Attachment E

Borrow Area Mixing Zone Study

Bathtub Beach Restoration Project

Prepared for

Florida Department of Environmental Protection

Joint Coastal Permit Application RAI

JCP File Number: 0163447-002-JC

by

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DREDGE Module Mixing Zone Study for Bathtub Beach Borrow Area
JCP File Number: 0163447-002-JC, Martin County
Taylor Engineering, Inc.
December 2008

Taylor Engineering conducted a mixing zone study to estimate the distance that the project may generate turbidity during dredging. The DREDGE Module, developed by the U.S. Army Corps of Engineers (USACE) provided the analysis tool to predict total suspended solids (TSS) resulting from dredge operation. Taylor Engineering ran the DREDGE Module for a hydraulic cutterhead dredge under the conditions listed below.

Dredge Characteristics:

1. A 16 in (0.41 m) hydraulic cutterhead dredge
2. Settling velocity of 0.001 m/sec
3. An in-situ dry density of 1,000 kg/m3

Site characteristics of the proposed borrow area:

1. 0.00 m water depth (removing a shoal – worst case scenario)
2. Specific gravity of 2.65
3. Ambient water velocity of 0.27 m/sec (0.9 ft/sec)
4. Mean particle size of 410 µm (0.41 mm)
5. 0.2% particles smaller than 74 µm (fines) average
6. 0.8% particles smaller than 74 µm (fines) "worst case" scenario
7. 25% particles smaller than particles with critical settling velocity, again a "worst case" scenario

The DREDGE Module produces TSS values as output, but the Florida Administrative Code uses turbidity (in Nephelometric Turbidity Units or NTU) as a water quality standard related to TSS. Each location or sediment provides a somewhat different relationship between turbidity and TSS and no relationship exists for the proposed borrow site. Thus, general equations of the relationship between TSS and turbidity must provide results useful for predictive purposes. To estimate expected turbidity from dredging the proposed borrow area, Taylor Engineering used equations relating TSS concentration (mg/l) to NTU values from four technical papers (see below for reference citations). We input each TSS value generated by the DREDGE Module to each of the four equations. We selected the highest resulting turbidity value as the appropriate result for this analysis.

The following pages provide a tabular and graphical representation of the anticipated water-surface plume results from the DREDGE Module. The models predict that maximum turbidity nearest the dredge head will not exceed 0.79 mg/L TSS or 0.7 NTU. The lateral diffusion cross current reduces TSS (and turbidity) to less than 0.27 TSS or 0.3 NTU 50 meters from the dredge head. At a distance of 150 meters downcurrent from the dredge head, the models predict less than 0.05 TSS or 0.1 NTU.

Hydraulic Dredge Characteristics for Cutter head

Input	Value	Units
Cutter head Diameter	0.41	m
Cutter head Length	1.22	m
Thickness of cut	0.30	m
Swing Velocity of Cutter	0.30	m/sec
In situ Dry Density	1000	kg/m^3

Site Characteristics

Input	Value	Units
Water Depth	0.00	m
Ambient Water Velocity	0.27	m/sec
Mean Particle Size	410	μm
Specific Gravity	2.65	--
Fraction of particles smaller than 74 μm	0.002	--
Fraction of particles smaller than particles with critical settling velocity	0.25	--

Cutter head - TGU

Input	Value	Units
Cutter head Length	1.22	m
Thickness of Cut	0.30	m
Width of Turbidity Area	257.7	m
Turbidity Generation Unit*	300	g/m^3

*Turbidity Generation Unit gathered from Nakai's TGU Values presented in the DREDGE Module User's Guide Help Menu

Far Field Model Data

Input	Value	Units
Lateral Diffusion Coefficient	100,000	cm^2/sec
Vertical Diffusion Coefficient	10	cm^2/sec
Settling Velocity	0.001	m/sec
Downstream Locations	300	m
Downstream Step	10	m
Lateral Locations	150	m
Lateral Step	25	m
Desired Water Depth	0.00	m

<< Input Data Summary >>

<< Input Data File >> = C:\ADDAMS\DREDGE\BT.DAT
<< Dredge Type >> = Cutterhead

<< Cutterhead Dredge Data >>
Cutterhead diameter = 0.4 (m)
Cutterhead length = 1.2 (m)
Thickness of cut = 0.3 (m)
Swing velocity at cutter = 0.3 (m / sec)
In-situ dry density = 1000 (kg/m^3)

<< Near-Field Model - TGU method >>
Cutterhead length = 1.2 (m)
Thickness of cut = 0.3 (m)
Width of turbid area = 250 (m^2)
Turbidity generation unit = 300 (g/m^3)

