2009 Kenai River Hydrocarbon Assessment
November, 2010

Abstract

In 2006, the Kenai River was listed by the State of Alaska as impaired under § 303(d) of the Clean Water Act. The impairment listing resulted from repeated exceedances of State Water Quality Standards established for Total Aromatic Hydrocarbons (TAH). Documented exceedances of 10 parts per billion (ppB) of TAH exist from the period 1991 to 2007 and have been attributed to outboard motor use. Relative to outboard motor use, the concentration of TAH depends on the spatial and temporal distribution of the number and type of outboards operating on the river. TAH exceedances were found in every year the Kenai River was monitored (1991, 2000-2007) until 2008 when two State of Alaska regulations requiring the use of cleaner motor were enacted. The new regulations required the use of less polluting 4-stroke or 2-stroke Direct Fuel Injection motors. Since the clean motor regulations were enacted, two years of 3-day/year intensive sampling has been conducted during peak motorboat activity and no TAH exceedances have been observed.

This report is intended to serve several purposes: (1) summarize and reference relevant historical studies related to hydrocarbon research and monitoring of the Kenai River; (2) transmit TAH and Boat Census data results from the July 18-21, 2009 intensive monitoring event to the Alaska Department of Environmental Conservation (ADEC), supplemented by in-situ water quality measurements; (3) provide information to the Alaska Department of Environmental Conservation to support decisions related to hydrocarbons in the Kenai River, including removal from the § 303(d) listing within the State's 2010 Integrated Report; (4) to document and report that the enactment of the clean motor regulations has unequivocally resulted in reduced hydrocarbon pollution and petroleum hydrocarbon standards are attained for all designated uses of the Kenai River since regulations went into effect in 2008.

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Project Background

Introduction

The Kenai River, located in Southcentral Alaska, is among the most popular sportfishing destinations within the State of Alaska. Salmon fishing is considered to be world class, evidenced by a number of world record catches that have come from the river, most notably a 97lb 4oz Chinook Salmon caught in 1985. The river is located on the road system, within a three and a half hour drive to more than half of the State's resident population. Although not formally tracked, it receives some of the most concentrated in-river motorized boat traffic in the State. In recent years, more than 700 outboard motorboats have been documented to be in operation at the same time in the lower 50 miles of the river.

Along with its' notable fishing opportunity comes concern about the impacts such levels of use may have on the riverine environment. Tens of millions of dollars have been invested in protecting the banks and providing responsible access to the river. Numerous studies have been conducted to evaluate a wide range of natural and anthropogenic impacts in the Kenai River Watershed.

This report is concerned only with hydrocarbon pollution. Previous studies have isolated the source of known hydrocarbon pollution to raw gasoline, input from outboard motorboat use. The primary source appears to have been traditional two-stroke motors. Newer two-stroke motors that incorporate Direct Fuel Injection (DFI) technology, as well as all four-stroke motors, are much cleaner.

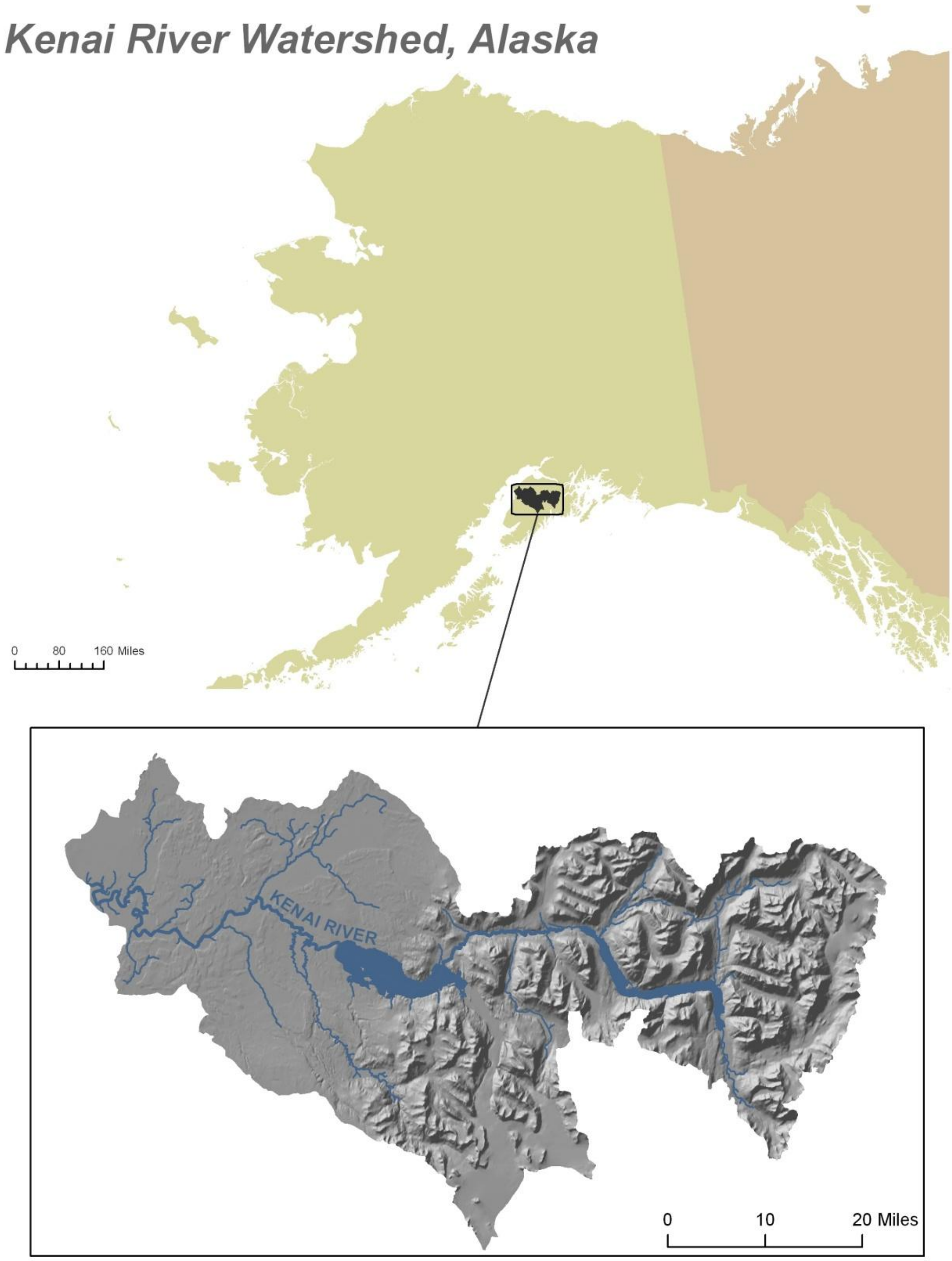

Fig. 1 Regional Location map – Alaska Context, the Kenai River is ~150 road miles from the largest city of Anchorage.

History

Hydrocarbon pollution in the Kenai River was identified by the Alaska Department of Fish and Game in the early 1990s (Litchfield and Kyle, 1992). The 1992 report is the first known documented hydrocarbon detection in the Kenai River.

In 1998, the Nature Conservancy of Alaska convened multiple governmental agencies and non-profit partners to develop the "Framework for Water Quality Monitoring of the Kenai River". The "Framework" led to an action plan whereby 14 partners signatory to a Memorandum of Understanding agreed to provide funding and staff-support to carry out systematic water-quality monitoring of the Kenai River; hereafter referred to as baseline monitoring. The baseline monitoring began in July 2000.

In 2002 a summary of results from the baseline monitoring was compiled and compared to State water quality standards. It was noted that in July of both years 2000 and 2001, Total Aromatic Hydrocarbons (TAH) exceeded State water quality standards; whereas identical tests in April did not detect any hydrocarbons during the spring thaw. The baseline monitoring documented the systematic downstream pattern of increasing hydrocarbons in July. This provided the first insight into the seasonal variation and the whole-river spatial variation of hydrocarbons.

In the summer of 2002 a small-scale sampling strategy was added at the end of the in-river motorized fishery season. The additional effort was designed to span the week surrounding the annual closure of a Chinook sport fishery and a personal use Sockeye dipnet fishery. The results of the 2002 field season indicated a correlation between the number of motorized boats and the observed levels of hydrocarbons. A Fact Sheet summarized the findings and identified the potential impacts of 2-stroke motors, while also calling for independent verification of the findings to date (KWF Fact Sheet NPS-FS-001, Jan. 2003).

The multi-agency baseline monitoring remains active as of this report (2010), monitoring hydrocarbons at multiple index stations along the Kenai River every July. Data from this effort has been compiled, submitted to the Alaska Department of Environmental Conservation (ADEC) and the US Environmental Protection Agency (EPA) through their nationwide database, STORET. The complete baseline monitoring data was most recently summarized in a written report, containing data through 2006 (McCard, 2007). In addition to the baseline effort and following a recommendation contained within the 2003 KWF Fact Sheet, the ADEC commissioned an independent study to evaluate potential hydrocarbon sources in the Kenai River. Consistent with previous studies, TAH concentrations exceeding the standard were documented and reported (OASIS Environmental, Inc., 2004). The 2003 sampling by commissioned study was a comprehensive sampling throughout the spring and summer of 2003, designed to evaluate potential sources of hydrocarbon pollution.

The 2003 OASIS study found no significant source of hydrocarbon pollution in the Kenai River other than outboard motor use. The outboard motor pollution source was present in sufficient quantities to cause water quality exceedances of the Kenai River. It was the first study to sample a fixed location (River Mile 10.1) at regular intervals for a consecutive 72-hour period. This intensive "round-the-clock" effort provided insights into the daily temporal variation of hydrocarbon loading, documenting an observed pattern of increasing hydrocarbon concentration during the day and decreasing through the evening and subsequent early morning hours. This diurnal pattern appeared to correlate with motorized boat traffic, but was not quantified. The majority of early morning samples were below detection limits, demonstrating that majority of daily hydrocarbon pollution was transported out of the Kenai River and into downstream Cook Inlet on a daily basis.

The River Mile 10.1 location was chosen for the first intensive sampling in 2003 to minimize the tidal influence of Cook Inlet. It was however recognized, that a significant amount of motorized boat traffic occurs in the lower 10 miles of the Kenai River. Building on results from the 2003 study, the Kenai Watershed Forum conducted round the clock sampling in 2004 at three lower river sites (River Mile 7, 3.8, and 1.5). Results demonstrated that concentrations of hydrocarbons were progressively higher in the downstream locations, despite tidal influences (Ruffner and Andersson, 2005).

In 2005 the Kenaitze Indian Tribe was awarded a Target Watershed Grant through a competitive grant program offered by the US EPA. This grant contained funding for multiple objectives, including a voluntary incentive motor buyback program to encourage the use of cleaner motor technology and to collect additional water quality data. Sampling for TAH in 2005 and 2006 focused on the lower 7 miles of the river. During these two years, no round-the-clock intensive sampling occurred, but rather targeted sampling was conducted, focused on times of peak-motorized activities. The buyback component of the grant program provided funding for 200 individuals using traditional carbureted two-stroke engines on the Kenai River to trade their outboard engines into the tribe in exchange for a voucher toward the purchase of a new cleaner four-stroke or two-stroke Direct Fuel Injection motor type. The voluntary program lasted 2 years, with all 200 motor vouchers being utilized.

In December of 2006, the State of Alaska, in its Integrated Report, listed the lower 19 miles of the Kenai River as impaired (category five /section 303(d) listed water) for persistent exceedances of the State's petroleum hydrocarbon (TAH) water quality standard. The 303(d) list refers to a section of the federal Clean Water Act, which requires all States to report to congress every two years on the quality of waters within their respective States. The 303(d) list contains those waters that are not meeting State established standards for the State designated uses of the waterbody.

Two intensive, high-density sampling efforts were conducted in 2007 in the lower 10 miles of the Kenai River. Both efforts occurred on the third weekend of July, during a period of peak in-river motorized use. One effort was lead by OASIS Environmental INC. designed to closely replicate the earlier 2003 study at river mile 10.1 and added a sampling station at river mile 5.0 (OASIS Environmental, Inc. 2008). Kenai Watershed Forum led the second study, conducted on the same dates as the OASIS study, in collaboration with the Kenaitze Indian Tribe (Ruffner and Czarnezki, 2008). The latter consisted of regularly scheduled samples taken from the lower 7 miles of the river between 10AM and 10PM. The results from the two studies have a general temporal agreement, with progressively higher TAH concentrations at each of the three downstream sampling locations. The 2007 maximum was 22.7 ppB, at the furthest downstream location (river mile 1.5), recorded in the early afternoon of Saturday 7/21/07.

In addition to the 2007 hydrocarbon sampling, a detailed boat census data was also collected during the 3-day sampling period. Total boats were counted from an airplane while simultaneously conducting a subset of the type of motor in operation from on-the-water. The sub-sample counts were used to determine the ratio of motor types (2-stroke/ 4-stroke). Five counts were conducted each of the 3-days during the hydrocarbon sampling events. The maximum number of boats in 2007 was 720 unique boats operating at the same time as counted from all aerial surveys. The peak boat count of 720 boats corresponded with the highest recorded hydrocarbon levels 22.7ppB, occurring in the water samples that were collected in the sampling event that immediately followed the peak boat count.

