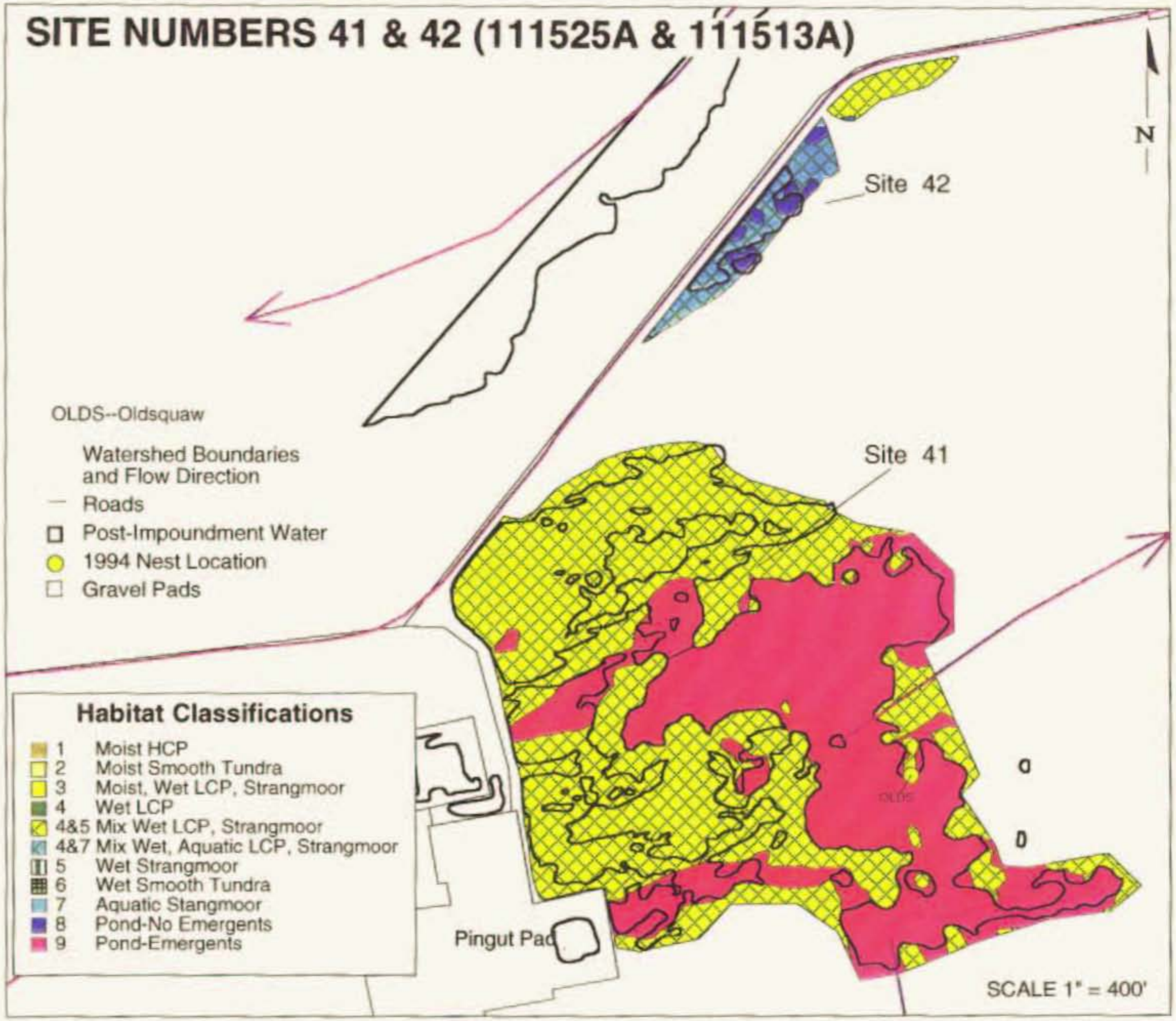

Figure 12. Study Sites 41 and 42 (Impoundments 111525A and 111513A) map showing pre-development habitat mapping based on 1955 aerial photography, post-impoundment open water boundaries based on July 1993 aerial photography, and waterfowl nest locations from summer 1994 field studies in the Prudhoe Bay oil field, Alaska.
A total of 112 birds of 12 species were recorded at Sites 41 and 42 during periods 2, 3 and 4, summer 1994.

