May 2, 2007

Lynn Kent
Director, Division of Water
Alaska Department of Environmental Conservation
555 Cordova Street
Anchorage, Alaska 99501

Re: Amended Final Report and Additional Scenario - Lower Kenai River Petroleum Hydrocarbon Estimate

Dear Ms. Kent:

This letter refers to two recently amended reports both submitted electronically on April 26, 2007 for the Lower Kenai River Petroleum Hydrocarbon Estimate project. OASIS Environmental, Inc. (OASIS) amended these reports in response to an error that Alaska DEC personnel discovered in *Task 2* from the original report dated February 5, 2007. The error was an incorrect conversion factor used to change cubic feet to liters. This error occurred in the *S* factor calculations (percentage of TAH that remains dissolved in the river) and affected calculated values throughout the report.

Following recognition of this error, which prompted a thorough review by OASIS of all assumptions and calculations used to complete this work, the assumptions used to establish the *S* factor were determined unreasonable. Therefore, OASIS further researched the S factor and identified a reference which placed the S factor higher than originally determined. The calculation error and the revised *S* factor resulted in an increase to the percentage of TAH that remains dissolved in water (from approximately 11% to approximately 37%). These revisions caused a change in the resulting estimated loads for Task 2. Additionally, the revision of the *S* factor in Task 2 affected the calculations in Task 5, Task 6, and the results of the additional scenario provided to Alaska DEC in a letter report dated April 17, 2007.

OASIS apologizes for the error regarding the conversion factor and the last-minute changes to the reports. We appreciate the opportunity provided by Alaska DEC to revise the reports because OASIS believes the changes have produced more accurate estimates of petroleum loading in the Lower Kenai River.

Sincerely,
OASIS Environmental, Inc.

Ben Martich
Project Manager

SITE REMEDIATION
WATER RESOURCES
ECOLOGICAL SCIENCES
EHS MANAGEMENT

April 17, 2007 (Amended April 26, 2007)

Tim Stevens
Non-Point Source Water Pollution Control Program
Division of Water, Alaska Department of Environmental Conservation
555 Cordova Street
Anchorage, Alaska 99501

Re: Amended Additional Scenario - Lower Kenai River Petroleum Hydrocarbon Estimate

Dear Mr. Stevens:

OASIS Environmental, Inc. (OASIS) has prepared this additional scenario for petroleum hydrocarbon loading in the lower Kenai River as tasked in Notice-to-Proceed 18-2011-26-2. The additional scenario addresses the estimated loading of petroleum hydrocarbons in the lower Kenai River if all boats operated with 2-stroke direct fuel injected (DFI) or 4-stroke 35-horsepower (hp) engines. This scenario is a variation on Task 2 in the OASIS 5 February 2007 report (Amended 26 April 2007), which analyzed the amount of total aromatic hydrocarbons (TAH) dissolving in the lower Kenai River for all currently allowed boat engine types. This additional scenario limits the engine types by excluding 2-stroke engines from the calculations. The assumptions used below are taken directly from Task 2 of the 5 February 2007 (Amended 26 April 2007) report, and the reader should refer to that report for references.

Task: Calculate the Volume of Total Aromatic Hydrocarbons Dissolving in the Lower Kenai River from Boat Engines that are either 35-hp 2-stroke DFI or 4-stroke:

Two main elements must be estimated for this task

1) Volume of TAH dissolving in the lower Kenai River over a set time period for 2-stroke DFI or 4-stroke 35-hp engines,

2) Number of boat hours per day in July on the lower Kenai River.

The following two sub-sections detail the data and assumptions used to estimate each element.

Volume of TAH

The following equation is used to determine the volume of TAH dissolving in the lower Kenai River during one hour of outboard engine operation:

$$TAH_g = E_g * I * G * S \quad (1)$$

where TAH_g = amount of TAH dissolved in river (in gallons per hour [gph])

E_g = amount of gasoline used per hour (fuel economy in gph)

I = percentage of gasoline lost during combustion (unitless)

G = percentage of TAH in gasoline (unitless)

S = percentage of TAH that remains dissolved in the river (unitless)

Each factor in Equation (1) has a realistic range of possibilities. These ranges are discussed below based on "Average Estimate," "Low Average Estimate," and "High Average Estimate."

- E_g (fuel economy [gph]): Performance data for Yamaha motors were used for 4-stroke 40-hp carbureted engines because detailed fuel economy data were not available for 35-hp engines. In addition, it is assumed that 2-stoke DFI engines have the same fuel efficiency as 4-stoke engines. At idle (1,000 revolutions per minute [rpm]), a 4-stroke 40-hp engine will burn 0.2 gph of fuel. At half-throttle (3,000 rpm), a 4-stroke engine will burn 1.2 gph of fuel. At full throttle (maximum rpm), a 4-stroke engine will burn 4.3 gph of fuel.

- I (percentage of fuel lost in combustion): The "Average Estimate" of the percentage of fuel that may exit the cylinder unburned for 4-stroke engines is 4.1%; the "Low Average Estimate" of I for 4-stroke engines is 1.3%; and the "High Average Estimate" of I for 4-stroke engines is 7.5%.

- G (percentage of TAH in gasoline): TAH data for Tesoro and Flints Hills regular gasoline were used for this factor. The "Average Estimate" of G is 36.9%, which is an average of the two gasolines. The "Low Average Estimate" of G is 33.1%, which represents 70% usage of Flint Hills gasoline and 30% usage of Tesoro gasoline. The "High Average Estimate" of G is 40.7%, which represents 70% usage of Tesoro gasoline and 30% usage of Flint Hills gasoline.

- S (percentage of TAH that dissolves in river): The "Average Estimate" of the percentage of hydrocarbons likely to stay dissolved in water is 37.5%. Professional judgment for variation around the "Average Estimate" is 15%. Therefore, the "Low Average Estimate" of S is 31.9%, and the "High Average Estimate" of S is 43.1%.