In the winter 2008, the State of Alaska implemented a pair of regulations that banned almost all non-DFI (Direct Fuel Injected) two stroke motors from operating in the waters of the Kenai River. A collaborative hydrocarbon monitoring plan was designed by the Alaska Department of Environmental Conservation that commissioned both of the previous teams of principle investigators, OASIS Environmental Inc and the Kenai Watershed Forum to conduct the most thorough hydrocarbon sampling of the Kenai River during the peak-use month of July (OASIS Environmental, Inc., 2009). This effort included round-the-clock sampling of three lower river stations that had been part of regular monitoring efforts over the past decade, coupled with substantially the same boat census methodology conducted in 2007. No exceedances of TAH were documented in the Kenai River in July 2008. This marked the first year in over a decade of sampling effort where no TAH exceedances were detected (Fig 2). A maximum TAH value of 6.9 ppB was reported at the farthest downstream monitoring station in 2008 with the corresponding peak boat count of 603 boats occurring 6 hours prior to the sampling event on the same day. The year-to-year maximum value observed reduction of TAH reflects a 70% decrease between 2007 and 2008. The 2008 reduction can be attributed to several factors: 1) higher river discharge providing more dilution of TAH, 2) fewer number of boats in operation, 3) enactment of clean motor regulation. The latter of these factors is believed to be the most significant contributor to TAH pollution reduction in the Kenai River. The 2009 studies reported herein further substantiate the hypothesis that clean motors are the most significant factor for TAH reduction in the Kenai River.

Figure 2 Maximum value of Total Aromatic Hydrocarbon (TAH) reported from all known data sources by year

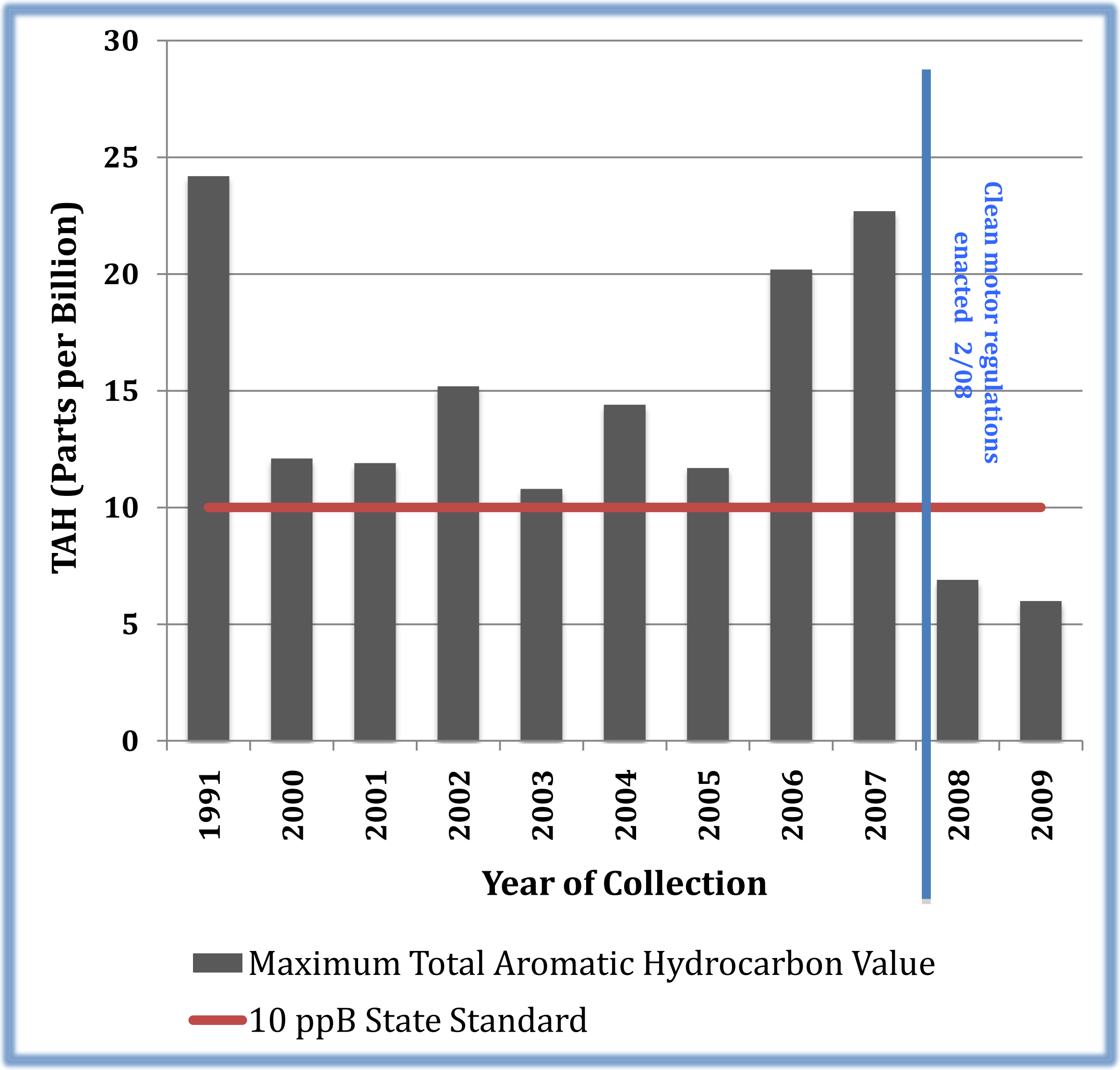

Fig. 2 Maximum TAH values reported from the Kenai River from all known sources. Values presented without respect to sampling location, methodology, effort or those factors known or suspected to influence the observed concentration, including: river discharge (flow volume), tide, number and type of motorized craft operating on the river. Only after regulation requiring cleaner technology was enacted in 2008, were the maximum TAH observations below the state standard. Source data cited in table 1.

Table 1 Maximum Annual Total Aromatic Hydrocarbon Summary

Year	Date	Sample Time	Max TAH	Location River Mile	Source/ Citation
1991	7/30	Not reported	24.2	6	Litchfield and Kyle 1992
2000	7/18	11:30	12.1	6.5	McCard 2007
2001	7/24	11:40	11.9	6.5	McCard 2007
2002	7/16	13:45	15.2	1.5	McCard 2007
2003	7/20	14:00	10.8	10.1	OASIS 2004
2004	7/20	13:20	14.4	1.5	McCard 2007
2005	7/17	9:35	11.7	7	KIT unpublished
2006	7/21	18:15	20.2	1.5	KIT unpublished
2007	7/21	16:45	22.7	1.5	Czarnezki and Ruffner 2008
2008	7/19	20:00	6.9	1.5	OASIS 2009
2009	7/18	13:47	6	1.5	This report

Table 1
Summary of the Maximum TAH values recorded by year from all known sources

2009 Monitoring Overview

The fundamental objective in the 2009 hydrocarbon monitoring of the lower Kenai River was a targeted, short-term, three-day sampling effort to assess petroleum hydrocarbon concentrations, designed to coincide with the peak motorized use period. The monitoring was designed to determine compliance with the State of Alaska TAH (Total Aromatic Hydrocarbon) petroleum hydrocarbon water quality standard [18 AAC 70.020(b)(5)(C)]. The TAH data must be of sufficient quality and resolution to test against the established standard of 10ppB.

There are three distinct, but related design components of the monitoring: (1) Analysis of samples for petroleum hydrocarbon concentrations using EPA method 624 for quantification of Benzene, Toluene, EthylBenzene and the m,p,o Xylene isomers, collectively referred to and interchangeably described as BTEX or TAH, (2) a motorboat census to determine the number and distribution of motorized boats operating on the river, including the relative percentage of motor type being used (2-stroke/ 4-stroke). The boat census is used to correlate with analytical hydrocarbon results and, (3) an in-situ field analysis of pH, specific conductance (SpCond.), temperature, dissolved oxygen and turbidity. With the reference of the Kenai River mouth at Cook Inlet being River Mile 0, Table 2 provides an overview of the location and river reach for each sampling location as outlined by ADEC.

Table 2 2009 Sample Sites

Site	Site Description	Parameter collected
River Mile 0 – 50	Cook Inlet to Skilak Lake	Aerial boat count w/ supporting video documentation, divided into 6 reaches
River Mile 0 – 5	Cook Inlet to Warren Ames Bridge	On-water survey of motor type (2-stroke vs. 4-stroke) n ≥ 100
River Mile 12	Pillars Boat Ramp	On-water survey of motor type (2-stroke vs. 4-stroke) n ≥ 100
River Mile 1.5	Thalweg Kenai River downstream of all motorized fishing effort	Total Aromatic Hydrocarbon pH, SpCond, temp, DO, turbidity

Total Aromatic Hydrocarbon Sampling

Water grab samples were collected every 2 hours, from 06:00 to midnight on Saturday 7/18/2009, Sunday 7/19/2009, and Tuesday 7/21/2009 for the analysis of TAH. Grab samples were collected using a Wildco VOC sampler, following USGS protocol (Shelton 1997). The sampling device is specifically designed for aquatic hydrocarbon sampling and was used in previous sampling efforts in 2008, 2007 and 2003. The Wildco collection device was lowered from the starboard boat davit to predetermined sampling depth and allowed to fill with river water according to the sampling's Quality Assurance Project Plan.

Fig. 3 Hydrocarbon sampling location, River Mile 1.5 refers to the location upstream from the Kenai River mouth at Cook Inlet.

In-situ water measurements

Simultaneous with the TAH water sample the collection field parameters of the in-situ water characteristics were documented using a Hydrolab MS-5 electronic multi-parameter sonde. The MS-5 has a 15 meter waterproof cable connected to an onboard handheld readout screen. The MS-5 was lowered to the same depth as the Wildco grab sampler, but off the boats portside davit and used to record the water pH, Specific Conductivity, Temperature, Dissolved Oxygen and Turbidity. Throughout the sampling event, water samples were collected every two hours at two depths from River Mile 1.5 in the channel's thalweg. Twenty regular samples were collected per day for each of the three days; in addition, 10% field replicates were collected for quality assurance purposes, yielding a total of 66 samples.

Motor Boat Census

To characterize the maximum seasonal values of TAH in the Kenai River, the 2009 strategy relied on the 3 selected sampling days and location being downstream of and coinciding with the expected peak motorized fishing activity; July 18, 19 and 21. Monitoring boat traffic throughout July was not conducted; however, previous studies and local knowledge suggests that 7/18/09 was the peak motorized use day for 2009. The anticipated peak was later verified in the 2009 Kenai River Dipnet Fishery Report, produced by the City of Kenai. The City's report verified that Saturday 7/18/09 was in fact the busiest day for the boat launches.

As in the previous two years, the peak boat-count occurred during the TAH sampling event. Also consistent with the previous two years, the peak number of boats in operation on the Kenai River at one time occurred in the early afternoon of the 3rd Saturday of July, this year the peak count occurred on 7/18/09, 2pm. The 2009 aerial count documented the highest number of boats from any previous year, with 765 unique boats operating at one time, the second highest count occurred in 2007 with 720 unique boats.

The total boat count was documented by a three-person crew from a small plane flying the 50-mile length of the river from tidewater to Skilak Lake, the latter being the upstream limit of motorized boating activity. The crew consisted of one pilot, one observer and one video camera operator. Simultaneous with the aerial counting, two teams of on-the-water observers documented the percentage of 2-stroke and 4-stroke motors. One on-the-water team was stationed in the lower river dipnet fishery and one team at river mile 12, counting the in-river Chinook sport fishery.

Similar to previous years in which boat census data was collected contemporaneously with water samples, the highest TAH concentration corresponded with the peak boat count. However the correlation was unlike previous years, in that the 2009 peak TAH concentration (6.0 ppB) was observed at the same time as the peak boat count was observed, whereas in the past two years, there was a lag of 2 to 6 hours between the peak boat count and the peak TAH observation. This observation may be explained by a much higher percentage of the total riverboat activity being further downstream and within 3 miles of the sampling location.

In addition to the temporal and spatial patterns of motorized boat traffic, flow and tidal flushing have a direct effect on the hydrocarbon concentration measured in the Kenai River. It is noteworthy that during the 4-day monitoring period, the discharge in the Kenai River was near the 80^{th} percentile of the mean. This equates to a flow about 12 % above the average flow for these dates, based on a 45-year period-of-record at the closest USGS station (15266300) located at the Soldotna River Bridge, 19 miles upstream of the sample site.

Sampling Preparations

Individual samples for analysis were placed in the appropriate pre-cleaned sample containers as shown in Table 3. To ensure sample integrity, specific sampling and documentation procedures were followed according to the Quality Assurance Project Plan (QAPP) (KWF 2009). These procedures included labeling containers prior to sampling, extensive sample and site information recording, appropriate sample handling, and comprehensive chain-of-custody procedures. Sample and site information was recorded in the field notebooks. Quality control samples or additional sample volume for laboratory QC was collected as appropriate and are discussed in more detail in the QAPP. All samples were immediately placed in coolers and packed with gel ice after sampling and remained chilled to 4°C (+/- 2°C) during transportation to the laboratory. Samples were transported by boat, truck, and commercial airplanes to the analytical laboratory. All samples shipped were accompanied with a completed chain-of-custody form, and coolers were sealed with signed and dated fiber tape for shipment. Holding times and sample preservation requirements are described in Table 3. Holding times and temperature specifications for each sample analysis type were met.

