Final Report
Jim Creek Water Quality Assessment
FY08-09

The Wildlifers
20390 East Birch Hill Drive
Palmer, AK 99645

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ALASKA
Department of
Environmental
Conservation

1.0 ABSTRACT

Jim Creek is a clear tributary of the Knik River in Upper Cook Inlet of south-central Alaska, and is important for the spawning, rearing, and migration of anadromous fish. Jim Creek is adjacent to one of the fastest growing areas, the Matanuska-Susitna (Mat-Su) Borough, and to Anchorage, which contains nearly 50% of Alaska's overall population. Concerns about the exponential increase in recreational use and associated impacts to aquatic habitat and water quality have resulted in the listing of Jim Creek as a priority waterbody in protection track under the Alaska Clean Water Actions (ACWA) program. For that reason, the Alaska Department of Environmental Conservation (ADEC) funded, in part, an ACWA project to monitor and assess Jim Creek. The Wildlifers sampled water quality and riparian habitat along Jim Creek to provide baseline data in 2008 and spring 2009. Systematic sampling of water quality and riparian habitat along Jim Creek was completed from the confluence with the Knik River upstream to Upper Jim Creek. Physicochemical characteristics of water (pH, specific conductivity, dissolved oxygen, temperature, and turbidity) were estimated from over 10,000 samples taken from 16 sites between the mouth and Leaf Lake during 22 and 2 sampling events in 2008 and 2009, respectively. Stream channel characteristics, substrate, and embeddedness were also assessed for each site. Riparian habitat near the mouth of Jim Creek (downstream from site C2-AB) and along Jim Creek Flats appeared to be substantially modified from a long history of recreational activities. No residential or commercial development was present in 2008-09 along Jim Creek so effects to habitat and water quality were limited to natural influences and recreational activities. Recreational activities, including riding off-road vehicles (ORV), boating, camping, hunting, and sport fishing, were the primary human-caused changes to the stream bank and riparian habitat and occurred primarily within the lower stream reaches. An additional set of creek crossings, however, was present in Upper Jim Creek, but was only sampled using continuous temperature monitors. The predominant source of human-caused changes in the middle reaches of Jim Creek was due to watercraft activities. Water pH was above neutral and declined as flow declined thru time. Specific conductance was relatively high, especially along stream reaches

between Swan Lake and McRobert's Creek. Dissolved oxygen in 2008 declined from supersaturated levels to <65% in late-October. During the sampling period with the lowest recorded dissolved oxygen, dissolved oxygen was lowest at upstream sites but that trend was opposite in spring when upstream sites were supersaturated. Turbidity was often below detection limits but the proportion of samples with elevated NTU values was highest at sites with ORV traffic and at the furthest upstream site, downstream from an airboat crossing and 2 ORV trails in Upper Jim Creek. Water temperature, which was highly correlated with air temperature, repeatedly exceeded state water quality standards for fish migration and rearing (15°C) and for spawning and incubation (13°C) at all sites downstream from Leaf Lake from June 6 thru September 8. In contrast, water temperature at the sample site along Upper Jim Creek was nearly 8°C lower than downstream sites in late August. Based on the baseline data and observations from these surveys, the primary non-target sources of potential pollution and habitat modification were from high-density ORV use near the mouth from site C1-100BE upstream to C2-AB, from watercraft from site S1-05 upstream to S2-01, and from lower-density ORV use along Rippy Trail in Upper Jim Creek. Management recommendations include streamside restoration and conservation practices (enclosure or fencing) to minimize erosion, especially along the eastern bank of Jim Creek from site C1 upstream to C2-AB and from C2-AB directly east along the "dune" toward Friday Creek. Assessments of potential impacts from watercraft and ORV traffic are highly encouraged as are continued baseline monitoring of water quality and riparian habitat. This project provides a defensible, statistically rigorous baseline with voluminous data and large numbers of samples for future studies to expand upon.

2.0 STUDY AREA

Jim Creek, a clear tributary of the Knik River in Upper Cook Inlet of south-central Alaska, is a diverse, productive, and complex watershed. The lower portion of the creek forms a wetland complex of interconnected lakes, ponds, flooded marshes, and relatively slow moving streams and sloughs; then, forms a partially-clear mixing zone with the glacially-fed water of the Knik River at the confluence and for over 1.5 km downstream. The lower elevations (<100') near the confluence with the Knik River thaw earlier in spring and freeze later in fall than most surrounding habitats, and are characterized by relatively warm water and numerous interconnected water bodies and wetlands, including McRobert's Creek and Jim Creek along with Jim, Mud, Leaf, and Swan Lakes. Jim Creek originates as a high mountain stream near 5,000' elevation and descends steeply from remnants of hanging glaciers in the Chugach Mountains until just above the confluence with Leaf Lake near 100' elevation, where wetland complexes begin at the wide and flat valley floor carved by the Knik Glacier. The extreme elevation change from the headwaters to the confluence with the Knik River creates an extremely diverse ecosystem, ranging from high arctic alpine to naturally diverse wetland complexes along the lower reaches, all within a few miles.

Jim Creek, especially the lower elevations and the interconnected wetlands, provides valuable spawning, rearing, migratory, and over-wintering habitat for rainbow trout (*Oncorhynchus mykiss*), Dolly Varden (*Salvelinus malma*), coho (*Oncorhynchus kisutch*) and sockeye (*Oncorhynchus Nerka*) salmon. The State of Alaska has specified Jim Creek as important for the spawning, rearing, and migration of anadromous fish (AS 41.14.870). The fishery is a heavily used recreational resource, as it is the second largest sport fishery for silver salmon in the entire Knik Arm Fishery (Ivy et al. 2007). In addition, the Jim Creek region is among the most popular destinations for off-road vehicle (ORV) recreation in Alaska. Between 1977-2006, fisherman averaged over 11,000 angler-days of effort annually catching an estimated harvest of over 5,000 and 1,500 coho and sockeye salmon, respectively (Ivy et al. 2007). More recently between 2001-2005, average annual effort by fisherman has increased to over 16,000 angler-days resulting in an average annual harvest of over 12,500 coho and sockeye salmon. No known radio-tracking studies have been conducted to determine the full extent of fish distribution, movements, and migration in Jim Creek; consequently, the proportions of fish spawning and using specific reaches is unknown as is the upper elevation limit of salmon migration and spawning.

The Knik River Public Use Area (KRPUA), including Jim Creek, receives intensive and extensive multiple-use recreation due to the proximity to most of Alaska's population and the diversity of outdoor activities provided there. In 2006, the State of Alaska passed legislation to designate Jim Creek and adjoining wetland complexes as part of the >250,000 acre KRPUA. The KRPUA is jointly owned and managed by multiple private, state, and federal agencies, thereby complicating efforts to manage the natural resources. Camping, fishing, horseback riding, hiking, ORV riding, hunting, aircraft take-off and landing practice, and other recreational activities are very popular throughout the watershed. The highest densities of recreational use along Jim Creek occur near the confluence with the Knik River where primary access is located. Watercraft operators (ranging from airboats to float tubes) also navigate those stream sections below ~100’ elevation.

Concerns about the exponential increase in recreational use and associated impacts to aquatic habitat and water quality have resulted in listing Jim Creek as a priority waterbody in protection track under the Alaska Clean Water Actions (ACWA) program. As the surrounding human population has increased, recreational activities have increased, thereby exacerbating any potential impacts to water quality and riparian habitats. Riparian habitat loss and bank erosion is evident near fishing and camping areas (KRWG 2006) and ORV crossings. Water quality concerns from this high-level, widespread use includes pollution (e.g.; lead, petroleum hydrocarbons, fecal coliform bacteria, etc.), damage to riparian habitat, increased temperature associated with vegetation loss, erosion and changes in stream channels and hydrology, stream widening and shallowing, changes in macroinvertebrate density and distribution, and increased turbidity, sedimentation, and suspended sediments.

Sustainability of the water quality and habitats vital to this important fishery requires (1) collection of baseline data, (2) identification of the causes and implications of habitat and fish population modification, (3) evaluation of potential impacts from human activities on stream condition, and (4) a well-designed, adaptive management strategy to mitigate for potential impacts.

3.0 INTRODUCTION

Alaska contains nearly 50% of the total area of surface waters within the United States and Alaskan waters are considered to be relatively unimpaired, overall. The Alaska Department of Environmental Conservation (ADEC) identified <0.1% of Alaska’s water resources as impaired, primarily due to the shear abundance of Alaskan waters across the entire state (>3 million lakes, >700,000 miles of streams and rivers, >35,000 miles of coastline, and >170,000,000 acres of wetlands) and the relatively limited spatial extent of potential sources of degradation (generally limited to specific, relatively small areas near human developments and activities) (ADEC 2008). Most of Alaska's human population is concentrated near Anchorage, Fairbanks, Juneau, the Matanuska-Susitna Valley, and Kenai/Soldotna; with the remainder sparsely scattered in relatively small villages, many not connected by roads.

Although Alaskan surface waters are considered to be relatively unimpaired overall, specific sources and locations of impairment have been identified, mostly near urban areas (cities, towns, and villages). Known historical impairments of water quality include increased sediment, turbidity, and fecal coliform bacteria. Other documented impairments include sediment and turbidity from mining activities, residues from seafood processing facilities, toxins from contaminated military sites, bark and wood residues from timber processing and transfer facilities, and petroleum products from oil spills and fuel leaks (ADEC 2008).

Jim Creek is adjacent to one of the fastest growing areas, the Matanuska-Susitna (Mat-Su) Borough, and to Anchorage, which contains nearly 50% of Alaska's overall population. In 2007, Anchorage and the Mat-Su Borough contained over 250,000 and 80,000 residents, respectively, with 3,890 people residing in the Butte area, the small community closest to Jim Creek. Jim Creek is easily accessible to the largest urban population in Alaska and, hence, receives intensive, recreational use. The Jim Creek area is particularly notorious for target shooting, noise pollution, partying, vandalism, uncontrolled ORV, improper disposal of human waste, littering, dumping toxic and solid wastes, burning vehicles, leaving unattended fires, and destroying habitat.

Throughout the past 25 years, several government agencies have identified the habitats surrounding Jim Creek as important for moose, bear, waterfowl, and salmon (Ritchie, et.al. 1981; Timm 1976; Alaska Department of Natural Resources, Alaska Department of Fish & Game, Mat Su Borough 1985; Sweet, et. al. 2004, Bureau of Land Management 2005). The Department of Natural Resources (DNR) and the Alaska Department of Fish and Game (ADFG) manage the Jim Creek area and its wildlife, respectively. This project complements planning efforts by providing baseline data and by assessing potential impacts from recreational activities to water quality and riparian habitat.

The ADEC funded, in part, an Alaska Clean Water Actions (ACWA) project to monitor and assess Jim Creek. The Wildlifers surveyed water quality and riparian habitat along Jim Creek to provide baseline data. This report describes baseline information for water quality and riparian habitat of Jim Creek including a monitoring and quality assurance plan, results, and discussion to assist in management actions.

4.0 METHODS

4.1 STUDY SITES AND DESIGN

Other than 1 small cabin on the northeast edge of Swan Lake, no permanent residential or commercial development was located in 2008-09 along Jim Creek; therefore, sampling was focused on establishing a baseline assessment and monitoring program. The Quality Assurance Project Plan describes the sampling design, data collection methods and handling, and quality assurance procedures. The sampling followed an experimental design to evaluate and compare data among areas with different levels and types of recreational use; sampling locations were selected to characterize and represent these areas to the extent possible. Instead of making assumptions about the expected level of impact, Jim Creek was divided into segments for sampling based upon natural features of the stream. The number of sites for each stream segment sampled included 11 sites along lower Jim Creek (between McRobert's Creek and the mouth of Jim Creek above the confluence with the Knik River), 5 sites along middle Jim Creek (between Leaf Lake and McRobert's Creek), and 4 sites along Upper Jim Creek (above Leaf Lake) [Figure 1]. The 16 sites along the lower and middle sections were sampled weekly throughout the summer, fall, and once in spring whereas the 4 sites in Upper Jim Creek were only sampled once due to the ecological differences between the upper section and the lower and middle sections.

A paired sampling approach was used to estimate current conditions at 16 sites. Sampling sites to specifically assess potential impacts from ORV crossings were

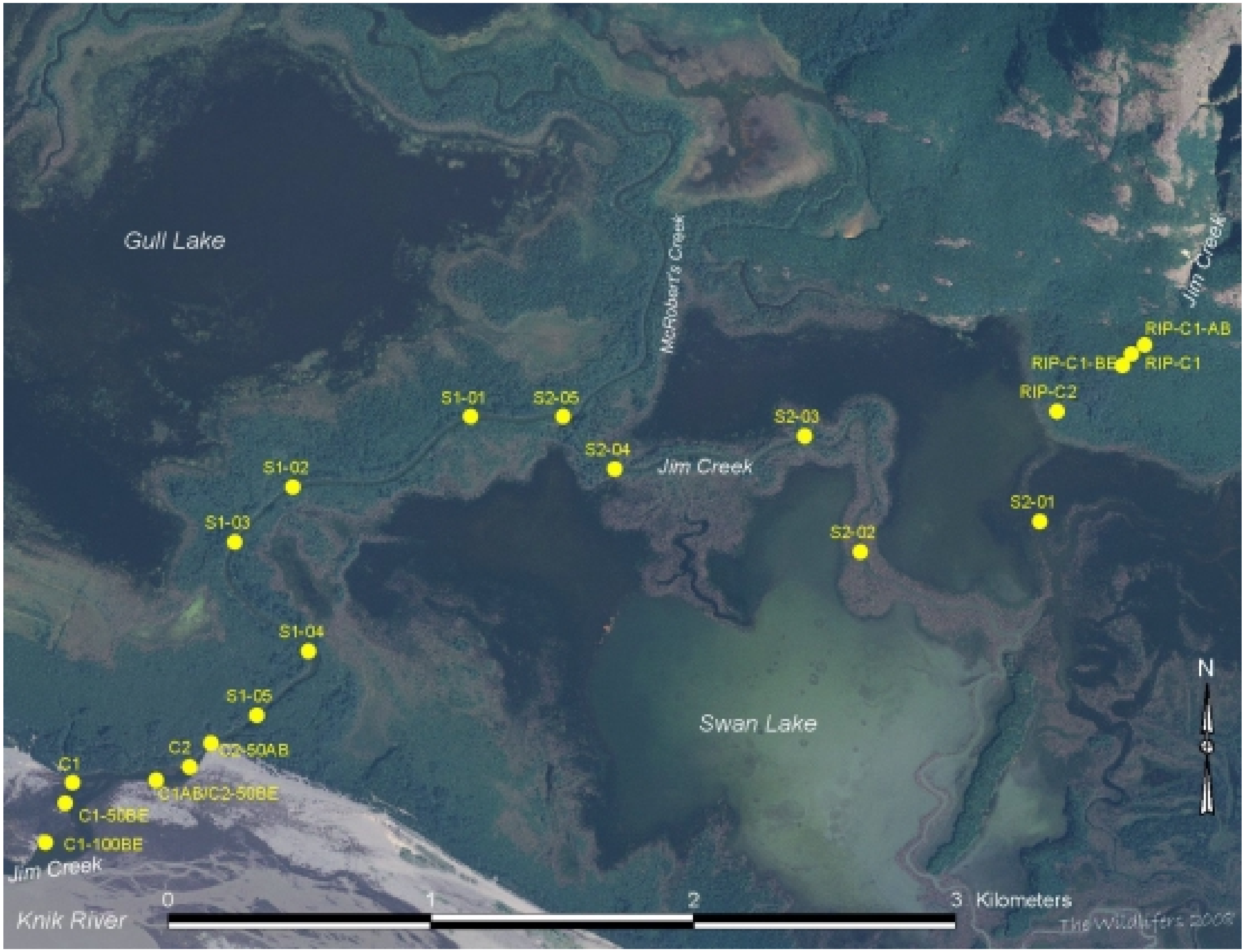

Figure 1. Sites of standardized sampling of water quality and riparian habitat between August 6 and October 18 2008, and in spring 2009, Jim Creek, Alaska.

located at, above, and below vehicle crossings and compared to each other, to reference sites with no ORV use, and to the entire creek as a baseline. No ORV crossings were present at sampling sites along middle Jim Creek upstream from and including site S1-05, but boating of all types (airboats, jet-boats, 2-cycle outboards, canoes, and other watercraft) was common, especially on weekends. Two ORV crossings, originating from the same access trail (Rippy Trail), crossed Upper Jim Creek above Leaf Lake but only water temperature was sampled repetitively there.

4.2 PHYSICOCHEMICAL CHARACTERISTICS

At sample sites between and including C1-BE100 and S2-01 (Figure 1), water was sampled every 10-seconds for 10 minutes during each of 22 sampling events in 2008 on August 6, 12, 14, 19, 21, 23, and 30; September 1, 5, 8, 9, 10, 15, 16, 22, 23, 29, and 30; October 6, 8, 16, and 18; and in 2009 on May 26 and 28. Sample site RIP-C2 and those sites upstream in Upper Jim Creek were sampled once using a hand-held Hanna meter on August 26, 2008. Monitoring was conducted in accordance with EPA-approved analytical procedures and in compliance with 40 CFR Part 136, Guidelines Establishing Test Procedures for Analysis of Pollutants. Water samples were taken directly from the water body, rather than from a container filled from the water body. Water was sampled at a consistent subsurface depth of ~0.5m, or within 0.1m of the stream bottom in water <0.5m deep. Water samples were analyzed on-site, in-stream for temperature, pH, conductivity, turbidity, and dissolved oxygen by using a Water Quality Monitoring System (WQMS) developed by Global Water Instrumentation, Inc. Sampling equipment was tested and calibrated following the manufacturers manuals.

4.3 TEMPERATURE

A stationary, air temperature datalogger was placed, in collaboration with Cook Inlet Keeper (CIK), near site S1-04 to continuously monitor air temperature at 15-minute intervals between June 4 and October 18, 2008 (Figure 2).

Water temperature was monitored at 15-minute intervals with continuous data loggers at 5 sample locations during the summer and fall 2008 prior to freeze-up, and at site HOBO-3 in spring 2009 (Figure 2). Water temperature data loggers were cleaned

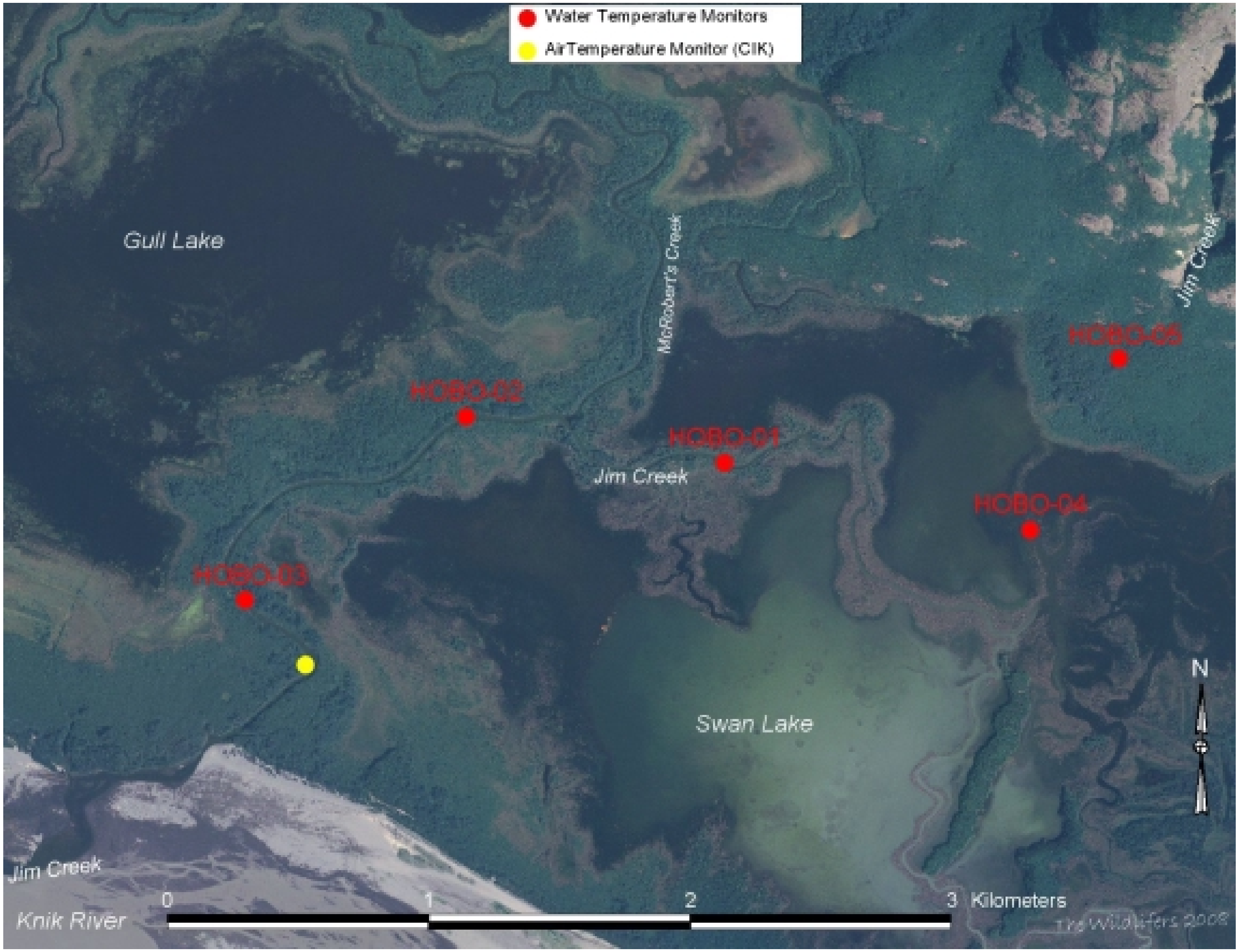

Figure 2. Sites of stationary, continuous temperature monitoring stations, Jim Creek, Alaska, 2008.

weekly and downloaded monthly. Because the benthos was too soft to reliably hold rebar as an anchor as suggested by CIK (Mauger 2007), temperature loggers were, instead, suspended in the water column by attaching them via cable to submerged or overhanging trees (Figure 3.). An additional water temperature data logger, deployed in conjunction with CIK personnel, was connected via rebar and pushed into the stream bottom (near the air temperature data logger also deployed with CIK), but, it was not found again until spring 2009 after considerable effort because the extremely soft benthos broke loose and the data logger drifted downstream.

4.4 PHYSICAL CHARACTERISTICS

Stream embeddedness was assessed by using stream embeddedness survey rings with replicate samples at each sampling site; relatively few samples were needed due to extremely low variance in the results. Type and amount of human-made debris was identified and mapped, including GPS coordinates, below ordinary high water (OHW) of Jim Creek or immediately adjacent to Jim Creek with potential of sloughing below OHW. In addition, a casual account of some historical observations of “human incidents”, 1988-2005, including observations of man-made debris (e.g.; fuel barrels, burned vehicles, trash dumps, etc.) along Jim Creek, was gathered through collaborative efforts. Most of the incidents presented were limited to data from Army National Guard cleanups of abandoned vehicles along Jim Creek Flats.

Stream channel characteristics were assessed at each sample site, including water depth, undercut, channel width, rut depth, and trail width. In addition, stream flow and water depth was monitored using a flow probe and staff gauge, respectively, during each sampling event at each sampling site. In addition to assessing stream crossings of Jim Creek in 2008, collaboration was developed to incorporate 2006 data from condition inventories of trails throughout the Jim/Swan wetland complex (Moore et al. 2006). The same methods for assessing ORV impacts (Meyer, Davis and Ryland, Loomis and Lieberman) were also used in 2008 for calculations by ranking trail attributes to classify stream crossings into the following condition categories: good ($\leq$10), fair (11 to 26), degraded (27 to 52), very degraded (53 to 77), and extremely degraded ($\geq$78).

Figure 3. Submerged trees provided a secure attachment for suspending water temperature loggers just above the stream bottom and in the natural shade provided by the logs in Jim Creek, Alaska.

