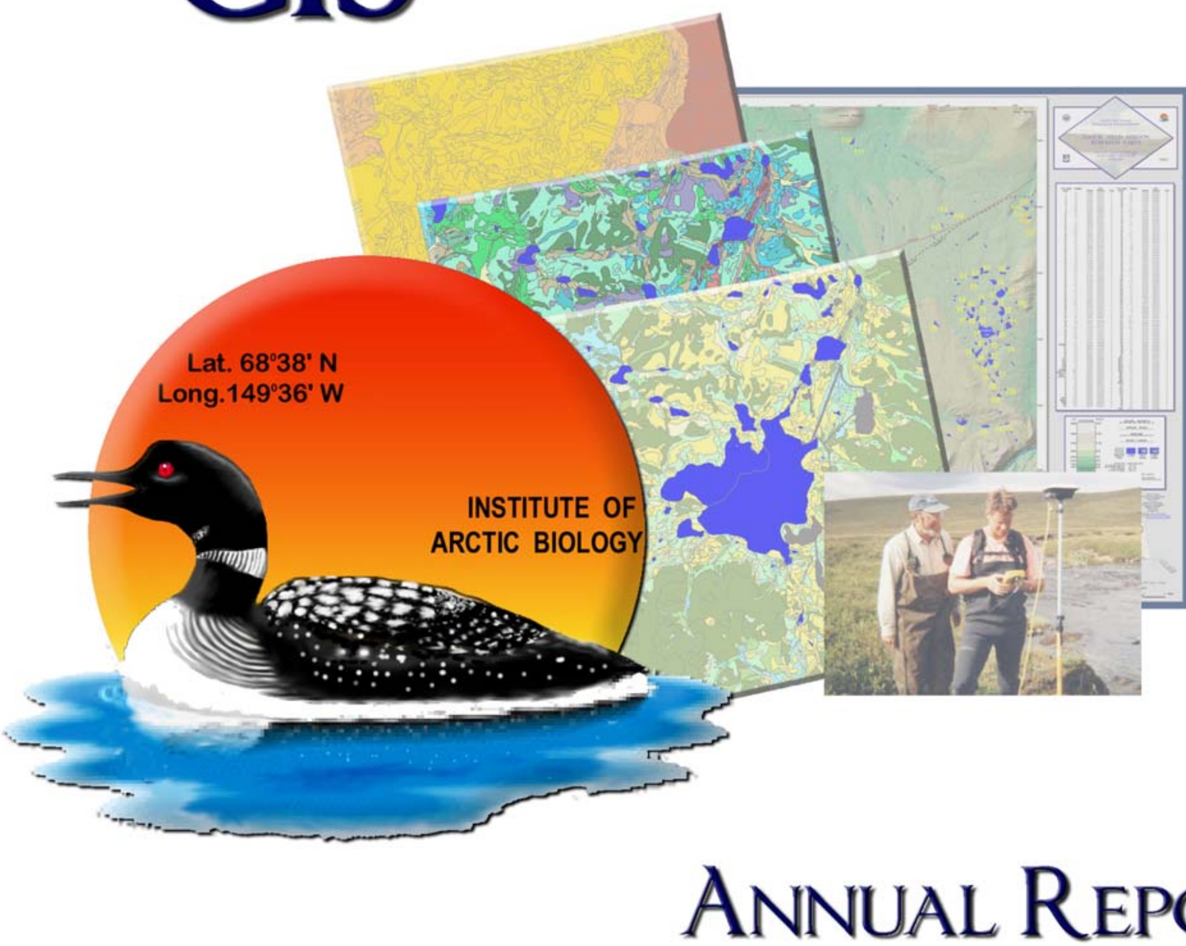
TOOLIK FIELD STATION
GIS



ANNUAL REPORT
2007

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Institute of Arctic Biology
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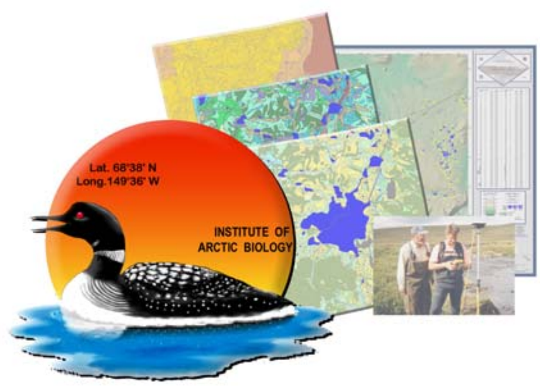
October 3, 2007

GIS & Remote Sensing

for

Toolik Field Station

2007



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Support funded by the National Science Foundation Office of Polar Programs
Toolik Field Station (Cooperative Agreement), NSF Award No. 0455541

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1.0 SUMMARY

1.1 Background - Toolik Field Station

Toolik Field Station (est. 1975) is located in the foothills of the Brooks Range on Alaska's north slope and is administered by the Institute of Arctic Biology at the University of Alaska Fairbanks. The station supports a long-standing and rapidly expanding community of scientists and research projects representing individual and collaborative efforts from US and international institutions. Research based at Toolik covers topics in terrestrial and aquatic ecology, atmospheric science, physical sciences, physiology of arctic breeding birds, mammals and insects, and includes a broad range of temporal and spatial scales. Toolik also provides leadership integrating pan-arctic research, and developing relationships among other key, international nodes of arctic science. These efforts, such as the Arctic Observing Network (IPY-AON), allow research results to be compared and scaled globally. The ability to successfully conduct rich, integrated research requires a multi-faceted support structure at the station. As a component of Toolik Field Station, the Geographic Information Systems (GIS) Program fills an expansive role working directly with scientists and administrators for the advancement of research and management, at Toolik and regionally, and provides logistical and management support as an enterprise GIS.

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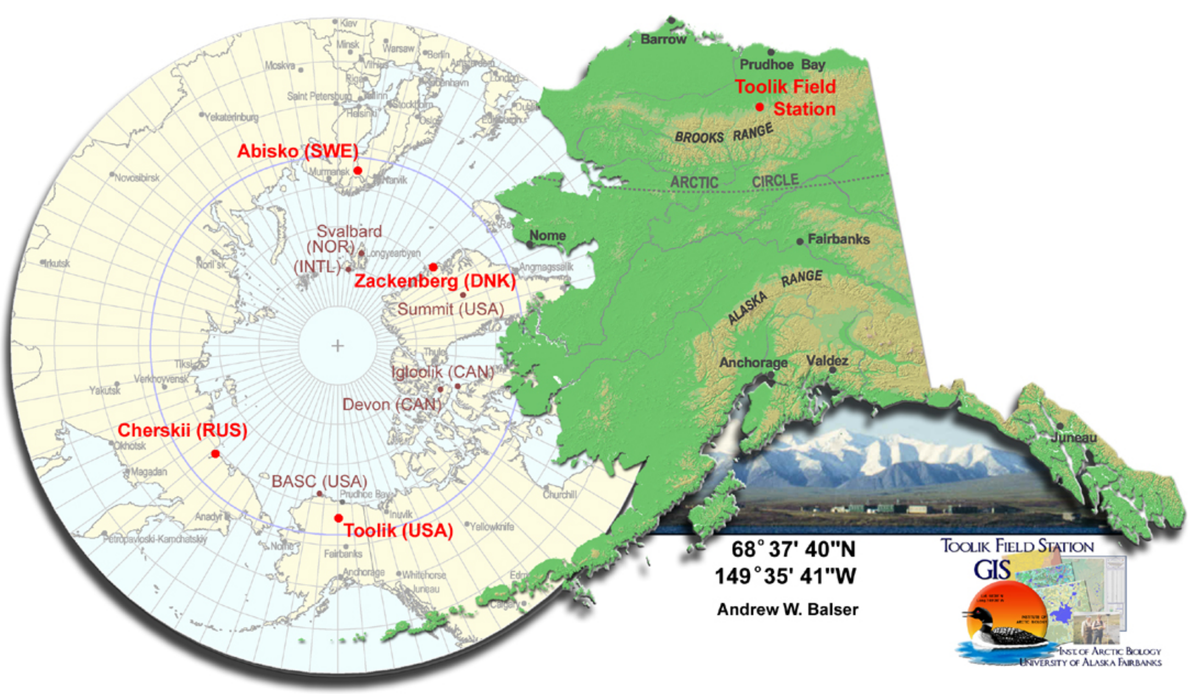


Figure 1. Toolik Field Station and other key nodes of the Arctic Observing Network (AON), associated with the International Polar Year (IPY).

1.2 Mission Statement

The mission of Toolik Field Station GIS is to facilitate and enhance arctic research, and to increase research and management efficiency, effectiveness and capability. This is accomplished: 1) through direct consultation and participation with scientists, incorporating spatial data and analyses into pre-existing research, 2) through GIS support of administrative and management infrastructure and production of planning tools for land management and permitting, 3) through comprehensive project-level participation; from proposal to publication, and 4) through outreach to agencies and participation in regional and international entities developing Arctic Spatial Data Infrastructure (ASDI) and Decision Support Systems (DSS). Toolik GIS provides a rich spatial database, project-specific data development, spatial analysis, technical expertise, consultation and documentation toward achieving these goals. Services are available at the station during the summer field season, and through the Toolik GIS Office at UAF year round.

1.3 Scope

The Toolik Field Station GIS Program has grown steadily in function and capacity since its inception in 2001. Early efforts focused on small-scale analytical and data development services, and on acquisition, creation and incorporation of framework and other data. From the beginning, heavy emphasis was placed on frequent, direct interaction and services for members of the Toolik community; this has remained the program's single most fundamental function. These activities also laid the foundation for expanded capabilities in the years to follow. The plan for program growth, as presented at the Arctic LTER Annual Meeting in 2002, has included increased capacity for more sophisticated analyses, improved equipment and technological capability, expanded interaction with the larger science, spatial data, and management communities, and project-level participation in research science.

The NSF sponsored Arctic GIS Workshop in January 2001 concluded that an Arctic Spatial Data Infrastructure (ASDI) had been developing both formally and informally for a number of years (Sorenson et al., 2001). Optimized coordination and communication maximize the infrastructure's benefits to science, management and the public. As an ASDI continues to take shape, Toolik GIS is evolving into a primary node for data and services (Sorenson et al., 2004). Toolik GIS is also an active participant in planning, coordination and implementation efforts at state, regional and arctic scales, such as the North Slope Science Initiative (NSSI), and the Circumarctic Environmental Observatories Network (CEON).

Trends toward pan-arctic, interconnected science have only gained momentum since 2001, and are greatly augmented by International Polar Year initiatives and funding. In addition to participation in ASDI initiatives, Toolik Field Station GIS actively participates in project-level science that extends the knowledge gained at Toolik Field Station beyond the immediate borders of the Toolik Lake Research Natural Area. In this way, the rich, long-term data and research record from Toolik acts as a point of departure and a context for comparison with the larger landscape on the North Slope and in Arctic Alaska.

The future trajectory of the Toolik Field Station GIS Program should continue to emphasize 1) direct interaction with research science, 2) active participation in efforts to integrate, organize and distribute key information through ASDI and associated web resources, 3) continual upgrade and expansion of technological capability and topical expertise, and 4) maximization of the relevance of Toolik research within both the traditional context, and in the context of northern Alaska and the arctic as a whole.

2.0 SUPPORT

2.1 Direct Support

Direct support provided by Toolik GIS includes many types of specific services; no two examples are exactly alike. Each instance generally includes one or more of the following major categories: 1) data development, 2) spatial analysis, 3) logistical support, 4) statistical summary and 5) production of maps/graphs/tables/figures for talks/reports/publications. Direct support is usually initiated by request from a Toolik-based researcher or administrator, and addresses particular needs of a given project or a specific management issue. The following examples for FY2006 illustrate typical direct support requests.

2.1.1 Science

Lake & watershed statistics/metrics: Upper Kuparuk

Marc Stieglitz (Georgia Tech.) has been working on linking field data with climate models and observations to gain a better process-based understanding of climate change. His efforts include the need for statistical summaries and metrics for lakes and watersheds in the Upper Kuparuk River basin, just east of Toolik Field Station.

This request was filled within a several hour period on the same day as requested, leveraging pre-existing TFS GIS framework data, and custom on-the-fly spatial analyses specific to Marc's request. This type of request, and the time required to fill it, are typical of the short, simple requests that we still frequently address. The response included the following:

. . . The Upper Kuparuk is 132.34km2 using the WERC stream gauge as the pour point. It is located 500m upstream of the Dalton Highway (analysis using Rivertools, D8 algorithm and the 2002 Star3i DEM data).

Within that area, there are 77 small lakes (some of these are very small; the smallest is only 29m x 30m). The lakes comprise 33,288m2 of standing water (USGS National Hydrographic Dataset, NHD). Total lake coverage then comes to 0.025% for that portion of the Upper Kuparuk. . .

Correlation of Landsat spectral data with riparian habitat and isotope signatures in aquatic habitats

Angela Allen (Brown U / MBL) is studying subsidies from riparian vegetation to stream ecosystems. Her work includes classification/characterization of vegetation using remotely sensed imagery, and the relationship between benthic insect communities and the status of riparian habitat and biogeochemistry (as evident in stable isotope signatures). TFS GIS assisted in several ways, with services totaling several days work spread over the course of the field season.

