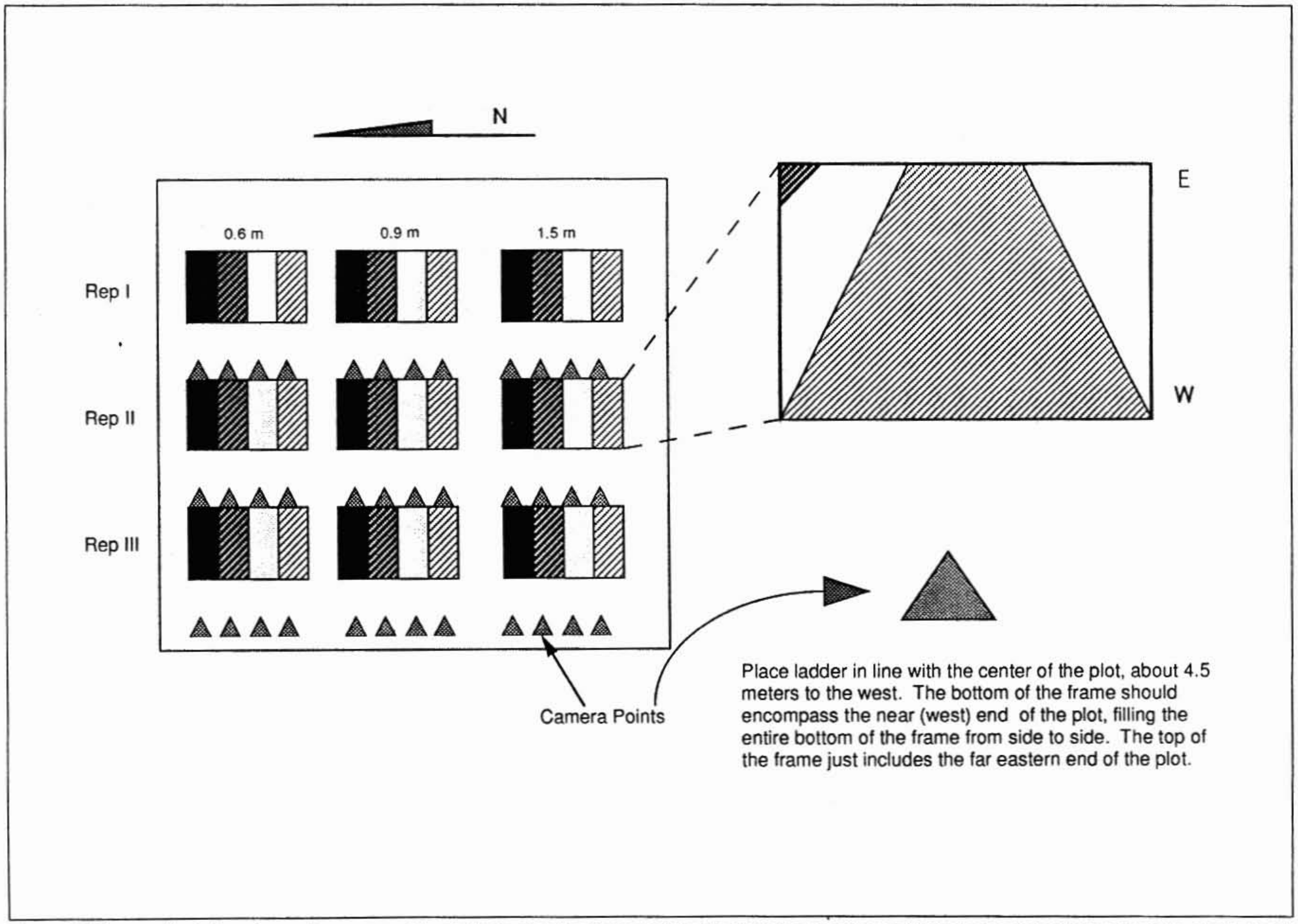

Figure 15. Diagram illustrating view and camera-points relative to plots for photographing the gravel treatment experimental area on the BP Put River No. 1 gravel pad.

pletely across the frame. The camera was positioned so the eastern end of the experimental unit was across the top of the frame, as illustrated in Figure 15. The camera was focused on a stake or other object near the middle of the experimental unit and depth of field checked to ensure as much of the photo as possible was in focus.

At least one duplicate, with a slightly different exposure, of each photopoint was taken for backup. The roll and slide numbers were noted on a field photo data sheet, which included date and photographer's name. The rolls were numbered sequentially so that each slide has a unique roll/slide number. After processing, the slides were labelled by the photographer and archived for reference.

The first set of photopoints was established to generate views of plots from the east edge. These photographs were taken with the photographer standing at the edge of the plot. Each image included all five subplots (1990, 1991, and 1993 plantings, and two unplanted checks) in each experimental unit. A 35-mm single-lens reflex camera with a 50-mm lens was used. Color reversal film was used to produce transparencies. The entire set of photos numbers 144 each time the experiment is photographed.

Identifying Indigenous Plants to Colonize Gravel Fill

Botanical Garden at BP Put River No. 1 Gravel Pad

This phase involved establishing a botanical garden of indigenous colonizing plant species on a portion of the area at the BP Put River No. 1 gravel pad. Because this phase included identifying, collecting, and testing the suitability of species for vegetating gravel structures, the same procedures described for seed acquisition, cleaning, storage, and germination for the gravel plots were used for the botanical garden. Actually, the species in the botanical garden included all species and seedlots used to prepare mixtures for the gravel modification experiment, plus a few others which were not used in the gravel plot mixtures. Because practical application of such a procedure depends on acquiring adequate supplies of indigenous plant seed, the harvesting, handling, storage, and planting of such seeds were fundamental to this phase of the project.

The botanical garden is a rectangular area measuring 31 by 38 m on the northwest side of the BP Put River No. 1 gravel pad (Fig. 3). Fifteen centimeters of topsoil were added to the garden area. It was divided (north-south) into east, mid, and west sections, each approximately 10 by 38 m. Rows were oriented northeast and southwest and spaced approximately 0.7 m apart.

During planting, the soil along the row was loosened with a 10-cm ripping rake. A string was stretched between stakes to mark the ends of each row, and a furrow was formed with the back of a hoe along the string. Seed for each row was mixed with approximately 0.5–0.75 liters of sand, as it was for the gravel plot applications, and then hand sprinkled into the furrow. The seed was covered with soil and tamped. Stakes at the ends of each row were sequentially numbered, with a unique number referring to a specific species/lot planted (Appendix D). Each row in the garden was planted with seed from a single species. Seeding of rows began in the spring of 1990 at the south edge of the east section of the botanical garden.

In 1990, the botanical garden rows were 9.5 m in length. In 1991, rows were shortened from 9.5 to 9.0 m in length to accommodate snow fencing installed during the previous autumn. Snow fences were installed between the sections and on the northeast (prevailing upwind) side during late September 1990, because the gravel berms had proved to be ineffective in creating a snow cover in winter 1989/90.

Seed for the botanical garden in 1990 was prepared by simply using seed remaining after needs for planting the 144 experimental plots had been met. The quantity of seed applied to the botanical garden rows was not recorded. In 1991, the seed for each row in the botanical garden was weighed, and the application was 1.6 PLS/cm of row. That application will be used for the remaining plantings. The application is high compared to the number of plants needed for each row in the botanical garden. However, at the time of planting, field responses were unclear, and abundant amounts of seed were selected to ensure a stand. It was believed that thinning dense stands would be preferred to filling in sparse stands by interseeding during subsequent seasons.

At the end of the growing season in 1990 and 1991, each row of the botanical garden was examined for seedling emergence. Emerged stands were evaluated on a six-level scale from none to dense. Maximum seedling heights were measured and recorded.

Surveys of Gravel Fill Sites Throughout Region

Ten gravel habitats and/or abandoned gravel fills in the National Petroleum Reserve in Alaska (NPRA) and along the Sagavanirktok River were examined for the number of plant species colonizing those sites during the period from July 1984 through July 1991. Observers walked these areas and recorded plant species growing in the gravel. If a plant species was not identified, a portion was collected for later identification. Botanical references used were: Argus (1973), Hultén (1968), Viereck and Little (1972), and Welsh (1974). Species were listed for each site and summarized by families and genera by location. Information from these lists was used to gain an understanding of which plant species were prominent colonizers and well distributed across the region. A paper based on these data was published elsewhere (McKendrick 1991).

RESULTS

Measuring Physical and Chemical Conditions of the Gravel

Soil (Gravel) Sampling

Sampling gravel and overburden material at the BP Put River No. 1 gravel pad began in 1989, with collection of grab samples of these two materials to provide background information prior to imposing any fertilization treatment. There were 14 samples in this collection (27-28 July 1989). Samples were also collected from each of the 144 gravel experimental units on 12 July 1990. These samples were taken after the fertilizer had been applied and were screened to separate the fine soil fractions from the gravel. Sixteen bulk density samples were collected from the upper 10 cm of Replicate II, Plot 2 (Fig. 3), within each of the four blocks on the BP Put River No. 1 gravel pad, 23 August 1991. At the same time, four bulk density samples were taken from the upper 10 cm of the botanical garden surface. Twenty-four gravel samples were collected from Block 1, Replicate III, Plots 1, 2, and 3, on 12 September 1991, to evaluate fertility conditions, because plants were showing signs of stress.

