# **APPENDIX A**

# **Remedial Alternative Cost Estimates**

#### **Table A-1 - Summary of Cost Estimates for Remedial Alternatives**

Project No. 070188, Chlor-Alkali RAU, GP West Site, Bellingham, Washington

	Remedial Alternatives for Chlor-Alkali RAU	Tota	l Estimated Cost
1)	Containment and In-Situ Treatment of Accessible Soils with Visible Hg, Removal of Hg-Impacted Soils Near Log Pond, Capping of Residual Impacted Soils, and Groundwater MNA	\$	12,200,000
2)	Aggressive Removal of Obstructions and In Situ Treatment of Soils with Visible Hg, Removal of Hg-Impacted Soils Near Log Pond, Capping of Residual Impacted Soils, and Groundwater MNA	\$	16,200,000
3)	Removal of Soils with Visible Hg and Hg-Impacted Soils Near Log Pond, Capping of Residual Impacted Soils, and Groundwater MNA	\$	22,800,000
4)	Neutralization of "Caustic Core," Aggressive Removal of Obstructions and In-Situ Treatment of Soils with Visible Hg, Removal of Hg-Impacted Soils Near Log Pond, Capping of Residual Impacted Soils, and Groundwater MNA	\$	18,400,000
5)	Neutralization of Groundwater with pH > 8.5, Aggressive Removal of Obstructions and In-Situ Treatment of Soils with Visible Hg, Removal of Hg-Impacted Soils Near Log Pond, Capping of Residual Impacted Soils, and Groundwater MNA	\$	24,200,000
6)	Neutralization of Groundwater with pH > 8.5, Removal of Hg-Impacted Soils to Achieve Groundwater Protection, Capping of Residual Impacted Soils, and Groundwater MNA	\$	39,100,000
7)	Removal of All Soils Exceeding Cleanup Levels, Neutralization of Groundwater with pH > 8.5, and Groundwater MNA	\$	63,800,000
8)	Removal of All Soils Exceeding Cleanup Levels, Neutralization of Groundwater with pH > 8.5, In-Situ Treatment of Fill Unit Groundwater Impacted by Hg and PAHs, and MNA for Residual Impacted Groundwater	\$	69,800,000

Notes:

 Costs are in 2017 dollars. Costs were estimated using Net Present Value (NPV) analysis, assuming a discount rate of 0.7 percent. Long-term inspection, monitoring, and maintenance ("O&M") costs were evaluated over a 30-year period, consistent with EPA guidance. The estimates are order-of-magnitude, with an intended accuracy in the range of -30 to +50 percent.

2) Estimates are rounded to the nearest \$100,000.

### Table A-2 - Alternative 1 Cost Estimate

Project #070188 - Chlor-Alkali RAU, GP West Site, Bellingham, Washington

Remedial Action Description:	Alternative:	1 Cont	ainment and	In-Situ Treatment of Accessible Soils with Visible Hg, Removal of Hg-Impacted Soils Near			
Cost Estimate Accuracy:	FS Screening Level (+50/-3	Log 30 percer	rona, Cappin it)	ig or residuar impacted Solis, and Groundwater MINA			
Key Assumptions and Quantities:		Сар	Quantities				
	7.4 acre 1.5 ton/BCY	capp soil d	bing area density				
	15 each 21.897 ton	MNA Visil weig	wells ble Mercury \$ ht of soil and	Soils Containment and In Situ Stabilization Quantities debris in target area			
	1,533 ton 383 ton	weig weig	ht of surficial ht of surficial	debris requiring encapsulation			
	75% 25%	% of auge	target area a er overlap	accessible for in situ stabilization			
	25% 2% 5.600 BCX	perc perc	entage cemei entage sulfur	nt amendment (in situ) amendment (in situ) oth grade after ISS			
	1,293 ft 107,886 ft2	total	containment alt pavement	wall length			
	2,501 BCY	Soil over	Excavation ( burden soil ex	Quantities - WW Settling Basin Soils with [Hg] > 300 mg/kg xcavation volume			
	2,189 BCY 1,094 BCY	impacted soil excavation volume volume classified as hazardous					
	700 lf	SW :	Swale Quant	as non-nazardous ities - Stockpiling Overburden and Consolidating BNSF Soils with [Hg] > 24 mg/kg remove/replace			
	900 BCY 675 BCY	volui volui	me of concret me of BNSF s	soil to consolidate			
	1,291 BCY	Soil exca	Excavation (	Quantities - TPH-Impacted Soils in SE Corner of Cell Building			
	0 BCY 1,291 BCY	volui volui	me classified me classified	as hazardous as non-hazardous			
CONSTRUCTION COSTS Item	Quantity Unit	l	Jnit Cost	Total Cost Notes			
Caustic Plume-Cell Building Interim Actions (2013-2014 and 2017)	1 1 5	ዮ	4 000 000	• 4.000.000 including remedial design construction and eversight			
Sunk cost Subtotal Caustic Plume-Cell Building Interim Actions	1 LS	Ф	4,900,000	<ul> <li>4,900,000 Including remedial design, construction, and oversignt</li> <li>4,900,000</li> </ul>			
Soil Capping Mobilization/demobilization	1 LS	\$	70,000	\$ 70,000			
Existing Cap -No Cost	<b>50%</b> 3.7 acre	\$	-	\$ -			
Soil Cover as Cap -Site Preparation	0% - acre	\$	4,500	\$ - clearing and leveling			
-Geotextile marker layer -Import, place, and compact fill	- SY 0 CY	\$ \$	2 18	<ul> <li>Specification 9 33.2(1) Table 3 (WSDOT, 2012)</li> <li>2' thick</li> </ul>			
Asphalt Pavement as Cap -Site Preparation -Pregrading	<i>100%</i> 1.2 acre 1.2 acre	\$ \$	4,500 5.200	<ul> <li>\$ 5,507 clearing and leveling</li> <li>\$ 6,364 light grading for asphalt</li> </ul>			
-Asphalt Buildings as Cap	1.2 acre 0%	\$	115,400	\$ 141,224 6" stone base, 2" binder layer, 1" topping layer			
-No Cost Stormwater collection and conveyance system Institutional Controls Plan	- 6,450 LF 1 LS	\$ \$	- - 50.000	<ul> <li>Assume buildings cost are redevelopment, not cleanup</li> <li>Assumed redevelopment cost</li> <li>50,000 includes I&amp;M manual for cover systems legal support</li> </ul>			
Remedial design Construction management and reporting	10% 10%	φ	50,000	\$ 27,309 \$ 27,309			
Subtotal	<b>o 7</b> 0/	¢	222.004	\$ 327,713 \$ 10,400			
Contingency Subtotal Soil Cap Cost	15%	\$ \$	347,122	\$ 52,068 \$ 399,190			
Containment and ISS of Accessible Soils with Visible Hg	4.40	•	000.000				
Mobilization/demobilization Transport/disposal of surficial concrete as Non-hazardous Waste Transport/disposal of contaminated debris - Hazardous Waste	1 LS 1,150 ton 383 ton	ծ \$ \$	300,000 80 650	<ul> <li>\$ 300,000</li> <li>\$ 91,966</li> <li>\$ 249.076 Subtitle C landfill with macro-encapsulation</li> </ul>			
Auger solidification Portland cement amendment	16,423 ton 4,106 ton	\$ \$	70 45	<ul> <li>\$ 1,149,581 accessible soils containing visible elemental Hg</li> <li>\$ 184,754 25% by wt</li> </ul>			
Sulfur amendment Import, place, and compact fill Soil/bentonite slurry wall	328 ton 5,600 BCY 1,293 LF	\$ \$ \$	40 20 150	<ul> <li>\$ 13,138 2% by wt</li> <li>\$ 112,000 to smooth surface following ISS</li> <li>\$ 193,950</li> </ul>			
Asphalt pavement Remedial design & pre-design testing	107,886 SF 20%	\$	2.9	<ul> <li>\$ 311,791</li> <li>\$ 521,251 includes add'l characterization</li> </ul>			
Construction management and reporting Subtotal	15%		-	\$ 390,938 \$ 3,518,445			
Tax Contingency	8.7% 15%	\$ \$	2,606,256 3,745,190	\$ 226,744 \$ 561,778			
Subtotal Containment and ISS of Accessible Soils with Visible Hg			-	\$ 4,306,968			
Mobilization/demobilization Dewatering	1 LS 12 day	\$ \$	60,000 800	\$ 60,000 \$ 9,380			
Excavate/stockpile/replace overburden soil Excavation, transport, and disposal - Non-Hazardous Waste	2,501 BCY 1,642 ton	\$ \$	20 100	\$ 50,027 \$ 164,150			
Excavation, transport, and disposal - Hazardous Waste Import, place, and compact fill Remedial design	1,642 ton 2,189 BCY 10%	\$ \$	240 20	\$ 393,960 \$ 43,773 \$ 72,129			
Construction management and reporting Subtotal	8%		-	\$ 57,703 \$ 851,122			
Tax Contingency	8.7% 10%	\$ \$	721,290 913,874	\$ 62,752 \$ 91,387			
Subtotal Removal of Soils with [Hg] > 300 mg/kg from North WW Settling Basin		Ψ		\$ 1,005,262			
Stockpiling Crushed Concrete and Consolidating Soils with [Hg] > 24 mg/kg in Stormwater Swale Mobilization/demobilization Remove/replace chain link fence	1 LS	\$ \$	20,000	\$ 20,000 includes BNSF access agreement, flagger, etc.			
Remove/stockpile crushed concrete Consolidate soils from BNSF onto Port property	900 BCY 675 BCY	\$ \$	4 8 6	\$ 7,201 \$ 4,050			
Import, place, and compact fill Remedial design Construction management and reporting	1,125 BCY 20% 30%	\$	20	<ul> <li>\$ 22,502 restore BNSF grade (no import fill needed on Port property)</li> <li>\$ 11,311</li> <li>\$ 16,966</li> </ul>			
Subtotal	30%		-	\$ 84,829			
Tax Contingency Subtotal Stocknilling Concrete & Concellidating Spile in Otermustar Courts	8.7% 10%	\$ \$	56,553 89,749	\$ 4,920 \$ 8,975 \$ 08,724			
Removal of TPH-Impacted Soils in SE Corner of Cell Building				φ 30,124			
Mobilization/demobilization Dewatering	1 LS 3 day	\$ \$	40,000 800	<ul> <li>\$ 40,000</li> <li>\$ 2,581 based on 400 yd/day removal rate, includes daily sampling</li> <li>\$ 102,000 Output D log with</li> </ul>			
Excavation, transport and disposal - Non-Hazardous Waste Import, place, and compact fill Remedial design	1,936 ton 1,291 BCY 15%	\$ \$	100 20	<ul> <li>193,600 Subtitle D landfill</li> <li>25,813</li> <li>39,299 includes add'l characterization</li> </ul>			
Construction management and reporting Subtotal	10%		-	\$ 26,199 \$ 327,493			
Tax	8.7% 20%	\$ \$	261,995	\$ 22,794 \$ 70.057 increase due to likelihood of encountering debris			
Subtotal Removal of TPH-Impacted Soils in SE Corner of Cell Building	20 /0	φ		\$ 420,344			
Monitored Natural Attenuation Groundwater monitoring plan Monitoring wells	1 LS	\$	15,000	\$ 15,000 \$ 60,000			
Remedial design Construction management and reporting	15 each 15% 20%	Φ	4,000	\$ 11,250 \$ 15,000			
Subtotal			-	\$ 101,250			
Lax Contingency Subtotal Monitored Natural Attenuation	8.7% 20%	\$ \$	75,000 107,775	\$       6,525         \$       21,555         \$       129,330			
Professional Services (as percent of capital costs)				Ψ 120,000			
Project administration	3%	\$	11,259,819	\$337,795			
I otal Estimated Capital Costs O&M COSTS - Net Present Value				\$ 11,597,613			
Item	Start Year End Yea	ar Ar	inual Cost	NPV Cost Notes			
Periodic O&M Inspection and maintenance of cover systems	1	30 \$	6,000	\$ 180,000			
Groundwater quality monitoring, Years 1 and 2 Groundwater quality monitoring, Years 3+	1 3	2\$ 30\$	16,000 8,000	\$ 32,000 \$ 224,000 \$ 426,000			
Contingency	00	.0%		φ 430,000 \$ 87,200			
Professional Services (as percent of Periodic O&M costs)	20.		-	\$ 523,200			
Project administration Project management/reporting		5% 6%		\$ 26,160 \$ 31,392			
Total, Periodic O&M Net Present Value:				\$ 580,752			
TOTAL ESTIMATED COST				\$ 12,180,000			

Notes:

0.7% discount rate for NPV analysis based on real interest rate on US Treasury 30-year notes and bonds, Circular A-94 Appendix C, Office of Management and Budget (Revised November 2016). Mobilization/Demobilization costs are assumed to include equipment transport and setup, temporary erosion and sedimentation control (TESC) measures, bonds, and insurance. Contingency costs include miscellaneous costs not currently itemized due to the current (preliminary) stage of design development, as well as costs to address unanticipated conditions encountered during construction. Taxes are not applied to project administration, design, and reporting costs.