TABLE 3: PRESERVATION AND HOLDING TIMES FOR SAMPLE ANALYSIS

Analyte/ Method	Matrix	Container	Preservative	Holding Time
BTEX/ EPA 624	Water	3 x 40 mL vials	HCL to <2 pH, chill to 4°C	14 days

Sample documentation procedures included project field notebooks, chain-of-custody forms, and sample labels. Specific information such as site identification, sample identification numbers, sampling observations, and sample collection time and date were recorded in field notebooks and data sheets. Additionally, photographic documentation was collected during each sampling event.

Procedures

Sampling procedures followed the ADEC approved July 2009 Sampling and Quality Assurance Project Plan (QAPP). All samples were collected in a consistent manner, from the same location, using the same methods and same principal investigator as were collected by the Kenai Watershed Forum in 2007 and 2008, making these results as comparable as possible to the previous three years.

Data collection began on Saturday, July 18th, 2009 and continued on Sunday, July 19th and Tuesday July 21st. On each day sampling began at 6am and continued with a pre-planned water sampling event every 2 hours until midnight. Water sampling consisted of specified grab samples for the laboratory analysis of TAH, along with the simultaneous measurement of in-situ field parameters, including: temperature, pH, dissolved oxygen, specific conductivity and turbidity.

Concurrent with the water chemistry sampling, aerial boat counts were conducted at 5 regularly scheduled intervals during each of the three sampling days. These counts provided data on the total number and distribution of motorboats operating in the river during the three-day sampling event. While whole-river boat observations were made from the aerial overflights, two teams of on-the-water observers simultaneously documented the type of motors (2-stroke vs. 4-stroke) operating in the two distinct fisheries that operate on the Kenai River in July. The on-the-water observers used a fixed cross-section and counted each type of boat motor as it crossed the chosen cross-section of the river. On-the-water counts were conducted until enough boats were observed to ensure a statistical significant count (n>100) was completed.

A three person field team conducted water sampling from an 18-foot, Stabicraft with a 50 HP 4-stroke Honda Engine. The vessel driver was responsible for fueling the craft and all aspects of motor operation, the driver did not assist with any aspect of the sampling equipment. To avoid contamination, the other two members of the team were dedicated to sampling and did not enter the stern of the boat or come into contact with the fuel or the motor. Samplers were also instructed not to fuel vehicles prior to their shift.

The sampling vessel was rigged with a cross member of angle iron at shoulder height. The cross member is located 3 feet behind the bow of the boat and extended 8 inches over the starboard and port sides of the bow, creating a Port and Starboard davit system. Pulleys were attached to both ends of the cross members to facilitate lowering and raising sampling devices to the required sampling depth. Each pulley was equipped with 50 feet of 3/8" braided white nylon rope, marked in 1' increments. One end of the rope attaches to the sampling device with a carabiner and the other end runs though a fast tie cleat on the side of the boat.

The vessel driver navigated to the sample site using visual reference markers. The reference marker to establish position is the Alaska Department of Fish and Game regulatory marker that limits the motorized personal use fishing boundary. The thalweg of the transect below the regulatory marker was located using a Garmin fathometer. The boat was positioned such that the bow is facing into the current to minimize the potential for contamination from the sampling vessel. Water velocity vectors (direction and magnitude) varied depending on the tide. During a strongest portion of the flood tide, the boat required to face downstream as the water flow was forced upstream by the incoming tide.

The hydrocarbon samples were collected by placing three uncapped 40-millilter amber sample vials in the Wildco hydrocarbon sampler and lowering the sampler from one side of the cross member, just off the vessel bow and to the desired depth. Samples were collected at two depths, one shallow and one deep. The shallow sample was collected 12” below the water surface. The deep sample was relative to the total depth and was uniquely determined for each sample from the fathometer, such that inlet ports on the top of the sampler were at a depth 80% of the total depth. The Wildco sampler released air bubbles as it filled, when bubbles ceased rising, the sampler was brought to the surface. Sample bottles were removed from inside the sampler where they were immersed in water and field-preserved with hydrochloric acid (HCl). The bottles were capped so that no air headspace remained in the bottles. Sample protocol followed the United States Geological Survey report “Field Guide for Collecting Samples for Analysis of Volatile Organic Compounds in Stream Water for the National Water Quality Assessment Program,” which is referenced in the QAPP.

Simultaneous with the hydrocarbon sampling, the second sampler lowered the MS-5 multiprobe to same depth off the opposite side of the bow. The multiprobe measured pH, temperature, specific conductivity, turbidity and dissolved oxygen according to the manufacturer’s instruction. Parameters were recorded when readings stabilized.

Prior to each sampling event, the Wildco sampler was submerged in river water, removed and rinsed with de-ionized water. For the collection of field replicate samples, two Wildco samplers were tethered to a single deployment line and lowered to the appropriate sampling depth. In each of samplers, three uncapped 40-millilter amber sample vials were placed in the Wildco hydrocarbon sampler and lowered to the required sample depth. Unique sample IDs were assigned to each set of 3 vials. One-three vial set was considered the regular sample, and the other three-vial set was considered the blind duplicate sample.

Results and Discussion

Analytical Hydrocarbon Results

The complete set of analytical results is included in Appendix C. There were no unusual circumstances or difficulties collecting samples, following the chain-of-custody or shipping to the laboratory. All sampling was done in accordance with the QAPP, except two of the three sample coolers were received by the laboratory at temperatures slightly above the targeted delivery temperature of 4°C, but below the 6°C specification.

Results indicate that all samples were well below the 10ppB State Water Quality Standard for TAH as illustrated in the following three charts. Saturday 7/18/09 had the highest value documented during the sampling period. A maximum value of 6.0 ppB was recorded during the 14:00 shallow-water sampling event. The 7/18/09 sample from 14:00 corresponds to the peak aerial boat count from the duration of the sampling period, and a rising tide near the slack high tide. Inspection of the sampling team's photo documents that the surface water was flowing downstream at the time this sample was collected, as determined by the direction of the commercial boats anchored in the photo. Conductivity indicates that saltwater mixing was occurring; however, there was still a strong salinity and density gradient present. The corresponding deep sample from this same time was below the analytical detection limits.

All TAH samples are considered valid and should be considered in the analysis. Shallow and deep samples agree when the water column was well mixed. Under conditions of the floodtide, the intruding saltwater wedge does not mix with the overriding less dense freshwater. The intrusion is evident in both the temperature and Specific Conductance field parameters. The TAH results show general agreement between shallow and deep samples except in the presence of the saltwater wedge. The overriding fresh water in the early afternoon corresponds with the peak boating activity and presents the highest observed concentration of TAH. The shallow and deep samples show a consistent departure from one another during the flooding tide. The single exception is the 22:00 Sunday 7/19/09 sample set. In this set, there is an unexplained departure from in the shallow and deep values; however, while the shallow sample value is suspect, there is no independent reason to consider this sample invalid. The higher than expected results from the shallow sample may be documenting a concentration of TAH that was not mixed with the water column at that particular location and time.

