Remediating and Monitoring White Phosphorus Contamination at Eagle River Flats (Operable Unit C), Fort Richardson, Alaska

FY 99 Report

July 2000

Prepared for

U.S. ARMY, ALASKA
DIRECTORATE OF PUBLIC WORKS
William A. Gossweiler, Remedial Project Manager
and
U.S. ARMY ENGINEER DISTRICT, ALASKA
JoAnn T. Walls, Project Engineer

Prepared by

U.S. ARMY ENGINEER RESEARCH AND DEVELOPMENT CENTER,
COLD REGIONS RESEARCH AND ENGINEERING LABORATORY
Charles M. Collins and Mark J. Hardenberg, Report Editors

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I. EXECUTIVE SUMMARY

INTRODUCTION

This is the tenth annual contract report prepared by researchers from CRREL and other Federal agencies for U.S. Army Engineer District, Alaska, and U.S. Army Alaska, Public Works, describing the results of research, monitoring, and remediation efforts addressing the white phosphorus contamination in Eagle River Flats, a 865-ha esturaine salt marsh on Fort Richardson, Alaska. Fort Richardson is on the National Priority List and Eagle River Flats is designated Operable Unit C (OU-C) under the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA). Documents produced under the CERCLA process, such as the *Ecological Risk Assessment, Remedial Investigation Report, Feasibility Study Report*, and the *Proposed Plan*, have used the research results first published in this series of annual contract reports.

This year marks the first of a planned 5-year remediation effort in Eagle River Flats. Pond pumping, using six remote-controlled pumps to temporarily drain contaminated ponds within several areas of Eagle River Flats, was conducted this year. The success of the pumping treatability studies conducted in 1997 and 1998 resulted in pond pumping being chosen as the preferred alternative in the *Record of Decision* for OU-C, signed in October 1998. The pumps keep the ponds drained for an extended period during the summer, thus allowing the pond bottom sediments to dry and the white phosphorus to sublime and oxidize. In addition, temporarily draining the ponds excludes waterfowl from these contaminated water bodies thus reducing potential exposure to white phosphorus.

Despite an expected poor season because of predicted flooding tides every month, the pond pumping resulted in significant sediment drying and loss of white phosphorus in treated ponds. A series of tide gates installed at the heads of tidal gullies that lead into the ponds being treated resulted in the prevention of significant flooding in July, August, and early September for five of the six ponds being treated.

Monitoring of the effectiveness of the remediation showed an over 76% reduction in the white phosphorus mass of planted particles in Pond 183 and lesser levels in other locations. Other studies reported on in this year's report include the waterfowl use and mortality studies, the additional sampling for white phosphorus contamination in ponds in Areas A and in C/D that had either not been sampled before or had only limited sampling, and the collection of environmental and habitat information for Eagle River Flats for inclusion in the GIS database.

II-1. WATERBIRD UTILIZATION OF EAGLE RIVER FLATS: APRIL–OCTOBER 1999

William D. Eldridge and Donna G. Robertson

Aerial surveys to monitor waterbird use of Eagle River Flats (ERF) during the spring, summer, and fall of 1999 were flown by the U.S. Fish and Wildlife Service as part of the on-going waterbird mortality and monitoring studies of ERF sponsored by the U.S. Army at Ft. Richardson, Anchorage, Alaska. Numbers of waterbirds were counted or estimated and recorded by species or species group at locations on ERF, using standardized study areas.

Nearly 100% of ERF remained snow-covered on 21 April 1999. By 3 May, however, the entire flats were approximately 85% open. Summer of 1999 was generally wet and water conditions throughout Cook Inlet were good. Pumping continued to keep parts of Areas A, C, and C/D dry, so, in general, less of the preferred habitat was available to ducks than in previous years. In late September flood tides again inundated ERF. Skim ice formed periodically in early October, but ERF was 90% open on 13 October, then frozen again, and open again from tides in late October.

Tundra and trumpeter swans utilized ERF in small numbers during 1999. Lesser snow geese made up 79% of the total geese counted in spring, followed by Canada geese. Duck species utilizing ERF in 1999 were similar to other years, dabbling ducks making up 99%. It is clear that in 1999 ERF supported fewer ducks than previous years. In spring the number of ducks peaked on 3 May and the peak was considerably higher than other recent years. Utilization of Area C remains reduced from 1997, but the most noticeable reduction is in use of Area C/D, which may be attributed to increased pumping in that area in 1999. Use of the permanent ponds of Areas D and B increased, perhaps reflecting the lack of availability of habitat in the treated areas. Numbers of bald eagles (*Haliaeetus leucocephalus*) were low, similar to recent years. Lower numbers of eagles in recent years may be ascribable to the decreased mortality of waterbirds on ERF. Numbers of shorebirds were lower than in recent years, and no breeding sandhill cranes were observed.

II-2. MOVEMENTS, DISTRIBUTION, AND RELATIVE RISK OF WATERFOWL USING EAGLE RIVER FLATS: 1999

John L. Cummings et al.

We determined spatial distribution, movements, turnover rate, and mortality of mallards using Eagle River Flats, Fort Richardson, Alaska, during fall migration, 4 August to 14 October 1999. We randomly captured 116 mallards between 4 and 18 August on ERF using a net-gun from a Bell 212 helicopter. Each mallard was banded and fitted with a 9.1-g backpack transmitter and released at its capture site. All 116 mallards were fitted with standard mortality transmitters that emit about 60 pulses per minute when the duck is alive. If the duck dies, the transmitter will emit about 120 pulses per minute. Tracking data indicated that transmitters did not appear to inhibit mallard movements or activities. LOCATE II was used to map telemetry locations. Mallard movements and distribution indicate that they spent about 82% of their time in Areas A, B, C, and C/D. In addition, mallards spent about 61% of their time in areas that are considered contaminated (A, BT, C, C/D, and RI). The average daily turnover rate for waterfowl was about 1.3%. The greatest turnover of waterfowl occurred from 20–31 August and 15–27 September when 29 and 20% of the mallards, respectively, departed ERF. Mortality of instrumented mallards that used ERF from 4 August to 14 October was 34. Of those, 24 were attributed to white phosphorus ingestion. The greatest mortality occurred in Area A, 9 of 24 (38%); Area C, 6 of 24 (25%); and Areas C and C/D, each 6 of 24 (25%). Overall, these areas accounted for 88% of the mallard mortality on ERF. We recovered 11 whole duck bodies from the 24 white phosphorus mortalities. Analysis showed that all 11 were positive for white phosphorus. A mortality model was developed for ERF to estimate the total individual dabblers using ERF, the peak number of dabblers using ERF, and the total number of duck mortalities on ERF during the fall migration period. In 1999, 1334 individual dabblers used ERF from 4 August to 14 October. Dabblers peaked at 650 between 21 and 24 August and 721 between 21 and 28 September. The overall mortality that occurred on ERF was 198 dabblers. The aerial counts and the model reflected a 55% decrease in the number of dabblers using ERF. In conclusion, the use of radio telemetry to collect data on mallard distribution and mortality on ERF since 1996 has been an effective and safe method to measure the effects of remediation actions, such as pumping, draining, and AquaBlok.

III-1. EAGLE RIVER FLATS POND PUMPING REMEDIATION PROJECT: FIRST-YEAR DEPLOYMENT UNDER THE RECORD OF DECISION

Michael R. Walsh and Charles M. Collins

The 1999 field season marks the beginning of the remediation phase for the Eagle River Flats project. This year, tidal predictions indicated a very poor year for remediation at the Flats because of monthly inundation during lunar high tides. However, owing to a slight shift in the riverbed at the south end of the Flats and the increased effectiveness of the tide gates in Area C because of continuing modifications, Areas C and A experienced a treatment season of 102 contiguous days without flooding.

Deployment changes were made over last season. Pond 290 in Area A is no longer being treated, as no significant contamination remained at the end of the 1998 season. A sump was blown in Pond 730, Area C/D, and a 126-L/s pump was placed there. A sump was also blasted in the dredge channel in Pond 146 for the large, 189-L/s pump. This allowed us to draw Pond 146 down significantly more than in 1998, thus addressing some of the contaminated areas in the vicinity on Canoe Point. Additional ditches were made using Bangalore torpedoes and detonation cord to expedite drainage in treated areas.

This year, we had three 1100-L, double-walled fuel tanks to supplement the two 1900-L tanks used in the field last year. The lack of flooding after the June high tides resulted in a sharp drop in the necessity to refuel the field systems. Logistics still need to be worked out to make the most efficient use of these assets. Three additional 1100-L tanks have been ordered to allow complete field refueling and defueling with a Bell 212 helicopter, thus reducing our reliance on the Blackhawks and significantly reducing costs.

A team from Weldin Construction, Inc., led by Terry Edwards, conducted the field operation and maintenance work this year. The results were excellent. They were able to address and work through a number of potentially crippling problems in the field. As a result, there was no significant unplanned downtime this year. The controls were once again reconfigured and rewired, this time to address stuck float switches. This will also increase the reliability of the systems, as the controls were simplified in the process. A developmental video monitoring system was deployed, with mixed results. Although it was a valuable tool, more work needs to be done before it becomes useful.

Next season looks to be unavoidably bad, with tides in excess of 9.75 m (32 ft) every month. The option of whether or not to deploy was considered, and the decision was made to recommend deployment to ensure continuity of the project, to reduce the effects of inundation of the ponds under treatment (especially Pond 730), and to work out the new communications structure of the meteorological station and the video monitoring system.

III-2. TREATMENT VERIFICATION: MONITORING THE REMEDIATION OF WHITE PHOSPHORUS CONTAMINATED SEDIMENTS OF DRAINED PONDS

Marianne E. Walsh, Charles M. Collins, and Ronald N. Bailey

The in-situ decontamination of white phosphorus contaminated sediments at ERF by pond pumping continued, and it was monitored with the three part approach developed in 1997. We used dataloggers to record sediment moisture and temperature to see if conditions were favorable for sublimation–oxidation, we measured residual white phosphorus from particles that we planted in the surface sediment, and we resampled areas of known contamination.

The main pond of Area C (Pond 183) has been pumped for three consecutive seasons. This year (1999), the pond was dewatered by pumping in early June and the sediments dried significantly until a series of flooding tides on 14–19 June. Sediments dried rapidly after the flood and were unsaturated for several weeks until persistent rainfall in late July and August. All measures of white phosphorus showed a continuing decline in contamination. Four of the five white phosphorus particles planted decreased from an initial mass of 5.6 ± 0.5 mg to less than or equal to 0.5 mg. One particle showed no change. The composite sample taken from the middle of Area C (C 100 m) has declined from 0.07 µg/g in June 1997 to 0.002 µg/g in September 1999. Discrete samples obtained on a 1.82-m square grid in the previously highly contaminated DWRC Pen 5 showed a decline in both the number of positive samples (from 48 in 1996 to 13 in 1999) and the highest concentration found (420 to 0.036 µg/g). We collected subsurface samples from six locations in Pond 183 that were cored in 1992 and had white phosphorus contamination along the core length. In 1999, white phosphorus was undetectable at five of the six locations. Finally, white phosphorus in Miller's Hole, the crater produced when a white phosphorus-containing UXO was detonated in 1992, is now just barely detectable (0.0008 µg/g) compared to 2400 µg/g in a sample collected on the day of the detonation. Pond pumping is successfully remediating Pond 183.

We sampled Pond 146 adjacent to Canoe Point in an area that showed contamination remaining after dredging. Contamination remains in the surface sediment. We frequently observe ducks using this area, and it may be an important source of poisoning. The sump for this pond was deepened significantly in September 1999 in an effort to enhance drying of this contaminated area during the next 4 years.

Pond 155, to the northeast of Pond 183, is also drained by pumping, but is more difficult to desaturate because of its location within a bulrush marsh. Some minimal drying occurred, but planted particles showed no change in mass. A grid for collecting composite samples was established last fall, but no decline in white phosphorus concentration is evident.

Ponds 258 and 256 were drained for the second consecutive season and both showed drying and a decline in the mass of planted white phosphorus particles of 50 and 48%, respectively. An additional 17 composite samples were taken for Pond 258, but no white phosphorus was detected.

Pond 730 in Area C/D was newly drained by pumping this year, based on the significant mortality of radio-collared ducks there. No white phosphorus was detectable within this pond, but we did locate a hotspot to the north of the pond. This pond was flooded frequently by flow from blasted Bread Truck gully. Some drying and sediment consolidation occurred in this pond and there was loss of white phosphorus from the planted particles at the monitoring stations.

The Bread Truck Pond (Pond 109) dried significantly on the north side, near the blasted ditch. Planted white phosphorus particles declined by 72%, and the white phosphorus concentration in the composite sample near the ditch (BT North 100 m) is only 0.0003 µg/g, declining from 0.012 µg/g in June 1997. The south side of the pond remains wetter owing to frequent flooding and incomplete drainage to the ditch, and decontamination has been minimal. Erosion of the ditch is significant. Advancement of the ditch towards the east exposed a white phosphorus mortar round, which we located by smoke wisping within a gully lobe. Serious consideration should be given to controlling the erosion and flooding from this ditch.

III-3. COMPOSITE SAMPLING AND ANALYSIS FOR WHITE PHOSPHORUS IN UNTREATED PONDS

Marianne E. Walsh, Charles M. Collins, and Ronald N. Bailey

Ponds that were unambiguous sources of waterfowl poisonings are undergoing remediation at ERF. Much of Area C has been drained by pumping, and the Bread Truck Pond and Racine Island ponds have been drained by ditching. These treatments remove severely contaminated ponds as waterfowl-feeding habitat for part of the year. Mortality of telemetry mallards indicates that localized areas of contamination (hotspots) may still be present in Area C/D and possibly Area A. In 1999, we collected composite samples from Areas A, C/D, and Coastal East, where previous sampling was sparse or non-existent. We found two small areas of contamination: 1) Pond 75, which is on the boundary of Area C/D and Coastal East, and 2) part of Pond 226 in Northern Area A. Contamination was not widespread in either case; neighboring composite samples were blank.

We also sampled two ponds where we suspected contamination based on the pond location or previous sampling. Pond 511 in Area C and Pond 680 on Racine Island were both blank.

III-4. 1999 WEATHER DATA FOR EAGLE RIVER FLATS

Charles M. Collins

The summer of 1999 had normal to slightly above-normal temperatures for June through September. Precipitation was below normal in June, slightly above normal in July, and considerably above normal in August and the first half of September. May and June are normally the driest months of the core drying season needed for treatment of contaminated pond bottom sediments. The cooler weather and flooding tides of May eliminated any effective drying that month, but June and the first week of July provided near ideal drying conditions. There were 30 days during the summer with maximum temperatures of 20°C or more. This compares to only 18 days during the summer of 1998. After 9 July, the net evaporation rate decreased dramatically because of the increased rainfall, more complete cloud cover, and resulting decreased evaporation. Several large rainfall events occurred in August, with 25 mm (1 in.) falling on 13 August.

IV-1. POND PUMPING-DITCHING AND HABITAT CHANGE ON EAGLE RIVER FLATS

Charles H. Racine

We monitored the changes in vegetation–habitat in and adjacent to five permanent ponds that were drained by summer pumping or by permanent ditching during 1, 2, 3, or 4 years between 1996 and 1999. While pond aquatic species disappeared almost immediately following dewatering, other emergent species, such as mare's tail, declined more slowly over 2 to 3 years. Sedges such as Ramenskii's sedge and Lyngbyei's sedge appear to be fairly stable and resistant to dewatering. Some sedges such as Mackenzei's and Lyngbyei's sedge have expanded onto the moist organic sediments on the bottom of a deeper pond pumped over the past 2 years. There is little evidence that salt-tolerant annuals associated with the mudflat zone are invading the newly exposed permanent pond bottoms. Pumping and ditching of deeper ponds in the bulrush marsh area began more recently and evidence of major change is hard to detect, although multispectral imagery shows a decline in "greenness." There is, in general, little evidence of a major readjustment of habitat and vegetation attributable to white phosphorus remediation.

IV-2. UPDATED SPECIES LIST FOR EAGLE RIVER FLATS, ALASKA

Charles M. Collins and Charles H. Racine

We present an updated species list of birds and vascular plants for Eagle River Flats. As monitoring studies and remediation efforts have been carried out over the last several years, additional species have been added to each of the two lists that were originally compiled as part of the extensive site investigation studies carried out in Eagle River Flats during 1990 through 1995 to evaluate white phosphorus distribution, persistence, and ecological risk. As of 1999 there have been 97 species of birds observed in or along the border of Eagle River Flats, indicating the rich diversity of this salt marsh complex and the important ecological role it plays in the Upper Cook Inlet Region. We also include the list of invertebrate species identified in sediment samples collected in Eagle River Flats.

IV-3. TIDAL CREEK AND DRAINAGE DITCH EROSION AT EAGLE RIVER FLATS IN 1999

Charles H. Racine

Active tidal creek and gully erosion is a major physical process in Eagle River Flats. The high tides and large volume of water that are drained by these gullies on the ebb tide result in large volumes of fast-moving water that can erode both lateral and headward walls of these gullies. This could result in pond drainage similar to that produced by blasting ditches. The erosion represents a loss of mudflat habitat and could also influence both the remediation success and our ability to restore the wetland habitat once remediation is completed. In addition, erosion can uncover buried munitions. In 1998, we developed a remote sensing technique for monitoring gully erosion and applied it to one gully. This extends some of this work by comparing erosional change from 1998 to 1999.

There has been little new erosion of the headwalls of the three natural gullies draining the treated ponds on the east side of Eagle River Flats during the past year (August 1998 to August 1999). However, two lobes at the headwall of the constructed ditch in the Bread Truck Pond continue to erode at an average of about 8–10 m per year. These will eventually develop into two separate gullies, which may uncover additional ordinance buried by sediments in the Bread Truck Pond as they erode. An effort may be required to stop this "runaway" erosion of the Bread Truck ditch, either by construction of a tide gate or by other means.

II-1. WATERBIRD UTILIZATION OF EAGLE RIVER FLATS: APRIL–OCTOBER 1999

William D. Eldridge
U.S. Fish and Wildlife Service

Donna G. Robertson
Harding Lawson Associates

INTRODUCTION

Aerial surveys to monitor waterbird use of Eagle River Flats (ERF) during the spring, summer, and fall of 1999 were conducted by the U.S. Fish and Wildlife Service as part of the on-going waterbird mortality and monitoring studies of ERF sponsored by the U.S. Army at Ft. Richardson, Anchorage, Alaska. The purpose and history of these investigations have been presented elsewhere (Racine and Cate 1996).

STUDY AREA

Eagle River Flats is a salt marsh complex of 870 ha located on the south side of Knik Arm, approximately 10 km east of Anchorage (Fig. II-1-1). A detailed description of this area is presented in Racine and Cate (1996).

METHODS

Aerial surveys of ERF were flown from April through October 1999. Surveys were conducted twice per week during fall, and once per week in spring and summer, except when weather or air space restrictions precluded flights. Surveys were flown using a fixed-wing aircraft at an airspeed of 100–120 km/hr and at an altitude 70–75 m. Total coverage of ERF was obtained by overlapping transects. Numbers of waterbirds were counted or estimated and recorded by species or species group with a cassette tape recorder. Waterfowl numbers were classified by locations on ERF, using standardized study areas (Fig. II-1-1). When possible, birds were also recorded by individual ponds within each study area, using a standardized pond numbering system. Areas (ha) of permanent and intermittent study ponds were obtained

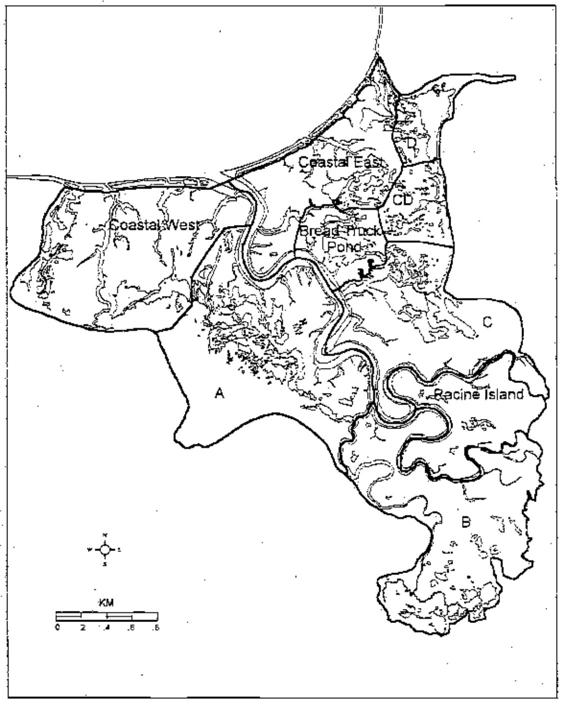

Figure II-1-1. Standardized ERF study areas surveyed for waterfowl.

from digitized maps provided by the Cold Regions Research and Engineering Laboratory and used to convert bird numbers to densities within the study areas.

RESULTS AND DISCUSSION

Moisture conditions

In contrast to 1998, when 90% of ERF was ice-free by mid-April, nearly 100% of ERF remained snow-covered by 21 April 1999. The late spring in 1999 was characteristic of much of Alaska. By 27 April there was considerable variation in snow and ice cover among the standardized study areas: Areas A and B were 50% frozen, Area C/D was mostly open and flooded, and Area D was 80% frozen. By 3 May, the entire flats were approximately 85% open, with Area A 20% frozen, Area B 70% frozen, Area C 20% frozen, and Area D still 80% frozen. Summer of 1999 was generally wet. Water conditions throughout Cook Inlet were good, and ERF marshes were wet, except where pumping or drainage occurred. Pumping was particularly effective in reducing water levels in parts of Areas A, C, and C/D. Fall in Cook Inlet was generally mild. Flood tides in early September inundated ERF but drained in a few days. Pumping continued to keep parts of Areas A, C, and C/D dry, so, in general, less of the preferred habitat was available to ducks than in previous years. In late September flood tides again inundated ERF. Skim ice formed periodically in early October, but ERF was 90% open on 13 October, then frozen again, and open again from tides in late October.

Table II-1-1. Number of birds, by species or species group, observed during aerial surveys of ERF in 1999.

	4/14	*4/21*	*4/27*	*5/3*	*5/11*	*5/19*	*5/26*	*6/2*	*6/18*	*6/30*	*7/8*	*7/19*	*7/28*	*8/16*
Swans	0	0	127	34	7	0	0	0	0	0	0	0	2	0
Geese														
Greater white-fronted	0	0	0	0	0	0	0	0	0	0	0	0	0	27
Lesser snow	0	0	3,335	25	0	0	0	0	0	0	0	0	0	0
Canada	0	0	720	109	17	13	0	2	23	19	0	25	15	105
Subtotal geese	0	0	4,055	134	17	13	0	2	23	19	0	25	15	132
Ducks														
Green-winged teal	0	0	0	282	114	25	3	34	42	11	6	0	11	73
Mallard	0	0	40	131	26	37	39	40	2	62	28	33	2	166
Northern pintail	0	0	50	433	172	5	31	15	2	2	0	4	0	65
Northern shoveler	0	0	0	89	25	0	11	10	0	0	0	0	0	0
American wigeon	0	0	5	487	102	48	57	93	39	16	36	20	12	84
Gadwall	0	0	0	0	0	0	0	0	0	0	0	0	0	10
Greater scaup	0	0	0	0	0	15	9	0	0	0	0	0	0	0
Unidentified duck	0	0	235	10	0	0	0	4	50	0	0	53	25	72
Subtotal ducks	0	0	330	1,432	439	130	150	196	135	91	70	110	50	470
Other birds														
Bald eagle	2	2	0	3	7	0	2	0	0	0	0	0	0	0
Sandhill crane	0	0	0	2	0	2	33	3	1	13	0	12	13	2
Shorebird	0	0	0	25	85	255	235	12	35	274	0	173	11	11
Gull	0	0	2	72	85	39	173	131	77	45	34	25	0	10
Arctic tern	0	0	0	0	13	3	56	9	42	12	5	4	2	0
Common raven	0	0	0	0	0	5	0	0	0	0	0	0	0	1

Abundance and distribution of waterbirds on ERF

In 1999, 31 aerial surveys were conducted. Numbers of birds by species or species groups are listed by survey date in Table II-1-1 and Figure II-1-2. Utilization of ERF study areas by major waterfowl groups by season is presented in Tables II-1-2 and II-1-3. A discussion of utilization of ERF by species or species groups is presented below.

Swans

Tundra (*Columbus columbianus*) and trumpeter swans (*C. buccinator*) utilized ERF in small numbers during spring of 1999, with a maximum of 134 observed on 27 April. Swans were observed on two other surveys in spring, and use was concentrated in Areas B and D, similar to other years (Table II-1-1, Fig. II-1-3).

In fall, swan numbers peaked in late September at 108 birds, considerably lower than recent years, and the fall mean of 19 swans was the lowest recorded since surveys began. Swans utilized areas D, B, and C/D most during fall (Fig. II-1-3), similar to other years. Two dead swans were observed during fall surveys, and one swan was observed alive, but likely sick or injured, on 28 October.

Geese

Peak counts of geese occurred on 27 April, primarily attributable to lesser snow geese (*Chen caerulescens caerulescens*) (Table II-1-1, Fig. II-1-4). Snow geese made up 79% of the total geese counted in spring, followed by

Table II-1-1 (cont'd).

	8/20	*8/24*	*8/30*	*9/3*	*9/8*	*9/14*	*9/16*	*9/20*	*9/28*	*10/4*	*10/7*	*10/13*	*10/20*	*10/28*
Swans	6	0	0	6	29	31	6	33	108	30	11	27	4	1
Geese														
Greater white-fronted	8	15	27	10	8	0	0	0	0	0	0	0	0	0
Lesser snow	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Canada	97	140	296	50	119	41	12	57	345	90	90	65	0	0
Subtotal geese	105	155	323	60	127	41	12	57	345	90	90	65	0	0
Ducks														
Green-winged teal	40	143	66	56	57	84	52	65	55	38	87	97	8	0
Mallard	184	197	142	182	45	117	105	67	432	188	158	123	29	40
Northern pintail	27	95	45	51	15	5	20	13	10	24	11	0	0	5
Northern shoveler	0	0	0	7	0	0	0	0	0	0	0	0	0	0
American wigeon	50	70	100	41	33	58	19	23	0	31	5	0	0	0
Gadwall	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Greater scaup	0	0	0	0	0	0	0	0	0	0	15	0	0	0
Unidentified duck	45	166	55	0	27	86	100	245	63	155	34	0	0	0
Subtotal ducks	346	671	408	337	177	350	296	413	560	436	310	220	37	45
Other birds														
Bald eagle	1	0	0	1	1	0	0	0	2	3	0	0	1	0
Sandhill crane	0	4	2	0	2	6	0	15	0	0	0	0	0	0
Shorebird	20	14	2	0	5	0	0	18	15	0	0	0	0	0
Gull	5	5	0	0	0	0	0	0	0	0	0	0	0	0
Arctic tern	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Common raven	8	0	0	2	0	0	0	0	0	0	0	0	0	0

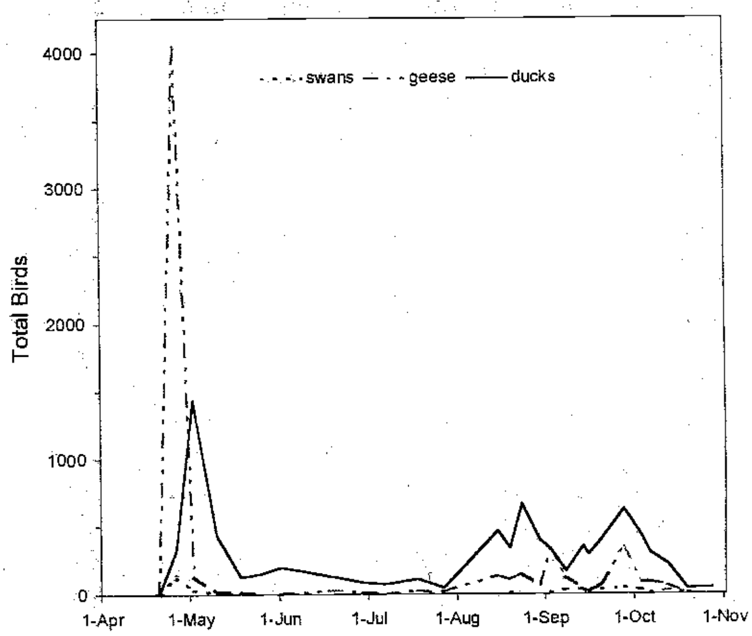

Figure II-1-2. Numbers of swans, geese, and ducks counted on ERF during aerial surveys in 1999.

Table II-1-2. Mean numbers of waterfowl groups in 1999 by season. The number of complete surveys used to classify observations by area, for spring, summer, and fall, were 8, 5, and 15, respectively.

	Coastal West	*A*	*B*	*Racine Island*	*C*	*C/D*	*Truck Pond*	*Coastal East*	*D*
					Spring				
Swans	1.0	0.0	4.6	0.0	0.0	0.0	0.0	0.6	17.9
Geese	45.7	233.7	129.4	0.9	161.4	0.9	27.9	2.9	0.0
Greater white-fronted	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lesser snow	12.1	182.1	114.3	0.0	150.0	0.0	21.4	0.0	0.0
Canada	33.6	51.6	15.1	0.9	11.4	0.9	6.4	2.9	0.0
Ducks	91.6	119.1	34.3	2.0	23.7	41.3	3.6	17.1	21.7
					Summer				
Swans	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Geese	0.0	1.8	1.0	2.5	6.2	0.0	0.0	2.5	0.0
Greater white-fronted	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lesser snow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Canada	0.0	1.8	1.0	2.5	6.2	0.0	0.0	2.5	0.0
Ducks	12.2	24.0	21.2	4.0	2.0	16.3	3.3	12.8	12.8
					Fall				
Swans	0.0	0.0	10.6	0.0	0.0	1.8	0.0	0.1	6.9
Geese	24.9	20.1	5.4	12.3	19.7	0.4	0.0	24.0	0.0
Greater white-fronted	1.1	0.9	1.3	0.0	3.0	0.0	0.0	0.0	0.0
Lesser snow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Canada	23.8	19.1	4.1	12.3	16.7	0.4	0.0	24.0	0.0
Ducks	63.5	50.3	68.0	5.2	16.3	28.7	7.7	30.9	67.7

Table II-1-3. Percent duck use of major habitat types by season on ERF in 1999.