Aerial photographs, maps of land ownership and known trails, data from historical studies, and other GIS layers were obtained from reliable sources, and were ground-truthed for accuracy in the field. The location of each sampling site was estimated using GPS coordinates taken directly at each site during each sampling event. Maps were fully integrated into geo-relational GIS databases for analysis and presentation purposes. Maps were compared with land features to ensure accuracy. Arcview (©ESRI, Redlands, CA) was used for GIS database management and analyses. Documentation for each GIS database followed content standards developed by the Federal Geographic Data Committee (FGDC) for digital geospatial metadata. S-Plus (ver. 2000, ©MathSoft, Seattle, WA) was used for statistical analyses. Data were tested for normality using Shapiro-Wilk tests. Because of the nonnormal distributions of most data, median and quartiles are presented throughout this report and nonparametric statistics (e.g.; Wilcoxon-Mann-Whitney Rank Sums, Kruskal Wallis) were used for analyses.

5.0 RESULTS

5.1 STUDY SITES

Alder (*Alnus*), willow (*Salix*), and cottonwood (*Populus*) dominated the vegetation communities along banks of Jim Creek, except where vegetation was absent at sites from C1-100BE upstream to C2-AB (figures 4 - 9) and except where aquatic vegetation was more abundant in the wetlands surrounding site S2-01. Sites downstream from C2-AB were devoid of vegetation along the southeast bank for over 800 m downstream to the confluence with the Knik River. Sites downstream from C1 were mostly devoid of vegetation on the northwest bank for ~1.5km.

Although the volume of recreational use along Jim Creek was not specifically quantified, recreational activities (ORV usage, boating, canoeing, camping, fishing, etc.) were observed on survey days in 2008-09 along all stream reaches surveyed. Areas in and/or adjacent to all sample sites between C1-100BE and C2-AB were used extensively by ORVs and watercraft; whereas, all sample sites between S1-05 and S2-01 (figures 10 - 19) appeared to be used only by watercraft and foot access from watercraft. Sample sites between RIP-C1-AB and RIP-C2 were not repetitively surveyed, but ORV trails and creek crossings at RIP-1 and RIP-2 were present along this reach in Upper Jim Creek.

During 2008-09 surveys, the highest density of recreational activities was observed as ORV travel in and adjacent to riparian habitats along reaches of Jim Creek at and downstream from site C2-AB. The stream reach with the most frequently observed creek crossings by ORVs spanned over 300m and was roughly between sample site C1 and the confluence with the Knik River downstream from C1-100BE. ORV travel across Jim Creek occurred daily at inconsistent crossing sites mostly near sites C1 and C1-50BE, but crossings were observed even downstream of C1-100BE. From site C-1 upstream to C2-AB, ORV travel was heaviest along the eastern bank whereas the western bank was mostly vegetated with a relatively narrow (~6’) trail paralleling the shoreline. Site C2 was an old ORV crossing that appeared to be crossed rarely in 2008-09, but the eastern shoreline received heavy ORV travel parallel to and including the bank.

Figure 4. Photos of site C1-100BE, facing (clockwise from upper left) upstream, downstream toward site, and toward west bank with east bank in foreground, Jim Creek, Alaska, August 2008.

Figure 5. Photos of site C1-50BE, facing (clockwise from upper left) upstream, downstream toward site, and of the east bank, Jim Creek, Alaska, August 2008.

Figure 6. Photos of Site C1, taken mid-August, facing (clockwise from upper left) upstream, downstream toward site, the west bank, facing west with east bank in foreground, Jim Creek, Alaska, August 2008.

Figure 7. Photos of site C1-50AB/C2-50BE, facing (clockwise from upper left) upstream along southeast bank, downstream, the northwest bank, and downstream along southeast bank, Jim Creek, Alaska, August 2008.

Figure 8. Photos of site C2, facing (clockwise from upper left) upstream along southeast bank, downstream toward site along east bank, the northwest bank, and the east bank, Jim Creek, Alaska, August 2008.

Figure 9. Photos of site C2-AB, facing (clockwise from upper left) upstream toward site, downstream along east bank, the west bank, and the east bank, Jim Creek, Alaska, August 2008.

Figure 10. Photos of site S1-05, facing (clockwise from upper left) upstream, downstream, the northwest bank, and the southeast bank, Jim Creek, Alaska, August 2008.

Figure 11. Photos of site S1-04, facing (clockwise from upper left) upstream, downstream, the southwest bank, and the northeast bank, Jim Creek, Alaska, August 2008.

Figure 12. Photos of site S1-03, facing (clockwise from upper left) upstream, downstream, the west bank, and the east bank, Jim Creek, Alaska, August 2008.

Figure 13. Photos of site S1-02, facing (clockwise from upper left) upstream, downstream, the northwest bank, and the southeast bank, Jim Creek, Alaska, August 2008.

Figure 14. Photos of site S1-01, facing (clockwise from upper left) upstream, downstream, the northwest bank, and the southeast bank, Jim Creek, Alaska, August 2008.

Figure 15. Photos of site S2-05, facing (clockwise from upper left) upstream, downstream, the north bank toward McRobert's Creek, and the east bank, Jim Creek, Alaska. *Note: photos August 2008 except bottom right photo in May 2009*.

Figure 16. Photos of site S2-04, facing (clockwise from upper left) upstream, downstream, the north bank, and the south bank toward Swan Lake, Jim Creek, Alaska, August 2008.

Figure 17. Photos of site S2-03, facing (clockwise from upper left) upstream, downstream, the west bank, and the east bank toward Swan Lake, Jim Creek, Alaska, August 2008.

Figure 18. Photos of site S2-02, facing (clockwise from upper left) upstream, downstream, the northeast bank toward Leaf Lake, and the southwest bank toward Swan Lake, Jim Creek, Alaska, August 2008.

Figure 19. Photos of site S2-01, facing (clockwise from upper left) upstream, downstream, the southwest bank, and the northeast bank, Jim Creek, Alaska, August 2008.

5.2 PHYSICOCHEMICAL CHARACTERISTICS, 2008

Between August 6 and October 18 2008, a total of 9,171 samples of water (average total of 573 per site) were recorded and analyzed for pH, specific conductivity, dissolved oxygen, turbidity, and temperature at the 16 sample sites from C2-100BE upstream to S2-01. On average, 62 samples were analyzed at each sample site during each sampling event.

Median pH for Jim Creek between August 6 and October 18, 2008 was 8.24 and ranged from 8.02 at site S2-01 to 8.34 at site C2-AB (Figure 20). The pH of water at sites S2-01 and S1-01 was slightly lower than that of the rest of the stream. Median pH during each sampling event during 2008 ranged from 8.68 on August 6 to 7.94 on October 18, 2008 (Figure 21). Median pH of sample sites during sampling events of Jim Creek declined significantly ($p<0.05$) through time from August 6 through October 18, 2008.

Median conductivity at each site ranged from 158.96 uS at site S2-01 to 263.33 uS at site S2-02 between August 6 and October 18, 2008 (Figure 22). The outflow from Swan Lake into Jim Creek between sites S2-01 and S2-02 substantially increased conductivity before steadily declining then stabilizing around 200 uS downstream of site S2-05. Site S2-01 was the only site significantly ($p<0.05$) lower than overall conditions: whereas, all sites between S2-02 and S2-05 were significantly ($p<0.05$) higher than overall conditions.

Median conductivity from all sites between August 6 and October 18, 2008 ranged from 195.89 uS on October 18 to 232.82 on August 19 (Figure 23). No significant ($p > 0.05$) temporal trend was detected.

Overall from August 6 thru October 18 2008, median dissolved oxygen (% saturated) was between 83.56% at site S2-05 and 89.72% at site S2-01 (Figure 24). Dissolved oxygen at site S2-01 was significantly higher ($p<0.05$) than the median for all other sites. In contrast, all sites downstream from S2-01 did not differ significantly ($p>0.05$) from baseline values.

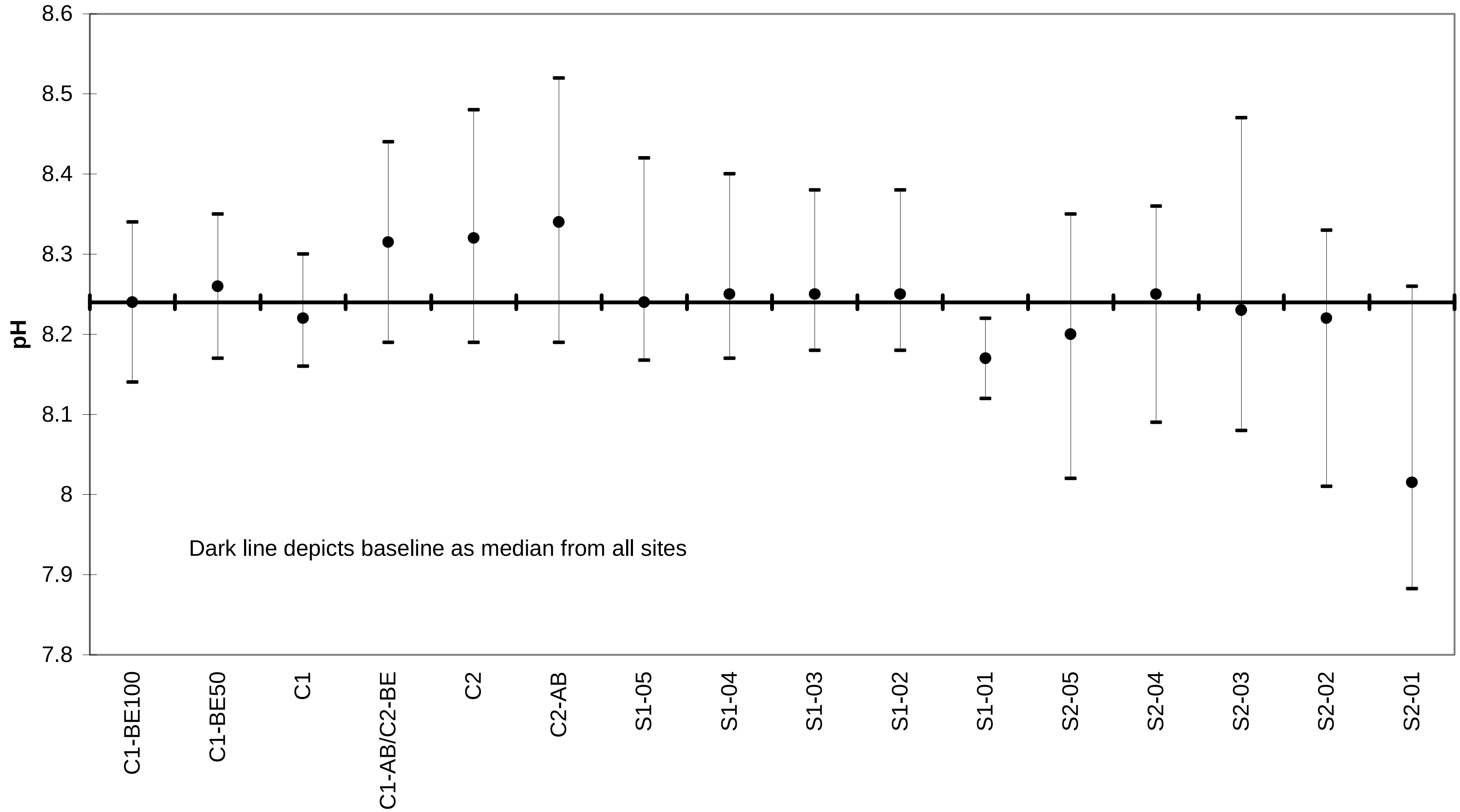

Figure 20. Median pH (error bars depict 1st and 3rd quartiles) for each sample site during sampling events of Jim Creek, Alaska, August 6 through October 18, 2008.

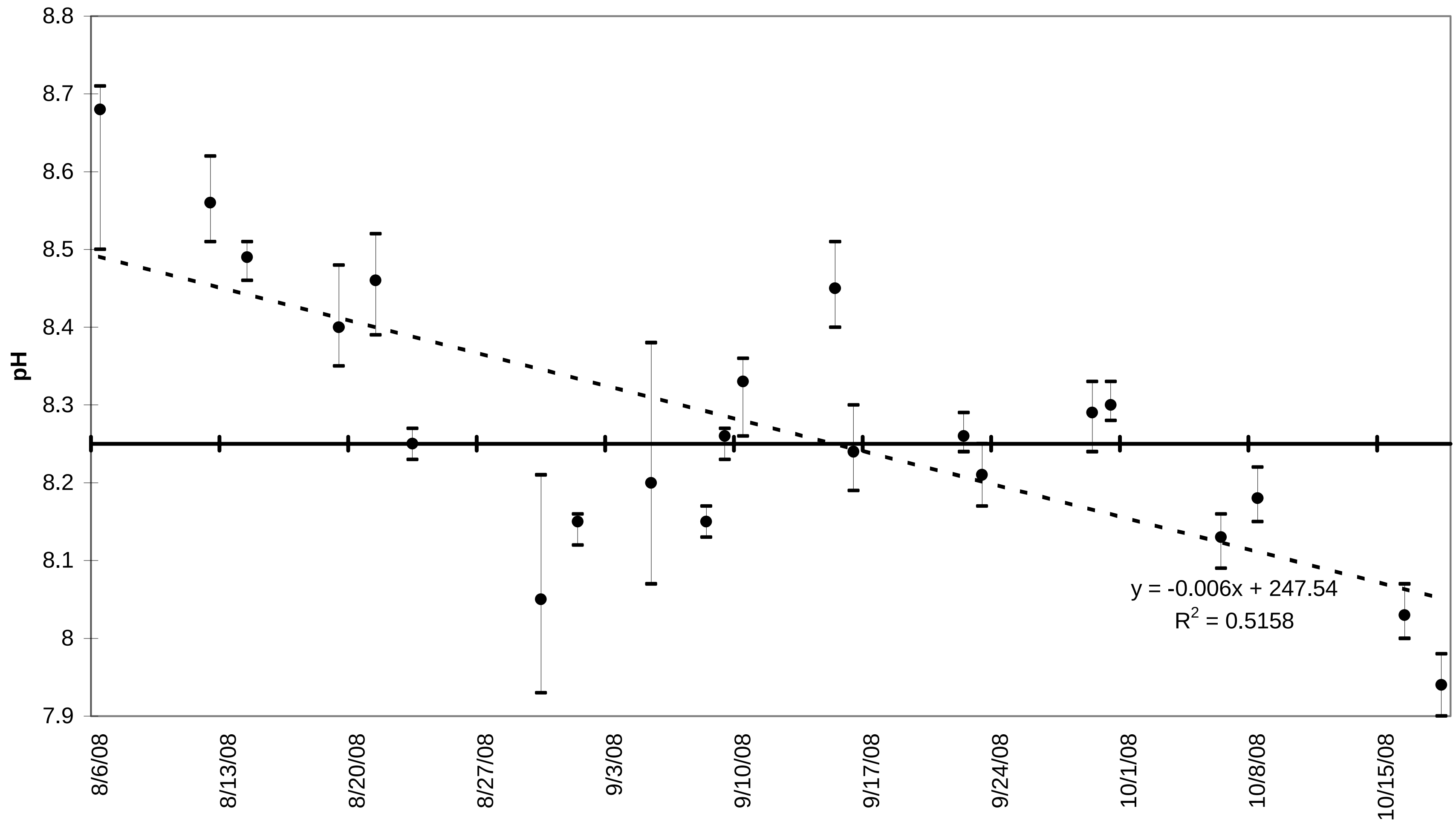

Figure 21. Median (error bars depict 1st and 3rd quartiles) pH of all sample sites during sampling events of Jim Creek, Alaska declined significantly ($p<0.05$) through time from August 6 through October 18, 2008.

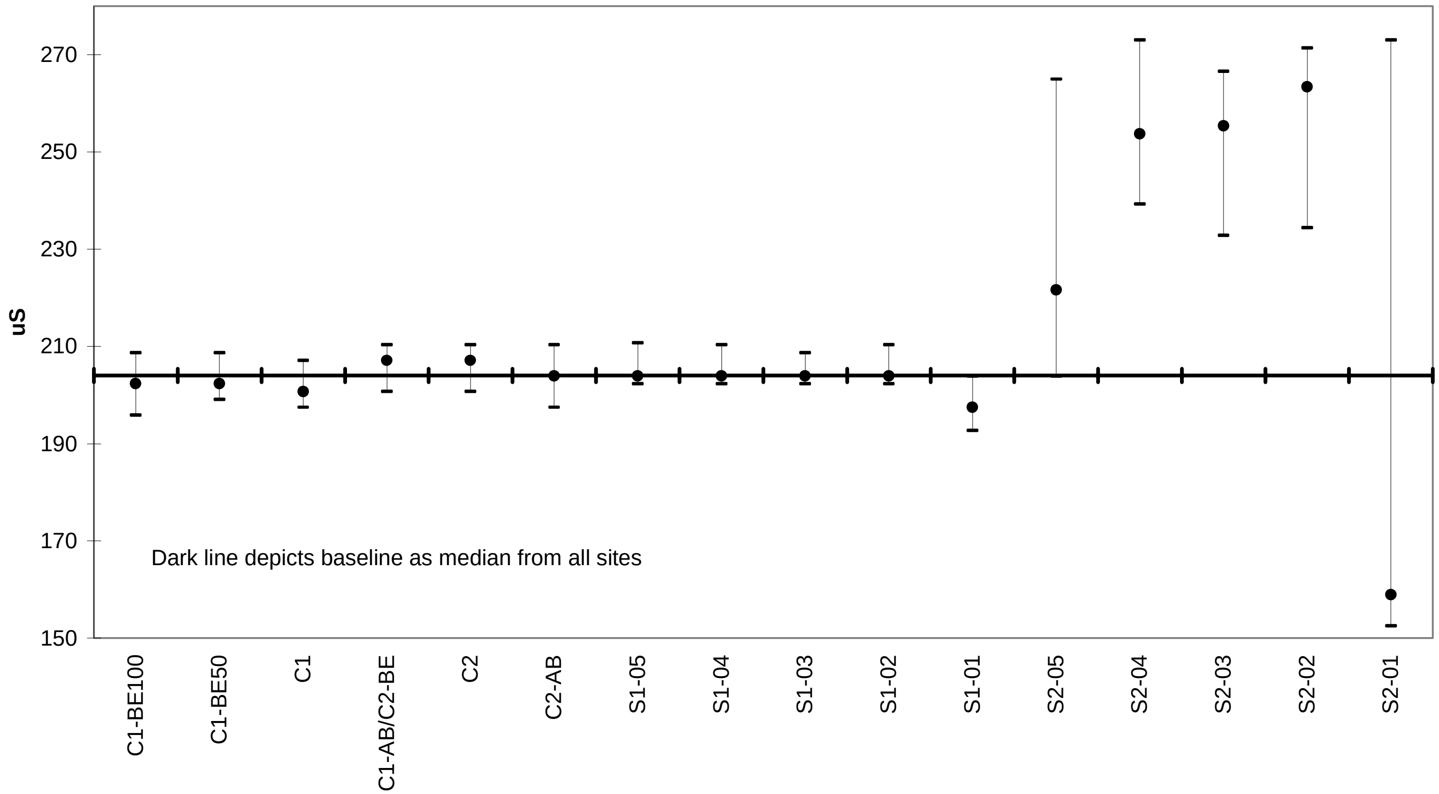

Figure 22. Median (error bars depict 1st and 3rd quartiles) conductivity estimated at each sample site during sampling events of Jim Creek, Alaska, August 6 thru October 18, 2008.

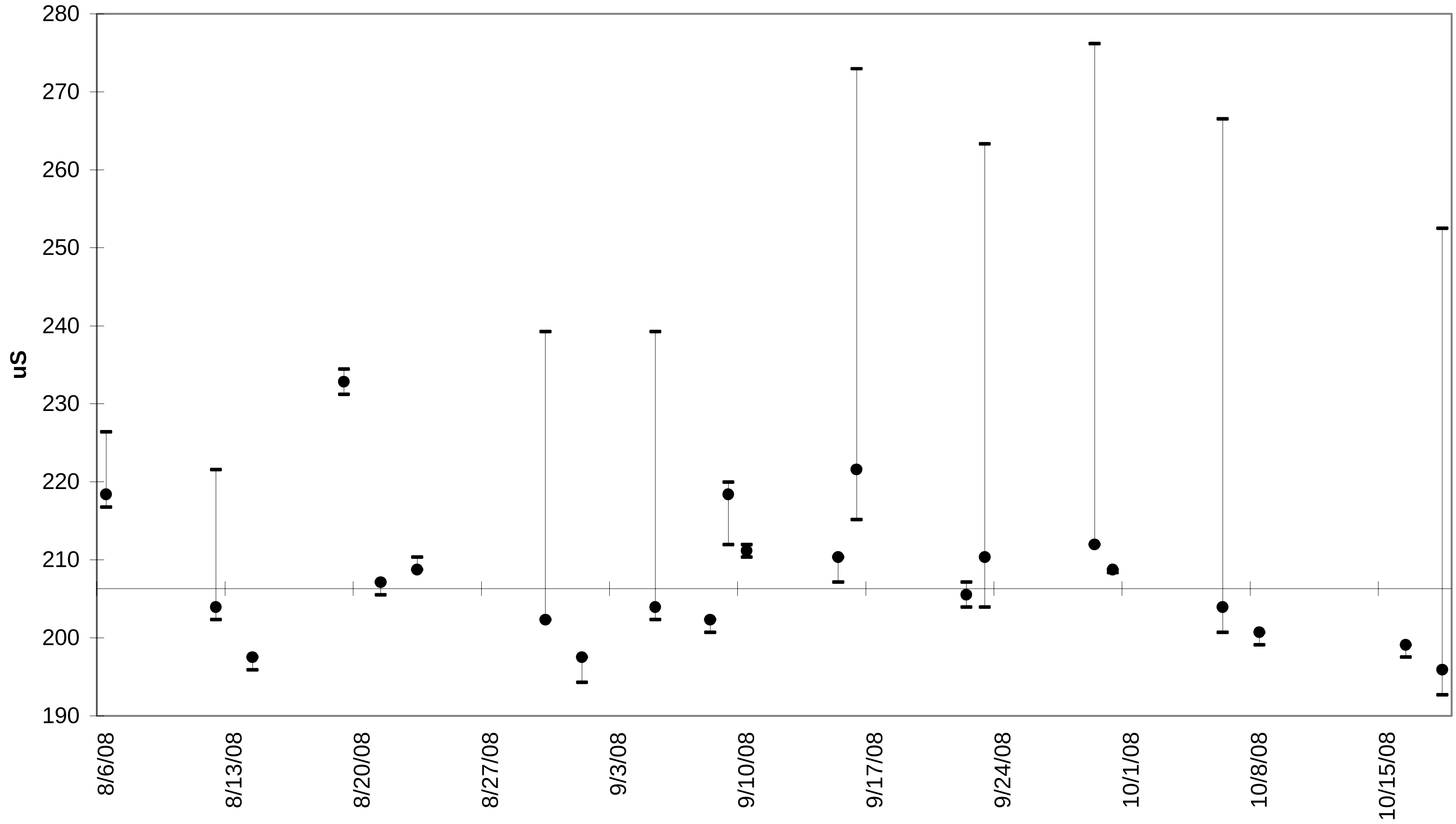

Figure 23. Median (error bars depict 1st and 3rd quartiles) conductivity from all sample sites during sampling events of Jim Creek, Alaska, August 6 thru October 18, 2008.