Saturday 7/18/09 TAH Chart

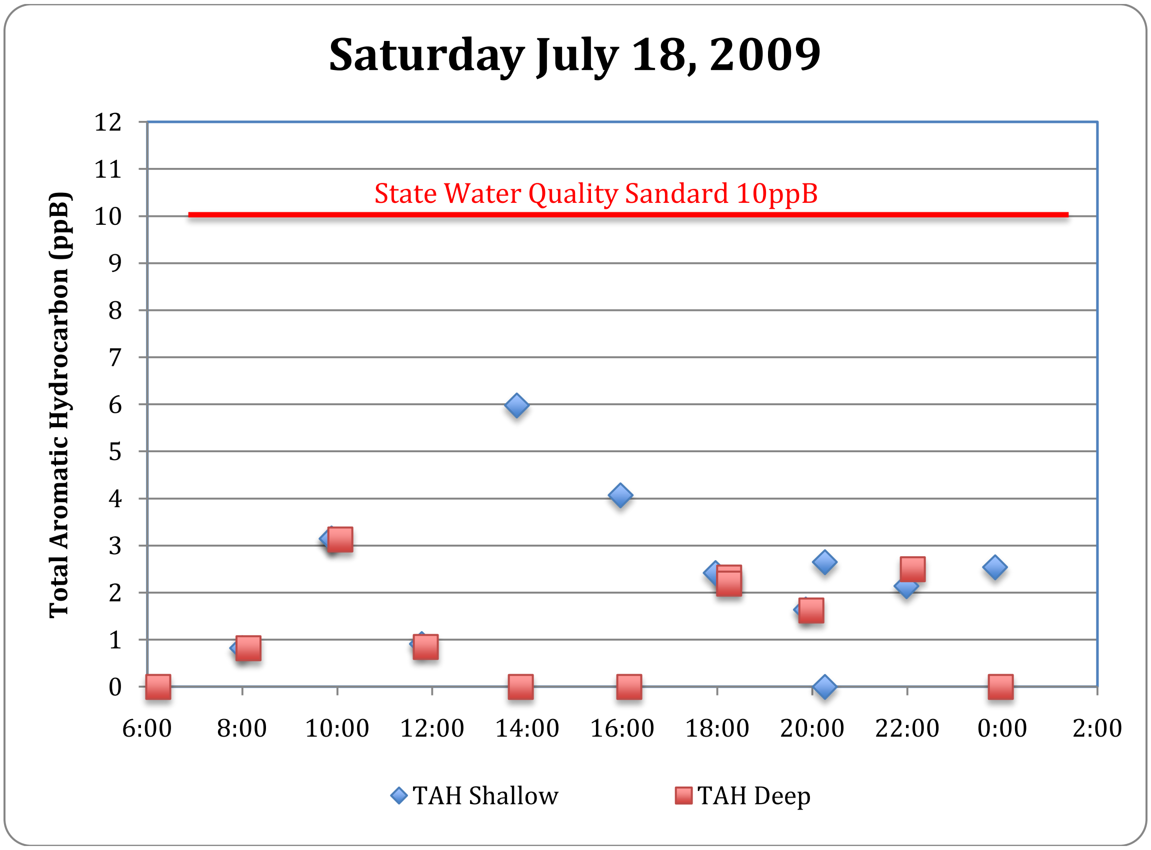

Fig. 4a Total Aromatic Hydrocarbon results for Saturday 7/18/2009

Sunday 7/19/09 TAH Chart

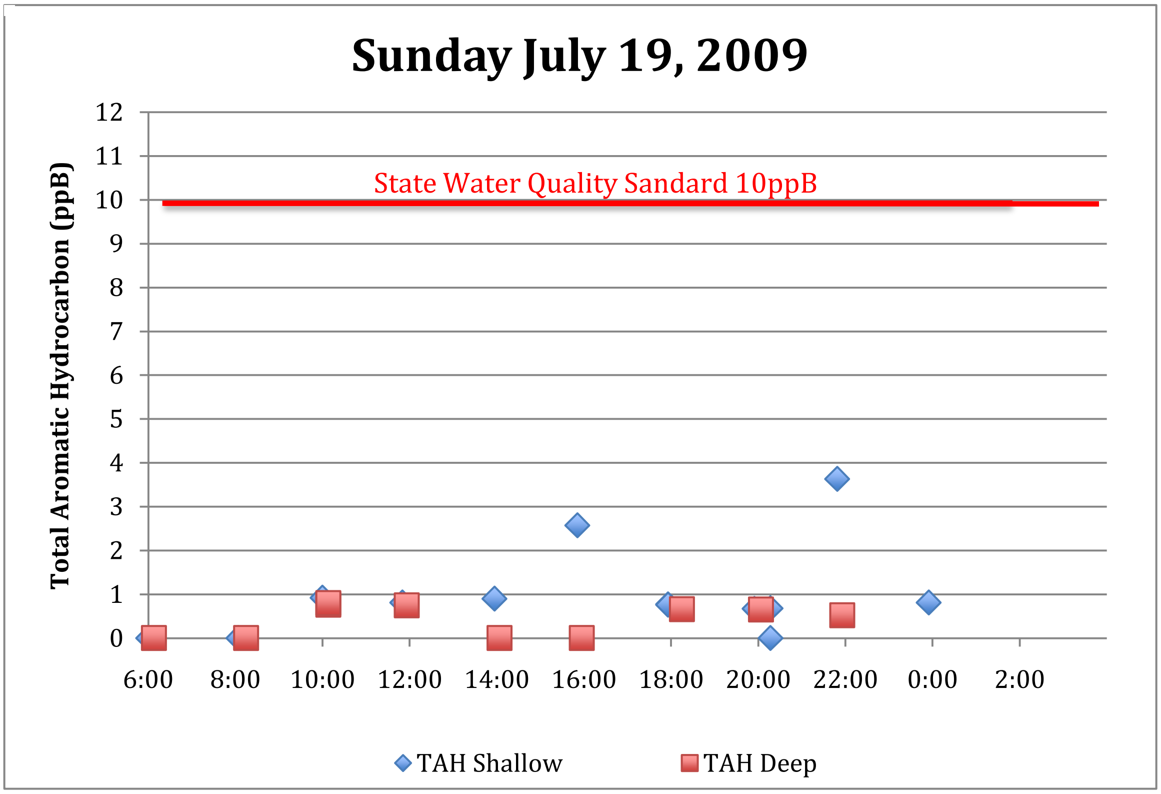

Fig. 4b Total Aromatic Hydrocarbon results for Sunday 7/19

Tuesday 7/21/09 TAH Chart

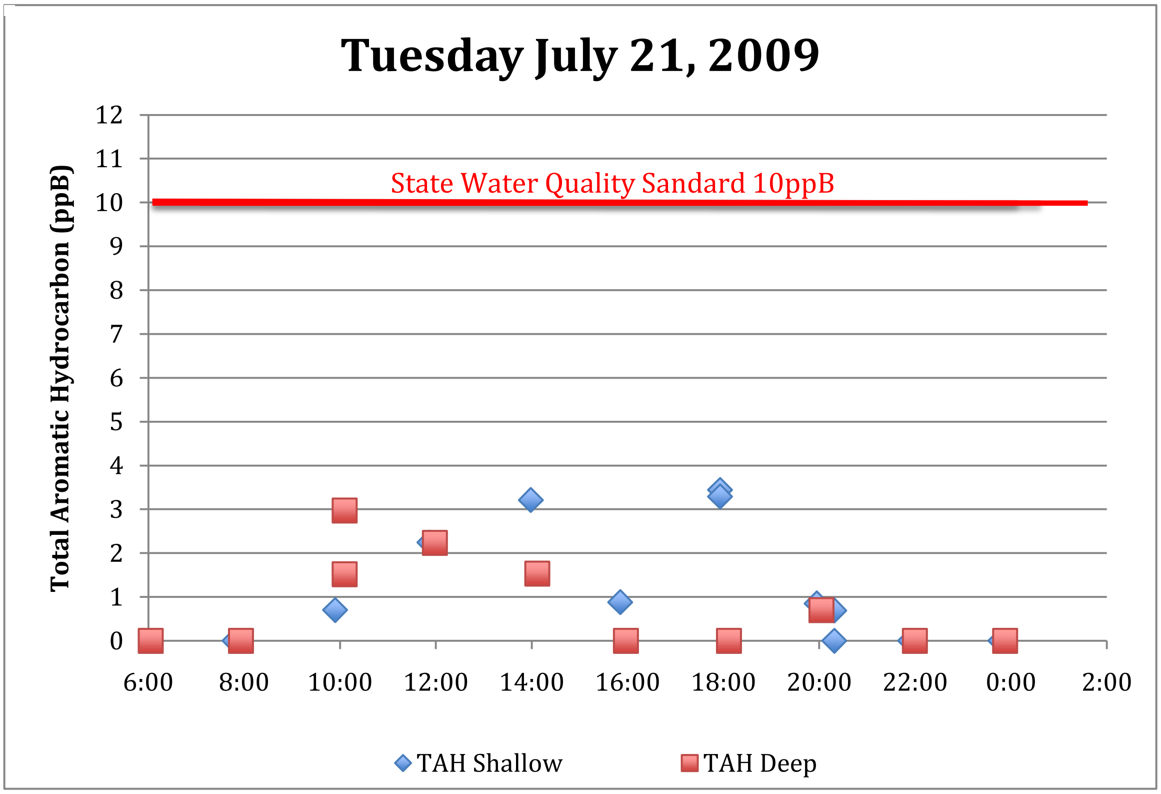

Fig. 4c Total Aromatic Hydrocarbon results Tuesday 7/21

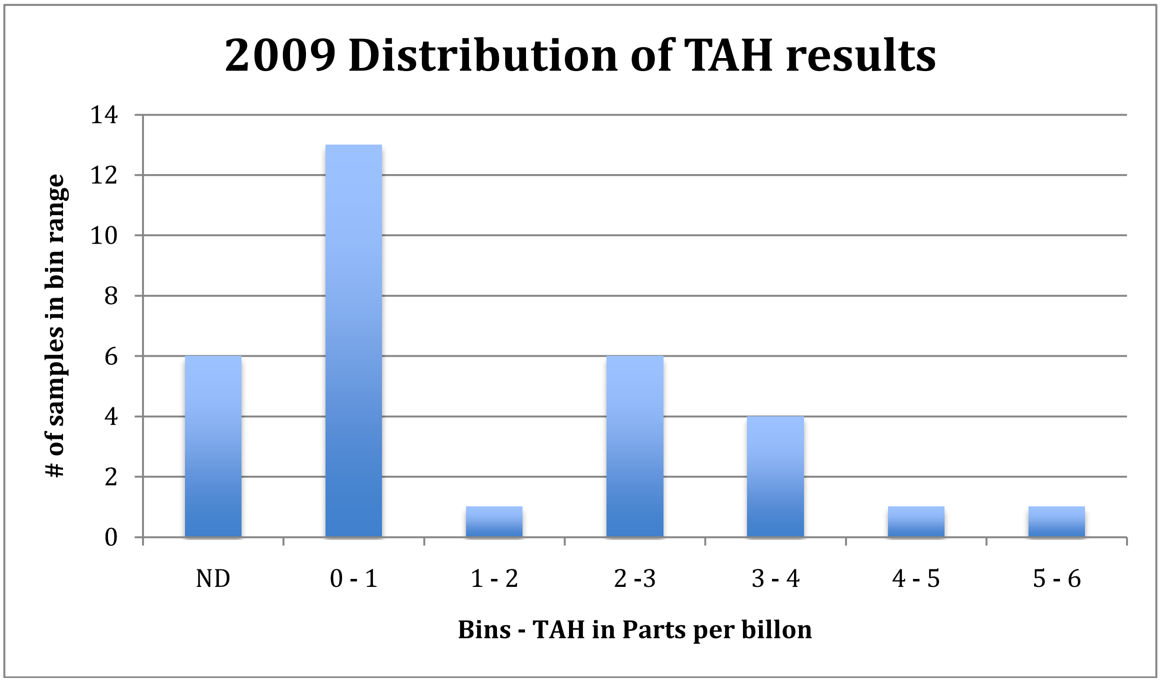

Fig. 5 Histograph illustrating the distribution of 30 samples taken 12" below the water surface at River Mile 1.5. Note one observation between 5 and 6 Parts Per Billion (ppB), one observation between 4 and 5 ppB. Remaining samples were less than 4ppB.

Field Measurements

The complete set of in-situ field measurements for turbidity, pH, specific conductivity, dissolved oxygen and temperature is included in Appendix B. There were no unusual circumstances or difficulties collecting field observations. Pre- and post-monitoring calibrations of the hydrolab MS-5 multisonde were completed in accordance with the manufacturer's instructions and consistent with the QAPP. A brief discussion of key observations of pH, temperature, Specific conductivity and turbidity are summarized below.

The field observations are important to understanding the environmental conditions present when the TAH grab samples were collected. The field parameters are also important because they add to the available pool of data for those cases where a background level or a natural condition may be of future importance, such as turbidity. Finally the three of the five field measurements are relevant to established water quality standards. Of the three parameters that can be compared to established standards (Temperature, Dissolved Oxygen and pH), only temperature exceeded state standards during the sampling period.

	Turbidity (NTU)	pH (std. units)	SpCond (µS/cm)	D.O. (mg/L)	Temp (°C)
max	443	7.09	73.1	8.6	16.4
min	18	8.08	38,000	10.1	13.0
Standard Achieved	Unknown, relative Natural Conditions	yes	N/A	yes	no

Table 4 – *In-situ range of parameters, with notation of standards achieved*

Turbidity

Measured and reported in nephelometric turbidity units (NTU).

Turbidity is not an indicator that helps interpret TAH data nor is it an indicator of other physical environmental conditions that might influence TAH. However, it is of interest as a stand-alone metric. No unexpected or unusual readings were observed. The highest observed value was recorded during the deep sample on Tuesday 7/21/09 corresponding to the largest incoming tide of the sampling period. The lowest turbidity reading occurred on Saturday 7/18/09 near the afternoon high slack tide.

Relative to State Water Quality Standards, turbidity is tied to natural conditions and those conditions have not yet been established, so no comparison can be made. The 2009 turbidity data may be useful in adding to the existing set of turbidity data if and when natural conditions for turbidity are contemplated for the lower Kenai River.

pH

Measured and reported in standard pH units.

pH is not an indicator that helps interpret TAH data. It is an indicator of other physical environmental conditions that might influence TAH and it is of interest as a stand-alone metric. No unexpected or unusual readings were observed in 2009. Higher than expected readings were documented in previous years.

pH exhibited daily variation that appeared to be inversely related to tidal stage on Saturday, and nearly in phase with the tide on Tuesday. The pattern of temporal variation with tide was not consistent between the shallow and deep measurements. It is unclear what mechanisms contribute to the observed daily variation of pH.

Relative to State Water Quality Standards, all pH measurements were within the standards and at reasonably expected values.

Specific Conductivity

Measured in mircoSiemens / centimeter (μS/cm)

For deep-water observations, specific conductivity (SpC) had a strong positive relationship to the tide stage (i.e. high tide, high SpC). For shallow observations a diurnal effect is present, but to varying degrees, it is out of phase with the tide. Observations at depth are often significantly higher than the equivalent shallow observations as would be expected with the intruding saltwater wedge that maintains its presence during flooding tide and partially into the ebb tide. The values of SpC were very similar between shallow and deep samples during the latter half of the ebb tide and beginning portion of the flood tide.

The primary purpose of monitoring SpC in this effort was to observe the degree of mixing between Cook Inlet and the Kenai River for a given set of paired shallow and deep-water samples. In general the intruding saltwater wedge was established at the sampling site within 2 to 3 hours after low slack tide. The stratification between freshwater and saltwater maintained its presence during the flooding tide until 2 to 4 hours after high slack tide. During this time and based on the SpC, there appeared to be little mixing between the overriding Kenai River freshwater and the underlying saltwater wedge.

In contrast, 2 to 4 hours after the high tide crest, the ebbing water appeared to become fully mixed and the outgoing waters stayed mixed until 2 to 3 hours after low tide. This is a complex relationship that depends on the flow volume of the

Kenai River and magnitude of the tidal deflection and would be expected to be different under differing flow regimes.

Using the SpC measurements to compare to the corresponding TAH concentration is insightful. There was generally good agreement between the shallow and deep TAH concentrations when the water column was mixed as measured by the SpC. However, when the saltwater wedge was well established, the deep samples contained lower levels of TAH and the overriding fresh water contained higher concentrations of TAH.

Specific Conductivity does not have a State Water Quality Standards. SpC was used as an indicator of the relative abundance of marine water at the time and location of the TAH sample. All values were within the expected range based on previous years sampling with the same equipment.

Dissolved Oxygen

Measured and reported in milligrams / Liter (mg/L).

Dissolved oxygen is not an indicator that helps interpret TAH data. Unusual or unexpected readings could be helpful in identifying other physical environmental conditions that might influence TAH. No such unusual or unexpected readings were observed.

For both deep and shallow dissolved oxygen (DO) had an inverse relationship with the tide stage (i.e. low DO levels were observed during high tidal stage). The observed range is relatively small and within State Water Quality Standards

Temperature

Measured and reported on the Celsius scale °C

Temperature is not an indicator that helps interpret TAH data nor is it an indicator of other physical environmental conditions that might influence TAH. However, it is of interest as a stand-alone metric.

During the three sampling days that spanned the four-day study period, all temperature observations exceeded the State Water Quality Standards (18 AAC 70) of 13° C for spawning areas and egg & fry incubation. For the majority of Saturday 7/18/09, from the first sample collected at 06:00, through 20:00, the standard of 15° C for salmon migration routes was also exceeded for all shallow water samples. Where conductivity suggests the sampling was occurring in the stratified saltwater intrusion layer, temperatures were between 13 and 15°C. When conductivity readings were similar between shallow-water and deep-water samples, the temperature readings were also similar, further suggesting the water column was well mixed.

For both shallow and deep measurements, water temperature dropped below 15°C in the evening of 7/18 and did not rise above 15°C for the remainder of the study period. The drop in water temperature is attributed to a drop in air temperature and increased wind velocity that mixes source water in two large lakes, Skilak and Kenai Lakes.