### Table A-3 - Alternative 2 Cost Estimate

Project #070188 - Chlor-Alkali RAU, GP West Site, Bellingham, Washington

Site: Remedial Action Description:	Former Georgia-F Alternative:	Pacific Wes	t Site -	Pulp/Tissue I ressive Remo	Mill Remedial Ac val of Obstructio	tion Unit ns and In Situ Treatment of Soils with Visible Hg, Removal of Hg- paring of Residual Imported Soils, and Crowndwater MNA		
Cost Estimate Accuracy:	FS Screening Lev	vel (+50/-30	) perce	acted Soils Ne nt)	ear Log Pond, Ca	pping of Residual Impacted Soils, and Groundwater MNA		
Key Assumptions and Quantities:			Сар	Quantities				
	7.4 1.5	acre ton/BCY	capping area soil density					
	15 21 897	each	MINA wells Visible Mercury Soils Aggressive Removal of Obstructions and In Situ Stabilization Quanti weight of soil and debris in target area					
	1,533 657	ton	weight of removed surficial debris weight of removed piles					
	25% 19,707	ton	percentage of surficial debris requiring encapsulation weight of soil in target area for in situ stabilization					
	1,150 25%	ton	weig auge	ht of inert sur er overlap	ficial debris			
	25% 2%	PCV	perc	entage cemer entage sulfur	nt amendment (in amendment (in s	n situ) situ)		
	2,500	BCY	Soil	Excavation C	Quantities - WW	So Settling Basin Soils with [Hg] > 300 mg/kg		
	2,189 1,094	BCY BCY	impa volui	acted soil exca	avation volume as hazardous			
	1,094	BCY	volui SW S	me classified Swale Quant	as non-hazardou ities - Stockpilin	is ig Overburden and Consolidating BNSF Soils with [Hg] > 24 mg/kg		
	700 900	lf BCY	leng volu	th of fence to me of concret	remove/replace e to excavate/sto	ockpile		
	675	BCY	volui Soil	me of BNSF s Excavation (	Soil to consolidate Quantities - TPH	e -Impacted Soils in SE Corner of Cell Building		
	0 1,291	BCY BCY	volui volui	me classified	as hazardous as non-hazardou	IS		
CONSTRUCTION COSTS	.,							
Item	Quantity	Unit	ι	Jnit Cost	Total Cost	Notes		
Sunk cost Subtotal Caustic Plume-Cell Building Interim Actions	1	LS	\$	4,900,000 _	\$ 4,900,000 \$ 4,900,000	including remedial design, construction, and oversight		
Soil Capping					<i>, , ,</i>			
Mobilization/demobilization Existing Cap	1 <b>50%</b>	LS	\$	70,000	\$ 70,000			
New Cap Soil Cover as Cap	3.7 <b>50%</b> 0%	acre	φ	-	φ -			
-Site Preparation -Geotextile marker layer	- -	acre SY	\$ \$	4,500 2	\$ - \$ -	clearing and leveling Specification 9 33.2(1) Table 3 (WSDOT, 2012)		
-Import, place, and compact fill Asphalt Pavement as Cap	0 100%	CY	\$	18	\$ -	2' thick		
-Site Freparation -Pregrading -Asphalt	3.7 3.7 3.7	acre acre acre	ъ \$ \$	4,500 5,200 115,400	<ul> <li>φ 16,652</li> <li>\$ 19,243</li> <li>\$ 427 037</li> </ul>	light grading for asphalt 6" stone base, 2" binder laver, 1" topping laver		
Buildings as Cap -No Cost	0%		↓ \$	-	\$ -	Assume buildings cost are redevelopment, not cleanup		
Stormwater collection and conveyance system Institutional Controls Plan	6,450 1	LF LS	\$ \$	- 50,000	\$ - \$ 50,000	Assumed redevelopment cost includes I&M manual for cover systems, legal support		
Remedial design Construction management and reporting Subtotal	10% 10%			-	<ul> <li>58,293</li> <li>58,293</li> <li>58,293</li> <li>600 519</li> </ul>	-		
Tax	8.7%		\$	532,932	\$ 46,365			
Contingency Subtotal Soil Cap Cost	15%		\$	745,884	\$ 111,883 \$ 857,766	-		
Aggressive Removal of Obstructions and ISS of Soils with Visible Hg	1	19	¢	300 000	¢ 300.000	includes dowatering equipment and installation		
Mobilization/demobilization Material removal (soil, foundation elements, etc.) Dewatering	ا 14,598 24	LS BCY dav	ъ \$ \$	300,000 125 800	\$ 300,000 \$ 1,824,731 \$ 19,464	based on 400 vd/day removal rate, includes daily sampling		
Transport/disposal of contaminated debris - Hazardous Waste Transport/disposal of surficial concrete as Non-hazardous Waste	1,040 1,150	ton	\$ \$	650 80	\$ 676,063 \$ 91,966	Subtitle C landfill with macro-encapsulation		
Portland cement amendment Sulfur amendment	4,927 394	ton ton	\$ \$	45 40 70	\$ 221,705 \$ 15,766 \$ 1,270,407	25% by wt 2% by wt		
Auger solidification Import, place, and compact fill Remedial design & pre-design testing	19,707 5,600 15%	ton BCY	ծ \$	20	\$ 1,379,497 \$ 112,000 \$ 696,179	accessible soils containing visible elemental Hg to smooth surface following ISS includes add'l characterization		
Construction management and reporting Subtotal	15%			-	\$ 696,179 \$ 6,033,550	-		
Tax	8.7%		\$	4,641,192	\$ 403,784			
Contingency Subtotal Aggressive Removal of Obstructions and ISS of Soils with Visible Hg	20%		\$	6,437,334 _	\$ 1,287,467 \$ 7,724,800	-		
Removal of Soils with [Hg] > 300 mg/kg from North WW Settling Basin Mobilization/demobilization	1	LS	\$	60,000	\$ 60,000			
Dewatering Excavate/stockpile/replace overburden soil	12 2,501	day BCY	\$ \$	800 20	\$ 9,380 \$ 50,027			
Excavation, transport, and disposal - Non-Hazardous Waste Excavation, transport, and disposal - Hazardous Waste	1,642 1,642 2,189	ton ton BCV	\$ \$	100 240 20	\$ 164,150 \$ 393,960 \$ 43,773			
Remedial design Construction management and reporting	10% 8%	DOT	Ψ	20	\$ 72,129 \$ 57,703			
Subtotal			•	-	\$ 851,122	-		
Tax Contingency Subtotal Removal of Soils with [Ha] > 300 mg/kg from North WW Settling Basin	8.7% 10%		\$ \$	721,290 913,874 _	\$ 62,752 \$ 91,387 \$ 1,005,262	-		
Stockpiling Crushed Concrete and Consolidating Soils with [Hg] > 24 mg/kg in Stormwater Swa	le				φ 1,000,202			
Mobilization/demobilization Remove/replace chain link fence	1 700	LS lf	\$ \$	20,000 4	\$ 20,000 \$ 2,800	includes BNSF access agreement, flagger, etc.		
Remove/stockpile crushed concrete Consolidate soils from BNSF onto Port property	900 675	BCY BCY	\$ \$ ¢	8 6	\$ 7,201 \$ 4,050 \$ 22,502	rectore DNCE grade (no import fill peopled on Dart property)		
Remedial design Construction management and reporting	1,125 20% 30%	BCY	Ф	20	\$ 22,502 \$ 11,311 \$ 16,966	restore BNSF grade (no import fill needed on Port property)		
Subtotal				-	\$ 84,829	-		
Tax Contingency Subtated Stockwilling Concerns & Concerns to Contract On the Concerns of C	8.7% 10%		\$ \$	56,553 89,749	\$ 4,920 \$ 8,975	_		
Removal of TPH-Impacted Soils in SF Corner of Cell Building					φ 98,724			
Mobilization/demobilization Dewatering	1 3	LS day	\$ \$	40,000 800	\$ 40,000 \$ 2,581	based on 400 yd/day removal rate, includes dailv sampling		
Excavation, transport and disposal - Non-Hazardous Waste Import, place, and compact fill Remodial design	1,936 1,291	ton BCY	\$ \$	100 20	\$ 193,600 \$ 25,813	Subtitle D landfill		
Remedial design Construction management and reporting	15% 10%			-	\$ 39,299 <u>\$ 26,199</u> <b>*</b> 337,403	includes add'l characterization		
Тах	8.7%		\$	261,995	<ul><li><i>y</i> 3∠1,493</li><li>\$ 22.794</li></ul>			
Contingency Subtotal Removal of TPH-Impacted Soils in SE Corner of Cell Building	20%		\$	350,287	\$ 70,057 \$ 420,344	increase due to likelihood of encountering debris		
Monitored Natural Attenuation Groundwater monitoring plan		19	ድ	15 000	\$ 15000			
Monitoring wells Remedial design	1 15 15%	each	9 \$	4,000	\$ 60,000 \$ 11.250			
Construction management and reporting Subtotal	20%			-	\$ 15,000 \$ 101,250	-		
Tax	8.7%		\$	75,000	\$ 6,525			
Contingency Subtotal Monitored Natural Attenuation	20%		\$	107,775 _	\$         21,555           \$         129,330	-		
Professional Services (as percent of capital costs) Project administration	30/		\$	15.136.227	\$454 087			
Total Estimated Capital Costs	070		Ŷ	.,. <b></b> , <i>L</i> I	\$ 15,590.314			
O&M COSTS - Net Present Value	-							
Item	Start Year	End Year	An	nual Cost	NPV Cost	Notes		
Periodic O&M Inspection and maintenance of cover systems Groundwater quality monitoring. Years 1 and 2	1	3	0 \$ 2 °	6,000	\$ 180,000 \$ 20,000			
Groundwater quality monitoring, Years 1 and 2 Groundwater quality monitoring, Years 3+ Subtotal Periodic O&M Cost	1 3	3	∠\$ 0\$	16,000 8,000	Description         32,000           \$ 224,000         \$ 426,000	-		
Contingency		20 00	%		<ul><li><i>y 4</i>30,000</li><li>\$ 87,200</li></ul>			
Professional Services (as percent of Periodic O&M costs)		20.07	-	-	\$ 523,200	-		
Project administration Project management/reporting		5% 6%	% %		\$ 26,160 \$ 31,392			
Total, Periodic O&M Net Present Value:					\$ 580,752			
TOTAL ESTIMATED COST					\$ 16,170,000			

Notes:

0.7% discount rate for NPV analysis based on real interest rate on US Treasury 30-year notes and bonds, Circular A-94 Appendix C, Office of Management and Budget (Revised November 2016). Mobilization/Demobilization costs are assumed to include equipment transport and setup, temporary erosion and sedimentation control (TESC) measures, bonds, and insurance. Contingency costs include miscellaneous costs not currently itemized due to the current (preliminary) stage of design development, as well as costs to address unanticipated conditions encountered during construction. Taxes are not applied to project administration, design, and reporting costs.

### Table A-4 - Alternative 3 Cost Estimate

Project #070188 - Chlor-Alkali RAU, GP West Site, Bellingham, Washington

Site: Remedial Action Description:	Former Georgia-Pacific W Alternative:	/est Site 3 Rer Soil	- Pulp/Tissue noval of Soils ls. and Ground	Mill Remedial Ac with Visible Hg a twater MNA	tion Unit nd Hg-Impacted Soils Near Log Pond, Capping of Residual Impacted
Cost Estimate Accuracy:	FS Screening Level (+50/	-30 perce	ent)		
Key Assumptions and Quantities:	7.4. acre	Cap	o Quantities		
	1.5 ton/BCY 15 each	′ soil MN	density A wells		
	21,897 ton	Vis wei	ible Mercury S ght of removed	Soils Removal, 1 d soil & debris	Freatment, and Offsite Disposal Quantities
	1,533 ton 657 ton 19,707 ton	wei wei	ght of removed ght of removed aht of soil in ta	d sufficial debris d piles arget area	
	25% 1,150 ton	pere	centage of sur ght of inert sur	ficial debris requ ficial debris	iring encapsulation
	25% 2%	pero pero	centage ceme centage sulfur	nt amendment (e amendment (ex	situ) situ)
	2,501 BCY	Soi ove	I Excavation ( rburden soil exc	Quantities - WW xcavation volume	Settling Basin Soils with [Hg] > 300 mg/kg
	1,094 BCY 1,094 BCY	volu volu	ume classified	as hazardous as non-hazardou	IS
	700 lf	<b>SW</b> leng	Swale Quant gth of fence to	i <b>ties - Stockpilir</b> remove/replace	ng Overburden and Consolidating BNSF Soils with [Hg] > 24 mg/kg
	900 BCY 675 BCY	volu volu Soji	ume of concret ume of BNSF s	te to excavate/sto soil to consolidate	ockpile e Jumpostod Soils in SE Corner of Coll Building
	1,291 BCY 0 BCY	exc volu	avation volume	e as hazardous	-Impacted Solis in SE Corner of Cell Building
	1,291 BCY	volu	ume classified	as non-hazardou	JS
CONSTRUCTION COSTS Item	Quantity Unit	t	Unit Cost	Total Cost	Notes
Caustic Plume-Cell Building Interim Actions (2013-2014 and 2017) Sunk cost	1 LS	\$	4.900.000	\$ 4.900.000	including remedial design, construction, and oversight
Subtotal Caustic Plume-Cell Building Interim Actions		Ŧ		\$ 4,900,000	
Soil Capping Mobilization/demobilization	1 LS	\$	70,000	\$ 70,000	
-No Cost New Cap	50% 3.7 acre 50%	\$	-	\$-	
Soil Cover as Cap -Site Preparation	0% - acre	\$	4,500	\$-	clearing and leveling
-Geotextile marker layer -Import, place, and compact fill Asphalt Pavement as Can	- SY 0 CY	\$ \$	2 18	\$ - \$ -	Specification 9 33.2(1) Table 3 (WSDOT, 2012) 2' thick
-Site Preparation -Pregrading	3.7 acre 3.7 acre	\$ \$	4,500 5.200	\$ 16,652 \$ 19,243	clearing and leveling light grading for asphalt
-Asphalt Buildings as Cap	3.7 acre 0%	\$	115,400	\$ 427,037	6" stone base, 2" binder layer, 1" topping layer
-No Cost Stormwater collection and conveyance system	6,450 LF	\$ \$	-	\$ - \$ -	Assume buildings cost are redevelopment, not cleanup Assumed redevelopment cost
Remedial design Construction management and reporting	1 LS 10% 10%	\$	50,000	\$ 50,000 \$ 58,293 \$ 58,293	includes law manual for cover systems, legal support
Subtotal	1070		-	\$ 699,518	-
Tax Contingency Subtotal Sail Cap Cast	8.7% 15%	\$ \$	532,932 745,884 _	\$ 46,365 \$ 111,883 \$ 957,766	_
Removal, Treatment, and Offsite Disposal of Soils with Visible Hg				φ 837,700	
Mobilization/demobilization Material removal (soil, foundation elements, etc.)	1 LS 14,598 BCY	\$ \$	300,000 125	\$ 300,000 \$ 1,824,731	includes dewatering equipment and installation
Dewatering Transport/disposal of contaminated debris - Hazardous Waste	24 day 1,040 ton	\$	800 650	\$ 19,464 \$ 676,063	based on 400 yd/day removal rate, includes daily sampling Subtitle C landfill with macro-encapsulation
I ransport/disposal of sufficial concrete as Non-hazardous Waste Portland cement amendment Sulfur amendment	1,150 ton 4,927 ton 394 ton	\$ \$ \$	80 45 40	\$ 91,966 \$ 221,705 \$ 15,766	25% by wt
Ex situ solidification and load for offsite transport Transport/disposal of solidified mix - Hazardous Waste	19,707 ton 26,999 ton	9 \$ \$	50 220	\$ 985,355 \$ 5,939,720	includes added water wt. @ 10% of soil wt.
Import, place, and compact fill Remedial design & pre-design testing	13,138 BCY 5%	\$	20	\$ 262,761 \$ 516,877	includes add'l characterization
Construction management and reporting Subtotal	5%		-	\$516,877 \$11,371,285	-
Tax Contingency	8.7% 15%	\$ \$	10,337,532 12,270,650	\$ 899,365 \$ 1,840,598	
Subtotal Removal, Treatment, and Offsite Disposal of Soils with Visible Hg			-	\$ 14,111,248	-
Removal of Soils with [Hg] > 300 mg/kg from North WW Settling Basin Mobilization/demobilization Dewatering	1 LS	\$	60,000	\$ 60,000 \$ 0,380	
Excavate/stockpile/replace overburden soil Excavation, transport, and disposal - Non-Hazardous Waste	2,501 BCY 1,642 ton	9 \$ \$	20 100	\$ 50,027 \$ 164,150	
Excavation, transport, and disposal - Hazardous Waste Import, place, and compact fill	1,642 ton 2,189 BCY	\$ \$	240 20	\$ 393,960 \$ 43,773	
Remedial design Construction management and reporting	10% 8%		-	\$ 72,129 \$ 57,703 \$ 851 122	_
Tax	8.7%	\$	721,290	\$ 62,752	
Contingency Subtotal Removal of Soils with [Hg] > 300 mg/kg from North WW Settling Basin	10%	\$	913,874 _	\$ 91,387 \$ 1,005,262	-
Stockpiling Crushed Concrete and Consolidating Soils with [Hg] > 24 mg/kg in Stormwater Swale Mobilization/demobilization	e 1   S	\$	20.000	\$ 20,000	includes BNSE access agreement flagger, etc.
Remove/replace chain link fence Remove/stockpile crushed concrete	700 lf 900 BCY	\$ \$	20,000 4 8	\$ 2,800 \$ 7,201	includes biver access agreement, hagger, etc.
Consolidate soils from BNSF onto Port property Import, place, and compact fill	675 BCY 1,125 BCY	\$ \$	6 20	\$ 4,050 \$ 22,502	restore BNSF grade (no import fill needed on Port property)
Construction management and reporting	20% 30%		-	\$ 11,311 <u>\$ 16,966</u> <u>\$ 84,829</u>	_
Tax	8.7%	\$	56,553	\$ 4,920	
Contingency Subtotal Stockpiling Concrete & Consolidating Soils in Stormwater Swale	10%	\$	89,749	\$ 8,975 \$ 98,724	-
Removal of TPH-Impacted Soils in SE Corner of Cell Building Mobilization/demobilization	1 19	¢	40 000	\$ 40.000	
Dewatering Excavation, transport and disposal - Non-Hazardous Waste	3 day 1,936 ton	<del>9</del> (\$ (\$	800 100	\$ 2,581 \$ 193,600	based on 400 yd/day removal rate, includes daily sampling Subtitle D landfill
Import, place, and compact fill Remedial design	1,291 BCY 15%	\$	20	\$ 25,813 \$ 39,299	includes add'l characterization
Construction management and reporting Subtotal	10%		-	<u>\$ 26,199</u> \$ 327,493	-
Tax Contingency	8.7% 20%	\$ \$	261,995 350,287	\$ 22,794 \$ 70,057	increase due to likelihood of encountering debris
Subtotal Removal of TPH-Impacted Soils in SE Corner of Cell Building			_	\$ 420,344	
Monitored Natural Attenuation Groundwater monitoring plan Monitoring wells	1 LS 15 each	\$	15,000	\$ 15,000 \$ 60,000	
Remedial design Construction management and reporting	15% 20%	φ	-,	\$ 11,250 \$ 15,000	
Subtotal			-	\$ 101,250	
Tax Contingency	8.7% 20%	\$ \$	75,000 107,775 _	\$ 6,525 <u>\$ 21,555</u>	_
Professional Services (as percent of capital costs)				φ 129,330	
Project administration	3%	\$	21,522,674	\$645,680	
Total Estimated Capital Costs				\$ 22,168,354	
O&M COSTS - Net Present Value Item	Start Year End Ye	ear A	nnual Cost	NPV Cost	Notes
Periodic O&M		- م^ ش	0.000	¢ 400.000	
Groundwater quality monitoring, Years 1 and 2 Groundwater quality monitoring, Years 3+	า 1 ว	30 \$ 2 \$ 3∩ ¢	0,000 16,000 8,000	<ul> <li></li></ul>	
Subtotal Periodic O&M Cost	J	υφ	0,000 _	\$ 436,000	-
Contingency	20	).0%	-	\$ 87,200 \$ 523,200	-
Professional Services (as percent of Periodic O&M costs) Project administration		5%		\$ 26,160	
Project management/reporting		6%		\$ 31,392 \$ 500	
				φ οδυ,/52 \$ 22 750 000	
				Ψ 22,130,000	

Notes:

0.7% discount rate for NPV analysis based on real interest rate on US Treasury 30-year notes and bonds, Circular A-94 Appendix C, Office of Management and Budget (Revised November 2016). Mobilization/Demobilization costs are assumed to include equipment transport and setup, temporary erosion and sedimentation control (TESC) measures, bonds, and insurance. Contingency costs include miscellaneous costs not currently itemized due to the current (preliminary) stage of design development, as well as costs to address unanticipated conditions encountered during construction. Taxes are not applied to project administration, design, and reporting costs.