All samples for nutrient analyses were air-dried, sieved to remove particles >2 mm in diameter, and stored in polyethylene bags. Where sufficient material was obtained, samples were split with a soil sample splitter, and half of the collection archived. The samples not archived have been submitted to the Palmer laboratory for standard nutrient analyses. The results were not available in time for inclusion in this report.

Bulk densities and soil moisture percentages are presented in Table 2 for the gravel plots and the botanical garden. The plots with topsoil added averaged 1.6 g/cm^3 (gravel plots) and 1.7 g/cm^3 (botanical garden); without topsoil, the average bulk density was 2.2 g/cm^3. Tilled gravel bulk density was lower than untilled gravel: 2.0 and 2.3 g/cm^3, respectively. There was no difference in bulk densities between tilled and untilled plots that received topsoil applications. Soil moisture averaged about 3.5% in the gravel plots and 12.9% in the plots with topsoil. Untilled topsoil plots contained slightly more moisture than the tilled topsoil plots: 14.0% vs. 11.8% soil moisture. Soil moisture in the botanical garden, which has 15 cm topsoil, averaged 16.1% in the portion seeded in 1990 and 13.3% in the portion seeded in 1991.

The fine-fraction percentages for gravel samples collected in 1990 were summarized by treatment and are presented in Table 3. The mean fine percentage for all experimental units was 44.2%. There were no differences among treatments, except between topsoil thicknesses. With 8 cm of topsoil, fines constituted 63% of the matrix mass, and without topsoil, fines amounted to only 25% of the matrix mass.

Measuring Snow Cover

Snow depths and water contents in the gravel plots were measured on 7 May 1991, and in the botanical garden on 8 May 1991. Data were summarized by treatment block and the botanical garden and are presented in Table 4. Snow depths were markedly different between areas with and without snow fencing. Where there were no snow fences, the upper elevations within the block (i.e., the 0.9 m and 1.5 m gravel thicknesses) had the least snow cover; and within these lifts, the experimental units with topsoil, which had surfaces slightly elevated (about 8 cm from the adjacent ground) were mostly free of snow. With snow fencing, the snow cover averaged about 109 cm. Water content of this snow accumulation averaged 43 cm.

Monitoring Temperatures

Air and soil temperature data collected at a coastal site (Big Skookum) and a foothill site (MP 62) were included in this study. Air temperatures monitored at the two locations during the 1988 through 1991 growing seasons were summarized by generating graphs and calculating the degree-hours greater than zero and equal to or less than zero. Degree-hours were calculated from hourly mean temperatures with the STATS module in SYSTAT® (Wilkinson 1988). Positive

Table 2. Listing of bulk densities (g/cm³) and soil moisture (%) for the upper 10 cm of the 0.9-m gravel lift plots and the botanical garden at the BP Put River No. 1 gravel pad (23 August 1991).

Plot Identification	Treatment	Bulk Density (g/cm^3)	Soil Moisture (%)
Block 1, Rep II, Plot 2	Gravel, Tilled	1.8	4.6
Block 1, Rep II, Plot 2	Gravel, Untilled	2.3	3.8
Block 1, Rep II, Plot 2	Topsoil, Tilled	1.9	9.2
Block 1, Rep II, Plot 2	Topsoil, Untilled	1.6	15.0
Block 2, Rep II, Plot 2	Gravel, Tilled	2.1	2.7
Block 2, Rep II, Plot 2	Gravel, Untilled	2.3	3.4
Block 2, Rep II, Plot 2	Topsoil, Tilled	1.7	9.8
Block 2, Rep II, Plot 2	Topsoil, Untilled	1.6	15.0
Block 3, Rep II, Plot 2	Gravel, Tilled	1.9	2.9
Block 3, Rep II, Plot 2	Gravel, Untilled	2.3	3.5
Block 3, Rep II, Plot 2	Topsoil, Tilled	1.5	12.8
Block 3, Rep II, Plot 2	Topsoil, Untilled	1.5	12.7
Block 4, Rep II, Plot 2	Gravel, Tilled	2.2	3.8
Block 4, Rep II, Plot 2	Gravel, Untilled	2.3	3.4
Block 4, Rep II, Plot 2	Topsoil, Tilled	1.5	16.3
Block 4, Rep II, Plot 2	Topsoil, Untilled	1.7	13.4
Means:	Gravel, Tilled	2.0	3.4
	Gravel, Untilled	2.3	3.5
	Topsoil, Tilled	1.6	11.8
	Topsoil, Untilled	1.6	14.0
Botanical Garden	1990 Planting #1	1.7	16.0
Botanical Garden	1990 Planting #2	1.6	16.2
Botanical Garden	1991 Planting #3	1.8	14.1
Botanical Garden	1991 Planting #4	1.7	12.4
Means:	1990 Plantings	1.7	16.1
	1991 Plantings	1.8	13.1

hourly mean data greater than zero were summed by month, after selecting the subset of data points >0°C. Negative degree hours were summations of hourly means ≤0°C. The hourly means, which consisted of the average temperature measured every 5 minutes, were plotted for the months of July, August, and September for the coastal (Fig. 16), and foothill (Fig. 17) sites. These show the seasonal trends for each of the four years of data. There is a general pattern for air temperatures to decline over the sampling period. The coastal location daily maximum temperatures were lower than those at the foothills location during the growing season, whereas daily minimum temperatures near the coast were often higher than the minimums in the foothills. The range between daily maximum and minimum temperatures was much greater in the foothills

Table 3. Mean percentages and standard error of the means (S.E.M) of fines (<2 mm) for various treatments at the BP Put River No. 1 gravel pad (12 July 1990).

Treatment	Mean (%)	S.E.M.
Block 1	43.89	3.326
Block 2	45.43	3.493
Block 3	44.12	3.218
Block 4	43.48	3.333
All 144 Plots	44.23	1.655
Replicate 1	43.30	2.817
Replicate 2	44.11	2.886
Replicate 3	45.28	2.951
0.6-m Lift Height	43.94	2.899
0.9-m Lift Height	45.08	2.979
1.5-m Lift Height	43.67	2.778
No Topsoil	25.06	0.287
8-cm Topsoil Added	63.40	0.777
No Snow Fence	44.45	2.400
1.2-m Snow Fence	44.01	2.298
No *Poa glauca*	43.80	2.301
Poa glauca Planted	44.66	2.390
Untilled	46.40	2.466
Tilled	42.06	2.197

Table 4. Summary of average snow-depths (cm) and water contents (cm) on gravel plots and the botanical garden at the BP Put River No. 1 gravel pad, 7 and 8 May 1991.

Location	Treatment	Snow Depth (cm)	Water Content (cm)
Block 2 Gravel Plots	No Snow Fencing	<10	2.36
Block 4 Gravel Plots	No Snow Fencing	<10	0.68
Block 1 Gravel Plots	Snow Fencing	113.03	44.20
Block 3 Gravel Plots	Snow Fencing	106.17	40.89
Botanical Garden	Snow Fencing	104.65	42.67

