GOOSE GREEN GULCH: FISH AND WILDLIFE HABITAT IN A FORMER GRAVEL MINE SITE

by

Jack F. Winters

Technical Report No. 90-1

Alaska Department of Fish & Game
Division of Habitat

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Introduction

During construction of the North Slope Haul Road (later renamed the Dalton Highway) and the Trans-Alaska Pipeline, river floodplain material sites commonly supplied gravel for roads, facilities, and pipeline workpads. These sites provided an easily accessible source of gravel with shallow overburden. Gravel removal from these alluvial terraces and gravel bars generally involved shallow scraping to or slightly below water level, although at some sites, contractors excavated gravel to a depth of about 2 m (6.5 ft) below water level. Alyeska Pipeline Service Company (APSC) material site MS 122-3, located approximately 150 km (93 mi) south of Deadhorse/Prudhoe Bay, was one of many material sites established within the Sagavanirktok River floodplain. Staff from Alaska Department of Fish and Game, Habitat Division, referred to this site as "Goose Green Gulch."

This report reviews available historical information on this rehabilitated gravel mine site, reports the results of limited biological and chemical limnological sampling conducted in 1990, and reports the results of limited fisheries investigations conducted during the summers of 1989 and 1990. This report also describes and discusses several features of Goose Green Gulch not found in most former gravel mine sites in Alaska that make this gravel mine site attractive to fish and wildlife.

Site History

Goose Green Gulch is located on an alluvial terrace between the Dalton Highway and the west bank of the Sagavanirktok River at T5S, R14E, Sec. 21 and 28, Umiat Meridian (Figure 1). An initial site evaluation, which included an aerial and surface reconnaissance and soil borings, was completed in April 1972 and a mining plan for the site was developed in January 1974 (Michael Baker, Jr. Inc. 1974). The material site was delineated in 1974 at about 28 ha (70 ac) divided into 6 aliquots estimated to yield approximately 386,000 m^3 (500,000 yd^3) of material. An expansion of the site by about 18 ha (44 ac), adding 163,600 m^3 (214,000 yd^3) to the total yield of the site, was proposed in January 1975 (Alyeska Pipeline Service Company 1975); however, this component of the site was not mined.

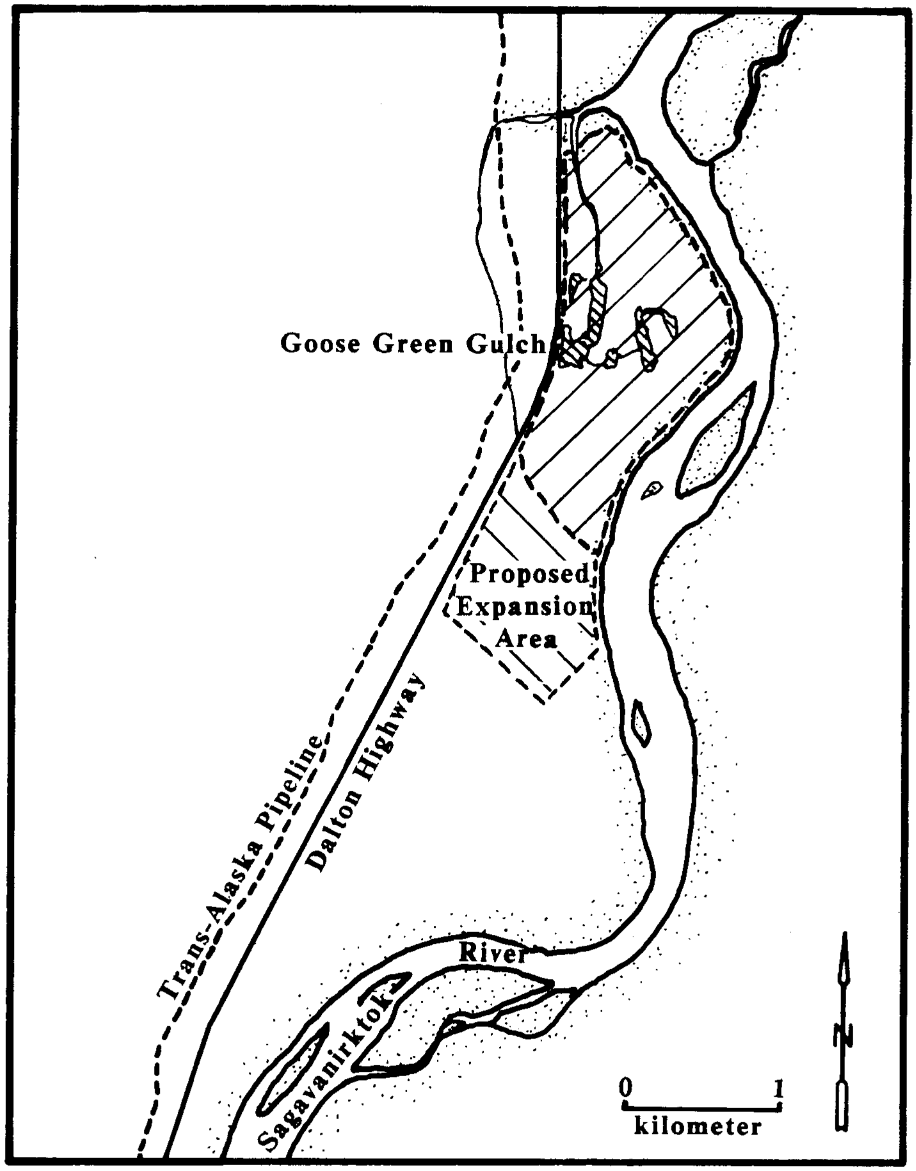

Figure 1. The location of Goose Green Gulch within the floodplain of the Sagavanirktok River.