### Table A-5 - Alternative 4 Cost Estimate

Project #070188 - Chlor-Alkali RAU, GP West Site, Bellingham, Washington

Site: Remedial Action Description:	Former Georgia-Pacific We Alternative:	est Site - <b>4</b> Neu Visit	Pulp/Tissue Mill tralization of "Ca ble Hg, Removal	Remedial Actio ustic Core," Ag of Hg-Impacted	n Unit gressive Removal of Obstructions and In-Situ Treatment of Soils with d Soils Near Log Pond. Capping of Residual Impacted Soils, and		
Cost Estimate Accuracy: Key Assumptions and Quantities:	FS Screening Level (+50/-3	30 percer	t)				
	7.4 acre	Cap Quantities capping area					
	15 each	soil density MNA wells Visible Mercury Soils Aggressive Removal of Obstructions and In Situ Stabilization Quantit					
	21,897 ton 1,533 ton 657 ton	weig weig weig	ht of soil and de ht of removed so ht of removed p	bris in target ar urficial debris iles	ea		
	25% 19,707 ton	perc weig	entage of surficients of surficients of soil in targe	al debris requiri et area for in site	ng encapsulation u stabilization		
	1,150 ton 25% 25%	weig auge	ht of inert surfici or overlap entage cement a	al debris	situ)		
	2% 5,600 BCY	perc perc impo	entage sulfur an ort soil to smooth	nendment (in sit	sud) S		
	2,501 BCY	Soil over	Excavation Que	antities - WW S vation volume	Settling Basin Soils with [Hg] > 300 mg/kg		
	2,189 BCY 1,094 BCY 1,094 BCY	impa volu volu	ne classified as	ntion volume hazardous non-hazardous			
	700 lf	SW leng	Swale Quantitie th of fence to rer	es - Stockpiling nove/replace	g Overburden and Consolidating BNSF Soils with [Hg] > 24 mg/kg		
	900 BCY 675 BCY	volu volu <b>Soil</b>	me of BNSF soil Excavation Qu	to consolidate antities - TPH-	Impacted Soils in SE Corner of Cell Building		
	1,291 BCY 0 BCY	exca volu	vation volume me classified as	hazardous			
	1,291 BCY	Elev exca	ne classified as v <b>ated Groundwa</b> ivation volume	non-nazardous ater pH Neutra	lization Quantities		
	1,035 ft 1,413 ton	total ferro	trench length ous sulfate				
	10 each	mon	itoring wells				
CONSTRUCTION COSTS Item	Quantity Unit	l	Jnit Cost	Total Cost	Notes		
Caustic Plume-Cell Building Interim Actions (2013-2014 and 2017) Sunk cost Subtotal Caustic Plume-Cell Building Interim Actions	1 LS	\$	4,900,000 _\$	4,900,000	_including remedial design, construction, and oversight		
Soil Capping			Ψ	4,000,000			
Mobilization/demobilization Existing Cap	1 LS <b>50%</b> 3.7 acre	\$ \$	70,000 \$	70,000			
New Cap Soil Cover as Cap	50% 0%	Ψ	Ψ	-			
-Site Preparation -Geotextile marker layer -Import, place, and compact fill	- acre - SY 0 CY	\$ \$ \$	4,500 \$ 2 \$ 18 \$	-	clearing and leveling Specification 9 33.2(1) Table 3 (WSDOT, 2012) 2' thick		
Asphalt Pavement as Cap -Site Preparation	100% 3.7 acre	\$ \$	4,500 \$	16,652	clearing and leveling		
-Pregrading -Asphalt Buildings as Cap	3.7 acre 3.7 acre <i>0%</i>	\$ \$	5,200 \$ 115,400 \$	19,243 427,037	iignt grading for asphalt 6" stone base, 2" binder layer, 1" topping layer		
-No Cost Stormwater collection and conveyance system Institutional Controls Plan	6,450 LF	\$ \$ ¢	- \$ - \$	- - 50,000	Assume buildings cost are redevelopment, not cleanup Assumed redevelopment cost includes I&M manual for cover systems, local support		
Remedial design Construction management and reporting	1 LS 10% 10%	2	ວບ,ບບບ \$ \$ _\$	50,000 58,293 <u>58,29</u> 3	nouues ion manual for cover systems, legal support		
Subtotal Tax	8.7%	\$	\$ 532,932	699,518 46,365			
Contingency Subtotal Soil Cap Cost	15%	\$	745,884 <u>\$</u> \$	111,883 857,766	-		
Aggressive Removal of Obstructions and ISS of Soils with Visible Hg Mobilization/demobilization Material removal (soil, foundation elements, etc.)	1 LS	\$ \$	300,000 \$ 125 \$	300,000	includes dewatering equipment and installation		
Dewatering Transport/disposal of contaminated debris - Hazardous Waste	24 day 1,040 ton	9 \$ \$	800 \$ 650 \$	19,464 676,063	based on 400 yd/day removal rate, includes daily sampling Subtitle C landfill with macro-encapsulation		
Transport/disposal of surficial concrete as Non-hazardous Waste Portland cement amendment Sulfur amendment	1,150 ton 4,927 ton 394 ton	\$ \$ \$	80 \$ 45 \$ 40 \$	91,966 221,705 15,766	25% by wt 2% by wt		
Auger solidification Import, place, and compact fill	19,707 ton 5,600 BCY	\$ \$	70 \$ 20 \$	1,379,497 112,000	accessible soils containing visible elemental Hg to smooth surface following ISS		
Construction management and reporting Subtotal	15% 15%		\$ \$ \$	696,179 696,179 6,033,550	Includes add'I characterization		
Tax Contingency	8.7% 20%	\$ \$	4,641,192 \$ 6 437 334 \$	403,784 1 287 467			
Subtotal Aggressive Removal of Obstructions and ISS of Soils with Visible Hg	2078	Ψ	5,457,554 <u>\$</u>	7,724,800	-		
Removal of Soils with [Hg] > 300 mg/kg from North WW Settling Basin Mobilization/demobilization Dewatering	1 LS 12 day	\$ \$	60,000 \$ 800 \$	60,000 9,380			
Excavate/stockpile/replace overburden soil Excavation, transport, and disposal - Non-Hazardous Waste	2,501 BCY 1,642 ton	\$ \$	20 \$ 100 \$	50,027 164,150			
Excavation, transport, and disposal - Hazardous Waste Import, place, and compact fill Remedial design	1,642 ton 2,189 BCY 10%	\$ \$	240 \$ 20 \$ \$	393,960 43,773 72,129			
Construction management and reporting Subtotal	8%		\$ \$	57,703 851,122	-		
Tax Contingency	8.7% 10%	\$ \$	721,290 \$ 913,874 <u>\$</u>	62,752 91,387	_		
Subtotal Removal of Solis with [Hg] > 300 mg/kg from North WW Settling Basin Stockpiling Crushed Concrete and Consolidating Soils with [Hg] > 24 mg/kg in Stormwater Swale	e		\$	1,005,262			
Mobilization/demobilization Remove/replace chain link fence Remove/stockpile crushed concrete	1 LS 700 lf 900 BCY	\$ \$ \$	20,000 \$ 4 \$ 8 \$	20,000 2,800 7 201	includes BNSF access agreement, flagger, etc.		
Consolidate soils from BNSF onto Port property Import, place, and compact fill	675 BCY 1,125 BCY	\$ \$	6 \$ 20 \$	4,050 22,502	restore BNSF grade (no import fill needed on Port property)		
Remedial design Construction management and reporting Subtotal	20% 30%		\$ \$ \$	11,311 <u>16,966</u> <i>84.829</i>	-		
Tax	8.7%	\$	56,553 \$	4,920			
Subtotal Stockpiling Concrete & Consolidating Soils in Stormwater Swale	10%	φ	69,749 <u>\$</u> \$	98,724	-		
Neutralization of Elevated Groundwater pH Mobilization/demobilization Trenching	1 LS	\$ \$	80,000 \$ 375 \$	80,000 388 125	One Pass trencher transport, assembly and disassembly		
Transport and disposal - Non-Hazardous Waste Treatment media	2,588 ton 1,413 ton	\$ \$	80 \$ 300 \$	207,000 423,833	Subtitle D landfill ferrous sulfate heptahydrate, includes transport		
Import, place, and compact fill Monitoring well installation Remedial design & pre-design testing	115 BCY 10 each 25%	\$ \$	20 \$ 4,000 \$ \$	2,300 40,000 285,314	soil replaced above treatment media		
Construction management and reporting Subtotal	15%		\$	171,189 1,597,761	_		
Tax Contingency	8.7% 20%	\$ \$	1,141,258  \$ 1,697,050 <u>\$</u>	99,289 339,410			
Subtotal Neutralization of Elevated Groundwater pH Removal of TPH-Impacted Soils in SE Corner of Cell Building				2,036,460			
Mobilization/demobilization Dewatering	1 LS 3 day	\$ \$	40,000 \$ 800 \$	40,000 2,581	based on 400 yd/day removal rate, includes daily sampling		
Excavation, transport and disposal - Non-Hazardous Waste Import, place, and compact fill Remedial design	1,936 ton 1,291 BCY 15%	\$ \$	100 \$ 20 \$ \$	193,600 25,813 39,299	subtitle D landfill includes add'l characterization		
Construction management and reporting Subtotal	10%		\$	<u>26,199</u> 327,493	-		
Tax Contingency	8.7% 20%	\$ \$	261,995 \$ 350,287 _\$	22,794 70,057	_increase due to likelihood of encountering debris		
Subtotal Removal of TPH-Impacted Soils in SE Corner of Cell Building Monitored Natural Attenuation			\$	420,344			
Groundwater monitoring plan Monitoring wells Remedial design	1 LS 15 each	\$ \$	15,000 \$ 4,000 \$	15,000 60,000			
Construction management and reporting Subtotal	15% 20%		\$ \$ \$	11,250 15,000 101,250	_		
Tax	8.7% 20%	\$ \$	75,000 \$ 107 775 \$	6,525 21 555			
Subtotal Monitored Natural Attenuation	2078	Ψ	\$	129,330	-		
Professional Services (as percent of capital costs) Project administration	3%	\$	17,172,687	\$515,181			
Total Estimated Capital Costs			\$	17,687,867			
O&M COSTS - Net Present Value Item	Start Year End Yea	ar Aı	nnual Cost	NPV Cost	Notes		
Periodic O&M Inspection and maintenance of cover systems	1	30 \$	6,000 \$	180,000			
Groundwater quality monitoring, Years 1 and 2 Groundwater quality monitoring, Years 3+ Subtotal Periodic O&M Cost	1 3	2\$ 30\$	24,000 \$ 12,000 <u>\$</u> ¢	48,000 336,000 564,000	-		
Contingency	20.	.0%	φ _\$	112,800	_		
Professional Services (as percent of Periodic O&M costs) Project administration		5%	\$	676,8 <u>00</u>			
Project management/reporting		6%	\$	40,608			
TOTAL ESTIMATED COST			\$	751,248			
			Ψ	-,,			

Notes: 0.7% discount rate for NPV analysis based on real interest rate on US Treasury 30-year notes and bonds, Circular A-94 Appendix C, Office of Management and Budget (Revised November 2016). Mobilization/Demobilization costs are assumed to include equipment transport and setup, temporary erosion and sedimentation control (TESC) measures, bonds, and insurance. Contingency costs include miscellaneous costs not currently itemized due to the current (preliminary) stage of design development, as well as costs to address unanticipated conditions encountered during construction. Taxes are not applied to project administration, design, and reporting costs.