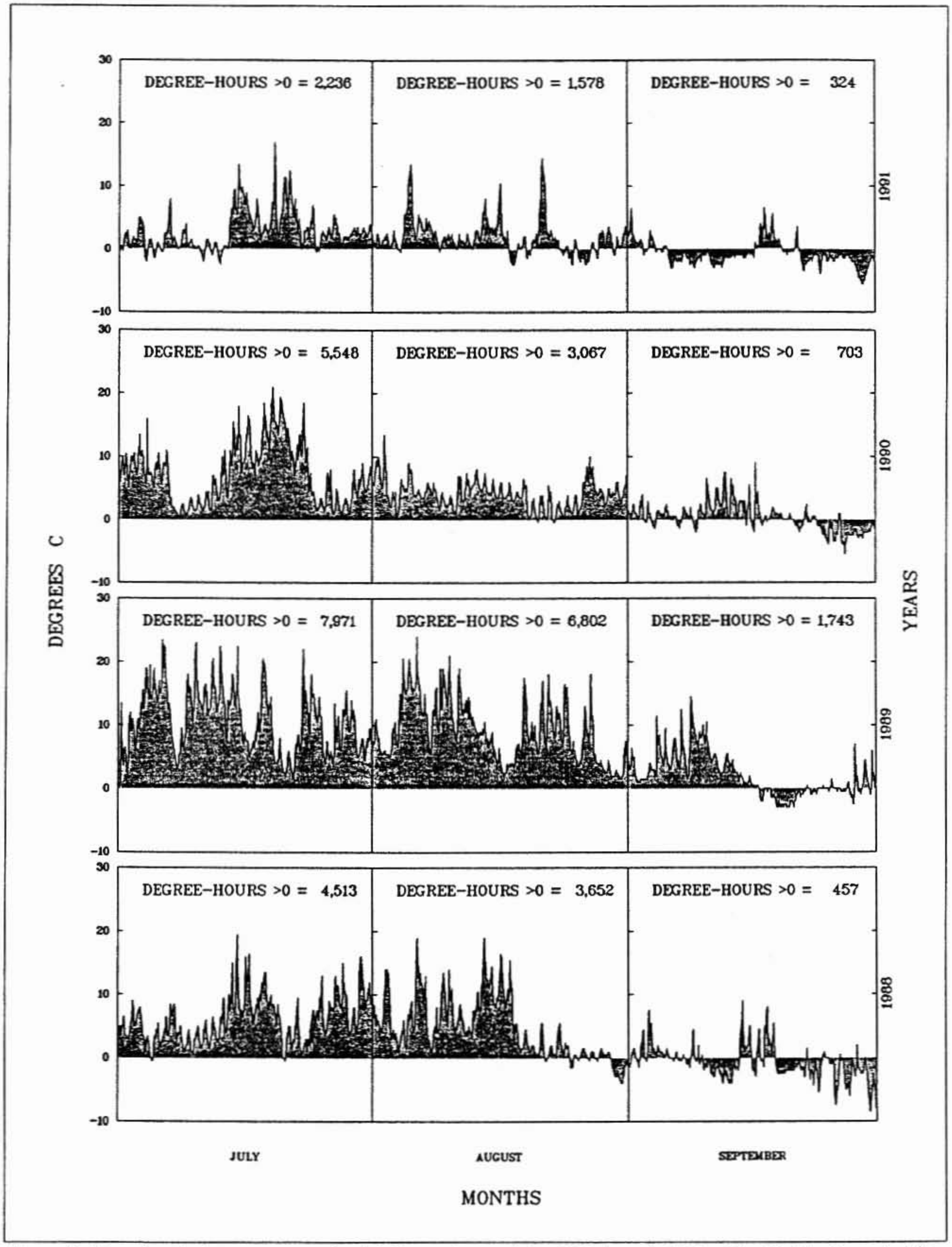

Figure 16. Mean hourly air temperatures for July-September periods, 1988 through 1991, at the Big Skookum site in the Sagavanirktok River delta, near the seacoast.

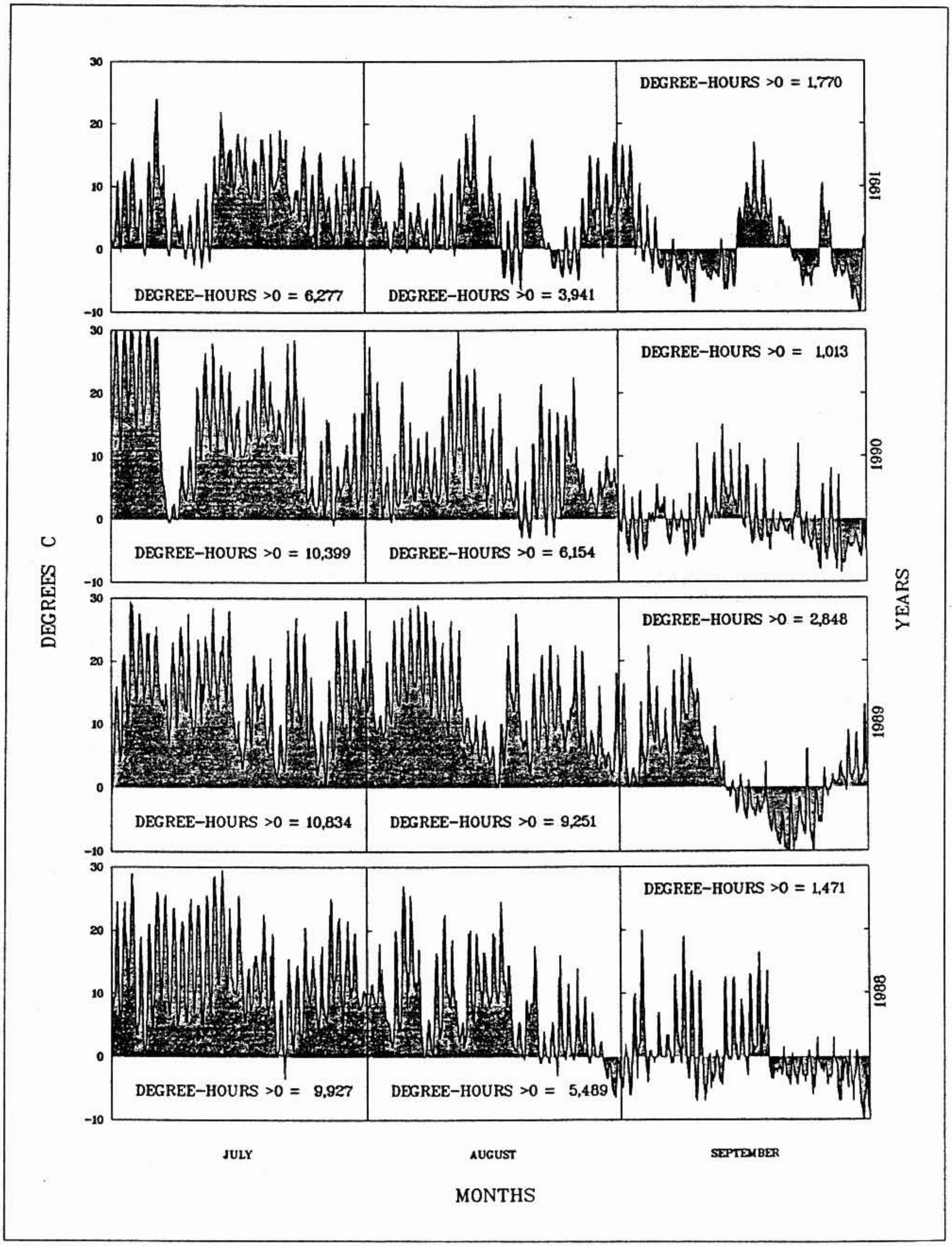

Figure 17. Mean hourly air temperatures for July-September periods, 1988 through 1991, at the MP 62 site in the foothills of the Brooks Range.

than near the coast. Warm and cool periods corresponded between these two locations, i.e., the pattern of occurrence was similar.

Within years, cumulative positive air degree-hours (°C) were substantially greater in the foothills than at the coastal site (Fig. 18). Among years, the positive degree-hours recorded at the coastal site during 1989 exceeded those recorded at the foothill location in 1991. The positive air degree-hours at the foothill location was usually about two times the number at the coastal location, even though the daily temperature at the foothill location fluctuated more than at the coast. Cumulative negative air degree-hours recorded in the foothills also always exceeded that recorded at the coastal location (Fig. 18).

It is important to observe the differences in air temperatures among years. In 1989, the warmest season in our records, air temperatures remained above freezing from the first of July through mid-September on the coastal plain. In contrast, during the coolest season in our records (1991), air temperatures during the July through mid-September period dropped to either freezing or below freezing approximately 26 times.

Substantial inter-annual variations in temperatures were recorded among the four seasons monitored. The cumulative positive air degree-hours for the 1988 and 1990 growing seasons were nearly equal. At the coastal site, the total positive air degree-hours recorded for the 1989 growing season was nearly twice that of the years 1988 and 1990, and almost four times that of 1991 (Figs. 16, 17, and 18). The pattern among years at the foothills location was similar to that for the coastal site, but the relative magnitude among years was proportionally less. The increase between the 1989 and 1988-1990 cumulative positive degree-hours was 125%, as opposed to 150% found at the coastal site.

Cumulative positive soil temperature degree-hours data for the coastal and foothill locations revealed a consistent pattern, with the growing-season soil temperatures near the coast being warmer than those in the foothills (Fig. 18). This was opposite of the air temperatures between these two locations.

Measuring Effects of Modifying Gravel Fill with Plant Indicators

Seed Collections, Germination Tests, and Planting Mixtures

Seed Collections. Complete listings of seed collection inventories, including species harvested, location, date, grams in the cleaned seedlot, and notes about the collection are exhibited in Appendix B. This information was arranged by year in Tables B-1 through B-3 for years 1989, 1990, and 1991, respectively. The numbers of species and seedlots among these collections are summarized in Table 5.

As previously mentioned, the 1989 growing season was unusually warm in the Prudhoe Bay area (Fig. 18). Plants flowered profusely; seeds of *Arctophila fulva* matured at locations where we had previously found none (McKendrick 1990). However, relatively little time was allocated in the autumn of 1989 to seed harvest, although a total of 42 species was harvested. There were 19 species of graminoids (monocotyledonous) in 37 collections, 22 species of forbs (dicotyledonous) in 26 collections and a single collection of a shrub (dicotyledonous) species (Table 5).

Temperatures in 1990 were about average (based on our limited records) for heating degree-hours. There appeared to be some carry-over effects from the previous year, which had been extraordinarily favorable. These effects were exhibited through abundant flowering and seed formation by indigenous plants. Favorable seed production does not guarantee an abundant harvest, however. Strong winds shattered much of the seed crop before it could be harvested. In spite of those conditions, seeds from 62 species were collected. The 1990 seed harvest was principally directed toward forbs and shrubs, because grasses had dominated the previous collection. The 1990 harvest consisted of 21 graminoid species among 40 seedlots, 37 forb species among 62 seedlots, and 4 shrub species among 9 seedlots (Table 5).

Temperature conditions in 1991 were unfavorable for plant growth. Many plant species failed to flower, and seeds did not form or mature. The effects were more pronounced on the coastal plain than in the foothills. To compensate for limited availability of seeds to harvest, a greater seed collecting effort was expended in the autumn of 1991, including use of a helicopter to access sites which had not been previously harvested. The 1991 harvest consisted of 55 vascular plant species among 87 seedlots: 21 graminoid species among 40 seedlots, 29 forb species among 40 seedlots, and 5 shrub species among 7 seedlots (Table 5).