	(n)	*Ponds*	*Knik shoreline*	*Eagle River*	*Tidal sloughs*
Spring	(2,481)	56	1	3	0
Summer	(652)	48	10	4	0
Fall	(5,076)	63	7	3	1

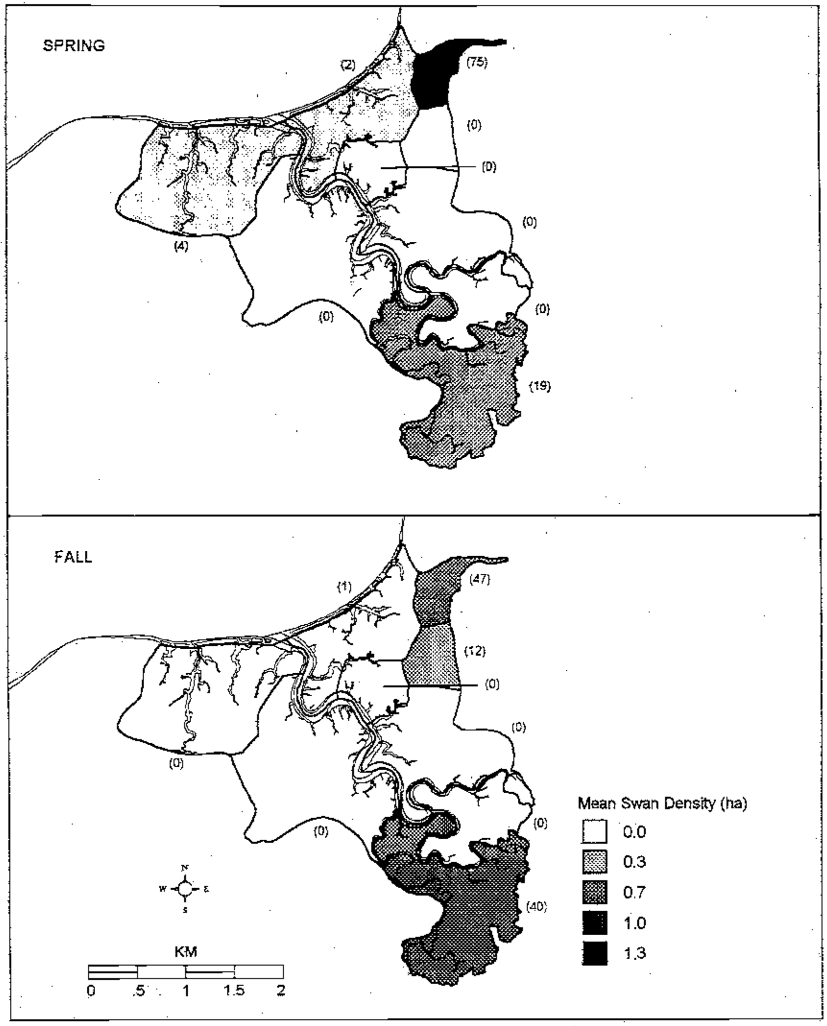

Figure II-1-3. Mean densities of swans on ERF study areas in spring and fall 1999. Numbers in parentheses are the percent of total swans observed in each area. The area (ha) of permanent and intermittent ponds in each area was used to calculate densities.

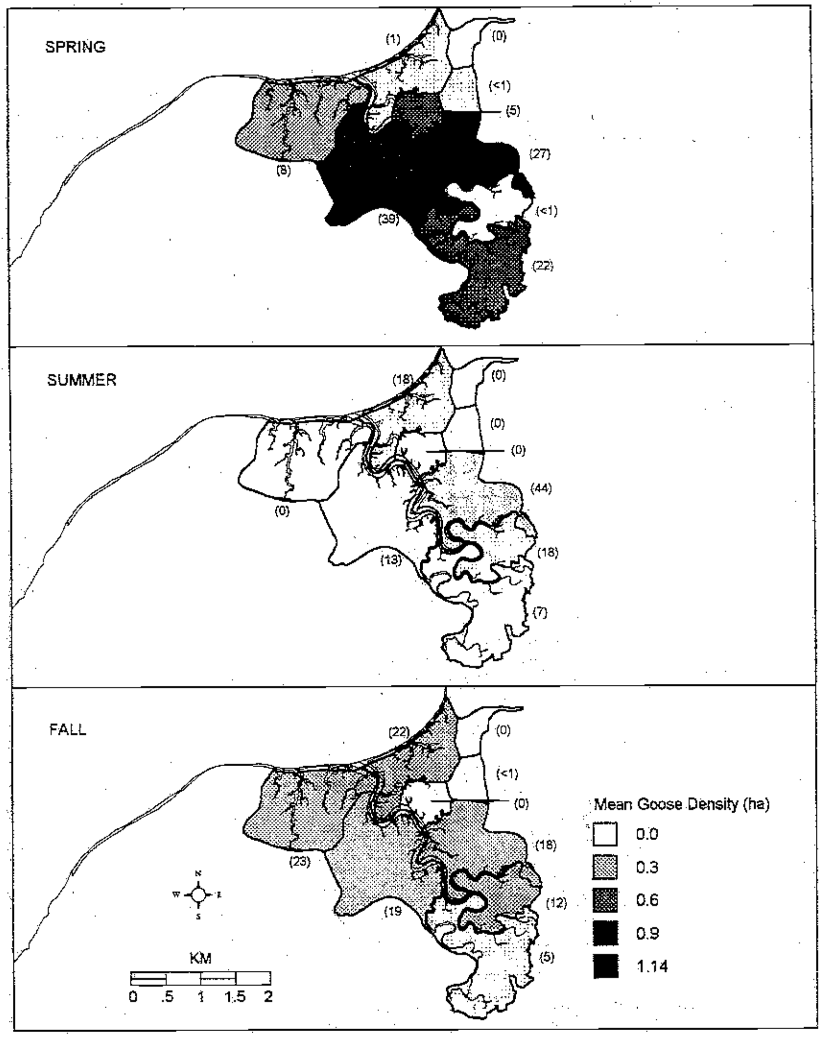

Figure II-1-4. Mean densities of geese on ERF study areas in spring, summer, and fall 1999. Numbers in parentheses are the percent of total geese observed in each area.

Canada geese (*Branta canadensis*). Geese utilized Areas A, B, and C most in spring (Fig. II-1-4).

A small number of Canada geese used ERF during summer for nesting or brood-rearing (Table II-1-1), with most use occurring along the river banks of Area C (Fig. II-1-4). Fall goose migration was similar to other years, except that fewer geese used ERF. Peaks occurred in late August and again in September, with heaviest utilization of Coastal East and Coastal West Areas (Table II-1-1, Fig. II-1-4). Tule white-fronted geese (*Anser albifrons frontalis*) were observed in small numbers in fall, and snow geese generally do not migrate through Cook Inlet in fall.

Ducks

Duck species utilizing ERF in 1999 were similar to other years (Table II-1-1). Dabbling ducks made up 99% of the ducks counted through the season. Mallards (*Anas platyrhynchos*), American wigeon (*A. americana*), American green-winged teal (*A. crecca*), and northern pintail (*A. acuta*) were the most common species observed. Of the

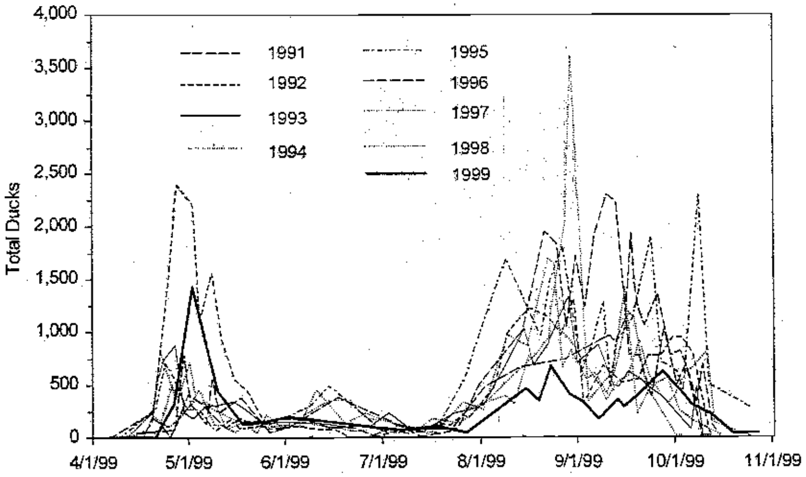

Figure II-1-5. Numbers of ducks observed during aerial surveys of ERF, 1991–1999.

four major habitat types used to classify duck locations, ponds were the most important (Table II-1-3). Numbers of all species of ducks combined are presented for 1991–1999 in Figure II-1-5. It is clear that in 1999 ERF supported fewer ducks than in previous years.

In spring the number of ducks peaked on 3 May (Table II-1-1, Fig. II-1-5) and the peak was considerably higher than other recent years. Ducks spent little time on ERF during April or May. Ducks utilized Areas A and Coastal West most in spring, but the highest density was recorded in Area C/D (Fig. II-1-6).

The mean number of ducks per survey during summer, 160, was considerable higher than the mean of 78 of 1998, and similar to the 1988–97 mean of 190. Ducks utilized Areas B and A most during summer (Fig. II-1-6). As in previous years, broods of American wigeon and mallards were observed in ERF during summer.

Migration phenology for ducks during fall 1999 was somewhat different from recent years in that the numbers of ducks utilizing ERF did not exhibit dramatic peaks or fluctuations as in most other years, and numbers were fewer (Table II-1-1, Fig. II-1-2). The mean number of ducks observed in the fall, 384, was considerably lower than the 684 mean of 1998, and 54% lower than the 1988–97 mean of 836. Ducks utilized Areas B and D most in fall, with the highest densities in Areas B, C/D, and D (Fig. II-1-6). The high percentage of ducks reported for Coastal West reflects more use of permanent ponds in the far west corner this year over previous years, rather than increased use of the tidal mudflats. Observations of ducks were also recorded by individual pond when possible. While it was not possible to separate out small ponds in complex systems, use of important, distinguishable ponds was recorded (Fig. II-1-7). The large permanent ponds of Areas B and D were important, as well as the Beaver Pond in Area C/D, similar to other years.

Changes in fall pond use by ducks

Because of the ongoing treatability studies and attempts to reduce exposure of ducks to white phosphorus, duck utilization of the standard study areas of ERF from 1997 through 1999 are compared in Table II-1-4. Utilization of Area C remains reduced from 1997, but the most noticeable reduction is in use of Area C/D, which may be attributed to increased pumping in that area in 1999. Use of the permanent ponds of Areas D and B increased, perhaps reflecting the lack of availability of habitat in the treated areas.

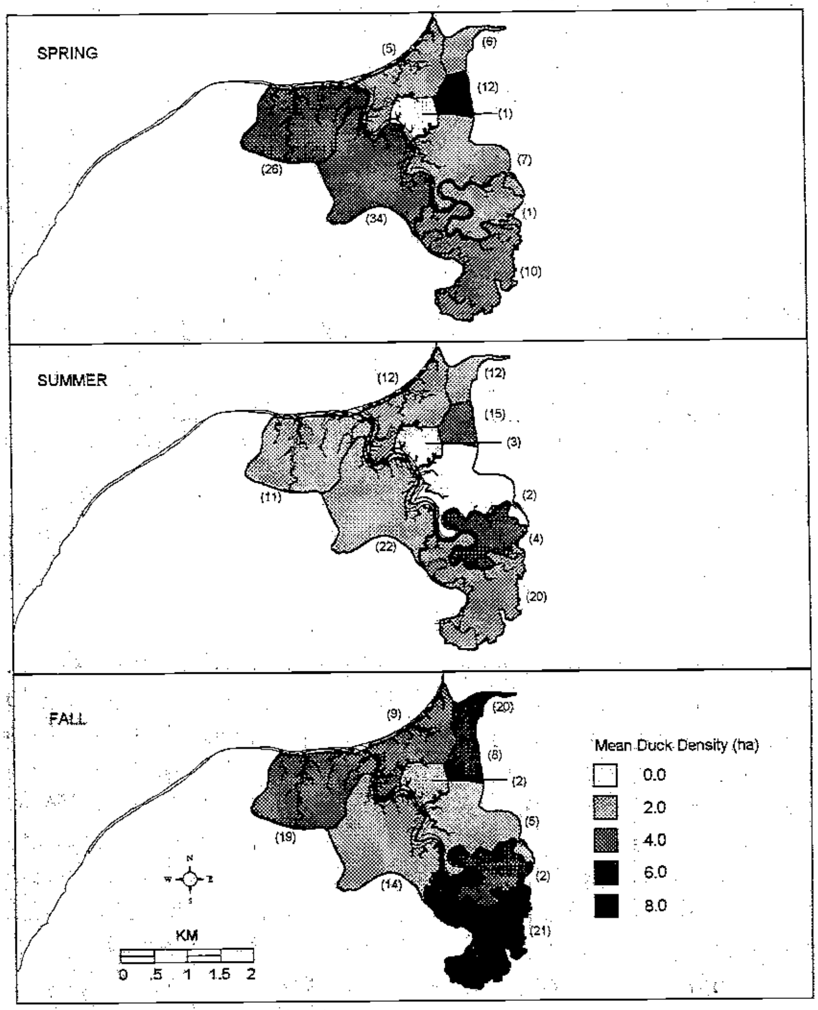

Figure II-1-6. Mean densities of ducks on ERF study areas in spring, summer, and fall 1999. Numbers in parentheses are the percent of total ducks observed in each area. The area (ha) of permanent and intermittent ponds in each area was used to calculate densities.

Bald eagles

Numbers of bald eagles (*Haliaeetus leucocephalus*) were low (Table II-1-1), similar to recent years. While specific shoreline surveys for eagles were not conducted, concentrations similar to earlier years of 50 or more eagles would have been noticed. Lower numbers of eagles in recent years may be ascribable to the decreased mortality of waterbirds on ERF.

Shorebirds

Numbers of shorebirds were combined for all species, since individual species were not identified from the airplane (Table II-1-1). Numbers of shorebirds were lower than in recent years. Common species on ERF include least sandpipers (*Calidris minutilla*), semipalmated sandpipers (*C. pusilla*), western sandpiper (*C. mauri*), dowitchers (*Limnodromus* spp.), and greater and lesser yellowlegs (*Tringa* spp.).

Gulls and terns

Gull species were combined for aerial surveys (Table II-1-1). They include mew gulls (*Larus canus*), glaucous-winged gulls (*L. glaucescens*), and herring gulls (*L. argentatus*).

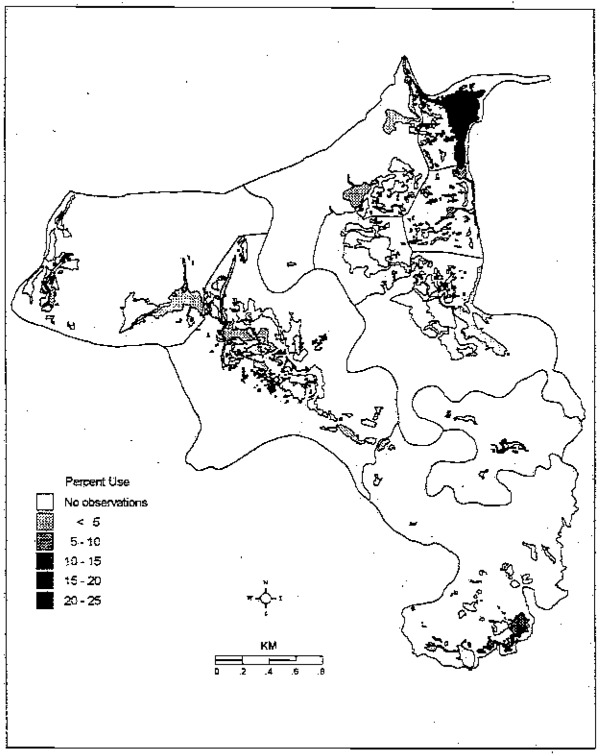

Figure II-1-7. Percent use of ponds by ducks classified to ponds during aerial surveys in fall, 1999.

Arctic terns (*Sterna paradisaea*) were common into July. The mew gull colony formerly in Area D now consists of just a few pairs.

Sandhill cranes

Sandhill cranes (*Grus canadensis*) were observed on ERF in small numbers sporadically from spring to mid-September (Table II-1-1). No breeding sandhill cranes were observed on ERF in 1999.

REFERENCES

Racine, C.H., and D.W. Cate (Eds.) (1996) Interagency expanded site investigation: Evaluation of white phosphorus contamination and potential treatability at Eagle River Flats, Alaska. FY 95 Final Report. CRREL Contract Report to U.S. Army, Alaska Directorate of Public Works.

Table II-1-4. Percent use of ERF study areas and major habitat types by ducks in fall 1997, 1998, and 1999. Habitat types within study areas used by fewer than 1% of ducks are not listed.

	Percent use		
Area/habitat	*1997*	*1998*	*1999*
Coastal West	**9.9**	17.6	18.8
Ponds	5.6	9.1	10.9
Knik Shoreline	4.3	7.6	6.6
A	14.6	**5.6**	14.9
Ponds	14.5	5	11.5
B	**25**	**19.2**	**20.1**
Ponds	19.2	18.2	16.1
Eagle River	5.8	1	1.4
Racine Island	**0.6**	1.1	**1.5**
C	17.9	4.8	4.8
Ponds	2.4	4.7	1.0
Eagle River	15.5	0.1	1.0
C/D	11.4	**15.3**	**8.5**
Ponds	11.4	15.3	3.7
Bread Truck	**1.3**	**1.9**	**2.3**
Ponds	1.3	1.9	1.1
Coastal East	**9.1**	21.1	**9.1**
Ponds	2.8	9.3	5.0
Knik Shoreline	6.3	11.7	0.9
D	**10.7**	**13.4**	**20.0**
Ponds	10.7	13.4	20.0

II-2. MOVEMENT, DISTRIBUTION AND RELATIVE RISK OF MALLARDS USING EAGLE RIVER FLATS: 1999

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INTRODUCTION

The U.S. Army has used Eagle River Flats (ERF), Fort Richardson, Alaska, since 1945 as an impact area for artillery shells, mortar rounds, rockets, grenades, illumination flares, and Army/Air Force Door Gunnery Exercises. In August 1981, hunters discovered large numbers of duck carcasses in ERF. Since that time, the Army and other Federal and state agencies have been involved in identifying the cause of the waterfowl mortality. On 8 February 1990, the Army temporarily suspended firing into Eagle River Flats due to the suspected correlation between explosives and duck deaths. In July 1990, a sediment sample collected from ERF was suspected of containing white phosphorus. By February 1991, it was concluded that white phosphorus in ERF was the cause of waterfowl mortality.

Waterfowl populations, overall, have been decreasing continent-wide (U.S. Fish and Wildlife Service and Canadian Wildlife Service 1989). Many factors affect their numbers, such as the availability of breeding, loafing, and feeding habitat. ERF is an important spring (April to May) and fall (August to October) waterfowl feeding and staging area. Contamination of waterfowl feeding areas in ERF with white phosphorus represents a serious hazard. From 1993 through 1995, August through October, movement, distribution, turnover rate and site-specific exposure of waterfowl species most susceptible to white phosphorus poisoning were determined at Eagle River Flats, Fort Richardson, Alaska, at the same time that waterfowl hazing was being conducted on the Flats (Cummings et al. 1993, 1994, 1995). Starting in 1996, waterfowl hazing was terminated so that baseline data on waterfowl movements and mortality under natural conditions could be collected. In addition, an effort was made to increase the sample size of mallards used to meet the objectives. The target number was a minimum of 100 mallards.

In 1996, 158 ducks were captured on ERF using primarily a net-gun from a helicopter. Of these, 107 mallards and 29 northern pintails were fitted with radio transmitters. Movements and distribution of mallards indicated that they spent about 91% of their time in Areas A, B, C, and C/D. In addition, mallards spent about 83% of their time in areas that are considered contaminated (A, BT, C, C/D, EOD, and RI). The average number of days spent on ERF by mallards was 47. The average daily turnover rate for waterfowl was about 1.4%. The greatest turnover of waterfowl occurred from 1 to 15 October, when 62% of the mallards departed ERF. The number of mortalities of instrumented mallards using ERF from 3 August to 15 October was 37, or about 35%. The greatest mortality occurred in Area C (35%), Area A (22%), and Areas C/D and RI (16%, respectively).

In 1997, 136 mallards were captured; 55 were fitted with standard transmitters and 82 were fitted with mortality transmitters. Mallard movements and distribution indicate that they spent about 88% of their time in areas A, B, C, and C/D. In addition, mallards spent about 69% of their time in areas that are considered contaminated (A, BT, C, C/D, and RI). The average number of days spent on ERF by mallards was 42. The average daily turnover rate for waterfowl was about 1.1%. The greatest turnover of waterfowl occurred from 7 to 16 October, when 52% of the mallards departed ERF. Mortality of instrumented mallards that used ERF from 2 August to 22 October was 35. Of those, 21 were attributed to white phosphorus ingestion. We recovered 15 ducks, of those seven were analyzed for white phosphorus. Five were positive for white phosphorus. The mortality model estimated that 6063 individual dabblers used ERF from 2 August to 22 October. Dabblers peaked at 4398 individuals between 9 and 10 September. The overall mortality on ERF was 240 dabblers.

In 1998, 4–13 August, 109 mallards were captured from random locations on ERF using a net-gun from a Bell 212 helicopter. Of the 109 mallards, 60 were fitted with standard transmitters and 49 were fitted with mortality transmitters. Tracking data indicated that transmitters did not appear to inhibit mallard movements or activities. Mallard movements and distribution indicate that they spent about 75% of their time in Areas A, B, C, and C/D. In addition, mallards spent about 65% of their time in areas that are considered contaminated (A, BT, C, C/D, and RI). The average daily turnover rate for waterfowl was about 1.3%. The greatest turnover of waterfowl occurred from 12–19 August and 13–16 October, when 24 and 54% of the mallards, respectively, departed ERF. Mortality of instrumented mallards that used ERF from 4 August to 22 October was 33. Of that, 29 were attributed to white phosphorus ingestion. The greatest mortality occurred in Area C/D, 12 of 29 (41%); Area A, 5 of 29 (17%); and Area C, 5 of 29 (17%). Overall, these areas accounted for 82% of the mallard mortality on ERF. No mallard mortality was noted from capture, handling, or the transmitter. We recovered 13 whole duck bodies from the 29 white phosphorus mortalities. Analysis showed ten were positive for WP. A mortality model was developed for ERF to estimate the total individual dabblers using ERF, the peak number of dabblers using ERF, and the total number of duck mortalities on ERF during the fall migration period. In 1996, 5413 individual dabblers used ERF from 3 August to 16 October. Dabblers peaked at 2333 individuals between 13 and 16 September. The overall mortality that occurred on ERF was 655 dabblers. In 1997, 6063 individuals dabblers used ERF from 2 August to 22 October. Dabblers peaked at 4398 individuals between 9–10 September. The overall mortality that occurred on ERF was 240 dabblers. In 1998, 3722 individual dabblers used ERF from 4 August to 22 October. Dabblers peaked at 1583 individuals between 27 August and 2 September. The overall mortality that occurred on ERF was 355 dabblers.

In 1999, we continued to focus on issues outlined under the CERCLA process for ERF. The objectives, as outlined below, of this study are designed to contribute to remedial decisions concerning ERF. The objectives for 1999 were:

1. Determine the daily and seasonal movements and distribution, turnover and mortality rates of mallards using ERF.
2. Establish baseline data for mallards with respect to proposed remediation actions.

METHODS

Beginning 4 August 1999, we captured mallards from random locations on ERF using a net-gun from a Bell 212 helicopter. Ducks were individually banded with a U.S.

Fish and Wildlife Service band and fitted with a radio transmitter weighing 9.1 g. Each transmitter was position on the upper back of the duck and attached with a Teflon ribbon harness (Cummings et al. 1993). Transmitters provided daily movement, distribution, and mortality data. Each transmitter would emit 60 pulses per minute when the duck was active and 120 pulses per minute when activity ceased (mortality). The capture and release location and date, band number, age, and sex were recorded for each bird.

Mallards were tracked from three strategically located fixed telemetry towers on ERF (Fig. II-2-1). Each tracking tower was equipped with a notebook containing radio tracking forms, a directional yagi antenna, a compass for determining telemetry bearings, and a two-way radio for communications. Ducks were located simultaneously from each tracking tower. The birds were assumed to be near the point where the bearings crossed, and each bearing location was entered onto a radio tracking form. Also, the Cole Point tower tracker was radioed the telemetry locations for each mallard from the other two tracking towers. The data were immediately entered into the computer program LOCATE II (Pacer, Truro, Nova Scotia, Canada). The program imports each telemetry reading from each telemetry tower and triangulates the location of the duck on a map of ERF. The program uses the length technique, which estimates the most likely true location of the duck (Nams 1990). Data that had an error polygon of greater than 50,000 m^2 were not included in the data set. The average and median error polygon for mallards on ERF during 1999 was 11,865 m^2 and 2878 m^2. The data set was transferred from LOCATE to EXCEL and mapped using GIS ARC/INFO or ARC/VIEW, or both.

Birds were also tracked on foot, from

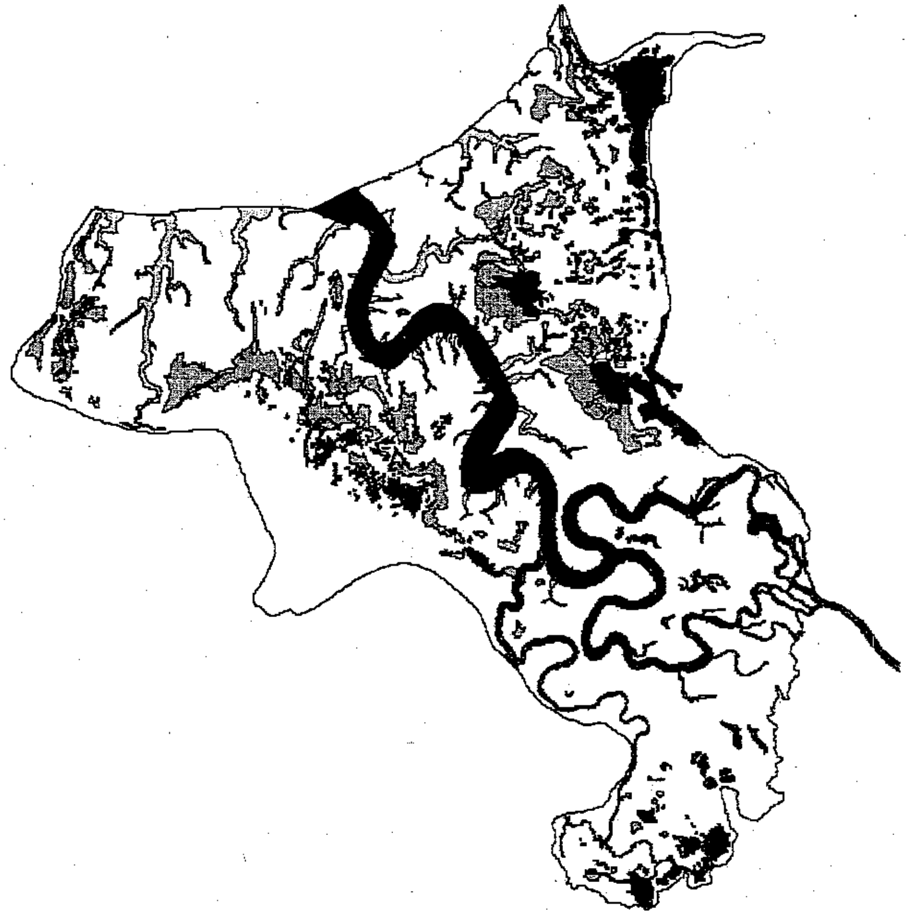

Figure II-2-1. Geographic information system map depicting Eagle River Flats.

hovercraft or helicopter to determine their status. Towers could receive radioed birds up to 15 km from the Flats. On occasion, helicopters were used to track ducks that had departed the Flats. Areas, such as the Susitna Flats, Palmer Hay Flats, and Chickaloon Flats, that were up to 90 km from the Flats were checked for transmitted ducks.

Telemetry locations were determined daily between 0700 to 1000 and 1500 to 2000 during August, September, and October. Birds that could not be detected as moving or did not move more than 10° in one day were visually located to determine their status. Every effort was made to recover dead ducks to determine the cause of death. The location of each duck was recorded with a Global Positioning System.

In 1995, ERF was divided into ten areas representing sites that waterfowl used for foraging and loafing (Fig. II-2-1). Since that time, telemetry data have been plotted and analyzed based on these ten areas. The areas were synonymous with areas used by the U.S. Army to identify specific areas on ERF. The ten areas are A, B, RI (Racine Island), C, C/D, D, BT (Bread Truck), EOD, Coastal West, and Coastal East. Areas A, RI, C, and BT have documented high levels of white phosphorus.

In 1999, mallard activity in different areas of ERF was determined by counting the number of telemetry locations within an area, divided by the total number of telemetry locations for that bird, and expressing it as a percentage. These data were used to address concerns about the relative risk to mallards and to establish baseline data with respect to proposed remediation actions.

The daily turnover rate of instrumented mallards on ERF was determined by dividing the number of radio-instrumented mallards that departed ERF each day by the total mallards instrumented. The daily turnover rate was used to determine the relative white phosphorus risk to birds using ERF.

Mallard mortality and the location of that mortality was determined by telemetry. The mortality rate was determined by dividing the number of mallard mortalities by the total number of mallards captured and radioed. A mortality model developed for ERF uses duck census data (W. Eldridge, 1999, unpublished data) and telemetry, turnover, and mortality data from 1999 to determine the number of dabblers using ERF, peak number of dabblers, and the projected mortality (Cummings et al. 1995). The model adjusts for turnover and shows the number of dabblers by duck census periods. The total number of individual dabblers using ERF is calculated by totaling the positive increases in dabblers by survey period, i.e., period 1 = 370 dabblers, period 2 = 650 dabblers, and period 3 = 363 dabblers. The total for these periods would be 370 + 280 + 0 = 650. The peak dabblers is determined by the period having the greatest number of dabblers during that period.

The model formula is:

$$A_1 = \frac{A_2}{(D/R)-1} \rightarrow M = \frac{A_1(M_1)}{R}$$

A_1 = actual number of dabblers using ERF
A_2 = number of dabblers surveyed
D = number of dabblers departing ERF
M = projected number of dabbler mortalities on ERF
M_1 = number of radioed duck mortalities
R = number of radioed ducks.

RESULTS

From 4–18 August 1999, 116 mallards were captured from random locations on ERF using a net-gun from a Bell 212 helicopter (Table II-2-1). We used 36 hours of helicopter time to capture the mallards. The best capture rate was 9 mallards in 1 hour. Each mallard was tagged per its capture site, transported to a holding site on ERF, banded and fitted with a 9.1 g backpack transmitter, held for 24 hours to assess its condition, and released at its capture site. All 116 mallards were fitted with standard/mortality transmitters that emit about 60 pulses per minute when the duck is alive and 120 pulses per minute when the duck dies. The movement of instrumented mallards following release indicated that transmitters did not appear to inhibit movements or activities. Observations indi-

Table II-2-1. Radio transmitters fitted to mallards since 1996 on Eagle River Flats, Fort Richardson, Alaska.

Year	*Total*
1999	116
1998	109
1997	136
1996	107

cated that the behavior of instrumented mallards did not differ from that of other ducks in its associated flock. On some occasions, instrumented birds were observed leading flights of ducks.

The GIS system produced two types of maps for each mallard. The first map ($n = 104$) showed mallard telemetry points from August 4 to October 14 (Fig. II-2-2—actual example). The second map ($n = 24$) depicts the last 5 to 10 telemetry locations of mallards that died from white phosphorus (Fig. II-2-3—actual example). These maps ($n = 128$) were useful in determining a general area where mallards could have been exposed to white phosphorus. Exact locations and, on occasion, even the general location of where the duck might have ingested white phosphorus were difficult to discern because the death of a duck occurred on the weekend when personnel did not work.

