Montana Creek Ecological and Water Quality Assessment

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Abstract

Montana Creek is a 3rd order stream in the northern Matanuska-Susitna Borough that supports a highly popular salmon and trout fishery. The Matanuska-Susitna Borough is the fastest growing borough in the State. The intense sport fishery and increasing residential population has caused concern over the potential for fish habitat and water quality degradation of Montana Creek. Evaluating the degree of bank and riparian area modification due to these causes and the current ecological condition of Montana Creek was established as a priority through the Alaska Clean Water Action Plan and the objectives of this study.

Stream surveys and ecological measures were conducted from the Yoder Road Bridge Crossing to the Susitna River, or the lower eight stream miles. Bank and riparian area modifications due to differing anthropogenic causes was evaluated through the review of aerial photographs and stream surveys. Stream water chemistry (pH, specific conductance, dissolved oxygen, alkalinity, and macronutrients) was measured within three sampling sections biweekly from late July through August 2005. Total fecal coliform bacteria were sampled during the last 2 weeks of June 2006. Stream channel form, water surface slope, substratum size distribution and percent embeddedness were measured along with samples of the benthic macroinvertebrates, benthic organic matter and algae.

An estimated 7% of the stream bank and 4% of the riparian area has been modified due to residential clearing and development, recreation and transportation infrastructure. Recreation, including remote camping, private campgrounds, and sport fishing was the primary cause of changes to the stream bank and riparian area and occurred primarily within the lower stream open to salmon fishing. Residential development was the second leading cause of riparian area changes but caused less bank modification than roads and railroads.

Stream water pH was above neutral and saturated with oxygen during the sample period. Specific conductance, alkalinity, and nutrient concentrations were low. Ammonia nitrogen was the dominant form of inorganic nitrogen and averaged 0.11 mg/L. Both total and total dissolved phosphorus was often below detection limits but increased following precipitation events. Ratios of inorganic nitrogen to total phosphorus suggest phosphorus limitation on most sampling dates. Average total fecal coliform bacteria counts were higher in the lower river below campgrounds and most recreational fishing when compared with samples collected upstream of the salmon fishery. Fecal coliform sampling during precipitation events suggested surface rather than subsurface contamination. Maximum stream water temperatures often were above 15°C, higher in the lower river, and strongly correlated with air temperature.

Stream channel characteristics were very similar among sites. The substratum was dominated by large cobble with very few fines and low embeddedness. Estimates of stream energy relative to channel substrate suggest a stable channel along with a low amount of large woody debris. The stable and open channel likely supported the abundant algal chlorophyll-a. Water quality was evaluated as “Good” based upon the macroinvertebrate community composition at the upper two sites but “Poor” at the sampling site located below the Parks Highway.

Introduction

Montana Creek is a productive clear-water tributary to the Susitna River. Montana Creek has been specified by the State of Alaska as important for the spawning, rearing, or migration of anadromous fish (AS 41.14.870). It supports the spawning and rearing of chinook, coho, pink, and chum salmon, and provides critical spawning, rearing, and overwintering habitat. Montana Creek provides an important salmon and trout fishery. Sport fishing for salmon is limited to the lower reaches from ¼ mile upstream of the Parks Highway to the confluence with the Susitna River, while the upper river is managed as a trophy rainbow trout fishery.

Montana Creek is a 3rd order stream composed of three major tributaries: north, middle, and south forks that flow into the Susitna River. The headwaters of the Middle Fork are at 3,200 feet and the elevation at the confluence is near 350 feet. The riparian vegetation on low banks and point bars is closed tall willow scrub, and on higher banks (0.5 to 1.0 m) is a closed mixed forest of spruce, birch and balsam poplar.

There has been very little development along Montana Creek upstream of the Yoder Road Bridge Crossing. Yoder Road parallels the South Fork of Montana Creek, with some residential and small agricultural development occurring on the south side of the Road. The Luthman Trail follows the Middle Fork upstream roughly 3 miles to the Middle Fork Falls and is open to foot, horse and all-terrain-vehicle traffic. Camping, fishing and other outdoor recreation activities are centered near the Yoder Road Bridge Crossing and around the Parks Highway downstream to the Susitna River. Subdivisions and some residential development has occurred along the eight-mile long length of river downstream from Yoder Road and are accessed on the west by the Talkeetna Spur Road and on the east from Montana Creek Road.

Concern has been raised over the apparent loss of habitat within the lower river due to intense recreational use and the potential for residential development to further the loss of riparian habitat and lead to the degradation of water quality. Due to these concerns, the Alaska Clean Water Action Plan (ACWA) prioritized Montana Creek for the assessment of current water quality and habitat conditions. The objectives of this study were to (1) quantify the current extent of bank and riparian modification due to recreation and development and (2) characterize the current chemical, physical, and biological characteristics of the stream. These data would be used to determine current areas and causes of habitat losses, prioritize restoration efforts and evaluate changing conditions over time.

Methods

Sampling design, data collection methods and handling, and quality assurance procedures are provided in Appendix A. Three sampling sites were selected (Table 1). The upper river reference site is referred to as MC-1 and is located downstream from Yoder Road. The lower river reference site (MC-2) was located just upstream from where Montana Creek Road approaches Montana Creek. The lower river impacted site (MC-3) is located between the George Parks Highway and the Alaska Railroad Bridge crossings.

A staff gauge was placed under the Yoder Road Bridge on June 27, 2005. Stream discharge was measured just upstream from the Yoder Road Bridge on June 27 and August 11. Temperature loggers were placed at the Yoder Road Bridge, at the end of Helena Street, and at the Railroad Bridge on July 19, 2005. The upper river temperature logger was removed on November 15, the lower river logger was removed on August 29, and the middle river logger was removed the following spring.

Water samples for chemical analyses were collected on July 19, August 1, August 11, and August 29, from all three sampling locations. Macroinvertebrates were collected in mid August. Algal samples were collected from all three sites on August 22, 2005.

Aerial photographs were downloaded from the University of Alaska Fairbanks server. The aerial photographs were obtained by the National Resource Conservation Service in the summer of 2004. Land ownership boundaries were identified from the Matanuska-Susitna Borough tax maps obtained from their web site. Property boundaries were displayed on the aerial photographs from visual inspection of major physical features.

Results

Riparian Modifications

An estimated 1,814 m of stream bank has been modified by human activity. This represents approximately 7% of the total amount of stream bank from the Yoder Road Bridge to the Susitna River (Table 1 and Appendix B). Approximately 4%, or 99,000 m^2 of the 2.6 million m^2 of riparian area has been modified to date. The predominant cause of both bank and riparian area modification has been recreational use. Recreational use accounts for 75% and 45% of the total modified bank and riparian area, respectively. Transportation, roads and railroads, were the second leading cause of bank modification (17%), followed by residential development (8%). Sixteen lots were cleared for homes or cabins; however, only two of these lots resulted in stream bank modification. Residential development was the 2nd leading cause of riparian area modification at 38%, followed by transportation at 17%.

Physical Characteristics

Channel Geometry and Substrate

Stream channel characteristics were very similar for the three sampling reaches and are shown in Table 2. The water surface slope decreased downstream and channel depth increased, while average channel width was similar among sites. Ratios of width to depth ranged from 34 to 39 with the highest values at the upstream site. Undercut banks were observed only within the straight reach upstream from Montana Creek Road (MC-2). The stream banks at the upstream reference site (MC-1) were less than 1 m high and composed of vegetated deposits of cobble sediment.

Table 1. Summary of bank and riparian modification by lot and type of use.

Town-ship and Range	Section(s)	Lot	Length of Bank Modification (m)	Area of Riparian Modification (m^2)	Primary Use	Secondary Use	Tertiary Use
T24NR4W	11	C2	164.00	5,000.38	Recreation	Camping	
T24NR4W	14	B2	14.40	1,440.00	Recreation	ATV	
T24NR4W	14 and 15	B2 and A14	255.12	16,666.65	Recreation	ATV	
T24NR4W	15	A14	22.00	367.33	Recreation	Camping	
T23NR4W	32	D14	2.00	200.00	Recreation	ATV	
T23NR4W	5	C1	93.32	1,866.66	Recreation	Camping	
T23NR4W	8	B7	0.00	2,812.30	Recreation	Parking	
T23NR4W	8	B3	106.25	5,859.00	Recreation	Camping	Bank Stabilization
T23NR4W	8	B5	0.00	2,685.40	Recreation	Fishing	
T23NR4W	7	A3	712.50	7,792.50	Recreation	Fishing	
T24NR4W	15	A10	0.00	903.48	Residential	Land Clearing	House
T24NR4W	15	A11	0.00	487.92	Residential	Land Clearing	House
T24NR4W	15	A12	67.00	4,879.20	Residential	Land Clearing	House
T24NR4W	15	D5	0.00	400.00	Residential	Land Clearing	Trailer
T24NR4W	15	D7	0.00	2,028.67	Residential	Land Clearing	House
T24NR4W	22	A4	0.00	18,297.00	Residential	Land Clearing	House
T24NR4W	28	Birch Terrace Add. #1 Lot 2	0.00	2,740.00	Residential	Land Clearing	House
T24NR4W	28	Montana Creek Add. No 3 Lot 1	70.00	2,439.60	Residential	Land Clearing	House
T24NR4W	28	Montana Creek Add. No 3 Lot 2	0.00	487.92	Residential	Land Clearing	House
T24NR4W	28	Montana Creek Add. No 3 Lot 3	0.00	591.70	Residential	Land Clearing	House
T24NR4W	28	Montana Creek	0.00	1,065.00	Residential	Land	House

Town-ship and Range	**Section(s)**	**Lot**	**Length of Bank Modification (m)**	**Area of Riparian Modification (m^2)**	**Primary Use**	**Secondary Use**	**Tertiary Use**
		Add. No 3 Lot 4				Clearing	
T24NR4W	33	11	0.00	117.18	Residential	Land Clearing	House
T24NR4W	33	12	0.00	703.08	Residential	Land Clearing	House
T24NR4W	33	Blankenship Subd. Tract A	0.00	1,289.00	Residential	Land Clearing	House located >100m from channel
T23NR4W	5	B7	0.00	0.00	Residential	Land Clearing	House
T23NR4W	5	D2	0.00	1,367.00	Residential	Land Clearing	House
T24NR4W	15	ROW between D5 and D7	36.00	3,630.00	Transportation	Residential Road	
T24NR4W	28	Michelle Dr.	20.00	2,000.00	Transportation	Residential Road	
T24NR4W	28	C8	7.81	781.00	Transportation	Residential Road	
T24NR4W	33	Kalispell Drive	0.00	236,17	Transportation	Residential Road	
T23NR4W	5	Montana Creek Road	199.98	3,999.60	Transportation	Residential Road	
T23NR4W	8	George Parks Highway	18.75	3,984.12	Transportation	Primary Road	
T23NR4W	7	Alaska Railroad	25.00	2,500.00	Transportation	Commercial	
			Bank (m)	Riparian Area (m^2)			
Total Modified			1,814.13	99,381.69			
Total Available			26,200.00	2,620,000.00			
Percent Modified			6.92	3.79			
Total Recreation			1,369.59	44,690.22			
Percent of Modification			75.50	44.97			

Town-ship and Range	Section(s)	Lot	Length of Bank Modification (m)	Area of Riparian Modification (m^2)	Primary Use	Secondary Use	Tertiary Use
Total Residential			137.00	37,796.75			
Percent of Modification			7.55	38.03			
Total Transportation			307.54	16,894.72			
Percent of Modification			16.95	17.00			

Nearshore riparian vegetation consisted of tall alder and willow scrub. Average bank slopes above the vegetation line were near 15 degrees. Banks at MC-1 were not undercut. Stream banks at the lower reference site (MC-2) were slightly higher but also less than 1 meter. Upper vegetated bank slopes were greater than 45 degrees. Riparian vegetation was closed tall alder shrub and banks were undercut on average 15 to 20 cm with maximum values of 45 cm. The right bank at the lower river site (MC-3) is an eroding road. The bank was nearly 1.5 m high with an average slope of 36 degrees. The left bank was composed of vegetated alluvial deposited cobble and abandoned or overflow channels.

Table 2. Channel characteristic for the three Montana Creek sites. UC=bank undercut.

	MC-1	MC-2	MC-3
Width (m)	23.85	21.57	26.52
Area (m2)	13.35	13.90	19.49
Depth (m)	0.56	0.65	0.76
w/d ratio	42.61	34.56	39.21
R bank ht. (m)	0.61	0.70	1.46
R lower bank slope (°)	9.32	14.12	21.97
R upper bank slope (°)	12.27	45.09	36.02
L bank ht. (m)	0.47	0.99	0.31
L lower bank slope (°)	8.66	17.49	5.21
L upper bank slope (°)	15.55	61.43	3.68
Water surface slope	0.0043	0.0031	0.0026
R UC (m)	0.00	0.15	0
L UC (m)	0.00	0.23	0

The substrate size distribution and percent of substrate embedded in fines are shown in Figures 1 and 2. Channel substrate at these three sites was primarily composed of large cobble to boulder sized material with slightly larger sized material at the upper site. There were very few fines at any of the sites. Embeddedness at the lower two sites was similar, and greater than at the upper site.

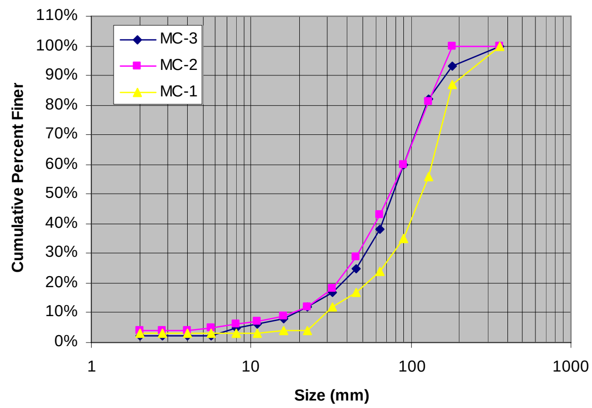

Figure 1. Substratum size distribution showing similar curves for all three sites.

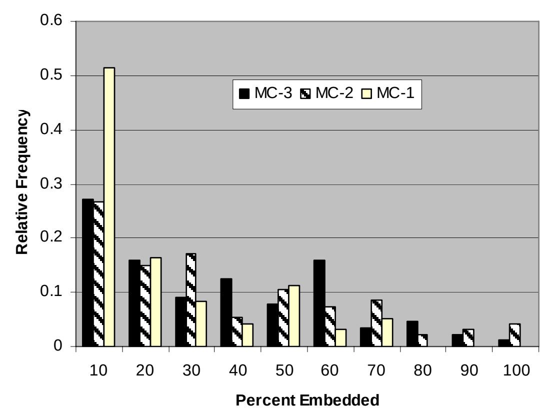

Figure 2. Portion of substrate embedded with fine material for the three sites.

Tractive forces were calculated using mean depth at ordinary high water and at maximum depths (lower terrace heights) and measured water surface slopes. Tractive forces were near 20 N/m^2 at ordinary high water and near 50 N/m^2 as banks were overtopped. These values were only 20 to 50% of critical tractive forces based upon substrate size distribution suggesting a stable stream bed.

No large woody debris or debris dams were observed within any of the three 100-m long sampling reaches. Large woody debris and debris dams were then counted from the Yoder Road Bridge downstream 1.2 km. Within this sampling section 5 individual pieces and 9 debris dams were observed. The Large Woody Debris Index (LWDI) score for the 1.2 km section of river was 531 or 43 for 100 m. Most of the wood was large diameter (40 to 50 cm) poplar.

Stream Temperatures

Daily stream water temperatures for sites located at the Yoder Road Bridge (MC-1) and the Railroad Bridge (MC-3) are shown in Figure 3. Maximum daily temperatures occurred between 17:00 and 20:00, while minimums generally occurred around 08:00. Seasonal maximum water temperatures occurred in August and coincided with maximum air temperatures at the Talkeetna Airport. On average, maximum water temperatures were 1.6 °C higher at the Railroad Bridge.

