Evaluating Chukchi Sea Trace Metals and Hydrocarbons in the Yukon River Delta, Alaska

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ABSTRACT

Yukon River sediments may comprise the majority of the deposits currently present in the Chukchi Sea. Currently, one-third of the Yukon River's sediment load may be carried to the Chukchi Sea, and it is estimated that as much as 81% of Yukon sediments reached the Chukchi Sea during the Holocene period (Nelson and Creager, 1977). This suggests that the majority of sediment present in the Chukchi Sea is derived from the Yukon River. This work focused on evaluating the trace metal concentrations and polycyclic aromatic hydrocarbons (PAHs) of the Yukon Basin, the largest contributor to the overall sediment budget of the eastern Chukchi Sea.

This project provided a snapshot of trace metal and PAH concentrations in the Yukon River water and active bedload. Seventeen PAH targets were sought in bed load sediments, water samples with suspended and dissolved material, and cores up to three meters in depth. No PAH targets were detected at a concentration above 4 ppb. The project also provided the first trace metal values published for the study area and provided historical radioisotope data from core samples. The data presented in this report reflect the current state of a non-tidally influenced stretch of the lower Yukon River and can be used as baselines to inform future work.

INTRODUCTION

Metals and hydrocarbons from offshore drilling operations can alter the natural biogeochemical state of marine ecosystems (Neff et al., 1987; Neff, 2005; Trefry et al., 2014). Previous studies have added to knowledge of concentrations of metals and hydrocarbon pollutants near oil lease areas (e.g., Brown et al., 2004; Brown, 2010; Naidu et al., 2011; Trefry et al., 2012; Trefry et al., 2014). However, some ambient levels of metals and hydrocarbons in Arctic marine sediments and seawater are thought to be derived from terrestrial sources (Brown, 2010; Trefry et al., 2012). The work reported here complements pollutant studies by examining terrestrial inputs to the Chukchi Sea from upstream sources in the Yukon River.

Yukon River sediments may constitute the majority of the deposits present in the Chukchi Sea. It is estimated that one-third of the Yukon River's sediment load may be carried to the Chukchi Sea and that as much as 81% of Yukon sediments reached the Chukchi Sea during the Holocene (Nelson and Creager, 1977). This suggests that the majority of Chukchi Sea sediment is derived from the Yukon River. Evaluating the trace metal and hydrocarbon concentrations of the Yukon River system, and the temporal trends in fluctuations of these constituents to the Chukchi Sea, will contribute important baseline data for the Chukchi Sea region. This work focuses on evaluating the trace metal concentrations and polycyclic aromatic hydrocarbons (PAHs) of the Yukon basin, the largest contributor to the overall sediment budget of the eastern Chukchi Sea. Identifying upstream sources is important because the Yukon River naturally erodes substantial natural hydrocarbon sources such as coal beds in the Tanana tributary and carries trace metals from many Alaska Range, Brooks Range, and Tanana upland rocks and ore bodies (Beikman, 1980; Dornblaser and Halm, 2006). The Yukon Basin may also collect PAHs from coal and oil processing, PAHs from wild fires in the Alaska Interior, and metal contaminants introduced from two of Alaska’s largest ore mining operations (Fort Knox and Pogo gold mines). These sources may substantially contribute to sediment concentrations apparent in the Chukchi Sea.

A variety of meteorological mechanisms may impact the temporal delivery of metals and hydrocarbons from the Yukon Basin. The Yukon River has been shown to be responsive to, and operate in-phase with, the Pacific Decadal Oscillation (PDO; Brabets and Walvoord, 2009), a natural climate cycle similar to the El Nino Southern Oscillation (Mantua et al., 1997; Mantua, 2001). The PDO affects marine ecosystems around Alaska (Francis and Hare, 1994) and could have considerable influence on riverine fluxes to the Chukchi Sea, including metals and hydrocarbons. Yukon River discharge has been trending to earlier onset at higher rates, (Dornblaser and Streigl, 2007; Streigl et al., 2007) and wild fires in Alaska have increased as a result (Westerling et al., 2006). Increased runoff delivers more sediment and associated trace metals and hydrocarbons to the Chukchi Sea. Increased fire activity leads to higher hydrocarbon concentrations in runoff because there is less vegetation to hold down sediment. Loss of vegetative cover also leads to higher erosion rates, which promote increased release of metals from rocks and soil (Swanson, 1981).

The purpose of this project was to develop an inventory of trace metals and PAHs derived from the Yukon Basin and delivered to the Chukchi Sea. We also explored whether sediment cores taken from high-sedimentation-rate Yukon delta deposits provide a complete historic record (~150 years) of metal and hydrocarbon delivery to the Chukchi Sea and whether trace metal concentrations in Yukon River sediments are significantly different in sand, silt, and clay-sized particles.

METHODS

Field Methods

Active river channel bedload and suspended-load sediments were collected from the Yukon River at five points for trace metal and PAH analyses (Figure 1). Bedload samples were collected from riverbanks or midstream sandbars. Suspended-load samples were collected from water pumped at 1 m below the river surface. Water samples were subsequently filtered in the field for trace metal analysis and frozen to be filtered in the laboratory for PAH samples. Suspended-load and water samples were collected in the summers of 2012 and 2013 and in early spring of 2013 before break-up.

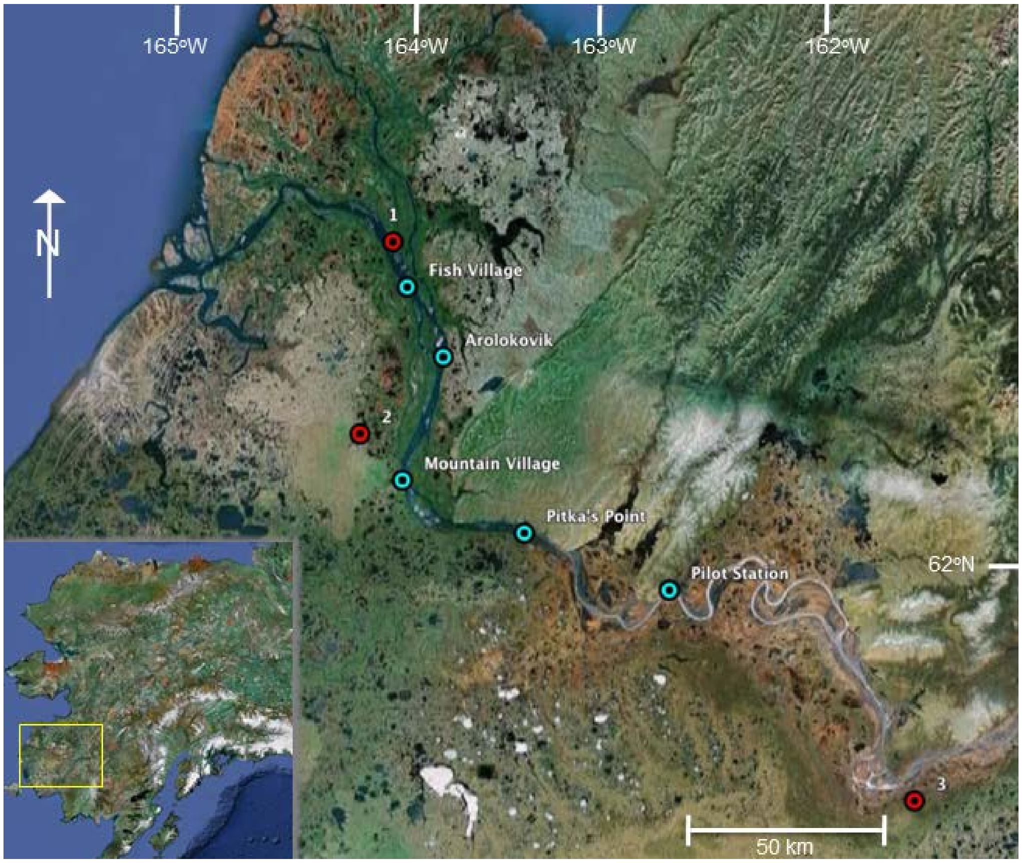

Figure 1: Map of study area. Location of core samples (red dots) and suspended sediment and water samples (blue dots) along the Yukon River delta. (Geographic coordinates: appendix Table A1)

Sediment cores were extracted from three permafrost-free locations selected in the active delta lobe of the river (Figure 1) using a percussion corer. Cores were taken from the active channel (Site 1–YD1) and from abandoned channels upstream (Site 2–YUK1 and Site 3–Y1). Core samples were 1–3 m long and non-continuous.