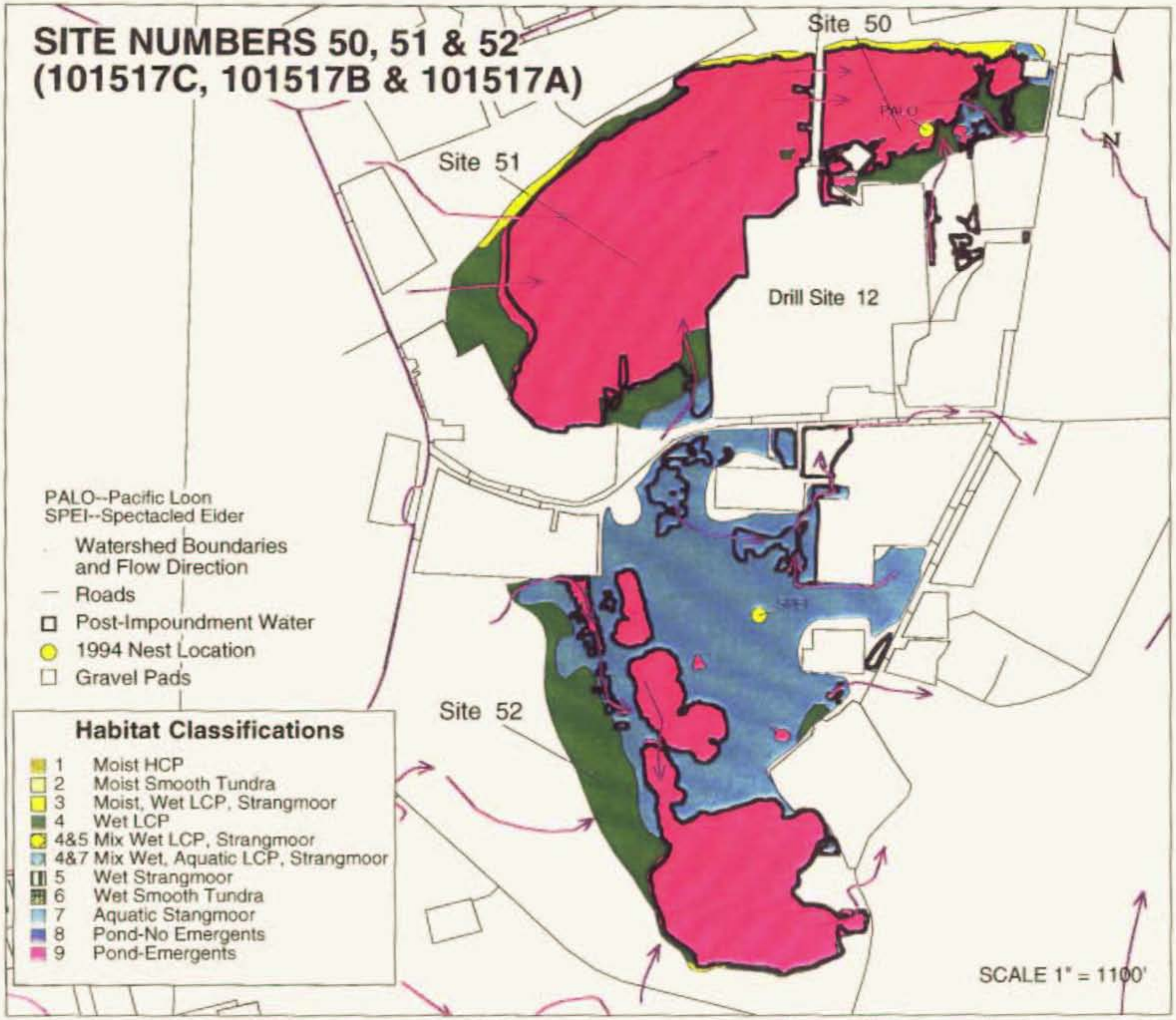

Figure 13. Study Sites 50, 51 and 52 (Impoundments 101517C, 101517B and 101517A) map showing pre-development habitat mapping based on 1955 aerial photography, post-impoundment open water boundaries based on July 1993 aerial photography, and waterfowl nest locations from summer 1994 field studies in the Prudhoe Bay oil field, Alaska.
A total of 939 birds of 21 species were recorded at Sites 50, 51 and 52 during periods 2, 3 and 4, summer 1994.