<< Far-Field Model >>
Lateral diff. coeff. = 100000 (cm^2/sec)
Vertical diff. coeff. = 10 (cm^2/sec)
Settling velocity =.001 (m/sec)
Downstream locations = 300 (m)
X-step = 10 (m)
Lateral locations = 150 (m)
Y-step = 10 (m)
Desired water depth = 0 (m)

<< Site Characteristics >>
Water depth = 0.1 (m)
Ambient water velocity = 0.27 (m/sec)
Mean particle size = 410 (um)
Specific gravity of sedi. = 2.65
R74 = 0.1
Ro = 0.25

<< DREDGE Model Output Summary >>

Resuspended material selected : Total Suspended Solid

Downstream Distance(m)	Lateral Position(m)					Unit:(mg/l)
	-150	-140	-130	-120	-110	-100	-90
10	.000	.000	.000	.000	.000	.001	.003
20	.000	.001	.001	.003	.007	.013	.025
30	.002	.003	.006	.010	.017	.027	.042
40	.004	.007	.011	.017	.025	.035	.049
50	.007	.011	.016	.022	.030	.039	.051
60	.010	.014	.019	.025	.032	.041	.050
70	.012	.016	.021	.027	.033	.041	.049
80	.014	.018	.022	.027	.033	.040	.047
90	.015	.019	.023	.028	.033	.038	.044
100	.016	.019	.023	.027	.032	.037	.042
110	.016	.020	.023	.027	.031	.035	.040
120	.017	.020	.023	.026	.030	.034	.038
130	.017	.020	.023	.026	.029	.032	.036
140	.017	.019	.022	.025	.028	.031	.034
150	.017	.019	.022	.024	.027	.029	.032
160	.017	.019	.021	.023	.026	.028	.030
170	.016	.018	.020	.023	.025	.027	.029
180	.016	.018	.020	.022	.024	.026	.028
190	.016	.018	.019	.021	.023	.025	.026
200	.015	.017	.019	.020	.022	.024	.025
210	.015	.017	.018	.020	.021	.023	.024
220	.015	.016	.018	.019	.020	.022	.023
230	.014	.016	.017	.018	.020	.021	.022
240	.014	.015	.017	.018	.019	.020	.021
250	.014	.015	.016	.017	.018	.019	.020
260	.013	.014	.016	.017	.018	.019	.019
270	.013	.014	.015	.016	.017	.018	.019
280	.013	.014	.015	.015	.016	.017	.018
290	.012	.013	.014	.015	.016	.017	.017
300	.012	.013	.014	.015	.015	.016	.017

<< DREDGE Model Output Summary >>

Resuspended material selected : Total Suspended Solid

Downstream Distance(m)	Lateral Position(m) Unit:(mg/l)						
	-80	-70	-60	-50	-40	-30	-20
10	.010	.029	.069	.146	.268	.429	.602
20	.045	.075	.116	.168	.228	.288	.341
30	.061	.086	.115	.147	.180	.211	.236
40	.065	.084	.104	.126	.146	.165	.179
50	.064	.078	.093	.108	.122	.135	.144
60	.061	.072	.084	.095	.105	.113	.120
70	.057	.066	.075	.084	.091	.098	.103
80	.054	.061	.068	.075	.081	.086	.089
90	.050	.056	.062	.067	.072	.076	.079
100	.047	.052	.057	.061	.065	.068	.071
110	.044	.048	.052	.056	.059	.062	.064
120	.041	.045	.048	.052	.054	.056	.058
130	.039	.042	.045	.048	.050	.052	.053
140	.037	.039	.042	.044	.046	.048	.049
150	.035	.037	.039	.041	.043	.044	.045
160	.033	.035	.037	.039	.040	.041	.042
170	.031	.033	.035	.036	.038	.039	.039
180	.029	.031	.033	.034	.035	.036	.037
190	.028	.030	.031	.032	.033	.034	.035
200	.027	.028	.029	.030	.031	.032	.033
210	.025	.027	.028	.029	.030	.030	.031
220	.024	.025	.026	.027	.028	.029	.029
230	.023	.024	.025	.026	.027	.027	.028
240	.022	.023	.024	.025	.025	.026	.026
250	.021	.022	.023	.024	.024	.025	.025
260	.020	.021	.022	.023	.023	.024	.024
270	.020	.020	.021	.022	.022	.022	.023
280	.019	.019	.020	.021	.021	.021	.022
290	.018	.019	.019	.020	.020	.021	.021
300	.017	.018	.019	.019	.019	.020	.020