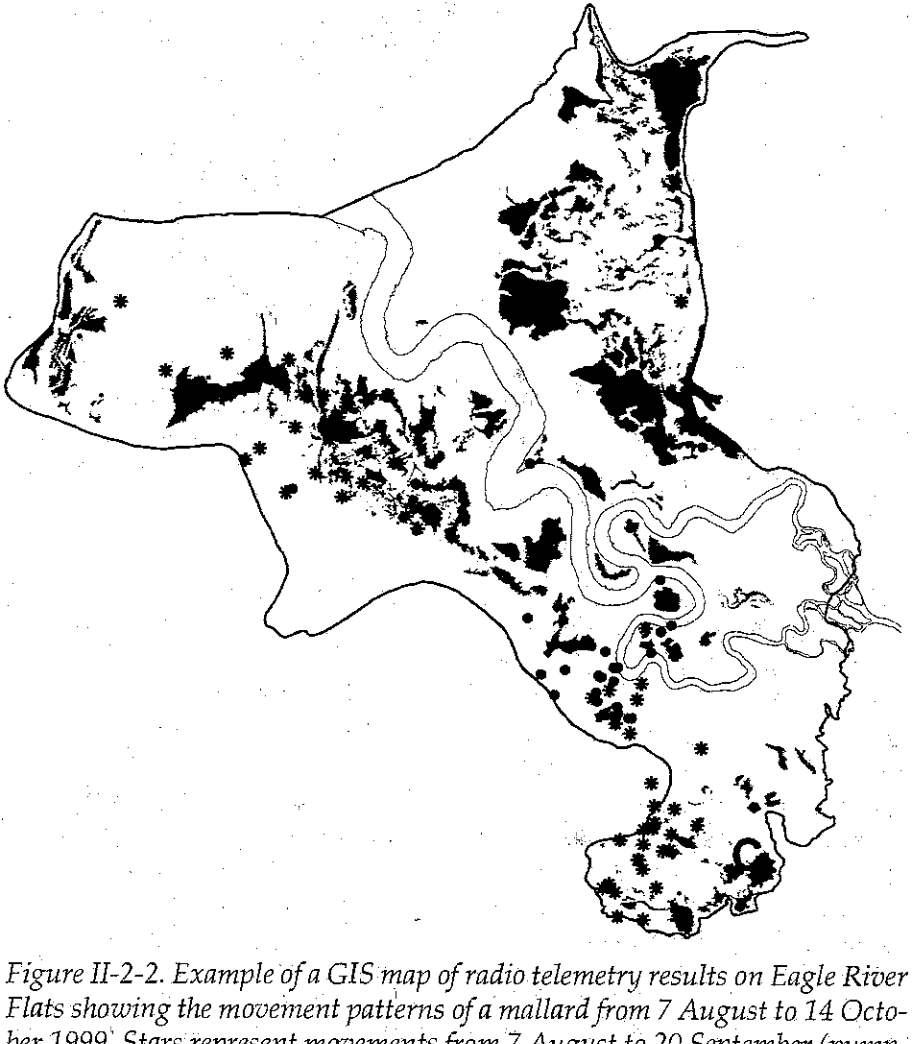

Figure II-2-2. Example of a GIS map of radio telemetry results on Eagle River Flats showing the movement patterns of a mallard from 7 August to 14 October 1999. Stars represent movements from 7 August to 20 September (pumping) and circles represent movements from 21 September to 14 October (no pumping). One symbol may represent several telemetry locations.

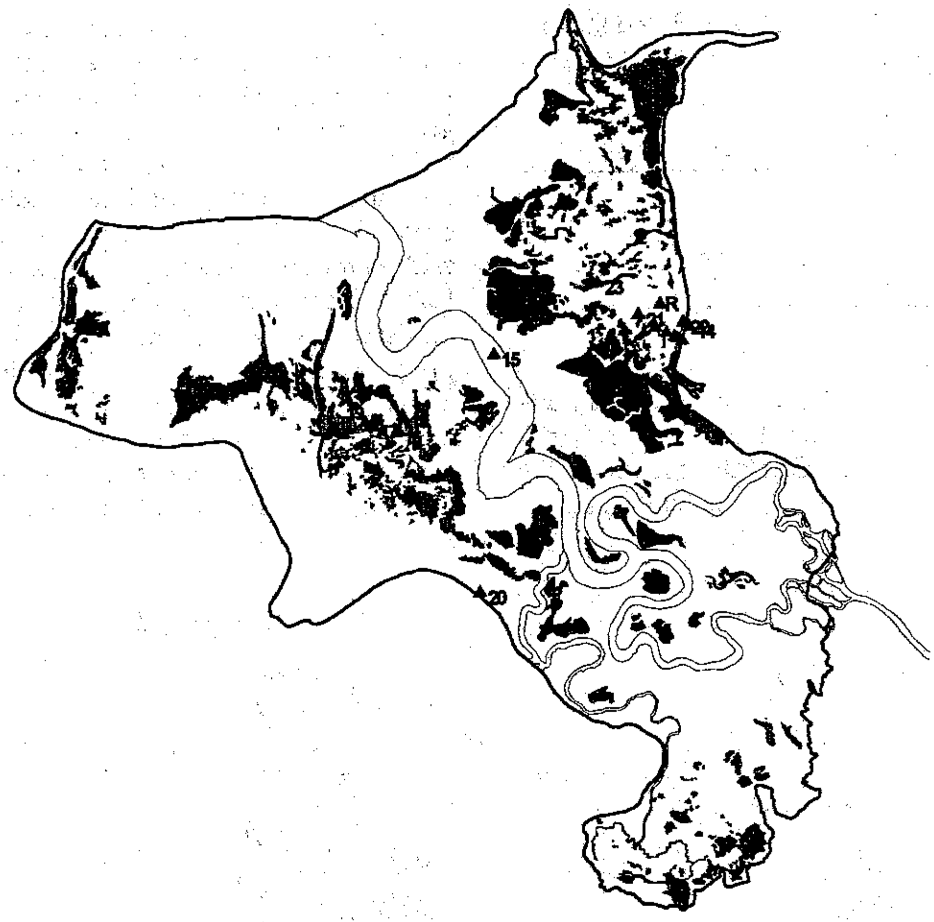

Figure II-2-3. Example of a GIS map depicting radio telemetry results of a mallard that died from ingesting white phosphorus. Numbered dots represent movements prior to death. C is the capture location, T is the location at which the transmitter went into mortality mode, and R is where the carcass was recovered.

Mallard ($n = 104$) movements and distribution on ERF during the fall indicated that they spent the majority (82%) of their time from 4 August to 14 October in Areas A, B, C, and C/D (Fig. II-2-4). In addition, mallards spent about 61% of their time in areas that are considered to be contaminated (A, BT, C, C/D, and RI). Of the 4848 telemetry locations, 182 were in the Racine quadrant, 1544 were in the A quadrant, 77 were in the BT quadrant, 418 were in the C quadrant, and 715 in the C/D quadrant. Mallards were only located 14 of 182 times in the actual Racine Pond and 17 of 77 times in the actual Bread Truck Pond. Several mallards were documented moving to various locations near ERF, such as Gwen, Otter, and Six Mile Lakes, Palmer Hay Flats, Susitna Flats and the Anchorage Bowl.

Mallard use of Area A decreased about 30% from 1996 to 1999 (Fig. II-2-4). The use of Areas B and C/D by mallards increased 15 and 6%, respectively, during this same period. Use of all other areas on ERF remained about the same from 1996 to 1999 (Fig. II-2-4).

To evaluate the effects of pumping on mallards, we compared mallard movements and distribution during (prior to 9/21) and following (9/21 to 10/14) pond pumping in 1999 (Fig. II-2-5). Pumps were placed in Areas A, C, and C/D. Pumping systems were able to drain ponded areas of most water. However,

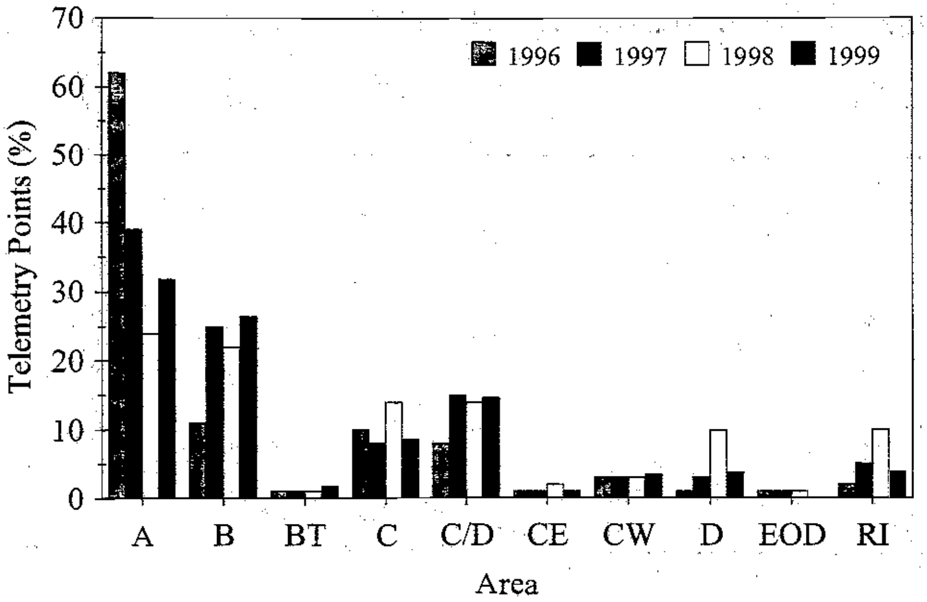

Figure II-2-4. Distribution of radioed mallards on Eagle River Flats during August, September, and October, 1996 to 1999.

on occasion, waterfowl were attracted to standing water that was retained in these areas by low spots or depressions. Overall use of Areas A and C was reduced about 6 and 10% during pumping, respectively. However, the use of Area C/D increased about 4% during pumping. The area that is being affected by pumps in Areas A, C, and C/D is minimal compared to the availability of overall waterfowl habitat on the Flats.

The average and median number of days mallards ($n = 104$) spent on ERF was 33. The

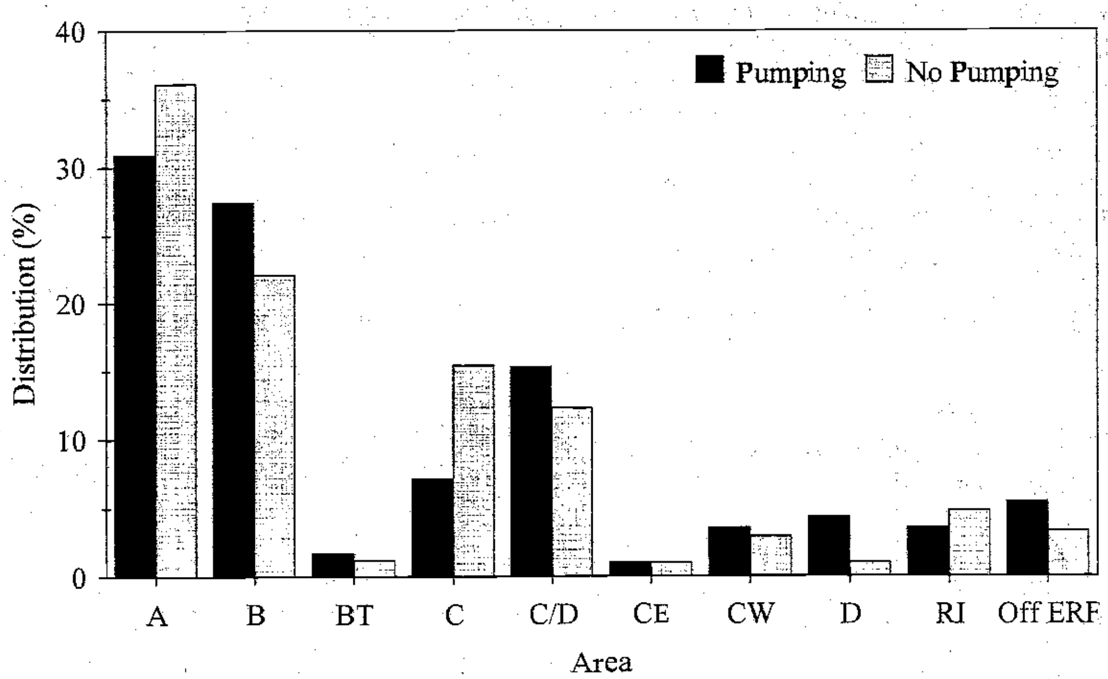

Figure II-2-5. Distribution of mallards relative to pond pumping on Eagle River Flats before 21 September and from 21 September to 14 October 1999.

Table II-2-2. Mortality model for Eagle River Flats, 4 August to 20 October 1999.

Date	Radioed mallards (no.)	Turnover (no.)	Mortality (no.)	Aerial counts (no.)	Unknown dabblers (no.)	Total dabblers (no.)	Adjusted for turnover (no.)	Projected mortality (no.)
8/4–8/20	116	23	2	251	45	296	370	6
8/21–8/24	93	7	1	435	166	601	650	7
8/25–8/30	86	13	5	253	55	308	363	21
8/31–9/3	73	7	2	289	0	289	320	9
9/4–9/8	66	7	2	117	27	144	161	5
9/9–9/14	59	6	2	206	86	292	325	11
9/15–9/16	53	8	2	177	100	277	326	12
9/17–9/20	45	9	3	145	245	390	488	33
9/21–9/28	36	8	4	497	63	560	721	80
9/29–10/4	28	0	1	250	155	405	405	14
10/5–10/7	28	1	0	256	34	290	301	0
10/8–10/13	27	13	0	220	0	220	425	0
10/14–10/20	14	0	0	37	0	37	37	0
Total	116	102	24	3133	976	4109	4892	**198**

range was from 1–69 days. At the conclusion of the study, 14 October, 14 mallards remained on ERF. These birds were using the Eagle River and some open water in Areas B, C/D, and D. The average daily turnover rate for mallards was about 1.3%. The greatest turnover of mallards occurred from 4 to 20 August, 25 to 30 August, and 8 to 13 October, whereas 49 (42%) of the mallards departed ERF during these time periods (Table II-2-2).

Of the radioed instrumented mallards that used ERF from 4 August to 14 October, 34 died (Table II-2-3). Of those mallards, 24 (71%) were attributed to white phosphorus, 3 were shot by hunters, 1 was tangled in its harness, 3 were predated, and 3 were unknown mortalities (Table II-2-4). Mallards that were found dead on ERF had used the Flats from 1 to 56 days. The average exposure before mortality was 23 days. Mortality occurred in Areas C/D, 6 of 24 (25%); A, 9 of 24 (38%); C, 6 of 24 (25%); BT, 1 of 24 (4%); and B, 1 of 24 (4%) (Fig. II-2-6, II-2-7). Additional dead ducks not instrumented with a radio transmitter were also recovered from these areas. No mallards were found dead in the drained portion of Racine Island. No mallard mortality was noted from capture or handling but one mallard got its leg tangled in the harness. Mallards mortalities varied by year (Fig. II-2-7). We recovered 11 whole duck bodies from the 24 white phosphorus mortalities. Analysis showed all 11 were positive for white phosphorus (Tables II-2-5, II-2-6). White phosphorus levels in a mallard collected from Area A was 0.633 µg/g; 6 mallards collected from area C were $x = 311$ µg/g (range: 0.228 to 1,170 µg/g); ten malards collected from Area C/D were $x = 791$ µg/g, (range: 0.04 to 3,210 µg/g; one was ND); one mallard collected from the

Table II-2-3. Mallard mortalities from white phosphorus (WP) during August, September, and October on Eagle River Flats.

Year	Captured (no.)	Mortalities (no.)	WP Mortalities (no.)
1999	116	34	24
1998	109	36	29
1997	136	34	21
1996	107	44	39

Table II-2-4. Mallards recovered from Eagle River Flats and believed to have died from reasons other than white phosphorus, 1996 to 1999.

Year	Hunting	Predated	Attachment method	Unknown	Total
1999	3	3	1	3	10
1998	6	0	0	1	7
1997	8	2	3	0	13
1996	1	3	1	0	5

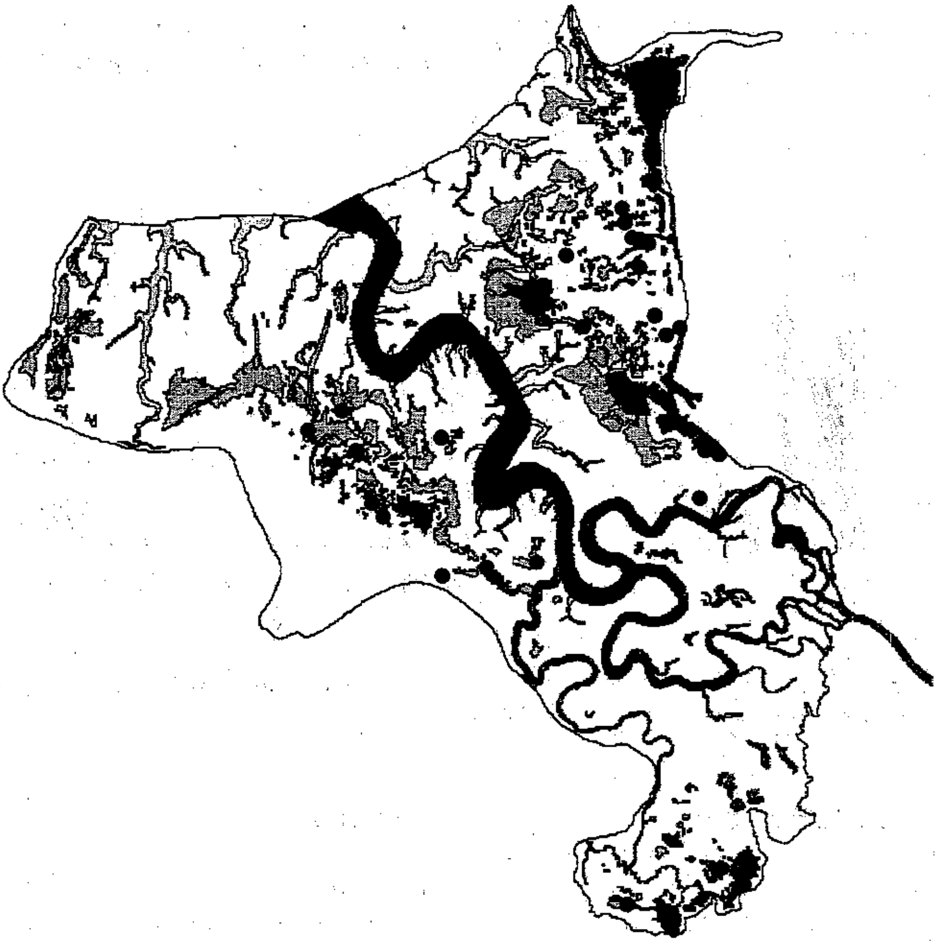

Figure II-2-6. Mallard mortality locations on Eagle River Flats in 1999.

AquaBlok pen was 0.51 µg/g; and one mallard collected in area D was 10 µg/g (Fig. II-2-8). In addition, of five mallards collected from Area B, two had WP levels of 0.0013 and 0.6 µg/g, respectively.

A mortality model was developed for ERF to estimate the total individual number of dabblers using ERF, the peak number of dabblers using ERF, and the total number of dabblers mortalities on ERF during the fall migration period. We used the number of radioed mallards, the aerial census counts of waterfowl on ERF, and the number of mallard mortalities on ERF in the mortality model. In 1996, 5413 individual dabblers used ERF from 3 August to 16 October. Dabblers peaked at 2333 individuals between 13–16 September. The overall mortality that occurred on ERF was 655 dabblers. In 1997, 6063 individual dabblers used ERF from 2 August to 22 October. Dabblers peaked at 4398 individuals between 9 and 10 September. The overall mortality that occurred on ERF was 240 dabblers. In 1998, 3772 individual dabblers used ERF from 4 August to 22 October. Dabblers peaked at 1583 individuals between 27 August and 2 September. The overall mortality that occurred on ERF was 355 dabblers. In 1999, 1334 individual dabblers used ERF from 4 August to 14 October (Table II-2-2). There were two small peaks of dabblers on ERF: 650 between 21 and 24 August and 721 between 21 and 28 September. The overall mortality that occurred on ERF was 198 dabblers. These data represent a minimum number of mortalities on ERF during the fall migration period. Mallard mortality during the spring migration has been estimated at about

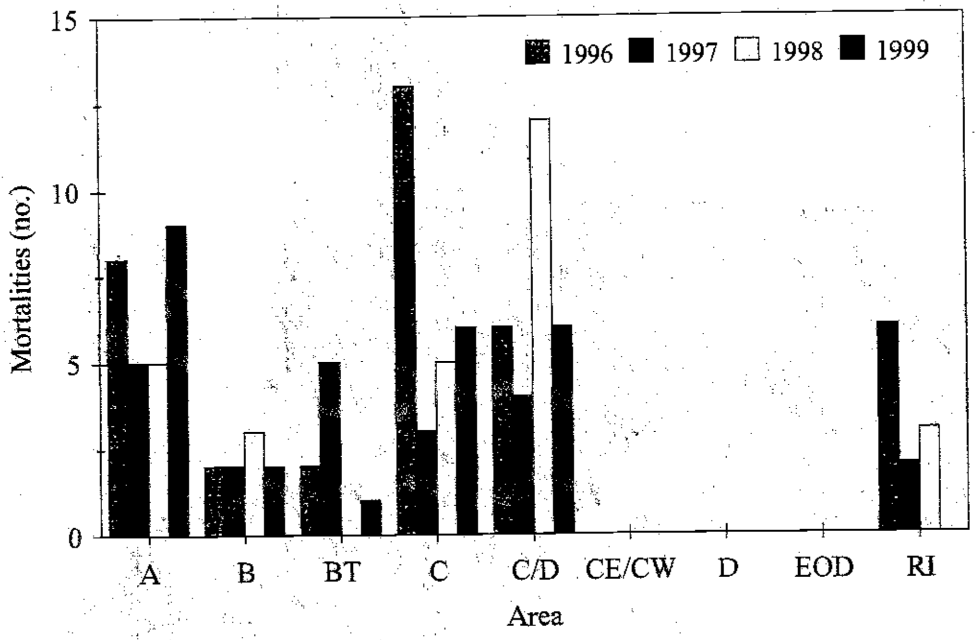

Figure II-2-7. Distribution of mallard mortalities on Eagle River Flats during August, September, and October, 1996–1999.

50% of the fall migration period (Cummings et al. 1994, 1995, 1996). Thus, overall mortality for 1996 was 983 dabblers, for 1997 was 360 dabblers, for 1998 was 532 dabblers and 1999 was 297 dabblers. Overall waterfowl mortality in the fall has decreased about 70% from 1996 to 1999. Mortality of transmittered mallards has decreased about 40% from 1996 to 1999. The decrease is attributed to remediation actions such as pumping, draining, and aqua-blok.

Table II-2-5. Mallards recovered from Eagle River Flats and tested for white phosphorus, 1996 to 1999.

Year	*Mortalities (no.)*	*Tested (no.)*	*Positive (no.)*
1999	24	11	11
1998	29	13[a]	10
1997	21	10[b]	8
1996[c]	39	8	8

[a] Three mallards <MLOD (0.014 µg).
[b] Two mallards <MLOD (one was <0.003 µg/g and one was <0.013 µg).
[c] One mallard captured in 1996 died in 1998, but is included in the 1996 data.

DISCUSSION

In 1996, 1997, 1998, and 1999 mallards were selected as the indicator species to measure the effects of any treatability studies or remedation actions on ERF. The 1996, 1997, 1998, and 1999 sample sizes of 107, 136, 109, and 116, respectively, radioed mallards were large enough to establish a baseline that future changes in mallard movements, distribution, turnover, and mortality can be de-

Table II-2-6. Unbanded and non-radio transmittered waterfowl collected from 4 August to 14 October 1999 and analyzed for white phosphorus on Eagle River Flats, Fort Richardson, Alaska.

Site	*Carcasses collected (no.)*	*WP (µg/g)*
B	1 Mallard	0.60
C	2 Mallards	0.92; 1,170
C/D	4 Mallards	0.04; 0.35; 1.34; 61.6
D	1 Mallard	9.74
AquaBlok Pen	1 Mallard	0.51[a]

[a] The test tube broke during centrifugation and some of the sample was lost. The actual concentration was probably higher.

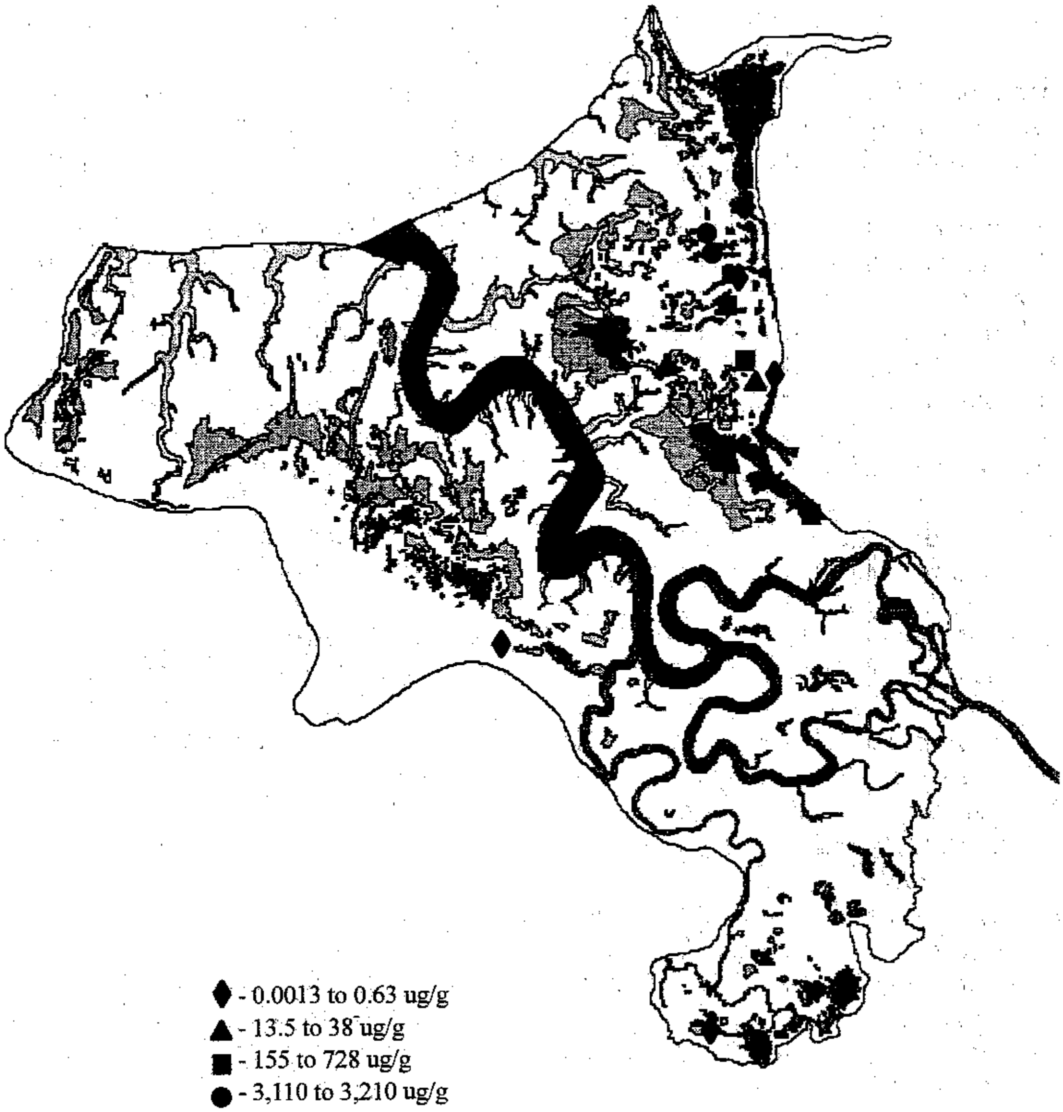

Figure II-2-8. Mallard mortality locations by white phosphorus concentration on Eagle River Flats in 1999.

tected with confidence.

Mallards highly preferred Area A in 1999, followed by Areas B, C/D, and C. These were the same areas that mallards preferred in 1996, 1997, and 1998. If 1996 can be considered a true baseline year, then the remediation actions on the Flats are probably having an effect on mallard distribution and mortality. There has been an increase in the use of Areas B and C/D and decrease in the use of Area A. However, with the increase in remediation actions, ducks are distributing more into potentially contaminated areas. Waterfowl mortality tends to support this scenario by which mortality decreased significantly between 1996 and 1997 when Racine Island and Breadtruck were drained. Since then overall mortality has only fluctuated 5% among years, suggesting the exposure rate has leveled off until there is more remediation or remediated areas are returned to waterfowl habitat.

The average number of days mallards spent on ERF was 40 in 1995, 47 in 1996, 42 in 1997, 48 in 1998, and 55 in 1999. Weather is a factor that affects the length of time mallards spend on the Flats. In 1995 and 1997, pond areas started freezing in the later part of September, which caused ducks to leave ERF for open water. In many cases ducks will move to the river until ice flows eliminate foraging opportunities.

Mallard mortality was 36% in 1996, 15% in 1997, 27% in 1998, and 20% in 1999. The mortality model predicted 655 duck mortalities in the fall migration period in 1996, 240 in 1997, 355 in 1998, and 198 in 1999. Overall mortality has decreased since 1996, which can be attributed to remediation actions.

The mortality model for ERF is a more accurate predictor of the actual numbers of ducks that die from white phosphorus ingestions than trying to extrapolating the percentage of telemetry mortalities to the ERF duck population. The model combines all the data from telemetry ducks, which includes numbers, mortality, and turnover, and the aerial census to predict the actual number of ducks that die from white phosphorus ingestion. The advantage of the model is that it uses the above factors to project the mortality each day, week, or month; whereas by trying to extrapolate the percent mortality from telemetry ducks to the ERF duck population, a problem is encountered such that this percentage represents what has occurred over the entire period and does not take into account when ducks use the Flats, the exact number of individual ducks using the Flats, and the turnover rates.

RECOMMENDATIONS

Assessment endpoints

The biological assessment endpoint for ERF is the reduction in waterfowl mortality. To measure this endpoint, we suggest that mallards continue to be used as the indicator species for ERF and telemetry be used to monitor their activities. Showing a significant effect will depend on having a sample size that exceeds 100 mallards captured in a relatively short period of time. In addition, a board evaluation of factors affecting remediation actions can be achieved by converting all transmitters to a combination of standard and mortality signals.

Of importance is being able to determine if remediation actions reduce mortality. Because waterfowl use the entire ERF, remediation of one area doesn't necessarily mean that mortality will decrease. Waterfowl might redistribute to other sites. It has been shown that telemetry can account for factors affecting mortality, whereas transects, which are tied to a specific ponded site, cannot. It is recommended that we continue to integrate telemetry data into the risk assessment process, that future remediation actions be assessed with telemetry birds, and that mortality on ERF be assessed by instrumenting more than 100 waterfowl with mortality transmitters.

Use of telemetry

Telemetry does the following:

- Reduces human exposure to UXO's.
- Supports measuring the assessment endpoints with relatively good confidence limits.

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III-1. Eagle River Flats Pond Pumping Remediation Project: First-Year Deployment under the Record of Decision

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INTRODUCTION

Eagle River Flats has been the subject of far-reaching research over the past 10 years. The discovery of extensive waterfowl mortality in the Flats in the mid-1980s led to initial investigations into the magnitude and possible causes of the problem. With the determination that the die-offs were restricted to the Flats, more intensive studies were begun in 1989. After an extensive remedial investigation that determined the cause of the die-offs—white phosphorus (WP)—the effect of WP on native flora and fauna, the extent of contamination, and the interaction of the physical environment at the Flats with the persistence of the contaminant, feasibility studies were begun to examine alternative methods of remediation. One alternative under consideration was to pump water out of permanently ponded areas, thus allowing the saturated sediments to desaturate and warm. This process, according to a theory advanced by M.E. Walsh (M.E. Walsh et al. 1995), may enhance the process of natural attenuation observed in the intermittently ponded areas bordering the permanent ponds. In 1997, a system was set up in a large, representative pond and run throughout the summer. Results were much better than predicted, with an 85% decrease in WP concentration, thus verifying the theory of enhanced natural attenuation by pumping (M.R. Walsh et al. 1999). The method also proved to be a feasible remediation method for a single, easily accessible pond.