### Table A-6 - Alternative 5 Cost Estimate

Project #070188 - Chlor-Alkali RAU, GP West Site, Bellingham, Washington

Site: Remedial Action Description:	Former Georgia-Pacific V Alternative:	Vest Site - <b>5</b> Neu	Pulp/Tissue M tralization of G	lill Remedial Actic	on Unit pH > 8.5, Aggressive Removal of Obstructions and In-Situ Treatment of		
Cost Estimate Accuracy:	FS Screening Level (+50	Soil: /-30 percer	s with Visible H nt)	Hg, Removal of H	g-Impacted Soils Near Log Pond, Capping of Residual Impacted Soils, and		
Key Assumptions and Quantities:		Car	Quantities				
	7.4 acre 1.5 ton/BC	cap quantities capping area CY soil density					
	15 each	MNA wells Visible Mercury Soils Aggressive Removal of Obstructions and In Situ Stabilization Quantiti					
	21,897 ton 1,533 ton	weig weig	of soil and of removed	debris in target ar d surficial debris	ea		
	657 ton 25% 19 707 ton	weig perc weig	centage of surf	i piles ficial debris requiri rget area for in sit	ing encapsulation		
	1,150 ton 25%	weię aug	ght of inert sur er overlap	ficial debris			
	25% 2%	percentage cement amendment (in situ) percentage sulfur amendment (in situ)					
	5,600 BCY	import soil to smooth grade after ISS Soil Excavation Quantities - WW Settling Basin Soils with [Hg] > 300 mg/kg					
	2,501 BCY 2,189 BCY	over	overburden soil excavation volume impacted soil excavation volume				
	1,094 BCY 1,094 BCY	volume classified as hazardous volume classified as non-hazardous					
	700 lf 900 BCY	leng volu	th of fence to me of concret	remove/replace e to excavate/stop			
	675 BCY	5 BCY volume of BNSF soil to consolidate Soil Excavation Quantities - TPH-Impacted Soils in SE Corner of Cell Building					
	1,291 BCY 0 BCY	exca volu	avation volume	e as hazardous			
	1,291 BCY	volu Elev	me classified a vated Ground	as non-hazardous water pH Neutra	lization Quantities		
	7,815 BCY 4,689 ft 6,400 top	exca tota	trench length	<del>)</del>			
	521 BCY 20 each	topp	bing soil				
CONSTRUCTION COSTS			5				
Item	Quantity Un	nit	Unit Cost	Total Cost	Notes		
Sunk cost Subtotal Caustic Plume-Cell Building Interim Actions	1 LS	\$	4,900,000	\$ 4,900,000 \$ 4,900,000	_including remedial design, construction, and oversight		
Soil Capping				\$ 1,000,000			
Mobilization/demobilization Existing Cap	1 LS <b>50%</b>	\$	70,000	\$ 70,000			
-No Cost New Cap	3.7 acre <b>50%</b>	\$	-	\$-			
Son Cover as Cap -Site Preparation -Geotextile marker laver	0% - acre - ∽✓	\$ ¢	4,500	\$- \$-	clearing and leveling Specification 9 33.2(1) Table 3 (WSDOT 2012)		
-Import, place, and compact fill Asphalt Pavement as Cap	0 CY 100%	գ \$	18	\$ -	2' thick		
-Site Preparation -Pregrading	3.7 acre 3.7 acre	\$ \$	4,500 5,200	\$ 16,652 \$ 19,243	clearing and leveling light grading for asphalt		
-Asphalt Buildings as Cap -No Cost	3.7 acre 0%	\$ ¢	115,400	\$ 427,037 \$	o" stone base, 2" binder layer, 1" topping layer		
Stormwater collection and conveyance system Institutional Controls Plan	- 6,450 LF 1 LS	Դ Տ Տ	- - 50.000	\$- \$50.000	Assumed redevelopment cost includes I&M manual for cover systems, legal support		
Remedial design Construction management and reporting	10% 10%	Ý	2,000	\$ 58,293 \$ 58,293	-		
Subtotal Tax	8 7%	\$	532 032	\$ 699,518 \$ 46.365			
Contingency Subtotal Soil Cap Cost	15%	\$	745,884	\$ 111,883 \$ 857,766	_		
Aggressive Removal of Obstructions and ISS of Soils with Visible Hg	1 1 5	¢	200.000	¢ 200.000	includes devetoring equipment and installation		
Mobilization/demobilization Material removal (soil, foundation elements, etc.) Dewatering	1 LS 14,598 BCY 24 day	ծ \$ \$	300,000 125 800	\$ 300,000 \$ 1,824,731 \$ 19464	based on 400 vd/day removal rate includes daily sampling		
Transport/disposal of contaminated debris - Hazardous Waste Transport/disposal of surficial concrete as Non-hazardous Waste	1,040 ton 1,150 ton	\$ \$	650 80	\$ 676,063 \$ 91,966	Subtitle C landfill with macro-encapsulation		
Portland cement amendment Sulfur amendment	4,927 ton 394 ton	\$ \$	45 40	\$ 221,705 \$ 15,766	25% by wt 2% by wt		
Auger solidification Import, place, and compact fill Remedial design & pre-design testing	19,707 ton 5,600 BCY 15%	\$ \$	70 20	\$ 1,379,497 \$ 112,000 \$ 696 179	accessible soils containing visible elemental Hg to smooth surface following ISS includes add'l characterization		
Construction management and reporting Subtotal	15%			\$ 696,179 \$ 6,033,550			
Tax	8.7%	\$	4,641,192	\$ 403,784			
Contingency Subtotal Aggressive Removal of Obstructions and ISS of Soils with Visible Hg	20%	\$	6,437,334	\$ 1,287,467 \$ 7,724,800	_		
Removal of Soils with [Hg] > 300 mg/kg from North WW Settling Basin Mobilization/demobilization	1 LS	\$	60.000	\$ 60.000			
Dewatering Excavate/stockpile/replace overburden soil	12 day 2,501 BCY	\$ \$	800 20	\$ 9,380 \$ 50,027			
Excavation, transport, and disposal - Non-Hazardous Waste Excavation, transport, and disposal - Hazardous Waste	1,642 ton 1,642 ton	\$ \$	100 240	\$ 164,150 \$ 393,960			
Import, place, and compact fill Remedial design Construction management and reporting	2,189 BCY 10% 8%	\$	20	\$ 43,773 \$ 72,129 \$ 57,703			
Subtotal	070		-	\$ 851,122	_		
Tax Contingency Subjects Demonstrate Californial and the fit for the section benefits Middle California Design	8.7% 10%	\$ \$	721,290 913,874	\$ 62,752 \$ 91,387	_		
Stockpiling Crushed Concrete and Consolidating Soils with [Hg] > 24 mg/kg in Stormwater Swale	e			φ 1,000,202			
Mobilization/demobilization Remove/replace chain link fence	1 LS 700 lf	\$ \$	20,000 4	\$ 20,000 \$ 2,800	includes BNSF access agreement, flagger, etc.		
Remove/stockpile crushed concrete Consolidate soils from BNSF onto Port property	900 BCY 675 BCY	\$ \$	8 6	\$ 7,201 \$ 4,050			
Import, place, and compact fill Remedial design Construction management and reporting	1,125 BCY 20% 30%	\$	20	\$ 22,502 \$ 11,311 \$ 16,966	restore BNSF grade (no import fill needed on Port property)		
Subtotal	0070			\$ 84,829	-		
Tax Contingency Subtotal Stocknilling Concrete & Concellidating Seile in Stormwerter Courts	8.7% 10%	\$ \$	56,553 89,749	\$ 4,920 \$ 8,975	_		
Neutralization of Elevated Groundwater pH				φ 98,724			
Mobilization/demobilization Trenching	1 LS 4,689 LF	\$ \$	80,000 375	\$ 80,000 \$ 1,758,375	One Pass trencher transport, assembly and disassembly excavation and media placement		
Transport and disposal - Non-Hazardous Waste Treatment media	11,723 ton 6,400 ton	\$ \$	80 300	\$ 937,800 \$ 1,920,146	Subtitle D landfill ferrous sulfate heptahydrate, includes transport		
Import, place, and compact fill Monitoring well installation	521 BCY 20 each	\$ \$	20 4,000	\$ 10,420 \$ 80,000 \$ 718,011	soil replaced above treatment media		
Construction management and reporting Subtotal	15% 8%						
Tax	8.7%	\$	4,786,741	\$ 416,446			
Contingency Subtotal Neutralization of Elevated Groundwater pH	20%	\$	6,304,137	\$         1,260,827           \$         7,564,965	_		
Removal of TPH-Impacted Soils in SE Corner of Cell Building Mobilization/demobilization	1 1 5	.\$	40.000	\$ 40 000			
Dewatering Excavation, transport and disposal - Non-Hazardous Waste	3 day 1,936 ton	\$ \$	800 100	\$ 2,581 \$ 193,600	based on 400 yd/day removal rate, includes daily sampling Subtitle D landfill		
Import, place, and compact fill Remedial design	1,291 BCY 15%	\$	20	\$ 25,813 \$ 39,299 \$ 22,151	includes add'l characterization		
Subtotal	10%		-	→         26,199           \$         327,493	-		
Tax Contingency	8.7% 20%	\$ \$	261,995 350,287	\$ 22,794 \$ 70,057	_increase due to likelihood of encountering debris		
Subtotal Removal of TPH-Impacted Soils in SE Corner of Cell Building			-	\$ 420,344			
Groundwater monitoring plan Monitoring wells	1 LS 15 each	\$ .\$	15,000 4,000	\$ 15,000 \$ 60,000			
Remedial design Construction management and reporting	15% 20%	Ý	.,	\$ 11,250 \$ 15,000	_		
Subtotal Tax	0.70/	<b>^</b>	75 000	\$ 101, <u>250</u>			
Contingency Subtotal Monitored Natural Attenuation	8.7% 20%	\$ \$	107,775	ψ 0,525 \$ 21,555 \$ 120 320	_		
Professional Services (as percent of capital costs)				0,000			
Project administration Total Estimated Capital Costs	3%	\$	22,701,192	\$681,036			
O&M COSTS - Net Present Value				Ψ <b>∠</b> 3,382,227			
Item	Start Year End	Year A	nnual Cost	NPV Cost	Notes		
Periodic O&M Inspection and maintenance of cover systems	1	30 \$	6,000	\$ 180,000			
Groundwater quality monitoring, Years 1 and 2 Groundwater quality monitoring, Years 3+ Subtotal Periodic O&M Cost	1 3	2 \$ 27 \$	32,000 16,000	→         64,000           \$         400,000           \$         644,000	_		
Contingency	c	20.0%		<ul><li>↓ 044,000</li><li>\$ 128 800</li></ul>			
Professional Services (as percent of Periodic O&M costs)	2		-	\$ 772,800	_		
Project administration Project management/reporting		5% 6%		\$ 38,640 \$ 46,368			
Total, Periodic O&M Net Present Value:				\$ 857,808			
TOTAL ESTIMATED COST				\$ 24,240,000			

Notes: 0.7% discount rate for NPV analysis based on real interest rate on US Treasury 30-year notes and bonds, Circular A-94 Appendix C, Office of Management and Budget (Revised November 2016). Mobilization/Demobilization costs are assumed to include equipment transport and setup, temporary erosion and sedimentation control (TESC) measures, bonds, and insurance. Contingency costs include miscellaneous costs not currently itemized due to the current (preliminary) stage of design development, as well as costs to address unanticipated conditions encountered during construction. Taxes are not applied to project administration, design, and reporting costs.

 Table A-7 - Alternative 6 Cost Estimate

 Project #070188 - Chlor-Alkali RAU, GP West Site, Bellingham, Washington

Site: Remedial Action Description:	Former Georgia-Pacific Alternative:	West Site - 6 Net	Pulp/Tissue Mi utralization of G	ill Remedial Actio Groundwater with	n Unit pH > 8.5, Removal of Hg-Impacted Soils to Achieve Groundwater			
Cost Estimate Accuracy:	FS Screening Level (+5	0/-30 perce	Protection, Capping of Residual Impacted Soils, and Groundwater MNA -30 percent)					
Key Assumptions and Quantities:	7.4 acre	Caj	Cap Quantities					
	1.5 ton/B 15 each	CY soil MN	density IA wells					
	21,897 ton 1,533 ton	vis wei wei	ight of removed	I soil & debris	reatment, and Offsite Disposal Quantities			
	657 ton 19,707 ton 25%	wei wei	ight of removed ight of soil in tai	l piles rget area ficial dobris roquir				
	25% 1,150 ton 25%	per wei per	centage of surf ight of inert surf centage cemer	ficial debris requir ficial debris nt amendment (ex	k situ)			
	2%	per SW	centage sulfur / Swale Quanti	amendment (ex s ities - Stockpiling	situ) g Overburden and Consolidating BNSF Soils with [Hg] > 24 mg/kg			
	900 BCY 675 BCY	volu volu	gth of fence to ume of concret ume of BNSF s	remove/replace e to excavate/stoc oil to consolidate	ckpile			
	1,291 BCY	Soi exc	il Excavation ( avation volume	Quantities - TPH-	Impacted Soils in SE Corner of Cell Building			
	1,291 BCY	volu volu <b>Soi</b>	ume classified a ume classified a il Excavation (	as nazardous as non-hazardous <b>Quantities - Addi</b>	s tional Soils Exceeding Cleanup Levels or Groundwater Protection Level			
	28,385 BCY 4,461 BCY	exc volu	avation volume ume classified	e as hazardous				
	23,924 BCY 6.858 BCY	VOIU Ele exc	ume classified a vated Ground avation volume	as non-nazardous water pH Neutra	S lization Quantities			
	4,115 ft 5,617 ton	tota ferr	al trench length rous sulfate					
	20 each	mo	nitoring wells					
CONSTRUCTION COSTS Item	Quantity U	Jnit	Unit Cost	Total Cost	Notes			
Caustic Plume-Cell Building Interim Actions (2013-2014 and 2017) Sunk cost	1 LS	\$	4,900,000	\$ 4,900,000	including remedial design, construction, and oversight			
Subtotal Caustic Plume-Cell Building Interim Actions Soil Capping				\$ 4,900,000				
Mobilization/demobilization Existing Cap	1 LS 50%	\$	70,000	\$ 70,000 \$				
New Cap Soil Cover as Cap	5.7 acre 50% 0%	Φ	-	÷ -				
-Site Preparation -Geotextile marker layer -Import, place, and compact fill	- acre - SY 0 CY	\$ \$ \$	4,500 2 18	\$- \$- \$-	clearing and leveling Specification 9 33.2(1) Table 3 (WSDOT, 2012) 2' thick			
Asphalt Pavement as Cap -Site Preparation -Pregrading	100% 3.7 acre	\$	4,500	\$ 16,652 \$ 10,242	clearing and leveling			
-Asphalt Buildings as Cap	3.7 acre 3.7 acre 0%	э \$	5,200 115,400	\$ 427,037	6" stone base, 2" binder layer, 1" topping layer			
-No Cost Stormwater collection and conveyance system Institutional Controls Plan	- 6,450 LF 1 LS	\$ \$ \$	- - 50.000	\$ - \$ - \$ 50.000	Assume buildings cost are redevelopment, not cleanup Assumed redevelopment cost includes I&M manual for cover systems, legal support			
Remedial design Construction management and reporting Subtotal	10% 10%	Ý	,000	\$ 58,293 \$ 58,293 \$ 58,293				
Tax	8.7%	\$	532,932	\$ 699,518 \$ 46,365				
Contingency Subtotal Soil Cap Cost	15%	\$	745,884	\$ 111,883 \$ 857,766	-			
Removal, Treatment, and Offsite Disposal of Soils with Visible Hg Mobilization/demobilization	1 LS	\$	300,000	\$ 300,000	includes dewatering equipment and installation			
Dewatering Transport/disposal of contaminated debris - Hazardous Waste	14,598 BCY 24 day 1,040 ton	» \$ \$	800 650	\$ 1,824,731 \$ 19,464 \$ 676,063	based on 400 yd/day removal rate, includes daily sampling Subtitle C landfill with macro-encapsulation			
Transport/disposal of surficial concrete as Non-hazardous Waste Portland cement amendment Sulfur amendment	1,150 ton 4,927 ton 394 ton	\$ \$ \$	80 45 40	\$ 91,966 \$ 221,705 \$ 15,766	25% by wt 2% by wt			
Ex situ solidification and load for offsite transport Transport/disposal of solidified mix - Hazardous Waste	19,707 ton 26,999 ton	\$ \$	50 220	\$ 985,355 \$ 5,939,720	includes added water wt. @ 10% of soil wt.			
Import, place, and compact fill Remedial design & pre-design testing Construction management and reporting	13,138 BCY 5% 5%	\$	20	\$ 262,761 \$ 516,877 \$ 516,877	includes add'l characterization			
Subtotal	8 7%	\$	10 337 532	\$ 11,371,285 \$ 899,365				
Contingency Subtotal Removal, Treatment, and Offsite Disposal of Soils with Visible Hg	15%	\$	12,270,650	\$ 1,840,598 \$ 14,111,248	-			
Stockpiling Crushed Concrete and Consolidating Soils with [Hg] > 24 mg/kg in Stormwater Swale Mobilization/demobilization	1 LS	\$	20,000	\$ 20,000	includes BNSF access agreement, flagger, etc.			
Remove/replace chain link fence Remove/stockpile crushed concrete Consolidate soils from BNSE onto Port property	700 lf 900 BCY 675 BCY	\$ \$	4 8 6	\$ 2,800 \$ 7,201 \$ 4,050				
Import, place, and compact fill Remedial design	1,125 BCY 20%	\$	20	\$ 22,502 \$ 11,311	restore BNSF grade (no import fill needed on Port property)			
Subtotal	30%		-	\$ 10,900 \$ 84,829	-			
Tax Contingency Subtotal Stockpiling Concrete & Consolidating Soils in Stormwater Swale	8.7% 10%	\$ \$	56,553 89,749	\$ 4,920 \$ 8,975 \$ 98,724	_			
Neutralization of Elevated Groundwater pH	1 1 5	¢	80.000	\$ 80.000	One Pass trencher transport, assembly and disassembly			
Trenching Transport and disposal - Non-Hazardous Waste	4,115 LF 10,288 ton	\$ \$	375 80	\$ 1,543,125 \$ 823,000	excavation and media placement Subtitle D landfill			
I reatment media Import, place, and compact fill Monitoring well installation	5,617 ton 457 BCY 20 each	ծ \$ \$	300 20 4,000	\$ 1,685,093 \$ 9,144 \$ 80,000	soil replaced above treatment media			
Remedial design & pre-design testing Construction management and reporting	15% 8%			\$ 633,054 \$ 337,629 \$ 5,191,045	includes add'l characterization			
Tax	8.7%	\$	4,220,362	\$ 367,171				
Contingency Subtotal Neutralization of Elevated Groundwater pH	20%	\$	5,558,217	\$ 1,111,643 \$ 6,669,860	_			
Removal of TPH-Impacted Soils in SE Corner of Cell Building Mobilization/demobilization Dewatering	1 LS 3 day	\$ \$	40,000	\$ 40,000 \$ 2,581	based on 400 vd/day removal rate, includes daily sampling			
Excavation, transport and disposal - Non-Hazardous Waste Import, place, and compact fill	1,936 ton 1,291 BCY	\$ \$	100 20	\$ 193,600 \$ 25,813	Subtitle D landfill			
Remedial design Construction management and reporting Subtotal	15% 10%		-	\$ 39,299 \$ 26,199 \$ 327,493	includes add'l characterization			
Tax	8.7%	\$	261,995	\$ 22,794 \$ 70,057	increase due to likelihood of encountering debris			
Subtotal Removal of TPH-Impacted Soils in SE Corner of Cell Building	2070	Ψ		\$ 420,344				
Mobilization/demobilization Dewatering	1 LS 71 day	\$ \$	100,000 800	\$ 100,000 \$ 56,770	based on 400 yd/day removal rate, includes daily sampling			
Excavation, transport and disposal - Non-Hazardous Waste Excavation, transport and disposal - Hazardous Waste Surcharge for difficult/uperpected subsurface conditions	35,886 ton 6,692 ton 8,515 ton	\$ \$	100 240 100	\$ 3,588,575 \$ 1,605,960 \$ 851 545	Subtitle D landfill Subtitle C landfill, assuming no treatment required applied to 20 percent of excavated material			
Import, place, and compact fill Remedial design	28,385 BCY 5%	9 \$	20	\$ 567,697 \$ 338,527	includes add'l characterization			
Subtotal	8%		-	\$ 541,644 \$ 7,650,717	-			
Tax Contingency Subtotal Removal of Additional Soils Above Cleanup Levels	8.7% 20%	\$ \$	6,770,546 8,239,755	\$ 589,038 \$ 1,647,951 \$ 9,887,706	increase due to likelihood of encountering debris			
Monitored Natural Attenuation		¢	15 000	\$ 45.000				
Monitoring wells Remedial design	15 each 15%	ծ \$	4,000	\$ 15,000 \$ 60,000 \$ 11,250				
Construction management and reporting Subtotal	20%			\$ 15,000 \$ 101,250	-			
Tax Contingency	8.7% 20%	\$ \$	75,000 107,775	\$ 6,525 \$ 21,555				
Subtotal Monitored Natural Attenuation Professional Services (as percent of capital costs)			-	\$ 129 <u>,33</u> 0				
Project administration	3%	\$	37,074,978	\$1,112,249				
I otal Estimated Capital Costs O&M COSTS - Net Present Value				\$ 38,187,227				
Item	Start Year End	d Year A	Annual Cost	NPV Cost	Notes			
Inspection and maintenance of cover systems Groundwater quality monitoring, Years 1 and 2	1 1	30 \$ 2 \$	6,000 32,000	\$ 180,000 \$ 64,000				
Groundwater quality monitoring, Years 3+ Subtotal Periodic O&M Cost	3	27 \$	16,000	\$ 400,000 \$ 644,000	-			
Contingency		20.0%	-	\$ 128,800 \$ 772.800	-			
Professional Services (as percent of Periodic O&M costs) Project administration Project management/reporting		5%		\$ 38,640 \$ 40,000				
Total, Periodic O&M Net Present Value:		0%		<ul><li>40,368</li><li>\$ 857,808</li></ul>				
TOTAL ESTIMATED COST				\$ 39,050,000				

Notes: 0.7% discount rate for NPV analysis based on real interest rate on US Treasury 30-year notes and bonds, Circular A-94 Appendix C, Office of Management and Budget (Revised November 2016). Mobilization/Demobilization costs are assumed to include equipment transport and setup, temporary erosion and sedimentation control (TESC) measures, bonds, and insurance. Contingency costs include miscellaneous costs not currently itemized due to the current (preliminary) stage of design development, as well as costs to address unanticipated conditions encountered during construction. Taxes are not applied to project administration, design, and reporting costs.