Initially, TFS GIS provided consultation and advice in 1) selecting research sites 2) refining the remote sensing approach, 3) honing site layout within the context of the field work and remote sensing, and 4) collecting, processing, distributing and archiving plot-level spatial data for the research. At each site, a 30m x 30m grid was established in the stream riparian zone. GPS points were collected every 5m to coincide with vegetation samples collected for site characterization, and for correlation with spectral values in Landsat ETM+ imagery, which was provided from the TFS GIS image archive. Deliverables included tabular output, spatial data files and maps.

Bacterial Communities related to sub-watershed characteristics.

Byron Crump (U of Maryland) investigates bacterial community dynamics in the context of spatial proximity within subwatersheds, and in relation to specific characteristics of those subwatersheds.

TFS GIS provided analyses for spatial characterization of these subwatersheds, and developed maps and graphics in support of the project. Nested subwatersheds were delineated based on Dr. Crump's field sampling locations, with summary statistics of landscape variables delivered for each one.

Dr. Crump's ongoing study has taken advantage of these services for several years running, with a continually building dataset of spatial information maintained by TFS GIS.

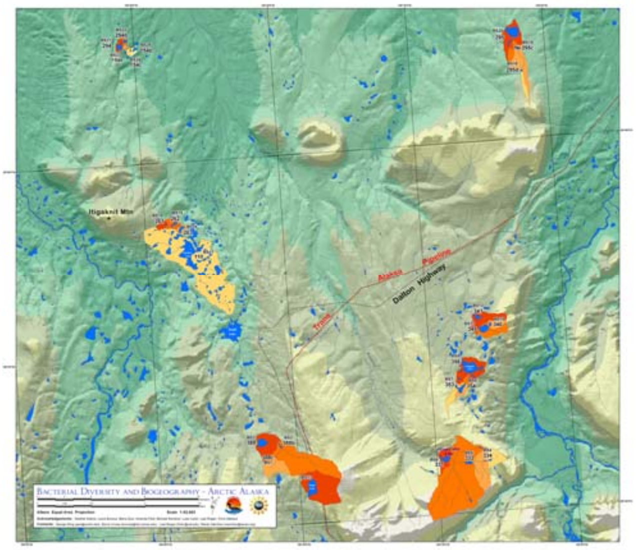


Figure 2. Nested subwatersheds near TFS

Data sharing: Framework & thematic data

Roy Stine (U of North Carolina Greensboro) conducts cooperative research with the Geomorphic Trophic Hypothesis (GTH) project, which identifies links between landscape-level variables and lake trophic structure. He conducts the spatial analyses himself, and needs a Toolik-centric database to support his multivariate analyses. The significance of this example is not how much time it required of our staff (several hours) but that TFS GIS was able to provide several gigabytes of vector and raster data in a convenient, cohesive package, saving the researcher weeks or months of data compilation and processing.

Data included thematic (landform, vegetation, geologic) layers, SAR and optical remotely sensed data, and framework layers (roads, trails, hydrography, topography).

Lake trophic dynamics related with bathymetry

Gretchen Gettel (UNH / Cornell U) studies ecology in lakes, linking benthic community characteristics with lake physical parameters, and with overall lake trophic structure. Part of this research linked lake bathymetry with biological data, and required detailed information on total lake volume above and below specific depth intervals, expressed in a variety of areal and volumetric calculations.

Microsoft Excel - f2_gretchen.xls

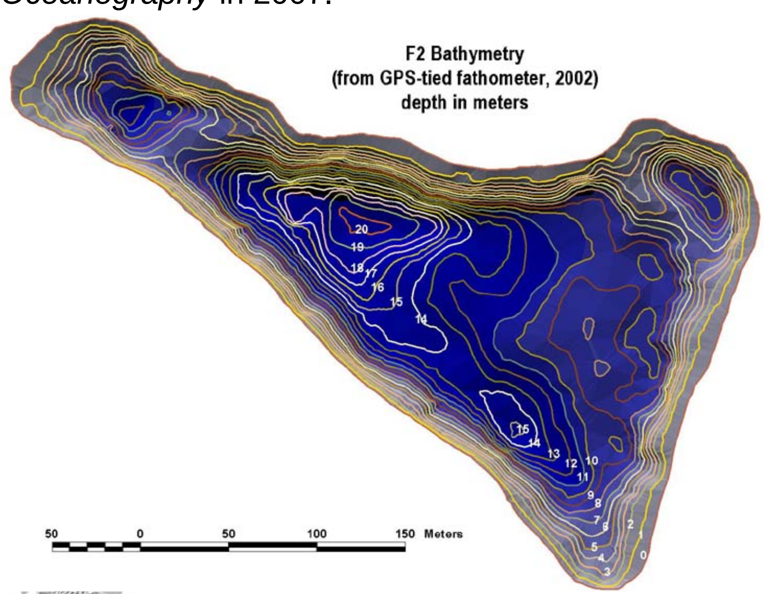
BATHYMETRIC CALCULATIONS FOR LAKE F2

DEPTH (m)	AREA (m2)	AREA Benthos Above (m2)	AREA Benthos Below (m2)	Volume Above Column (m3	Volume Above Strip (m3	Volume Above All (m3)	Volume Above Wafer (m3	Depth Interval (m)
0	0.00	0.00	56561.57	0.00	0.00	0.00	0	n/a
1	5293.86	5293.86	51267.71	51267.71	5293.86	56561.57	56561.57	0-1
2	3459.21	8753.07	47808.50	95617.00	6918.41	107829.28	51267.71	1-2
3	2517.12	11270.19	45291.38	135874.13	7551.37	155637.78	47808.50	2-3
4	2422.15	13692.34	42869.23	171476.92	9688.59	200929.16	45291.38	3-4
5	2458.28	16150.62	40410.95	202054.76	12291.39	243798.39	42869.23	4-5
6	2790.98	18941.60	37619.97	225719.82	16745.89	284209.34	40410.95	5-6
7	2841.05	21782.65	34778.92	243452.43	19887.35	321829.31	37619.97	6-7
8	2798.84	24581.49	31980.08	255840.62	22390.74	356608.23	34778.92	7-8
9	5205.27	29786.76	26774.81	240973.29	46847.40	388588.31	31980.08	8-9
10	5790.58	35577.34	20984.23	209842.30	57905.80	415363.12	26774.81	9-10
11	4095.37	39672.71	16888.86	185777.46	45049.07	436347.35	20984.23	10-11
12	3331.86	43004.57	13557.00	162683.94	39982.38	453236.20	16888.86	11-12
13	3225.23	46229.81	10331.76	134312.91	41928.03	466793.20	13557.00	12-13
14	3253.01	49482.82	7078.75	99102.53	45542.14	477124.96	10331.76	13-14
15	2310.04	51792.86	4768.71	71530.66	34650.62	484203.71	7078.75	14-15
16	1169.68	52962.54	3599.03	57584.49	18714.88	488972.42	4768.71	15-16
17	828.54	53791.08	2770.49	47098.34	14085.18	492571.46	3599.03	16-17
18	832.96	54624.04	1937.53	34875.48	14993.35	495341.95	2770.49	17-18
19	968.97	55593.01	968.56	18402.56	18410.44	497279.47	1937.53	18-19
20	775.70	56368.71	192.86	3857.21	15513.91	498248.03	968.56	19-20
21	192.86	56561.57	0.00	0.00	4049.97	498440.79	192.86	20-21
TOTAL	**56561.57**					**498440.79**	**498440.88**	

NOTES: A) "AREA (m2)" is the same as area between contours, and is area above that contour line

Figure 3. Areal and volumetric data for Lake F2, derived from spatial analyses of detailed bathymetric data.

TFS GIS processed and analyzed detailed bathymetric data (collected in 2002 in cooperation with John Bonde of the University of Minnesota) to develop the desired metrics for five different lakes in the Toolik region. The results were provided in a series of tables with documentation. Further support included production of maps and figures culminating in publication in *Limnology & Oceanography* in 2007.



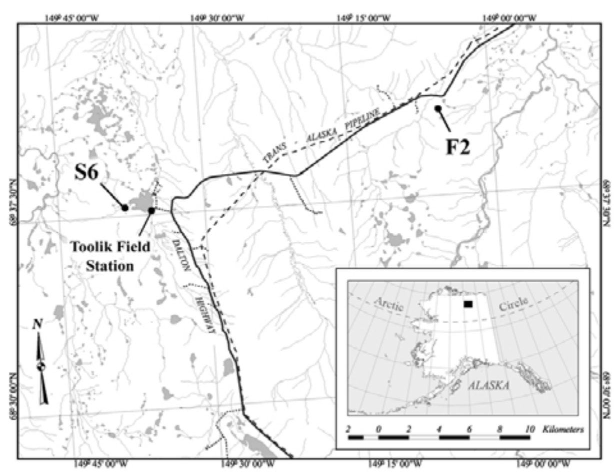


Figure 4. Lake F2 shown with shaded bathymetry and labeled isopleths. Figure 5. Study map for publication.

2.1.2 Administration & Management

Facility and infrastructure support

A suite of science support services for Toolik are provided annually through contracts to VECO. Spatial data and mapping are frequently essential to enhance their efficiency and effectiveness. In this example, VECO planned to add several hundred meters of boardwalk to support Arctic LTER terrestrial research. The volume and weight of building material favored late winter operations; moving supplies and building segments while snow cover permitted snowmachine use. TFS GIS provided coordinate locations and routes with accompanying maps to ensure the boardwalks arrived in the correct locations, and that no research plots were compromised in the transport and construction process. This request required airphoto and infrastructure data developed and maintained by TFS GIS, as well as reference to the comprehensive GeoDatabase of Toolik-based research plots, which tracks the location of all known research emanating from Toolik Field Station.

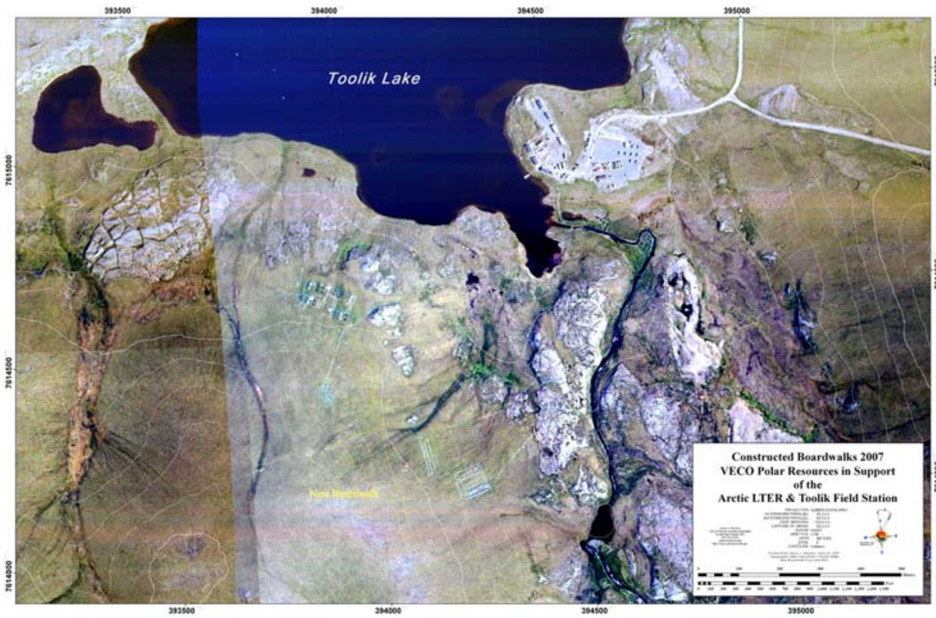


Figure 6. Map of new boardwalk area, VECO, 2007.

Landscape-level Science Planning

Background

Continued expansion of planning and logistical requirements at Toolik Field Station reflects the site's evolution from a seasonal tented camp to a year-round, full-service science facility. Wise and responsible spatial distribution of research activities has become a significant category within this planning function. The integrity of the landscape is a critical characteristic to maintain Toolik's status as a flagship arctic research station. It is in everyone's best interest to ensure that there are no inappropriate co-locations of research, and that projects with natural synergies can be easily identified and coordinated for maximum mutual benefit. While an informal approach to landscape use for scientific research has worked very well in the past, the current number of users and expanding scope and scale of research necessitates a more formal, transparent, and information-intensive approach.

A recent example illustrates the nature of the growing need. In 2005 three different investigators, each with over ten years experience at Toolik, inadvertently co-located research in Moist Acidic Tundra near the station. While each is quite familiar with the others' research, it was unclear that one of them had been using the area as control, and that his research would suffer compromise should that area sustain scientific manipulation.

Three key points derive from this example: 1) control areas are required for many projects, 2) research expansion without comprehensive, community-based planning will result in the eventual loss of suitable control areas, and 3) even the most seasoned Toolik researchers cannot be expected to keep abreast of their colleagues' research sites without help from an updated, centralized information resource of plot locations and characteristics.

The Planning Process: Status and Future

In anticipation of such needs, groundwork for the information resource began in 2001 with the systematic collection of GPS data for field sites of all Toolik researchers. An ongoing process, the GeoDatabase now contains over 14,000 records. While the database alone has been helpful, the intellectual investment of informed scientists is what creates an invaluable tool from objective data.

Toolik Landscape Planning Meeting

In November/December 2005, TFS GIS called, scoped and developed a meeting subsequently held in conjunction with the annual LTER March Meeting in Woods Hole, MA. A dozen senior scientists met with staff and administrators to lay initial groundwork for a formal planning process, and identified several key steps in this, its first iteration.

