INJURY TO WETLANDS RESULTING FROM THE CHALK POINT OIL SPILL

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INTRODUCTION

On 7 April 2000, an estimated 126,000 gallons of a mixture of No. 6 and No. 2 fuel oils spilled from a ruptured subsurface pipeline that supplies oil to the PEPCO Chalk Point Facility on the Patuxent River. The spill affected a variety of natural resources, including approximately 80 acres of brackish marsh habitat (i.e., wetlands). As part of natural resource damage assessment activities associated with the spill, the designated natural resource Trustees (Maryland Department of Natural Resources, Maryland Department of the Environment, U.S. Fish and Wildlife Service, and National Oceanic and Atmospheric Administration) and representatives of the Responsible Parties (PEPCO, the pipeline owner and ST Services, the pipeline operator) collected and analyzed data to determine the nature and extent of wetland "injuries" caused by the spill.[2] This report presents the Trustees' assessment and analysis of the available data to generate a quantitative measure of wetland injury due to the Chalk Point spill.

Wetlands provide a variety of ecosystem services that generate beneficial outcomes, such as better fishing and hunting, cleaner water, better views, and reduced human health and ecological risks (King et al., 2000). Exhibit 1 presents several categories of services and examples of many specific services provided by wetlands. Injury, for purposes of this injury assessment, is measured in terms of the area of wetlands affected and the time during which the wetland is unable to function at less than 100 percent of its baseline condition.

This report consists of four major sections. First, the Trustees present their methodology for data collection and interpretation. The second section contains a summary of data collected as part of wetlands injury assessment activities. The third and largest section of the report presents the Trustees' findings, including the quantification of the spatial and temporal extent of wetland injury, based on assessment data, information from the literature, and professional judgment of Trustee experts. The fourth and final section describes the Trustees' preliminary efforts at scaling a restoration project to compensate for the quantified wetland loss, as well as losses to muskrats and beaches.

Five appendices present additional data and findings relevant to the wetlands injury assessment. Appendix A contains maps showing the location of all wetland survey stations and the location of the pipeline break, Appendix B presents the raw benthic community data, and Appendix C provides graphical representations of the recovery curves described in the injury assessment section and summarized in Exhibit 6. Appendix D provides an assessment of the injuries to muskrats in the oiled marshes, including calculations to ensure that the scale of restoration needed to restore wetlands losses will also be sufficient to restore muskrat losses. Appendix E provides the total area of oiled sand beaches oiled by the spill, along with an estimate of needed restoration.

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[2] As defined by the Oil Pollution Act of 1990 regulations, injury is defined as "an observable or measurable adverse change in a natural resource or impairment of a natural resource service."

Exhibit 1. Examples of Wetland Services (King et al., 2000)	
Active	**Passive**
Commercial Uses • Agriculture • Trapping • Mining • Forestry • Fisheries	**Property Damage Avoided** • Flooding • Storm/Waves/Surge • Siltation/Sedimentation • Overnutrification • Noxious Weed Infestations
Recreational Uses • Fishing • Swimming • Hiking • Nature Viewing • Hunting • Birding • Boating	**Human Health Risks/Costs Avoided** • Nutrient Cycling • Carbon Cycling • Chemical Cycling • Oxygen Cycling **Ecosystem Health Risks Avoided** • Biodiversity Support • Endangered Species Protection • Protection of Ecological Infrastructure
Municipal Uses • Groundwater Recharge/Discharge • Drinking Water Purification • Pollution Prevention	**Climate Regulation** • Global Climate Effects/Attenuation • Microclimate Effects/Attenuation
Other Active Uses • Aesthetics - visibility, odor, noise • Education/Learning Opportunities • Research/Scientific Opportunities • Cultural/Spiritual Enrichment	**General Nonuse** • Existence Values • Options Values • Bequest Values

METHODOLOGY

Wetland Categories

Immediately following the spill, the Trustees and Responsible Parties conducted several initial field surveys to assess the extent of oiling. During these surveys, the Trustees identified several "categories" of marsh habitat reflecting both different species of marsh vegetation and different degrees of oiling. The categories were as follows:

- Lightly oiled wetlands: Light oiling was defined as less than 10 percent oil distribution and oil thickness less than 0.01 cm based on Shoreline Comprehensive Assessment Team (SCAT) data from 12-24 April 2000 (Entrix, 2001c). This category included all plant species, throughout the entire spill zone.

- Moderately oiled wetlands: All areas located outside of Swanson Creek that did not meet the definition lightly oiled were considered to be moderately oiled. Several species of vegetation were found in moderately oiled wetlands, including *Spartina alterniflora, S. cynosuroides,* and *Iva spp.* Separate categories were established for each of these species.

- Heavily oiled wetlands: All areas within Swanson Creek that did not meet the definition lightly oiled were considered to be heavily oiled. Separate categories were established for each of the predominant vegetation types: *Typha spp., S. alterniflora,* or *S. cynosuroides.* Each of these marsh types were further segregated into shoreline and interior areas, resulting in six heavily oiled categories.

- W1A wetlands: The area of wetlands in the immediate vicinity of the pipeline break that were the most heavily oiled (fresh oil pooled on the surface for long periods, etc.) and where the degree of cleanup activities was most aggressive (flooding, flushing, trenching, construction of boardwalks, nutrient augmentation, replanting, etc.) was treated separately. For purposes of establishing survey quadrats (see below), this category was divided into three subcategories: areas where vegetation was replanted; areas where ditches had been dug in the marsh interior to assist with oil recovery, backfilled with clean sand, and replanted; and areas of natural revegetation. In areas of natural revegetation, the survey efforts focused on areas of *Scirpus spp.* vegetation, because the Trustees felt that *Spartina spp.* and *Typha spp.* in this area were similarly affected as those in other heavily oiled areas.

Data Collection

Three permanent one square meter quadrats were established in marsh habitat representing each wetland category, with the exception of lightly oiled areas. Quadrats for *Iva spp.* were circles of 2 meter radius**.** No quadrats were established for lightly oiled areas because it has been shown that vegetation impacts from such light oiling are undetectable (Michel et al., 1998). Quadrats were also established at unoiled "reference" areas that were otherwise similar to impacted marsh areas. Exhibit 2 lists each study quadrat, along with designated habitat code; Exhibits A1-A4 in Appendix A show the location of the quadrats, also identified by habitat code.[3]

Field surveys were conducted by technical representatives for the Trustees and Responsible Parties (the Wetlands Assessment Team (WAT)) in July and September 2000 and July 2001. The initial July 2000 survey did not include W1A sites, because cleanup operations were still underway in that area. The WAT surveyed the W1A sites in September 2000 and visited all other sites to collect fruit, flower, and oiling information. The July 2001 survey included all of the established sites, both within and outside the W1A area.

Parameters measured at each quadrat included stem density by species, stem height, percent cover, oiling descriptors, flowering and seed condition, and chlorosis. Each quadrat was

[3] Fewer than three reference quadrats were established for some categories.

photographed, and sediment samples were collected for chemical analysis and benthic community assessment.[4]

Exhibit 2. Wetland Survey Locations	
Survey Location ID	**Wetland Category**
AH1S, AH2S, AH3S	*S. alterniflora* heavy shoreline
AH1I, AH2I, AH3I	*S. alterniflora* heavy interior
AMI2S, AMI3S	*S. alterniflora* moderate shoreline Indian Creek
AMT1S	*S. alterniflora* moderate shoreline Trent Hall Creek
CH1S, CH2S, CH3S	*S. cynosuroides* heavy interior
CH1I, CH2I, CH3I	*S. cynosuroides* heavy shoreline
CMI1S CMI3S	*S. cynosuroides* moderate shoreline Indian Creek
CMT1S	*S. cynosuroides* moderate shoreline Trent Hall Creek
TH1I, TH2I, TH3I	*Typha spp* heavy interior
TH1S, TH2S, TH3S	*Typha spp* heavy shoreline
IH1S	*Iva spp* heavy shoreline
IMI1S	*Iva spp* moderate shoreline Indian Creek
IMT2	*Iva spp* moderate Trent Hall Creek
IMT2I	*Iva spp* moderate interior Trent Hall Creek
DH1I, DH2I, DH3I	Ditched heavy interior
PH1I, PH2I, PH3I	Planted heavy interior
SH1I, SH2I, SH3I	*Scirpus spp.* heavy interior
Reference Location ID	
ARH3S	*S. alterniflora* shoreline Hunting Creek
ARP1S, ARP2S	*S. alterniflora* planted shoreline
ARH1I, ARH2I, ARH3I	*S. alterniflora* interior Hunting Creek
CRH1I, CRH3I	*S. cynosuroides* interior Hunting Creek
CRH1S, CRH2S, CRH3S	*S. cynosuroides* shoreline Hunting Creek
CRT2I	*S. cynosuroides* interior Trent Hall Creek
IRR2I, IRH3I	*Iva spp* interior Hunting Creek
IRT4	*Iva spp* Trent Hall Creek
SRI1I, SRI2I	*Scirpus spp.* interior Indian Creek
SRT3I	*Scirpus spp.* interior Trent Hall Creek
TRI3I	*Typha spp* interior Indian Creek
TRT1I, TRT2I	*Typha spp* interior Trent Hall Creek
TR1S, TR2S, TR3S	*Typha spp* shoreline

FIELD DATA SUMMARIES

This section presents brief summaries of the data collected during field surveys in July and September 2000 and July 2001. Detailed information from these surveys is provided in data reports prepared by Entrix (2000; 2001a; 2001b).

Vegetation

Exhibit 3 provides a summary of the vegetative parameters measured in July 2000 (or September 2000 in the case of the W1A wetlands) and July 2001. For each parameter (i.e.,

[4] Sediment cores measured 12 inches (length) by 4 inches (diameter).

percent cover, stem count, and stem height), observed values from the three quadrats for each wetland category in heavily and moderately oiled areas are averaged. The average values from the reference areas also are presented.

Benthic community

The benthic community was sampled using a 4-inch diameter PVC core tube driven to a depth of 1 foot. The cores were sieved in the field through a 500 micron sieve and preserved in formalin. Cores collected at heavily oiled wetland quadrat sites and reference areas were analyzed for benthic community composition. Species were identified to species or taxa as appropriate and counted. Exhibit 4 presents a summary of the data; the original data are included in Appendix B. The data for *S. cynosuroides* are summarized with and without station CH-2S, which had relatively low oiling relative to the other sites, thus raising questions about its comparability to other samples.

Chemistry

The field survey teams collected sediment samples using a pre-cleaned 4-inch diameter Lexan core tube driven to a depth of 1 foot. The cores were stored upright on ice in the field, frozen each night, and sent to a laboratory frozen in the core tubes at the end of the field survey. The laboratory extruded and sub-sectioned the cores into the requested sediment intervals. There was variable compaction of the sediment core during collection; as a result, reported intervals may vary slightly from actual depths. Exhibit 5 summarizes the results of chemical analyses conducted on sample cores collected by the Wetlands Assessment Team. Data are **not** averaged among quadrats for each category. Exhibit 5 includes total petroleum hydrocarbon (TPH) and total polynuclear aromatic hydrocarbon (PAH) concentrations for each sample.[5] Also presented is a qualitative assessment of the degree of weathering of the residual oil in the samples based on concentrations of saturated hydrocarbons (SHC, primarily n-alkanes), which are known to degrade relatively rapidly, and PAHs, which are known to be more resistant to weathering.

[5] TPH was measured by summing the total resolved hydrocarbons and the unresolved complex mixture using GC-FID. Total PAH was measured by summing 41 individual target PAHs, using GC/MS.

Exhibit 3. Summary of Vegetative Parameters, Reported as the Three-quadrat Average for Each Survey

	Percent cover[1]			Stem Count (/m^2)[2]			Stem Height (m)		
July, 2000									
	Heavy	**Moderate**	**Reference**	**Heavy**	**Moderate**	**Reference**	**Heavy**	**Moderate**	**Reference**
S. alterniflora shoreline	36.67	63.33	75	88	324	421.3	1.09	0.88	1.06
S. alterniflora interior	90	N/A	88.33	261	N/A	150	1.3	N/A	1.17
S. cynosuroides shoreline	85	93.33	93.33	181.3	216	237.3	1.50	1.7	1.76
S. cynosuroides interior	63.33	N/A	67.5	45	N/A	141.3	1.56	N/A	2.09
Typha spp. shoreline	40	N/A	56.67	44	N/A	120.7	2.1	N/A	2.18
Typha spp. interior	66.67	N/A	66.67	111.6	N/A	55.6	2.26	N/A	2.13
Iva spp.		75	85		7.75[3]	8[3]		1.61	1.55
September, 2000									
	Percent cover[1]			**Stem Count (/m^2)[2]**			**Stem Height (m)**		
	Heavy	**Moderate**	**Reference**	**Heavy**	**Moderate**	**Reference**	**Heavy**	**Moderate**	**Reference**
W1A									
S. alterniflora ditched	20	N/A	88.33	45.67	N/A	150	1.11	N/A	1.17
S. alterniflora planted	6.67	N/A	88.33	19.33	N/A	150	0.71	N/A	1.17
Scirpus spp. Interior	91.67	N/A	80	701	N/A	500	1.35	N/A	1.23
July, 2001									
	Percent cover[1]			**Stem Count (/m^2)[2]**			**Stem Height (m)**		
	Heavy	**Moderate**	**Reference**	**Heavy**	**Moderate**	**Reference**	**Heavy**	**Moderate**	**Reference**
S. alterniflora shoreline	66.67	46.7	73.3	187	85	260	1.30	0.89	1.08
S. alterniflora interior	73.3	N/A	96	95	N/A	233	1.02	N/A	1.02
S. cynosuroides shoreline	73.3	63.3	68.3	139	111	89	1.37	1.58	1.64
S. cynosuroides interior	61.7	N/A	85	77	N/A	94	1.35	N/A	1.62
Typha spp. shoreline	75	N/A	75	61	N/A	93	2.21	N/A	1.50
Typha spp. interior	46.7	N/A	52	93	N/A	55	2.24	N/A	2.06
Iva spp.		60	65		4[3]	5.33		1.4	1.58
W1A									
S. alterniflora ditched	35.7	N/A	96	47.3	N/A	233	0.92	N/A	1.02
S. alterniflora planted	27.3	N/A	96	61	N/A	233	0.86	N/A	1.02
Scirpus spp. Interior	44	N/A	47	258	N/A	148	1.12	N/A	1.20

N/A indicates that no habitat of that type was considered to be moderately oiled.
[1] Average percent coverage by all live vegetation.
[2] Stem count for predominant species only.
[3] Stem density for *Iva spp.* was measured as the number of shrubs/trees per 2-m radius circle.

Exhibit 4. Summary of the Benthic Data from 44 Cores Collected from Heavily Oiled and Reference Sites

	July 2000		Sept 2000		July 2001	
	Heavy Oil	Ref	Heavy Oil	Ref	Heavy Oil	Ref
S. alterniflora habitat						
Avg. number of species	6.3	13.0	10.0	8.0	11.0	11.7
Avg. density of tubificids w/o hair	193.7	99.7	51.0	55.7	219.7	50.0
Avg. amphipod density	0.3	6.3	0.3	0.7	5.0	1.3
Avg. amphipods plus isopods	1.3	12.0	1.3	2.3	8.0	4.3
	(n=3)	(n=3)	(n=3)	(n=3)	(n=3)	(n=3)
S. cynosuroides habitat						
Avg. number of species	8.0	14.0	[8.5] 11.7	10.3	6.3	9.0
Avg. density of tubificids w/o hair	132.7	25.0	[38.0] 35.3	47.3	32.3	3.7
Avg. amphipod density	0.0	4.0	[1.0] 4.3	1.7	0.0	1.7
Avg. amphipods plus isopods	0.3	8.5	[3.5] 9.3	4.0	0.0	1.7
	(n=3)	(n=2)	(n=2) (n=3)	(n=3)	(n=3)	(n=3)
Typha habitat						
Avg. number of species	no data	10.3	no data	11.0	no data	
Avg. density of tubificids w/o hair	no data	42.3	no data	32.0	no data	
Avg. amphipod density	no data	1.0	no data	2.3	no data	
Avg. amphipods plus isopods	no data	3.8	no data	5.3	no data	
		(n=4)		(n=3)		
[ ] - without site CH2S, which had low oiling						

The degree of weathering (Wx) is estimated on a scale of 1 to 4, as defined below:

1 = Evidence of evaporative weathering only; significant amount of C_{10-12} n-alkanes still present; naphthalenes more abundant than phenanthrenes/anthracenes, with parent naphthalene still present.

2 = Evidence of some microbial degradation, with a reduction in the 2-ringed PAH relative to the 3+ ringed PAHs, and reduction in the low to middle weight SHCs.

3 = Moderately weathered, with near complete removal of 2-ringed PAHs and a reduction in the 3-ringed PAHs, and for the SHCs, complete removal of the low and middle-weight SHCs.

4 = Near complete removal of all 2- and 3-ringed PAHs; all SHCs are at "background."

To facilitate comparison of the weathering state of the oil over time, Exhibit 5 provides the mean weathering value for each category of wetland. Means are calculated across all available data in a category, regardless of depth interval.