Daily Temperature Observations: Shallow water (12 inches below surface):

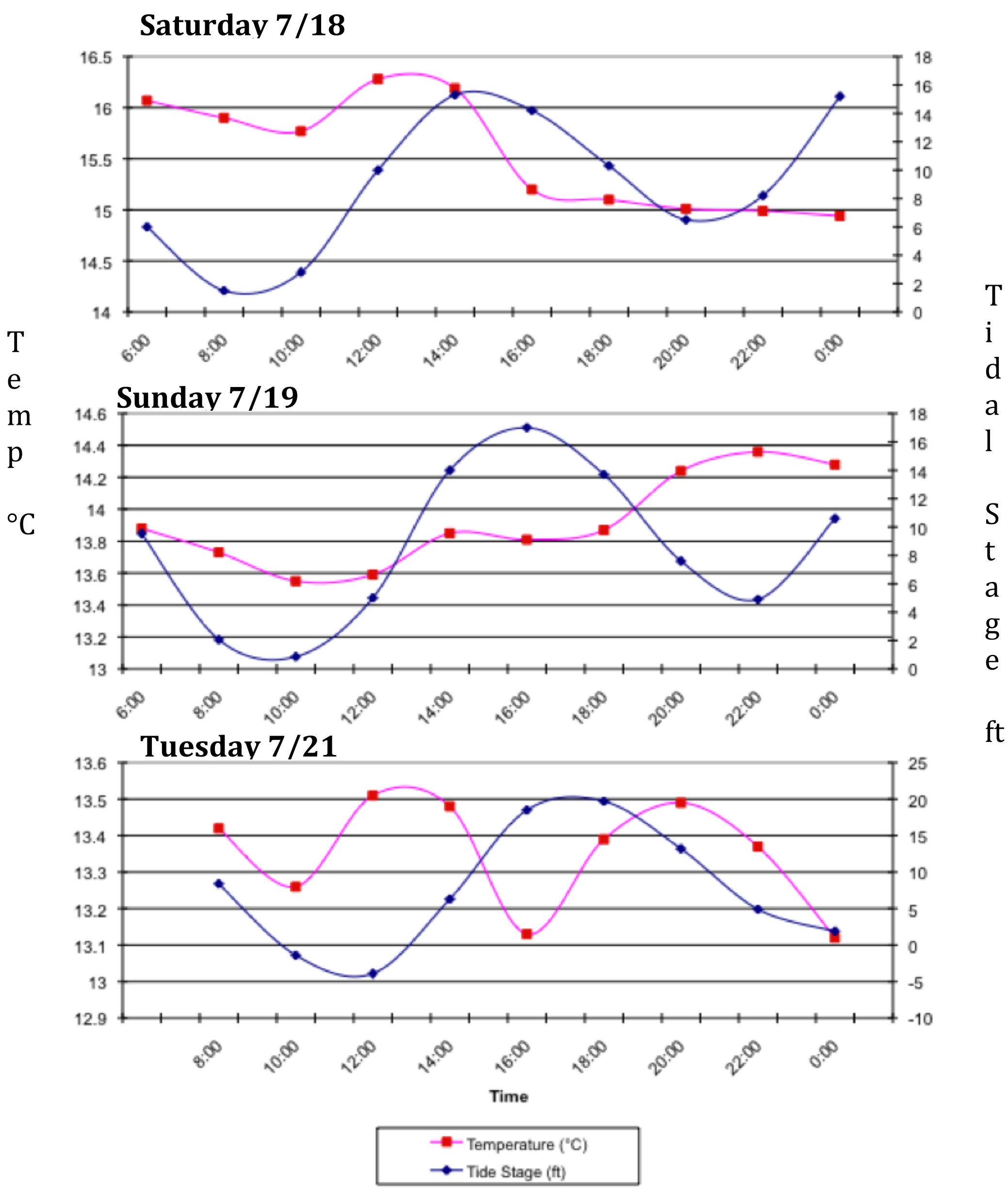

Fig. 6 *Shallow water temperature results tidal stage tidal stage*

Quality Assurance

All samples were collected in accordance with the sampling plan. This includes samples for TAH, aerial boat counts, on-the-water estimates of motor type (compliant and non-compliant), and field parameters. All data collected was considered valid, included in the data tables, and considered in the analysis.

Ten percent of the TAH samples were duplicated and submitted to the lab. Duplicates were blind to the lab and the Relative Percent Differences (RPD) were calculated for all six samples. Five of the 6 duplicate samples agreed within single digit percentage, despite having analytical values near the practical quantification limits. Only one of the six duplicates was significantly different from the regular sample. The discrepancy of the sixth duplicate is due to the detection of two compounds in the regular sample, and four compounds in the duplicate. Benzene and Ethylbenzene were reported in the duplicate sample near the practical quantification limit, but were not reported in the regular sample. (Table 5)

Reviewing all data collected since 1991, Toluene has consistently been the most abundant of all compounds that comprise TAH. These compounds include the suite commonly referred to as BTEX. The compounds are Benzene, Toluene, Ethylbenzene and Xylene respectively. Each of the BTEX constituents is reported from the lab individually. In addition, xylene has three isomers, the meta (1,3) and para (1,4) isomers are combined and reported as single (m,p) value. The third xylene isomer is the 1,2 ortho (O) isomer and is reported as a separate value.

For all samples collected in 2009, Toluene was the most abundant compound. In samples near the detection limits, it is frequently the only compound reported. Toluene is expected to be the most abundant constituent when comparing all BTEX compounds against the percentage of BTEX found in locally manufactured gasoline. If future work is considered in analyzing Kenai River datasets, it would be very valuable to compare the ratios of the BTEX constituents, as there are some unexplained differences in the expected ratio of observed Toluene/ TAH during some previous sampling events.

Events	TAH constituents Present	Normal (ppB)	Field replicate (ppB)	RPD (dimensionless)
1 Sat. 10:00 Shallow	(T, $X_{(m,p)}$, B)	3.15	3.15	0.0%
2 Sun. 18:00 Shallow	(T)	0.77	0.76	1.3%
3 Tues. 18:00 Deep	(T, $X_{(m,p)}$, B)	3.44	3.29	4.5%
4 Sat. 18:00 Deep	(T, $X_{(m,p)}$, B)	2.19	2.32	-5.8%
5 Sun. 10:00 Deep	(T)	0.8	0.76	5.1%
6 Tues. 10:00 Deep	Normal (T, $X_{(m,p)}$) Replicate - (T, $X_{(m,p)}$, E, B)	1.52	2.97	-64.6%
6* Toluene only	T only	0.99	1.1	-10.5%

Table 5 – *Illustrates the reproducibility of replicate field samples. While the relative percent difference is high in one sample, the magnitude of the differences are considered to be minimal, particularly if examining only the most abundant Toluene constituent.*

Conclusions

As work to characterize hydrocarbon pollution from outboard motors in the Kenai River has progressed in the past decade, it is clear that a significant reduction in the TAH loading has occurred since 2007, and the reduction coincides with regulations requiring cleaner outboard technology. Ignoring all potential variables that contribute to TAH concentrations and focusing solely on the observed TAH results, the Kenai River only met the TAH standard two years out of eleven years it has been monitored. The attainment of the State of Alaska's TAH standard occurred only after the enactment of cleaner motor regulations. Invoking the clean motor regulations has yielded results that are consistent with other studies across the country (Lico, 2004).

Isolating and quantifying the reductions of hydrocarbon pollution that resulted solely from the clean motor regulations is more complex. Introducing other independent variables and adjusting the 2009 TAH results to allow for predicted estimates is instructive to aid in evaluating all possible causes of improved water quality other than clean motor regulations. In addition to the type of outboard motors used, at least three other significant variables are thought to contribute to the concentration of TAH, including (1) the volume of the receiving water available for dilution of the TAH, (2) the total number of boats as a source of pollutant, and

(3) the distribution or concentration of the boats on the river. Other factors also changed between 2007 and 2009, including the tidal fluctuation and the maximum horsepower allowed on the Kenai River. It is unknown how these latter two changes may have affected TAH pollution.

Influence of Flow Volume

For a fixed amount of TAH emission into the river, the resulting concentration will depend on the amount of water available for dilution. The USGS has an established discharge-monitoring site approximately 19 river miles upstream of the TAH sampling site. Flow has been recorded at this location in the Kenai River for a 45-year period of record. These flow volumes are used as the best available basis to make statistical inferences about Kenai River discharge and the relationship to TAH concentrations.

For 7/18/09, the mean flow based on 45 years of record is 14,000 cubic feet/ second (cfs). During this study on 7/18/09, the flow was above average with a reading of 15,700 (near the 80^{th} percentile of 15,800). Compared to mean flow for this date, there was 12% more receiving water available for TAH dilution on the 2009 sampling date when a maximum TAH value of 6.0 ppB was observed. Adjusting for the 12% above mean flow and assuming there is a 1:1 relationship between river flow volume and the concentration of TAH based on dilution, the expected TAH value under mean flow conditions would also be expected to increase by 12%, resulting in 6.7ppB. This is a simple inverse ratio equation, to solve for the predicted concentration at various river discharge flow volumes (i.e. double the flow halves the concentration and vice-versa):

$$(1)\quad predicted\_concentration = observed\_concentration \times \frac{observed\_flow}{percentile\_flow}$$

The following table illustrates the expected concentrations at various flow levels using the maximum 2009 TAH value and 2009 observed flow as a basis for anticipated TAH maximums under various flow conditions. Holding all other variables constant to conditions present in 2009, the TAH water quality standard would be exceeded at flows less than 9500 cfs, a low flow condition that has not been observed during the last two weeks of July in 45 years of record.

Flow Percentile Statistic for July 18th	Min.	5^{th}	10^{th}	20^{th}	mean	80^{th}	90^{th}	95^{th}	Max.
Flow as kcfs	9,86	10,8	11,6	12,5	14,0	15,8	16,7	18,5	20,0
TAH ppB adjusted for flow	9.6	8.7	8.1	7.5	6.7	6.0	5.6	5.1	4.7

Table 6 – *Summary table of predicted 2009 maximum TAH concentration under the full range of recorded Kenai River flow conditions on record for July 18^{th}.*

Boat Numbers

In comparison to all years when hydrocarbons have been measured in the lower Kenai River, 2009 had the lowest annual maximum value for TAH recorded of 6.0ppB (see table 1). The 2009 peak TAH value of 6.0ppB corresponds to the highest aerial boat-count on record which documented 765 total in-river boats in operation in a single pass of the lower 50 miles of the Kenai River. The second highest aerial boat count was 720 total boats in 2007, prior to the enactment of the clean motor requirements. The 2007 count corresponded with a maximum TAH concentration of 22.7 ppB at a river flow of 11,000cfs. From table 6, 11,000 cfs is near the 10^{th} percentile and as describe in the preceding flow section, the expected value based on the 2009 post clean motor regulation would have been 8.6 ppB.

Without making adjustments to flow and boat counts, the reduction in peak TAH concentrations between 2007 and 2009 equates to more than a 73% decrease. Both increased flow and reduced number of boats as variables would have proportionally and independently reduced the TAH concentration between 2007 and 2009, independent of the clean motor regulations.

Using a simple ratio with a positive correlation between TAH concentration and the number of boats and the inverse relationship with flow, based on the 2007 maximum TAH, the anticipated maximum TAH value for 2009 would have been predicted to be 16.7 ppB.

(2) $$p\_con = o\_con\_07 \times \left(\frac{f\_07}{f\_09}\right) \times \left(\frac{bc\_09}{bc\_07}\right)$$

Where:
p_con = predicted maximum concentration
o_con_07 = 2007 maximum observed concentration
f_07= flow during sampling 2007

f_09= flow during sampling 2009
bc_09= maximum boat count 2009
bc_07= maximum boat count 2007

Considering adjustments to boat numbers and flow, the actual value of 6.0ppB is more than 60% less than the predicted value. In the absence of any other quantifiable factors, the clean motor regulations appear to be responsible for the majority of TAH reduction.

The simple ratio estimates for the maximum TAH values, can be used to forecast future TAH concentrations as a very simple statistical model. Table 7 uses the 2009 observations of flow and maximum TAH to calculate and illustrate the amount of increased motorized traffic might be necessary to exceed state water quality standards for TAH.

Flow Percentile Statistic for July 18th	Min.	5th	10th	20th	mean	80th	90th	95th	Max.
Flow as kcfs	9,86	10,8	11,6	12,5	14,0	15,8	16,7	18,5	20,0
TAH ppB adjusted for flow	9.6	8.7	8.1	7.5	6.7	6.0	5.6	5.1	4.7
# of additional motors est. to reach 10 ppB.	36	112	177	250	372	518	591	737	859

Table 7 – rearranges *equations (1) and (2) to solve for the addition of the number of boats required reach the state established standard of 10ppB under various flow volumes.*

Boat Densities

The comparison of maximum total in-river boat counts between 2007 (720) and 2009 (765) are not significantly different, roughly 6% more were observed in operation in 2009 compared to 2007. In addition to considering the total number of boats operating in the Kenai River, the distribution of boats should also be carefully considered.

In the reach immediately upstream of the sampling transect, between river miles 1.5 and 5.0, there was a substantial increase in boat activity between 2007 and 2009. In 2007, there was a peak of 248 in-river boats operating in the 3.5 mile reach above the sampling site, and in 2009, at approximately the same time of day, there were 382 boats operating in this same reach.

The aerial boat counts from 2007 and 2009 document boat densities of 70.8 boats/ mile in 2007 increasing to 109.1 boats/ mile in 2009. Since each outboard motor is assumed to be a small point-source of pollution, the density of motors in operation is important to the accounting of TAH concentrations.

There is a positive correlation between the maximum TAH value and the maximum boat count for each day; however, this is an oversimplification of the mechanisms that contribute to the observed TAH value. It is an oversimplification because there is no consideration for the transport of TAH once it enters the flowing waters of the river. In addition to flow and the absolute number of boats, the density of boats in a given reach of river may be significant to the future management of water quality in the Kenai River. For given flow and tidal deflection, it is expected that the relationship between the maximum number of boats and the maximum expected TAH value will hold only to the degree that, on-average, the spatial distribution of boats stays relatively similar.

To illustrate why the above statement must be true, consider two hypothetical extreme cases.

