Memorandum

To: *Sean Sheldrake, US EPA Region 10*

From: *Lance Peterson, RG*

Date: *August 26, 2011*

Subject: *Estimates of Contaminant Releases during Arkema Dredging*

This memorandum presents CDM Federal Programs Corporation's (CDM) estimate of dredging releases associated with the Arkema removal action. This work was performed as part of a preliminary evaluation of the dredging project described in the June 14, 2011 settlement proposal submitted to EPA by Legacy Site Services, LLC (LSS) to resolve the current dispute over the Arkema early action project.

The settlement proposal includes the removal of 46,000 cubic yards of sediment contaminated with 2,4' and 4,4' DDD, DDE and DDT (Total DDx). The purpose of this memorandum is to estimate the mass of DDx contamination that could be released during the implementation of the proposed removal action. The memorandum also considers the use of physical controls such as silt curtains and rigid containment (e.g., sheet pile walls) to control DDx release during implementation of the removal action.

This evaluation considered the following information:

- The Four Rs of Environmental Dredging: Resuspension, Release, Residual, and Risk, 2009 (Four Rs Report)
- Sediment Dredging at Superfund Megasites: Assessing the Effectiveness, Natural Research Council, 2007 (NRC Report)
- Hudson River Phase 1 Dredging Peer Review Report, 2010 (Hudson River Peer Review Report)
- Final Removal Action Completion Report for the Removal Action at the GASCO site, 2006 (GASCO Completion Report)
- Draft Removal Action Area Characterization Report, Arkema Early Action

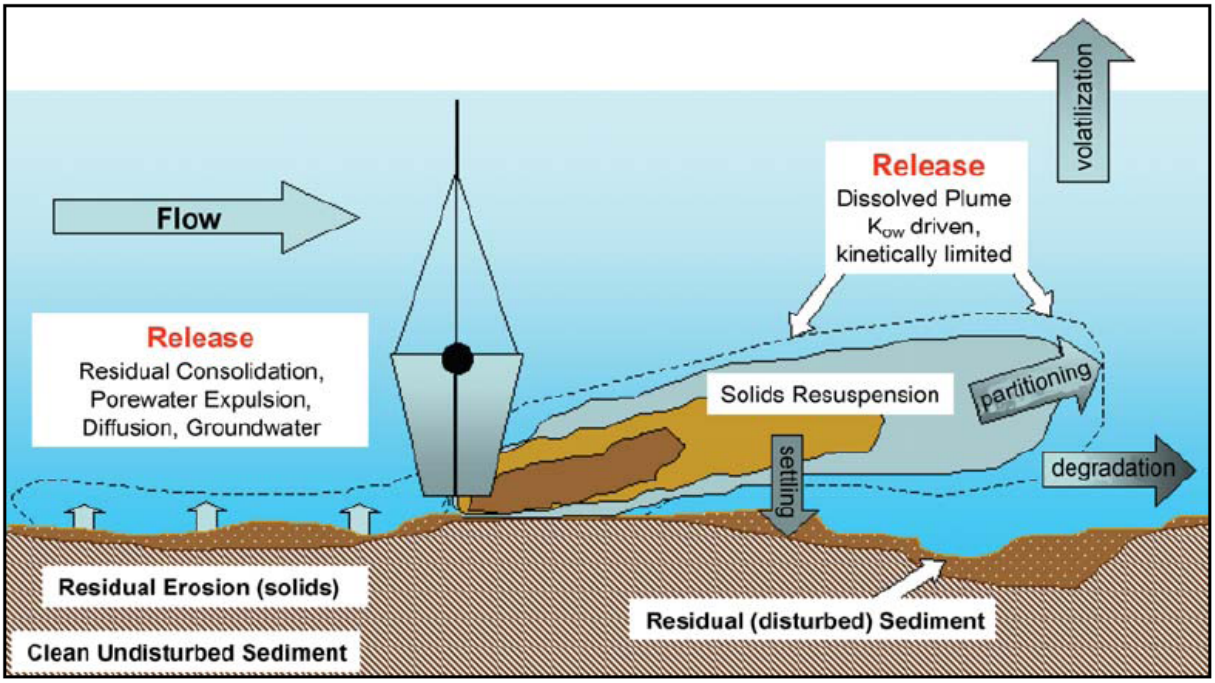
- U.S. Army Corps of Engineers DREDGE Module (DREDGE Module)