<< DREDGE Model Output Summary >>

Resuspended material selected : Total Suspended Solid

Downstream Distance(m)	Lateral Position(m) Unit:(mg/l)						
	-10	0	10	20	30	40	50
10	.737	.788	.737	.602	.429	.268	.146
20	.378	.391	.378	.341	.288	.228	.168
30	.252	.258	.252	.236	.211	.180	.147
40	.189	.192	.189	.179	.165	.146	.126
50	.150	.152	.150	.144	.135	.122	.108
60	.124	.125	.124	.120	.113	.105	.095
70	.106	.107	.106	.103	.098	.091	.084
80	.092	.092	.092	.089	.086	.081	.075
90	.081	.081	.081	.079	.076	.072	.067
100	.072	.073	.072	.071	.068	.065	.061
110	.065	.065	.065	.064	.062	.059	.056
120	.059	.059	.059	.058	.056	.054	.052
130	.054	.054	.054	.053	.052	.050	.048
140	.050	.050	.050	.049	.048	.046	.044
150	.046	.046	.046	.045	.044	.043	.041
160	.043	.043	.043	.042	.041	.040	.039
170	.040	.040	.040	.039	.039	.038	.036
180	.037	.037	.037	.037	.036	.035	.034
190	.035	.035	.035	.035	.034	.033	.032
200	.033	.033	.033	.033	.032	.031	.030
210	.031	.031	.031	.031	.030	.030	.029
220	.029	.030	.029	.029	.029	.028	.027
230	.028	.028	.028	.028	.027	.027	.026
240	.026	.027	.026	.026	.026	.025	.025
250	.025	.025	.025	.025	.025	.024	.024
260	.024	.024	.024	.024	.024	.023	.023
270	.023	.023	.023	.023	.022	.022	.022
280	.022	.022	.022	.022	.021	.021	.021
290	.021	.021	.021	.021	.021	.020	.020
300	.020	.020	.020	.020	.020	.019	.019

<< DREDGE Model Output Summary >>

Resuspended material selected : Total Suspended Solid

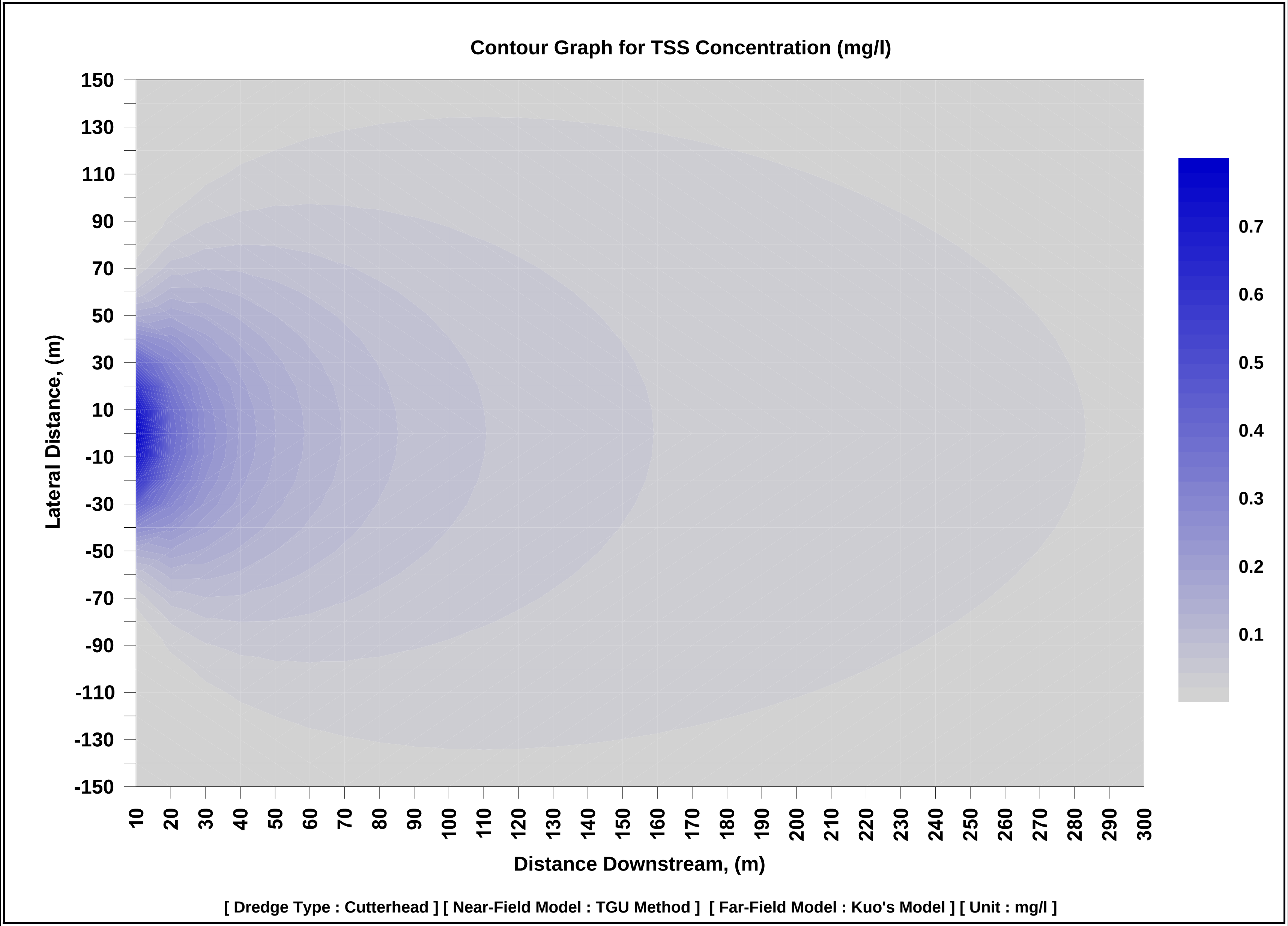
Downstream Distance(m)	Lateral Position(m)					Unit:(mg/l)	
	60	70	80	90	100	110	120
10	.069	.029	.010	.003	.001	.000	.000
20	.116	.075	.045	.025	.013	.007	.003
30	.115	.086	.061	.042	.027	.017	.010
40	.104	.084	.065	.049	.035	.025	.017
50	.093	.078	.064	.051	.039	.030	.022
60	.084	.072	.061	.050	.041	.032	.025
70	.075	.066	.057	.049	.041	.033	.027
80	.068	.061	.054	.047	.040	.033	.027
90	.062	.056	.050	.044	.038	.033	.028
100	.057	.052	.047	.042	.037	.032	.027
110	.052	.048	.044	.040	.035	.031	.027
120	.048	.045	.041	.038	.034	.030	.026
130	.045	.042	.039	.036	.032	.029	.026
140	.042	.039	.037	.034	.031	.028	.025
150	.039	.037	.035	.032	.029	.027	.024
160	.037	.035	.033	.030	.028	.026	.023
170	.035	.033	.031	.029	.027	.025	.023
180	.033	.031	.029	.028	.026	.024	.022
190	.031	.030	.028	.026	.025	.023	.021
200	.029	.028	.027	.025	.024	.022	.020
210	.028	.027	.025	.024	.023	.021	.020
220	.026	.025	.024	.023	.022	.020	.019
230	.025	.024	.023	.022	.021	.020	.018
240	.024	.023	.022	.021	.020	.019	.018
250	.023	.022	.021	.020	.019	.018	.017
260	.022	.021	.020	.019	.019	.018	.017
270	.021	.020	.020	.019	.018	.017	.016
280	.020	.019	.019	.018	.017	.016	.015
290	.019	.019	.018	.017	.017	.016	.015
300	.019	.018	.017	.017	.016	.015	.015