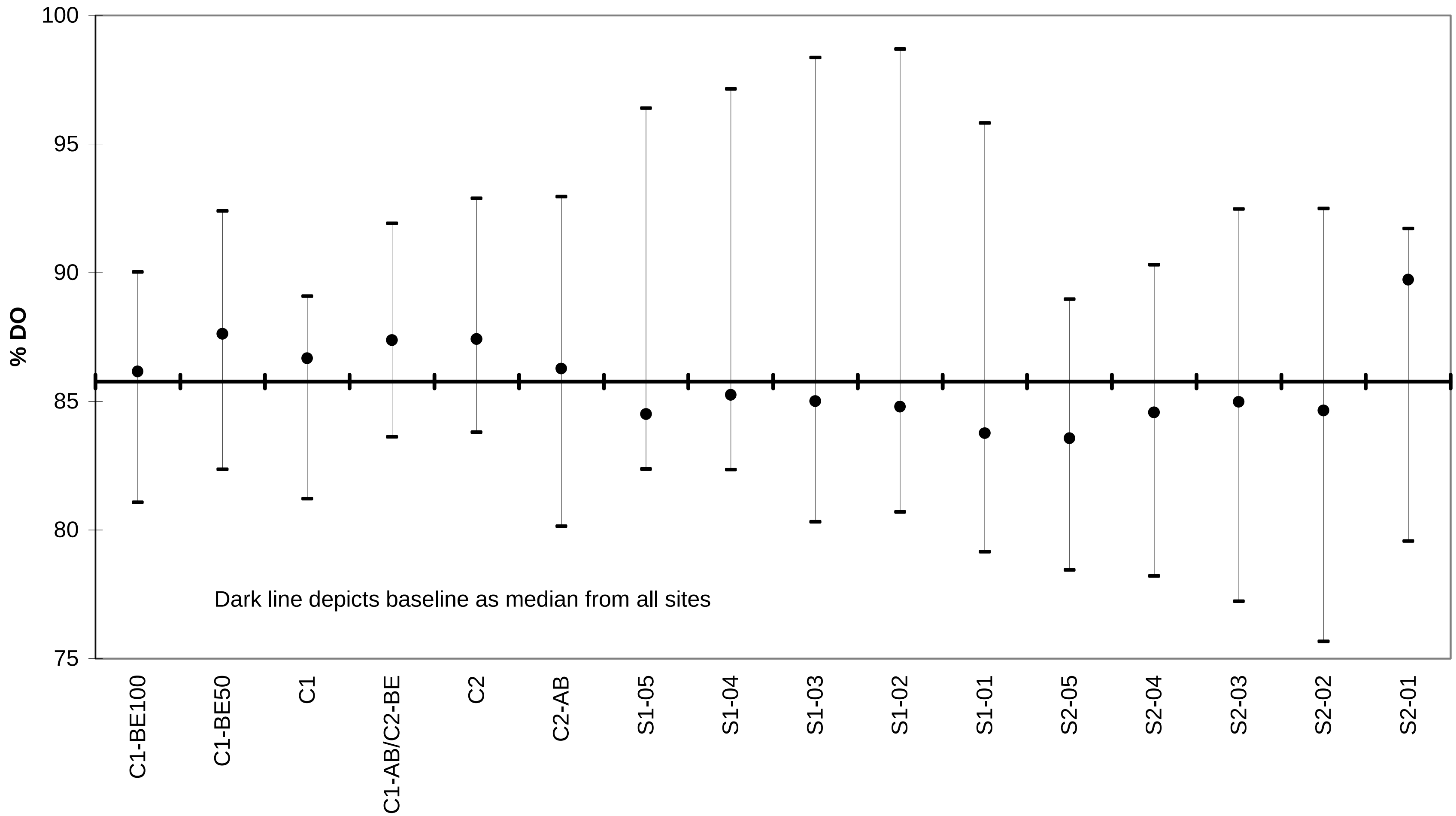

Figure 24. Median (error bars depict 1st and 3rd quartiles) dissolved oxygen (% saturated) for each sample site during sampling events of Jim Creek, Alaska, August 6 thru October 18, 2008.

Median dissolved oxygen (% saturated) during sampling events ranged from >100% on August 12 to 63.98% on October 18 (Figure 25). Dissolved oxygen content of water declined significantly ($p<0.05$) through time during the 2008 sampling period.

During late October, the period with the lowest dissolved oxygen content, all sites upstream from S1-02 were significantly ($p<0.05$) lower than medians for the entire stream (Figure 26). Median dissolved oxygen was lowest at sites S1-04, C2-AB, and between S1-01 and S2-01. Dissolved oxygen was highest at sites downstream from C2-AB.

The 1 sampling event of Upper Jim Creek occurred on August 26, 2008 at sites RIP-C1-AB, RIP-C1, RIP-C1-BE, and RIP2 and resulted in an average pH of 8.13 (did not differ from median pH at sites downstream on August 23), conductivity of 184.5 uS (~23 uS lower than median at sites downstream on August 23), and water temperature of 8.25°C (~8°C lower than median at sites downstream on August 23).

Overall, Jim Creek was clear with median turbidity (NTU) of near 0 from August 6 thru September 30, then an exponential increase of turbidity from 3.42 NTU on October 8 to 50 NTU on October 16 (Figure 27). From August 6 thru October 8, 2008, median turbidity was significantly ($p < 0.05$) higher at sample site C1-BE100 than at all other sites, except C2-AB (Figure 28). Most of the variance in turbidity was detected at sites C1-BE100 and C2-AB. Turbidity during clear flow from August 6 thru September 30 was unrelated to precipitation, but turbidity increased substantially during fall turnover in October, especially from unknown sources coming from Leaf Lake.

Because turbidity during summer base-flows was near 0 and the turbidity data were not normally distributed, the percentage of samples above 5 NTU, 10 NTU, 15 NTU, and 20 NTU are presented in Figures 29 - 32. Turbidity at all pooled sites between C1-100BE and C2-AB was significantly ($p<0.05$) higher than at all sites between S1-05 and S2-01 (Figure 33).

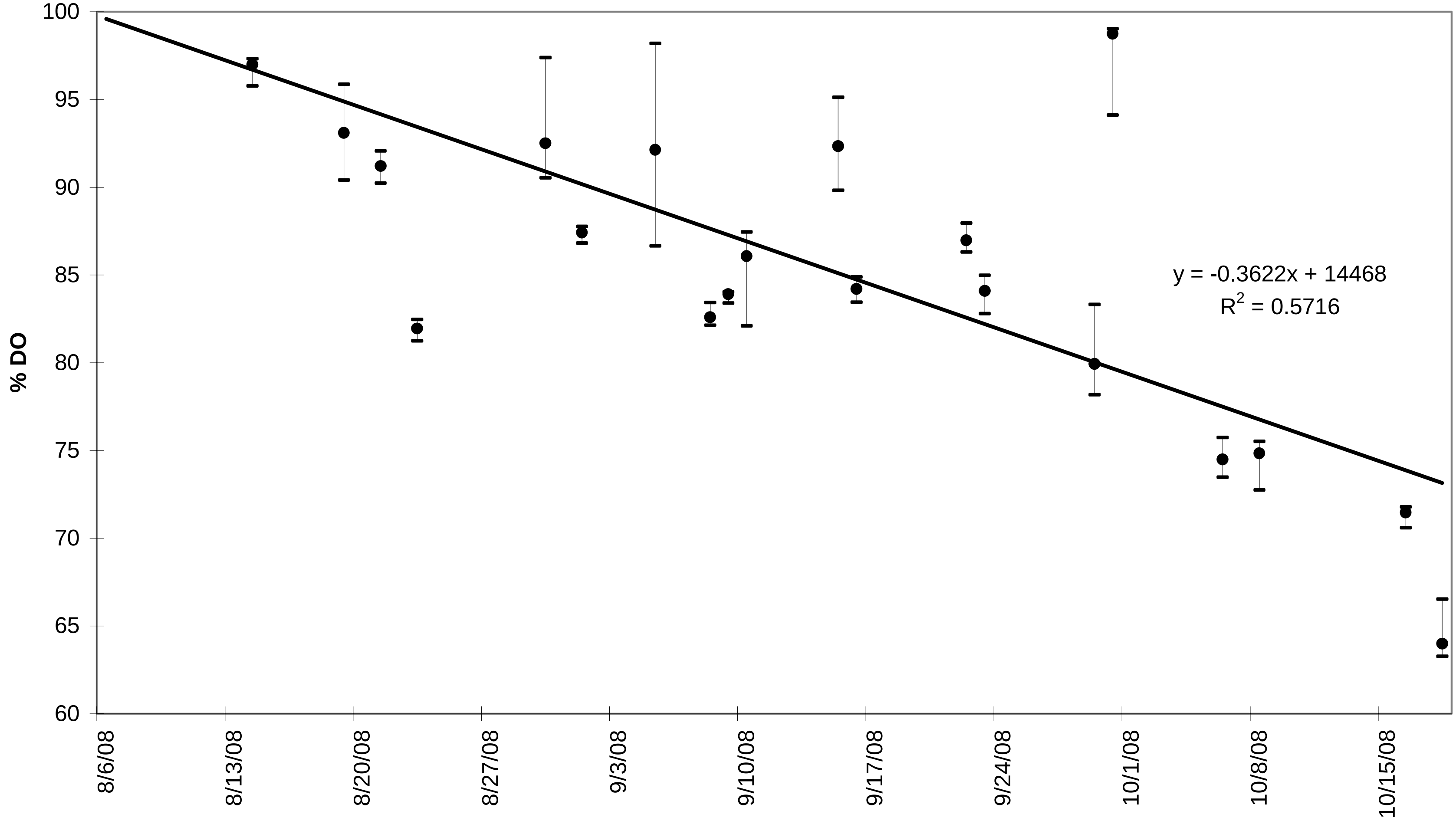

Figure 25. Median (error bars depict 1st and 3rd quartiles) dissolved oxygen (% saturated) from all sample sites during sampling events of Jim Creek, Alaska, August 6 thru October 18, 2008.

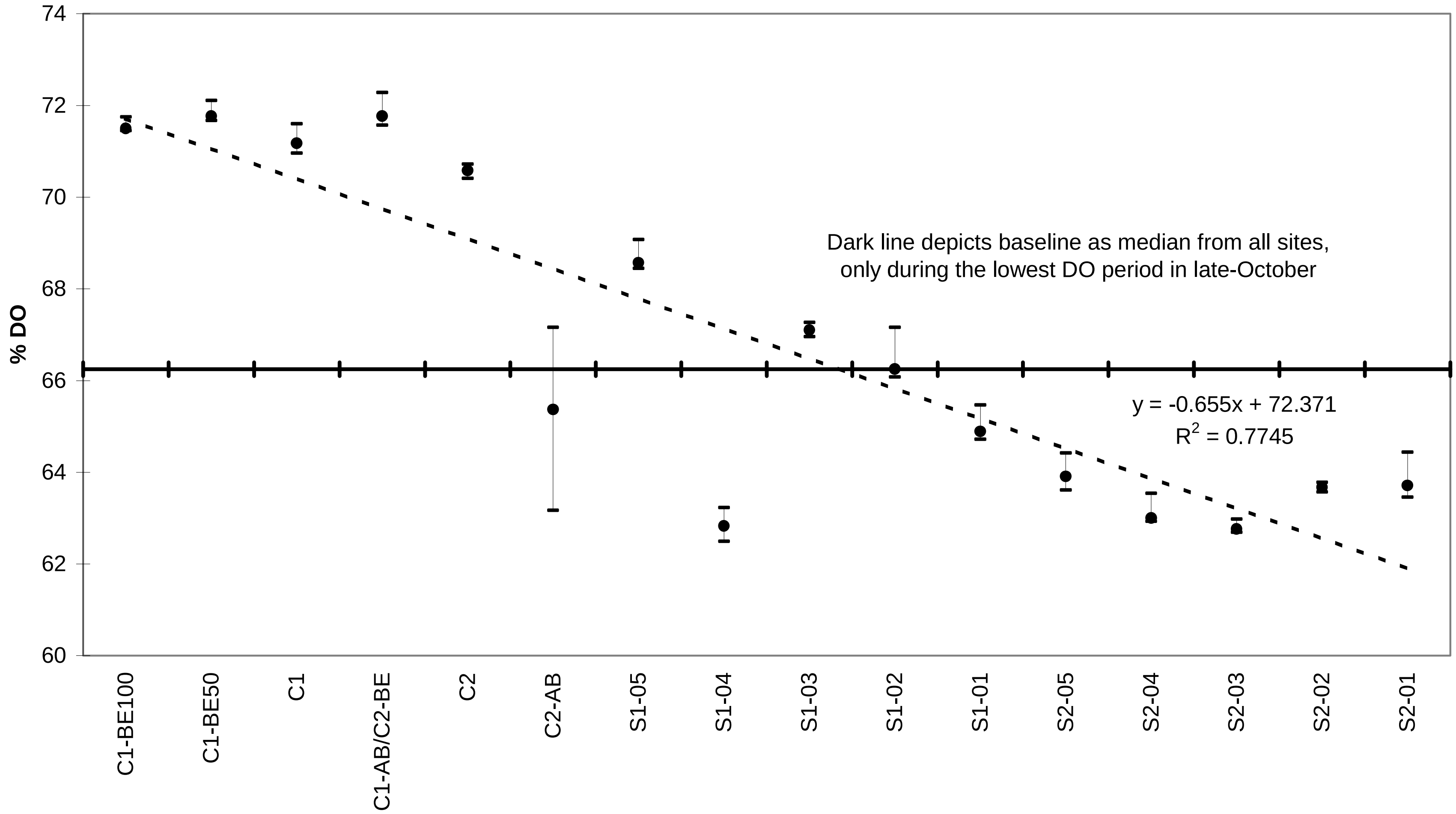

Figure 26. Median (error bars depict 1st and 3rd quartiles) dissolved oxygen (% saturated) from each site during sampling events of Jim Creek, Alaska, during late October, 2008, the period with the lowest dissolved oxygen content.

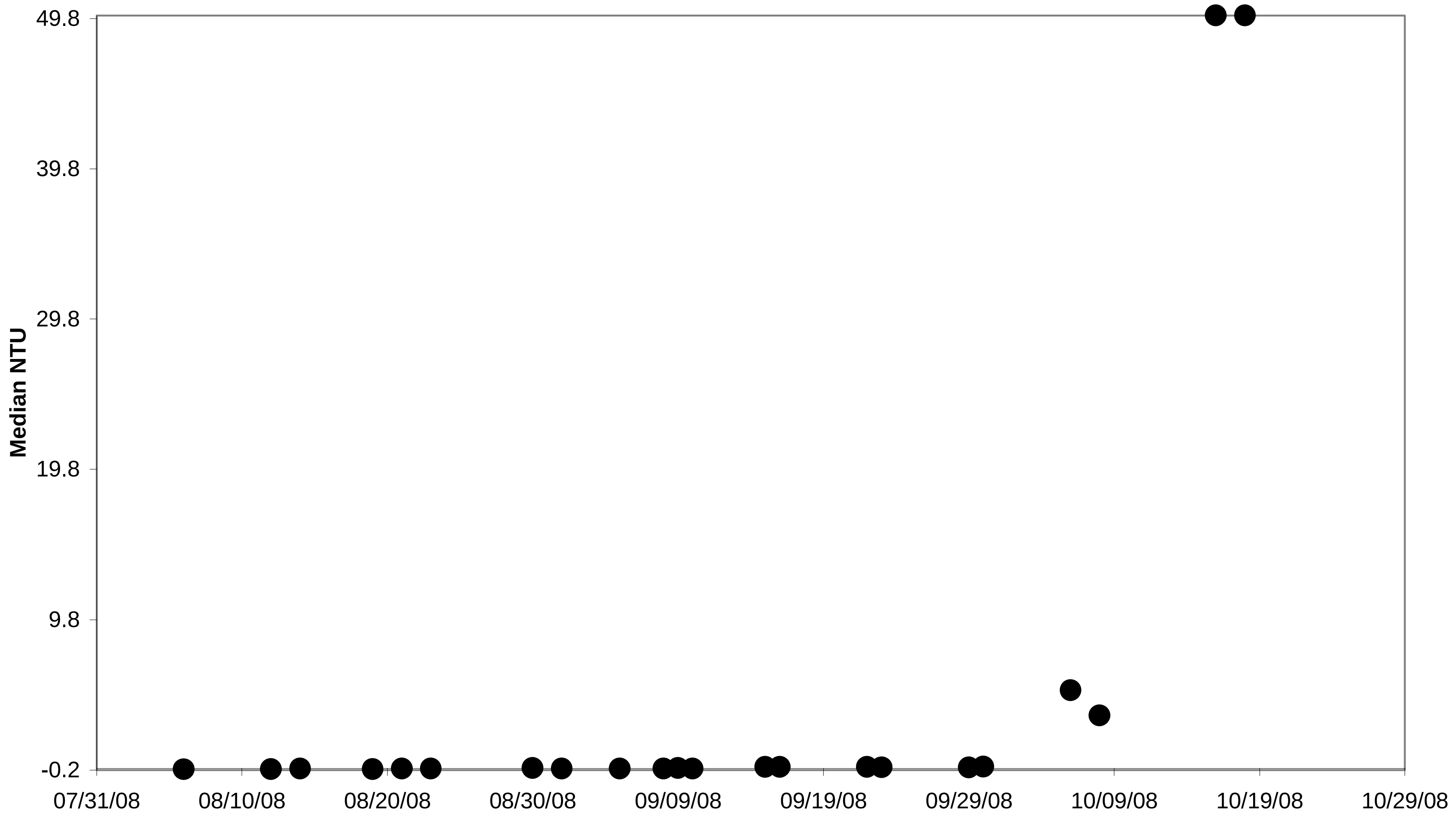

Figure 27. Median turbidity (NTU) from all sample sites of Jim Creek, Alaska, August 6 thru October 18, 2008.

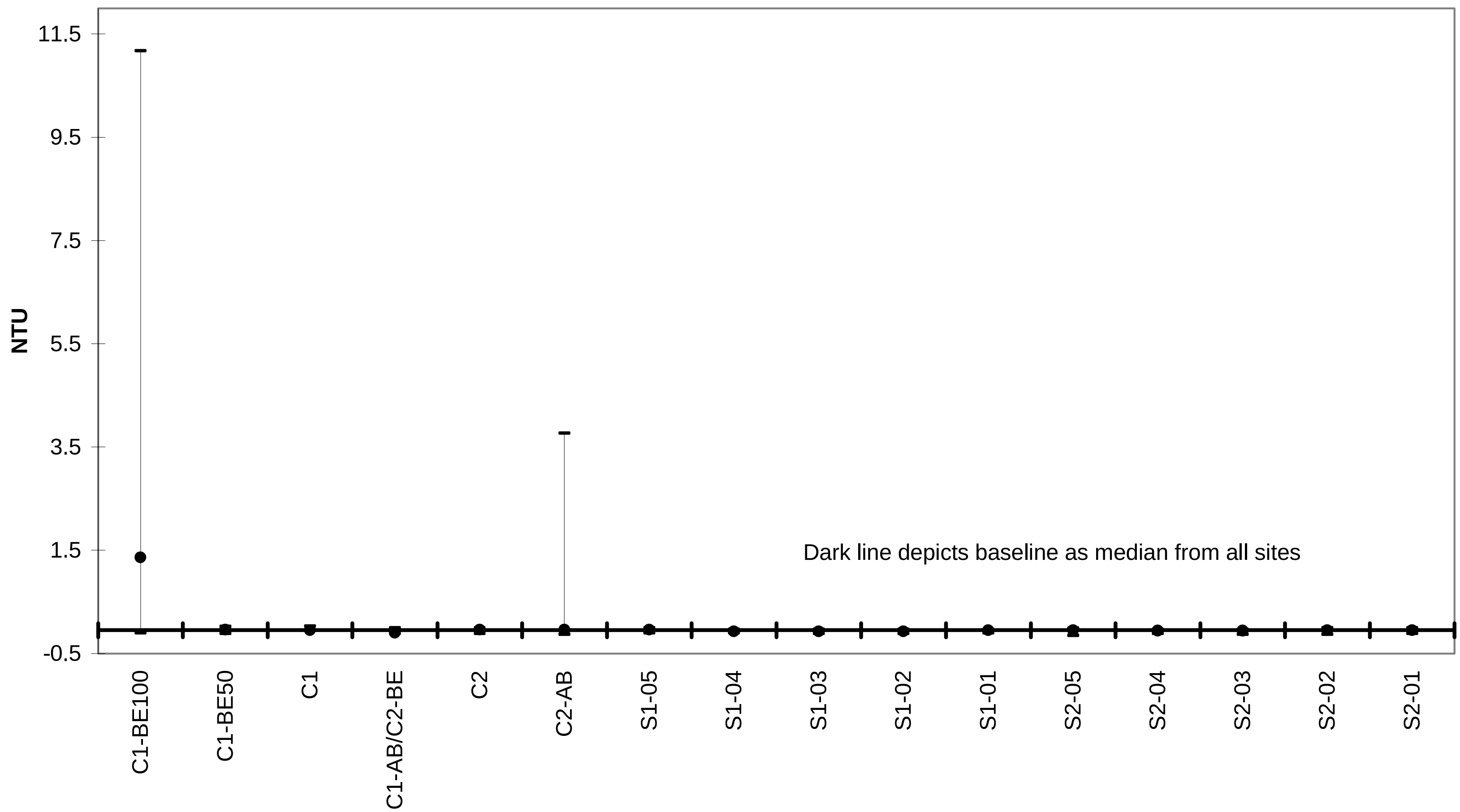

Figure 28. Median turbidity (NTU - error bars depict 1st and 3rd quartiles) at each sample site of Jim Creek, Alaska, August 6 thru October 8, 2008.

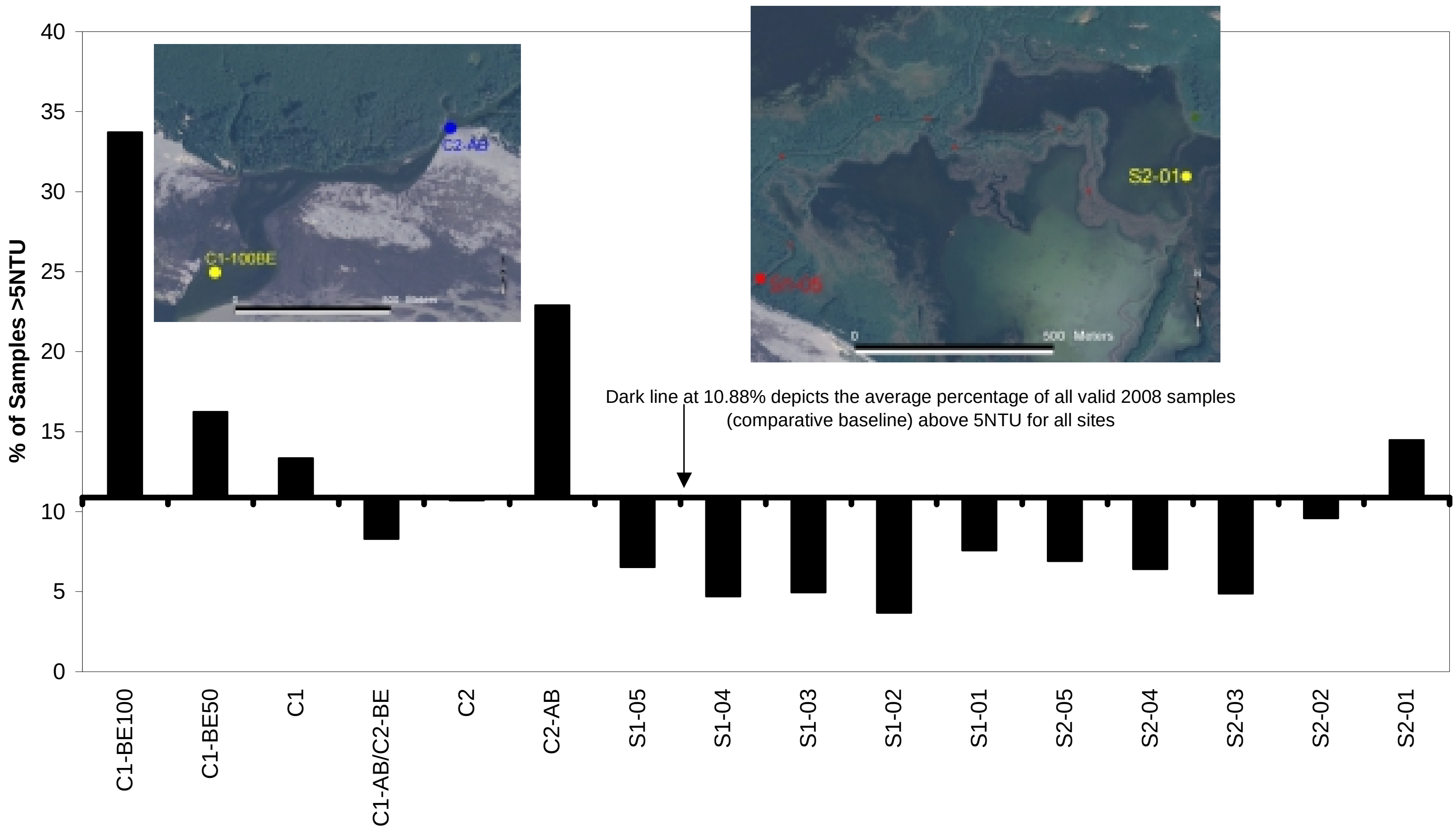

Figure 29. Percentage of samples with turbidity exceeding 5 NTU at each sample site of Jim Creek, Alaska, August 6 thru October 18, 2008.