The following table shows the assumptions outlined above and the calculated TAH_g based on the assumptions.

35-hp 4-stroke of 2-stroke DFI engine			
	Average Estimate	Low Average Estimate	High Average Estimate
Speed	Idle (1,000 rpm)		
Economy (E_g)	0.2 gph	0.2 gph	0.2 gph
Inefficiency (I)	0.041	0.013	0.075
%-TAH (G)	0.369	0.331	0.407
%-TAH Dissolved (S)	0.375	0.319	0.431
Volume of TAH (TAH_g)	**0.0011 gph**	**0.0003 gph**	**0.0026 gph**
Speed	Half Throttle (3,000 rpm)		
Economy (E_g)	1.2 gph	1.2 gph	1.2 gph
Inefficiency (I)	0.041	0.013	0.075
%-TAH (G)	0.369	0.331	0.407
%-TAH Dissolved (S)	0.375	0.319	0.431
Volume of TAH (TAH_g)	**0.0068 gph**	**0.0016 gph**	**0.0158 gph**
Speed	Full Throttle (max rpm)		
Economy (E_g)	4.3 gph	4.3 gph	4.3 gph
Inefficiency (I)	0.041	0.013	0.075
%-TAH (G)	0.369	0.331	0.407
%-TAH Dissolved (S)	0.375	0.319	0.431
Volume of TAH (TAH_g)	**0.0244 gph**	**0.0059 gph**	**0.0566 gph**

For each "estimate" scenario, the calculated TAH_g should be combined to reflect a single value that best represents the multitude of engine operating conditions that may exist during an hour of operation on the river. Based on details presented in the OASIS 5 February 2007 report (Amended 26 April 2007), it is assumed that approximately 50% of engine operating time is at idle, 25% of engine operating time at half throttle, and 25% of engine operating time at full throttle. Therefore, the TAH_g result is averaged across one hour to yield the following estimates:

- 35-hp 4-stroke engine: "Average Best Estimate" = 0.0084 gph

  "Low Average Estimate" = 0.0020 gph

  "High Average Estimate" = 0.0194 gph

Number of Boat Hours per Day

The second element requires estimating the number of boat hours per day in July on the lower Kenai River. This is a 2-step process. The first step estimates the average number of boats per day on the lower Kenai River in July. Alaska Department of Fish and Game, KWF, Kenaitze Tribe, and OASIS have conducted boat counts on various days in July from 2000 to 2006; however, not all available data was used to calculate an average number of boats per day. Data was trimmed to include days for which at least four boat counts occurred so that utilized boat counts most accurately reflect a full day of usage. Based on this criterion, the average number of counted boats per day is 642; however, this statistic must be adjusted to account for potential re-counts of the same boat during one day. The best professional estimate of accounting for re-counts was arbitrarily set so that 25% of boats counted per day in July were assumed to have previously been counted. This assumption means that only 75% of counted boats are unique, which equates to 482 different boats per day. Professional judgment for variation around the "Average Estimate" is 15%. Therefore, the "Low Average Estimate" for the number of unique boats on the river daily in July is 63.8%, or 410 unique boats per day; the "High Average Estimate" is 86.3%, or 554 unique boats per day.

The second step is to account for the length of time (in hours) each unique boat operates on the river. The best professional estimate of the average length of each boat trip was arbitrarily set at 10 hours, which balances the assumptions that most guides on the river operate 12 hours daily and personal users are more likely to operate near 8 hours daily. Professional judgment for variation around the "Average Estimate" is 15%. Therefore, the "Low Average Estimate" is 8.5 hours, and the "High Average Estimate" is 11.5 hours. Given these assumptions, the following are the three scenario estimates for the number of boat hours per day in July on the lower Kenai River:

- "Average Estimate" = 482 boats * 10 hours per day = 4,820 boat hours per day,
- "Low Average Estimate" = 410 boats * 8.5 hours per day = 3,485 boat hours per day, and
- "High Average Estimate" = 554 boats * 11.5 hours per day = 6,371 boat hours per day.

Given the estimations and assumptions described above for the two elements, the following table shows the projected loadings in gallons per day (gpd) of TAH into the lower Kenai River for 2-stroke DFI or 4-stroke 35-hp engines:

Scenario	Estimations	TAH Load
Average Estimate	0.0084 gph * 4,820 hours per day	40 gpd
Low Average Estimate	0.0020 gph * 3,485 hours per day	7 gpd
High Average Estimate	0.0194 gph * 6,371 hours per day	124 gpd

The following table is a comparison of calculated loadings of TAH from Tasks 2 and 5 of the OASIS 5 February 2007 report (Amended 26 April 2007) along with the calculated loading from the additional scenario above:

Scenario	TAH Load for 35-hp Engines (2-Stroke and 4-Stroke) Task 2	TAH Load for 50-hp Engines (4-Stroke and 2-Stroke DFI) Task 5	TAH Load for 35-hp Engines (4-Stroke and 2-Stroke DFI) Additional Scenario
Average Estimate	140 gpd	49 gpd	40 gpd
Low Average Estimate	41 gpd	8 gpd	7 gpd
High Average Estimate	352 gpd	151 gpd	124 gpd

The TAH loading rate was converted to a concentration estimate and presented in the following table. The calculation assumes instantaneous mixing throughout the water column, which is convenient calculation tool, but is unlikely to actually occur. Concentrations near the sources, i.e. the engine exhaust, are likely several times higher than represented. In addition, the hydrocarbon loading does not occur at a single point, but rather along a reach of the river. Consequently, concentrations would be expected to increase with increasing downstream position.

Scenario, all concentrations in ug/L	TAH Concentration for 35-hp Engines (2-Stroke and 4-Stroke) Task 2	TAH Concentration for 50-hp Engines (4-Stroke and 2-Stroke DFI) Task 5	TAH Concentration for 35-hp Engines (4-Stroke and 2-Stroke DFI) Additional Scenario
Average Estimate	16.0	5.60	4.56
Low Average Estimate	4.44	0.91	0.76
High Average Estimate	41.3	17.7	14.5

OASIS appreciates this opportunity to collaborate with Alaska DEC on this interesting project. Please feel free to call or email with questions.