Analytical Methods

PAH analyses

Dry core samples were taken at the Woods Hole Oceanographic Institute. Suspended sediment samples were frozen in 1 L Teflon bottles until analysis. The entire volume of water and sediment samples were evaporated at 40^{o}C and the bottle rinsed with dichloromethane. Bedload samples were also frozen until analysis and then evaporated at 40^{o}C until dry. All dry samples were then spiked with a 1.56 ppm d8 Naphthalene standard and soaked in 25 mL of dichloromethane. The resulting mixtures of sediment, standard, and solvent were placed in a sonication bath for 30 minutes, centrifuged at 4500 rpm for 15 minutes and subsampled as 1 mL aliquots for analysis. Spiked samples were run to demonstrate extraction efficiency (see Appendix Table A2).

Suspended-load and bedload sediment samples were analyzed for PAH concentrations at the Water and Environmental Research Center (WERC, University of Alaska Fairbanks) laboratory using an Agilent 6890N Gas Chromatograph machine following EPA Method 8270 for semi-volatile organics; 35^{o} C (hold 4 minutes), to 245^{o} C @ 7^{o} C/minute.

PAH compounds were measured using a gas chromatograph in selective ion mode (SIM). Compounds were selected to match those targeted in the Chukchi Sea Offshore Monitoring in the Drilling Area (COMIDA) Chemistry and Benthos Study (CAB) (Dunton et al., 2012). These compounds (Table 1) were selected because they represent high-temperature combustion PAHs, key representatives of PAHs often attributed to oil (natural or contaminant), and PAHs known to have a natural origin.

Table 1: PAH targets. (*found in COMIDA-CAB study)

Naphthalene*	Acenapthylene	Acenapthene
Fluorene	Phenanthrene*	Anthracene
Fluoranthene*	Pyrene*	Retene*
Benz(a)anthracene*	Chrysene	Benzo(b)fluoranthene
Benzo(k)fluoranthene	Benzo(a)pyrene*	Indeno(1,2,3-c,d)pyrene
Dibenz(a,h+ac)anthracene	Benzo(g,h,i)perylene*	

Trace metal analyses

Trace metal analyses for water samples were performed on an Agilent 7500ce ICP-MS at the University of Alaska Fairbanks Advanced Instrumentation Laboratory (AIL). RF power was set to 1500 W. The instrument was tuned upon startup to optimize the sensitivity at masses 7, 89, and 205. Oxides (156/140) were tuned to less than 2% and doubly charged ions (70/140) were tuned to less than 3%. Li7, Be9, Fe 56, and Fe57 were analyzed in H2 mode; Mg 24, V51, Cr52, Ni60, Cu63, and As75 were analyzed in Helium mode; and Al27, Ca43, Ca44, Cr53, Mn55, Co59, Zn66, Sr88, Ag107, Cd111, Sb121, Ba137, Hg202, Tl205, Pb208, and U238 were analyzed in no gas mode. Internal standards were Sc45, Ge72, and Te125. Calibration standards were made from single element standards (Ultra Scientific) ranging from 0.1–50 ppb for all elements except for Mg, Ca, Fe, and Sr which were calibrated from 1–500 ppb, and Hg202 which was calibrated from 0.01–5 ppb. Continuing calibration verifications (CCVs) and continuing calibration blanks (CCBs) were analyzed every 10 samples. NIST 1640 was analyzed as a secondary standard. Trace metal targets were selected to match the 2002–2003 USGS Yukon River study targets (Table 2), providing a continued, overlapping record downriver from Pilot Station, the furthest downriver site sampled by USGS.

Table 2: Trace metal targets. Targets complement the USGS Yukon River study, 2002–2003.

Barium (Ba)	Chromium (Cr)	Lithium (Li)	Lead (Pb)	Thallium (Tl)
Cadmium (Cd)	Cesium (Cs)	Manganese (Mn)	Rubidium (Rb)	Uranium (U)
Cerium (Ce)	Copper (Cu)	Molybdenum (Mo)	Rhenium (Re)	Vanadium (V)
Cobalt (Co)	Iron (Fe)	Nickel (Ni)	Strontium (Sr)	Zinc (Zn)

Bedload samples for trace metal analysis were collected in the field using clean plastic bags. Samples were gathered from the river bank or sandbar at the locations shown in Figure 1. Portions of the gathered sample were dried at 50^{o}C for up to 24 hours, depending on water content in the sample, and then ground and mixed with a polyvinyl alcohol binder. The sample was then pressed into a pellet at 20,000 psi and analyzed using a PANalytical Axios four kilowatt wavelength dispersive X-ray fluorescence spectrometer (XRF). Calibration standards used were SO-4 (*) and GXR-4 (*), following Barker et al., 2014 and Ilgen et al., 2011.

Radioisotope analyses

Radiocarbon dates, and ^{210}Pb, ^{214}Pb, and ^{137}Cs radioisotopes were determined at Woods Hole Oceanographic Institute.

RESULTS AND DISCUSSION

Organic Compounds

Of the 17 PAH targets sought in this survey, none were detected in any water, core, or bedload samples above the established base detection limit of 4–8 ppb (See Appendix Figure A1, Appendix Table A3) Future work that concentrates the remaining sample portions may be able to improve the lower detection limit and find smaller concentrations if they are present.

Trace metals

Water samples

Tables 3–5 show trace metal data, and selected major elements, from Yukon River water samples. Three locations, Pilot Station, Pitka's Point, and Fish Village, were sampled during both summer 2012 and summer 2013. In general, values for trace metals in water samples were higher in summer 2013 than in summer 2012, except for Strontium at all locations, Uranium at Pitka's Point and Fish Village, and Mercury at Fish Village, which were all lower.

Four stations were sampled during July 2012 (Pilot Station, Pitka's Point, Arolokovik, and Fish Village). No general trends in trace metal concentrations are detected in Yukon River water moving downstream. Mercury levels at Fish Village were higher than at the other stations; the reasons for this are unclear.

Samples taken from Pilot Station during March and June 2013 were analyzed. Concentrations of trace metals were generally higher in June than in March, except for Strontium and Uranium. Samples were also taken in March 2013 at Mountain Village, downstream from Pilot Station. Comparison of these two stations during March 2013 shows an increase in all trace metal concentrations downstream, in marked contrast to the variable downstream concentrations during summer 2012 and 2013.

Table 3: Selected trace metal data from Yukon River water samples at Pilot Station, Alaska. Values that were below lower level of detection (LLD) are shown as (-).

	PILOT STATION 7/21/2012		PILOT STATION BANK 7/22/2012		PILOT STATION 3/11/2013		PILOT STATION 6/13/2013	
	ppb	%rsd	ppb	%rsd	ppb	%rsd	ppb	%rsd
Beryllium	0.08	3.51	0.08	1.75	0.07	0.58	0.09	2.54
Magnesium	7587.00	1.97	6357.00	0.41	10270.00	2.30	4728.00	0.62
Aluminum	44.89	2.92	60.79	2.15	0.69	5.45	318.20	1.78
Calcium	20690.00	0.36	20400.00	0.75	22700.00	1.50	18150.00	0.87
Vanadium	0.92	1.21	0.90	1.96	0.30	0.72	2.01	1.45
Chromium	0.44	1.05	0.49	1.01	0.28	0.48	1.01	0.74
Manganese	5.62	0.75	12.23	0.37	48.58	1.47	62.85	1.12
Iron	129.00	0.37	213.50	1.90	70.26	0.27	832.90	0.38
Cobalt	0.48	0.22	0.50	0.23	0.48	0.34	0.85	0.65
Nickel	1.00	0.53	1.10	0.68	0.92	1.19	2.57	1.56
Copper	2.61	0.93	2.33	0.80	0.60	0.86	4.93	0.74
Arsenic	1.07	1.84	1.05	3.31	0.50	4.81	1.60	1.83
Strontium	143.20	0.27	147.50	0.85	180.70	2.58	107.30	0.22
Silver	0.21	0.26	0.21	0.07	0.21	0.30	0.22	0.34
Antimony	0.07	6.67	0.05	9.79	-	3.60	0.24	2.82
Barium	50.33	1.08	55.76	1.66	62.39	0.44	66.05	1.07
Mercury	0.01	29.56	0.01	16.63	0.00	64.61	0.03	10.52
Uranium	0.40	19.68	0.74	0.69	0.76	2.08	0.17	14.31

Table 4: Selected trace metal data from Yukon River water samples at Pitka Point and Mountain Village, Alaska. Values that were below lower level of detection (LLD) are shown as (-).

