

Long Term Ecological Research in the Toolik Lake Research Natural Area: Request for Continued Access, Sampling, Monitoring, and Maintenance.

Introduction: WHY this request?

Granting of this request would establish long-term access to ecological research sites on BLM land in northern Alaska and would allow continued monitoring, sampling, and experimentation on these sites. All sites are located in or near the Toolik Lake Research Natural Area, on BLM land in northern Alaska. All sites have been established and used in research for varying lengths of time over the past 35 years as part of the Arctic Long Term Ecological Research (LTER) Project and its predecessors, through a series of grants from the US National Science Foundation. Research on these sites is carried out by a large group of collaborating scientists and students from research and education institutions throughout the US and several foreign countries. The lead institution, and holder of the current Arctic LTER research grant (NSF#DEB-1026843) is the Marine Biological Laboratory, Woods Hole, MA.

Since 2003, the research covered in this request has been permitted under BLM Land Use Permit #F-85682, also to the Marine Biological Laboratory. After discussions with BLM personnel in June, 2014, however, it was agreed that establishment of a BLM Right-of-Way (ROW) agreement was more appropriate to the present situation. Research on these sites, including sampling, monitoring and maintenance of long-term experiments and observation points, is expected to continue indefinitely with funding from the National Science Foundation and other Federal agencies. To complete the goals of these Federal research grants, continued access to established, long-term research sites is essential. Scientists and students from diverse research and educational institutions must be able to return to these sites repeatedly in the future to continue monitoring of long-term changes in tundra, lake, and stream ecosystems in response to climate change and long term experimental treatments.

WHO is making this request?

The current leader of the Arctic LTER project, and the person who is overall responsible for this request, is Gaius R Shaver (Marine Biological Laboratory, Woods Hole, MA). Including Shaver there are six total members of the current ARC LTER Executive Committee including W. Breck Bowden (University of Vermont), Phaedra Budy (Utah State University), Anne Giblin (Marine Biological Laboratory), Laura Gough (University of Texas, Arlington), and George Kling (University of Michigan). The Executive Committee, in consultation with collaborating investigators (Table 1), meets whenever necessary by conference call throughout the year, as well as in person at an annual winter meeting in Woods Hole, MA and during the summer field season at Toolik Field Station, to decide issues of project management including use of BLM-permitted LTER research sites near Toolik Lake. All members of the Executive Committee have carried out research on the sites included in this permit request for at least 10 years; most have worked there for more than 25 years.

In addition to research by the Arctic LTER Executive Committee and their students, postdoctoral fellows, and technicians, research on sites permitted to the Arctic LTER is carried

out by collaborating scientists and students from research and education institutions through the U.S. and several foreign countries. In 2014 there are about 33 institutions represented among LTER collaborators (see list below; *note this is not a complete list of all scientists working at Toolik Lake RNA, but only includes scientists currently collaborating with the Arctic LTER project and using sites covered in this BLM ROW request*). Many of these collaborators have also worked at the Toolik RNA for decades and have a strong interest in maintaining long term observations at LTER research sites included in this request. Most of these collaborators also have separately-funded research that is carried out at other locations within the Toolik Lake RNA, with separate permits from BLM or other agencies.

Each summer a total of 50-100 people visit ARC LTER research sites and collect data. Most of these are undergraduate and graduate students, postdoctoral fellows, and summer technicians who are not hired until a few weeks or months before each season starts. The exact array of collaborating projects and institutions also changes each summer depending on funding of federal research grants to collaborating investigators. Thus it is not possible to provide the names of all individuals expected to be carrying out research at Arctic LTER sites until a few weeks before each summer starts.

Table 1. Current Arctic LTER Collaborators (Principal Investigators) and Collaborating Institutions, 2014

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|--|---|
| 1. Boelman, Natalie, Columbia University | 24. Mack, Michelle, Northern Arizona University |
| 2. Bowden, Breck, University of Vermont | 25. McGraw, James, West Virginia University |
| 3. Bret-Harte, Marion Sydonia, University of Alaska Fairbanks | 26. Moore, John, Colorado State University |
| 4. Cory, Rose, University of Michigan | 27. Neilson, Bethany, Utah State University |
| 5. Crump, Byron, Oregon State University | 28. Peterson, Bruce, Marine Bio Lab, Woods Hole |
| 6. Deegan, Linda, Marine Bio Lab, Woods Hole | 29. Potosnak, Mark, DePaul University, Illinois |
| 7. Eugster, Werner, ETH Zurich, Switzerland | 30. Rastetter, Edward, Marine Biological Laboratory, Woods Hole |
| 8. Euskirchen, Eugenie, University of Alaska Fairbanks | 31. Rocha, Adrian, Notre Dame University, Indiana |
| 9. Fetcher, Ned, Wilkes-Barre University, Pennsylvania | 32. Rowe, Rebecca, University of New Hampshire |
| 10. Flynn, Michael, Murray State Univ, Kentucky | 33. Schimel, Joshua, University of California, Santa Barbara |
| 11. Giblin, Anne, Marine Bio Lab, Woods Hole | 34. Shaver, Gaius, Marine Biological Laboratory, Woods Hole |
| 12. Godsey, Sarah, Idaho State University | 35. Stieglitz, Marc, Georgia Institute of Technology |
| 13. Gooseff, Michael, Colorado State University | 36. Tang, Jianwu, Marine Biological Laboratory, Woods Hole |
| 14. Gough, Laura, University of Texas, Arlington | 37. Vierling, Lee, University of Idaho |
| 15. Griffin, Kevin, Columbia University | 38. Wallenstein, Matthew, Colorado State University |
| 16. Groffman, Peter, Cary Institute of Ecosystem Studies, New York | 39. Williams, Matthew, University of Edinburgh, Scotland |
| 17. Hobbie, Erik, University of New Hampshire | |
| 18. Hobbie, John, Marine Bio Lab, Woods Hole | |
| 19. Hu, Feng Sheng, University of Illinois | |
| 20. Huryn, Alex, University of Alabama | |
| 21. Kling, George, University of Michigan | |
| 22. Luecke, Chris, Utah State University | |
| 23. MacIntyre, Sally, University of California, Santa Barbara | |

WHAT, WHERE, and WHEN:

Research sites included in this application are located in tundra, lakes, streams, and small whole catchments within the Toolik Lake RNA and nearby BLM-administered lands. The sites include an array of contrasting kinds of tundra vegetation and soils; contrasting sizes, depths, and catchment locations of lakes; and contrasting sizes and reaches of streams (see attached maps). Structures erected as part of the research (see attached photos) include small plastic-covered greenhouses and shade frames, rafts on lakes, and drippers needed for stream fertilizer experiments. At several sites, small meteorological towers (less than 3 m tall) are erected to support weather and climate instrumentation. Data loggers and sensors of various kinds are commonly used for remote, automated data collection, and individual plots and sampling points are marked with permanent or temporary stakes and flagging. There are no direct manipulations of the land surface, but long-term fertilizer additions do create changes in vegetation that are visible from at least one hundred meters distance. The impact that is most visible from a distance is the construction of boardwalks at several sites, for the purpose of minimizing damage to the natural vegetation and soils due to foot traffic. During the main summer season, sites are accessed mainly by foot and occasionally by helicopter; at sites near Toolik Lake and at Imnavait Creek a system of boardwalks has been constructed to provide access to the sites along the most heavily used trails. Vehicles are used only on established roads, canoes and boats are used on lakes, and snowmobiles are used rarely and only under appropriate conditions of snow depth and soil freezing. In all cases, research at these sites is designed to minimize long term impacts to the natural landscape and its scenic values.