### Table A-8 - Alternative 7 Cost Estimate

Project #070188 - Chlor-Alkali RAU, GP West Site, Bellingham, Washington

Site: Remedial Action Description:	Former Georgia-Pacific V Alternative:	West Sit	e - Pulp/Tissue l Removal of All So	Mill Remedial Acti	on Unit eanup Levels, Neutralization of Groundwater with pH > 8.5, and					
Cost Estimate Accuracy:	FS Screening Level (+50	Groundwater MNA S Screening Level (+50/-30 percent)								
Key Assumptions and Quantities:	0.0 acre 1.5 ton/BC	C C CY S	Cap Quantities capping area soil density							
	15 each 21.897 ton	V V W	MNA wells Visible Mercury Soils Removal, Treatment, and Offsite Disposal Quantities weight of removed soil & debris							
	1,533 ton 657 ton	w w	weight of removed sufficial debris weight of removed piles							
	19,707 ton 25%	w p	veight of soil in ta ercentage of sur	arget area ficial debris requi	ring encapsulation					
	1,150 ton 25% 2%	w p	weight of inert surficial debris percentage cement amendment (ex situ)							
	2% 700 lf	р <b>S</b> Іе	percentage summamentment (ex situ) SW Swale Quantities - Stockpiling Overburden and Consolidating BNSF Soils with [Hg] > 24 mg/kg length of fence to remove/replace							
	900 BCY 0 BCY	V	volume of concrete to excavate/stockpile volume of BNSF soil to consolidate							
	1,291 BCY	<b>S</b> e	Soil Excavation Quantities - TPH-Impacted Soils in SE Corner of Cell Building excavation volume							
	0 BCY 1,291 BCY	v v	volume classified as hazardous volume classified as non-hazardous							
	105,691 BCY 13,261 BCY	e v	xcavation volum olume classified	as hazardous						
	92,430 BCY	v E	olume classified	as non-hazardou dwater pH Neutra	s alization Quantities					
	6,523 BC f 3,914 ft 5,343 ton	e to fe	otal trench length	ופ ז						
	435 BCY 20 each	to m	opping soil nonitoring wells							
CONSTRUCTION COSTS Item	Quantity Un	nit	Unit Cost	Total Cost	Notes					
Caustic Plume-Cell Building Interim Actions (2013-2014 and 2017)	115	ç	\$ 4 900 000	\$ 4 900 000	including remedial design, construction, and oversight					
Subtotal Caustic Plume-Cell Building Interim Actions			4,000,000	\$ 4,900,000	including remedial design, construction, and oversight					
Removal, Treatment, and Offsite Disposal of Soils with Visible Hg Mobilization/demobilization	1 LS		\$ 300,000	\$ 300,000	includes dewatering equipment and installation					
Dewatering Transport/disposal of contaminated debris - Hazardous Waste	14,598 BCY 24 day 1,040 ton		125       800       650	\$ 1,824,731 \$ 19,464 \$ 676,063	based on 400 yd/day removal rate, includes daily sampling Subtitle C landfill with macro-encapsulation					
Transport/disposal of surficial concrete as Non-hazardous Waste Portland cement amendment	1,150 ton 4,927 ton		\$ 80 \$ 45	\$ 91,966 \$ 221,705	25% by wt					
Sulfur amendment Ex situ solidification and load for offsite transport Transport/disposal of solidified mix - Hazardous Waste	394 ton 19,707 ton 26,999 ton		5     40       5     50       5     220	\$ 15,766 \$ 985,355 \$ 5,939,720	2% by wt					
Import, place, and compact fill Remedial design & pre-design testing	13,138 BCY 5%		\$ 20	\$ 262,761 \$ 516,877	includes add'I characterization					
Construction management and reporting Subtotal	5%			\$ 516,877 \$ 11,371,285	-					
Tax Contingency Subtotal Removal, Treatment, and Offsite Disposal of Soils with Visible Hg	8.7% 15%		<ul> <li>10,337,532</li> <li>12,270,650</li> </ul>	\$ 899,365 <u>\$ 1,840,598</u> \$ 14,111,248	-					
Neutralization of Elevated Groundwater pH	1 1 8	c	000 08	¢ 00.000	One Deep transher transport, accomply, and discover why					
Trenching Transport and disposal - Non-Hazardous Waste	3,914 LF 9,785 ton		\$         80,000           \$         375           \$         80	\$ 1,467,750 \$ 782,800	excavation and media placement Subtitle D landfill					
Treatment media Import, place, and compact fill	5,343 ton 435 BCY		\$ 300 \$ 20	\$ 1,602,783 \$ 8,698	ferrous sulfate heptahydrate, includes transport soil replaced above treatment media					
Monitoring well installation Remedial design & pre-design testing Construction management and reporting	20 each 15% 8%		\$ 4,000	\$ 80,000 \$ 603,305 \$ 321,762	includes add'l characterization					
Subtotal	070			\$ 4,947,098	-					
Tax Contingency Subtotal Neutralization of Elevated Groundwater pH	8.7% 20%		\$     4,022,031 \$     5,297,015	\$ 349,917 <u>\$ 1,059,403</u> <u>\$ 6,356,417</u>	-					
Removal of TPH-Impacted Soils in SE Corner of Cell Building				• • • • • • • • • • • • • • • • • • • •						
Mobilization/demobilization Dewatering Excavation, transport and disposal - Non-Hazardous Waste	1 LS 3 day 1 936 ton		\$ 40,000 \$ 800 \$ 100	\$ 40,000 \$ 2,581 \$ 193,600	based on 400 yd/day removal rate, includes daily sampling Subtitle D landfill					
Import, place, and compact fill Remedial design	1,291 BCY 15%		\$ 20	\$ 25,813 \$ 39,299	includes add'I characterization					
Construction management and reporting Subtotal	10%			\$ 26,199 \$ 327,493	-					
Tax Contingency	8.7% 20%		\$261,995\$350,287	\$ 22,794 \$ 70,057	increase due to likelihood of encountering debris					
Subtotal Removal of TPH-Impacted Soils in SE Corner of Cell Building				\$ 420,344						
Mobilization/demobilization Dewatering	1 LS 264 day		\$ 100,000 \$ 800	\$ 100,000 \$ 211,381	based on 400 yd/day removal rate, includes daily sampling					
Excavation, transport and disposal - Non-Hazardous Waste Excavation, transport and disposal - Hazardous Waste	138,644 ton 19,892 ton 31,707 top		\$ 100 \$ 240	\$ 13,864,433 \$ 4,773,960 \$ 3,170,717	Subtitle D landfill Subtitle C landfill, assuming no treatment required					
Import, place, and compact fill Remedial design	105,691 BCY 5%		\$ 100 \$ 20	\$ 2,113,811 \$ 1,211,715	includes add'I characterization					
Construction management and reporting Subtotal	8%			\$ 1,938,744 \$ 27,384,762	-					
Tax Contingency Subtotal Removal of Additional Soils Above Cleanup Levels	8.7% 20%		\$ 24,234,302 \$ 29,493,146	\$ 2,108,384 \$ 5,898,629 \$ 35,391,775	increase due to likelihood of encountering debris					
Monitored Natural Attenuation Groundwater monitoring plan	4.10		\$ 4F 000	\$ 45.000						
Monitoring wells Remedial design	15 each 15%		\$ 15,000 \$ 4,000	\$ 60,000 \$ 11.250						
Construction management and reporting Subtotal	20%			\$ 15,000 \$ 101,250	-					
Tax Contingency	8.7% 20%		\$	\$ 6,525 \$ 21,555	_					
Professional Services (as percent of capital costs)				φ 129,330						
Project administration	3%		\$ 61,309,114	\$1,839,273 \$ 63 148 388						
O&M COSTS - Net Present Value				÷ 00,140,008						
Item	Start Year End	Year	Annual Cost	NPV Cost	Notes					
Inspection and maintenance of cover systems Groundwater quality monitoring, Years 1 and 2 Groundwater quality monitoring, Years 3+	1 3	2 S 27 S	\$ - \$ 32,000 \$ 16,000	\$- \$64,000 \$_400,000						
Subtotal Periodic O&M Cost		00.057		\$ 464,000						
Contingency Professional Services (as percent of Periodic ORM costs)	2	20.0%		\$         92,800           \$         556,800	-					
Project administration Project management/reporting		5% 6%		\$ 27,840 \$ 33.408						
Total, Periodic O&M Net Present Value:				\$ 618,048						
И					II					

TOTAL ESTIMATED COST
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#### \$ 63,770,000

Notes:

0.7% discount rate for NPV analysis based on real interest rate on US Treasury 30-year notes and bonds, Circular A-94 Appendix C, Office of Management and Budget (Revised November 2016). Mobilization/Demobilization costs are assumed to include equipment transport and setup, temporary erosion and sedimentation control (TESC) measures, bonds, and insurance. Contingency costs include miscellaneous costs not currently itemized due to the current (preliminary) stage of design development, as well as costs to address unanticipated conditions encountered during construction. Taxes are not applied to project administration, design, and reporting costs.

#### Aspect Consulting

1/16/2018 V:\070188 Port Bellingham\Deliverables\Chlor-Alkali RAU Feasibility Study\Feb 2018 Public Review Draft\Appendices\Apps AandB\_CA RAU\_Feb 2018

### Table A-9 - Alternative 8 Cost Estimate

Project #070188 - Chlor-Alkali RAU, GP West Site, Bellingham, Washington

Site: Remedial Action Description:	Former Georgia-Pacific West Alternative:	t Site - <b>8</b> Rer Tre	<ul> <li>Pulp/Tissue Mill moval of All Soils atment of Fill Un</li> </ul>	Remedial Actio Exceeding Clea t Groundwater I	n Unit anup Levels, Neutralization of Groundwater with pH > 8.5, In-Situ mpacted by Hg and PAHs, and MNA for Residual Impacted Groundwater
Cost Estimate Accuracy:	FS Screening Level (+50/-30	) perce	nt)		
Key Assumptions and Quantities:	0.0 acre	<b>Car</b> cap	p Quantities		
	1.5 ton/BCY 3 each	soil MN	density IA wells	ile Demonal T	
	21,897 ton 1.533 ton	Vis wei wei	ible Mercury So ight of removed s ight of removed s	oils Removal, T oil & debris ourficial debris	reatment, and Offsite Disposal Quantities
	657 ton 19,707 ton	wei wei	ight of removed p ight of soil in targ	viles et area	
	25% 1,150 ton	per wei	centage of surfic ight of inert surfic	al debris requiri ial debris	ng encapsulation
	25% 2%	per per	centage cement centage sulfur ar	amendment (ex nendment (ex si <b>es - Stockpilin</b>	situ) itu) g Overburden and Consolidating BNSE Soils with [Hg] > 24 mg/kg
	700 lf 900 BCY	lenç volu	gth of fence to re ume of concrete	move/replace to excavate/stoc	skpile
	0 BCY	volu <b>Soi</b>	ume of BNSF soi il Excavation Qu	l to consolidate antities - TPH-	Impacted Soils in SE Corner of Cell Building
	1,291 BCY 0 BCY 1,291 BCY	volu volu	avation volume ume classified as ume classified as	hazardous non-hazardous	
	105,691 BCY	Soi exc	il Excavation Qu avation volume	antities - Addit	ional Soils Exceeding Cleanup Levels or Groundwater Protection Lev
	13,261 BCY 92,430 BCY	volu volu	ume classified as ume classified as	hazardous non-hazardous	lization Quantition
	6,523 BCY 3,914 ft	exc tota	avation volume		
	5,343 ton 435 BCY	ferr top	ous sulfate		
	20 each	moi Ada 7\/I	nitoring wells ditional GW Trea Ltrench excavation	atment Quantit	ies
	3,111 lf 2,397 ton	tota ZVI	al trench length		
	2,397 ton 1,152 BCY	san top	nd mass ping soil		
	91 each 19 dav	∠vı nun dav	nber of injection   /s required for inj	ooints ection	
	2,730 lb 6 each	tota EAI	al injected mass B monitoring well	S	
CONSTRUCTION COSTS Item	Quantity Unit		Unit Cost	Total Cost	Notes
Caustic Plume-Cell Building Interim Actions (2013-2014 and 2017)			vvol	ייטו	
Sunk cost Subtotal Caustic Plume-Cell Building Interim Actions	1 LS	\$	4,900,000 <u>\$</u> \$	4,900,000 4,900,000	including remedial design, construction, and oversight
Removal, Treatment, and Offsite Disposal of Soils with Visible Hg Mobilization/demobilization	1 LS	\$	300,000 \$	300,000	includes dewatering equipment and installation
Material removal (soil, foundation elements, etc.) Dewatering Transport/disposal of contaminated debries Hazerdous Wests	14,598 BCY 24 day	\$ \$ ¢	125 \$ 800 \$	1,824,731 19,464	based on 400 yd/day removal rate, includes daily sampling
Transport/disposal of surficial concrete as Non-hazardous Waste Portland cement amendment	1,040 ton 1,150 ton 4,927 ton	ծ \$ \$	ەەں \$ 80 \$ 45 \$	076,063 91,966 221,705	25% by wt
Sulfur amendment Ex situ solidification and load for offsite transport Transport/disposal of solidified mix - Hazardous Weste	394 ton 19,707 ton 26,999 top	\$ \$ ¢	40 \$ 50 \$	15,766 985,355 5 939 720	2% by wt
Import, place, and compact fill Remedial design & pre-design testing	20,999 ton 13,138 BCY 5%	ծ \$	∠∠∪ \$ 20 \$ \$	5,959,720 262,761 516,877	includes added water wit. I 10% of Soll Wit.
Construction management and reporting Subtotal	5%		\$	516,877 11,371,285	-
Tax Contingency	8.7% 15%	\$ \$	10,337,532 \$ 12,270,650 \$	899,365 1,840,598	_
Subtotal Removal, Treatment, and Offsite Disposal of Soils with Visible Hg			\$	14,111,248	
Mobilization/demobilization Trenching	1 LS 3,914 LF	\$ \$	80,000   \$ 375   \$	80,000 1,467,750	One Pass trencher transport, assembly and disassembly excavation and media placement
Transport and disposal - Non-Hazardous Waste Treatment media Import, place, and compact fill	9,785 ton 5,343 ton 435 BCY	\$ \$ \$	80 \$ 300 \$ 20 \$	782,800 1,602,783 8,698	Subtitle D landfill ferrous sulfate heptahydrate, includes transport soil replaced above treatment media
Monitoring well installation Remedial design & pre-design testing	20 each 15%	\$	4,000 \$ \$	80,000 603,305	includes add'I characterization
Construction management and reporting Subtotal	8%		\$	321,762 4,947,098	-
Tax Contingency	8.7% 20%	\$ \$	4,022,031   \$ 5,297,015 <u>\$</u>	349,917 1,059,403	_
Subtotal Neutralization of Elevated Groundwater pH			\$	6,356,417	
Mobilization/demobilization Trenching	1 LS 3,111 LF	\$ \$	- \$ 375 \$	- 1,166,625	One Pass trencher mobilization included above excavation and media placement
Transport and disposal - Non-Hazardous Waste Treatment media Sand filler	6,222 ton 2,397 ton 2,397 ton	\$ \$ \$	80 \$ 1,127 \$ 20 \$	497,760 2,700,993 47 932	Subtitle D landfill ZVI, includes transport by rail
Media/Filler mixing Import, place, and compact fill	4,793 ton 1,152 BCY	\$ \$	5 \$ 20 \$	23,966 23,044	soil replaced above treatment media
Monitoring well installation Remedial design & pre-design testing Construction management and reporting	10 each 20% 10%	\$	4,000 \$ \$ \$	40,000 900,064 450,032	includes add'l characterization
Subtotal	0.70	۴		4,683,793	-
Contingency Subtotal ZVI Treatment Walls	20%	5 \$	4,500,321 \$ 5,075,321 \$ \$	1,015,064 6,090,385	-
Enhanced Aerobic Biodegredation	1 1 5	¢	5 000 ¢	5 000	Direct push probe miving tanks
Probe injection event Treatment media	18 day 2,730 lb	9 \$ \$	2,000 \$ 2,000 \$ 10 \$	36,400 27,300	5 injection points per day, 91 points total ORC, 30lb per injection point
Monitoring well installation Remedial design & pre-design testing	6 each 30% 15%	\$	4,000 \$ \$	24,000 27,810 13,005	includes add'l characterization
Subtotal	13%		<u>+</u> \$	134,415	-
Tax Contingency Subtotal Enhanced Aerobic Biodegradation	8.7% 20%	\$ \$	92,700 \$ 142,480 <u>\$</u>	8,065 28,496	-
Removal of TPH-Impacted Soils in SE Corner of Cell Building			φ	110,970	
Mobilization/demobilization Dewatering Excavation_transport and disposal - Non-Hazardous Waste	1 LS 3 day 1 936 top	\$ \$ ¢	40,000 \$ 800 \$	40,000 2,581	based on 400 yd/day removal rate, includes daily sampling Subtitle D landfill
Import, place, and compact fill Remedial design	1,291 BCY 15%	э \$	20 \$ \$	25,813 39,299	includes add'I characterization
Construction management and reporting Subtotal	10%		\$	26,199 327,493	-
Tax Contingency	8.7% 20%	\$ \$	261,995 \$ 350,287 \$	22,794 70,057	increase due to likelihood of encountering debris
Subtotal Removal of TPH-Impacted Soils in SE Corner of Cell Building Removal of Additional Soils Exceeding Cleanup Levels or Groundwater Protection Levels			\$	420,344	
Mobilization/demobilization Dewatering	1 LS 264 day	\$ \$	100,000 \$ 800 \$	100,000 211,381	based on 400 yd/day removal rate, includes daily sampling
Excavation, transport and disposal - Non-Hazardous Waste Excavation, transport and disposal - Hazardous Waste Surcharge for difficult/unexpected subsurface conditions	138,644 ton 19,892 ton 31,707 ton	\$ \$ <u>\$</u>	100 \$ 240 \$ 100 \$	13,864,433 4,773,960 3.170 717	Subtitle D landfill Subtitle C landfill, assuming no treatment required applied to 20 percent of excavated material
Import, place, and compact fill Remedial design	105,691 BCY 5%	\$	20 \$ \$	2,113,811 1,211,715	includes add'I characterization
Construction management and reporting Subtotal	8%		\$	1,938,744 27,384,762	-
Tax Contingency Subtotol Removal of Additional Optic Alexan Classics in the	8.7% 20%	\$ \$	24,234,302 \$ 29,493,146 <u>\$</u>	2,108,384 5,898,629	increase due to likelihood of encountering debris
Monitored Natural Attenuation			\$	<i>35,391,775</i>	
Groundwater monitoring plan Monitoring wells Remedial design	1 LS 3 each	\$ \$	15,000 \$ 4,000 \$	15,000 12,000	
Construction management and reporting Subtotal	20%		\$ \$ 	4,050 5,400 36.450	-
Tax	8.7%	\$	27,000 \$	2,349	
Contingency Subtotal Monitored Natural Attenuation	20%	\$	38,799 <u>\$</u> \$	7,760 46,559	-
Professional Services (as percent of capital costs) Project administration	3%	\$	67,487,704	\$2,024,631	
Total Estimated Capital Costs			\$	69,512,335	
O&M COSTS - Net Present Value Item	Start Year End Year	ir A	Annual Cost	NPV Cost	Notes
Periodic O&M		-			
Inspection and maintenance of cover systems Groundwater quality monitoring, Years 1 and 2 Groundwater quality monitoring. Years 3+	1 २ 1	\$ 2 \$ 11 \$	+ - \$ 40,000 ¢ 12 000	- 80,000 108,000	
Subtotal Periodic O&M Cost	5 1	Ψ	\$	188,000	-
Contingency Professional Services (as percent of Periodia CRM costs)	20.09	)%	\$ \$	37,600 225,600	-
Project administration Project management/reporting	59	5% 5%	\$ ¢	11,280 13,536	
Total, Periodic O&M Net Present Value:			\$	250,416	
TOTAL ESTIMATED COST			\$	69,760,000	