Results

11 critical watersheds were delineated by that group (including some possible control areas), and maps / data about those areas and the research they contain were made public. With the support of the U.S. Bureau of Land Management (the landowner) new requests for research permits will cross-reference this information to flag potential conflicts and synergies. When necessary, proposed sites will be reviewed in a transparent manner by the Landscape Advisory Panel and either be granted approval or offered reasonable alternatives.

It was also agreed that future meetings should specifically address dormant sites, and more honed criteria for identifying new critical watersheds in the future.

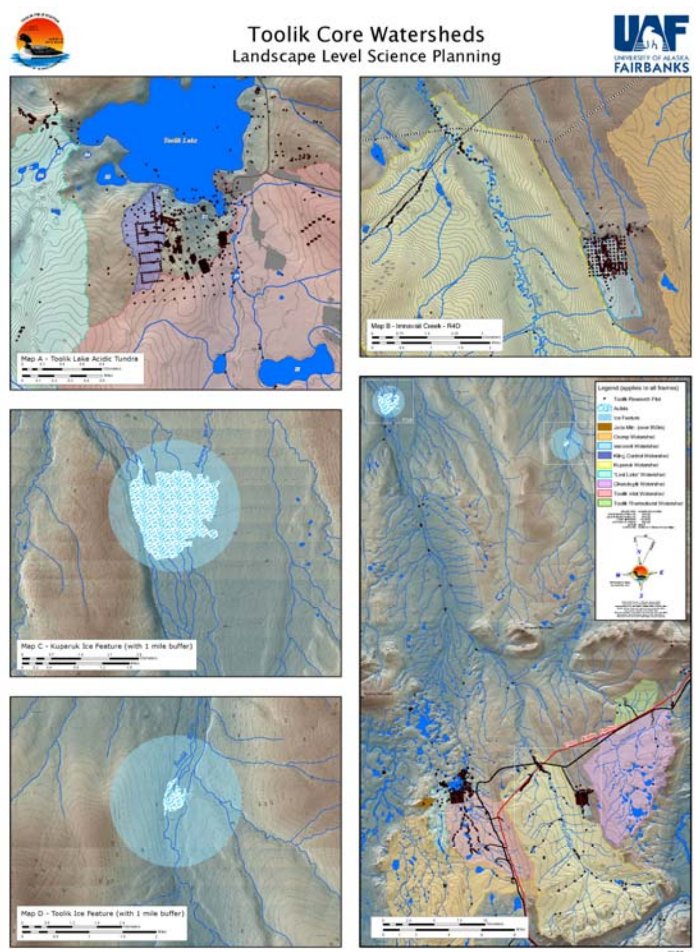


Figure 7. Toolik Core Watersheds Primary and inset maps. This is posted at Toolik Field Station for on-site reference and discussion

The first test came in the summer of 2006, when a new snow fence project requested sites near the station. A series of digital maps of research from the plots database in that area were distributed to the researcher, to BLM, to IAB, and to the Landscape Advisory Panel. The requested site was deemed disadvantageous for Toolik science, but the group was able to quickly identify an alternative site that is agreeable to the researcher. The entire process transpired in about 13 days, and the situation was considered resolved at the end of that time.

Aside from resolution of the issue at hand, the result of this first test was an assertion that the process was valuable and effective, and that further development should aim toward further streamlining information flow and refining a list of specific guidelines.

Future plans involve use of the Toolik Data Service, including an integrated, targeted tool for research planning to increase the clarity, efficiency and effectiveness of the process. The working title is the Toolik Natural Resource Tool, and it will use a web-interface to summarize and distribute information to Principal Investigators, while cataloguing requests and changes for the Toolik Management Team, BLM, and the Landscape Advisory Panel.

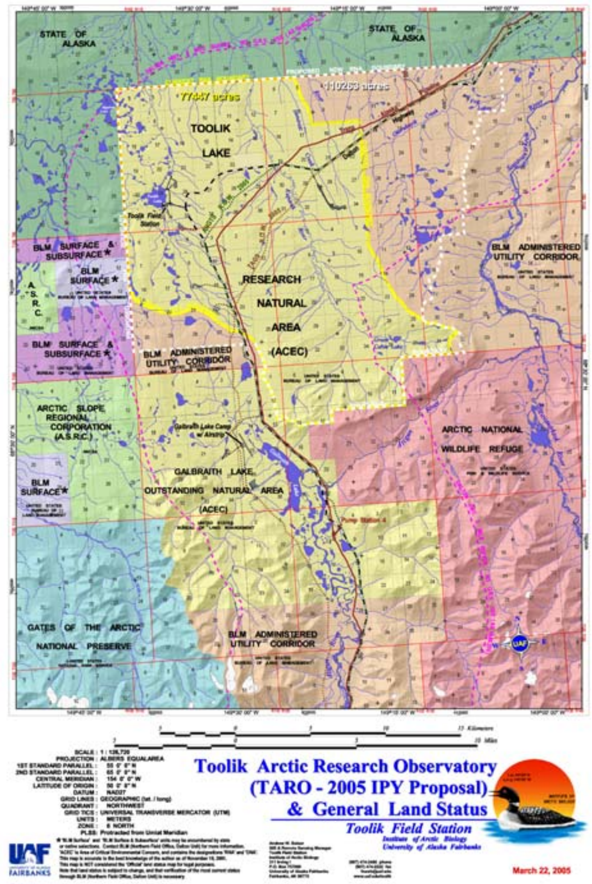


Figure 8. Administrative Boundaries near Toolik Field Station

Oil Spill Containment Sites

The Joint Pipeline Office (JPO) is charged with overseeing Trans-Alaska Pipeline permit, safety, regulation and operational issues, and is comprised of state and federal agency employees who serve specified terms at the JPO.

Among their responsibilities is oversight of the Oil Spill Containment Sites (OSCS), which are placed strategically along the pipeline corridor to provide emergency response teams the necessary on-site equipment and staging area in the event of a spill or other emergency.

In 2006, the Bureau of Land Management (BLM) realty specialist at the JPO oversaw permits for further development of OSC sites along the Dalton Highway. Activities included upgrading and maintaining pre-existing sites, and adding some new ones. These activities were required for compliance with the Federal Grant that renewed the Trans-Alaska Pipeline (TAPS) right of way in 2003 (effective dates 2004 - 2034). These activities address the Contingency Plan (C-Plan) requirements in that grant.

Characteristics of each site vary depending on the scope of the containment activities that would be required. Some sites simply have a sign. Others are small, flat areas cleared of overstory brush. More developed sites include a helicopter landing pad, a Conex box for storage of response equipment/materials, and they may be used in Alyeska spill response training exercises comprised of up to several dozen people.

Some of these sites are in or near core Toolik research areas. We have been fortunate that JPO, BLM & Alyeska all consider Toolik science an important activity on the north slope, and they are willing to consider impacts of these activities in their planning and implementation.

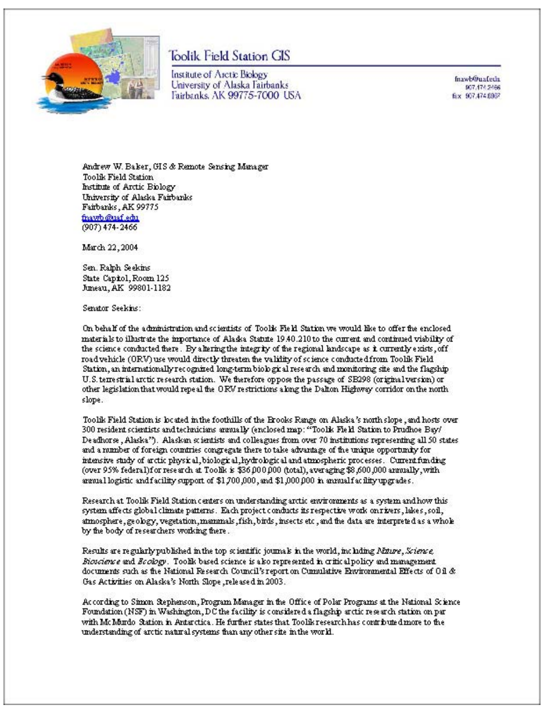
TFS GIS was contacted in October 2006 to help coordinate information relating these existing and proposed sites with current research locations, and to identify any potential consequences on Toolik science of OSCS development or of proposed training exercises. In response, TFS GIS created a webpage with background information, maps and contacts, and initiated an e-mail discussion of possible impacts. Comments and observations were compiled, and the results forwarded to Patricia Perry of BLM/JPO. These were included in their documentation and considered in the development plan.

For more information: http://www.uaf.edu/toolik/gis/TFS_GIS_JPO_Mitigation.html

Legislative testimony (Alaska Senate Bills 298 & 85)

The utility of comprehensive spatial information extends beyond typical science, administration and management functions. It can also help frame discussions germane to legislative proposals impacting natural resources. In 2004 and 2005, bills were presented in the Alaska legislature promoting the repeal of Alaska Statue 19.40.210. AS 19.40.210 prohibits general use of off-road vehicles (ORVs – to include ATVs and snowmachines) within a five mile wide strip along the Dalton Highway corridor north of the Yukon River bridge.

Toolik Field Station is a rare node within that corridor; a location where information of distinct societal value is produced, and for which there is a great deal of empirical information on the landscape and on the research conducted there. As such, Toolik Field Station had the opportunity to provide significant factual information to help inform the debate on these bills. TFS GIS participated directly by A) authoring open letters to legislative committee members, and B) offering oral testimony at legislative committee hearings.



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March 22, 2004

Sen. Ralph Seekins
State Capitol, Room 125
Juneau, AK 99801-1182

Senator Seekins:

On behalf of the administration and scientists of Toolik Field Station we would like to offer the enclosed materials to illustrate the importance of Alaska Statute 19.40.210 to the current and continued viability of the science conducted there. By altering the integrity of the regional landscape as it currently exists, off road vehicle (ORV) use would directly threaten the validity of science conducted from Toolik Field Station, an internationally recognized long-term biological research and monitoring site and the flagship U.S. terrestrial arctic research station. We therefore oppose the passage of SB298 (original version) or other legislation that would repeal the ORV restrictions along the Dalton Highway corridor on the north slope.

Toolik Field Station is located in the foothills of the Brooks Range on Alaska's north slope, and hosts over 300 resident scientists and technicians annually (enclosed map: "Toolik Field Station to Prudhoe Bay/ Deadhorse, Alaska"). Alaskan scientists and colleagues from over 70 institutions representing all 50 states and a number of foreign countries congregate there to take advantage of the unique opportunity for intensive study of arctic physical, biological, hydrological and atmospheric processes. Current funding (over 95% federal) for research at Toolik is $36,000,000 (total), averaging $8,600,000 annually, with annual logistic and facility support of $1,700,000, and $1,000,000 in annual facility upgrades.

Research at Toolik Field Station centers on understanding arctic environments as a system and how this system affects global climate patterns. Each project conducts its respective work on rivers, lakes, soil, atmosphere, geology, vegetation, mammals, fish, birds, insects etc, and the data are interpreted as a whole by the body of researchers working there.

Results are regularly published in the top scientific journals in the world, including *Nature*, *Science*, *Bioscience* and *Ecology*. Toolik based science is also represented in critical policy and management documents such as the National Research Council's report on Cumulative Environmental Effects of Oil & Gas Activities on Alaska's North Slope, released in 2003.

According to Simon Stephenson, Program Manager in the Office of Polar Programs at the National Science Foundation (NSF) in Washington, DC the facility is considered a flagship arctic research station on par with McMurdo Station in Antarctica. He further states that Toolik research has contributed more to the understanding of arctic natural systems than any other site in the world.

Figure 9. Letter to Sen. Ralph Seekins, 2004

While not specifically supporting or opposing the proposed legislation, the policy of Toolik Field Station and IAB administration was to express clear and detailed concerns regarding impacts of ORV use on tundra environments. These concerns were expressed with description of the location, density and scope of research efforts surrounding Toolik Field Station, in the context of quantified land cover and aquatic resources, and in reference to prior studies published on the effects of ORVs on these environments.

Testimony recorded by KTOO's 'Gavel to Gavel' (Balser testimony begins at minute 49:40):
http://www.uaf.edu/toolik/gis/SB298_3_09_2004.mp3

Contributed letters and ORV impact references:
http://www.uaf.edu/toolik/gis/SB298_open_letter.pdf
http://www.uaf.edu/toolik/gis/SB85_Jones_letter.pdf
http://www.uaf.edu/toolik/gis/ORV_refs.pdf

2.2 Indirect Support

Responsive functionality for the Toolik community requires TFS GIS to pay substantial attention to continued acquisition, ingest and maintenance of primary framework data, and to the update and expansion of critical infrastructure – primarily equipment. In addition, continued trends toward interlinking of data, research, and information distribution on the north slope, statewide, and beyond, underscore the importance of continued active participation in state and regional initiatives and scoping meetings developing Arctic Spatial Data Infrastructure (ASDI). Below are some examples of TFS GIS activities/involvement that do not address any one project or research question in particular, but instead maintain the program's ability to remain current, responsive, well-informed, and efficient.

2.2.1 Data

The term 'framework data' refers to data used for a large percentage of projects regardless of scope or discipline. These include transportation, hydrography, topography, landcover, administrative boundaries etc. Some of these data sets are relatively immutable (e.g. hydrography), while others can change substantially within a few years (e.g. administrative boundaries or transportation). In some cases more accurate versions become available with technological improvements (e.g. topography, landcover). For a variety of reasons, periodic update and ingest of these framework layers is necessary to keep the program current and responsive. The following examples describe some of the framework layer development undertaken during FY2006.