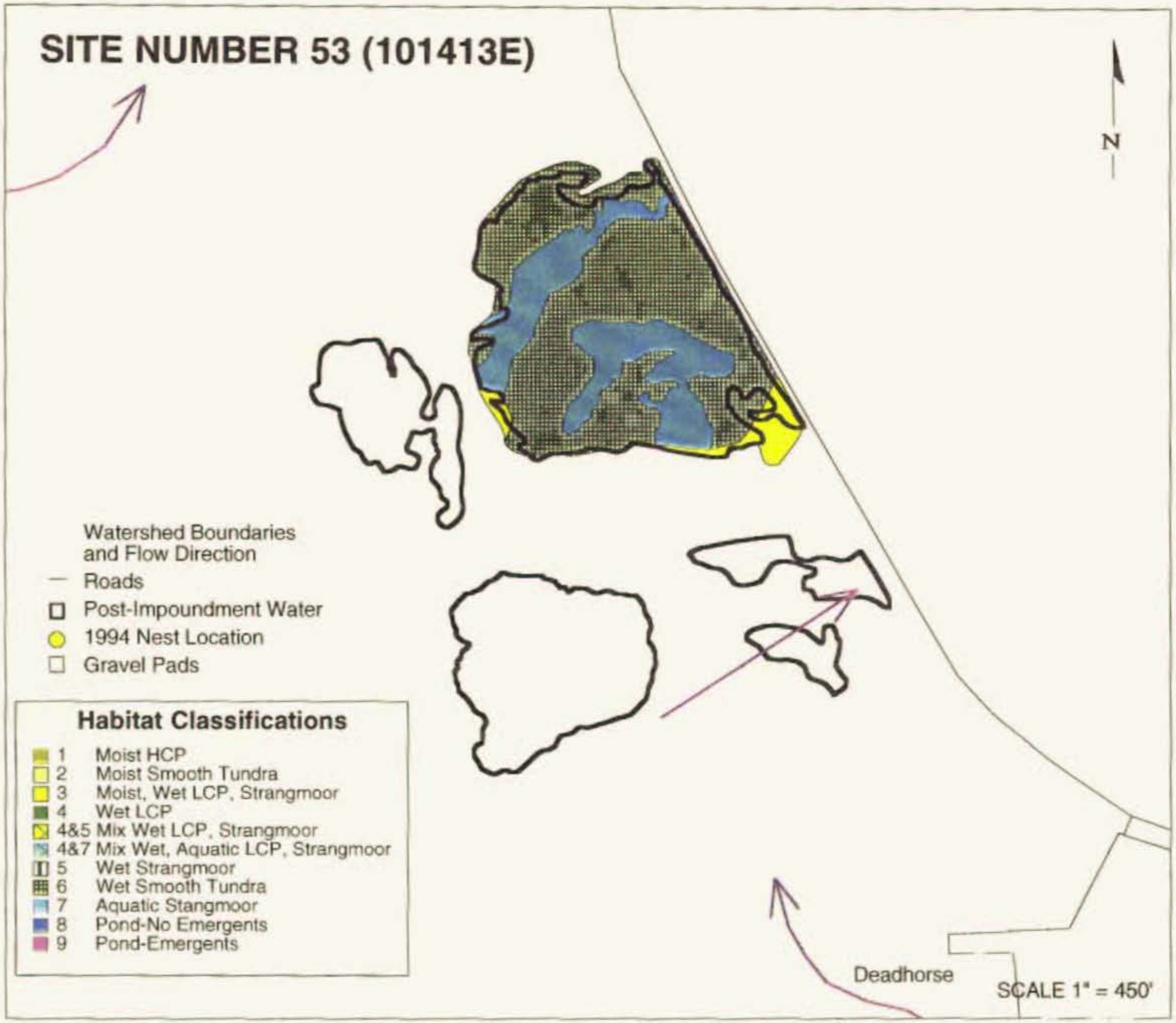

Figure 14. Study Site 53 (Impoundment 101413E) map showing pre-development habitat mapping based on 1955 aerial photography, post-impoundment open water boundaries based on July 1993 aerial photography, and waterfowl nest locations from summer 1994 field studies in the Prudhoe Bay oil field, Alaska.
A total of 102 birds of 10 species were recorded at Site 53 during periods 2, 3 and 4, summer 1994.

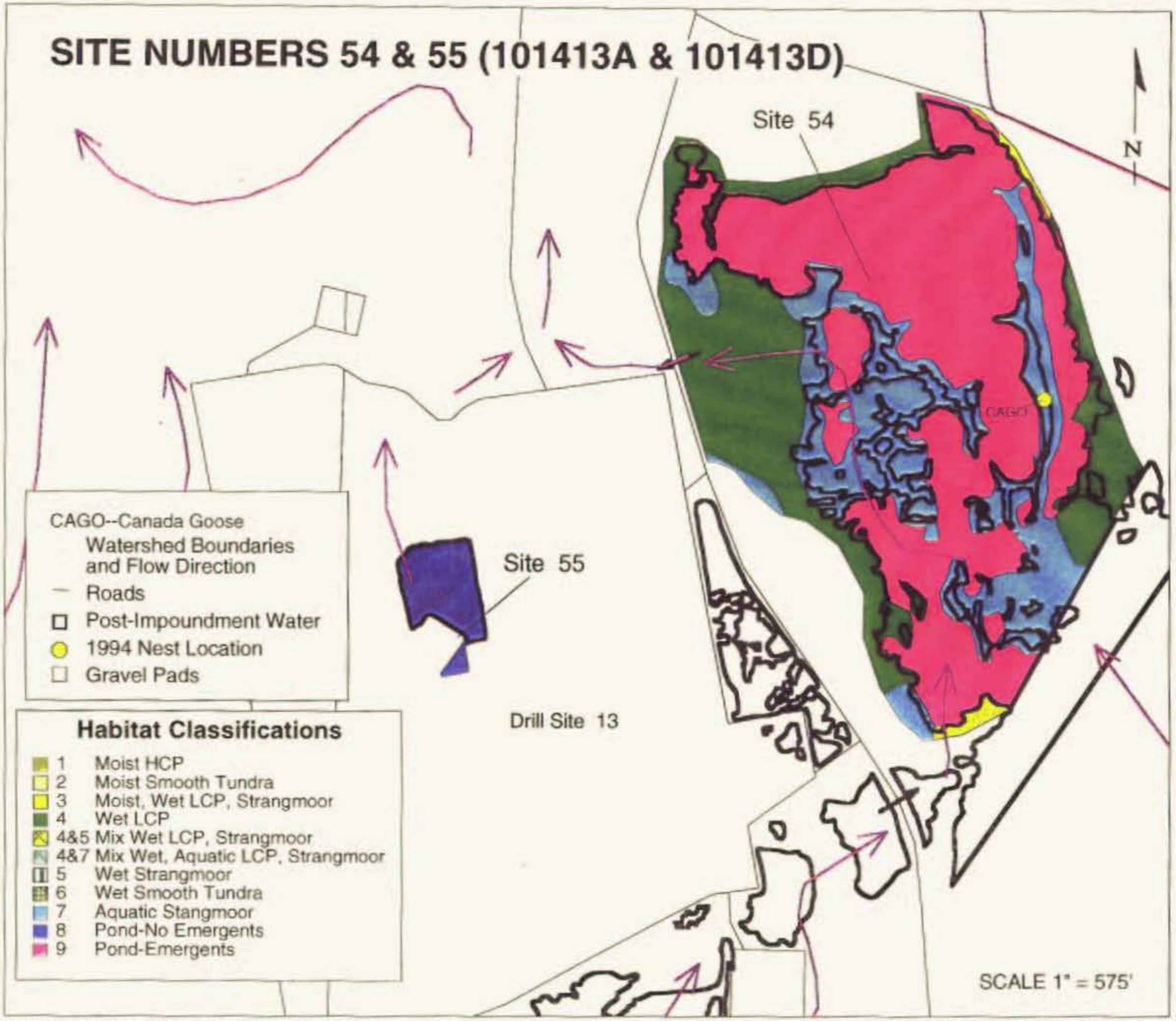

Figure 15. Study Sites 54 and 55 (Impoundments 101413A and 101413D) map showing pre-development habitat mapping based on 1955 aerial photography, post-impoundment open water boundaries based on July 1993 aerial photography, and waterfowl nest locations from summer 1994 field studies in the Prudhoe Bay oil field, Alaska.
A total of 209 birds of 12 species were recorded at Sites 54 and 55 during periods 2, 3 and 4, summer 1994.

Table 9. Comparisons of the weighted mean densities of 14 common bird species and bird nests prior to and after impoundment of tundra habitats in the Prudhoe Bay oil field, Alaska, 1994.

