Simplified Evaluation of Dredging Resuspension Effects

Susan E. Bailey and Paul R. Schroeder

The turbidity plume resulting from a clamshell or cutterhead dredge under steady conditions can be estimated using the USACE DREDGE model (Hayes and Je 2000), but does not attempt to characterize the effects on environmental resources. The DREDGE model requires input of several operating parameters such as clamshell or cutterhead dimensions, production information, cutterhead swing velocity, and open bucket cycle time as well as sediment characteristics and site characteristics including settling velocity and grain size, water depth, velocity and diffusion coefficients. As a simplification, the tables presented here were generated to allow quick estimation of dredging effects for sustained dredging operations within typical ranges of channel characteristics and operating parameters. The most critical parameters are the rate of sediment mass being lost during dredging (mass loss potential, kg/s) and the dilution available in the waterway (dilution potential, m^2/s). As mass loss increases, the plume total suspended solids (TSS) concentrations increase, whereas TSS concentrations decrease with increasing dilution. Since TSS plumes are known to have a range of effects on various aquatic species, the stepwise procedure and tables below can be used for a simplified resuspension evaluation to estimate TSS plumes and resulting biological effects. Potential effects on a representative sensitive water column organism are projected.

1. Select Mass Loss Rate Potential Based on Dredge Type, Dredge Size and Sediment % Fines

First determine the mass loss rate potential, which is a function of production rate. For a hydraulic cutterhead dredge, the mass loss rate of fines during dredging is a function of the dredge size and percent fines. For a clamshell dredge, the mass loss rate potential depends on dredge (bucket) size and percent fines, as well as operational factors such as bucket loading and cycle times. Mass loss rate potential was determined over ranges of these factors as shown in Table 1a and Table 2a for a cutterhead dredge or clamshell, respectively. Tables 1b and 2b, then classifies the results into “high”, “medium” and “low” categories for ranges of dredge size and percent fines. For a cutterhead dredge, mass loss rate potential is considered “low” below 0.5 kg/s, “medium” between 0.5 and 1.5 kg/s and “high” above 1.5 kg/s (respectively shown in green, yellow and red in Figure 1a). Mass loss rate potential for a clamshell dredge is considered “low” below 1.0 kg/s and “high” above 4.0 kg/s (similarly shown in green, yellow and red in Figure 2a).

Table 1a. Calculated Mass Loss Rate Potential (kg/s) – Cutterhead Dredge

Dredge Size (in.)	Percent Fines						
	2.5	5	15	45	65	77.5	100
6	0.04	0.05	0.10	0.13	0.12	0.11	0.08
10	0.10	0.14	0.26	0.36	0.34	0.30	0.23
14	0.19	0.28	0.52	0.71	0.66	0.60	0.45
19	0.35	0.52	0.95	1.32	1.22	1.10	0.82
24	0.56	0.83	1.52	2.10	1.95	1.75	1.31
30	0.88	1.30	2.38	3.28	3.05	2.74	2.05
36	1.27	1.88	3.42	4.72	4.39	3.95	2.95

Table 1b. Mass Loss Rate Potential* – Cutterhead Dredge

Dredge Size (in.)	Percent Fines: 0 to 5	5 to 15	15 to 65	65 to 100
6 to 14	Low	Low	Low to Med	Low to Med
14 to 24	Low to Med	Low to Med	Med to High	Med to High
24 to 36	Med to High	Med to High	High	Med to High

* Increases with Dredge Size and % Fines up to 65%, then decreases above 65% Fines.