Sincerely,
OASIS Environmental, Inc.

Ben Martich

Ben Martich
Project Manager

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February 5, 2007 (Amended April 26, 2007)

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RE: Amended Final Report - Lower Kenai River Petroleum Hydrocarbon Estimate

Dear Mr. Stevens,

Under Notice-to-Proceed No. 18-9001-14-7, OASIS Environmental, Inc. (OASIS) has prepared this letter report to analyze the volume of total aromatic hydrocarbons (TAH) dissolving in the lower Kenai River (river) on a daily basis in July. Our term-subcontractor, Kinnetic Laboratories Inc. (KLI), was instrumental in assisting in the development of this report.

This letter presents only a summary of the findings. Details that support these findings are included in the three attachments: supporting documentation, glossary of terms, and references.

Summary of Findings

This section provides findings for the five required tasks of the scope of work, plus an additional task requested after review of the draft report.

Task 1: Back-Calculate Volume of Total Aromatic Hydrocarbons Dissolving in the Lower Kenai River:

OASIS evaluated three plausible scenarios for estimating the volume of TAH dissolving in the lower river based on existing TAH concentration data from samples collected in July. The three scenarios include a most likely (average) estimate determined by using statistical measures of central tendency for existing data; an average estimate on the low-range determined by using low percentile ranges for existing data; and an average estimate on the high-range determined by using high percentile ranges for existing data. The three scenarios yielded the following results:

- Average Estimate: 78 gallons per day (gpd) of TAH dissolve in the lower river based on TAH concentrations from samples previously collected in July.
- Low Average Estimate: 57 gpd of TAH dissolve in the lower river based on TAH concentrations from samples previously collected in July.
- High Average Estimate: 105 gpd of TAH dissolve in the lower river based on TAH concentrations from samples previously collected in July.

Task 2: Calculate the Volume of Total Aromatic Hydrocarbons Dissolving in the Lower Kenai River from Boat Engines:

OASIS evaluated three plausible scenarios ("Average Estimate," "Low Average Estimate," and "High Average Estimate) for estimating the volume of TAH dissolving in the river based on performance data for boat engine types currently allowed on the river. For each scenario, assumptions were made for fuel consumption, engine efficiency, percentage of TAH in gasoline, percentage of TAH that remains dissolved in the river, percentage of boats that are 2-stroke and 4-stroke, the number of boats in the river daily, and the number of hours each boat operates on the river. The three scenarios yielded the following results:

- Average Estimate: 140 gpd of TAH dissolve in the lower river based on engine types and data for engine performance.
- Low Average Estimate: 41 gpd of TAH dissolve in the lower river based on engine types and data for engine performance.
- High Average Estimate: 352 gpd of TAH dissolve in the lower river based on engine types and data for engine performance.

Task 3: Summary of Usage Patterns on the River:

The most common fishing techniques used on the lower Kenai River for the July Chinook salmon fishery are back-trolling and bait-bouncing. The back-trolling technique requires motor use to match current speed or move downstream a bit slower than current speed. Bait-bouncing is normally done with the engine running at idle. The remainder of time is spent near full throttle getting to desired fishing locations. Fuel consumption rates likely will be 7 to 10 gallons for an 8-hour day.

Task 4: Calculate Volume of Hydrocarbons Entering Cook Inlet from Permitted Facilities:

Trading Bay Production Facility contributes approximately 96% of the total amount of produced water discharged to Cook Inlet by permitted dischargers. Based on this statistic, approximately 40.6 gpd of TAH are discharged into Cook Inlet in July from permitted facilities.

Task 5: Calculate Change in Hydrocarbon Loading for 50-Horsepower Engines:

OASIS compared daily loading rates of TAH between currently allowed 35-horsepower (hp) engines (2-stroke and 4-stroke) and proposed 50-hp 4-stroke or 50-hp 2-stroke direct fuel injected (DFI) engines. Assuming that all boats are running 35-hp engines or 50-hp engines, the table below compares loading rates:

Scenario	TAH Load for 35-hp Engines (2-Stroke and 4-Stroke)	TAH Load for 50-hp Engines (4-Stroke and 2-Stroke DFI)
Average Estimate	140 gpd	49 gpd
Low Average Estimate	41 gpd	8 gpd
High Average Estimate	352 gpd	151 gpd

Task 6: Compare Expected Concentrations from Projected Total Aromatic Hydrocarbons Loads for 50-Horsepower Engines to the Water Quality Standard for TAH:

OASIS computed the expected concentration of TAH in the lower Kenai River based on projected TAH loads for 50-hp engines from Task 5. The expected concentrations then were compared to the TAH water quality standard of 10 micrograms per liter (µg/L). The following table shows the comparison for the three scenarios:

Scenario	Projected TAH Load from Task 5	Expected TAH Concentration in River	Water Quality Standard for TAH
Average Estimate	49 gpd	5.60 µg/L	10 µg/L
Low Average Estimate	8 gpd	0.91 µg/L	10 µg/L
High Average Estimate	151 gpd	17.7 µg/L	10 µg/L

OASIS appreciates this opportunity to collaborate with Alaska DEC on this important project. Please feel free to call or email with questions.

Respectfully submitted,
OASIS Environmental, Inc.

Ben Martich
Project Manager

Attachments: 1 – Supporting Documentation
2 – Glossary of Terms
3 – References

ATTACHMENT 1

SUPPORTING DOCUMENTATION

(AMENDED APRIL 26, 2007)

The determinations for loading of total aromatic hydrocarbons (TAH) described below required the use of assumptions and estimations in every step of the process. When possible, available data from the lower Kenai River was used to provide the best estimate available. Some examples of such data include stream flow, sample data for TAH concentrations, and boat counts. If data was not available for the lower Kenai River, available data of a general nature was used. Some examples of such data include industry and government reports on the efficiency and fuel economy of outboard engines. If data of a general nature was not available, then best professional judgment was used. Some examples of such assumptions include the number of hours of operation per boat on the river and the amount of variation between "Average Estimates" and "Low and High Average Estimates." All of these estimations and assumptions are outlined below.