Contaminant Release Mechanisms

Contaminant losses during dredging activities are divided into three categories – resuspension, residuals, and release. Resuspension is the dislodgement and dispersal of sediment into the water column where the finer sediment particles and flocculants are subject to transport and dispersion by currents. Residuals are defined as sediment dislodged, but not removed, by dredging which falls back, spills, sloughs, or settles in or near the dredging footprint and forms a new sediment layer. Release is defined as the process by which the dredging operation results in the transfer of contaminants from sediment pore water and sediment particles into the water column or air. These processes are shown on Figure 1 taken from the Four Rs Report.

The evaluation presented in this memorandum considers the potential for contaminants that may be released to the water column through resuspension or release from resuspended sediments and generated residuals.

Figure 1 – Contaminant Release Mechanisms during Dredging



NRC Report

The Committee on Sediment Dredging at Superfund Megasites was convened by the National Research Council of the National Academies (NRC). The committee evaluated the effectiveness of dredging of contaminated sediments at Superfund megasites. The committee was asked to consider such aspects of

dredging as short-term and long-term changes in contaminant transport and ecologic effects. The results of the committee's evaluation were presented in the 2007 NRC Report.

As part of its evaluation, the committee reviewed information on various sediment dredging projects to assess short term releases of contamination during dredging and effectiveness of controls to minimize such releases. The NRC Report notes that in the absence of controls, up to 10% of the mass of sediment may be resuspended during dredging. The NRC Report evaluated the effects of resuspension and contaminant release at three sites that are particularly relevant to the Arkema site: 1998 Pilot Dredging Project, Deposit N, Lower Fox River Site; 2005 Remedial Options Pilots Study, Grasse River; and the 2005 GM Central Foundry Dredging Project, St. Lawrence River.

At Deposit N in the Lower Fox River, silt curtains were used to contain any resuspended sediment. Sampling during the 1998 pilot studies found that turbidity downstream of the dredging action was similar to upstream. However, polychlorinated biphenyl (PCB) concentrations were found to increase downstream of the dredging project. It was estimated that approximately 4% of the PCB mass removed from the deposit was released to the water column by dredging. The NRC Report stated that a good correlation between suspended solids and contaminant resuspension would be expected if the contaminant remained strongly associated with the solid phase.

The Grasse River Remedial Options Pilot Study was implemented in 2005. Silt curtains were deployed to minimize the release of contaminants during dredging activities. The NRC Report estimated that during dredging activities about 3% of the PCBs removed from the river bottom were released downriver, largely as PCBs that had desorbed from resuspended sediments. The NRC Report stated that data collected during implementation of the Grasse River removal actions suggested that most of the contamination released during dredging activities is in the dissolved form. Analysis indicated that although total suspended solid (TSS) concentrations were about 2 times greater inside the curtain than outside the curtain, the dissolved-PCB concentrations were similar 0.5 miles downstream of the dredging activities. The NRC Report concluded that approximately 75% of the PCBs released to the water column were in the dissolved form.

The NRC Report used the results of the dredging project at the GM Massena site as evidence that contaminant releases from dredging can be reduced through the use of rigid containment such as sheet pile walls. At the GM Massena project, a sheet pile wall was erected around the dredging zone because silt curtains were unable to withstand the river currents in the St. Lawrence River. PCBs were not detected above the action level of 2 micrograms per liter (µg/l) during monitoring conducted outside the sheet pile walls and the majority of water samples collected were below the detection limit.