Airphotos

A series of airphotos, representing a framework information layer in the Toolik GIS database, were acquired, processed and incorporated into the GIS in 2007. These are repeat photos flown with the same specifications as the 2002 originals. They are part of a plan to provide synoptic information on changes to landscape features, vegetation, aquatic resources, research sites, facilities and infrastructure for the Toolik community. The vision is to continue this service on a five year interval. It is likely that the next acquisition, in 2012, will take advantage of rapidly expanding capabilities of satellite-based, digital imagery rather than airphotos. Satellite-based sensors do not currently offer adequate spatial resolution, and are not yet cost effective to cover the suite of primary research areas surrounding Toolik Field Station.

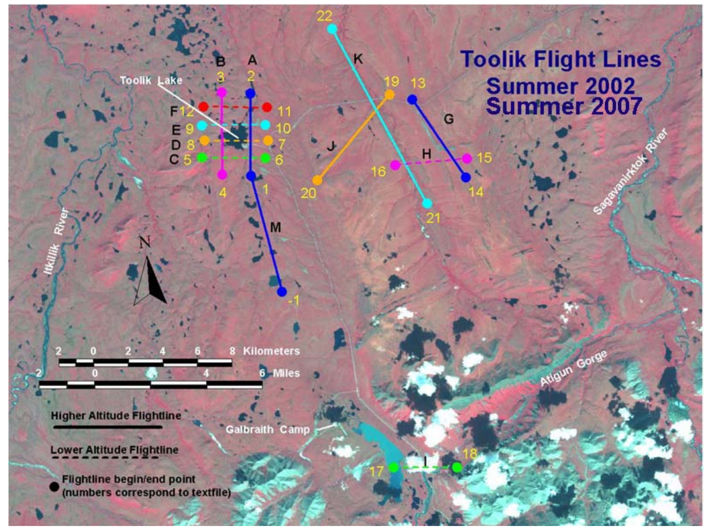
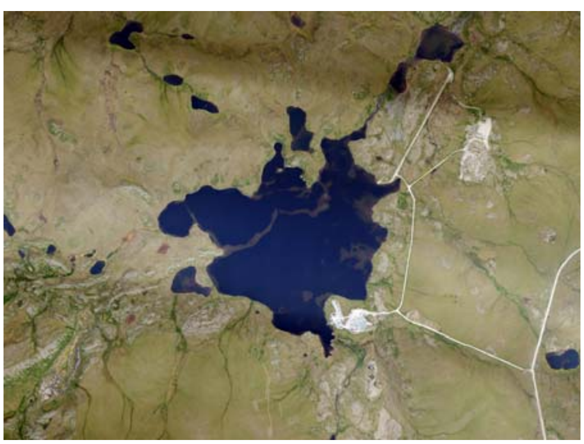


Figure 10. Airphoto Flight Lines, 2002 and 2007.

For comparison, the airphotos flown in 2002 and 2007 in cooperation with Terraterpret Inc. cost less than $7000.00, and delivered 20cm to 50cm pixel resolution in digital real color. The best available satellite-based platform would deliver digital imagery with 160cm color/color-ir, and 40cm black and white resolution. While the resolution of the satellite imagery is comparable, the cost of roughly $25,000.00 for the same coverage area is not. However, high-resolution satellite systems are evolving very quickly, and it is our expectation that in 2012 the cost and quality of the satellite-based options will out-compete the capabilities of digital aerial photography for this application.



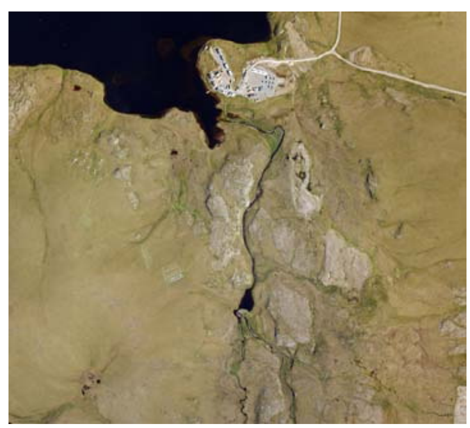


Figure 11. Mosaic of 24 frames from 2 flight lines covering the area around Toolik Lake. Photo mosaic is rectified with accuracy to ~2m in ground coordinates.
Figure 12. Closeup of Toolik Field Station and the Moist Acidic Tundra terrestrial study area and part of the aquatic Inle Series south of Toolik Lake.

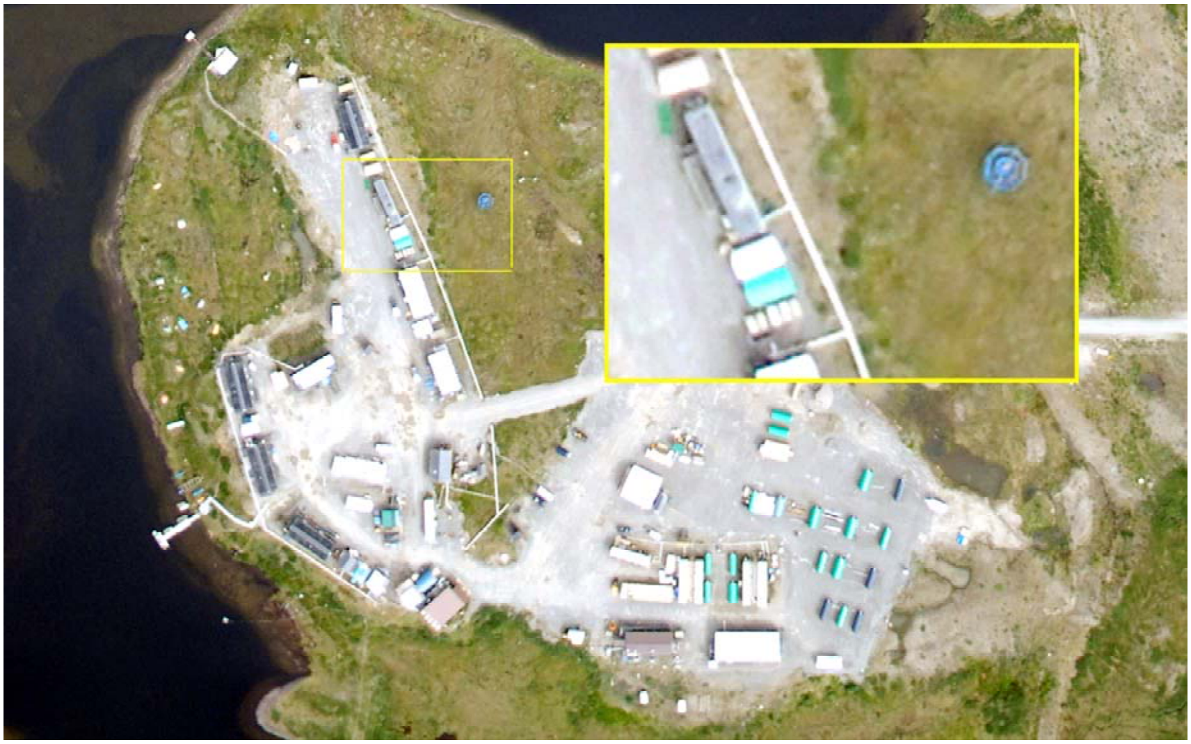


Figure 13. Closeup of Toolik Field Station, 2007. Inset shows full resolution of the image.

National Hydrography Dataset (NHD)

The National Hydrography Dataset is an example of a next-generation, comprehensive GeoDatabase produced by the US Geological Survey and distributed by web interface. It is based on the original 1:63,360 scale USGS map quadrangles, but the data from the separate quad sheets has been assembled and integrated on a per-catchment basis, and edited for spatial consistency, attribute accuracy and analytical capability. This represents an enormous improvement over the NHD's predecessor datasets.

The NHD is a typical example of invaluable data that support TFS GIS capabilities, but that must undergo significant additional processing to be of most use within the existing TFS GIS database. A great deal of attribute and spatial enhancements have been added to Toolik hydrographic information by TFS GIS since 2001. These enhancements (e.g. tightly GPSed lake margins, additional naming of lakes and stream reaches to include terms used by TFS researchers) must be added to provide the functionality necessary for dynamic use by TFS GIS. This processing, while initially tedious, vastly improves the response time to incoming requests, and the capacity to generate rich information from analyses.

For more information:
http://nhd.usgs.gov/

2.2.2 Infrastructure

As with framework data, key infrastructure must remain current for the program to operate effectively. In part, this simply involves computer hardware, software and peripherals; needs common to all professions which rely on modern technology. There are two categories, however, which warrant mention outside of the Upgrades section of this report: 1) High-precision GPS and 2) Internet map service.

GPS

High precision GPS capabilities have become a fundamental component of multidisciplinary arctic science. Studies looking at biotic and abiotic processes, and ranging from terrestrial to aquatic environments to include gradients in between have made extensive use of survey and mapping grade GPS technology at Toolik Field Station. Some examples include stream channel morphology (Oatley, WERC/UAF), impacts of stream bed change dynamics on benthic ecology (Peterson, MBL), active layer and permafrost dynamics (Nelson, U Delaware), plot-level community composition/dynamics (Walker, AGC/UAF), and thermokarst feature development and impacts to aquatic systems (Bowden, UVM).

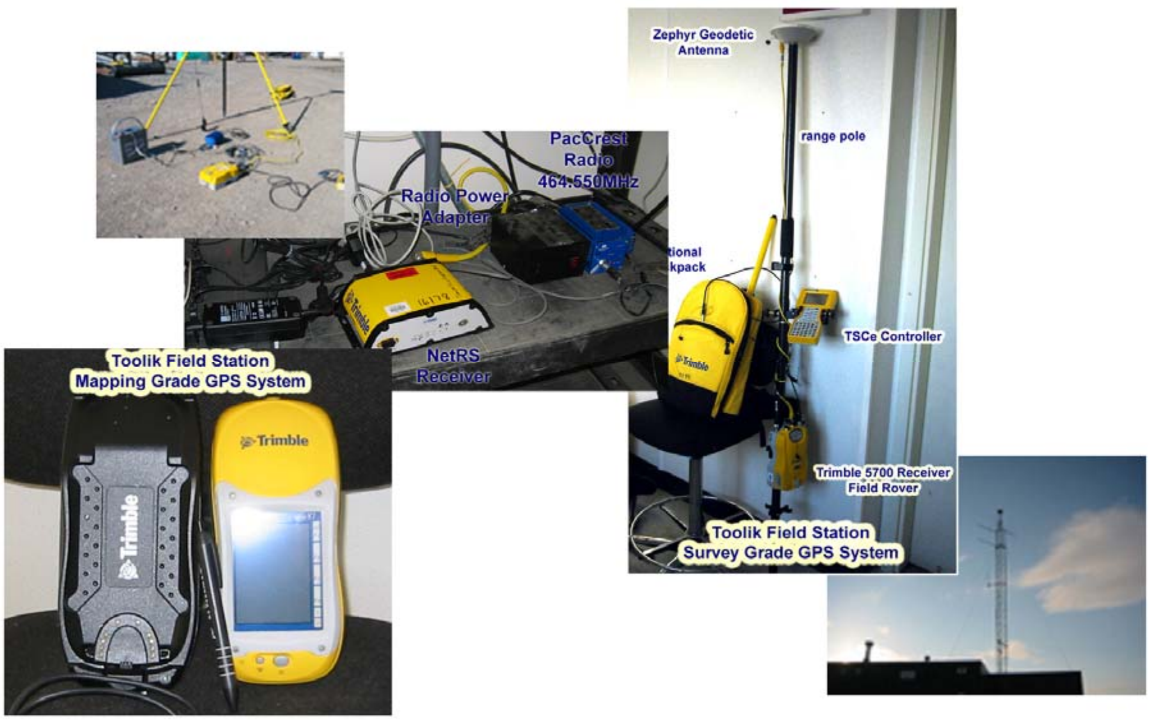


Figure 14. Toolik Field Station GPS equipment – Permanent Base Station, Mobile Base Station, Survey & Mapping Grade rover units, real-time corrected (RTK): accuracy ranges from 2m to 5mm depending on survey style.

GPS precision and capabilities vary greatly depending primarily on two things: 1) distance from a reliable GPS base station or base network, and 2) particular survey style used in the field. The impact of the survey style is simple; the longer a stable GPS unit collects data for a given point, the more accurate the coordinate result. The dichotomy, then, is deciding between longer GPS occupations for accuracy and shorter GPS occupations for efficiency in the field. One way to improve the accuracy while reducing the necessary occupation time is to collect data with a nearby GPS base station. This allows either 1) real-time corrected (RTK) positioning, which is highly efficient, or 2) more accurate results from post-processed (PPK) positioning techniques.

In all cases, the capacity to operate with a nearby base station improves both accuracy and efficiency. To this end, TFS GIS has acquired and configured a survey-grade mobile base station GPS unit that can be easily deployed at any field site to which a 25lb utility box can be carried/driven/flown. To support the use of the mobile base, TFS GIS is also developing a network of very tight (sub-centimeter) accuracy ground control benchmarks, upon which the mobile base can operate. These control benchmarks are 1) from pre-exisiting benchmarks (NGS, USGS, BLM) on which TFS GIS performs a long-term GPS occupation and processing to determine a highly accurate, updated coordinate, and 2) control benchmarks installed by TFS GIS.