The text below also refers to concentrations of TAH in terms of milligrams per liter (mg/L) and micrograms per liter (μg/L). The following represents the relationship between these two units of measure:

1 mg/L = 1,000 μg/L

A common question from the public regarding the mass-volume concentrations of mg/L and μg/L are how do they relate to the more common concentration units of parts per million (ppm) and parts per billion (ppb). For the purposes of this analysis,

1 mg/L of TAH in water = 1 ppm of TAH in water, and

1 μg/L of TAH in water = 1 ppb of TAH in water.

This relationship exists because the low mass of TAH (1 mg or less) per unit of water (1 L) discussed below has minimal effect on concentration even though the densities of TAH and water are not the same.

Task 1: Determine the rate that total aromatic hydrocarbons are entering river daily in July based on existing sampling data.

The calculation for determining the gallons per day (gpd) of TAH entering the lower Kenai River in July is the product of the concentration of TAH and the rate of flow in the lower river:

$$Q_d = Q_r C_r \quad (1)$$

where Q_d = Rate of discharge of TAH from outboard engines (in gpd)
Q_r = Rate of flow in lower river (in gpd)
C_r = Concentration of TAH in lower river (in mg/L)

Data for Q_r is obtained from United States Geological Survey (USGS 2007) gage station 15266300 located at the Sterling Highway bridge in Soldotna, Alaska. Data for C_r is obtained from analytical data for water samples collected in the lower Kenai River from 2000 to 2006 by representatives of the Kenai Watershed Forum (KWF), Kenaitze Tribe, and OASIS Environmental, Inc. In addition, all Cr present in analytical data is assumed to be the result of discharge from outboard engines, and not the result of other potential sources on or near the lower Kenai River.

The following are three scenarios for calculating Q_d using Equation (1). The scenarios include an average estimate based on statistical measures of central tendency for the factors of Equation (1); a low average estimate if all the factors of Equation (1) are adjusted to produce a result that minimizes the average gpd of TAH entering the lower river; and a high average estimate if all the factors of Equation (1) are adjusted to produce a result that maximizes the average gpd of TAH entering the lower river.

Scenario 1 (Average Estimate):

- Q_r = 13,577 cfs (mean daily flow in July at Soldotna bridge since 1965)
- C_r = 0.00664 mg/L (mean of annual mean concentrations for 212 TAH samples collected from the lower Kenai River on July days [except on non-motorized use Mondays] in 2000, 2003, 2004, 2005, and 2006)

Solving Equation (1) with these assumptions yields:

Q_d = 13,577 cfs * 0.00664 mg/L = 90.15 cfs*mg/L (2)

This result now must be converted using constants to derive a result in gpd. Given that 1 cfs = 2,446,576 liters per day (L/day), Equation (2) converts to:

Q_d = 90.15 cfs*mg/L * 2,446,576 (L/day)/cfs = 220,558,826 mg/day (3)

Given that 1 mg = 0.0000022 pounds (lbs), Equation (3) becomes:

Q_d = 220,558,826 mg/day * 0.0000022 lbs/mg = 485 lbs/day (4)

Given that one gallon of gasoline weighs an average of 6.2 pounds (DOE 1980), Equation (4) becomes:

Q_d = 485 lbs/day / 6.2 lbs/gallon = 78 gpd

Therefore, the "Average Estimate" for the rate at which TAH enters the lower Kenai River in July is 78 gpd.

Scenario 2 (Low Average Estimate):

- Q_r = 13,200 cfs (30th percentile daily flow in July at Soldotna bridge since 1965)
- C_r = 0.00517 mg/L (30th percentile concentration of TAH samples collected from the lower Kenai River on July days [except on non-motorized use Mondays] in 2000, 2003, 2004, 2005, and 2006)

Solving Equation (1) with these assumptions yields:

Q_d = 13,200 cfs * 0.00517 mg/L = 68.24 cfs*mg/L (2)

This result now must be converted using constants to derive a result in gpd. Given that 1 cfs = 2,446,576 liters per day (L/day), Equation (2) converts to:

Q_d = 68.24 cfs*mg/L * 2,446,576 (L/day)/cfs = 166,954,346 mg/day (3)

Given that 1 mg = 0.0000022 pounds (lbs), Equation (3) becomes:

Q_d = 166,954,346 mg/day * 0.0000022 lbs/mg = 367 lbs/day (4)

Given that the upper range of weight for one gallon of gasoline is 6.5 pounds (DOE 1980), Equation (4) becomes:

Q_d = 367 lbs/day / 6.5 lbs/gallon = 57 gpd

Therefore, the "Low Average Estimate" for the rate at which TAH enters the lower Kenai River in July is 56 gpd.

Scenario 3 (High Average Estimate):

- Q_r = 14,300 cfs (70th percentile daily flow in July at Soldotna bridge since 1965)
- C_r = 0.00789 mg/L (70th percentile concentration of TAH samples collected from the lower Kenai River on July days [except on non-motorized use Mondays] in 2000, 2003, 2004, 2005, and 2006)

Solving Equation (1) with these assumptions yields:

Q_d = 14,300 cfs * 0.00789 mg/L = 112.8 cfs*mg/L (2)

This result now must be converted using constants to derive a result in gpd. Given that 1 cfs = 2,446,576 liters per day (L/day), Equation (2) converts to:

Q_d = 112.8 cfs*mg/L * 2,446,576 (L/day)/cfs = 275,973,773 mg/day (3)

Given that 1 mg = 0.0000022 pounds (lbs), Equation (3) becomes:

Q_d = 275,973,773 mg/day * 0.0000022 lbs/mg = 607 lbs/day (4)

Given that the lower range of weight for one gallon of gasoline is 5.8 pounds (DOE 1980), Equation (4) becomes:

Q_d = 607 lbs/day / 5.8 lbs/gallon = 105 gpd

Therefore, the "High Average Estimate" for the rate at which TAH enters the lower Kenai River in July is 105 gpd.