Exhibit 5. Soil Analytic Chemistry Results for Heavily Oiled Wetland Categories, Including Mean Degree of Weathering

Station	Interval (cm)	TPH (ppm) 2000	TPH (ppm) 2001	SHC Wx 2000	SHC Wx 2001	PAH (ppm) 2000	PAH (ppm) 2001	PAH Wx 2000	PAH Wx 2001
***Typha spp.* Interior**									
TH1I	0-5	286		2.5					
	5-10	577							
TH2I	0-5	653							
TH2I	10-15	510							
TH3I	0-5	7,567		1.5		540		1.5	
***Typha spp.* Interior Mean**				**2.0**				**1.5**	
***Typha spp.* Shoreline**									
TH1S	0-5	839	739	3.0	3.0	5	9	2.5	2.5
TH1S	10-15		545				6		2.5
TH3S	0-5	36,839	27,773	1.5	2.5		1,472		2.0
TH3S	5-10	669		2.5					
TH3S	11-15		454		3.0		3		2.0
***Typha spp.* Shoreline Mean**				**2.3**	**2.5**				**2.3**
***S. alterniflora* Interior**									
AH1I	0-5	383	516		4	2	3	2.5	
AH2I	0-5	3,728	1,853	2.5	3.0	205	54	2.5	2.5
AH2I	8-10	2,890	662	2.5	3.0*	194	8	2.5	2.0*
AH2I	20-25		756		3.0		14		2.5
AH3I	0-5	15,347	583	1.5	3.0	887	1		1.5*
AH3I	5-10	897		2.5					
AH3I	11-15		442		3.0		1		2*
AH3I	15-20	381		3.0					
***S. alterniflora* Interior Mean**				**2.4**	**3.2**			**2.5**	**2.1**
***S. alterniflora* Shoreline**									
AH2S	0-5	734		3.0					
AH3S	0-5	3,376				157		2.0	
***S. alterniflora* Shoreline Mean**				**3.0**				**2.0**	

Station	Interval (cm)	TPH (ppm) 2000	TPH (ppm) 2001	SHC Wx 2000	SHC Wx 2001	PAH (ppm) 2000	PAH (ppm) 2001	PAH Wx 2000	PAH Wx 2001
***S. cynosuroides* Interior**									
CH1I	0-5	6,417	40,205	1.0		473	2,160		
CH1I	5-10	11,740	22,142	1.0	1.0	722	1,216		1.0
CH1I	10-15	2,652		1.5		189			
CH1I	18-20	318	6,391	3.0	1.0	6	372		1.0
CH2I	0-5	40,580	51,867	1.5	3.0	2,600	4,326	1.5	
CH2I	13-15		35,948		1.0		2,186		1.0
CH3I	0-5	11,698	2,064	1.0	3.0	760	110		1.5
CH3I	10-15	4,585		1.5					
CH3I	18-20	3,391		1.5		173		2.0	
CH3I	16-19		892		3.0		28		2.0
CH3I	22-25	1,658							
***S. cynosuroides* Interior Mean**				**1.5**	**2.2**			**1.8**	**1.3**
***S. cynosuroides* Shoreline**									
CH1S	0-5	39,267				2,610		1.0	
CH2S	0-5	1,329		2.5					
CH3S	0-5	13,919		1.5					
CH3S	10-15	10,209		1.5					
***S. cynosuroides* Shoreline Mean**				**1.8**				**1.0**	
***Scirpus spp.* Interior**									
SH1I	0-5	46,861		1.5		3,192			
SH1I	12-17	3,353		2.0					
SH1I	21-25	2,884		2.0		183			
SH2I	0-5	17,554	3,772	1.5	2.0	901	147		2.0
SH2I	12-17	6,318		1.5					
SH2I	25-28	10,290	4,116	1.0	1.5		292		1.5
SH2I	30-32	2,341		1.5		167		2.0	
***Scirpus spp.* Interior Mean**				**1.6**	**1.8**			**2.0**	**1.8**

Station	Interval (cm)	TPH (ppm) 2000	TPH (ppm) 2001	SHC Wx 2000	SHC Wx 2001	PAH (ppm) 2000	PAH (ppm) 2001	PAH Wx 2000	PAH Wx 2001
Planted Interior									
PH1I	0-5	77,758	41,238	1.5	2.0	7,020	2,522	2.0	2.0
PH1I	18-20	6,298	12,540	2.0	1.5	408	847	2.0	1.5
PH1I									
PH2I	0-5	8,121	14,794	3.0	3.0	486	999		
PH2I	10-15	759							
Planted Interior Mean				**2.2**	**2.2**				**1.8**
Ditched Interior									
DH1I	0-5	3,923		2.5					
DH1I	5-10	5,640		1.0					
DH1I	20-25	2,410		2.5					
DH2I	0-5	1,328		2.0					
DH2I									
DH3I	10-15	195		3.0					
Ditched Interior Mean				**2.2**					

* Concentration of SHCs or PAHs was near background.
Blank cell indicates no data.
TPH= total petroleum hydrocarbons; PAH = polynuclear aromatic hydrocarbons; SHC = saturated hydrocarbons.
See text for explanation of the weathering (Wx) scale

INJURY ASSESSMENT

The Trustees assess injury to the wetlands impacted by the spill using the data described above, information from the scientific literature, and professional judgement. The first step is to develop a final list of injured wetland categories. Next, the area of each of these categories is estimated using a combination of remotely-sensed and field-collected data. Finally, recovery curves describing both the magnitude of service loss and the time to recovery for each category of wetland are developed. The following sections describe these steps in more detail.

Finalization of Wetland Categories for Injury Determination

The Wetlands Assessment Team (WAT) is responsible for the assessment and quantification of injury. Based on the field surveys, the final list of wetland categories for which injury will be assessed and quantified is as follows:

- All lightly oiled wetlands are grouped into a single category.

- All moderately oiled wetlands are grouped into a single category. Although separate quadrats were established for *Spartina alterniflora* and *S. cynosuroides*, few differences were noted between them, and they often formed mixed stands. In addition, *Iva spp.* (a woody shrub or tree) were found among the *Spartina spp.,* rather than as isolated stands. Therefore, the WAT combines all moderately oiled areas into one injury category.

- Heavily oiled wetlands are divided into shoreline and interior areas for each of the predominant vegetation types (*Typha spp., S. alterniflora,* or *S. cynosuroides),* resulting in six heavily oiled categories.

- As described above, quadrats were established in the W1A area for three different categories: planted areas, ditched and planted areas, and *Scirpus spp.* Based on field observations of the W1A area during the July 2001 survey, the WAT determines that impact and recovery are most appropriately assessed for two different categories: "less-impacted areas" and "more-impacted areas." These areas are shown on Exhibit A5 in Appendix A. The red line delineates the "more-impacted" area, representing approximately half of the W1A. The remainder of W1A, where the vegetation showed better recovery, is considered "less-impacted."

- Areas of un-oiled wetlands that were surrounded or nearly surrounded by oiled wetlands compose the final category of injured wetland, because access to these areas would be restricted to wildlife during the time oil persisted in adjacent areas.

The WAT estimates the area of each category of wetland using methods described in a report by Entrix (2001c), which includes maps showing the distribution of each category. Briefly, areas are determined using one of two methods. Interior areas of oiled wetlands are based on interpretation of April 2000 aerial photography and McCormick vegetation maps (McCormick and Somes 1982), with a major effort by the WAT to ground-truth the vegetation maps. Fringing areas of oiled vegetation are based on vegetation type and the length and width of oiling as reported by the WAT during the field surveys. The second column of Exhibit 7 presents the estimated area for each category.

Service Losses and Recovery Rates

Determining the degree of initial injury and rate of recovery curves for wetlands is a complex process. Several factors are known to influence the severity of impact to wetland vegetation from oiling, including vegetation coverage, substrate oiling, and exposure to natural removal processes. There have been very few long-term studies of oiled wetlands recovery rates. Most studies have focused on qualitative monitoring of vegetative recovery. For example, Alexander and Webb (1983) showed a reduction in biomass for plants where No. 6 fuel oil was applied to the entire plant surface. Baca et al. (1985) found reduced stem density two years after a spill in brackish wetlands along the Cape Fear River in North Carolina where the plants had been completely coated with oil, but not where oiling was limited mainly to the plant stems.

Studies on the effects of oil on benthic communities are similarly lacking, and there are no long-term studies on recovery of biological communities. The available quantitative measures of benthic community impact (e.g., total abundance, species richness, diversity indices) each suffer from one or more disadvantages when applied to the task of projecting recovery for a specific wetland. For these reasons, the vegetation and benthic community data are most appropriately used to determine large-scale differences between oiled and reference sites, and cannot be used alone to determine the shape of recovery curves for wetland services provided by soil and vegetation. The field data were used as relative indicators of the degree of injury, and to guide development of the recovery curves for each injury category. Given natural variability and the complex set of factors that can affect marsh structure, health, and productivity, it is extremely difficult to extract simple relationships between oiling, injury, and recovery.

Determining service losses and recovery rates for the areas affected by the Chalk Point spill therefore requires integration of available site data (summarized in the previous section of this document), knowledge of the published literature on oil spill impacts to wetlands (see reference list at the end of this document), and use of professional judgment. Care has been taken to make sure that the recovery curves are consistent with the WAT's understanding of the relative rates of weathering and removal expected for the different wetland categories. The scientific literature provides support for this approach of using multiple sources of data to estimate loss of ecological services. In a review article, Strange et al. (2001) concluded that

> "While structural metrics such as vegetative cover may indicate full recovery within a relatively short time, functional metrics may reveal a significant lag in the recovery of ecological processes such as nutrient cycling that are necessary for a fully functioning salt marsh. As a result, 100 percent recovery of some ecological services may represent only partial recovery of the system as a whole."

Two metrics were selected to represent the lost services and functions of the wetlands as a result of the oil spill: above-ground vegetation and soils. Above-ground vegetation represents a broad range of services related to primary production, habitat structure, recreational and aesthetic value, food chain support, and fish and shellfish production. It is an appropriate metric because it can be readily used for both injury quantification and restoration scaling. Use of a soil-related metric is particularly important for this spill site because of the nature of oiling and the importance of soil development and biogeochemical cycling to the overall ecological services of wetlands.

Exhibit 6 summarizes the WAT's estimates of the extent and duration of service loss for each wetland category. Service loss is expressed as the level of services in the oiled area after the spill as a percentage of the pre-spill level of services. For example, the WAT estimates an initial 75 percent loss of soil-related services in heavily oiled *S. alterniflora* wetlands. This is shown on Exhibit 6 as post-spill services of 25 percent. Services are assumed to recover linearly (i.e., at a constant rate) over the period of time noted. In some cases, the WAT estimates a "two phase" recovery period, reflecting an expected change in recovery rates between initial and later years of the recovery period. In these cases, recovery rates are assumed to be linear within each "phase." Appendix C presents graphical representations of all recovery curves.

Exhibit 6. Estimated impacts to ecological service flows and recovery rates for wetland vegetation oiled during the Chalk Point oil spill						
	VEGETATION			**SOILS**		
Category	**Services Post Spill (% of Pre-Spill)**	**Recovery Phase 1 %/years**	**Recovery Phase 2 %/years**	**Services Post Spill (% of Pre-Spill)**	**Recovery Phase 1 %/years**	**Recovery Phase 2 %/years**
All Light	90	100/0.5		90	100/0.5	
Spartina spp. Moderate	50	100/1		50	100/3	
Typha spp. Heavy Shoreline	0	100/1		25	60/3	100/10
Typha spp. Heavy Interior	0	100/1		50	80/5	100/10
S. alterniflora Heavy Shoreline	0	50/1	100/5	25	80/3	100/5
S. alterniflora Heavy Interior	0	50/1	100/5	25	75/5	100/10
S. cynosuroides Heavy Shoreline	0	50/1	100/10	25	60/3	100/10
S. cynosuroides Heavy Interior	0	50/1	100/10	25	50/5	100/20
W1A-Less Impacted	0	50/1	100/10	0	35/1	100/20
W1A-More Impacted	0	20/1	100/10	0	20/1	100/20
Restricted Access Areas	0	100/1		N/A		

<u>Injury by Category</u>

Lightly Oiled Wetlands

All wetlands with less than 10 percent oil distribution and oil thickness less than 0.01 cm based on April 2000 SCAT data (Entrix, 2001c) and "transitional area" (defined as a five-meter band on the landward side of moderately and heavily oiled marsh shorelines) are defined as "lightly oiled." As described below, impacts to lightly oiled wetlands are expected to be minimal. No investigative quadrats were established for lightly oiled wetlands, and no quantitative vegetative data or soil samples for chemical analysis were collected. As a result, the WAT combines all lightly oiled wetlands into one category, without distinction among vegetation types.

Oiling exposure and impacts for the lightly oiled wetlands can be summarized as follows:

- Initial oil distribution on a segment was no more than 10 percent, with an average distribution of eight percent for all lightly oiled areas (Entrix, 2001c).

- There was one major oiling event, in April.

- Oil was mostly on the stems and lower leaves of vegetation and on surface soils.

- The oiled stems sloughed off when the new shoots appeared. New vegetation was not oiled.

- Oil on vegetation and soils was 0.01 cm thick or less, and complete oil degradation likely occurred within 6 months of the spill.

Numerous studies (primarily related to *S. alterniflora)* document the rapid recovery of lightly oiled salt marsh vegetation. For example, *S. alterniflora* lightly oiled with IFO 180 from the *Julie N* spill had the same stem density and stem height as unoiled controls one year later (Michel et al. 1998). Sediments and lower plants sprayed with No. 6 fuel oil had the same biomass, new stems, seedlings and decomposition rates as unoiled controls after five months (Alexander and Webb 1983). In another study, brackish wetlands exhibiting oil banding showed no impacts from oil exposure (Levine et al. 1995).

Although no acute or chronic vegetative impacts are expected for lightly oiled areas, impacts may have occurred to epiphytic communities on the oiled vegetation. Given the literature cited above, the WAT technical experts estimate that the oil spill resulted in a 10 percent reduction in overall service flows for both soils and vegetation. Using similar available information and expertise, the WAT estimates that recovery was complete in one-half year, following the first growing season. Recovery curves for lightly oiled wetlands are shown in Exhibit C1.

Moderately Oiled *Spartina* spp.

Wetlands outside of Swanson Creek with more than 10 percent oil distribution or oil thickness greater than 0.01 cm, based on SCAT data (Entrix, 2001c), are categorized as moderately oiled. Although separate quadrats were established for *Spartina alterniflora* and *S. cynosuroides*, few differences were noted between them, and these species often formed mixed stands. Therefore, both species (when moderately oiled) are combined into one injury category.

Oiling exposure and impacts for the moderately oiled *Spartina spp.* wetlands can be summarized as follows:

- Initial oil distribution was greater than 10 percent, and averaged 60 percent.

- There was one major oiling event, in April.

- Oil was initially on the stems and lower leaves of vegetation and on surface soils.

- The oiled stems sloughed off when the new shoots appeared. New vegetation was not oiled; during the July survey, there was little or no visible oil on the vegetation.

- The July 2000 survey found no visible oil or only a light film of oil on the soil surface.

- At most sites, when the soils were disturbed underwater in 2000, they released sheens. By 2001, slight sheening was observed after soil disturbance at just two quadrat sites.

- At one site in 2001, disturbed soils released black oil droplets. Based on field observations in July and September 2000, an estimated 25 percent of the soils in moderately oiled *Spartina spp.* wetlands would release black oil droplets when disturbed.

- One of the three *S. alterniflora* quadrats, located in an area that received intensive cleanup, showed reduced cover and stem count in 2000 and 2001.

- Total petroleum hydrocarbon (TPH) concentrations in soils from two quadrats in 2000 were 3,270 and 4,230 parts per million (ppm); concentrations of polynuclear aromatic hydrocarbons (PAH) in soils from these sites were 90 and 330 ppm, and the oil was characterized as weathered to significantly weathered. The Trustees did not collect any soil samples from moderately oiled habitats in 2001.

Krebs and Tanner (1981) reported no impacts to *S. alterniflora* vegetation when soil concentrations were below 2,000 ppm oil at a No. 6 fuel oil spill in the Potomac River. Above 2,000 ppm, they reported decreased stem height, density, and aboveground biomass; above 10,000 ppm, most of the underground rhizomes were killed (Krebs and Tanner, 1981). For a spill of crude oil in Louisiana, Alexander and Webb (1987) reported no impacts to vegetative growth for marshes with soil oiling levels less than 5,000 ppm TPH.

With respect to natural removal processes, the outer fringe of a marsh is often exposed to tidal flushing and wave action. Hershner and Moore (1977) studied a No. 6 fuel oil spill on the lower Chesapeake Bay and reported an increase in net productivity of oiled marshes after one growing season. They attributed the lack of long-term impact to the relatively exposed setting. In contrast, Bender et al. (1977, 1980) conducted a field oiling experiment with fresh and weathered South Louisiana crude oil in an isolated mesohaline marsh off the York River, Virginia. In these studies, oiling of the *S. alterniflora* vegetation resulted in a 50 percent reduction in biomass one year post-oiling.[6] Nearly all of the areas classified as moderately oiled *Spartina spp*. are marsh fringes.

Based on the literature referenced above, field observations in 2000 and 2001, and experience at previous spills, technical representatives on the WAT estimate that there was an

[6] The correlation of recovery with degree of exposure to natural removal processes has been observed at many spills, and was the basis for establishing quadrats in both shoreline and interior sites for this spill.

initial vegetative service loss in the moderately oiled wetlands of 50 percent, with full recovery in one year. This recovery curve is applied to all species of vegetation found in moderately oiled areas.

Impacts associated with contaminated marsh soils are more difficult to assess because few studies have addressed this issue. Oil degradation rates have been correlated with oil loading and depth of penetration into sediments (Michel and Hayes, 1999). Hoff et al. (1993) studied a spill of Alaska crude oil in a *Salicornia virginica* wetland in Puget Sound and found extensive weathering in lightly oiled soils after one summer and slower weathering (as determined by elevated PAH levels in the soils 16 months post-spill) in soils with thicker layers of oil. Considering that most of the oil in the moderately oiled areas was along the outer marsh fringe and did not penetrate very deep into the sediments, oiled soils in these areas are expected to recover in three years. Exhibit C2 shows the recovery curves for moderately oiled areas.

Heavily Oiled *Typha spp.* (Shoreline and Interior)

Typha spp. wetlands inside Swanson Creek with more than 10 percent oil distribution and oil thickness greater than 0.01 cm are categorized as heavily oiled (Entrix, 2001c). Quadrats were established at both shoreline and interior locations.

Oiling exposure and impacts for heavily oiled *Typha spp.* can be summarized as follows:

- Initial oil distribution occurred as a band of heavy oil on the substrate and lower vegetation (stems and lower leaves).

- There were multiple oiling events throughout the summer of 2000, as pooled oil was released from adjacent heavily oiled marshes.

- In July 2000, stain and coating on stems were visible. By July 2001, no oil was visible on any vegetation.

- Percent cover, stem density, and stem height were highly variable, but generally comparable with controls in July 2000 and 2001.

- At all quadrats, the soils released black oil droplets when disturbed underwater in 2000. By 2001, only sheens were released after disturbance.

- The soils were highly organic (15 percent total organic carbon, TOC).

- Analysis of two shoreline samples (0-5 cm depth) collected in 2000 revealed widely different degrees of soil contamination, with one site having 40 times more TPH (37,000 ppm) than the other (840 ppm). Only slight decreases were observed by 2001. PAH levels in surface soils in 2001 were 9 and 1,500 ppm and moderately weathered, indicating highly variable but very high and toxic levels. Some of these habitats had high initial loadings and apparently relatively low natural removal and weathering rates.

- Concentrations of TPH for all three interior sites from 2000 were typically lower than those on the shoreline, and ranged from background to 7,600 ppm. Only one PAH analysis was performed in 2000, with a result of 540 ppm and slight weathering.

- The WAT did not conduct benthic community analysis on heavily oiled *Typha spp,* although analysis was completed on reference sites.

The available literature on heavily oiled salt marshes indicates a moderate recovery trajectory. In a study of the rate of recovery of twenty heavily oiled salt marshes, the majority of marshes recovered within five years (Sell et al. 1995). Exceptions were the result of extensive mechanical cleanup, thick oil residues that smothered the vegetation, and/or deep penetration of a highly toxic oil (No. 2 fuel oil). There are very few studies on the effects of oil specifically on *Typha spp.* wetlands. The notable exception is a study of a No. 6 fuel oil spill in the St. Lawrence River where most of the oiled vegetation was cut (Alexander et al., 1981). Studies of the cut versus uncut areas showed normal or enhanced vegetation growth for the oiled areas after one year. The only impact observed was that the cut vegetation did not produce flowers.

Based on field data at both shoreline and interior sites, and observations at other spills, the WAT assumes that *Typha spp.* vegetation recovered completely within one year of the spill. Because the soils were highly organic and contained black oil droplets in 2000 and continued to release sheens in 2001, the WAT estimates that the effect on soils in the interior was a 50 percent initial reduction of services, with a return to 80 percent services in 5 years and 100 percent services in 10 years. For the shoreline fringe, where the soils were initially more heavily oiled yet are more exposed to natural removal processes, the WAT estimates an initial 75 percent reduction in services, with a return to 60 percent services in 3 years, and 100 percent services in 10 years. Recovery curves for heavily oiled *Typha spp.* wetlands are shown in Exhibits C3 and C4.

Heavily Oiled *S. alterniflora* (Shoreline and Interior)

Oiled *S. alterniflora* wetlands in Swanson Creek with more than 10 percent oil distribution and oil thickness greater than 0.01 cm are categorized as heavily oiled (Entrix, 2001c). Quadrats were established at both shoreline and interior settings.

Oiling exposure and impacts for the heavily oiled *S. alterniflora* wetlands can be summarized as follows:

- Initial oil distribution occurred as a band of heavy oil.
- Multiple oiling events occurred throughout the summer of 2000, as pooled oil was released from adjacent heavily oiled marshes.