	PITKA'S POINT 7/20/2012		PITKA'S POINT 6/13/2013		MOUNTAIN VILLAGE 3/13/2013	
	ppb	%rsd	ppb	%rsd	ppb	%rsd
Beryllium	0.08	0.99	0.10	4.37	0.08	1.48
Magnesium	7725.00	0.99	4734.00	1.82	10390.00	1.08
Aluminum	20.37	0.78	613.10	1.54	8.00	2.10
Calcium	19990.00	0.22	18030.00	1.37	27330.00	0.36
Vanadium	0.89	0.71	2.81	0.54	0.39	0.90
Chromium	0.36	0.25	1.69	2.37	0.33	1.09
Manganese	2.95	1.15	64.23	0.91	66.90	0.44
Iron	72.06	1.46	1520.00	2.76	357.60	1.27
Cobalt	0.45	0.62	1.11	0.45	0.51	0.37
Nickel	0.99	1.40	3.27	0.27	1.04	0.73
Copper	2.50	0.94	5.75	1.04	0.72	0.93
Arsenic	1.04	4.60	1.79	3.12	0.70	5.90
Strontium	143.10	2.15	111.50	0.72	212.40	1.94
Silver	0.21	0.01	0.22	0.55	0.21	0.29
Antimony	0.08	7.63	0.28	0.73	-	1.47
Barium	51.49	2.09	62.76	0.29	78.97	3.78
Mercury	0.01	3.72	0.02	2.00	0.01	7.80
Uranium	0.84	1.43	0.12	31.64	0.86	0.23

Table 5: Selected trace metal data from Yukon River water samples at Arolokovik and Fish Village, Alaska.

	AROLOKOVIK 7/21/2012		FISH VILLAGE 7/21/2012		FISH VILLAGE 6/13/2013	
	ppb	%rsd	ppb	%rsd	ppb	%rsd
Beryllium	0.08	1.05	0.08	1.85	0.11	1.55
Magnesium	4153.00	1.32	8334.00	0.77	4887.00	0.45
Aluminum	19.18	4.15	122.20	2.48	1061.00	0.58
Calcium	16600.00	0.13	22020.00	0.15	18860.00	0.34
Vanadium	1.34	1.11	1.12	0.08	4.61	0.94
Chromium	0.32	0.93	0.97	0.29	2.91	0.96
Manganese	20.83	2.78	7.11	1.20	113.90	0.52
Iron	80.88	1.36	215.40	3.32	2731.00	0.70
Cobalt	0.50	1.30	0.54	0.73	1.62	0.39
Nickel	0.70	1.56	1.54	0.50	4.48	1.29
Copper	1.51	1.16	2.95	0.64	7.03	1.40
Arsenic	0.82	4.56	1.16	1.63	2.39	2.35
Strontium	117.00	1.45	143.50	0.88	122.50	0.34
Silver	0.21	0.33	0.21	0.14	0.23	0.31
Antimony	0.08	8.21	0.10	2.77	0.35	1.58
Barium	45.80	7.10	55.93	4.82	78.50	1.16
Mercury	0.01	65.73	0.06	25.56	0.02	9.12
Uranium	0.34	55.12	0.67	32.01	0.13	15.84

Mean discharge for the Yukon River at Pilot Station is given in Table 6 for the dates the water samples were taken. Higher trace metal concentrations in summer 2013 than in summer 2012 can be attributed to higher discharge in the river. Higher discharges in summer than in March probably also account for the generally higher concentrations of trace metals in summer. Some of the variation in metal concentrations at different stations during summer 2012 may also be related to discharge variations.

Table 6: Yukon River discharge at Pilot Station, Alaska. (source: http://waterdata.usgs.gov/)

Date	Discharge (cubic ft./second)
7/20/2012	518,000
7/21/2012	515,000
7/22/2012	511,000
3/11/2013	51,000
6/13/2013	71,000

Rember and Trefry (2004) suggested that dissolved trace metal concentrations are strongly influenced by the discharge of soil interstitial water and shallow surface water that is flushed into arctic rivers during spring snowmelt. They further suggested that pools of standing water and lakes store leached trace metals from surrounding soils that are released during the spring thaw. It seems likely that a similar mechanism would also be active in the Yukon River watershed during heavy rains in summer as the permafrost continues to thaw. Other variations in dissolved trace metal concentrations from station-to-station may also result from differences in regional lithology and pH (Rember and Trefry, 2004) or from recent fire activity, which would increase sediment runoff and release of metals from rocks and soil (Swanson, 1981).

Bedload samples

Table 7: Selected trace metal data from Yukon River bedload sediment samples. Values that are below lower level of detection (LLD) are shown as (-), error is reported in counting standard error (CSE).

Sample name		Ba (ppm)	Cd (ppm)	Ce (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Cu (ppm)	Mn (ppm)
Arolokovik Bar 072112	Concentration	549.165	-	19.938	-	128.241	-	-	456.897
	LLD (ppm)	Not calc.	3.971	15.018	Not calc.	2.247	5.441	0.899	3.860
	CSE	2.911	1.241	3.284	0.417	1.176	1.974	0.391	2.672
Arolokovik Bank 072112	Concentration	570.370	-	22.616	-	79.323	-	-	448.292
	LLD (ppm)	Not calc.	3.966	14.144	Not calc.	2.098	5.111	0.868	3.615
	CSE	2.778	1.236	3.101	0.399	1.020	1.840	0.372	2.550
Mountain Village Bank 072112	Concentration	569.277	-	-	0.168	64.426	-	-	244.424
	LLD (ppm)	Not calc.	3.750	13.713	Not calc.	2.020	4.919	0.816	3.541
	CSE	2.736	1.172	2.954	0.357	0.963	1.772	0.344	2.039
Mountain Village Bank 092813	Concentration	498.636	-	-	-	67.866	-	-	299.026
	LLD (ppm)	Not calc.	3.811	13.997	Not calc.	2.054	5.040	0.835	3.656
	CSE	2.642	1.193	3.009	0.375	0.984	1.816	0.353	2.217
Pilot Station South Bank 072112	Concentration	727.770	-	19.634	-	88.644	-	16.139	536.840
	LLD (ppm)	Not calc.	3.673	14.119	Not calc.	2.099	5.171	0.866	3.671
	CSE	3.052	1.151	3.082	0.409	1.033	1.876	0.412	2.726
Pilot Station North Bank 072212	Concentration	826.614	-	25.376	-	101.592	-	10.844	642.546
	LLD (ppm)	Not calc.	4.091	14.712	Not calc.	2.206	5.362	0.909	3.795
	CSE	3.293	1.280	3.221	0.436	1.100	1.951	0.420	2.996
Pilot Station South Bank 092713	Concentration	579.328	-	-	0.864	100.168	-	-	309.470
	LLD (ppm)	Not calc.	3.811	14.174	Not calc.	2.093	5.156	0.848	3.679
	CSE	2.834	1.191	3.091	0.384	1.065	1.859	0.364	2.252
Pitka's Point Bar 092813	Concentration	494.332	-	24.603	-	153.279	-	-	613.825
	LLD (ppm)	Not calc.	4.352	15.688	Not calc.	2.340	5.603	0.955	4.048
	CSE	2.938	1.358	3.442	0.454	1.261	2.052	0.408	3.087
Pitka's Point Bar 072112	Concentration	530.0253	-	19.781	-	150.646	-	-	470.828
	LLD (ppm)	Not calc.	3.947	14.897	Not calc.	2.232	5.383	0.897	3.865
	CSE	2.864	1.235	3.254	0.417	1.213	1.956	0.382	2.703

Table 7: Continued.