<u>Case 1</u>: 500 boats are equally distributed along the 50 miles of the Kenai River from Skilak Lake to Cook Inlet. This results in a density of 10 boats per mile. The river's flow will accept this loading rate and create a concentration of TAH that will be transported to Cook Inlet over some period of time. The hydrocarbon input in the lower reaches of the river will be transported out of the river system and into the larger waterbody of Cook Inlet some time before those hydrocarbons that are input into the river tens of miles upstream.

<u>Case 2:</u>
If one takes the same 500 boats and arbitrarily places all 500 boats in a one-mile reach of the river, the net hydrocarbon load to the river will be the same as in case 1; however the density of boats per mile is now 50 times greater in the one-mile reach. The hydrocarbon loading is much more concentrated and will result in a much higher concentration of TAH in that one-mile reach and every subsequent mile below that one mile reach as the hydrocarbon load is transported to Cook Inlet. The TAH concentration in Case 2 will be lower each mile it travels downstream as it volatilizes and attenuates though eddy diffusion; however, the maximum TAH value would be expected to be much greater than in Case 1 as the higher density input continues to travel downstream.

Clean Motor Regulations

Given that the total number of boats was the highest ever recorded in 2009 and that the highest density of boats ever recorded was immediately above the River Mile 1.5 sampling site during this study, 2009 had the greatest potential for the highest volume of TAH input compared to previous years. While the potential input due to the number and distribution was the highest, the potential for the highest concentration was not at a peak because there was above average water volume, near the 80th percentile of the mean. The above average flow conditions allow for more dilution; however as previously stated, dilution alone would only account for a small fraction of the reduced concentration of TAH recorded between the pre clean motor regulations in 2007 and the TAH concentrations measured in 2008 and 2009. We can attribute some decrease in TAH concentration due to flow volumes between the 2007 and 2009 sampling years, however the observed 70+ % reduction can only be explained by the enactment and adherence to the clean motor regulations.

Year	Est. maximum daily gasoline discharged (gallons)	Total observed boats	Discharge (cfs)	Resulting max TAH (ppB)
2007	254	720	11,000	22.7
2008	67	603	14,400	6.7
2009	70	754	15,700	6.0

Table 8. *Uses the best available data from 2007-2009 to estimate the discharge of raw gasoline into the Kenai River. TAH data was adjusted to account for the full suite of BTEX constituents as follows: Toluene 42% Xylene (m,p) 26%, Benzene 14%, Xylene (o) 11%, Ethylbenzene 7%. If a TAH sample only reported Toluene in the sample, the complete adjusted BTEX value would be (T/.42). If T and X(m,p) were the only two constituents present, the adjusted BTEX value would be (T+X(m,p))/(.42+.26), etc.*

With adjustments to account for the entire suite of expected BTEX, we assume that BTEX comprises 40% of raw gasoline. The final accounting to derive the daily estimate for gallons of gasoline discharged into the Kenai River was to integrate the daily TAH readings, from 6am to the following 4am. We used a linear interpolation between sample values. For consistency, we only considered samples that were from River Mile 1.5, shallow and collected from the channel thalweg.

Recommendations

Future exceedances of the 10 ppB TAH standard are possible, but unlikely in the near future.

With the present day distribution of motorized boat activity and low flow conditions at the 20th percentile, there is still a margin of safety between the predicted maximum TAH concentrations and the 10ppB standard. The two most likely factors to change that would likely lead to exceedances of the TAH standard include: 1) changes in the type of motors operating on the Kenai River; 2) increases in the number of motorboats as shown in Table 7. The change in motor types operating in the river could occur through changes to the 2008 regulations or a reduction in compliance with the clean motor requirements. Enforcement of the regulation is a key factor in ensuring water quality standards will be met in the future. The clean motor regulations have proven to be very effective and are essential to meeting the TAH water quality standards.

If the clean motor regulations are adhered to as they were in 2008 and 2009, exceedances would likely occur under mean flow conditions with growth in the number or density of motorized boat traffic. If the density of motorized activity remain relatively constant, 1150 "compliant clean-motors" could exceed the water quality standard under mean flow conditions. This would represent a significant growth, 1150 boats would represent a 50% increase in the number of motorized boats operating in the river compared to present day activities.

To address the effects of boat density, it would be instructive to create a numerical model that more clearly and more explicitly defines the benefits that were achieved with the enactment of the clean motor regulations. Such a model would need to incorporate both the input and transport of contaminates. A better numeric model would also be useful in generating more sophisticated scenarios under which the TAH standard might be reached in the Kenai River, as well as helping to predict the benefits that might be gained in other high-use river systems were similar regulations are to be considered.

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Appendices

Appendix A – Sample Location Detail

2009 Data Tables
Three tables (1a-c) document the time and physical location of samples relative to the tide. One table for each of the three dates samples were collected in or near the thalweg of the river channel near river mile 1.5.

Table 1a – Saturday July 18th

Date	Sample ID	Time	Tide Stage	Depth Indicator	Sample Depth (ft)	Total Depth (ft)
7/18/09	TAH_09_1S	6:04	6' ebb	s	1	8
7/18/09	TAH_09_2D	6:14	6' ebb	d	5.5*	7.7
7/18/09	TAH_09_3S	8:00	1.5' ebb	s	1	8.3
7/18/09	TAH_09_4D	8:08	1.5' ebb	d	5	7-9
7/18/09	TAH_09_5S	9:53	2.8' flood	s	1	8
7/18/09	**TAH_09_6S**	9:53	2.8' flood	sx	1	8
7/18/09	TAH_09_7D	10:04	2.8' flood	d	5	8.5
7/18/09	TAH_09_8S	11:47	10' flood	s	1	16
7/18/09	TAH_09_9D	11:52	10' flood	d	12.5	16
7/18/09	TAH_09_10S	13:47	15.3' flood	s	1	20
7/18/09	TAH_09_11D	13:52	15.3' flood	d	16	20
7/18/09	TAH_09_12S	15:58	14.2' ebb	s	1	20
7/18/09	TAH_09_13D	16:09	14.2' ebb	d	16	20
7/18/09	TAH_09_14S	17:58	10.3' ebb	s	1	16
7/18/09	TAH_09_15D	18:15	10.3' ebb	d	12	15
7/18/09	**TAH_09_16D**	18:15	10.3' ebb	dx	12	15
7/18/09	TAH_09_17S	19:52	6.5' ebb	s	1	14
7/18/09	TAH_09_18D	19:59	6.5' ebb	d	11.2	14
7/18/09	TAH_09_19MS	20:16	6.5' ebb	ms	1	14
7/18/09	***TAH_09_20MSX***	20:16	6.5' ebb	msx	1	14
7/18/09	TAH_09_21S	21:59	8.2' flood	s	1	16
7/18/09	TAH_09_22D	22:07	8.2' flood	d	12.8	16
7/18/09	TAH_09_23S	23:51	15.2' flood	s	1	22
7/18/09	TAH_09_24D	23:58	15.2' flood	d	17.6	22

Table 1a – Saturday July 18th
*Note on 7/18/09 6am deep sample the sample depth was recorded on field sheets at 1.5ft but confirmed to 5.5 ft (1.5ft off the bottom).
Bolded lines indicate QA samples that were taken.
Italicized matrix spike samples.

Table 1b – Sunday July 19th

Date	Sample ID	Time	Tide Stage	Depth Indicator	Sample Depth (ft)	Total Depth (ft)
7/19/09	TAH_09_25S	6:00	9.54' ebb	s	1	14
7/19/09	TAH_09_26D	6:08	9.54' ebb	d	10	14
7/19/09	TAH_09_27S	8:04	2.06' ebb	s	1	9
7/19/09	TAH_09_28D	8:15	2.06' ebb	d	6	9
7/19/09	TAH_09_29S	10:00	-0.86' flood	s	1	8
7/19/09	TAH_09_30D	10:08	-0.86' flood	d	5	7.5
7/19/09	**TAH_09_31D**	10:08	-0.86' flood	dx	5	7.5
7/19/09	TAH_09_32S	11:50	5.0' flood	s	1	9.5
7/19/09	TAH_09_33D	11:56	5.0' flood	d	8	9.5
7/19/09	TAH_09_34S	13:57	14.4' flood	s	1	19
7/19/09	TAH_09_35D	14:04	14.0' flood	d	16	19
7/19/09	TAH_09_36S	15:51	16.9' ebb	s	1	22
7/19/09	TAH_09_37D	15:57	16.9' ebb	d	17.6	22
7/19/09	TAH_09_38S	17:56	13.7' ebb	s	1	17
7/19/09	**TAH_09_39S**	17:56	13.7' ebb	sx	1	17
7/19/09	TAH_09_40D	18:15	13.7' ebb	d	13.6	17
7/19/09	TAH_09_41S	19:55	7.6' ebb	s	1	16
7/19/09	TAH_09_42D	20:04	7.6' ebb	d	11.8	14
7/19/09	TAH_09_43MS	20:17	7.6' ebb	ms	1	12
7/19/09	***TAH_09_44MSX***	20:17	7.6' ebb	msx	1	12
7/19/09	TAH_09_45S	21:49	4.9' low	s	1	12
7/19/09	TAH_09_46D	21:56	4.9' low	d	9.6	12
7/19/09	TAH_09_47S	23:55	10.6' flood	s	1	19
7/20/09	TAH_09_48D	0:02	10.6' flood	d	15.2	19

Table 1b – Sunday July 19th

Bolded sample IDs indicate QA samples that were taken.
Italicized matrix spike samples.

Table 1c – Sunday July 18th

Date	Sample ID	Time	Tide Stage	Depth Indicator	Sample Depth (ft)	Total Depth (ft)
7/21/09	TAH_09_49S	5:55	18.2' ebb	s	1	18
7/21/09	TAH_09_50D	6:03	18.2' ebb	d	15	18
7/21/09	TAH_09_51S	7:48	8.4' ebb	s	1	12
7/21/09	TAH_09_52D	7:56	8.4' ebb	d	10	12
7/21/09	TAH_09_53S	9:54	-1.4' ebb	s	1	7.5
7/21/09	TAH_09_54D	10:06	-1.4' ebb	d	5	7.5
7/21/09	**TAH_09_55D**	10:06	-1.4' ebb	dx	5	7.5
7/21/09	TAH_09_56S	11:52	-3.9' flood	s	1	6
7/21/09	TAH_09_57D	11:59	-3.9' flood	d	4.5	6
7/21/09	TAH_09_58S	13:59	6.3' flood	s	1	15
7/21/09	TAH_09_59D	14:07	6.3' flood	d	12	15
7/21/09	TAH_09_60S	15:51	18.5' flood	s	1	24
7/21/09	TAH_09_61D	15:58	18.5' flood	d	20	25
7/21/09	TAH_09_62S	17:56	19.7' ebb	s	1	25
7/21/09	**TAH_09_63S**	17:56	19.7' ebb	sx	1	25
7/21/09	TAH_09_64D	18:07	19.7' ebb	d	20	25
7/21/09	TAH_09_65S	19:57	13.2' ebb	s	1	18
7/21/09	TAH_09_66D	20:03	13.2' ebb	d	14.1	18
7/21/09	TAH_09_67MS	20:19	13.2' ebb	ms	1	16
7/21/09	***TAH_09_68MSX***	20:19	13.2' ebb	msx	1	16
7/21/09	TAH_09_69S	21:54	4.9' ebb	s	1	12
7/21/09	TAH_09_70D	22:00	4.9' ebb	d	8.8	11
7/21/09	TAH_09_71S	23:47	1.9' flood	s	1	9
7/21/09	TAH_09_72D	23:53	1.9' flood	d	7.2	9

Table 1c – Sunday July 18th

Bolded sample IDs indicate QA samples that were taken.
Italicized matrix spike samples.

Appendix B - In-situ Field Observations

The following three tables (2a-c) document the in-situ field parameters of the water conditions where and when the hydrocarbon grab samples were collected. One table for each of the three dates samples were collected in or near the thalweg of the river channel near river mile 1.5. Sample locations details may be cross-referenced with the corresponding sample ID in Appendix A tables.