- Vegetation showed oiling mainly on stems and lower leaves. By July 2000, stain and coating on stems were still visible, mostly in trace amounts.
- Shortly after the spill, the WAT observed reduced percent cover and stem densities at shoreline vegetation quadrats as compared to reference sites. Although values were still lower than reference sites in 2001, percent cover and stem density had increased by about a factor of two.
- Black oil had penetrated into the substrate, along stem cavities and roots.
- In July 2000, sediments in four of six quadrats released black oil droplets when disturbed underwater. By July 2001, these sediments released only sheens.
- TPH levels in interior surficial soils in 2000 were highly variable, ranging from background to over 15,000 ppm, with evidence of penetration to greater than 10 cm. Levels of SHCs and TPHs indicated intermediate and moderate amounts of weathering, respectively. By 2001, TPH levels had decreased (maximum 1,850 ppm), and all saturated hydrocarbons had weathered significantly.
- PAH levels in interior soils in 2000 ranged from 2-200 ppm; levels in 2001 were 1-54 ppm and characterized as moderately weathered.
- The Trustees found reduced overall species numbers and numbers of oil-sensitive species (amphipods and isopods) as compared to reference sites in samples collected in July 2000. Species numbers were similar to reference sites by September 2000.

The available literature on heavily oiled salt marshes indicates a moderate recovery trajectory. In a study of the rate of recovery of twenty heavily oiled salt marshes, the majority of marshes recovered within five years (Sell et al. 1995). Exceptions were the result of extensive mechanical cleanup, thick oil residues that smothered the vegetation, and/or deep penetration of a highly toxic oil (No. 2 fuel oil). The impacts to *Spartina spp.* vegetation and the degree of soil contamination at Chalk Point are similar to that reported by Krebs and Tanner (1981) for a No. 6 fuel oil spill in the Potomac River, where significant impacts to vegetation occurred and marsh sediments showed no decreasing trend in oil concentration in the first year after the spill. These authors also observed a delay in vegetation mortality in oiled but not replanted areas.

Based on these studies, the WAT expects the heavily oiled *S. alterniflora* vegetation in both shoreline and interior habitats to recover in five years. Because field data indicate significant vegetative recovery, the WAT assumes first year recovery to 50 percent. Soil-related service recovery is expected to be slower than for vegetation-related services. Based on results of sediment chemistry and professional judgment, the WAT assumes an initial reduction in soil-related services of 75 percent. Along the shoreline fringe, the WAT expects 80 percent recovery within 3 years and 100 percent within 5 years. As interior soils experience higher initial oil levels and are subject to lower natural removal rates, the WAT estimates 75 percent recovery within 5 years and 100 percent recovery within 10 years. Exhibits C5 and C6 present these recovery curves graphically.

Heavily Oiled *S. cynosuroides* (Shoreline and Interior)

Oiled *S. cynosuroides* wetlands in Swanson Creek with more than 10 percent oil distribution and oil thickness greater than 0.01 cm are categorized as heavily oiled (Entrix, 2001c). Quadrats were established at both shoreline and interior settings.

Oiling exposure and impacts for heavily oiled *S. cynosuroides* wetlands can be summarized as follows:

- Initial oil distribution occurred as a band of heavy oil.
- Multiple oiling events occurred throughout the summer of 2000, as pooled oil was released from adjacent heavily oiled marshes.
- Vegetation showed oiling mainly on stems and lower leaves. Stain and coating on stems remained visible in July 2000.
- Impacts to vegetation varied widely. Some interior areas were completely devoid of vegetation while others had reduced stem densities or appeared normal. By 2001, two interior sites showed good recovery (similar to reference sites) while a third showed very little re-growth. Shoreline vegetation showed good recovery by 2001.
- Black oil penetrated deeply into root clumps, along stem cavities, roots, and burrows, to a greater extent than in *S. alterniflora* marshes. Visual observation of subsurface oil at the interior sites described oil-filled pores and partially filled pores (2000-2001). In July 2000, disturbed sediments released black oil droplets at all quadrats. In July 2001, one shoreline site had oil-filled pores and one site had no visible oil.
- Sediments were highly organic (20 percent TOC) and the marsh surface was hummocky with root mats forming higher clumps.
- *S. cynosuroides* wetlands had the highest degree of oil contamination of any shoreline habitat, with a July 2000 surface soil sample containing 39,300 ppm TPH and 2,610 ppm PAH; the oil was characterized as slightly weathered. The Trustees did not analyze any shoreline samples collected in 2001.
- *S. cynosuroides* wetlands also had the highest degree of oil contamination of any interior habitat except the wetlands immediately adjacent to the pipeline break. Surface samples collected in both 2000 and 2001 contained over 40,000 ppm TPH. The WAT found evidence of alkane weathering in the surficial soils between 2000 and 2001, but little to no weathering of the PAHs.
- Oil penetrated to 20+ cm in some cores, and this deeper oil showed much slower weathering.
- Benthic communities showed partial recovery by September 2000, but poor recruitment of oil-sensitive species in July 2001.

Overall, the field data demonstrate that heavily oiled *S. cynosuroides* wetlands displayed the highest degree of impact of all habitat types. The highly organic soils contained the highest levels of oil contamination (outside of W1A), both on the surface and with depth, and exhibited the slowest rate of oil weathering. PAHs were only slightly weathered and showed little change in weathering by 2001. Oil entered these sheltered interior habitats via many “micro-channels” and muskrat runs, where tidal flushing rates are almost zero. An important consideration in the analysis for this category of wetland is the available evidence from a marsh in Buzzards Bay, Massachusetts oiled with No. 2 fuel oil. There, concentrations in soil 30 years after the spill were similar to those observed immediately after the spill (Reddy et al., 2001). As a result, the WAT expects long-term impacts to heavily oiled *S. cynosuroides* wetlands.

The WAT estimates recovery rates for this category to be twice as long as those of other heavily oiled wetlands. Based on field observations, vegetation-related services for both shoreline and interior habitats are assumed to have returned to 50 percent after one year, but full recovery may take up to 10 years because of the degree of substrate oiling and slow recovery of vegetation. Soil-related services are estimated to have been reduced by 75 percent initially, with shoreline habitats returning to 60 percent services in 3 years and 100 percent in 10 years. Soil services for interior habitats will recover even slower, to 50 percent in 5 years and 100 percent in 20 years. Please refer to Exhibits C7 and C8 for graphical depictions of these curves.

Wetlands Immediately East of Pipeline Break ("W1A" Less Impacted and More Impacted)

The wetlands adjacent to the pipeline break are treated as a separate category because the heavily oiling (fresh oil pooled on the surface for long periods, etc.) and the aggressive cleanup activities conducted in the area (flooding, flushing, trenching, construction of boardwalks, nutrient augmentation, replanting, etc.) distinguish them from other wetlands oiled by the spill. In addition, these areas were not accessible until September 2000 because of ongoing cleanup activities. Within this category, the WAT established quadrats in areas where vegetation appeared to have completely died and thus was replanted; areas where ditches had been dug in the marsh interior to assist in oil recovery, backfilled with clean sand, and replanted; and areas of interior (rather than shoreline) *Scirpus spp.* vegetation that appeared to be heavily oiled.

Oiling exposure and impacts for W1A wetlands can be summarized as follows:

- Initial oiling occurred as thick slicks of fresh oil (mixture of No. 2 and No. 6 fuel oils) pooled on the marsh surface that persisted for several weeks as the cleanup progressed.

- Chronic re-oiling occurred through 2001, as residual oil was re-mobilized from oiled areas within W1A.

- Soils at most quadrats released black oil droplets when disturbed during the July 2001 surveys.

- Black oil penetrated deeply into the root clumps, along stem cavities, roots, burrows, etc. In September 2000, one replanted site contained 77,800 ppm TPH and 7,140 ppm PAH in the top 5 cm, with 6,300 ppm TPH and 420 ppm PAH at the interval 18-20 cm. At this same site in

ERRATA SHEET

INJURY TO WETLANDS RESULTING FROM THE CHALK POINT OIL SPILL

July 2002

Page 22, first Paragraph after the bullets, should read:

> "Exhibit A5 in Appendix A shows an aerial photograph of W1A obtained in September 2000. Based on field observations during the July 2001, . . ."

Explanation: Exhibit A5 in Appendix A indicates that the photo was obtained in July 2001. The photo was actually taken on September 27, 2000.

2001, the surficial oiling decreased by about half, but the subsurface oiling increased by about a factor of two, with no evidence of further weathering.

- Ditched areas, although backfilled with clean sand, contained 1,300 and 3,900 ppm TPH in September 2000, indicating a substantial amount of re-oiling.

- *Scirpus spp.* habitat also showed extensive oil contamination on the surface and the deepest penetration observed anywhere (2,340 ppm TPH and 167 ppm PAH at depths of 30-32 cm in September 2000). Data from this same quadrat in 2001 showed reductions both at the surface and with depth.

- Vegetation in the replanted areas (whether ditched or not) showed large reductions in cover and stem density.

Exhibit A5 in Appendix A shows an aerial photograph of W1A obtained in July 2001. Based on corresponding field observations during the July 2001 survey, the WAT designates two sub-areas in W1A. The red line on Exhibit A5 delineates a "more-impacted" area representing approximately half of the W1A. These "more-impacted" areas include those that were planted and ditched and planted, as well as areas of extensive physical disturbance during pipeline repair activities. The remainder of W1A, where the vegetation showed significant recovery, is considered "less-impacted," and includes areas represented by *Scirpus* habitat.

The most applicable case study of the likely recovery rate for W1A is of the *T/V Amoco Cadiz* spill of crude oil in Brittany, France in March 1978. Heavy oiling of a coastal marsh was followed by intensive cleanup using high-pressure flushing, extensive vehicular and foot traffic, channelization, and sediment removal. Replanting efforts were conducted one and three years later. Baca et al. (1987) reported that restoration was "complete" within eight years, although only vegetative parameters were measured.

Based on the similarity of the *Amoco Cadiz* site to the "more-impacted" areas in W1A, the WAT estimates a ten-year recovery curve for vegetation. For the less-impacted areas, the vegetation is estimated to have recovered to 50 percent services within one year, similar to the other interior habitats discussed above. For the more-impacted areas, the WAT estimates first year recovery of only 20 percent services. For soil-related services, the initial injury is assumed to be 100 percent loss of services, with complete recovery in 20 years. The WAT estimates first year recovery of 35 percent for less-impacted areas and 20 percent for more-impacted areas. Recovery curves for the W1A wetlands can be found in Exhibits C9 and C10.

Restricted Access Wetlands

After the spill, there were areas of unoiled wetlands in Swanson Creek that were nearly surrounded by oiled wetlands. These areas are clearly visible on the aerial photographs and computer maps delineating the oiled habitats. Access to these areas would be restricted to wildlife during the time that oil persisted in adjacent areas. The Wetlands Assessment Team believes that access to these areas would return to normal within one year of the spill, when the oiled vegetation would no longer be a deterrent. Therefore, vegetation services were completely lost immediately following the spill, but recovered fully in one year; there were no reductions in soil-related services for this injury category. This recovery curve is presented in Exhibit C11.

RESTORATION SCALING

Habitat Equivalency Analysis

The process of scaling a restoration project involves adjusting the size of a restoration action to ensure that the present discounted value of project gains equals the present discounted value of interim losses. There are two major scaling approaches: the valuation approach and the simplified service-to-service approach. Habitat Equivalency Analysis (HEA) is an example of the service-to-service approach, and the approach implemented by the Trustees in this case. The principal concept underlying the method is that the public can be compensated for past losses of habitat resources through habitat replacement projects providing additional resources of the same type. The implicit assumption of HEA is that the public is willing to accept a one-to-one trade-off between a unit of lost habitat services and a unit of restoration project services.[7] That is, the public equally values a unit of services at the injury site and the restoration site. HEA does not necessarily assume a one-to-one trade-off in resources, but instead in the services they provide.

The basic steps for implementation of HEA are:

- Document and estimate the duration and extent of injury, from the time of injury until the resource recovers to baseline (or possibly to a maximum level below baseline);
- Document and estimate the services provided by the replacement project, over the full life of the habitat;
- Calculate the size of the replacement project for which the total increase in services provided by the replacement project equals the total interim loss of services due to the injury; and
- Calculate the costs of the replacement project, or specify the performance standards in cases where the responsible party will be implementing the project.

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[7] The concept of services refers to functions a resource serves for other resources and for humans. For example, a wetland habitat may provide on-site ecological services such as faunal food and shelter, sediment stabilization, nutrient cycling, and primary production. Off-site services may include commercial and/or recreational fishing, bird watching, water quality improvements due to on-site water filtration, and storm protection for on-shore properties due to the creation of wave breaks. Human services include both use and non-use services, so the HEA approach measures and accounts for non-use services in the damage claim.

Addendum

The Extent of Oiling Report and the Wetland Injury Report differ in the number of acres that were reported as oiled. This difference is not an error but results from differences in the treatment of heavily oiled interior marsh and interior transitional areas in the two reports. The area of heavily oiled marsh was determined from aerial photographs taken of the spill site. During the damage assessment, the marsh assessment group agreed that a 5-meter wide band adjacent to the heavily oiled marsh would be added to account for areas that were oiled but were not visible on the aerial photographs. This 5 meter wide band was designated as the interior transitional area in Table 4-2 of the Extent of Oiling Report and treated as a separate oiling category.

In the estimating the wetland injury, the marsh assessment group agreed that the interior transitional areas suffered half the injury of the heavily oiled interior marsh. To facilitate the calculation of injury in the Wetland Injury Report, the acreage of the interior transition area associated with each species was divided by two and added to the area of heavy interior oiling. For any heavily oiled interior injury category, the acreage from the Wetland Injury Report can be calculated by adding one half the acreage from the interior transition area to the acreage from the injury category in Extent of Oiling Report. For example, Exhibit 7 of the Wetland Injury Report shows 2.3 acres of heavily oiled interior *Typha angustifolia* which includes 1.49 acres of heavily oiled marsh that was visible on the aerial photographs plus one half of the 1.63 acres of *T. angustifolia* from the adjacent interior transitional area. The 1.49 acres of heavily oiled interior *T. angustifolia* marsh and the 1.63 acres if interior transitional *T. angustifolia* marsh are reported separately in Table 4.2 of the Extent of Oiling Report. The same method of calculation can be used to reconcile the acreage of *Spartina* injury, W1A injury, and the total acres impacted in the two reports.

Injury to Wetlands

This report presents the Trustees' efforts to complete the first three steps of the HEA process for injury to wetlands. The measure of injury combines the level of services lost and the time over which this loss occurred. In this case the Trustees express injury in discounted acre-years of wetland services. For each category of injured wetland, the fraction of wetland services lost in each year from the time of the spill to full recovery (as described by the recovery curves in Exhibit 6 and Appendix C) is discounted at three percent per year to the year of the spill (2000) and summed. Total injury is the product of this total discounted loss and the area of wetlands in that category.[8] Exhibit 7 shows the final estimated area for each of the 11 oiled wetland categories and the associated lost services for both vegetation and soils.

Exhibit 7. Summary of Wetland Injury by Category

Wetland	Total Area (Acres)	Vegetation Injury (Acre-years)	Soil Injury (Acre-years)
All Lightly Oiled Wetlands	40.46	1.012	1.012
Spartina spp. Moderate	12.02	3.005	8.870
Typha spp. Heavy Shoreline	0.16	0.080	0.463
Typha spp. Heavy Interior	2.3	1.150	4.794
S. alterniflora Heavy Shoreline	1.52	2.579	2.396
S. alterniflora Heavy Interior	3.8	6.446	11.047
S. cynosuroides Heavy Shoreline	1.66	4.618	4.808
S. cynosuroides Heavy Interior	7.6	21.141	44.143
W1A: Less Impact	3.2125	8.936	18.994
W1A: More Impact	3.2125	13.334	23.006
Restricted Access Areas	4.11	2.055	N/A
Total	**80.055**	**64.355**	**119.532**

Injury to wetlands totals approximately 64 acre-years for vegetation-related services and approximately 120 acre-years for soil-related services. Assuming that the contributions of vegetation and soils to overall wetland services are equal, the total injury is approximately 92 wetland acre-years.[9]

The Trustees and RP are working to identify potential wetland restoration options. One preferred option is the creation of new wetlands from an upland site in the immediate vicinity of the spill impact area. The Wetlands Assessment Team bases its predicted recovery trajectory for created wetlands at this site on the professional knowledge of its members; input from a wetlands

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[8] For example, vegetation in moderately oiled *Spartina spp.* wetlands suffered an initial 50 percent service loss. This loss decreased over time, until full services were restored one year after the spill. Assuming a linear recovery, 25 percent of the total services provided by those wetlands over the course of the year were lost. Multiplying this loss by the total acreage of 12.02 gives the vegetation injury for this category of wetland, 3.005 acre-years.

[9] If we assume that soil and vegetation provide the entirety of wetland services and further assume that each makes an equal contribution to these services, each acre-year of soil- or vegetation-related services is equal to one-half acre-year of total wetland services.

restoration specialist (Ed Garbish, pers. comm., 2001)[10]; the recent National Research Council publication on Compensating for Wetland Losses Under the Clean Water Act (NRC, 2001); and a synthesis of studies of created wetlands (Strange et al., 2001). Strange et al reported that metrics such as above-ground biomass and stem density recovered to 100% of natural wetlands within 2-6 years of an oil spill. On the other hand, they also reported that services related to soil development and biogeochemical cycling often took decades to recover and seldom reached the equivalent of natural wetlands by the end of the study.

The input parameters for the restoration credit, based on the preferred site, are:

- Project completion in 2003;
- 50 percent services in 5 years;
- 75 percent services in 10 years;
- 80 percent services in 20 years and beyond[11]; and
- Project life-span of 50 years.

Based on these inputs and assuming a three percent discount rate, each restored acre provides a credit of 16.23 acre-years. Therefore, an area of 5.66 acres at the preferred restoration site will compensate for the 92 acre-year wetland injury determined above.

Injury to Other Resources

The Trustees also assessed spill-related injury to a variety of other resources. The Trustees believe it is feasible to restore two of these, injury to muskrats and injury to beach areas, in conjunction with a wetlands restoration project.

Appendix D describes the Trustees' estimate of injury to muskrats and the area of wetland required to restore this loss. Based on an estimate of 373 muskrat-years lost due to the spill, approximately 5.48 acres of wetland are required as compensation. Because this area is less than that needed for restoration of injury to wetlands (i.e., 5.66 acres), the wetland restoration is expected to fully compensate for the muskrat injury. The area required for muskrat restoration is **not** additive to that for wetland restoration, because these services are one part of the overall set of services provided by the restored wetlands.

Appendix E describes the Trustees' estimate of injury to beaches oiled by the Chalk Point spill. Based on an estimated 4.7 acre-year loss, approximately 0.06 acres of wetland are required as compensation. Restoring beach injury with wetlands assumes that wetland services can be

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[10] Ed Garbisch. Environmental Concern, Inc., St. Michaels, MD.

[11] That is, the created wetland will never provide the equivalent level of services as an otherwise-comparable natural wetland.

traded for beach services.[12] In contrast with the muskrat injury, this area **is** additive to the wetland injury restoration area. Compensation for injured beach habitat is in addition to habitat needed to address wetland losses. The services provided by the 0.06 acres of wetland are required to compensate for the beach injury, and therefore must be in addition to the area provided as compensation for wetland injury. The Trustees also estimated the scale of a beach restoration project. Please refer to Appendix E for details of this calculation.

ACKNOWLEDGEMENTS

This report was prepared for the Chalk Point NRDA Council by the Wetlands Assessment Team, consisting of representatives from the USF&WS, NOAA, Maryland Department of the Environment, Maryland Department of Natural Resources, PEPCO, and ST Services. James Hoff of NOAA and Ralph Markarian and Wayne Kicklighter of Entrix, Inc. are acknowledged for their review and comments on the draft report.

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[12] As described in Appendix E, the Trustees assume that wetlands are five times as productive as beaches. Therefore, one acre-year of wetland services is equivalent to five acre-years of beach services.