State Water Quality Standards are 13°C for fish spawning and incubation and 15°C for migration and rearing. At the Yoder Road Bridge, maximum water temperatures exceeded 13°C on 33 days and 15°C on 10 days. In the lower river, maximum water temperatures exceeded 13°C on 34 days and 15°C on 20 days. Average water temperatures in the upper river; however, were only greater than 15°C on two days (Table 3). Water temperatures did not exceed 20°C at either site.

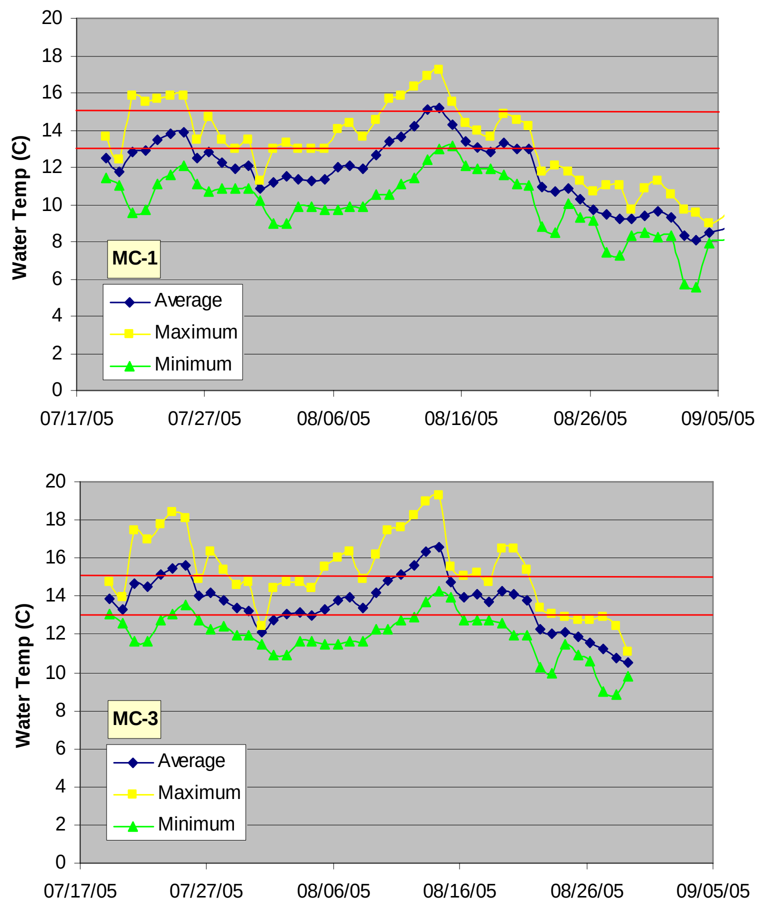

Figure 3. Daily water temperature statistics for the upper and lower river sites. Red lines indicate State Water Quality Standards.

Stream water temperatures were closely related to air temperatures recorded at the Talkeetna Airport (located approximately 10 miles to the north). Daily maximum air temperatures at the airport were correlated with the daily temperature increase (daily maximum minus daily minimum) and maximum stream water temperatures. At the upper river site, daily water temperatures increased at a rate of 0.25°C and at a rate of 0.29°C at the lower site for every degree increase in air temperature (Figure 4). Similarly, maximum water temperatures are 0.40°C and 0.45°C higher with every degree increase in air temperature for the upper and lower river, respectively (Figure 4). Based upon the regression equations, the upper river maximum water temperatures will exceed 15°C when maximum air temperatures are greater than 74 °F; however, air temperatures in excess of 96°F will need to occur before water maximums exceed 20°C. For the lower river, maximum water temperatures will be over 15°C and 20°C, when maximum air temperatures exceed 67°F and 87°F, respectively.

Table 3. Number of days average and maximum water temperatures exceeded 13 and 15°C.

	MC-1	MC-3
Average >13	12	31
Average >15	2	7
Maximum >13	33	34
Maximum >15	10	20

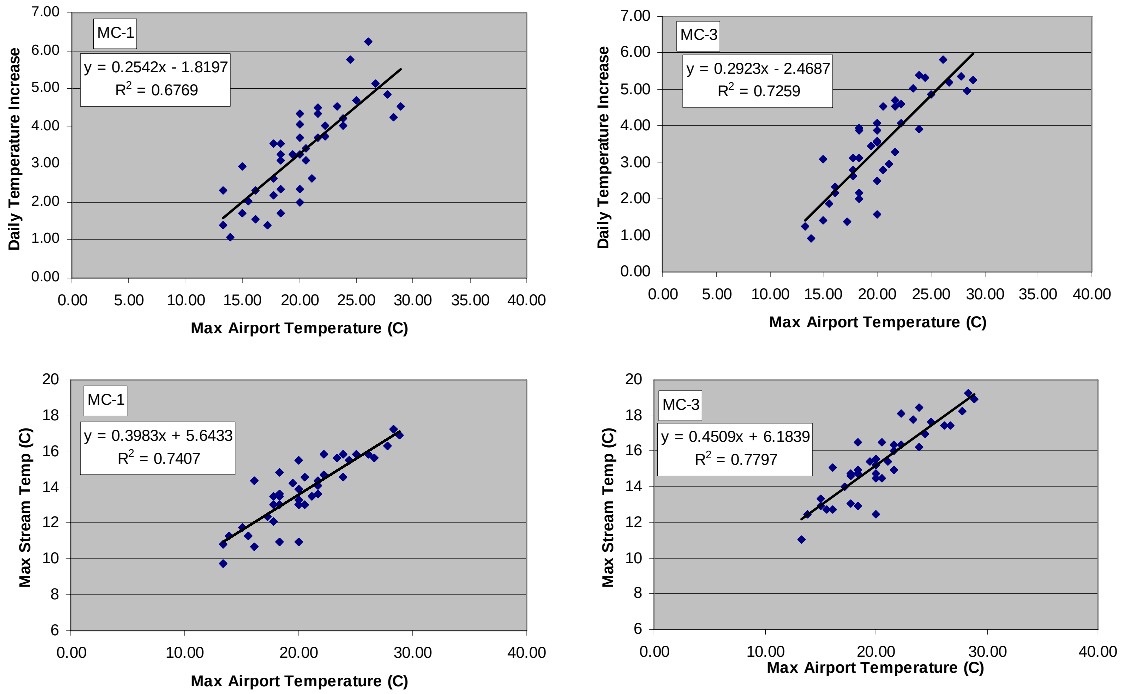

Figure 4. Relationships between maximum air temperature at the Talkeetna Airport and daily stream temperature change and maximum stream temperature.

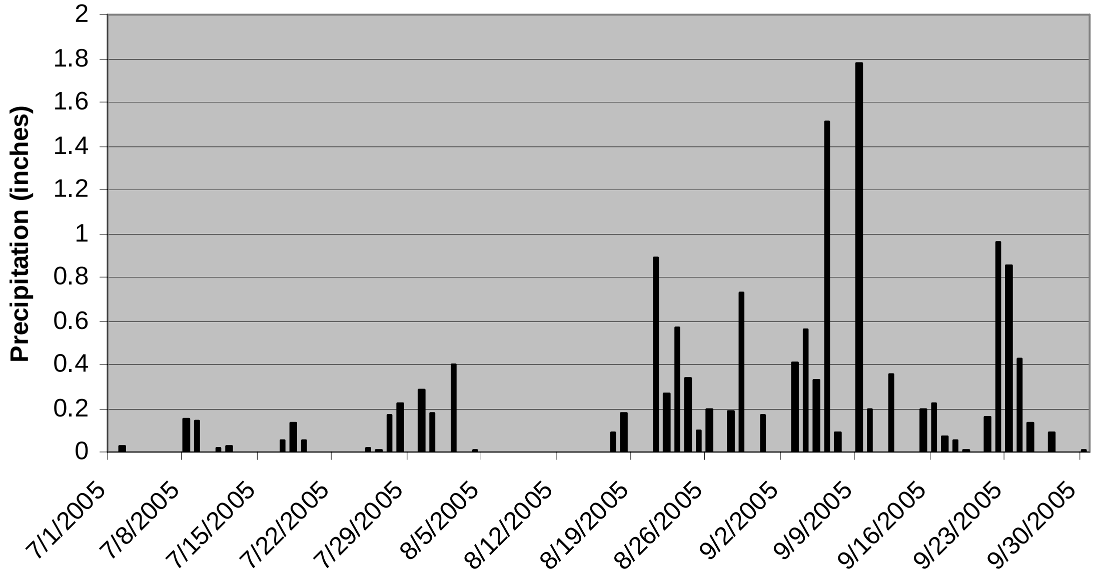

Figure 5. Precipitation data recorded at the Talkeetna Airport.

Chemical Characteristics

Based upon collected samples, Montana Creek is saturated with dissolved oxygen. Stream pH is near neutral, carbonate alkalinity and concentrations of ions and macronutrients are very low. Increases in concentration of nitrogen coincided with anadromous fish returns. Precipitation events that increased stream flow coincided with decreases in pH and increases in total dissolved phosphorus. Ratios of nitrogen to phosphorus suggest phosphorus limitation.

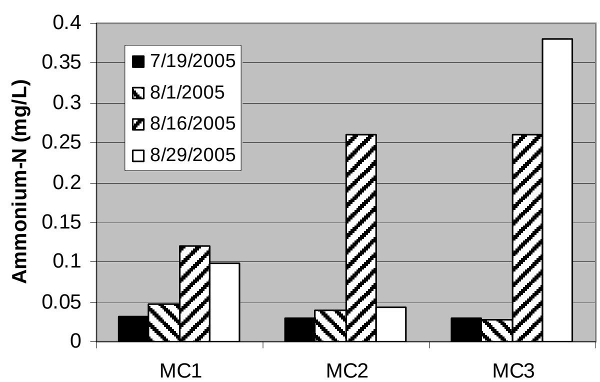

Figure 6. Concentrations of ammonium nitrogen in Montana Creek.

Water samples were collected on July 19, August 1, August 16, August 22 (pH, specific conductance, and turbidity only) and August 29. A small amount of precipitation was recorded at the Talkeetna Airport just prior to the August 1 sampling date with more substantial precipitation prior to August 22 and on August 29 (Figure 5). Similarly, stream gauge height at the Yoder Road Bridge was 0.3 on July 18, -0.1 ft. on August 11, and increased to 1.3 ft on August 29. A rating curve was not constructed; however, discharge was measured at 106 cfs with a gauge height of 0.7 ft and 47 cfs when the gauge height was -0.1 ft. Therefore, all samples except for those collected on August 22 and 29 represented base flow conditions.

Montana Creek is a clear-water stream with turbidities during base flow of below 1 NTU. Turbidity increased only slightly, to seasonal maximum values of 1.4 at the upper site, and 1.6 at the lower river site. The highest pH values (7.4 to 7.5) were recorded during the low flow period in mid August and decreased to 7.0 to 7.1 as flow increased at the end of August.

Specific conductivity was low at near 50 μS/cm with no obvious spatial or temporal trends. Alkalinities also were low ranging from 16 to 20 mg/L $CaCO_3$. These measures of low ion concentrations are reflected in concentrations of nitrogen and phosphorus.

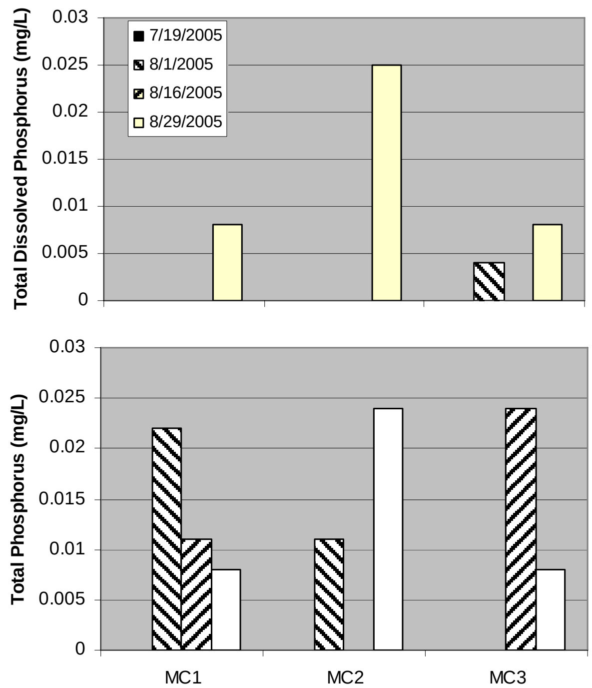

Figure 7. Total and total dissolved phosphorus concentrations in Montana Creek.

Nitrate plus nitrite-nitrogen concentrations were below detection limits (0.01 mg/L) on all sampling dates. Concentrations of ammonium nitrogen; however, were above detection limits on all sampling dates (Figure 6). Concentrations were highest in mid August at the lower reference and lower river sites and remained high at the lower river site into the end of August.

Montana Creek phosphorus concentrations are shown in Figure 7. Total and total dissolved phosphorus concentrations were below detection limits on July 19. On August 1 and 16, phosphorus concentrations were dominated by those suspended in the water column adsorbed to inorganic particles or incorporated into organic material. On August 29, total and dissolved concentrations were equal indicating that all of the measurable phosphorus was dissolved in the water column.

Primary production limited by phosphorus is suspected due to the high concentrations of nitrogen relative to phosphorus. Molar ratios of nitrogen to phosphorus were generally in the hundreds. Ratios dropped to 28 and 4 for sites MC-1 and MC-2 on August 29 with increases in dissolved phosphorus.

Total fecal coliform bacteria exceeded State Water Quality Standards below the Parks Highway. Samples were collected during the last 10 days of June and coincided with the chinook salmon sport fishery. Samples collected on June 23, 26, and 30 were during or following precipitation events. Sample collection preceded the opening of the salmon fishery on June 23 and followed the weekend opening on June 20 and 30. The June 26 sampling date was on the last day of a 4-day opening. The geometric mean value for samples collected at MC-2 (upstream of Montana Creek Road) was 12.75 cfu/100 ml, and 130.5 cfu/100 ml for samples collected below the Alaska Railroad Bridge Crossing (Table 4).

Table 4. Total fecal coliform bacteria (cfu/100 ml) for lower Montana Creek water samples during the chinook salmon sport fishery.

	8/23/2005	6/20/2006	6/23/2006	6/26/2006	6/30/2006	Ave
MC-2		5	30	6	10	12.75
MC-3	96	9	14	490	9	130.5

Biotic Characteristics

Periphyton chlorophyll-*a* samples were collected on August 22, 2005. The concentrations of chlorophyll-*a* were significantly higher at the lower river sites (ANOVA p=0.05) (Figure 8).

Total benthic organic matter ranged from 13 to 24 g/m^2 (Table 5). There was from 3 to 8 times more fine organic matter (0.63 to 1 mm) than coarse material. Coarse particulate organic matter (retained by 1-mm mesh net) ranged from 1.9 to 3.3 g/m^2. There were no significant differences in either coarse or fine fractions among sites (ANOVA p>0.05).

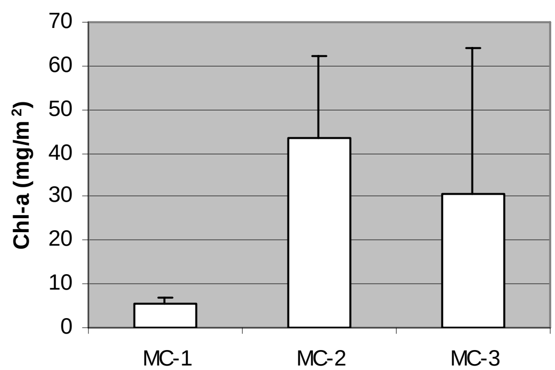

Figure 8. Chlorophyll-a concentrations for Montana Creek periphyton collected within the three sampling sites.

Macroinvertebrate metric scores showed a decrease in water quality when comparing the upper two sites to the site located below the Park's Highway and when comparing with previous studies (Table 6). The ASCI score for sites MC-1 located just below Yoder Road, and MC-2, located upstream of Montana Creek Road were 10 to 20 points higher than scores for MC-3, located below the Park's Highway. Water quality rankings for the upper two sites were "Good" and "Fair" for the downstream site. The downstream site differed from the other two locations in the number of Ephemeroptera Taxa, the percent Ephemeroptera that were not Baetidae, the high number of Baetidae and the low percent scrapers.