For more information on TFS GPS capabilities:
http://www.uaf.edu/toolik/gis/TFS_GIS_gps.html

For more information on equipment and accuracy specifications:
http://www.uaf.edu/toolik/gis/TFS_GIS_gps_equipment.html

For a current list of TFS GIS updated benchmarks:
http://www.uaf.edu/toolik/gis/TFS_GIS_gps_base.html#control

TFS GIS also helps develop best practices and standards for high-precision GPS campaigns, particularly for the non-traditional survey applications that are common at Toolik Field Station, and are becoming common in research and landscape management in general. In 2006, we co-authored a Best Practices Guide with several colleagues in the public and private sectors. This guide was unveiled at the 2007 Alaska Surveying and Mapping Conference's GIS Jam, and is available on the web through the TFS GIS website:

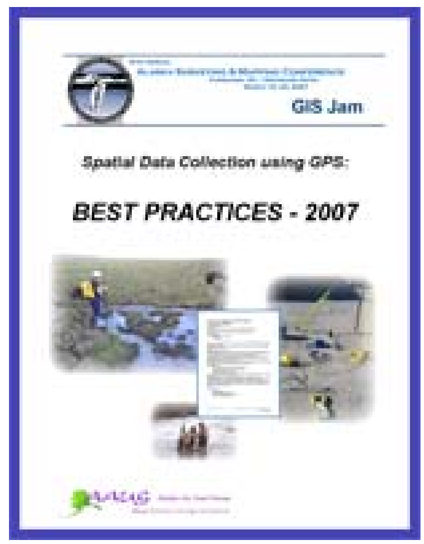


Figure 15. GPS Best Practices – 2007.
http://www.uaf.edu/toolik/gis/GPS_BestPractices_2007.pdf

High-Precision GPS Training

High-precision GPS techniques are more complicated than recreational or mapping grade techniques. More attention is required for field strategy, and the hardware and software are more difficult to set up and to use. To assist researchers who want to use this technology, but who prefer to do the fieldwork largely on their own, TFS GIS has teamed with UNAVCO (http://www.unavco.org/) to offer formal training. Our most recent 3 day course was offered in 2005, covering concepts and methods in detail. Case studies provided the basis for field exercises giving hand-on experience to participants. Response to this course was very favorable, and we anticipate offering this course every two to three years, or on request.

The formal announcement, distributed through the ARCUS 'ArcticInfo' listserv, describes the course goals and structure:

Geospatial Data Acquisition for Polar Research
Survey-grade GPS - Open Training
Fairbanks, AK
April 6 - 8, 2005

An open training course in the use of survey-grade GPS equipment will be held in Fairbanks, AK on the University of Alaska Fairbanks campus. The course is targeted at researchers working at Toolik Field Station (TFS) and the Barrow Arctic Science Consortium (BASC). The training will be conducted by UNAVCO, an NSF-supported facility providing GPS support for NSF funded research.

Survey-grade GPS measurements have augmented science for a broad spectrum of projects at Toolik and Barrow. Disciplines ranging from hydrology to plant ecology, geomorphology, geophysics and cryospheric research can benefit from high-precision spatial measurements using this technology. TFS and UNAVCO are sponsoring this course in the belief that arctic research science will see prominent benefits from increased awareness and broader application of these capabilities.

The overall goal of the course is to enable the researcher to develop the GPS method appropriate for their research.

The course will cover all phases of a survey project using survey-grade GPS. An initial overview will cover GPS methods and basic survey principles. Then, students will conduct a full GPS survey from start to finish including planning, field work, post-processing, troubleshooting and network adjustment. We will be using Trimble GPS systems similar to those available at TFS and BASC.

The course emphasizes a practical, hands-on approach to field and office sessions throughout. Days one and two of the course will consist of lecture and lab exercises. Day three will be dedicated to field scenarios by request, allowing participants to develop strategies for their own upcoming field work.

The training is appropriate for those with minimal GPS experience but a strong interest in using high-precision GPS measurements to expand or enhance their research.

- Course runs April 6 - 8, 2005 at the UAF campus, Fairbanks, AK
- There is no fee for the course.
- Class size is limited to 10.
- Participants from outside Fairbanks must provide for their own travel, meals and lodging.
- NSF funded personnel will get priority – please include a grant number with your inquiry

Please contact Jim Greenberg at UNAVCO for course registration
Jim Greenberg
UNAVCO
(303) 381-7482
Greenberg@unavco.org

Please contact Andrew Balser at UAF for travel/lodging questions
Andrew Balser
Toolik Field Station, UAF
(907) 474-2466
fnawb@uaf.edu

2.2.3 ToolikMapEngine

The ToolikMapEngine is an internet map service providing spatial and tabular information for Toolik based research, and for the surrounding landscape including basic thematic coverage for the north slope. ToolikMapEngine was conceived and engineered as a pilot project for the Toolik Data Service, a more comprehensive data delivery portal including non-spatial as well as spatial information, and developing targeted tools as Decision Support Systems (DSS). For more information on the Toolik Data Service concept, please see section 3.2, Program Development: the Next 5 Years in this report, and the section on Data Management in Bret-Harte et al., 2006.

ToolikMapEngine was designed cooperatively with the Geographic Information Network of Alaska (GINA) at the UAF Geophysical Institute, and is based on the ‘Chameleon’ implementation of the University of Minnesota’s ‘Map Server’ technology. As a pilot, its purpose was threefold: 1) establish a solid working relationship with GINA, 2) provide key landscape information in a fully-accessible and dynamic format, and 3) allow the Toolik community to get used to accessing information about Toolik through a web service. Implicit is the additional goal of using it as a straw-man during development of more sophisticated and linked services for the Toolik Data Service. Having this tool will allow the broad Toolik community to consider the types of information, presentation, and value-added analyses that would be most useful early on.

Though developed as a pilot, the utility of this service extends well beyond scoping purposes. The original intention to incorporate it as a permanent component of the Toolik Data Service remains, and it will continue to undergo periodic update as new plots are added to the body of Toolik research, as new landscape-relevant data sets become available, and as the delivery technology evolves.

ToolikMapEngine: http://www.uaf.edu/toolik/gis/ToolikMapEngine_Intro.html

Figure 16. ToolikMapEngine entry page and interface.

2.3 Comprehensive Project Participation

Aquatic Biodiversity, Community Composition and Ecosystem Processes in the Noatak Basin - In cooperation with the National Park Service Inventory & Monitoring Program (2005 – 2008)

Landscape characteristics at the catchment level are presumed to exert a strong influence on the chemical, physical and biological properties of lakes and streams. Toolik Field Station GIS is part of a collaborative effort to link field measurements of streams and lakes with synoptic landscape data to determine the nature and strength of relationships between the landscape and aquatic resources. This project leverages intensive work at Toolik against an extensive sampling regime beyond Toolik to enhance our regional understanding of relevant ecosystem processes and their variability.

Extrapolation of aquatic research includes comparisons with the Noatak basin, which acts as a large ecotone between arctic and boreal regions. Landcover percentages, stream and lake density, average slope and aspect and landscape surface age are among the variables summarized by catchment (defined as the upstream watershed from each specific sampling location).

Landscape data are drawn from pre-existing sources (USGS, NPS), from remotely sensed data (Landsat, SAR, airphotos) and from ground truth collected concurrently with aquatic sampling. Products will include peer-reviewed publications, agency reports (NPS), and digital datasets. The initial report from 2005 fieldwork (Bowden et al., 2006) and analyses was submitted in early 2007. Project completion is 2008.

http://www.uvm.edu/~wbowden/Research/Current_Projects/Arctic_Parks/Noatak_Frameset.htm
http://www.nature.nps.gov/im/units/arcn/project_detail.cfm?projectid=1

Stream characteristic	Landscape parameter	p	intercept	slope	r^2	obs.
Conductivity	Linear Regression					
EC (µS/cm)	Stream Density (km/km^2)	0.0074	-44.3061	789.2939	0.3525	19
	Total Stream Length (km)	0.0112	322.891	0.8628	0.3227	19
	Subwatershed Area (km^2)	0.0168	317.494	0.58441	0.2925	19
	Mean Subwatershed Slope (deg.)	0.0056	-302.835	24.31924	0.3716	19
	Barren Area (km^2)	0.0048	320.999	1.5837	0.3823	19
	Multiple Regression					
	Model	0.0295	8.8335		0.5138	19
	Stream Density (km/km^2)			457.678		
	Subwatershed Area (km^2)			0.7654		
	Mean Subwatershed Slope (deg.)			4.4919		
	Barren Area (km^2)			2.584		
Nitrates	Linear Regression					
NO_3 (µM)	Stream Density (km/km^2)	0.0479	10.91104	-6.47875	0.2229	18
Dissolved Organic Nitrogen	Linear Regression					
DON (TDN-NO_3)	Mean Subwatershed Slope (deg.)	0.0288	12.48394	-0.32113	0.265	18
	Vegetated Percentage	0.0054	-3.5768	0.1069	0.393	18
	Shrub Tundra Percentage	0.0044	-0.5325	0.2502	0.4069	18
	Shrub Tundra Area (km^2)	0.676	3.356	0.0143	0.0112	18
	Multiple Regression					
	Model	0.0097	5.085		0.4609	18
	Mean Subwatershed Slope (deg.)			0.1662		
	Shrub Tundra Percentage			0.199		

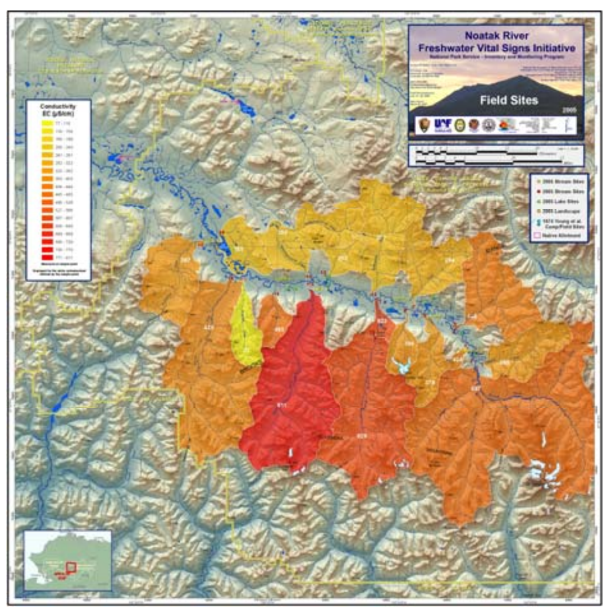


Table 1. Significant Relationships Among Landscape Parameters and Stream Characteristics (2005 data)
Figure 17. Stream Conductivity by Subwatershed (as defined by field sampling point) (2005 data)

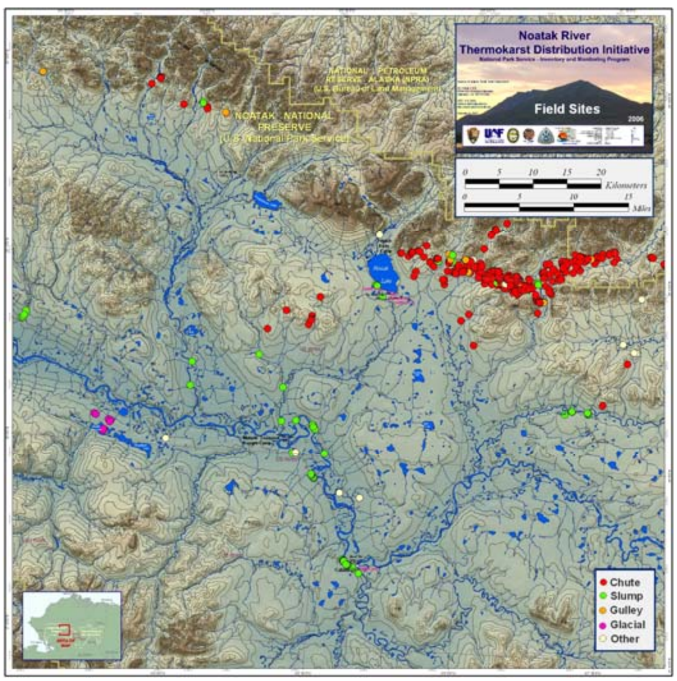
Thermokarst Distribution & Characterization in the Noatak Valley - In cooperation with the National Park Service Inventory & Monitoring Program (2006 – 2008)

This project is focused on landscape-level distribution and classification of thermokarst features in a gradient from the arctic foothills (Toolik) to the interior foothills of the Brooks Range. In 2003, a new thermokarst formed near Toolik Field Station after a heavy rain on August 12. As a new feature of known origin, it provided a unique opportunity to monitor thermokarst development from initial stages. Toolik GIS used survey-grade GPS to develop a surface model of the feature, which is updated annually.

A larger project ensued examining thermokarst distribution, chemistry and physical characteristics in the Toolik area and in the Noatak basin, and considering their impact on aquatic resources, hydrology and geomorphology. Toolik GIS is classifying thermokarst types and relating them to landscape characteristics, mapping their past and present distribution using satellite imagery and historic airphotos, and developing physical metrics for each thermokarst.