Hudson River Peer Review Report

The Final Peer Review Report for the Phase 1 Hudson River Dredging project was released in September 2010. The Peer Review Report evaluated the resuspension and release of PCBs during implementation of the Phase 1 dredging program. The Peer Review Report described the various mechanisms for contaminant release beyond resuspension including dredging induced release of porewater, dredging induced release of PCB oils, flux from exposed sediment surfaces, resuspension of

sediments from exposed surfaces, as well as partitioning from resuspended particles. The Peer Review Report estimated PCB releases under a range of conditions as summarized in the following table:

Location	Conditions	Approximate PCB Release (%)
Cleanup Unit 18	Very restricted flow and traffic by the use of a sheet pile enclosure[1]	0.5 – 1%
East Rogers Island Cleanup Units	Restricted flow by use of rock dike but unrestricted traffic	1.3 – 1.7 %
West Rogers Island Cleanup Units	Unrestricted flow and traffic. Below a weekly average flow at Fort Edward of 5,000 cubic feet per second (cfs)	0.9 – 4.3 % with an average of 2.1%
West Rogers Island Cleanup Units	Unrestricted flow and traffic Above a weekly average flow at Fort Edward of 6,000 cfs	Between 4.6 and 7.4 % with an average of 6.1%

The results suggest that in the absence of controls, releases range between 0.9% and 7.4% of total mass depending on flow conditions. The sheet pile enclosure was installed in an area of relatively high flow and was effective at reducing contaminant releases even with the partial openings to account for changes in water level elevation.

GASCO Site

The GASCO site is located on the Willamette River approximately 1 mile downstream of the Arkema site. In 2005, a removal action was performed at the GASCO site to remove sediments visibly contaminated with tar. The 2005 GASCO removal action is a good case study for evaluating the potential for contaminant losses at the Arkema site due to its close proximity to the Arkema site and the nature of the contamination. The sediments are expected to be similar in grain size and organic carbon content, the river hydrodynamics are expected to be similar, the benzo(a)pyrene concentration of the sediments that were targeted for removal is similar to the total DDx concentration in sediments off shore of the Arkema site, and free product is present in contaminated sediments at both sites. Average naphthalene and benzo(a)pyrene sediment concentrations within the removal area were estimated at 1,900 milligrams per kilogram (mg/kg) and 240 mg/kg, respectively. Silt curtains along with a bubble curtain were deployed during the dredging operation at the GASCO site to control contaminant releases. As a result, the GASCO site can be used to estimate the amount of contaminant mass that may be released during dredging at the Arkema site using silt curtains to control contaminant release.

During implementation of the removal action at the GASCO site, numerous water quality measurements were obtained. Water quality monitoring focused not only on turbidity but also on

[1] The sheet pile containment system used to control releases at the Hudson River site included a series of windows to allow water to move in and out of the containment structure. This feature was necessary due to hydraulic manipulation of the Hudson River water level.

polycyclic aromatic hydrocarbons (PAHs). Water quality was monitored at numerous locations up and downstream of the removal action as well as within the silt curtain. In addition to water quality measurements, sediment trap data were obtained at one upstream and two downstream locations. Section 5.8.4 of the Removal Action Completion Report estimates contaminant losses at 0.2% of the total mass of PAHs removed during the removal action based on evaluation of the sediment trap data. The report notes that this is far lower than the literature estimates which are in the 1 to 8% range. However, the sediment trap approach only accounts for contaminated material that settles out immediately downstream of the removal action. It does not account for contamination that remains in suspension nor does it take into account dissolved releases. It should be noted that the NRC Report notes that the majority of contaminant releases during dredging are typically in the dissolved phase. In addition, the Hudson River Peer Review Report noted that there is no reliable relationship between total PCBs and sediment particulates as measured by TSS and/or turbidity.

Water quality monitoring downstream of the GASCO removal action detected numerous exceedances of both the acute and chronic water quality criteria for PAHs such as benzo(a)pyrene, benzo(a)anthracene, and naphthalene. In order to better evaluate releases during implementation of the removal action, contaminant loss estimates were developed on the results of the water quality monitoring. This approach better accounts for dissolved phase release and particulate contaminants that remain in suspension.