Table 2a. Calculated Mass Loss Potential (kg/s) – Clamshell Dredge

Conditions		90 % Full Bucket							50 % Full Bucket						
Dredge Size	Cycle Time	Percent Fines							Percent Fines						
CY	sec	2.5	5	15	40	52	65	100	2.5	5	15	40	52	65	100
1	25	0.06	0.08	0.18	0.34	0.38	0.39	0.34	0.03	0.04	0.10	0.19	0.21	0.22	0.19
3.5	25	0.20	0.26	0.64	1.20	1.31	1.36	1.18	0.11	0.15	0.36	0.67	0.73	0.75	0.65
7	25	0.40	0.53	1.29	2.40	2.63	2.71	2.35	0.22	0.29	0.71	1.33	1.46	1.51	1.31
12.5	25	0.71	0.94	2.30	4.29	4.70	4.85	4.20	0.39	0.52	1.28	2.38	2.61	2.69	2.33
18	25	1.02	1.36	3.31	6.17	6.76	6.98	6.05	0.57	0.76	1.84	3.43	3.76	3.88	3.36
29	25	1.65	2.19	5.32	9.94	10.9	11.2	9.74	0.91	1.22	2.96	5.52	6.05	6.25	5.41
40	25	2.27	3.02	7.34	13.7	15.0	15.5	13.4	1.26	1.68	4.08	7.62	8.35	8.62	7.47
1	50	0.03	0.04	0.09	0.17	0.19	0.19	0.17	0.02	0.02	0.05	0.10	0.10	0.11	0.09
3.5	50	0.10	0.13	0.32	0.60	0.66	0.68	0.59	0.06	0.07	0.18	0.33	0.37	0.38	0.33
7	50	0.20	0.26	0.64	1.20	1.31	1.36	1.18	0.11	0.15	0.36	0.67	0.73	0.75	0.65
12.5	50	0.35	0.47	1.15	2.14	2.35	2.42	2.10	0.20	0.26	0.64	1.19	1.30	1.35	1.17
18	50	0.51	0.68	1.65	3.09	3.38	3.49	3.02	0.28	0.38	0.92	1.71	1.88	1.94	1.68
29	50	0.82	1.10	2.66	4.97	5.45	5.62	4.87	0.46	0.61	1.48	2.76	3.03	3.12	2.71
40	50	1.13	1.52	3.67	6.86	7.51	7.75	6.72	0.63	0.84	2.04	3.81	4.17	4.31	3.73
1	100	0.01	0.02	0.05	0.09	0.09	0.10	0.08	0.01	0.01	0.03	0.05	0.05	0.05	0.05
3.5	100	0.05	0.07	0.16	0.30	0.33	0.34	0.29	0.03	0.04	0.09	0.17	0.18	0.19	0.16
7	100	0.10	0.13	0.32	0.60	0.66	0.68	0.59	0.06	0.07	0.18	0.33	0.37	0.38	0.33
12.5	100	0.18	0.24	0.57	1.07	1.17	1.21	1.05	0.10	0.13	0.32	0.60	0.65	0.67	0.58
18	100	0.26	0.34	0.83	1.54	1.69	1.74	1.51	0.14	0.19	0.46	0.86	0.94	0.97	0.84
29	100	0.41	0.55	1.33	2.49	2.72	2.81	2.44	0.23	0.30	0.74	1.38	1.51	1.56	1.35
40	100	0.57	0.76	1.84	3.43	3.76	3.88	3.36	0.32	0.42	1.02	1.90	2.09	2.15	1.87
1	200	0.01	0.01	0.02	0.04	0.05	0.05	0.04	0.00	0.01	0.01	0.02	0.03	0.03	0.02
3.5	200	0.02	0.03	0.08	0.15	0.16	0.17	0.15	0.01	0.02	0.04	0.08	0.09	0.09	0.08
7	200	0.05	0.07	0.16	0.30	0.33	0.34	0.29	0.03	0.04	0.09	0.17	0.18	0.19	0.16
12.5	200	0.09	0.12	0.29	0.54	0.59	0.61	0.52	0.05	0.07	0.16	0.30	0.33	0.34	0.29
18	200	0.13	0.17	0.41	0.77	0.85	0.87	0.76	0.07	0.09	0.23	0.43	0.47	0.48	0.42
29	200	0.21	0.27	0.67	1.24	1.36	1.40	1.22	0.11	0.15	0.37	0.69	0.76	0.78	0.68
40	200	0.28	0.38	0.92	1.71	1.88	1.94	1.68	0.16	0.21	0.51	0.95	1.04	1.08	0.93

Table 2b. Mass Loss Rate Potential* –Clamshell Dredge

Conditions		90% Full Bucket			50% Full Bucket		
Dredge Size (CY)	% Fines	Cycle Time (sec) 25 to 50	50 to 100	100 to 200	Cycle Time (sec) 25 to 50	50 to 100	100 to 200
1 to 7	0 to 5	Low	Low	Low	Low	Low	Low
7 to 18	0 to 5	Low to Med	Low	Low	Low	Low	Low
18 to 40	0 to 5	Low to Med	Low to Med	Low	Low to Med	Low	Low
1 to 7	5 to 15	Low to Med	Low	Low	Low	Low	Low
7 to 18	5 to 15	Low to Med	Low to Med	Low	Low to Med	Low	Low
18 to 40	5 to 15	Med to High	Low to Med	Low to Med	Low to Med	Low to Med	Low
1 to 7	15 to 65	Low to Med	Low to Med	Low	Low to Med	Low	Low
7 to 18	15 to 65	Med to High	Low to Med	Low to Med	Low to Med	Low to Med	Low
18 to 40	15 to 65	Med to High	Med to High	Low to Med	Med to High	Low to Med	Low to Med
1 to 7	65 to 100	Low to Med	Low to Med	Low	Low to Med	Low	Low
7 to 18	65 to 100	Med to High	Low to Med	Low to Med	Med	Low to Med	Low
18 to 40	65 to 100	Med to High	Med to High	Low to Med	Med to High	High to Med	Low to Med

* Increases with bucket size and % Fines up to 65%, and decreases with increasing cycle time.

2. Select Dilution Potential

Second, the dilution potential can be determined based on channel velocity and water depth according to Table 3a. Dilution potential (depth times velocity) is considered "low" below 2 m^2/sec, "medium" between 2 and 7 m^2/sec, and "high" above 7 m^2/sec. Table 3b shows calculated dilution potential values for representative depths and velocities. As velocity and depth increase, dilution potential increases and TSS concentration decreases.

Table 3a. Calculated Dilution Potential (m^2/s)

Channel Depth		Velocity						
		0.20	0.45	0.70	1.25	1.80	2.90	4.00 ft/s
ft	m	0.06	0.14	0.21	0.38	0.55	0.88	1.22 m/s
10	3.05	0.19	0.42	0.65	1.16	1.67	2.69	3.72
15	4.57	0.28	0.63	0.98	1.74	2.51	4.04	5.57
20	6.10	0.37	0.84	1.30	2.32	3.34	5.39	7.43
27.5	8.38	0.51	1.15	1.79	3.19	4.60	7.41	10.22
35	10.67	0.65	1.46	2.28	4.06	5.85	9.43	13.01
50	15.24	0.93	2.09	3.252	5.81	8.36	13.47	18.58
65	19.81	1.21	2.72	4.227	7.55	10.87	17.51	24.15

Table 3b. Dilution Potential

Depth (ft)	Velocity (ft/sec) 0.2 to 0.7	0.7 to 1.8	1.8 to 4.0
10 to 20	Low	Low to Med	Med
20 to 35	Low	Low to Med	Med to High
35 to 65	Low to Med	Med to High	High