Mining plans suggested the site contained perennially frozen, well-graded sandy gravel with some cobble. About 30 cm (12 in) of sandy silt overburden covered over 70% of the work area. Vegetation at the site was about 75% shrubs. Excavations at the site were planned to an average depth of 1.4 m (4.5 ft) to keep the working floor of the site near or slightly above the water table, except during high flows in the Sagavanirktok River. In addition, a 91 m (300 ft) undisturbed buffer strip was to be maintained between the work areas and the river channels.

Upon completion of the mining operations, plans specified grading the site to an even bottom, grading any remaining stockpiles to blend into the terrain, and connecting the site to the Sagavanirktok River with a channel to ensure flow from the mine site during high water and to allow fish to pass freely to and from the site. The original 1974 mining plans considered seeding or planting of the mine site unfeasible because the area is subject to periodic erosion and deposition during periods of high water; however, a February 1977 rehabilitation plan (APSC 1977) specified that grading, surface preparation, and seeding take place between 1 May and 15 July 1977. An April 1977 revision to the rehabilitation plans approved revegetating 16 ha (40 ac) (the entire disturbed area of the site) with riparian willows.

The rehabilitation plans for this site specified the use of a tine harrow to enhance revegetation. Harrowing equipment was towed over the surface of many material sites before and after seeding (Johnson 1981). Harrowing appeared to increase germination rates and vegetation cover, probably due to burial of the seed which increased moisture available for germination and growth (Johnson 1981). Rehabilitation plans for this site directed the revegetation of the entire site using a mixture of perennial and annual grass seed (Table 1) applied at 56 kg/ha (50 lb/ac). Plans also directed fertilization of the site at a rate of 729 kg/ha (650 lb/ac) (Table 2). Zasada et al. (1981) reported this site was fertilized and planted with grass in 1977.

In addition to the revegetation of the site using grasses, Goose Green Gulch was a site selected for an experimental willow planting program conducted from 1978 to 1980 (Zasada et al. 1981). This program involved characterizing undisturbed willow habitat, examining natural regeneration and successional relationships of riparian shrub communities, evaluating natural revegetation of disturbed areas, testing of assisted revegetation techniques (e.g., cuttings, seedlings, seeding), and

Table 1. Revised 1977 Grass Seed Mix #1 used for revegetation at Goose Green Gulch and other sites from Toolik to Prudhoe Bay (adapted from Johnson [1981]).

Grass Species	Seed mix 1 kg/ha
Arctared fescue *(Festuca rubra)*	12.3
Nugget bluegrass *(Poa pratensis)*	12.3
Redtop *(Agrostis alba)*	1.1
Boreal red fescue *(Festuca rubra)*	10.1
Annual rye *(Lolium multiflorum)*	14.6
Tall arcticgrass *(Arctagrostis latifolia)*	1.1
Total	51.5

Table 2. Fertilizer mixture V composition and application rate for Goose Green Gulch and other sites from the Yukon River to Prudhoe Bay (adapted from Johnson [1981]).

Nutrient Elements	Composition %
N	10.9
P_2O_5	15.1
K_2O	14.5
S	5.2
Mg	3.6
Cu	0.36
Zn	0.48
B	0.12
Mo	0.0218
Application Rate (kg/ha)	715.0

making new recommendations for habitat restoration. Goose Green Gulch was selected as a site that had good potential for success of willow planting even though the site had been seeded to grass and fertilized during Alyeska's 1977 rehabilitation efforts. Test plots examining the survival of planted willow cuttings, the success of artificial seeding of willows, and natural regeneration of willow from seeds were established at Goose Green Gulch.

Site Conditions - 1989

Field investigations of Goose Green Gulch during June and August 1989, and review of aerial photographs taken after excavation of the site, indicated that Alyeska contractors mined only the six aliquots proposed in the initial mining plan. The contractors removed 226,994 m^3 (296,996 yd^3) of gravel from this material site for construction of the North Slope Haul Road and 5,783 m^3 (7,566 yd^3) for construction of the Trans-Alaska Pipeline System (D. Gohl, Bureau of Land Management pers. comm. to A. Ott, Alaska Department of Fish and Game). The 91 m (300 ft) undisturbed buffer between the work areas and the river channel described in the work plans appears to have been maintained during the excavation of this site.

Our field investigations of Goose Green Gulch centered on the northern half of the site (aliquots 1-3), where approximately 1.5 ha (3.7 ac) of shallow ponds currently exist. These ponds have extensive shoreline features including spits, embayments, and islands, features that are not often present in most flooded arctic gravel mine sites (Photo 1; photographs located in Appendix 5, page 29). A narrow channel at the north (downstream) end of the site connects the Sagavanirktok River to four of five interconnected ponds within the site (Figure 2). The five ponds range in depth from 20 cm (8 in) to more than 1.2 m (4 ft) in late August 1989 (Figure 2). A mud/silt bottom is present in most areas of the ponds. Silt also is a major component of the substrate immediately surrounding the ponds. The silt likely was spread in these areas during revegetation activities or deposited during Sagavanirktok River flood events. Organic debris from past flood events present in branches of willows surrounding the site indicates Goose Green Gulch is inundated periodically.