Products include refereed publications, a digital database of thermokarst distribution and characteristics, maps and figures and agency reports. Estimated project completion is 2008.

http://www.engr.psu.edu/mgooseff/tkarst_proj.html
http://www.uaf.edu/toolik/gis/tk/
http://www.nature.nps.gov/im/units/arcn/project_detail.cfm?projectid=4



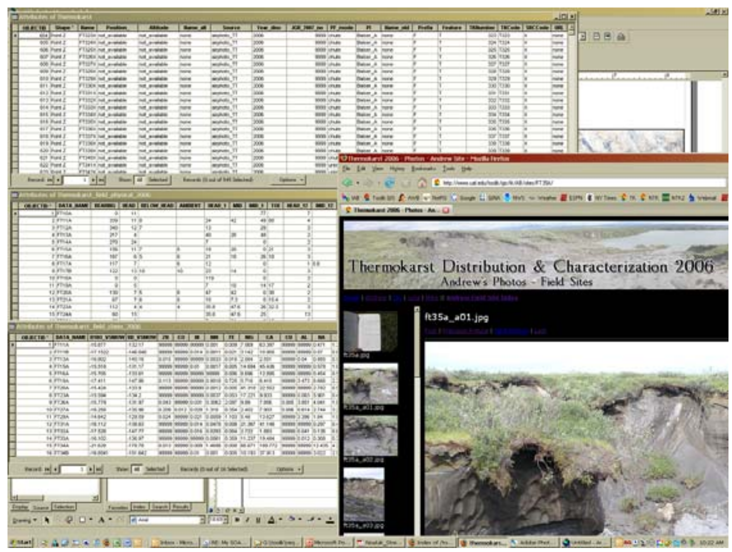


Figure 18. Thermokarst Distribution by type, Feniak Lake area (2006 data).
Figure 19 Selected tables from Comprehensive Thermokarst GeoDatabase (2006 data).

Landscape assessment of Arctic soil carbon in relation to vegetation, surface moisture and freeze-thaw regimes for the International Polar Year – in cooperation with NASA/JPL, U. of Montana and the USGS (not funded)

Though ultimately not funded, this proposal to IPY through NASA-ROSES in 2006 provides another good example of the type of project participation Toolik Field Station GIS has been asked to provide.

The goal of this project was to develop detailed mappings of soil organic carbon pools and surface moisture and freeze/thaw regimes centered around and extending from Toolik Field Station. An intensive field campaign would collect detailed metrics of soil and vegetation conditions, to be linked with ALOS and RADARSAT SAR data for the creation of multi-temporal moisture and freeze-thaw regime maps. These results would be analyzed against existing landscape data to include vegetation, soils, topography, landforms, hydrology, geology and geomorphology. The results would drive a better process-based understanding of soil moisture, temperature and carbon dynamics at the landscape scale, and provide the basis to extend the mapping process across transects along the north slope and into interior Alaska.

The role of Toolik GIS was to participate in scoping and proposal preparation, perform GIS analyses linking results of the SAR/field analyses with existing spatial data, develop summary statistics and results and author the corresponding sections of publications.

Obtaining baseline data to assess the potential for tree-line and shrub-line advance in Gates of the Arctic Park and Preserve and Noatak National Preserve - In cooperation with the National Park Service Inventory & Monitoring Program (2006 – 2008)

from the initial proposal, submitted by Dr. Syndonia Bret-Harte & Dr. Martin Sommerkorn:

"*In order to better understand the potential for shrub expansion and tree-line advance in much of GAAR and NOAT, we propose a baseline inventory to identify tree and shrub distributions, and to identify those areas that are most susceptible to tree-line advance or shrub expansion. We will identify the current positions of tree-line and shrub boundaries using high-resolution aerial photography. We will assess the susceptibility of tree and shrub boundaries to change through ground measurements. On the ground, we will characterize the vegetation, plant diversity, and associated small-scale topography, hydrology, and soil properties along altitudinal and ecotonal gradients within the Noatak Basin. The ground studies will be conducted at sites accessible from the Noatak River. By combining information from the*

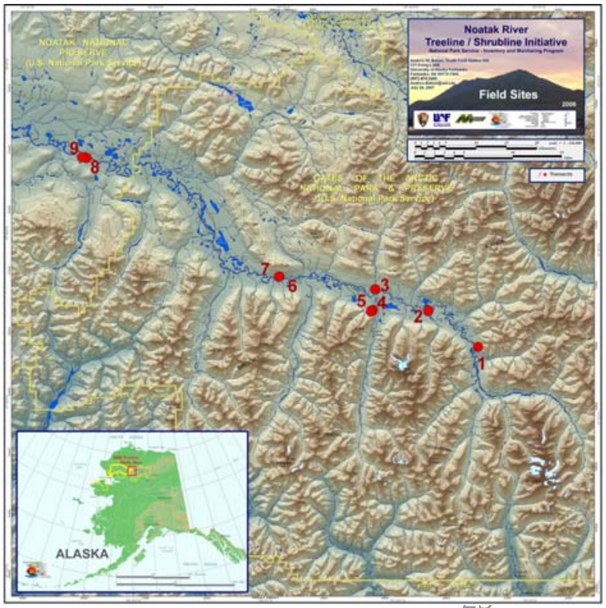


Figure 20. Tree-line & Shrub-line field sites, 2006.

photographs with ground measurements, we will document current tree and shrub distributions and identify areas throughout GAAR and NOAT that are potentially sensitive to tree-line advance or shrub expansion. This work, in collaboration with NPS personnel, will provide baseline data for possible future monitoring of shrub expansion and tree-line advance in GAAR and NOAT."

Toolik Field Station GIS lent GPS, airphoto, mapping and field expertise to the team, and contributed to the planning of the field effort.

http://www.nature.nps.gov/im/units/arcn/project_detail.cfm?projectid=5

The Arctic Geobotanical Atlas: a Heirarchical Geographic Information System

The Arctic Geobotanical Atlas (AGA) consists of a hierarchy of maps and supporting information from the circumpolar scale down to maps of 1 m^2 plots. It includes a diversity of geobotanical themes (geology, topography, landforms, surficial geomorphology, soils, and vegetation) focused at Toolik Lake and Imnavait Creek, Alaska, but also covers the Kuparuk River Basin, northern Alaska, Arctic Alaska, and the Circumpolar Arctic. The maps were developed during the course of several Component Projects.

This effort is the culmination of multiple projects overseen by the Alaska Geobotany Center (AGC) over the course of several decades. Toolik Field Station is a primary node and component project within this effort. Since 2001, Toolik GIS has been working cooperatively with the AGC to incorporate these rich datasets into a broader Toolik-centric database, and to scope and implement the steps necessary to incorporate them into the AGA in both static map form and as dynamic datasets suitable for web mapping applications.

http://www.arcticatlas.org/
http://www.geobotany.uaf.edu/

2.4 Outreach

North Slope Science Initiative (NSSI)

The North Slope Science Initiative is an inter-agency effort to increase collaboration at the local, state, and federal levels to address research, inventory, and monitoring needs as they relate to development activities on the North Slope. Its mission includes development of comprehensive and robust Spatial Data Infrastructure (SDI) and Decision Support Systems (DSS) in support of its mission. At this time, NSSI is the leading initiative in Alaska (and possibly northern North America) in implementation efforts of SDI for research and management.

The NSSI Science Technical Advisory Panel includes a GIS & Remote Sensing Subgroup, of which Toolik Field Station GIS is a charter member. TFS GIS has attended a number of scoping meetings in Alaska, and actively provided data, insights, and suggestions for structure, scope and implementation. It is our firm belief that NSSI SDI and DSS capabilities will be of direct and marked benefit to the Toolik community as they come online (initial tools scheduled for December 2007). In addition, NSSI participation has greatly extended knowledge and exposure of Toolik Field Station research to the community of federal and state land managers and agencies.

For more information:
http://www.northslope.org/

Alaska Surveying & Mapping Conference: GIS Jam

Each year, the ‘GIS Jam Sessions’ comprise roughly half of the Alaska Surveying & Mapping Conference program. Theme, structure, content, organization, scheduling and sponsor contact are all handled by a volunteer GIS Jam planning committee composed of people in the Alaska GIS community. For the 2007 GIS Jam, Andrew Balser of TFS GIS was specifically asked to serve as the GIS Jam Coordinator, overseeing and arranging all aspects of the Jam. In addition, he was invited to serve as a panelist for a special session discussing technical issues related to high-precision GPS measurement and practical applications in the field.

The information interchange and exposure to others in the GIS community was very helpful for Toolik GIS staff, and allowed our program to contribute insight and expertise that is of direct benefit to the Alaskan GIS community.

To organize the process, TFS GIS developed a website related to GIS Jam planning:
http://www.uaf.edu/toolik/gis/GIS_Jam/

3.0 PROGRAM DEVELOPMENT

3.1 The First 5 Years

The Toolik Field Station GIS & Remote Sensing Program has gone through several phases in its evolution from startup to enterprise GIS. First efforts were designed to lay solid groundwork for responsive services, establish an active working rapport with the entire Toolik community, and position the program as a valuable legacy resource for arctic science and management. The 5 year plan was developed during 2001 while in the startup phase of the program. It was presented to the community at the Arctic LTER annual meeting in Woods Hole, MA in March of 2002.

In simple terms, the goal is to leverage the resources and stability of a program-level enterprise to enable a broad and responsive suite of services, and to deliver these services with the best efficiency and the highest level of quality possible. Activities include full project involvement in scientific research, with assistance in scoping and initial proposal development, to fieldwork, analyses and results, and preparation of final documents and presentation materials.

As of 2007, this first 5 year plan has come to successful completion, culminating in multiple project participation, outreach to agencies and the GIS community, the ToolikMapEngine internet map server, and a continuing suite of services providing direct support through GPS work, data development, analysis, and cartography both at Toolik Field Station and through our offices in Fairbanks.

3.1.1 Conceptual outline of initial 5 Year Plan

Phase I: Startup (2001 – 2002)

A) Acquire equipment, including:
   1) GPS base station / rovers
   2) Computers
   3) Software
B) Assimilate framework data layers, including:
   1) Hydrography
   2) Topography
   3) Infrastructure
C) Provide basic services (small scope)
   1) site selection
   2) field maps
   3) GPS mapping services
   4) Simple analyses
      a) remote sensing
      b) GIS overlay
      c) Summarization / statistics

(continued next page)

Phase II: Base Development (2002 – 2005)

A) Upgrade / enhance equipment
B) Complete framework data assimilation
C) Acquire / archive Toolik specific data, including:
    1) plot locations
    2) thematic data, such as:
        a) vegetation
        b) landforms
        c) geomorphology
        d) glacial geology
    3) airphotos
    4) satellite imagery
D) Outreach to Agencies / other institutions
    1) Federal (BLM / USFWS / NPS)
    2) State (DNR / DOT)
    3) Research (BASC, SEARCH)
    4) Participate in regional and arctic initiatives, such as:
        a) North Slope Science Initiative
        b) Arctic GIS / ASDI
        c) Observing Networks (AON, CEON, NEON)
E) Provide more advanced services (moderate scope)
    1) Publication quality maps / figures
    2) Survey-grade GPS
    3) Data distribution
    4) More involved analyses
        a) synthesis
        b) cross-disciplinary data integration
        c) larger remote sensing projects

Phase III: Expansion & Maintenance (2004 – future)

A) Continue prior services / functions
B) Develop dynamic on-line data services
C) Provide beginning-to-end project support
    1) participate in proposal writing
    2) project planning
    3) data acquisition
    4) field support / data collection
    5) comprehensive, integrated spatial analyses
    6) report / manuscript participation
    7) presentation of results
    8) figures / maps

3.2 The Next 5 Years

The vision for the next five years of Toolik Field Station GIS develops from three points: 1) as technology advances, spatial data techniques and skills are becoming progressively more specialized, 2) integration of data (spatial and non-spatial), and distribution of such data via web portals is desirable and should be expected in the foreseeable future, and 3) the number of requests for more advanced analyses and comprehensive project support is increasing.

The activities described below are designed to address these realities in the short term. At minimum they are presented in the obligatory context of avoiding obsolescence, but they also represent the sincere hope that this program remains at the forefront rather than playing catch-up as technology and science evolve. Toolik Field Station is in a rare position to maintain a visionary program; one that can be a model for spatial data services and implementation in national and international arenas. It is in the context of a model example of an invaluable program that the points below, and in the Long Range Vision section, are presented.

3.2.1 Toolik Data Service

The initial vision for a Toolik Data Service included results from Arctic Spatial Data Infrastructure (ASDI) working groups in which Toolik GIS participated in 2001, 2002, 2003 & 2004. While a spatial emphasis is useful as an organizational construct, the larger goal is to include all relevant data rather than just ‘spatial’ data. The Toolik Science Vision Workshop in December 2004 (Bret-Harte et al., 2006) addressed the goals and initial implementation of a Toolik Data Service that will serve the broad Toolik community through a web portal within a distributed-node network of regional and arctic data sources (Sorenson et al., 2004).

On recommendations from the workshop, we are partnering with GINA to develop this service, having begun in 2005. The philosophy is to take an incremental approach, incorporating the most fundamental data first (e.g. meteorological, hydrological) and building more sophisticated data summarization, visualization and distribution services in response to community needs through time.

A key concept to this service is the ability to access relevant information from a variety of starting points. For example, some users will want to query all research near a given location, such as the R4D site at Imnavait Creek. In this case, an internet map server allowing the user to define an area of interest would return tabular information on research in that area. Another user might prefer to query the database by topic. For example all research using 15N additions could be queried, returning all hits by map, by table, or both. Yet others will want to find all research by Principal Investigator. In this case, the return would show all topics and locations used by that PI.

In all cases, the fully developed Toolik Data Service will require two things: 1) a well-scoped and flexible database and database management, and 2) multiple entry points by topic (e.g. internet map server, projects info page, topical query page, etc). The multiple entry points should be managed through a central web portal, all accessing the same database information through different user interface conduits.