3. Centerline Length of Effects

Effects from the resulting TSS plume depend on the behavior of the organism of interest. As the TSS decreases with distance from the dredge, the behavioral effects also decrease. Effects testing of juvenile salmonids (Clarke, 2009) resulted in the data shown in Figure 1 below. Juvenile salmonids are characteristic of a sensitive water column organism. Based on the data, the TSS levels at which low effects (behavioral), medium (physiological), and high (lethal) effects occur are indicated by the lines in Figure 1. These effects levels are represented in Table 4 as the TSS concentrations at which exposures of 1 hour or 1 day result in effects, which correspond to dosages (day*mg/L). Actual exposure time depends on the behavior of the organism as well as the movement of the dredge. For instance, some organisms may swim through the plume; henceforth exposure time is a function of plume width and swimming speed. Other organisms may be carried with the current and exposed to the length of the plume. Sessile organisms may receive continuous exposure if the dredge (and plume) remains stationary. Of course, some organisms may be attracted to the plume, whereas others may avoid it altogether. For most organisms and dredging operations, a reasonable exposure period is probably 1 hour. Given their inability to avoid exposures, sessile organisms are likely more tolerant of TSS; although their exposures may be longer, concentrations likely to induce effects would likely be much higher than those impacting juvenile salmonids. Henceforth, the 1-hr concentrations may be appropriate for sessile organisms despite the potential for longer exposures.

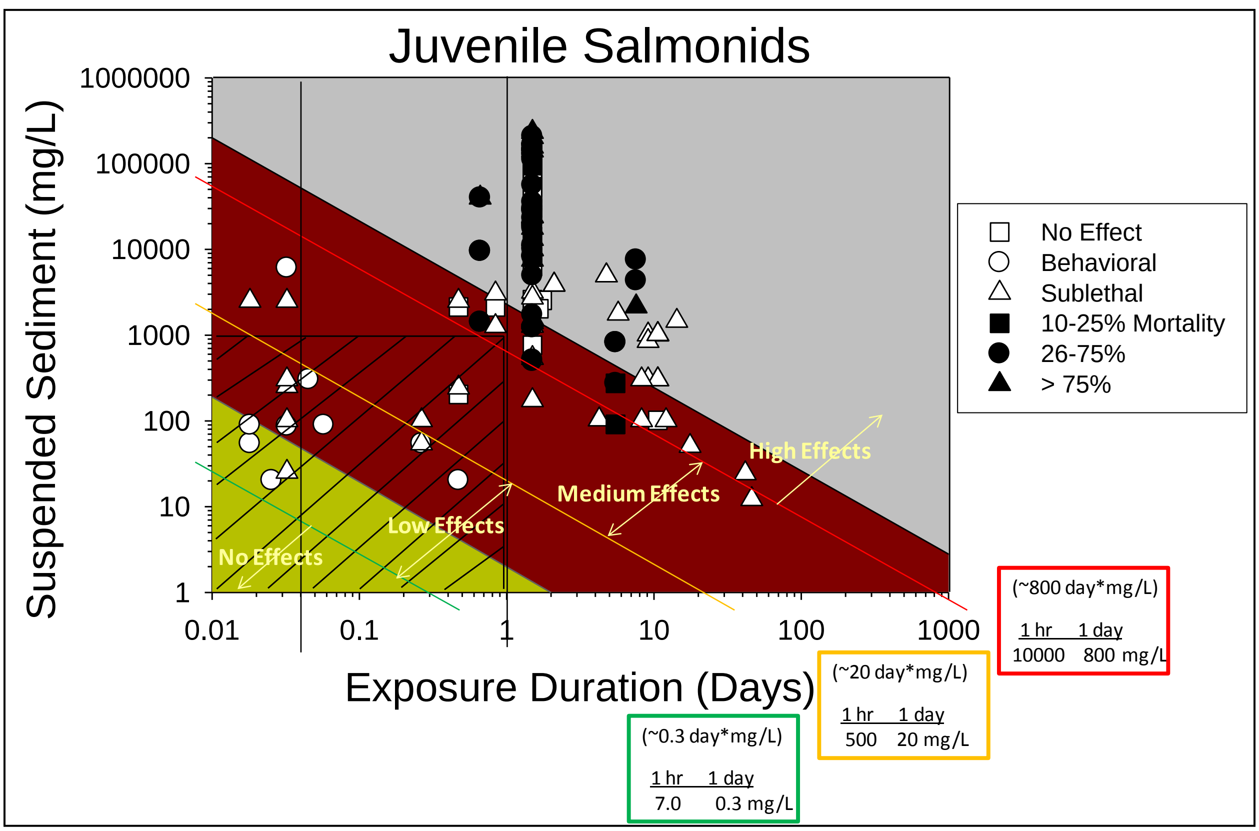

Figure 1. Effects of TSS as a Function of Concentration and Exposure Duration

Table 4. TSS Concentrations and Dosages Resulting in Effects on Juvenile Salmonids

Effects	TSS, mg/L		Cumulative Dosage day*mg/L
	1-hr exposure	1-day exposure	
Low (Behavioral)	7	0.3	0.3
Medium (Physiological)	500	20	20
High (Lethality)	10,000	800	800

A matrix of the variables (dilution potential, mass loss rate potential and water depth) was used to calculate TSS along the centerline of the plume for the given conditions. The results generated a range of potential TSS values within each category (low, medium, high) of dilution potential and mass loss rate potential. Biological effects resulting from 1-hr and 1-day exposures based on the TSS concentrations at distances along the plume centerline from the dredge were determined. Cumulative dosages for organisms traveling along the plume centerline at the current velocity were also calculated.