Table 5. Amounts of coarse (CPOM) and fine (FPOM) benthic organic matter at the three Montana Creek sampling locations.

Site	CPOM (g/m^2)	FPOM (g/m^2)	Total (g/m^2)	FPOM/CPOM
MC-1	3.3	20.3	23.6	6.2
MC-2	1.9	15.5	17.4	8.2
MC-3	3.2	10.1	13.3	3.2

Table 6. Macroinvertebrate metric values for the three sampling locations and ASCI scores for this study and previously reported samples collected below the Park's Highway Bridge (Major and others 2001).

Invertebrate Metrics and ASCI Scores	**MC-1**	**MC-2**	**MC-3**	**msmon01 5/98**
Total Organisms	272	218	223	
Ephemeroptera	13	13	20	
Plecoptera	2	9	3	
Trichoptera	15	40	13	
Diptera	241	139	181	
Richness	13	16	12	
Ephemeroptera Taxa	5	5	3	
Trichoptera Taxa	2	5	3	
% Plectopera	0.74	4.13	1.35	
% Ephemptera (no Baetidae)	4.04	4.13	1.79	
% Diptera	88.60	63.76	81.17	
Baetidae/Ephemeroptera	0.15	0.31	0.80	
% Non-insects	0.37	7.80	2.69	
HBI	5.46	3.84	4.52	
%Scrapers	7.35	9.63	1.79	
% Collectors	7.35	52.29	83.86	
% EPT no Baetids or Zapada	10.29	26.61	8.97	
Low /Gradient Coarse Substrate	**ASCI Scores**			
Ephemeroptera taxa 100 * X / 5.5	71.43	71.43	42.86	72.7
% Ephemeroptera (no Baetidae) 100 * X / 20	20.22	20.64	8.97	13.2
% Plecoptera 100 * X / 14	5.25	29.49	9.61	56.4
Baetidae / Ephemeroptera 100 * (100 - X) / 100	84.62	69.23	20.00	20.0
% non-insects 100 * (30 - X) / 30	98.77	74.01	91.03	91.2
O/E (family 75%) 2 100 * X	70	80	80	100
% scrapers 100 * X / 15	49.02	64.22	11.96	3.5
HBI 100 * (6.5 - X) / 2	52.02	100.00	98.90	51.5
Average	**56.42**	**63.63**	**45.42**	**51.0**
Ranking	**Good**	**Good**	**Fair**	**Good**

Discussion

Outdoor recreational use is the major cause of Montana Creek bank and riparian modification. Areas of impact are located at the Yoder Road Bridge Crossing and downstream of the Park's Highway. ATV trails and camping appear to be the major cause of bank and riparian habitat modifications at the Yoder Road Bridge crossing. The salmon fishery is closed at this location and the rainbow trout fishery is catch and release. Bank and riparian modifications adjacent to and below the Park's Highway appear to be associated with camping and bank fishing during the chinook and coho salmon sport fishery. Transportation (Montana Creek Road, the Park's Highway, and the Railroad) are additional causes of lower river bank and riparian area modification. In addition to bank and riparian area modification, the macroinvertebrate community of the lower river showed a decrease in water quality. ASCI scores resulted in a "Poor" ranking compared with upstream sites that ranked "Good". Water quality as indicated by macroinvertebrates also has decreased from samples collected in 1998 (Major et al. 2001).

The periodic high total fecal coliform bacteria counts are another indication of reduced water quality within the lower river. While average colony forming units exceeded State Standards in the lower river, high averages were due to one sampling date in 2006. However, bacteria counts in the lower river also were high during a single sampling event in August of 2005. The August 2005 sampling event and the June 2006 sampling event occurred during the peak of the coho and chinook salmon fisheries. Sampling was also conducted during or following storm events. Increases in fecal coliform bacteria appear to be related to surface rather than groundwater sources. Although not measured during this study, the intensive recreational use of the Yoder Road Bridge crossing for camping, and the lack of restroom facilities could also result in high fecal coliform bacteria counts during Holiday weekends or other peak times of use.

While residential development is the second leading cause of riparian modification, it is responsible for the lowest amount of bank modification. This was contrary to our expectations. There were only two properties where the riparian vegetation had been removed up to the steam bank with the direct or indirect result of bank erosion. One additional property at the end of Romano Drive has since cleared additional riparian vegetation up to the stream bank. This occurred following the data collection efforts of this study and it is unknown as to whether additional bank erosion has occurred. Many of the cleared residential sites have small foot paths leading toward the steam, which had not resulted in extensive bank modifications. It may be that concern over bank erosion and the loss of property and structures has played a role in many property owners maintaining bank vegetation.

Average and maximum stream water temperatures were higher in the lower river compared to the upstream site. Higher temperatures in the lower river could be influenced by the lack of riparian vegetation along the left or southern bank due to campgrounds, Montana Creek Road, the Park's Highway and the Alaska Railroad. Channel widening associated with bank erosion can increase stream surface area which influences water temperatures (Poole and Berman 2001). Based on the regression equations, water temperatures are not likely to exceed tolerance values for pacific salmon during critical life history stages. Water temperatures and the daily change in water temperature were strongly correlated with air temperatures. High changes in daily temperatures indicate low buffering capacity (Poole and Berman 2001). The maximum daily rate of change for Montana Creek was over 6°C. This compares with a maximum of 4.6°C for Cottonwood Creek. Johnson et al. (2004), measured daily temperature differences of over 10°C in a bedrock reach of a second order stream in the Oregon Cascades.

Roads and railroads combined to be the second leading cause of bank modifications. Montana Creek Road closely approaches the channel and the stream bank is the road shoulder. This is the largest source of bank modification due to road construction following the Park's Highway and associated upstream rip-rap bank stabilization. Both Michelle Road and the road through lot C8 of section 28 (Sunshine Town Site) dead-end at Montana Creek.

The stream substrate is large and based upon channel geometry and the absence of undercut banks, the stream bed is stable. It would be expected that channel migration would lead to increased sources of large woody debris. There was very little woody debris within the sampling locations. Observations of single trees within the channel due to bank undercutting was rare and most wood was observed in debris dam accumulations. The LWDI was considerably lower than within Willow Creek downstream of the Park's Highway, a similar sized stream, where 10 pieces and 5 debris dams were counted within a 100-m reach resulting in an index value of 580 compared to a value of 43 for a 100-m reach of Montana Creek (Davis and Davis 2005). However, these indications of channel stability are not supported by review of the aerial photographs that show multiple side channels and abandoned channels as the stream has migrated over time. It may be that pulses in smaller sediment result in periodic channel migration.

Montana Creek was characterized as a clear-water stream with only minor increases in turbidity during storm events. Water pH was above neutral and decreased with discharge as observed in previously and within other regional streams (Davis et al. 2006a, Davis et al 2006b, Boyer et al. 1997). Stream water alkalinity, specific conductance, and nutrient concentrations were all low relative to other regional streams.

Montana Creek stream water alkalinity was much lower than concentrations in other regional streams. Alkalinity within Montana Creek ranged from 14 to 22 mg/L $CaCO_3$. In comparison, alkalinity within the Little Susitna River within Hatcher Pass ranged from 22 to 40 (Davis et al. 2006), 40 to 90 within Wasilla Creek (Davis and Muhlberg 2002), and 40 to 150 mg/L $CaCO_3$ in Chester Creek (Davis and Muhlberg 2001). Invertebrate production has been shown to be lower in streams with low alkalinity (LaPerriere 1983).

Ammonia nitrogen was the dominant nitrogen source within Montana Creek during the growing season. Nitrate nitrogen concentrations were below detection limits through this study. The absence of nitrate nitrogen during the summer months also has been reported for Cottonwood Creek and the Little Susitna River. Alternately, nitrate nitrogen concentrations around 0.4 mg/L during the growing season were reported for Wasilla Creek and Chester Creek. Ammonia nitrogen concentrations were above detection limits on all sampling dates. Average ammonia nitrogen concentrations were 0.11 mg/L. These base-flow concentrations are similar to average concentrations observed in Cottonwood Creek (0.07 mg/L) and the Upper Little Susitna River (0.13 mg/L). Both total and total dissolved phosphorus concentrations were low and often below detection limits. Molar ratios of inorganic nitrogen to total phosphorus were generally above 18 suggesting phosphorus limitation (Redfield 1958, Kahlert 1998), except following precipitation events when rising phosphorus concentrations reduced ratios.

Algal chlorophyll-a used as a surrogate for biomass, exceeded values obtained from most regional streams in spite of low nutrient concentrations. High algal biomass and high amounts of fine benthic organic matter in 3rd order streams is consistent with tenets of stream ecology (Vannote et al. 1980), due to the open canopy and water depths where solar radiation penetrates to the stream bottom and upstream processing of coarse organic matter. Similar high algal biomass has been observed in the nutrient rich lower portion of Chester Creek (Davis and Muhlberg 2001). The amount of total benthic organic matter was similar to values obtained from samples collected in Wasilla Creek and Chester Creek (prior to leaf fall). However, Montana Creek differed from those two streams in the relative amounts of fine and coarse fractions, with the fine material being much more dominant within Montana Creek.

The large amounts of modified bank habitat, increases in water temperature, decrease in macroinvertebrate ASCI scores, and high numbers of fecal coliform bacteria suggest that continued water quality monitoring of Montana Creek is warranted. Stream water temperature regression equations were developed based upon a limited amount of information; however, water temperatures within the lower river exceeded 15°C when air temperatures exceed 67°F (19.6°C). Continued monitoring would refine this relationship and help to provide more information on how water temperatures relate to anadromous fish migration, spawning, and rearing in the lower river. In addition, due to the low buffering capacity, changes in upper river riparian conditions could alter lower river air and river temperature relationships. Other factors such as continued bank erosion and increasing channel width to depth ratios could cause increase heat loading within the lower river.

Monitoring of fecal coliform bacteria should continue. While average counts exceeded State Standards in this study, they are based upon one high value. In addition, fecal coliform bacteria sampling was only conducted within a two week time period. Sampling should be conducted at multiple times throughout high use periods. In addition, sampling within this study occurred during low flow and following precipitation events, so we can not be certain whether the increases in fecal coliform bacteria were the result of surface or subsurface runoff. Continued ammonia-N sampling also would help to monitor potential ground water nutrient loading from septic systems.

Annual macroinvertebrate monitoring within Montana Creek should be conducted to determine whether the apparent decrease in water quality can be replicated. Continued macroinvertebrate monitoring also could be used to determine whether current changes reflect a trend of decreasing water quality or whether changes were due to unique conditions during this study.

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Appendix A: QAPP

Quality Assurance Project Plan

Montana Creek Impact Assessment

July 2005

(Revision Number 1.2)

AQUATIC RESTORATION AND RESEARCH INSTITUTE

P.O. Box 923, Talkeetna, AK.
(907) 733-5432 (phone/fax). www.arrialaska.org

A1. Montana Creek Impact Assessment

Aquatic Restoration and Research Institute

Project Manager: _________________________________ **Date:** _______________

Quality Assurance Officer: _________________________ **Date:** _______________

Alaska Department of Environmental Conservation

Project Manager: _________________________________ **Date:** _______________

Quality Assurance Officer: _________________________ **Date:** _______________

Effective Date:_______________________________________

A2. Table of Contents

A3. Distribution List

Ms. Laura Eldred
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Ph: 907-465-5305
jim_gendron@dec.state.ak.us

Mr. Dave Rutz
Alaska Department of Fish and Game
Sport Fish Division
Palmer, Alaska

Ms. Mary Price
U.S. Fish and Wildlife Service
Anchorage, Alaska

A4. Project/Task Organization

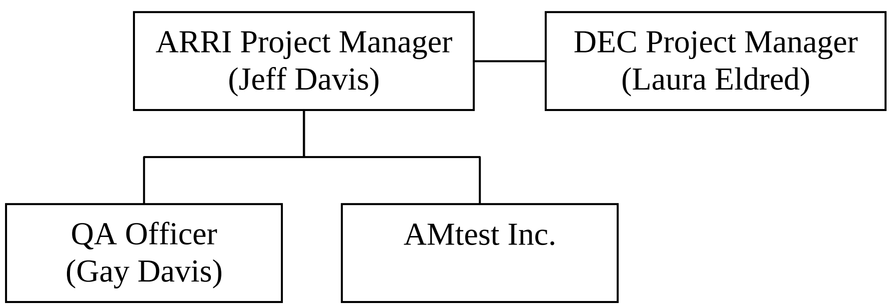
The project manager listed below will be responsible for all project components including data collection, entry, analyses, and reports.

Laura Eldred (DEC). DEC Project Manager. Ms. Eldred will oversee the project for DEC, provide technical support, QAPP review and approval, and the review of all quarterly reports and the final report.

Jeffrey C. Davis (ARRI): Project Manager. Mr. Davis will make sure that all field data are collected as specified in the QAPP. He will test and maintain all equipment prior to use and perform the review of data entry and analyses.

Gay A. Davis (ARRI) will act as Quality Assurance Officer. Ms. Davis will be responsible for making sure that all data are collected, replicate samples taken and analyzed, and all data entered and analyzed correctly.

AMtest Inc.—Redmond, WA. The testing laboratory will be responsible for analyzing all collected water chemistry samples.



A5. Problem Definition/Background

Montana Creek provides spawning and rearing habitat for most salmon species and Char present within southcentral Alaska. The lower portion of the drainage supports one of the more popular Chinook and coho salmon fisheries along the Park's Highway and the upper river provides a trophy rainbow trout fishery. However, recreation, including fishing, RV camping, and ATV use, along with increasing residential development has resulted in the loss of riparian vegetation and may be affecting the water quality and habitat components necessary to support the fish resources. The continued human benefits provided by Montana Creek can only be maintained by evaluating the current condition and causes of habitat modification, monitoring their effects on stream conditions, and addressing problems early. We propose to conduct surveys along Montana Creek and quantify habitat modification by type and location, develop monitoring stations, and discuss management and restoration options based upon project findings. Surveys will document the natural riparian vegetation community along the entire reach. Areas where the riparian (within 100 m of the channel) vegetation or stream channel have been modified will be identified and marked by GPS point, the type and extent of modification will be classified, photographs taken, and land ownership identified. Monitoring stations will be established at 3 locations; an upstream reference, one between Yoder Road and the Parks Highway, and one downstream of the Parks Highway and Railroad crossing. At each monitoring station the following parameters will be measured: channel morphometry and bank characteristics based on 5 surveyed cross-sections, substratum size distribution and embeddedness, near-shore water velocities, large woody debris distribution, macroinvertebrate community composition, algal biomass, benthic organic matter, temperature and water chemistry. Water chemistry will be based on bi-weekly sampling and analyses for macronutrients, pH, conductivity, turbidity, and dissolved oxygen. Discharge will be measured and a rating curve developed.

A6. Project/Task Description

The project objective is to obtain a comprehensive understanding of the current development along Montana Creek and the physical, chemical, and biological characteristics of the stream. Specific project tasks will include the following.

1. Identify and survey riparian development—Aerial photographs will be used to identify areas of development and divide Montana Creek into separate study reaches. Stream surveys will be conducted by ARRI staff to document changes to the stream channel and riparian vegetation within 100-m of the stream channel. The length of bank or riparian disturbance will be measured. The causes of riparian or bank modification will be identified.
2. Chemical Assessment—Water samples will be collected from three sampling sites for every other week for four sampling events. Samples will be returned to the ARRI laboratory and analyzed for pH (Hanna HI 9023), conductivity (SPER Scientific model 840039), and turbidity (HACH Chemical Co. Model 16800). Dissolved oxygen (YSI 550A) will be measured in the field. Water samples also will be collected, preserved (with sulphuric acid or at temperatures below 6°C) and sent to AMtest laboratory for alkalinity, nitrate and nitrite, ammonia, total phosphorus, and total dissolved phosphorus analyses.
3. Physical Assessments—Temperature will be measured using HOBO Stowaway temperature data loggers. Loggers will be placed at the three locations. At each sampling location, stream channel geometry will be determined from five surveyed transects separated by approximately 40 m. Wolman pebble counts will be conducted to determine substrate size distribution. Near-shore water velocities will be measured. Large scale channel measures of sinuosity and valley slope will be determined from USGS 1:63,000 maps.
4. Biotic Assessment—Macroinvertebrates, algae, benthic organic matter, and large woody debris within each of the three sampling sites will be measured. Invertebrates will be

sampling following the ASCI standard methods. Algae will be scraped from 5 stones or ceramic tiles and analyzed for chlorophyll-a and ash-free-dry-mass (AFDM). Benthic organic matter will be collected in nested nets to collect both coarse and fine fractions and analyzed for AFDM.