<< DREDGE Model Output Summary >>

Resuspended material selected : Total Suspended Solid

Downstream Distance(m) — Lateral Position(m) — Unit:(mg/l)

Downstream Distance(m)	130	140	150				
10	.000	.000	.000	.000	.000	.000	.000
20	.001	.001	.000	.000	.000	.000	.000
30	.006	.003	.002	.000	.000	.000	.000
40	.011	.007	.004	.000	.000	.000	.000
50	.016	.011	.007	.000	.000	.000	.000
60	.019	.014	.010	.000	.000	.000	.000
70	.021	.016	.012	.000	.000	.000	.000
80	.022	.018	.014	.000	.000	.000	.000
90	.023	.019	.015	.000	.000	.000	.000
100	.023	.019	.016	.000	.000	.000	.000
110	.023	.020	.016	.000	.000	.000	.000
120	.023	.020	.017	.000	.000	.000	.000
130	.023	.020	.017	.000	.000	.000	.000
140	.022	.019	.017	.000	.000	.000	.000
150	.022	.019	.017	.000	.000	.000	.000
160	.021	.019	.017	.000	.000	.000	.000
170	.020	.018	.016	.000	.000	.000	.000
180	.020	.018	.016	.000	.000	.000	.000
190	.019	.018	.016	.000	.000	.000	.000
200	.019	.017	.015	.000	.000	.000	.000
210	.018	.017	.015	.000	.000	.000	.000
220	.018	.016	.015	.000	.000	.000	.000
230	.017	.016	.014	.000	.000	.000	.000
240	.017	.015	.014	.000	.000	.000	.000
250	.016	.015	.014	.000	.000	.000	.000
260	.016	.014	.013	.000	.000	.000	.000
270	.015	.014	.013	.000	.000	.000	.000
280	.015	.014	.013	.000	.000	.000	.000
290	.014	.013	.012	.000	.000	.000	.000
300	.014	.013	.012	.000	.000	.000	.000


