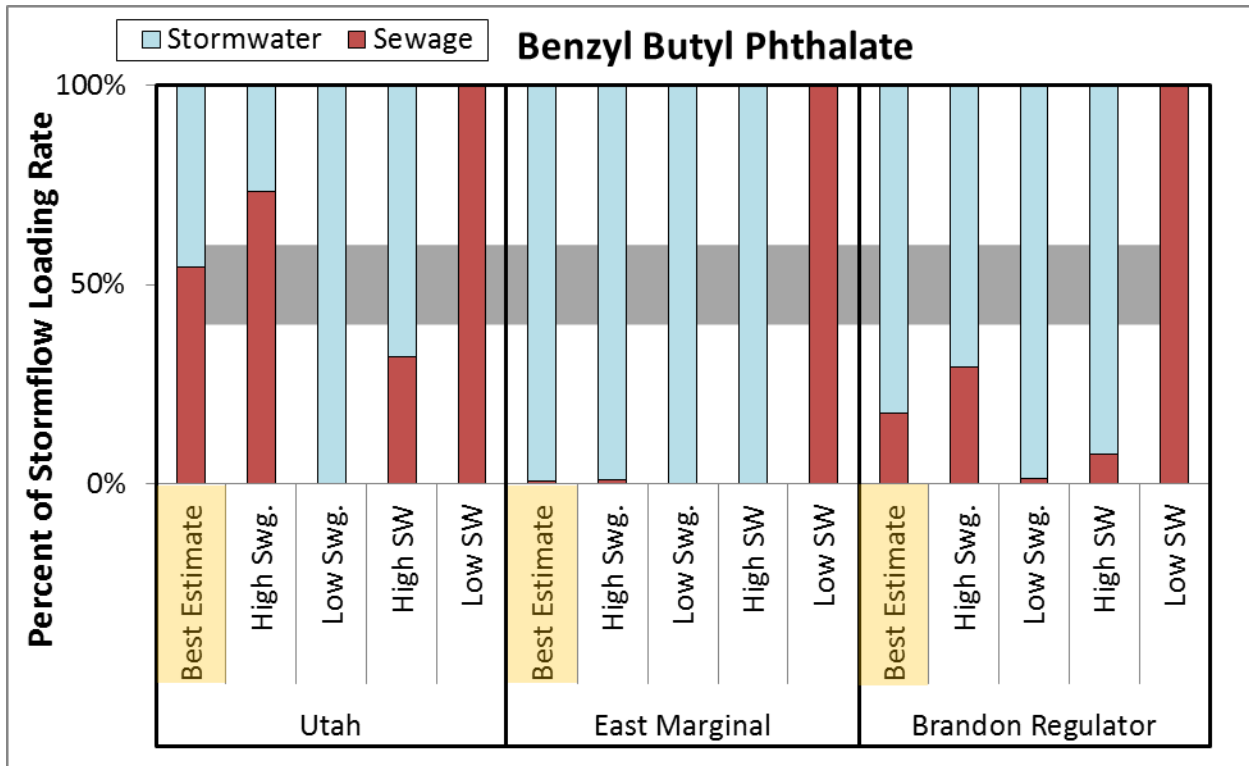


Figure F-27. Uncertainty Assessment: Relative Magnitude of Pathways During Stormflow for Benzyl Butyl Phthalate Estimated Under Five Different Scenarios.