The following workplan outlines the tasks, schedule, and products/reports.

OBJECTIVE 1: Develop a DEC approved sampling plan and revised QAPP

TASK 1: Develop the Montana Creek sampling plan.

Start and end date: July 1, 2005 – July 15, 2005
Description: The project sampling plan will be written by the project manager. A draft plan will be submitted to DEC within 1 week of receiving funding, and a final plan by week 2. The sampling plan will outline sampling locations, frequency, and timing. Sample collection, handling, and processing will be described. The sampling plan will discuss equipment calibration and maintenance. Plan will describe how collected data will be handled as well as reporting requirements.
Product: project sampling plan

TASK 2: Develop the Montana Creek QAPP for DEC approval.

Start and end date: July 1, 2005 – July 30, 2005
Description: The project manager will develop a QAPP for the project that contains all of the required elements. Submit draft QAPP within 2 weeks of receiving workplan approval. Work with the DEC project manager to address any problems in the draft document and submit final QAPP for approval.
Product: approved QAPP

OBJECTIVE 2: Survey Montana Creek for Riparian Modifications

TASK 3: Obtain current aerial photographs and Mat-Su Borough tax maps

Start and end date: July 15, 2005 – July 30, 2005
Description: Purchase most recent (2000 or later) aerial photographs of the area if available. Review photographs to determine the relationship between major roads, residential developments, and landscape features with Montanan Creek. Subdivide Montana Creek into distinct reaches based on topography and development. Contact the Mat-Su Borough and purchase most recent tax maps in either electronic or hard copy. Compare aerial photographs with tax maps to identify property boundaries and legal description of developed properties.
Product: the location and extent of developed properties along Montana Creek will be presented in the final report.

TASK 4: Conduct stream surveys

Start and end date: July 30, 2005 – September 30, 2005
Description: Survey each reach identified by aerial photography. Surveys will be conducted on foot or by boat depending on access and stream conditions. Obtain continuous GPS track data for each survey reach. Identify all developed properties, defined as properties where the riparian vegetation within 100-m of the stream or the stream bank have been modified. For developed lots identified through aerial photography, contact the land owner, describe project, and request permission to access their land. If access is denied, the following measures will be estimated from a boat or by foot if there is a public access easement. For each developed property obtain upstream and downstream latitude and longitude. Using a distance finder, measure the length of disturbed area along the stream bank. Measure perpendicular to the stream, the lengths of unvegetated zones and zones of distinct vegetation (i.e. lawn, grasses, willows, poplars etc.) up to 100-m. For naturally vegetated areas, classify the vegetation community type. Describe the type of development or cause of bank or vegetation modification (i.e. residential, undeveloped camping, developed camping, power line, road, ATV trail, etc.)
Product: Project photographs for 1st quarter report. Extent and type of bank modification along Montana Creek from the Yoder Road crossing to the confluence with the Susitna River, located by latitude and longitude and legal description will be provided in the Final Project Report.

OBJECTIVE 3: Conduct Physical, Biotic and Chemical Assessments

TASK 5: Conduct site selection and physical assessment

Start and end date: July 30, 2005 – June 30, 2006
Description: Three monitoring locations will be established: an upstream reference, a site below the Parks Highway and Railroad Crossings and a site just upstream of Montana Creek Road and the salmon fishery. The latitude and longitude at the upstream and downstream end of the reach will be recorded. Temperature data loggers will be placed at each sampling site. At each site the following physical parameters will be measured. Substrate size distribution and percent embeddedness, bankfull width, hydraulic radius, wetted perimeter, energy slope, bed slope, bank undercut, bank angle, bank height, width to depth ratio and entrenchment ratio. Physical parameters will be calculated from 5 surveyed cross-sections. At each cross-section, near-shore water velocities will be measured when water surface is at or near ordinary high water. Sinuosity and segment slope will be obtained from USGS maps. Montana Creek is a large stream and near the upper limits for wading. Cross-sectional surveys will be conducted in the Fall during low flows; however, depending on water levels it may be necessary to complete some measures the following Spring.

Product: Excel spreadsheet of field data with 2nd Quarter Report. The complete physical description of Montana Creek at three locations will be presented and discussed in the Final

Report.

TASK 6: Conduct biotic assessment of Montana Creek

Start and end date: July 30, 2005 – September 30, 2005
Description: The following biotic parameters will be measured at all three monitoring locations: macroinvertebrates, algal biomass, benthic organic matter, and large woody debris. Macroinvertebrates will be sampled, and processed using the Alaska Stream Condition Index standard methods. These methods result in a stream condition index score that assess the stream condition based upon values derived from samples collected at multiple impacted and reference sites throughout the Susitna Drainage. As sediment input is of concern additional metrics used by ENRI to assess sediment input from logging roads and ATV trails also will be calculated. Algae are the primary food source produced within a stream and changes in nutrient input following development can lead to excessive blooms. Algae will be sampled from 5 randomly selected stones and submitted to a laboratory for chlorophyll-a and ash-free-dry-mass (AFDM) analyses. The other major food source in streams is stored within the substrate, or benthos, and is referred to as benthic organic matter. This organic matter will be collected using standard methods from 5 locations at each sampling site, divided into fine and coarse fractions, and analyzed for AFDM. Large woody debris serves multiple functions within stream systems. Riparian habitat modifications can lead to alterations in the input and storage of woody debris. The amount, size, and type of woody material will be measured within each sampling reach.
Product: draft information will be presented with the 2nd quarterly report and the final results of biological data collection and analyses will be presented and discussed in the Final Report.

TASK 7: Conduct Montana Creek chemical assessment
Start and end date: July 15, 2005 – September 30, 2005
Description: Bi-weekly water samples will be collected from all three sampling locations (4 samples from each site). Depth integrated water samples will be collected in 60-ml syringes from a well mixed location. Water samples to be analyzed for nitrate-N, ammonia-N, total phosphorus, and dissolved reactive phosphorus will be contained within laboratory provided and pre-labeled sample bottles, placed within a cooler along with a completed chain-of-custody form, kept cold with gel-paks and shipped Federal Express to the laboratory for analyses. Additional water samples will be placed within clean, pre-labeled sample bottles and returned to the ARRI laboratory for turbidity, pH, conductivity, alkalinity, and dissolved oxygen analyses.
Product: All laboratory water chemistry results will be submitted with the 2nd Quarter Report. The results of the chemical data will be presented and discussed in the Final Report

OBJECTIVE 4: Analyze data and write Draft and Final Reports

TASK 8: Data analysis and draft final report preparation

Start and end date: September 1, 2005 – March 31, 2006
Description: All field and laboratory data will be entered into excel spreadsheets. Sample results will be discussed relative to other streams, and possible sources. Daily temperature data will be converted to daily maximum, minimums, and averages. Daily average temperature differences from successive sites will be evaluated relative to stream and riparian characteristics, and fish distribution and tolerance limits. Water temperatures will be compared to State Standards. Nutrient concentrations will be evaluated relative to previously identified limiting concentrations. Algal biomass will be compared among sites and discussed relative to other similar studies. The macroinvertebrate community will be compared among sites and with previous values to evaluate any changes in stream condition relative to increased development over space and time. Physical assessment values will be presented along with chemical and biotic characteristics. All data will be entered into STORET per DEC requirements.

Product: Draft Final Report Submitted by the end of the 3rd Quarter for DEC review and comment

TASK 9: Develop and submit Final Report

Start and end date: April 1, 2006 – June 30, 2006
Description: Draft report will be updated to include additional spring data. Additional analyses will be conducted and discussions added as directed through review comments. Final document will be edited and printed.

Product: final project report in electronic and hard copy formats

A7. Quality Objectives and Criteria for Measurement of Data

The parameters in the Table 1 will be measured at the indicated performance level. All parameters are critical to meeting project objectives. Criteria for Measurements of Data are the performance criteria: accuracy, precision, comparability, representativeness and completeness of the tests. These criteria must be met to ensure that the data are verifiable and that project quality objectives are met.

Table 7. Accuracy, precision, and completeness objectives for measurement parameters.

Parameter	Method	Resolution/ Limit	Expected Range	Accuracy%	Precision	Completeness
pH	Meter	0.01	6.5 to 8.5	95 to 105 @ 7.0	5%	90%
Turbidity (NTU)	Meter	0.1	1 to 6	75 to 125	20%	90%
Conductivity (μS/cm)	Meter	0.1	100 to 200	95 to 105 @ 100μS/cm	5%	90%
DO (mg/L)	Meter	0.1	8 to 16	95 to 105 @ 10mg/L	5%	90%
Nitrate-N (mg/L)	EPA 353.2	0.010	0.05 to 0.5	75 to 125	20%	90%
Ammonia-N (mg/L)	EPA 350.1	0.005	0.01 to 0.05	75 to 125	20%	90%

Total-P (mg/L)	EPA 365.2	0.005	0.001 to 0.005	75 to 125	20%	90%
Dissolved-P (mg/L)	EPA 365.2	0.001	0.001 to 0.005	75 to 125	20%	90%
Alkalinity ($CaCO_3$ mg/L)	SM 2320	0.1	50 to 150	75 to 125	10%	90%
Algae/BOM (mg/m^2)	APHA 10200	0.001/0.01	0.1 to 10.0	75 to 125	20%	90%
Substratum (mm)	Counts	N/A	0.2 to 500	N/A	10%	90%
Macroinvertebrates	ASCI	N/A	N/A	N/A	20%	90%
Temperature (°C)	Stowaway	0.1	0 to 15	97 to 103 @ 15°C	5%	90%

Accuracy

Accuracy is a measure of confidence that describes how close a measurement is to its "true" value. Methods to ensure accuracy of field measurements include instrument calibration and maintenance procedures discussed in Section B of this QAPP.

$$Accuracy = \frac{MeasuredValue}{TrueValue} \times 100$$

Precision

Precision is the degree of agreement among repeated measurements of the same characteristic, or parameter, and gives information about the consistency of methods. Precision is expressed in terms of the relative percent difference between two measurements (A and B).

$$\Pr ecision = \frac{(A - B)}{((A + B)/2)} \times 100$$

Representativeness

Representativeness is the extent to which measurements actually represent the true condition. Measurements that represent the environmental conditions are related to sample frequency and location relative to spatial and temporal variability of the condition one wishes to describe.

Comparability

Comparability is the degree to which data can be compared directly to similar studies. Standardized sampling and analytical methods and units of reporting with comparable sensitivity will be used to ensure comparability.

Completeness

Completeness is the comparison between the amounts of usable data collected versus the amounts of data called for.

Quality Assurance for Measurement Parameters

Accuracy

The percent accuracy for the acceptance of data is shown for each parameter in Table 1. Accuracy will be determined for those measurements where actual values are known. For pH, conductivity, turbidity, and dissolved oxygen, measurements of commercially purchased standards within the range of expected values will be used. For dissolved oxygen, 100% saturated air will be used as a standard. Measurement accuracy will be determined for each sampling event. Contract laboratories will provide the results of accuracy measures along with chemical analytical reports. Accuracy for Stowaway temperature loggers has been calculated to be 0.40°C by the manufacturer, which at 15°C is 97% to 103%. Accuracy will not be determined where true values are unknown: substratum, macroinvertebrates, algae and benthic organic matter.

Precision

Table 1 shows the precision value for the acceptance of data. Precision will be determined for all chemical measure by processing a duplicate for every per sampling event. Precision of stowaway meters will be determined by placing all meters in one location for 24 hours. Precision for substratum size distribution will be determined by repeating the pebble count at one location and comparing the number of stones within each size class.

Representativeness

The site locations, sampling frequency, and timing will ensure that the measurement parameters adequately describe and represent actual stream conditions for the sampling period. Single year data should not be interpreted to be representative of conditions over longer temporal scales. Repeated measures over multiple years are necessary to describe the variability among years. However this is beyond the scope of this project.

Comparability and Completeness

The use of standard collection and analytical methods will allow for data comparisons with previous or future studies and data from other locations. We expect to collect all of the samples, ensure proper handling, and ensure that they arrive at the laboratory and that analyses are conducted. Our objective is to achieve 90% completeness for all measures. Sample collection will be repeated if problems arise such as equipment malfunction or lost samples.

A8. Special Training Requirements/Certification Listed

Jeffrey C. Davis (Project Manager) has a B.S. degree in Biology from University of Alaska Anchorage and a M.S. degree in Aquatic Ecology from Idaho State University. He has 12 years of experience in stream research. Mr. Davis has experience in all of the assessment techniques outlined in this document. He has experience in macroinvertebrate collection pursuant to the USGS NAWQA program, the EPA Rapid bioassessment program, modification of these methodologies for Idaho and Alaska. Mr. Davis also has experience in aquatic invertebrate and vertebrate species identification.

Gay Davis (Quality Assurance Officer) has a B.S. degree In Wildlife Biology from the University of Maine. She has 13 years of experience in stream restoration and evaluation.

Chemical analyses will be conducted through AM Testing in Redmond Washington.

The project manager will provide all volunteers training on how to fill out data sheets prior to any data collection. Particular focus will be on ensuring that photograph roll and exposure numbers are recorded on the correct date.

With the combined experience of these investigators, no additional training will be required to complete this project.

A9. Documentation and Records

Field data including replicates measures for quality assurance will be recorded in Rite-in-the-Rain field books. Upon returning to the laboratory, the field book will be photocopied (daily or weekly). The field data book will be kept and stored by the project manager and the Quality Assurance Officer will store the photocopies. ARRI will maintain records indefinitely. The final data report will include as appendices photocopies of the field data book, Excel data sheets, and results of QC checks. Any sampling problems will be recorded on the data sheets and included in the field sampling report. Laboratory reporting and requested laboratory turn around times of 6 to 10 days are discussed in section B4.

The project reporting requirements are as follows:

- Quarterly Reports: Quarterly progress, financial, and MBE/WBE reports will be submitted for the periods ending **September 30, 2005**, **December 31, 2005 and March 31, 2006.** Reports are due 15 days after these dates and are considered late if received more than 20 days after these dates. A final progress, financial, MBE/WBE reports, and all required deliverables are due **July 31, 2006, and are considered late if received after August 5, 2006**. All reports will be submitted in written and electronic formats requested by DEC.

- Monitoring Data Entry. In addition to a written project report, any water quality monitoring data collected by the project will be entered into STORET or provided to DEC in accordance with guidance and templates at: hhttp://www.state.ak.us/dec/water/wqsar/storetdocumentation.htm. The guidance and templates show the layout required for STORET compatible files and detail the valid values for various fields used in STORET (e.g. characteristics, analytic procedures, HUCs, etc). The data will be provided to DEC electronically via email, CD, diskette, or via an FTP website (to be determined). Alternate options for data entry are a) the use of the DASLER-X MS Access application or, b) a custom application that will produce STORET compatible text files in accordance with the guidance at the website listed above. The DASLER-X application and training in its use will be provided to the Grantee by ADEC or its representative before December 31, 2005. All data collected by Dec 31, 2005 will be furnished to DEC by March 31, 2006, and all data collected by the project will be furnished to DEC by July 31, 2006.

- Project Photographs. At least 3 electronic photograph(s) of the project will be submitted in a format suitable for publishing to the web. These photos will represent all of the following: the problem the project addresses, the project in progress, and the environmental benefit of the project. At least one of these photos must be submitted with the first quarterly report; the remainder will be submitted with the final report or sooner if available. Each photo will be at least 800 x 600 pixels in size and in JPEG format or other format acceptable to the department. Included will be background information on what the photo represents and when and where it was taken. If possible, the information will be in the photo's file name, such as "Fish_Ck_samplesite1_iron_floc_101603". Alternatively, it may be provided with a caption that states the date, location, and describes the subject: for example "MCV-023X.JPG. Taken 10-3-02, Ditch along south side of Alaska Highway that empties into Fish Creek: Note channelization."