A table listing locations (latitude and longitude) of all sites covered in this request is provided as Appendix 1, and maps showing the locations of all sites are provided as Appendix 2. Appendix 3 provides photographs of typical equipment and structures deployed at these sites. Detailed descriptions of sampling and monitoring activities at individual research sites covered in this application are provided in the following pages, grouped by habitat (terrestrial, lakes, streams, catchments) and type of use (monitoring or experimental). Many additional details are available at the Arctic LTER web site (<http://ecosystems.mbl.edu/ARC/>) including current and past NSF proposals and progress reports funding and covering this research (http://ecosystems.mbl.edu/ARC/otherdocs/other_arctic_lter_documents.htm) as well as a list of scientific publications based on this research and a data archive. Additional information about other research based at Toolik Field Station, and additional maps and data, is available at the Field Station web site, <http://toolik.alaska.edu/index.php>.

1. Terrestrial Research---Long Term Experiments

A. WHERE are the experiments located?

Terrestrial Long Term Experimental plots	Latitude	Longitude	Map ID	MAP #
LTER Heath Tundra	68.64083	-149.5875200	Center of plot group	2, 4, 7, 23
LTER Low Nutrient Moist Acidic Tussock Tundra	68.621155	-149.608354	Center of plot group	2, 6, 7, 21
LTER Moist Acidic Tussock Tundra	68.62441	-149.611343	Center of plot group	2, 4, 7, 20
LTER Moist Acidic Tussock Tundra 1981 plots	68.629453	-149.576793	Center of plot group	2, 4
LTER Moist NonAcidic NonTussock Tundra	68.633959	-149.638566	Center of plot group	2, 5, 19
LTER Moist NonAcidic Tussock Tundra	68.634507	-149.643279	Center of plot group	2, 5, 18
LTER Shrub Tundra Block 1	68.63873	-149.568125	Center of plot group	2, 4, 7, 17
LTER Shrub Tundra Block 2	68.635606	-149.587429	Center of plot group	2, 4, 17
LTER Wet Sedge Tundra Block 1	68.62525	-149.602503	Center of plot group	2, 6, 7, 22
LTER Wet Sedge Tundra Block 2 & 3	68.647183	-149.577069	Center of plot group	2, 3, 22
Chapin Bret-Harte Species Removal	68.622297	-149.611766	Center of plot group	2, 6, 7
Tang experimental plots	68.621991	-149.607305	Center of plot group	2, 6
Walker 1994 Snow Fence Moist Acidic Tussock	68.620115	-149.603257	Center of plot group	2, 6
Walker 1994 Snow Fence Dry Heath	68.622465	-149.598047	Center of plot group	2, 6
Bret-Harte Fence#1 tussock	68.62112	-149.6141	West end	2, 6
Bret-Harte Fence#1 tussock	68.62108	-149.61261	East end	2, 4
Bret-Harte Fence#2 low_shrub	68.63354	-149.57623	East end	2, 4
Bret-Harte Fence#2 low_shrub	68.63357	-149.5777	West end	2, 4
Bret-Harte Fence#3 high_shrub	68.63738	-149.56853	East end	2, 4
Bret-Harte Fence#3 high_shrub	68.63743	-149.56935	West end	2, 4
Bret-Hart Fence#4 high_shrub	68.63872	-149.56651	West end	2, 4
Bret-Hart Fence#4 high_shrub	68.63873	-149.56573	East end	2, 4

B. WHAT equipment and materials are located at each site and what measurements are made and samples collected? WHEN is this work done?

These long-term experiments are all located within 800 M of the shore of Toolik Lake (see maps) and are normally accessed by foot from Toolik Field station. Where foot traffic is especially heavy, boardwalks extend from the lake shore to the experimental plots.

The overall aim of these long-term experiments is to determine how species composition, productivity, and carbon and nutrient cycling are controlled in a range of contrasting tundra ecosystem types. Terrestrial ecosystems take decades to respond to changes in environment, so observations of change must be continued over many years to understand long-term controls. This understanding is reached through periodic measurements of the responses to manipulations of the environment and species composition in several ways including:

- a. Addition of fertilizers including nitrogen (both ammonium and nitrate forms), phosphorus, sulfur, and lime.
- b. Reduction of incoming light (using greenhouse shade cloth).
- c. Increases in air temperature (using plastic-covered greenhouses).
- d. Exclusion of animal grazers (using fences of differing mesh size).
- e. Direct control of vegetation species composition (removal of selected individual species by weeding)
- f. Manipulation of winter snow accumulation (using snow fences).

The fertilizer used is nontoxic and nonhazardous; since 2011 we have converted from agricultural-grade ammonium nitrate fertilizer to separate additions of ammonium chloride and sodium nitrate. In all but the 2006 “Low Nutrient” plots the rate of addition is 10 grams per m² nitrogen (as ammonium chloride plus sodium nitrate) to all plots receiving nitrogen, and 5 grams per m² phosphorus (as superphosphate) to plots receiving phosphorus. In the 2006 “Low Nutrient” plots a range of lower additions is made, from 0.5 to 10 grams N per m² and from 0.25 to 5 grams P per m². All fertilizers, lime, and sulfur are carried by backpack or delivered by helicopter to the sites in the beginning of June. Generally only the amount needed for each year's application is brought to the sites. Any leftover materials are stored under cover at Toolik Field Station.

Measurement and sampling activity at these sites varies from year to year. At several of the sites (described below), data loggers record weather and microclimate data year round, using short (less than 3 m tall) weather instrument towers and thermocouples and other sensors distributed through the vegetation canopy and soil. Most other data collection occurs during the snow-free months (May-September).

Types of data collection include nondestructive canopy reflectance measurements, aerial cover estimates, and counts of individual plants and flowers. Other kinds of sampling include removal of vegetation by clipping within small quadrats (usually 20x20 cm, occasionally as large as 50x50 cm) and removal of smaller blocks of soil by cutting with a knife or taking a small-diameter soil core (usually ~5-10 cm diameter). Soil solutions are also sampled using suction methods, usually either syringes or suction lysimeters (small-diameter tubes). Insects are collected by sweep-netting or vacuuming the aboveground vegetation. All of these samples of soil and vegetation are then carried back to Toolik Field Station for sorting and processing.

Each site consists of 6-40 individual plots, marked at the corners with individual stakes. The size of individual plots varies from 1x1 meters to 5x20 meters. Plots are separated by 1-2

meter-wide walkways between plots. At heavily-used sites, wooden boardwalks run within these walkways to minimize trampling damage during sampling and data collections. Details of treatments and layout at individual sites vary as shown on attached site maps and described below:

LTER Heath Tundra site (established 1988)

- a) 3 blocks of 10 plots each 5x20 m in the main design, plus 2 10x10m enclosure plots. There are no boardwalks in these plots.
- b) 2 shade houses. Each house is 2.5 x 5 m, made of wooden 2 x 4's and covered in the summer with shade cloth. Covers are removed at end of each field season.
- c) Experimental enclosures made of 1.5 m high, 4 x 6 inch net wire' fence with smaller inside nested plots fenced with 1 inch or ½ inch hardware cloth. Two enclosures are 10 x 10 m and 6 enclosures are 5 x 10 m.
- d) Small 0.3 m round plastic rings set 0.45 m deep and flush with the tundra.
- e) Year-round weather station (3-meter maximum sensor height), including air and soil temperature probes.