Contour Graph for TSS Concentration (mg/l)
150
130
110
90
70
50
30
10
-10
-30
-50
-70
-90
-110
-130
-150
Lateral Distance, (m)
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
Distance Downstream, (m)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
[Dredge Type : Cutterhead] [Near-Field Model : TGU Method] [Far-Field Model : Kuo's Model] [Unit : mg/l]

Total Suspended Solids (TSS, mg/l) <> Turbidity (NTU) Conversion

convert from	**TSS**	**mg/l**	Select "convert from" with dropdown box
to	**Turb**	**NTU**	
TSS	0.788	**mg/l**	Enter quantity to convert
Walker	0.0	**NTU**	
Christensen	0.4	**NTU**	
Gray	0.4	**NTU**	
Packman	0.7	**NTU**	

References

Walker: Atcafalaya Bay, LA

Walker, N. (2001) "Tropical Storm and Hurricane Wind Effects on Water Level, Salinity and Sediment Transport in the River-Influenced Atchafalaya-Vermilion Bay System, Louisiana, USA." Estuaries, Vol. 24, No. 4, p. 498-508, August 2001

Christensen: L. Arkansas R., KS

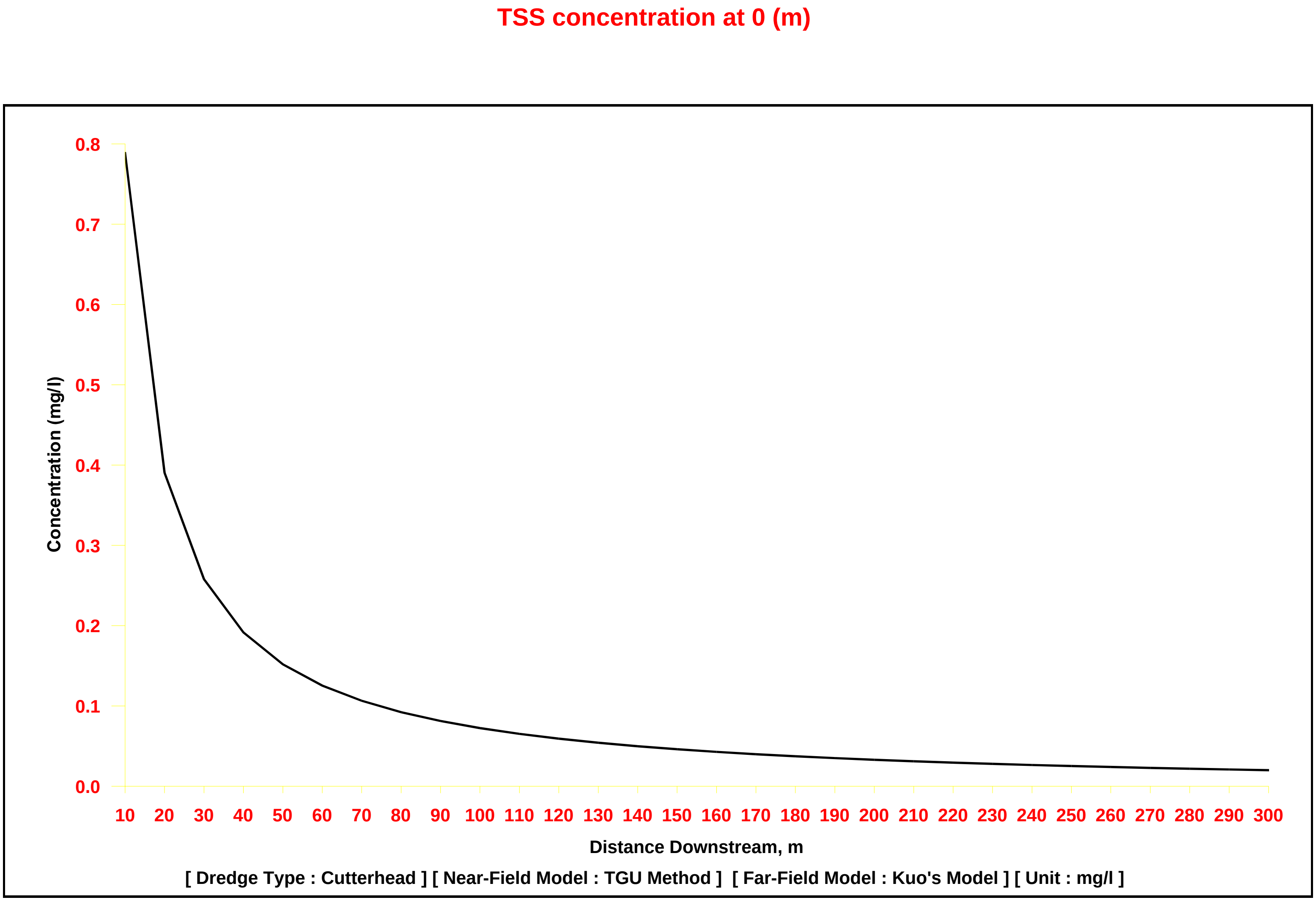
Christensen, V.G., Ziegler, A.C., and Jian, X. (2001) "Continuous Turbidity Monitoring and Regression Analysis to Estimate Total Time Suspended Solids and Fecal Coliform Bacteria Loads in Real Time." USGS Kansas Water Quality Center, 4821 Quail Crest Place, Lawrence, KS 66049