Notes:

0.7% discount rate for NPV analysis based on real interest rate on US Treasury 30-year notes and bonds, Circular A-94 Appendix C, Office of Management and Budget (Revised November 2016). Mobilization/Demobilization costs are assumed to include equipment transport and setup, temporary erosion and sedimentation control (TESC) measures, bonds, and insurance. Contingency costs include miscellaneous costs not currently itemized due to the current (preliminary) stage of design development, as well as costs to address unanticipated conditions encountered during construction. Taxes are not applied to project administration, design, and reporting costs.

## **APPENDIX B**

Engineering Calculations Supporting Remedial Alternative Development

#### Sheet B-1 - In-Situ Solidification/Stabilization (ISS) of Chlorine Plant Area Soils with Visible Elemental Hg

Project No. 070188, Chor-Alkali RAU, GP West Site, Bellignham, WA

Engineering (	Calculation Sheet B-1: In	Situ Solidification/Stabilization (ISS) of Chlorine Plant Area S	oils with Visible Elemental Hg							
Site:	Former GP West site			Engineer	Date					
Calculation:	Estimate the containmer	t area and length of containment wall (Alt 1).	Checked By:	DAH	1/19/2018					
	Estimate the amount of a	mendments for ISS.								
	Estimate the amount of c	ebris requiring removal.								
Assumptions:										
	Soil will be amended and mixed <i>in situ</i> using an 8-foot auger.									
	75% % of target area accessible for ISS (within Cell Bldg footprint, assume only grade beams are removed).									
	25 % % weight of surficial debris requiring macro-encapsulation									
	100 % weight of piles requiring macro-encapsulation									
	25 %	Assumed auger overlap								
	25 %	Cement amendment								
	2 %	Sulfur amendment								
	1,293 ft	Length of containment wall (Alt 1)								
	107,886 ft2	Area of containment (Alt 1)								
Stabilization /	Area Calculations									
	21,897 ton	Estimated total weight of soil containing visible Hg (Sheet B-2	<u>2)</u>							
	1,533 ton	Estimated weight of surficial debris to be removed (Sheet B-2	<u>?)</u>							
	657 ton	Estimated weight of piles to be removed (Sheet B-2)								
Equations:	Total accessible soil = %	of target area accessible * (Estimated weight of soil containing vis	sible Hg - Estimated weight of surficial	l debris)						
	14,890 ton	Calculated total weight of accessible soil for ISS								
	383 ton	Calculated weight of surficial debris requiring macro-encapsu	Ilation							
	1,150 ton	Calculated weight of debris disposed of as inert waste or use	d as base course							
	657 ton	Calculated weight of piles requiring macro-encapsulation								
Notes:										
Conversion fac	ctors:									
1 acre = 43,56	60 SF									
1 cy = 27 CF										

### **Sheet B-2 - Soil Excavation Volumes**

Project No. 070188, Chlor-Alkili RAU, GP West, Bellingham, Washington

Engineering C	alculation Sheet B-2: Soil Excavation Volumes										
Site:	Former GP West					Engineer	Date				
Calculations:	Estimate the volume of hazardous and non-hazardous soil to be				Checked By:	DAH	2/9/2018				
	removed in each Alternative.										
<b>A</b>											
Assumptions: Chemitx area soil removal volume assumed to be 10% greater than estimated slurry volume.											
	Soil containing elemental Hg or above industrial cleanup levels w	ould be designation	ted as hazard	ous waste, inc	luding a perce	entage of the C	hlorine Plant				
Equations:	Free values Setting Basin, and Chemick Area solis.										
Chlorine Plant Hazardous Soil Volume = Assumed Percentage x Excavated Soil Volume											
Chemfix Area Hazardous Soil Volume = 110% x Reported Slurry Volume											
	Total Haz Soil Volume = Chlorine Plant Haz Soil Volume + Chem	fix Area Haz Soi	l Volume + %	of Remaining	Volume for Mi	sc Haz					
	Non-Hazardous Soil Volume = Excavated Soil Volume - Hazardous Soil Volume										
	Assumed areal percentage of Chlorine Plant Soils containin	a elemental Ha:	20	%							
Assu	med percentage of removed material is surficial foundation comp	onents & debris:	7	%							
	Assumed percentage of removed	material is piles:	3	%							
	Ex Situ treatment cement amend	Iment by weight:	25	%							
	Ex Situ treatment sulfur amend	Iment by weight:	2	%							
	Assumed bank density for	soil and debris:	1.5	ton/CY							
	Reported volume of Che	mfix area slurry:	8,000	BCY							
Chlorine Plant	Area debris and soil containing visible Hg estimates	-									
		Estimated									
		Remaining in									
Alternatives	Description	Tons									
	Weight of surficial foundation components and debris	1,533									
2 thru 8	Weight of Piles	657									
2 1110 0	Weight of soil with visible Hg	19,707									
	Weight of soil and debris	21,897									
Ha Containing	Soil and Overburden Volumes										
			Average	Executed	Accumed %	Hozordouo					
		Area in Square	Thickness in		Haz (for	Soil Volume	Non-Haz Soil				
Alternative	Description	Feet <sup>(1)</sup>	Feet <sup>(2)</sup>	in BCY	disposal)	in BCY	Vol in BCY				
3, 6, 7, & 8	CPA Soils With Visible Hg <sup>(3)</sup>	28,153	14	14,598	100	14,598	0				
6, 7, & 8	CPA Soils Exceeding 100 mg/kg (but no visible Hg)	26,406	14	13,692	20	2,738	10,954				
7 & 8	Additional CPA Soils Exceeding 24 mg/kg	89,748	14	45,245	0	0	45,245				
1 thru 5	WW Settling Basin Area Soils Exceeding 300 mg/kg	8,442	7	2,189	50	1,094	1,094				
1 thru 5	OVERBURDEN SOIL w.r.t 300 mg/kg soil in WW Basin	8,442	8	2,501							
67&8	WW Settling Basin Area Soils, Exceeding 100 mg/kg	24 897	15	13 832	same BCY	1 094	12 737				
7 0 0		21,007	15	0,400	as previous	1,001	0.400				
7 & 8	Add I WW Settling Basin Area Soils Exceeding 24 mg/kg	11,523	15	6,402	0	0	6,402				
	Chemitx Area Solis	81,457	5	15,085	58	8,800	6,285				
٥, <i>1</i> , & ٥	Stormwater Swale Soils Exceeding 100 mg/kg	1,365	1.5	76	0	0	76				
/ & Ŏ 1.thru 9		22,837	1.5	000	U	U	1,274				
	Laural St. Dine Pack Soils Exceeding 100 mg/kg	24,302	10	900 795	<u>۵</u> ۵	629	157				
υ, Ι, α ο 7 & Q	Add'I Laural St. Pipe Rack Soils Exceeding 24 ma/kg	1,707	12 12	201 830	00 0	020 N	107 830				
100	Add Ladiel St. Fipe Nack Solis Exceeding 24 mg/Kg	1,007	12	000	0	U	030				
TPH Containin	q Soil Volumes										
			Average	Excavated	Assumed %	Hazardoue	Hazardoue				
		Area in Square	Thickness in		Haz (for						

Alternative	Description	Area in Square Feet <sup>(1)</sup>	Average Thickness in Feet <sup>(2)</sup>	Excavated Soil Volume in BCY	Assumed % Haz (for disposal)	Hazardous Soil Volume in BCY	Hazardous Soil Volume in BCY
1 thru 8	Cell Building Area	6,970	5	1,291	0	0	1,291
1 thru 8	Northwest Chlorine Plant Area	1,307	5	242	0	0	242
7, 8	Million Gallon Tanks Area	17,860	9	5,953	0	0	5,953
7, 8	Lignin Warehouse	16,988	4	2,517	0	0	2,517
Notes: <sup>(1)</sup> Areas based on AutoCAD area analysis from Figure 5-1. <sup>(2)</sup> Impacted soils are assumed to extend from ground surface (i.e., no overburden soils) with the exception of: a) soils in the WW Settling Basin w/ [Hg] > 300 mg/kg, which are assumed to be in the 8- to 15-foot depth interval; and b) soils in the Stormwater Swale, which are assumed to be in the 3- to 4.5-foot depth interval. <sup>(3)</sup> Amounts based on test pit investigation in February 2014 (Aspect, 2014d).							
Conversion factors: 1 cy = 27 CF							

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Sheet B-2 Feasibility Study Page 1 of 1

### Sheet B-3 - Ferrous Sulfate Trenches for Neutralization of Groundwater with Elevated pH

Project No. 070188, Chlor-Alkili RAU, GP West, Bellignham, Washington

Engineering Calculation Sheet B-3: Ferrous Sulfate Trenches for Neutralization of Groundwater with Elevated pH									
Site:	Former GP We	est Site						Engineer	Date
Calculations:	Estimate the ve	olume of soil to	be removed for	or groundwater	neutralization trei	nches.	Checked By:	DAH	9/29/2016
	Estimate volun	ne of amendme	nts for the grou	undwater neutra	alization trenches	s.			
Assumptions:									
	Excavated soil	xcavated soils are assumed to be non-hazardous.							
	I reatment mat	erial placed to	I-TOOT DEIOW Gr	ade.					
Equations:	Volume = Leng	gth x Width x De	epth						
	Ferrous Sulfate	e Volume = Tota	al Trench Leng	th x Width x De	epth x Density				
I rench Dimesions:		4	<b>F</b>			<b>65</b>	16./##3		
wiath Death	3	ft #	Ferrous	Sulfate Heptar	hydrate density:	65			
Depth	10	o it							
Top of material below grade	1	ft							
rop of material below grade.	•								
			Amount of						
		Total Longth	Ferrous						
	Number of	of Trenches	Sulfate	Volume of	Volume of				
Description	Trenches	in feet <sup>(1)</sup>	in tons	Soil in BCY	BCY				
Alt 4 - Caustic Core Only	5	1,035	1,413	1,725	115				
Alt 5 - Groundwater pH > 8.5	8	4,689	6,400	7,815	521				
Alt 6 - Groundwater pH > 8.5	11	4,115	5,617	6,858	457				
Alts 7 & 8 - Groundwater pH > 8.5	9	3,914	5,343	6,523	435				
Notes:	-								
<sup>(1)</sup> Total trench length based on AutoCAD	analysis from F	igures 7-5 thro	ugh 7-9.						
Conversion factors:									
1 cy = 27 CF									
1 ton = 2000 lb									

# Sheet B-4 - PRBs Containing ZVI for Treating Dissolved Hg Outside Areas of Elevated pH Project No. 070188, Chlor-Alkili RAU, GP West, Bellingham, Washington