Approximately 200 water quality measurements were obtained during implementation of the removal action at the GASCO site. The average naphthalene and benzo(a)pyrene surface water concentrations were 6 ug/l and 0.6 ug/l, respectively. Water samples collected from within the silt curtain and immediately outside the silt curtain show that the silt curtains were 72 to 84% effective at reducing contaminant releases downstream of the removal action. The amount of mass released was estimated using a cross sectional area of 6,000 square feet (ft^2) and an average water velocity of 0.5 foot per second (ft/sec). The GASCO Completion Report notes that dredging took place for 43 days. To develop the contaminant mass estimates, it was conservatively assumed that contaminant releases occurred for 12 hours per day. The total mass of contamination removed was developed based on a total sediment mass removed of 12,000,000 kilograms (kg) obtained from the Removal Action Completion Report and average naphthalene and benzo(a)pyrene sediment concentrations of 1,900 mg/kg and 240 mg/kg, respectively. Based on the methodology described above, contaminant losses are estimated in the 3 to 4% range. This is well within the literature ranges cited in the GASCO Completion Report, the NRC Report and the Hudson River Peer Review Report. The attached **Table 1** presents the assumptions and calculations used to develop the contaminant loss estimate.

Based on an assumption of 5,000 kg of total DDx removed and a contaminant loss rate of 3 to 4%, the amount of DDx expected to be released to the water column during implementation of the settlement proposal at the Arkema Site with silt curtain controls in place is in the 150 – 200 kg range.

It should be noted that the Arkema release estimate did not take into account background concentrations. However, upstream estimates during GASCO dredging activities were likely impacted by the dredging activities and should not be used to develop background estimates. The average

concentrations of benzo(a)pyrene and naphthalene detected upstream of the dredging area prior to the beginning of the removal action were 0.032 and 0.081 µg/l, respectively. These concentrations are 5% and 1% of the downstream concentrations.

DREDGE Module

DREDGE was developed to assist users in making a priori assessments of environmental impacts from proposed dredging operations. DREDGE estimates the mass rate at which bottom sediments become suspended into the water column as the result of hydraulic and mechanical dredging operations and the resulting suspended sediment concentrations. These are combined with information about site conditions to simulate the size and extent of the resulting suspended sediment plume. DREDGE also estimates particulate and dissolved contaminant concentrations in the water column based upon sediment contaminant concentrations and equilibrium partitioning theory.

A range of literature-based and site specific data were used to parameterize the DREDGE Module. Site specific data were taken from the draft Portland Harbor Remedial Investigation (RI) Report, the GASCO Completion Report and the Arkema Removal Action Area Characterization Report (RAAC Report). Whenever available, site specific data from the RAAC Report were utilized. Literature values were taken from the DREDGE Module Users Guide (Donald Hayes and Chung-Hwan Je, 2000). **Table 2** summarizes the input parameters for the DREDGE Module. **Table 3** presents the output from the DREDGE Module model run.

Based on the results of the DREDGE Module, an average DDx surface water concentration of 1.4 µg/l was estimated immediately downstream of the proposed Arkema removal action described in the settlement proposal. Based on a cross sectional area downstream of the removal action of 1,200 square meters (m^2), a water velocity of 0.15 meters per second (m/sec), and 30 days of dredging for 12 hours per day, the mass of DDx expected to be released to the water column is estimated at 327 kg.

Water quality monitoring data collected during implementation of the GASCO Removal Action suggest that the silt curtains were 72 to 84% effective at reducing contaminant releases downstream of the removal action. Assuming that the silt curtains deployed at the GASCO site would be similar to silt curtains deployed at the Arkema site, the mass of DDx expected to be released to the water column is in the 52 to 91 kg range. This estimate is 1.0% to 1.8% of the total DDx mass presented in the Arkema settlement proposal. These estimates are slightly lower than reported for the Lower Fox River and Grasse River dredging projects and estimated for the GASCO site. It should be noted that the modeling performed at the GASCO site underestimated contaminant losses.