LTER Low Nutrient Moist Acidic Tussock Tundra site (established 2006)

- a) 4 blocks of 10 plots each 5x20 m with 2 m wide walkways between blocks.
- b) Boardwalks (see maps): because this site is highly sensitive to trampling, boardwalks surround each plot.
- c) Two data loggers and weather stations, in Block 1 and Block 3, including air and soil temperature probes.

LTER Tussock Moist Acidic Tundra site (established 1988):

- a) Four each of greenhouses, four shade houses, four greenhouses with added N and P fertilizers, and four shade houses with added N and P fertilizers. Each house is 2.5 x 5 m, made of wooden 2 x 4's and covered in the summer with clear plastic or shade cloth. Covers are removed at end of field season.
- b) Experimental enclosures made of 1.5 m high 4 x 6-inch mesh wire fence with smaller inside nested plots fenced with 1 inch or ½ inch hardware cloth. Two enclosures are 10 x 10 m and 8 enclosures are 5 x 10 m.
- c) Year-round weather station (3-meter maximum sensor height), including a precipitation wet/dryfall collector, tipping bucket rain sensor, and soil temperature probes.
- d) Small 0.3 x 0.3 m aluminum squares or 0.3 m round plastic rings set 0.45 m deep and flush with the tundra.
- e) Boardwalks - see Maps.

LTER "Historic" Tussock Moist Acidic Tundra Site (established 1981)

An older site with only stakes and flags marking the various plots. Included are four 5x20 m plots with annual N+P fertilizer addition, and a plot that is a long-term reciprocal transplant garden of *Eriophorum vaginatum* tussocks, established in 1980. Measurements are made in this experiment about every 5-8 years. Transplanted tussocks are marked with wooden stakes.

LTER 1988 non-acidic Tussock

- a) Plots include factorial N and P fertilization treatment (3 replicate blocks) and 2 each of greenhouses and nutrient addition of N and P to greenhouses. Each house is 2.5 x 5 m and is made of 2 x 4's and covered in the summer with clear plastic. Covers are removed at end of field season.
- b) Boardwalks are installed between 5x20 m plots, and access to the site is by boardwalk running from the western shore of the lake (see maps)

LTER 1988 Wet Sedge Blocks 1-3

- a) Plots include factorial N and P fertilization treatment (3 replicate blocks) and 2 each of greenhouses and nutrient addition of N and P to greenhouses. Each house is 2.5 x 5 m and is made of 2 x 4's and covered in the summer with clear plastic. Covers are removed at end of field season.
- b) Boardwalks installed between plots and on paths to plots.
- c) At Site 1, a year-round weather station (3-meter maximum sensor height), including air and soil temperature probes

LTER 1988 Shrub Site 1 and 2.

- a) Plots include factorial N and P fertilization treatment (3 replicate blocks) and 2 each of greenhouses and nutrient addition of N and P to greenhouses. There are also two shade frames. Each house is 2.5 x 5 m and is made of 2 x 4's and covered in the summer with clear plastic. Covers are removed at end of field season.
- b) At Site 1, a year-round weather station (3-meter maximum sensor height), including air and soil temperature probes.

Chapin Bret-Harte Species Removal

- a) This is a grid of plots 2 x 4 in size, in which selected species have been removed by annual weeding. Half the plots receive annual N+P fertilizer addition.
- b) Boardwalks run between each row of plots, and a boardwalk path provides access to the plots (see attached maps).
- c) A data logger is used in these plots to monitor air and soil temperatures, soil moisture, and other environmental factors.

Tang experimental plots

This is a group of 10 small (1 x 1 m) plots adjacent to the LTER Low Nutrient Moist Acidic Tussock Tundra site, set aside for focused, long term measurements of plant and soil CO₂ exchange.

Walker 1994 snowfence plots

These plots include two large (2 m tall x ~50 m long) snow fences, located in moist tussock tundra and dry heath tundra near the south shore of Toolik Lake. The fences are oriented E-W, so winter winds from the South produce 2-3 m deep snowbanks on the North side of each fence. A grid of 1x1 m plots has been established within the area covered by each snowbank. Most of the plots are otherwise unmanipulated but ~ 1/3 of the plots in each grid are also treated with open-

topped plastic chambers that warm the surface of the tundra ~1 degree C during the summer period. Control plots (where snow accumulation is unaffected) are established on the North sides of each snowfence. Because the tussock tundra snowfence is particularly sensitive to thawing of permafrost beneath trampled areas, boardwalks have been installed between rows of plots in the tussock snowfence site. Access to these sites is also by boardwalks from Toolik Field Station.

Bret-Harte snowfence plots

In 2006, four more snowfences were installed in sites near Toolik Lake representing a gradient of shrub abundance in the vegetation. Because the aim of these experiments is to determine the long term (multidecadal) effects of snow distribution on vegetation and soils, the sites are accessed only a few times each summer to monitor changes in thaw depth, microclimate, soils, and plant cover in and out of the snow accumulation area.

2. Terrestrial—Monitoring sites

A. WHERE are the sites and experiments located?

Terrestrial Vegetation Monitoring Sites	Latitude	Longitude	Map ID	Map #
Toolik Grid NE corner	68.625626	-149.594645	Bounding Corner	6
Toolik Grid NW corner	68.625858	-149.621169	Bounding Corner	6
Toolik Grid SE corner	68.617299	-149.592993	Bounding Corner	6
Toolik Grid SW corner	68.616794	-149.620187	Bounding Corner	6
Imnavait Creek Grid NE corner	68.61733	-149.297434	Bounding Corner	8
Imnavait Creek Grid NW corner	68.617311	-149.323068	Bounding Corner	8
Imnavait Creek Grid SE corner	68.608344	-149.29827	Bounding Corner	8
Imnavait Creek Grid SW corner	68.608413	-149.322667	Bounding Corner	8
Terrestrial--Imnavait ¹⁵N monitoring plots				
Imnavait 15N Plots (all plots)	68.607936	-149.302743	~ center of all 15N plots	8
Imnavait 15N plot A	68.608878	-149.29917	Center of plot group	8
Imnavait 15N plot B	68.608132	-149.298997	Center of plot group	8
Imnavait 15N plot C&D	68.607815	-149.307386	Center of plot group	8
Imnavait 15N plot E&F	68.607433	-149.306729	Center of plot group	8
Imnavait 15N plot G&H	68.607398	-149.306628	Center of plot group	8
Imnavait 15N plot I&J	68.606972	-149.309186	Center of plot group	8
Imnavait 15N plot K	68.608363	-149.311638	Center of plot group	8
Imnavait 15N plot L	68.607565	-149.312629	Center of plot group	8

B. WHAT equipment and materials are located at each site and what measurements are made and samples collected?

This group of sites is used to follow long term changes in vegetation composition in undisturbed, unmanipulated ecosystems and long-term movement of a key element, nitrogen, down an undisturbed, unmanipulated hillslope. Except for annual soil thaw measurements, these sites are not sampled every year, and require no annual maintenance. Because the

changes in these plots take place over years to decades, major sampling of the vegetation plots, for example, is done only every six years. The major reason for including these sites in this request is thus to protect them and to guarantee access for future sampling.