- Final Report Evaluating Project Accomplishments and Benefits:
  A final report will be produced that evaluates and describes the project accomplishments and their environmental benefit. These environmental benefits will be determined by the assessment of water quality, habitat, and riparian vegetation condition in the lower 20 miles of Montana Creek.

- Deliverables: (at least 1 electronic and 3 hard copies of each)

In addition to submitting the information identified in the reporting requirements, the following products will be delivered to the Department. All written products will be submitted to the department in both hard copy and electronic format.

Project Sampling Plan...July 15, 2005
QAPP...July 30, 2005
Project Photographs... September 30, 2005
Project Data in Excel Format...December 30, 2005
Draft Final Report...March 31, 2006
Final Report...July 30, 2006

B1. Sampling Process Design

The physical, chemical and biological sampling will be designed to provide information on the undisturbed condition, unknown condition, and presumed impacted condition.

Sampling locations have been selected to describe the reference, potentially impacted and presumed impacted condition. The reference site will be selected upstream of most disturbance. Riparian and channel modification is apparent at the Yoder Road crossing of Montana Creek, which is just downstream from the confluence with the South Fork. Therefore it will not be possible to develop a reference site upstream of all disturbances. The reference site will be just downstream of the Yoder Road and Powerline crossings. Most of the residential development is between the Yoder Road and the Park's Highway bridges, with the commercial and recreational impacts at the Park's Highway and downstream. The potentially impacted site will be selected above the commercial development, but below most residential development; likely just upstream of where Montana Creek Road approaches the Creek. The presumed impacted site will be below the Parks Highway and above the railroad crossing where the right bank riparian vegetation has been removed at a private campground.

Sampling frequency will document the summer base-flow condition. Water temperature will be measured through the remainder of the summer months. Loggers will be removed prior to freeze-up. Physical measures do not vary within a season and will be taken when wading is possible. Water samples for chemical analyses will be taken every other week for four sampling events beginning in late July and extending into September.

Sample Parameters consist of chemical, physical, and biological measures. Recommended parameters as well as proposed methods are as follows (Table 2).

Water samples collected biweekly will be analyzed for the following parameters.

- pH. This is a measure of hydrogen ion activity. pH is controlled by the rock weathering, buffering capacity of the water, and influenced by biotic respiration. pH will be measured using a calibrated portable meter in the field (Hanna HI 9023 or equivalent).
- Turbidity (NTU). This measures of the reflective properties of the water sample relative to the amount of organic and inorganic particles. Turbidity will be measured in the laboratory using a Turbidimeter (Hach Chemical Co. 16800, or equivalent).
- Specific Conductance (µS/cm). Specific conductance is the inverse of electrical resistance and is relative to the concentration of ions in water. Specific conductance is used as a surrogate for Total Dissolved Solids. Specific conductance will be measured in the field using a conductivity probe and meter (Sper Scientific 840039 or equivalent).
- Dissolved Oxygen (mg/L). Oxygen concentration and percent saturation will be measured using membrane electrode (YSI 550A) in the field.
- Alkalinity (mg/L $CaCO_3$). This is a measure of the buffering capacity of water. Alkalinity will be measured by titration at the AM testing laboratory (APHA 2320).
- Nutrients—Nitrogen (mg/L-N). Water samples will be collected for Nitrate and Nitrite (NO_3 + NO_2) and ammonium (NH_4) analyses. Samples will be submitted to commercial laboratory for analyses using SM 4500-NO_3-E and 4500-NH_3-H. Currently AM testing is the proposed subcontractor.
- Nutrients—Phosphorus (mg/L-P). Water samples will be collected and analyzed for total and dissolved phosphorus (SM 4500-P E). Currently AM testing is the proposed subcontractor.

Sampling sites and frequency will vary for the following parameters as described below.

- Temperature (°C). Water temperature will be measured at 2 hour intervals using Stowaway data loggers (Onset Corporation). Temperature loggers will be placed at or near all three sampling locations.
- Morphometry/Substratum. The substratum particle size distribution and percent embeddedness will be estimated at 3 mainstem sites using pebble counts of 100 stones. Stream surveys to determine cross-section morphometry and energy slope will be conducted at substratum collection points.
- Macroinvertebrates/Habitat. Macroinvertebrates will be collected, processed, and analyzed following the Alaska Stream Condition Index (ASCI) methods. Samples will be collected from within the three sampling reaches.
- Algae/Benthic Organic Matter. Algae will be scraped from five different stones within the sampling reach. Benthic organic matter (BOM) will be collected from five randomly selected locations within each sampling reach.

External Data

No external data will be used.

Sample Timing

To minimize diel variability, water sample collection will be standardized to the time between 8:00 AM to 12:00 PM.

Table 8. Sampling frequency, location, and timing for storm flow and base flow conditions for each measurement parameter.

Parameter	Locations	Frequency/samples: Base flow	Timing	Total Samples
pH	3	Biweekly/4	Mid-Day	12
Sp. Conductance	3	Biweekly/4	Mid-Day	12
Turbidity	3	Biweekly/4	Mid-Day	12
Dissolved Oxygen	3	Biweekly/4	Mid-Day	12
Nutrients/Alkalinity	3	Biweekly/4	Mid-Day	12
Morphometry	3	Once/3	N/A	3
Substratum/Embeddedness	3	Once/3	N/A	3
Macroinvertebrates/Habitat	3	Once/3	N/A	3
Algae/BOM	3	Once/5	N/A	15
Water Temperature	3	Continuous	N/A	

B2. Sampling Methods Requirements

Field Data Collection

Field data collection will be conducted by ARRI staff. The latitude and longitude of sampling locations will be recorded and photographs taken. Sampling will occur on Monday or Tuesday of each week. Measures of dissolved oxygen will be conducted in the field. Samples for turbidity, pH, and specific conductance will be collected in clean sample bottles and returned to the ARRI Laboratory for analyses. Samples will be collected from a well-mixed area at each sampling site. Water-column integrated samples will be collected by drawing water into a 60 ml sterile syringe while drawing the syringe up from near the stream bottom to near the water surface. The water within the syringes will be discharged into pre-labeled sample bottles.

pH, Specific Conductance, Turbidity, and Dissolved Oxygen
Depth integrated water samples will be collected in 500 ml sample bottles. The sample bottles will be filled and emptied 3 times before a sample is retained. Water characteristics will be measured using appropriate meters. Meters, pH, Hanna HI 9023, conductivity, SPER Scientific model 840039, and turbidity, HACH Chemical Co. Model 16800. Support equipment will include extra batteries and sample bottles. Clean sample bottles will be used. All meters will be tested and calibrated prior to use.

Materials Required: Data book, pencils, sharpie, 500-ml sample bottles (16 minimum), 60-ml syringe, cooler, gel-paks, pH meter with standards, dissolved oxygen meter, thermometer, extra batteries, and camera.

Nitrogen, Phosphorus, and Alkalinity
Water samples will be collected in sample containers provided by AM Testing Inc. Sample bottles will contain preservative where required (H_2SO_4 for nitrogen and total phosphorus, 4°C for dissolved phosphorus and alkalinity). Samples will be collected using the “clean hands” method described below. Samples will be sealed within a cooler with frozen gel-paks and shipped by Federal Express to the laboratory for analyses. Maximum holding time for preserved samples is 28 days; however, sample turn-around is 14 to 21 days. Chain of custody forms will be used by ARRI staff and the receiving laboratory to track sample handling.

Materials Required: sample bottles, labels, markers, chain-of-custody forms, cooler, frozen gel-paks (6), 60-cc syringe (9), thermometer, and sterile gloves.

Substratum/Embeddedness
Substratum size distribution will be determined through Wolman pebble counts of 100 stones as modified by Bevenger and King (1995). Beginning at the downstream end of the sampling reach, the intermediate axis of rocks is measured at roughly one-meter intervals as the investigator moves upstream, continually moving at an angle from bank to bank. The rock axis will be determined using an aluminum measuring template. The portion of each rock submerged below the substrate will be estimated from differences in algae or other markings on the rock and recorded as percent embedded (Davis et al. 2001).

Materials Required: Rite-in-the-Rain data book, pencils, aluminum template, meter stick.

Macroinvertebrates/Habitat Assessment
Macroinvertebrates will be collected, processed, and analyzed using the Standard operating procedures for the Alaska Stream Condition Index (ASCI) (Major and Barbour 2001).

Composite invertebrate samples will be placed within pre-labeled whir-pak bags. Paper labels will be placed into the bags with the sample and the sample preserved with formalin. Labels will include date, time, location, and investigators. Stream invertebrate collections will be returned to the ARRI laboratory, sorted, and identified to genus (except for Chironomidae, Simuliidae, and Oligochaeta). Stream habitat will be evaluated using the habitat assessment methods of ASCI, or EMAP habitat assessment methods.

Materials Required: ASCI Habitat Assessment Data Sheets, whirl-pak bags, 5-gallon bucket, formalin, D-Nets, gauntlets, labels, pencils, sieve, and sharpies.

Temperature
Stream water temperature data loggers (Stowaway by Onset corp.) will be placed within the stream at three locations. Loggers will be secured to the bank using plastic coated wire rope. Loggers will be downloaded at least monthly.

Materials Required: 4-m sections of wire rope (3), clamps (6), stowaway temperature data loggers with backup (4), software, base station, coupler, and shuttle.

Morphometry
Stream cross-sections will be measured using a laser level and leveling rod. A meter tape will be secured across the stream channel. Elevations will be measured at 0.5 to 1.0 m intervals beginning and ending above bankfull flows. The location of bankfull flows, ordinary high water and undercut depth will be noted or measured.

Materials Required: Rite-in-the-Rain data book, pencils, 100-meter tape, laser level and tripod, leveling rod, meter stick.

Algae/Benthic Organic Matter
Algae will be sampled by scraping a known area of stone and collecting the dislodged material on to a Whatman GF/C filter with 0.45 µm pore site (Davis et al. 2001). The algal sample will be analyzed for chlorophyll-a and AFDM. Benthic organic matter will be collected in nested nets of different pore size held onto a Surber sampler frame. The sampler will be held on the stream bottom and the substrate from a known area upstream of the sampler will be disturbed, dislodging organic matter from the bottom, which will be carried into the nets by the current. The material from each net will be transferred into whirl-pak bags and preserved with alcohol. The AFDM of both the large and small size fractions will be determined through weight loss upon combustion at 500 C.

Materials Required. Surber sampler with nested nets, squirt bottle, whirl-pak bags, alcohol, sharpies, pencils, labels.

Corrective Actions
The QA officer will ensure that all equipment is prepared and ready for sampling and that all samples are collected as described. The QA officer will inform the project manager of any

problems with equipment or any missing data due to collection or laboratory errors. The project manager will be responsible for repairing or replacing equipment, taking additional samples, or replicating measurements as needed.

B3. Sample Handling and Custody Requirements

Water samples will be labeled in the field. Sample labels will record the date, time, location, preservation, and initials of collector. Chain of custody forms will be initiated in the field and completed each time samples are transferred to a laboratory, or other carrier. Field samples that are to be transferred to the contract laboratories will be placed within a cooler and the cooler sealed closed using plastic packing tape. Samples will be transported to the laboratory where they will be placed in a secure location until analyses are completed.

B4. Analytical Methods Requirements

Sample analytical methods are shown in Table 3. Field samples will be collected by ARRI staff and either delivered to the commercial laboratory for subsequent analyses by the identified standard method. Dissolved oxygen will be measured in the field. Turbidity, pH, and specific conductance will be analyzed at the ARRI laboratory.

Table 9. List of Analytical methods and detection limits for study parameters.

Measurement	Collection/ Analyses	Method	Limits	Turnaround Time (days)
Total Phosphorus	ARRI/AM Testing	EPA 365.2	0.005 mg/L	14-21
Dissolved Phosphorus	ARRI/AM Testing	EPA 365.2	0.005 mg/L	14-21
Ammonia-N	ARRI/AM Testing	EPA 350.1	0.005 mg/L	14-21
Nitrate + Nitrite-N	ARRI/AM Testing	EPA 353.2	0.01 mg/L	14-21
Alkalinity	ARRI/AM Testing	SM 2320	0.1 mg/L $CaCO_4$	14-21
Chlorophyl-a	ARRI/AM Testing	APHA 10200 H	0.001 mg/L	14-21
Benthic Organic Matter (AFDM)	ARRI	APHA 10200 I	0.01 mg/L	30
pH	ARRI/ARRI	Meter (Hanna HI 9023)	0.01 pH units	1
Conductivity	ARRI/ARRI	Meter (SPER 840039)	0.1 mhos (0 to 200) 1.0 mhos (>200)	1
Turbidity	ARRI/ARRI	Meter (HACH Model 16800)	0.1 NTU (0 to 10) 1.0 NTU (10 to 100)	1
Dissolved Oxygen	ARRI/ARRI	Meter (YSI Model 55)	0.01 mg/L (0 to 20)	1

Corrective Action

ARRI will be responsible for ensuring that all samples are collected and delivered to the laboratory. The QA officer will make sure all samples are labeled and stored correctly and that all equipment has been calibrated and accuracy tests completed as needed. The project manager will be informed of any errors and will be responsible for corrective action including repeating sample collection or analyses (for metered measures). If any samples are lost or are determined to be contaminated by the laboratory or if there are any laboratory problems, the project manager will be responsible for collecting new samples and delivering them to the laboratory.

B5. Quality Control Requirements

The following table (Table 4) lists the percent of field and laboratory replicates to be used for quality control (See section A7 for discussion on calculation of precision and accuracy). If accuracy and precision are not met for analyses ARRI is conducting the meters will be recalibrated and measures will be repeated or meters or probes will be replaced. Data measurements that do not meet the limits described in A7 may or may not be used in the final report depending on degree to which limits are not met. However, the report will clearly state if there are any questions regarding used data.

Table 10. Field and laboratory replicates for quality control.

Parameter	Field Replicates	Laboratory Replicates	Comments
pH, Cond, Turb, DO.	33 %	33%	Replicate measurements one of every 3 samples.
Alkalinity, phosphorus, nitrogen,	10 %	10%	Duplicate sample collected at one of the sites every sampling event. One laboratory replicate each sampling event.
Morphometry/ Substrate	None	None	Pebble counts will be repeated at one site. Descriptions of channel characteristics will be based upon the average or other statistic developed from the 5 transects.
Algae /BOM	5 replicate samples	None	5 replicates will be collected. Accuracy will be based upon statistics describing the variability among the replicates.
Temperature	1%	None	Water temperature will be measured on each sampling event with meters and compared with stowaway readings. Stowaways will be placed in the same location for 24 hours and reading compared.

B6. Instrument/Equipment Testing, Inspection, and Maintenance Requirements

Instruments and meters will be tested for proper operation as outlined in respective operating manuals. Inspections and calibration will occur prior to use at each site. Equipment that does not calibrate or is not operating correctly will not be used. For most parameters (temperature, conductivity, and pH), duplicate instruments and meters are available. In the case of complete equipment failure, new equipment will be purchased. The Project Manager will be responsible for calibrating and testing and storing equipment and completing log sheets. All calibrating, testing and storage will follow the manufacturer's recommendations. The QA Officer will inspect the log sheets. Spare batteries and repair equipment will be taken during field sampling events.

B7. Instrument Calibration and Frequency

The pH meter, conductivity meter, dissolved oxygen, and turbidity meter will be calibrated in accordance to instructions in the manufacturer's operations manual by the project manager prior to each use and a log will be maintained documenting calibration. Standards are required for pH, and turbidity and will be used for conductivity.

B8. Inspection/Acceptance Requirements for Supplies and Consumables

Sample containers will be obtained from AMtest Inc.. Any needed standards for equipment calibration will be purchased directly from the equipment manufacturer if possible or from a well established chemical company. The QA officer will be responsible for ensuring that standards are not outdated and for the purchase of replacements. The date and source of all purchased materials will be recorded within a separate file for each piece of equipment and kept on file by ARRI along with equipment calibration records.

B9. Data Acquisition Requirements for Non-Direct Measurements

Aerial photographs and Matanuska-Susitna Borough tax maps will be obtained. The maps will be assumed accurate and the aerial photographs will be compared with land features to ensure accuracy.