In addition to the Alaska North Slope collections, seeds of arctic species were collected on the Yamal Peninsula and in Yamburg, Russia (western Siberia) in 1991. These included four grass species among four seedlots and 5 forb species among 6 seedlots (Table B-

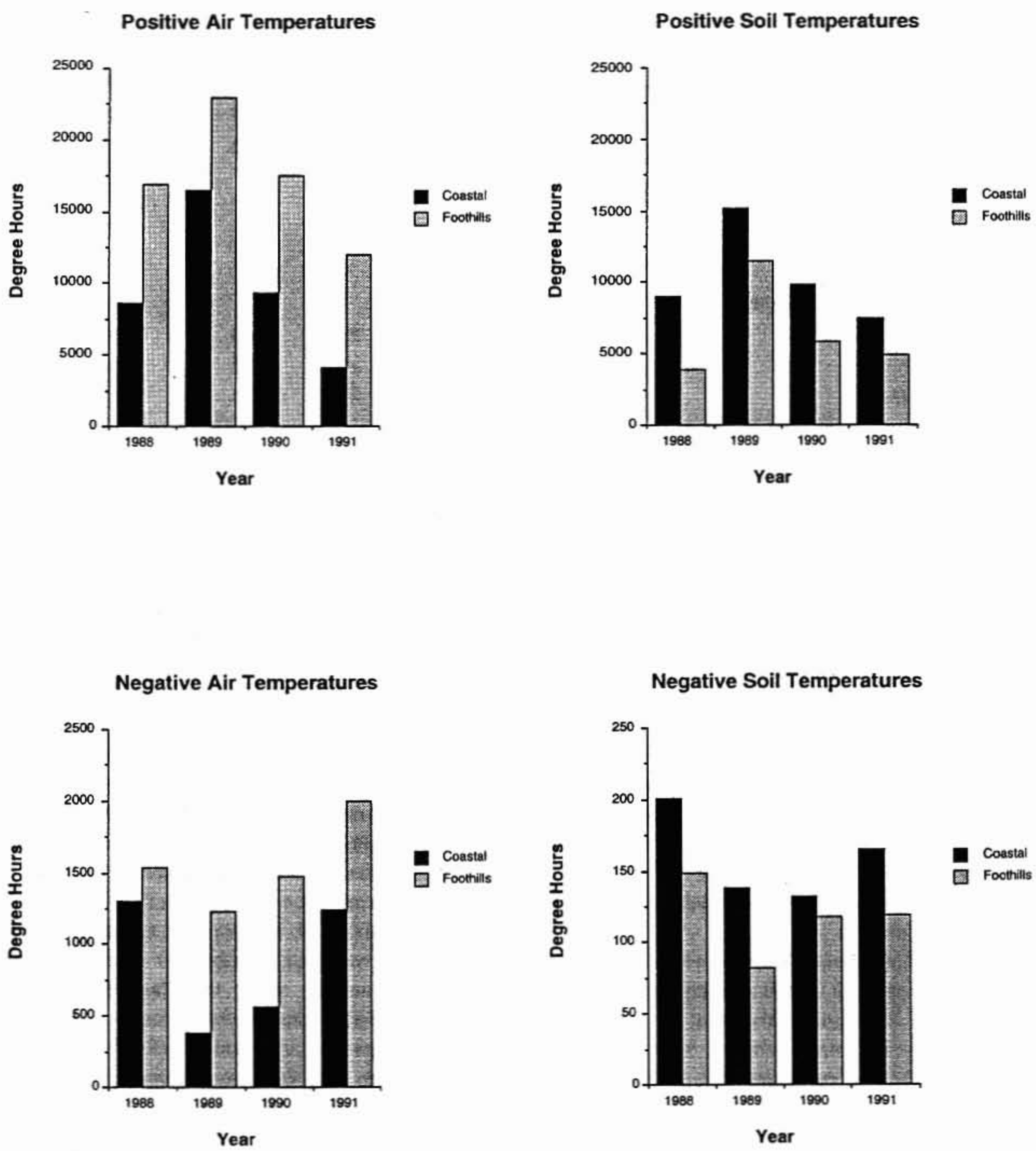

Figure 18. Cumulative positive and negative degree-hours (°C) for July-September periods, 1988 through 1991, at a coastal (Big Skookum) and a foothills (MP 62) location.

Table 5. Number of plant species collected, tested for germination, and planted in gravel vegetation plots and the botanical garden at the BP Put River No. 1 gravel pad for years 1989 through 1991.

	Collection Years					
	1989		1990		1991	
	Species	Seedlots	Species	Seedlots	Species	Seedlots
Seed Collections						
Graminoids	19	37	21	40	21	40
Forbs	22	26	37	62	29	40
Shrubs	1	1	4	9	5	7
Germination Tests						
Graminoids	21	35	21	40	.	.
Forbs	21	26	36	65	.	.
Shrubs	0	0	4	9	.	.
Gravel Plot Plantings						
Graminoids	.	.	17	28	3	4
Forbs	.	.	17	19	22	30
Shrubs	.	.	0	0	3	7
Botanical Garden Plantings						
Graminoids	.	.	17	34	4	6
Forbs	.	.	16	20	22	26
Shrubs	.	.	0	0	4	7

4, Appendix B).

Most of the Alaska collections contained relatively little viable seed for planting. Poor growing conditions resulting from low temperatures were believed responsible for the lack of mature seed produced in 1991. The Siberia collections were small. Consequently, there was not sufficient seed gathered in 1991 for a planting in 1992, except to add rows to the botanical garden. The final planting in the gravel manipulation plots will depend on seed produced during the 1992 growing season.

Germination Tests. Twenty-one graminoid species in 35 seedlots and 21 forb species in 26 seedlots in the 1989 seed collection were tested for germination percentages (Table 5 and Table C-1, Appendix C). The average germination percentage for graminoids from this collection was 81.5%. The lowest percentage (1%) was recorded for *Deschampsia beringensis*, a grass introduced to the Prudhoe Bay region several years ago from southcentral Alaska by other researchers. Seed from indigenous *Deschampsia caespitosa* plants germinated profusely (92% to 95.3%). The highest germination percentage (99%) recorded for graminoids was observed in a seedlot of *Agropyron boreale* that originated from the coastal plain. The average germination percentage for forb seed collected in 1989 was 49.2%. Forb seed germination percentages for seed collected on the coastal plain ranged from 0% in *Androsace chamaejasme* to 99.7% for *Artemisia arctica* (Appendix C).

Twenty-one graminoid species among 40 seedlots, 36 forb species among 65 seedlots, and 4 species of shrubs in 9 seedlots for the 1990 seed collections were tested for germination percentages (Table 5 and Table C-2, Appendix C). In addition, ten special germination tests were conducted on five forb seedlots. One test compared soaking seeds in Clorox® against no Clorox® soaking, another compared germination percentages between large and small seeds within the same species, and three compared germination percentage between seeds of the same species with and without hulls.

Overall germination percentages for graminoids were lower in the 1990 collections compared to those for the 1989 collections: 42.1% and 81.5%, respectively. The mean germination percentage for graminoids in 1990 ranged between 0% for two *Bromus pumpellianus* and one *Calamagrostis* *inexpansa* seedlot (all from the coastal plain) to 93% for one seedlot of *Bromus pumpellianus* from the foothills (Appendix C). The mean germination percentages of forbs collected in 1990 was also lower than for forb seeds harvested in 1989: 33% vs 49.2%, respectively. Germination percentages of 1990 forb seed collections ranged between 0% and 99.3%. A seedlot of *Artemisia arctica* collected near the Kuparuk River Bridge in 1990 yielded the highest germination percentage (99.3%) of forb seeds harvested that year. The mean germination percentage for 1990 shrub seed (51.9%) exceeded that for either graminoids or forbs collected that year. The range in germination percentages for shrubs was similar to that of grasses and forbs. Shrub seed germinations ranged from 0% for *Dryas octopetala* to 92.3% for one collection of *Salix ovalifolia*.

The average germination percentage of *Descurainia sophoides* seeds treated with Clorox® was lower (67.7%) than the non-treated seeds (89.7%). Germination percentage for large *Eutrema edwardsii* seeds was twice that of small seeds (36% to 16%), and there was no difference between hulled an unhulled seedlots of *Hedysarum mackenzii*.

Planting Mixtures. During 21–27 June 1990, 14 species of graminoids from 28 collections and 17 species of forbs from 19 collections were planted in the 144 experimental units (Table 5). There were 8,339 graminoid PLS and 1,130 forb PLS/m^2, for a total of 9,469 PLS/m^2 planted. The 1990 planting was predominantly graminoids, which comprised 88% of the seeds planted in gravel plots that year (Appendix E. Note that seeding rates are given in PLS/ft^2 in Appendix E.).

In 1991, the focus of the gravel plot planting shifted away from graminoids toward shrubs and forbs. During 25–27 June 1991, a total of 28 species, from 41 collections, was planted: 3 graminoids, 22 forbs, and 3 shrubs (Table 5). The number of seeds planted per experimental unit was an order of magnitude lower than the number planted in 1990: a total of 947 PLS/m^2. Of these, 70% were forbs and 15% each graminoid and shrub (Appendix E).