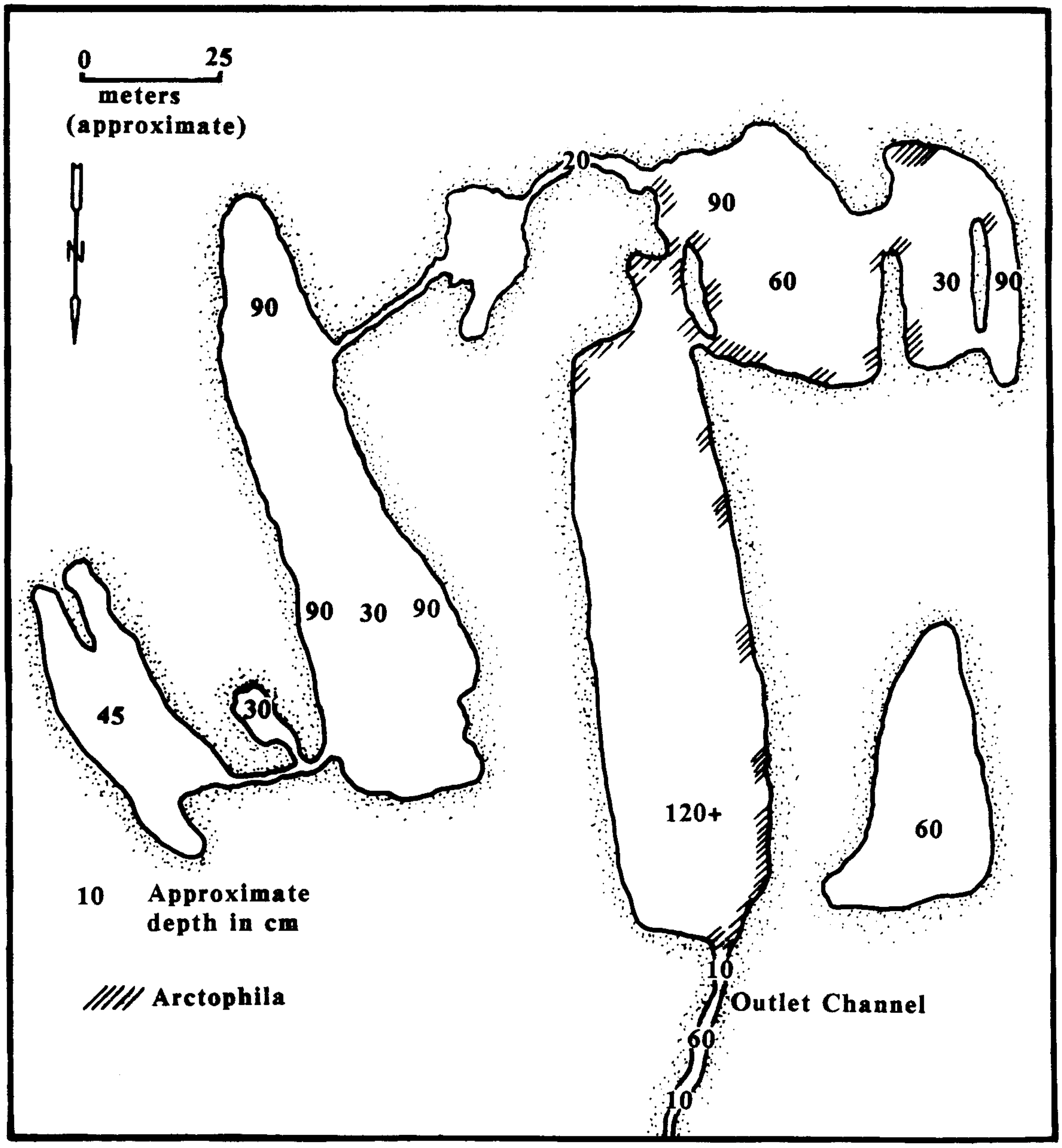

Figure 2. Schematic drawing of Goose Green Gulch, August 1989.

The outlet channel connecting Goose Green Gulch with the Sagavanirktok River is approximately 4 m (13 ft) wide and extends approximately 250 m (820 ft) from the site to where it intersects a small mid-to-high water channel of the river. The channel has a gravel/cobble bottom for its initial 50-75 m (165-245 ft) from Goose Green Gulch and then contains progressively more silt with decreasing distance to the Sagavanirktok River. Water depth in the outlet channel ranged from 10 to 70 cm (4 to 28 in) in late August. A flow of about 0.02-0.05 m^3/sec (1-2 cfs) was present in the outlet channel. Groundwater generated this flow, as no upstream connection existed between the Goose Green Gulch ponds and the Sagavanirktok River in June or August 1989.

Grasses, sedges, willows, and forbs currently grow within much of Goose Green Gulch. Within the immediate vicinity of the ponds and in the channels connecting ponds are extensive stands of sedges (*Carex aquatilis, Eriophorum angustifolium*, and *E. Scheuchzeri*), and occasional stands of pendent grass (*Arctophila fulva*) (Photos 2 and 3). These species are common along the margins of these waterbodies, although in areas where water depths are less than 30 cm (12 in), emergent aquatic species (*Hippuris vulgaris, Arctophila fulva)* grow throughout the shallow areas. Stands of the sedge *Carex aquatilis* are dense, particularly within the channels connecting the ponds. These channels are generally less than 25 cm (10 in) deep (in August) and apparently provide excellent conditions for growth of sedges.

Arctophila fulva is a conspicuous emergent aquatic plant at Goose Green Gulch, particularly in late August when this species' leaves turn red (Photo 2). This plant is common in wetlands throughout the arctic, and wetlands containing *Arctophila* are valuable for waterbirds. *Arctophila* grows in dense stands in selected locations along pond margins of Goose Green Gulch and scattered in areas of the ponds that are generally less than 30 cm (12 in) deep.

Submerged aquatic vegetation (e.g., *Hippuris vulgaris*) also grows within the ponds of Goose Green Gulch. Submerged aquatic vegetation is present from the shallow (less than 30 cm [12 in]) areas to areas deeper than 1.2 m (4 ft).

In drier portions of Goose Green Gulch, grasses and forbs predominate. Much of the area covered by sparse grasses, particularly the southern half of the site, appears to be the result of revegetation activities conducted in 1977. The horsetail *Equisetum arvense*, the legumes *Hedysarum Mackenzii*, *Astragalus alpinus*, and *A.*

Sealei, the forbs *Stellaria longipes* and *Parnassia Kotzebuei*, and the grasses *Poa arctica* and *Festuca rubra* have recolonized Goose Green Gulch and are important components of the vegetation on drier sites.