Table 5a shows minimum and maximum concentrations resulting from a clamshell dredge for the matrix of mass loss rate and dilution potential over a range of distances. Table 5b predicts the typical effects for a 1-hr exposure at those concentrations, representing the majority of the cases within the selected class. For the same matrix, Table 6a shows the minimum and maximum dosages at the given distances that would be experienced by an organism traveling with the current along the plume centerline. Table 6b displays the typical effects of the cumulative exposure dosages on an organism traveling with the current along the plume centerline along the entire length of the plume (nominally 2500 ft).

Table 5a. Centerline TSS Concentrations as a Function of Distance from a Clamshell Dredge

Conditions		Distance from Dredge (ft)							
Mass Loss Rate Potential	Dilution Potential	25 - 75		75 - 250		250 - 750		750 - 2500	
		Min	Max	Min	Max	Min	Max	Min	Max
Low	**Low**	0.12	740	0.07	425	0.04	227	0.02	123
Low	**Med**	0.05	63	0.03	36	0.01	20	0.01	11
Low	**High**	0.01	13	0.01	8	0.00	4.2	0.00	2.4
Med	**Low**	12	2960	6.6	1698	3.8	909	2.0	492
Med	**Med**	4.6	252	2.5	146	1.5	80	0.80	46
Med	**High**	1.3	53	0.71	30	0.41	17	0.22	10
High	**Low**	49	11840	27	6790	15	3640	8.2	1970
High	**Med**	19	1010	10	582	5.8	318	3.2	183
High	**High**	5.2	211	2.8	122	1.6	67	0.89	38

	None	Low	Medium	High	
TSS Causing Effects for 1-hr exposure:	< 7	7 – 500	500-10,000	> 10,000	mg/L
Mass Loss Rate Potential:		< 1	1 – 4	> 4	kg/s
Dilution Potential:		< 2	2 – 7	> 7	m^2/s

Table 5b. Typical Centerline Effects as a Function of Distance from a Clamshell Dredge -- Based on 1-hour Exposure

Conditions		Biological Effects			
Mass Loss Rate Potential	Dilution Potential	Distance (ft) 0 to 75	75 to 250	250 to 750	750 to 2500
Low	Low	Low	Low	None	None
Low	Medium	None	None	None	None
Low	High	None	None	None	None
Medium	Low	Medium	Low	Low	Low
Medium	Medium	Low	Low	Low	None
Medium	High	Low	None	None	None
High	Low	Medium	Medium	Low	Low
High	Medium	Low	Low	Low	Low
High	High	Low	Low	Low	None

Low Effect - Behavioral Response
Med Effect - Physiological Response
High Effect - Lethal Response

Table 6a. Cumulative Dosages (day*mg/L) for Entrained Organism along Centerline of a Plume from a Clamshell Dredge

Conditions		Distance from Dredge (ft)					
Mass Loss Rate Potential	Dilution Potential	75 - 250 Min	75 - 250 Max	250 - 750 Min	250 - 750 Max	750 - 2500 Min	750 - 2500 Max
Low	Low	0.00	5.9	0.001	10.7	0.001	19
Low	Med	0.000	0.17	0.000	0.31	0.000	0.59
Low	High	0.000	0.01	0.000	0.02	0.000	0.036
Med	Low	0.03	24	0.057	43	0.104	75
Med	Med	0.003	0.68	0.007	1.25	0.013	2.3
Med	High	0.000	0.04	0.001	0.08	0.002	0.14
High	Low	0.11	95	0.227	172	0.418	301
High	Med	0.01	2.72	0.027	5.0	0.050	9.4
High	High	0.002	0.17	0.004	0.31	0.007	0.6

	None	Low	Medium	High	
Dosage causing effects:	< 0.3	0.3 - 20	20 - 800	800	day*mg/L
Mass Loss Rate Potential:		< 1	1 - 4	> 4	kg/s
Dilution Potential:		< 2	2 - 7	> 7	m^2/s

Table 6b. Typical Centerline Effects for an Entrained Organism along Centerline of Turbidity Plume from a Clamshell Dredge -- Based on Cumulative Dosage

Conditions		Biological Effects
Mass Loss Rate Potential	**Dilution Potential**	**Distance 2500 ft**
Low	**Low**	None
Low	**Medium**	None
Low	**High**	None
Medium	**Low**	Low
Medium	**Medium**	None
Medium	**High**	None
High	**Low**	Medium
High	**Medium**	Low
High	**High**	None

Low Effect - Behavioral Response
Med Effect - Physiological Response
High Effect - Lethal Response

A clamshell dredge moves vertically through the water column and generates a plume that is relatively uniform throughout the water depth. The plume from a cutterhead dredge originates near the bottom and becomes more dilute away from the dredge and toward the surface. TSS concentrations and effects (1-hour exposure) at the surface, mid-depth and bottom are shown in Table 7a and Table 7b, respectively. Resulting dosages and effects are given in Table 8a and 8b.