Basal and Canopy Cover of Gravel Vegetation Plots

Point data should have been recorded by plant species, to rank importance of species. However, the plants were immature on the 1990 planting in 1991, and distinguishing among grass species was difficult. Therefore, canopy and basal cover categories were recorded either as grass or forb. Basal and canopy cover data collected in early September 1991 are listed in Appendix F. These data have not been completely analyzed, but vascular plant canopy and basal cover treatment-means are given in Table 6.

The mean canopy cover (graminoid plus forb) was 47% for the 0.6-m gravel thickness, 34% for the 0.9-m thickness, and 35% for the 1.5-m thicknesses. Without topsoil added, the canopy cover averaged 32%, while with topsoil, the mean cover was 51%. Untilled plots produced a mean canopy cover of 26%, and tilled plots averaged 46%. Canopy cover averaged 41% without snow fences and 40% with. Plots without a light planting of *Poa glauca* averaged 36% canopy cover, and those with averaged 48%. Relative amounts of canopy cover between and among the various treatments on the gravel pad are shown in Figures 19 and 20. Forb canopy cover was a magnitude less than graminoid, but generally followed the same pattern, except that it varied less between treatments than did graminoid. The one exception was that forb canopy cover was highest on the 0.9-m lifts, whereas graminoid canopy cover was highest on the 0.6-m lifts (Fig. 19).

Basal cover data are summarized in Figures 21 and 22. Since very few dead plants were present, points for live and dead vascular plant basal cover were combined into a single category of vascular plant basal cover. Most of the basal points encountered rock, followed by bare (sand or soil). Moss was present only on the 0.6-m-gravel-thickness, snow-fenced treatments that had been lightly planted with *Poa glauca* (Block 1, Fig. 3). Mean vascular basal cover was usually 10% or less, except in the experimental units treated with topsoil, where it averaged 11% (Table 6). However, the basal plant cover was overestimated due to errors in recording live leaves on the ground as basal cover rather than canopy cover. The least vascular plant basal cover (2%) was recorded on the plots without topsoil.

The patterns of vascular plant basal cover generally followed those of vascular plant canopy cover (Table 6). The 0.6-m gravel thickness had the highest basal plant cover (10%), whereas the 0.9-m and 1.5-m lifts each averaged 6% basal plant cover. Without topsoil added, the basal plant cover averaged 2%, and with topsoil, the mean cover was 11%. Untilled plots produced a mean basal plant cover of 6%, and tilled plots averaged 9%. Plots without a light planting of *Poa glauca* averaged 5% basal plant cover, and those with averaged 10%. The only treatment that differed from

Table 6. Listing of mean vascular plant canopy (graminoid plus forb) and basal cover by treatment on plots seeded June 1990 at the BP Put River No. 1 gravel pad. Data were collected September 1991 with a point frame.

Gravel Modification Treatments		Mean Canopy Cover (%)	Mean Basal Cover (%)
Gravel Thickness:	0.6 m	47	10
	0.9 m	34	6
	1.5 m	35	6
Topsoil:	None	32	2
	8 cm	51	11
Tillage:	None	26	6
	Tilled	46	9
Snow Fencing:	None	41	7
	1.2 m	40	8
Poa glauca	None	35	5
	Planted	48	10

the canopy cover was the snow fence treatment. Without snow fences, basal plant cover averaged 7% and with snow fences 8%, which was opposite the canopy cover results.

Only Replicate II (Fig. 3) of the unplanted plots was sampled with the point-frame in 1991. This left the sample array unbalanced for statistical testing between unplanted and planted treatments. However, there was no need for a statistical analyses to clarify whether or not there was a difference in plant cover between seeded and unseeded treatments (Figs. 19 and 21). Plots planted to mixtures of native plant seeds contain relatively uniform stands of vegetation. These stands are dense enough to appear on color infrared aerial photography. Where seeding had not occurred, there was only a few scattered volunteers, mostly *Puccinellia langeana*, presumably originating from nearby stands of that species.

Tissue Tests

Results from the laboratory tests of plant tissues collected in September of 1991 are given in Table 7. From T-Test comparisons, it was apparent that nitrogen and calcium were significantly higher in tissues produced by plants where topsoil had been applied. Plants without topsoil contained 0.855% N compared to 2.145% N in tissues from plants grown in topsoil-treated experimental units. Calcium averaged 0.773% in tissues from non-topsoil plants and 1.085% for topsoil-grown plants. Tillage appeared to significantly increase tissue phosphorus and sodium and decrease tissue magnesium concentrations, according to T-Test analyses of the preliminary tissue data (Table 7).

Photopoints

The west photopoints were re-photographed 27 June 1993. The east photopoints (from stepladder) were photographed 28 and 29 August 1991. The slides have been developed and are in the process of being identified and labelled. They will be archived at the Palmer Research Center. Figure 23 is an illustration of a typical view of a plot from a photopoint.

Identifying Plants to Colonize Gravel Fill

Botanical Garden at BP Put River No. 1 Gravel Pad

Thirty-three vascular plant species from 54 seedlots were seeded in Rows 1–33 of the botanical garden on 27 June 1990 (Table 8 and Appendix D). The species seeded included 17 graminoids from 34

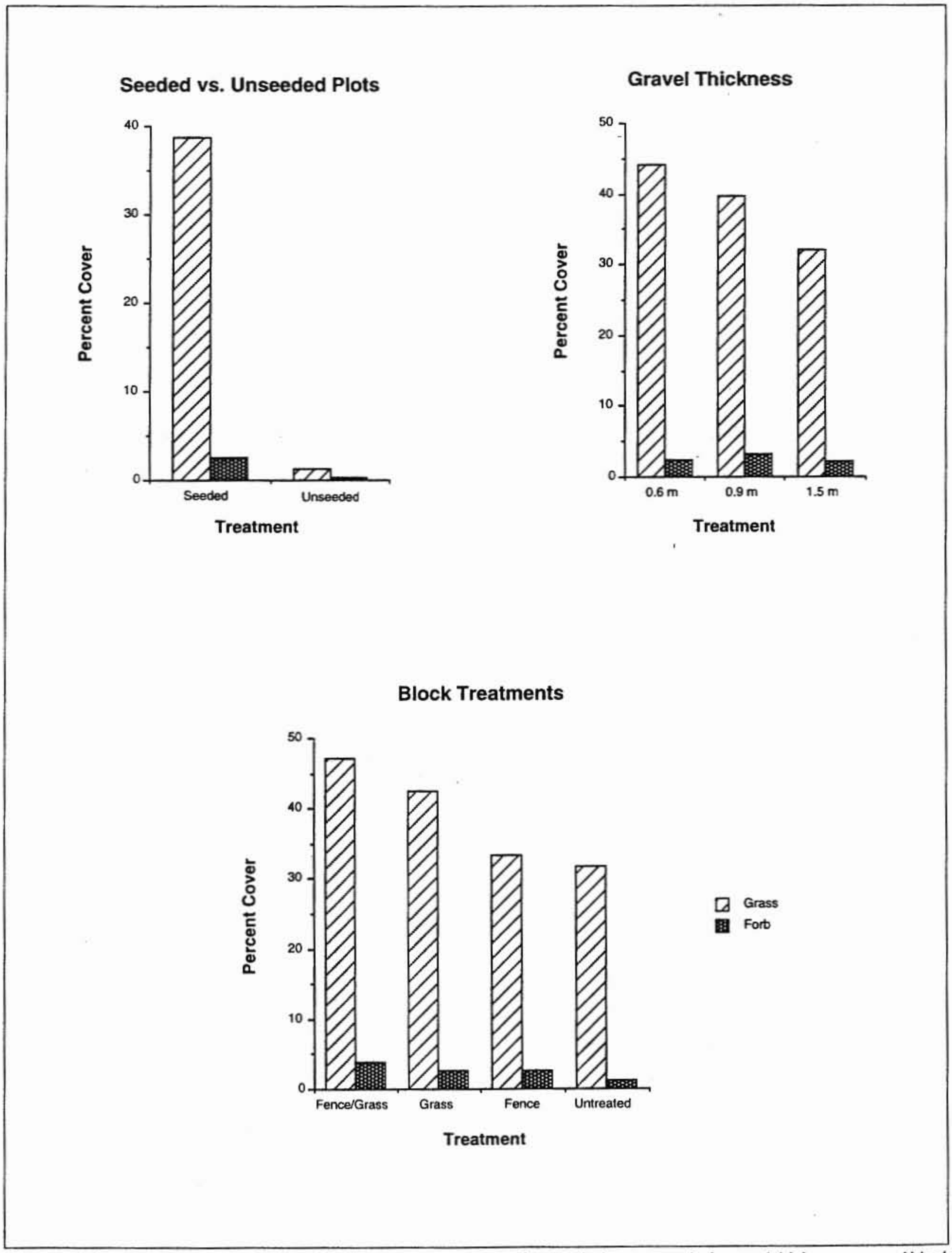

Figure 19. Comparison of graminoid and forb canopy cover means for seeded vs. unseeded, gravel thicknesses, and block treatments on the 1990-seeded plots of the BP Put River No. 1 gravel pad. The plots were measured September 1991.