Willows are present throughout the site, but are most abundant in the area of the ponds and along the outer margins of the site (Photo 4). Willows are less abundant in the drier portions of the site that support higher densities of grass. Feltleaf willow (*Salix alaxensis*) is the most common willow within the site. Several *S. alaxensis* plants approach 2 m (6.5 ft) in height, and may be survivors of the 1978 Alyeska experimental willow planting program. Most of the willows within the site, however, are less than 1 m (3.3 ft) tall. The 91 m (300 ft) buffer zone left between the work area and the Sagavanirktok River channel contains extensive stands of willows that likely contributed to the seed source for recolonization of the site by willows. Lesser numbers of *Salix hastata* and *Salix glauca* also occur in the site.

Site Conditions - Late Winter/Spring 1990

Aufeis covered most of Goose Green Gulch in April (A. Ott, ADF&G; K. Durley, APSC, pers. comm.). Aufeis also covered the site in 1989 (K. Durley, APSC, pers. comm.), and in 1980 (Moore 1982). Although the observations of aufeis at this site are limited, they suggest that some degree of aufeis formation may occur frequently at the site.

In 1990, breakup in the Sagavanirktok River at Goose Green Gulch peaked around 16 May (K. Durley, APSC, pers. comm.). At this time, about 80% of the river flowed through the site because of extensive aufeis in the river channel near the site (K. Durley, APSC, pers. comm.). On 23 May, floodwaters still flowed over the entire site. The Sagavanirktok River did not appear exceptionally high as some gravel bars were exposed and ice blocks were grounded on some gravel bars. There was no ice jam in the immediate area of Goose Green Gulch that could have backed up or diverted water into the site.

Floodwaters entered Goose Green Gulch through the slough channel that forms the southern border of the site. Standing waves 0.3 to 0.6 m (1 to 2 ft) high were in the area of the outlet channel, at the center of the site near the site's original access road, and at the southern end of the site. May floodwaters were approximately 1.8 m (6 ft) higher than water levels recorded in the ponds of the site in late June.

There were several blocks of ice grounded in the upper and lower ends of Goose Green Gulch on 23 May. Whether these ice blocks floated into the site and grounded, or if these blocks were remnants of the site's aufeis formation is unknown. Observations of erosion and deposition within this site later in the year suggested that floodwaters eroded or melted the aufeis in situ rather than simply flowing over the ice. To what degree the aufeis protected the site from scour during the spring flood is unknown.

Site Conditions - Summer 1990

Some extensive modifications to Goose Green Gulch occurred during the spring flood. Sedimentation occurred in the northern half of the site, but did not completely fill any of the five ponds. Floodwaters deposited a substantial amount of sand and silt at the southern end of the pond complex. Floodwaters created a sand island about 45 cm (1.5 ft) high, 1-4 m (3-13 ft) wide, and 12 m (40 ft) long at the southern end of the primary pond. Sediments have reduced the depth of the primary pond to less than 1.2 m (4 ft). Floodwaters deposited additional sediments on the southwest shoreline of the primary pond and along the large boulders at the south end of the pond complex. Sediments filled one channel connecting two of the secondary ponds. Sediments buried some emergent and submerged vegetation within the southern portions of the pond complex. Some terrestrial vegetation in low-lying areas of the site also was buried.

In addition to the effects of sedimentation, scour and erosion modified extensive areas of Goose Green Gulch. An extensive area of cobble and boulders up to 75 m (245 ft) wide begins where floodwaters entered the site at its southern end (Photos 5 and 6). This disturbed area extends to the pond complex. Scour holes up to 1.2 m (4 ft) deep occur along the western edge of the disturbed area. Floodwaters leaving the site along the northeast site boundary also removed a portion of the willow buffer/transition zone such that the site now almost merges directly with the sparsely vegetated gravel bar to the east. Floodwaters also widened the outlet channel from about 5 m (16 ft) to about 15 m (50 ft) for much of its length.

Water from the Sagavanirktok River flowed continuously through Goose Green Gulch in summer 1990; in 1989, groundwater generated the discharge from the site. In 1990, water entered the site through the slough channel at the south end of the site and maintained a single channel through the cobble/boulder disturbed area before splitting into three channels (in late June) immediately upstream of the pond complex. Each of these channels entered one of the ponds. In late June, a flow of water of about 0.85-1.13 m^3/sec (30-40 cfs) left the site through the outlet channel. By late August, this flow had diminished to about 0.02 m^3/sec (1 cfs).

Fisheries Investigations

Surveys conducted on foot around the ponds of Goose Green Gulch in June 1989 revealed small arctic grayling (*Thymallus arcticus*) in sections of the ponds less than 30 cm (12 in) deep. Based on the presence of fish in these sites in June, staff from the ADF&G set one fyke net in a deeper pond (Photo 2) to capture arctic grayling of suitable size for transplant into Kuparuk Mine Site B in the Kuparuk oilfield (Winters 1990). This net caught 121 fish during one overnight set; except for 2 round whitefish (*Prosopium cylindraceum*), all were arctic grayling (Appendix 1). Seventy three percent of the arctic grayling exceeded 200 mm in length. We transplanted 87 of the arctic grayling from this net to Kuparuk Mine Site B; we measured and released the remainder of the catch at the capture site.

In late August 1989, we fished one fyke net overnight in the same pond that we sampled in late June. The abundance and species composition of the catch in August differed considerably from that observed in June (Appendix 2). Arctic grayling were six times more abundant in June than in August. No arctic grayling caught during August was larger than 194 mm; 73% of those caught in June exceeded 200 mm in length (Figure 3). Slimy sculpin (*Cottus cognatus*), ninespine stickleback (*Pungitius pungitius*), and burbot (*Lota lota*) were three species caught in limited numbers in late August that were not caught in late June.

In 1990, the species composition of fish caught in the fyke net was similar to that recorded in 1989 (Appendix 3, 4). Arctic grayling and round whitefish were the most common species caught in 1990. In both years, larger arctic grayling and round whitefish used the site in June, and smaller fish used the site by mid July and August (Figure 3). We caught four small Dolly Varden (*Salvelinus malma*) in this net in 1990.