Key point: Both of these 1 x 1 km vegetation monitoring grids INCLUDE areas also described separately as individual Terrestrial Long Term Experimental Plots and Land-Water Interactions Sites. For example, the *LTET Tussock Moist Acidic Tundra* site, the *Tussock Watershed and Weir* sites, the *Tang experimental plots*, the *LTET Wet Sedge Tundra Block 1*, and the *Wet Sedge Fen Flux Station* are all located entirely within the Toolik Lake vegetation monitoring grid. These other sites are all described separately because different activities take place in them, but in fact there is significant overlap in the use of the same land.

Terrestrial vegetation monitoring sites

These two sites consist of two 1 x 1 km grids of stakes, with the stakes 100 m apart. One grid is located on the South shore of Toolik Lake and the other covers most of the upper watershed of Imnavait Creek (see maps). Adjacent to each stake is a 1x1 m plot, also marked with smaller stakes and outlined with twine. Every six years a frame is placed over the smaller plots, and cover by species is determined (with 1 cm resolution) by lowering metal pins through the vegetation. This is a nondestructive method, used so that investigators can return to exactly the same locations to document long term change at fine spatial scale. The stakes are also used to locate annual thaw depth measurements, made twice each year on July 11 and August 2.

Imnavait ¹⁵N monitoring plots

These plots were established in 2003, with the goal of determining the rate of downslope movement of a key element, nitrogen, in undisturbed tundra. This was done by introducing a nonhazardous, nonradioactive, nonregulated isotope of nitrogen, ¹⁵N, in the form of ammonium chloride, to the surface of several plots distributed along a hillslope at Imnavait creek (see maps). This ¹⁵N is moving extremely slowly down slope, on the order of a few cm to less than 1 m per year. To document this rate of movement precisely will require returning to these plots and sampling plants and soils for 1-100 m downslope; this needs to be done only every 5-10 years and there is no current schedule for sampling. The plots are included in this request principally as a means of ensuring access in the future.

The ¹⁵N plots are marked with wooden stakes and surrounded by boardwalks or wooden planks laid directly on the tundra. The plots are accessed by foot from the MS117 materials site.

3. Land-Water Interactions Sites

The Land-Water Interactions group within the ARC LTER makes routine collections of soil water, lake water, and stream water samples for analysis of chemistry (mostly gases, inorganic chemistry, and dissolved organic carbon), biology (bacteria and chlorophyll), and thaw depth (thin metal probe inserted into the ground) during the summer. No equipment is left at the sites, there is no destructive sampling on land, and nothing is taken from the site except for small bottles of water. Access to the sites is by foot, boat, or helicopter.

In addition, at some sites we maintain a small stream gauge (weir) and small data loggers (20 x 20 cm) and instruments to measure the water level and temperature, and nearby soil temperature. The one weir we maintain at Tussock Watershed and the one stand-pipe for water level measurements we maintain at the Toolik Inlet stream remain on site through the winter; all other equipment or instrument housings are installed in May and removed at the end of the summer.

A. **WHERE are the sites located?**

The terrestrial plots are located at the Tussock Watershed, a small 0.1 km² area due south of Toolik Lake, and at Imnavait Creek, a 2.2 km² area 11 km East of Toolik Lake. At these two sites we measure soil water and stream water chemistry, stream discharge and temperature, and thaw depth.

The stream and lake sites include Imnavait Creek, the small Tussock Watershed stream, the inlet and outlet of Toolik Lake, sites on the “Inlet Series” of lakes and streams that drain into Toolik Lake, and sites on the Kuparuk River. Except for Imnavait Creek and the Tussock Watershed stream, all the Land-Water stream and lake collection sites are listed in the Tables providing locations for the Streams and Lakes LTER Groups (*Note the Toolik Lake Climate station and Eddy flux station are also described as part of the Lakes research sites below*).

Land Water Interactions Sites	Latitude	Longitude	Map ID	Map #
Tussock Watershed	68.62155	-149.615492	Center of Plot Group	2, 6, 7
Tussock Watershed Weir	68.6235	-149.616864	Center of weir	2, 6, 7
Imnavait WT 7&8	68.610685	-149.310741	Center of Plot Group	8
Imnavait Weir	68.616928	-149.317407	Center of Weir	8
Imnavait pools	68.603	-149.311	Center of stream section	8
LTER Imnavait FS Data Logger	68.6111984	-149.3099976	Data logger location	8
LTER Imnavait UB Data Logger	68.611702	-149.3009949	Data logger location	8
LTER Imnavait LB Data Logger	68.6113968	-149.3070068	Data logger location	8
Toolik Inlet Data Logger	68.6259995	-149.5930023	Data logger location	7
Toolik Lake Climate station	68.6306	-149.6089935	Raft in lake	7
Toolik Lake Eddy flux station	68.630378	-149.605992	Raft in lake	7
Wet Sedge Fen Eddy Flux Station	68.624319	-149.60225	Flux Station location	7

B. WHAT equipment and materials are located at each site and what measurements are made and samples collected?

a. Tussock Watershed and Weir

- i. 14 collection points for soil water along an elevation gradient, including 14 plastic white PVC tubes which mark the sites and extend 30 cm into the soil with about the same length extending above ground. There is raised wooden raised boardwalk along the sampling locations, about 150 m total length.
- ii. Tussock weir – 40 ft. wide wings of plywood by 4 ft. tall, “V”-shaped structure that drains water to a 8 ft. by 4 ft. wooden “channel” for measurement of stream discharge. At the weir there is an 8 ft. x 6 ft. platform for sampling and ~30 m of board walk.
 1. Data logger (size is 6”x6”x9”) on a wooden post (4”x4”x4 ft.) recording stage height and water temperature.
 2. Data logger (enclosed in a 14"x14"x6" weatherproof box) on a metal post (2" square pipe) recording temperature, pH, and conductivity of water and soil temperature.
 3. Auto-sampler (in a 30 gallon barrel) with ½” diameter tygon tubing extending from the auto-sampler to the water to collect water for chemical analyses. This auto-sampler is removed at the end of every summer.
 4. Thaw depth survey done in the Tussock Watershed using a thin steel probe. *No equipment is installed.*

b. Innavaik Creek Weir, Pools, and Data Loggers

- i. Innavaik Water tracks 7 & 8; 17 collection points for soil water along elevation gradient from the stream to the top of the hill slope. Each point is marked with a 1 inch diameter PVC pipe inserted into the soil. Raised wooden boardwalks extend to each location or cluster of locations.
- ii. Innavaik Creek sample collection point (near the Weir maintained by UAF).
 1. Data logger (size is 6”x6”x9”) on a metal post with solar panel for recording conductivity and water temperature.
 2. Data logger (size is 6”x6”x9”) on a metal post with solar panel for measuring conductivity and water temperature.
 3. Auto-sampler (in a 30 gallon barrel) with ½” diameter tygon tubing extending from the auto-sampler to the water to collect water for chemical analyses. This auto-sampler is removed at the end of every summer.
 4. Thaw depth survey done in the Innavaik Creek watershed using a thin steel probe. *No equipment is installed as part of the thaw depth survey.*

c. Toolik Inlet data logger

- i. Data logger (size is 24"x 24"x9") on a metal stand (12"x 12"x 4 ft.) with solar panel for recording water height, conductivity, and temperature.
- ii. Auto-sampler (in a 30 gallon barrel) with ½" diameter tygon tubing extending from the auto-sampler to the water to collect water for chemical analyses. This auto-sampler is removed at the end of every summer.
- iii. Two 2 ft tall PVC posts are installed to attach an 8m rope across the stream channel while making discharge measurements. This rope is removed after measurements have been made.