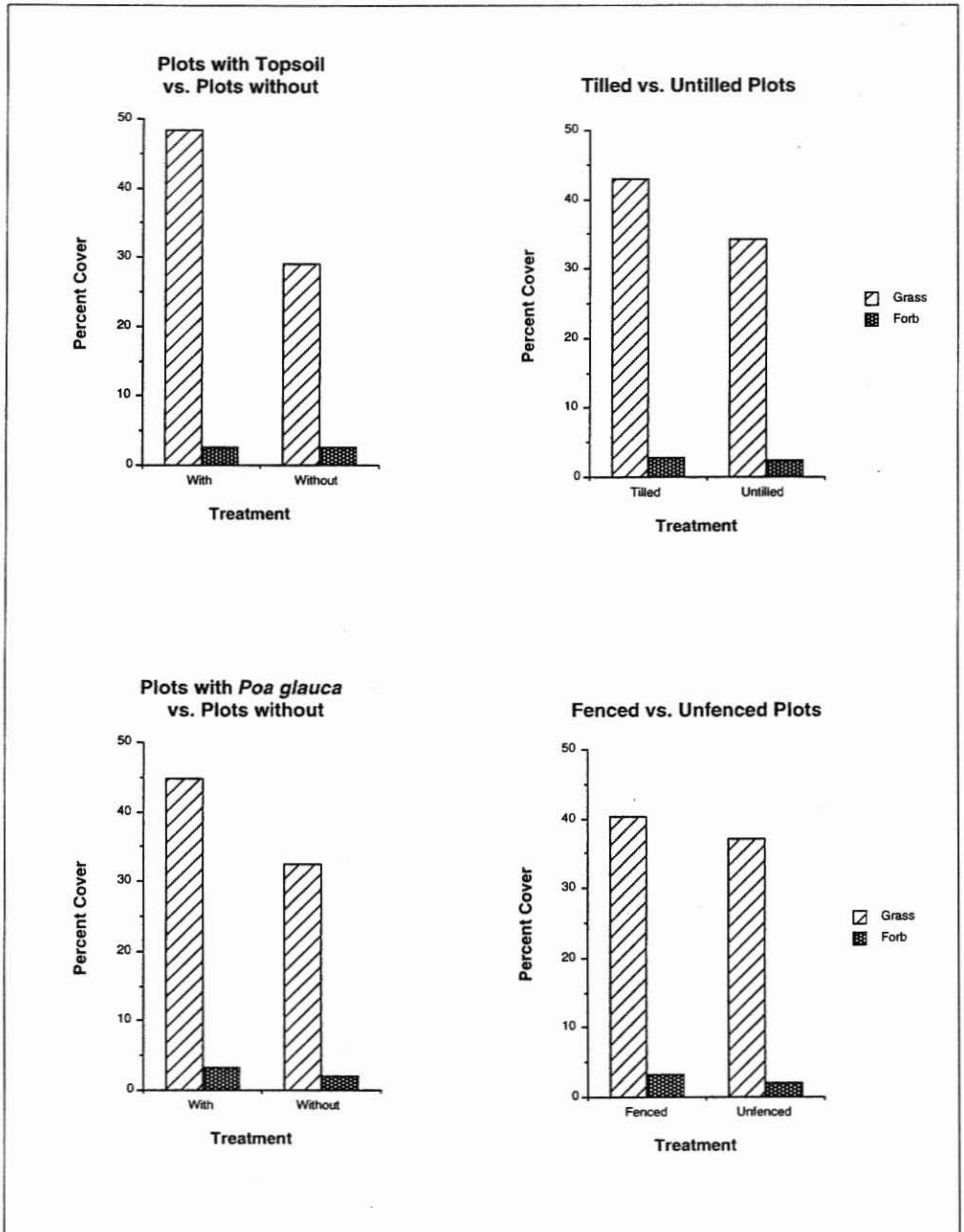

Figure 20. Comparison of graminoid and forb canopy cover means (1991) for topsoil vs. none, tilled vs. untilled, Poa glauca *vs. none and snow fenced vs. none in 1990-seeded plots on the BP Put River No. 1 gravel pad.*

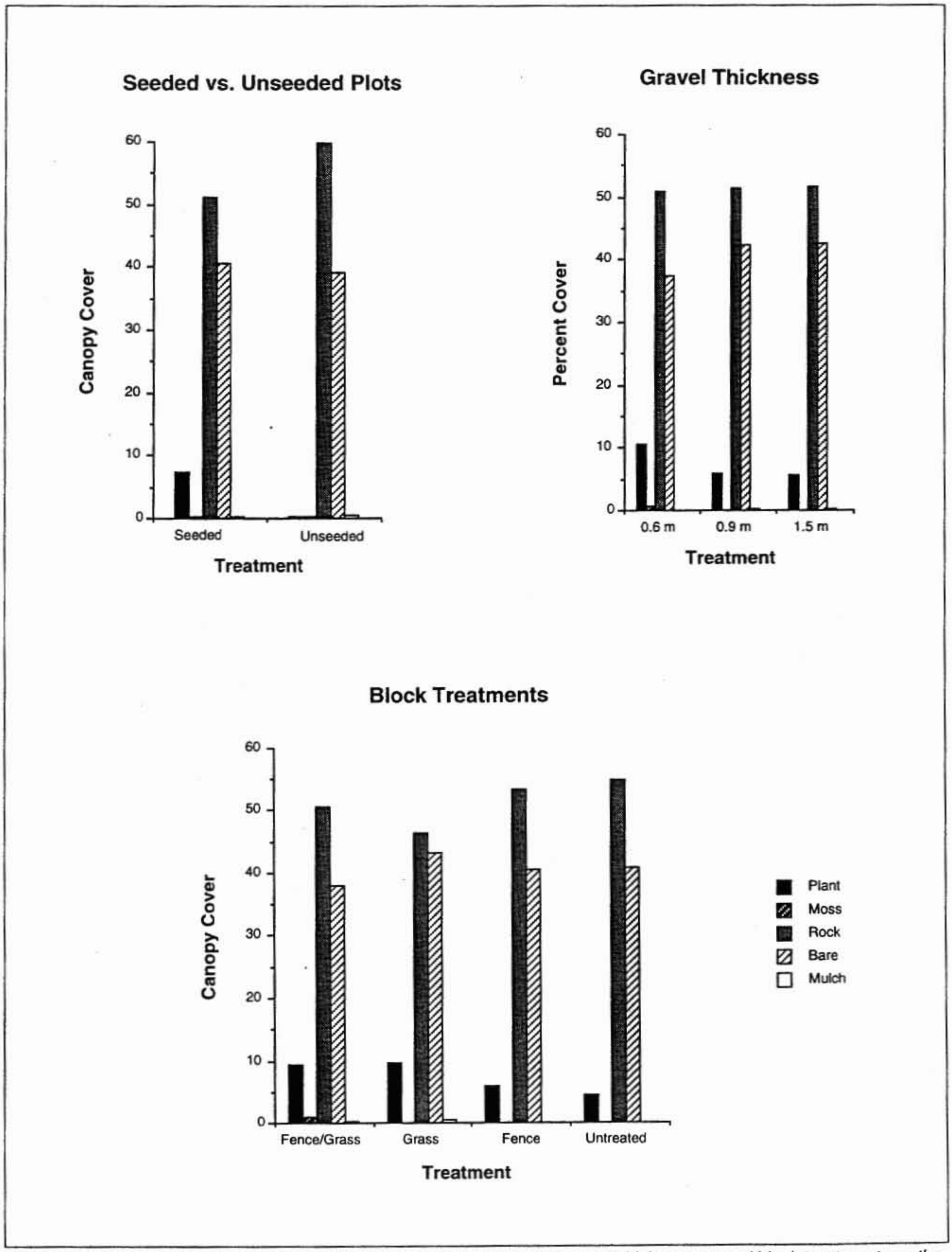

Figure 21. Comparison of basal cover means for seeded vs. unseeded, gravel thicknesses, and block treatments on the BP Put River No. 1 gravel pad. Plots were measured early September 1991 in 1990-seeded plots.