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Appendix A

Location Maps

Exhibit A1 - Chalk Point Oil Spill Wetland Survey Index Map

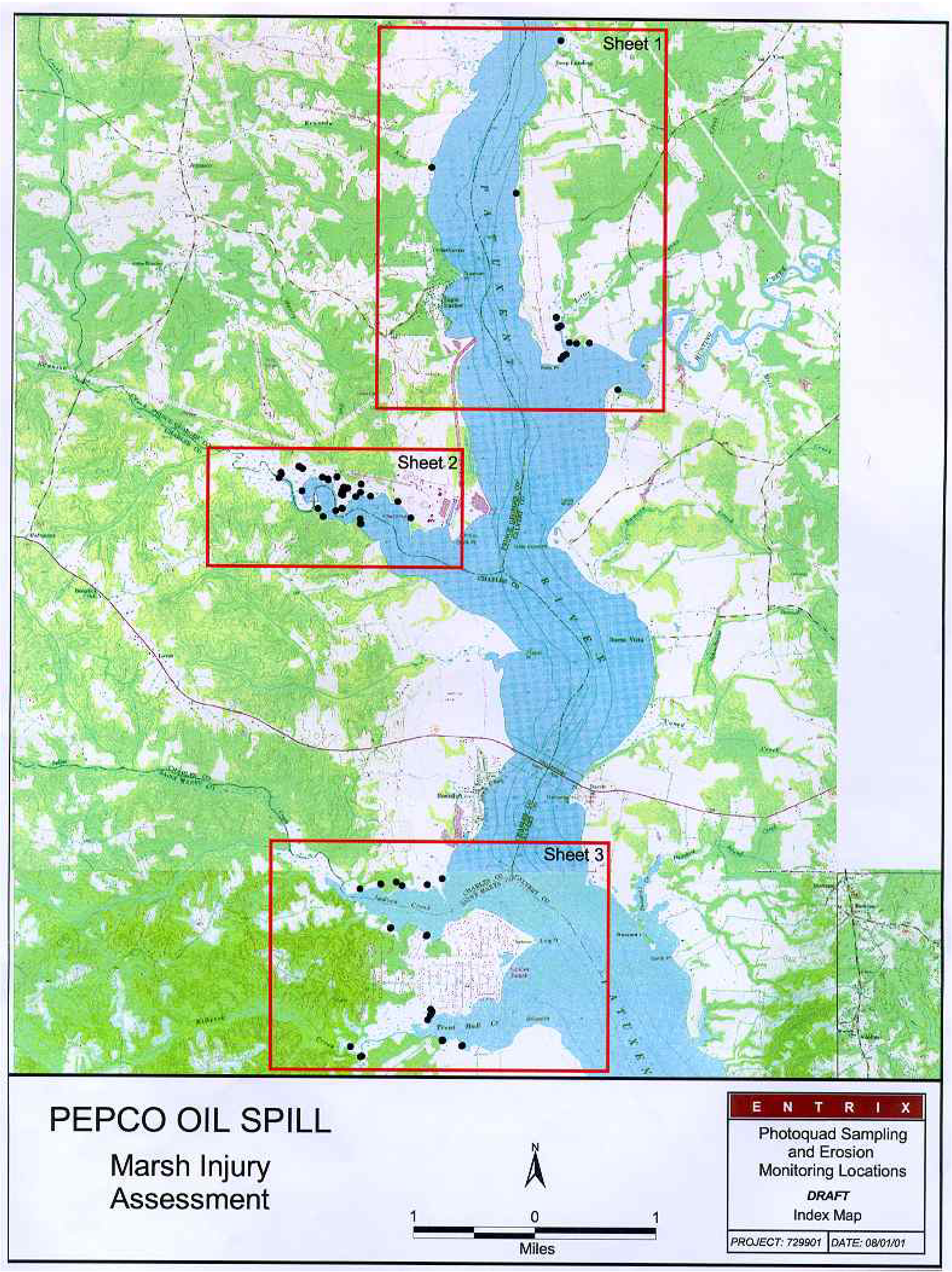


Exhibit A2 - Chalk Point Oil Spill Wetland Survey - Reference Areas

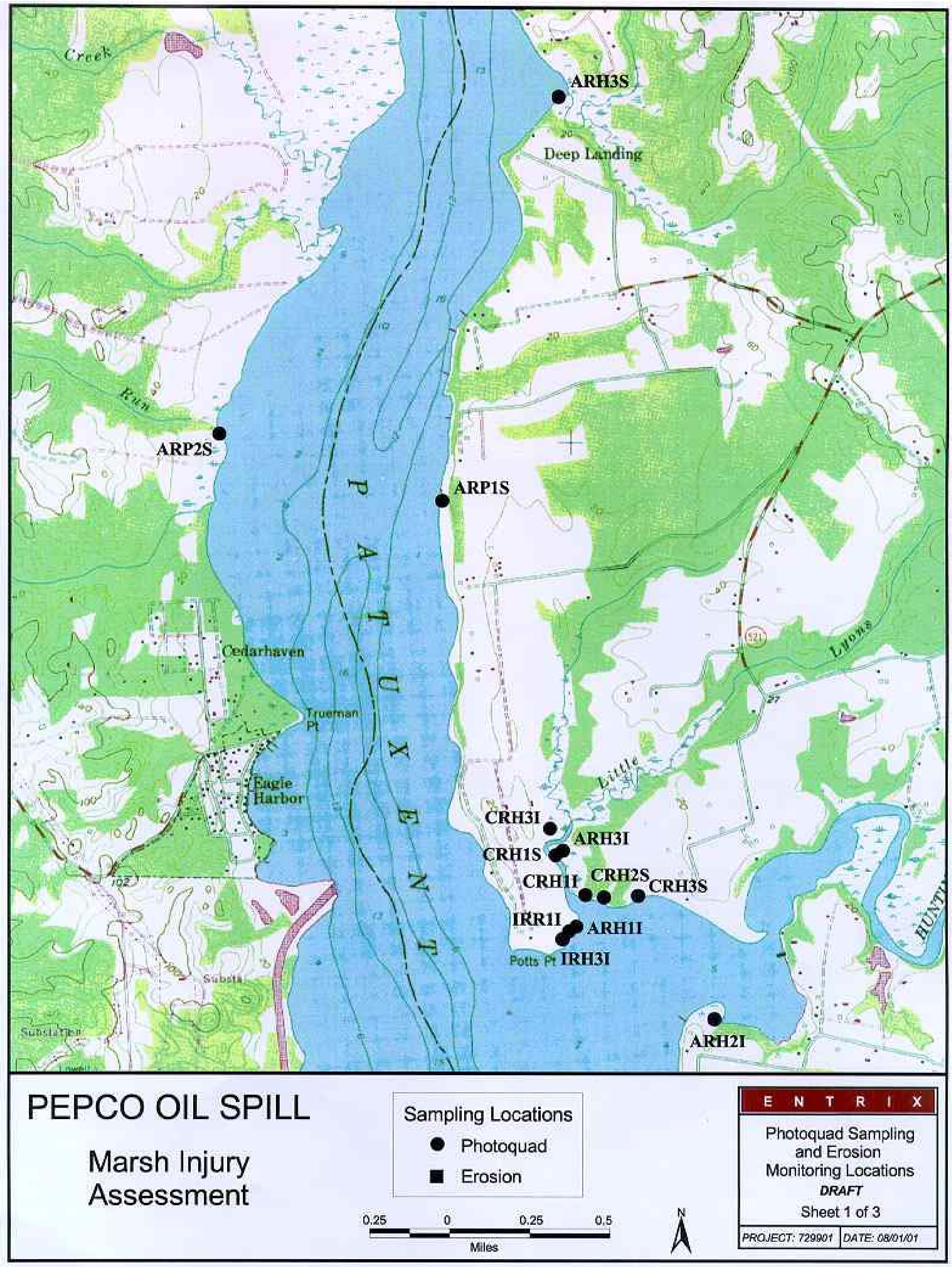


Exhibit A3 - Chalk Point Oil Spill Wetland Survey - Swanson's Creek

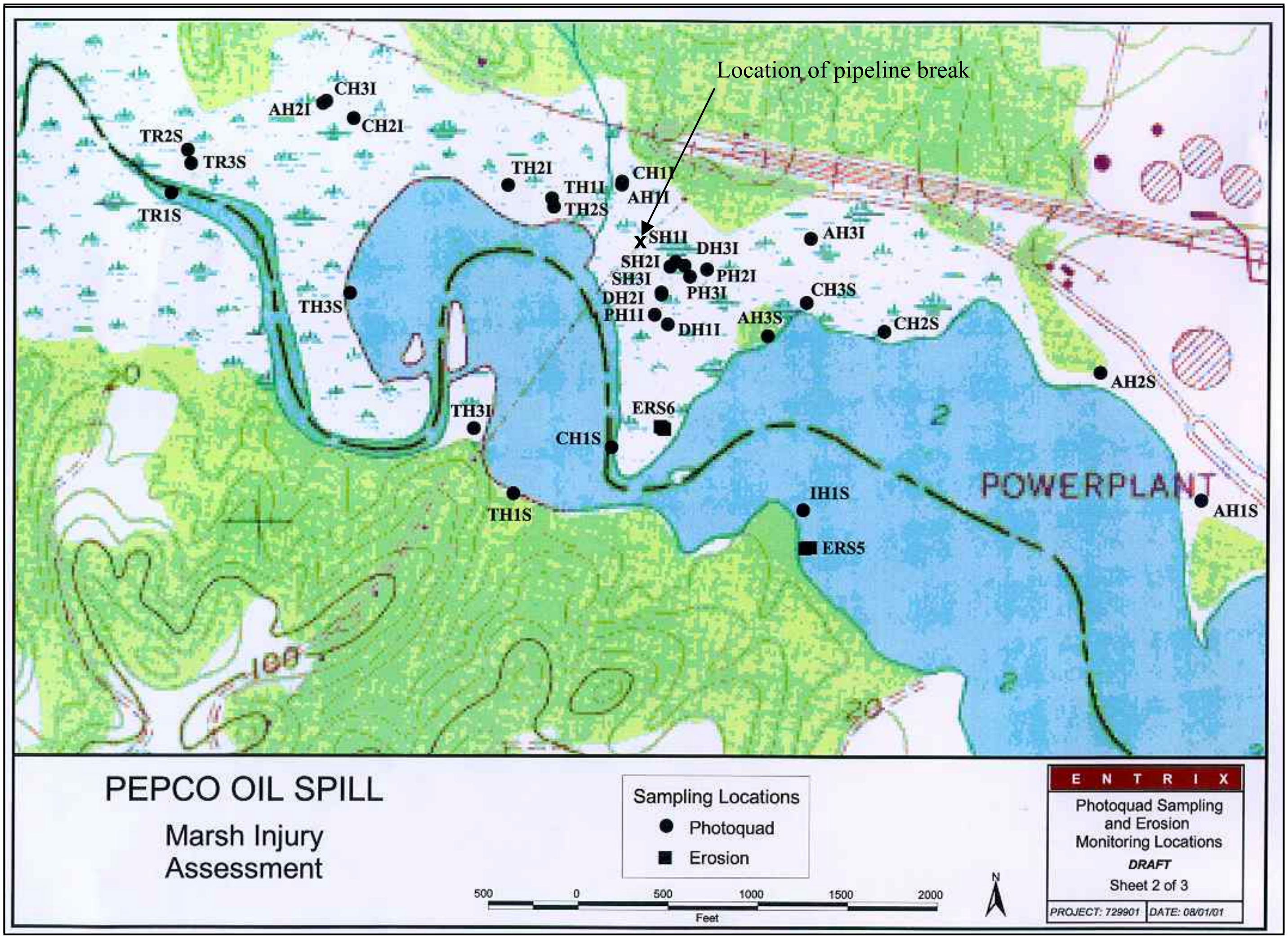


Exhibit A4 - Chalk Point Oil Spill Wetland Survey - Trent Hall and Indian Creeks

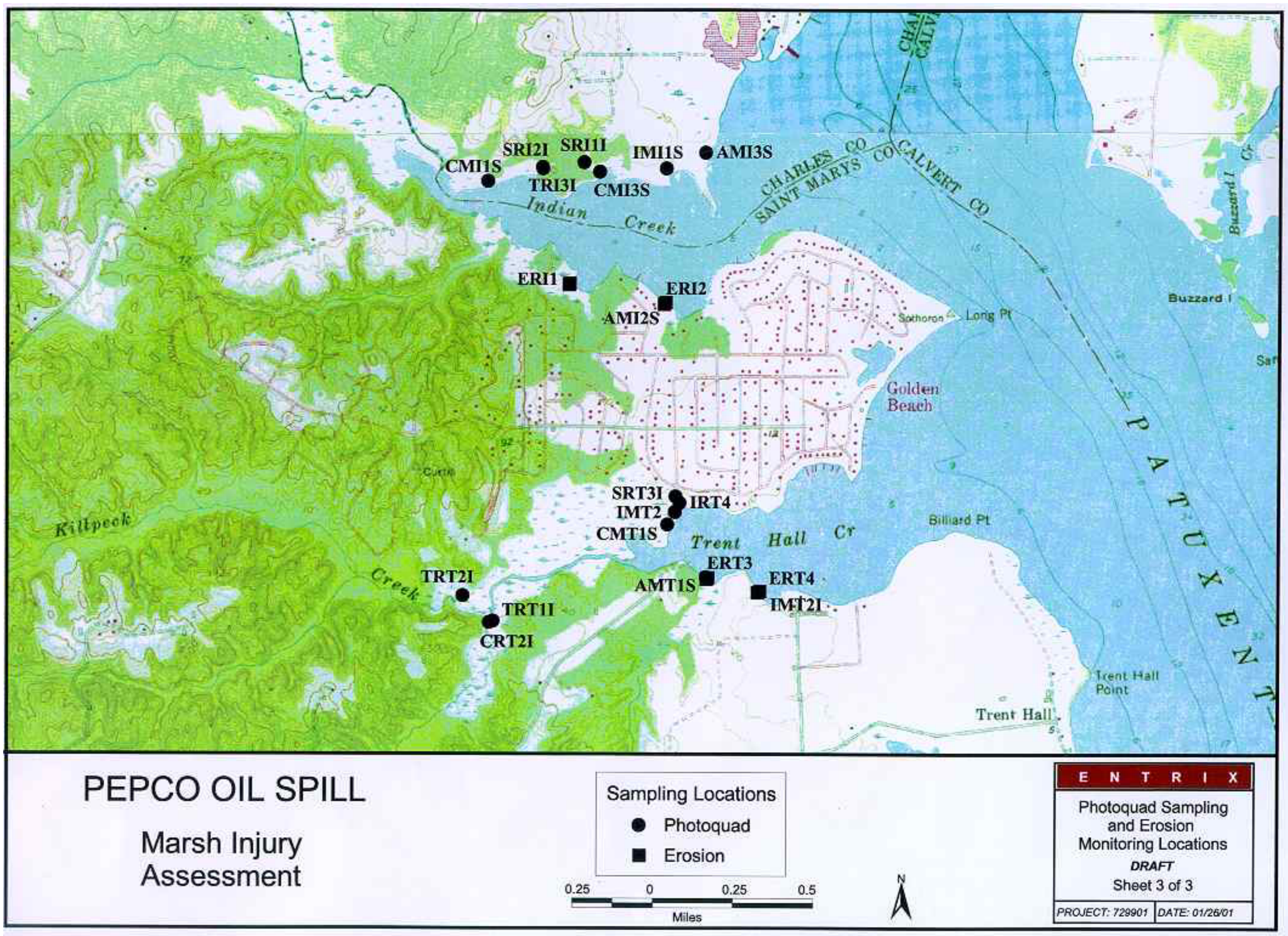


Exhibit A5 - Aerial Photograph of the W1A Area

Red line delineates "more impacted" area of W1A.

Appendix B

Benthic Community Data Sheets

Chalk Point Marsh reference samples for Entrix											
Batch 1	Total number of samples:12										
Completed by Versar Inc.											
Taxonomist: Lisa Scott											
Group	Species or taxa	Station/Date									
		ARH2I/July	CRH1I/July	TR2S/July	ARH3S/Sept	ARP1S/Sept	CRH1S/Sept	CRH2S/Sept	CRH3S/Sept	SRT3I/Sept	TR1S/Sept
Annelida/Polychaeta											
	Boccardiella ligerica				3	1		36	10		
	Hobsonia florida				6		1				1
	Laeonereis culveri				1						
	Manayunkia speciosa		94	6		8	29	717	1183		3
	Neanthes succinea					4		1			
Annelida/Oligochaeta											
	Enchytracidae		66	8			9	9	36		26
	Immature Tubificidae without hair chaetae	188	20	15	116	11	23	75	44	58	4
	Immature Tubificidae with hair chaetae				9			24			2
	Nais variablilis										
	Paranais litoralis	3		4			60	69	24		4
Mollusca/Gastropoda											
	Littoridinops tenuipes	9		1						1	
	Lymnaeidae		74								
Mollusca/Bivalvia											
	Pisidium spp.		16								
Crustacea/Amphipoda											
	Orchestia uhleri		5					1			2
	Gammarus daiberi					2					
	Gammarus spp. (juvenile)		1	4				2	2		
	Leptocheirus plumulosus										
Crustacea/Isopoda											
	Cassidinidea ovalis					1			1		
	Cyathura polita			5		3	1	5			
Crustacea/Tanaidacea											
	Leptochelia dubia		2					48			
Crustacea/Decapoda											
	Rhithropanopeus harrisi							1			
Hydrachnidia											
	Acari		46					9			1
Insecta/Coleoptera											
	Coleoptera terrestrial adult		1								
	Coleoptera terrestrial larva		1								
Insecta/Diptera											
	Bezzia/Palpomyia spp. group		1	1							1
	Culicoides spp.		1						1		
	Dashyhelea spp.		58								
	Dolichopodidae		21			2	2	2	1		2
Insecta/Chironomidae											
	Dicrotendipes modestus	5	2						1		
	Goelidichironomus devineyae			14							
	Pseudosmittia spp.		3								
	Tanypus neopunctipennis	2									
Total Benthos		200	407	44	135	32	125	999	1302	59	46

Chalk Point Marsh reference samples for Entrix											
Batch 2	Total number of samples:12										
Completed by Versar Inc. 3/30/01											
Taxonomist: Lisa Scott											
Group	Species or taxa	Station/Date									
		ARH1I/July	ARH3I/July	CTR2I/July	IRH3I/July	IRR1I/July	IRT4/July	TRT1I/July	TRT2I/July	TRT3I/July	ARP2S/Sept
Annelida/Polychaeta											
	Boccardiella ligerica	3	1			25				1	8
	Heteromastus filiformis										1
	Hobsonia florida	1			4	1			4		2
	Laeonereis culveri									2	10
	Manayunkia speciosa	231	76	2	2	259		1		16	
	Neanthes succinea					4	1			3	12
	Streblospio benedicti					6				1	3
Annelida/Oligochaeta											
	Enchytracidae	9	60	32			60	60	75	12	
	Immature Tubificidae without hair chaetae	102	9	30	84	299	20	20	132	2	40
	Immature Tubificidae with hair chaetae	3				39	6		3	2	2
	Paranais litoralis	6		2	6	71	2		9	6	
	Tubificoides spp.				24	299					18
Mollusca/Gastropoda											
	Gastropoda (unidentified)		4				1			2	
	Littoridinops tenuipes				1	1					
Mollusca/Bivalvia											
	Pisidium spp.		1				7			9	
Crustacea/Amphipoda											
	Apocorophium lacustre	5									
	Orchestia uhleri	4	4	1							
	Gammarus daiberi	5	1								
	Gammarus spp. (juvenile)			1	3	2					
Crustacea/Isopoda											
	Cassidinidea ovalis					1	1				
	Cyathura polita	14	3	9	1	9		1	5		1
Crustacea/Tanaidacea											
	Leptochelia dubia	9				11		1			4
Crustacea/Decapoda											
	Rhithropanopeus harrisi					2					
Crustacea/Mysidacea											
	Neomysis americana	1									
Hydrachnidia											
	Acari	11				2					
Insecta/Diptera											
	Atrichopogon spp.							1			
	Bezzia/Palpomyia spp. group							3	2	2	
	Ceratopogonidae (unidentified)	25	5	4	2	2	3		1		
	Chrysops spp.	1		1							
	Dashyhelea spp.	27						4			
	Dolichopodidae	4	3	1		1	2				
	Ephydridae	4									
	Pilaria spp.						1	1			
	Tipula spp.									1	
Insecta/Chironomidae											
	Chironomus spp.										
	Dicrotendipes spp.	10				2					
	Goelidichironomus devineyae	42	2	2	22	68			1		
	Pseudosmittia spp.		1								
	Tanytarsus spp.					2	2		1		
Total Benthos		465	167	83	127	1034	104	92	231	59	101