Sample name		Mo (ppm)	Ni (ppm)	Pb (ppm)	Rb (ppm)	Sr (ppm)	Tl (ppm)	U (ppm)	V (ppm)	Zn (ppm)
Arolokovik Bar 072112	Concentration	2.242	21.184	8.020	41.671	254.166	-	4.078	82.441	71.089
	LLD (ppm)	0.492	0.937	1.883	0.599	0.442	2.069	1.434	3.685	0.896
	CSE	0.168	0.443	0.652	0.202	0.335	0.780	0.566	1.079	0.384
Arolokovik Bank 072112	Concentration	2.166	14.926	8.602	47.288	216.861	-	4.330	65.308	58.151
	LLD (ppm)	0.475	0.910	1.794	0.583	0.428	1.965	1.376	3.052	0.867
	CSE	0.163	0.399	0.623	0.203	0.307	0.745	0.544	0.946	0.361
Mountain Village Bank 072112	Concentration	1.808	15.265	8.598	49.441	216.940	-	2.109	54.914	48.380
	LLD (ppm)	0.454	0.795	1.721	0.558	0.411	1.876	1.329	2.845	0.824
	CSE	0.156	0.366	0.597	0.197	0.296	0.711	0.522	0.893	0.336
Mountain Village Bank 092813	Concentration	1.356	18.711	8.639	40.316	249.260	-	3.102	60.465	52.025
	LLD (ppm)	0.459	0.844	1.756	0.566	0.418	1.921	1.346	2.921	0.844
	CSE	0.158	0.400	0.610	0.191	0.317	0.728	0.531	0.921	0.347
Pilot Station South Bank 072112	Concentration	1.893	28.972	15.760	69.475	233.560	2.372	6.163	86.629	104.957
	LLD (ppm)	0.470	0.935	1.724	0.567	0.420	1.863	1.345	3.267	0.859
	CSE	0.161	0.476	0.618	0.222	0.315	0.710	0.537	1.011	0.400
Pilot Station North Bank 072212	Concentration	2.221	29.901	15.223	84.710	231.808	1.786	4.109	96.330	125.694
	LLD (ppm)	0.488	0.987	1.872	0.602	0.444	2.043	1.443	3.530	0.901
	CSE	0.168	0.500	0.667	0.245	0.325	0.778	0.570	1.087	0.433
Pilot Station South Bank 092713	Concentration	2.345	18.493	8.257	51.420	238.668	-	3.458	62.114	58.321
	LLD (ppm)	0.468	0.865	1.752	0.573	0.422	1.905	1.355	3.214	0.846
	CSE	0.161	0.405	0.607	0.204	0.314	0.725	0.535	0.960	0.354
Pitka's Point Bar 092813	Concentration	3.366	27.363	8.898	35.673	268.152	-	4.619	102.042	74.981
	LLD (ppm)	0.510	1.038	1.975	0.630	0.465	2.170	1.504	4.140	0.949
	CSE	0.176	0.507	0.686	0.205	0.355	0.824	0.596	1.197	0.407
Pitka's Point Bar 072112	Concentration	2.776333	21.89067	8.913333	42.05533	236.369	-	3.589667	83.57667	62.253
	LLD (ppm)	0.486667	0.935333	1.839333	0.594	0.439	2.002667	1.420667	3.688333	0.892
	CSE	0.1672	0.445867	0.6382	0.2013	0.3236	0.7583	0.560567	1.083533	0.374133

Radioisotopes and Radiocarbon Dating

Three sediment cores up to 4.5 m long were sampled in the Yukon River delta. Core physical characteristics are found in Appendix Table A4. Cores were taken from the active channel (YD1) and from inactive channels further upstream that had previously filled with sediment (YUK1 and Y1). The upstream core (Y1) is the oldest with a basal radiocarbon age of 10.3 ka, the intermediate core (YUK1) has a basal age of 0.5 ka, and the downstream core (YD1) has a modern basal age (younger than 1950) based on the presence of ^{137}Cs throughout the core (Figure 2). The upper parts of the cores, where ^{137}Cs is present, were described and sampled for trace metal and PAH analyses and Pb radioisotope distribution. Corresponding ^{137}Cs, ^{210}Pb and ^{214}Pb radioisotope curve data are shown in Appendix Table A5.

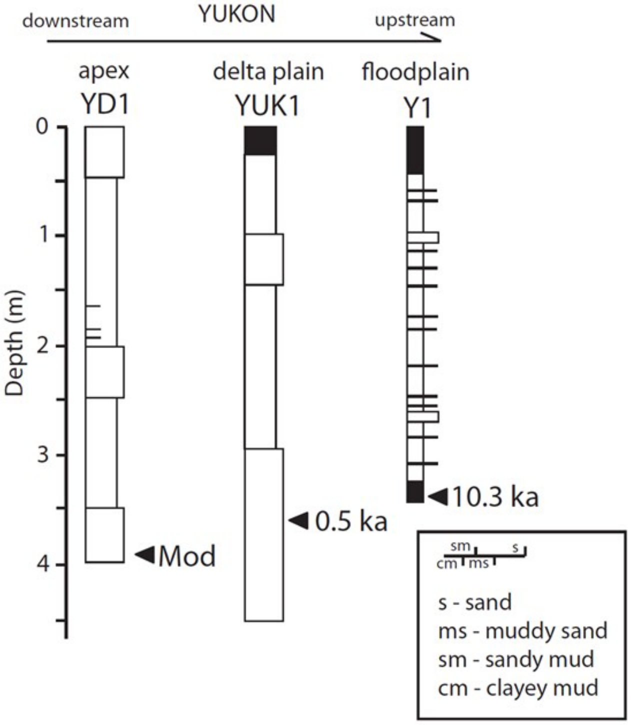

Figure 2: Cores taken from the Yukon River delta. Radiocarbon ages are shown at the base of the cores. Core YD1 (Site 1) is the most downstream core and core Y1 (Site 3) is the most upstream core. Width of the core indicates the sediment type at that depth in general. Detailed descriptions of the upper parts of the cores, where ^{137}Cs was present and from which PAH data were sampled, are in Table 10.

Radiocarbon dates, and ^{210}Pb, ^{214}Pb, and ^{137}Cs radioisotope data from this project will permit the future construction of a down-core chronology from Yukon delta sediment cores to resolve historical variability in trace metals and PAH abundance during deposition.

The primary use of ^{137}Cs as a dating tool is to locate peaks associated with the subaerial testing of nuclear weapons which led to an atmospheric dispersal of Cesium and other radioisotopes, particularly across the northern hemisphere. Nuclear testing began to appear in sediments in the western and central U.S. in the early 1950's. If the appearance and peak can be identified, then a rate may be obtained for sedimentation using these points in the core. However, there are complications in a river system for this method over a lacustrine core. Sediment mixing can obscure the peak, channel movement may truncate the sedimentation at an unknown date after the initial appearance of ^{137}Cs, and the channel return may remove the previous deposition, making the dating record shorter.

The best case scenario is to identify two peaks in ^{137}Cs, which are generally identified at 1957 and 1963 peak input years (Van Metre, et al, 2004), or to work from the start of occurrence to the peak value in 1964. We had mixed results identifying peaks in the cores (See Figure 3). Core YD1 displays two prominent peaks, but at very low concentrations. Core YUK1 shows one peak that may be the 1964 maximum atmospheric inventory of ^{137}Cs. YUK1 is also an abandoned channel, so the date of the top of the sediment column when new sedimentation from the Yukon ceased is unknown but after 1964. The furthest upstream core, Y1, is mostly likely oldest. It was gathered from a low sandbar in an active channel and is modern. There is a prominent peak in ^{137}Cs activity and a depth of only 10 cm, with a smaller peak at 45 cm, with two points of significant error in between, at 25 cm and 35 cm depth. This sample can clearly be stated to be modern, but the rate of sedimentation can only be poorly determined due to the likelihood of upstream sediment contributing to the near surface peak in this location when it was active.