	Mean Number of Birds per sq km						Mean Number of nests per sq km					
Major Species	Pre-Impound.	% of Total	Rank	Post-Impound.	% of Total	Rank	Pre-Impound.	% of Total	Rank	Post-Impound.	% of Total	Rank
Pacific Loon	3.20	1.53	10	10.15	5.88	6	2.19	34.89	1	4.39	60.80	1
Red-throated Loon	1.31	0.62	14	0.28	0.16	13	1.43	22.78	2	0.28	3.88	4
King Eider	6.40	3.06	8	4.01	2.32	8	0.97	15.42	4	0.57	7.89	3
Greater White-fronted Goose	2.45	1.17	12	8.22	4.76	7	0.56	8.97	5	1.84	25.48	2
Oldsquaw	9.54	4.56	7	10.58	6.13	5	1.12	17.94	3	0.14	1.94	5
Red-necked Phalarope	10.00	4.78	6	81.26	47.09	1						
Red Phalarope	28.64	13.68	4	3.64	2.11	9						
Pectoral Sandpiper	36.25	17.32	2	15.49	8.98	3						
Semipalmated Sandpiper	35.96	17.18	3	21.34	12.37	2						
Dunlin	19.43	9.28	5	0.42	0.24	12						
Stilt Sandpiper	1.67	0.80	13	1.04	0.60	10						
Lapland Longspur	47.49	22.68	1	15.30	8.87	4						
Lesser Golden Plover	4.46	2.13	9	0.85	0.49	11						
Buff-breasted Sandpiper	2.54	1.21	11	0.00	0.00	14						

Table 10. Results of regression analyses and paired-sample statistics for weighted mean densities of birds (birds/sq km) in areas affected by impoundments. Pre-impoundment densities were computed from historical bird density data for 11 tundra habitats (Troy 1988, Troy unpublished data), and impoundment densities were based on systematic sampling during three periods at 51 randomly selected impoundments, Prudhoe Bay oil field, Alaska, summer 1994. Densities were also corrected for 1994 variation by a correction factor provided by D. Troy (pers. comm.).

Test	n				Probability (α=0.05)
Simple Regression					
		Equation			
Data uncorrected for 1994 variation. Figure 4.	14	y = 0.18x + 9.6		r^2 = 0.019	p = 0.64
Data corrected for 1994 variation. Figure 5.	14	y = 0.13x + 6.7		r^2 = 0.020	p = 0.64
Mann-Whitney U test		Mean Rank			
		Pre-Impoundment	Post-Impoundment		
Data uncorrected for 1994 variation.	14	16	13	Z = -0.965	p = 0.33
Data corrected for 1994 variation.	14	16.6	12.4	Z = -1.332	p = 0.18
Wilcoxon signed rank (paired-sample) test		Mean Rank			
		Positive Rank	Negative Rank		
Data uncorrected for 1994 variation.	14	7.3 (n=10)	8(n=4)	Z=-1.287	p = 0.20
Data corrected for 1994 variation.	14	7.1(n=11)	9(n=3)	Z=-1.601	p = 0.11