Engineering C	alculation Sheet B-4: PRBs Containing ZVI for	Treating Dissolved Hg Outside Are	as of Elevated pH		
Site:	Former GP West			Engineer	Date
Calculations:	Estimate volume of zero valent iron (ZVI) require	d	Checked By:	DAH	9/29/2016
ouloulation of	Estimate breakthrough time of permeable reactive	e barrier (PRB)	enconce by:	27.11	0/20/2010
Assumptions:					
,	Groundwater flux based test results from June-Ju	ulv 2011 (see Section 4.2.2.1 of the R	l).		
	ZVI usage rate calculated from column testing un	nder similar groundwater conditions (V	/ Veisener et al., 2005)		
Equations:					
	ZVI Usage Rate (tons <sub>ZVI</sub> /ft <sup>3</sup> <sub>Water</sub> ) = ZVI mass / Flo	w Rate / Breakthrough Time			
	Time to Breakthrough (years) = ZVI Mass (tons)	ZVI Usage Rate (tons/ft <sup>3</sup> ) / Flowrate	(ft <sup>3</sup> /dav) / 365 (davs/vear)		
	Volume – Depth x Width x Length		(,,		
	Mass – Density x Volume				
	Column Test Results (Weisener et al., 2005)				
	ZVI weig	ht 1066.85 g	Conversions:		
	ZVI % by weig	ht 50 %	1 cubic foot = $28.3168$ L		
	Flowra	te 1 96 L/day	1  year = 365  days		
	Ha Concentratio		1  top = 2000  lb		
	Residence Tim		1  lb = 453592  g		
	Breaktbrough Tim		1 ib – 433.332 g		
	Estimated ZVI Usage Ra	te 0.00060066 tons <sub>ZVI</sub> /ft <sup>°</sup> <sub>Water</sub>			
	Treatment Walls -	Within low-level Ha plume			
Parameter		Value	Notes/Assumptions		
Treatment Wal	I				
	Minimum Width	2 ft			
	Lenath	3.111 ft			
	Average Treatment Media Height	13 ft	18' Total Depth		
Composition C	alculations				
	Average Groundwater Flux	0.0147 ft3/ft2/day	see RI Section 4.2.2.1		
	Assumed porosity	0.49			
	Velocity	0.0300 ft/day			
	Wall Width	2 ft			
	Residence Time	67 days			
	ZVI Composition	50 percent by weight			
	Mass of ZVI per ft2 of cross section area	0.05926			
	Time to Breakthrough	18 4 years			
	Target Lifetime	10 years			
	·				
Earthwork Calc	culations				
	Average Width	2.0 ft			
	Average Depth	18 ft	18' total depth		
	Volume of Soil Excavated	4,148 cy			
	Volume Sand Fill	2,996 cv	sand		
	Volume of Fill to Grade	1.152 cv	-		
	Total Mass	4.793 tons	Assumed density of 1.6 tons per c	ubic vard	
	ZVI Mass	2.397 tons		, and yourd	
	Sand Mass	2.397 tons			
		,			
l					

Conversions:

1 cubic foot = 7.48 gallons 1 year = 365 days

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Sheet B-4 Feasibility Study Page 1 of 1

### Sheet B-5 - Enhanced Aerobic Biodegradation for Treating PAHs in Groundwater

Project No. 070188, Chlor-Alkili RAU, GP West, Bellingham, Washington

Engineering Calculation Sheet B-5: E	Enhanced Aerobic Biodegradation for Treating PAHs in Groundwater			
Site:	Former GP West Site		Engineer	Date
Calculations:	Estimate the mass of ORC to be injected at each point. <sup>(1)</sup>	Checked By:	DAH	9/29/2016
Assumptions:				
	Injections are completed by direct-push probe.			
	A single round of ORC injection is sufficient to achieve the treatment objective.			
Equations:				
Injections per day Number of injection points <sup>(2)</sup> Mass to be injected at each point <sup>(3)</sup>	5 per day 91 each 30 lb			
Days required to complete injections	: <b>19</b> days			
Total injection mass	2730 lb			
Notes:				
<ul> <li><sup>(1)</sup> Calculations are based on enhancing</li> <li><sup>(2)</sup> Number of injection points based on 2 60-foot intervals; refer to Figure 7-9.</li> </ul>	the aerobic biodegradation of PAHs by injecting Oxygen-Release Compound (ORC) suppl 20-foot injection spacing along rows oriented perpendicular to groundwater flow direction ar	ied by Regenesis. nd spaced at		
<sup>(3)</sup> ORC mass based on successful treat	ment of PAHs at Florida site (Regenesis case study).			
Conversion factors:				
1 cy = 27 CF				
1 ton = 2000 lb				

# **APPENDIX C**

### **Restoration Time Frame Estimation for Mercury in Groundwater and Soil Vapor**



### DRAFT MEMORANDUM

To:	Steve Germiat (Aspect Consulting)	Date:	November 11, 2016
From:	Masa Kanematsu, Minna Carey, and Dimitri Vlassopoulos (Anchor OEA, LLC)	Project:	150204-04.01
Re:	Chlor-Alkali RAU Alternatives Modeling, G-P West S	Site	

This memorandum presents a summary of reactive transport modeling performed to evaluate the effectiveness and estimate groundwater restoration timeframes of selected remedial alternatives being considered to address mercury (Hg) concentrations and elevated pH in groundwater within the Chlor-Alkali Remedial Action Unit (RAU) as part of the Feasibility Study (FS) conducted for the Georgia-Pacific West Site in Bellingham, Washington.

#### **MODELING METHODS**

The reactive transport model was developed using the numerical groundwater flow and geochemical transport simulator PHAST (Parkhurst et al. 2010). PHAST is a well-documented, robust computer code capable of simulating 3-dimensional groundwater flow and multicomponent chemical transport with equilibrium and kinetic reactions. PHAST couples the flow and transport finite-difference code HST3D (Kipp 1997) with the geochemical modeling code PHREEQC (Parkhurst and Appelo 1999) to simulate geochemical reactions in groundwater flow systems. Modeling approaches to simulate the remediation scenarios are described in the following sections.

#### **Model Development**

#### Input Data

Site-specific hydraulic, groundwater, and soil chemistry data from the Remedial Investigation (RI) were used as input for the reactive transport model. A high quality, internally consistent thermodynamic database developed by the Lawrence Livermore National Laboratory (llnl.dat) was used with several updates and modifications, which are summarized in Table A1.

#### Model Configuration

The 3-dimensional model domain was constructed to encompass groundwater flowing from the Chlorine Plant Area and Caustic Plume towards Bellingham Bay and Whatcom Waterway (Figure 1). The horizontal extents (X and Y directions) of the model domain are 2,500 and 1,800 feet, respectively, with 15–foot grid spacing (refined [9-foot] grid spacing surrounding the PRB treatment trenches). The vertical extent (i.e., Z direction) of the model domain is 48 feet with 4-foot grid spacing. The model domain is divided into three layers: Fill Unit (16 to -4 ft MLLW), Tidal Flat Aquitard (-4 to -10 ft MLLW), and Lower Sand (-10 to -32 ft MLLW). Different hydrologic parameters are assigned to the different vertical layers as described below (Table 1). The caustic Hg plume was defined based on Figure 1 in the *Results from Supplemental Groundwater and Porewater Sampling and Analysis, Chlor-Alkali RAU*Memorandum (October 22, 2015). The soil Hg concentration, treatment trench, and PRB boundaries were defined based on RI Figures 7-1 to 7-10 (Remedial Design Concepts). Trenches and PRBs extend to the base of the Fill Unit. Boundary conditions were defined to reproduce the Fill Unit groundwater elevation contours shown in RI Figure 4-5.

#### Hydrologic Parameters

Hydrogeologic parameters used in the model were derived largely from previous field work and preliminary modeling conducted as part of the RI. For modeling purposes, the aquifer is treated as unconfined and homogenous, and steady state flow is assumed. A list of aquifer parameters are summarized in Table 1.

Parameter	Units	Fill Unit	Lower Sand	Tidal Flat Aquitard
Horizontal hydraulic conductivity	feet/day	2.55	5.67	0.0085
Vertical hydraulic conductivity	feet/day	0.255	0.567	8.5e-7
Effective porosity	-	0.25	0.25	0.20
Longitudinal dispersivity	Feet	13.8	13.8	13.8
Horizontal dispersivity	feet	1.38	1.38	1.38
Vertical dispersivity	feet	0.135	0.135	0.135

Table 1 Hydrologic Model Parameters

#### Groundwater Chemistry

Groundwater data collected in October 2009 and April 2010 include groundwater geochemistry analyses that were used to define initial solution chemistry conditions in the PHAST model. The model domain is divided into five different solution chemistry zones, and it is assumed that within each zone, groundwater chemistry is homogeneous and extends to the base of the Fill Unit. Initial groundwater chemistry in each zone was assigned based on water chemistry data from specific wells as summarized in Table 2. The solution chemistries of the different groundwater chemistry zones are listed in the Appendix in Table A1.

#### Table 2

#### **Groundwater Chemistry Zones and Representative Chemistry**

Zone	Description	Representative Groundwater Chemistry
1	Caustic Plume Zone A (Hg > 0.059 μg/L, pH < 8.5)	CP-MWB2 (04/06/2010)
2	Caustic Plume Zone B (Hg > 10 μg/L, pH > 10)	AMW-02 (10/02/2009)
3	Groundwater with Hg > 0.059 $\mu\text{g/L}$ and pH > 8.5	CP-MWC1 (04/06/2010)
4	Wastewater Settling Basin	EMW-14S (10/01/2009)
5	Background Groundwater and Soil Removal Zones	CP-MWA2 (10/02/2009)

#### **Remedial Alternative Model Scenarios**

Table 3 describes the remedial alternative scenarios that were set up in PHAST to simulate post-remediation Hg plume evolution and estimate groundwater restoration timeframes.

#### Table 3

#### **Remedial Alternatives**

Remedial Alternative	Components of Remedy
5	• Aggressive removal of obstructions and <i>in situ</i> stabilization (ISS) of soils with
	visible elemental Hg
	Soil capping
	<ul> <li>Neutralization of "caustic core" groundwater (pH greater than 10)</li> </ul>
	Groundwater monitored natural attenuation (MNA)
6	Aggressive removal of obstructions and ISS of soils with visible elemental Hg
	Soil capping

	Neutralization of groundwater with pH greater than 8.5
	Groundwater MNA
7	Removal of all soils with Hg greater than 100 mg/kg to achieve groundwater
	protection
	Soil capping
	Neutralization of groundwater with pH greater than 8.5
	Groundwater MNA
9	Removal of all soils exceeding Hg cleanup levels (24 mg/kg)
	• Neutralization of groundwater with pH greater than 8.5,
	• Permeable reactive barrier (PRB) for <i>in situ</i> treatment of Fill Unit groundwater
	impacted by Hg
	MNA for residual impacted groundwater

All four of the modeled remedial alternative scenarios include installation of treatment trenches containing ferrous sulfate (FeSO<sub>4</sub>·7H<sub>2</sub>O) for neutralization of groundwater pH. The associated groundwater solution chemistry in the trenches was initially equilibrated with melanterite (FeSO<sub>4</sub>·7H<sub>2</sub>O) which was included as solid phase within the trenches at a concentration of 0.1 mole/L. Alternative 9 also includes installation of PRBs containing zero-valent iron (ZVI) for Hg removal from groundwater prior to discharge to surface water. ZVI is oxidized in water to iron oxides, which adsorb Hg. A concentration of iron oxide sorption sites of 2 moles/L was assigned to the model cells located within the PRBs to simulate removal of Hg from groundwater by the PRB media. This is approximately equivalent to the amount of ferrihydrite [Fe(OH)<sub>3</sub>] that would be produced by an initial concentration of 50 % by weight of ZVI in the PRB with a sorption capacity of 0.2 mole/mole Fe. Model simulations were run for a simulation period of 100 years in 1 year time steps. The simulations evaluated the effect of geochemical attenuation mechanisms on the evolution of dissolved Hg concentrations following completion of active remediation at the site to estimate aquifer restoration timeframes. The simulated attenuation and remediation mechanisms include:

- Hg sulfide (i.e., metacinnabar) precipitation
- Adsorption of inorganic Hg on iron oxides
- Adsorption of Hg-DOM complexes on iron oxides

Surface complexation reactions used to simulate Hg adsorption on ferrihydrite are taken from Dzombak and Morel (1990). Hg speciation and solubility reactions and equilibrium

constants are largely sourced from Leterme et al. (2014). Sorption of Hg-DOM complexes is modeled by the Langmuir equation (Kothawala et al. 2008). The relevant reactions are summarized in the Appendix in Table A2.

#### **MODEL RESULTS**

### Evolution of the Groundwater Mercury Plume Following Remediation *Alternative 5*

This remedial alternative involves aggressive removal of obstructions and *in situ* stabilization (ISS) of soils with visible elemental mercury (to the base of the Fill Unit), neutralization of groundwater pH by ferrous sulfate emplaced within trenches across the caustic core plume (defined as the area where groundwater pH is greater than 10 and dissolved Hg concentrations are greater than  $10 \mu g/L$ ), and monitored natural attenuation (MNA). Post active remediation dissolved Hg concentrations in groundwater are shown in Figure 1 and model predicted concentrations after 1, 10, 20 and 50 year simulation times are shown in Figures 2 through 5, respectively. Within the caustic core, pH neutralization induces metacinnabar (HgS) precipitation which reduces dissolved Hg concentrations. Dissolved Hg concentrations outside the caustic core are attenuated relatively slowly, requiring several decades for concentrations less than 0.059  $\mu g/L$  are predicted to reach the property boundary and shoreline.

#### Alternative 6

This remedial alternative involves aggressive removal of obstructions and ISS of soils with visible elemental mercury (to the base of the Fill Unit), neutralization of groundwater pH by ferrous sulfate emplaced within trenches across the area where groundwater pH exceeds 8.5, and MNA. Post active remediation dissolved Hg concentrations in groundwater are shown in Figure 6 and model predicted concentrations after 1 and 10 years simulation times are shown in Figures 7 and 8, respectively. Following neutralization of groundwater pH neutralized, rapid and significant reduction of dissolved Hg concentrations are predicted across the site. Further attenuation of dissolved Hg concentrations occurs at a slower rate, with concentrations across the site predicted to drop below 0.059  $\mu$ g/L within a few decades. Due to the lower Hg concentrations resulting immediately following completion of active

remediation, Hg concentrations reaching the property boundary and shoreline are predicted to exceed 0.059  $\mu$ g/L for a few years.

#### Alternative 7

This remedial alternative involves removal of all soils with Hg concentrations greater than 100 mg/kg to the base of the Fill Unit to achieve groundwater protection, neutralization of groundwater pH by ferrous sulfate emplaced within trenches across the area where groundwater pH exceeds 8.5, and MNA. Post active remediation dissolved Hg concentrations in groundwater are shown in Figure 9 and model predicted concentrations after 1 and 10 years simulation times are shown in Figures 10 and 11, respectively. The predicted Hg plume evolution following completion of active remediation is similar overall to Alternative 6, with minor differences primarily due to the additional removal of Hg impacted soils.

#### Alternative 9

This remedial alternative involves removal of all soils with Hg concentrations exceeding the standard for unrestricted direct contact (24 mg/kg) to the base of the Fill Unit, neutralization of groundwater pH by ferrous sulfate emplaced within trenches across the area where groundwater pH exceeds 8.5, installation of permeable reactive barriers to treat the Hg plume where it reaches the shoreline, and groundwater MNA. Post active remediation dissolved Hg concentrations in groundwater are shown in Figure 12 and model predicted concentrations after 5 years simulation time are shown in Figure 13.

#### **Groundwater Restoration Timeframes**

Table 4 summarizes the groundwater restoration timeframes to achieve dissolved Hg concentrations lower than the cleanup level of 0.059  $\mu$ g/L for the different remediation alternatives at the following locations: the entire site, the port property boundary, and the shoreline (Bellingham Bay and Whatcom Waterway).