The reliability of age dating between cores can vary and is difficult to quantify. Using professional judgment, these cores were classified similar to Van Metre, et al, 2004. YD1 is rated “good” for clear ^{137}Cs peaks and reliable data. Error size and less clearly identifiable peaks contributed to a “fair” rating for core YUK1, and “poor” for Y1, for reasons noted above.

The sedimentation rate for core YD1 and Y1was determined as 12.8 cm/year for YD1 and 5.8 cm/year for Y1, respectively, using the equation: ***sedimentation rate = cumulative depth/time interval*** The sedimentation rate was determined as 0.79 cm/yr. for core YUK1, using 1952 (first appearance in the core of ^{137}Cs) to a peak in 1964 as the time interval.

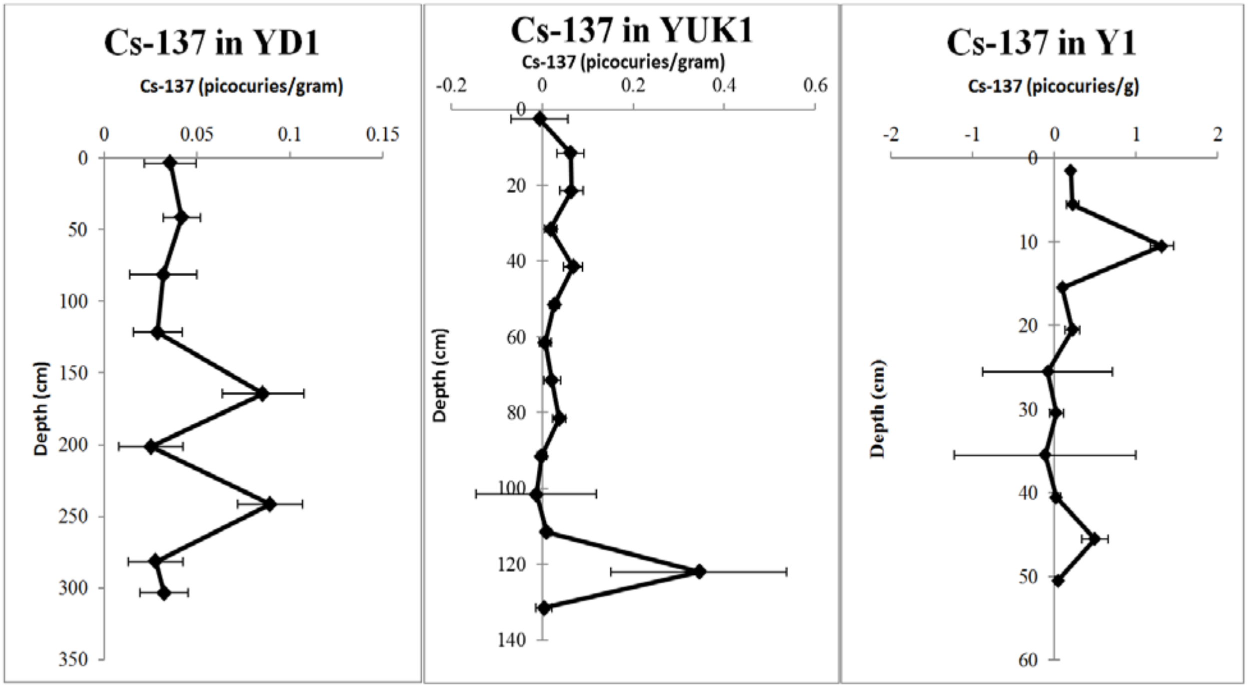

Figure 3: Cesium-137 activity per mass unit at core depths in centimeters. Cores were taken from the active channel (Site 1– YD1) and from abandoned channels upstream (Site 2–YUK1 and Site 3– Y1).

SUMMARY

This report provides a snapshot of the active water and bedload and allows for future construction of a historical data set through cored material of both a suite of trace metals and polycyclic aromatic hydrocarbons. The data presented here serves two purposes. It shows the current state of the last non-tidally influenced stretch of the Yukon River, and it helps to establish a baseline for comparison for future work that may lead to more conclusive studies as climate conditions in the Yukon River basin evolve and potentially alter the contributions of trace metals and hydrocarbons from the many tributaries and drainage areas.

Seventeen PAH targets were sought in bedload sediments, water samples with suspended and dissolved material, and cores up to three meters in depth. None were detected at a concentration above 4 ppb. Further work may increase detection of PAHs by concentrating remaining samples.

Trace metal values on this part of the Yukon River have not been previously published. In 2002–2003, the USGS sampled as far downriver as Pilot Station, which is the furthest upriver sampling station in this study. This study complements the USGS data to complete a full survey of the Yukon River trace metal content from Eagle, Alaska to the opening of the delta at the river mouth. Future work will also be able to look at the historical trace metal values and PAH values using the cores acquired here.

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APPENDIX

Table A1. Sampling site coordinates.

Site	Latitude	Longitude
Core Site 1 – YD1	62.645583	164.027000
Core Site 2 – YUK1	62.257	164.156861
Core Site 3 – Y1	61.558722	161.548917
Fish Village	62.572583	164.007389
Arolokovik	62.396417	163.801583
Mountain Village	62.165222	163.960472
Pitka’s Point	62.075000	163.474556
Pilot Station	61.954139	162.845111

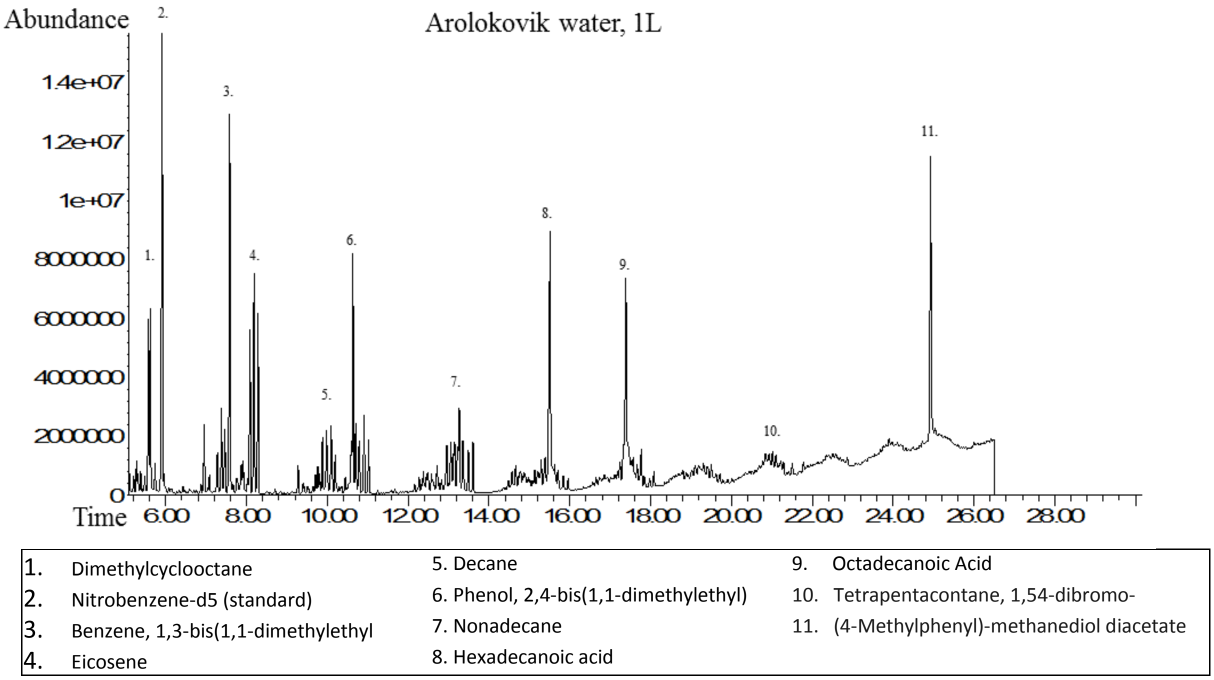

Figure A1: Organic compounds identified in the Arolokovik suspended water sample (06/13/2013).