d. Toolik Lake Climate Station and Eddy Flux Station (two)

- i. Climate Station: 4 m x 8 m floating wooden raft with solar powered climate station (metal tripod 10 ft tall) to record air temperature, relative humidity, solar radiation, and wind direction and speed. The climate station is anchored in the lake for the May-September season and is then removed and stored near the TFS pad during the winter months.
- ii. Eddy Flux Station: 4 m x 8 m floating aluminum raft with wooden deck and climate station (metal tripod 6 ft tall) to measure gas flux and record air temperature, relative humidity, solar radiation, and wind direction and speed. The station is anchored in the lake for the May-September season and is then removed and stored near the TFS pad during the winter months. Electric power to this station is supplied via an underwater electric cable connected to Toolik Field Station.
- iii. Both stations: thermistor chain anchored at the bottom and connected to each raft. The chain has 11 4" x 8" x 2" thermistors to measure water temperature attached to a cable running to a data logger box on the raft. These Thermistor chains are removed from the lake during the winter months.

e. Wet Sedge Fen Eddy Flux Station

- i. Metal tripod (2 m tall) to measure gas flux and record air temperature, relative humidity, solar radiation, and wind direction and speed. This instrumentation is the same as that on the Lake Eddy Flux Station.
- ii. Electric power to this station is supplied via an electric cable connected to Toolik Field Station.

4. Streams research sites

A. WHERE are the sites and experiments located?

A.1 Seasonal and long-term installations

Seasonal and Long-Term Installations	Latitude	Longitude	Map ID	Map #
Long-term Oksrukuyik Creek reference monitoring (Potential NEON/STREON site)				
Oksrukuyik 0.1k	68.6724	-149.1273	HOBO Temperature Probe (Year Round)	11, 14
Oksrukuyik stage recorder	68.6860	-149.0990	HOBO Pressure Transducer (Year Round)	11, 14
Long-term Kuparuk Fertilization Experiment				
Kuparuk 3.0k	68.6537	-149.4209	HOBO Temperature Probe	11, 12
Kuparuk 2.5k	68.6523	-149.4152	YSI Sonde (Summer)	11, 12
Kuparuk 2.0k	68.6495	-149.4162	Game Camera (Year Round)	11, 12
Kuparuk 1.39k	68.6462	-149.4091	YSI Sonde (Summer), Turbidity Sensor (Summer)	11, 12
Kuparuk 1.4k	68.6463	-149.4100	Phosphoric Acid Dripper (Summer)	11, 12
Kuparuk 1.2k / Kuparuk 4.5 Fish Antenna	68.6463	-149.4097	Fish Antenna (Year Round)	11, 12
Kuparuk 0.74k	68.6432	-149.4033	HOBO Pressure Transducer (Year Round)	11, 12
Kuparuk 0.5k	68.6415	-149.4019	YSI Sonde (Summer)	11, 12
Kuparuk 0.0k / Kuparuk 4 Fish Antenna	68.6391	-149.3943	Phosphoric Acid Dripper (Summer), Game Camera, Fish Antenna (Year Round)	11, 12
Kuparuk -0.1k	68.6381	-149.3930	YSI Sonde (Summer)	11, 12
Upper Kup WS1-WS2	68.5500	-149.3096	Game Camera (Year Round)	11, 13
Long-term thermokarst monitoring				
Toolik River Met Station	68.6914	-149.2070	Meteorological station and associated soil monitoring (Year Round)	11, 14
NE-14 Met Station	68.6779	-149.6210	Meteorological station and associated soil monitoring (Year Round)	11

Seasonal and Long-Term Installations	Latitude	Longitude	Map ID	Map #
I Minus 2 Met Station	68.5427	-149.5240	Meteorological station and associated soil monitoring (Year Round)	11, 15
Long-term fish monitoring				
Kuparuk 1- GCL inlet	68.5338	-149.2070	Fish Antenna (Year Round)	11, 13
GCL Lake - multiplex antenna	68.5369	-149.2428	Fish Antenna (Year Round), Fish weir (Seasonal)	11, 13
Kuparuk 2- GCL outlet	68.5389	-149.2616	Fish Antenna (Year Round)	11, 13
Kuparuk 3	68.5577	-149.3311	Fish Antenna, Game Camera (Year Round)	11, 13
Kuparuk Spring (KUS) pool	68.5721	-149.3470	Fish Antenna, Game Camera (Year Round)	11, 13
Kup 4- 0.0k	68.6393	-149.3948	Fish Antenna (Year Round)	11, 13
Kuparuk 5	68.6546	-149.4237	Fish Antenna (Year Round)	11, 13
Toolik Outlet	68.6902	-149.6058	Fish Antenna (Year Round)	11, 13
Oksrukuyik(-1) - Zev Lake outlet	68.6194	-149.1876	Fish Antenna (Year Round)	11, 14
Oksrukuyik 0 - Wolverine Lake confluence	68.6367	-149.2164	Fish Antenna (Year Round)	11, 14
Oksrukuyik 1 - Wolf creek	68.6724	-149.1255	Fish Antenna (Year Round)	11, 14
I-minus 1 Lake outlet	68.5565	149.5763	Fish Antenna (Year Round), Fish weir (Seasonal)	11, 15
Long-term stream-bed thermal monitoring				
Inlet Series - I8 inlet	68.6050	-149.5864	Datalogger with buried thermistors (Year Round)	11, 15
Inlet Series - I8 outlet	68.6122	-149.5906	Datalogger with buried thermistors (Year Round)	11, 15
Inlet Series - Peat Inlet (I-Swamp)	68.6072	-149.5932	Datalogger with buried thermistors (Year Round)	11, 15

A.2 Occasional use stream sampling locations (no seasonal or long-term installations)