The next step in the regulatory process was a treatability study, which entails the development of the methods and technology for deploying multiple systems throughout Eagle River Flats. A total of six sites were chosen, two near the edge of the Flats and easily accessible, one away from shore but still easily accessible, and three across the Eagle River in an area accessible only by helicopter or a long walk. Again, the results were quite positive. The success of these studies led the Remediation Project Managers to recommend pond pumping with the application of a fill material for untreatable areas as the preferred remediation method in the *Record of Decision* (ROD), signed in September of 1998. With the signing of the ROD, the cleanup project at Eagle River Flats shifts into the remediation phase. This year marks the first year of remediation under the ROD. This report covers the pond pumping remediation work done over the course of the 1999 ERF field season.

DEPLOYMENT

In 1999, we planned to again deploy six pump systems. In Area C, the pumps were deployed in the same ponds as in 1998: the 189-L/s (3000-gpm) pump in Pond 146, the 63-L/s (1000-gpm) pump in Pond 155, and a 126-L/s (2000-gpm) system in Pond 183. In Area A, only two systems were deployed this year. Ponds 256 and 258 would again have

126-L/s systems, but no pump would be deployed in Pond 290. The results of sampling at the end of last fall indicated no white phosphorus contamination in Pond 290 (M.E. Walsh et al. 1999). The 126-L/s unit that was freed up was deployed in a new location, Pond 730 in Area C/D (T-Pond), due east of Bread Truck Pond. Table III-1-1 depicts the pump system locations for 1999.

Prior to deployment of the pump systems, some additional site preparation work needed to be carried out. A shallow sump was blown in Pond 146 (Fig. III-1-1) for Pump 3, the 189-L/s tandem pump unit (Fig. III-1-2). Last year, when this pump was initially deployed, it was set in bottom of the old dredge channel that was excavated in 1996. This proved unsatisfactory, as the shallow channel quickly emptied during pumping, causing excessive cycling of the pump system. A deeper sump than the dredge channel was needed to increase the efficiency of the pumping. To create the sump in the bottom of the channel, four shaped charges, followed by four cratering charges, were employed instead of the normal two and two owing to the large size of the pump unit. Bangalore torpedoes were then used to breach the newly created crater rim and create access channels to the sump. A sump was also blown in Pond 730 (T-Pond) in Area C/D: a standard two-charge sump, with access created with Bangalores.

The discharge line was deployed next. The pipe was flown out on a commercial Bell 212 helicopter from ERA. Deployment took about a day and a half, with each of the discharge lines requiring less than 2 hours to deploy and assemble. To expedite transport, a load chart was formulated prior to the operation. Changes were radioed from the field to the EOD Pad while the helicopter was travelling back to the pad. The pipes were carried through the open doors of the helicopter. A crew of four on the EOD Pad and six in the field worked well, although an additional person in the field would have worked better. The EOD Pad crew loaded the pipe through the open doors of the helicopter. The pipe was loaded so that their connector ends would be facing the proper direction when they were unloaded in the field. Depending on the size pipe, eight to ten of the sections were loaded on each trip (cross section of the pipe and load stability were the limiting factors for load size, not weight). The line was assembled as the pipe was unloaded from the helicopter. The helicopter progressively unloaded pipe along the right-of-way as the line

Table III-1-1. Pump system locations for 1999 season.

System	*Location*	*Pump capacity (L/s)*	*Genset fuel capacity (L)*	*Auxillary fuel capacity (L)*
1	Area A Pond 183	126	940	1100*
2	Area C/D Pond 730	126	1020	1890
3	Area C Pond 146	63 / 126 / 189	1890	1890
4	Area A Pond 258	126	1320	1100
5	Area A Pond 256	126	1320	1890
6	Area C Pond 155	63	1020	1100

*Auxiliary fuel tank for System 1 moved to Pond 730 in August.

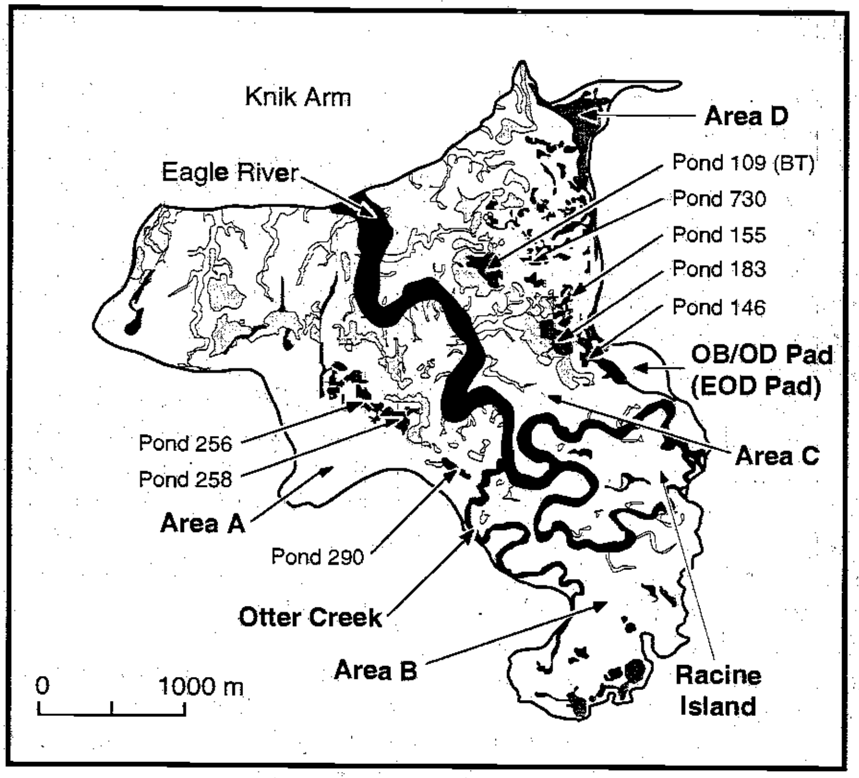

Figure III-1-1. Map of Eagle River Flats.

was assembled, limiting the distance the pipe had to be carried by hand. Discharge points were located at least 20 m from gully headwalls to reduce the erosion caused by the flow from the pipe. Where possible, the discharge end was located in the gully to further reduce erosion.

Following the deployment of the discharge line, the pump systems and fuel tanks were flown into position. We started in Area A, as this is the most difficult area to access. We then worked our way towards the EOD Pad. Although we had problems with incorrect rigging and missing personnel at the start of the operation, we deployed almost everything on the first day. This year, every system had a double-walled fuel tank, so the number of trips required by the AKANG UH-60L Blackhawk helicopter was increased to 16, including the deployment of C-Tower in Pond 183. The following day, the final system components were flown to their sites, and fuel was transferred from the auxiliary tanks. The aux-

Figure III-1-2. Blasting of sump for Pond 146.

iliary tanks were then refueled and returned to the field. At least 1 day between initial deployment and refueling should be scheduled next year, as this operation was very difficult to do on the same day.

Over the next 2 days, the final assembly of the systems was completed, and by 27 May, all systems were operational. At this time, work began on reinforcing the tide gate in B-Gully (Area C) and on installing tide gates in Area A. We hoped to stop higher tides from flooding Area C by using sand bags to extend the wing walls off the gate in B-Gully (Fig. III-1-3). We also started ditching around Pond 730, connecting low points and increasing the efficiency of water flow into the sump. On 28 May, Ponds 155, 183, and 258 had drained, and very little water was flowing into the sumps. Ponds 256 and 730 still had substantial amounts of water flowing in, and Pond 146 was receiving water from the beaver channel along the east side of the Flats, although only the old dredge channel still held water.

On 2 June, the Blackhawk returned and we refueled the field units. The field data stations for the monitoring effort were brought out and we started installing them. At this time, the pump controls were rewired to prevent the systems from malfunctioning when the low water float switch became lodged in the down position. All units were rewired and tested by 7 June. The operation and maintenance of the systems was turned over to Terry Edwards of Weldin Construction, Inc., at this time.

During the spring deployment, the meteorological station was once again installed off the EOD Pad. With the loss of the person who originally set up the data transfer system to the web at CRREL, bringing the system "on line" took much longer than expected, although data were available through an ftp site as well as stored on the data station storage module. A web-based video monitoring system, designed and built over the spring, was installed on C-Tower and tested (Fig. III-1-4). Communication for the video system is based on a cell phone link, and the Flats are in what is termed a gray area. The system intermit-

Figure III-1-3. Tide gate in B-Gully, Pond 183, during flooding tide.

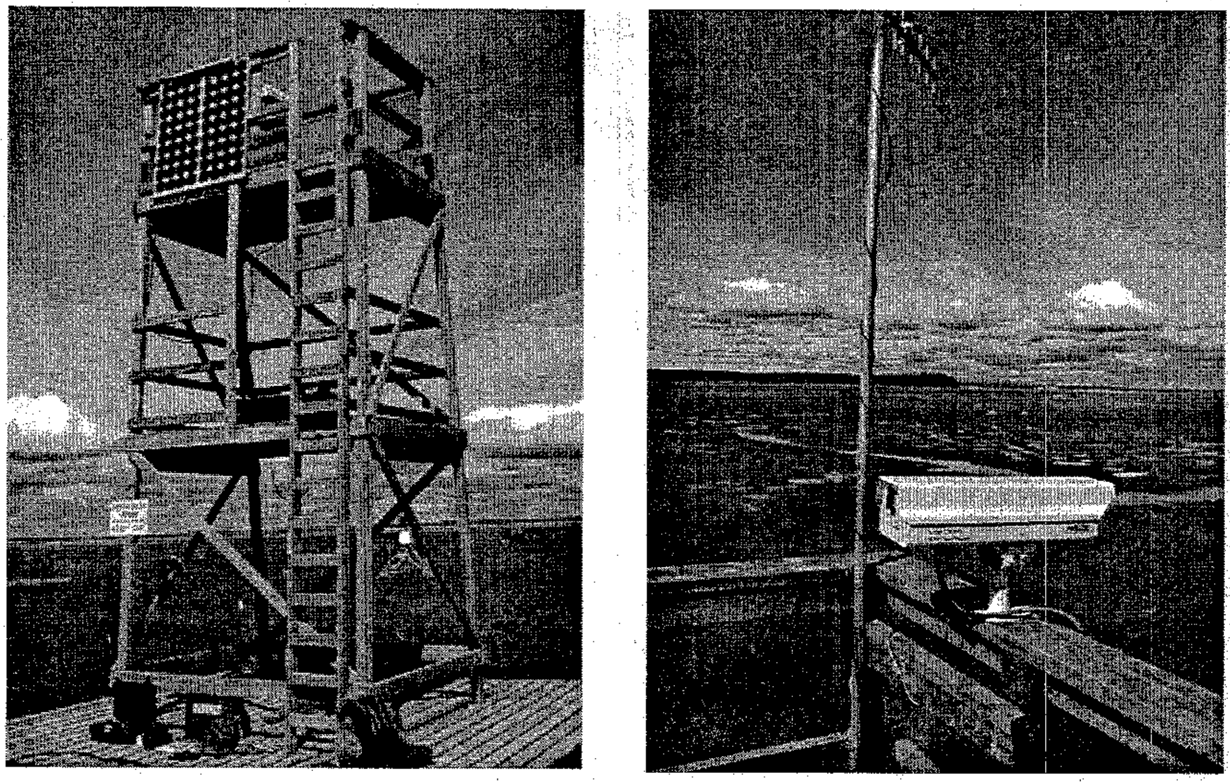

Figure III-1-4. Experimental web camera installation on C-Tower.

tently sent images back to Hanover, but was too unreliable to be of much use.

IMPLEMENTATION

Tidal predictions for the summer of 1999 indicated that flooding tides would be occurring at the Flats for every month of the season (Table III-1-2). There was nothing we could do about the tides in June, but we hoped to contain some of the tides in July, August, and early September using tide gates installed at the heads of tidal gullies. With four new tide gates in Area A and the four beefed up gates in Area **C**, we felt that the effects of the flooding tides could be minimized.

As predicted, there was widespread flooding in June with the 9.91-m tides (9.48 m is considered the threshold flooding tide level). The pumps quickly drained the area following the recession of the last flooding tide on 16 June (9.72 m), and there was substantial drying over the next 3-$^1/_2$ weeks (see M.E. Walsh et al., this volume). In July, the river, the winds, and the weather all cooperated, and the tide gates kept out all the flooding tides for that period, including a 9.75-m tide on 14 July. In August, heavy rains swelled the Eagle River and caused minor flooding in Area C from the Bread Truck Pond (109) direction on 12 August, but no flooding was evident in Area A. The early September flooding tides (<9.57 m) were easily handled by the gates. The result was a very good season with respect to flooding tides, with only one minor partial flooding event over the course of 103 contiguous days, 91 of which occurred during the core drying period of 15 May to 15 September. This compares quite favorably with the predicted maximum contiguous span of only 28 days. In total, from start up on 27 May to completion on 27 September, the Flats were drained for 117 days out of a total of 123, 105 of which occurred during the core period. However, a very wet summer prevented much drying after mid-July (see Collins, this volume).

Table III-1-2. Predicted flooding tides for 1999 season.

	Time	*Height (m)*	*Time*	*Height (m)*
May 14	0558	9.63		
15	0639	9.94	1923	9.54
16	0720	10.13	2011	9.60
17	0804	10.13	2059	9.54
18	0850	9.63		
19	0938	9.51		
June 12	0527	9.54		
13	0614	9.78		
14	0700	9.94		
15	0747	9.91		
16	0835	9.72		
July 12	0558	9.54		
13	0647	9.69		
14	0735	9.72		
15	0823	9.63		
August 11	0639	9.54		
12	0724	9.66		
13	0808	9.60		
September 10	0810	9.54		
11	0851	9.54		
25	0652	9.51	1920	9.57
26	0734	9.69	1953	9.75
27	0816	9.72	2028	9.85
28	0900	9.57	2105	9.85
29			2145	9.69

Notes: Pre-season Anchorage tidal predictions. Add 1/2 hour for ERF tides. ERF tidal classifications: 9.48- to 9.54-m tides, minor / preventable; 9.55- to 9.63-m tides, substantial/may be preventable; >9.63-m tides, major/unpreventable.

This year was the first of a formal operation and maintenance (O&M) agreement with an outside contracting firm, Weldin Construction, Inc. All pump systems were checked three times a week, along with the non-automated monitoring sensors located at the instrumentation stations in the treated ponds. More system functions were checked than in the past, as well. Cell phone communications were employed to troubleshoot and repair faulty equipment in the field, thus greatly increasing the time all the systems were on line. The only times the systems were down were during short periods in June and July when the gensets were shut down to conserve fuel in anticipation of flooding tides. The exception was system 2 in Pond 730, which will be discussed later.

Because of the blocking of the flooding tides by the tide gates, the systems needed refueling much less frequently than we had planned. After the final refueling of the systems during the initial deployment phase on 2 June, refueling was not necessary again until 30 June, following the flooding tides of late June, and then not again until 18 August. Only the systems in Ponds 256 and 730 required refueling, Pond 730 because of influx from the Bread Truck Pond ditch and Pond 256 because of infiltration from the west side of Area A. This cut in half the requirement for the Blackhawk for fueling.

Table III-1-3. Pump operation statistics for 1999 season.

System	*System start date*	*System stop date*	*Total genset hours*	*Total pump hours*	*Total pump cycles*	*Pump to genset hrs ratio*	*Fuel use (Est)(L)*	*Fuel use rate (L/hr)**
1	26 May	21 Sept	89	49	N/A	1.8	1,290	14.5/26.3
2	27 May	21 Sept	780	316	N/A	2.5	9,730	12.5/30.8
3	21 May	23 Sept	637	284 83	2,669 200	2.2	11,000	17.3/38.7
4	26 May	21 Sept	179	116	442	1.5	2,540	14.2/21.9
5	27 May	21 Sept	533	351	1,571	1.5	6,930	13.0/19.7
6	26 May	21 Sept	174	100	204	1.7	2,160	12.4/21.6

*Fuel consumption rates: Rate based on genset hours/rate based on pump hours. Cycle counter on system 6 non-functional until 30 June. System 3 has two pumps, 63-L/s and 126-L/s. The 63-L/s pump always ran with the 126-L/s pump. Fuel use estimates based on Weldin and CRREL data.

Statistics from the system monitoring readouts and O&M observations give a good indication of the active remediation process at the Flats (Table III-1-3). Systems 2, 3, and 5 all ran frequently. Cycling of systems 2 and 3 is indicated by the high ratio of genset hours to pump hours, reflecting short pump times along with frequent warm-up and cool-down cycles. This is indicative of a shallow sump, which quickly fills and is drained by the pump. Both sumps were thus scheduled to be deepened by reblasting during the fall during retrograde operations.

Operating time for system 2 really shows the susceptibility of Pond 730 to flooding. As mentioned above, Terry Edwards from Weldin turned the system off during periods of high tides during the latter half of the field season, as this area was affected by every flooding tide of the season and by some tides not normally considered flooding. As a consequence, there was some minor flooding in mid-August in Area C, but heavy rains during that period negated any deleterious effects that would have been caused by that flooding.

RETROGRADE

Refueling of the systems in September was planned to minimize the on-board fuel load of the gensets. All units except genset 6 have a maximum fuel capacity of 250 L (15-cm fuel depth in each tank) for retrograde because of the lift limitations of the Blackhawk. Genset 6 can carry up to 790 L (48 cm) and still be under the 4100-kg lift limit. A 12-VDC portable pump was purchased for the retrograde operation to pump fuel from the genset tanks into their respective auxiliary tanks to allow airlifting of the gensets. This eliminated the necessity of running the gensets under no load to burn off fuel, which is harmful to them.

Retrograde of the discharge line took place over the course of two days. In preparation, the gensets were shut down (with the exception of system 3), and the pipe was disconnected and piled in lift quantities of eight to ten pieces, depending on size. With the pipe in place, two crews were deployed and the pipe was flown back to the marshalling yard on the EOD Pad. System 3 was left operational to prevent flooding in Area C from the inflow of the beaver channel and to allow drainage of the Pond 146 sump prior to deepening.

The retrograde of the heavy equipment was conducted simultaneously with year-end excavations with explosives. This was done to minimize the amount of water present during excavation. Excess water limits access for the Engineers and decreases the effectiveness of the explosives, resulting in shallow holes, a problem we encountered in the spring with the sumps in Ponds 146 and 730. Operations were conducted first on the east side of the river. All equipment was removed, the pump in Pond 146 being the last to be airlifted after the inlet channel to the sump was sandbagged. The sump was then deepened substantially using four shaped charges, followed by four cratering charges. Several Bangalores were then used to breach the crater and expand the sump. The following day, the final pieces of equipment were removed from Area A, and additional explosive ditching was done in Pond 258 using detonation cord. Finally, the sump in Pond 730 was further deepened with two sets of explosive charges.

During this period, the meteorological station was dismantled and components either stored in Building 992 or sent back to Hanover for recalibration. Some work was done on a new hard-wire phone link we had installed on the Rt. Bravo Bridge over the Eagle River. A relay station has been established there to eliminate the need for cell phone communications when transmitting met data. Instead, radio modems will transmit the data from the met station, as well as the pond-site instrumentation stations, directly to the relay station at Rt. Bravo Bridge, where the data can then be transmitted to CRREL-Hanover over an Autovon line. Preliminary testing of the new line and relay station was successful. This should vastly increase reliability, while cutting down significantly on transmission costs. A similar arrangement is being developed for the web-based video monitoring system.

With the cessation of pumping activities at the Flats, preparation for storage began. All the pipe will once again be stored on the EOD Pad over winter, and the hose and check valves will be stored under cover back within the DPW-Environmental storage yard. The heavy equipment is also stored in the yard behind Building 724, where the oil and filters were changed with the help of Weldin. The radiator on genset 3 will need to be replaced, and that unit was left at Building 704.

PERFORMANCE EVALUATION

Once again, the systems performed beyond our expectations. This year, we attribute the better-than-expected results largely to the effectiveness of the tide gates. A slight change in the course of the river at the head of the Flats also helped, resulting in a decrease of sheet flow from that direction into Area C during normally flooding tides. Blasting a sump allowed the lowering of the water level in Pond 146, thus exposing more of the highly contaminated sediments in the vicinity of Canoe Point and the bird tower. The additional blasting done this fall to deepen the sump should allow for even more remediation, and decrease the cycling of systems in Ponds 146 and 730 as well (Fig. III-1-5).

Pond 730 remains problematic. Although some drying occurred in this area, frequent wetting via influx from Bread Truck Pond resulted in a near steady stream of water infiltrating the area. The lowered threshold for flooding caused by the large drainage ditch blasted in 1996 needs to be addressed. Installing a large "tide gate" in the ditch has been discussed with both Bill Gossweiler and Weldin. Further investigations are necessary. Meanwhile, the deepening of the sump at Pond 730 should reduce the cycling of the system and the consumption of fuel.

All areas experienced some drying. Area A dried more completely than in 1998, with some cracks measuring 10 cm wide by 35 cm deep. As mentioned, Pond 146, including Clunie Inlet, dried to a much larger extent than in 1998. Pond 183 was so dry during the first part of July that the sensors topped out, the first time that has happened. Pond 155 dried somewhat, and Pond 730, a new pond this year, saw a lot of sediment consolidation

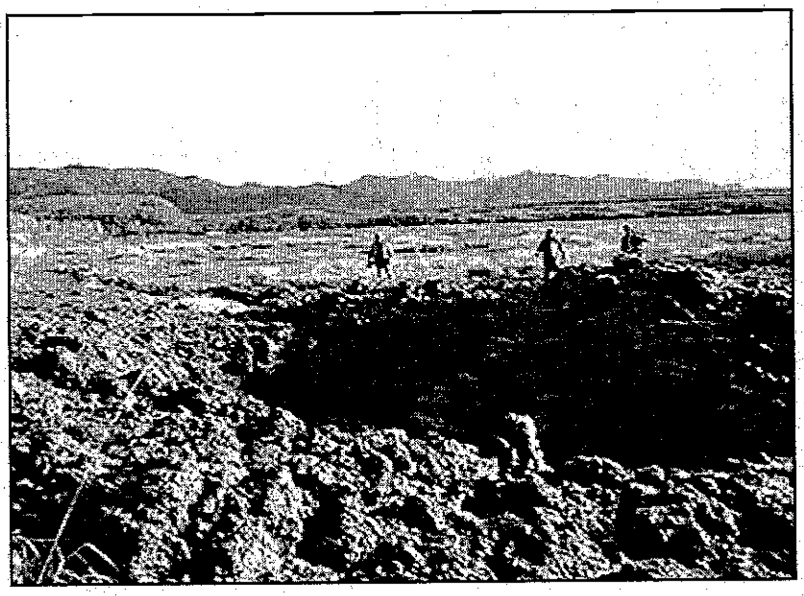

Figure III-1-5. Deepened sump in Pond 146, September 1999.

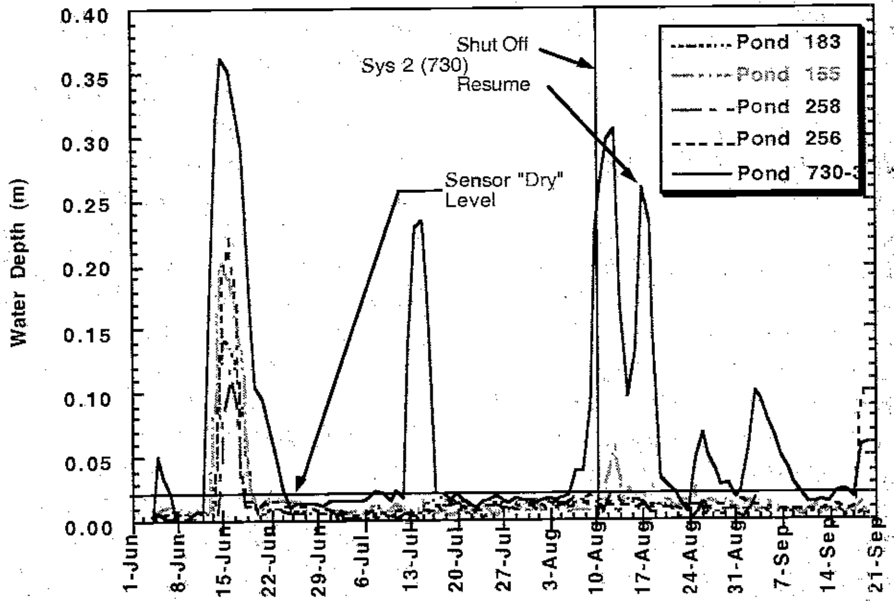

Figure III-1-6. Water level in the five off-shore ponds (1999).

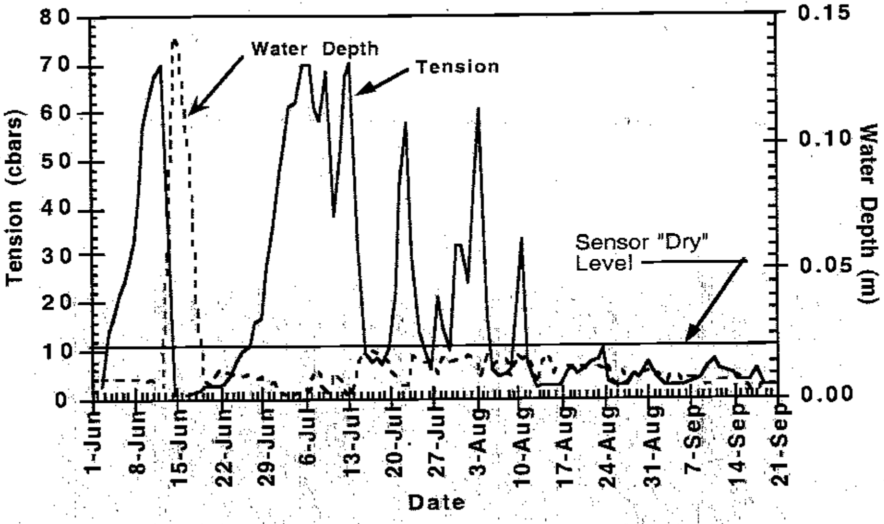

Figure III-1-7. Relationship between pond water levels and soil tension (1999).

but only marginal drying. This is typical of a new pond. Again, we should emphasize that although a maximum dry period of only 28 days was predicted owing to flooding tides, we were able to achieve more than 100 contiguous days without widespread flooding (Fig. III-1-6). Rains starting in mid-July greatly reduced the effectiveness of the remediation method for the remainder of the season, but it was a very successful season all the same (Fig. III-1-7).

EQUIPMENT IMPROVEMENTS

This is the fourth year of operation of the pump systems and the third year of actual deployment. The systems have evolved significantly since the first unit arrived in 1995 for limited testing and developmental work. Table III-1-4 lists some of the equipment modifications that were implemented in 1999. These changes have greatly increased the systems' reliability as well as decreased fuel consumption. But, as with any complex system, there is always room for improvement.

The control logic was modified so that if the low water switch becomes lodged in the down position or the high water switch becomes lodged in the up position, the controls default to a standby status, thereby preventing the generator from starting or the pump from continuing to run in a dry sump. New stand-offs were manufactured for the shore-based high water and flood switches that prevent the connectors from submerging and the switches from loosening and falling out of position.

Three 1100-L double-walled auxiliary fuel tanks were added this season to complement the two 1900-L units deployed last year, thus reducing the frequency of and the time required for refueling (Fig. III-1-8). The portable 12-VDC fuel pump mentioned above enables us to transfer fuel back to the auxiliary tanks prior to retrograde. Four tide gates were installed in Area A and the existing tide gates in Area C were expanded to reduce tidal influence on remediation. An additional check valve for the 30-cm line on system 3 was manufactured and tested late in the season. Additional hose for system 3 was also made up, which will add flexibility to the configuration of the discharge line for that system, as well as reduce the work required in the deployment and retrograde of the line between the EOD Pad and the Eagle River near the entrance to the Pad.

Development work continues on the equipment. Additional tide gates of a modi-

Table III-1-4. Equipment and system modifications for 1999.

System	*Modification*	*Date*	*Purpose*	*Result*
1	Extended tide gate.	May	Prevent flooding from tide >9.5m.	Successful up to 9.75 m.
	Rewired control.	July	Prevent fault due to stuck low water switch.	Tested successful. Further work necessary.
2	Replaced strobes.		Better visibility.	Successful.
	Rewired control.	July/ Sept.	Prevent fault due to stuck low water or high water switch.	Tested successful.
3	Rewired control.	July/ Sept.	Prevent fault due to stuck low water or high water switch.	Tested successful. Tested successful.
	Added check valve.	Sept	To relieve pressure on pump check valves due to head.	Tested successful; needs further work.
	New switch standoffs.	July	Better control of switch locations. Less stress on control cables.	Successful.
	Added hose to discharge line.	July	More flexible configuration. Lower stress on line at pump end.	Successful.
4	Rewired control.	July/ Sept.	Prevent fault due to stuck low water or high water switch.	Tested successful.
	Added 4 tide gates.	May	Prevent flooding from tide >9.5 m.	Successful up to 9.8 m.
5	Rewired control.	July/ Sept.	Prevent fault due to stuck low water or high water switch.	Tested successful.
6	Rewired control.	July/ Sept.	Prevent fault due to stuck low water or high water switch.	Tested successful.
Generic	Added three 1100-L field fuel tanks.	May	Reduce the number of required Blackhawk refueling runs.	Successful.
	New field fuel transfer pump.	Sept.	Allow transfer of fuel out of genset tanks to field tanks at retrograde.	Successful.
	Use of lift schedule during movements.	May/ Sept.	Increase efficiency during expensive airlift operations.	Successful.
	Purchase of three more 1100-L tanks.	Sept.	To allow refueling to occur with the contract helicopter (A-Star).	Not yet implemented.
	Video monitoring system in Area C.	June	Visually monitor conditions at the Flats through a web-based system.	Unreliable. System modifications in development.