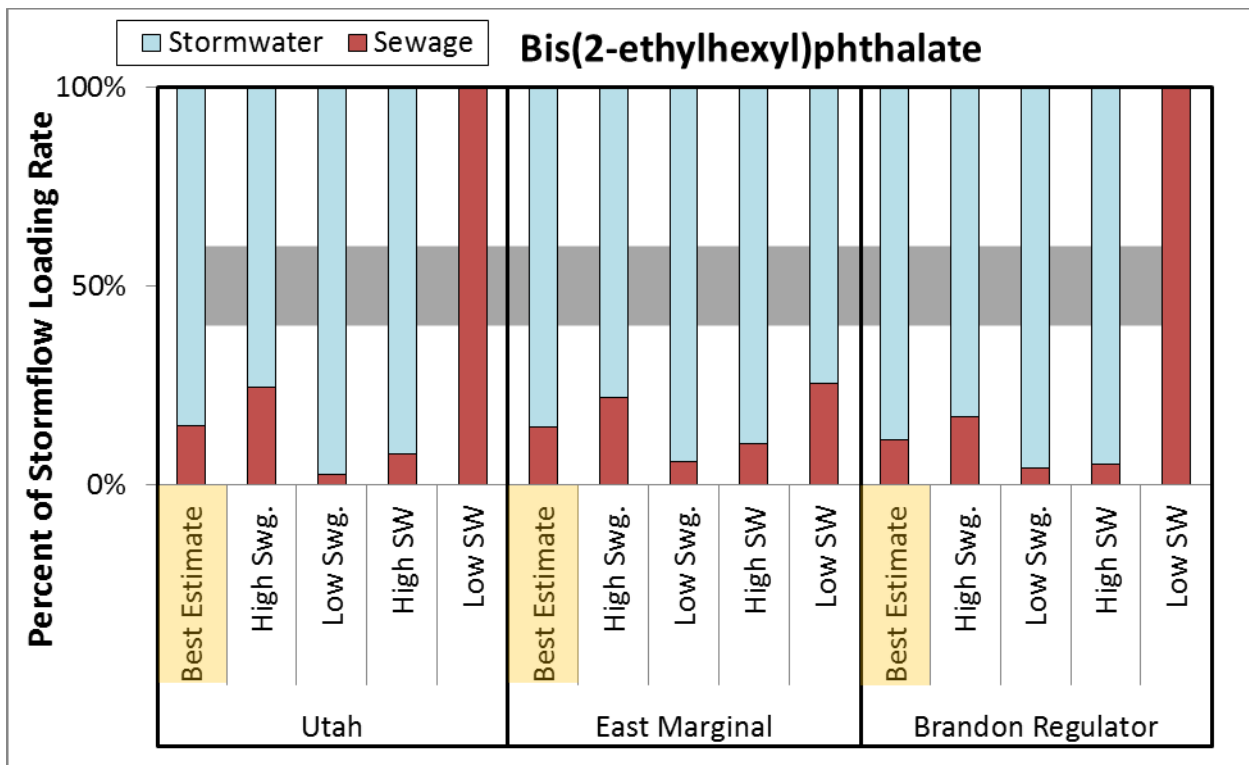


Figure F-28. Uncertainty Assessment: Relative Magnitude of Pathways During Stormflow for Bis(2-ethylhexyl)phthalate Estimated Under Five Different Scenarios.