Occasional Use Stream Sampling Sites	Latitude	Longitude	Map ID	Map #
Oksrukuyik Long-Term Reference Stream Monitoring				
Oksrukuyik -0.1k	68.6715	-149.1281	Sampling point	11, 14
Oksrukuyik -0.3k	68.6714	-149.1312	Sampling point	11, 14
Oksrukuyik -0.7k	68.6710	-149.1379	Sampling point	11, 14
Oksrukuyik 0.8k	68.6772	-149.1218	Sampling point	11, 14
Oksrukuyik 1.37k	68.6798	-149.1142	Sampling point	11, 14
Kuparuk River Long-Term Experimental Fertilization Experiment				
Kuparuk 5.5k	68.6670	-149.4386	Sampling point	11, 12
Kuparuk 4.0k	68.6588	-149.4245	Sampling point	11, 12
Kuparuk 2.4k	68.6517	-149.4165	Sampling point	11, 12
Kuparuk 1.8k	68.6478	-149.4157	Sampling point	11, 12
Kuparuk 1.0k	68.6447	-149.4052	Sampling point	11, 12
Kuparuk 0.85k	68.6436	-149.4025	Sampling point	11, 12
Kuparuk 0.56k	68.6421	-149.4035	Sampling point	11, 12
Kuparuk 0.3k	68.6407	-149.4006	Sampling point	11, 12
Kuparuk -0.177k	68.6381	-149.3918	Sampling point	11, 12
Kuparuk -0.377k	68.6384	-149.3892	Sampling point	11, 12
Kuparuk -0.47k	68.6374	-149.3867	Sampling point	11, 12
Kuparuk -0.7k	68.6367	-149.3832	Sampling point	11, 12
Hershey Creek	68.6447	-149.4120	Sampling point	11, 12
Occasional Stream Sampling Locations				
Imnavait A	68.6166	-149.3180	Sampling point	11
Imnavait AA	68.6177	-149.3183	Sampling point	11
Imnavait B	68.6206	-149.3186	Sampling point	11
Imnavait C	68.6229	-149.3210	Sampling point	11
Imnavait D	68.6253	-149.3246	Sampling point	11
Imnavait E	68.6420	-149.3430	Sampling point	11
Upper Kup WS1	68.5494	-149.3062	Sampling point	11, 13
Upper Kup WS2	68.5492	-149.3084	Sampling point	11, 13
Itkillik Trib East	68.5901	-149.7242	Sampling point	11
Itkillik Trib West	68.5902	-149.7262	Sampling point	11
Thermokarst-Impacted Stream Sampling Locations				
Toolik River REF	68.6957	-149.2048	Sampling point	11, 14
Toolik River IMP	68.6955	-149.2078	Sampling point	11, 14
Toolik River TK Low	68.6938	-149.2041	Sampling point	11, 14
Toolik River TK Mid	68.6922	-149.2068	Sampling point	11, 14

Toolik River TK Above	68.6907	-149.2084	Sampling point	11, 14
I Minus 2 REF	68.5481	-149.5213	Sampling point	11, 15
I Minus 2 IMP	68.5482	-149.5220	Sampling point	11, 15
I Minus 2 TK Low	68.5479	-149.5216	Sampling point	11, 15
I Minus 2 TK High	68.5441	-149.5222	Sampling point	11, 15
I Minus 2 TK High Side	68.5444	-149.5215	Sampling point	11, 15
Toolik River Above Road	68.6926	-149.1857	Sampling point	11, 14
Toolik River TK-4 "Gurgler"	68.6922	-149.1955	Sampling point	11, 14

B. WHAT equipment and materials are located at each site and what measurements are made and samples collected?

Long-Term Kuparuk River Fertilization Experiment

This initiative is the longest running stream experiment of its kind in any biome and uses a section of the upper Kuparuk River from about 3 km above the bridge crossing at the Dalton Highway to approximately 4.5 km downstream. In some years we have done sampling as far as 10 km downstream of the road crossing, but this occurs rarely. A suite of sites within this experimental reach (indicated in the table above) have been visited several times each year since 1983. Some of these sites have been adopted by collaborating projects (e.g. FISHSCAPES) as regular sampling locations. Two locations (Kuparuk 0.0 km and Kuparuk 1.4 km) have seasonal installations that drip a small volume of phosphoric acid (the fertilizer source) into the stream via a battery powered metering pump. The drippers consist of a rope tied across the stream, rebar anchors, tubing, a large (2 m x 2m x 1m) black plastic fish tote box to store acid not in use (for 0k only), and the pump which is powered by a marine-grade automotive battery and topped off by a small solar panel. The drippers are installed in mid-June and are operational June 25th to August 15th. They are then removed shortly after the 15th of August. The two drippers are located at 0k and 1.4k.(large with storage fish tote) and 1.4k (small, pump installation only).

Long-Term Kuparuk River Ecological Surveys

Approximately three times a year, water samples are collected for nutrient analyses at the 11 main fertilization experiment monitoring sites noted in the table above. Representative rocks (~6 from two locations at each site) from the bottom of the stream are temporarily removed and lightly scrubbed to remove algal chlorophyll for biomass analyses. The rocks are returned to the river to recolonize with algae. We also take up to three "Surber" samples to collect benthic macroinvertebrate organisms. At each sampling location a small (~0.25 m²) frame is temporarily placed on the stream bottom and rocks in the top 10-20 cm of this enclosed area are lightly brushed to remove the benthic invertebrates, which are captured in a net attached to the downstream edge of the frame. The frame and net are removed after the sample is taken. Moss transect inventories are completed identifying benthic composition once in late June and again

in late July or early August. Young of the Year Arctic Grayling are caught and measured weekly. This is an empirical, data gathering activity only, in which we temporarily install a tape measure across the width of the stream and then remove it once the data collection is complete (about 15 min). Young of the Year Arctic Grayling are caught with a small aquarium net and measured weekly. We maintain permits with the Alaska Fish and Game and with our local Institutional Animal Care and Use Committees (IACUCs) to make these collections and report our activities annually to these groups, as required. None of these sampling activities requires that anything be installed in the stream (i.e., there is no evidence of sampling after the fact). Dissolved oxygen sensors (YSI sondes) are installed at sites 2.5k, 1.39k, 0.5k, and -0.1k. Light sensors on the banks of the stream are found at 2.5k and -0.1k. These sensors are anchored with a short PVC pipe and several pieces of short rebar at the bottom of the stream bed. At 1.39k, a turbidity sensor is also deployed which also is anchored with rebars, and is connected with a cable to a data logger on the side of the stream. All of these installations are seasonal and are removed from the river in mid-August. At 0.74k a pressure transducer is present year round, along with a pressure transducer on the side of the stream. The pressure transducer inside the river is attached to a 1 meter long stage ruler that is anchored with a rebar inside the stream. At 3.0k, a temperature sensor is deployed year round, anchored in the stream with a rebar.

Long-Term Oksrukuyik Creek Ecological Surveys

Sampling of water for nutrients and benthic nutrient composition takes place using similar approaches as used in the Kuparuk River, at three reference sites (-0.1k, -0.3k, and -0.7k) three times each field season. Sampling of Young of the Year Arctic Grayling take place weekly throughout the field season at the reference and two downstream sites (1.37k, 0.8k, -0.1k, -0.3k, and -0.7k). A temperature sensor is located at 0.1k, anchored in the stream with a rebar. A pressure transducer, similar to the one deployed at the Kuparuk, is deployed year round just upstream of the road crossing. These are the only installations at this site associated with this effort.

Long-Term Monitoring of Selected Thermokarst-Impacted Stream Sites

Water samples for nutrients and benthic nutrients are collected two or three times a year at several stream sites that have been impacted by thermokarst (thermal erosion of permafrost). These sites include Innaviat Creek, Toolik River TK, and I-Minus 2 TK. These sites complement sites that have similar impacts but that lie on lands managed by the State of Alaska. At two of the sites on BLM land (Toolik River and I-Minus 2), we maintain small meteorological stations (temperature, humidity, light, wind) with associated soil temperature and moisture monitoring equipment, to monitor the local microclimate conditions in the vicinities of these features. These installations are a legacy of the earlier NSF-funded “Arctic Systems Science Thermokarst Project”. We maintain these sites because they provide valuable long-term and seasonal information about the local environmental conditions near these evolving, thermo-erosional features.