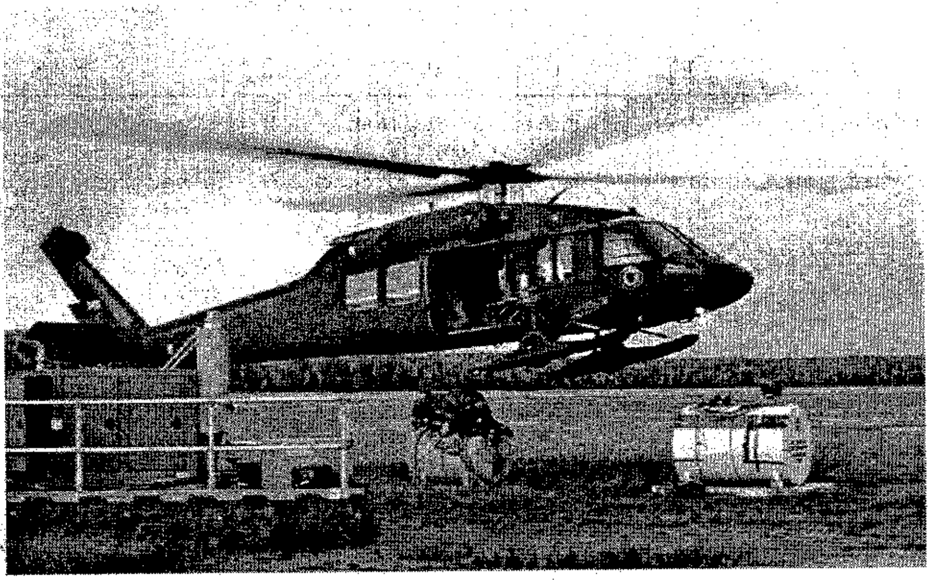

Figure III-1-8. Airlifting new 1100-L fuel tank. A 1900-L tank is to right.

fied design are being built at this time for deployment in other areas of the Flats and to replace some of the older gates. The check valve seals are being replaced with a more robust sealing arrangement to improve their performance. Three additional 1100-L auxiliary tanks are ordered and will be modified to enable refueling of field tanks with the commercial helicopters, thus reducing the logistical nightmare of lining up four different entities for a simple refueling operation. Sling-loading pipe during aerial transport, as opposed to loading it on board the helicopter, is also being discussed as an option to speed that segment of the project.

Finally, the Eagle River Flats web page is up and running. It is accessible through the CRREL public web site at www.crrel.usace.army.mil/erf. From this site, access to the bibliography and met data is currently available, as well as several other features such as Points of Contact. In the future, we hope to link to the output of the web cameras. Daily and seasonal met data should be available next year for the Flats as well. This will be integrated into the CRREL met database, so site maintenance should be much better this year.

THE 2000 SEASON AND BEYOND

The 2000 season is predicted to be a poor one for remediation at the Flats. There are spring lunar flooding tidal cycles in excess of 9.75 m occurring once a month in both May and June, and two overlapping flooding cycles exceeding 9.75 m in July, August, and September (Table III-1-5). It was debated as to whether deployment in 2000 makes sense from a remediation standpoint, but the decision at this time is to go forward. The primary reason is that, without pumping next year, the pond bottom sediments will deconsolidate and the sumps will slump, making future remediation efforts more difficult. In addition, by deploying next year, the team will keep up to speed on the systems and procedures. As a compromise, the end of the season is projected to be 28 August, when the second flooding tidal cycle in August will begin.

Additional development work also needs to be done on the remote monitoring systems associated with the pumping project. The video system's problems need to be rectified, and the new met station communications procedure needs to be tested. We

Table III-1-5. Predicted flooding tides for 2000 season.

Day	*Time*	*Height (m)*	*Time*	*Height (m)*
May				
4	0135	**9.63**		
5	0216	**9.82**		
6	0257	**9.82**		
7	0339	**9.66**		
June				
2	0107	9.63		
3	0155	9.82		
4	0242	9.85		
5	0329	9.66		
July				
1	0044	**9.54**		
2	0139	**9.69**		
3	0230	**9.72**		
4	0319	**9.63**		
5	0407			
30	0030	9.51		
31	0128	9.78		
August				
1	0219	9.94		
2	0306	9.91	2111	9.51
3	0352	9.66	2153	9.51
28	0024	9.51		
29	0118	**9.82**	1930	**9.51**
30	0206	**9.97**	2006	**9.63**
31	0250	**9.97**	2042	**10.00**
September				
1	0856	**9.75**	2119	**9.63**
27	0016		1830	**9.60**
28	0106	**9.69**	1906	**9.69**
29	0151	**9.85**	1939	**9.75**
30	0232	**9.82**	2011	**9.78**
29	0311	**9.63**	2043	**9.63**

Notes: Pre-season Anchorage tidal predictions. Add 1/2 hour for ERF tides. ERF tidal classifications: 9.48- to 9.54-m tides, minor/preventable; 9.55- to 9.72-m tides, substantial/may be preventable; >9.72-m tides, major/unpreventable.

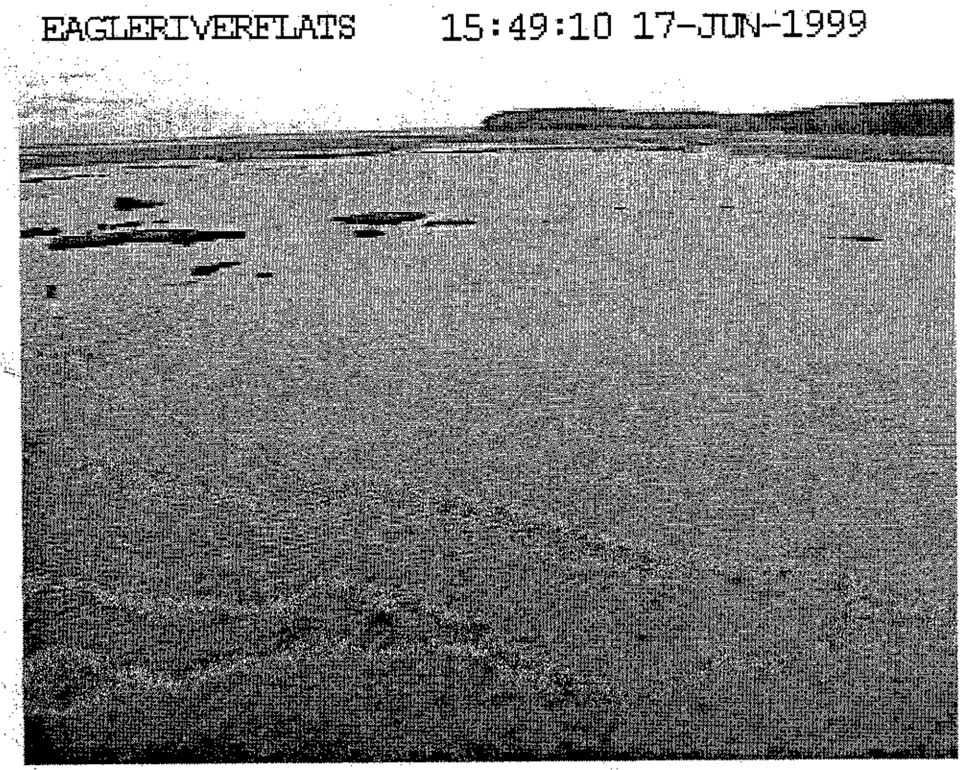

Figure III-1-9. Image from web camera of flooded Flats taken off internet.

Table III-1-6. Possible effect of tide gates on 1998-2003 seasons.*

	Duration between flooding tides (days)				*Overall extension of season† (days)*		
Year	*< 9.48 m***	*≤ 9.57 m*	*≤ 9.66 m*	*≤ 9.72 m*	*9.57 m*	*9.66 m*	*9.72 m*
1998	45	100	102	102	55	57	57
1999	27	28	52	102	1	25	75
2000	25	27	27	27	2	2	2
2001	67	70	70	104	3	3	37
2002	74	75	102	115	1	28	41
2003	74	91	91	118	17	17	44

*1998 and 1999 data included for reference. 9.48-m tide is the normal threshold flooding tide elevation for Area C. Area A floods about 0.15 m above area C.

†Gain in contiguous days over core season (15 May to 15 September).

**Tide heights.

are especially interested in the web camera, as this is a great method for remotely monitoring the conditions at the Flats (Fig. III-1-9).

The years 2001–3 are predicted to be much better, especially if the tide gates continue to work as well as they did this year (Table III-1-6). In each of those years, there will be a minimum of 67 contiguous core days without flooding, primarily during the earliest part of the season when conditions tend to be more favorable for remediation. If the gates work well with tides between the 9.57 and 9.72 m during those seasons, the contiguous period without flooding will be much longer. The 2004 season is much like the 1999 season, and if the tide gates work well, it could turn into a good season. The out years, 2005–7, are almost ideal, with no flooding tides in June and few in July. If the project is extended for any reason, the outlook is excellent in these years for further remediation.

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III-2. TREATMENT VERIFICATION: MONITORING THE REMEDIATION OF WHITE PHOSPHORUS CONTAMINATED SEDIMENTS OF DRAINED PONDS

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INTRODUCTION

The white phosphorus-contaminated sediments at Eagle River Flats are remediated by pumping selected ponds and allowing the sediments to dry. The 1999 season is the first year of treatment under the *Record of Decision* signed in September 1998, although Area C was pumped in 1997 and 1998 during development of the pumping procedure. Coinciding with the development of the treatment methodologies, we developed a variety of methods to monitor the success of the remediation. Sublimation–oxidation conditions are monitored using sensors linked to a datalogger, discrete or composite surface sediment samples, or both, are collected from known areas of contamination to see if the concentrations have declined with time, and residual white phosphorus from planted particles is measured to see if loss occurred. Also, this year we collected several subsurface samples within Area C to see if decontamination is occurring at depth.

METHODS

Composite sampling

Pond 183 (Area C) and Pond 109 (BT Pond)

In 1997, we established 200-m long west-to-east transects in Area C and the Bread Truck (BT) Pond (Fig. III-2-1) to monitor sublimation–oxidation conditions and for

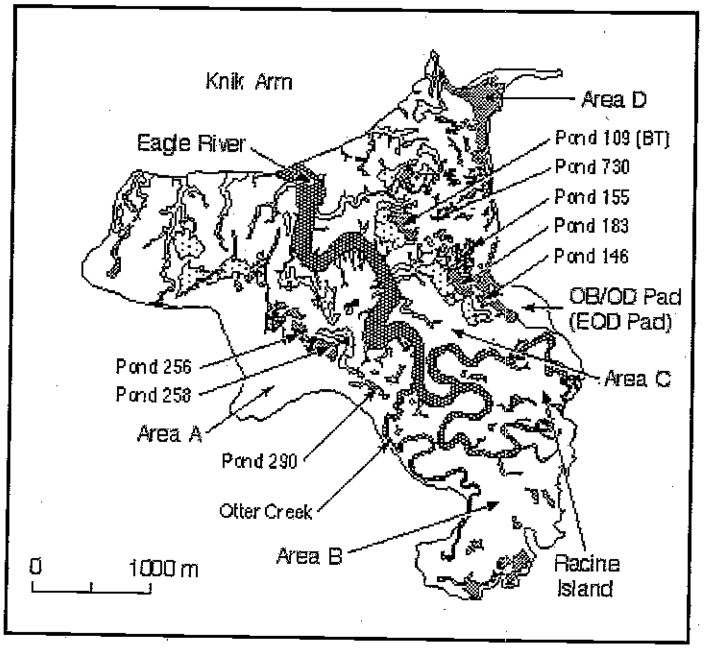


Figure III-2-1. Map of Eagle River Flats showing areas and pond identification numbers.

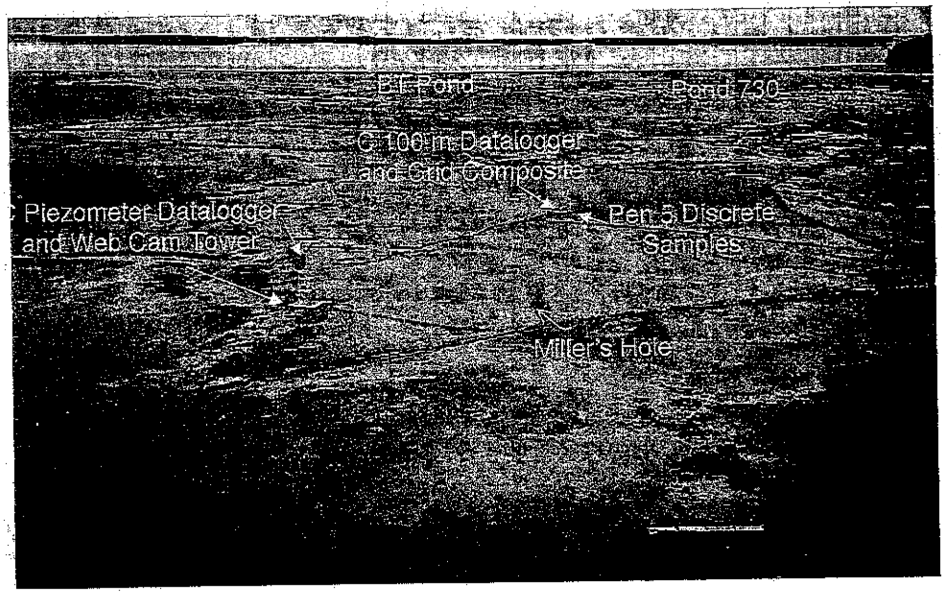


Figure III-2-2. View looking north of Pond 183 in June 1999 showing sample locations.

baseline and verification sediment sampling (M.E. Walsh et al. 1998). Three transects were established, one in Area C (Ponds 164 and 183) and two in the Bread Truck Pond (Ponds 99 and 109). Along each west–east transect at 0, 50, 100, 150, and 200 m, composite samples were collected to determine if hot spots (localized areas containing white phosphorus particles) were present. Each composite sample was made up of 92 sediment cores obtained at the nodes of a 1.82-m square grid covering a 5.46-m-wide area extending 20 m north and south of the west–east transect. For each of the three transects, the highest white phosphorus concentrations were found in the middle of the ponds (samples taken at the grid 100 m along the transect). In 1999, we again resampled these grids (Fig. III-2-1, III-2-2, and III-2-3), and collected duplicate composite samples from each grid at C 100 m, BT South 100 m, and BT North 100 m.

In Area C, 50-mL samples were obtained using a plastic syringe corer (2.65-cm i.d., 9-

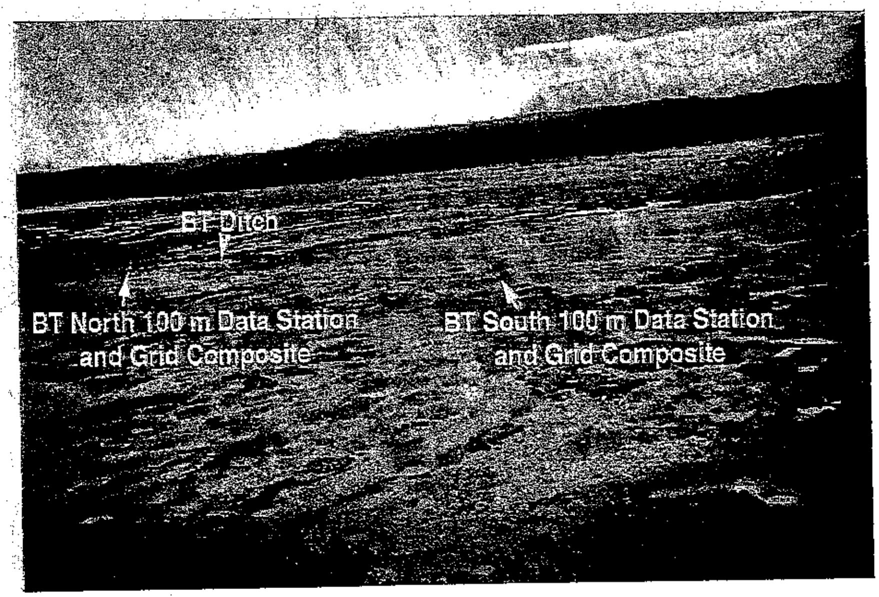


Figure III-2-3. View from helicopter of former Bread Truck Pond showing locations of data stations, grid composite samples, and Bread Truck Ditch.

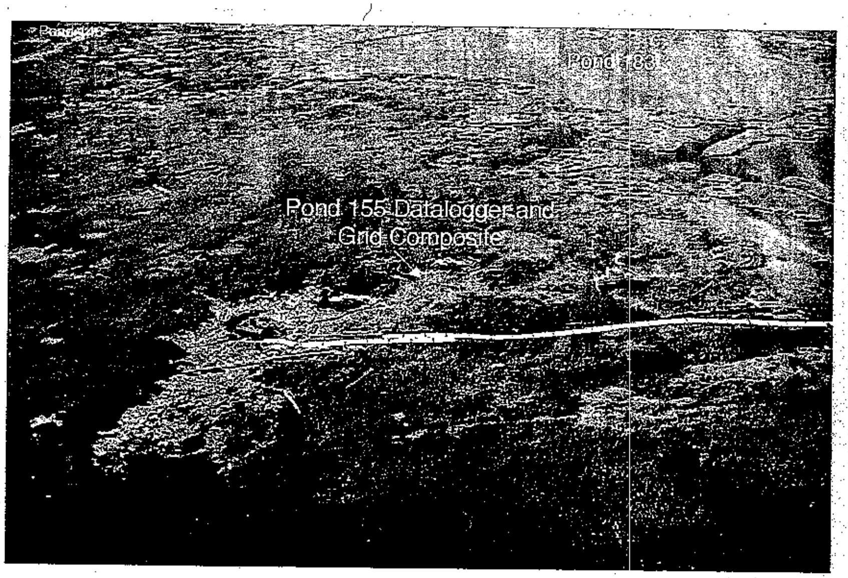


Figure III-2-4. Pond 155 showing locations of datalogger and grid composite sample.

cm length) as was done in previous years (M.E. Walsh et al. 1997, 1998). Because of sediment consolidation attributable to draining, insertion of the plastic corer into the sediment was very difficult. In the Bread Truck area and other areas, we substituted an Oakfield corer, which has a handle and tapered tip that greatly facilitated insertion of the corer into the consolidated sediment. The corer's internal diameter was 2 cm, and when a 10-cm length core was taken, it resulted in a 31-mL sediment sample.

Pond 155 (Northern C)

Pond 155 is a small 0.35-ha (0.70-acre) permanent pond (Fig. III-2-1 and III-2-4) located north of the main pond in Area C (Pond 183). This pond was first sampled in 1992 after Dan Lawson found over 30 waterfowl carcasses in the pond and in the surrounding bulrush. Of the eight sediment samples collected by Charles Racine in August 1992 from the pond, seven had detectable concentrations of white phosphorus (Racine et al. 1993). In September 1997, a sump was explosively excavated in the middle of this pond, and in June 1998 the pond was pumped. Because this pond was relatively small, the sump hole covered a significant portion of what was open water habitat. In August 1998 we collected composite samples made up of 48 subsamples from two grids covering the remainder of what will be open water habitat when the pond is not pumped (Fig. III-2-4). Only one of the composite samples was positive. In 1999 we resampled the positive grid in June and September.

Pond 146

Pond 146 is a permanent pond (Fig. III-2-1 and III-2-5) located adjacent to the EOD pad, Canoe Point, and Clunie Inlet on the east side of ERF. The pond is 5.5 ha, of which 0.45 ha was dredged in 1996–1997. Post-dredging sampling located a small area of contamination remaining, but at the time, the water depth was sufficient to prevent dabbling ducks from feeding. With the lowering of water depth by pond pumping and the slumping of sediments into the dredged area, contaminated sediments may once again be available to waterfowl periodically throughout the summer.

In 1999 we established two grids extending through and beyond the dredged area where the post-dredging sampling showed contamination remaining (Fig. III-2-5). Each composite sample was made up of 48 subsamples.

Pond 258 and 256 (pumped ponds in Northern A)

Ponds 258 and 256 are located on the west side of ERF in Area A (Fig. III-2-1). Pond 258 is a large pond of 1.72 ha (3.44 acres) (Fig. III-

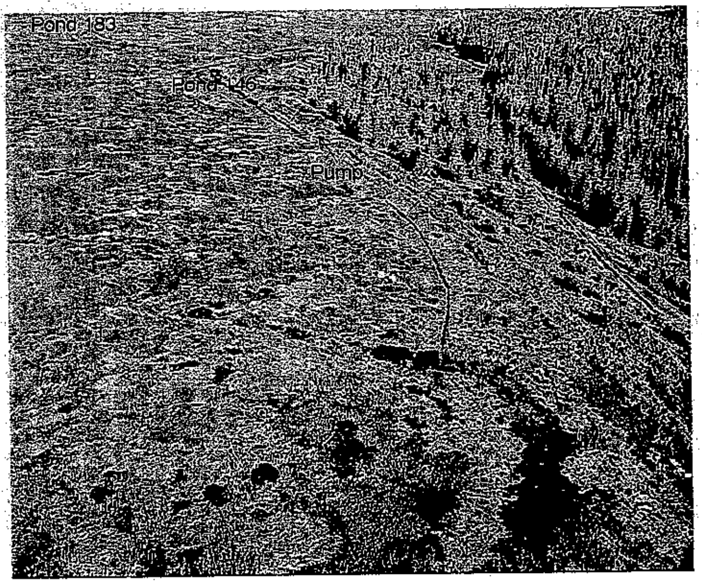


Figure III-2-5. View of Pond 146. a. Looking north toward Clunie Point.

2-6), where over 50 discrete samples were collected between 1991 and 1994. Sampling was prompted by the large number of waterfowl carcasses that have been found in this pond (70 carcasses in August 1992). Only four sediment samples were positive; the highest concentration found was 0.04 µg/g. Several positive samples were collected just north of Pond 258, but again concentrations and frequency of detection were much lower than in Area C, the BT Pond, and Racine Island. In August 1998, we established three west-to-east transects labeled 258 south, 258 middle, and 258 north (Fig. III-2-7). Composite samples were collected from the nodes of grids extending south and north of the west-to-east transects. Samples taken on grids north and south of the transects were designated "plus" and "minus," respectively. Of these 29 composite samples, only one was positive. An additional 14 samples were taken along lines, with a subsample collected every 2 m. Two of these samples were positive.

In June 1999, we established two more west-to-east transects, labeled north central

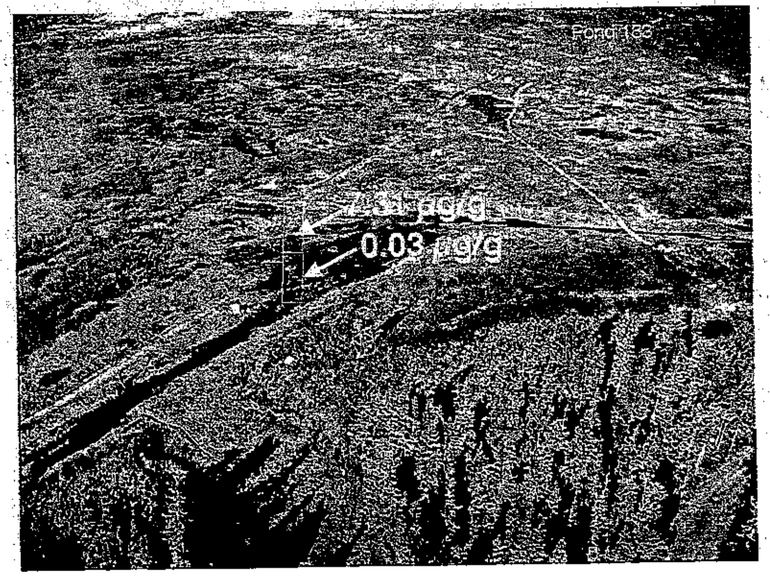


Figure III-2-5 (cont'd). b. Close-up of locations of grid composites.

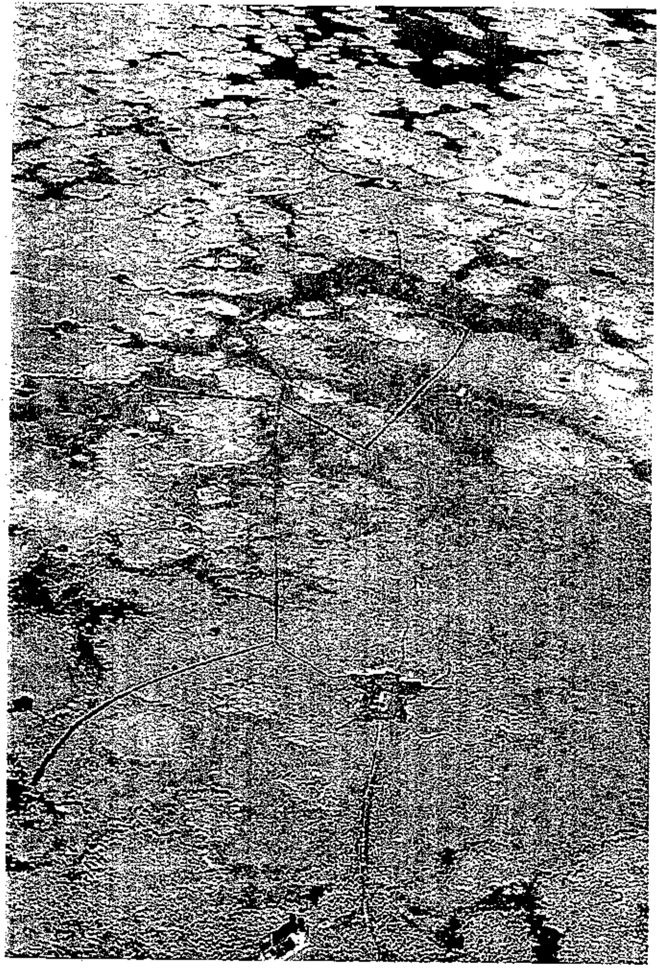


Figure III-2-6. Aerial view looking down on of Ponds 258 and 256 (18 August 1999).

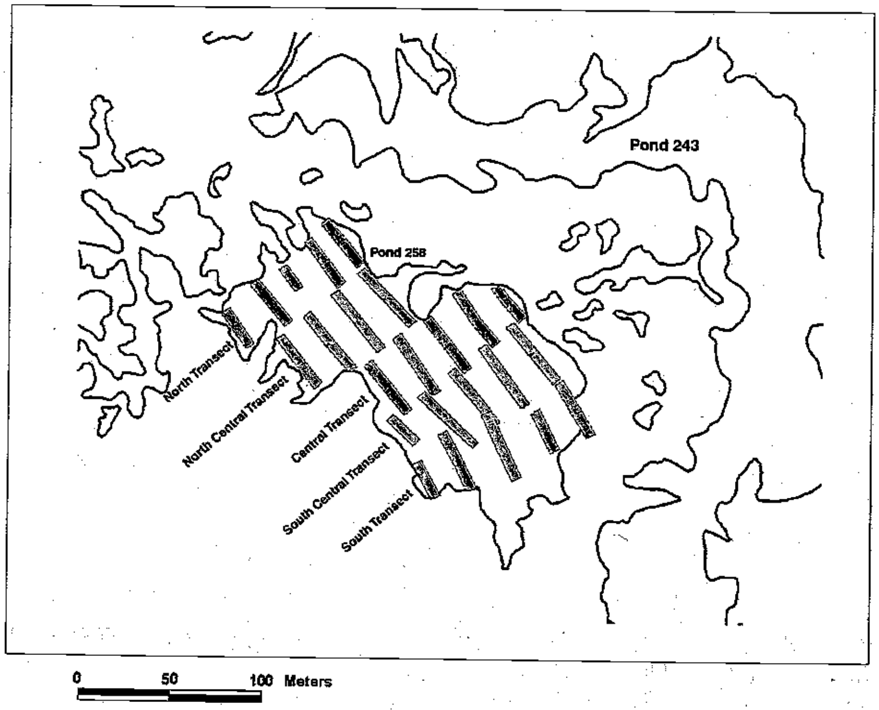


Figure III-2-7. Map of Pond 258 showing location of grid composite samples collected in 1998 (light color) and 1999 (dark color).

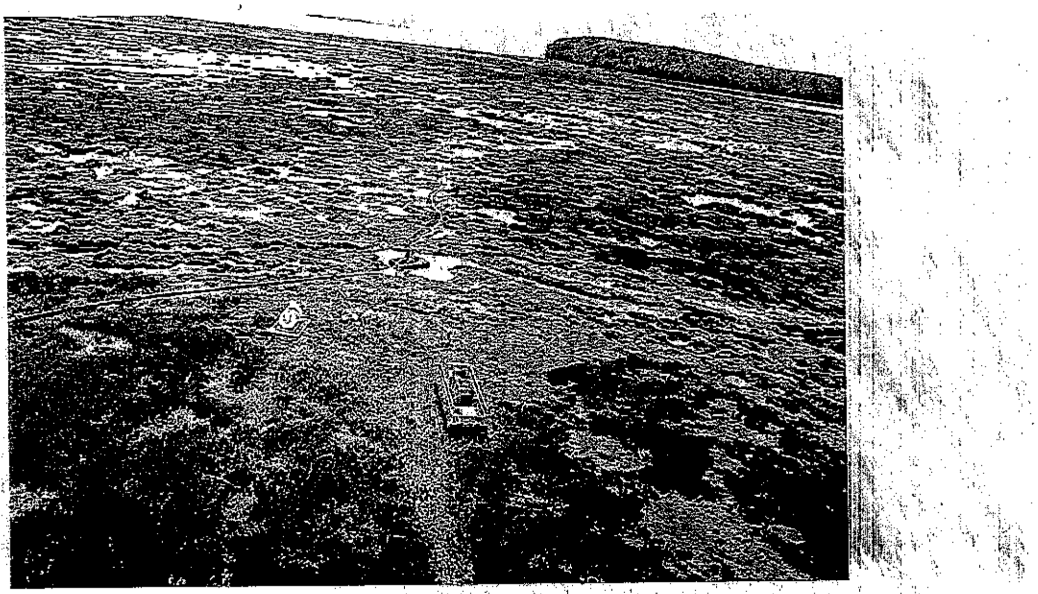


Figure III-2-8. Pond 730 (looking north) after draining.

and south central and collected 17 more grid composite samples (Fig. III-2-7).

Pond 730

Pond 730 in Area C/D (Fig. III-2-1 and III-2-8) was treated by pumping this year because of the mortality of radio-collared ducks in this region. Drainage of this pond greatly facilitated our ability to sample within Pond 730 and locations to the north. We collected 10 grid composite samples within the pond and one line composite along a channel in the southwest part of the pond.

Discrete surface and subsurface sampling

Area C

We collected discrete surface and subsurface samples from sites that had high concentrations of white phosphorus prior to drainage of the ponds. We again intensively sampled the location of the DWRC Pen 5 in Area C (Fig. III-2-2), used 1992 to 1993 for the evaluation of methyl anthranilate. In 1996 and 1998, we sampled a 5.46- by 20-m area surrounding this pen, taking discrete samples at the nodes of a 1.82-m-square grid (M.E. Walsh et al. 1997). The 1998 sampling revealed a dramatic reduction in white phosphorus concentrations (Fig. III-2-9). We resampled this grid in September 1999.

We collected eight sets of subsurface samples in Area C (seven from Pond 183 and one from Pond 146). The locations were chosen on the basis of results of extensive core sampling in 1992 (Fig. III-2-10) (Racine et al. 1993). Locations were chosen where white phosphorus was detectable over most of the core length (Fig. III-2-10). Previous cores were obtained from pond bottoms using a sludge sampler. This method was necessary owing the standing water present in each pond, but it made depth estimates inaccurate because of core compression. In 1999, we obtained subsurface samples while the ponds were pumped dry by digging holes 30 cm deep, and using a corer to take sediment samples from the wall of each hole at 0-, 5-, 10-, 15-, 20-, 25-, and 30-cm depth. This method allowed accurate depth measurements.

Two cores were taken from Miller's Hole (Fig. III-2-2), the crater produced when a white phosphorus mortar round was detonated in May 1992. At this site, we used an Oakfield corer pushed to a depth of 20 cm.