Date	Sample ID	Time	Conductivity (µS/cm)	DO (mg/L)	pH (Std units)	Temperature (°C)	Turbidity (NTU)
7/18/09	TAH_09_1S	6:04	86.8	9.48	7.57	***16.07***	141.3
7/18/09	TAH_09_2D	6:14	88.8	9.36	7.54	***16.1***	135.5
7/18/09	TAH_09_3S	8:00	84.3	9.28	7.51	***15.9***	186.1
7/18/09	TAH_09_4D	8:08	84.3	9.27	7.45	***15.88***	160.3
7/18/09	TAH_09_5S	9:53	78	9.31	7.38	***15.77***	154.9
7/18/09	TAH_09_6S	9:53	78	9.31	7.38	***15.77***	154.9
7/18/09	TAH_09_7D	10:04	79.1	9.42	7.39	***15.77***	161.5
7/18/09	TAH_09_8S	11:47	254.1	9.17	7.3	***16.28***	208.4
7/18/09	TAH_09_9D	11:52	300.6	9.17	7.42	***16.37***	234.8
7/18/09	TAH_09_10S	13:47	1053	9.05	7.32	***16.19***	143
7/18/09	TAH_09_11D	13:52	33000	8.87	7.62	*14.09*	28
7/18/09	TAH_09_12S	15:58	353.1	9.38	7.54	***15.2***	56.8
7/18/09	TAH_09_13D	16:09	37654	8.73	7.53	*13.96*	18
7/18/09	TAH_09_14S	17:58	2900	9.57	7.58	***15.1***	50.3
7/18/09	TAH_09_15D	18:15	3694	9.48	7.44	***15.06***	91.3
7/18/09	TAH_09_16D	18:15	3694	9.48	7.44	***15.06***	91.3
7/18/09	TAH_09_17S	19:52	79.4	9.7	7.59	***15.01***	109.6
7/18/09	TAH_09_18D	19:59	81.8	9.68	7.46	***15***	156.2
7/18/09	TAH_09_19MS	20:16	76.3	9.68	7.4	***15***	109
7/18/09	TAH_09_20MSX	20:16	76.3	9.68	7.4	***15***	109
7/18/09	TAH_09_21S	21:59	93.5	9.63	7.47	*14.99*	120.5
7/18/09	TAH_09_22D	22:07	92.6	9.59	7.43	*14.99*	118
7/18/09	TAH_09_23S	23:51	370	9.64	7.48	*14.94*	60.7
7/18/09	TAH_09_24D	23:58	36700	8.74	7.51	*13.67*	34.7

Table 2 a – Saturday

Date	Sample ID	Time	Conductivity (µS/cm)	DO (mg/L)	pH (Std units)	Temperature (°C)	Turbidity (NTU)
7/19/09	TAH_09_25S	6:00	543	9.84	7.64	*13.88*	84
7/19/09	TAH_09_26D	6:08	352	9.79	7.6	*13.88*	113.9
7/19/09	TAH_09_27S	8:04	79.1	9.77	7.57	*13.73*	174.5
7/19/09	TAH_09_28D	8:15	81.6	9.8	7.51	*13.72*	189.2
7/19/09	TAH_09_29S	10:00	79.5	9.83	7.45	*13.55*	190
7/19/09	TAH_09_30D	10:08	78.5	9.9	7.43	*13.54*	179
7/19/09	TAH_09_31D	10:08	78.5	9.9	7.43	*13.54*	179
7/19/09	TAH_09_32S	11:50	80.5	9.77	7.41	*13.59*	121
7/19/09	TAH_09_33D	11:56	81.3	9.74	7.38	*13.58*	120
7/19/09	TAH_09_34S	13:57	1684	9.6	7.25	*13.85*	127
7/19/09	TAH_09_35D	14:04	36900	8.82	7.73	*13.52*	62.7
7/19/09	TAH_09_36S	15:51	695.8	9.61	7.8	*13.81*	138
7/19/09	TAH_09_37D	15:57	37997	8.59	7.43	*13.55*	25.1
7/19/09	TAH_09_38S	17:56	998	9.8	7.51	*13.87*	43.7
7/19/09	TAH_09_39S	17:56	998	9.8	7.51	*13.87*	43.7
7/19/09	TAH_09_40D	18:15	6213	9.58	7.35	*13.83*	96.4
7/19/09	TAH_09_41S	19:55	80.6	9.81	7.64	*14.24*	124
7/19/09	TAH_09_42D	20:04	87.4	9.78	7.55	*14.6*	129
7/19/09	TAH_09_43MS	20:17	78.7	9.82	7.56	*14.28*	119.8
7/19/09	TAH_09_44MSX	20:17	78.7	9.82	7.56	*14.28*	119.8
7/19/09	TAH_09_45S	21:49	73.1	9.8	7.48	*14.36*	91.9
7/19/09	TAH_09_46D	21:56	74	9.78	7.5	*14.36*	101.4
7/19/09	TAH_09_47S	23:55	207	9.77	7.55	*14.28*	74.4
7/20/09	TAH_09_48D	0:02	26000	9	7.33	*13.6*	93

Table 2b – Sunday

Date	Sample ID	Time	Conductivity (µS/cm)	DO (mg/L)	pH (Std units)	Temperature (°C)	Turbidity (NTU)
7/21/09	TAH_09_49S	5:55	16200	9.68	7.09	*13.78*	76.3
7/21/09	TAH_09_50D	6:03	28216	8.91	7.44	*13.36*	274.5
7/21/09	TAH_09_51S	7:48	89.4	9.97	8.08	*13.42*	93.6
7/21/09	TAH_09_52D	7:56	91.7	10.1	7.87	*13.42*	150.8
7/21/09	TAH_09_53S	9:54	82.9	9.78	7.59	*13.26*	232.8
7/21/09	TAH_09_54D	10:06	82.3	9.87	7.57	*13.26*	242.8
7/21/09	TAH_09_55D	10:06	82.3	9.87	7.57	*13.26*	242.8
7/21/09	TAH_09_56S	11:52	81.1	9.84	7.48	*13.51*	180.2
7/21/09	TAH_09_57D	11:59	82.2	9.82	7.45	*13.52*	191
7/21/09	TAH_09_58S	13:59	314.5	9.77	7.46	*13.48*	330.4
7/21/09	TAH_09_59D	14:07	295.1	9.81	7.48	*13.47*	443
7/21/09	TAH_09_60S	15:51	28150	8.86	7.73	*13.13*	41.4
7/21/09	TAH_09_61D	15:58	37460	8.58	7.79	*13.05*	128
7/21/09	TAH_09_62S	17:56	3800	9.58	8.03	*13.39*	115.8
7/21/09	TAH_09_63S	17:56	3800	9.58	8.03	*13.39*	115.8
7/21/09	TAH_09_64D	18:07	36650	8.79	7.6	*13.04*	29.9
7/21/09	TAH_09_65S	19:57	3400	9.66	7.77	*13.49*	60
7/21/09	TAH_09_66D	20:03	7000	9.52	7.56	*13.45*	238
7/21/09	TAH_09_67MS	20:19	2030	9.75	7.74	*13.49*	126
7/21/09	TAH_09_68MSX	20:19	2030	9.75	7.74	*13.49*	126
7/21/09	TAH_09_69S	21:54	80.9	9.86	7.89	*13.37*	155
7/21/09	TAH_09_70D	22:00	84.1	9.77	7.67	*13.37*	200
7/21/09	TAH_09_71S	23:47	77.5	9.82	7.62	*13.12*	137.3
7/21/09	TAH_09_72D	23:53	78.7	9.8	7.55	*13.12*	144

Table 2c – Tuesday

Appendix C - Total Aromatic Hydrocarbons Analytical Results

Three tables (3a-c) document the Total Aromatic Hydrocarbon (TAH) concentrations, by compound constituents. One table for each of the three dates samples were collected in or near the thalweg of the river channel near river mile 1.5.

Date	Sample ID	Time	Benzene (ug/L)	Ethylbenzene (ug/L)	m-, p-Xylene (ug/L)	o-Xylene (ug/L)	Toluene (ug/L)	Total BTEX (ug/L)
7/18/09	TAH_09_1S	6:04	ND	ND	ND	ND	ND	ND
7/18/09	TAH_09_2D	6:14	ND	ND	ND	ND	ND	ND
7/18/09	TAH_09_3S	8:00	ND	ND	ND	ND	0.82	0.82
7/18/09	TAH_09_4D	8:08	ND	ND	ND	ND	0.82	0.82
7/18/09	TAH_09_5S	9:53	0.7	ND	0.85	ND	1.6	3.15
7/18/09	TAH_09_6S	9:53	0.7	ND	0.85	ND	1.6	3.15
7/18/09	TAH_09_7D	10:04	0.76	ND	0.77	ND	1.6	3.13
7/18/09	TAH_09_8S	11:47	ND	ND	ND	ND	0.91	0.91
7/18/09	TAH_09_9D	11:52	ND	ND	ND	ND	0.85	0.85
7/18/09	TAH_09_10S	13:47	1.2	ND	1.4	0.58	2.8	5.98
7/18/09	TAH_09_11D	13:52	ND	ND	ND	ND	ND	ND
7/18/09	TAH_09_12S	15:58	0.97	ND	1	ND	2.1	4.07
7/18/09	TAH_09_13D	16:09	ND	ND	ND	ND	ND	ND
7/18/09	TAH_09_14S	17:58	0.6	ND	0.62	ND	1.2	2.42
7/18/09	TAH_09_15D	18:15	0.53	ND	0.56	ND	1.1	2.19
7/18/09	TAH_09_16D	18:15	0.54	ND	0.58	ND	1.2	2.32
7/18/09	TAH_09_17S	19:52	ND	ND	0.54	ND	1.1	1.64
7/18/09	TAH_09_18D	19:59	ND	ND	0.52	ND	1.1	1.62
7/18/09	TAH_09_19MS	20:16	0.61	ND	0.64	ND	1.4	2.65
7/18/09	TAH_09_20MSX	20:16	ND	ND	ND	ND	ND	ND
7/18/09	TAH_09_21S	21:59	0.64	ND	ND	ND	1.5	2.14
7/18/09	TAH_09_22D	22:07	0.57	ND	0.63	ND	1.3	2.5
7/18/09	TAH_09_23S	23:51	0.57	ND	0.67	ND	1.3	2.54
7/18/09	TAH_09_24D	23:58	ND	ND	ND	ND	ND	ND

Table 3a *TAH results from 7/18/09 River Mile 1.5*

Date	Sample ID	Time	Benzene (ug/L)	Ethylbenzene (ug/L)	m-, p-Xylene (ug/L)	o-Xylene (ug/L)	Toluene (ug/L)	Total BTEX (ug/L)
7/19/09	TAH_09_25S	6:00	ND	ND	ND	ND	ND	ND
7/19/09	TAH_09_26D	6:08	ND	ND	ND	ND	ND	ND
7/19/09	TAH_09_27S	8:04	ND	ND	ND	ND	ND	ND
7/19/09	TAH_09_28D	8:15	ND	ND	ND	ND	ND	ND
7/19/09	TAH_09_29S	10:00	ND	ND	ND	ND	0.92	0.92
7/19/09	TAH_09_30D	10:08	ND	ND	ND	ND	0.8	0.8
7/19/09	TAH_09_31D	10:08	ND	ND	ND	ND	0.76	0.76
7/19/09	TAH_09_32S	11:50	ND	ND	ND	ND	0.81	0.81
7/19/09	TAH_09_33D	11:56	ND	ND	ND	ND	0.75	0.75
7/19/09	TAH_09_34S	13:57	ND	ND	ND	ND	0.9	0.9
7/19/09	TAH_09_35D	14:04	ND	ND	ND	ND	ND	ND
7/19/09	TAH_09_36S	15:51	0.56	ND	0.61	ND	1.4	2.57
7/19/09	TAH_09_37D	15:57	ND	ND	ND	ND	ND	ND
7/19/09	TAH_09_38S	17:56	ND	ND	ND	ND	0.77	0.77
7/19/09	TAH_09_39S	17:56	ND	ND	ND	ND	0.76	0.76
7/19/09	TAH_09_40D	18:15	ND	ND	ND	ND	0.66	0.66
7/19/09	TAH_09_41S	19:55	ND	ND	ND	ND	0.67	0.67
7/19/09	TAH_09_42D	20:04	ND	ND	ND	ND	0.65	0.65
7/19/09	TAH_09_43MS	20:17	ND	ND	ND	ND	0.68	0.68
7/19/09	TAH_09_44MSX	20:17	ND	ND	ND	ND	ND	ND
7/19/09	TAH_09_45S	21:49	0.76	ND	0.97	ND	1.9	3.63
7/19/09	TAH_09_46D	21:56	ND	ND	ND	ND	0.52	0.52
7/19/09	TAH_09_47S	23:55	ND	ND	ND	ND	0.81	0.81
7/20/09	TAH_09_48D	0:02	ND	ND	ND	ND	ND	ND

Table 3b *TAH results from 7/19/09 River Mile 1.5*

Date	Sample ID	Time	Benzene (ug/L)	Ethylbenzene (ug/L)	m-, p-Xylene (ug/L)	o-Xylene (ug/L)	Toluene (ug/L)	Total BTEX (ug/L)
7/21/09	TAH_09_49S	5:55	ND	ND	ND	ND	ND	ND
7/21/09	TAH_09_50D	6:03	ND	ND	ND	ND	ND	ND
7/21/09	TAH_09_51S	7:48	ND	ND	ND	ND	ND	ND
7/21/09	TAH_09_52D	7:56	ND	ND	ND	ND	ND	ND
7/21/09	TAH_09_53S	9:54	ND	ND	ND	ND	0.7	0.7
7/21/09	TAH_09_54D	10:06	0.55	0.64	0.68	ND	1.1	2.97
7/21/09	TAH_09_55D	10:06	ND	ND	0.53	ND	0.99	1.52
7/21/09	TAH_09_56S	11:52	0.56	ND	0.58	ND	1.1	2.24
7/21/09	TAH_09_57D	11:59	0.53	ND	0.5	ND	1.2	2.23
7/21/09	TAH_09_58S	13:59	0.55	0.62	0.64	ND	1.4	3.21
7/21/09	TAH_09_59D	14:07	ND	0.53	ND	ND	1	1.53
7/21/09	TAH_09_60S	15:51	ND	ND	ND	ND	0.88	0.88
7/21/09	TAH_09_61D	15:58	ND	ND	ND	ND	ND	ND
7/21/09	TAH_09_62S	17:56	0.75	ND	0.79	ND	1.9	3.44
7/21/09	TAH_09_63S	17:56	0.79	ND	0.8	ND	1.7	3.29
7/21/09	TAH_09_64D	18:07	ND	ND	ND	ND	ND	ND
7/21/09	TAH_09_65S	19:57	ND	ND	ND	ND	0.85	0.85
7/21/09	TAH_09_66D	20:03	ND	ND	ND	ND	0.7	0.7
7/21/09	TAH_09_67MS	20:19	ND	ND	ND	ND	0.69	0.69
7/21/09	TAH_09_68MSX	20:19	ND	ND	ND	ND	ND	ND
7/21/09	TAH_09_69S	21:54	ND	ND	ND	ND	ND	ND
7/21/09	TAH_09_70D	22:00	ND	ND	ND	ND	ND	ND
7/21/09	TAH_09_71S	23:47	ND	ND	ND	ND	ND	ND
7/21/09	TAH_09_72D	23:53	ND	ND	ND	ND	ND	ND