Chalk Point Marsh samples for Entrix											
Batch 3	Total number of samples:12										
Completed by Versar Inc. 7/01/01											
Taxonomist: Lisa Scott											
						Sampling Date and Station					
Group	Species or taxa	7/20/00	7/18/00	7/27/00	9/19/00	9/18/00	9/19/00	7/20/00	7/18/00	7/20/00	9/19/00
		AH-1I	AH-2I	AH-3I	AH-1S	AH-2S	AH-3S	CH-1I	CH-3I	CH-3I	CH-1S
Annelida/Polychaeta											
	Heteromastus filiformis										
	Hobsonia florida										
	Laeonereis culveri				2	25	5				
	Manayunkia speciosa				122	2	7				3
	Neanthes succinea				2	5	2				
	Polydora cornuta				5		157				
	Streblospio benedicti					1	1				
Annelida/Oligochaeta											
	Enchytracidae	7	15		1				3		4
	Immature Tubificidae without hair chaetae	10	189	382	14	1	138	2	183	213	56
	Immature Tubificidae with hair chaetae						15				6
	Limnodrilus hoffmeisteri	1									
	Nais pardalis							1			
	Nais simplex							1			
	Paranais litoralis				1		12				4
	Tubificoides spp.										
Mollusca/Gastropoda											
	Littoridinops tenuipes			1					10	11	
Mollusca/Bivalvia											
	Unidentified bivalvia				7						
	Macoma mitchelli					1					
Crustacea/Amphipoda											
	Apocorophium lacustre					1					
	Orchestia uhleri	1									
	Gammarus daiberi										
Crustacea/Isopoda											
	Cassidinidea ovalis										
	Cyathura polita	3			2		1	1			
Crustacea/Decapoda											
	Rhithropanopeus harrisi				3						
Hydrachnidia											
	Acari										
Insecta/Diptera											
	Culicoides spp.	1									
	Dashyhelea spp.	1		11			2			4	
	Dolichopodidae				4				1		
	Ephydridae	1									
Insecta/Chironomidae											
	Chironomus spp.			1						3	
	Cricotopus/Orthocladius spp.						1	1		2	
	Dicrotendipes spp.				3			1		9	1
	Goelidichironomus devineyae	4		12				1		2	
	Larsia spp.	4									
	Polypedilus illinoense	1									
	Tanypus spp.	1							1	1	
	Unidentified Chironomini								1		
	Unidentified Orthocladini							1		1	
	Unidentified Tanypodinae								1		
Total Benthos	Total organisms	35	204	407	166	36	341	9	200	246	74

Chalk Point Marsh 2001 benthic samples for Entrix													
Batch 4	Total number of samples:12												
Completed by Versar Inc. 9/04/01													
Taxonomist: Lisa Scott													
					Sampling Date and Station								
Group	Species or taxa	7/16/01	7/16/01	7/18/01	7/10/01	7/18/01	7/17/01	7/16/01	7/16/01	7/16/01	7/18/01	7/17/01	7/17/01
		AH-1I	AH-2I	AH-3I	ARH-1I	ARH-2I	ARH-3I	CH-1I	CH-2I*	CH-3I	CRH-1I	CRT-2I	CRH-3I
Turbellaria	Turbellaria			4									
Annelida/Polychaeta													
	Hobsonia florida			34	7	21							
	Laeonereis culveri				2								
	Manayunkia speciosa	7	4	79	39	1	4			9	29		1
	Polydora cornuta			3									
Annelida/Oligochaeta													
	Enchytracidae	28	36	18	6	156	8	12	3	24	20	6	5
	Immature Tubificidae without hair chaeta	392	129	138	26	108	16	26	5	66	6		5
	Immature Tubificidae with hair chaetae		6	9	6		6	10			8	1	5
	Limnodrilus hoffmeisteri	42							1	9			
	Tubificoides spp.			10									
Mollusca/Gastropoda													
	Littoridinops tenuipes		36	1		29		10	7	136			1
	Littorina spp.						1			1	1		
Mollusca/Bivalvia													
	Sphaeridae			19			1						
Crustacea/Amphipoda													
	Leptochelia rapax				3								
	Orchestia uhleri						1				3	1	
	Gammarus spp.	6	1	8							1		
Crustacea/Isopoda													
	Cassidinidea ovalis				2								
	Cyathura polita			9	7								
Hydrachnidia													
	Acari				2								
Insecta/Diptera													
	Bezzia/Palpomyia			2	1			4			2	1	
	Chaoborus punctipennis						1						
	Culicoides spp.			2									1
	Dolichopodidae		1				4	2			1	1	4
	Ephydridae	5	1					1		1		1	
	Pilaria spp.												2
	Tabanidae					1							
	Tipula spp.	1						2				1	
Insecta/Chironomidae													
	Ablabesmyia spp.	3											
	Chironomidae pupae				1								
	Cricotopus/Orthocladius spp.	2			12		2				1		
	Dicrotendipes spp.	1		52	12	2							3
Insecta/Lepidoptera													
	Pyralidae						1						
Insecta/Coleoptera													
	Curculionidae						2				1		
	Elmidae adult						1						
	Hydrophilidae larvae						1						
Total Benthos	Total organisms	487	214	388	126	318	49	67	16	246	73	12	27

Chalk Point Marsh 2001 benthic samples for Entrix							
Batch 5	Total number of samples:6						
Completed by Versar Inc. 10/05/01							
Taxonomist: Lisa Scott							
			Sampling Date and Station				
Group	Species or taxa	7/16/01	7/16/01	7/17/01	7/17/01	7/16/01	7/16/01
		SH-2I	SH-3I	SRI-1I	SRT-3I	PH-1I	PH-2I
Annelida/Polychaeta							
	Manayunkia speciosa			6			
Annelida/Oligochaeta							
	Enchytracidae	7	16	165	6	1	9
	Immature Tubificidae without hair chaetae		142	81	36	9	792
	Immature Tubificidae with hair chaetae			42			81
Mollusca/Gastropoda							
	Littoridinops tenuipes					16	
	Physella spp.			1			
Crustacea/Amphipoda							
	Orchestia uhleri			2			
	Gammarus spp.						1
Insecta/Diptera							
	Bezzia/Palpomyia		1	16	1		5
	Ceratopogonidae pupa		12			1	1
	Culicoides spp.	1	94	2		5	7
	Dolichopodidae			2			1
	Limnophila spp	3		15			
	Tipula spp.			1			
Insecta/Chironomidae							
	Cricotopus/Orthocladius spp.	1				8	
	Dicrotendipes spp.		3			22	12
	Tanytarsus spp.			24			
	Tanypus spp.						6
Insecta/Trichoptera							
	Hydropsychidae	1					
Insecta/Coleoptera							
	Hydrophilidae larvae			1			
Total Benthos	Total organisms	13	268	358	43	62	915