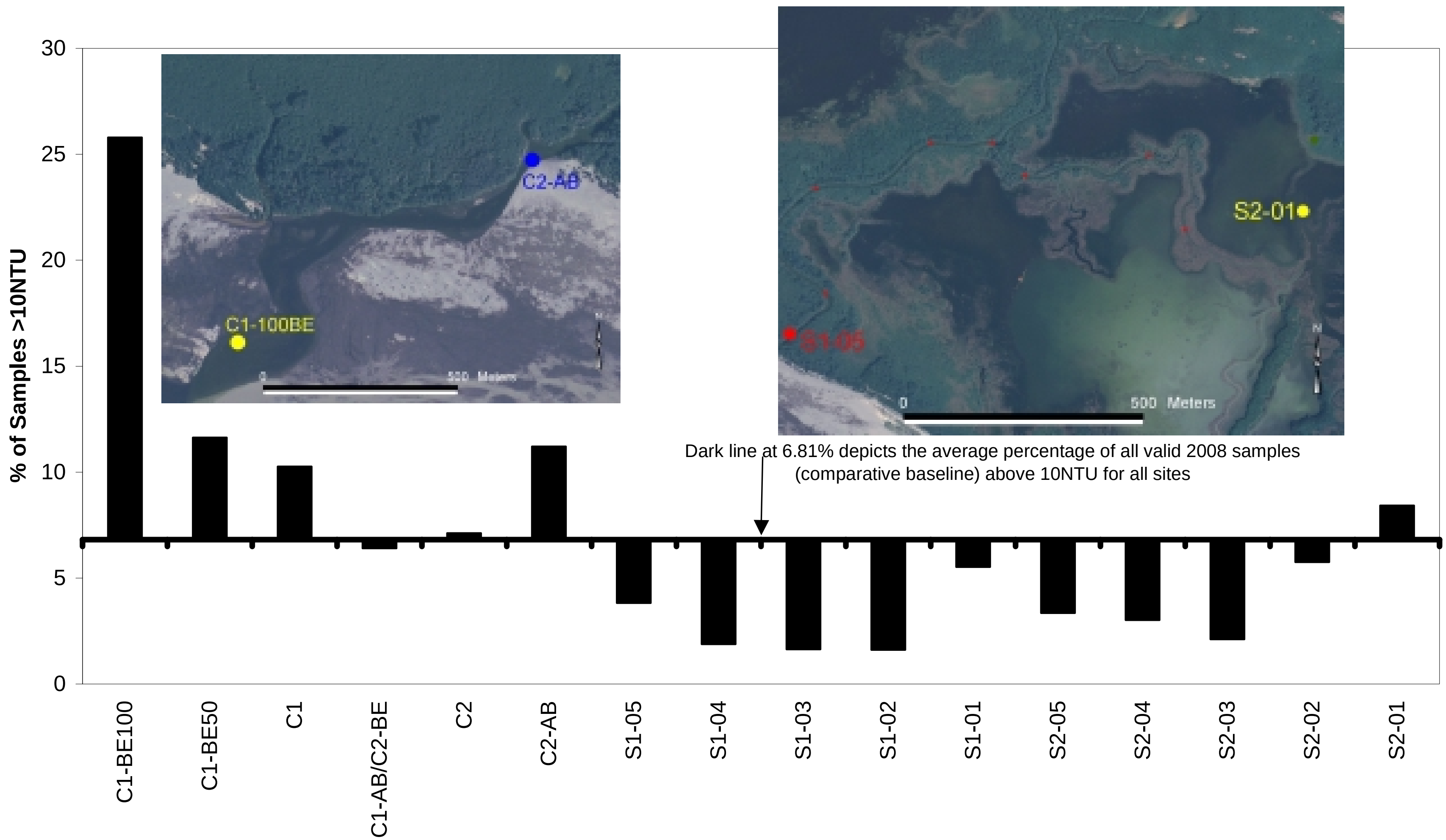

Figure 30. Percentage of samples with turbidity exceeding 10 NTU at each sample site of Jim Creek, Alaska, August 6 thru October 18, 2008.

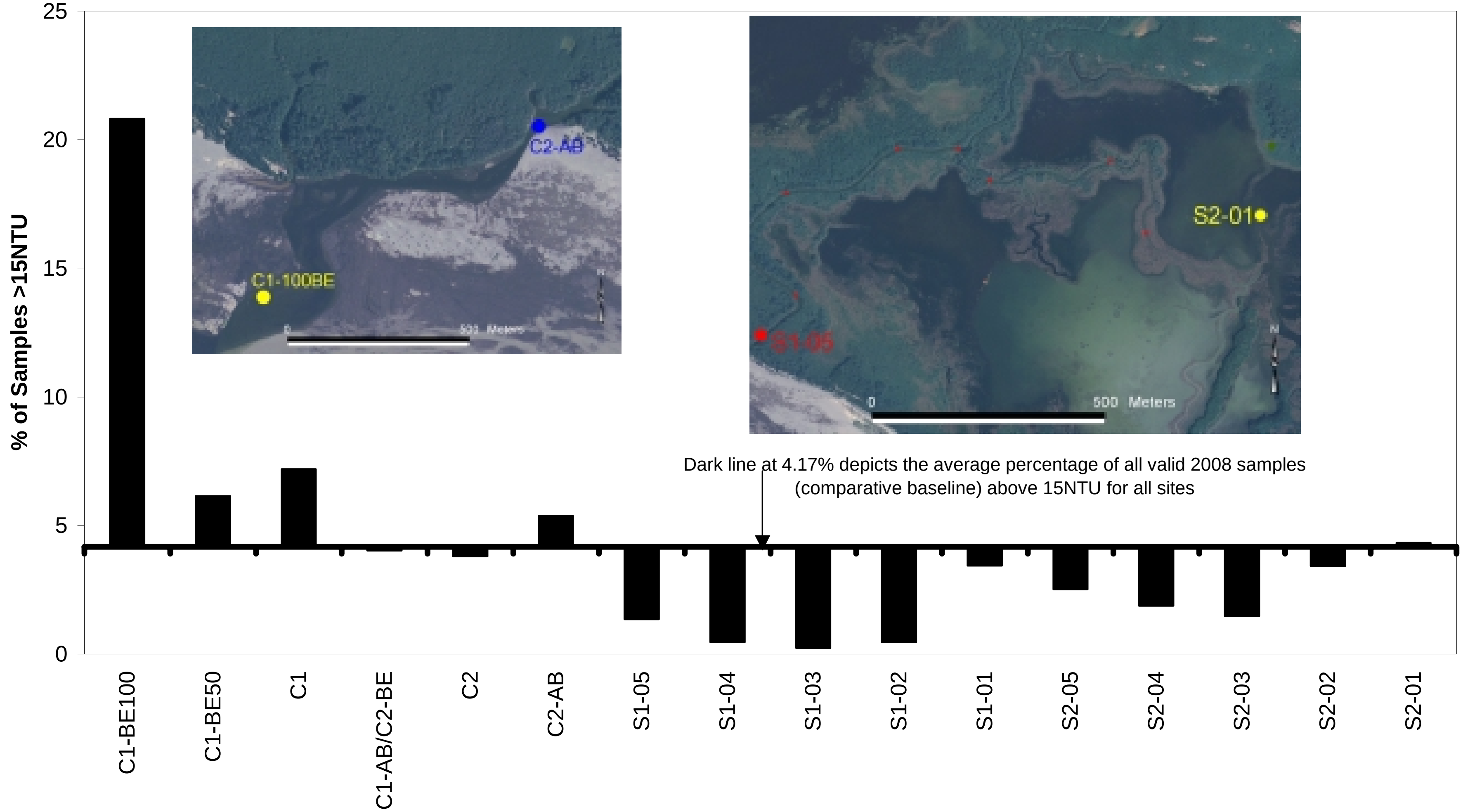

Figure 31. Percentage of samples with turbidity exceeding 15 NTU at each sample site of Jim Creek, Alaska, August 6 thru October 18, 2008.

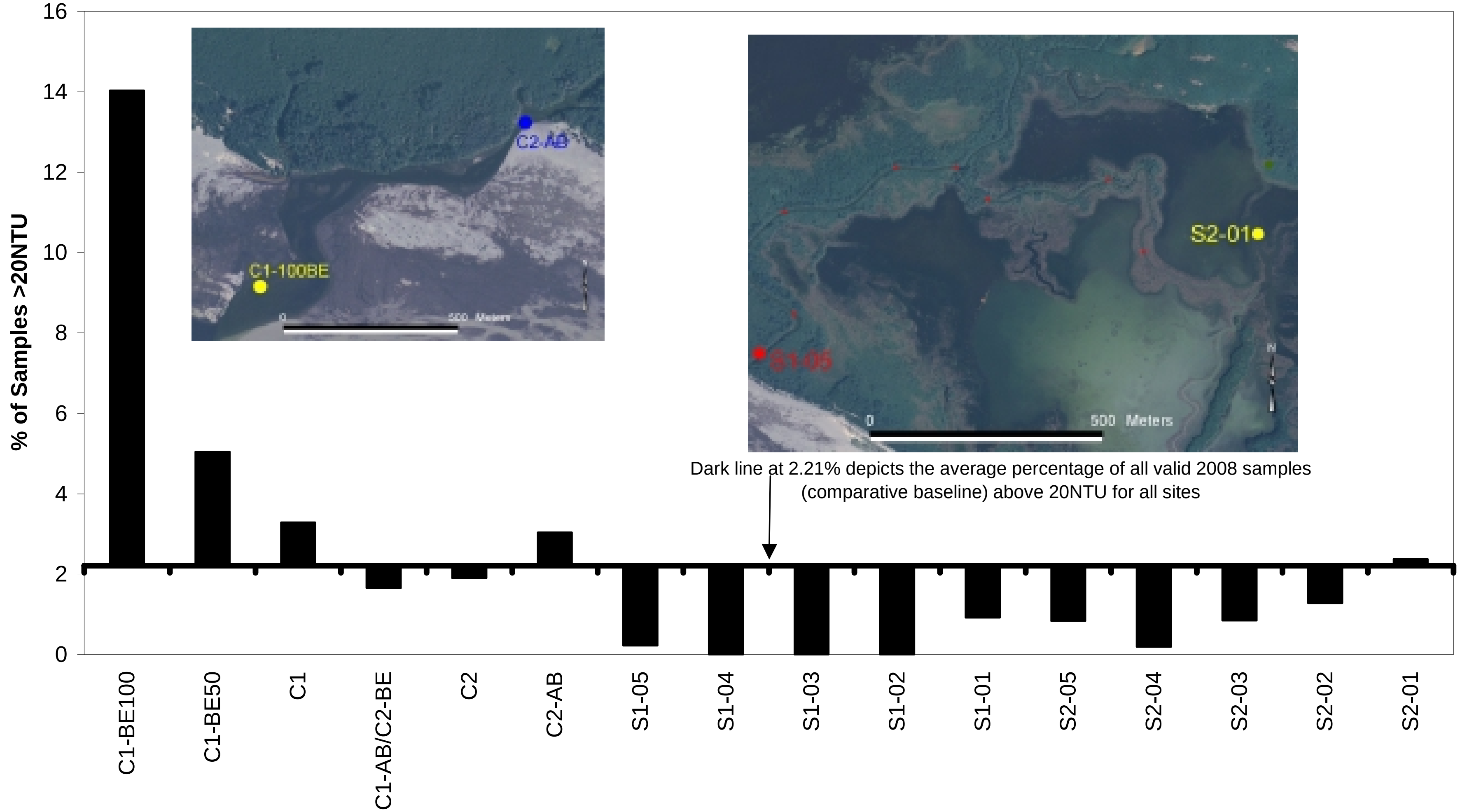

Figure 32. Percentage of samples with turbidity exceeding 20 NTU at each sample site of Jim Creek, Alaska, August 6 thru October 18, 2008.

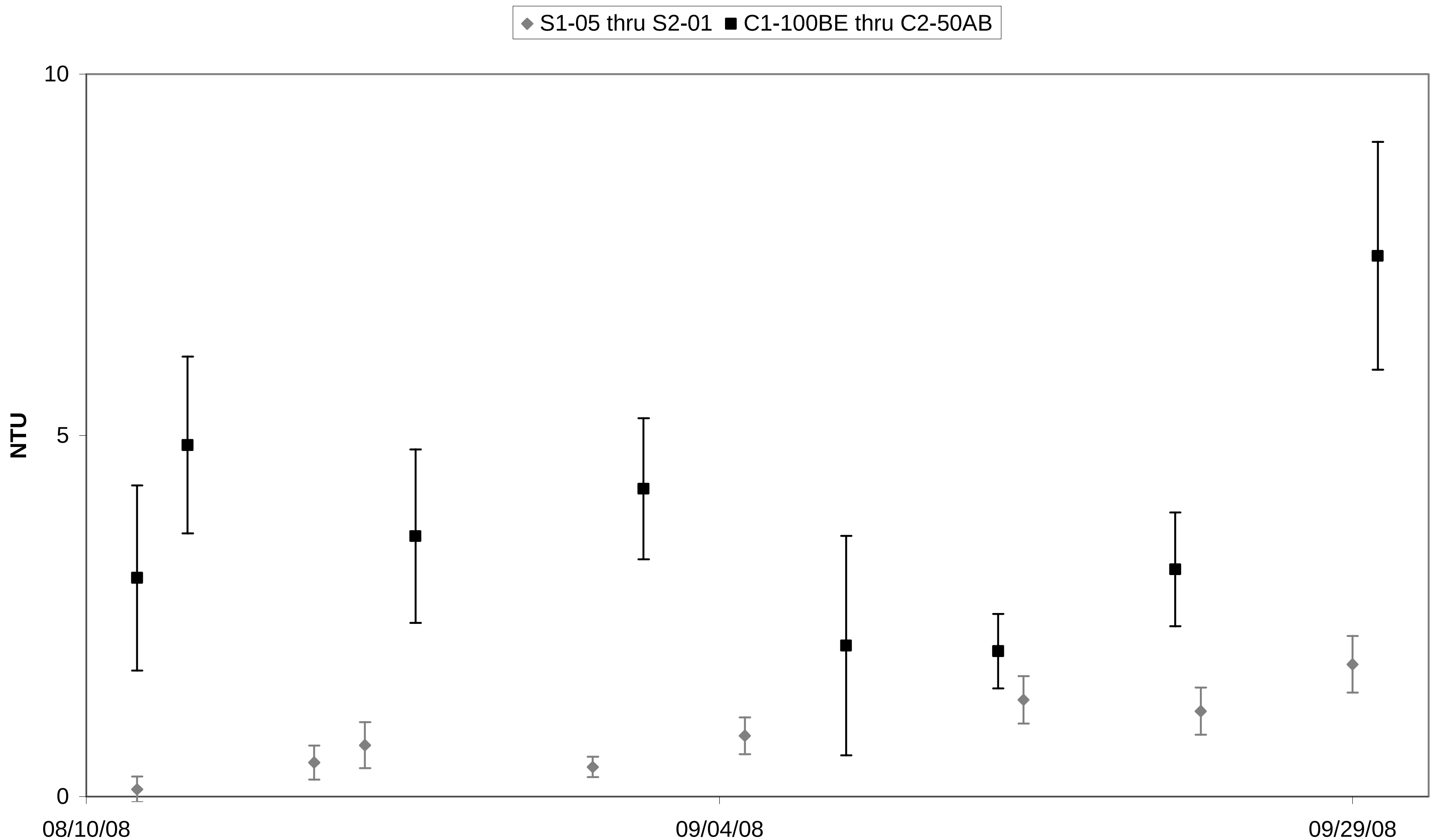

Figure 33. Median turbidity (means and 95% confidence intervals from pooled data) from sites S1-05 upstream to S2-01 and from sites C1-100BE upstream to C2-AB between August and October 2008 along Jim Creek, Alaska.

5.3 PHYSICOCHEMICAL CHARACTERISTICS, 2009

Results of the spring sampling during May 26-28, 2009 are depicted in Figures 34 - 37. Median pH was 7.9, near that of the last sample on October 16-18, 2008, and ranged from 7.68 at site C1 to 8.05 at site S2-03 (Figure 34).

Median dissolved oxygen was 98% overall, substantially higher than during October 16-18, 2008 (Figure 35). Each site upstream from S1-04 was supersaturated (>100%) with dissolved oxygen. In contrast, median dissolved oxygen at sites downstream and including site S1-04 was significantly below that for the stream as a whole. The spatial pattern of dissolved oxygen content was opposite of that detected on October 16-18, 2008; instead, median dissolved oxygen increased significantly ($p<0.05$) from downstream sites to upstream sites during spring 2009 (Figure 35).

Median specific conductivity was 214, and ranged from 322.74 at site S2-01 to 142.9 at site S2-05 (Figure 36). Clearly, conductivity was highest at the sites furthest upstream (S2-04 thru S2-01), was substantially lower at the ouflow of McRoberts Creek at site S2-05, and was then similar to the median among sites downstream from S1-01.

Median turbidity was 8.25, lower than during October 16-18 2008 but higher than during August 6-October 8 2008, and ranged from 40 at site S2-01 to 0 at several sites (Figure 37). No clear spatial pattern was evident for turbidity on May 26-28, 2009 but the variance in turbidity was highest during this sampling period (i.e. variance in turbidity was nearly 0 at upstream sites for most of the sampling period in 2008). Keep in mind that error bars represented quartiles, which appeared much larger than 95% confidence intervals presented by many researchers, but required no assumptions about the distribution of collected data.

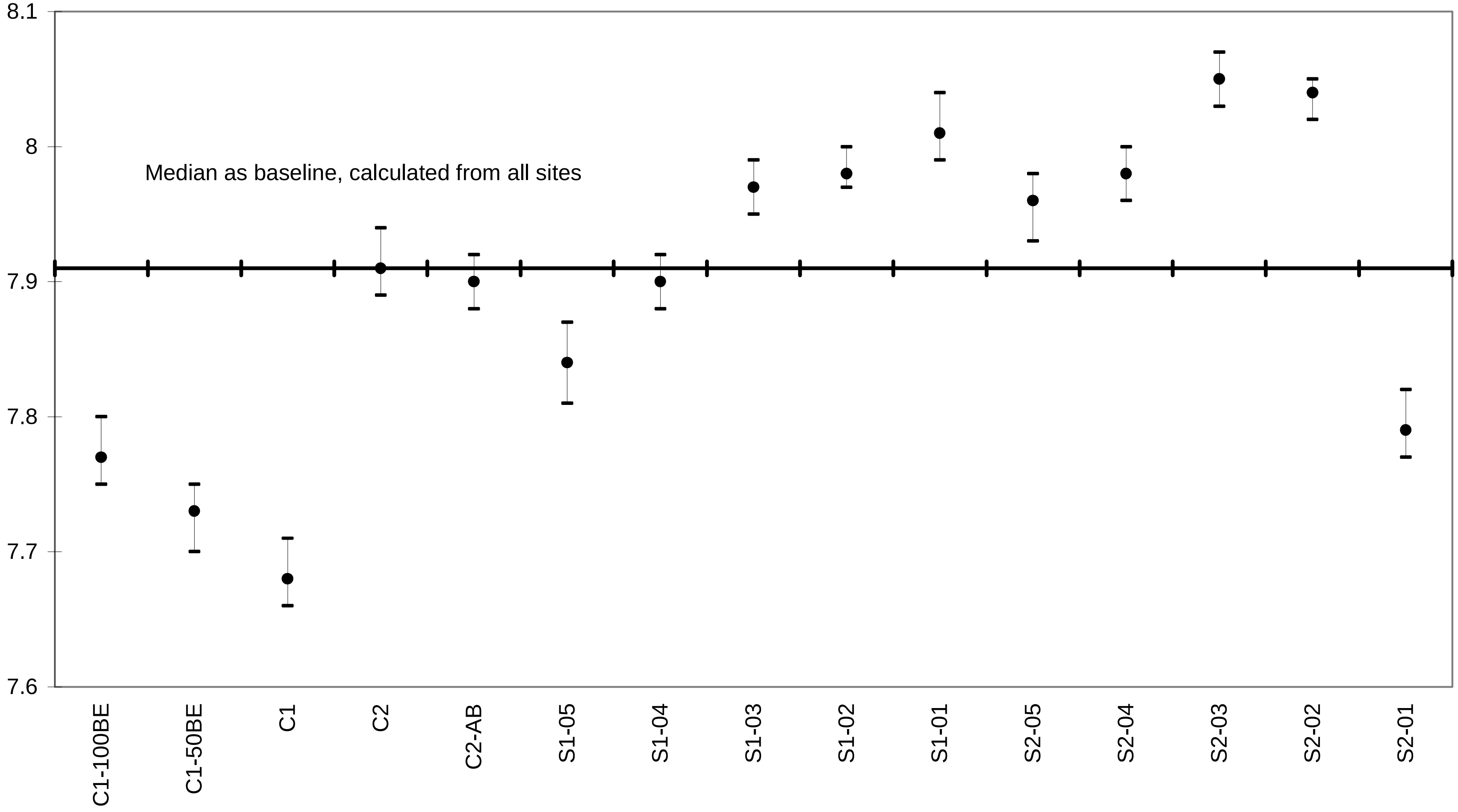

Figure 34. Median pH (error bars depict first and third quartiles) for each sample site during sampling events of Jim Creek, Alaska, on May 26-28, 2009.

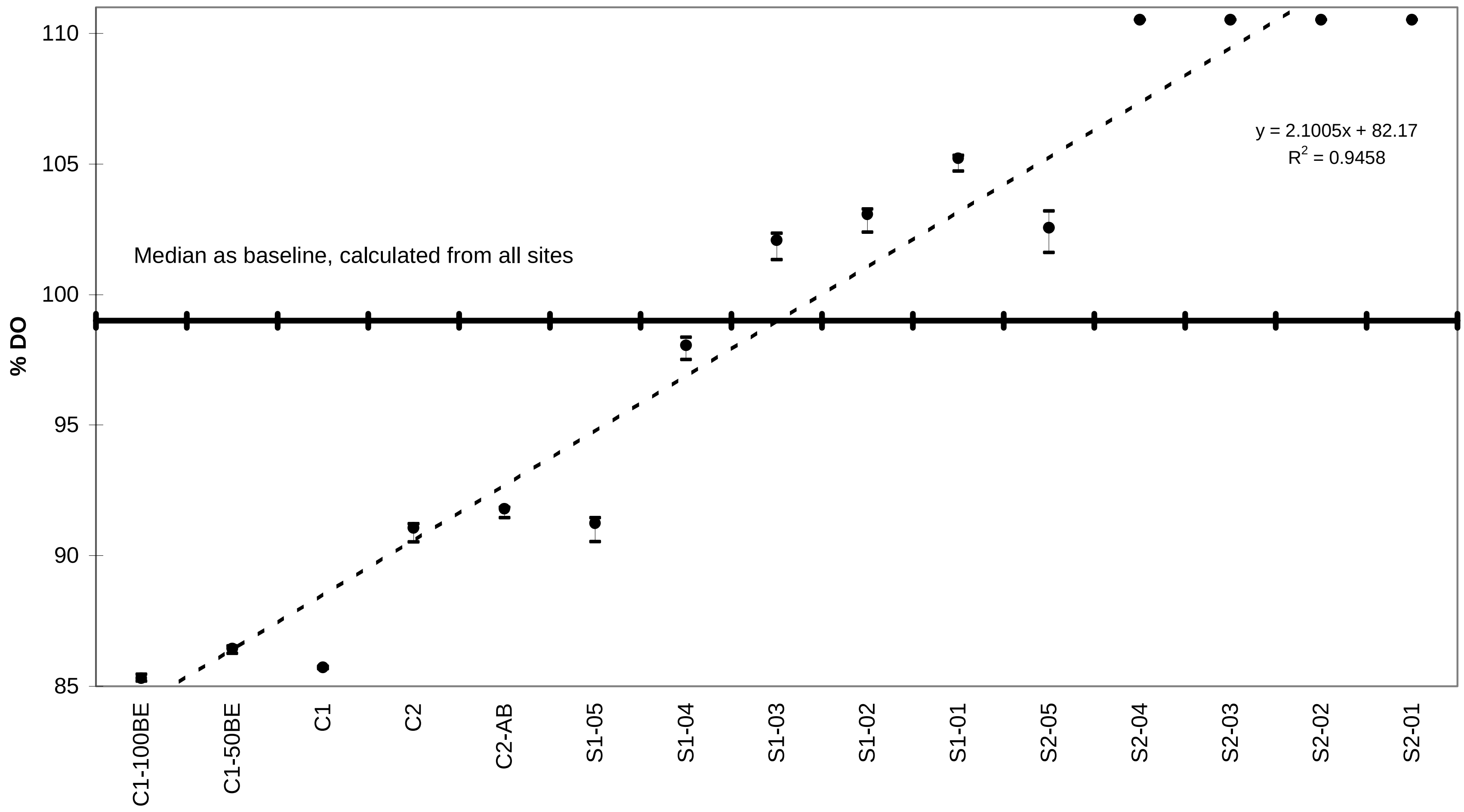

Figure 35. Median dissolved oxygen (% saturated) and data distribution (first and third quartiles) for each sample site during sampling events of Jim Creek, Alaska, on May 26-28, 2009.