Also on recommendation of the workshop, TFS hired an Environmental Monitoring Technician whose responsibilities will include facilitation of data assimilation to this system. This position will work closely with the future Toolik Field Station Data Manager (deemed a vital future hire by workshop participants) to ensure the availability of reliable data in near real-time. As of this writing, GINA has begun writing code for the portal, and TFS and GINA are assembling and integrating data with spatial information in the Toolik Map Engine. A Toolik Data Service beta-test site is planned for 2008.

While the initial vision was largely an outgrowth of GIS-related discussions, the Toolik Data Service is not a simple subset of the Toolik GIS Program. TFS GIS will have notable oversight, a high degree of integration, and will dedicate significant time toward database development and maintenance.

3.2.2 Current Needs

Growth of the Toolik Field Station GIS program has followed the 5-year plan presented in 2001, offering a comprehensive set of services and consultation commensurate with a flagship US Arctic Research Station. Functions are rapidly expanding beyond the core GIS and Remote Sensing services common in the past, and both the volume and sophistication of tasks increase annually. It is the desire, intention and premise of Toolik Field Station GIS to continue to provide high-quality, timely services while responding to new needs and requests as the community presents them. In 2003, with requests for more involved analyses, new interactions with agencies other research institutions, and development of the pilot Toolik Map Engine, more labor was required to ensure that prior services remained up to par. The hiring of an additional GIS analyst in spring 2004 filled these needs and met with strong approval during the summer field season, and in the years since.

Project-level support, the Toolik Data Service, Toolik Landscape Planning, the Toolik Natural Resource Tool and new technical functions have all arisen since that hiring. Not all of these things can be done at once by two staff members, and it is clear that without additional support the program will not be able to meet these needs in a timely and effective fashion. Further, technological evolution leads to progressive specialization of skills and tasks. In this environment, there is greater emphasis on assembling a complementary team rather than relying on one or two talented staff. It is our hope and intention to do just that; build a balanced, complementary team to maximize program stability, services offered, and inter-operability with similar programs at other agencies/institutions.

Part of the future workload should be transferred to temporary/term analysts, hired with funds provided for project-level support from specific research grants and cooperative agreements. Based on the current workload and requests for future support, it seems likely that individual project funds could support such a position into the foreseeable future.

Toolik GeoDatabase Developer

To ameliorate the workload in other arenas and provide vital, new functionality we propose a new, permanent position focused on database/geodatabase development, automation and maintenance. The purpose is to integrate all spatial data beginning with the geodatabase of research locations and attributes, and ensure that it functions seamlessly within Observing Networks (AON, CEON, NEON), the Toolik Data Service, the Toolik Natural Resource Tool, and Toolik Landscape Planning functions. This position will also assimilate newly created scientific data from project-level work, update relevant databases in near real-time, and reconcile formatting, distribution and organizational issues associated with these multiple-use datasets.

Tom Heinrichs, Associate Director of the Geographic Information Network of Alaska (GINA), directly endorses such a hire to provide an indispensable complement to the future Toolik Data Manager, and to GINA staff with whom we are collaborating on these efforts. For this position to provide adequate new functions without redundancy, the basic qualifications should include:

Skills:

1) Database design, automation and management (preferably Oracle, Postgres or similar package)

2) Object-oriented programming (VB, ArcObjects, .NET or combination thereof)

3) ESRI GeoDatabase design and development

Experience:

1) 2 – 5 years in the above areas

2) Background in ecological science and ecoinformatics (preferred) or general research science and informatics (required)

3.2.3 Web Feature Services (WFS), ArcSDE and ArcGIS Server

As of 2007, the TFS GIS program operates internally by informal data sharing using auxiliary hard drives which are periodically synchronized. While this is a functional approach in the near term, it is not the most efficient solution for the long term. The goal is to retain GIS data on a single server with stable backups, and to access the data on that server dynamically from all locations where TFS GIS staff may be working: Toolik Field Station, Toolik offices in Fairbanks, The Marine Biological Laboratory at Woods Hole, MA, or elsewhere. This will allow all staff and approved non-TFS GIS users to access the most current version of data with only a laptop computer equipped with the appropriate software.

Several technical avenues to create this functionality now exist. At present, ArcSDE (Spatial Database Engine) is designed to allow multiple users access to data on a single server. Other products, collectively known as Web Feature Services (WFS) provide data over Ethernet and internet connections and rely on web interface tools for query, analysis and manipulation. ArcGIS Server is one leading example of this type of software. All of these solutions share one major difference with Web Mapping Services (e.g. Internet Map Server, or IMS, of which The ToolikMapEngine is an example). WMS creates a map from data on the central server, and then translates that map as a picture which it sends to the client computer. WFS sends the data itself for use by the client computer. This is a critical distinction in the context of TFS GIS functionality, since WFS-type service would be required to support the analyses and workflow of the TFS GIS program.

There are two factors which prevent implementation of ArcSDE or WFS solutions at this time. The primary hurdle is internet bandwidth. The UAF Office of Information Technology (OIT) informs us that dynamic usage needs of such a system would not be supported by the currently available bandwidth to/from Toolik Field Station. Thus, a server stationed in Fairbanks could not be reached effectively from Toolik – a primary goal of this upgrade. The second hurdle is system administration. Initially, ArcSDE was designed to serve programs of 15 or more GIS analysts, in which a dedicated IT/SysAdmin position is justifiable. At present, the time requirement for administration of such a system would far outweigh the time required to operate in our current mode. This design is, however, rapidly changing based on customer feedback to ESRI, the producers of ArcGIS. In the next release of ArcGIS Desktop the required administration time may cease to be prohibitive.

It is reasonable to expect both factors to be resolved within the next three to five years. At that time, it is expected that a period of one to three months should be allocated among TFS GIS staff to successfully complete a transition to this mode of operation, using the best technology available at that time.

3.3 Long Range Vision

The most notable changes and directions beyond the current five year window should revolve around collaborative and integrated approaches to data management and sharing, and the availability of Decision Support Systems (DSS) and other value-added tools. Many efforts are currently underway to implement these sorts of services. The North Slope Science Initiative (NSSI) is already building a beta test site designed to provide reconciled and vetted data for across the north slope to managers at multiple agencies using several simple DSSs. This is a long and tedious process, and the full realization will not come until several years from now. Yet, this effort will not only test the waters in terms of scoping and implementation, but will also provide a logical platform onto which a Toolik-centric equivalent could be added.

The product will be a web portal similar to the Toolik Data Service concept, and leveraging a distributed-node architecture (Sorenson et al., 2004). Toolik would logically fit as a primary node accessible through this portal, as well as through other Toolik web pages. The Toolik relevant data, whether physically housed at IAB or at GINA, would be produced, controlled and maintained by Toolik personnel. Access via web connection would be handled in tiers, with read and edit access assigned appropriately per dataset.

Use and analysis would also be heavily web-based (as per WFS). Right now, web-based and desktop-based tools use distinct and separate software. In the near future these two will bleed together, with customized tools and analysis routines more easily distributed among community members, and more amenable to direct incorporation on client computers.

The scope of TFS GIS services should also shift as technology and data management approaches evolve. Greater efficiency in data handling will likely be balanced with greater data production, and so should require a continued effort on the part of TFS GIS staff. Direct support, however, could be expected to shift in emphasis from requests that are smaller in scope to more involvement with sophisticated analyses and project support. As web-based GIS becomes more prevalent and user-friendly, fewer researchers will need TFS GIS help for the types of simple analyses and map production that comprise smaller requests. Instead, the ever increasing volume and complexity of available data will require knowledgeable staff with strong technical skills, science background, and institutional memory to undertake more complicated analyses, generate reliable results, and operate with efficiency. In short, it will still make more sense to concentrate such staff within a single program than to expect each individual research lab to develop and maintain such staff on their own.

4.0 UPGRADES

The following upgrade topics are relevant to the present time in the TFS GIS program. However, they constitute the type of upgrades that have been and will continue to be necessary to maintain function and efficiency commensurate with a program supporting a flagship arctic research station. Of note is that the costs of these upgrades tends to stay consistent (inflation adjusted) through the years. The reason is that spatial data storage and analysis needs evolve almost in lock-step with technological advances in personal computing, and this relative level of computing typically hovers at around the same cost. Similarly for GPS equipment, it has been eminently justifiable to maintain high-end equipment that takes advantage of evolving GPS capabilities, given the needs and requests for GPS data among Toolik researchers.

4.1 Technology

4.1.1 Computing

Primary workstations for TFS GIS staff need to be replaced toughly every three years. This is due to a pressing need for greater speed and capacity, as well as to the tendency for component parts to fail. For 2007, a total of two high-end Dell laptop computers will be purchased with requisite docking stations and minor peripherals. The total cost will be roughly $8800.00, which is very close to the $9000.00 budgeted for this purpose in the Cooperative Agreement with NSF (2006 – 2010). Related peripherals and low-end printers have dropped in price to the point of being almost negligible within the context of the overall budget. Typically these costs average less than $1000.00 / year, and include 1 and 2 terabyte hard drives for basic storage and backup, monitors, inkjet printers etc.

High-end peripherals – primarily printers – require less frequent upgrades. A mid-range printer capable of producing 24"x36" cut-sheet maps on site at Toolik Field Station has needed replacement roughly every 4 years at a cost of about $1200.00 to $1800.00. The top-end large format printer that is the enterprise plotter for the program was purchased with startup funds in 2001 ($11,000.00) and has not needed replacement. It continues to operate without incident, and its life is expected to exceed ten years.

Two desktop servers are also in use, purchased in 2002 for $3000.00 each. As backup and simple, regular-function machines, they do not endure the frequency or intensity of use characteristic of the laptops. In addition, their components tend to be more durable, and are cheaply and easily replaced. They are expected to continue, with component upgrades of negligible cost, for at least another four years.

4.1.2 GPS

TFS GPS equipment falls into three basic categories: 1) base station, 2) mapping grade rover, and 3) survey grade rover. Each of these categories is subject to periodic upgrade to provide a high-level of quality and maximize field efficiency in high-precision GPS data collection. TFS GIS has been very fortunate to have access to UNAVCO (www.unavco.org) resources in support of GPS for

NSF-funded science. UNAVCO has provided more than half of TFS GIS's survey grade equipment, to include our permanent base station, and has provided invaluable consultative support over the phone and on-site over the years as well.

The benefits of the UNAVCO support are threefold from the perspective of the TFS GIS program. First, UNAVCO is able to leverage NSF funding for bulk purchase of key equipment, which saves NSF money overall, and eliminates the need for NSF to fund separate programs like TFS separately at higher cost. Second, it promotes better standardization of equipment and software among flagship US research facilities. This means that scientists working at Toolik, McMurdo, Barrow, South Pole, Thule, etc will find roughly the same resources at each site, allowing better familiarity, ease of use, and comparability of data and results. Third, UNAVCO consultation is an important part of keeping expertise at its best among staff. Overall, it takes a great deal of interaction with the GPS and surveying communities in Alaska and beyond to retain the level of skill and currency necessary for effective service at Toolik. However, without UNAVCO assistance, this process would be much more time consuming and difficult.

For more information on TFS GPS equipment and its uses, please see section 2.2.2 – 'Indirect Support: Infrastructure' of this report.

Periodicity of upgrade needs are less regular for GPS equipment compared with computing resources because advances in GPS technology are less regular. There are, however, basic ranges of time when upgrades could be considered likely. The following descriptions provide those ranges as well as they can be predicted right now.

Base Station (http://www.uaf.edu/toolik/gis/TFS_GIS_gps_equipment.html#base)

The TFS GPS base station is currently a Trimble NetRS receiver with RTK radio and capability. This configuration and hardware are expected to remain useful and current for at least another five years. GPS base files produced are publicly available on the TFS GIS website at:
http://www.uaf.edu/toolik/gis/TFS_GIS_gps_base.html

The retail cost of this configuration is roughly $19,000.00. In our case, the equipment was supplied in full by UNAVCO, at a cost to NSF of roughly $8,500.00. We will plan to arrange any future upgrades of this unit to be handled through UNAVCO.

Mobile Base Station (http://www.uaf.edu/toolik/gis/TFS_GIS_gps_equipment.html#mobilebase)

Our mobile base station is a Trimble 5700 receiver w/ accessories purchased by TFS GIS with GPS upgrade funds in 2004. The receiver was purchased refurbished for $6,000.00, while new ones typically cost around $12,000.00. We expect this unit to remain useful and current for at least another three years. We will plan to arrange any future upgrades of this unit to be handled through UNAVCO, as described above.

Survey Grade Rover (http://www.uaf.edu/toolik/gis/TFS_GIS_gps_equipment.html#survey)

Similar to the Mobile Base Station, we expect this unit to remain useful and current for at least another three years. This suite of receiver and accessories would cost roughly $20,000.00 retail, but was supplied to TFS GIS via UNAVCO, whom we would look to for future upgrade as well.

Mapping Grade Rovers (http://www.uaf.edu/toolik/gis/TFS_GIS_gps_equipment.html#mapping)

All mapping grade equipment is scoped, purchased and maintained directly by TFS GIS, since UNAVCO does not offer any mapping grade GPS support. Direct NSF support through the Toolik Field Station Cooperative Agreement covers these purchases in full.

The original rover is a Trimble ProXR backpack model, which is commercially obsolete, but which continues to provide useful data. We do not plan to upgrade this unit in the future. We will simply surplus it once it suffers component failure or becomes practically obsolete.