Appendix C

WETLAND CATEGORY RECOVERY CURVES

Exhibit C1. All Light Recovery Curves

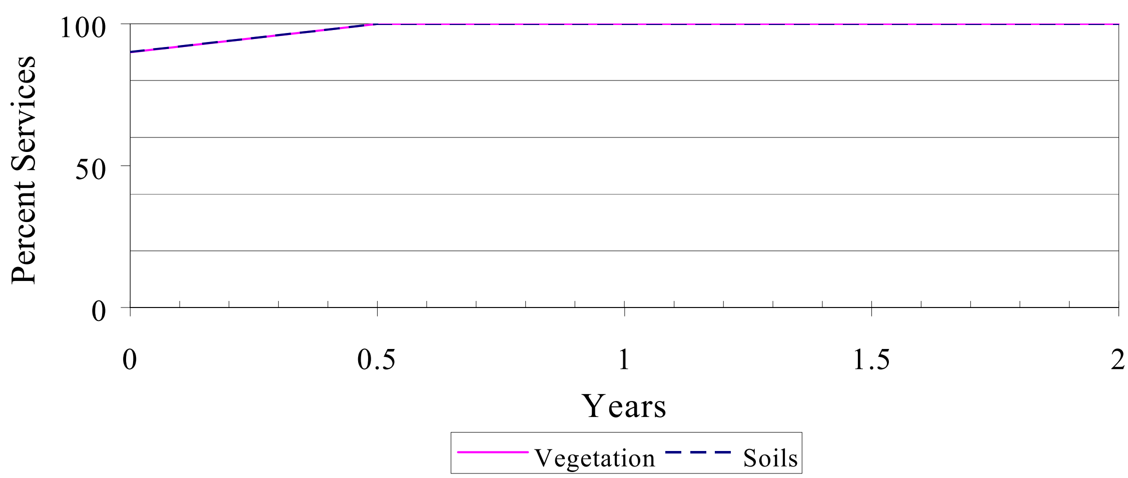


Exhibit C2. *Spartina spp*. Moderate Recovery Curves

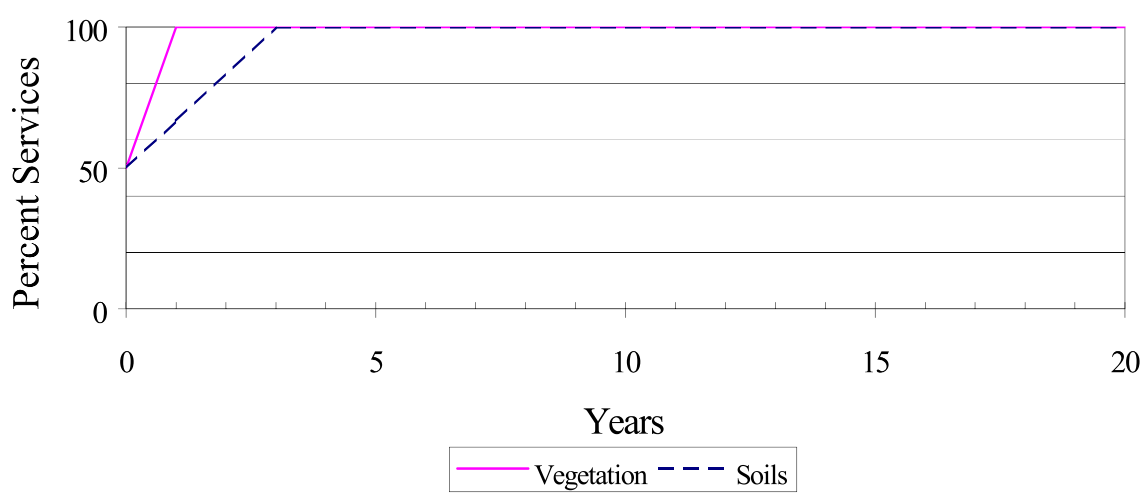


Exhibit C3. *Typha spp*.- Heavy Shoreline Recovery Curves

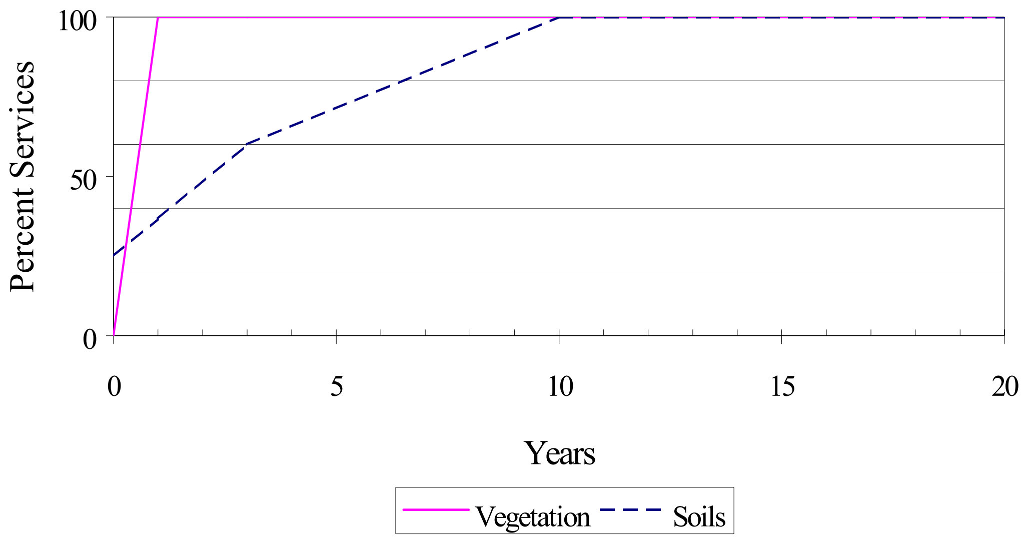


Exhibit C4. *Typha spp*.- Heavy Interior Recovery Curves

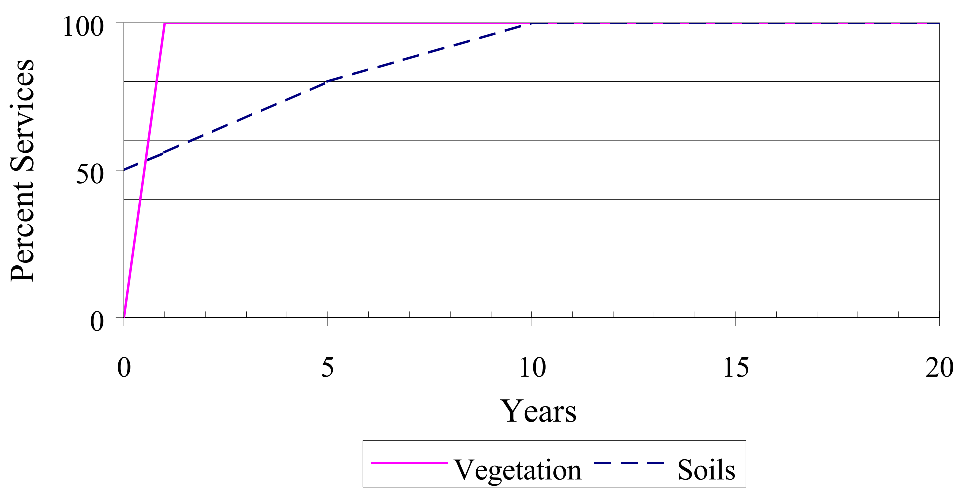


Exhibit C5. *S. alterniflora* - Heavy Shoreline
Recovery Curves

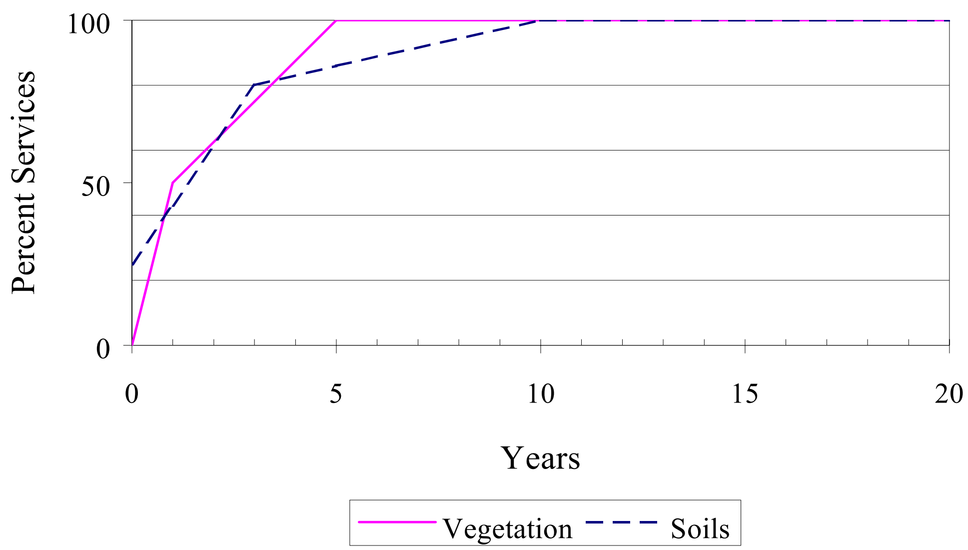


Exhibit C6. *S. alterniflora* - Heavy Interior
Recovery Curves

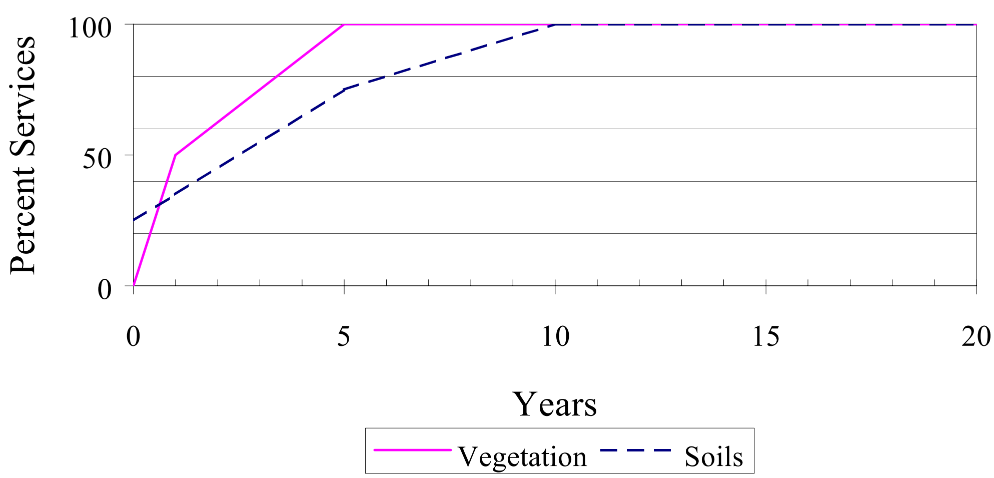


Exhibit C7. *S. cynosuroides* - Heavy Shoreline
Recovery Curves

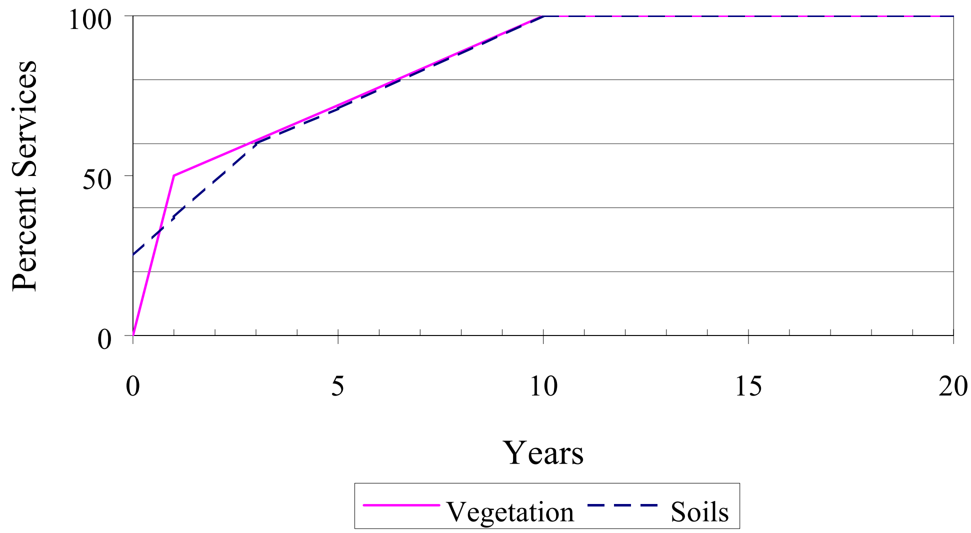


Exhibit C8. *S. cynosuroides* - Heavy Interior
Recovery Curves

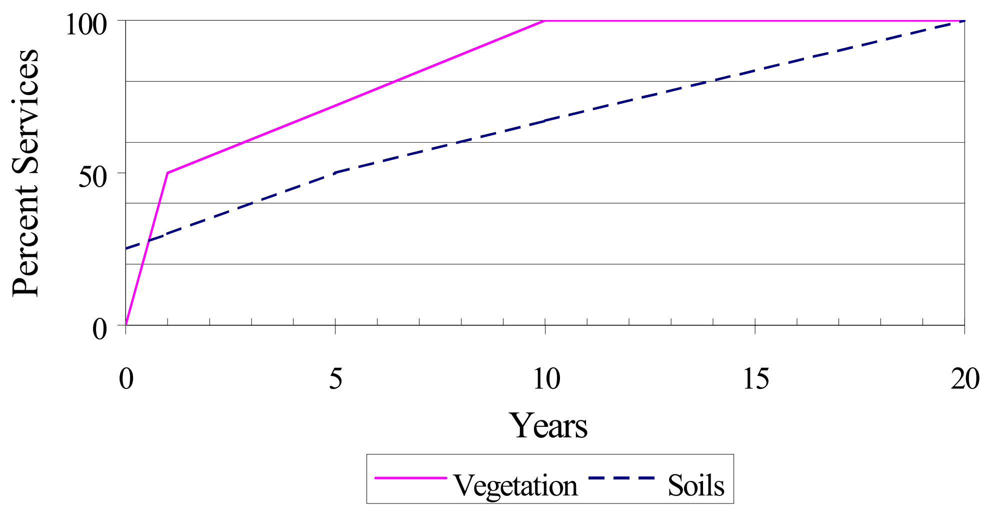


Exhibit C9. W1A- Less Impacted Recovery Curves

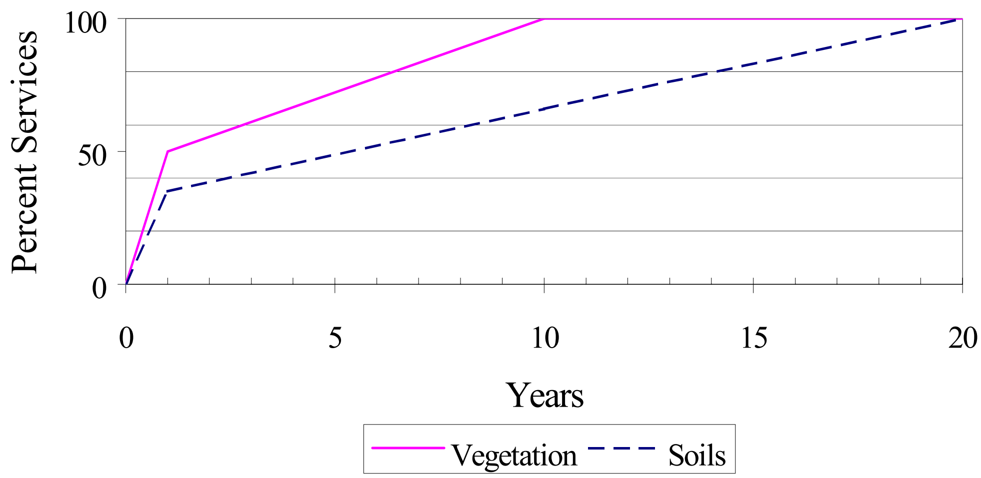


Exhibit C10. W1A- More Impacted Recovery Curves

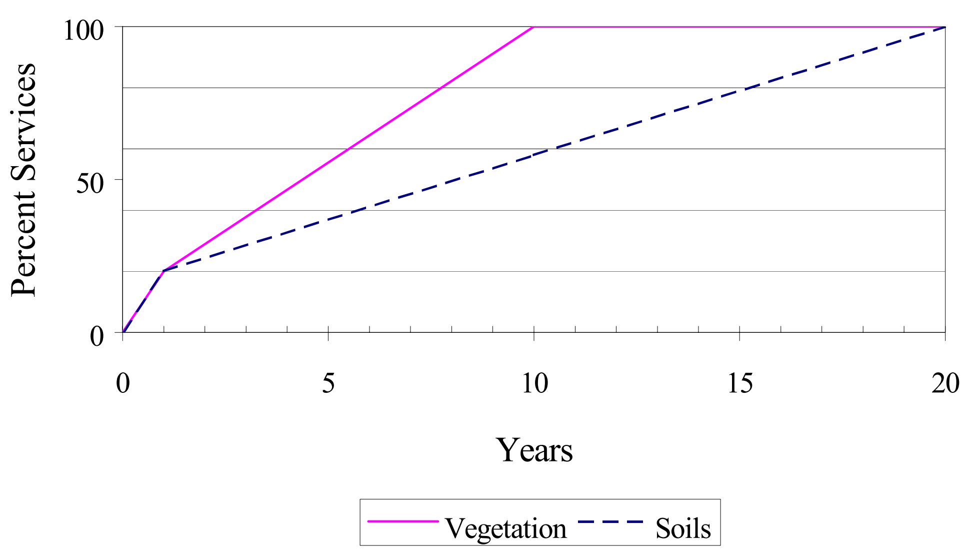
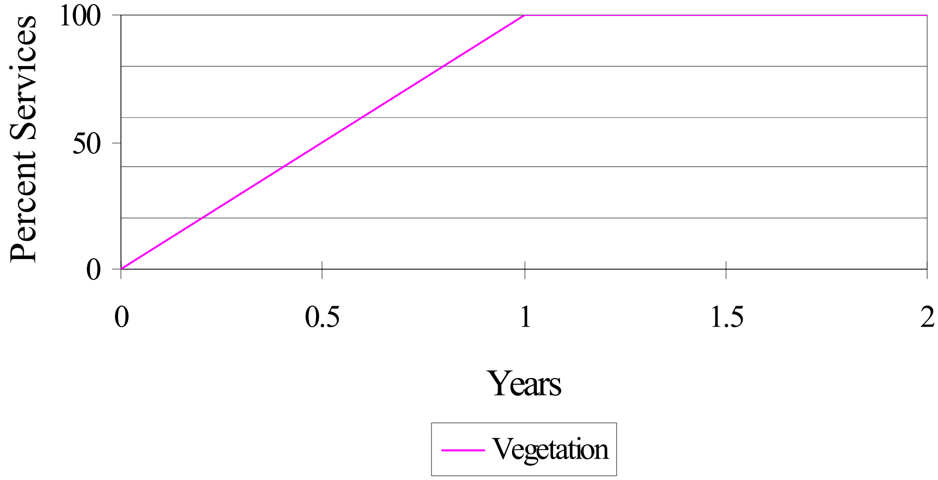


Exhibit C11. Restricted Access Areas Recovery Curve



APPENDIX D

ESTIMATE OF TOTAL MORTALITY TO MUSKRATS RESULTING FROM THE CHALK POINT OIL SPILL

A Report Prepared by the Wildlife Injury Workgroup
For the Chalk Point Natural Resource Damage
Assessment Trustee Council

February 13, 2002

I. INTRODUCTION

As part of the natural resource damage assessment for the Chalk Point oil spill, natural resource trustees are assessing injuries to marsh habitats and the compensation required for these injuries. That assessment identifies all the marsh services lost due to the spill in marsh years and computes the acreage of created marsh that will produce sufficient marsh years to compensate for the injuries.[1] One of the many important services provided by marshes is habitat for wildlife, including muskrats. In order to corroborate the marsh services assessment, an independent analysis of injuries to muskrats and the marsh acres needed to compensate for these injuries has been undertaken. This document reports the methods and results used in that analysis.

Wildlife rescue efforts began immediately after the spill, and resulted in the collection of 63 dead and 8 live muskrats. Seven of the captured live muskrats died in rehabilitation and one was released, for a total of 70 dead muskrats (USFWS, 2000b). One muskrat died in rehabilitation with no visible oil, and three were collected dead with no visible oil.

The number of oiled muskrats retrieved after a spill represents a fraction of the actual number adversely affected. Oiled and/or dead muskrats may not be recovered because they can sink, become scavenged, can be overlooked by search teams, or hide. The adverse effects of oil on muskrats have been investigated. McEwan, Aitchison, and Whitehead (1974) evaluated the energy metabolism of oiled muskrats. They demonstrated that fur treated with 25.6-42.3 g of oil became wet, resulting in loss of buoyancy. Behavior manifested by muskrats placed in oily water consisted of trying to escape, preening, and shivering. They found that heavy crude oil increased the thermal conductivity of muskrats by as much as 122 percent. To compensate for the loss of thermal insulation, oiled muskrats increased their dry-matter intake 2.5 fold. The investigators doubted that muskrats exposed to moderate quantities of oil could survive under natural conditions. Similarly, Wragg (1954) found that oil had a persistent and cumulative wetting effect on muskrats. He showed that muskrats exposed to 4 ml of fuel oil were almost completely submerged in 40 minutes.

Literature regarding the impacts of oil spills on muskrat populations is scarce. Fifteen dead oiled muskrats were found following an oil spill in the Gasconade River, Missouri in 1988 (Heatherly, 1993), and 28 were collected following a spill in the Arthur Kill, Staten Island in 1990 (Burger, 1997). In neither case was total oil-related mortality estimated.

II. INJURY ASSESSMENT

Data and Assumptions

From the total of 70 dead muskrats that were found, 66 were collected from the Swanson Creek area, and one each was collected from Indian Creek, Trent Hall Creek, the Benedict Bridge area, and Ramsey Creek.

[1] For more information about the Chalk Point oil spill natural resource damage assessment, please go to the following web site: *www.darp.noaa.gov/neregion/chalkpt.htm* .

Muskrat habitat acreage within Swanson Creek was delineated by manually circumscribing the marsh habitat type on 1:300 true color aerial photographs of the area, as shown on Figure 1. Total habitat acreage was quantified by digitizing the marsh boundaries, and calculating the area enclosed using GIS (ArcView). Total marsh habitat within Swanson Creek was determined to be 189.37 acres.

Muskrat density in Swanson Creek was estimated by two methods: 1) local expert knowledge; and 2) extrapolation from densities reported for Blackwater National Wildlife Refuge on the Eastern Shore of Maryland. No population studies or trapping records were available for Swanson Creek or any other creek in the spill area. The yearly trapping harvest of muskrats from Swanson Creek was estimated to be 150-300 individuals, with a local population of 2-3 times the harvest (Mask, 2000-2001). Based on these ranges, the population abundance of muskrats in Swanson Creek prior to the spill was estimated to be 300 to 900 individuals. At the Blackwater National Wildlife Refuge, the 16-year (1984-2000) mean density of muskrats was 4.2 muskrats/acre (USFWS, 2000a). The acreage of marsh habitat in Swanson Creek was estimated to be 189.37 acres, as shown above. Thus, the population abundance of muskrats in Swanson Creek was estimated to be 795 individuals (4.2 muskrats/acre x 189.37 acres). This population estimate (795 individuals) lies within the bounds of the range estimated by Mask (2000-2001). The estimate of 4.2 muskrats per acre was also used in calculations to determine total mortality for injury assessment purposes.

Acreage of oiled marsh habitat within the three creeks was estimated by manually circumscribing the extent of oiling on 1:300 scale true color aerial photographs of each creek. Along the marsh shorelines, individual segment lengths and widths were determined using Shoreline Clean-up Assessment Team (SCAT) data (ENTRIX, 2000) and interpretation by the NRDA Wetlands Subgroup.

Restricted Access areas (marsh areas essentially enclosed within oiled polygons that would be unavailable as habitat) were included in the oiled acreage. Finally, a 5-m transitional zone buffer was delineated around all oiled acreage, including the shorelines. This transitional zone was added to the oiled acreage to consider total area of habitat that could present oiling risk to muskrats. Figures 2 through 4 show the total oiled areas in Swanson, Indian, and Trent Hall Creeks in red.

These oil exposed marsh areas (including oiled polygons, shorelines, restricted access areas, and 5-m transition zones) were digitized. Using GIS (ArcView), total areas of oil exposed marsh habitat in Swanson, Indian, and Trent Hall Creeks were calculated to be 34.87 acres, 3.83 acres, and 1.57 acres, respectively.

In addition to the oiling of muskrats within the spill zone, oiling was also likely to have occurred to muskrats living outside the immediate spill area whose home ranges included oiled marsh. The area occupied by a muskrat depends upon the size, configuration, and diversity of aquatic habitat; social pressures; sex; age; season; and environmental conditions. After a muskrat becomes established in an area in the early spring, under normal conditions the area is occupied until the following spring (Perry 1982).

Muskrats have a relatively small home range that varies in configuration depending on aquatic habitat (Perry 1982), and is normally within 7 to 30 meters of its main dwelling (McConnell and Powers, 1995). For a marsh in Maine, Takos (1944) reported that about 50 percent of the recaptures were within a 7.6-meter radius of the original tagging site, and less than 30 percent were beyond 30.5 meters. For Iowa populations, Errington (1963) estimated that the radius of summer home range averaged approximately 30.5 meters. Caley (1986) showed an average intercapture distance of 25.3 meters, with an upper 95% confidence interval of 101 meters. MacArthur (1978) found muskrats within 15-meter of their primary dwelling lodge during 50 percent or more of the position determinations. Most foraging occurred within 5- to 10-meter radius of the lodge or pushup, and few muskrats movements exceeded 150 meter. Similarly, Coon (1965) found the majority of movements of muskrats in an Illinois lake within 15 meters of the home den.

For purposes of this assessment, Trustees assumed a muskrat home range radius of 30 meters from their huts (and into potentially oiled habitat). Thus, all muskrats within 30 meters of oil exposed habitat (exposure zone) would potentially be at-risk of becoming oiled. Muskrats beyond 30 meters of oil exposed habitat would not be considered at-risk of becoming oiled.

To determine the muskrat home range acreages beyond the oil exposed marsh area (including oiled polygons and shorelines, the restricted access areas, and 5-meter transition zone), a 30-meter boundary was defined along the border of the oil exposed areas for each of the three creeks. This boundary area is shown on Figures 2 through 4 in yellow. The areas within these 30-meter boundary zones for Swanson, Indian, and Trent Hall Creeks were quantified using GIS (ArcView) to be 40.15 acres, 15.72 acres, and 7.55 acres, respectively.

The exposure zone acreage for muskrats was determined by summing the 30-meter boundary areas and oil exposed marsh areas for each of the three creeks. Thus, total acreage of the exposure zones is: 75.02 acres (40.15 + 34.87) for Swanson Creek, 19.55 acres (15.72 + 3.83) for Indian Creek, and 9.12 acres (7.55 + 1.57) for Trent Hall Creek.

Estimated Exposure and Mortality

Exposure of the muskrat population within Swanson Creek was estimated by multiplying the exposure zone acreage (75.02 acres) by the density of muskrats (4.2 per acre). Thus, the potentially exposed population in Swanson Creek was 315 individuals.

Of the 70 muskrats collected, one each was collected from the Indian and Trent Hall Creek areas. Although clean-up workers collected the majority of muskrats from Swanson Creek, equivalent recovery efforts were not undertaken at Indian and Trent Hall Creeks. Thus, muskrat mortality was also estimated for these two creeks.

Muskrat abundance in Indian and Trent Hall Creeks is not known, but would be expected to be lower than Swanson Creek because of lower habitat suitability (i.e., less marsh acreage, relatively more forested habitat bordering the creeks rather than marsh (Mask, 2000-2001). An index of the muskrat population size in these creeks was developed using hut counts (Best 1982, Proulx and Gilbert 1984). On aerial photographs, houses are defined as light dots, often surrounded by a circle of dark open water where the vegetation has been cleared for food and construction (Best 1982). These houses, along with feeding huts, were evident on the 9-in. by 9-in. true color aerial photographs of the spill area that were taken in April 2000 at 1:300 scale. Active houses, inactive houses, and feeding huts could not be distinguished on these photographs, and all were counted for the hut index. Hereafter all houses and huts appearing as light dots on the photographs will be designated as “huts”.

In order to estimate the muskrat population sizes for Indian and Trent Hall Creeks, we developed hut indices to compare to the hut index and population density estimate for Swanson Creek. For each of the three creeks, all huts were counted within the exposure zones (oiled area, 5 m buffer, and 30 meter home range) and compared to the count from Swanson Creek. Hut counts for Swanson, Indian, and Trent Hall Creeks were 239, 24, and 22 respectively. The hut count per acre for Swanson Creek was 3.19 (239/75.02), for Indian Creek was 1.23 (24/19.55), and for Trent Hall Creek was 2.41 (22/9.12). The percentages of huts per acre in Indian and Trent Hall Creeks compared to Swanson Creek were 0.39 (1.23/3.19), and 0.76 (2.41/3.19), respectively. Applying these percentages to the density in Swanson Creek (4.2 muskrats per acre, as shown above) yields muskrat densities in Indian and Trent Hall Creeks of 1.64 (0.39 x 4.2), and 3.19 (0.76 x 4.2) muskrats per acre, respectively.

Muskrat exposures in Indian and Trent Hall Creeks were determined by multiplying the estimated muskrat density in each creek by the exposure zone acreage in each creek. The exposed population was therefore calculated to be 32 muskrats (1.64 per acre x 19.55 acres) for Indian Creek, and 29 muskrats (3.19 per acre x 9.12 acres) for Trent Hall Creek.

Swanson Creek supported the largest muskrat population, and was much more heavily oiled than the other two creeks. Assuming 100% mortality for muskrats potentially exposed to oiled marsh habitat, the total acute mortality was estimated to be 376 individuals (i.e. 315 in Swanson Creek, 32 in Indian Creek, and 29 in Trent Hall Creek). Note: this estimate assumes all muskrats within 30 meters of oiled marsh habitat would be killed independent of actual exposure or oiling level.

Total Muskrat Years Lost

Muskrats are prolific breeders with high levels of reproductive success. For purposes of this study, based on McCabe (2001) we assume that the muskrat population in the exposure zone was in equilibrium at the time of the spill. Muskrats are highly successful breeders and they will likely rapidly return to prespill population levels following a loss of a fraction of the individuals located in the vicinity (see, for example, Krolls, et al., 1985; and Heatherly, 1993). Therefore, it is assumed that the equilibrium population level was restored, linearly, over a period of two years following the spill.

Because muskrats are prolific breeders, many pups born to adults in populations that have reached density dependent equilibrium, as in the area in question in the Patuxent River prior to the spill, are redundant and suffer high mortality rates (McCabe, 2001). Those mortality rates appear to go down when population levels are reduced below equilibrium and return to normal levels once population equilibrium is restored (Krolls, et al., 1985 and Heatherly, 1993). Thus, for purposes of this analysis, it is assumed that the spill did not have an adverse effect on the number of young produced by the affected Patuxent River muskrat population.

Our analysis is, therefore, confined to quantifying the total number of muskrat years lost due to acute mortality alone. Since recovery of the loss is linear and continuous over a two year period, approximately half, i.e. 188, of the dead muskrats are returned to the population after the first year (April, 2000 to April, 2001), with the remainder returning in year two (April 2001 to April 2002). The estimated muskrat years lost are discounted at the standard 3% discount rate, resulting in a total estimated loss of 373 muskrat years. The total muskrat years lost (373) is less than the total estimated to have been killed (376) primarily because a linear two-year recovery process beginning immediately after the spill implicitly assumes that half of the dead muskrats are replaced in one year or less. Discounting further reduces the total number of muskrat years lost in the second year of recovery (discounting is not applied to the first year of losses as a matter of standard trustee policy).