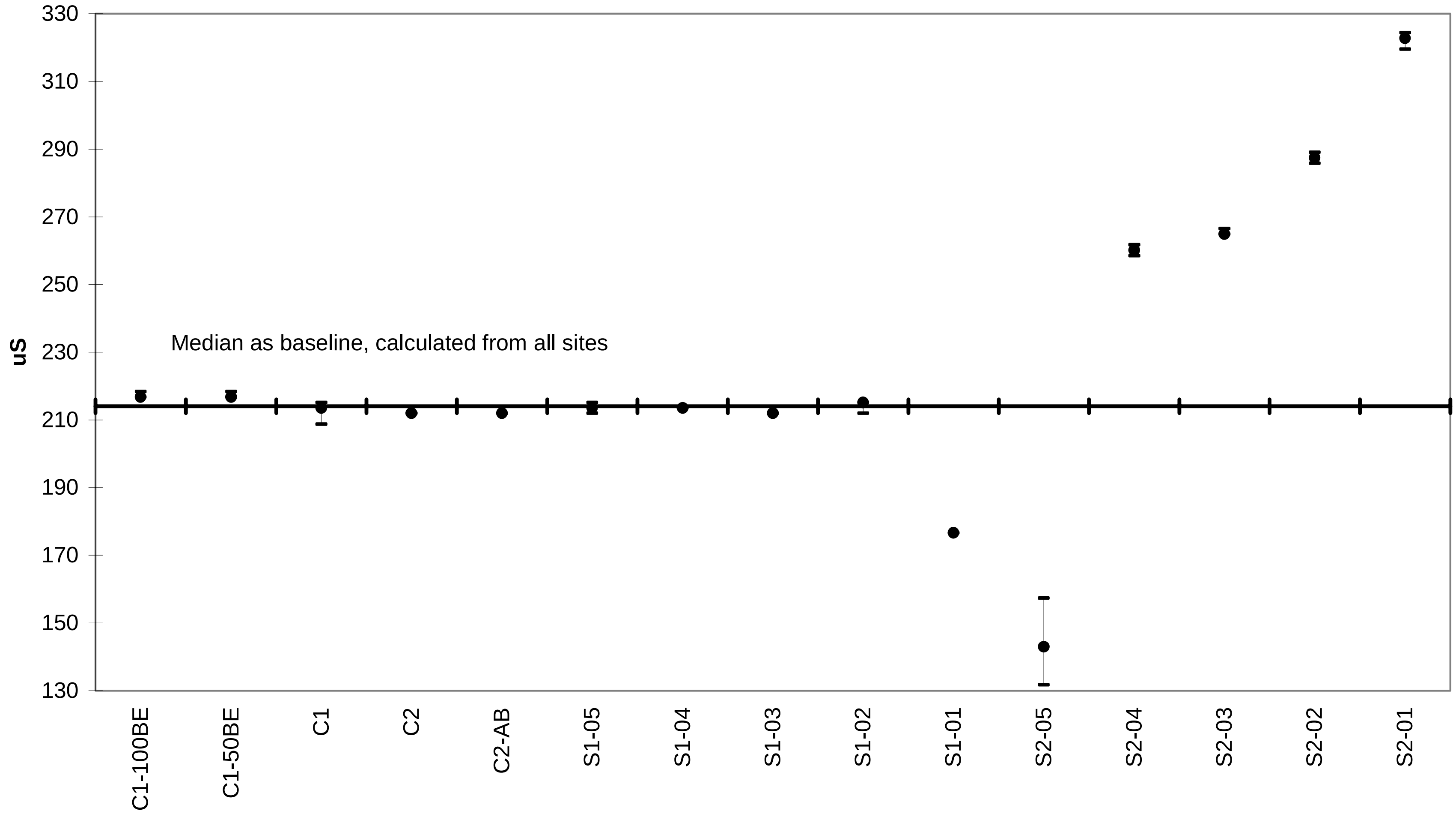

Figure 36. Median specific conductivity (uS) and data distribution (first and third quartiles) for each sample site during sampling events of Jim Creek, Alaska, on May 26-28, 2009.

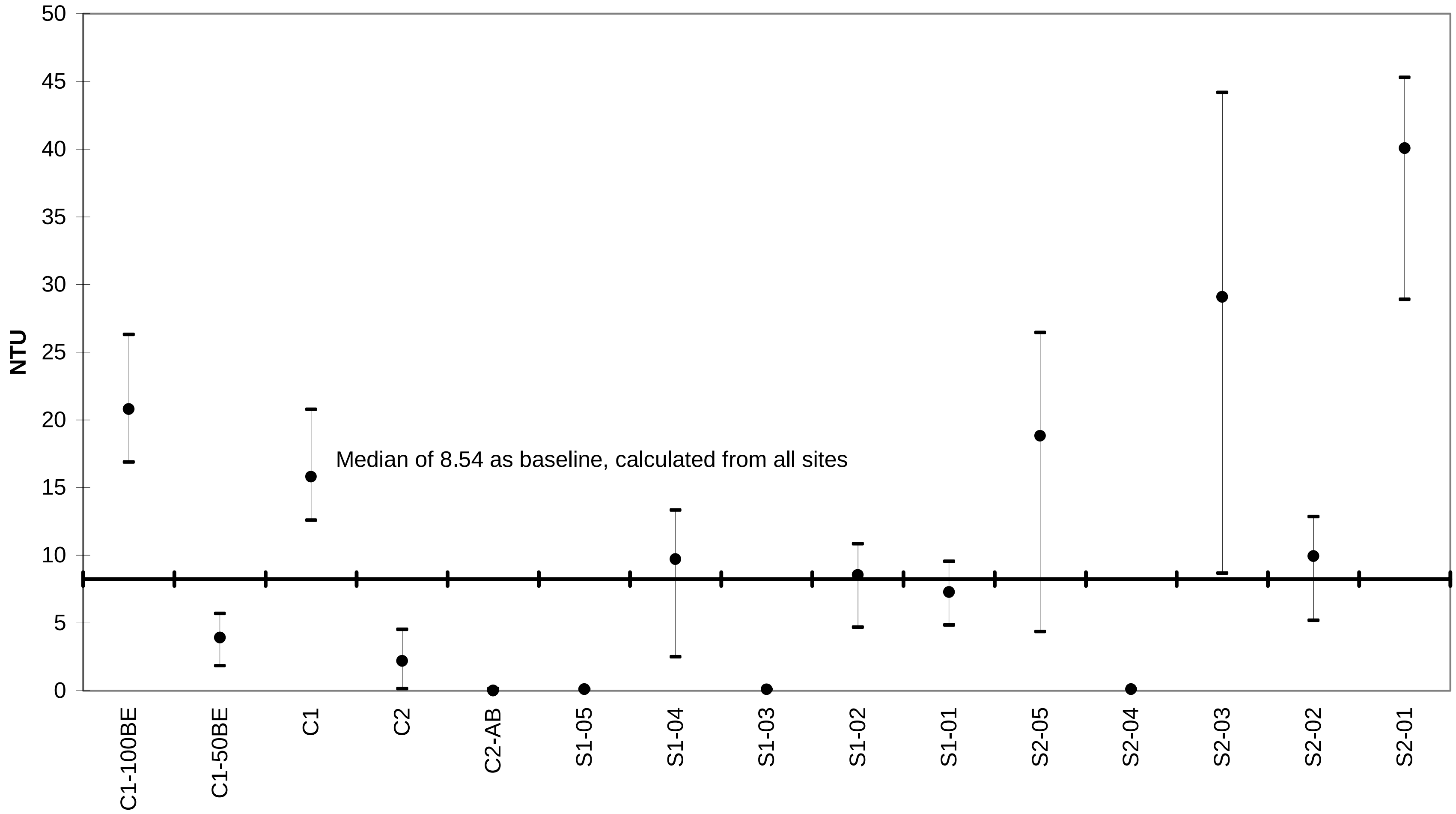

Figure 37. Median turbidity (NTU) and data distribution (first and third quartiles) for each sample site during sampling events of Jim Creek, Alaska, on May 26-28, 2009.

5.4 TEMPERATURE, 2008

Average air temperature between June 4 and October 18 2008 was 10.3°C, while maximum and minimum temperatures were 22.2°C and -7.6°C, respectively (Figure 38). Despite the variability in air temperature, average daily air temperature was directly and positively related ($p < 0.05$, $r^2 = 0.86$) to average daily water temperature (Figure 39). Until September 2008, water temperature was often slightly warmer than air temperature (Figure 40).

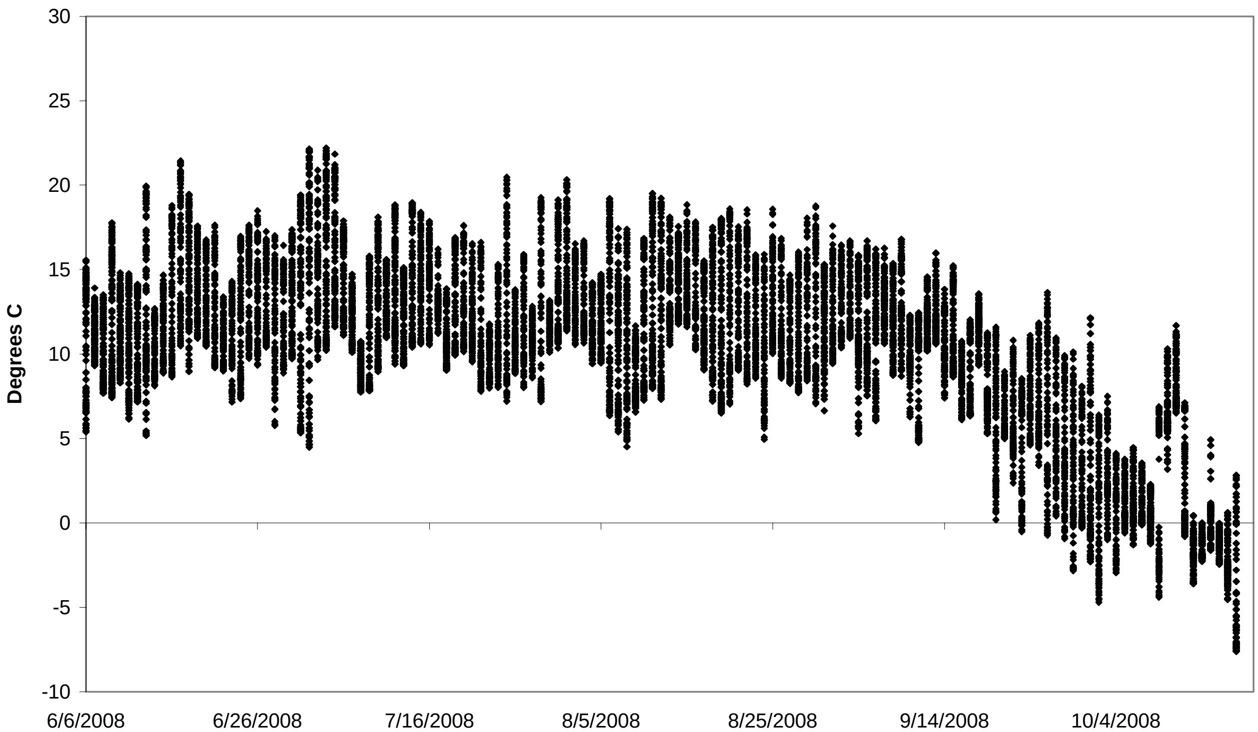

Figure 38. All air temperature measurements between June 6 and October 18, 2008, near site S1-04 along Jim Creek, Alaska.

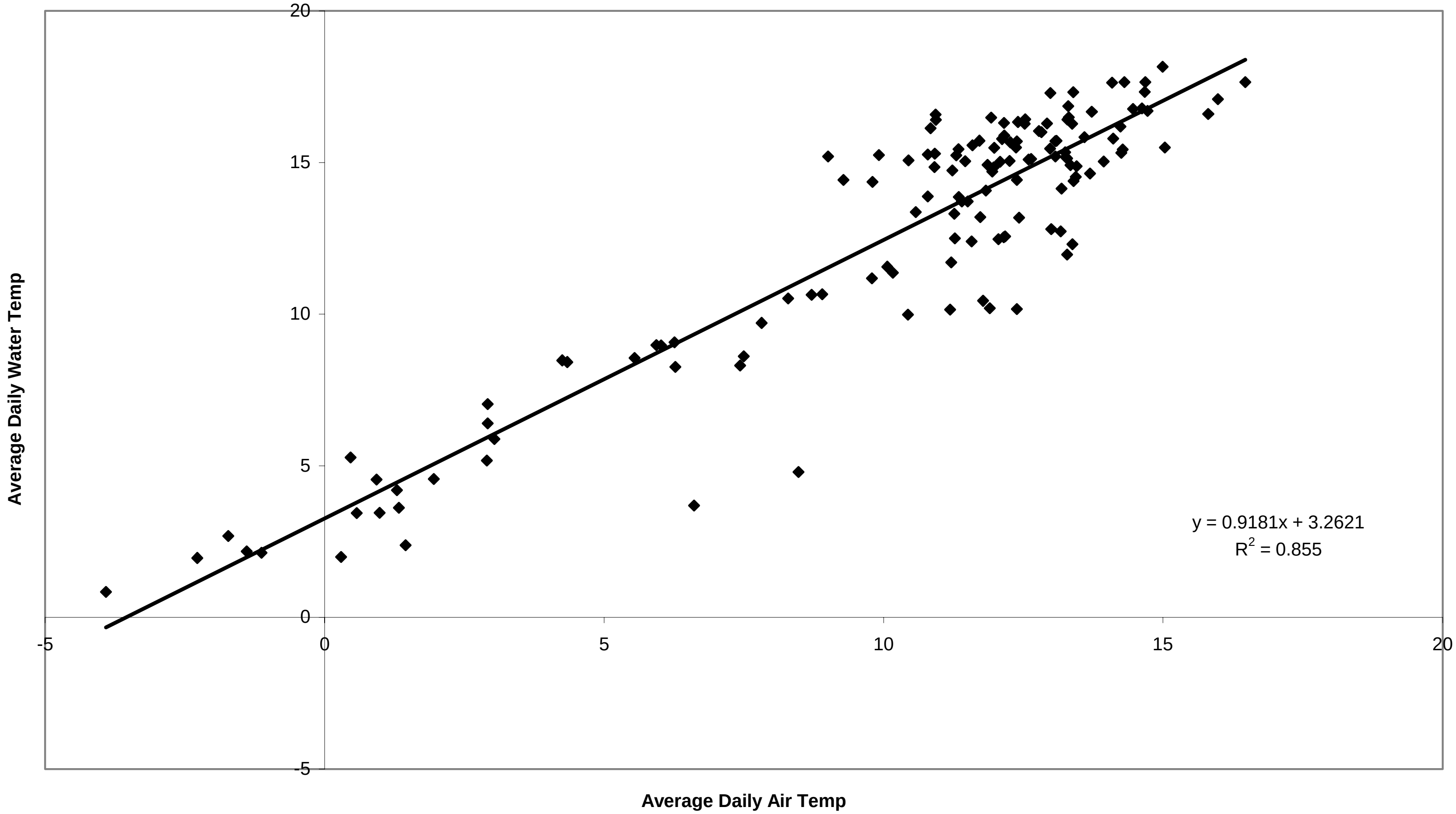

Figure 39. Average daily water temperature in relation to average daily air temperature (near site S1-04) along Jim Creek, Alaska, between June 6 and October 18, Alaska 2008.

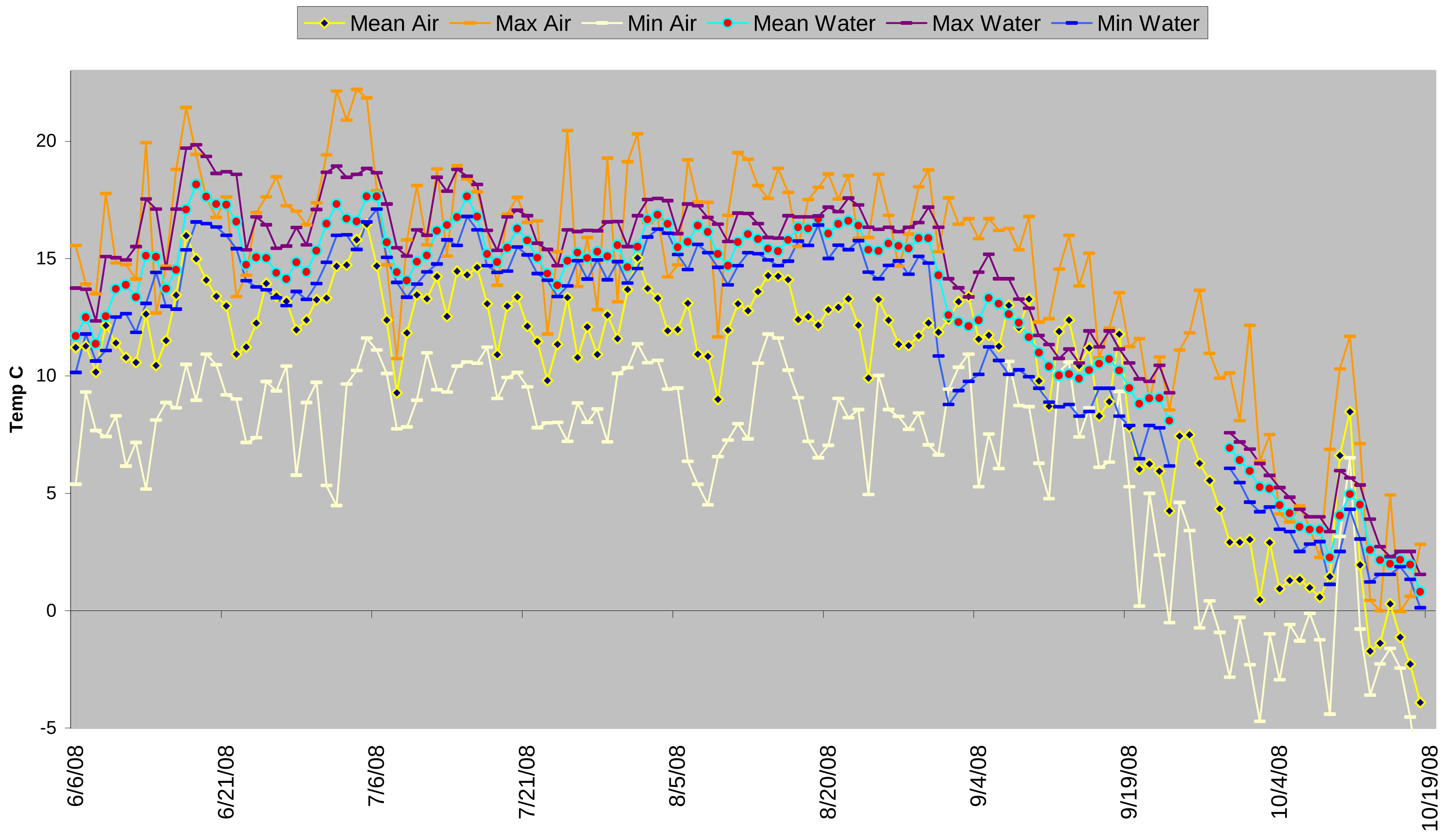

Figure 40. Daily mean, minimum, and maximum air (near site S1-04) and water (all dataloggers, except HOBO-05) temperatures along Jim Creek, Alaska, between June 6 and October 18, Alaska 2008.

Water temperature data for 24-hour periods from the 5 stationary data loggers depicted similar spatial and temporal patterns as those estimated using the WQMS data logger (Figure 41). Water temperatures near Leaf Lake at site HOBO-4, upstream from the outlet of Swan Lake, averaged 2.6°C colder than average water temperatures from all of the downstream sites. In addition, minimum and maximum water temperatures at site HOBO-4 were on average 2.3°C and 1.6°C colder, respectively, than at downstream sites. Water temperatures in Upper Jim Creek at site HOBO-5 averaged 4.8° colder than average water temperatures from all sites downstream of HOBO-04. Clearly, flow from Upper Jim Creek into Leaf Lake introduces cooler water, whereas flow from the Swan Lake outlet introduces warmer water into the Jim Creek system.

At all sites between HOBO-01 and HOBO-04 (downstream from Leaf Lake), maximum water temperature repeatedly exceeded State Water Quality Standards (WQS) for fish migration and rearing (15°C) and for spawning and incubation (13°C) even though summer 2008 weather was cooler than average (NWS 2008). Maximum water temperature was 19.84°C, recorded on June 18, 2008 at 9:30 PM. Between June 4 and August 31 2008, maximum daily water temperature of Jim Creek exceeded 13^{o}C on 84 of 89 days (94%) and exceeded 15°C on 68 of 89 days (76%). Then, maximum daily water temperature exceeded 13°C on all days at all HOBO sites, except Hobo-5, thru September 8. Thereafter, maximum daily water temperatures steadily dropped from 12°C to 1.5°C on October 18, with 1 warming trend from October 10th – 12th due to warmer air temperatures on those days.

In contrast to sites HOBO-01 thru HOBO-04, water temperature between August 25 and October 18, 2008 at HOBO-05 in Upper Jim Creek remained below Alaska WQS for salmon spawning, incubation, migration, and rearing. Average and maximum water temperature at HOBO-05 was 4.06°C and 8.08°C, respectively. Fortunately, HOBO-05 was deployed for a couple weeks before a significant drop in air and, hence, water temperatures. Unfortunately, the deployment date was probably too late to detect the maximum temperature for Upper Jim Creek during 2008.