TFS GIS currently maintains 4 handheld rover units with capabilities similar to the Trimble ProXR. Two of these are Trimble GeoExplorer 3s, which are commercially obsolete, but they have also been the most durable and reliable units we have, continuing to provide valuable data. These will be retained as long as they continue to function effectively, and then surplused.

The other two handhelds are Trimble GeoXTs, which are the replacement models for the old Geo3s. These GeoXTs have been extremely problematic, suffering multiple hardware and software failures since purchase in 2004. This trend has been reported elsewhere with GeoXTs from the early part of their production run. We are presently upgrading these to Trimble GeoXHs, which have proven reliability, and also make use of the SBAS satellites to improve accuracy in real time to sub-meter. These costs are covered through GPS upgrades funds scheduled into the TFS GIS budget for 2007, augmented by the trade-in value of the older GeoXTs.

We do expect to upgrade these two handheld units in the future. At present, these GeoXHs along with our older Geo3s cover our handheld mapping needs, but it is reasonable to expect that we might need more in the future given the relative ease of use and popularity among Toolik users.

4.2 Data

Data have not typically been a significant consideration in the overall budget of the program, but this may change as more commercially distributed datasets become available, and as their quality and necessity increase. In the near future, it is expected that high-resolution satellite imagery will not only displace aerial photographs as a default backdrop for feature identification and change detection, but will also be used on a much more regular basis in analyses linking field measurements with landscape variables. In many cases, it will be appropriate for individual projects to fund the purchase of such data when those data are specific to a season that isn't of general interest, or cover an area in which few other projects are working. However, there will be occasions when the best overall value will come from a centralized purchase of imagery, licensed and available to the entire Toolik community. TFS GIS is the natural program to scope, buy, archive, and distribute data in this context. TFS GIS would also benefit directly from access to these images for use in analysis requests and in ad-hoc products like field maps and presentation figures.

The likely cost of such imagery will depend on the area of coverage and the particular type of imagery. It is difficult to predict the range of those costs given the present climate of rapid change in the field of high-resolution imagery and distribution. Nonetheless, this future need should be considered now, from the initial standpoint of a likely one-time supplemental request to NSF, and as a regular item in the TFS GIS budget in the cooperative agreement thereafter. Options for cost-sharing among other institutes and programs will almost certainly exist, and these relationships should be considered now as well. They should begin with programs like GINA, and possibly include the LTER program, observing network initiatives, and research hubs such as MBL.

It is unclear the degree to which vector data will also be needed from outside sources, but it is wise to consider that possibility. Vector data as a commercially available commodity is still a nascent idea – one that may or may not gain prominence. However, more private businesses – consultancies in particular – are producing comprehensive, enterprise datasets that are of clear value far beyond any single project, and which could easily become licensed, saleable items.

4.3 Expertise

In many professions and industries, key skills and knowledge become subject to progressive division of labor as technology improves, scope of work increases, and specialties develop. This is true of remote sensing, GIS and GPS; more so now than any time in the past twenty years. It is becoming uncommon for enterprise level programs to rely on the services of only one or two individuals. Among organizations with a comparable scope of service to TFS GIS, a staff of four to six individuals is typical. Specialties vary among organizations, but general categories include: GeoDatabase/Database, High-Precision GPS, remote sensing analysis and interpretation, vector analysis, cartography and figure production, and IMS. The most successful organizations have some overlap in skills among staff, but not redundancy. Four to six individuals also increase program stability by reducing the loss of institutional knowledge when an employee moves on or retires.

In the first seven years of operation, TFS GIS has managed to succeed with only one or two staff at a given time. For the moment, the program has retained the ability to remain current with changes in technology and methods, and has not suffered catastrophically from delayed projects due to staffing. It is a near certainty that this condition will not persist for very much longer. It would not be surprising to encounter a noticeable degradation of efficiency and effectiveness within one or two years if the program's stability and balance of specialization are not examined and augmented. Possible solutions could come in the form of additional full-time staff, or possibly through a more progressive approach pooling and co-locating some staff and specialties among existing research groups or institutions. Regardless of the approach, detailed consideration should be given to this issue in 2007 and 2008 in order to avoid noticeable problems in the near future.

5.0 MEETINGS & TRAVEL (FY06)

5.1 Meetings Attended

Meeting	Location	Dates
North American Benthological Society (NABS)	Anchorage, AK	June 4-8, 2006
LTER All Scientists Meeting	Estes Park, CO	September 19-23, 2006
NSSI Science Tech. Adv. Panel, GIS & Remote Sensing Sub-group	Anchorage, AK	November 13, 2006
Monitoring of climate and climate change within Arctic National Parks	Bodega Bay, CA	December 7-9, 2006
American Geophysical Union	San Francisco, CA	December 10-13, 2006
Toolik Field Station Steering Committee Meeting	Fairbanks, AK	December 14-15, 2007
NSSI Science Tech. Adv. Panel, GIS & Remote Sensing Sub-group	Fairbanks, AK	February 6-7, 2007
State of the Arctic Parks	Fairbanks, AK	February 15-16, 2007
Permafrost Young Res. Network Org. Meeting	Abisko, SWE	February 17-24
Arctic LTER Annual Meeting	Woods Hole, MA	February 25-27, 2007
Alaska Surveying & Mapping Conference	Fairbanks, AK	March 19-23, 2007

5.2 Presentations

Thermokarst Characterization & Distribution in a Transitional Arctic Biome: New Discoveries and Possible Monitoring Directions in a Climate Change Scenario. Arctic LTER Annual Meeting, Woods Hole, Massachusetts, February 2007.

Thermokarst Characterization & Distribution in a Transitional Arctic Biome: New Discoveries and Possible Monitoring Directions in a Climate Change Scenario. State of the Arctic Parks – SOAP Symposium, Fairbanks, Alaska, February 2007.

Integrated Information Delivery for Toolik: Deconstructing a Conceptual Framework and Building Incrementally. Toolik Field Station Steering Committee Meeting, Fairbanks, AK, December 2007.

Freshwater ecosystems of the Arctic wilderness: The challenge of inventory and monitoring in Alaska's National Parks. Special Symposium on Arctic Stream Ecosystems in a Changing Environment. North American Benthological Society Meeting, Anchorage, Alaska, June 2006.

Toolik Field Station GIS: Program Development 2001-2005, Expansion Beyond Traditional Boundaries. Arctic LTER Annual Meeting, Woods Hole, Massachusetts, March 2006.

6.0 SERVICES AVAILABLE

6.1 Year Round Services

- Map reproduction and distribution
- Custom cartography/figures
  - Hardcopy maps
  - Powerpoint figures
  - Publication figures
- Data and metadata distribution
- Custom data development
- Simple metrics
  - Coordinate locations
  - Estimates of area, distance
  - Landscape characteristics
  - Presence/absence/number of specific features
- Custom analyses
  - Site selection
  - Landscape characteristics
  - Synthesis of field data with spatial data
  - Modeling
  - Data manipulation
- Project Level Support
  - Scoping
  - Proposal help
  - Analysis & data development
  - Written & Verbal presentation

6.2 Field Season Services (additional to Year Round Services)

- GPS equipment available to Toolik users
  - Post-processed (code and carrier phase; to sub-meter precision)
  - RTK (real-time kinematic) processed (to sub-meter in real-time)
  - Survey grade (to sub-centimeter precision)
- GPS technical training (informal)
- GPS field work/consultation
  - Mission planning
- Data collection
- Post-processing
- Data manipulation
- Data distribution and archiving
- Assistance for site location and landscape/permit management
- Assistance for field planning and last-minute adjustment
- Spatial data support for aircraft-based work (helicopter and small fixed-wing)

7.0 PEOPLE & INSTITUTIONS SERVED (FY06)

PI/Administrator/Group	Affiliation	Daily Request (< 5 days)	Larger Request (> 5 days)
Dr. Brian Barnes *	UAF / TFS Steering Committee	Y	X
Boyce Bush *	U.S. BLM	Y	
Julie Deslippe	UBC	X	X
Alaska Surv & Mapping Conf	Alaska Arc Users Group		X
Dr. Jerry Brown *	IPA	Y	X
Dr. Syndonia Bret-Harte *	UAF	Y	X
Erin Trochim	UAF		X
Dr. Michael Gooseff	Penn State U.	Y	
Dr. John Hobbie *	Marine Biological Lab	Y	
Aurora Bouchier	Colorado School of Mines	Y	
Dr. John O'Brien *	UNCG	Y	
Dr. Skip Walker *	UAF	Y	Y
Dr. Gaius Shaver *	Marine Biological Lab	Y	
Dr. Anne Giblin *	Marine Biological Lab	Y	
Dr. John Moore	Colorado State University	Y	
Yiwei Cheng	UAF	Y	
Dr. Jeff Welker	UAA/ENRI	Y	
Dr. Marc Steiglitz *	Georgia Tech	Y	
Dr. Peter Ray	UAF		X
Angela Allen	Brown U.	Y	X
Lena Taneva	UAA	X	
Dr. Anne Hershey *	UNCG	Y	
Peter van Buuren	Wageningen University	X	
Dr. Chris Luecke *	Utah State U.	Y	
Dr. Byron Crump	U. of Maryland	Y	
Amy Breen	UAF	X	
Cr. Gretchen Gettel	UNH	Y	
Dr. Bruce Peterson *	Marine Biological Lab	Y	Y
Dr. Breck Bowden	U. of Vermont	Y	X
Laura Reynolds	Florida International University	Y	
Naomi Whitty *	VECO	Y	
Dr. Alex Huryn *	U. of Alabama	Y	
Dr. John Bradford	Boise St. U.	X	
John Payne *	BLM/NSSI	Y	
Jay Burnside	VECO	Y	

*** indicates a group (PI s, research assistants, students, post-docs, staff)**
X indicates single request
Y indicates multiple requests

(continued next page)

PI/Administrator/Group	Affiliation	Daily Request (< 5 days)	Larger Request (> 5 days)
Jay Zarnetske	Oregon St. U.	X	
Dr. Sally MacIntyre	UC Santa Barbara	Y	
Dr. George Kling *	U. of Michigan	Y	
Dr. Steve Oberbauer *	Florida International University	X	
Carol Moulton	U. of Texas	X	
Dr. William Fitzgerald *	U. of Connecticut	Y	
Dr. Kyle McDonald	NASA/JPL	X	
Dr. Doug Kane *	UAF	Y	X
Dr. Martin Sommerkorn	Macauley Institute	X	
Dr. Linda Deegan	Marine Biological Lab	Y	
Julie Keener	Shannon & Wilson Inc.	X	
Katey Walter	UAF	Y	
Dr. Matt Nolan	UAF	Y	
Morgan Greenwald	UVM	Y	
Dr. Roy Stine	UNCG	X	
Dr. Corien Bakermans	Michigan St. U.	X	
Lee Hanson	Petro-Canada	X	
Heidi Rantala	U. of Alabama	X	
Dr. Jeffrey Freymueller	UAF	X	
Dr. Larry Hinzman	UAF	X	
Dr. David Leverington	Texas Tech. U.	X	
Melanie Schimek	U. of Delaware		X
Peter Mackinnon	Utah St. U.	X	
Dr. Rob Rhew *	UC Berkeley	Y	
Dr. Thomas Douglas	US Army CRREL	X	

*** indicates a group (PI s, research assistants, students, post-docs, staff)**
X indicates single request
Y indicates multiple requests

	Science Support Requests		Management Support Requests		Data Development		Comp. / Network Support
	daily	larger	daily	larger	Framework	Project Specific	
Field Season	20%	15%	20%	<5%	5%	25%	<10%
Rest of Year	15%	20%	10%	25%	20%	10%	<5%

Generalized time allocation percentages by category and time of year.

8.0 CATALOG OF EQUIPMENT

8.1 Computers

Dell
- M60 Mobile Workstations (2)
- PowerEdge Servers (2)

8.2 Peripherals

EPSON Stylus Pro 9500 large format (44”) Color Plotter
Hewlett-Packard 2500CM Color Printer
EPSON Expression 1600 Scanner

8.3 GPS (full description at: http://www.uaf.edu/toolik/gis/TFS_GIS_gps_equipment.html)

Trimble
- GeoExplorer3 (2)
- GeoXH (2)
- ProXR
- 5700 (2)(Rover & Mobile Base)
- NetRS (Permanent Base)

PacCrest
- 2w/35w Base/Rover Radio
- 2w Base Radio
- 2w Rover Radio

8.4 Major Software

ESRI (GIS)
- ArcGIS (full) 9.2
- ArcView 3.2

ERDAS Imagine 8.7 (Image processing)

Adobe (Figures, graphics)
- Photoshop CS2
- Acrobat 6.0

Trimble (GPS)
- Pathfinder Office 3.0
- GeoMatics Office 1.63

Macromedia (Figures, graphics, web)
- Flash 5.0
- Freehand 9.0
- Dreamweaver 4.0

PTGui (image mosaicking, panorama)

9.0 LINKS

Toolik Field Station GIS & Remote Sensing Program:
http://www.uaf.edu/toolik/gis/

Toolik Field Station GIS Annual Report 2007:
http://www.uaf.edu/toolik/gis/TFS_GIS_Annual_Report_2007.pdf (Acrobat file 2.5Mb)

Static Maps of Toolik Field Station:
http://www.uaf.edu/toolik/gis/TFS_GIS_maps.html

ToolikMapEngine (internet map server):
http://www.uaf.edu/toolik/gis/ToolikMapEngine_Intro.html

Toolik Field Station GPS Equipment & Services
http://www.uaf.edu/toolik/gis/TFS_GIS_gps.html

10.0 REFERENCES

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