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Task 2: Determine the volume of total aromatic hydrocarbons dissolving in the lower Kenai River on a daily basis in July for two common types of engines currently used: 35-horsepower 2-stroke and 35-horsepower 4-stroke.

In order to make a determination for Task 2, three main elements must be estimated:

1) Volume of TAH dissolving in the lower Kenai River over a set time period based on the types of outboard engines used,
2) Percentage of boats that are 4-stroke and 2-stroke, and
3) Number of boat hours per day in July on the lower Kenai River.

The following three sub-sections detail the data and assumptions used to estimate each of the three elements above.

Volume of TAH

The following equation is used to determine the volume of TAH dissolving in the lower Kenai River during one hour of outboard engine operation:

$TAH_g = E_g * I * G * S$ (5)

where TAH_g = amount of TAH dissolved in river (in gallons per hour [gph])
E_g = amount of gasoline used per hour (fuel economy in gph)
I = percentage of gasoline lost during combustion (unitless)
G = percentage of TAH in gasoline (unitless)
S = percentage of TAH that remains dissolved in the river (unitless)

Each factor in Equation (5) has a realistic range of possibilities. These ranges are discussed below based on "Average Estimate," "Low Average Estimate," and "High Average Estimate" scenarios similar to the process used in Task 1.

- E_g (fuel economy [gph]): Performance data for Yamaha motors were used for both 2-stroke and 4-stroke 40-horsepower (hp) carbureted engines because detailed fuel economy data were not available for 35-hp engines (Yamaha 2006). At idle (1,000 revolutions per minute [rpm]), a 2-stroke 40-hp engine will burn 0.6 gph, and a 4-stroke 40-hp engine will burn 0.2 gph. At half-throttle (3,000 rpm), a 2-stroke engine will burn 1.8 gph, and a 4-stroke engine will burn 1.2 gph. At full throttle (maximum rpm), a 2-stroke engine will burn 5.3 gph, and a 4-stroke engine will burn 4.3 gph.
- I (percentage of fuel lost in combustion): For 2-stroke engines, 25- to 30-percent of fuel consumed may exit the cylinder unburned (EPA 1996). 4-stroke engines reduce fuel lost in the combustion process by 75% to 95% (ODEQ 1999). Based on these statistics, the "Average Estimate" of I for 2-stroke engines is 27.5% and for 4-stroke engines it is 4.1% (0.275 * 0.15); the "Low Average Estimate" of I for 2-stroke engines is 25% and for 4-stroke engines it is 1.3% (0.25 * 0.05); and the "High Average Estimate" of I for 2-stroke engines is 30% and for 4-stroke engines it is 7.5% (0.30 * 0.25).
- G (percentage of TAH in gasoline): TAH data for Tesoro and Flints Hills regular gasoline were used for this factor (Geosphere 2005). The "Average Estimate" of G is 36.9%, which is an average of the two gasolines. The "Low Average Estimate" of G is 33.1%, which represents 70% usage of Flint Hills gasoline and 30% usage of Tesoro gasoline. The "High Average Estimate" of G is 40.7%, which represents 70% usage of Tesoro gasoline and 30% usage of Flint Hills gasoline.
- S (percentage of TAH that dissolves in river): An estimated 35- to 40-percent of hydrocarbons likely stay dissolved in water while the remainder is released to the atmosphere (St. Croix 1997). Based on this statistic, the "Average Estimate" of S is 37.5%. Professional judgment for variation around the "Average Estimate" is 15%. Therefore, the "Low Average Estimate" of S is 31.9%, and the "High Average Estimate" of S is 43.1%.

The following table shows the assumptions outlined above for both engine types and the calculated TAH_g based on the assumptions.

35-hp 2-stroke engine			
	Average Estimate	Low Average Estimate	High Average Estimate
Speed	Idle (1,000 rpm)		
Economy (E_g)	0.6 gph	0.6 gph	0.6 gph
Inefficiency (I)	0.275	0.25	0.30
%-TAH (G)	0.369	0.331	0.407
%-TAH Dissolved (S)	0.375	0.319	0.431
Volume of TAH (TAH_g)	**0.0228 gph**	**0.0158 gph**	**0.0316 gph**
Speed	Half Throttle (3,000 rpm)		
Economy (E_g)	1.8 gph	1.8 gph	1.8 gph
Inefficiency (I)	0.275	0.25	0.30
%-TAH (G)	0.369	0.331	0.407
%-TAH Dissolved (S)	0.375	0.319	0.431
Volume of TAH (TAH_g)	**0.0685 gph**	**0.0475 gph**	**0.0947 gph**
Speed	Full Throttle (max rpm)		
Economy (E_g)	5.3 gph	5.3 gph	5.3 gph
Inefficiency (I)	0.275	0.25	0.30
%-TAH (G)	0.369	0.331	0.407
%-TAH Dissolved (S)	0.375	0.319	0.431
Volume of TAH (TAH_g)	**0.2017 gph**	**0.1399 gph**	**0.2789 gph**
35-hp 4-stroke engine			
	Average Estimate	Low Average Estimate	High Average Estimate
Speed	Idle (1,000 rpm)		
Economy (E_g)	0.2 gph	0.2 gph	0.2 gph
Inefficiency (I)	0.041	0.013	0.075
%-TAH (G)	0.369	0.331	0.407
%-TAH Dissolved (S)	0.375	0.319	0.431
Volume of TAH (TAH_g)	**0.0011 gph**	**0.0003 gph**	**0.0026 gph**
Speed	Half Throttle (3,000 rpm)		
Economy (E_g)	1.2 gph	1.2 gph	1.2 gph
Inefficiency (I)	0.041	0.013	0.075
%-TAH (G)	0.369	0.331	0.407
%-TAH Dissolved (S)	0.375	0.319	0.431
Volume of TAH (TAH_g)	**0.0068 gph**	**0.0016 gph**	**0.0158 gph**
Speed	Full Throttle (max rpm)		
Economy (E_g)	4.3 gph	4.3 gph	4.3 gph
Inefficiency (I)	0.041	0.013	0.075
%-TAH (G)	0.369	0.331	0.407
%-TAH Dissolved (S)	0.375	0.319	0.431
Volume of TAH (TAH_g)	**0.0245 gph**	**0.0057 gph**	**0.0566 gph**