Table 3c *TAH results from 7/21/09 River Mile 1.5*

Appendix D – Aerial Boat Count Results

Table 1, Aerial Kenai River Boat Survey on 7/18/09

7/18/09 Pilot: Tom ? - Aircraft, BushHawk XP
Time: 09:00 Observer: Jim Czarnezki, Bill Garthwaite
Tape # 7-18 # 1

Location	Total Power Boats in use
Mouth to Warren Ames Bridge	180
Kenai Bridge to ADF&G Sonar Site	71
Sonar Site to Beaver Creek	57
Beaver Creek to Pillars Boat Launch	70
Pillars Boat Launch to Soldotna Bridge	120
Soldotna Bridge to Moose River	15
Moose River to Kenai Keys	5
Kenai Keys to Skilak Lake	43
Overall Total	561
Percent 2-stroke estimate (non-DFI)	
Above Warren Ames Bridge (from 7/18 8:00 ground survey)	<1% (0/100)
Below Warren Ames Bridge (from 7/18 8:30 ground survey)	<1% (0/110)

7/18/09
Time: 12:00 Observer: Jim Czarnezki, Bill Garthwaite
Tape # 7-18 #2

Location	**Total Power Boats in use**
Mouth to Warren Ames Bridge	285
Kenai Bridge to ADF&G Sonar Site	87
Sonar Site to Beaver Creek	71
Beaver Creek to Pillars Boat Launch	39
Pillars Boat Launch to Soldotna Bridge	119
Soldotna Bridge to Moose River	19
Moose River to Kenai Keys	14
Kenai Keys to Skilak Lake	37
Overall Total	671
Percent 2-stroke estimate (non-DFI)	
Above Warren Ames Bridge (from 7/18 8:00 ground survey)	<1% (0/100)
Below Warren Ames Bridge (from 7/18 8:30 ground survey)	<1% (0/110)

7/18/09
Time: 14:00 Observer: Jim Czarnezki, Sam Fox
Tape # 7-18 # 3

Location	**Total Power Boats in use**
Mouth to Warren Ames Bridge	382
Kenai Bridge to ADF&G Sonar Site	16
Sonar Site to Beaver Creek	79
Beaver Creek to Pillars Boat Launch	85
Pillars Boat Launch to Soldotna Bridge	137
Soldotna Bridge to Moose River	18
Moose River to Kenai Keys	15
Kenai Keys to Skilak Lake	33
Overall Total	765
Percent 2-stroke estimate (non-DFI)	
Above Warren Ames Bridge (from 7/18 8:00 ground survey)	<1% (0/100)
Below Warren Ames Bridge (from 7/18 8:30 ground survey)	<1% (0/110)

7/18/09 Observer: Sam Fox, Bill Garthwaite

Time: 16:00
Tape # 7-18 # 4

Location	Total Power Boats in use
Mouth to Warren Ames Bridge	329
Kenai Bridge to ADF&G Sonar Site	27
Sonar Site to Beaver Creek	32
Beaver Creek to Pillars Boat Launch	52
Pillars Boat Launch to Soldotna Bridge	142
Soldotna Bridge to Moose River	19
Moose River to Kenai Keys	18
Kenai Keys to Skilak Lake	33
Overall Total	652
Percent 2-stroke estimate (non-DFI)	
Above Warren Ames Bridge (from 7/18 16:00 ground survey)	<1% (0/100)
Below Warren Ames Bridge (from 7/18 16:30 ground survey)	<1% (0/100)

7/18/09

Observer: Sam Fox, Bill Garthwaite, Megan Haserodt

Time: 20:00
Tape # 7-18 # 5

Location	Total Power Boats in use
Mouth to Warren Ames Bridge	171
Kenai Bridge to ADF&G Sonar Site	15
Sonar Site to Beaver Creek	27
Beaver Creek to Pillars Boat Launch	18
Pillars Boat Launch to Soldotna Bridge	83
Soldotna Bridge to Moose River	17
Moose River to Kenai Keys	10
Kenai Keys to Skilak Lake	34
Overall Total	375
Percent 2-stroke estimate (non-DFI)	
Above Warren Ames Bridge (from 7/18 16:00 ground survey)	<1% (0/100)
Below Warren Ames Bridge (from 7/18 16:30 ground survey)	<1% (0/100)

Table 2, Aerial Kenai River Boat Survey on 7/19/09

7/19/09 Pilot: Gary, Aircraft, BushHawk XP
Time: 08:00 Observer: Jim Czarnezki, Sam Fox
Tape # 7-19 # 1

Location	Total Power Boats in use
Mouth to Warren Ames Bridge	129
Kenai Bridge to ADF&G Sonar Site	11
Sonar Site to Beaver Creek	44
Beaver Creek to Pillars Boat Launch	60
Pillars Boat Launch to Soldotna Bridge	114
Soldotna Bridge to Moose River	17
Moose River to Kenai Keys	4
Kenai Keys to Skilak Lake	23
Overall Total	402
Percent 2-stroke estimate (non-DFI)	
Above Warren Ames Bridge (from 7/19 8:00 ground survey)	<1% (0/100)
Below Warren Ames Bridge (from 7/19 8:30 ground survey)	2% (2/100)

Time: 12:00 Observer: Jim Czarnezki, Megan Haserodt
Tape # 7-19 #2

Location	Total Power Boats in use
Mouth to Warren Ames Bridge	132
Kenai Bridge to ADF&G Sonar Site	37
Sonar Site to Beaver Creek	22
Beaver Creek to Pillars Boat Launch	55
Pillars Boat Launch to Soldotna Bridge	117
Soldotna Bridge to Moose River	12
Moose River to Kenai Keys	10
Kenai Keys to Skilak Lake	33
Overall Total	418
Percent 2-stroke estimate (non-DFI)	
Above Warren Ames Bridge (from 7/19 8:00 ground survey)	<1% (0/100)
Below Warren Ames Bridge (from 7/19 8:30 ground survey)	2% (2/100)

7/19/09

Time: 14:00 Observer: Jim Czarnezki, Megan Haserodt

Tape # 7-19 # 3

Location	Total Power Boats in use
Mouth to Warren Ames Bridge	205
Kenai Bridge to ADF&G Sonar Site	10
Sonar Site to Beaver Creek	33
Beaver Creek to Pillars Boat Launch	90
Pillars Boat Launch to Soldotna Bridge	140
Soldotna Bridge to Moose River	19
Moose River to Kenai Keys	12
Kenai Keys to Skilak Lake	22
Overall Total	531
Percent 2-stroke estimate (non-DFI)	
Above Warren Ames Bridge (from 7/19 16:00 ground survey)	<1% (0/100)
Below Warren Ames Bridge (from 7/19 16:30 ground survey)	<1% (0/100)

7/19/09

Time: 16:00 Observer: Sam Fox, Megan Haserodt

Tape # 7-19 # 4

Location	Total Power Boats in use
Mouth to Warren Ames Bridge	183
Kenai Bridge to ADF&G Sonar Site	15
Sonar Site to Beaver Creek	30
Beaver Creek to Pillars Boat Launch	75
Pillars Boat Launch to Soldotna Bridge	110
Soldotna Bridge to Moose River	16
Moose River to Kenai Keys	14
Kenai Keys to Skilak Lake	25
Overall Total	468
Percent 2-stroke estimate (non-DFI)	
Above Warren Ames Bridge (from 7/19 16:00 ground survey)	<1% (0/100)
Below Warren Ames Bridge (from 7/19 16:30 ground survey)	<1% (0/100)

7/19/09
7/19/09
Time: 20:00 Observer: Sam Fox, Megan Haserodt
Tape # 7-19 # 5

Location	Total Power Boats in use
Mouth to Warren Ames Bridge	75
Kenai Bridge to ADF&G Sonar Site	12
Sonar Site to Beaver Creek	11
Beaver Creek to Pillars Boat Launch	34
Pillars Boat Launch to Soldotna Bridge	97
Soldotna Bridge to Moose River	4
Moose River to Kenai Keys	4
Kenai Keys to Skilak Lake	20
Overall Total	257
Percent 2-stroke estimate (non-DFI)	
Above Warren Ames Bridge (from 7/19 16:00 ground survey)	<1% (0/100)
Below Warren Ames Bridge (from 7/19 16:30 ground survey)	<1% (0/100)

Table 3, Aerial Kenai River Boat Survey on 7/21/09

7/21/09 Pilot: Tom, Aircraft, BushHawk XP
Observer: Bill Garthwaite, Sam Fox, Megan Haserodt
Time: 08:00
Tape # 7-21 # 1

Location	Total Power Boats in use
Mouth to Warren Ames Bridge	56
Kenai Bridge to ADF&G Sonar Site	53
Sonar Site to Beaver Creek	43
Beaver Creek to Pillars Boat Launch	127
Pillars Boat Launch to Soldotna Bridge	239
Soldotna Bridge to Moose River	22
Moose River to Kenai Keys	8
Kenai Keys to Skilak Lake	19
Overall Total	567
Percent 2-stroke estimate (non-DFI)	
Above Warren Ames Bridge (from 7/21 8:00 ground survey)	<1% (0/100)

Below Warren Ames Bridge (from 7/21 8:30 ground survey)	7% (3/45) *note that there were less than 100 boats on this section of the river.

7/21/09

Time: 12:00 Observer: Sam Fox, Bill Garthwaite

Tape # 7-21 #2

Location	Total Power Boats in use
Mouth to Warren Ames Bridge	99
Kenai Bridge to ADF&G Sonar Site	22
Sonar Site to Beaver Creek	15
Beaver Creek to Pillars Boat Launch	60
Pillars Boat Launch to Soldotna Bridge	188
Soldotna Bridge to Moose River	12
Moose River to Kenai Keys	11
Kenai Keys to Skilak Lake	28
Overall Total	435
Percent 2-stroke estimate (non-DFI)	
Above Warren Ames Bridge (from 7/21 8:00 ground survey)	<1% (0/100)
Below Warren Ames Bridge (from 7/21 8:30 ground survey)	7% (3/45) *note that there were less than 100 boats on this section of the river.

7/21/09

Time: 14:00 Observer: Jim Czarnezki, Megan Haserodt

Tape # 7-21 # 3

Location	Total Power Boats in use
Mouth to Warren Ames Bridge	169
Kenai Bridge to ADF&G Sonar Site	49
Sonar Site to Beaver Creek	21
Beaver Creek to Pillars Boat Launch	48
Pillars Boat Launch to Soldotna Bridge	164
Soldotna Bridge to Moose River	22
Moose River to Kenai Keys	21
Kenai Keys to Skilak Lake	25
Overall Total	519
Percent 2-stroke estimate (non-DFI)	
Above Warren Ames Bridge (from 7/21 16:00 ground survey)	<1% (0/100)
Below Warren Ames Bridge	<1% (0/111)

(from 7/21 16:30 ground survey)

7/21/09
Time: 16:00
Tape # 7-21 # 4

Observer: Bill Gartwaite, Megan Haserodt

Location	Total Power Boats in use
Mouth to Warren Ames Bridge	202
Kenai Bridge to ADF&G Sonar Site	28
Sonar Site to Beaver Creek	68
Beaver Creek to Pillars Boat Launch	76
Pillars Boat Launch to Soldotna Bridge	65
Soldotna Bridge to Moose River	21
Moose River to Kenai Keys	10
Kenai Keys to Skilak Lake	28
Overall Total	498
Percent 2-stroke estimate (non-DFI)	
Above Warren Ames Bridge (from 7/21 16:00 ground survey)	<1% (0/100)
Below Warren Ames Bridge (from 7/21 16:30 ground survey)	<1% (0/111)

7/21/09
Time: 20:00
Tape # 7-21 # 5

Observer: Bill Garthwaite, Megan Haserodt

Location	Total Power Boats in use
Mouth to Warren Ames Bridge	94
Kenai Bridge to ADF&G Sonar Site	4
Sonar Site to Beaver Creek	8
Beaver Creek to Pillars Boat Launch	42
Pillars Boat Launch to Soldotna Bridge	65
Soldotna Bridge to Moose River	11
Moose River to Kenai Keys	11
Kenai Keys to Skilak Lake	24
Overall Total	259
Percent 2-stroke estimate (non-DFI)	
Above Warren Ames Bridge (from 7/21 16:00 ground survey)	<1% (0/100)
Below Warren Ames Bridge (from 7/21 16:30 ground survey)	<1% (0/111)