Conclusions

A review of dredging activities presented in the NRC Report and the Hudson River Report suggest that contaminants released during dredging activities are in the 1 to 10% range based on in situ contaminant mass estimates. In addition, monitoring data suggest that the majority of the contaminant releases are expected to be in the dissolved phase. At the GASCO site, water quality monitoring data suggest that the mass of contamination released to the water column during dredging activities, taking into account

the silt curtain controls, is 3 to 4% of the total mass. This is similar to the release estimate presented in the NRC Report for the Lower Fox River pilot dredging project of 4% (also using silt curtains). The DREDGE Module estimated DDx releases at the Arkema site of 6.5% of the contaminant mass presented in the settlement proposal. Using data regarding the effectiveness of the silt curtains obtained from monitoring during the GASCO removal action, DDx releases under the Arkema settlement proposal are expected to range from 1.0 to 1.8% of the total mass.

By a range of methods, the mass of DDx that may be released during Arkema settlement proposal dredging activities is in the 50 to 200 kg (1 – 4%) range. This can be contrasted with some of the estimates of DDx flux developed by the Lower Willamette Group and presented in the 2009 draft RI Report for the Portland Harbor site. The draft RI estimated the stormwater DDx load to range between 0.34 and 0.51 kilograms per year (kg/yr) while the upstream DDx load was estimated to range from 3 to10 kg/yr.

The data suggest that silt curtains may not be effective at reducing the release of dissolved phase contaminants during an Arkema early action dredging project. The results of the GM Massena dredging project suggest that the use of sheet pile walls will reduce the loss of contaminants during dredging although some release may occur during placement and removal of the sheet pile wall. Additional benefits to rigid containment include the ability to control contaminant releases during periods of high current. As a result, the engineering evaluation/cost analysis (EE/CA) for the removal of contaminated sediments at the Arkema site should include an evaluation of rigid containment such as sheet pile wall controls in addition to silt curtains and operational controls.

References

Hudson River PCBs Site Peer Review of Phase 1 Dredging, Final Report. Hudson River Peer Review Panel; September 10, 2010

Draft Removal Action Area Characterization Report, Arkema Early Action. Prepared for Legacy Site Services LLC by Integral Consulting Inc. and ARCADIS; December 24, 2010.

Dredge Module User's Guide. Hayes and Je; July 2000

Final Removal Action Completion Report; Removal Action; NW Natural "Gasco" Site. Prepared for NW Natural by Anchor Environmental LLC; April 2006

The Four Rs of Environmental Dredging: Resuspension, Release, Residual, and Risk; ERDC/EL TR-08-4; Bridges et. al.; January 2008

Sediment Dredging at Superfund Megasites: Assessing the Effectiveness, Natural Research Council, 2007

Table 1 – Estimation of Contaminant Losses At the GASCO site

Parameter	Estimate (Source)
Average Naphthalene Concentration within Removal Area	1,900 mg/kg (GASCO Construction Completion Report)
Average Benzo(a)Pyrene Concentration within Removal Area	240 mg/kg (GASCO Construction Completion Report)
Mass of Sediment Removed	12,000,000 kg (GASCO Construction Completion Report)
Contaminant Mass Removed – Naphthalene	23,000 kg (calculated)
Contaminant Mass Removed – Benzo(a)Pyrene	2,900 kg (calculated)
Naphthalene Surface Water Concentration	6 µg/l (Average concentration; GASCO Construction Completion Report)
Benzo(a)Pyrene Surface Water Concentration	0.6 µg/l (Average concentration; GASCO Construction Completion Report)
Dredging Days	43 days (GASCO Construction Completion Report)
Hours Dredging per day	12 hours (Assumption)
Surface Water Velocity	0.5 ft/sec (Average; GASCO Construction Completion Report)
Cross Sectional Area	6000 ft^2 (GASCO Construction Completion Report)
Contaminant Mass Loss (Naphthalene)	95 kg
Contaminant Mass Loss (Benzo(a)Pyrene)	9.5 kg
Percent Loss (Naphthalene)	4.1%
Percent Loss (Benzo(a)Pyrene)	3.3%

Contaminant Loss (Mass):
Naphthalene = 6 µg/l x 0.5 ft/sec x 6000 ft^2 x 1,857,600 sec x 28.3 l/ft^3 x 1 x 10-9 kg/µg = 950 kg