For each engine type and each “estimate” scenario, the calculated TAH_g should be combined to reflect a single value that best represents the multitude of engine operating conditions that may exist during an hour of operation on the river. Based on limited data presented in Task 3 and professional judgment, it is assumed that approximately 50% of engine operating time is at idle, 25% of engine operating time at half throttle, and 25% of engine operating time at full throttle. Therefore, the TAH_g result for each engine type is averaged across one hour to yield the following estimates:

- 35-hp 2-stroke engine: “Average Estimate” = 0.0790 gph
  “Low Average Estimate” = 0.0548 gph
  “High Average Estimate” = 0.1092 gph
- 35-hp 4-stroke engine: “Average Best Estimate” = 0.0084 gph
  “Low Average Estimate” = 0.0019 gph
  “High Average Estimate” = 0.0194 gph

Percentage of Engine Types

The second element requires estimating the percentage of boats that operate either a 4-stroke or 2-stroke engine. The Kenai Watershed Forum (KWF) conducted engine counts in 2003 and 2004, and the Kenaitze Tribe conducted engine counts in 2006. The total engine count over the 3 years of data is 4,902. 3,462 of these engines were counted as 4-stroke for an "Average Estimate" percentage of 70.6%; therefore, the 2-stroke "Average Estimate" percentage is 29.4%. Professional judgment for variation around the "Average Estimate" is 15%. Therefore, the "Low Average Estimate" is 81.2% for 4-stroke engines and 18.8% for 2-stroke engines. The professional judgment for "High Average Estimate" is 60.0% for 4-stroke engines and 40.0% for 2-stroke engines.

Number of Boat Hours Per Day

The third element requires estimating the number of boat hours per day in July on the lower Kenai River. This is a 2-step process. The first step estimates the average number of boats per day on the lower Kenai River in July. Alaska Department of Fish and Game, KWF, Kenaitze Tribe, and OASIS have conducted boat counts on various days in July from 2000 to 2006; however, not all available data was used to calculate an average number of boats per day. Data was trimmed to include days for which at least four boat counts occurred so that utilized boat counts most accurately reflect a full day of usage. Based on this criterion, the average number of counted boats per day is 642; however, this statistic must be adjusted to account for potential re-counts of the same boat during one day. The best professional estimate of accounting for re-counts was arbitrarily set so that 25% of boats counted per day in July were assumed to have previously been counted. This assumption means that only 75% of counted boats are unique, which equates to 482 different boats per day. Professional judgment for variation around the "Average Estimate" is 15%. Therefore, the "Low Average Estimate" for the number of unique boats on the river daily in July is 63.8%, or 410 unique boats per day; the "High Average Estimate" is 86.3%, or 554 unique boats per day.

The second step is to account for the length of time (in hours) each unique boat operates on the river. The best professional estimate of the average length of each boat trip was arbitrarily set at 10 hours, which balances the assumptions that most guides on the river operate 12 hours daily and personal users are more likely to operate near 8 hours daily. Professional judgment for variation around the "Average Estimate" is 15%. Therefore, the "Low Average Estimate" is 8.5 hours, and the "High Average Estimate" is 11.5 hours. Given these assumptions, the following are the three scenario estimates for the number of boat hours per day in July on the lower Kenai River:

- "Average Estimate" = 482 boats * 10 hours per day = 4,820 boat hours per day,
- "Low Average Estimate" = 410 boats * 8.5 hours per day = 3,485 boat hours per day, and
- "High Average Estimate" = 554 boats * 11.5 hours per day = 6,371 boat hours per day.

Given the estimations and assumptions described above for each of the three elements, the following table shows the projected loadings of TAH into the lower Kenai River for currently permitted engine types:

Scenario	Estimations	TAH Load
Average Estimate	((0.0790 gph * 0.294) + (0.0084 gph * 0.706)) * 4,820 hours per day	140 gpd
Low Average Estimate	((0.0548 gph * 0.188) + (0.0019 gph * 0.812)) * 3,485 hours per day	41 gpd
High Average Estimate	((0.1092 gph * 0.400) + (0.0194 gph * 0.600)) * 6,371 hours per day	352 gpd

The following table is the comparison of calculated loadings of TAH from Tasks 1 and 2:

Scenario	TAH Load - Forward Calculation for 35-hp Engines (Task 2)	TAH Load - Back Calculation for 35-hp Engines from River Concentration (Task 1)
Average Estimate	140 gpd	78 gpd
Low Average Estimate	41 gpd	57 gpd
High Average Estimate	352 gpd	105 gpd

Task 3: Determine information on fuel consumption, duration times, and usage patterns for boats on the lower Kenai River.