Gray: Kansas R., KS

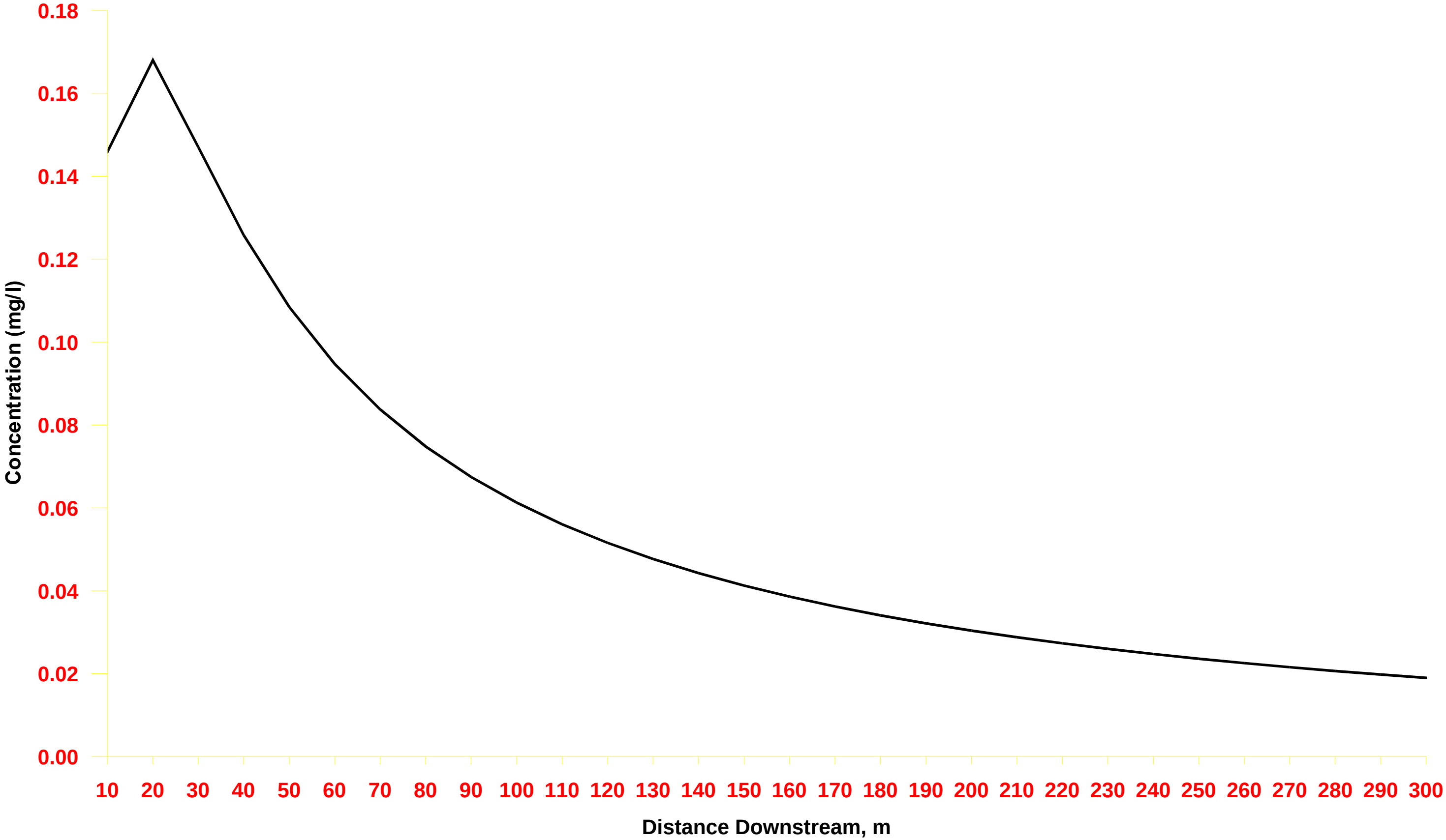
Gray, J.R., Melis, T.S., Patino, E., Larsen, M.C., Topping, D.J., Rasmussen, P.P., and Figueroa-Alamo, C. (2003) "U.S. Geological Survey Research on Surrogate Measurements for Suspended Sediment." First Interagency Conference on Research in the Watersheds, October 27-30, 2003. U.S. Department of Agriculture, Agricultural Research Service