Table 7a. Centerline TSS Concentration as a Function of Distance from a Cutterhead Dredge

Conditions			Distance from Dredge (ft)									
Mass Loss Rate	Dilution	Depth	0 to 25		25 to 75		75 to 250		250 to 750		750 to 2500	
			Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Low	Low	Surface	0.00	0.05	0.00	11.6	0.00	35.4	0.00	35.4	0.00	22.9
Low	Low	Mid-Depth	0.00	82.4	0.00	144	0.00	144	0.00	77.2	0.00	30.3
Low	Low	Bottom	0.19	1710	0.06	1020	0.02	341	0.01	102	0.00	34.0
Low	Medium	Surface	0.00	0.00	0.00	1.14	0.00	3.49	0.00	3.49	0.00	2.26
Low	Medium	Mid-Depth	0.00	7.88	0.00	13.8	0.00	13.8	0.00	7.39	0.00	2.91
Low	Medium	Bottom	0.05	158	0.02	95.1	0.01	31.7	0.00	9.51	0.00	3.17
Low	High	Surface	0.00	0.00	0.00	0.02	0.00	0.42	0.00	0.53	0.00	0.48
Low	High	Mid-Depth	0.00	0.25	0.00	1.90	0.00	2.10	0.00	1.70	0.00	0.77
Low	High	Bottom	0.02	45.3	0.01	27.2	0.00	9.06	0.00	2.72	0.00	0.91
Medium	Low	Surface	0.00	0.14	0.00	34.8	0.00	106	0.01	106	0.35	68.7
Medium	Low	Mid-Depth	0.00	247	0.00	432	0.14	432	1.81	232	0.79	90.9
Medium	Low	Bottom	95.1	5118	31.7	3070	9.51	1020	3.17	307	0.95	102
Medium	Medium	Surface	0.00	0.01	0.00	3.43	0.00	10.5	0.00	10.5	0.10	6.78
Medium	Medium	Mid-Depth	0.00	23.6	0.00	41.4	0.04	41.4	0.53	22.2	0.23	8.73
Medium	Medium	Bottom	27.2	476	9.06	285	2.72	95.1	0.91	28.5	0.27	9.51
Medium	High	Surface	0.00	0.00	0.00	0.05	0.00	1.25	0.00	1.59	0.03	1.45
Medium	High	Mid-Depth	0.00	0.75	0.00	5.69	0.01	6.31	0.15	5.09	0.07	2.32
Medium	High	Bottom	7.87	136	2.62	81.5	0.79	27.2	0.26	8.15	0.08	2.72
High	Low	Surface	0.00	0.55	0.00	139	0.00	425	0.04	425	1.06	275
High	Low	Mid-Depth	0.00	988	0.00	1730	0.42	1730	5.44	926	2.38	364
High	Low	Bottom	285	20470	95.1	12280	28.53	4090	9.51	1230	2.85	408
High	Medium	Surface	0.00	0.05	0.000	13.7	0.00	41.9	0.01	41.9	0.31	27.1
High	Medium	Mid-Depth	0.00	94.6	0.00	166	0.12	166	1.58	88.7	0.69	34.9
High	Medium	Bottom	81.5	1900	27.17	1140	8.15	380	2.72	114	0.82	38.0
High	High	Surface	0.00	0.00	0.000	0.210	0.00	4.99	0.00	6.37	0.09	5.80
High	High	Mid-Depth	0.00	3.00	0.00	22.8	0.04	25.2	0.46	20.4	0.20	9.28
High	High	Bottom	23.6	543	7.87	326	2.36	109	0.79	32.6	0.24	10.9

	None	Low	Medium	High	
TSS Causing Effects for 1-hr Exposure:	< 7	7 – 500	500-10,000	> 10,000	mg/L
Mass Loss Rate Potential:		< 0.5	0.5 – 1.5	> 1.5	kg/s
Dilution Potential:		< 2	2 - 7	> 7	m^2/s

Table 7b. Centerline Effects as a Function of Distance from a Cutterhead Dredge, Assuming a 1-hr Exposure at the Selected Distance

Conditions			Distance (ft)									
Mass Loss Rate Potential	Dilution Potential	Depth	0 to 25		25 to 75		75 to 250		250 to 750		750 to 2500	
			Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Low	Low	Surface	None	None	None	Low	None	Low	None	Low	None	Low
Low	Low	Mid-Depth	None	Low	None	Low	None	Low	None	Low	None	Low
Low	Low	Bottom	None	Medium	None	Medium	None	Low	None	Low	None	Low
Low	Medium	Surface	None	None	None	None	None	None	None	None	None	None
Low	Medium	Mid-Depth	None	Low	None	Low	None	Low	None	Low	None	None
Low	Medium	Bottom	None	Low	None	Low	None	Low	None	Low	None	None
Low	High	Surface	None	None	None	None	None	None	None	None	None	None
Low	High	Mid-Depth	None	None	None	None	None	None	None	None	None	None
Low	High	Bottom	None	Low	None	Low	None	Low	None	None	None	None
Medium	Low	Surface	None	None	None	Low	None	Low	None	Low	None	Low
Medium	Low	Mid-Depth	None	Low	None	Low	None	Low	None	Low	None	Low
Medium	Low	Bottom	Low	Medium	Low	Medium	Low	Medium	None	Low	None	Low
Medium	Medium	Surface	None	None	None	None	none	Low	None	Low	None	None
Medium	Medium	Mid-Depth	None	Low	None	Low	none	Low	None	Low	None	Low
Medium	Medium	Bottom	Low	Low	Low	Low	none	Low	None	Low	None	Low
Medium	High	Surface	None	None	None	None	None	None	None	None	None	None
Medium	High	Mid-Depth	None	None	None	None	None	None	None	None	None	None
Medium	High	Bottom	Low	Low	None	Low	None	Low	None	Low	None	None
High	Low	Surface	None	None	None	Low	None	Low	None	Low	None	Low
High	Low	Mid-Depth	None	Medium	None	Medium	None	Medium	None	Medium	None	Low
High	Low	Bottom	Low	High	Low	High	Low	Medium	Low	Medium	None	Low
High	Medium	Surface	None	None	None	Low	None	Low	None	Low	None	Low
High	Medium	Mid-Depth	None	Low	None	Low	None	Low	None	Low	None	Low
High	Medium	Bottom	Low	Medium	Low	Medium	Low	Low	None	Low	None	Low
High	High	Surface	None	None	None	None	None	None	None	None	None	None
High	High	Mid-Depth	None	None	None	Low	None	Low	None	Low	None	Low
High	High	Bottom	Low	Medium	Low	Low	None	Low	None	Low	None	Low