Table A2: PAH targets and results of standards. Standards 1-7 were spiked with PAH targets to quantify counts at given concentrations. Targets are most common fragments of given compounds. Ratios are calculated to confirm fragments are from given targets. Single responses of three most common fragment masses are not confirmation of a target presence. D8 Naphthalene standards were added to clean soil and to the samples to confirm extraction efficiency, and values should be consistent through blanks and samples. Values that were below lower level of detection (LLD) are shown as (-).

PAH Target *Time of target*	Target	blank	1	2	3	4	5	6	7	d8 Naphthalene	d8 Naphthalene B
d8 naphthalene	136.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5326.00	5831.00
7.036	108.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	521.00	647.00
	137.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	646.00	734.00
	136/108	NA	NA	NA	NA	NA	NA	NA	NA	10.22	9.01
	136/137	NA	NA	NA	NA	NA	NA	NA	NA	8.24	7.94
	108/137	NA	NA	NA	NA	NA	NA	NA	NA	0.81	0.88
Naphthalene	128.00	167.00	758.00	1488.00	3282.00	5063.00	10159.00	20650.00	39777.00		
7.07	129.00	-	-	223.00	381.00	472.00	1095.00	1909.00	4531.00		
	102.00	-	-	144.00	313.00	416.00	816.00	1592.00	2598.00		
	128/129	NA	NA	6.67	8.61	10.73	9.28	10.82	8.78	NA	NA
	128/102	NA	NA	10.33	10.49	12.17	12.45	12.97	15.31	NA	NA
	129/102	NA	NA	1.55	1.22	1.13	1.34	1.20	1.74	NA	NA
Acenaphthylene	152.00	-	399.00	657.00	1620.00	3087.00	6549.00	14094.00	34736.00		
10.26	151.00	-	-	174.00	336.00	532.00	1212.00	3076.00	6823.00		
	76.00	-	-	135.00	189.00	407.00	630.00	1372.00	3488.00		
	152/151	NA	NA	3.78	4.82	5.80	5.40	4.58	5.09	NA	NA
	152/76	NA	NA	4.87	8.57	7.58	10.40	10.27	9.96	NA	NA
	151/76	NA	NA	1.29	1.78	1.31	1.92	2.24	1.96	NA	NA
Acenaphthene	153.00	-	408.00	733.00	1307.00	2993.00	5962.00	13440.00	28176.00		
10.64	154.00	-	361.00	579.00	1395.00	2643.00	5699.00	12744.00	26472.00		
	152.00	-	169.00	401.00	752.00	1440.00	2903.00	6214.00	13141.00		
	153/154	NA	1.13	1.27	0.94	1.13	1.05	1.05	1.06	NA	NA
	153/152	NA	2.41	1.83	1.74	2.08	2.05	2.16	2.14	NA	NA
	154/152	NA	2.14	1.44	1.86	1.84	1.96	2.05	2.01	NA	NA
Fluorene	166.00	-	364.00	653.00	1398.00	2914.00	6029.00	13212.00	28056.00		
12.1	165.00	-	320.00	772.00	1525.00	3001.00	6714.00	14940.00	30400.00		
	167.00	-	-	125.00	231.00	415.00	862.00	1866.00	3960.00		
	166/165	NA	1.14	0.85	0.92	0.97	0.90	0.88	0.92	NA	NA
	166/167	NA	NA	5.22	6.05	7.02	6.99	7.08	7.08	NA	NA
	165/167	NA	NA	6.18	6.60	7.23	7.79	8.01	7.68	NA	NA

Table A2 Continued.

PAH Target *Time of target*	**Target**	**blank**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**d8 Naphthalene**	**d8 Naphthalene B**
Phenanthrene	178.00	-	473.00	992.00	2034.00	4352.00	9378.00	20496.00	45672.00		
14.049	176.00	-	123.00	173.00	479.00	740.00	1636.00	3915.00	8357.00		
	179.00	-	113.00	200.00	359.00	675.00	1377.00	3350.00	6614.00		
	178/176	NA	3.85	5.73	4.25	5.88	5.73	5.24	5.47	NA	NA
	178/179	NA	4.19	4.96	5.67	6.45	6.81	6.12	6.91	NA	NA
	176/179	NA	1.09	0.87	1.33	1.10	1.19	1.17	1.26	NA	NA
Anthracene	178.00	-	227.00	605.00	1153.00	2391.00	5348.00	12786.00	34928.00		
14.169	176.00	-	-	100.00	248.00	450.00	971.00	2477.00	6421.00		
	179.00	-	-	NA	163.00	387.00	938.00	1977.00	5039.00		
	178/176	NA	NA	6.05	4.65	5.31	5.51	5.16	5.44	NA	NA
	178/179	NA	NA	NA	7.07	6.18	5.70	6.47	6.93	NA	NA
	176/179	NA	NA	NA	1.52	1.16	1.04	1.25	1.27	NA	NA
Fluoranthene	202.00	-	308.00	570.00	1286.00	2898.00	5870.00	14250.00	36564.00		
16.879	200.00	-	-	111.00	233.00	594.00	1274.00	2980.00	7242.00		
	201.00	-	-	136.00	230.00	430.00	824.00	2190.00	5321.00		
	202/200	NA	NA	5.14	5.52	4.88	4.61	4.78	5.05	NA	NA
	202/201	NA	NA	4.19	5.59	6.74	7.12	6.51	6.87	NA	NA
	200/201	NA	NA	0.82	1.01	1.38	1.55	1.36	1.36	NA	NA
Pyrene	202.00	-	395.00	719.00	1366.00	2828.00	6342.00	16396.00	38800.00		
17.416	203.00	-	-	140.00	244.00	679.00	1123.00	2993.00	6572.00		
	200.00	-	-	182.00	298.00	646.00	1286.00	3287.00	7995.00		
	202/203	NA	NA	5.14	5.60	4.16	5.65	5.48	5.90	NA	NA
	202/200	NA	NA	3.95	4.58	4.38	4.93	4.99	4.85	NA	NA
	203/200	NA	NA	0.77	0.82	1.05	0.87	0.91	0.82	NA	NA
Benzo(a)anthracene	228.00	-	174.00	338.00	685.00	1119.00	2928.00	6845.00	21504.00		
20.314	226.00	-	-	-	195.00	281.00	671.00	1779.00	5444.00		
	229.00	-	-	-	141.00	264.00	613.00	1425.00	4167.00		
	228/226	NA	NA	NA	3.51	3.98	4.36	3.85	3.95	NA	NA
	228/229	NA	NA	NA	4.86	4.24	4.78	4.80	5.16	NA	NA
	226/229	NA	NA	NA	1.38	1.06	1.09	1.25	1.31	NA	NA
Chrysene	228.00	-	246.00	464.00	1124.00	2378.00	5738.00	15278.00	36030.00		
20.394	226.00	-	122.00	157.00	309.00	698.00	1666.00	4495.00	9914.00		
	229.00	-	-	-	217.00	446.00	1194.00	3045.00	6985.00		
	228/226	NA	2.02	2.96	3.64	3.41	3.44	3.40	3.63	NA	NA
	228/229	NA	NA	NA	5.18	5.33	4.81	5.02	5.16	NA	NA
	226/229	NA	NA	NA	1.42	1.57	1.40	1.48	1.42	NA	NA