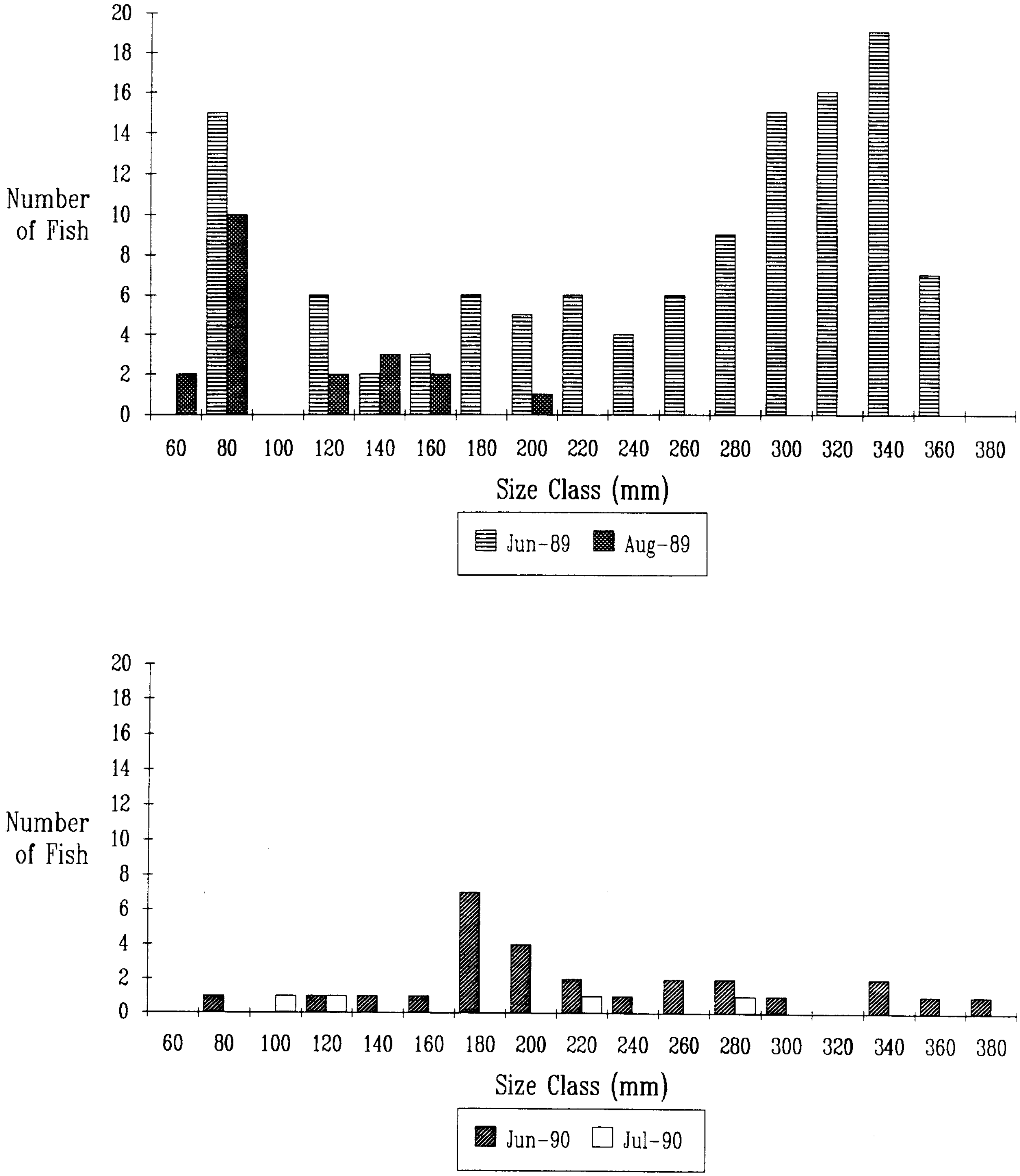

Figure 3. Lengths of arctic grayling captured at Goose Green Gulch, 25 June and 26 August 1989, and 28 June and 17 July 1990 (length categories in 20 mm increments: e.g., 21-40 mm).

Limnological Investigations

In July 1990, we measured dissolved oxygen concentrations, alkalinity, hardness, temperature, pH, and estimated phytoplankton standing crop in the primary pond at Goose Green Gulch (Table 3). At this time about 0.28 m^3/sec (10 cfs) of water was flowing through the primary pond. Phytoplankton standing crop, estimated as concentrations of chlorophyll-a, was low (see Hemming et al. 1989 for a description of the procedures used to assess phytoplankton standing crop).

Use of Goose Green Gulch by Wildlife

Although we did not conduct detailed investigations of the use of Goose Green Gulch by wildlife species, casual observations indicated birds and large mammals used the area. In late June of both years, we observed up to 20 Canada geese (*Branta canadensis*) grazing sedges along the margins of the site's ponds. These birds probably were failed breeders or non-breeding geese. There was no indication of geese nesting at this site. *Arctophila* and *Carex* plants grazed by geese were abundant, as were fresh goose droppings, even in late August.

At least one shorebird species and perhaps a second species nested at Goose Green Gulch in 1990. In late June, an adult semipalmated plover (*Charadrius semipalmatus*) performed a broken wing display near the ponds which suggested its nest or young were nearby. In mid July, two adult and four young semipalmated sandpipers scurried about the pond margins. One pair and a single adult lesser yellowlegs (*Tringa flavipes*) were present in late June but were not seen during any of our subsequent site visits.

Large mammals that used or traveled through Goose Green Gulch included moose (*Alces alces*) and caribou (*Rangifer tarandus*). Tracks from both species were present in the site during both years. In July 1990, we observed one bull moose feeding on feltleaf willow shoots in the area of the pond complex (Photo 4).