B10. Data Management

Field data will be entered onto rite-in-the-rain books. The Quality Assurance Officer will copy the field books and review the data to ensure that it is complete and check for any errors. Field and laboratory data sheets will be given to the project manager. The project manager will enter data into Excel spreadsheets. The Quality Assurance Officer will compare approximately 10% of the field and laboratory data sheets with the Excel files. If any errors are found they will be corrected and the Project Manager will check all of the field and laboratory data sheets with the Excel files. The Quality Assurance Officer will then verify correct entry by comparing another 10% of the sheets. This process will be repeated until all errors are eliminated. The Project Manager will then summarize and compare the data. The Quality Assurance officer will review any statistical or other comparisons made. Any errors will be corrected. The Project Manager will write the final report, which will be proofed by the Quality Assurance officer and submitted to the DEC project manager.

Water quality data will be provided to DEC in a modernized STORET compatible format. Data will be formatted into STORET compatible files as described at the following DEC web site (https://www.dec.state.ak.us/water/wqsar/storetdocumentation.htm).

C1. Assessments and Response Actions

Project assessment will primarily be conducted through the preparation of field sampling event reports for DEC by the project manager. Section A6 contains more information on the type and date of each required report. At that time the project manager will review all of the tasks accomplished against the approved workplan to ensure that all tasks are being completed. The project manager will review all data sheets and entered data to make sure that data collection is complete. If necessary, data collection processes or data entry will be modified as necessary. Any modifications of the data collection methods will be reviewed against the processes described within the QAPP to determine whether the document needs to be updated.

The Project Manager will check on contractor's laboratory practices to ensure that samples are handled correctly and consistently. The final report will contain an appendix that will detail all of the QA procedures showing precision and accuracy. Representativeness, completeness, and comparability will be discussed in the body of the report. Any QA problems will be outlined and discussed relative to the validity of the conclusions in the report. Any corrective actions will be discussed as well as any actions that were not correctable, if any.

The QA officer will report to ARRI management any consistent problems in data collection, analyses, or entry identified either internally or through a 3rd party audit. ARRI management will be responsible for developing and implementing a course of action to correct these problems. Where consistent problems may have affected project validity, these will be identified and reported to the DEC project manager directly and included in project reports as directed.

C2. Reports to Management

Reports will be prepared by the ARRI Project Manager and distributed to the Department of Environmental Conservation Project Manager. Reports will update the status of the project relative to the schedule and tasks of the work plan. Reports include Quarterly Reports, Draft Final Report, and Final Report. The Project Manager will prepare the draft and final reports. The final report also will be submitted in electronic format. Any potential problems with data due to QA will be identified and reported in all submitted reports.

D1. Data Review, Validation, and Verification

The Project Manager and the Quality Assurance Officer will conduct data review and validation. This process for data review is described under section B10 and A7. Data that are obtained using equipment that has been stored and calibrated correctly and that meets the accuracy and precision limits will be used. Data that does not meet the accuracy and precision limits may be used; however, we will clearly identify these data and indicate the limitations.

D2. Validation and Verification Methods

The Project Manager and the Quality Assurance Officer will conduct data validation and verification. The Project Manager will enter all data from laboratory and field data sheets into Excel worksheets. The Project Manager will double-check all entries to ensure that they are correct. The Quality Assurance Officer will compare 10% of the laboratory and field data sheets with the Excel worksheets. The Project Manager will enter all formulas for calculation of parameters and basic statistics. All of these formulas will be checked by the Quality Assurance Officer. If any errors are found, the Project Manager will correct the errors and then check all entries. The Quality Assurance Officer will then repeat a check of 10% of the data entry and all of the formulas and statistics. This process will be repeated until any errors are eliminated. The Project Manager will organize and write the final report. The Quality Assurance Officer will check the results in the report and associated statistical error (i.e. standard deviation and confidence interval) against those calculated with computer programs. Any errors found will be corrected by the Project Manger.

D3. Reconciliation with User Requirements

The project results and associated variability, accuracy, precision, and completeness will be compared with project objectives. If results do not meet criteria established at the beginning of the project, this will be explicitly stated in the final report. Based upon data accuracy some data may be discarded. If so the problems associated with data collection and analysis, or completeness, reasons data were discarded, and potential ways to correct sampling problems will be reported. In some cases accuracy project criteria may be modified. In this case the justification for modification, problems associated with collecting and analyzing data, as well as potential solutions will be reported.

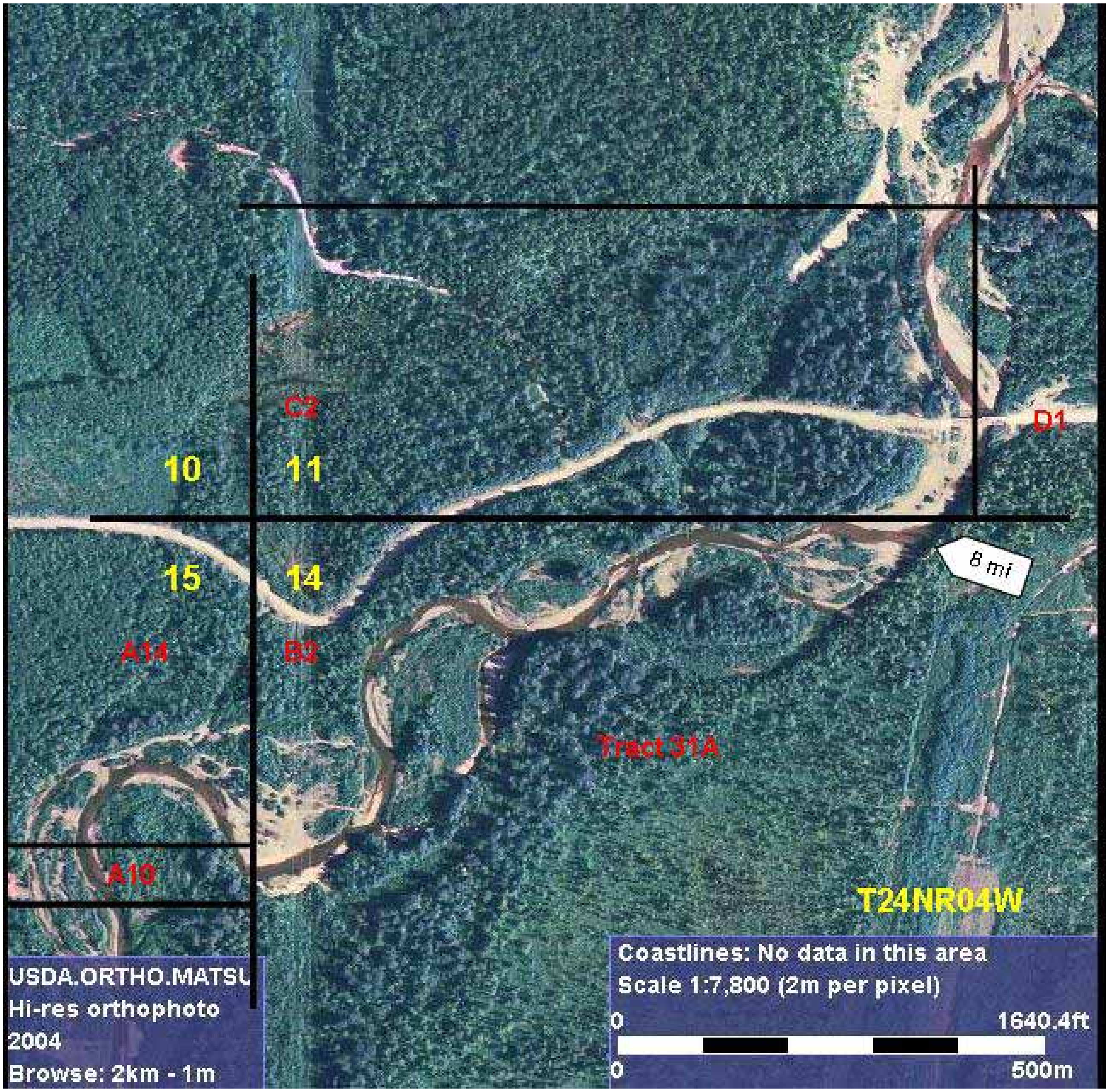
Literature Cited

Bevenger, G. S., and R. M. King. 1995. A pebble count procedure for assessing watershed cumulative effects. USDA Forest Service. Rockey Mountain Forest and Range Experiment Station. Fort Collins, CO. Research Paper RM-RP-319.

Davis, J.C., G.W. Minshall, C.T. Robinson, and P. Landres. 2001. Monitoring wilderness stream ecosystems. Gen. Tech. Rep. RMRS-GTR-70. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 137p.

Major, E.B., and M.T. Barbour. 2001. Standard operating procedures for the Alaska Stream Condition Index: A modification of the U.S. EPA rapid bioassessment protocols, 5th edition. Prepared for the Alaska Department of Environmental Conservation, Anchorage, Alaska.