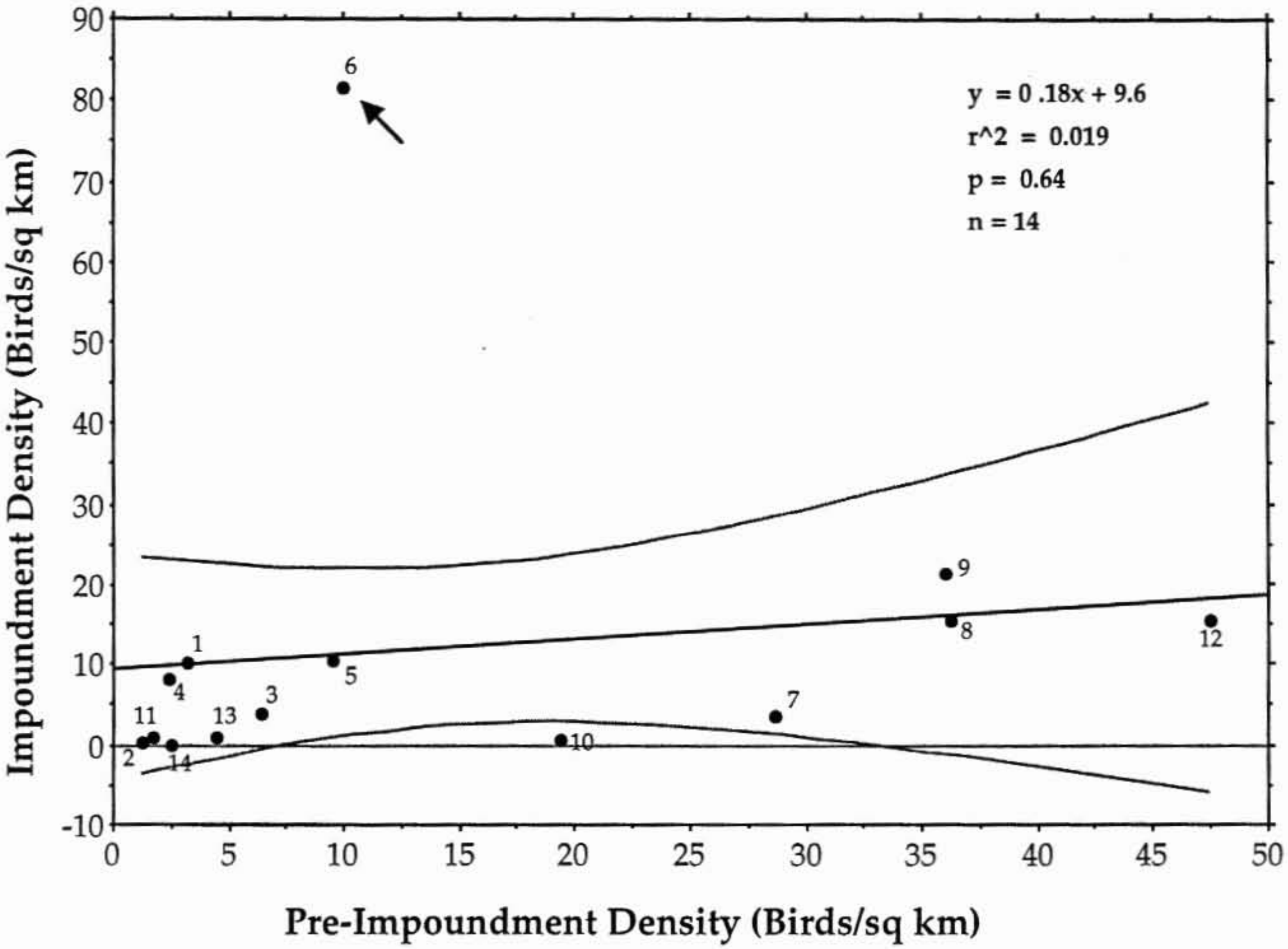

Figure 16. Comparisons of weighted mean densities of birds (birds/sq km) in areas affected by impoundments. Pre-impoundment densities were computed from historical bird density data for 10 typical tundra habitats (Troy 1988, Troy unpub. data), and impoundment densities were based on systematic sampling during three periods at 51 randomly selected impoundments. Numbers next to data points indicate the 14 species of tundra nesting birds used in the comparison: 1=Pacific Loon, 2= Red-throated Loon, 3=King Eider, 4=Greater White-fronted Goose, 5=Oldsquaw, 6=Red-necked Phalarope, 7=Red Phalarope, 8=Pectoral Sandpiper, 9=Semipalmated Sandpiper, 10=Dunlin, 11=Stilt Sandpiper, 12=Lapland Longspur, 13=Lesser Golden Plover, 14=Buff-breasted Sandpiper.

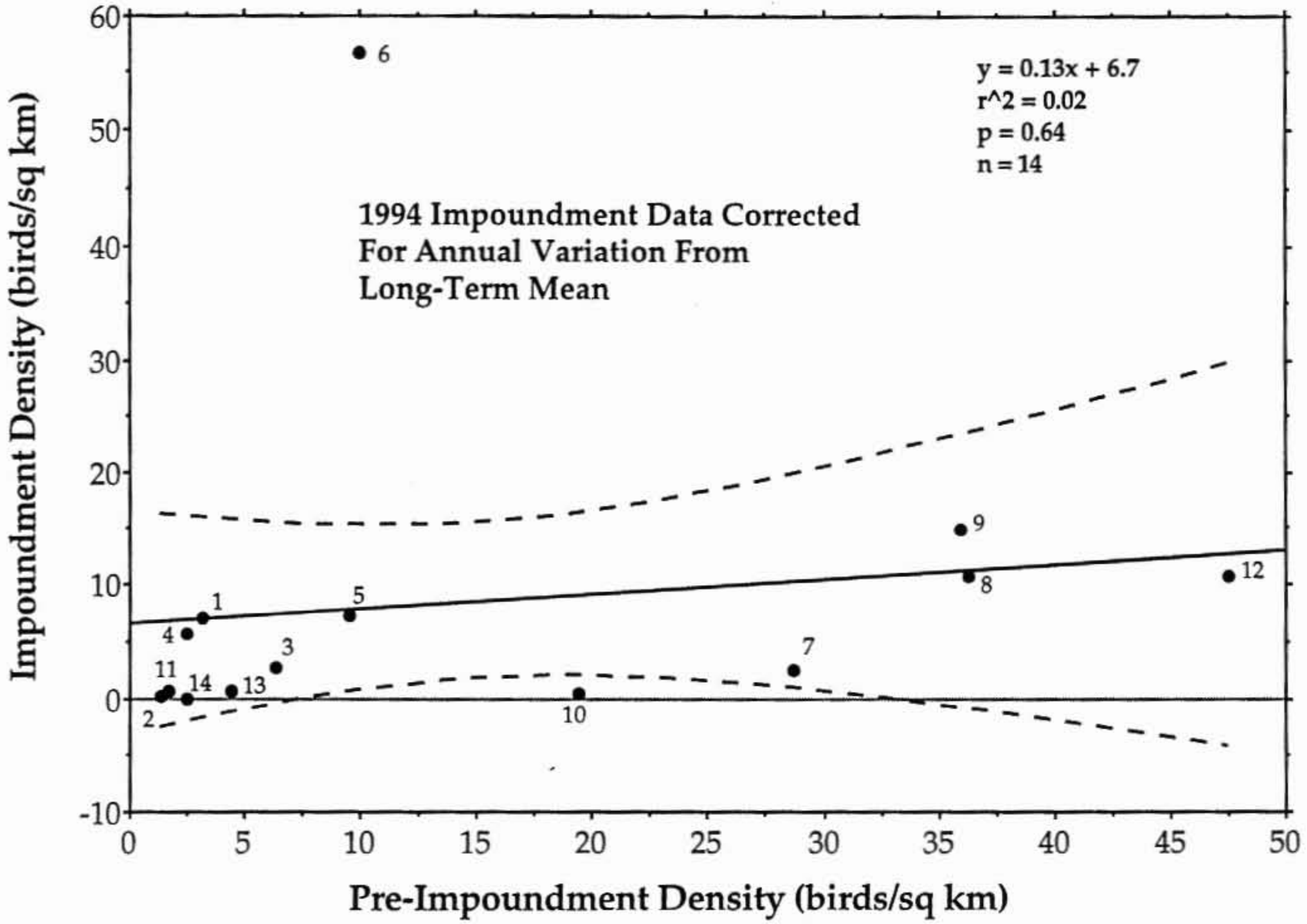

Figure 17. Comparison of corrected weighted mean densities of birds (birds/sq km) in areas affected by impoundments. Pre-impoundment densities were computed from historical bird density data for 10 typical tundra habitats (Troy 1988, Declan Troy unpub. data), and impoundment densities were based on systematic sampling during three periods at 51 randomly selected impoundments. Impoundment densities shown in Figure 4 were corrected for annual variation from the long-term means in Troy (1988) with 1994 densities provided by D. Troy (pers. comm.). Data points represent the same 14 species indicated in Figure 16.

were no significant differences and non-significant regression in bird densities for the pre-impoundment bird densities versus the post impoundment bird densities (Table 10).