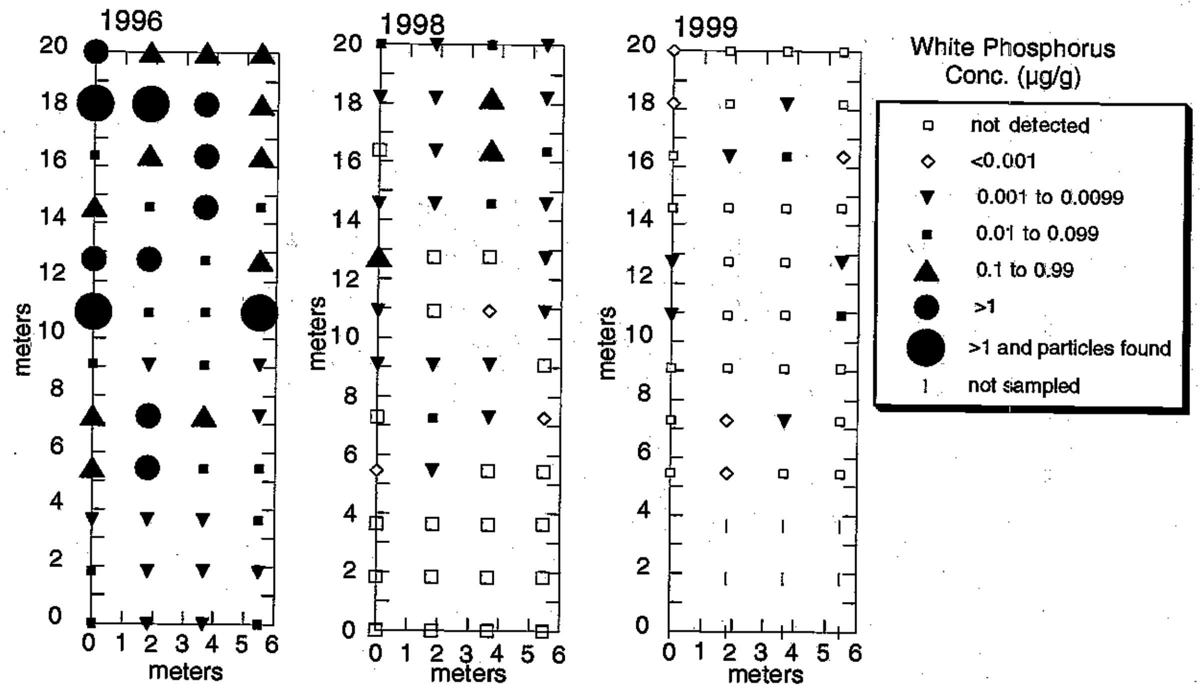


Figure III-2-9. Plot of white phosphorus concentrations found on a 1.82-m square grid in 1996, 1998, and 1999 in DWRC Pen 5. Large black circles show locations of discrete samples that contained solid macroscopic pieces of white phosphorus.

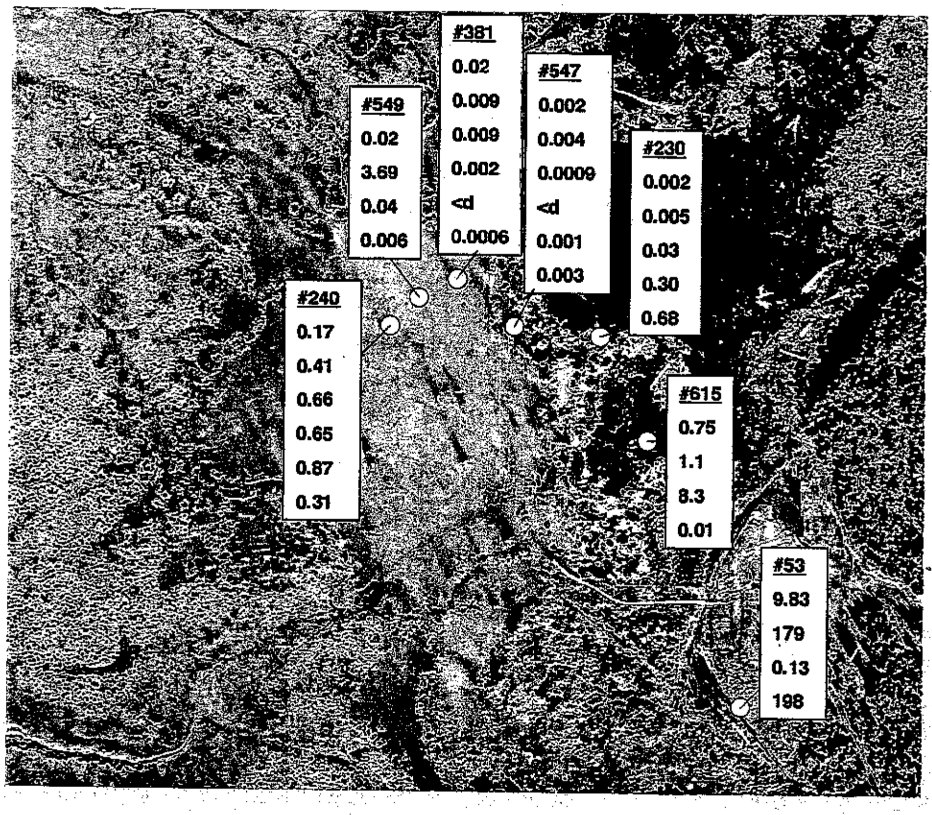


Figure III-2-10. Aerial color-infrared photograph of Area C showing locations (circles), site identification numbers, and white phosphorus concentrations (µg/g) found along length of cores collected in 1992. In June 1999, white phosphorus was undetectable in samples taken 5-cm intervals down to 30 cm at locations 240, 549, 381, 547, and 230.

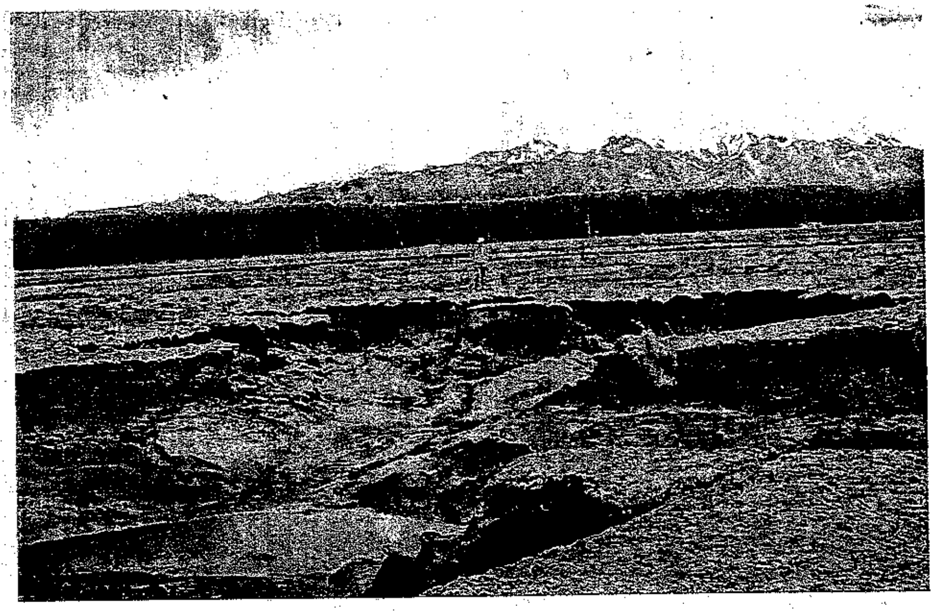


Figure III-2-11. View of eroding Bread Truck Gully. Ronald Bailey is looking down on an exposed white phosphorus mortar round.

We divided each core in half, the top being surface sediment and the bottom subsurface sediment.

BT Gully

The surface sediment surrounding the Bread Truck Ditch is eroding into the ditch with each ebb tide (Fig. III-2-11). We sampled some of this eroded sediment that was deposited in the newly eroded lobes of the Bread Truck ditch. At the time we sampled, water covered the bottom of the lobes, and we collected three samples just above the water line. When we returned to survey our sample points, we observed a white cloud within one of the lobes. On closer inspection, we saw a slow burning tail end of a white phosphorus 60-mm mortar, which was leaving the bright orange residue characteristic of suboxides of phosphorus. The round appeared to have been exposed by the erosion of the advancing gully. After the round stopped burning, Sherri Butters collected sediment surrounding the round, then we collected an additional four samples at evenly spaced intervals down the gully lobe, towards the main ditch.

Laboratory analysis of sediments for white phosphorus residues

In the laboratory, each composite sample was thoroughly mixed by stirring and kneading. To obtain an estimate of average white phosphorus concentration, a 200-g subsample was taken from each composite and analyzed using solvent extraction (100 mL isooctane) and gas chromatography (EPA SW-846 Method 7580). If concentrations were high, the remainder of each composite was rinsed through a 30-mesh sieve (0.59-mm sieve opening) to remove the fine-grained sediment. Material remaining on the sieve was placed in a septa-jar and equilibrated at room temperature. To determine if white phosphorus particles had been retained on the sieve, we performed headspace solid-phase microextraction (SPME) followed by gas chromatography (M.E. Walsh et al. 1995a). When the SPME method indicated that white phosphorus was present, the sample was spread in a thin layer on an aluminum pan and heated until all water evaporated. If white phosphorus particles were present, they are detected by the observation of a localized area of intense smoke and flame, and the formation of a bright orange residue.

Discrete samples were subsampled by taking a 40-g portion of each soil and extracting the white phosphorus with 20 mL of isooctane. Subsurface samples, which were obtained in the field with corers, were placed directly in isooctane. After shaking overnight, the extracts were analyzed by gas chromatography (EPA SW-846 Method 7580).

Sublimation–oxidation conditions

We installed sensors and dataloggers to monitor sediment temperature and moisture conditions using the same configuration of sensors as in 1997 for most of the stations. At each station (Table III-2-1, Fig. III-2-12, III-2-13), sediment temperatures were monitored at 5- and 10-cm depths using Campbell Scientific (Logan, Utah) Model 107B soil/water thermistor probes. Sediment moisture conditions were monitored at 5- and 10-cm depths using Campbell Scientific Model 257 (Watermark 200) soil moisture sensors. Output from both sets of sensors was taken every 10 minutes, and the hourly and 24-hour averages were recorded by a Campbell CR10 Measurement and Control Module and an SM716 Storage Module.

Tensiometers provided another measure of surface sediment moisture conditions. SoilMoisture® (SoilMoisture Equipment Corp., Santa Barbara, California) Series 2725 tensiometers equipped with dial gauges were installed, one at a 10-cm depth and another a 20-cm depth at most sites, and were read periodically by Sherri Butters and Terry Edwards (Weldin Construction). A third tensiometer was equipped with a pressure transducer and wired to the datalogger, where 1-hour and 24-hour averages were computed and recorded on a storage module.

To monitor subsurface water level in Area C, we relocated a shallow piezometer well used in 1994 and 1998 (Site 3 in M.E. Walsh et al. 1995b), and placed the Druck pressure transducer 1.04 m below the sediment surface. We also installed Drucks to monitor depth of any standing water in the ponds. Last year, most of the Drucks gave erratic readings because they were exposed in the drained ponds. This year we placed the Drucks within piezometer tubes and fastened the tubes to the mast of the tripod so that the tip of the Druck was just above the sediment surface. With this method, eight out of ten sensors satisfactorily recorded the flood events in each of the drained ponds. The two Drucks that failed were in the Bread Truck Pond.

From 4–7 June 1999, at each datalogger station, we planted 10 white phosphorus particles (1.8 mm diameter, 5.6 mg) that were made in the laboratory (M.E. Walsh et al. 1995b). Each white phosphorus particle was

Table III-2-1. UTM coordinates and elevations of data loggers used to record sublimation/oxidation conditions 5 June to 21 September 1999.

Datalogger site	*E (m)*	*N (m)*	*Elevation (m)*
C 100m	355,024.49	6,801,302.48	4.68
BT N 100m	354,536.42	6,801,826.00	4.74
BT S 100m	354,521.08	6,801,724.34	4.76
Pond 155	355,112.37	6,801,536.84	4.58
Pond 730 – Station 1	354,844.15	6,801,828.52	4.48
Pond 730 –Station 2	354,890.25	6,801,841.72	4.46
Pond 730 –Station 3	354,880.02	6,801,880.65	4.42
A Ponds - 1 (Pond 258)	353,990.20	6,800,707.95	4.61
A Ponds - 2 (Pond 256)	353,823.82	6,800,780.01	4.51
C (piezo site from '94)	355,013.18	6,801,196.88	4.78

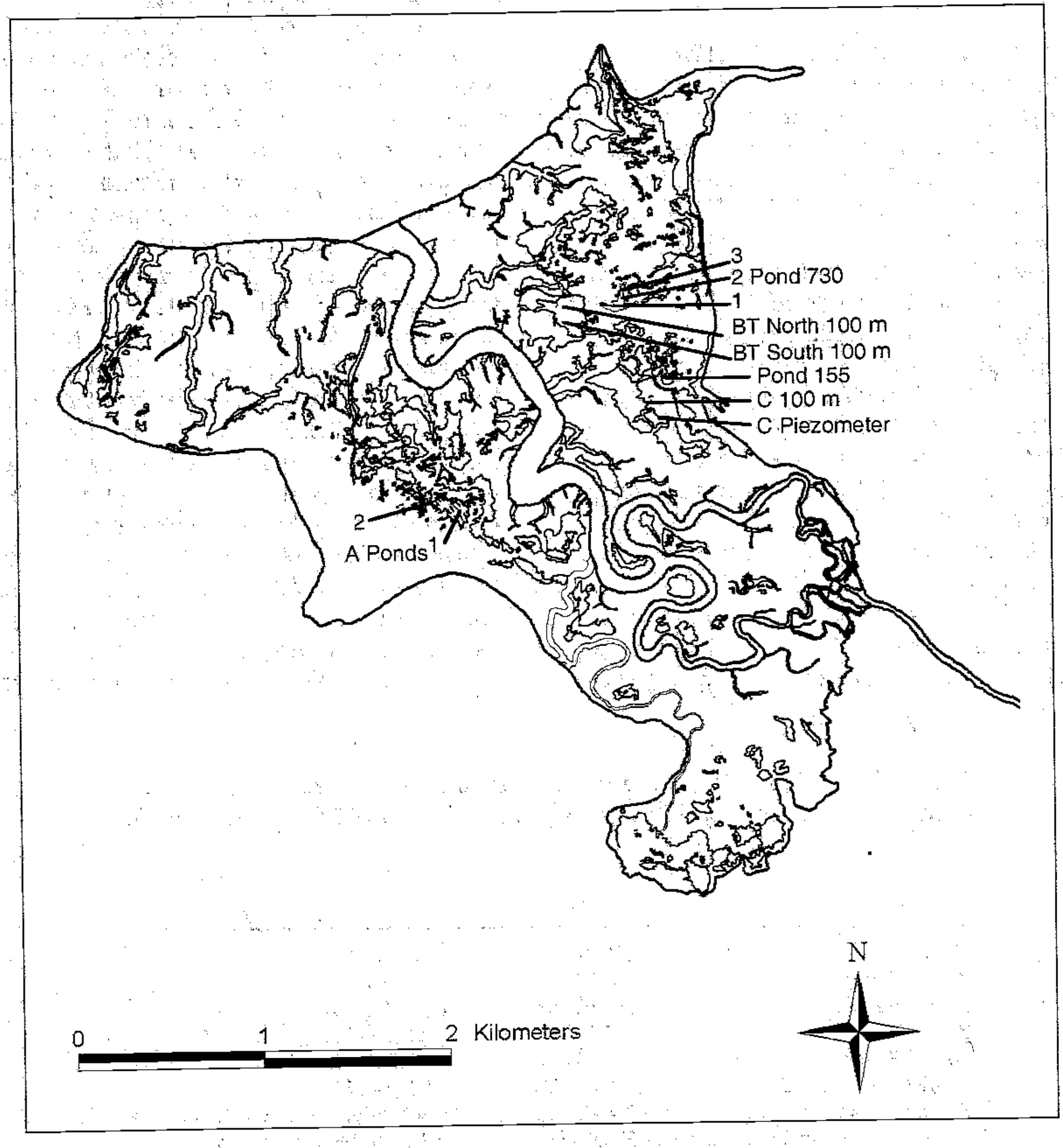


Figure III-2-12. Map of 1999 datalogger locations.

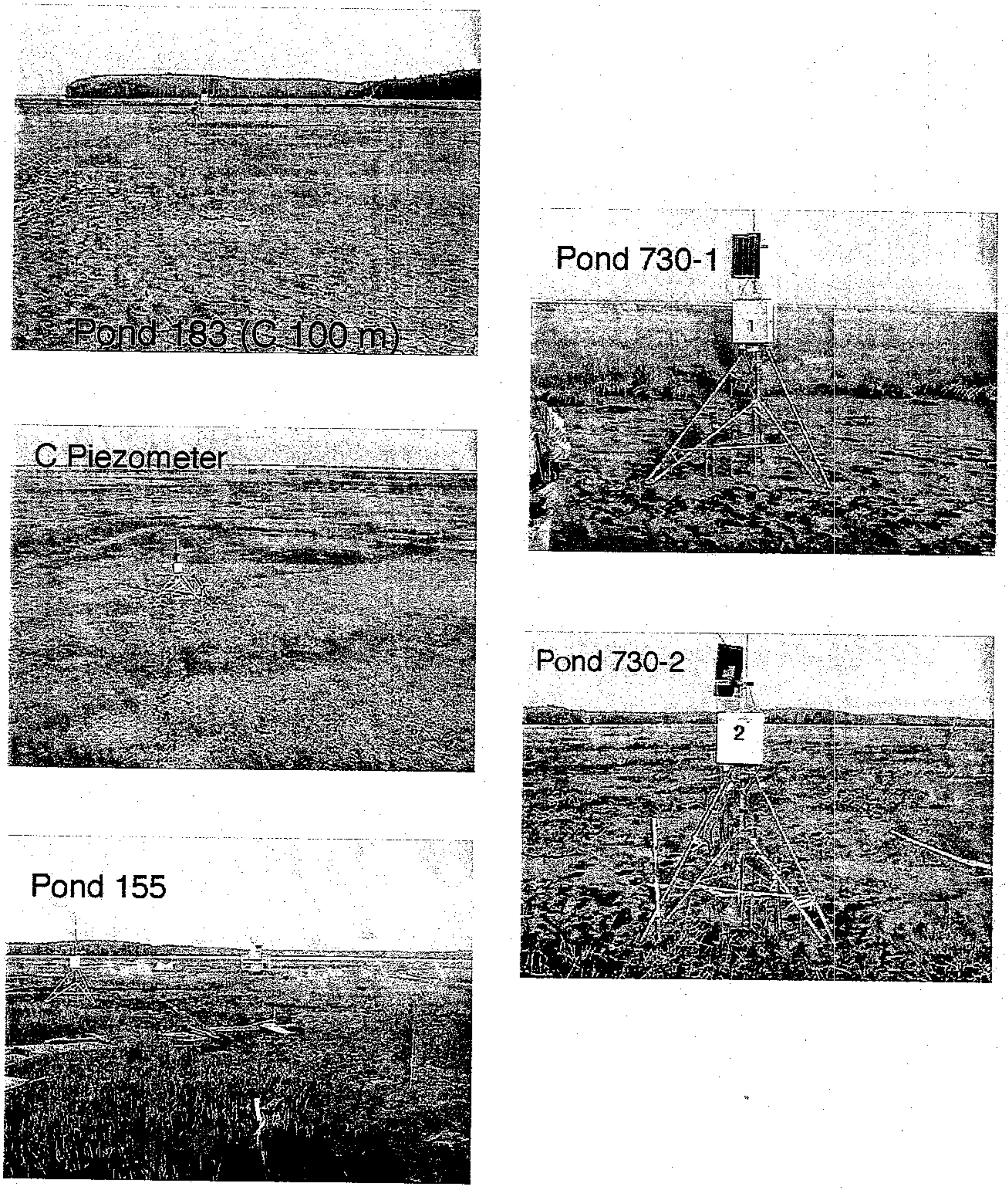


Figure III-2-13. Datalogger stations photographed on 7 July 1999 during a period of ideal drying conditions. (Photographs curtesy of Terry Edwards, Weldin Construction.)

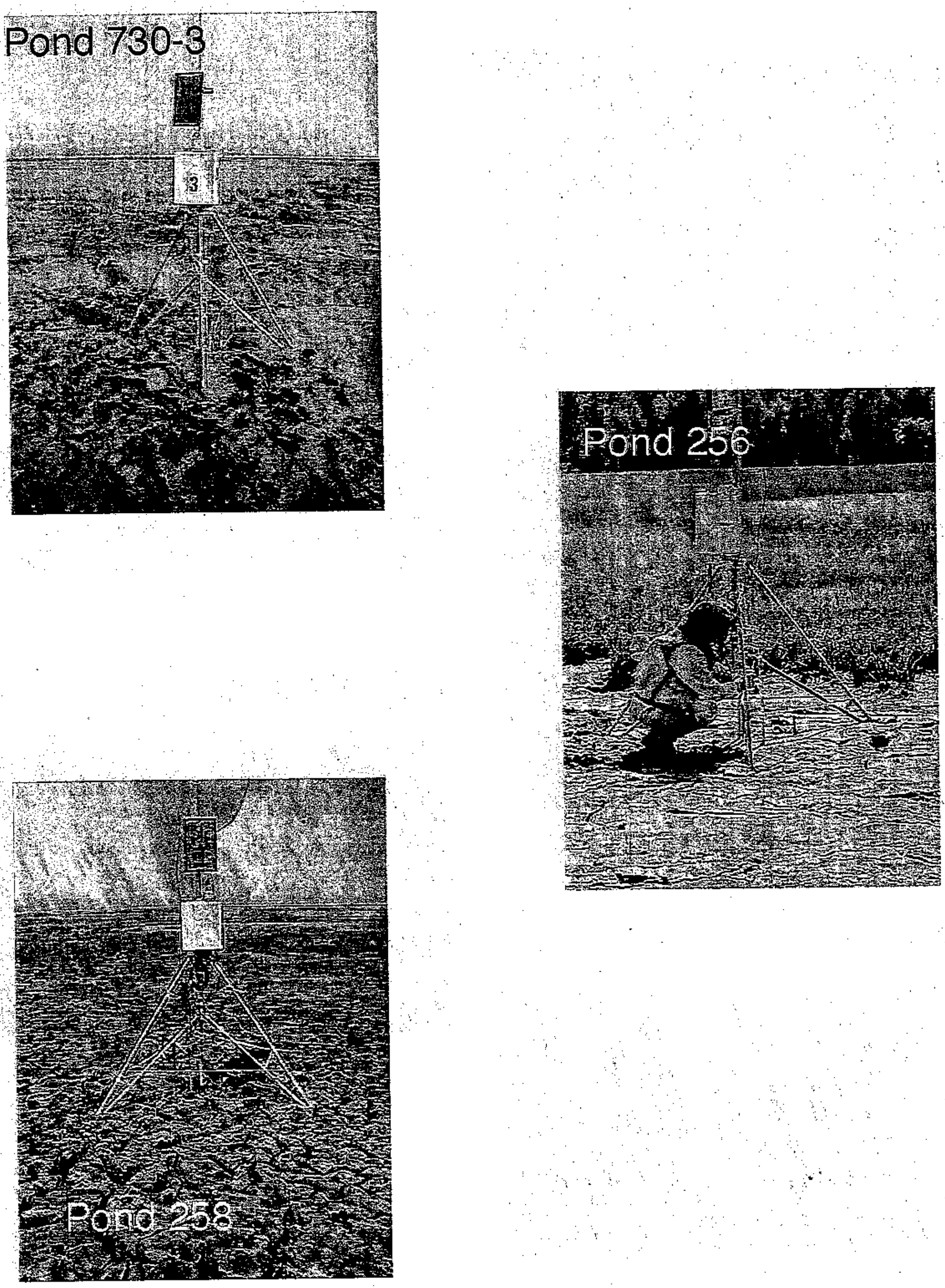


Figure III-2-13 (cont'd). Datalogger stations photographed on 7 July 1999 during a period of ideal drying conditions. (Photographs curtesy of Terry Edwards, Weldin Construction.)

first inserted into a plug of saturated sediment, then the plug of sediment was placed in a nylon stocking, which was then placed within the top 5 cm of saturated sediment at each monitoring station. We recovered five of the 1999 plugs from each station on 21 September 1999 to see if white phosphorus mass had decreased. To determine if the white phosphorus particles had changed, the sediment samples containing particles were placed into isooctane to extract white phosphorus residue prior to analysis by gas chromatography. The remaining five plugs were left for recovery at a later date.

Surveying

Universal Transverse Mercator (UTM) horizontal coordinates (North American Datum 27) and elevations were obtained using a Wild Total Station. Surveying methods were similar to those described in past years. For the pond 730 sample points and Bread Truck Gully samples, we used a benchmark set up in 1998 on the north side of the Bread Truck. For Area A, we used a benchmark established in 1998 near Pond 258. Area C locations were obtained from a benchmark on Clunie Pad.

RESULTS AND DISCUSSION

Results of monitoring are discussed by location within ERF. White phosphorus concentrations for all composite and discrete samples are listed in Appendix III-2-A.

Area C

Sediment temperature and moisture conditions were monitored at two sites within Area C (Fig. III-2-2). Previous work has shown that to promote sublimation–oxidation of white phosphorus particles, sediments must first be desaturated. Then sublimation–oxidation will take place, and the rate at which it occurs increases exponentially with increased temperature. Moisture sensors at the C 100 m and C piezometer sites (Fig. III-2-14) showed that the sediments desaturated (increase in resistance and tension above baseline) around 4 June and remained unsaturated until a flooding tide on 14 June. Sediments were again desaturated by 27 June and remained unsaturated until 15 July, when heavy rains soaked the sediments. The June flooding sequence was recorded on a web cam (Fig. III-2-15). For the rest of the summer, there were

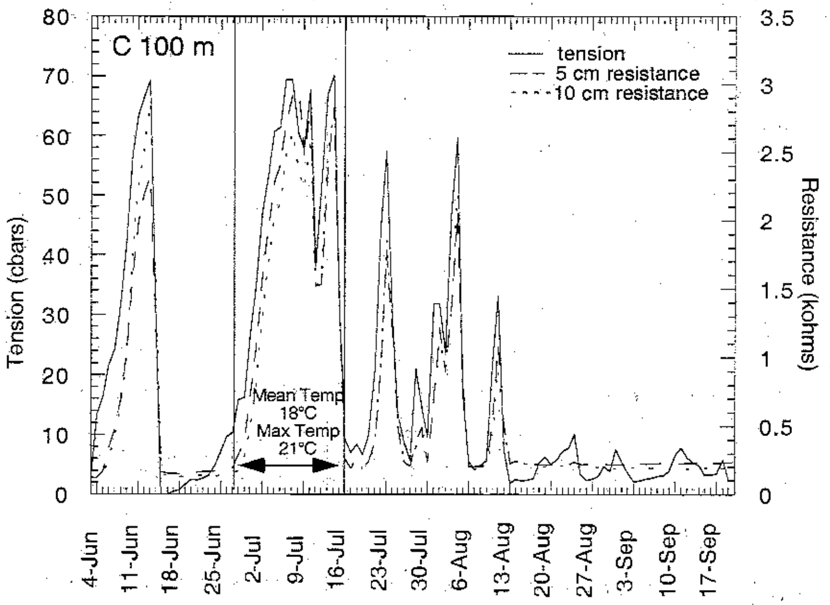


Figure III-2-14. Output from moisture sensors during the summer of 1999. Increases in resistance and tension indicate drying.

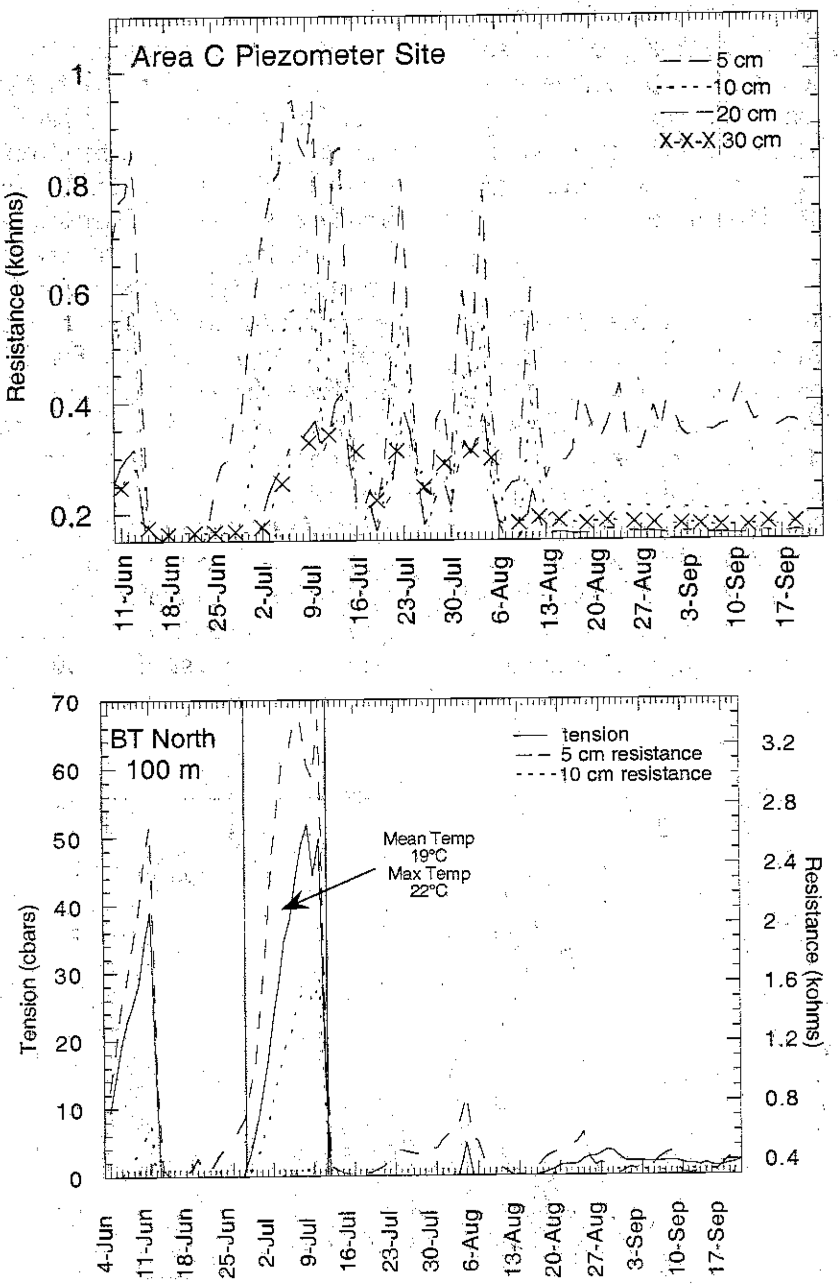


Figure III-2-14 (cont'd). Output from moisture sensors during the summer of 1999. Increases in resistance and tension indicate drying.