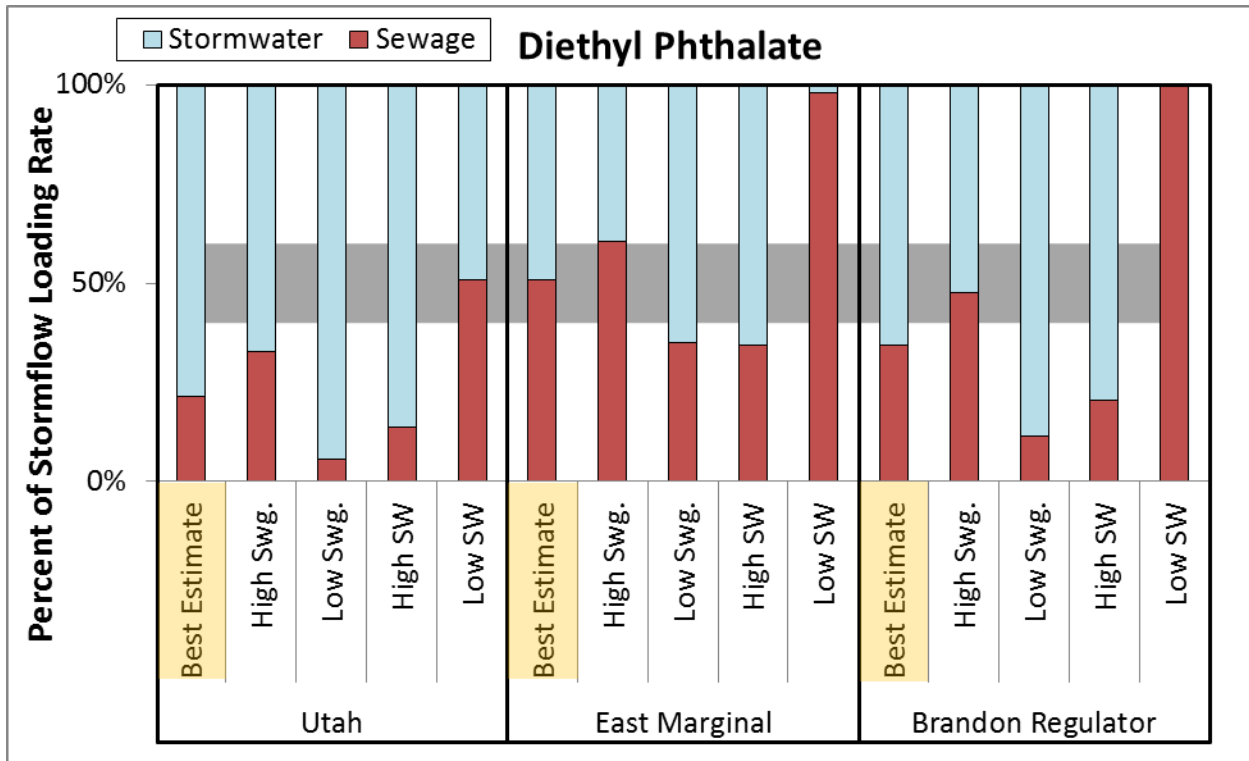


Figure F-29. Uncertainty Assessment: Relative Magnitude of Pathways During Stormflow for Diethyl Phthalate Estimated Under Five Different Scenarios.