#### Table 4

#### **Groundwater Restoration Timeframes**<sup>1</sup>

Remedial	Restoration Timeframe (years)				
Alternative	Site-Wide	Port Property Boundary	Shoreline		
5	74	55	54		
6	26	11	5		
7	26	10	4		
9	10	10	2		

Note:

1. As defined by the groundwater cleanup level for mercury of 0.059  $\mu\text{g/L}$ 

#### REFERENCES

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### Figure 1 Hg concentrations in groundwater post active remediation for Alternative 5



Simulated Hg concentrations in groundwater 1 year after active remediation for Alternative 5



Simulated Hg concentrations in groundwater 10 years after active remediation for Alternative 5



Simulated Hg concentrations in groundwater 20 years after active remediation for Alternative 5



Simulated Hg concentrations in groundwater 50 years after active remediation for Alternative 5



Hg concentrations in groundwater post active remediation for Alternative 6



Simulated Hg concentrations in groundwater 1 year after active remediation for Alternative 6



Simulated Hg concentrations in groundwater 10 years after active remediation for Alternative 6



Hg concentrations in groundwater post active remediation for Alternative 7



Simulated Hg concentrations in groundwater 1 year after active remediation for Alternative 7



Simulated Hg concentrations in groundwater 10 years after active remediation for Alternative 7





Hg concentrations in groundwater post active remediation for Alternative 9



Simulated Hg concentrations in groundwater 5 years after active remediation for Alternative 9

#### APPENDIX

#### Table A1

#### Initial groundwater chemistry zones and mineral distributions

Zone	1	2	3	4	5
Demonstern	Caustic Plume	Caustic Plume	Hg > 0.059	Wastewater	Background
Parameter	Zone A	Zone B	μg/L, pH > 8.5	Settling Basin	Groundwater
Solution Chemist	ſY¹				
рН	7.11	10.92	9.76	8.36	6.72
ре	-0.89	-4.63	-0.13	-0.36	-1.86
Alkalinity <sup>2</sup>	1.73E-02	8.34E-02	1.05E-02	5.09E-02	1.23E-02
Calcium	1.00E-03	8.32E-06	1.21E-05	1.06E-04	2.41E-03
Chloride	1.91E-01	2.44E-02	2.40E-02	1.78E-02	1.83E-03
DOM (thiol)	5.70E-06	1.07E-04	5.35E-06	5.70E-06	5.70E-06
Iron	6.28E-07	2.94E-07	1.35E-06	1.87E-07	1.73E-05
Mercury	2.69E-09	2.08E-07	1.37E-08	8.83E-10	1.55E-11
Magnesium	1.99E-03	2.85E-05	1.57E-05	2.62E-05	4.53E-03
Potassium	7.67E-05	675E-04	7.93E-05	4.58E-05	1.31E-03
Sodium	2.02E-01	3.28E-01	3.47E-02	2.31E-02	1.54E-02
Sulfate	5.21E-05	5.41E-04	1.56E-04	2.39E-04	2.08E-06
Sulfide	8.62E-05	1.23E-03	1.49E-04	1.86E-05	6.55E-06
Minerals <sup>1,3</sup>					·
Metacinnabar <sup>4</sup>		0.0023	/ 0.0006 / 0*		0*
Mackinawite	0.1	0.1	0.1		0.1
Ferrihydrite	0*	0*	0*		0*
Siderite	0*	0*	0*		0*
Calcite	0.1	0.1	0.1		0.1

Notes:

1. Concentrations in moles/L water

2. As CaCO<sub>3</sub>

3. An asterisk indicates the mineral is not present initially but is allowed to precipitate as a result of reactions and transport

4. Initial distribution of metacinnabar in the model domain is based on soil Hg concentrations: 0.0023 mole/L in areas where soil Hg > 100 mg/kg; 0.0006 mole/L in areas where soil Hg > 24 mg/kg; 0 where soil Hg < 24 mg/kg.

#### Table A2

### Updated, modified, and additional chemical equilibrium reactions

Reaction	log K	Reference	
Aqueous Species		·	
$Hg^{2+} + H_2O = HgOH^+ + H^+$	-3.40	Powell et al. (2005)	
$Hg^{2+} + 2H_2O = Hg(OH)_2 + 2H^+$	-5.98	Powell et al. (2005)	
$Hg^{2+} + 3H_2O = Hg(OH)_{3^-} + 3H^+$	-21.1	Powell et al. (2005)	
$Hg^{2+} + CI^{-} = HgCI^{+}$	7.31	Powell et al. (2005)	
$Hg^{2+} + 2CI^{-} = HgCI_{2}$	14.0	Powell et al. (2005)	
$Hg^{2+} + 3Cl^{-} = HgCl_{3}^{-}$	14.93	Powell et al. (2005)	
$Hg^{2+} + 4Cl^{-} = HgCl_4^{2-}$	15.54	Powell et al. (2005)	
$Hg^{2+} + Cl^{-} + H_2O = HgOHCl + H^+$	4.27	Powell et al. (2005)	
$Hg^{2+} + CO_3^{2-} = HgCO_3$	11.46	Powell et al. (2005)	
$Hg^{2+} + OH^{-} + CO_3^{2-} = Hg(OH)CO_3^{-}$	19.32	Powell et al. (2005)	
$Hg^{2+} + CO_3^{2-} + H^+ = HgHCO_3^+$	15.79	Powell et al. (2005)	
$Hg^{2+} + SO_4^{2-} = HgSO_4$	2.40	Powell et al. (2005)	
$Hg^{2+} + 2HS^{-} = Hg(SH)_{2}$	39.1	Drott et al. (2013)	
$Hg^{2+} + 2HS^{-} = HgS_2H^{-} + H^{+}$	32.5	Drott et al. (2013)	
$Hg^{2+} + 2HS^{-} = HgS_{2}^{2-} + 2H^{+}$	23.2	Drott et al. (2013)	
$RS^{-} + H^{+} = RSH$	10.0	Skyllberg (2008)	
$Hg^{2+} + 2RSH = Hg(RS)_2 + 2H^+$	22.0	Skyllberg (2008)	
Mineral Solubility			
Mackinawite: $FeS(s) + H^+ = Fe^{2+} + HS^-$	-4.65	wateq4f.dat	
Metacinnabar: $HgS(s) + H^+ = Hg^{2+} + HS^-$	-36.9	Drott et al. (2013)	
Surface Complexation Reactions			
$Hfo_sOH + Hg^{2+} = Hfo_sOHg^+ + H^+$	7.76	Dzombak and Morel (1990)	
$Hfo_wOH + Hg^{2+} = Hfo_wOHg^+ + H^+$	3.75	Dzombak and Morel (1990)	
Sorption of Dissolved Organic Matter and Hg-NOM comple	exes		
$S + Ls^- = S_Ls^-$	2.05	Kothawala et al. (2008)	
S + LsH = S_LsH	2.05	Kothawala et al. (2008)	
$2 S_Ls^{-} + Hg(RS)_2 = (S_Ls)_2Hg + 2RS^{-}$	0	Kothawala et al. (2008)	

### **APPENDIX D**

**Restoration Time Frame Estimation for Naphthalene in Groundwater** 

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### **D.1. Objectives**

This appendix presents the methods and results of the natural attenuation modeling of naphthalene concentrations in the Million Gallon Tanks (MGT) Subarea within the Chlor-Alkali Remedial Action Unit (RAU). The modeling was conducted to estimate the restoration time frame for naphthalene in Million Gallon Tanks subarea groundwater, as a component of evaluation for remedial alternatives for the RAU. The natural attenuation model was constructed using data presented in the remedial investigation for the Georgia Pacific West Site (RI; Aspect, 2013).

### **D.2 Model Methods**

The BIOSCREEN model simulates contaminant natural attenuation in groundwater. The model was developed for EPA and is programmed into an Excel spreadsheet based on the Domenico three-dimensional analytical solute transport model (EPA, 1986). The model has the ability to simulate dissolved contaminant advection, dispersion, adsorption, and aerobic decay as well as anaerobic decay reactions. The model also presents results from three different levels of biodegradation (decay) including no biodegradation, first-order decay, and instantaneous reaction.

The model assumes one-dimensional groundwater flow conditions along the centerline of the naphthalene plume. First-order biodegradation (decay) model was selected based on data calculated from MGT Subarea wells, as outlined below. Well MG-MW05 has the highest naphthalene concentration measured within the plume and is assumed to be in the source area. Downgradient wells MG-MW03 and CF-MW01 are located along the centerline of the plume and have concentrations that decrease exponentially with distance (see Figure D-1). Wells EMW-12S and EMW-7S bound the upgradient and downgradient extents of the plume, respectively, along the centerline of the plume. Wells EMW-16S and MG-MW01 are within the high-concentration portion of the plume, and have been used to calculate the first-order decay rate constant for naphthalene used in the model.

### **D.2.1 Input Data**

The BIOSCREEN model requires input data in the following categories:

- Hydrogeology—Data inputs include the groundwater seepage velocity (Vs); alternatively, BIOSCREEN can calculate Vs by applying Darcy's Law of the form Vs = hydraulic conductivity (K) x average annual hydraulic gradient (i) ÷ porosity (n). The chosen values for the MGT Subarea, as presented in Table 4-1 of the RI, are listed below:
  - Vs = 75 ft/yr
  - $K = 2.4 \times 10^{-3} \text{ cm/sec}$

- I = 0.0075 ft/ft (seasonal average from wet and dry seasons)
- n = 0.25
- 2. Dispersion—Data inputs include the estimated plume length (Lp). The estimated plume length is assumed to be the distance between MG-MW05 (the source) and CF-MW01, which is approximately 500 feet. Longitudinal, transverse, and vertical dispersivity calculations are calculated by the model based on the estimated plume length:
  - Lp = 500 ft
- **3.** Adsorption—Data inputs include either an assumed retardation factor, or a calculated retardation factor based on the soil bulk density ( $\rho$ ), partition coefficient (K<sub>oc</sub>), and fractional organic carbon (f<sub>oc</sub>). For this model, the retardation factor was used as a calibration parameter with final value of:
  - R = 1.5
- **4.** Biodegradation—Data inputs include a first-order decay coefficient ( $\lambda$ ). The first-order decay coefficient was calculated using the average rate of decay from groundwater naphthalene concentrations at higher-concentration wells MG-MW01 and EMW-16S between March 2004 and December 2010 (see Table D-1), as follows:
  - λ = 0.35 yr<sup>-1</sup>
- **5.** General—Data inputs include an estimated length and width of the model area, and a simulation time for the model. The numbers were assumed such that the entire plume area of interest would be captured, as follows:
  - Length = 550 ft
  - Width = 115 ft
  - Simulation Time = 100 yr
- 6. Source Data—Data inputs include source thickness in the saturated zone, concentration of source, width of the source, and the amount of soluble mass within the source, all of which are estimates. The source thickness is assumed to be the smear zone based on seasonal high/low water tables, which have been observed to fluctuate up to 1 foot in the plume vicinity. The soluble mass was used as a calibration parameter. The source concentration was assumed to be the approximate solubility limit of naphthalene in water obtained from the Groundwater Chemicals Desk Reference (Montgomery, 1996).
  - Width = 40 ft
  - Source Thickness = 2 ft
  - Concentration = 25 mg/L
  - Soluble Mass = 10.5 kg
- **7.** Field Data for Comparison—Data inputs include measured concentration data along the centerline of the plume at specified distances downgradient of the source. Three data points were entered along the plume centerline based on naphthalene

concentrations at MG-MW05, MG-MW03, and CF-MW01. See Table D-2 for concentration and distance data developed in the RI. Figure D-1 provides a plot of naphthalene concentrations versus distance down the plume; a logarithmic regression closely fits the measured data ( $R^2 = 0.986$ ; Figure D-1), providing confidence in using the data set.

### **D.2.2 Model Calibration**

The exact time and amount of naphthalene release at the MGT Subarea is unknown and likely occurred over a period of time. For the purposes of this model, it was assumed that the spill happened 40 years prior to the last (2010) RI sampling event. Regardless of when the spill actually occurred, the BIOSCREEN model run at 40 years is taken to be the year 2010 and calibrated in order to match the measured groundwater concentrations collected at that time.

The amount of soluble mass and the retardation factor were the main calibration parameters used to match the concentration versus distance curve. Values of 10.5 kg for soluble mass and 1.5 for the retardation factor resulted in the closest fit to the actual analytical data collected in 2010.

The predicted naphthalene centerline concentration curves for 2010 conditions, assuming both first-order decay and no degradation as modeled by BIOSCREEN, are shown on Figure D-2. The 2010 analytical data points ("field data from site") are also displayed for comparison. The first-order decay model (blue line on Figure D-2) proves to be an excellent match for the 2010 analytical data, indicating that model is adequately calibrated to allow its use for predictive evaluation. Without decay (red line on Figure D-2), the model predicts a more uniform distribution of naphthalene along the plume centerline, which is completely inconsistent with the measured data.

The model results demonstrate that biological degradation (permanent destruction) of naphthalene is occurring in MGT Subarea groundwater, consistent with the groundwater quality measurements over time.

### **D.3 Model Results**

The calibrated BIOSCREEN model predicts a MGT Subarea naphthalene plume restoration time frame of approximately 40 years from 2010, based on first-order decay. Specifically, the BIOSCREEN model predicts a concentration of 8  $\mu$ g/L at the source (well MG-MW05) in the year 2050, just below the groundwater cleanup level of 8.9  $\mu$ g/L based on vapor intrusion for unrestricted site use (residential exposure). Figure D-3 presents the model results for year 2050.

The model also predicts that the groundwater naphthalene concentrations will decline to an 83  $\mu$ g/L concentration based on marine protection at well MG-MW05 by the year 2027 (17 years from the year 2010). In other words, the model predicts an 82 percent reduction (450 to 83  $\mu$ g/L) in the 2010 naphthalene concentration occurring in the first 17

years with an additional 17 percent reduction (83  $\mu$ g/L to 8  $\mu$ g/L) occurring in the subsequent 23 years.

In conclusion, the modeling predicts a groundwater naphthalene restoration time frame of 34 years from 2016, the preparation date for this FS.

### **D.4 References for Appendix D**

- Aspect Consulting, LLC (Aspect), 2013, Remedial Investigation, Georgia-Pacific West Site, Bellingham, Washington, Final, August 5, 2013.
- U.S. Environmental Protection Agency (EPA), 1986, BIOSCREEN Natural Attenuation Decision Support System, User's Manual Version 1.3, EPD/600/R-96/087. http://www.epa.gov/ada/csmos/models/bioscrn.html.
- Montgomery, J.H., 1996, Groundwater Chemicals Desk Reference, Second Edition, Lewis Publishers, Boca Raton, 1345 p.

#### Table D-1 - Naphthalene First-Order Decay Coefficient Estimation

Project 070188, Chlor-Alkali RAU, GP West Site, Bellingham, Washington

#### Estimate first-order degradation rate constant ( $\lambda$ , in units of t<sup>-1</sup>) for naphthalene in MGT groundwater plume

 $ln(C/Co) = -\lambda t$  $\lambda = -\ln(C/Co)/t$ 

Use data for the high-concentration naphthalene-impacted wells with data spanning 5 years (EMW-16S and MG-MW05). Use the average concentration and time from the three 2009-2010 sampling events to define the "now" condition (C, t).

	Well EMW-16S				Well MG-MW05				
	(C <sub>o</sub> , t <sub>o</sub> )	(C, t)				(C <sub>o</sub> , t <sub>o</sub> )		(C, t)	
	EMW-16S 07/26/04 Pre-RI	EMW-16S 09/30/09 RI	EMW-16S 03/30/10 RI	EMW-16S 12/16/10 RI		MG-MW01 07/27/04 Pre-RI	MG-MW01 09/28/09 RI	MG-MW01 03/29/10 RI	MG-MW01 12/16/10 RI
Sample Date:	7/26/2004	9/30/2009	3/30/2010	12/16/2010	۱ ۱	7/27/2004	9/28/2009	3/29/2010	12/16/2010
Naphthalene Concentration (ug/L):	210	64	59	42	۱ ۱	27	5.4	0.072	0.31 U
Elapsed Time (day):	0	1892	2073	2334	۱ ۱	0	1889	2071	2333

	EMW-16S	MG-MW05
Average Time (t, in day):	2100	2098
Average Concentration (C, in ug/L):	55	2
$\lambda = -\ln(C/Co)/t \; (day^{-1}):$	6.4E-04	1.3E-03
-		

Average  $\lambda$  from two wells (day<sup>-1</sup>) 9.5E-04 Average  $\lambda$  from two wells (year<sup>-1</sup>)

ug/L = micrograms per liter

Notes:

 $C_0$  = initial contaminant concentration at time = 0 ( $t_0$ ).

C = contaminant concentration at time = t.

0.35

# Table D-2 - Groundwater Napthalene Data Along Plume Centerline, Million Gallon Tanks Subarea

Project No. 070188, Chlor-Alkali RAU, GP West, Bellingham, Washington

Chemical Name	CF-MW01 09/30/09 RI	CF-MW01 03/31/10 RI	MG-MW03 03/29/10 RI	MG-MW03 12/16/10 RI	MG-MW05 12/20/10 RI
Distance from Source (ft)	500		18	1	
Polycyclic Aromatic Hydrocarbons (PAHs)					
Naphthalene in ug/L	0.045	0.062	87	160	450
Average Naphthalene in ug/L	0.054		12	450	

ft = feet

ug/L = micrograms per liter

### Table D-2



Figure D-1 Groundwater Naphthalene Concentrations versus Distance Down Plume Centerline

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Aspect Consulting

Chlor-Alkali RAU Feasibility Study



#### DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

495	550	
).436	0.463	
).019	0.015	
).436	0.463	
0.000		
te		
	<b></b>	
500		
500		600

Figure D-2 **BIOSCREEN Model Results Simulating Measured 2010 Conditions (Calibration)** Chlor-Alkali RAU Feasibility Study



#### DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

495	550
.008	0.008
.000	0.000
.008	0.008
.000	

Figure D-3 **BIOSCREEN Model Results Simulating Restoration Timeframe (2027)** Chlor-Alkali RAU Feasibility Study