DISCUSSION

Habitat Alteration

The total 11.3 km^2 temporarily and permanently flooded by impoundments in 1993 is less than the comparable 1983 estimate of 14 km^2 reported by Walker et al. (1987). This difference may be due to several factors. Drainage and culvert maintenance throughout the oil field have been improved since Walker et al. (1987) conducted their study. The effects of secondary impacts from impounded water have been reduced in the last decade, and are not as extensive as previously reported. In addition, the 14 km^2 Walker et al. (1987) found was based on 1:24000 scale mapping and was measured using planimetry. Our study was based on 1:6000 scale mapping and GIS calculated areas. The area of pre-development open water within the impoundment flood areas was not determined on the 1:24000 mapping used to calculate the 14 km^2 impact area (Walker et al. 1987) . In this study, we mapped all impoundments larger than 0.0002 km^2 in size at a 1:6000 scale throughout the entire PBOF. Because these values include areas of pre-development open water, they do not accurately represent the tundra area impacted by flooding. In this case, our calculation of 8.0 km^2 temporarily and permanently flooded tundra most accurately describes the area affected by impoundments in the PBOF.

Annual variation in snowfall, precipitation and temperatures during spring thaw, can also influence the progression and extent of flooding during June. To determine if weather conditions were similar in 1983 and 1993, and to determine if these years represent average conditions for the North Slope weather data from Barrow, Alaska, were summarized (NOAA 1995, Fig. 18). Barrow was the closest continuously recording weather station covering 1982 to 1993, which included temperature and precipitation records. Conditions during 1983 were generally drier and cooler than in 1993, suggesting that the extent of flooding during 1993 should have been at least as large as in 1983. These data indicate that conditions during 1993 were higher than average for snowfall, slightly below average for July precipitation and slightly warmer than average in June. These conditions may have led to an increased impoundment flood area over dryer annual conditions. Snowfall and precipitation were similar in 1993 and 1994, when impoundment mapping and bird use were recorded, but June temperature averaged cooler in 1994 (Fig. 18).

On a landscape scale, considering the entire PBOF unit area of 968 km^2, the total area flooded by impoundments represents 1.1% of the PBOF (11.3 km^2 of 968 km^2). The total tundra

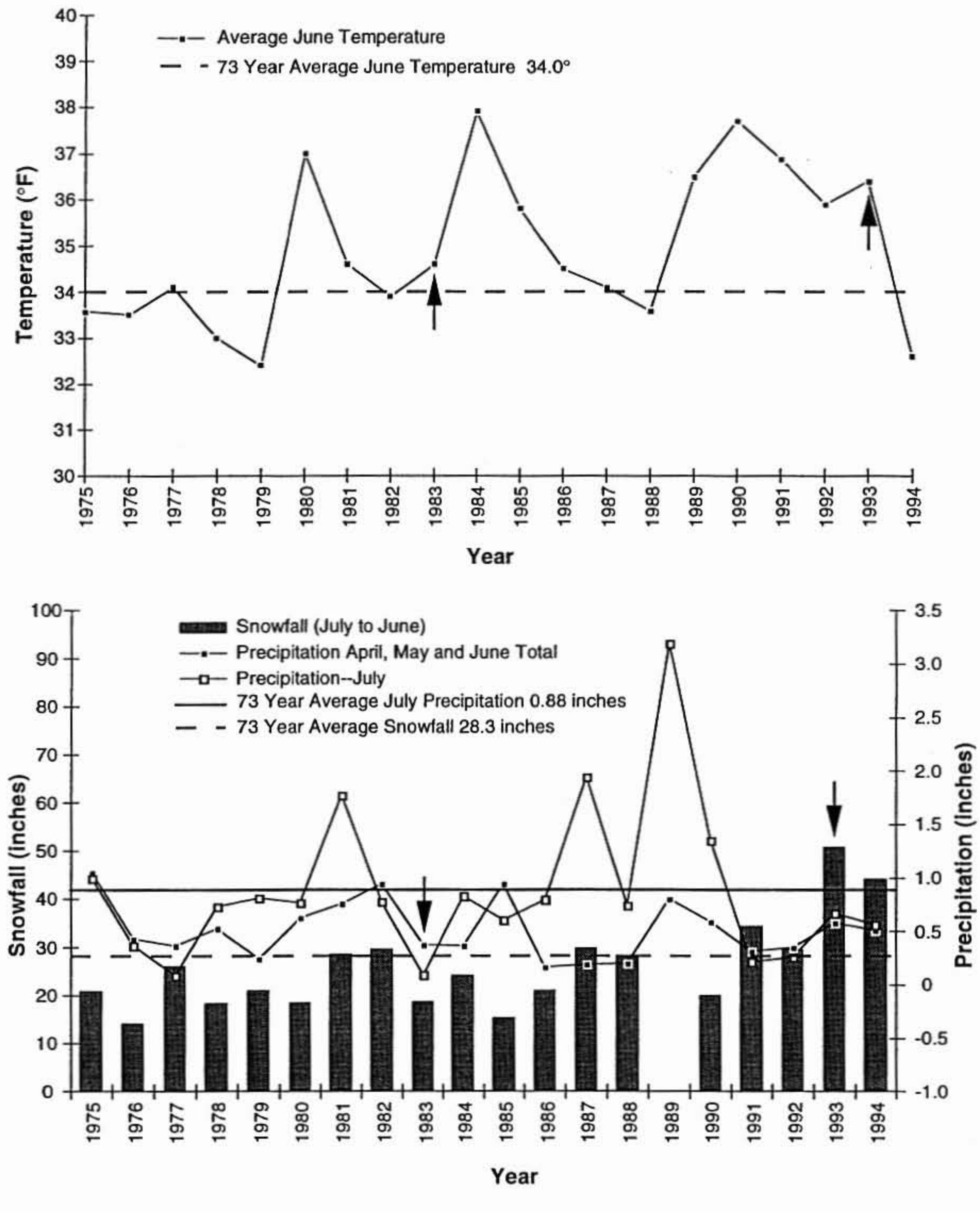

Figure 18. Barrow, Alaska weather station summary for 1975 through 1994 for mean temperature in June, annual (June to July) snowfall, and precipitation (NOAA 1995). Years for impoundment mapping aerial photography were 1983 for Walker et al. (1986) and 1993 for this study.