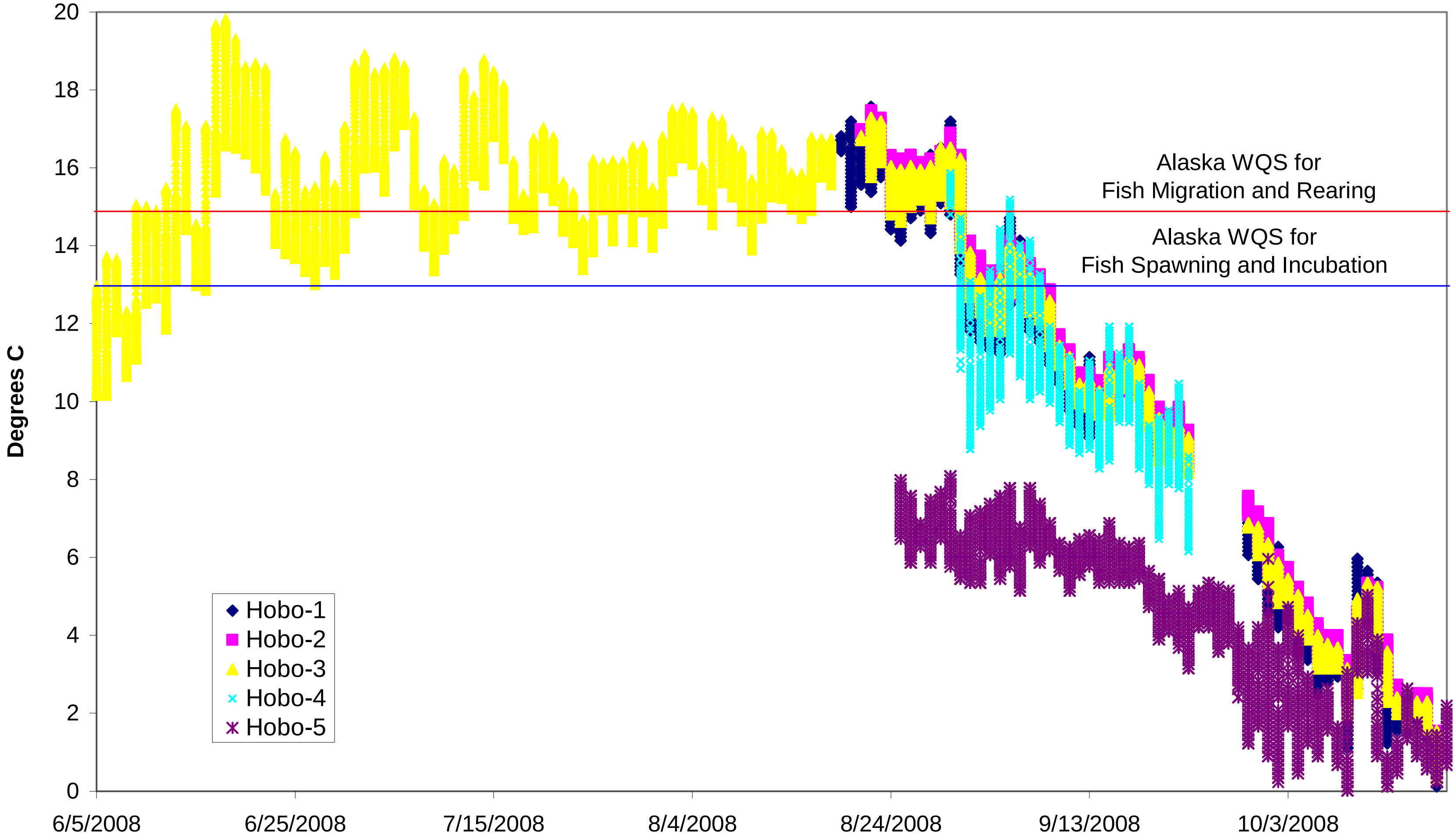

Figure 41. All water temperature (°C) estimates for each sample taken every 15 seconds during 24-hour periods at 5 sites along Jim Creek, Alaska, from June 6 to October 18, 2008. Hobo-4 became exposed to air and inaccessible due to a drop in water levels in early October so data are not presented during that entire period for that data logger.

Water temperature data between 12:00PM and 6:00PM from the WQMS data logger (Figure 42) depicted similar spatial and temporal patterns as those estimated using the continuous (HOBO) data loggers. During all 7 sampling events at each sample site from S1-100BE upstream to S2-01, average daily water temperature of Jim Creek significantly ($p<0.05$) exceeded 16°C from August 6 thru August 30, 2008. Then, average daily water temperature exceeded 13° during all 3 sampling events thru September 9. Thereafter, average daily water temperature dropped from 12° on September 10 to 1°C on October 18.

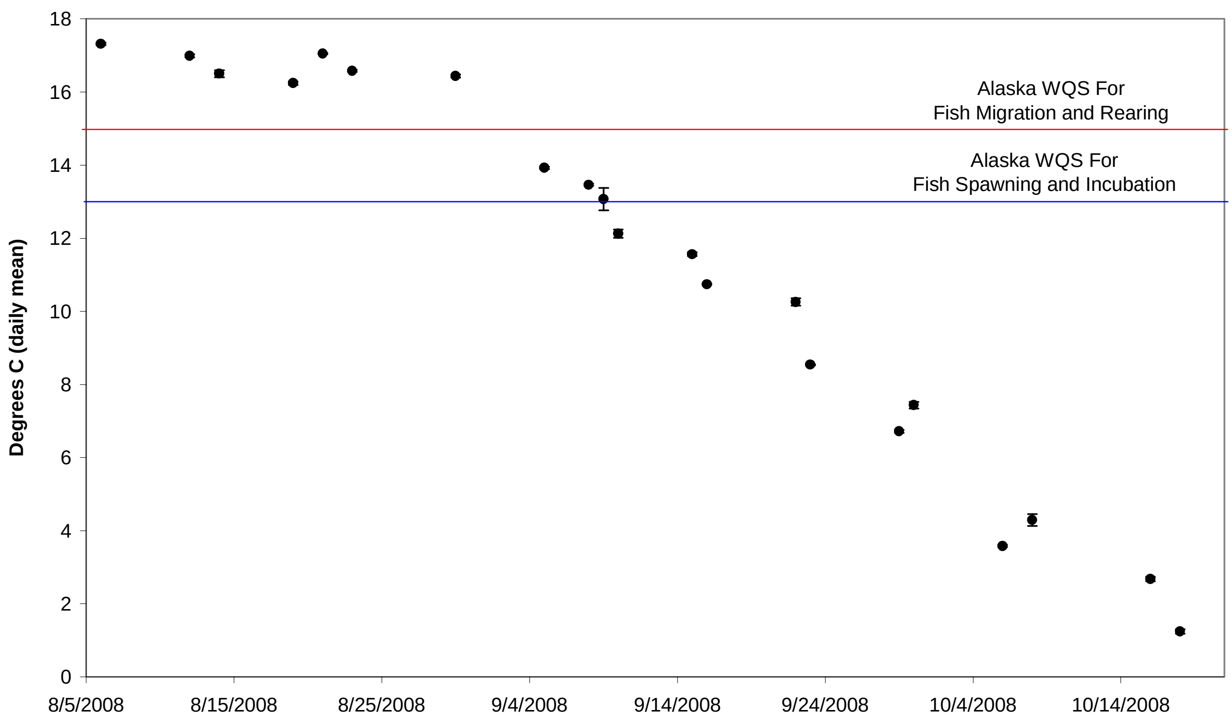

Figure 42. Mean daily water temperature (°C) between 12PM and 6PM during sampling events of Jim Creek, Alaska, August 6 thru October 18, 2008. Error bars depict 95% confidence intervals.

Median water temperature between August 6 thru October 18, 2008 was lowest at site S2-01 and highest at C1-BE50 (Figure 43). The coldest water entered from Upper Jim Creek where the high mountain stream tumbles down thru the rugged canyon before joining the wetland complex at Leaf Lake. Between sites S2-01 and S2-02, slightly warmer water entered from the outlet of Swan Lake. Sites downstream from S1-05 were slightly warmer than upstream sites.

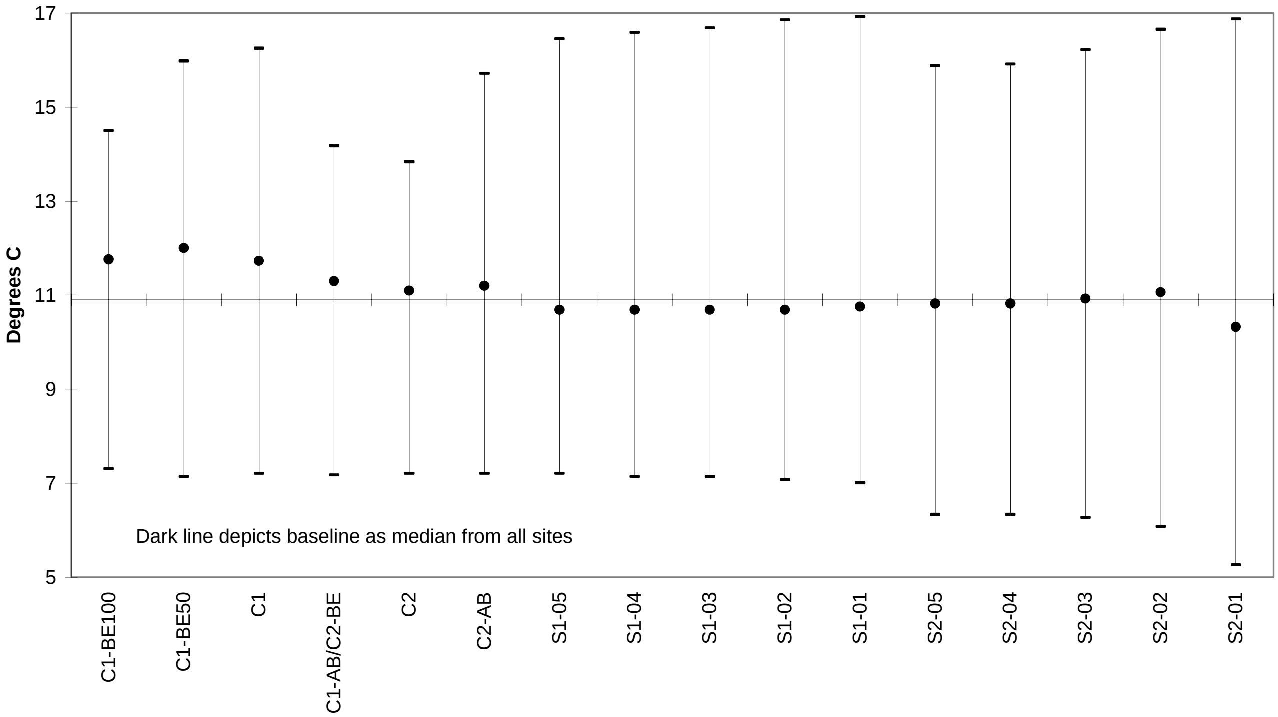

Figure 43. Median water temperature (°C) between 12PM and 6PM estimated during sampling events of Jim Creek, Alaska, August 6 thru October 18, 2008.

5.5 TEMPERATURE, 2009

Average daily air temperature was, as in 2008, directly and positively related ($p < 0.05$, $r^2 = 0.53$) to average daily water temperature (Figure 44). Average daily water temperature between May 29 and June 25 2009 was 15.2°C, while maximum and minimum water temperatures were 19.6°C and 9.7°C, respectively (Figure 45). Water temperature was, as in 2008, often slightly warmer than air temperature.

Maximum water temperature between May 29 and June 25 2009 at HOBO-03 repeatedly exceeded state WQS for fish migration and rearing (15°C) and for spawning and incubation (13°C) (Figure 46). Maximum daily water temperature of Jim Creek exceeded 13°C on 28 of 28 days (100%) and exceeded 15°C on 21 of 28 days (75%). Maximum water temperatures approached 20°C by June 6, 2009.

The Wildlifers will continue continuous temperature monitoring until fall 2009 in collaboration with CIK.

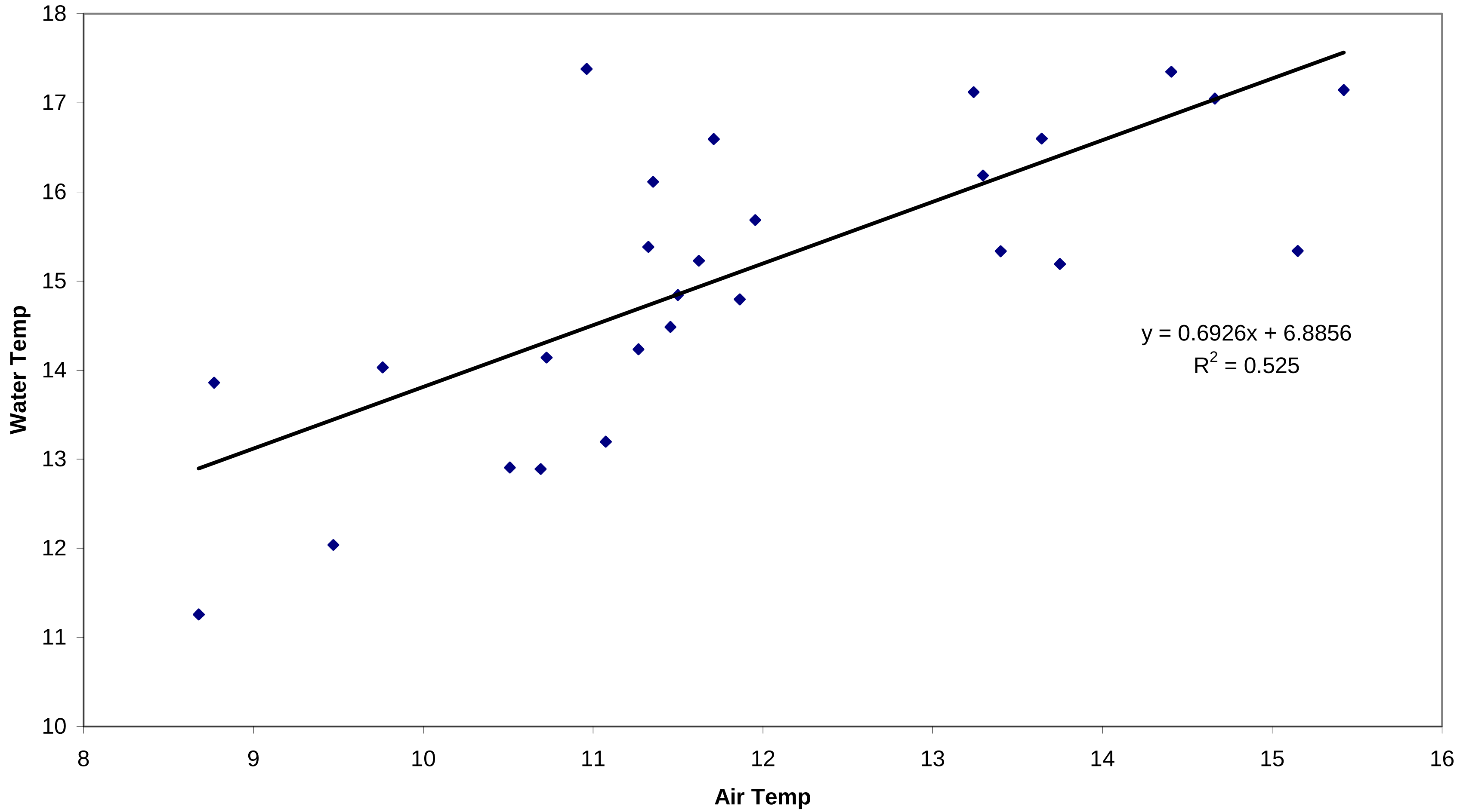

Figure 44. Daily mean, minimum, and maximum air and water (HOBO-03) temperatures along Jim Creek, Alaska, between May 29 and June 25, Alaska 2009.

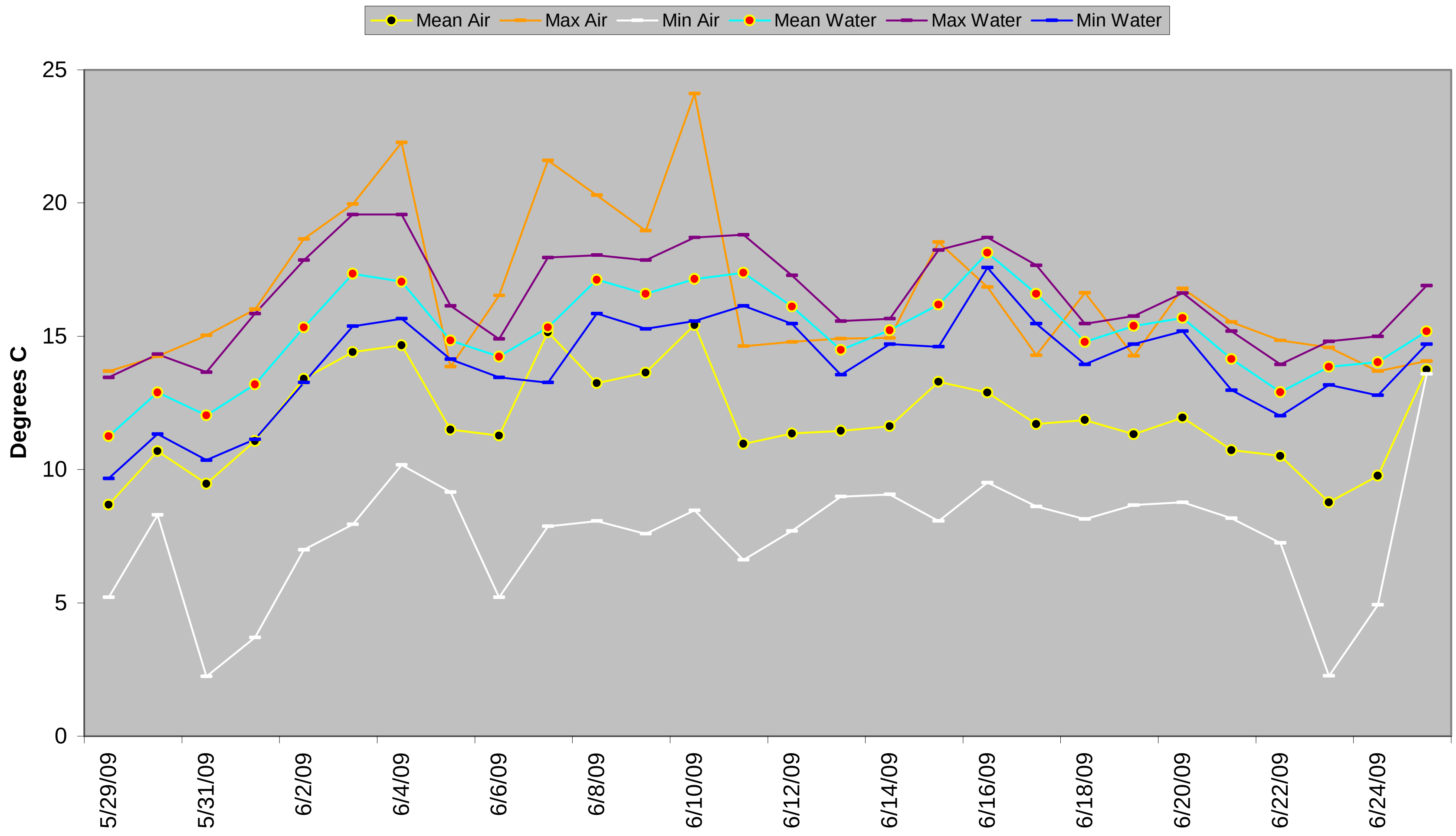

Figure 45. Daily mean, minimum, and maximum air and water (HOBO-03) temperatures along Jim Creek, Alaska, between May 29 and June 25, Alaska 2009.

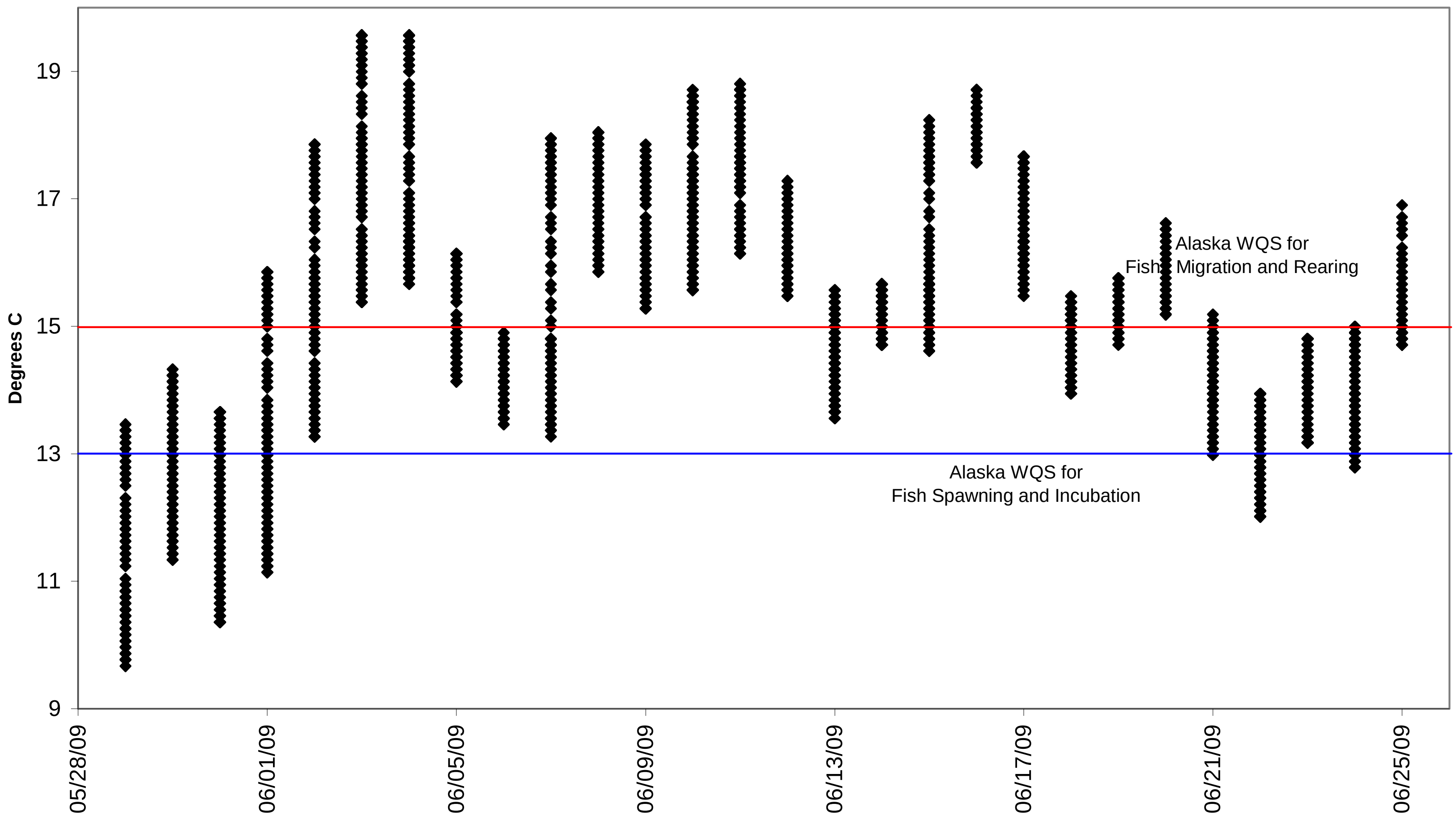

Figure 46. All water temperature (°C) estimates for each sample taken every 15 seconds during 24-hour periods at site HOBO-3 along Jim Creek, Alaska, from May 29 to June 25, 2009.

5.6 PHYSICAL CHARACTERISTICS

Average, maximum, and the range of flow rates, along with average depth are presented in Table 1 for each sample site. Average water depths for sample sites C1-100BE thru C2-AB (~0.51 m) were significantly ($p<0.05$) less than average depths from upstream sites S1-05 thru S2-01 (~1.28 m). Water level at all sites in spring 2009 was, on average, 50cm less than in August-September 2008, while average and maximum flow rates in spring 2009 were, on average, 0.13m/s and 0.34m/s less, respectively, than in August-Sept 2008. In fact, water levels during May sampling in 2009 were so low, and the channel along sample site C1-AB/C2-BE had changed so much, that no water was present at the location sampled in 2008 (Figure 47). Average flow rates for sample sites C1-100BE thru C2-AB did not differ ($p>0.05$) between average flow rates for upstream sites S1-05 thru S2-01. However, average flow rates for sites upstream from the confluence with McRobert's Creek (upstream from S2-05) were significantly ($p<0.05$) lower (0.17 m/s) than flow rates from sites downstream (0.37 m/s), suggesting that nearly half of Jim Creek flow originates from McRobert's Creek.

Water level fluctuations were observed as both seasonal variation within a year and as variation across years within the same season. Water levels in August-September 2008 dropped about 0.2m by October 18 and over 0.5m by May 26, 2009 (Figure 48). Water levels on May 26, 2009 were also considerably lower than that on June 10 2004 (Figure 49). Recent rainfall, changes in upstream hydrology, or other confounding factors obviously influenced water levels.