Using habitat equivalency analysis (U.S. Department of Commerce, 2000), based on the assumption that an acre of restored marsh can support 4.2 muskrats per year for 50 years, it will take 5.48 acres (discounted at 3% per annum) to restore the estimated 373 acre years lost

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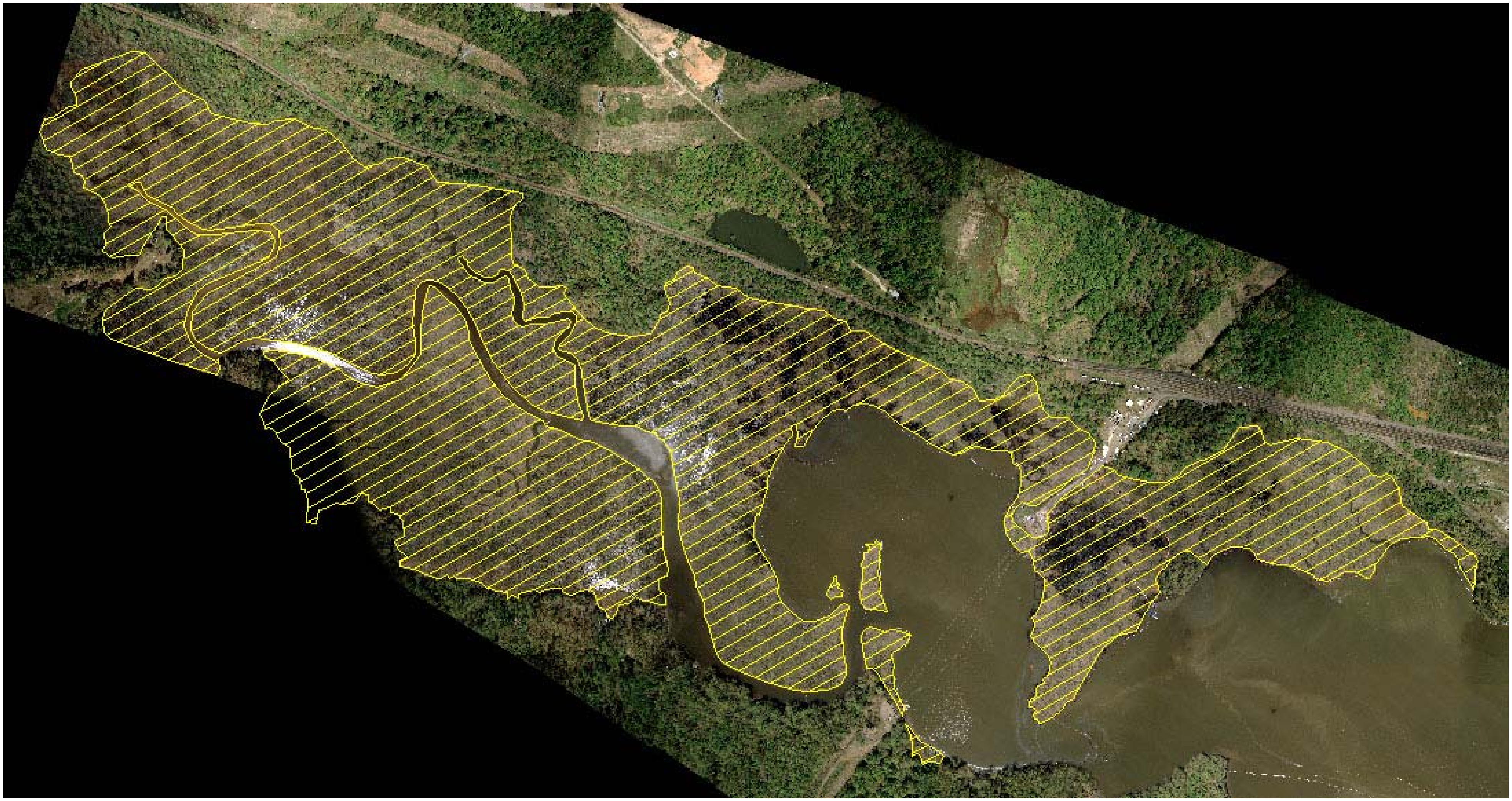

Figure 1. Marsh habitat area delineated for Swanson Creek.

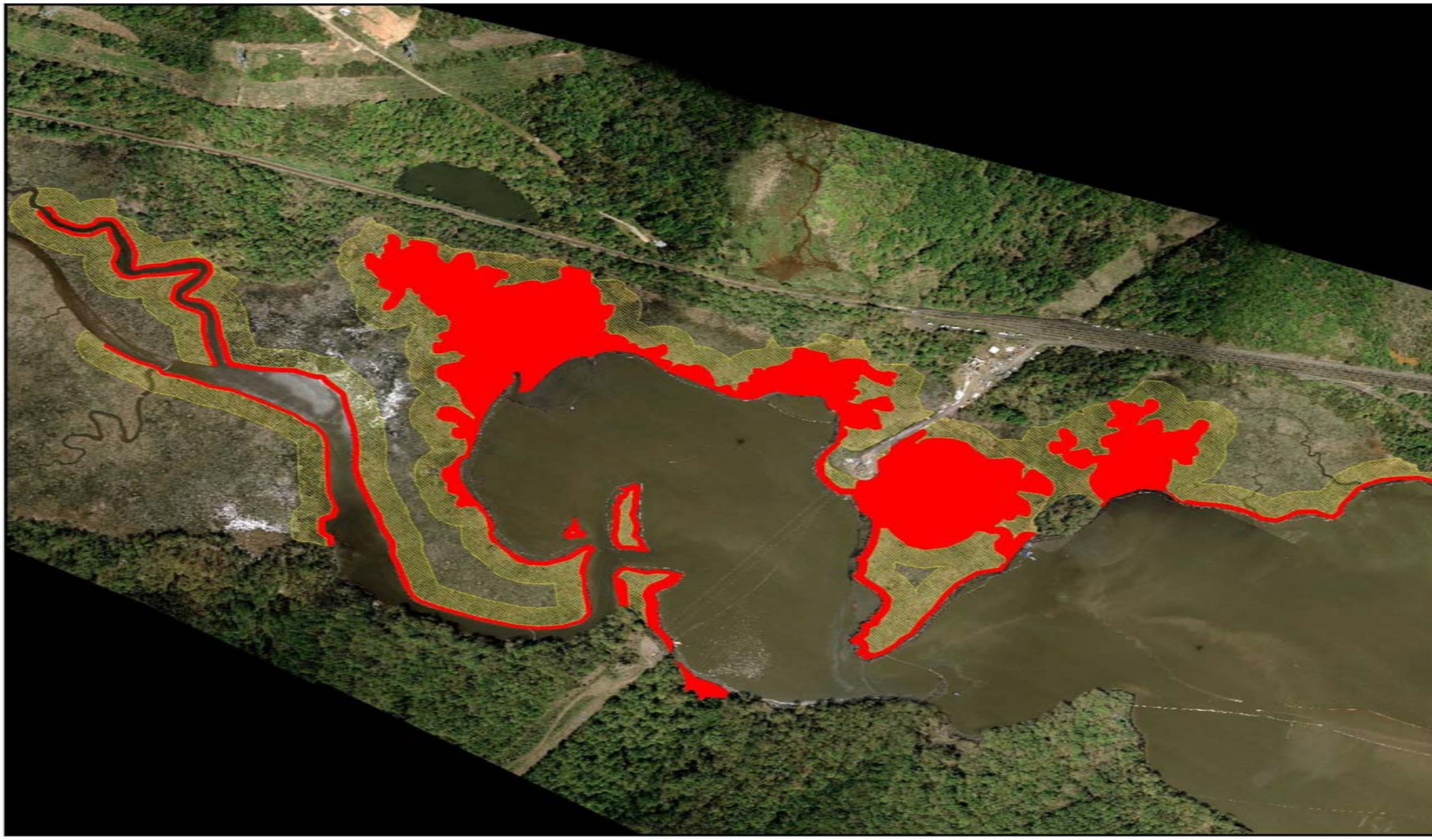

Figure 2. Oil exposed marsh area delineated for Swanson Creek in red. This area includes oiled polygons and shorelines, restricted access areas, and the 5-meter transition zone. The 30-meter home range area for muskrats is shown in yellow.

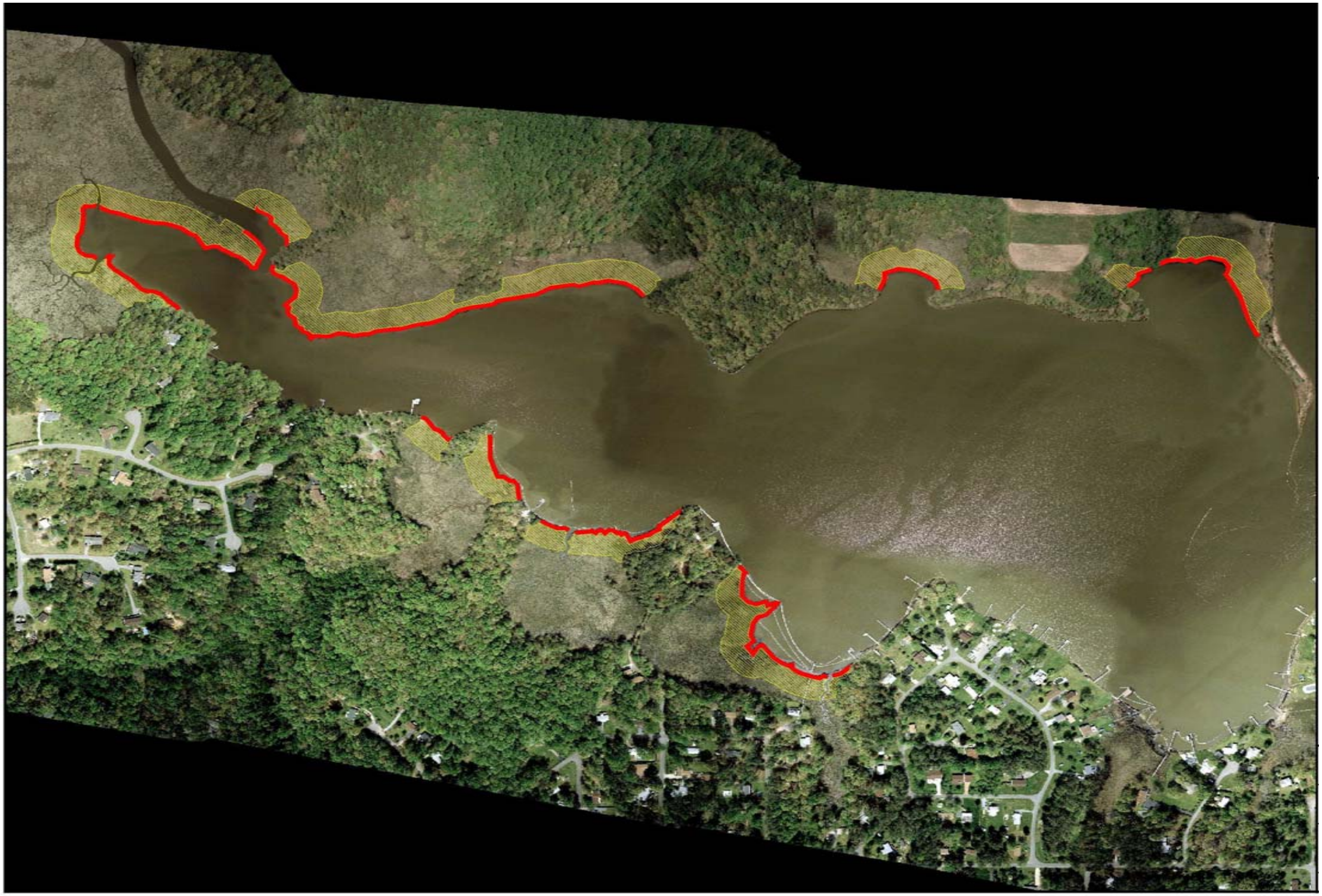

Figure 3. Oil exposed marsh area delineated for Indian Creek in red. This area includes oiled shorelines and the 5-meter transition zone. The 30-meter home range area for muskrats is shown in yellow.

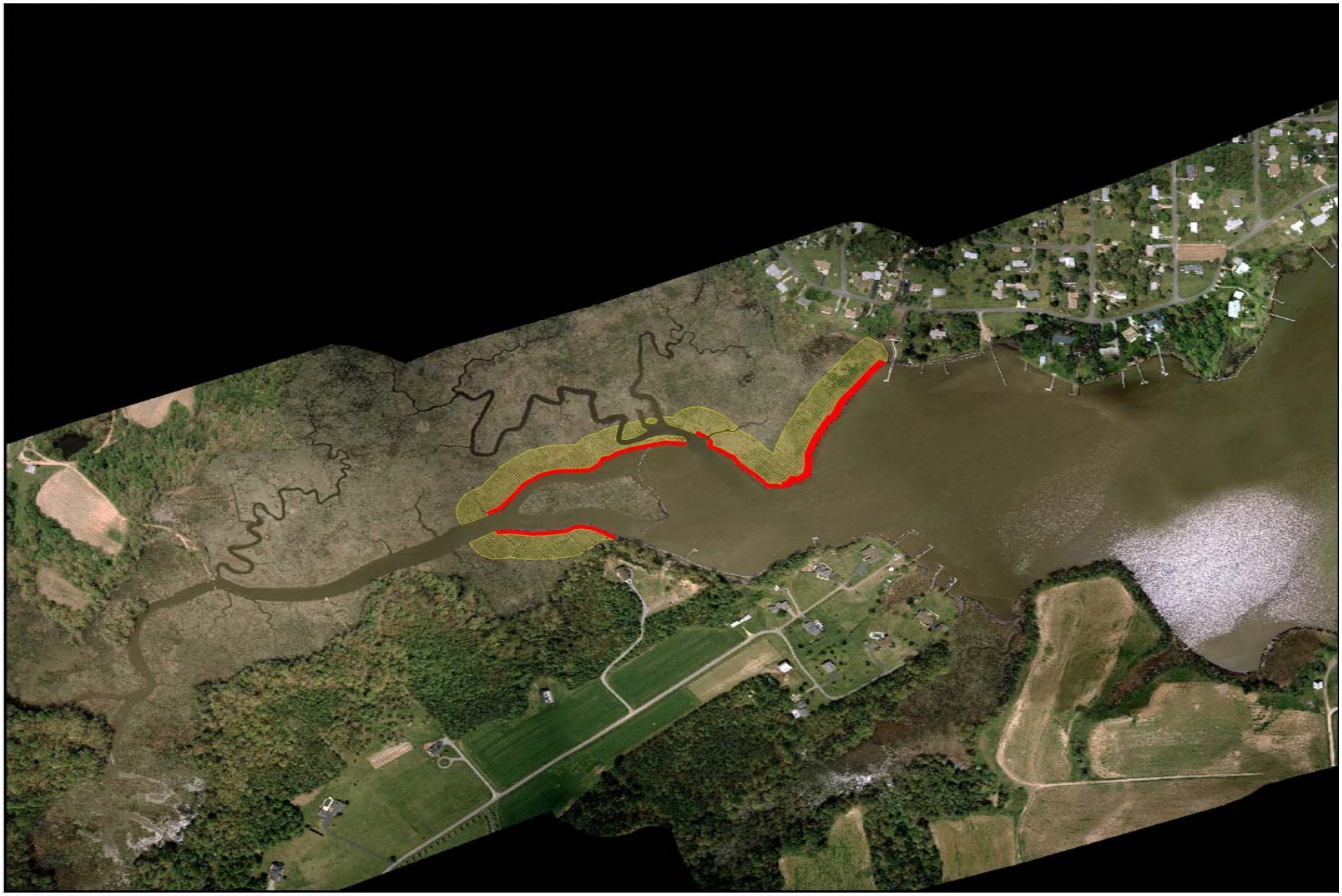

Figure 4. Oil exposed marsh area delineated for Trent Hall Creek in red. This area includes oiled shorelines and the 5-meter transition zone. The 30-meter home range area for muskrats is shown in yellow.

Appendix E

QUANTIFICATION AND SCALING OF BEACH INJURY

ERRATA SHEET

INJURY TO WETLANDS RESULTING FROM THE CHALK POINT OIL SPILL

3 May 2002

Appendix E: Quantification and Scaling of Beach Injury

To quantify injury to beach habitat, each subdivision of oiled beach area was assigned to one of three categories (A, B or C), based on if/when it met Phase I and Phase II SCAT cleanup criteria. Category C was defined as those areas that met Phase I criteria within approximately fourteen months of the spill, but have not yet met Phase II criteria.

Although Appendix E of the Injury to Wetlands report dated 8 March 2002 states that all Category C areas have met Phase I criteria, the Trustees inadvertently included area W1 in Category C even though this area has not yet met Phase I criteria. Area W1, the area immediately surrounding the pipeline break, contains a total of 0.144 acres of oiled beach, representing 4.5 percent of the total area of Category C (3.19 acres).

A new category (i.e., Category D) would be necessary to estimate the injury from the W1 area. However, based on initial calculations, the resulting change in total beach injury would be too small to affect the beach restoration requirement of 0.06 wetland acres as estimated in the 8 March 2002 Injury to Wetlands Report. Therefore, no such change has been made to the beach injury or beach restoration calculations.

This appendix describes our quantification and scaling efforts for injury to beach habitat. Specifically, this analysis addresses potential productivity-related injuries to beach habitat not accounted for in the human use or terrapin analyses already completed by the Trustees.

Methodology

Existing SCAT data were used to develop reasoned judgements about the duration and extent of beach habitat productivity loss caused by oiling associated with the Chalk Point oil spill.[1] While SCAT data provide qualitative information about the degree and extent of oiling on beach habitat, no spill-specific quantitative data were collected to document associated impacts to invertebrates or other biota that utilize beach habitat (other than terrapins, which are addressed in other spill assessment efforts). Nevertheless, based on the degree of oiling, potential impacts associated with cleaning operations and other documented injuries caused by the spill, it is reasonable to expect some impacts.

For restoration, we propose two options for restoring quantified beach injuries: (1) restoring an equivalent area of beach; and (2) restoring wetlands, using an appropriate conversion between beaches and wetlands based on their relative productivity. In this way, equivalencies between beach acre years lost and wetland acre years gained can be estimated. Our proposed translation factor reflects the reasonable expectation that wetland habitat is more productive than beach habitat.

Injury Quantification

The "Swanson Creek Incident Extent of Oiling Report" (July 6, 2001) indicates that 10.11 acres of beach shoreline were oiled by the Chalk Point spill. In the first step of the injury quantification analysis, each subdivision of oiled beach area was assigned to one of three categories (A, B or C), based on if/when it met Phase I and Phase II SCAT cleanup criteria.[2] These categories are defined in Exhibit 1.

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[1] Dr. Jacqui Michel of Research Planning, Inc. provided input used in the development of these judgments.

[2] Consistent with the "Swanson Creek Incident Extent of Oiling Report" we assume that subdivisions identified as "area unvegetated" are beach habitat. Furthermore, because Phase I/II status is only tracked at the segment level, we categorize each subdivision based on the status of parent segment. Because of the possibility that one or more subdivisions within the segment were "clean" enough to meet the Phase I/II criteria sooner than the overall segment, this approach may overstate recovery time for some subdivisions. The area of each subdivision (measured in square meters) was obtained from Appendix 1 of the same report.

Exhibit 1 BEACH AREA CATEGORIES				
Beach Area Categories	Phase I met in Spring 2000	Phase I met in Spring 2001	Phase II met in Fall 2000	Phase II not yet met
A	X		X	
B	X			X
C		X		X

Exhibit 2 provides an annotated matrix of recovery curves and associated service levels for each category (A, B or C) of oiled beach habitat. As shown in the exhibit, beach areas in each category (A, B or C) were further subdivided into "light", "moderate" or "heavy" oiling based on their "NRDA Oiling Category" classification in the "Swanson Creek Incident Extent of Oiling Report" (July 6, 2001).