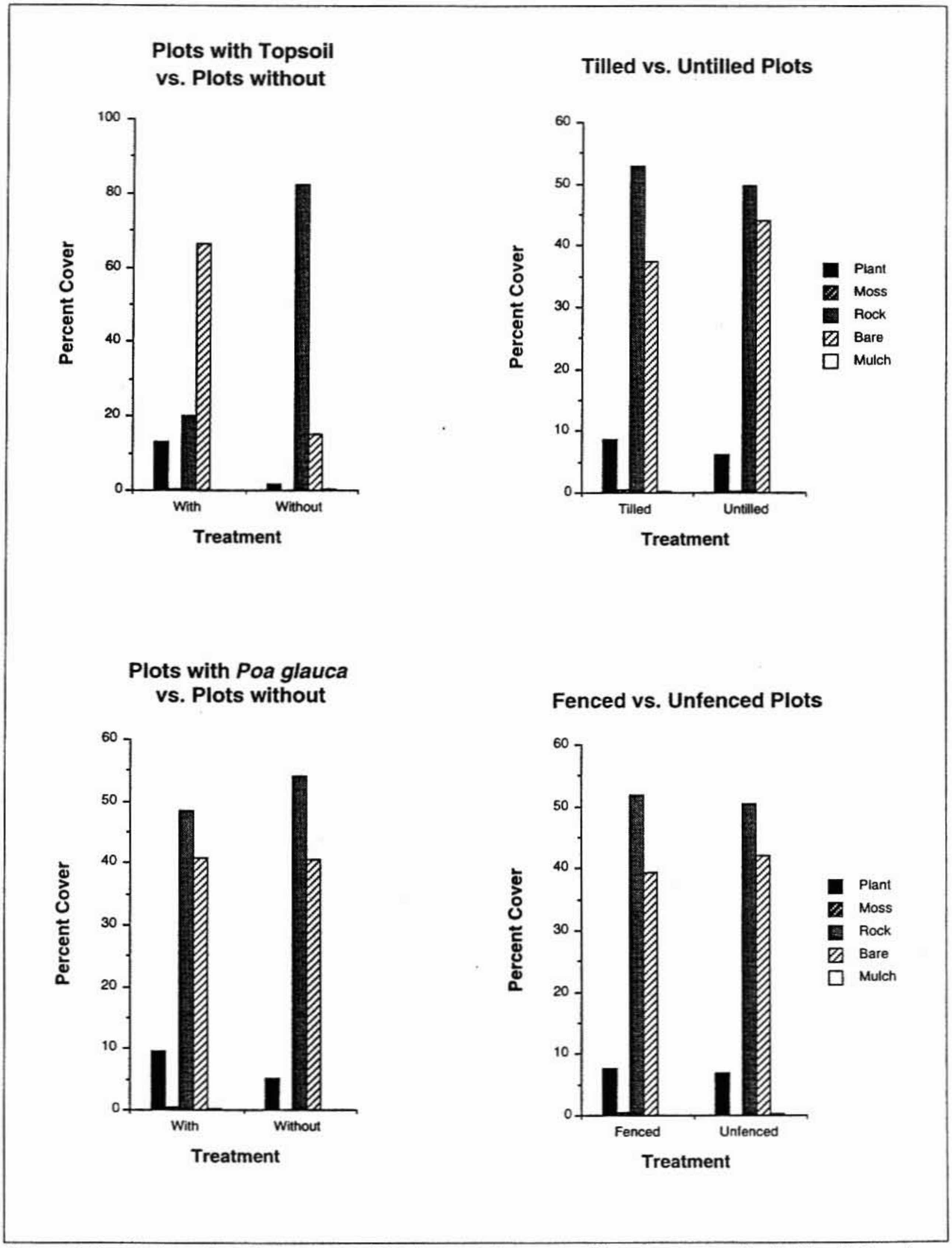

Figure 22. Comparison of basal cover means (1991) for topsoil vs. none, tilling vs. none, seeding lightly with Poa glauca *vs. none, and snow fencing vs. none on 1990-seeded plots at the BP Put River No. 1 gravel pad.*

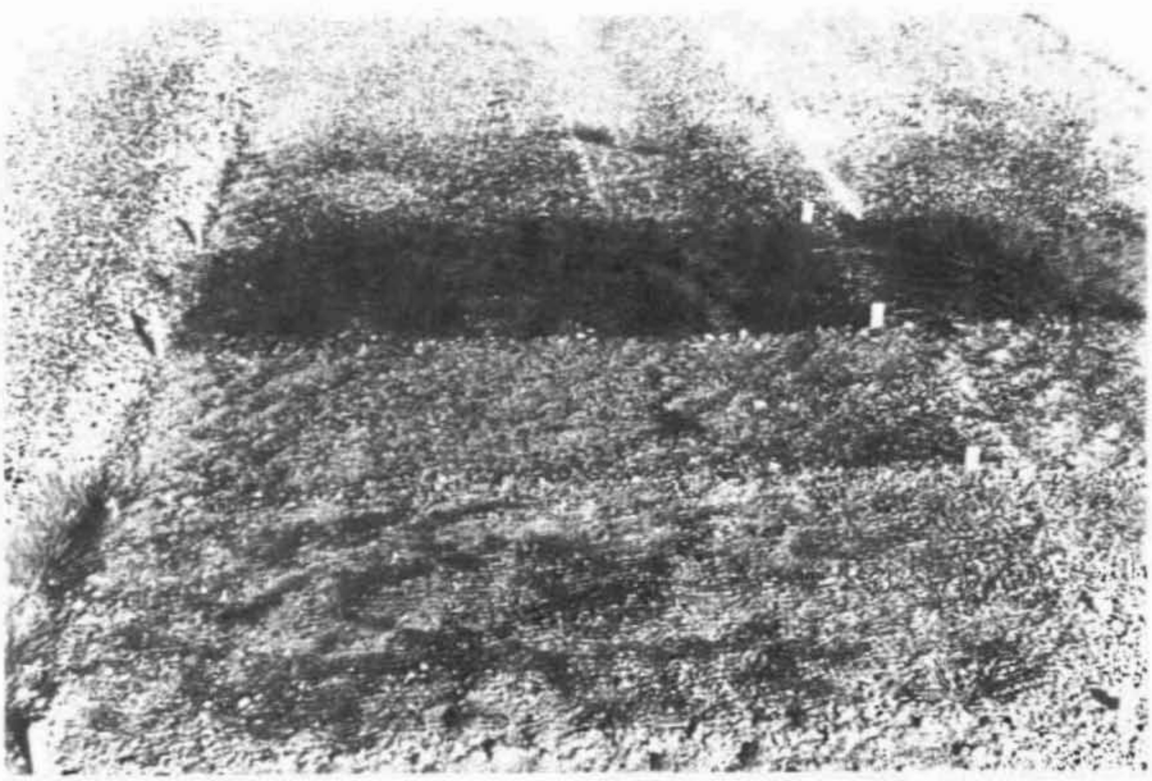

Figure 23. Photoplot - BP Put River No. 1, Block 2, Rep II, Plot 3. The treatment is 0.6 m gravel lift, 8 cm soil, and untilled (28 August 1991).

Figure 24. A 30 May 1991 view of persisting snow accumulation in Block 3, BP Put River No. 1 gravel pad.

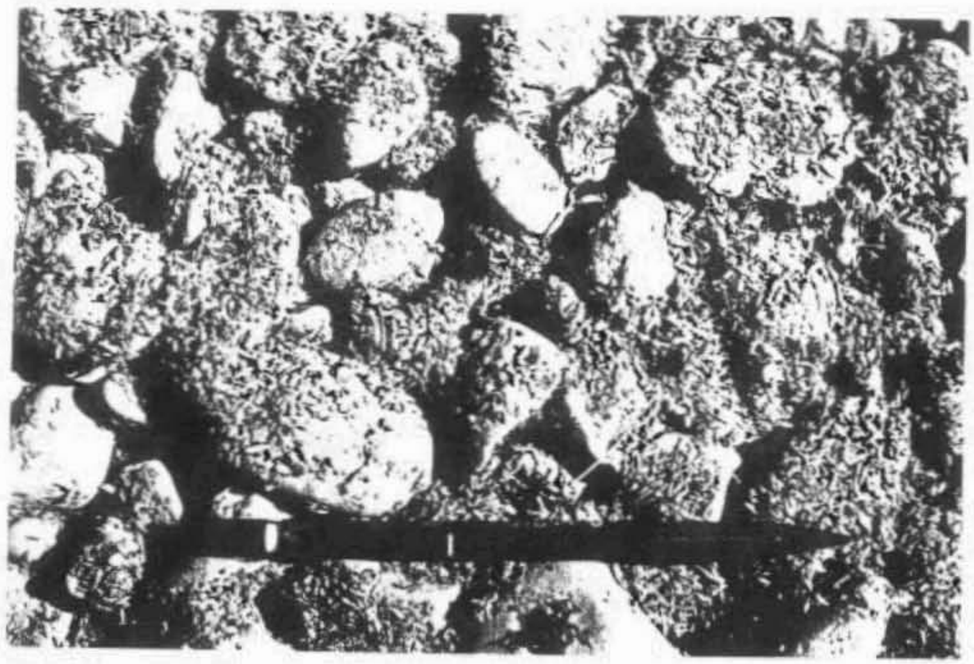

Figure 25. Accumulation from one winter of seed, other plant fragments, and soil particles on gravel surface where snow drifted between snow fences on Block 3, BP Put River No. 1 gravel pad. (21 June 1991)

Table 7. Listing of mean concentrations for six plant nutrients measured in leaf tissues collected from four gravel vegetation plots at the BP Put River No. 1 gravel pad, 12 September 1991.

	Topsoil			Tillage		
	None	8 cm	T-Test	None	Tilled	T-Test
Plant Nutrient	Means (%)[1]		Probability[2]	Means (%)[1]		Probability[2]
Nitrogen	0.855	2.145	0.001*	1.243	1.758	0.368
Phosphorus	0.270	0.193	0.107	0.185	0.278	0.040*
Potassium	0.998	1.085	0.454	0.960	1.123	0.135
Calcium	0.773	1.085	0.000*	0.920	0.938	0.898
Magnesium	0.103	0.090	n/a	0.105	0.088	0.100*
Sodium	367	363	0.865	338	342	0.004*

[1]All values are reported as percentages, except for sodium, which is mg/kg.
[2] * = significant at 95% probability.

seedlots and 16 forbs from 20 seedlots (Table 5). There were five collections planted to half-rows, because seed originated from separate sources. By 29 August 1990, seed in 25 of 39 rows had germinated. Average shoot height was 2.9 cm. By 29 August 1991, all but three of the seedlots planted in 1990 had germinated, and the average height was 6.7 cm (Table 8). The four species which had not germinated consisted of one woodrush, *Luzula arctica*, and two forbs: *Aster sibiricus* and *Armeria maritima* (Little Put River and 72 Haul Road collections). The collection of *Armeria maritima* from ARCO State 1 had germinated, but the stand was very sparse (Table 8). With few exceptions, stands were more vigorous on the east than on the west ends of the rows.