Low Effect - Behavioral Response

Med Effect - Physiological Response

High Effect - Lethal Response

Table 8a. Cumulative Dosages (day*mg/L) for an Entrained Organism along Centerline of a Turbidity Plume from a Cutterhead Dredge

Conditions			Distance (ft)									
Mass Loss Rate Potential	Dilution Potential	Depth	0 to 25 Min	0 to 25 Max	25 to 75 Min	25 to 75 Max	75 to 250 Min	75 to 250 Max	250 to 750 Min	250 to 750 Max	750 to 2500 Min	750 to 2500 Max
Low	Low	Surface	0.00	0.00	0.00	0.01	0.00	0.30	0.00	1.147	0.00	2.55
Low	Low	Mid-Depth	0.00	0.1	0.00	0.4	0.00	1.5	0.00	2.9	0.00	4.6
Low	Low	Bottom	0.00	2.2	0.00	4.0	0.00	5.8	0.00	7.5	0.00	9.3
Low	Medium	Surface	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.03
Low	Medium	Mid-Depth	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.1
Low	Medium	Bottom	0.00	0.1	0.00	0.2	0.00	0.3	0.00	0.4	0.00	0.5
Low	High	Surface	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0.0	0.00	0.003
Low	High	Mid-Depth	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
Low	High	Bottom	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
Medium	Low	Surface	0.00	0.00	0.00	0.04	0.000	0.91	0.00	3.44	0.003	7.65
Medium	Low	Mid-Depth	0.00	0.2	0.00	1.3	0.00	4.5	0.01	8.8	0.03	13.8
Medium	Low	Bottom	0.01	6.7	0.02	11.9	0.03	17.4	0.05	22.5	0.06	28.0
Medium	Medium	Surface	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.03	0.00	0.10
Medium	Medium	Mid-Depth	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.1	0.00	0.3
Medium	Medium	Bottom	0.00	0.4	0.00	0.7	0.01	1.0	0.01	1.3	0.01	1.6
Medium	High	Surface	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.01
Medium	High	Mid-Depth	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
Medium	High	Bottom	0.00	0.0	0.00	0.1	0.00	0.1	0.00	0.1	0.00	0.1
High	Low	Surface	0.00	0.00	0.00	0.16	0.00	3.651	0.000	13.8	0.010	30.6
High	Low	Mid-Depth	0.00	0.7	0.00	5.1	0.00	18.1	0.02	35.0	0.08	55.2
High	Low	Bottom	0.04	27.0	0.06	47.7	0.10	69.4	0.15	90.1	0.19	112.1
High	Medium	Surface	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.13	0.00	0.39
High	Medium	Mid-Depth	0.00	0.0	0.00	0.0	0.00	0.2	0.00	0.5	0.01	1.4
High	Medium	Bottom	0.01	1.5	0.01	2.7	0.02	3.9	0.02	5.1	0.03	6.3
High	High	Surface	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.03
High	High	Mid-Depth	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.1
High	High	Bottom	0.00	0.1	0.00	0.2	0.00	0.3	0.01	0.4	0.01	0.5

	None	Low	Medium	High	
Dosage causing effects:	< 0.3	0.3 - 20	20 - 800	> 800	day*mg/L
Mass Loss Rate Potential:		< 0.5	0.5 - 1.5	> 1.5	kg/s
Dilution Potential:		< 2	2 - 7	> 7	m^2/s

Table 8b. Typical Centerline Effects for an Entrained Organism along Centerline of Turbidity Plume from a Cutterhead Dredge -- Based on Cumulative Dosage

Conditions			Biological Effects
Mass Loss Rate Potential	Dilution Potential	Depth	Distance 2500 ft
Low	Low	Surface	None
Low	Low	Mid-Depth	None
Low	Low	Bottom	Low
Low	Medium	Surface	None
Low	Medium	Mid-Depth	None
Low	Medium	Bottom	None
Low	High	Surface	None
Low	High	Mid-Depth	None
Low	High	Bottom	None
Medium	Low	Surface	None
Medium	Low	Mid-Depth	Low
Medium	Low	Bottom	Low
Medium	Medium	Surface	None
Medium	Medium	Mid-Depth	None
Medium	Medium	Bottom	None
Medium	High	Surface	None
Medium	High	Mid-Depth	None
Medium	High	Bottom	None
High	Low	Surface	Low
High	Low	Mid-Depth	Low
High	Low	Bottom	Low
High	Medium	Surface	None
High	Medium	Mid-Depth	None
High	Medium	Bottom	Low
High	High	Surface	None
High	High	Mid-Depth	None
High	High	Bottom	None

Low Effect - Behavioral Response

Med Effect - Physiological Response

High Effect - Lethal Response

4. Plume Width

Dredging plumes typically have an ellipsoidal shape as shown in Figure 2. The peak width of the plume relative to the length for a given TSS concentration depends on channel conditions. The ratio of the plume length, L (distance from the dredge at which a given TSS concentration occurs), to width, W (maximum distance from the centerline at which the same TSS concentration occurs), is a function of mass loss rate potential, TSS concentration, channel velocity and depth. For a clamshell dredge, the L:W can be closely calculated as:

–

(Equation 1)

where:

m_R = mass loss rate potential, kg/s
TSS = total suspended solids concentration, mg/L
u = channel velocity, m/s
h = channel depth, m.