Packman: King Co., WA

Packman, J.J., Comings, K.J., and Booth, D.B. (1999) "Using Turbidity to Determine Total Suspended Solids in Urbanized Streams in the Puget Lowlands." Center for Water and Watershed Studies, University of Washington, Civil and Environmental Engineering Department.

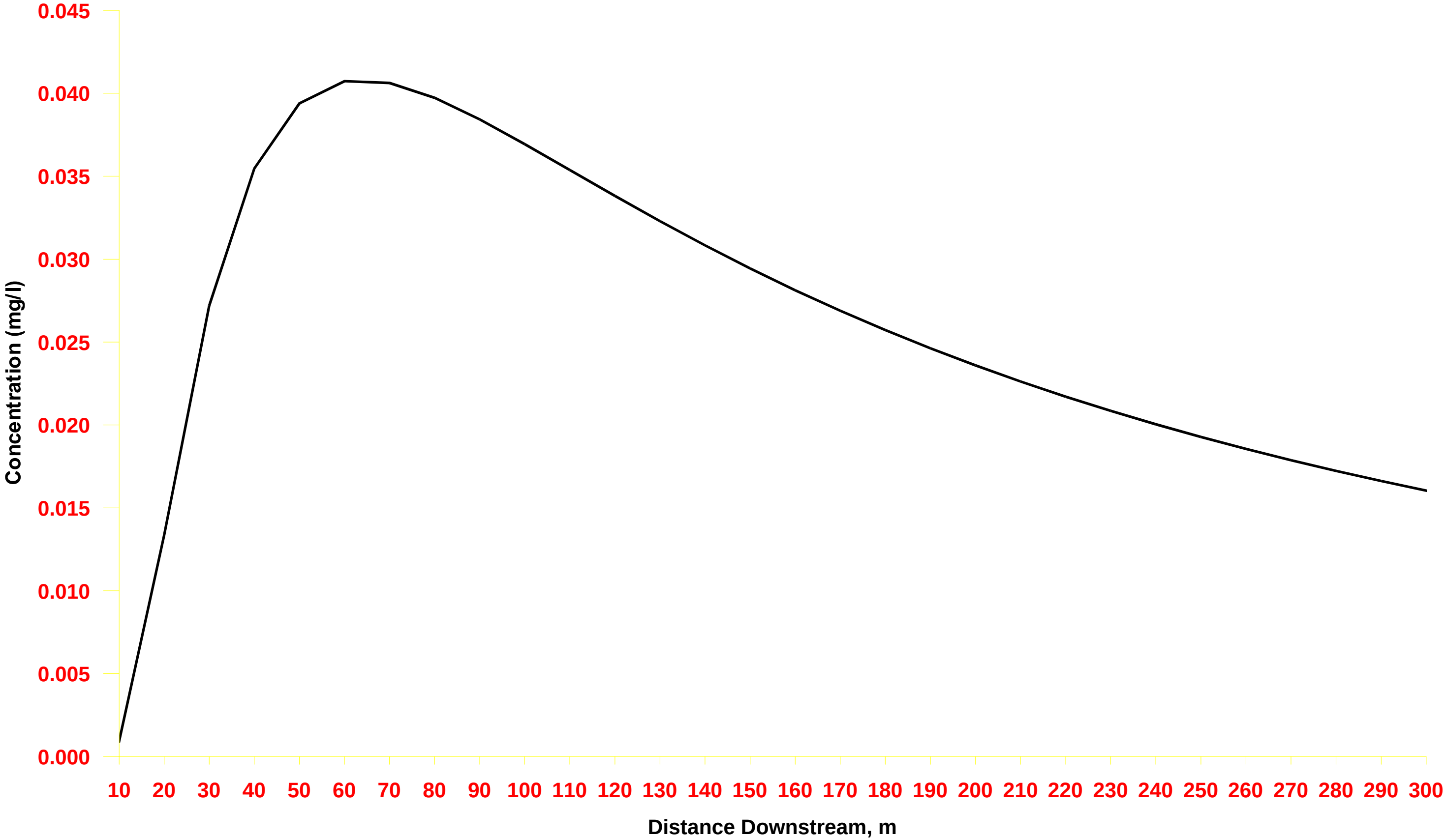

TSS concentration at 0 (m)
Concentration (mg/l)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300
Distance Downstream, m
[Dredge Type : Cutterhead] [Near-Field Model : TGU Method] [Far-Field Model : Kuo's Model] [Unit : mg/l]