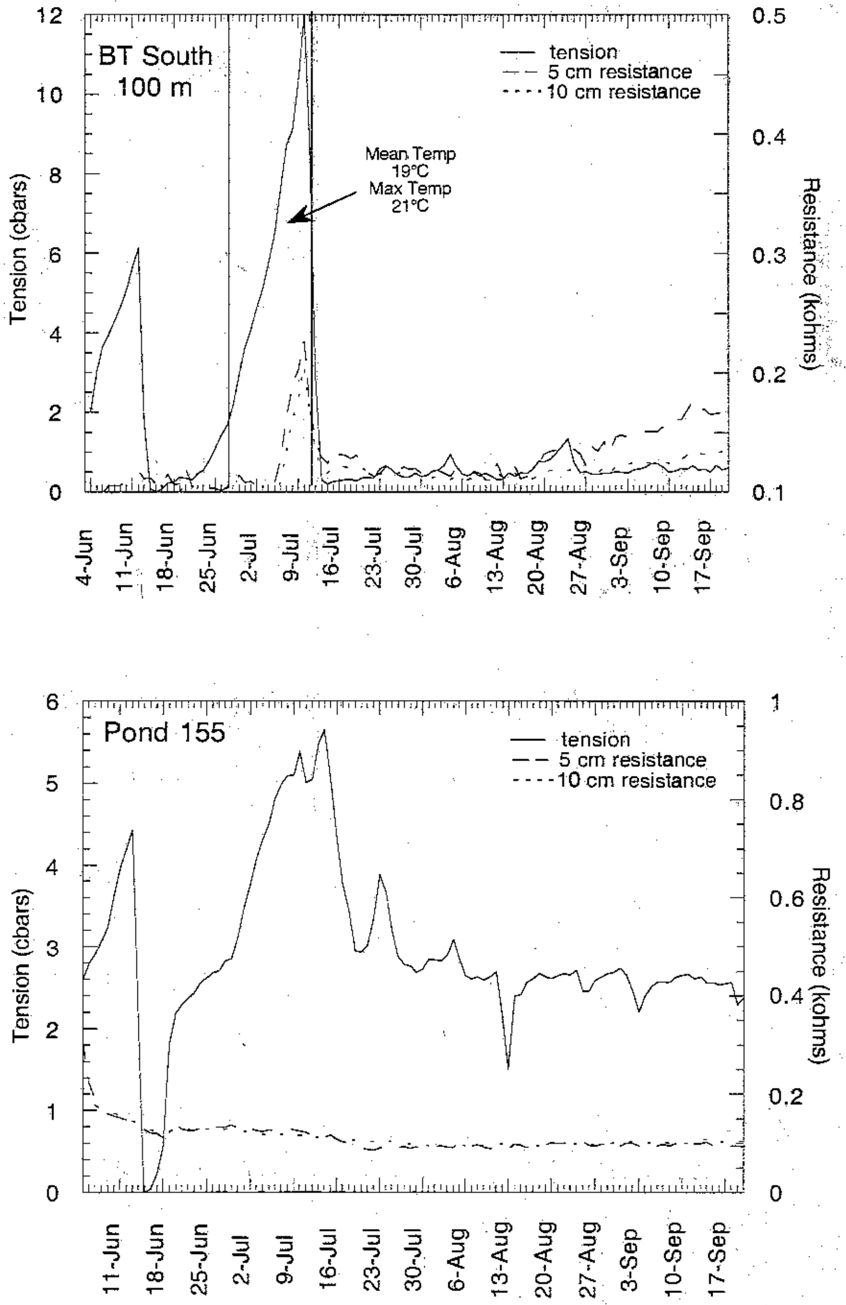
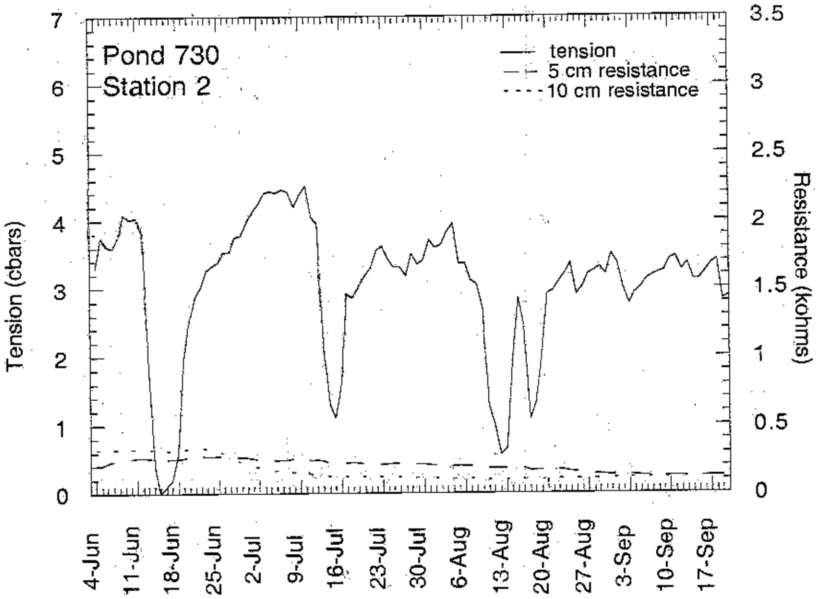


Figure III-2-14 (cont'd).



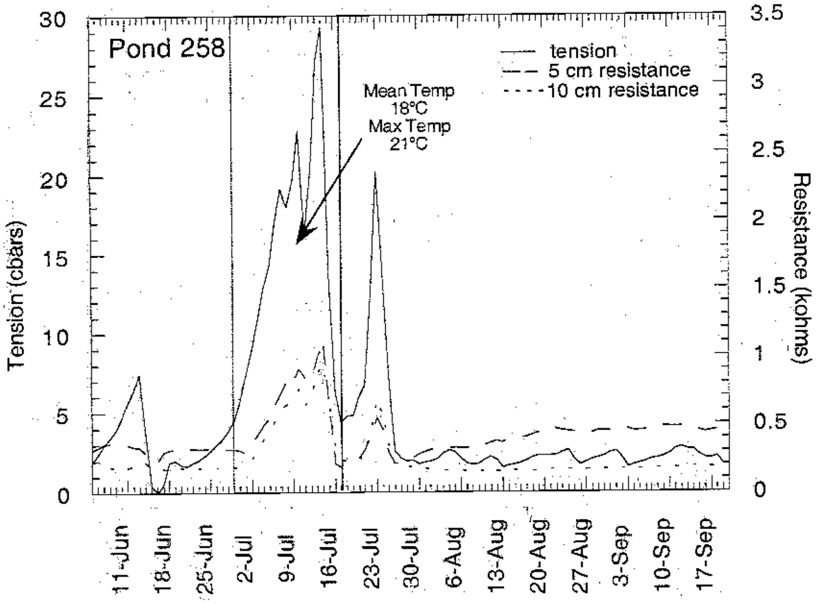


Figure III-2-14 (cont'd). Output from moisture sensors during the summer of 1999. Increases in resistance and tension indicate drying.

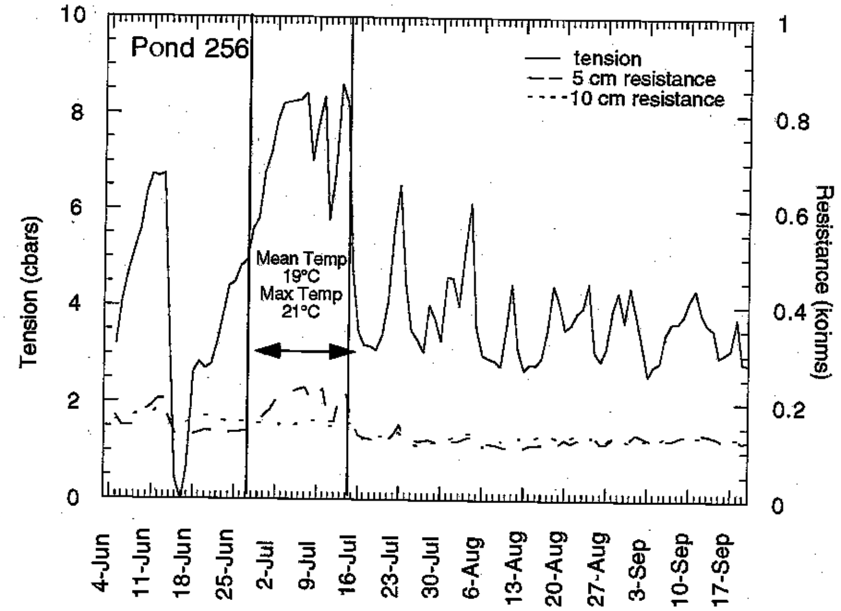


Figure III-2-14 (cont'd).

brief periods where the sediments were unsaturated, but frequent rain constantly rewetted them. Sediment temperatures were between those observed in 1997 and 1998 at the C 100 m station. During the time that sediments were unsaturated, maximum 24-hour average temperatures at 5 cm depth were 21.7, 18.3, and 21.1°C for 1997, 1998, and 1999, respectively. Mean temperatures at 5 cm depth were 17.53, 15.79, and 16.8°C for 1997, 1998, and 1999, respectively. The maximum temperature occurred on 4 July 1999 during a 19-consecutive-day spell of unsaturated conditions.

The relationship between groundwater elevation and tension in the surface sediments is revealed in data from our piezometer data station. When groundwater elevations

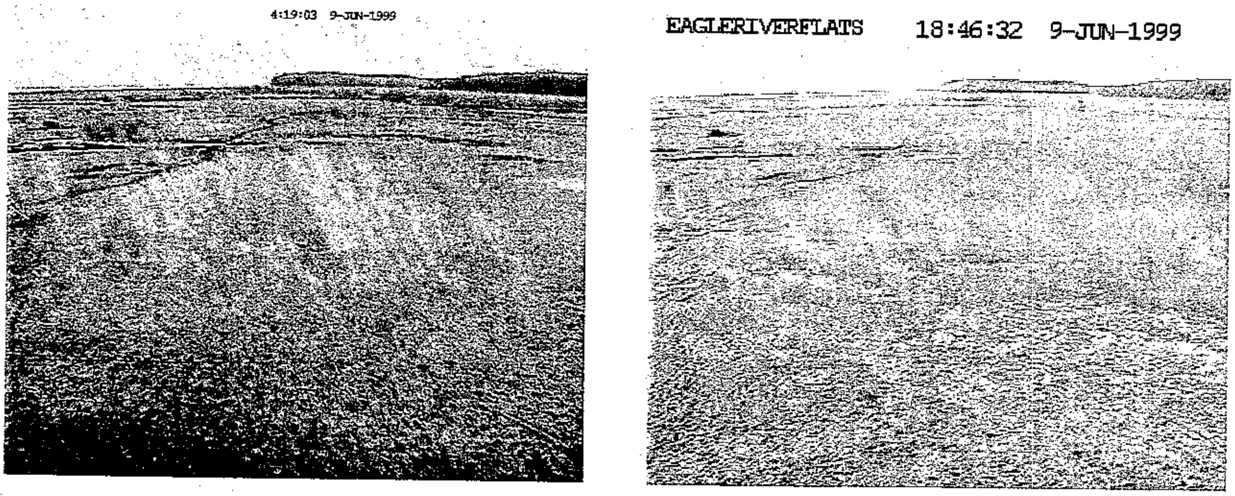


Figure III-2-15. Pictures from web cam showing flooding of Pond 183 in June 1999. Salt crust visible on 9 June is an indication of drying sediments. Sensors showed that the sediments were again unsaturated by 27 June.

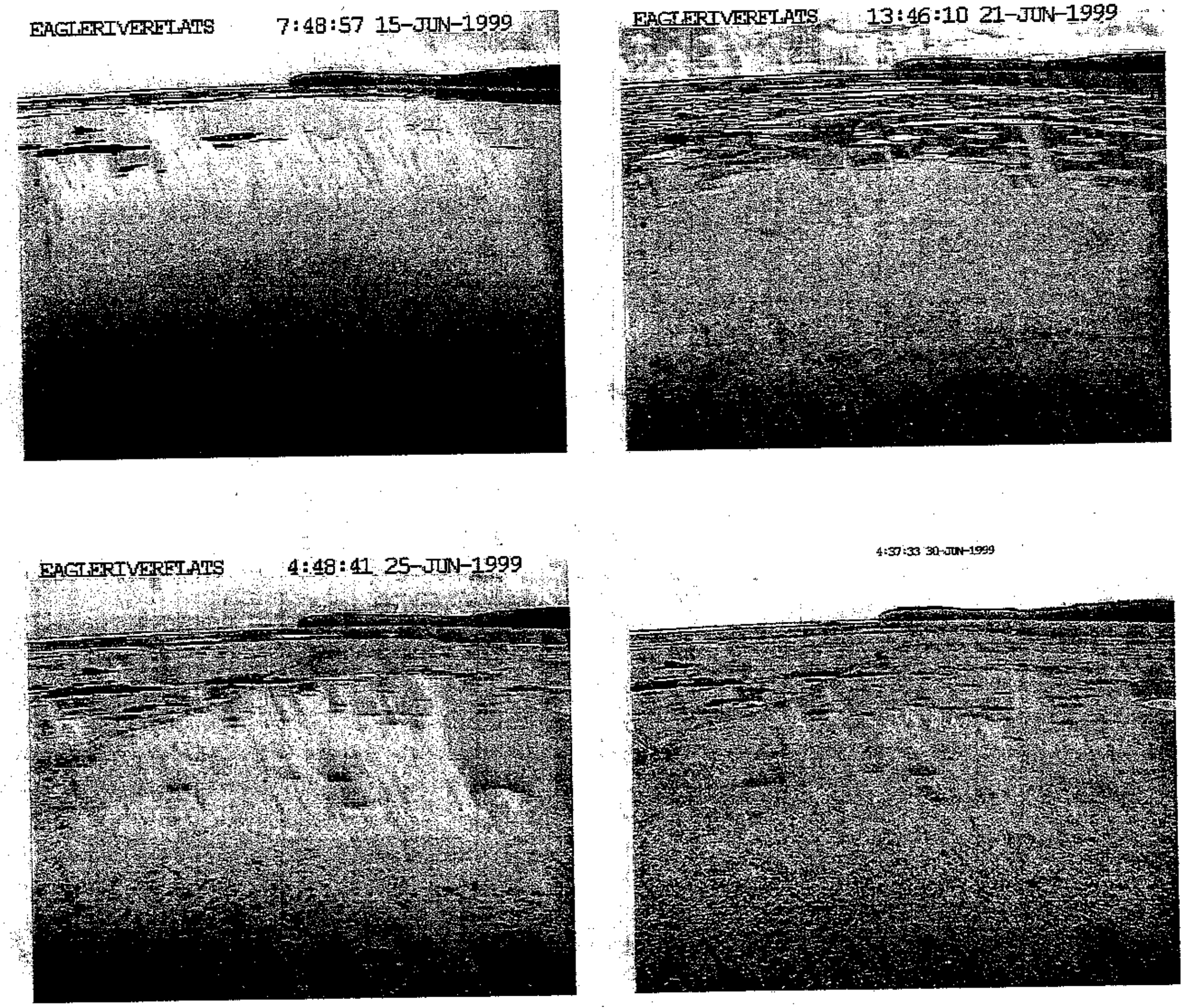


Figure III-2-15 (cont'd). Pictures from web cam showing flooding of Pond 183 in June 1999. Salt crust visible on 9 June is an indication of drying sediments. Sensors showed that the sediments were again unsaturated by 27 June.

dropped to 50 cm below the sediment surface, tension rises above 5 cbars, the estimated air entry point (Hemond and Chen 1990) for sediment in this part of ERF (M.E. Walsh et al. 1995b). The groundwater elevation dropped below the bottom of the piezometer well (1-m depth) on 6 July (Fig. III-2-16), and did not rise into the well again until 6 August, following heavy rainfall. While the sediment was unsaturated, rewetting by precipitation is shown by the wide fluctuations in tension.

We recovered the remains of white phosphorus particles that we planted in 1999. Four of the five white phosphorus particles planted decreased from an initial mass of 5.6±0.5 mg to less than or equal to 0.5 mg. One particle showed no change. Given that in June we planted five 5.6-mg particles for a total mass of 28 mg and we recovered a total mass of 6.6 mg in September, removal by sublimation–oxidation was 76% (Table III-2-2).

In 1997, we collected composite samples from five grids in Area C, and found the highest concentrations in the sample (C 100 m) taken from the west side of Pond 183. In 1999 we again collected replicate composite samples from this grid. White phosphorus is still detectable within this grid but the con-

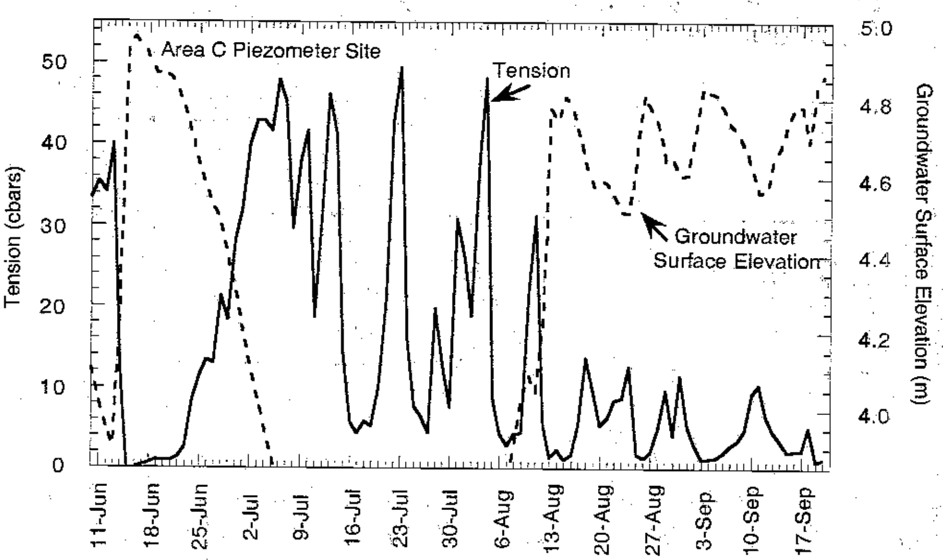


Figure III-2-16. Groundwater surface elevation in piezometer well located in Area C and the corresponding moisture content (tension) of the surface (elevation 4.77 m) sediment. A rise in tension indicates drying.

Table III-2-2. Loss of white phosphorus from particles planted in the top 5 cm of drained ponds. The locations correspond to data stations in Table III-2-1.

Data logger location	*Loss**
C 100 m	76%
BT North 100 m	72%
BT South 100 m	61%
Pond 155	0%
Pond 730 Station 1	52%
Pond 730 Station 2	62%
Pond 730 Station 3	21%
Pond 258	50%
Pond 256	48%

*Nominal initial mass was 5.6 ± 0.5 mg for each of five particles yielding an initial total mass of 28 mg. Loss was computed as follows: 1-(sum of mass remaining)/(total initial mass).

Table III-2-3. White phosphorus concentrations found in composite samples collected from grids in Area C and the Bread Truck Pond.

	Median White Phosphorus Concentration (μg/g)		
Date	*C m*	*BT North 100 m*	*BT South 100 m*
4 June 1997	0.069	0.012	0.0049
4 September 1997	0.0063	0.0056	0.00087
22 August 1998	0.0074	0.0038	0.0035
15 September 1999	0.0016	0.0003	0.0045

centration is declining (Table III-2-3).

We have observed the most dramatic declines in white phosphorus concentrations in Pond 183 in discrete samples collected from sites where high concentrations of white phosphorus were found prior to draining. The first site was the location of the DWRC Pen 5 (Fig. III-2-2), used in 1992 to 1993 for the evaluation of methyl anthranilate. We intensively sampled this pen in 1996, taking discrete samples at the nodes of a 1.82-m-square grid four columns wide and 12 rows long (Fig. III-2-9). In 1996, all 48 samples contained detectable white phosphorus concentrations ranging from 0.0024 to 421 μg/g (Table III-2-4). Over 300 white phosphorus particles were found, one of which weighed 150 mg (M.E. Walsh et al. 1997). By the fall of 1998, white phosphorus was detectable in only 28 of the 48 samples. The concentration range in the positive samples was 0.00062 to 0.84 μg/g. In all cases where white phosphorus was found, the concentrations were lower in 1998 then in 1996 (Table III-2-4), and no white phosphorus particles were found in sieved samples. In 1999, we again sampled rows 4 to 12, and only 13 samples had detectable white phosphorus. The concentration range was 0.0002 to 0.036 μg/g.

The subsurface samples we collected also showed a decline in white phosphorus residues. The first series of samples was collected from Ponds 183 and 146 where 1992 sampling showed contamination at depth. Figure III-2-10 shows the locations of the subsurface samples and results from 1992 where each number in the columns represents an increase in depth of 3 to 5 cm. This year white phosphorus was undetectable down to 30 cm at locations 240, 549, 381, 547, and 230 and in one additional location between 547 and 240. White phosphorus was still detectable at location 615, which is within the bulrush marsh, and at location 53, which is adjacent to the dredge channel in Pond 146.

The second set of subsurface samples was from Miller's Hole, the crater produced in 1992 from the detonation of a WP UXO. Repeated sampling shows significant decreases in concentrations in the surface sediments since the initiation of the pumping project (Table III-2-5). In 1997 we collected two narrow cores down to 20 cm from the center of the crater and found high concentrations (up to 1730 μg/g) in the deepest (20 cm) part of the core. By the fall of 1998, when duplicate cores were taken, the concentrations in the deepest parts of the cores were 0.25 and 0.10 μg/g. This year, the concentrations were only 0.0012 and 0.0016 μg/g in the deepest parts of the core. We will continue to sample this site until white phosphorus is undetectable.

In light of all of the above, pumping has been very successful at decontaminating Pond 183. Pond 146 needs additional attention, but the increased depth of the sump should help to dry the sediments.

Table III-2-4. White phosphorus concentrations (µg/g) found on a 1.82-m-square gird in 1996, 1998 and 1999 in DWRC Pen 5.

Row	*Column*	*1996*	*1998*	*1999*
1	1	0.049	not detected	not sampled
1	2	0.005	not detected	not sampled
1	3	0.003	not detected	not sampled
1	4	0.018	not detected	not sampled
2	1	0.022	not detected	not sampled
2	2	0.002	not detected	not sampled
2	3	0.003	not detected	not sampled
2	4	0.003	not detected	not sampled
3	1	0.008	not detected	not sampled
3	2	0.004	not detected	not sampled
3	3	0.008	not detected	not sampled
3	4	0.016	not detected	not sampled
4	1	0.102	0.0006	not detected
4	2	4.30	0.0014	0.00042
4	3	0.032	not detected	not detected
4	4	0.012	not detected	not detected
5	1	0.135	not detected	not detected
5	2	5.38	0.0505	0.00061
5	3	0.551	0.0067	0.00103
5	4	0.010	0.0007	not detected
6	1	0.029	0.0055	not detected
6	2	0.009	0.0015	not detected
6	3	0.076	0.0042	not detected
6	4	0.008	not detected	not detected
7	1	22.9	0.0048	0.0024
7	2	0.039	not detected	not detected
7	3	0.058	0.0007	not detected
7	4	25.3	0.0034	0.035
8	1	8.52	0.2101	0.00238
8	2	6.01	not detected	not detected
8	3	0.015	not detected	not detected
8	4	0.760	0.0037	0.0093
9	1	0.129	0.0033	not detected
9	2	0.061	0.0010	not detected
9	3	1.73	0.0889	not detected
9	4	0.063	0.0010	not detected
10	1	0.034	not detected	not detected
10	2	0.112	0.0021	0.0029
10	3	19.7	0.187	0.0363
10	4	0.279	0.0530	0.00033
11	1	421	0.0029	0.00018
11	2	3.63	0.0024	not detected
11	3	1.28	0.840	0.00798
11	4	0.691	0.0074	not detected
12	1	5.24	0.0258	0.00087
12	2	0.616	0.0042	not detected
12	3	0.320	0.0146	not detected
12	4	0.337	0.0035	not detected

Table III-2-5. White phosphorus concentrations found at Miller's Hole, a crater produced by the detonation of a WP UXO (81-mm mortar round). The crater center is 30 cm below the rim.

		White phosphorus concentration (µg/g)	
Sampled	*Days since explosion*	*Center of crater*	*Rim*
5/20/92	0	2,394	979
6/18/92	29	5,572	0.237
8/21/92*	93	184	0.00427
6/23/93	399	187	0.0175
8/27/93*	464	81.5	0.00177
5/16/94*	726	49.5	34.1
8/30/94	832	9.5	not detected
6/1/95†	1107	10,497	0.0051
9/17/95†	1215	166	0.0006
9/3/97	1932	1.6	not detected
8/25/98	2288	0.037	not detected
9/21/99	2681	0.0008	not detected

*Crater under water when sampled.
†Crater under water all summer.

Pond 155 (Northern C)

Pond 155 (Fig. III-2-4 and III-2-13) was drained by pumping but had minimal drying because of its location within a bulrush marsh. Planted particles at this site showed no change (Table III-2-2). We collected grid composite samples from a part of the pond that was sampled last year and had a white phosphorus concentration of 0.023 µg/g. A sample taken in June 1999 was 0.45 µg/g, and duplicate samples in September 1999 were 0.018 and 0.014 µg/g. Over the many years of taking repeated samples in contaminated locations, we frequently observed higher concentrations in the spring versus the fall. Although the topmost layer of sediment may dry, temperatures decrease and moisture content increases with depth, which slows the rate of loss of white phosphorus at depth. Consequently, highly contaminated sediment may underlie sediment that has been decontaminated. Freeze–thaw cycles may then renew the surface contamination by deconsolidation and frost action. Slower decontamination of the deeper sediments is one of the reasons that repeated seasons of pumping are needed.

This pond should benefit from the deeper sump installed in Pond 146 this fall. We hope that, with the deeper sump in Pond 146, water levels throughout Area C will be lowered and Pond 155 will dry.

Bread Truck Pond

The former Bread Truck Pond (Pond 109) (Fig. III-2-3) is no longer a permanent pond because of the drainage ditch excavated in April 1996 connecting an existing tidal gully with the pond (Collins et al. 1997). Since its excavation, the ditch has continued to enlarge each year as headward erosion extends it southward and eastward into the former pond area. In addition to the gully advancement, there has been significant erosion of the surface sediment within 20 m of the ditch (Fig. III-2-11). Our monitoring station on the north side of the Bread Truck pond (BT North 100 m) is affected by this erosion.

The north side of the former pond drains readily through to the drainage ditch but is also more frequently flooded owing to the lower flooding threshold of the ditch. Unlike Pond 183 in Area C, which flooded only between 14 and 19 June, the Bread Truck Pond flooded on 13–16 June, 12–15 July, 11–13 August, 28–31 August, and 10–11 September. Moisture sensors (Fig. III-2-14) at the BT North 100 m monitoring station indicate that the north side of the pond dried significantly during the first two weeks of June and July. White phosphorus is just barely detectable in the BT North 100 m composite samples (0.00027 and 0.00037 µg/g), although the decrease from 0.012 µg/g in June 1997 (Table III-2-3) may be attributable to both drying and erosion. Residual white phosphorus from the particles we planted was extremely variable, ranging from 0.0001 to 4.7 mg. The total mass recovered from the five particles planted was 7.78 mg. Given a total initial mass of 27.8 mg, the removal was 72% (Table III-2-2).

The south side of the Bread Truck pond was wetter than the north side because of poorer drainage to the ditch (Fig. III-2-3). However, it dried out more than it did last summer, when saturated conditions were the norm. White phosphorus concentrations in the two composite samples taken at BT South 100 m were 0.0005 and 0.0085 µg/g. In June of 1997 the concentration range of five replicates was 0.003 to 0.0079 µg/g, so no significant reduction in concentration is evident in the composite samples. However, there was a 61% loss of the white phosphorus from the particles we planted this year. This loss is a big improvement over last summer when the loss was only 1%.

We sampled sediment that was deposited in the Bread Truck ditch by erosion of the pond surface sediment. We did not detect white phosphorus in the newly deposited sediment; however, at the bottom of the gully, we found the tail end of a white phosphorus mortar round that was exposed by the advancing gully (Fig. III-2-17). The white phosphorus filler in the tail end of mortar rounds is typically not ejected when the rounds explode (Walsh and Collins 1993), leaving residual filler that is uncovered as the rounds corrode. Adjacent to the round, the concentration of white phosphorus was 68 µg/g. In

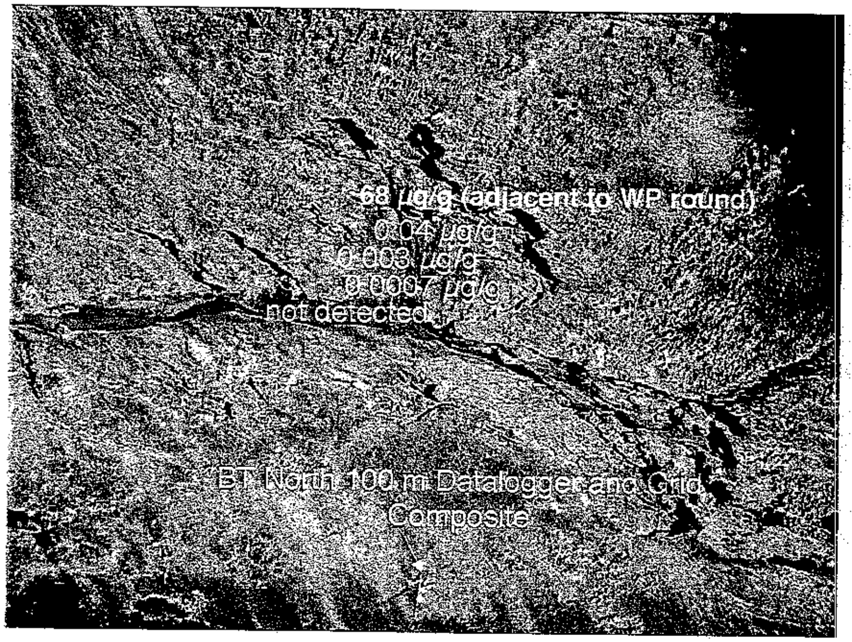


Figure III-2-17. Overhead view of Bread Truck ditch showing lobes formed by continuing erosion. Also shown is the location of an exposed white phosphorus mortar round and white phosphorus concentrations found in sediment between the round and the ditch.

samples taken at approximately 5-m intervals between the round and the main channel of the ditch, white phosphorus concentrations were 0.04, 0.003, and 0.0007 µg/g, and it was undetectable in the main channel.

Given the increased frequency of flooding and the exposure of new white phosphorus by erosion, the continued advancement of this drainage ditch should be arrested by installation of a tide gate. A tide gate would result in better drying of the south side of the pond and help possible future remediation actions in Area C/D.

Pond 258 and 256 (Northern A)

Pond 258 dried considerably more this year than last year (Fig. III-2-14, III-2-18, and III-2-19). Loss from planted white phosphorus particles was 50%. No white phosphorus was detected in the 17 additional grid composite samples collected this year. Extensive composite sampling last year and this year, plus the discrete samples collected previously, show that this pond had some white phosphorus contamination, but its distribution is very sporadic. Unlike Area C, Bread Truck Pond, and Racine Island, we have not located hotspots that we can resample to monitor concentration declines over the long term.

Pond 256 dried less than Pond 258, but loss of white phosphorus from the planted particles was similar (48%).

Pond 730

This pond experienced frequent flooding from the Bread Truck ditch that constantly rewetted the drying sediments (Fig. III-2-14). Some drying did occur as the sediment consolidated and cracked (Fig. III-2-13). Loss of white phosphorus from the planted particles was 52, 62, and 21%. We did not detect white phosphorus in the 10 grid composite samples collected from this pond.

Pumping this pond facilitated our ability to sample in the C/D Area. We found one hotspot (localized area of contamination) in Pond 75, north of Pond 730. Mortality data from the telemetry mallards suggest that ponds northeast of Pond 730 may be contaminated.