Long-Term Monitoring of Thermal Conditions in Selected Stream Beds

At three sites in the Inlet Series (I-Series) of Toolik Lake we maintain dataloggers that are connected to thermistors installed at various depths in the adjacent stream beds. These sites are above and below Lake I-8 (I-8 inlet and I-8 outlet) and adjacent to the stream that enters I-Swamp (Peat Inlet). The three sampling sites are all in close proximity (~1 km) but are in stream reaches that have different geomorphological characteristics. Each installation consists of a low (~1.5 m tall) metal tripod onto which there is affixed a weather-resistant box (~30 cm x 20 cm x 15 cm) that contains the datalogging electronics. An external 12V battery powers the datalogger and a single solar panel maintains the battery. Between 6 and 8 thermistor wires lead from the datalogger to stream bed, where they have been inserted to different depths. We maintain these sites because they provide valuable long-term and seasonal information about the thermal regime under these streams.

Long-Term Monitoring of Arctic Grayling Population Dynamics

One of the core initiatives of the Long-Term Ecological project's Stream Research initiative has been to better understand the basic ecology of Arctic Grayling – the dominant fish in these streams – and the likely impacts of future climate change on these critical populations. Over a period of 30 years approximately 20,000 individual fish have been tagged with passive identification tags to study growth and demographic dynamics of this important fish. This work has been done in close association with BLM and with the Alaska Department of Fish and Game, among others. Current work has begun to utilize more sophisticated technologies to monitor fish movement over broader spatial extents and with greater intensity over time. This new technology is also passive, but employs passive integrated transponder (PIT) tags that can be detected by an external antenna. Once implanted in an individual fish, these tags send a unique code that allows the sensing equipment to note the time that individual fish have passed the location. At several locations (identified in the table above) antennas and recording devices have been installed to monitor fish movement and migration. The installations consist of a loop of wire that has been threaded through flexible plastic tubing for physical protection, with iron rebar to maintain the position of the antenna loop across the width of the stream. The antenna is connected to a small recording device that is situated on the nearby stream bank. The sensing device is powered by a marine-grade battery that is maintained by three solar panels. Associated with some of the antenna installations, we have also installed commercial game cameras, pressure transducers, and temperature loggers that we use to monitor the state of flow in the river during periods that we are not present.

5. Lakes research sites

LTER lakes research includes:

- Long term monitoring of the chemical, physical, and biological parameters of a variety of Arctic Lakes. These lakes differ in morphometry, food webs and the age of the substrate in the watershed.
- Long term monitoring of lakes where nutrient enrichment or food web alterations had previously taken place.
- Collection of baseline data for a possible future lake warming experiment.
- Studies to examine how fires in the watershed and land failures due to thermokarst impact lake processes.
- Studies of lake sediments to understand long-term changes in climate and the biology of the lakes and watershed.
- Studies to better understand the processing of organic matter in the water column and the relative importance of chemical and biological processes.
- Studies to track seasonal and interannual variability in bacterial production and phylogenetic diversity

Sampling sites are on the lakes themselves or at the lake inlet or outlet stream for some locations, as indicated in the following Table:

A. WHERE are the sites and experiments located?

Lake Name	Latitude	Longitude	Map ID	Map #
Campsite Lake	68.59734133	-149.1792861	Lake Centroid	9
E1	68.6261956	-149.5525451	Lake Centroid	9, 10
E2	68.62289495	-149.5404817	Lake Centroid	9, 10
E3	68.62391083	-149.528384	Lake Centroid	9, 10
E4	68.62776981	-149.4949366	Lake Centroid	9, 10
E5	68.64223639	-149.4553129	Lake Centroid	9
E6	68.64342706	-149.4377658	Lake Centroid	9
Fog1	68.68356703	-149.0789002	Lake Centroid	9
Fog2	68.67948025	-149.0897977	Lake Centroid	9
Fog3	68.67286025	-149.0850284	Lake Centroid	9
Fog4	68.6797388	-149.0724402	Lake Centroid	9
Fog5	68.67854136	-149.0618096	Lake Centroid	9
Green Cabin Lake	68.53698153	-149.2346134	Lake Centroid	9
I Minus 1	68.55632969	-149.5634806	Lake Centroid	9, 10
I Minus 2	68.5536117	-149.5311622	Lake Centroid	9, 10
I1	68.56871308	-149.5852724	Lake Centroid	9, 10
I2	68.57131956	-149.5630787	Lake Centroid	9, 10
I3	68.57553663	-149.5808408	Lake Centroid	9, 10
I4	68.57956715	-149.5812557	Lake Centroid	9, 10
I5	68.58738744	-149.586822	Lake Centroid	9, 10
I6	68.5965924	-149.5898393	Lake Centroid	9, 10
I7	68.6008748	-149.5937779	Lake Centroid	9, 10
I8	68.61015752	-149.5794079	Lake Centroid	9, 10
I9	68.61896451	-149.5926932	Lake Centroid	9, 10
I swamp	68.610942	-149.600635	Lake Centroid	9, 10
N1	68.63989394	-149.6041605	Lake Centroid	9
N2	68.64094723	-149.6222805	Lake Centroid	9
N3	68.64238534	-149.6279638	Lake Centroid	9
N4	68.6451207	-149.6374738	Lake Centroid	9
N5	68.6454282	-149.6260492	Lake Centroid	9
N6	68.66995995	-149.6386386	Lake Centroid	9
N7	68.67299589	-149.652117	Lake Centroid	9
NE1	68.64378317	-149.5866898	Lake Centroid	9
NE10	68.65258828	-149.6048351	Lake Centroid	9
NE11	68.64740772	-149.6065605	Lake Centroid	9
NE12	68.6623557	-149.6195447	Lake Centroid	9
NE14	68.67501937	-149.6228162	Lake Centroid	9
NE15	68.65587404	-149.5827542	Lake Centroid	9
NE16	68.66104528	-149.5838597	Lake Centroid	9
NE2	68.64632501	-149.5799181	Lake Centroid	9
NE3	68.65019252	-149.5797552	Lake Centroid	9
NE7	68.65357228	-149.5781065	Lake Centroid	9
NE8	68.65255128	-149.5839553	Lake Centroid	9
NE9	68.65353613	-149.5934167	Lake Centroid	9

NE9B	68.65264548	-149.5966684	Lake Centroid	9
S1	68.62453597	-149.5993617	Lake Centroid	9, 10
S2	68.62716908	-149.6085481	Lake Centroid	9
S3	68.62881862	-149.6220165	Lake Centroid	9
S4	68.63094993	-149.6271258	Lake Centroid	9
S5	68.63143192	-149.6338867	Lake Centroid	9
S6	68.62937978	-149.6388174	Lake Centroid	9
S7	68.63006274	-149.6416358	Lake Centroid	9, 10
S11	68.63014805	-149.6477731	Lake Centroid	9
S12	68.6296278	-149.6530747	Lake Centroid	9, 10
S13	68.63148657	-149.656296	Lake Centroid	9
S14	68.63603501	-149.6484494	Lake Centroid	9
Toolik Lake	68.63257175	-149.6040778	Lake Centroid	7, 9
Toolik Inlet Data Logger	68.6259995	-149.5930023	Data logger location	7
Toolik Lake Climate station	68.6306	-149.6089935	Raft in lake	7
Toolik Lake Eddy flux station	68.630378	-149.605992	Raft in lake	7
Galbraith Lake	68.45932	-149.424398	Lake Centroid	9
Itkillik Lake	68.40256062	-149.9188446	Lake Centroid	9
Wolverine Lake (LTER345)	68.623297	-149.157408	Lake Centroid	9
Wounded Caribou Lake (LTER346)	68.625734	-149.140009	Lake Centroid	9
LTER347	68.632155	-149.164483	Lake Centroid	9
LTER348	68.636431	-149.143902	Lake Centroid	9

- B. WHAT equipment and materials are located at each site and what measurements are made and samples collected?