Benzo(a)Pyrene = 0.6 µg/l x 0.5 ft/sec x 6000 ft^2 x 1,857,600 sec x 28.3 l/ft^3 x 1 x 10-9 kg/µg = 95 kg

Contaminant Loss (Percent):
Naphthalene = 950 kg/23,000 kg = 4.1%

Benzo(a)Pyrene = 95 kg/2,900 kg = 3.3%

Table 2 – DREDGE Module Parameters

Parameter	Estimate (Source)
Bucket Size	8 m^3 (GASCO Completion Report)
Cycle Time	6o sec (Mid-Range Value, Dredge Module Users Guide)
Settling Velocity	10-5 m/sec (Portland Harbor Sediment Transport Model)
Dry Density	980 kg/m^3 (Calculated based on average Portland Harbor percent solids sediment data)
Turbidity Generation Unit (TGU)	89,000 g/m^3 (Table 3 of Dredge Users Guide (Nakai (1978))
Fraction < 74 um	0.72 (Average value from Arkema RAAC Report)
Fraction smaller than critical settling velocity	0.5 (Best professional judgment)
DDT Average Concentration	280 ug/kg (Average concentration between dock areas from RAAC Report
Organic Content	6.7 % (Average of three values from Arkema RAAC Report)
Water Depth	12 m (Portland Harbor bathymetric study)
Water Velocity	0.15 m/sec (Site specific measurements; GASCO completion report)
Mean particle size	190 um (Site wide average, Portland Harbor RI data base)
Specific gravity	2.6 g/cm^3 (Arkema RAAC Report)
Lateral Diffusion Coefficient	100,000 cm^2/sec (Dredge Module Users Guide)
Vertical Diffusion Coefficient	5 cm^2/sec (Dredge Module Users Guide)
Dredging Time	30 days (1,296,000 sec) [2]

Contaminant Loss (Mass; No Controls):
Total DDx = 1.4 µg/l x 0.15 m/sec x 1,200 m^2 x 1,296,000 sec x 1000 l/m^3 x 1 x 10-9 kg/µg = 327 kg

Contaminant Loss (Mass; Silt Curtain Controls):
327 kg x 16% = 52 kg; 327 kg x 28% = 91 kg

Contaminant Loss (Percent; Silt Curtain Controls):

52/5000 kg = 1.0%; 91/5000 = 1.8%

[2] Dredging time is based on the following assumptions: Bucket size = 8 m^3, cycle time = 60 s, bucket recovery = 50%, 12 hours dredging per day, downtime = 50% and dredge volume = 50,000 m^3. This results in an approximate dredge period of 30 days. It is further assumed that releases to the water column occur during the entire 12 hour period but that no releases occur outside the 12 hour period.

Table 3 – DREDGE Module Output

Dredge Type : Open Clamshell
Near-Field Model : TGU Method
Far-Field Model : Kuo's Model
Resuspended Material Selected : DDT
Units ug/l
Source Strength 8.24 kg/sec

	50	100	150	200	250	300	350	400
-50	1.219	0.266	0.051	0.009	0.002	0	0	0
-40	1.331	0.28	0.053	0.009	0.002	0	0	0
-30	1.423	0.291	0.055	0.01	0.002	0	0	0
-20	1.493	0.3	0.056	0.01	0.002	0	0	0
-10	1.536	0.305	0.057	0.01	0.002	0	0	0
0	1.551	0.307	0.057	0.01	0.002	0	0	0
10	1.536	0.305	0.057	0.01	0.002	0	0	0
20	1.493	0.3	0.056	0.01	0.002	0	0	0
30	1.423	0.291	0.055	0.01	0.002	0	0	0
40	1.331	0.28	0.053	0.009	0.002	0	0	0
50	1.219	0.266	0.051	0.009	0.002	0	0	0

C (ug/l)	A (m2)	V (m/s)	T (s)	kg/ug	l/m3	Release (kg)
1.4	1200	0.15	1944000	1.00E-09	1000	3.27E+02