Discussion

The differences between the June 1989 and June 1990 catches of fish in fyke nets may be a factor of the changes created at Goose Green Gulch by the 1990 spring floodwaters. The continuous flow of Sagavanirktok River water through the site

Table 3. Average limnological values recorded at Goose Green Gulch, 17 July 1990. Sampling depth at 0.1 m.

Dissolved oxygen[1]	9.3 mg/L (n=3)
Alkalinity[2]	75.0 mg $CaCO_3$/L (n=2)
Hardness[3]	101.5 mg $CaCO_3$/L (n=2)
pH[4]	6.7 (n=2)
Chlorophyll-a[5]	0.27 µg/L (n=3)
Water temperature[6]	11°C (n=2)

Techniques used:

1 azide modification of the Winkler titration procedure
2 carbonate alkalinity by 0.16 N sulfuric acid titration with color indicator
3 titration by EDTA with color indicator
4 indicator strips
5 monochromatic method
6 mercury thermometer

in 1990 may have created conditions less favorable to fish than existed in 1989. Lower water temperatures, possibly decreased aquatic productivity, or perhaps the increased current in the primary pond may have made the site less favorable. Also, the partial filling of the primary pond with sediments may have reduced available habitat or the pond's attractiveness to fish.

The size structure of arctic grayling captured in Goose Green Gulch differed considerably between the June and August 1989, and the June and July 1990 sampling periods. Although we removed 86 arctic grayling from the site in June 1989, we captured and released an additional 25 to 30 large arctic grayling at this time; thus, the absence of large arctic grayling in late August 1989 should not be a consequence of the removal of 86 arctic grayling in June. One possibility for the difference in the catches is that large arctic grayling may have left the site in August before sampling, when water levels or temperatures may have changed. Another possibility is that preferred food items of large arctic grayling were not present during late August, and larger fish may have gone elsewhere to feed.

The differences in size composition of fish collected in fyke nets over the course of the summer at Goose Green Gulch reflected a pattern of use by arctic grayling similar to that recorded at an artificially-created pond connected to the upper Atigun River (Winters, unpubl. data) and to that recorded in the Kavik River drainage (Craig and Poulin 1975). Large arctic grayling were common in the upper reaches of these systems early in the open water period, whereas small fish were more common at the same locations later in summer. Although Goose Green Gulch is not a stream system comparable to the upper Atigun or Kavik river drainages, the use of Goose Green Gulch by arctic grayling may reflect the general pattern of dispersal of fish throughout the Sagavanirktok River system as summer progresses.

Besides having features that benefit fish, Goose Green Gulch also has habitat components that are attractive to birds. Songbirds likely use the site during summer, particularly areas where shrubs are established. The sparsely vegetated silt/sand shorelines provide feeding habitat for some shorebird species. Emergent aquatic vegetation, and grasses and sedges near pond margins, provide food for geese. Much of the site contains short vegetation, which is attractive to geese and other waterfowl in that it does not restrict the bird's visibility of potential predators. The proximity of Goose Green Gulch to the Dalton Highway's dust shadow likely promotes earlier snow melt along the western margins of this site.

Whether the majority of Goose Green Gulch is attractive habitat to migrant waterfowl in early spring, when snow and ice-free areas sought by waterfowl are limited, likely depends on the degree to which aufeis forms within the site each year. Years with extensive aufeis formation probably provide limited early spring waterfowl habitat.

Several factors make Goose Green Gulch an excellent example of a floodplain material site with planned and unplanned features that contribute to its rehabilitation and use by fish and wildlife. Planned features include site contouring that contributes to providing an adequate moisture supply for recolonization of the area by plants, a buffer strip that contains vegetation that serves as a seed source for the site, and connection of the site with the Sagavanirktok River. Unplanned features include a series of ponds with diverse shapes and depths. The location of the site adjacent to a river that provides nutrient input and sediments through periodic flooding also contributes to the rehabilitation of the site.

The connection between the ponds of Goose Green Gulch and the Sagavanirktok River serves two functions. It gives fish access to the site for rearing during the open water period. It also gives fish that may be carried into the site during flood events a means of leaving the site before freeze-up, as this site likely does not support overwintering by fish. All ponds in Goose Green Gulch are considerably less than 1.2 m (4 ft) deep, and probably freeze to the bottom during winter.

The ponds in Goose Green Gulch contain a diversity of features that are beneficial to and used by fish. The irregular shape of the ponds provides extensive shoreline for development of emergent vegetation. This vegetation provides cover for fish and may provide food and cover for aquatic invertebrates that in turn may be eaten by fish. This vegetation also may contribute to site productivity by stabilizing the shoreline and pond bottom, and by adding nutrients to the system through leaching or plant decomposition. The variation in depths of the ponds also contributes to this site's productivity by enabling the establishment of diverse emergent and submerged aquatic plants.

The variation in depths of the ponds also may create variations in water temperature within a site that can contribute to productivity and use by fish and aquatic invertebrates. Previous studies at other North Slope gravel sites (Hemming

1988, Hemming et al. 1989) suggest that shallow flooded mine sites have a higher phytoplankton standing crop and zooplankton abundance than do deep sites with limited shallow water habitat. Site conditions at Goose Green Gulch (e.g., shallow water, emergent vegetation) suggest that primary productivity, phytoplankton standing crop, and zooplankton abundance would be high in the ponds. Chlorophyll-a concentrations, an indicator of phytoplankton standing crop, recorded at Goose Green Gulch in 1990 were three to eight times lower than those recorded in summer at other North Slope gravel mine sites (Hemming et al. 1989), and two to six times lower than those recorded for gravel mine sites south of the Brooks Range (Winters, unpubl. data). Chlorophyll-a concentrations at the Sten Creek material site pond, a small pond connected to a mountain stream tributary of the Atigun River, were nearly identical with those recorded at Goose Green Gulch (Winters, unpubl. data). Aquatic productivity at Goose Green Gulch probably was higher in 1989 than in 1990. The continual flow of water through the site in 1990 may have kept phytoplankton populations lower (through removal of phytoplankton, probable lower water temperatures) than if the ponds were isolated, or nearly so, as in 1989.