On 27 June 1991, 4 graminoids from 6 seedlots, 22 forbs from 26 seedlots and 4 shrubs from 7 seedlots were planted in Rows 34–63 of the botanical garden (Table 9 and Appendix D). There were nine species planted to half-rows, because seed originated from separate sources. Rows 34–48 were located in the northeast section of the botanical garden. Row 49 was located at the south edge of the mid-section. By 29 August 1991, only six species from eight seedlots had germinated (Table 9). These were all members of the Leguminosae family: *Astragalus aboriginum*, *A. alpinus*, *A. eucosmus*, *A. nutzotinensis*, *Hedysarum mackenzii*, and *Oxytropis borealis*. Only four species of graminoids were included in the 1991 planting at the botanical garden. None of those species germinated during the 1991 growing season, which was very cold.

Species Colonizing on Gravel Sites on Alaska's North Slope

One hundred and twenty-five vascular plant species were found colonizing ten gravel sites examined on the Alaska North Slope (Appendix H). Some of the sites had been seeded with grasses: *Poa glauca*, *Festuca rubra*, and *Arctagrostis latifolia*. *Poa pratensis* was seeded on at least one of the gravel sites in NPRA, and perhaps all of the locations along the Trans-Alaska Pipeline. No one species occurred at all ten locations. *Arctagrostis latifolia*, *Poa glauca*, and *Festuca rubra* were the most widely distributed grasses among the locations. *Epilobium latifolium* was the most common forb. Families well-represented in this listing included: Gramineae, Cyperaceae, Salicaceae, Caryophyllaceae, Cruciferae, Leguminosae, and Compositae, as the genera appear in the flora by Hultén (1968). The largest number of colonizing species (58) was found on the Lisburne Test Wellsite No. 1 drilling pad in NPRA. The fewest colonizing vascular species were found on the Inigok Test Wellsite No. 1 drilling pad (four in 1984), also in NPRA, and on the Franklin Bluffs Camp pad (eight in 1987) in the Sagavanirktok River valley. Both of the NPRA sites were seeded and fertilized in 1980, and the Franklin Bluffs camp in 1984. Numbers of species increased on sites re-evaluated after six growing seasons had lapsed. In this survey, the numbers of family, genera, and species were similar between foothill and coastal plain locations. These were for foothill and coastal plain locations, respectively: 22 and 20 fami-

Table 8. Ratings and average maximum plant heights (cm) for species planted 27 June 1990 in the botanical garden at BP Put River No. 1 gravel pad. Plants were evaluated 29 August 1990 and 29 August 1991.

Row No.[1]	Species	Growth Form[2]	1990 Stand Rating[3]	1990 Mean Maximum Height	1991 Stand Rating[3]	1991 Mean Maximum Height	Height Net Change[4]
1E	*Agropyron boreale* (Kuparuk River)	G	2	3.8	1	6.3	2.5
1W	*Agropyron boreale* (Put River)	G	4	4.0	2	7.7	3.7
2	*Alopecurus alpinus*	G	3	1.1	2	4.5	3.4
3	*Arctagrostis latifolia*	G	4	1.8	1E/2W	5.6	3.8
4	*Bromus pumpellianus*	G	5	1.5	2E/3W	5.1	3.6
5	*Deschampsia caespitosa*	G	2	1.5	1E/3W	9.0	7.5
6	*Dupontia fisheri*	G	5	1.0	4	3.0	2.0
7	*Elymus arenarius ssp. mollis*	G	2	3.8	1	10.8	7.0
8	*Festuca brachyphylla*	G	5	1.8	3E/4W	1.6	(0.2)
9	*Festuca ovina*	G	3	2.0	2E/3W	8.6	6.6
10	*Festuca vivipara*	G	3	1.3	3	7.6	6.3
11	*Poa arctica*	G	3	2.0	2E/3W	8.1	6.1
12E	*Poa glauca* (BP Plots)	G	2	1.4	1	15.8	14.4
12W	*Poa glauca* (1972 Haul Road)	G	2	1.4	1,2	16.9	15.5
13E	*Puccinellia langeana* (Put River)	G	1	1.5	3	2.0	0.5
13W	*Puccinellia langeana* (IBP Plots)	G	1	1.5	1	3.3	1.8
14	*Trisetum spicatum*	G	2	1.3	2	4.3	3.0
15E	*Festuca rubra* (Kuparuk River)	G	3	1.6	2	5.8	4.2
15W	*Festuca rubra* (IBP Plots)	G	2	1.5	1	9.2	7.7
16	*Carex maritima*	G	6	.	5	1.0	1.0
17	*Luzula arctica*	G	6	.	6	.	.
18E	*Armeria maritima* (Put River)	F	6	.	6	.	.
18W	*Armeria maritima* (ARCO State No. 1)	F	6	.	5	1.0	1.0
19	*Artemisia arctica*	F	2	0.6	2	1.5	0.9
20	*Artemisia borealis*	F	2	0.5	3	2.0	1.5
21	*Artemisia glomerata*	F	2	0.4	2E/3W	1.0	0.6
22	*Aster sibiricus*	F	6	.	6	.	.
23	*Braya pilosa/B. purpurascens*	F	6	.	3E/5W	0.2	0.2
24	*Cerastium beeringianum*	F	6	.	3E/5W	0.3	0.3
25E	*Descurainia sophioides*	F	6	.	2	13.3	13.3
25W	*Descurainia sophioides*	F	6	.	3	1.0	1.0
26	*Draba spp.*	F	6	.	5	0.5	0.5
27	*Epilobium latifolium*	F	4	0.3	6	0.0	(0.3)
28	*Eutrema edwardsii*	F	6	.	3E/4W	0.3	0.3
29	*Melandrium apetalum*	F	4	0.3	3E/4W	1.5	1.2
30	*Parrya nudicaulis*	F	6	.	3	1.0	1.0
31	*Sedum rosea*	F	4	0.2	2	0.2	0.0
32	*Senecio congestus*	F	6	.	3	1.5	1.5
33	*Silene acaulis*	F	6	.	3	0.2	0.2

[1] E and W refer to the east and west sections of the rows, respectively.
[2] G = graminoid; F = forb.
[3] 1 = very dense; 2 = dense; 3 = medium; 4 = thin; 5 = sparse, few plants; 6 = no plants.
[4] Height Net Change = (1991 average maximum height) - (1990 average maximum height).

Table 9. Ratings and average maximum plant heights (cm) for species planted 27 June 1991 in the botanical garden at BP Put River No. 1 gravel pad. Plants were evaluated 29 August 1991.

Row No.[1]	Species	Growth Form[2]	Stand Rating[3]	Mean Maximum Height (cm)
34E	*Arctophila fulva* (Lonnie Lake)	G	6	.
34W	*Arctophila fulva* (Pump Station No. 1)	G	6	.
35	*Elymus innovatus*	G	6	.
36E	*Festuca baffinensis* (72 Haul Road)	G	6	.
36W	*Festuca baffinensis* (Endicott Road)	G	6	.
37	*Carex ursina*	G	6	.
38E	*Androsace chamaejasme* (72 Haul Road)	F	6	.
38W	*Androsace chamaejasme* (E. Dock Dunes)	F	6	.
39	*Arabis arenicola*	F	6	.
40	*Astragalus aboriginum*	F	4	0.1
41	*Astragalus alpinus*	F	5	0.1
42	*Astragalus eucosmus*	F	5	0.1
43	*Astragalus nutzotinensis*	F	5	0.1
44	*Castilleja elegans*	F	6	.
45	*Tanacetum bipinnatum*	F	6	.
46	*Draba corymbosa*	F	6	.
47E	*Hedysarum mackenzii* (MP 369)	F	5	0.1
47W	*Hedysarum mackenzii* (MP 405)	F	5	0.1
48E	*Minuartia obtusiloba* (MP 354.5)	F	6	.
48W	*Minuartia obtusiloba* (MP365)	F	6	.
49E	*Oxytropis borealis* (8 Aug 1990)	F	5	0.1
49W	*Oxytropis borealis* (16 Aug 1990)	F	5	0.1
50	*Oxytropis nigrescens*	F	6	.
51	*Pedicularis capitata*	F	6	.
52	*Pedicularis labradorica*	F	6	.
53	*Pedicularis lanata*	F	6	.
54	*Polymonium boreale*	F	6	.
55	*Potentilla hookeriana*	F	6	.
56	*Saxifraga tricuspidata*	F	6	.
57	*Silene acaulis*	F	6	.
58	*Silene wahlbergella*	F	6	.
59	*Wilhelmisa physoides*	F	6	.
60E	*Dryas integrifolia* (E. Dock Dunes)	S	6	.
60W	*Dryas integrifolia* (Endicott Road)	S	6	.
61	*Dryas octopetala*	S	6	.
62E	*Salix arctica* (72 Haul Road)	S	6	.
62W	*Salix arctica* (Endicott Road)	S	6	.
63E	*Salix ovalifolia* (Endicott Road)	S	6	.
63W	*Salix ovalifolia* (E. Dock Dunes)	S	6	.

[1] E and W refer to the east and west sections of the row, respectively.
[2] G = graminoid; F = forb; S = shrub/woody.
[3] 1 = very dense; 2 = dense; 3 = medium; 5 = sparse, few plants; 6 = no plants.