Based on informal contact with a couple of private boat owners who regularly fish the Kenai during the king salmon fishery, the most common fishing techniques used on the Kenai River during the king fishery are back-trolling and bait-bouncing. The back-trolling technique requires motor use to some extent to match current speed or inch downstream a bit slower than current speed. Bait-bouncing is normally done with the engine running but in the neutral position. The majority of guides use one motor which is typically a de-tuned 50-hp 4-stroke. This motor is used for traveling from hole to hole (full throttle) and used at a lesser throttle speed for back-trolling (throttle speed above true idle). Some guides also have a smaller engine that that can be used for back-trolling. For these boats, the larger engine can be shut off once the fishing location has been reached and the smaller engine is then used for back trolling. The remainder of time is spent near full throttle getting back to the head of the run or to a different location. Fuel consumption rates vary widely depending on time spent fishing, location, technique, engine type, and travel times between fishing holes. Using a 50-hp, de-tuned, 4-stroke engine in combination with a smaller trolling 4-stroke may result in approximately 7-10 gallons of fuel burned during an 8-hour day.

It has been anecdotally observed that some boats (primarily guides) spend significantly more time traveling at full throttle between locations in an attempt to find bigger fish for their clients or better fishing conditions. This is facilitated by relaying fishing reports via cellular phones from guide to guide who work for the same outfit.

Task 4: Determine gallons per day of total aromatic hydrocarbons entering Cook Inlet for July from permitted facilities.

Permitted discharges of produced water into Cook Inlet include four facilities operated by Unocal: Platform Anna, Platform Bruce, Granite Point Tank Farm, and the Trading Bay Production Facility (TBPF). The TBPF is an onshore facility that receives produced water from the Dolly Varden, Grayling, King Salmon, Monopod, and Steelhead Platforms. XTO Energy also operates an onshore facility called East Foreland Treatment Facility that receives produced water from two offshore platforms: Platforms A and C (Parametrix 2004).

Based on discharge monitoring reports (DMRs) for all facilities, TBPF contributes approximately 96% of the total mount of produced water discharged to Cook Inlet. Assuming that 99% of TAH concentrations reported on DMRs is associated with produced water discharges and that the June 2006 DMR for TBPF is representative of recent operations, all permitted facilities in Cook Inlet discharge approximately 40.6 gpd of TAH into Cook Inlet (DEC 2006).

Task 5: Determine the change in loading of total aromatic hydrocarbons in July to the lower Kenai River if all outboard engines were either 50-hp 4-stroke or 50-hp 2-stroke direct fuel injected.

Alaska Department of Natural Resources is proposing to adopt regulatory changes that would increase maximum allowable horsepower on the lower Kenai River from 35-hp to 50-hp, but all boat engines would have to be 4-stroke or 2-stroke DFI. Based on these proposed changes in engine size and type, a projected change in TAH loading also will occur. The calculation for loading related to the 50-hp engines must account for the three elements of Task 2.

For the volume of TAH, Equation (4) is still used, but the assumptions for factor E_g change because of the change in engine requirements. Given that a DFI engine reportedly is as efficient as a 4-stroke engine (ODEQ 1999), the following table includes new assumptions for E_g based on performance data for a 4-stroke 50-hp electronic fuel injected Yamaha (2006) motor and unchanged assumptions for the other factors.

50-hp 2-stroke DFI engine or 50-hp 4-stroke engine			
	Average Estimate	Low Average Estimate	High Average Estimate
Speed	Idle (1,000 rpm)		
Economy (E_g)	0.3 gph	0.3 gph	0.3 gph
Inefficiency (I)	0.041	0.013	0.075
%-TAH (G)	0.369	0.331	0.407
%-TAH Dissolved (S)	0.375	0.319	0.431
Volume of TAH (TAH_g)	**0.0017 gph**	**0.0004 gph**	**0.0039 gph**
Speed	Half Throttle (3,000 rpm)		
Economy (E_g)	1.8 gph	1.8 gph	1.8 gph
Inefficiency (I)	0.041	0.013	0.075
%-TAH (G)	0.369	0.331	0.407
%-TAH Dissolved (S)	0.375	0.319	0.431
Volume of TAH (TAH_g)	**0.0103 gph**	**0.0024 gph**	**0.0237 gph**
Speed	Full Throttle (max rpm)		
Economy (E_g)	4.8 gph	4.8 gph	4.8 gph
Inefficiency (I)	0.041	0.013	0.075
%-TAH (G)	0.369	0.331	0.407
%-TAH Dissolved (S)	0.375	0.319	0.431
Volume of TAH (TAH_g)	**0.0272 gph**	**0.0066 gph**	**0.0632 gph**

TAH_g results are averaged using the same hourly engine usage assumptions as outlined in Task 2 to yield the following estimates:

- 50-hp engine: "Average Estimate" = 0.0102 gph
  "Low Average Estimate" = 0.0024 gph
  "High Average Estimate" = 0.0237 gph

Since it is assumed that 2-stroke DFI engines are as efficient as 4-stroke engines, there is no need to account for the second element of Task 2; namely, the percentages of 2-stroke and 4-stroke engines that are on the river. The last step is to account for the third element of Task 2, which are the average boat hours per day in July. The resulting loadings for TAH are presented in the table below.

Scenario	Estimations	TAH Load
Average Estimate	0.0102 gph * 4,820 hours per day	49 gpd
Low Average Estimate	0.0024 gph * 3,485 hours per day	8 gpd
High Average Estimate	0.0237 gph * 6,371 hours per day	151 gpd

The following table shows the comparison of calculated loadings from Tasks 2 and 5.

Scenario	TAH Load for 35-hp Engines (2-Stroke and 4-Stroke) - Task 2	TAH Load for 50-hp Engines (4-Stroke and 2-Stroke DFI) - Task 5
Average Estimate	140 gpd	49 gpd
Low Average Estimate	41 gpd	8 gpd
High Average Estimate	352 gpd	151 gpd

Based on the comparison in the table above, the proposed regulatory change to 50-hp engines, 4-stroke or 2-stroke DFI, will decrease the projected load of TAH dissolving in the lower Kenai River.

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Task 6: Determine expected concentrations of TAH from projected total aromatic hydrocarbon loads for 50-horsepower engines and compare these estimates to the TAH water quality standard.