Periodic flooding of Goose Green Gulch by the Sagavanirktok River contributes nutrients to both the aquatic and terrestrial components of the site. Floodwaters bring to the site nutrients dissolved in water, as silt and other mineral particles, and as leached organic compounds, leaves, stems, and other organic material. These nutrients, deposited as floodwaters recede, serve to maintain and enhance the productivity of the site.

Periodic flooding also aids in bringing plant propagules to the site. Although seeds are the most easily dispersed plant propagule, floodwaters may carry to the site viable stem or root segments, particularly those of willows. Floodwaters also may deposit entire plants or vegetation mats at a site, depending on the severity of the flood and the proximity of the plant source. This type of establishment of vegetation in the area of Goose Green Gulch appears to be rare (Zasada et al. 1981). Joyce (1980) also considered intact transport of vegetated organic mats an insignificant means of revegetating gravel mine sites in arctic and subarctic floodplains as it occurred on a small scale and was not a widespread phenomenon.

The establishment of willows within Goose Green Gulch appears to be the result of a combination of natural seedling establishment, vegetative reproduction, and survival of planted cuttings. Feltleaf willow seedlings were sufficiently abundant and vigorous to repopulate the northern third of the site, where fine sediments and soil moisture were sufficient (Zasada et al. 1981). Young willows continue to be abundant in this portion of the site (refer to Photo 4). Natural regeneration of willow in the rest of the site is poor where the substrate is generally drier and contains a greater density of grasses. Vegetative reproduction of willows, stimulated by periodic flooding of the site, also appears to have occurred at Goose Green Gulch. Fine sediments deposited during floods may bury branches which then root adventitiously and send up new shoots (Moore 1982). Several stands of willow at the northern end of Goose Green Gulch appear to have expanded by this process. Only 37% of the 2357 willow cuttings planted by Alyeska at Goose Green Gulch in 1978 were alive in 1980, and survival of these plants was expected to continue to decline as these plants were nutrient deficient and growing very slowly (Zasada et al. 1981). There are a few plants that are spaced uniformly in a pattern similar to that at other planted sites, suggesting that some of these cuttings did survive. However, it appears that natural seedling establishment and vegetative reproduction of existing plants have been a more significant factor in the reestablishment of willows at Goose Green Gulch.

The profile and contours of Goose Green Gulch have contributed to the establishment of wetland and riparian vegetation on the disturbed portions of the site. Much of the mined portions of the site are at or near the water table, thus providing sufficient surface soil moisture, the lack of which appears to be a limiting factor in the revegetation of some disturbed or filled wetlands in the arctic (Jorgenson 1988). Fine-grained sediments carried to the site during periodic flooding, also contribute to the retention of soil moisture necessary for the germination and seedling establishment of pioneer riparian species on newly exposed substrate. Water from periodic flood events and from spring breakup replenishes and maintains soil moisture. As the vegetation community develops on the site and stabilizes the growing conditions through increased soil retention by the development of plant root systems and increased moisture retention by the development of an organic layer in the soil, a more diverse and extensive community may develop.

Although Goose Green Gulch has maintained a generally stable conformation since site closure in 1977, significant changes to the site have occurred in recent years.

The extensive erosion within the site from the 1990 spring flood suggests the site is becoming less stable. Should erosion continue, Goose Green Gulch likely will be bisected longitudinally by a newly formed channel of the Sagavanirktok River (see photo 5). The rate at which this site transformation occurs will depend on the frequency, timing, and severity of flood events. The vegetated buffer along the southeastern border of the site probably moderates the effects of flood events through stabilization of the streambank and by decreasing the velocity of a portion of the floodwaters flowing through the site during a flood event. Construction of an erosion-control structure along the southeastern border of Goose Green Gulch, along with blockage of the slough forming the southern boundary of the site, could reduce or eliminate erosion within Goose Green Gulch's boundaries. Such a structure, however, may require yearly maintenance, considering the magnitude of flood events of the Sagavanirktok River in this portion of its drainage.

Should erosion of the site proceed such that a channel of the Sagavanirktok River forms through the site, some major effects to the suitability of the site for fish and wildlife will occur. The primary pond likely will be engulfed by the new channel as it flows through the site and out the existing pond outlet channel. If a channel forms in the northeast corner of the site, all or a portion of the other ponds in the site will be eliminated. Depending on the size and configuration of any future channels, portions of the ponds may remain as backwaters or eddies that could serve as rearing areas for fish. In any event, the conditions found within an active channel probably would be less favorable to fish than those found in the current system of ponds. Use of the site by waterbirds likely would continue to some degree as both unvegetated silt/sand shoreline preferred by shorebirds and vegetated shoreline preferred by waterfowl would remain to some degree.

Stability of future alluvial terrace material sites could be enhanced by establishing larger buffer zones between the site and active river channels. Siting alluvial terrace material sites distant from active channels or sloughs would minimize the easy entry of floodwaters to the site and reduce the possibilities of site erosion. For instance, siting Goose Green Gulch upstream of the slough forming its southern boundary rather than downstream would have greatly reduced the easy entry of floodwaters into this site and probably would have prevented the erosion occurring throughout much of the site. Additional recommendations for siting and development of material sites are discussed by Joyce et al. (1980).

Relevance to Future Mine Sites

Future development projects will require large amounts of gravel, either from existing gravel mine sites, by removal from existing gravel pads, or from new locations. Reexcavation or expansion of existing sites may provide opportunities to add features that may increase use by fish and wildlife. Incorporation of rehabilitation plans into the initial design and siting of new mine sites will allow rehabilitation to progress with development of the site, increasing the chances that features useful to fish and wildlife will exist upon closure of the site. Examining a variety of potential mine locations, including upland, river terrace, and floodplain sites, will provide the opportunity to determine which setting may provide the least impact and greatest potential for enhancement of local fish and wildlife values.