area affected by impoundments represents 0.8% of the PBOF unit area (8.0 km^2 of 968 km^2). These numbers are representative of the entire unit area, because the entire area was assessed to locate impoundments. Pre-development habitat mapping shows that many impoundments in the PBOF were originally either water bodies or various types of aquatic tundra. Habitat alterations caused by impoundments have predominately altered aquatic and wet habitats by retaining additional melt water. Similarly, Walker et al. (1987) found most impoundment flooding occurred in drained lake basins. Of the 11.3 km^2 altered by impoundments, 3.3 km^2 was open water prior to development and 4.2 km^2 was probably aquatic strangmoor; both of these habitats retain natural standing water throughout the summer, and are augmented by flooding (Appendix A, Table A-1). In fact, lakes, ponds, and aquatic tundra represented 74% of the historical habitats currently affected by impoundments (Table 3). In addition, most of the tundra area which is currently affected by impounded water is flooded only temporarily, and most has drained by mid-July (6.0 km^2 temporary versus 2.0 km^2 permanently flooded tundra, Appendix A, Table A-1)).

It seems likely that the impounding currently present in the PBOF may have only moderately altered pre-development habitats. Based on pre-development habitat mapping at the 51 bird use sites, 59% of the tundra area affected by impoundments was aquatic strangmoor which may normally contain standing water into July (Table 3). Comparison of pre-development habitats covered by the maximum flood area (11.3 km^2) with Walker et al. (1987) findings also indicates that a substantial portion (49%) of the area covered by impoundments was historically aquatic tundra (Fig. 19). Walker's analysis indicates that larger portions of wet (42%) and moist tundra (8%) were affected by impoundments, however it is unclear if the area of pre-development water was removed from consideration (Walker et al. 1987). If we consider only the area of tundra affected by impoundments in 1993 (Fig. 19), the proportion of wet and moist tundra are more similar to Walker's evaluation (Walker et al. 1987).

Wet tundra (2.96 km^2, 37%) and moist tundra (0.34 km^2, 4%) categories may represent the largest change in habitat within the PBOF (Table 3, Fig. 19). For the temporarily flooded tundra areas, increased water retention tends to make moist and wet vegetation categories, wet and aquatic categories. This generally leads to a reduction in vegetation diversity favoring *Arctophila fulva* and *Carex aquatilis* in the wettest areas. However, these areas represent a very small portion, 0.3%, of the entire PBOF unit. For the areas where permanent open water has been added, previous comparative impoundment studies of productivity and waterbird use indicated that although there is a great deal of diversity between individual impoundments and individual natural ponds, they may be functionally equivalent (Kertell 1993, Kertell 1994). The primary difference