Equipment and Materials Kept on Site:

Toolik Lake (*note the Toolik Lake Climate Station and Eddy Flux Station are also described as part of the Land-Water Interactions Sites*)

- Climate Station: 4 m x 8 m floating wooden raft with solar powered climate station (metal tripod 10 ft. tall) to record air temperature, relative humidity, solar radiation, and wind direction and speed. The climate station is anchored in the lake for the May-September season and is then removed and stored near the TFS pad during the winter months.
- Eddy Flux Station: 4 m x 8 m floating aluminum raft with wooden deck and climate station (metal tripod 6 ft. tall) to measure gas flux and record air temperature, relative humidity, solar radiation, and wind direction and speed. Electric power to this station is supplied via an underwater electric cable connected to Toolik Field Station. The station is anchored in the lake for the May-September season and is then removed and stored near the TFS pad during the winter months.
- Both the climate station and the eddy flux station: thermistor chain anchored at the bottom and connected to each raft. The chain has 11 4" x 8" x 2" thermistors to measure water temperature attached to a cable running to a data logger box on the raft. These Thermistor chains are removed from the lake during the winter months.
- On the lake surface, two climate stations on small rafts operate during the ice-free field season and they are removed at the end of each season and stored on shore. In addition various water temperature dataloggers and suspended apparatus used for sediment/water sample incubation and primary production experiments.
- Three boats with motors are on Toolik Lake year-round. In the summer they are docked at camp, in the winter pulled up on shore. The boats are 12, 16 and 20 feet long, and powered by 8, 15 and 15 hp Honda 4 stroke engines respectively. A removable floating dock is placed out at the beginning of every field season and removed at the end of the season and placed on shore near the lake.

Lakes E5 and E6

- One row boat will remain on lakes E5 and E6 during the summer.
- Lakes E5 and E6 have dataloggers or rafts in the center of the lake. On Lake E5, there is a 1.5 m x 1.5 m floating wooden raft with solar powered climate station to record air temperature, relative humidity, solar radiation, and wind direction and speed. The climate station is anchored near the middle of the lake is removed and stored on the north shore of the lake during the winter months.
- On Lake E5 there are 1-2 thermistor strings anchored at the bottom and supported by orange floats. One chain has ~8 6" long x 2" diameter cylindrical thermistors attached to a nylon rope suspended by a float and located just south of the climate station, and the other chain has ~10 4" x 8" x 2" thermistors

attached to nylon rope suspended by a float and located just north of the climate station. All these thermistors measure water temperature at the depth which they are placed. These strings are removed from the lake during the winter months.

All lakes sampled have a temporary float placed at the deepest point for the summer - floats are removed at the end of the field season. In addition to floats, Lakes Fog 1, Fog2, Fog 3, Fog 5 each have one row boat that remains on the lakes during the summer months. These lakes will also have a small raft or a buoy in the center of the lake containing a chain of temperature loggers, and other physical and chemical monitoring instruments.

How are sites accessed?

Lakes are accessed via foot (some by crossing Toolik in boat first) or helicopter. If conditions allow (e.g., enough snow), snowmachines may be used to access lakes for over ice sampling.

Period of use?

The principal period of use is from May 1 to September 30 each summer.

Sampling and methods:

- a) Water column surveys - The water columns of all of the lakes listed above and in Appendix I are sampled for physical, biological, and chemical parameters 1-12 times a year.

Physical sampling – physical sampling involves lowering instruments into the water and does not involve removing any samples from the lake.

1. pH, temperature, conductivity, fluorescence, light and oxygen, measured at every lake. These measurements using instruments lowered through the water column from a raft or a boat. Normally these measurements are made at every meter to the bottom in the deepest part of the lake.
2. Secchi depth (light penetration) is measured on every lake.
3. At some lakes more detailed physical parameters are measured including measuring specific wavelengths of light.
4. At some lakes various instruments are used to measure currents or vertical mixing.

Biological sampling – biological sampling involves collecting organisms from the lake and bringing them back to the laboratory:

1. Zooplankton and phytoplankton samples are collected on each sampling trip. Zooplankton are collected in a net brought up from the bottom to the surface. An integrated sample for phytoplankton is made using a

piece of tubing which is lowered into the water. The tube is then sealed and the water is brought back to the lab.

2. Microplankton samples are taken at only a few lakes. Approximately 4 L of water is filtered through a net for these samples.
3. Primary Production is measured in water samples (about 125 mL) taken from the photic zone in about 10 lakes.
4. Chlorophyll *a* samples are used as a proxy for phytoplankton biomass. 0.3 to 1 L of water from several depths is taken and filtered back at the laboratory.
5. Picoplankton for cell abundance measurements are sampled from each depths in 5-10 lakes by collecting 5 mL of water and preserving with gluteraldehyde (2.5% final concentration) for analysis with flow cytometry.
6. DNA for biodiversity studies is collected by filtering 1-4 L of water through a filter cartridge and preserved for extraction and DNA sequencing.
7. Samples for benthic invertebrates are taken using a grab. These samples are only taken on a few lakes occasionally for special projects.
8. Fishes are sampled periodically during each field season with authorization and approved methods via an Alaska Department of Fish and Game Fish Resource Permit.

Chemical sampling - Chemical sampling involves taking approximately 1-2 L of water from several depths in the lakes and bringing it back to the lab for further processing and preservation. These samples include:

1. Cation and anion samples – these are usually taken from each depth in each lake where we measure biological parameters.
2. Inorganic nutrient samples (NH_4 , NO_3 , and PO_4) are collected from each depth sampled in each lake (or inlet).
3. Total dissolved nitrogen (TDN) and total dissolved phosphorus (TDP) samples are collected from each depth sampled in each lake (or inlet).
4. Particulate (N, C, P) samples are collected from each depth sampled in each lake (or inlet).
5. Dissolved organic carbon (DOC) samples are collected from each depth sampled in Toolik, N1, N2, S6, S7, and the I-series.

b) Local climate and gas fluxes

1. Small rafts are located on the lake or on shore for the measurements of basic climate parameters (temperature, wind, solar radiation, etc.) to obtain the local micro meteorological conditions influencing the exchange of gases between the lake and the atmosphere (raft described above).
2. In addition on Toolik, we maintain a small raft with an eddy covariance system to monitor the exchange of CO_2 and methane between the air and the water (raft described above).

- c) Lake water column continuous measurements of temperature, oxygen
These are sensors which monitor temperature or oxygen at various depth in the water column. They are attached to the rafts where local climate and gas fluxes are monitored, or suspended from small buoys.

- d) Sediment processes
 1. Sediment cores are taken using a corer for the measurement of benthic primary production and for the measurement of Chlorophyll *a*. 3-4 cores per lake are sampled 1-3 times a season. In some cases nutrient release and gas fluxes are also monitored.
 2. In some cases small chambers are deployed on the sediment surface instead of taking cores. These are also used to monitor benthic primary production and gas fluxes across the sediments.

- e) Lake history
To understand the long term history of the region, sediment cores are taken in the lake, usually by sampling through the ice. These cores are used for the analysis of pollen, diatom remains, a variety of biomarkers, and bulk parameters including C, N, S, P, Fe, Mn, and Ca.