For a cutterhead dredge, the equation below provided a close fit (R^2 = 0.9998) to the L:W ratio:

(Equation 2)

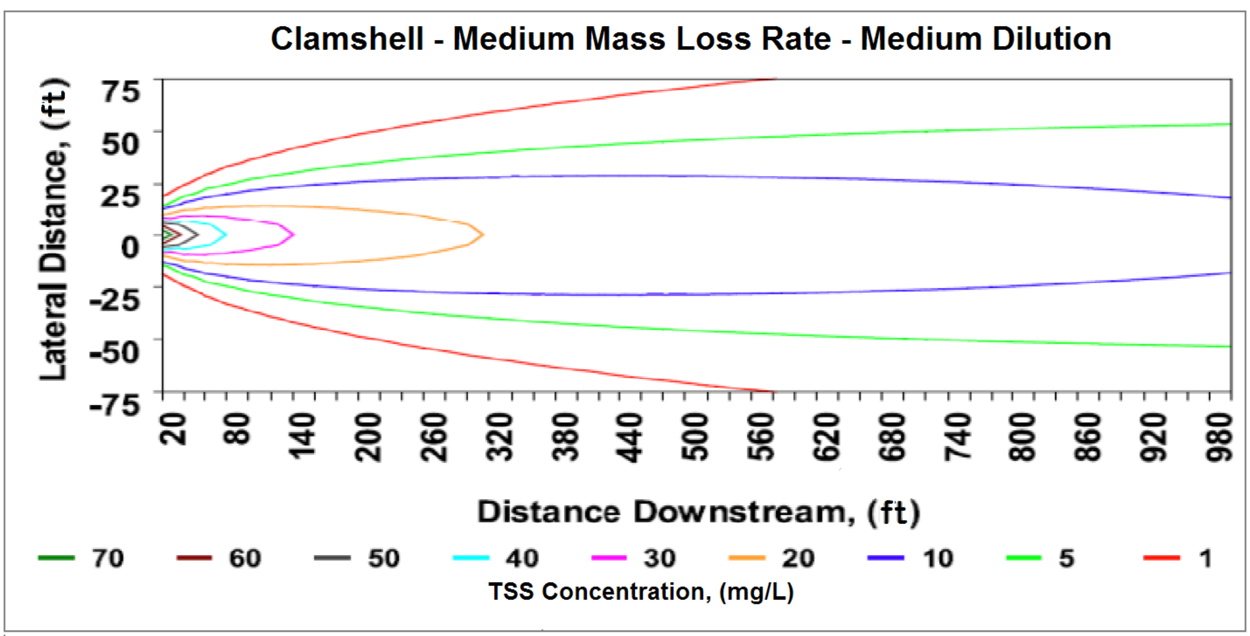

Figure 2. Typical TSS Plume Resulting from a Dredge

Using typical values of mass loss rates, water depth, current speed with representative TSS concentrations that produce the various levels of biological effects as given in Table 5a for clamshell dredges and Table 7a for cutterhead dredges respectively in Equation 1 and Equation 2, representative L:W ratios were calculated for the three levels of biological effects as given in Table 9.

Table 9. L:W Ratio as a Function of Dredge Type, Exposure Duration, and Biological Effects Level

Dredge	Exposure Duration	Length to Width Ratio		
		Biological Effects Level		
		Low	Med	High
Clamshell	**1-hour**	3.0	0.5*	0.5*
	1-day	73.	4.5	0.74
Cutterhead	**1-hour**	1.5	0.86	0.5*
	1-day	13.	3. 6	1.4

* Typically, the length of the plumes exhibiting these effects levels are so short that a 1-hour exposure does not occur even with very low current speed. The plumes are essentially circular around the dredge.

5. Simplified Effects Analysis using the Tables

The tables presented above can be used to obtain a quick estimate of the effects level caused by the TSS plume from dredging.

Step 1: Using Table 1b (cutterhead) or 2b (clamshell), determine the degree of mass loss rate potential based on the dredge and sediment properties.

Step 2: Using Table 3b, determine the dilution potential based on channel velocity and depth.

Step 3: Based on the mass loss rate potential and dilution potential from Step 1 and Step 2, respectively, use the tables to determine the biological effects at the distance of interest from the dredge.

— For a clamshell dredge, Table 5b can be used to estimate the typical effects resulting from a 1-hr exposure at the plume centerline concentration from an organism passing through the plume. For organisms entrained in the plume, Table 6b can be used to estimate effects based on cumulative dosage. Tables 5a shows the range in TSS concentrations that may be encountered and Table 6a shows the range in dosages that an entrained organism may experience. Both of these tables also show the range in effects that may occur if your conditions are at the extremes for the range of conditions (Max = combination of high end of the range for mass loss rate, low end of the range for dilution, and low end of the range for distance from the dredge; Min = combination of low end of the range for mass loss rate, high end of the range for dilution, and high end of the range for distance from the dredge).