Although each potential material site would require site specific design, many features important to fish and wildlife found at Goose Green Gulch can be incorporated into a new site to enhance its rehabilitation and eventual use by fish and wildlife. Techniques such as establishing connections to rivers, using a combination of shallow scraping and deep excavation to provide fish and waterfowl habitat, and contouring the site to retain adequate soil moisture for the growth of plants will go a long way toward mitigating the loss of the original habitat and enhancing the use of the site by some species. Designing sites with features similar to those found at Goose Green Gulch should no longer restrict future gravel mines to deep, unproductive rectangles; shallow scrapes that create shallow, unstable and undefined stream channels; or to dry, barren upland sites excavated over the last 50 years in Alaska and that receive little use by fish and wildlife.

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Appendix 1. Length and ages of fish captured at Goose Green Gulch, 25 June 1989.

Species	Length (mm)	Age (yr)	Tag #*
Arctic Grayling	347	9	002125
	317	6	002126
	324	6	002127
	298	5	002128
	295	7	002129
	276	5	002130
	326	8	002131
	215	3	002132
	351	10	002133
	283	5	002134
	251	4	002135
	235	4	002136
	309	-	002137
	329	8	002138
	219	4	002139
	352	-	002140
	332	7	002141
	353	8	002142
	311	-	002143
	216	3	002144
	271	5	002145
	315	8	002146
	295	-	002147
	246	3	002148
	206	3	002149
	337	8	002150
	194	4	002151
	312	6	002152
	330	7	002153
	321	8	002154
	286	6	002155
	329	-	002156
	264	5	002157
	301	6	002158
	323	7	002159
	198	3	002160
	289	5	002161
	301	6	002162
	331	7	002163
	189	3	002164
	193	3	002165

Appendix 1. continued

Species	Length (mm)	Age (yr)	Tag #*
	253	5	002166
	183	3	002167
	289	6	002168
	259	4	002169
	323	-	002170
	303	6	002171
	269	6	002172
	296	8	002173
	227	4	002174
	312	7	002175
	312	7	002176
	277	5	002177
	320	-	002178
	329	-	002179
	350	-	002180
	262	4	002181
	260	5	002182
	229	4	002183
	324	6	002184
	341	8	002185
	281	5	002186
	273	-	002187
	323	-	002188
	360	-	002189
	282	6	002190
	284	6	002191
	315	7	002192
	277	3	002193
	335	-	002194
	324	7	002195
	292	4	002196
	322	7	002197
	335	8	002198
	314	7	002199
	246	4	002200
	265	5	002201
	230	4	002202
	307	-	002203
	296	6	002204
	328	8	002205
	203	3	002206
	306	7	002207
	212	3	002208
	306	8	002209
	290	6	002210

Appendix 1. continued

Species	Length (mm)	Age (yr)	Tag #*
	290	6	002211
	66	-	**
	66	-	**
	68	-	**
	69	-	**
	70	-	**
	71	-	**
	71	-	**
	72	-	**
	72	-	**
	73	-	**
	75	-	**
	75	-	**
	76	-	**
	78	-	**
	79	-	**
	104	-	**
	109	-	**
	110	-	**
	113	-	**
	115	-	**
	115	-	**
	128	-	**
	139	-	**
	144	-	**
	157	-	**
	158	-	**
	162	-	**
	163	-	**
	164	-	**
	165	-	**
	169	-	**
	176	-	**
Round Whitefish	332	-	**
	335	-	**

* arctic grayling tagged and released at Kuparuk Mine Site B
** fish released at Goose Green Gulch

Appendix 2. Species and lengths of fish captured at Goose Green Gulch, 26 August 1989.

Species	Length (mm)
Arctic grayling	45
	60
	63
	65
	65
	65
	66
	68
	68
	69 *
	70
	72
	105
	115
	126
	129
	139
	144
	148
	194
Round Whitefish	59
	60
	61
	63
	64
	70
Slimy Sculpin	44
	47
	88
Burbot	45
	60
	60
	62
	63
	64
	124
	125
	128
	170
	183
Ninespine Stickleback	**

* mortality

** approximately 80-100 ninespine stickleback were captured

Appendix 3. Species and lengths of fish captured at Goose Green Gulch, 28 June 1990.

Species	Length (mm)
Arctic grayling	72
	117
	136
	145
	162
	168
	168
	169
	170
	177
	178
	185
	194
	195
	196
	202
	204
	225
	224
	255
	267
	276
	298
	323
	337
	341
	365(est)
Dolly Varden	90
	112
	130
Round Whitefish	168
	198
	208
	345
	356
Burbot	325

Appendix 4. Species and lengths of fish captured at Goose Green Gulch, 17 July 1990.

Species	Length (mm)
Arctic grayling	98
	112
	213
	272
Dolly Varden	123
Round Whitefish	45
	46*
	47*
	47
	48*
	49
	50*
	51
	52
	52*
	56*
	57
	114
	120
	224
	365
Burbot	325

* mortality

Photograph 1. Primary pond of Goose Green Gulch with shoreline features such as islands, spits, embayments, and emergent vegetation. (Photo by M.H. Robus)

Photograph 2. Fyke net in the primary pond of Goose Green Gulch. Pendent grass (*Arctophila fulva*) is in the foreground. (Photo by M.H. Robus)

Photograph 3. Dense sedges (*Carex* spp.) in one of the shallow channels connecting two ponds within Goose Green Gulch. (Photo by M.H. Robus)

Photograph 4. Willows and sedges are abundant in the northern half of Goose Green Gulch. Bull moose browsing willows. (Photo by J.F. Winters)

Photograph 5. Aerial view of Goose Green Gulch, 1 July 1990. View from the south end of the site, looking north. (Photo by C.R. Hemming)

Photograph 6. Typical erosion in the southern half of the site from the 1990 spring flood. (Photo by J.F. Winters)