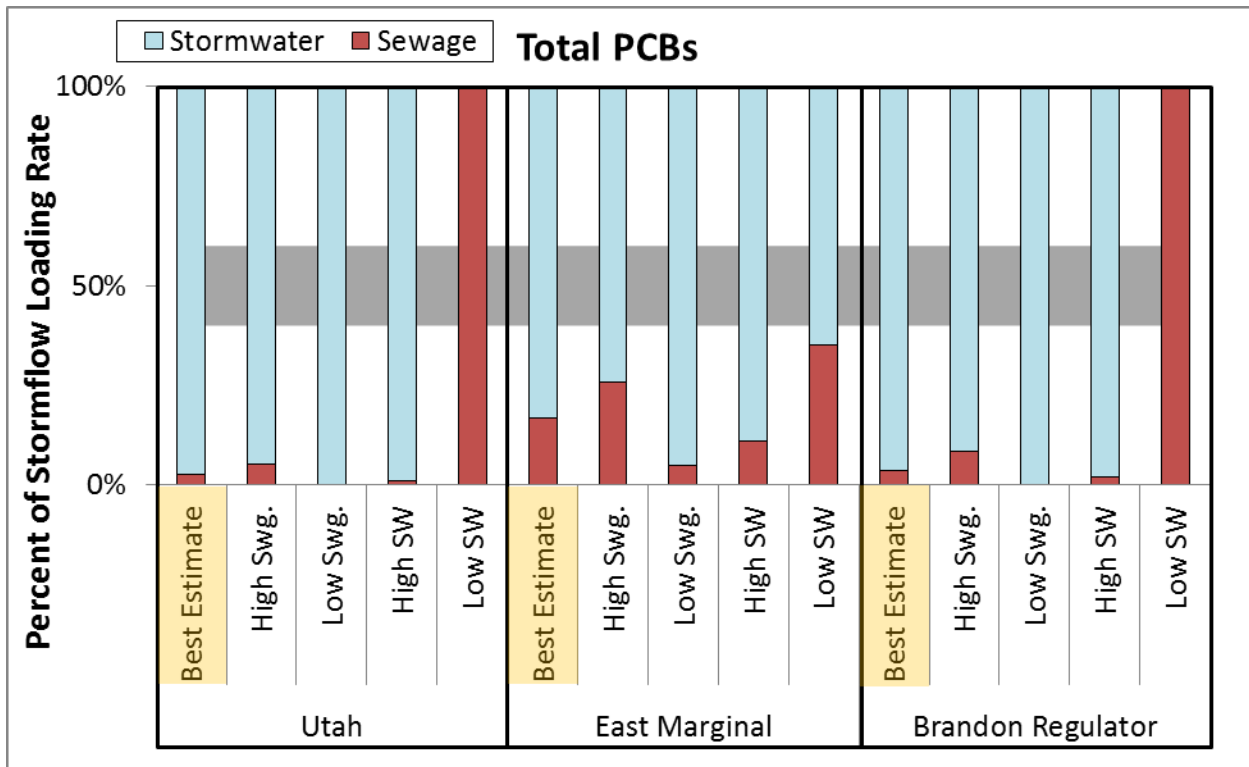


Figure F-30. Uncertainty Assessment: Relative Magnitude of Pathways During Stormflow for Total PCBs Estimated Under Five Different Scenarios.