Appendix B—Aerial photographs and Property Boundaries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Hi-res orthophoto
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Coastlines: No data in this area
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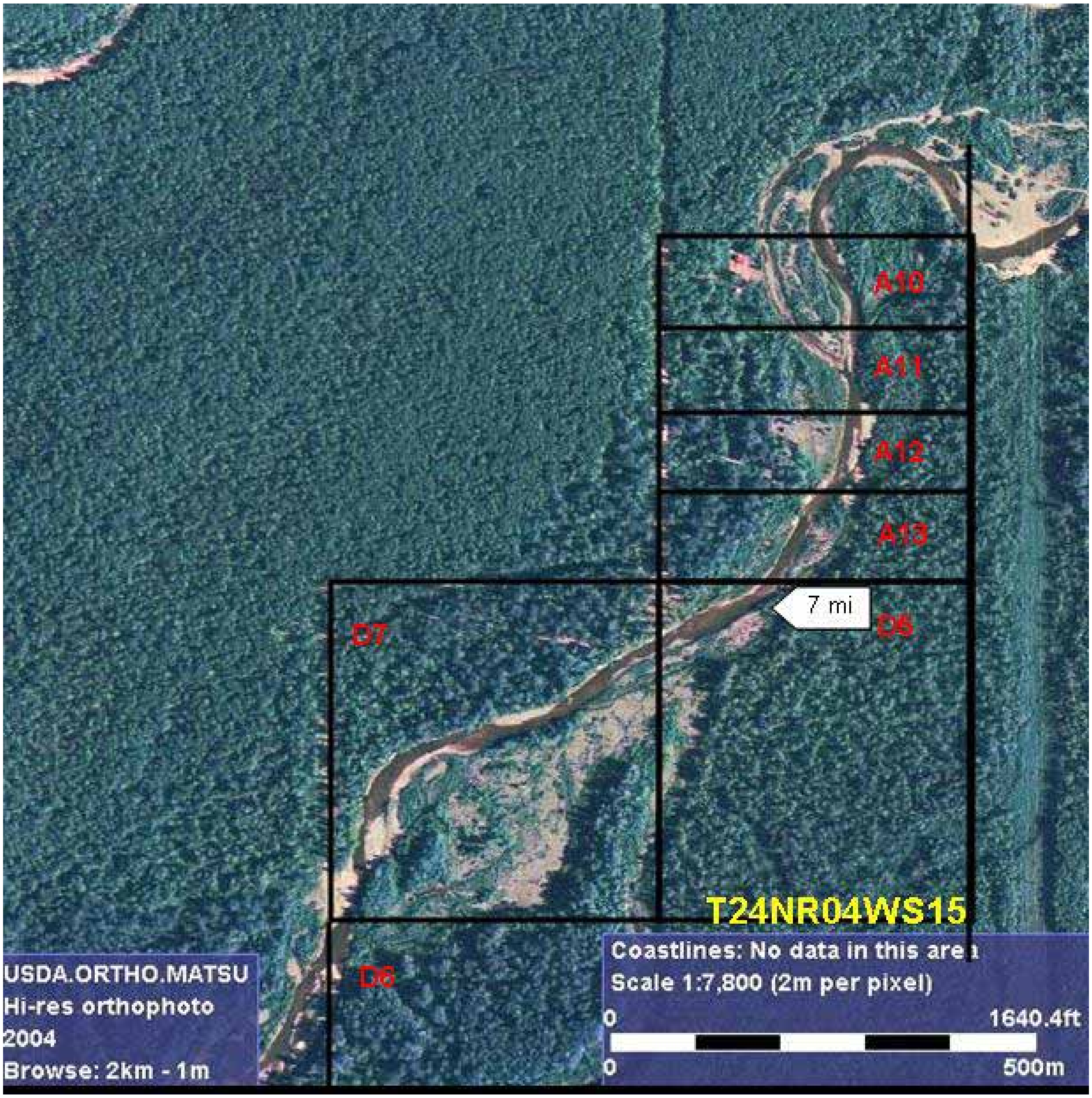
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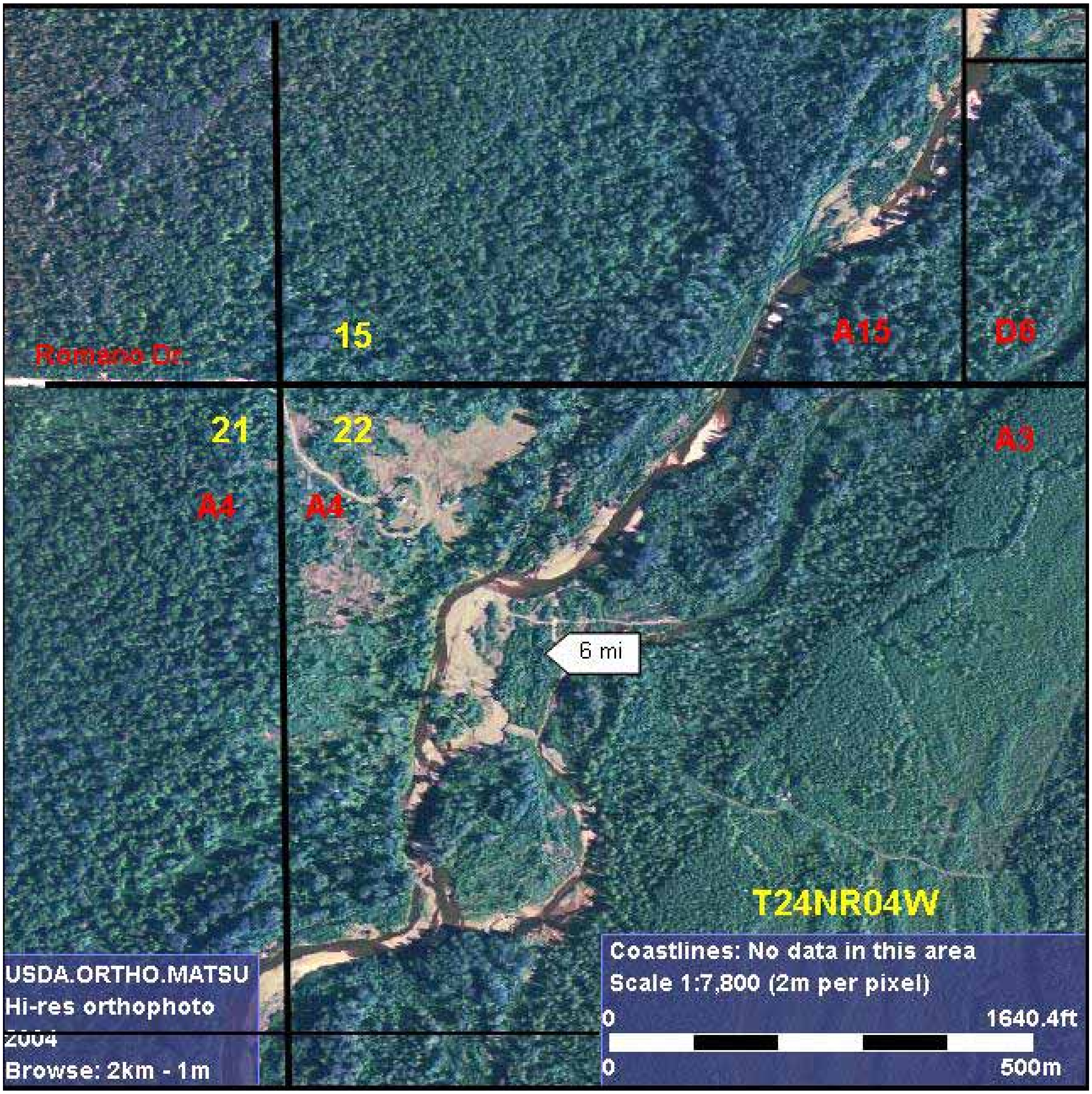
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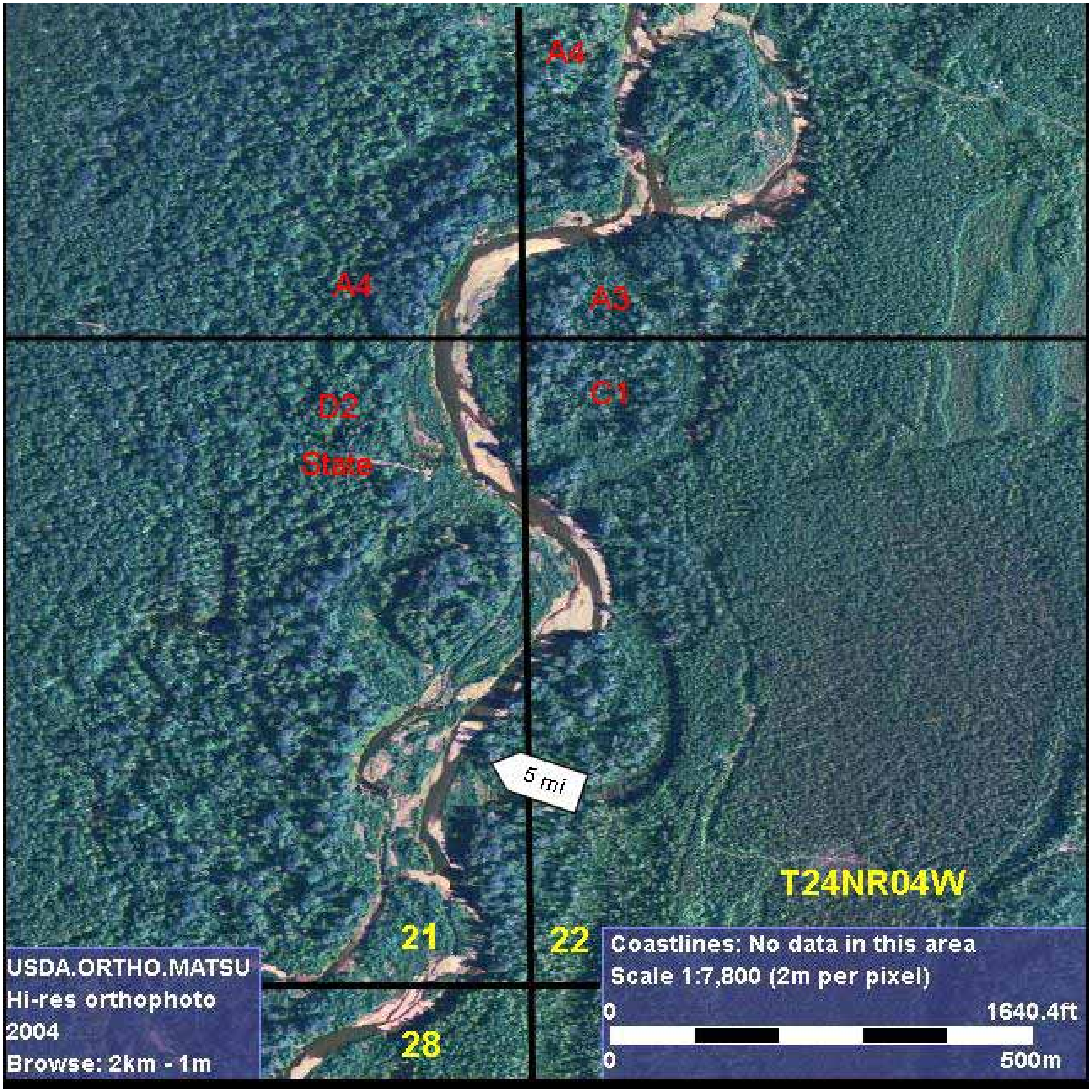
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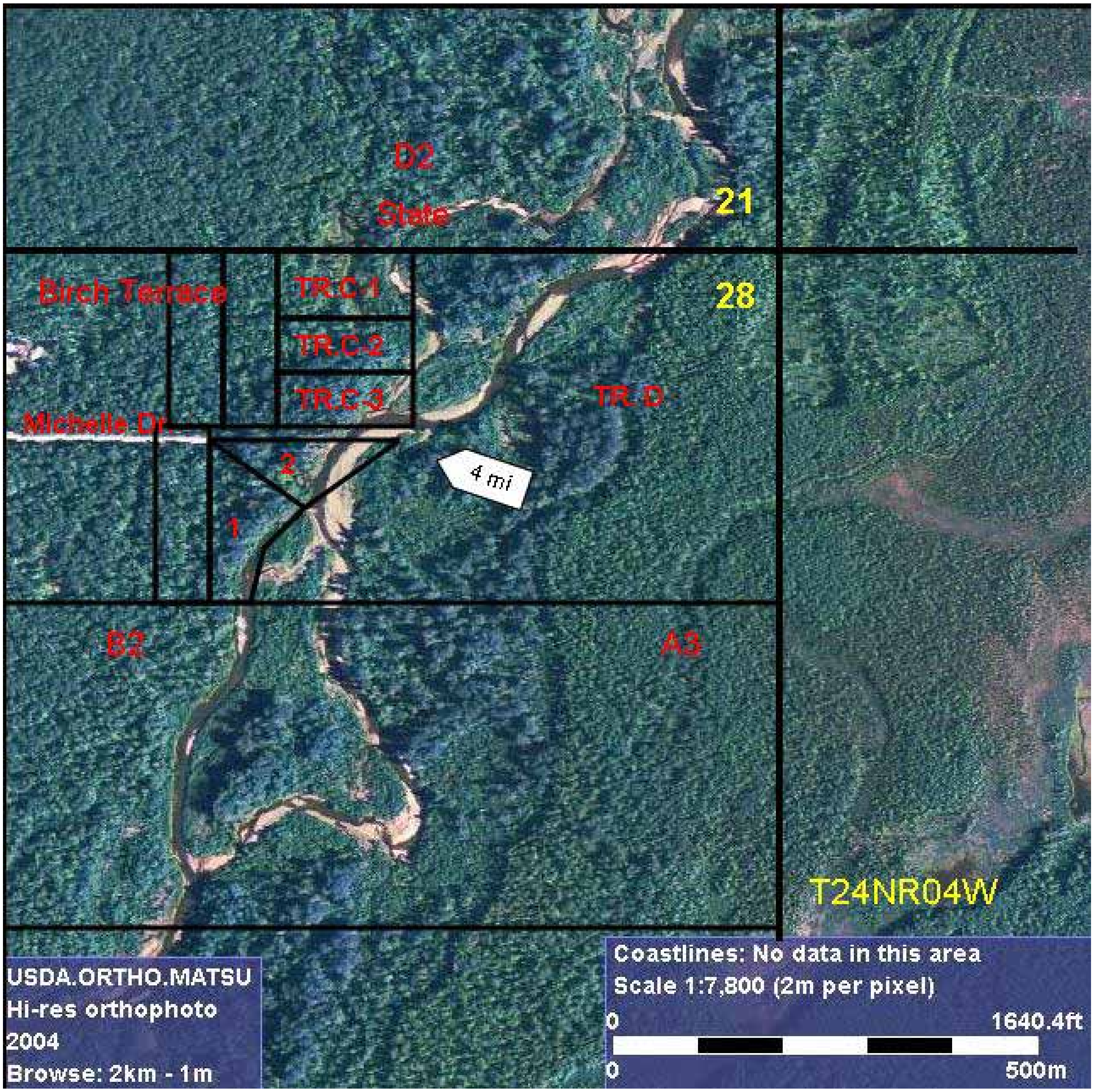
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Hi-res orthophoto
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Coastlines: No data in this area
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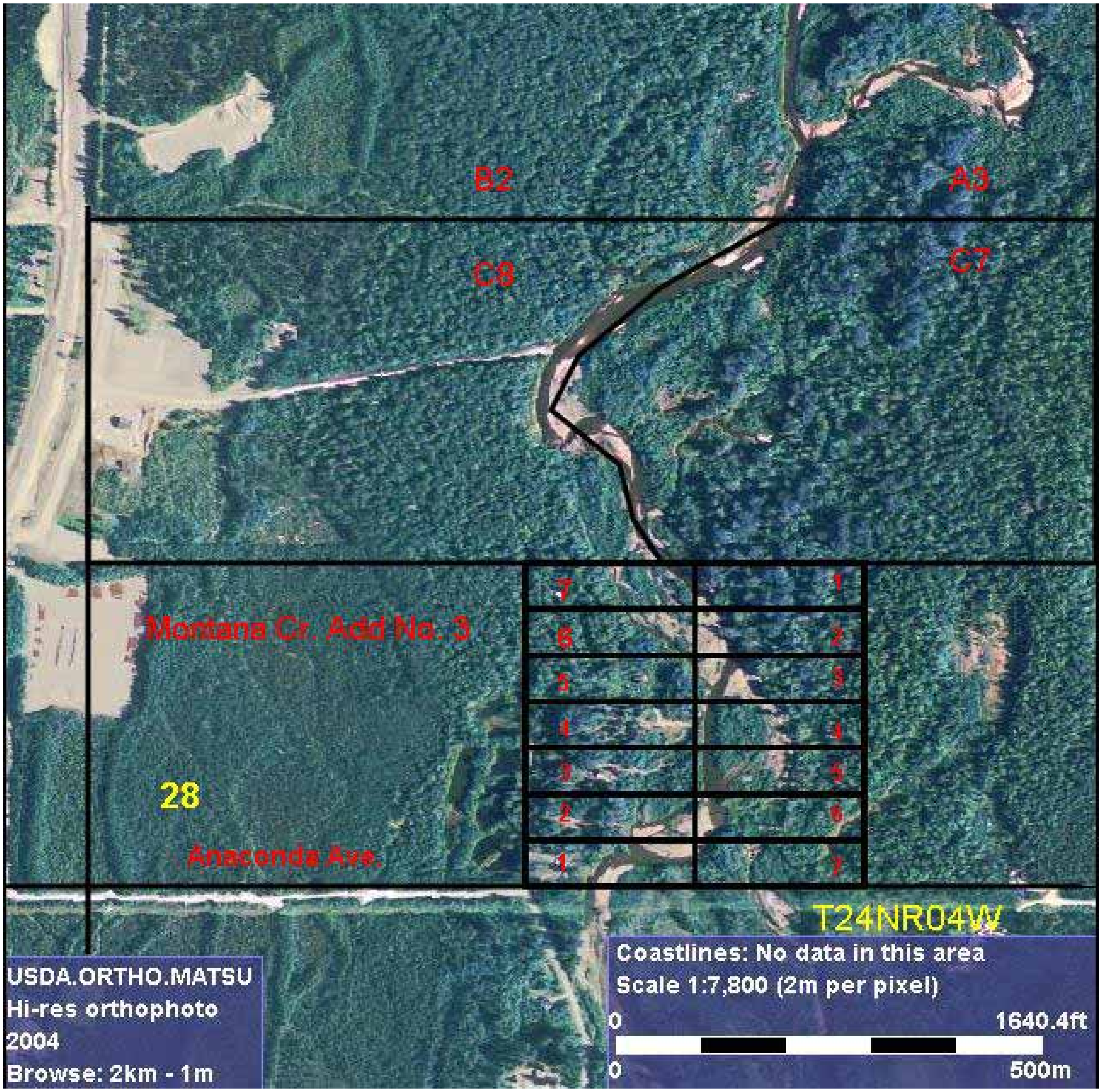
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USDA.ORTHO.MATSU
Hi-res orthophoto
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Browse: 2km - 1m
Coastlines: No data in this area
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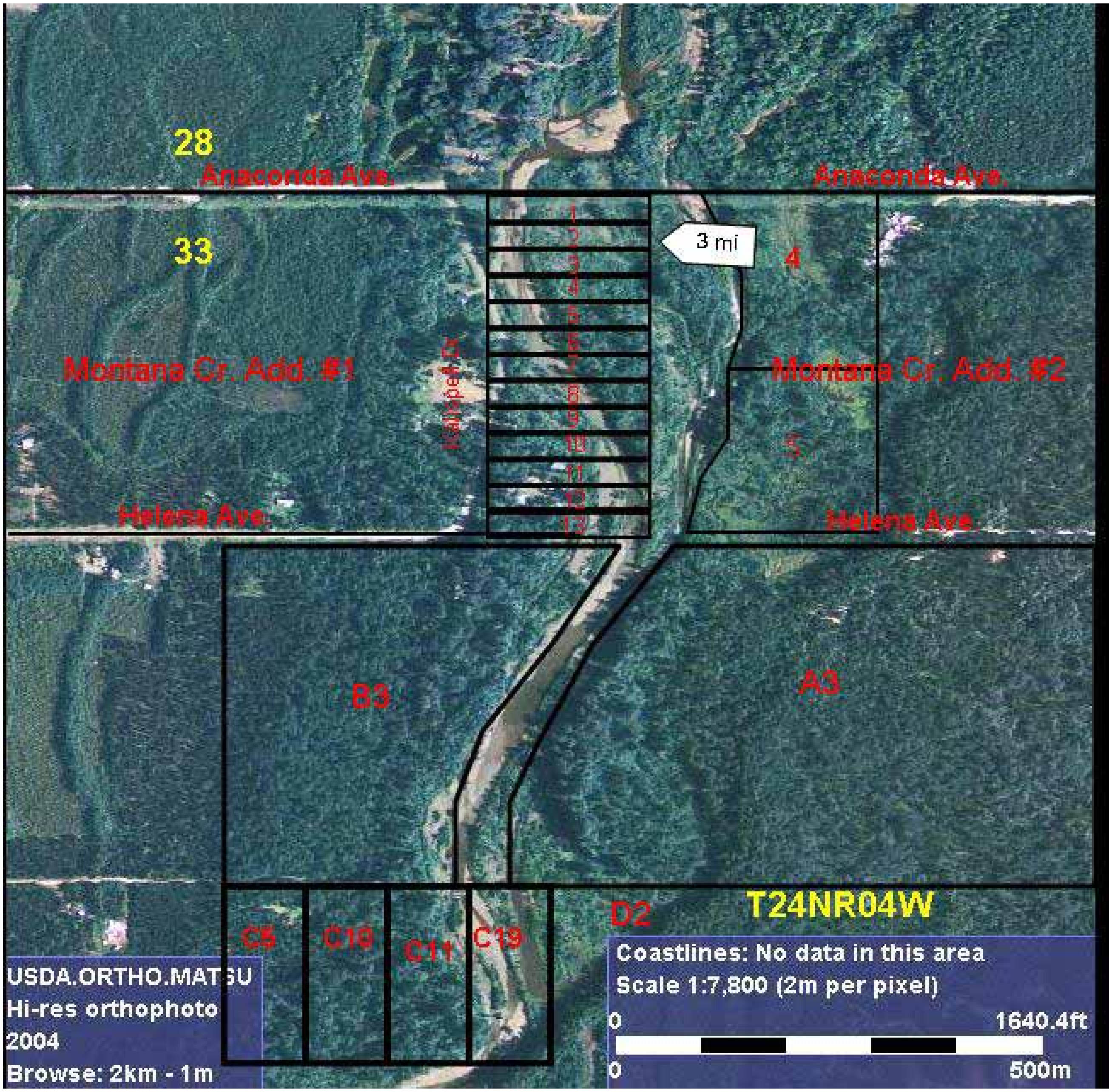
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C19
D2
T24NR04W
USDA.ORTHO.MATSU