Table A2 Continued

PAH Target *Time of target*	**Target**	**blank**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**d8 Naphthalene**	**d8 Naphthalene B**
Benzo(b)fluoranthene	252.00	-	187.00	366.00	672.00	1470.00	3339.00	7992.00	23528.00		
22.726	126.00	-	-	-	113.00	349.00	644.00	1196.00	4120.00		
	253.00	-	-	131.00	177.00	352.00	801.00	1725.00	5179.00		
	252/126	NA	NA	NA	5.95	4.21	5.18	6.68	5.71	NA	NA
	252/253	NA	NA	2.79	3.80	4.18	4.17	4.63	4.54	NA	NA
	126/253	NA	NA	NA	0.64	0.99	0.80	0.69	0.80	NA	NA
Benzo(k)fluoranthene	252.00	-	161.00	299.00	682.00	1439.00	3355.00	9207.00	28163.00		
22.783	253.00	-	-	107.00	183.00	340.00	680.00	2193.00	6322.00		
	250.00	-	-	-	153.00	251.00	768.00	2016.00	5819.00		
	252/253	NA	NA	2.79	3.73	4.23	4.93	4.20	4.45	NA	NA
	252/250	NA	NA	NA	4.46	5.73	4.37	4.57	4.84	NA	NA
	253/250	NA	NA	NA	1.20	1.35	0.89	1.09	1.09	NA	NA
Benzo(a)pyrene	252.00	-	133.00	278.00	531.00	1074.00	2247.00	4763.00	15953.00		
23.4	126.00	-	-	-	133.00	245.00	504.00	834.00	2984.00		
	125.00	-	-	-	130.00	140.00	372.00	377.00	2134.00		
	252/126	NA	NA	NA	3.99	4.38	4.46	5.71	5.35	NA	NA
	252/125	NA	NA	NA	4.08	7.67	6.04	12.63	7.48	NA	NA
	126/125	NA	NA	NA	1.02	1.75	1.35	2.21	1.40	NA	NA
Dibenzo(a,h)anthracene	278.00	-	175.00	423.00	756.00	1582.00	3889.00	9449.00	27464.00		
25.544	139.00	-	-	112.00	117.00	286.00	725.00	1515.00	4207.00		
	279.00	-	-	110.00	198.00	357.00	1012.00	2522.00	6592.00		
	278/139	NA	NA	3.78	6.46	5.53	5.36	6.24	6.53	NA	NA
	278/279	NA	NA	3.85	3.82	4.43	3.84	3.75	4.17	NA	NA
	139/279	NA	NA	1.02	0.59	0.80	0.72	0.60	0.64	NA	NA
Indeno(1,2,3-cd)pyrene	276.00	-	161.00	297.00	584.00	1061.00	2681.00	5890.00	17432.00		
25.492	277.00	-	-	-	155.00	279.00	681.00	1259.00	4024.00		
	274.00	-	-	-	169.00	221.00	684.00	1239.00	3532.00		
	276/277	NA	NA	NA	3.77	3.80	3.94	4.68	4.33	NA	NA
	276/274	NA	NA	NA	3.46	4.80	3.92	4.75	4.94	NA	NA
	277/274	NA	NA	NA	0.92	1.26	1.00	1.02	1.14	NA	NA
Benzo(ghi)perylene	276.00	-	165.00	359.00	772.00	1657.00	5416.00	9132.00	27240.00		
25.949	277.00	-	-	-	187.00	420.00	1292.00	2115.00	6349.00		
	138.00	-	-	118.00	239.00	433.00	1554.00	2536.00	7659.00		
	276/277	NA	NA	NA	4.13	3.95	4.19	4.32	4.29	NA	NA
	276/138	NA	NA	3.04	3.23	3.83	3.49	3.60	3.56	NA	NA
	277/138	NA	NA	NA	0.78	0.97	0.83	0.83	0.83	NA	NA

Table A3: PAH targets and results of core samples. D8 Naphthalene standards are added the samples to confirm extraction efficiency, and values should be consistent through blanks and samples. Targets are most common fragments of given compounds. Ratios are calculated to confirm fragments are from given targets. Single responses of three most common fragment masses are not confirmation of a target presence. Values that were below lower level of detection (LLD) are shown as (-).

PAH Target *Time of target*	Target PPB	YD 1-1 20-23	YD 1-4 120-123	YD 1-5 163-166	YD 1-5 180-183	YD 1-7 260-263	YUK 1-1 1-4	YUK 1-1 30-33	YUK 1-3 80-83	YUK 1-3 110-113	YUK 1-4 120-124
d8 naphthalene	136.00	5142.00	4581.00	5756.00	5621.00	5052.00	5444.00	6293.00	5574.00	4656.00	6175.00
7.036	108.00	427.00	464.00	540.00	492.00	571.00	595.00	572.00	501.00	445.00	658.00
	137.00	518.00	639.00	639.00	632.00	616.00	632.00	733.00	646.00	520.00	688.00
	136/108	12.04	9.87	10.66	11.42	8.85	9.15	11.00	11.13	10.46	9.38
	136/137	9.93	7.17	9.01	8.89	8.20	8.61	8.59	8.63	8.95	8.98
	108/137	0.82	0.73	0.85	0.78	0.93	0.94	0.78	0.78	0.86	0.96
Naphthalene	128.00	-	-	-	-	-	-	-	-	-	-
7.07	129.00	-	-	-	-	-	-	-	-	-	-
	102.00	-	-	-	-	-	-	-	-	-	-
	128/129	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	128/102	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	129/102	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acenaphthylene	152.00	-	-	-	-	-	-	-	-	-	-
10.26	151.00	-	-	-	-	-	-	-	-	-	-
	76.00	-	-	-	-	-	-	-	-	-	-
	152/151	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	152/76	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	151/76	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acenaphthene	153.00	-	-	-	-	-	-	-	-	-	-
10.64	154.00	-	-	-	-	-	-	-	-	-	-
	152.00	-	-	-	-	-	-	-	-	-	-
	153/154	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	153/152	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	154/152	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fluorene	166.00	-	-	-	-	-	-	-	-	-	-
12.1	165.00	-	-	-	-	-	-	-	-	-	-
	167.00	-	-	-	-	-	-	-	-	-	-
	166/165	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	166/167	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	165/167	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table A3 Continued.

PAH Target *Time of target*	Target PPB	YD 1-1 20-23	YD 1-4 120-123	YD 1-5 163-166	YD 1-5 180-183	YD 1-7 260-263	YUK 1-1 1-4	YUK 1-1 30-33	YUK 1-3 80-83	YUK 1-3 110-113	YUK 1-4 120-124
Phenanthrene	178.00	-	-	-	-	-	-	-	-	-	-
14.049	176.00	-	-	-	-	-	-	-	-	-	-
	179.00	-	-	-	-	-	-	-	-	-	-
	178/176	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	178/179	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	176/179	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Anthracene	178.00	-	-	-	-	-	-	-	-	-	-
14.169	176.00	-	-	-	-	-	-	-	-	-	-
	179.00	-	-	-	-	-	-	-	-	-	-
	178/176	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	178/179	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	176/179	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fluoranthene	202.00	-	-	-	-	-	-	-	-	-	-
16.879	200.00	-	-	-	-	-	-	-	-	-	-
	201.00	-	-	-	-	-	-	-	-	-	-
	202/200	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	202/201	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	200/201	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pyrene	202.00	-	-	-	-	-	-	-	-	-	-
17.416	203.00	-	-	-	-	-	-	-	-	-	-
	200.00	-	-	-	-	-	-	-	104.00	-	-
	202/203	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	202/200	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	203/200	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(a)anthracene	228.00	-	-	-	-	-	-	-	-	-	-
20.314	226.00	-	-	-	-	-	-	-	-	-	-
	229.00	-	-	-	-	-	-	-	-	-	-
	228/226	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	228/229	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	226/229	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chrysene	228.00	-	-	-	-	-	-	-	-	-	-
20.394	226.00	-	-	-	-	-	-	-	-	-	115.00
	229.00	-	-	-	-	-	-	-	-	-	-
	228/226	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	228/229	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	226/229	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table A3 Continued.