Table 1. Mean flow, maximum flow, and water depth estimated at each sampling site along Jim Creek, Alaska.

Site	Average Flow[1]	Range (Average) Min	Range (Average) Max	Average Maximum Flow[1]	Range (Maximum) Min	Range (Maximum) Max	Average Depth[2]
C1	0.41	0.34	0.58	0.53	0.40	0.80	0.40
C1-AB/C2-BE	0.39	0.14	0.46	0.46	0.20	0.50	0.39
C1-BE100	0.23	0.00	0.67	0.29	0.00	0.90	0.56
C1-BE50	0.48	0.25	0.68	0.65	0.30	0.90	0.64
C2	0.37	0.27	0.60	0.48	0.30	0.70	0.53
C2-AB	0.29	0.18	0.37	0.36	0.20	0.50	0.55
S1-01	0.35	0.30	0.43	0.42	0.30	0.50	0.97
S1-02	0.46	0.32	0.56	0.58	0.40	0.60	1.51
S1-03	0.44	0.38	0.53	0.55	0.40	0.60	1.62
S1-04	0.31	0.24	0.39	0.43	0.40	0.50	1.05
S1-05	0.30	0.23	0.36	0.41	0.30	0.60	1.25
S2-01	0.04	0.00	0.11	0.04	0.00	0.10	0.98
S2-02	0.15	0.10	0.19	0.22	0.20	0.30	1.35
S2-03	0.20	0.14	0.23	0.30	0.20	0.50	1.02
S2-04	0.21	0.14	0.29	0.30	0.20	0.50	1.80
S2-05	0.23	0.16	0.32	0.29	0.20	0.40	1.26

[1] water flow estimated as average in meters/second from samples taken every second during each sampling event at each sample site

[2] water depth estimated in meters from averages of samples taken during each sampling event at each sample site

Figure 47. Low water levels and major channel rerouting occurred at site C1-AB/C2-BE, June 2009.

NOTE: Field worker is standing at the former sampling site from 2008.

Figure 48. Water levels on May 26, 2009 (left photo) were >0.5m lower than that in August-September, 2008 (right photo).

Figure 49. Water levels on May 26, 2009 (left photo) were significantly lower than that at the exact same location on nearly the same date 5 years before on June 10, 2004 (right photo).

Stream embeddedness of fine sediment averaged 100% across samples sites between C1-100BE and S2-01, with little spatial variance. The stream substrate downstream from Leaf Lake was almost entirely composed of very fine silts, sand, and extremely soft organic detritus. Sample site S2-03 was the least embedded site with 18 (90%) of 20 samples 100% embedded and 2 samples that were 75-100% embedded. Upper Jim Creek was not sampled but appeared to differ considerably from sample sites downstream from Leaf Lake; pebble, cobble and boulder were present in Upper Jim Creek whereas rocks were either absent or completely embedded in fine silt at sample sites between C1-100BE and S2-01. The density of aquatic vegetation upstream from C2-AB was incredible with many plants growing over 1.5m from their roots on the organic substrate.

Human-made debris during the 1 survey in 2008 was concentrated where most recreational activity occurred along Jim Creek Flats, below OHW of Jim Creek and the Knik River sloughs near the mouth (Figure 50). Over 70 debris sites along Jim Creek Flats were identified and mapped in 2008 (table 2), resulting in 1 debris site for every 3 acres of land within a 200-acre survey area below OHW immediately adjacent to the mouth of Jim Creek. However, some debris sites actually encompassed over 100 m^2, so the actual spatial extent of debris was much larger. What appeared to be sheens of oil were commonly observed in the water downstream from site C1. Most of the debris sites were concentrated on the northwest bank of Jim Creek Flats below OHW.

The number of locations and the actual amount of debris items deposited along Jim Creek in 2008 was underrepresented in the 2008 survey. First, the survey was conducted only on 1 day due to other priorities such as water quality sampling. Second, small debris items were difficult to locate and/or covered quickly in glacial silt while light items quickly blew away during wind gusts. Third, community clean-ups of the area occurred every year, and have become more popular. In addition, high water levels likely either covered or carried smaller debris items downstream into the Knik River and Knik Arm. Thus, repeated debris surveys conducted more often would result in substantially more debris.

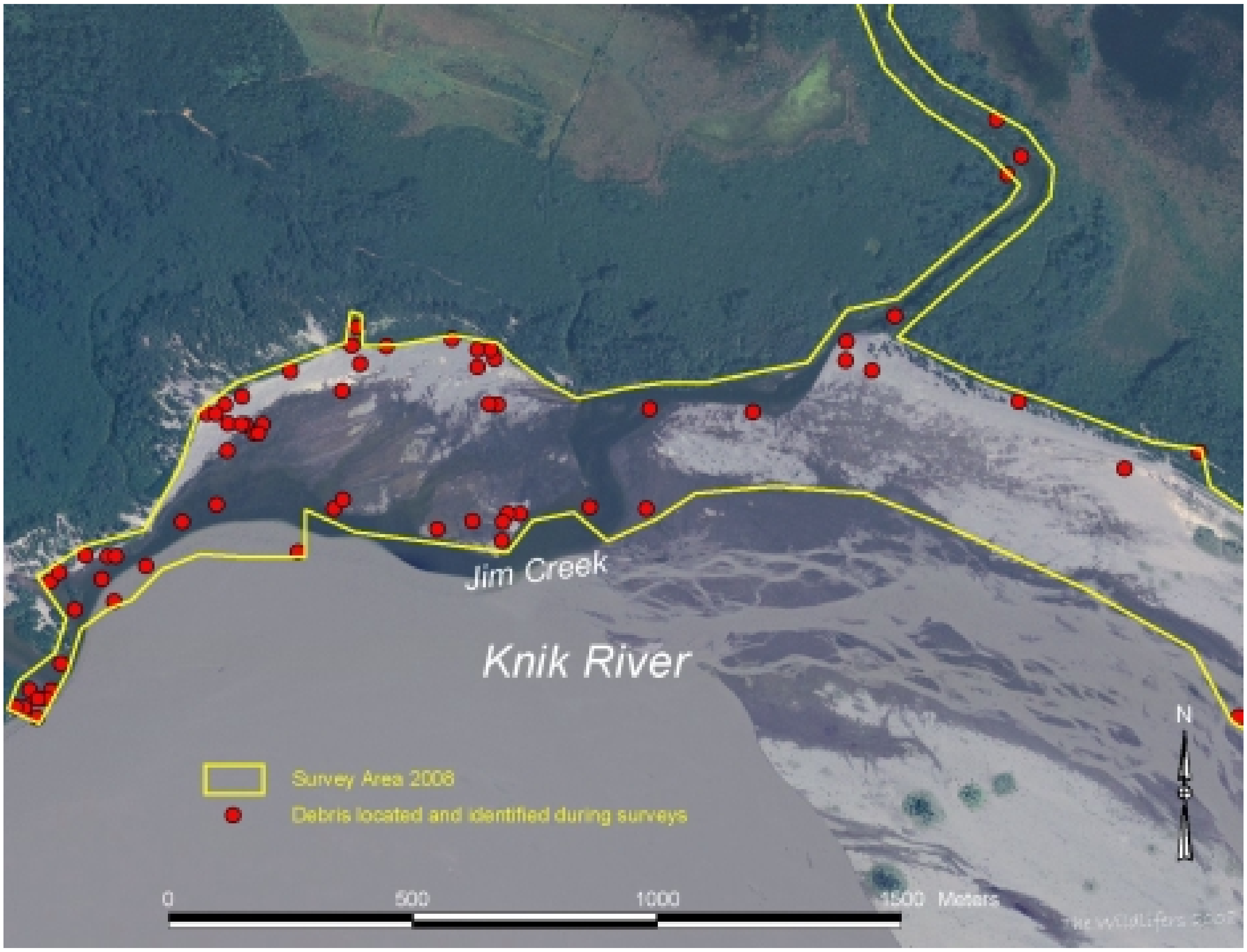

Figure 50. Sites of Debris identified during the debris survey in 2008, Jim Creek, Alaska.

Table 2. Type and amount of debris identified during the 2008 debris survey, Jim Creek, Alaska.

DEBRIS TYPE	Total
2 TVS/GLASS/LUMBER/CAR PARTS	1
BED FRAME	1
BED/MATTRESS	1
BROKEN CHAIR	1
BURNED VEHICLE	2
CAN PILE	1
CAR BUMPER	1
CAR PARTS	2
CAR PARTS/BURN PILE/CEMENT BRICKS/PARTY LITTER	1
CAR PARTS/LUMBER/FURNITURE/MISC LITTER	1
CAR RACK	1
CAR BURNING AREA WITH 1 BURNED CAR	4
CLOTHING/FIRE PIT	1
FIRE PIT	5

DEBRIS TYPE	Total
FIRE PIT/LITTER	13
FIRE PITS/TARGET SHOOTING AREA	1
FIREWORKS	2
FISHING LITTER	1
FOOTBALL/MISC. LITTER	1
GLASS/FIRE/LITTER	2
LITTER PILE	5
LUMBER PILE	1
MILITARY VEHICLE PARTS	1
MISC. DEBRIS FIELD	1
OIL CONTAINER	1
PLASTIC SHEETING	1
PORTA POTTY	1
RAIN GEAR/CLOTHES	1
RUBBER MATTING	1
RUBBER TOTE LID	1
SNOW MACHINE PARTS/BUCKET/FIRE PIT	2
CAR STEREO	1
TARGET SHOOTING AREA (Heavily Used)	6
TARP/RUBBER/CLOTHING	1
TREE STUMP – the location was ~60m from current vegetation border along creek	1
VEHICLE PARTS	3
WOOD PILE	1

Historical observations of "incidents", 1988-2005, included hundreds of observations of man-made debris (e.g.; fuel barrels, burned vehicles, trash dumps, etc.) along Jim Creek (Figure 51). Because of the long history of cleanups in the area, low reporting rate of incidents, and high wind and sedimentation rates, most historical human-caused debris was underreported and, hence, underrepresented in the historical data. Nevertheless, these historical data depicted a long history of human activities that could directly affect water quality. Burned and abandoned vehicles represented over 43% of the >200 reported incidents and were widespread along Jim Creek Flats, often below OHW (Figure 52). Reported incidents included ongoing documentation of abandoned and burned vehicles, abandoned bear baiting stations and camps, unauthorized construction of boat docks and structures, extensive trash dumping, firework usage, fuel barrel disposal, poaching, ORV trail construction, repeated ORV traffic in anadromous streams and wetlands, extensive shooting and abandonment of cartridges and targets, use of trees and vehicles as targets, unattended fires, vegetation destruction, and repeated harassment of fish and wildlife.

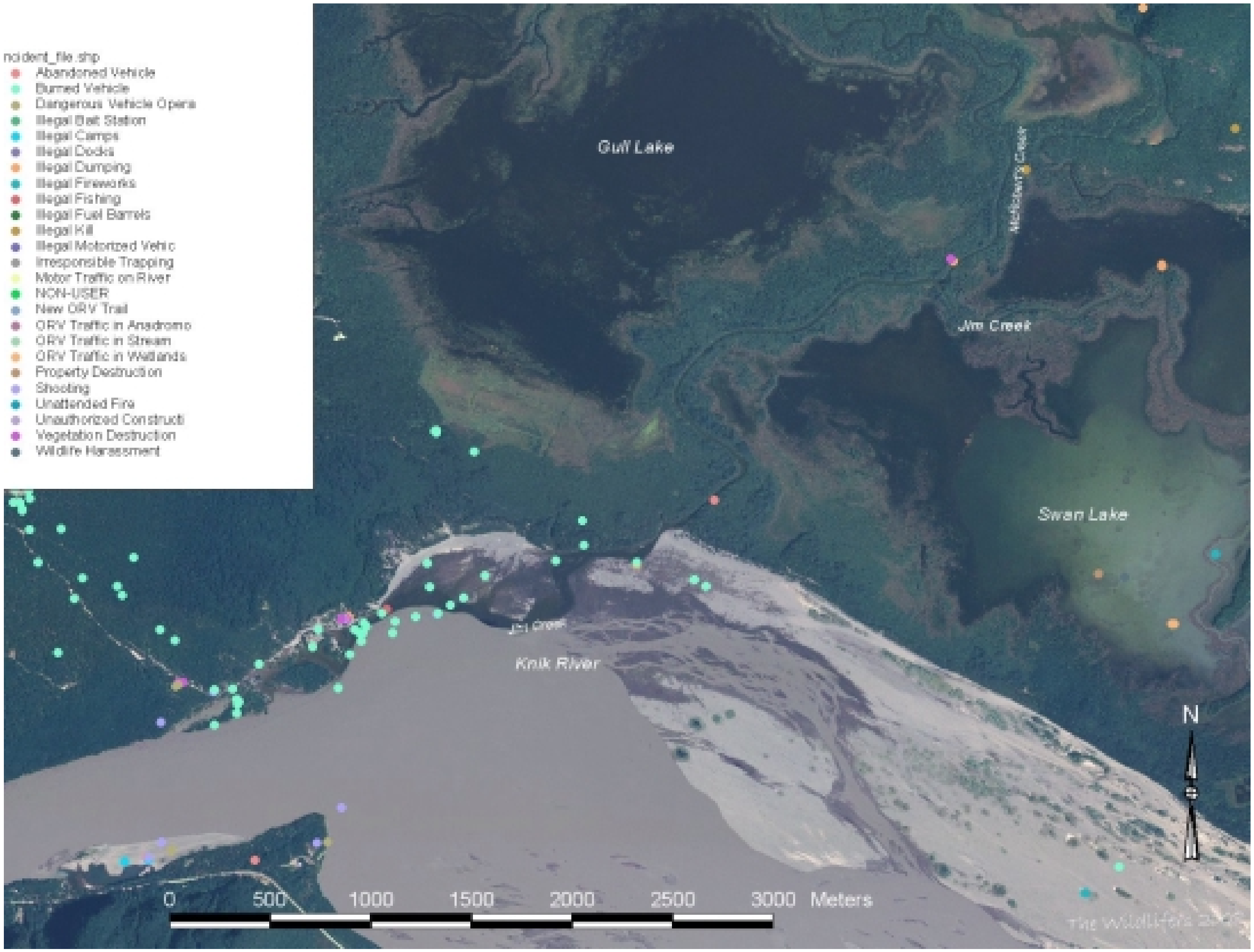

Figure 51. Reported and identified "human-incidents" near Jim Creek, Alaska, 1988-2005. Most data were from Army National Guard cleanups and contributed by Butte Area Residents Civic Organization.

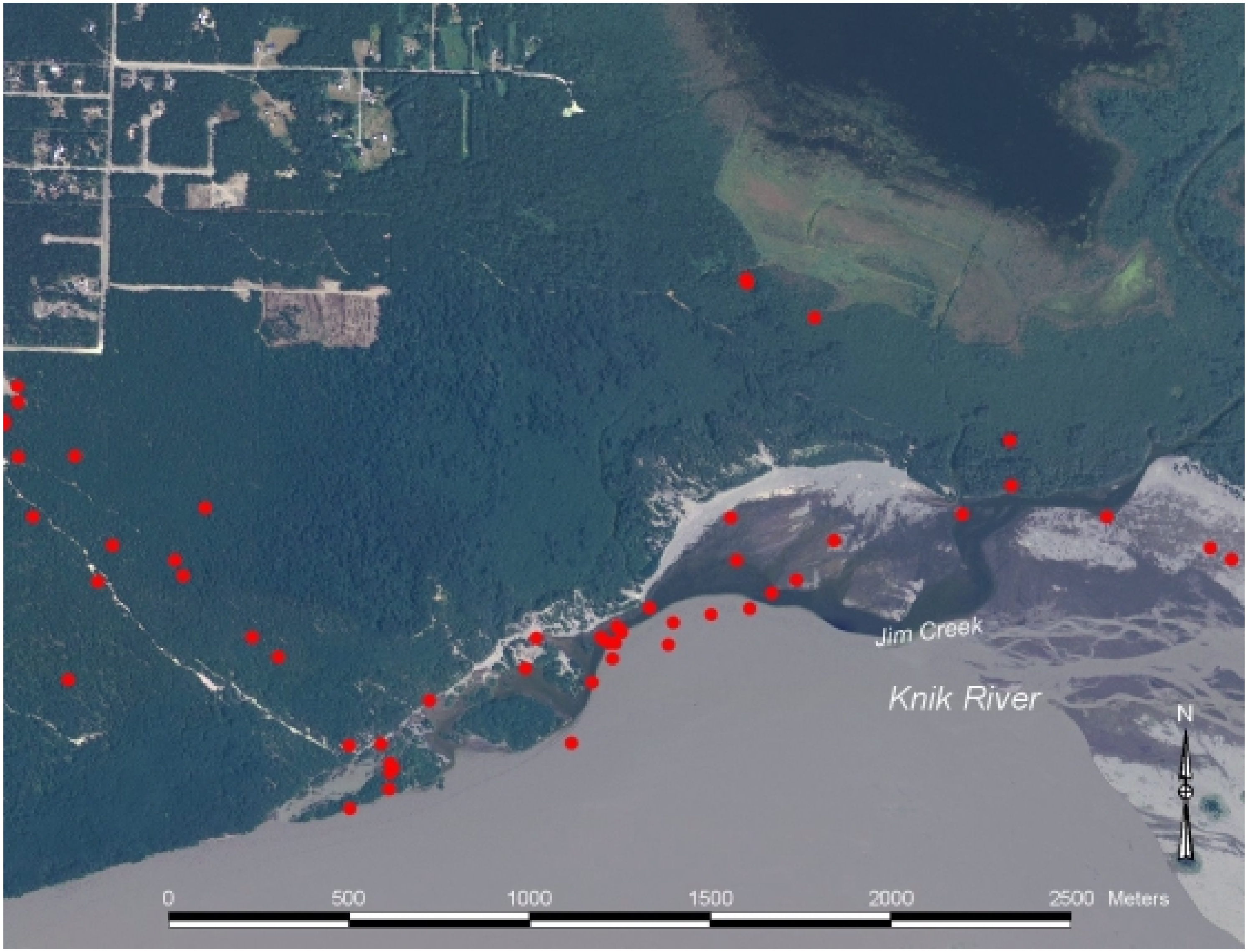

Figure 52. Abandoned and burned vehicles cleaned up by the Army National Guard near Jim Creek, Alaska.

Based on data from 2006 (Moore et al. 2006) and that collected in 2008 during this project, ORV trails were inventoried in six areas including the Jim Creek mouth, Northern Trail, Rippy Trail, Southern Trail, Swan Lake, and Upper Jim/Swan/Friday. Of the trail segments assessed, 30% were ranked as fair, 42% as degraded, 22% as very degraded, and 6% as extremely degraded (Table 3). Crossings of Jim Creek by ORVs in 2008 between sites C1-100BE and C2 ranked as extremely degraded, mostly due to trail width, multi-braided tracks, stripped vegetation, and exposed roots.

Table 3. Rank of trail condition by survey areas in the Jim/Swan wetland complex.

	Trail Condition Index				
Survey Areas	Fair	Degraded	Very Degraded	Extremely Degraded	Total
Jim Creek Mouth	0	2	5	2	9
Northern Trail	6	6	0	0	12
Rippy Trail	16	10	5	2	33
Southern Trail	2	5	1	0	8
Swan Lake	5	11	7	0	23
Upper Jim/Swan/Friday	5	13	9	3	30
Total	34	47	25	7	115

Stream channel characteristics were different among sites with the largest differences between sites near the mouth and sites upstream from C2-AB. Channel depths and widths were similar among sites from C1-100BE upstream to C2-50AB and similar among sites from S1-05 upstream to S2-01. Sites downstream from and including C2-AB were significantly ($p<0.05$) shallower (0.51m vs. 1.28m) and wider (average 60m vs. 22m) than sites upstream. Moreover, the width to depth ratio (width divided by depth) was substantially larger at sites downstream from and including C2-AB (mean = 122) than at sites between S1-05 and S2-01 (mean = 19). Undercut banks were observed at all stream reaches but were less apparent in the lower section because of more unstable banks. The stream banks and substrate were composed mostly of silty peat, glacial silt and sand, and organic detritus.

Visual evidence of bank erosion and vegetation loss (Figure 53) was apparent along Jim Creek Flats from the western edge to the eastern edge of the mouth of Jim Creek up to the top of the “dune”, then continued eastward toward Friday Creek. Bank

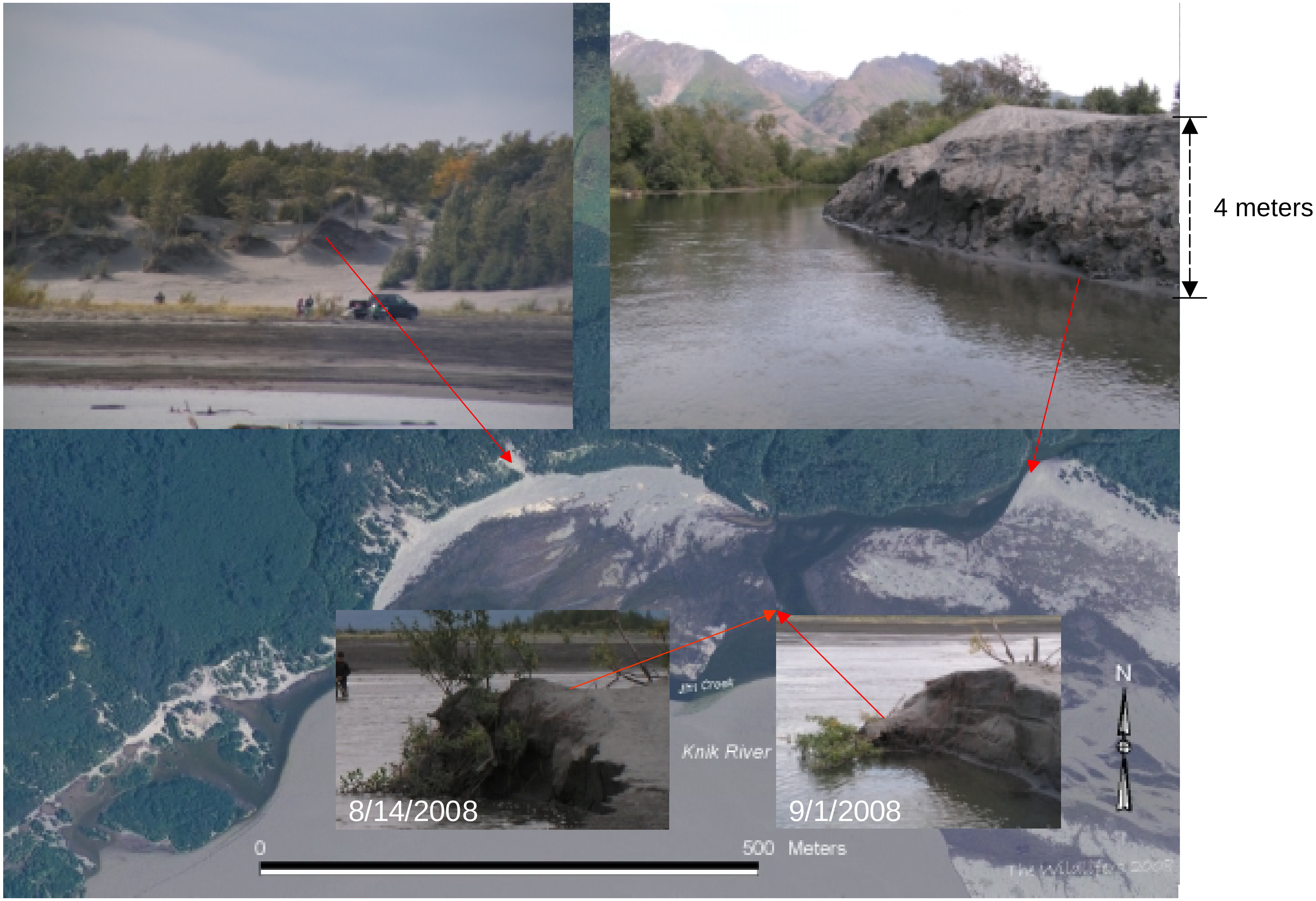

Figure 53. Example 2008 photos and locations of severe bank erosion and vegetation loss along Jim Creek Flats, Alaska.

erosion and vegetation loss upstream to Leaf Lake was less evident and appeared mostly limited to areas immediately adjacent (<2 m) to the creek, likely due to fluctuations in water levels of ~0.5m from high to low flow periods and wave-induced erosion from boat wakes. Vegetation trampling along stream banks was apparent from foot and watercraft access (Figure 54). Vegetation loss and channel modification by watercraft (primarily air- and jet- boats) was also observed (Figure 55). Because of the rugged mountains and cliffs above Rippy Trail, access was restricted and, hence, less human activity occurred above Rippy Trail. However, recreational activities were not restricted to the area sampled during surveys or during survey periods.