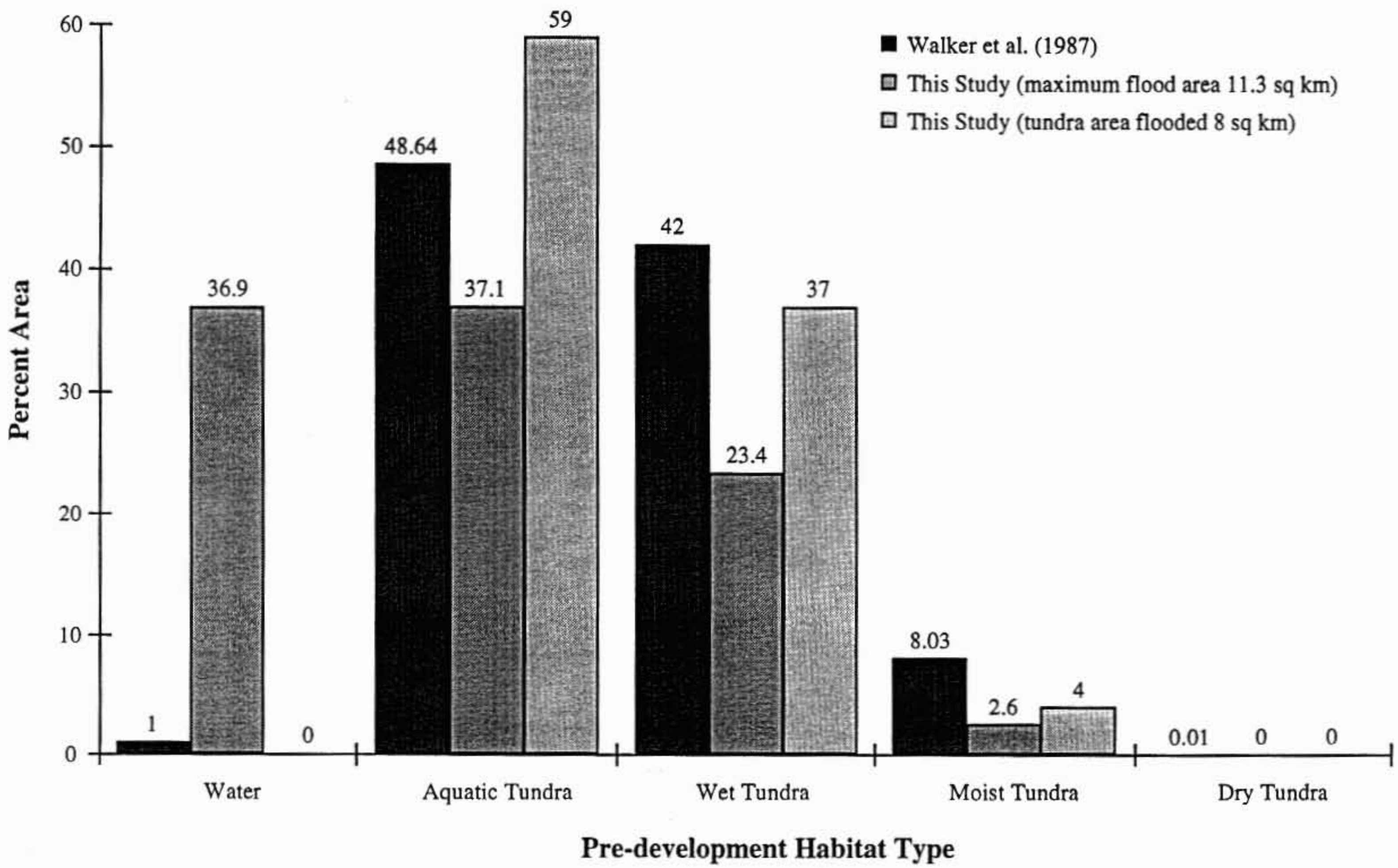

Figure 19. Comparison of pre-development habitat types covered by flooding from Walker et al. (1987) and this study. Walker et al. (1987) estimates are based on 63 sq km of 1:6000 scale mapping within the Prudhoe Bay oil field, vegetation types are from July 1949 black and white 1:24000 scale aerial photography, and flood areas are from July 1983 natural color 1:18000 aerial photography.

between impoundments and natural ponds was in the amount and timing of water level fluctuations (Kertell 1994).

Bird Use of Impounded Sites

In contrast to the perception that impoundments may restrict nesting and effectively displace birds in the PBOF (Walker et al. 1987; NRDC 1991), we found 17 species to nest in impounded areas. These results are not unexpected; many impounded areas are also natural water bodies, pond complexes, or drained lake basins which now retain some additional melt water which either drains by mid-summer or remains throughout the summer. Many of the nests recorded in impoundments, primarily those of geese and ducks, were located on small islands and peninsulas within pond complexes, and others, primarily those of loons and phalaropes, were in emergent vegetation. In addition, we recorded 37 species using impounded sites for foraging. The Spectacled Eider, currently listed federally as a Threatened Species, was recorded feeding and nesting in impounded sites (Appendix B, Table B-1). Studies of Spectacled Eiders in the PBOF (TERA 1995) and elsewhere (Bergman et al. 1977, Derksen et al. 1981) document use of shallow *Carex*-lined ponds and deep lakes by Spectacled Eiders. These habitat characteristics were typical of the impoundments used by Spectacled Eiders in this study (Table 5 and 6).

To evaluate habitat changes within impoundments, we compared bird densities obtained in summer 1994 with expected densities based on the historical habitat composition (as of 1955) in the impounded sites we sampled. For the Wilcoxon and Mann-Whitney U tests, no significant differences were found between pre-development calculated bird densities and post-development measured bird densities. These analyses are designed to detect unidirectional changes; either consistent increases or consistent decreases. Pre-impoundment and impoundment bird densities, while generally showing a decrease in density, exhibit bi-directional changes with large increases for a few species, and decreases for others. The changes for individual species show that Pacific Loons, Greater White-fronted Geese, Red-necked Phalaropes, (and, in the uncorrected data set, Oldsquaw) increased in abundance in impounded areas. These species are attracted to habitat types with permanent water (Troy 1988). The remaining 10 species decreased in abundance in impounded areas. Of the species which decreased in abundance, several prefer drier habitats: Lapland Longspurs, Lesser Golden-Plovers, and Buff-breasted Sandpipers (Troy 1988). Although these differences must be interpreted with caution considering the high variability in bird densities typically found in the PBOF (TERA 1993), they suggest that the increased flooding from impoundments has attracted species which prefer permanent water and emergent vegetation, and has displaced species which may have used the drier habitats in impoundments which are now flooded.

The regression analyses do not show a significant relationship between the bird densities currently found in PBOF impoundments and those expected in the pre-development habitats. In agreement with the results discussed above, the lack of a positive correlation between the two data sets suggests some habitat alteration. The point for Red-necked Phalaropes is a statistical outlier (Figs. 16 and 17) and, when this point is removed, the correlations are significant and positive. This suggests that perhaps the most substantial change is the large increase in sightings of Red-necked Phalaropes in impounded areas. Because Red-necked Phalaropes are naturally more common in the PBOF than in more coastal sites (TERA 1993), and because the bird densities used to produce pre-development expected values are biased towards data from more coastal sites, we would expect *a priori to* find more Red-necked Phalaropes in the oil field area. This coastal bias in the pre-development density estimates cannot completely explain the large increase in sightings of Red-necked Phalaropes, however, because three other species, Semipalmated Sandpiper, Stilt Sandpiper, and Lapland Longspur (TERA 1993), are also naturally more abundant in the oil field than they are at coastal sites, and these species are all within the 95% confidence bounds for the regression lines (Figs. 16 and 17). Thus, one of the most significant effects of impounding in the PBOF may be the attraction of Red-necked Phalaropes to impoundments.

CONCLUSIONS

This study evaluated the extent and affect of impoundments on bird habitat and bird use in the PBOF.

- Most impoundments generally occur in areas with natural lakes and ponds, specifically drained lake basins, and their effect is to cause a retention of melt water.

- Open water and aquatic tundra were 74% of the pre-development habitats affected by impoundments. These habitats normally may retain water into July.

- Although impoundments have altered bird habitat in the PBOF, the area of permanently and temporarily flooded tundra, 8.0 km^2, represents only 0.8% of the PBOF unit area.

- Thirty-seven species of birds were recorded at impoundments, and 17 species, including Spectacled Eiders (which are federally listed as a Threatened Species), nested on impoundments. Shorebird density was 59%, waterfowl density was 23%, and duck density was 15% of the density of all bird combined

- Impoundments generally support higher waterfowl and lower shorebird and passerine densities than pre-development habitats, but bird habitat density relationships are highly variable and these trends were not statistically significant.

- The most substantial change from pre-development conditions was an eight-fold increase in Red-necked Phalaropes in impounded areas.

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LIST OF APPENDIXES