PAH Target *Time of target*	Target PPB	YD 1-1 20-23	YD 1-4 120-123	YD 1-5 163-166	YD 1-5 180-183	YD 1-7 260-263	YUK 1-1 1-4	YUK 1-1 30-33	YUK 1-3 80-83	YUK 1-3 110-113	YUK 1-4 120-124
Benzo(b)fluoranthene	252.00	-	-	-	-	-	-	-	-	-	-
22.726	126.00	-	-	-	-	-	193.00	-	130.00	227.00	196.00
	253.00	-	-	-	-	-	-	-	-	-	-
	252/126	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	252/253	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	126/253	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(k)fluoranthene	252.00	-	-	-	-	-	-	-	-	-	-
22.783	253.00	-	-	-	-	-	-	-	-	-	-
	250.00	-	-	-	-	-	-	-	-	-	-
	252/253	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	252/250	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	253/250	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(a)pyrene	252.00	-	-	-	-	-	-	-	-	-	-
23.4	126.00	-	-	-	-	-	110.00	-	-	130.00	130.00
	125.00	123.00	-	114.00	117.00	165.00	279.00	248.00	189.00	317.00	347.00
	252/126	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	252/125	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	126/125	NA	NA	NA	NA	NA	0.39	NA	NA	0.41	0.37
Dibenzo(a,h)anthracene	278.00	-	-	-	-	-	-	-	-	-	-
25.544	139.00	-	-	-	-	115.00	132.00	114.00	146.00	160.00	146.00
	279.00	-	-	-	-	-	-	-	-	-	-
	278/139	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	278/279	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	139/279	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Indeno(1,2,3-cd)pyrene	276.00	-	-	-	-	-	-	-	-	-	-
25.492	277.00	-	-	-	-	-	-	-	-	-	-
	274.00	-	-	-	-	-	-	-	-	-	-
	276/277	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	276/274	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	277/274	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(ghi)perylene	276.00	-	-	-	-	-	-	-	-	-	-
25.949	277.00	-	-	-	-	-	-	-	-	-	-
	138.00	-	-	-	-	112.00	154.00	-	139.00	153.00	152.00
	276/277	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	276/138	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	277/138	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table A4: Physical description of core samples.

YD1			YUK1			Y1		
Depth (cm)	Sediment Type	Other Features	Depth (cm)	Sediment Type	Other Features	Depth (cm)	Sediment Type	Other Features
2-5	sand	upper 2 cm missing	1-4	clayey mud	root present (removed)	0-3	clayey mud	peaty, grass, twigs, wood
20-23	sand		10-13	clayey mud		5-6	clayey mud	peaty, plant fragments
40-43	sand	sand	20-23	clayey mud	woody organics (removed)	10-11	clayey mud	peaty, plant fragments
60-63	sand	some Fe-oxide streaks	30-33	clayey mud		15-16	clayey mud	peaty, roots present
80-83.5	sand		40-43	clayey mud	Fe-oxide striping	20-21	clayey mud	small roots
100-103	sand	some Fe-oxide streaks	50-53	clayey mud	Fe-oxide striping	25-26	clayey mud	
120-123	sand		60-63	clayey mud	Fe-oxide striping	30-31	clayey mud	roots?
140-143	sand	green foam covered core	70-73	clayey mud	orange color	35-36	clayey mud	roots? Fe-oxide mottles
163.2-166.5	sand	mica present	80-83	clayey mud	gray color	40-41	clayey mud	no organic fragments
180-183	sand	mica present	90-93	clayey mud	gray, Fe-oxide mottles	45-46	clayey mud	
200-203	sand		100-103	clayey mud	gray color	50-51	clayey mud	cemented
220-223	sand	some mica, Fe-oxide	110-113	clayey mud	gray, Fe-oxide mottles			
240-243	muddy silt		120-124	muddy clay				
260-263			130-133	muddy clay	large Fe-oxide mottle			
280-283			140-143	clayey mud				
302.5-305.5	sandy mud	300-302.5 removed prior	150-153	clayey mud				

Table A5: Core sample radioisotope curve data values.

Core	Depth (cm)	Pb-210 (Bq/g)	210 error	Pb-214 (Bq/g)	214 error	Cs-137 (Bq/g)	Cs Error
YD1-1_2-5	3.5	0.021208225	0.003048	0.064123907	0.001045	0.001319944	0.0005
YD1-2_40-43	41.5	0.0310477	0.002828	0.033900521	0.000702	0.001548779	0.0004
YD1-3_80-83	81.5	0.027637934	0.005005	0.032572622	0.001319	0.001181228	0.0007
YD1-4_120-123	121.5	0.023885119	0.004428	0.031941066	0.00123	0.001066422	0.0005
YD1-5_163-166	164.5	0.022544548	0.005167	0.026021133	0.001306	0.003163933	0.0008
YD1-6_200-203	201.5	0.022058387	0.00487	0.02774328	0.00134	0.000934626	0.0006
YD1-7_240-243	241.5	0.035415219	0.005266	0.038484752	0.001305	0.003306853	0.0006
YD1-8_280-283	281.5	0.023649225	0.003957	0.037183567	0.001045	0.001029614	0.0005
YD1-8_302-305	303.5	0.025917305	0.004606	0.036588697	0.001204	0.001200741	0.0005
YUK1-1_1-4	2.5	0.035207407	0.003831	0.039592165	0.000978	-0.000229703	-0.002
YUK1-1_10-13	11.5	0.039392482	0.009096	0.037071599	0.002087	0.002316257	0.0011
YUK1-1_20-23	21.5	0.028935293	0.00719	0.032263927	0.001755	0.002370402	0.0009
YUK1-1_30-33	31.5	0.019974557	0.005589	0.035397769	0.001246	0.000678316	0.0005
YUK1-1_40-43	41.5	0.023738976	0.005448	0.036253728	0.001153	0.002505496	0.0008
YUK1-2_50-53	51.5	0.020580788	0.00609	0.034410027	0.001452	0.000984275	0.0004
YUK1-2_60-63	61.5	0.028553924	0.005197	0.032238158	0.001141	0.000237636	0.0005
YUK1-2_70-73	71.5	0.02293892	0.005141	0.034937568	0.001363	0.000805425	0.0007
YUK1-3_80-83	81.5	0.027380952	0.005755	0.036466855	0.00167	0.001389501	0.0005
YUK1-3_90-93	91.5	0.03834609	0.003328	0.035211331	0.000757	-3.84037E-05	-4E-04
YUK1-3_100-103	101.5	0.033468928	0.007095	0.034297222	0.001399	-0.00049158	-0.005
YUK1-3_110-113	111.5	0.017517934	0.006238	0.034142026	0.001349	0.000347215	0.0003
YUK1-4_120-124	122	0.01965187	0.005479	0.032534466	0.001467	0.012758977	0.0071
YUK1-4_130-133	131.5	0.036031345	0.005585	0.032734737	0.001381	0.000116534	0.0006
YI-0_0-3	1.5	0.06984977	0.008557	0.033154179	0.002085	0.007578897	0.0011
YI-0_5-6	5.5	0.023280856	0.030777	0.060521881	0.006482	0.008304348	0.0027
YI-0_10-11	10.5	0.134431961	0.032815	0.070447916	0.007925	0.048756535	0.0052
YI-0_15-16	15.5	0.042423336	0.007377	0.031559148	0.001628	0.003452559	0.0012
YI-0_20-21	20.5	0.064230835	0.016392	0.034871203	0.003829	0.008262044	0.0033
YI-0_25-26	25.5	0.064383066	0.013932	0.0355761	0.002778	-0.002944176	-0.029
YI-0_30-31	30.5	0.035882075	0.358821	0.045752359	0.004365	0.001053725	0.0032
YI-0_35-36	35.5	0.077579893	0.024701	0.040893515	0.004531	-0.004097826	-0.041
YI-0_40-41	40.5	0.052219616	0.015504	0.047189871	0.003969	0.001080883	0.0018
YI-0_45-46	45.5	0.037688923	0.016707	0.035712638	0.006453	0.018584313	0.006
YI-1_50-51	50.5	0.043564797	0.007833	0.030548784	0.00198	0.001639189	0.0012

The Department of the Interior Mission

As the Nation’s principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the sound use of our land and water resources, protecting our fish, wildlife and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation.The Department assesses our energy and mineral resources andworks to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island communities.

The Bureau of Ocean Energy Management

The Bureau of Ocean Energy Management (BOEM) works to manage the exploration and development of the nation's offshore resources in a way that appropriately balances economic development, energy independence, and environmental protection through oil and gas leases, renewable energy development and environmental reviews and studies.