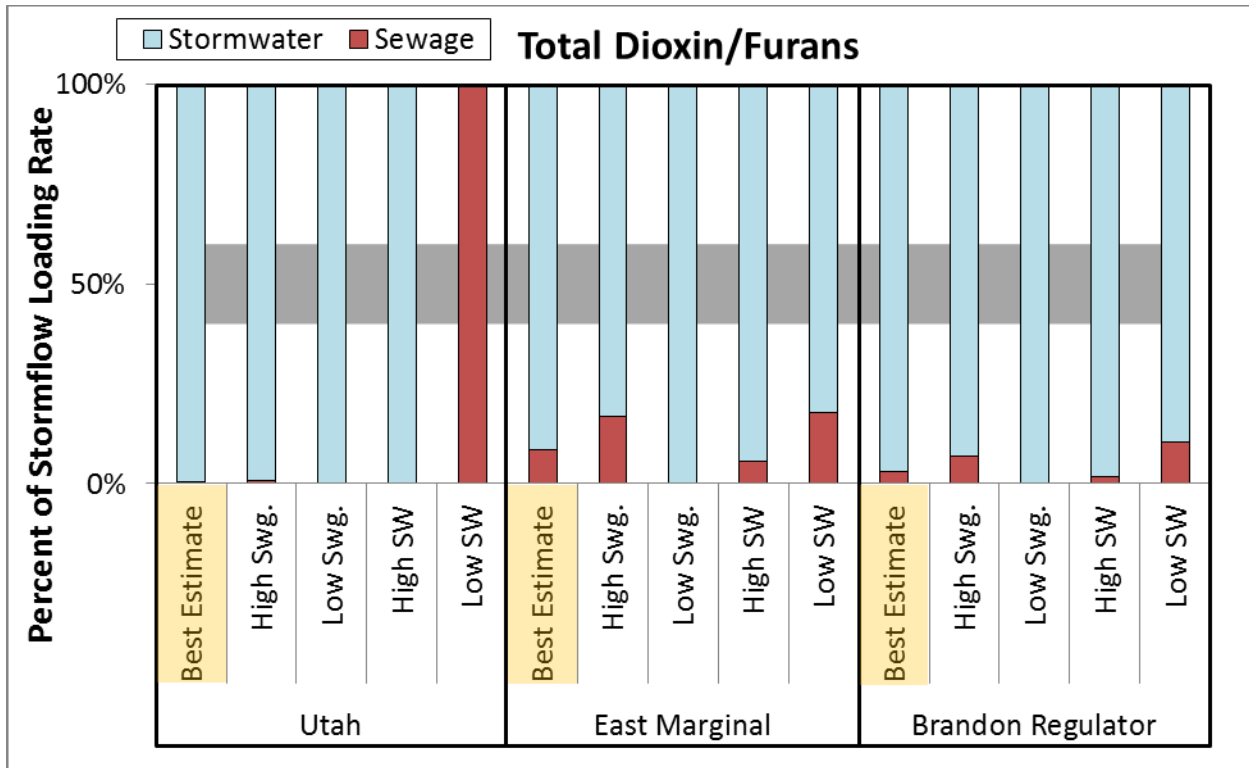


Figure F-31. Uncertainty Assessment: Relative Magnitude of Pathways During Stormflow for Total Dioxin/Furans Estimated Under Five Different Scenarios.

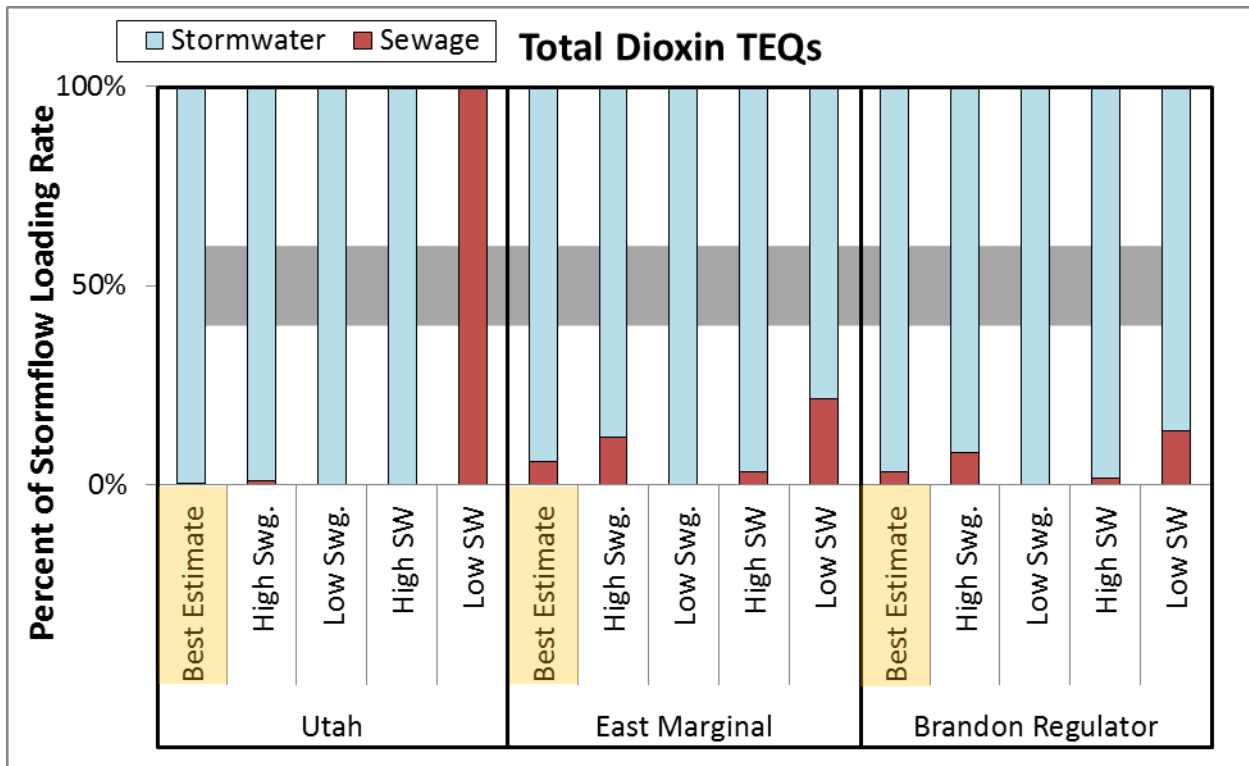


Figure F-32. Uncertainty Assessment: Relative Magnitude of Pathways During Stormflow for Total Dioxin TEQs Estimated Under Five Different Scenarios.