A substantial amount of nearshore riparian vegetation within 2m of stream banks was either dead and/or leaning over the stream channel (Figure 56). Certainly, observed fluctuations in water levels, potential disease, climatic conditions, and other natural processes influenced the survival of nearshore vegetation, but wave-induced impacts from fast-moving watercraft were also possible along all navigable sections. Most watercraft was traveling fast and on-step, creating relatively large wakes. Aquatic vegetation was measured hanging from leaning branches >40cm above the water surface immediately after watercraft passed, demonstrating that waves from passing watercraft were at least 40cm high (Figure 57). In addition, dead aquatic vegetation was commonly observed "washed up" onto banks over 40cm above the OHW mark. Based on anecdotal observations, the outside banks around stream bends appeared to have larger areas of standing and leaning dead trees and shrubs, perhaps another indication wave-induced erosion. Further evidence of channel modification was observed; standing stumps in the creek were observed ~2m or more from the bank edge, and sections of entire banks had eroded away and now appear at a flatter angle than intact banks. Although dead vegetation and stumps along streambanks are not uncommon, riparian vegetation that is no longer in the root zone increases the susceptibility of erosion along streambanks. However, more investigation and quantification is necessary to differentiate the potential impacts from watercraft from natural influences.

Figure 54. Example photo of vegetation trampling at a campsite accessed by watercraft, Jim Creek, Alaska, May 2009.

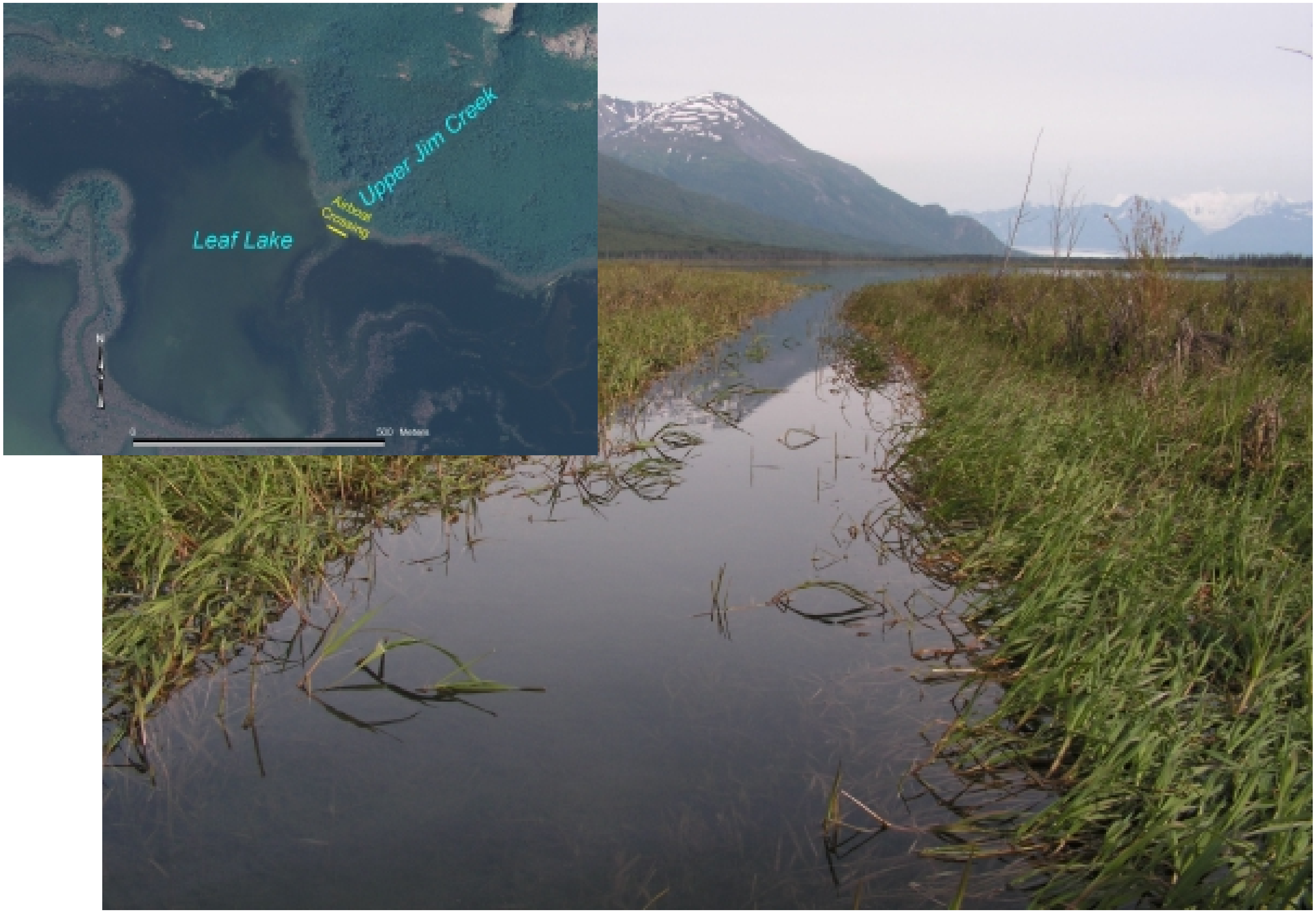

Figure 55. Example photo and location (map in upper left) of vegetation loss and channel creation/modification by watercraft access across the outlet of Upper Jim Creek into Leaf Lake, Alaska, August 2008.

Figure 56. Many trees and shrubs, especially alder, along banks were dead and leaning over Jim Creek, Alaska, 2008.

Figure 57. Aquatic vegetation suspended from branches after watercraft passed along Jim Creek, Alaska, demonstrating that boat wakes exceeded 40cm, 2009.

6.0 DISCUSSION

Sample sites from C2-AB downstream thru C1-100BE differed in vegetation composition and bank condition than all sites upstream. Nearshore riparian vegetation, where present, consisted mostly of dense alder, willow, and cottonwood. All sites upstream from C2-AB were densely vegetated along both banks; whereas, reaches downstream from C2-AB lacked riparian vegetation on the entire southeast bank and for over 1.5 km downstream from C1 along the northwest bank to the western edge of Jim Creek Flats. In contrast, the northwest bank between sites C1 upstream to C2-AB was densely vegetated with cottonwood, willow, and alder thickets, more similar to both banks at sample sites upstream from C2-AB; this western bank between sites C1 upstream to C2-AB corresponded with less flooding from the Knik River during high water and with substantially less ORV traffic. Undercut banks were present along banks upstream from C2-AB but absent downstream from C2-AB, the area with the highest observed bank erosion, channel modification, loss of vegetation, wind exposure, temperatures, turbidity, and ORV traffic.

Vegetation along the entire southeast bank of Jim Creek downstream from C2-AB was either absent or had exposed roots from active erosion, which was observed for over 800 m downstream to the confluence with the Knik River. After crossing near sites C1 thru C1-100BE, ORV traffic between C1 and C2-AB was braided but typically paralleled the southeast bank of the creek up to the top of the “dune”, a deposit of glacial silt from the natural geography associated with the direction of high winds and historical flooding of the Knik River. This east bank and the “dune” were, obviously, more densely vegetated in the recent past based on the photographic evidence showing the rutting and parallel trails thru the vegetation and the recently exposed roots from vegetation trampled by ORV traffic.

Historical flooding of the Knik River and Jim Creek, prevailing winds during high-wind periods, and recreational activities all likely contributed to the seemingly accelerated processes of erosion and vegetation modification at the mouth of Jim Creek and along Jim Creek Flats. Seasonal fluctuations in water level of the Knik River and Jim Creek, historical flooding from annual jökulhlaups of Lake George (ice-dam breakouts from glacial lakes and rivers), potential tidal influences from Knik Arm, and active erosion especially during high-wind events were all likely natural influences upon the characteristics of the banks thru time. However, photographic evidence, along with data on water quality and riparian habitat, in 2008-09 suggested that recent levels of recreational use along the banks and riparian habitats at sites downstream from C2-AB likely contributed to the cumulative amount of erosion, vegetation loss, soil compaction, and turbidity. Neither the rising of the Knik River nor the tidal influence of Knik Arm ever flooded any of our sample sites in 2008-09 as those waters remained well below site C1-100BE from May 2008 thru June 2009. Historical flooding of Lake George had large annual flooding events from ice-outbreaks between 1918 and 1966, but Knik Glacier has since retreated creating no floods from those annual jökulhlaups ever since. Evidence of historical flooding was observed; however, large roots from recently cut trees were also observed over 100m from the current vegetation mark, suggesting that the vegetation boundary along Jim Creek Flats has subsided higher than that from the recent (~10-15 years) past.

Sites between C-100BE and C2-50AB were considerably wider and about half as deep as sites upstream from C2-AB. The average width:depth ratio for sites C-100BE thru C2-50AB (122) was nearly 7 times that for upstream sites S1-05 thru S2-01 (19), clearly indicative of the shallower, wider section of the creek downstream from C2-AB. It is typical for downstream alluvial reaches of streams to become wider and shallower at the mouth. It is also typical for reaches downstream from ORV crossings to become wider and shallower (Meyer 2002).

The relatively large number of replicate samples and experimental design from this project clearly demonstrated complex spatial and temporal patterns for the chemical properties of water in Jim Creek. Water pH was somewhat variable spatially but remained above neutral, generally decreasing as flow decreased, similar to other regional streams (Davis et al. 2006, Boyer et al. 1997). Conductivity upstream from McRobert’s creek was much higher than at sites downstream, and was even higher than that for Ship Creek in 2005 (Alaska Hydrologic Survey, ADNR 2005). The source of the highest conductivity in 2008 appeared to be mostly from the outflow of Swan

Lake. Site S2-01 had the lowest overall conductivity in 2008 but had high overall variance and the highest median conductivity of any site in May 2009.

From August 6 thru October 18 2008, a significant decline in dissolved oxygen occurred, especially in late-October. During late-October 2008, sites upstream from McRobert's Creek had the lowest dissolved oxygen. In contrast, those upstream sites had the highest overall dissolved oxygen and were supersaturated with dissolved oxygen in August 2008 and in May 2009. Dissolved oxygen dynamics in the interconnected lakes and wetlands of the entire watershed likely contributed substantially to the seasonal fluctuations in dissolved oxygen.

Turbidity between August 6 and early October 2008 was near 0 then increased exponentially by mid- to late- October and remained variable and higher in May 2009 than summer 2008 turbidity. The highest median turbidity, variance, and proportion of estimates above selected values (5, 10, 15, and 20 NTU) were detected between sites C1-100BE and C2-AB, where most recreational activities occurred. Sediment plumes were easily visible upon ORV passage at crossing sites, which contributed to the frequency of turbidity measurements above median values thereby influencing the distribution and, hence, variance in the turbidity data at these sites. The exponential increase of turbidity in October was likely due to cumulative factors such as increased nutrients and aerobic decomposition from dying salmon and aquatic and terrestrial vegetation, changes in current upwelling and turnover of interconnected lakes and wetlands in the region, and other sources of turbidity in and above Swan Lake. Clearly, further investigation is necessary to determine the primary source of turbidity in fall because it appeared to come mostly from the outflow of Swan Lake, an area not sampled during 2008-09.

The study design and WQMS used for this study proved to be reliable, useful methods for assessing water quality parameters. Spatial and temporal patterns were detected that could not have been detected using small sample sizes and infrequent estimates at a few sites. The time-integrated series of data for each sampling event provided a means for not just calculating values for each parameter at each sample site but also for examining data distributions, variance, and statistical significance in both time and space. Moreover, the data logger prevented the possibility of errors related to data recording, transcribing, and entry. The negligibly negative turbidity values detected in this study by the WQMS during August 6 thru September 30 reflect several potential, yet somewhat trivial, variables. Calibration was performed in laboratory conditions with distilled water (to represent 0 NTU) and samples of known concentration (40 and 1000 NTU) in a beaker and artificial light; whereas, field sampling was conducted in flowing waters with influences from both the natural color of the water and outdoor lighting conditions. Thus, during several sampling events, a Lamotte Precision Monitoring 5854-01 kit was used for comparative purposes to ensure the field accuracy of the WQMS in extremely clear water, and negative samples were as clear (or clearer) as distilled water. Calibrations were extremely accurate and precise using solutions of known concentrations of 40 and 1000 NTU. And, the overall variance for turbidity estimates in the field was extremely small; 89% of all >10,000 samples were less than 5 NTU, below the minimum detection limit for many sampling devices. We were willing to accept the possibility of a negligible negative bias in field estimates because it only resulted in conservative estimates for turbidity when NTU was 0.

Elevated turbidity and very high embeddedness were likely surrogate measures for high sedimentation, although sedimentation and total suspended solids should also be estimated in future studies. Certainly, the bank erosion and channel modification downstream from C2-AB contributed to sedimentation, as did the extremely soft substrate of mostly silt, sand, and organic matter along reaches downstream from Leaf Lake. Increased levels of suspended sediments may result in decreases in survival of salmon eggs (Lloyd, 1987; Redding et al., 1987; Newcombe & MacDonald, 1991; Servizi & Martens, 1992; Pentz and Kostaschuk, 1999; Rinella & Bogan, 2003; Shrimpton et al., 2007) and fertilization success of sockeye and coho salmon (Galbraith et al., 2006). Fine sediments, such as glacial silt, can cover eggs thereby reducing the oxygen supply and, hence, survival (Reiser & White, 1988). High embeddedness results in less space between substrate particles and effectively constrains the amount of area and cover available for small fish, fish eggs, alevin, macroinvertebrates, and periphyton (Kondolf and Wilcock 1996, Osmundson and Scheer 1998). Fine sediment accumulations typically reduce dissolved oxygen levels in water and spawning beds (Moring 1982, Chapman 1988, Platts et al. 1989, Rinne 1990), thereby reducing rates of fry survival and emergence, and fry size (Tappel and Bjornn 1983). However, no such data were available to test for potential effects of elevated turbidity levels on salmon.

Water temperatures generally increased further downstream with the highest temperatures recorded between sites C2-AB and C1-100BE. Higher temperatures near the mouth were probably influenced by the lack of riparian vegetation along the banks. Another potential influence included channel widening associated with the observed bank erosion, which increases the surface area of water (Poole and Berman 2001). Width:depth ratios at each site strongly supported this hypothesis.

Water temperature readings above state WQS were detected frequently during August-September 2008 and in May-June 2009, and average water temperature was often slightly (1-2°C) warmer than average air temperature. Multiple potentially confounding factors, such as runoff from warmer water of the multiple lakes and wetland complexes, upwelling currents, warm springs, and dead, decadent, or lack of streamside vegetation likely contributed to warm water temperatures. The daily increase (daily maximum minus minimum) in temperature between June 6 and October 18 2008 averaged 1.6°C with a maximum of 4.5°C on June 13. The maximum daily change of 4.5°C is lower than that for Montana Creek (>6°C), and nearly equal to that for Cottonwood Creek (4.6°C) (Davis et al. 2006); hence, buffering capacities of Jim Creek may be similar to Cottonwood Creek.

Temperatures above state WQS could potentially have long-term consequences to coho and sockeye salmon in Jim Creek but the extent of the effects are unknown. Salmon fry were commonly observed dying of unknown causes. Warm stream temperatures could result in reduced survivorship of salmon eggs and fry, reduced growth rates, increased respiration and metabolic rates, increased likelihood of premature smolting, potential shifts in the timing of immigration and emigration, higher susceptibility to pollution due to increased toxicity of several toxins, and greater risk of predation and disease (Richter and Kolmes 2005). Coho salmon were observed spawning at high densities in Upper Jim Creek, where temperatures were substantially cooler than reaches downstream. However, spawning and rearing was observed downstream from Upper Jim Creek in the warmer water as well. Spawning and rearing by sockeye salmon was observed mostly downstream from Upper Jim Creek, as sockeye salmon spawn at relatively high frequencies in main-river channels, side channels, tributary streams, and upland sloughs (Eiler et al. 1992). Concentrations of sockeye salmon were observed near upwellings and near entrances of small tributaries along the edges of many lakes, wetlands, and sloughs throughout the wetland complex. Perhaps, upwellings and small tributaries supplying the lakes, sloughs, and wetlands helped maintain enough oxygen flow and cooler temperatures for eggs to survive when buried in the fine sediment substrate at these warmer sites. However, more detailed research on fish distribution and ecology is needed in Jim Creek to assess the potential effects from warm temperatures.

Data presented in this report likely underestimate potential immediate influences to water quality from ORV and watercraft activities because direct measurements of water quality were not performed under experimental, controlled conditions or collected at the exact time of ORV crossings or watercraft passing. In addition, the inconsistent and braided locations of ORV crossings near the mouth of Jim Creek precluded attempts to consistently sample at exact and consistent distances above and below creek crossings (Rinella and Bogan 2003) for assessing reference and treatment conditions within short, stratified distances from crossings. ORV use of the entire eastern bank of Jim Creek from site C-1 upstream to C2-50AB prevented any definition of these sites as reference sites upstream from potential pollutant sources. Further, human behavior likely biased the actual location of active crossings that occurred during sampling: while sampling at site C1, upstream crossings by ORVs occurred only once because ORVs would inevitably cross downstream from the sampler; whereas, while sampling at site C1-100BE, upstream crossings occurred more regularly.

MANAGEMENT RECOMMENDATIONS

The results of this baseline study demonstrated a need for an active, continued monitoring program for water quality and riparian habitat and for development of conservation practices to mitigate for potential increases in erosion, loss of riparian vegetation, soil compaction and damage, pollutants (e.g.; hydrocarbons, e. coli, etc.), and sedimentation rates from recreational activities in riparian habitats of Jim Creek and along Jim Creek Flats. The following studies would be useful:

- Continue water quality and riparian assessments to build upon this project
- Place bank pins for monitoring erosion

  Place multiple bank pins at each site, along straight reaches, along bends of meandering sections, and along outside edges of bends.
- Expand study area to include sampling of water quality and riparian habitat near the outlet of and at locations upstream from Swan Lake, and along Upper Jim Creek
- Conduct further field sampling of stream cross-sectional and flow data to monitor for potential changes in stream channel characteristics
- Estimate bank to stream sediment transfer rates, uptake rates of nutrients, and the relative amount of organic matter input
- Monitor water and flow levels using permanent staff gauges and meters
- Estimate watercraft numbers, types, size, speeds, activities (reasons for boating), height of wave incurred, bank sloughing
- Estimate off-road vehicle numbers, types, size, speeds, activities, number of crossings, parallel travel, depth of rutting, bank sloughing
- Sample the invertebrate community such as biomass and species richness
- Conduct research on fish distribution, habitat selection, and survival

Because of the observed bank sloughing, lack of bank vegetation, high ratio of stream width to depth, and lack of undercut banks at all sites from C2-AB and downstream, stream restoration is highly recommended for stream banks from C2-AB downstream to the C1-100BE. Conservation practices are recommended immediately to mitigate for the observed acceleration in erosion, loss of vegetation, compaction to soils, and potential damage to fish habitat. Because persistent erosion and high-density ORV traffic for several km was also observed on the “dune” to the east of site C1-AB along the Knik River and to the west of site C1 along Jim Creek Flats, restoration of native vegetation and prevention of further vegetation destruction is highly encouraged along all of these riparian habitats. Setbacks and fences may be necessary for the vegetation to recover especially because wind erosion and some flooding are evident. Practices to reduce stream width and create undercut banks are recommended. In the meantime, placement of fish cover such as logs is recommended along the southeast bank from site C-1 upstream to C2-AB to provide riparian structure for fish habitat. Restoration projects should follow carefully designed plans to address and measure the success of specific objectives (e.g.; re-vegetation of riparian areas, reducing soil loss to wind erosion along the dunes, reestablishment of undercut banks or other cover, etc.).

Water level fluctuations resulted in exposure of undercut banks and tree roots, leaving riparian vegetation and soils vulnerable to wave-induced erosion, and stressed by drying and saturation. Nearshore vegetation and stream banks of Jim Creek were also susceptible to erosion because banks were mostly composed of silty peat, water depth was relatively shallow, and stream width was narrow. All of these characteristics affect the susceptibility of banks to erosion and suggest high vulnerability for Jim Creek.

The potential impacts from watercraft (Liddle and Scorgie 1980, Wagner 1991, and WHOI 1998), such as fuel and exhaust emissions, direct contact with flora and fauna, and wake-induced erosion of shorelines, warrant further investigation. Fast-moving watercraft was observed on a daily basis in the shallow, narrow channels of Jim Creek, McRobert's Creek, and the associated wetlands and lakes (Jim, Mud, Swan, Leaf, Chain, etc.). In addition, aerial photography depicted many more watercraft trails (mostly air boats) along Mud Lake, Swan Lake, Leaf Lake, Jim Lake, and other wetlands in the Jim/Swan Wetland Complex (Moore et al. 2006) than that documented in this report. Sediment plumes were observed after passage of fast-moving boats but instantaneous relationships with turbidity or other factors were not examined due to boating safety and our stringent protocol to sample the same way at each site during this pilot year study. We recommend designing and deploying a sampling strategy to examine potential relationships between the timing and speed of boat passage and potential increases in turbidity, total suspended sediment, total dissolved solids, nutrient levels, and other sedimentation and erosion (e.g.; erosion pins) indices for future projects if proper safety precautions can be met during boat passage (Yousef et al. 1980, Beachler and Hill 2002). Research projects to calculate the total energy dissipated (and sheer bank stress) annually against the banks of Jim Creek, along with that proportion from stream flow and that proportion from boat wakes, are recommended to differentiate between natural and boat-wake influences on energy dissipation. In addition, examination of potential impacts from prop wash on salmon egg survival and sediment redistribution are recommended due to observed boating patterns in relation to salmon spawning; wakes and prop wash from fast-moving boat traffic could increase shoreline erosion and sedimentation rates, stir and redistribute sediments, and decrease egg survival (Sutherland and Ogle 1975).

We recommend examining the stream macroinvertebrate populations of Jim Creek to further understand spatial and temporal characteristics of this complex wetland ecosystem. Such investigations should assess not only the presence or absence of an effect but attempt to quantify ecosystem level effects that could affect fish species, such as salmonids (Major & Barbour 2001, Rinella and Bogan 2003, Black et al. 2004). We also suggest quantification of macroninvertebrate taxa richness and biomass in relation to ORV fords, boating traffic, and natural influences.

Although an ORV bridge across Jim Creek could be built to potentially decrease turbidity, sedimentation, erosion, pollution, etc., more data from longer-term, well-designed research are necessary prior to constructing a crossing bridge as a management strategy. A bridge would certainly increase the amount of ORV traffic east of Jim Creek because many ORV riders turn around before crossing Jim Creek. More research is recommended before permitting increased access because the documented data suggest some level of potential effect already. Thus, it would be premature to increase access before understanding the consequences.

Estimation of the net effect of recreational activities on water quality and riparian habitats will require long-term research and quantitative assessment of the cumulative effects from natural and human-caused effects. Further advances in understanding the implications of recreational activities will require cumulative effects assessment at annual and regional scales. Based on an extensive literature review, some level of cumulative effect is likely. But, clear separation of cumulative effects of recreational activities from natural variation in water quality and riparian habitat could be difficult to detect in field studies; confounding factors may limit our ability to detect change. Even though cumulative effects could remain unknown, the prudent course of management action will be to minimize potential effects from recreational activities that could alter water quality and riparian habitat, and to mitigate for known or observed effects.

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