— For a cutterhead dredge, Table 7b can be used to estimate typical 1-hr exposure effects from an organism passing through the plume at different depths. Table 8b estimates effects for a cumulative dosage for organisms entrained along the centerline of the plume at different depths. Tables 7a shows the range in TSS concentrations that may be encountered and Table 8a shows the range in dosages that an entrained organism may experience. Both of these tables also show the range in effects that may occur if your conditions are at the extremes for the range of conditions (Max = combination of high end of the range for mass loss rate, low end of the range for dilution, and low end of the range for distance from the dredge; Min = combination of low end of the range for mass loss rate, high end of the range for dilution, and high end of the range for distance from the dredge).

Step 4: The width of the plume over which effects occur can be determined by dividing the length of an effect by the L:W ratio provided in Table 9 for the same effect, dredge and exposure. If the critical resource to be protected is off to the side of the channel being dredged, the distance from the centerline of the plume should be compared with the half-width of the plume projected to have potential biological effects. If the offset from the plume is greater than the half-width of the plume, the exposure would be insufficient for potential impacts to the receptors.

6. Summary

Based on the equations from the DREDGE model, TSS was predicted as a function of distance from the dredge for a range of parameters. The most important parameters, dilution potential and mass loss rate potential were grouped into categories of high, medium and low. TSS concentrations at distances from the dredge were calculated for a matrix of these two parameters for both clamshell and cutterhead dredges. Based on effects testing with juvenile salmonids, TSS dosages were determined for low (behavioral), medium (physiological) and high (lethal) effects levels. Tables were generated to estimate the maximum biological effects as a function of distance from dredges operating within the specified ranges of mass loss rate potential and dilution potential.

REFERENCES

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Clarke, D. G. 2009. Effects Assessment, Presentation at US Army Engineer Research and Development Center Dredged Material Assessment and Management Seminar, Detroit, MI, 17 September 2009. *http://el.erdc.usace.army.mil/training.cfm?Topic=Workshop&List=09sep-dots*

Questions from NYSDEC on the Dredging Technical Matrix

Subject: Dredging Technical Matrix
Date: Tue, 04 Mar 2014 15:41:00 -0500
From: Jay Tanski
Organization: New York Sea Grant
To: John Tavolaro
CC: Nash, Beth K, Cornelia Schlenk, Henry Bokuniewicz

Hello John,

We received the information developed by ERDC on the technical aspects of dredging and plan on incorporating it into the report as an appendix along with the workshop presentations and the other matrices. Thank you.

We also discussed the ERDC report with the NYSDEC (Dawn McReynolds and Charlie DeQuillfeldt). They thought it contained useful information but had two questions. Perhaps we could ask the authors at ERDC to consider these.

The first question was why juvenile salmonids were selected as the surrogate species for describing potential impacts. The DEC didn't feel juvenile salmonids were necessarily representative of the species or life stages of interest in New York. They indicated that information, similar to that provided in this report, on the effects of TSS and burial on winter flounder eggs, larvae and juveniles would be more helpful in evaluating potential dredging impacts. Has ERDC done a similar analysis for this winter flounder or can they provide some documentation about how the salmonid results would be the same or different for winter flounder?

Second, since potential burial of eggs is also important, DEC asked if it would be possible to provide estimates of sedimentation spatially in relation to the plume. In addition to the concentration plotted as a function of distance, could the results be used to also plot the deposition as a function of distance? We thought this would be possible using the information provided in Figure 2 of the report and making some assumptions about sedimentation rates.

We look forward to hearing from you. If you think it is appropriate I could arrange a Project Team conference call, but that would have to happen fairly quickly given the project deadline of end of April.

Regards,

Jay

Jay Tanski

New York Sea Grant Program
146 Suffolk Hall
Stony Brook University
Stony Brook, NY 11794-5002

Phone: (631) 632-8730
Fax: (631) 632-8216

email: jjt3@cornell.edu

ERDC Response to NYSDEC Questions on Dredging Technical Matrix

-----Original Message-----
From: Schroeder, Paul R ERDC-RDE-EL-MS
Sent: Tuesday, March 11, 2014 2:03 AM
To: Nash, Beth K NAN02; Bailey, Susan ERD; Schroeder, Paul R ERD-MS; Tavolaro, John F NAN02
Subject: RE: [EXTERNAL] Dredging Technical Matrix (UNCLASSIFIED)

Beth,

Juvenile salmonids were selected as the surrogate species for describing potential impacts to water column because there was a wealth of TSS effects data for the organism and the organism is generally sensitive and would likely be representative of flounder juveniles and, to some extent, flounder larvae. The results would not be representative of burial of flounder eggs because the analysis was limited to resuspension effects and not deposition. The results would be driven by potential losses, dredge advancement rate and velocity like resuspension effects but not in the same way on water depth.

ERDC has done analysis to compute the potential depth of generated residuals (deposition) from dredge induced resuspension and have effects data of extent of burial on flounder egg survival. Therefore, a similar analysis could be done for flounder eggs. Deposition could be plotted as along the centerline of the channel and distance off of the centerline. Deposition should not vary along the centerline as long as the sediment properties, hydrodynamic conditions, dredged material quantities due not change as the dredge progresses down the reach.

This analysis for the same range of conditions as used for the resuspension analysis is not a trivial task and cannot be completed in the next six weeks, particularly with our existing work load. One cannot merely compute settling from Figure 2 because you have to integrate Figure 2 as a function of the advancement rate and consider the range in bottom shear stress on the probability that the particle will remain deposited. I would expect that we would not be able to deliver the matrix for deposition until about the end of June and it would require about $30K to $40K for labor.

Paul