Hi-res orthophoto
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Coastlines: No data in this area
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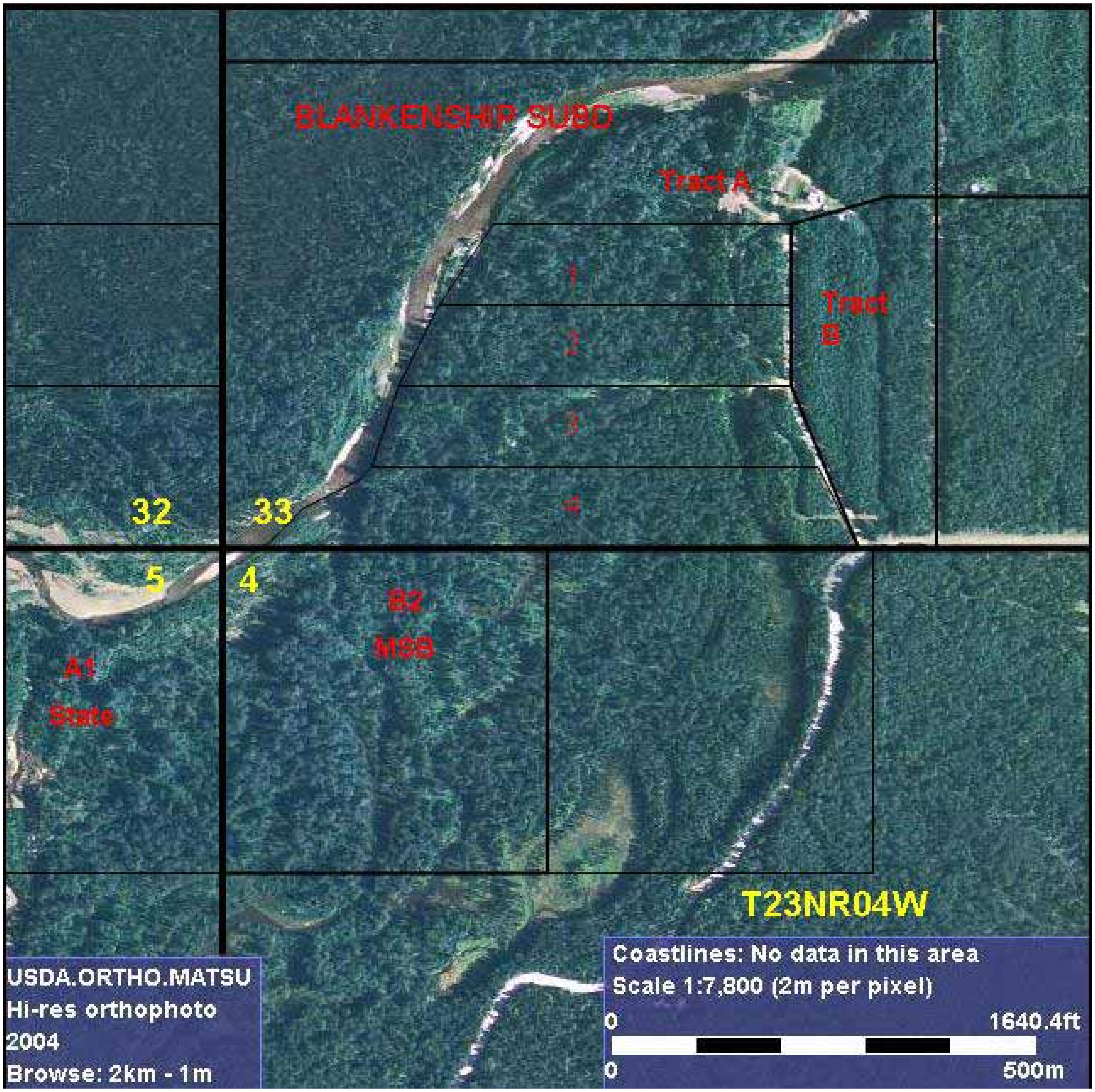
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MSB
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State
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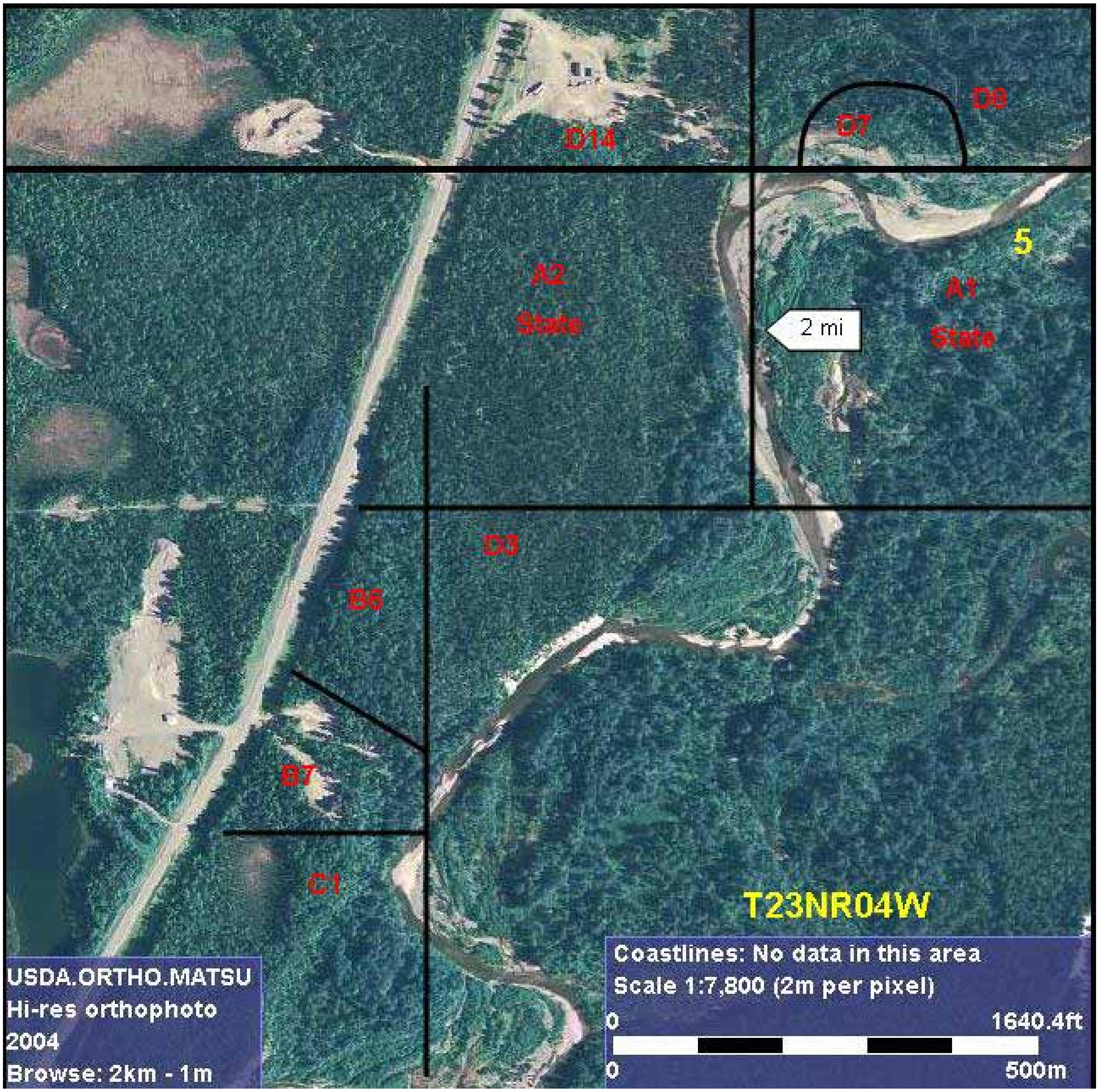
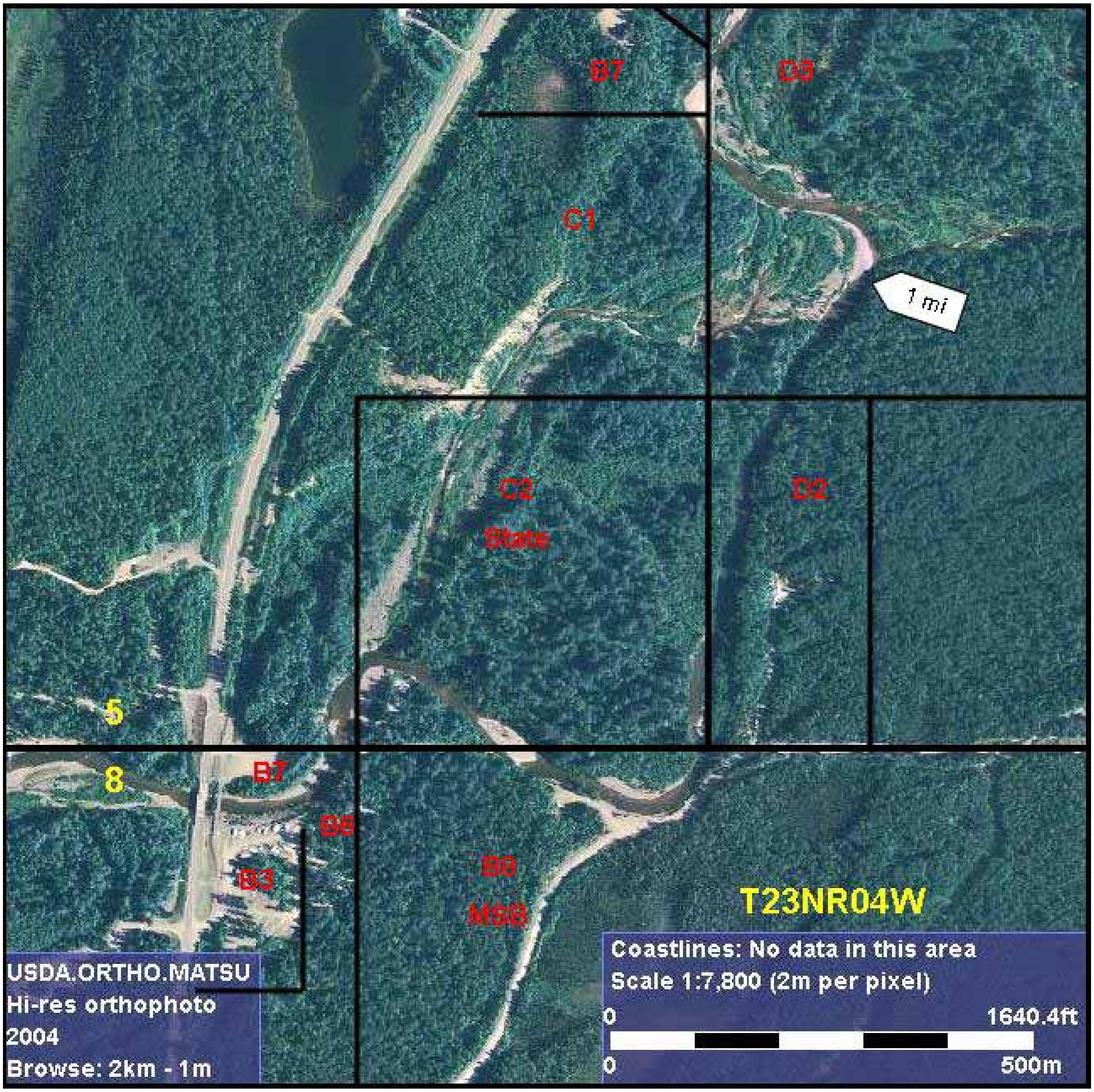
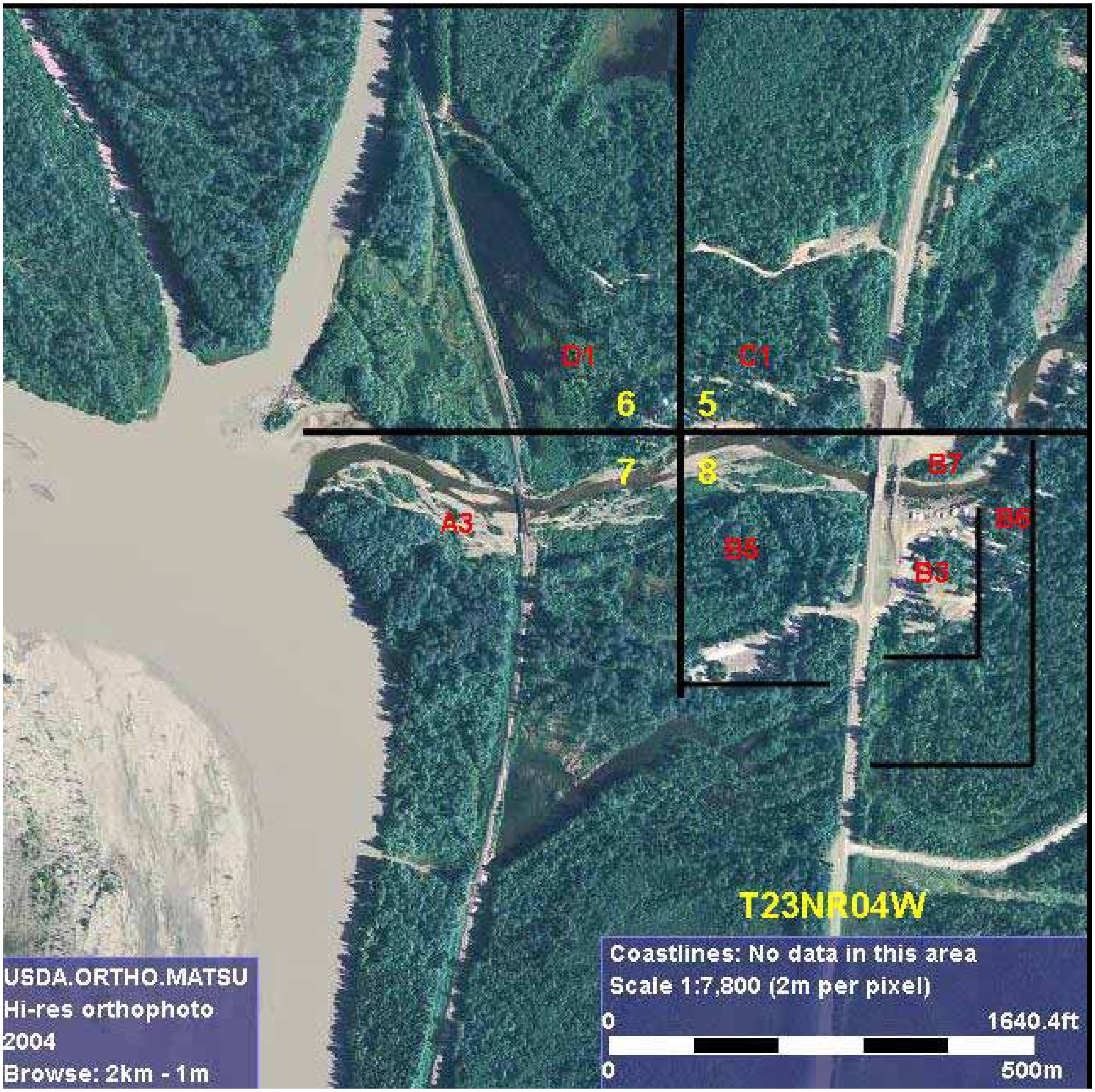
USDA.ORTHO.MATSU
Hi-res orthophoto
2004
Browse: 2km - 1m
Coastlines: No data in this area
Scale 1:7,800 (2m per pixel)
0
1640.4ft
0
500m


D14
D7
D8
5
A2
State
2 mi
A1
State
D3
B6
B7
C1
T23NR04W
USDA.ORTHO.MATSU
Hi-res orthophoto
2004
Browse: 2km - 1m
Coastlines: No data in this area
Scale 1:7,800 (2m per pixel)
0
1640.4ft
0
500m



B7
D3
C1
1 mi
C2
State
D2
5
8
B7
B6
B3
B8
MSB
T23NR04W
USDA.ORTHO.MATSU
Hi-res orthophoto
2004
Browse: 2km - 1m
Coastlines: No data in this area
Scale 1:7,800 (2m per pixel)
0
1640.4ft
0
500m


D1
C1
6
5
7
8
B7
A3
B6
B5
B3
T23NR04W
Coastlines: No data in this area
Scale 1:7,800 (2m per pixel)
0
1640.4ft
0
500m
USDA.ORTHO.MATSU
Hi-res orthophoto
2004
Browse: 2km - 1m