Task 5 detailed how proposed changes to engine size for the lower Kenai River will decrease projected loads of TAH that dissolve in the river. The logical question that follows the findings of Task 5 is whether the range of projected loads for 50-hp engines are low enough so that expected concentrations of TAH which will result from these loads are less than the Alaska water quality standard of 10 μg/L for TAH. The calculation for this question follows Equation (1) used in Task 1:

$$Q_d = Q_r C_r \quad (1)$$

except that for the current question, the unknown factor is C_r, concentration of TAH in lower river. Solving for C_r, Equation (1) becomes:

$$C_r = Q_d / Q_r \quad (6)$$

Then, as was done in Task 1, three scenarios are provided below to provide a range of realistic comparisons to the water quality standard for projected loadings from 50-hp engines.

Scenario 1 (Average Estimate):

- Q_d = 49 gpd = 0.000076 cfs ("Average Estimate" for TAH load from 50-hp engines [Task 5])
- Q_r = 13,577 cfs (mean daily flow in July at Soldotna bridge since 1965)

Solving Equation (6) with these assumptions yields:

$$C_r = 0.000076 \text{ cfs} / 13{,}577 \text{ cfs} = 0.00000000560 = 5.60 \text{ ppb.}$$

Given that 1 ppb is essentially equal to 1 μg/L, as was discussed in the introduction to this attachment, the "Average Estimate" for the expected concentration of TAH in the lower Kenai River using the "Average Estimate" TAH load from Task 5 is 5.60 μg/L, which is less than the water quality standard of 10 μg/L for TAH.

Scenario 2 (Low Average Estimate):

- Q_d = 8 gpd = 0.000012 cfs ("Low Average Estimate" for TAH load from 50-hp engines [Task 5])
- Q_r = 14,300 cfs (70th percentile daily flow in July at Soldotna bridge since 1965)

Solving Equation (6) with these assumptions yields:

C_r = 0.000012 cfs / 14,300 cfs = 0.00000000091 = 0.91 ppb.

Therefore, the "Low Average Estimate" for the expected concentration of TAH in the lower Kenai River using the "Low Average Estimate" TAH load from Task 5 is 0.91 μg/L, which is less than the water quality standard of 10 μg/L for TAH.

Scenario 3 (High Average Estimate):

- Q_d = 151 gpd = 0.000234 cfs ("High Average Estimate" for TAH load from 50-hp engines [Task 5])
- Q_r = 13,200 cfs (30th percentile daily flow in July at Soldotna bridge since 1965)

Solving Equation (6) with these assumptions yields:

C_r = 0.000234 cfs / 13,200 cfs = 0.0000000177 = 17.7 ppb.

Therefore, the "High Average Estimate" for the expected concentration of TAH in the lower Kenai River using the "High Average Estimate" TAH load from Task 5 is 17.7 μg/L, which is greater than the water quality standard of 10 μg/L for TAH.

A final consideration for Task 6 is that the TAH concentration in the lower river, C_r, for each scenario is an average concentration assumed for the entire lower river. In other words, Equation (6) assumes uniform distribution of the estimated discharge throughout the entire lower Kenai River. Of course, this assumption oversimplifies the situation, but the simplification allows for the necessary calculation of loads and receiving water concentrations. In reality, the concentration of TAH will be greater 1 foot behind an outboard engine than it will be 500 feet behind an outboard engine because of dilution, or mixing, caused by the river. This diluting effect does not solve the problem because the load of TAH is still in the river; the large volume of moving water in the lower river is just masking the presence of the discharged TAH. In addition, although the concentration of TAH in the river 500 feet behind an outboard engine may not exceed the water quality standard, it is almost guaranteed that the concentration one foot behind an outboard engine will exceed the standard. Therefore, there is still an exceedance of the water quality standard. This problem will occur regardless of which loading scenario – "Average Estimate," "Low Average Estimate," or "High Average Estimate" – is most accurate.

ATTACHMENT 2

GLOSSARY OF TERMS

(AMENDED APRIL 26, 2007)

C_d	Concentration of total aromatic hydrocarbons that is discharged from outboard engines.
Central Tendency	Measures of the middle or center of a distribution. The mean or average is the most common.
cfs	cubic feet per second
C_r	Concentration of total aromatic hydrocarbons in the receiving water body. In this case, the lower Kenai River.
DFI	direct-fuel injected
DMRs	discharge monitoring reports
E_g	Volume of gasoline used per hour by an outboard engine during operation on the lower Kenai River.
G	Percentage of total aromatic hydrocarbons in gasoline used by outboard engines on the lower Kenai River.
gpd	gallons per day
gph	gallons per hour
hp	horsepower
I	Percentage of gasoline lost during internal combustion of an outboard engine during operation.
KWF	Kenai Watershed Forum
lbs	pounds
Load	Volume or mass of pollutant that a water body receives from a point of discharge. In this case, the points of discharge are outboard engines.
μg/L	micrograms per liter
mg	milligrams
mg/L	milligrams per liter
ppb	part per billion
ppm	part per million
rpm	revolutions per minute
Q_d	Volume of total aromatic hydrocarbons discharged from outboard engines.
Q_r	Volume of moving water in the receiving water body. In this case, the lower Kenai River.
S	Percentage of total aromatic hydrocarbons that remain dissolved in the lower Kenai River after discharge from an outboard engine.
TAH	Total aromatic hydrocarbons. These are equal to the sum of the following volatile aromatic hydrocarbons: benzene, ethylbenzene, toluene, and total xylenes.

TAH_g	Volume of total aromatic hydrocarbons that are discharged per hour from an outboard engine and dissolve in the lower Kenai River.
TBPF	Trading Bay Production Facility
Water Quality Standard	Numeric or narrative degree of degradation that may not be exceeded in a water body as the result of human actions.
Water Solubility	Maximum amount of a substance that may dissolve in water at equilibrium at a given pressure and temperature.

ATTACHMENT 3

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(AMENDED APRIL 26, 2007)

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