The estimates of recovery curves and associated service levels are based on SCAT data and professional judgement. Key assumptions underlying the matrix are identified below:

- Immediately following the spill, we assume service levels (i.e., the productivity of beach habitat) dropped to 75 percent of baseline levels for areas classified as lightly oiled. We assume service levels dropped to 25 percent and 0 percent for moderately and heavily oiled areas, respectively.

- The choice of June 1st and October 1st in each year as the "transition" points for the recovery curves is based on the assumed start and end dates of the yearly benthic recruitment and production cycle.

Exhibit 2

ESTIMATE OF BEACH HABITAT RECOVERY AND ASSOCIATED SERVICE LEVELS

The different categories within A, B, and C refer to an area's initial designation of light, moderate, or heavy oiling, based on the "NRDA oiling category" identified in the Extent of Oiling Report.

Beach habitat at baseline service levels.

Spill occured. Beach productivity reduced to specified service level.

Phase I met for A and B; recovery of biota is assumed to begin after this date. Recovery also assumed to begin after this date for C areas, although at a slower rate because these areas have not yet met Phase I criteria.

For A, Phase II met. Recovery is assumed to be complete; productivity restored to baseline.

For B, Phase II has not been met, but we assume majority of productivity is restored.

For C, Phase I has not been met, but we assume partial recovery of productivity has occurred.

		Percent Service (100% = Baseline Productivity Level)						
Beach Category	**Acreage**	**04/06/00**	**04/07/00**	**06/01/00**	**10/01/00**	**06/01/01**	**10/01/01**	**10/01/02**
A light	0.97	100%	75%	75%	100%	100%	100%	100%
A moderate	0.42	100%	25%	25%	100%	100%	100%	100%
A heavy	0.00	100%	0%	0%	100%	100%	100%	100%
Sub-Total A	**1.39**							
B light	1.75	100%	75%	75%	85%	85%	95%	100%
B moderate	3.78	100%	25%	25%	85%	85%	95%	100%
B heavy	0.00	100%	0%	0%	85%	85%	95%	100%
Sub-Total B	**5.53**							
C light	0.52	100%	75%	75%	75%	75%	95%	100%
C moderate	2.20	100%	25%	25%	50%	50%	85%	100%
C heavy	0.47	100%	0%	0%	50%	50%	85%	100%
Sub-Total C	**3.19**							
Total	10.11							

Service recovery unchanged between 10/01/00 and 06/01/01, reflecting low natural productivity during these months. Phase I is met for C; recovery for C areas begins to accelerate.

B and C have not met Phase II, but we assume productivity is approaching baseline levels.

We assume Phase II will be met for B and C; all areas returned to baseline productivity levels.

- SCAT data indicate that all Category A areas met Phase I and II criteria within approximately six months of the spill. Therefore, we assume complete recovery of these areas by the end of this period.

- SCAT data indicate that all Category B areas met Phase I criteria within approximately two months of the spill, but have not yet met Phase II criteria. We assume Category B areas recovered to 85 percent of baseline service levels within six months of the spill, 95 percent of baseline levels 18 months after the spill, and complete recovery 30 months after the spill.

- SCAT data indicate that all Category C areas met Phase I criteria within approximately fourteen months of the spill, but have not yet met Phase II criteria. Similar to Category B, we assume Category C areas recover completely 30 months after the spill. However, because Category C areas took longer to meet Phase I criteria, we assume a slower rate of recovery during the beginning and middle of the injury period (see Exhibit 2).

The recovery curves and associated service loss estimates identified in Exhibit 2 are simplified representations of complex ecological processes and detailed SCAT data. While alternative estimates could be made and defended, reasonable variation in these parameters is unlikely to have a substantial impact on injury quantification. Approximately 70 percent of the oiled beach acreage (approximately 7 out of 10 acres; see Category A and B in our analysis) met the relatively rigorous Phase I criteria within several months of the spill, suggesting that recovery of any lost productivity was well underway relatively quickly. The remaining oiled acreage met Phase I criteria within approximately a year (or less). Overall, these data are indicative of a modest impact to beach productivity, particularly given the limited extent of oiling (roughly 10 acres).

Application of the recovery curves and service loss estimates specified in Exhibit 2 to relevant beach acreage results in a total injury of approximately 4.7 beach acre years of lost productivity. Although a portion of this injury occurs more than a year after the spill, we do not incorporate discounting in our analysis because its impact will be negligible.[3]

<u>Restoration Scaling</u>

We propose two options for restoring quantified beach injuries: (1) restoring an equivalent area of beach, and (2) restoring wetlands, using an appropriate conversion between beaches and wetlands based on their relative productivity.

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[3] Based on the methodology described in this analysis, approximately 77 percent of estimated service losses are restored within 14 months of the spill. After 18 months, service losses are 93 percent restored. Recovery is assumed to be complete within 30 months.

For restoring an equivalent area of beach, we use the following assumptions:

- Project implementation in 2003;
- Linear recovery of services from zero percent at implementation to 100 percent after five years (i.e., in 2008); and
- Project life-span of 25 years.

Using these parameters, each acre of restored beach provides approximately 14.5 beach acre years of services. Therefore, to restore the 4.7 beach acre year loss, approximately 0.32 acres of beach are required.[4]

To calculate the acreage of restored wetland needed to address the injury to beach habitat, a translation factor must be determined that reflects the relative productivity of these habitats. For the purposes of this analysis, we assume a ratio of 5:1 (i.e., wetland habitat is five times more productive than beach habitat). While this ratio is consistent with the notion that wetlands are more productive than beaches, other ratios could be selected. As noted below, given the magnitude of injury, the required restoration will be small over a relatively wide range of translation factors.

Based on a 5:1 translation factor, 4.7 acre years of lost beach productivity converts to approximately 0.94 acre years of lost wetland productivity.[5] Based on the scaling analysis performed for wetland injury, one acre of restored wetland will compensate for approximately 16 acre years of lost wetland productivity (see main text of wetland injury report, page 25). Given this figure, approximately 0.06 acres of restored wetland would be sufficient to compensate for the quantified injury to beach productivity.[6]

Based these results, we do not believe the assumptions used in the injury quantification and scaling analyses warrant further refinement. Additional time and effort is unlikely to result in substantial changes to the results presented in this analysis. Even if analytic assumptions understate injury by a factor of five (which we do not believe to be the case), less than 0.5 acres of wetland (or less than one acre of beach habitat) would be required to compensate for the beach injury. Potential variation in translation factors (e.g., between 2:1 and 20:1) also would result in a restoration requirement of less than 0.5 acres of wetland.

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[4] 0.32 acres of restored beach = 4.7 beach acre years of loss / 14.5 compensatory years per beach acre.

[5] 0.94 wetland acre years of loss = 4.7 beach acre years of loss / 5.

[6] 0.06 acres of restored wetland = 0.94 wetland acre years of loss / 16 compensatory years per wetlands acre.

To: The Trustees and Responsible Parties

From: Carl Hershner

Date: 16 February 2002

Re: Review of draft report
"Injury to wetlands resulting from the Chalk Point Oil Spill"

I have reviewed the subject report and the supporting materials provided me. In my opinion, the basic assumptions used in development of the injury assessment and the habitat equivalency analysis are appropriate and well within the bounds of general technical understandings. I believe the Trustees' conclusions regarding both the degree of impact and appropriate restoration are reasonable and consistent with accepted practices in this type of event.

The strengths of the report lie in the thoroughness of the field surveys, the specificity of injury class identification, and the use of best professional judgment. As a result of these elements, the derived assessment of wetland injury is clearly explained and easy to follow. The conclusions, estimating acre-years of both injuries sustained and potential for created wetland compensation, are straightforward and simple to understand.

It is clear that a lot of work was undertaken to document and quantify the wetland impacts associated with this spill. The detailed reports of conditions immediately following the spill and during the subsequent cleanup and recovery phases are useful and provide an informative record for evaluation of the injury characterization.

It is noteworthy, that most of the conclusions, and particularly the critical recovery curves, are primarily products of the professional judgment of the Wetland Assessment Team (WAT). A quick review of the quantitative data included in the report makes it clear that this data alone would not be not sufficient to lead precisely to the final conclusions regarding recovery curve forms. Best professional judgement was a critical element in developing the guidance necessary to conclude the study within the reported timeframe. This is true for a number of reasons.

The types of intertidal wetlands impacted by the Chalk Point oil spill are quite common in the mid-Atlantic region. There are decades of research documenting characteristics of these systems, and one common finding is that at the square meter scale they can be exceptionally variable. For example, comparison studies using plant morphometrics typically require many sample replicates (often about 20/strata in meso/oligohaline wetlands) to produce means with useful variances. In the follow-up study of this spill it was clearly impractical to mount the sampling effort necessary to develop statistically significant comparisons or trends.

In my opinion this is not a critical flaw in the report. It is a fact that it would require an enormous sampling program to be able to quantify responses in 11 different categories of oiled wetlands along with the necessary reference set. The only problem is that anyone reviewing the report and expecting the quantitative data to be a principal determinant of the conclusions, will be struck by several observations:

1. The sampling program does not address all categories of modeled responses. There was no sampling in lightly oiled areas, and it is not clear what sampling is pertinent to the W1A sub-categories.
2. Among categories sampled, many had no time series information. Not all categories were sampled both in 2000 and 2001, preventing any observation about trends.
3. When time series information is present in the quantitative data, indicated changes do not (and generally can not because of sample number) provide strong evidence to support the final recovery models. For example, much of the reported morphometric data (i.e. %cover, stem counts, stem heights) appears counter to the expected trends in a recovery model, and the chemical analyses provide either no trend data or equivocal indications. (This is most probably due to the inherent variability of these systems, the variable nature of short-term recovery, and the limited sample/replication number. All of these factors combine to keep this information from being really useful in developing the slopes of recovery curves.)

The fact of the matter is that the qualitative observational data was far more important to the final WAT conclusions. That information, combined with evidence from previous oil spill recovery studies and appropriate judgment, form the basis for the recovery model development.

This is appropriate. This spill covered 80 acres of wetlands, less than half with “heavy” amounts, and most of that in long narrow bands. Previous studies have shown tidal wetlands to be fairly resilient to spilled oil except in extreme amounts. These studies provide the background necessary to estimate recovery curves. Based on that record, the assumptions used for models in this study seem very appropriate. (Developing recovery curves de novo would have required extensive sampling, potentially involving sampling impacts on approximately 1 acre of wetlands each year for 3 or more years).

For this reason, I believe the report might benefit from being a little more direct about the utility and/or use of the quantitative data. It is useful as relative indicators of the degree of impact. It is of limited utility in recovery curve development.

A second area I believe might benefit from a bit more explicit treatment is the rationale for assessment of wetland injury. The table from King et al. provides a generally accepted list of potential wetland services. The report, however, requires the reader to make some significant independent assumptions to get from that comprehensive list to a conceptual model explaining the WAT simplification to ecological service flows from “vegetation” and “soils.”

I believe the simplification is appropriate. My point is that the report leaves some significant logic gaps in reducing all of the potential injuries suffered by the oiled wetlands and their potential users in the Chalk Point area, to an aerial vegetation metric and a soil contamination metric. I believe a concise description of which wetland services the WAT believes are most pertinent in the Chalk Point area, and how those services are potentially indexed by vegetation and soil contamination would be very useful.

A second reason for suggesting some attention to the logic underlying the injury assessment is that the wetland replacement evaluation should be driven by a consistent application of the same conceptual model. In other words, assume the WAT determines that habitat services (nee "protection of ecological infrastructure") is important. It would seem that there should be some thought given to the process by which a fringing tidal marsh provides this service, and how above ground vegetation and soil contamination affect that service. Those same assumptions should then be used to assess the capacity of replacement wetlands to provide the same service.

I mention this, not because I believe the two metrics selected are inappropriate. Actually, I believe they are excellent choices, consistent with generally accepted procedures in this type of incident. The issue, I believe, is whether the wetland replacement evaluation will actually reflect the state of the science. The entire Habitat Equivalency Analysis is based on a concern for functional replacement rather than simple area considerations. So, the pertinent question in the Chalk Point case is whether the habitat services provided by oiled fringe and interior wetlands, are equivalent to the habitat services provided by a wetland excavated from uplands. This amounts to a landscape analysis. The state of the science is to recognize that wetlands vary in performance of functions, and that much of the variance is based on landscape setting.

In short, I believe the report, and the conclusions, would be stronger if they were based on an explicit conceptual model of the wetland functions (services) injured and replaced. I do not believe this needs to be a highly sophisticated effort. It can be as simple as inclusion of a landscape position modifier in evaluation (e.g. level of habitat services/acre = % recovery of vegetation X factor for shape and position of wetland).

Finally, I found it interesting that no where in the report is the type or amount of oil spilled identified. There is also nothing (that I could find) in the various supporting documents that actually indicate exactly where the pipeline leak occurred. It can be fairly easily deduced from the damage maps, but there is no specific designation of the point of origin. Perhaps these are not really pertinent in the injury assessment report.

At your request I have also reviewed the appendices documenting the injury assessment and compensation calculations for the muskrat mortality and the beach injury. Based on the material presented and my experience, I believe the conclusions are appropriate.

The calculations of muskrat densities are founded on both available site specific information and appropriate reference to the extant literature. The method used to derive the final acute mortality estimation is well explained and results in numbers that seem reasonable for the type of setting. I believe the decision to limit the injury assessment to acute mortality is defensible, and the underlying assumptions are all adequately conservative to minimize the potential for either significant over or under estimation.

As with the marsh compensation planning, I believe the landscape position of the replacement wetlands will have some significant impact of the likelihood that compensation for lost muskrat habitat will in fact be accomplished. Evidence gathered in the injury assessment regarding the distribution of local muskrat populations would seem to provide some basis for addressing this issue (i.e. the difference in densities between Swanson Creek, Indian Creek and Trent Hall Creek).

The beach injury assessment is somewhat more difficult to evaluate. I believe the conclusion that recovery will be relatively rapid, with comparatively minor cumulative impacts is reasonable based on the setting and available information from other studies. The method used to develop the service recovery estimate is well documented. I believe the assumptions are defensible and/or explicit. The proposal to use marsh replacement as compensation for service loss is interesting, and not unprecedented. There are a number of technical reasons for preferring this option to intertidal beach creation (e.g. conversion of existing intertidal habitats, and long term maintenance issues). In the absence of compelling rationales for alternative approaches, I believe the conclusions and proposed resolution are adequate.

As a very minor point, I think the reader might be assisted in following all of the calculations if the units of some of the numbers reported in the text and footnotes were a bit more explicit. The calculations all appear to be correct, but it is easy to lose track in the welter of beach acre-years, marsh acre years, and acre-years per acre. Not all of these terms are as fully labeled as they might be. (In particular, see the final section of the beach appendix and the accompanying footnotes.)

In conclusion, I believe the draft report and appendices represent an effective and appropriate assessment of the Chalk Point oil spill impacts and compensation needs. It appears to me that the Trustees have used available information and professional judgement in judicious combination. The approach and findings are consistent with accepted practices, and within reasonable bounds for the type and extent of the incident.

Trustees' Responses to Comments
Chalk Point Wetlands Injury Report

This note documents the Trustees' responses to the peer review comments on the wetlands injury report submitted by Dr. Carl Hershner on 16 February 2002. Excerpts of comments requiring a response are found below, italicized, followed by the action taken by the Trustees, if any.

The sampling program does not address all categories of modeled responses. There was no sampling in lightly oiled areas, and it is not clear what sampling is pertinent to the W1A sub-categories.

The discussion of each injury category explains the need (or lack thereof) for field data to support the injury quantification (e.g., field data would not detect the injury expected for lightly oiled wetlands). The description of W1A on page 4 indicates the subdivision of this area into planted, ditched and planted, and areas of *Scirpus spp.* The corresponding sampling stations are shown on Exhibit 2 as "ditched heavy interior," "planted heavy interior," and "*Scirpus spp.* heavy interior."

Among categories sampled, many had no time series information. Not all categories were sampled both in 2000 and 2001, preventing any observation about trends.

The reviewer is correct in noting that chemical analyses for some categories were not performed, particularly from the 2001 sampling event. The Trustees selected samples for chemical analysis based on their assessment of which samples would provide the most useful information for establishing soil recovery curves.

Vegetation and benthic community sampling for all the injury categories were conducted in both 2000 and 2001. Note that the designation "N/A" in Exhibit 3 (vegetation data) indicates that the injury category did not exist. For example, there was no moderately oiled Typha shoreline category.

When time series information is present in the quantitative data, indicated changes do not (and generally can not because of sample number) provide strong evidence to support the final recovery models. For example, much of the reported morphometric data (i.e. %cover, stem counts, stem heights) appears counter to the expected trends in a recovery model, and the chemical analyses provide either no trend data or equivocal indications.

During a teleconference on 1 February 2002, Dr. Hershner clarified that he did not mean to imply that the morphometric data conclusively demonstrates a lack of recovery, but rather that it does not provide positive evidence of recovery. Instead, the Trustees relied primarily on their collective experience and judgement regarding wetland recovery. This approach was deemed appropriate by the reviewer.

For this reason, I believe the report might benefit from being a little more direct about the utility and/or use of the quantitative data. It is useful as relative indicators of the degree of impact. It is of limited utility in recovery curve development.

The following text was added to the first full paragraph on page 13: "The field data were used as relative indicators of the degree of injury, and to guide development of the recovery curves for each injury category."

A second area I believe might benefit from a bit more explicit treatment is the rationale for assessment of wetland injury...I believe a concise description of which wetland services the WAT believes are most pertinent in the Chalk Point area, and how those services are potentially indexed by vegetation and soil contamination would be very useful.

A paragraph describing the choice of wetland services used in the injury assessment was added to page 13, immediately following the quotation from Strange et al. (2001). It begins: "Two metrics were selected to represent the lost services and functions of the wetlands..."

It would seem that there should be some thought given to the process by which a fringing tidal marsh provides this service, and how above ground vegetation and soil contamination affect that service. Those same assumptions should then be used to assess the capacity of replacement wetlands to provide the same service...So, the pertinent question in the Chalk Point case is whether the habitat services provided by oiled fringe and interior wetlands, are equivalent to the habitat services provided by a wetland excavated from uplands...In short, I believe the report, and the conclusions, would be stronger if they were based on an explicit conceptual model of the wetland functions (services) injured and replaced. I do not believe this needs to be a highly sophisticated effort. It can be as simple as inclusion of a landscape position modifier in evaluation (e.g. level of habitat services/acre = % recovery of vegetation X factor for shape and position of wetland).

The Trustees agree that an adjustment for differences in services provided by the injured and restored wetlands is appropriate. As described on page 25 of the injury report, the Trustees assume that the restored wetlands will provide a maximum of 80 percent of the services of the injured wetlands. The Trustees believe this is a conservative value, and will monitor the restoration project to verify this assumption. Appropriate action will be taken if significant differences are found.

Finally, I found it interesting that no where[sic] in the report is the type or amount of oil spilled identified.

This information has been added to the opening paragraph of the report.

There is also nothing (that I could find) in the various supporting documents that actually indicate exactly where the pipeline leak occurred.

The location of the pipeline break is now marked on Exhibit A3 in Appendix A.

As a very minor point, I think the reader might be assisted in following all of the calculations [in Appendix E] if the units of some of the numbers reported in the text and footnotes were a bit more explicit. The calculations all appear to be correct, but it is easy to lose track in the welter of beach acre-years, marsh acre years, and acre-years per acre. Not all of these terms are as fully labeled as they might be. (In particular, see the final section of the beach appendix and the accompanying footnotes.)

Additional unit descriptors have been added to Appendix E, particularly in footnotes 4 through 6.