TSS concentration at -50 (m)

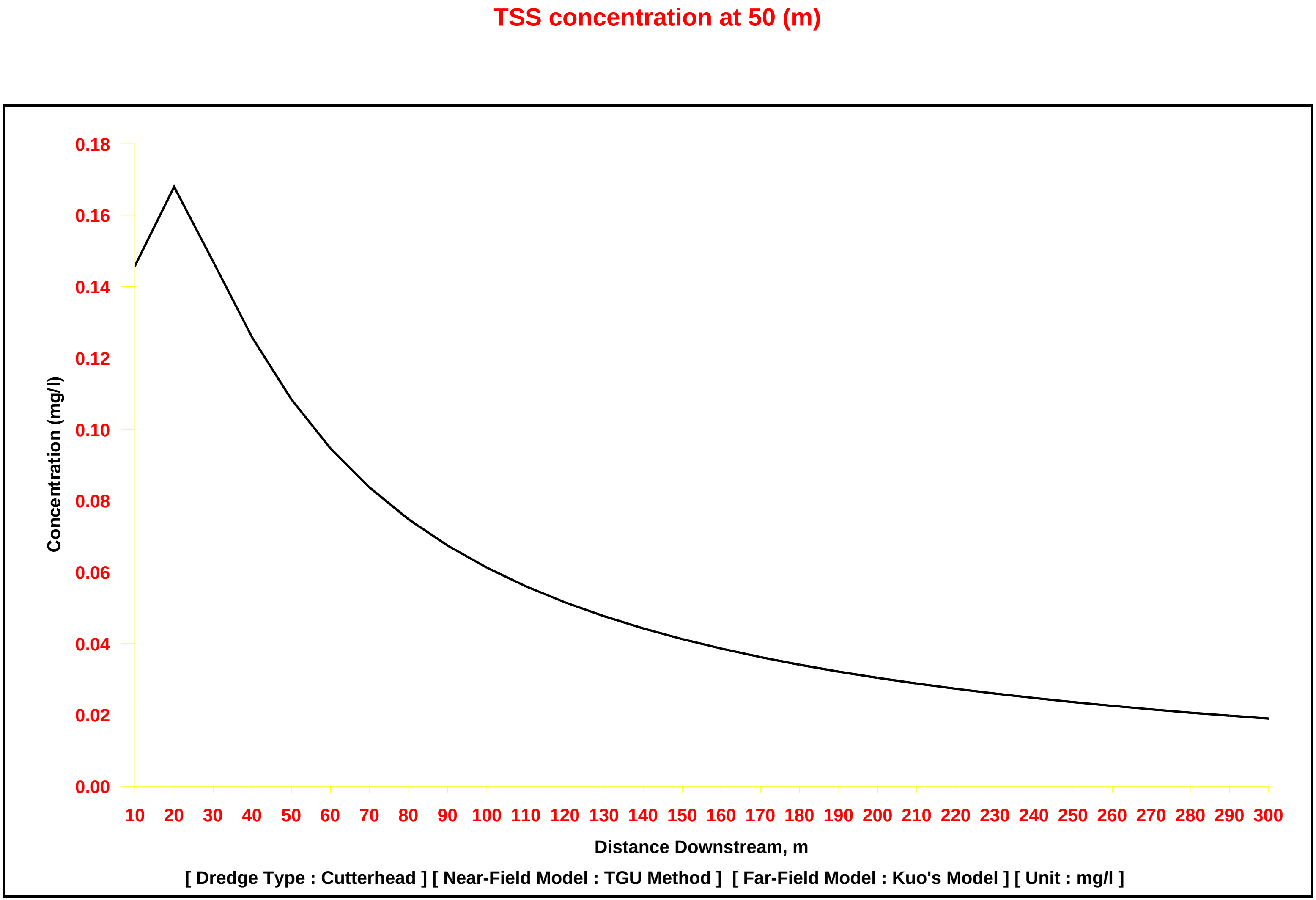


[Dredge Type : Cutterhead] [Near-Field Model : TGU Method] [Far-Field Model : Kuo's Model] [Unit : mg/l]

TSS concentration at -100 (m)



[Dredge Type : Cutterhead] [Near-Field Model : TGU Method] [Far-Field Model : Kuo's Model] [Unit : mg/l]


TSS concentration at 50 (m)
Concentration (mg/l)
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300
Distance Downstream, m
[Dredge Type : Cutterhead] [Near-Field Model : TGU Method] [Far-Field Model : Kuo's Model] [Unit : mg/l]

TSS concentration at 100 (m)