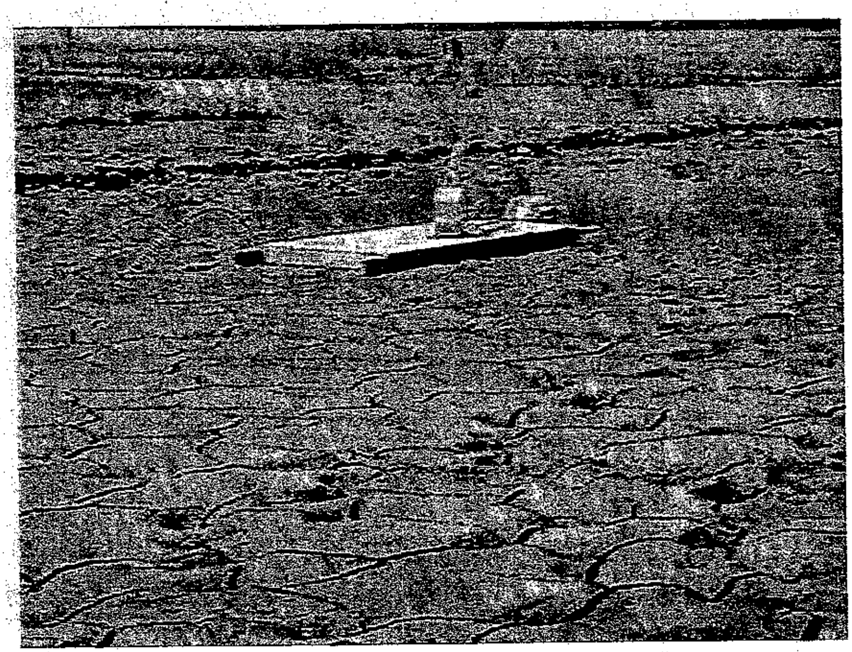


Figure III-2-18. Ground view of Pond 258 in early July 1999. (Photo courtesy of Terry Edwards, Weldin Construction.)

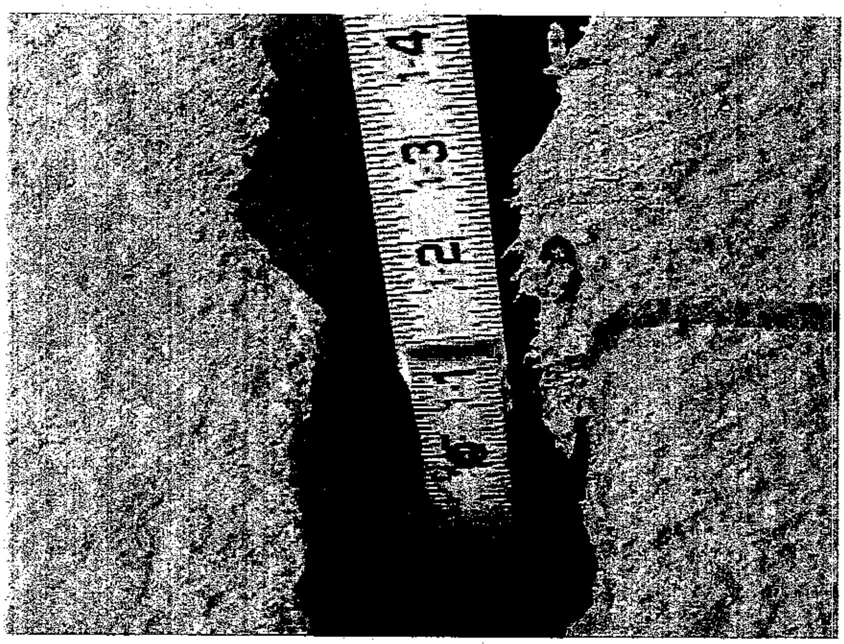


Figure III-2-19. Desiccation cracks in Pond 258 in early July 1999. (Photo courtesy of Terry Edwards, Weldin Construction.)

CONCLUSIONS

Pond pumping has been a major success in Pond 183 of Area C. White phosphorus contamination levels have declined dramatically and it may be undetectable in a few years. Present levels of white phosphorus contamination measured in Pond 183 indicate that there is little likelihood that hazardous amounts of white phosphorus particles remain. Ponds 155 and 146, which are east of Pond 183, still contain white phosphorus at hazardous levels. We hope that deepening of the sump in Pond 146 will enhance the drying of these ponds. Pond 258 in Area A dried significantly because of pumping, but Pond 730 in Area C/D was frequently flooded by tidal water from the Bread Truck ditch.

The north side of the Bread Truck Pond dried because of drainage through the blasted ditch, and as a result white phosphorus in the surface sediment has declined significantly. However, continuing advancement of the ditch exposed at least one white phosphorus mortar round in the gully wall. White phosphorus was detectable in sediment around and downstream from this round. Decontamination of the south side of the Bread Truck Pond is slow owing to poor drainage and frequent flooding.

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Table III-2-A-1. 1999 Composite samples.

Pond	Sample type	Collector	Unique ID	Date collected	WP conc. (µg/g)	East (m)	North (m)	Elevation (m)	Type of subsample	Mass of composite (g)	Number of subsamples in composite	Analysis method	Date analyzed
Area A Spring													
258	Grid	MEW-RNB-CMC	South Central 0 m +	4-June-99	not detected	353,960.79 353,942.54 353,946.48 353,956.90	6,800,679.05 6,800,689.19 6,800,693.16 6,800,675.09	4.61 4.59 4.57 4.66	a	1400	48	a	17-Jun-99
258	Grid	MEW-RNB-CMC	South Central 20 m +	4-June-99	not detected	353,958.97 353,963.06 353,973.63 353,977.60	6,800,702.25 6,800,706.05 6,800,688.34 6,800,691.91	4.57 4.60 4.62 4.56	a	1800	48	a	17-Jun-99
258	Grid	MEW-RNB-CMC	South Central 20 m –	4-June-99	not detected	353,973.63 353,977.60 353,989.34 353,992.52	6,800,688.34 6,800,691.91 6,800,674.34 6,800,677.57	4.62 4.56 4.90 4.61	a	1600	48	a	17-Jun-99
258	Grid	MEW-RNB-CMC	South Central 40 m +	4-June-99	not detected	353,975.47 353,979.60 353,992.62 353,988.50	6,800,715.51 6,800,719.04 6,800,703.99 6,800,700.26	4.58 4.59 4.59 4.59	a	1900	48	a	17-Jun-99
258	Grid	MEW-RNB-CMC	South Central 40 m –	4-June-99	not detected	353,992.62 353,988.50 354,004.16 354,001.58	6,800,703.99 6,800,700.26 6,800,689.56 6,800,684.90	4.59 4.59 4.62 4.77	a	1400	48	a	17-Jun-99
258	Grid	MEW-RNB-CMC	South Central 60 m +	4-June-99	not detected	353,991.89 353,996.24 354,008.24 354,003.73	6,800,728.82 6,800,732.23 6,800,715.93 6,800,712.56	4.61 4.60 4.60 4.59	a	1900	48	a	17-Jun-99
258	Grid	MEW-RNB-CMC	South Central 60 m –	4-June-99	not detected	354,008.24 354,003.73 354,015.80 354,020.24	6,800,715.93 6,800,712.56 6,800,696.51 6,800,699.72	4.60 4.59 4.74 4.76	a	1400	48	a	17-Jun-99
258	Grid	MEW-RNB-CMC	South Central 80 m +	4-June-99	not detected	354,007.03 354,011.43 354,024.18 354,019.90	6,800,740.83 6,800,744.22 6,800,729.05 6,800,725.35	4.62 4.63 4.63 4.64	a	1900	48	a	17-Jun-99
258	Grid	MEW-RNB-CMC	South Central 80 m –	4-June-99	not detected	354,024.18 354,019.90 354,037.12 354,032.91	6,800,729.05 6,800,725.35 6,800,713.43 6,800,710.01	4.63 4.64 4.60 4.63	a	1700	48	a	17-Jun-99
258	Grid	MEW-RNB-CMC	North Central 0 m +	8-June-99	not detected	353,881.51 353,885.98 353,898.41 353,893.98	6,800,733.36 6,800,736.72 6,800,720.88 6,800,717.60	4.69 4.72 4.56 4.62	a	1700	48	a	17-Jun-99

Table III-2-A-1 (cont'd). 1999 Composite samples.

Pond	Sample type	Collector	Unique ID	Date collected	WP conc. (µg/g)	East (m)	North (m)	Elevation (m)	Type of subsample	Mass of composite (g)	Number of subsamples in com-posite	Analysis method	Date analyzed
258	Grid	MEW-RNB-CMC	North Central 0 m –	8-June-99	not detected	353,898.41 353,893.98 353,903.20 353,907.31	6,800,720.88 6,800,717.60 6,800,706.18 6,800,709.83	4.56 4.62 4.58 4.62	a	1000	36	a	17-Jun-99
258	Grid	MEW-RNB-CMC	North Central 20 m +	8-June-99	not detected	353,896.24 353,900.61 353,913.68 353,909.13	6,800,745.47 6,800,748.97 6,800,733.11 6,800,729.89	4.58 4.62 4.58 4.61	a	1500	48	a	17-Jun-99
258	Grid	MEW-RNB-CMC	North Central 20 m –	8-June-99	not detected	353,913.68 353,909.13 353,922.36 353,926.57	6,800,733.11 6,800,729.89 6,800,714.76 6,800,718.49	4.58 4.61 4.59 4.58	a	1500	48	a	17-Jun-99
258	Grid	MEW-RNB-CMC	North Central 40 m +	8-June-99	not detected	353,911.38 353,916.04 353,928.63 353,924.30	6,800,757.54 6,800,760.84 6,800,745.51 6,800,742.06	4.79 4.63 4.57 4.59	a	1500	48	a	17-Jun-99
258	Grid	MEW-RNB-CMC	North Central 40 m –	8-June-99	not detected	353,928.63 353,924.30 353,937.09 353,941.50	6,800,745.51 6,800,742.06 6,800,726.57 6,800,729.97	4.57 4.59 4.60 4.62	a	1500	48	a	17-Jun-99
258	Grid	MEW-RNB-CMC	North Central 60 m +	4-June-99	not detected	353,925.70 353,929.98 353,943.90 353,939.89	6,800,769.34 6,800,773.13 6,800,758.59 6,800,754.87	4.64 4.66 4.59 4.57	a	1600	48	a	17-Jun-99
258	Grid	MEW-RNB-CMC	North Central 60 m –	4-June-99	not detected	353,943.90 353,939.89 353,953.90 353,958.25	6,800,758.59 6,800,754.87 6,800,740.68 6,800,744.18	4.59 4.57 4.57 4.55	a	1600	48	a	17-Jun-99
Area A Fall													
226	Grid	MEW-RNB-CMC	North 0 m +	17-Sept.-99	not detected	353,610.76 353,608.44 353,621.80 353,625.21	6,801,015.32 6,801,013.00 6,800,997.03 6,801,001.35	4.40 4.55 4.35 4.34	a	2000	48	a	6-Oct-99
226	Grid	MEW-RNB-CMC	North 15 m +	17-Sept.-99	not detected	353,620.21 353,616.54 353,631.25 353,635.04	6,801,026.23 6,801,022.75 6,801,008.67 6,801,012.59	4.38 4.39 4.39 4.40	a	2000	48	a	6-Oct-99

Table III-2-A-1 (cont'd). 1999 Composite samples.

Pond	Sample type	Collector	Unique ID	Date collected	WP conc. (µg/g)	East (m)	North (m)	Elevation (m)	Type of subsample	Mass of composite (g)	Number of subsamples in composite	Analysis method	Date analyzed
226	Grid	MEW-RNB-CMC	North 15 m –	17-Sept.-99	not detected	353,635.04	6,801,012.59	4.40	a	800	20	a	6-Oct-99
						353,631.25	6,801,008.67	4.39					
						353,637.65	6,801,002.60	4.58					
						353,641.89	6,801,006.08	4.36					
226	Grid	MEW-RNB-CMC	North 30 m +	17-Sept.-99	not detected	353,629.44	6,801,034.64	4.52	a	1900	44	a	6-Oct-99
						353,633.89	6,801,037.96	4.58					
						353,645.89	6,801,024.32	4.39					
						353,642.04	6,801,020.02	4.37					
226	Grid	MEW-RNB-CMC	North 30 m –	17-Sept.-99	not detected	353,645.89	6,801,024.32	4.39	a	2100	44	a	6-Oct-99
						353,661.65	6,801,008.96	4.37					
						353,657.89	6,801,005.20	4.58					
						353,642.04	6,801,020.02	4.36					
226	Grid	MEW-RNB-CMC	North 45 m +	17-Sept.-99	not detected	353,647.41	6,801,044.76	4.55	a	1400	32	a	6-Oct-99
						353,643.31	6,801,040.63	4.50					
						353,652.11	6,801,031.12	4.37					
						353,655.99	6,801,035.43	4.43					
226	Grid	MEW-RNB-CMC	North 45 m –	17-Sept.-99	not detected	353,655.99	6,801,035.43	4.43	a	900	20	a	6-Oct-99
						353,652.11	6,801,031.12	4.37					
						353,658.29	6,801,024.40	4.38					
						353,662.08	6,801,028.55	4.42					
226	Grid	MEW-RNB-CMC	North 60 m +	17-Sept.-99	not detected	353,658.97	6,801,055.38	4.50	a	1300	28	a	6-Oct-99
						353,654.80	6,801,052.08	4.52					
						353,662.58	6,801,043.36	4.47					
						353,666.42	6,801,047.10	4.47					
226	Grid	MEW-RNB-CMC	North 60 m –	17-Sept.-99	not detected	353,666.42	6,801,047.10	4.47	a	2000	44	a	6-Oct-99
						353,662.58	6,801,043.36	4.47					
						353,676.62	6,801,028.11	4.42					
						353,680.33	6,801,032.51	4.41					
226	Grid	MEW-RNB-AG	Central 0 m	18-Sept.-99	not detected	353,647.34	6,800,986.72	4.48	a	2100	48	b	7-Oct-99
						353,639.82	6,800,968.11	4.59					
						353,634.88	6,800,970.66	4.52					
						353,642.74	6,800,989.12	4.56					
226	Grid	MEW-RNB-AG	Central 20 m +	18-Sept.-99	not detected	353,640.37	6,801,009.55	4.45	a	1900	44	b	7-Oct-99
						353,642.77	6,801,014.59	4.46					
						353,659.78	6,801,003.85	4.44					
						353,656.29	6,800,998.98	4.38					
226	Grid	MEW-RNB-AG	Central 20 m –	18-Sept.-99	not detected	353,659.78	6,801,003.85	4.44	a	1900	44	b	7-Oct-99
						353,678.09	6,800,995.85	4.39					
						353,676.81	6,800,990.28	4.39					
						353,656.29	6,800,998.98	4.38					

Table III-2-A-1 (cont'd). 1999 Composite samples.

Pond	Sample type	Collector	Unique ID	Date collected	WP conc. (µg/g)	East (m)	North (m)	Elevation (m)	Type of subsample	Mass of composite (g)	Number of subsamples in composite	Analysis method	Date analyzed
226	Grid	MEW-RNB-AG	Central 40 m +	18-Sept.-99	not detected	353,673.73 353,665.31 353,661.83 353,670.30	6,801,022.05 6,801,029.06 6,801,024.91 6,801,018.17	4.44 4.44 4.40 4.49	a	1200	28	b	7-Oct-99
226	Grid	MEW-RNB-AG	Central 40 m –	18-Sept.-99	0.00576	353,670.30 353,688.57 353,690.85 353,673.73	6,801,018.17 6,801,008.37 6,801,013.18 6,801,022.05	4.49 4.45 4.47 4.44	a	1900	44	b,a	7-Oct-99
226	Grid	MEW-RNB-CMC	Central 60 m +	17-Sept.-99	not detected	353,685.55 353,670.03 353,667.74 353,681.82	6,801,038.05 6,801,050.38 6,801,048.29 6,801,034.22	4.45 4.59 4.49 4.43	a	1900	46	b	7-Oct-99
226	Grid	MEW-RNB-CMC	Central 60 m –	18-Sept.-99	not detected	353,681.82 353,693.21 353,696.48 353,685.55	6,801,034.22 6,801,024.83 6,801,029.68 6,801,038.05	4.43 4.49 4.68 4.45	a	1500	32	b,a	7-Oct-99
226	Grid	MEW-RNB-CMC	Central 80 m +	17-Sept.-99	not detected	353,680.79 353,691.25 353,695.22 353,685.82	6,801,057.32 6,801,048.29 6,801,052.38 6,801,060.69	4.53 4.47 4.50 4.44	a	1400	32	b,a	7-Oct-99
226	Grid	MEW-RNB-CMC	Central 80 m –	17-Sept.-99	not detected	353,691.25 353,695.04 353,697.92 353,695.22	6,801,048.29 6,801,044.79 6,801,049.73 6,801,052.38	4.47 4.55 4.54 4.50	a	600	16	b	7-Oct-99
226	Grid	MEW-RNB-AG	South 0 m	18-Sept.-99	not detected	353,669.67 353,664.89 353,654.34 353,658.11	6,800,981.61 6,800,979.43 6,800,993.67 6,800,997.48	4.46 4.56 4.35 4.39	a	2,100	44	b	7-Oct-99
226	Grid	MEW-RNB-AG	South 15 m	18-Sept.-99	not detected	353,686.50 353,682.62 353,676.90 353,680.84	6,800,986.88 6,801,005.60 6,801,005.56 6,800,985.68	4.46 4.45 4.44 4.46	a	2,050	48	b,a	7-Oct-99
226	Grid	MEW-RNB-AG	South 30 m	18-Sept.-99	not detected	353,702.08 353,696.48 353,692.88 353,698.23	6,800,998.98 6,801,000.82 6,800,984.84 6,800,984.10	4.45 4.61 4.62 4.65	a	1,700	40	b	7-Oct-99
226	Grid	MEW-RNB-AG	South 45 m	18-Sept.-99	not detected	353,710.42 353,715.50 353,709.99 353,705:28	6,800,999.97 6,800,982.73 6,800,981.94 6,800,998.76	4.48 4.59 4.50 4.45	a	1,800	44	b	7-Oct-99

Table III-2-A-1 (cont'd). 1999 Composite samples.

Pond	Sample type	Collector	Unique ID	Date collected	WP conc. (µg/g)	East (m)	North (m)	Elevation (m)	Type of subsample	Mass of composite (g)	Number of subsamples in composite	Analysis method	Date analyzed
226	Grid	MEW-RNB-AG	South 60 m	18-Sept.-99	not detected	353,719.53	6,801,005.31	4.56	a	800	18	b	7-Oct-99
						353,722.62	6,800,999.60	4.58					
						353,717.72	6,800,997.60	4.62					
						353,714.94	6,801,002.41	4.53					
228	Grid	MEW-RNB-CMC	228-1	20-Sept.-99	not detected	353,508.68	6,801,076.39	4.52	a	1,800	48	b	7-Oct-99
						353,510.94	6,801,081.49	4.51					
						353,529.61	6,801,073.22	4.53					
						353,526.95	6,801,068.39	4.53					
228	Grid	MEW-RNB-CMC	228-2	20-Sept.-99	not detected	353,503.81	6,801,037.87	4.40	a	2,100	48	b	7-Oct-99
						353,508.83	6,801,035.55	4.46					
						353,517.28	6,801,053.76	4.45					
						353,512.34	6,801,056.22	4.49					
228	Grid	MEW-RNB-CMC	228-3	20-Sept.-99	not detected	353,505.46	6,800,990.25	4.34	a	2,100	48	b	7-Oct-99
						353,501.03	6,800,986.51	4.34					
						353,486.88	6,801,001.42	4.36					
						353,491.27	6,801,004.46	4.36					
228	Grid	MEW-RNB-CMC	228-4	20-Sept.-99	not detected	353,515.32	6,800,957.99	4.34	a	2,200	48	b	7-Oct-99
						353,510.82	6,800,961.19	4.34					
						353,522.58	6,800,977.79	4.34					
						353,526.94	6,800,974.37	4.42					
228	Grid	MEW-RNB-CMC	228-5	20-Sept.-99	not detected	353,533.28	6,800,934.29	4.34	a	2,500	48	b	7-Oct-99
						353,531.06	6,800,929.15	4.30					
						353,549.59	6,800,921.49	4.43					
						353,551.88	6,800,926.26	4.44					
228	Grid	MEW-RNB-CMC	228-6	20-Sept.-99	not detected	353,533.76	6,800,961.01	4.34	a	2,300	48	b	7-Oct-99
						353,528.02	6,800,961.34	4.36					
						353,527.42	6,800,941.91	4.34					
						353,532.89	6,800,940.95	4.34					
228	Grid	MEW-RNB-CMC	228-7	20-Sept.-99	not detected	353,560.49	6,800,961.01	4.38	a	2,200	48	b	7-Oct-99
						353,560.21	6,800,966.62	4.39					
						353,540.30	6,800,964.64	4.40					
						353,540.68	6,800,958.90	4.36					
228	Grid	MEW-RNB-CMC	228-8	20-Sept.-99	not detected	353,570.70	6,800,973.86	4.45	a	2,200	48	b	7-Oct-99
						353,575.89	6,800,973.92	4.46					
						353,581.03	6,800,954.52	4.41					
						353,575.61	6,800,953.17	4.40					
228	Grid	MEW-RNB-CMC	228-9	20-Sept.-99	not detected	353,558.61	6,801,006.39	4.38	a	2,300	48	b	7-Oct-99
						353,539.19	6,801,008.52	4.52					
						353,538.63	6,801,002.78	4.29					
						353,558.58	6,801,000.81	4.41					

Table III-2-A-1 (cont'd). 1999 Composite samples.

Pond	Sample type	Collector	Unique ID		Date collected	WP conc. (µg/g)	East (m)	North (m)	Elevation (m)	Type of subsample	Mass of composite (g)	Number of subsamples in composite	Analysis method	Date analyzed
Bread Truck Pond														
109	Grid	MEW-RNB-CMC	BT North 100m	Rep 1	15-Sept.-99	0.00027	354,534.49	6,801,846.36	4.74	a	3,300	92	a	13-Oct-99
				Rep 2		0.00037	354,539.94	6,801,846.02	4.68		3,300	92	a	13-Oct-99
							354,538.77	6,801,826.12	4.73					
							354,538.67	6,801,825.18	4.70					
							354,533.37	6,801,826.35	4.73					
							354,534.26	6,801,805.62	4.71					
							354,528.95	6,801,806.84	4.69					
109	Grid	MEW-RNB-CMC	BT South 100m	Rep 1	15-Sept.-99	0.000496	354,523.73	6,801,744.54	4.70	a	3,600	92	a	13-Oct-99
				Rep 2		0.00843	354,518.27	6,801,744.61	4.68		3,600	92	a	13-Oct-99
							354,518.57	6,801,724.56	4.74					
							354,524.02	6,801,724.59	4.77					
							354,524.10	6,801,704.54	4.74					
							354,518.73	6,801,704.50	4.77					
Area C Spring														
146	Grid	MEW-RNB-CMC	Canoe Pt	1	8-June-99	0.027	355,333.31	6,801,171.85	4.17	a	1800	48	a	16-Jun-99
							355,330.25	6,801,176.99	4.51					
							355,313.46	6,801,168.12	4.11					
							355,312.53	6,801,173.56	4.08					
146	Grid	MEW-RNB-CMC	Canoe Pt	2	8-June-99	7.31	355,313.46	6,801,168.12	4.11	a	1800	48	a	16-Jun-99
							355,312.53	6,801,173.56	4.08					
							355,291.82	6,801,164.47	4.08					
							355,291.34	6,801,170.11	4.22					
155	Grid	MEW-RNB-CMC	SW		7-June-99	0.451	355,104.91	6,801,538.75	4.60	a	1600	48	a	16-Jun-99
							355,108.21	6,801,534.25	4.59					
							355,124.13	6,801,546.75	4.58					
							355,120.81	6,801,551.21	4.60					
Area C Fall														
146	Grid	MEW-RNB-CMC	Canoe Pt	1	14-Sept.-99	0.00512	355,333.31	6,801,171.85	4.17	a	1,527	48	b,a	6-Oct-99
							355,330.25	6,801,176.99	4.51					
							355,313.46	6,801,168.12	4.11					
							355,312.53	6,801,173.56	4.08					
146	Grid	MEW-RNB-CMC	Canoe Pt	2	14-Sept.-99	2.68	355,313.46	6,801,168.12	4.17	a	1,783	48	b,a	6-Oct-99
							355,312.53	6,801,173.56	4.51					
							355,291.82	6,801,164.47	4.08					
							355,291.34	6,801,170.11	4.22					
155	Grid	MEW-RNB-CMC	SW	Rep 1	14-Sept.-99	0.0178	355,104.91	6,801,538.75	4.60	a	1,532	48	b,a	6-Oct-99
				Rep 2		0.0146	355,108.21	6,801,534.25	4.59		1,669	48	b,a	6-Oct-99
							355,124.13	6,801,546.75	4.58					
							355,120.81	6,801,551.21	4.60					

Table III-2-A-1 (cont'd). 1999 Composite samples.

Pond	Sample type	Collector	Unique ID		Date collected	WP conc. (µg/g)	East (m)	North (m)	Elevation (m)	Type of subsample	Mass of composite (g)	Number of subsamples in composite	Analysis method	Date analyzed
183	Grid	MEW-RNB-CMC	C100m	Rep 1	14-Sept.-99	0.0021	355,029.84	6,801,283.52	4.72	b	6,800	92	a	13-Oct-99
				Rep2	14-Sept.-99	0.0011	355,024.31	6,801,282.98	4.70		6,900	92	a	13-Oct-99
							355,019.98	6,801,311.64	4.60					
							355,025.40	6,801,312.13	4.64					
							355,024.58	6,801,317.68	4.61					
							355,033.57	6,801,318.65	4.61					
511	Grid	MEW-RNB-CMC	C Swale 1		16-Sept.-99	not detected	354,763.06	6,800,900.94	4.61	a	2,100	48	b	8-Oct-99
							354,759.07	6,800,896.99	4.60					
							354,745.29	6,800,911.55	4.54					
							354,749.43	6,800,915.48	4.56					
511	Grid	MEW-RNB-CMC	C Swale 2		16-Sept.-99	not detected	354,744.22	6,800,920.33	4.51	a	2,300	48	b	8-Oct-99
							354,746.41	6,800,925.40	4.56					
							354,727.67	6,800,933.24	4.51					
							354,725.64	6,800,928.01	4.56					
511	Grid	MEW-RNB-CMC	C Swale 3		16-Sept.-99	not detected	354,719.38	6,800,930.49	4.49	a	2,100	48	b	8-Oct-99
							354,721.72	6,800,935.55	4.50					
							354,703.35	6,800,943.86	4.60					
							354,701.03	6,800,938.79	4.62					
511	Grid	MEW-RNB-CMC	C Swale 4		16-Sept.-99	not detected	354,688.53	6,800,943.60	4.55	a	2,100	48	b	8-Oct-99
							354,690.35	6,800,948.88	4.41					
							354,672.18	6,800,956.54	4.56					
							354,669.92	6,800,951.45	4.55					
Area C/D Spring														
730	Grid	MEW-RNB-CMC	SW Lobe	1	5-June-99	not detected	354,866.42	6,801,816.54	4.41	a	1300	48	a	16-Jun-99
							354,868.13	6,801,821.92	4.38					
							354,886.88	6,801,816.95	4.49					
							354,885.87	6,801,811.50	4.14					
730	Grid	MEW-RNB-CMC	SW Lobe	2	5-June-99	not detected	354,840.69	6,801,826.94	4.61	a	1500	48	a	16-Jun-99
							354,842.66	6,801,832.03	4.51					
							354,861.84	6,801,823.51	4.48					
							354,859.09	6,801,818.71	4.49					
730	Grid	MEW-RNB-CMC	SE Lobe	1	5-June-99	not detected	354,899.62	6,801,818.29	4.43	a	1400	48	a	16-Jun-99
							354,899.41	6,801,812.91	4.17					
							354,919.67	6,801,813.17	4.47					
							354,919.70	6,801,818.49	4.45					
730	Grid	MEW-RNB-CMC	SE Lobe	2	5-June-99	not detected	354,921.60	6,801,820.29	4.50	a	1300	48	a	16-Jun-99
							354,921.69	6,801,814.78	4.45					
							354,941.87	6,801,816.03	4.47					
							354,941.57	6,801,821.45	4.48					

Table III-2-A-1 (cont'd). 1999 Composite samples.

Pond	Sample type	Collector	Unique ID		Date collected	WP conc. (µg/g)	East (m)	North (m)	Elevation (m)	Type of subsample	Mass of composite (g)	Number of subsamples in composite	Analysis method	Date analyzed
730	Grid	MEW-RNB-CMC	SE Lobe	3	5-June-99	not detected	354,943.49 354,945.58 354,964.26 354,962.13	6,801,821.35 6,801,816.61 6,801,824.25 6,801,829.34	4.47 4.50 4.52 4.53	a	1500	48	a	16-Jun-99
730	Grid	MEW-RNB-CMC	Main Lobe	1	5-June-99	not detected	354,893.50 354,893.72 354,872.66 354,873.49	6,801,826.42 6,801,820.83 6,801,822.64 6,801,828.01	4.47 4.60 4.53 4.54	a	1500	48	a	16-Jun-99
730	Grid	MEW-RNB-CMC	Main Lobe	2	5-June-99	not detected	354,869.11 354,868.61 354,888.83 354,889.10	6,801,845.94 6,801,840.44 6,801,845.50 6,801,839.94	4.63 4.51 4.51 4.47	a	1900	48	a	16-Jun-99
730	Grid	MEW-RNB-CMC	Main Lobe	3	5-June-99	not detected	354,894.29 354,894.15 354,874.37 354,873.98	6,801,872.28 6,801,866.69 6,801,873.23 6,801,867.65	4.50 4.53 4.51 4.54	a	1700	48	a	16-Jun-99
730	Grid	MEW-RNB-CMC	Main Lobe	4	5-June-99	not detected	354,875.66 354,873.63 354,894.63 354,892.44	6,801,911.21 6,801,905.99 6,801,903.64 6,801,898.72	4.62 4.63 4.63 4.58	a	1700	48	a	16-Jun-99
730	Grid	MEW-RNB-CMC	Main Lobe	5	5-June-99	not detected	354,906.61 354,904.22 354,889.50 354,886.79	6,801,924.39 6,801,919.27 6,801,934.34 6,801,929.54	4.65 4.64 4.52 4.50	a	2100	48	a	16-Jun-99
Area C/D and Coastal East Fall														
90	Grid	MEW-RNB-CMC	CD-1		15-Sept.-99	not detected	354,882.76 354,886.53 354,871.94 354,868.08	6,801,948.66 6,801,952.54 6,801,966.17 6,801,962.38	4.48 4.47 4.58 4.42	a	2,100	48	b	8-Oct-99
no #	Grid	MEW-RNB-CMC	CD-2		15-Sept.-99	not detected	354,827.51 354,815.15 354,810.73 354,823.22	6,802,064.99 6,802,080.52 6,802,077.15 6,802,061.39	4.56 4.48 4.51 4.54	a	2,000	48	b	8-Oct-99
no #	Grid	MEW-RNB-CMC	CD-3		15-Sept.-99	not detected	354,810.51 354,806.87 354,791.11 354,794.73	6,802,055.14 6,802,050.83 6,802,063.45 6,802,067.85	4.42 4.54 4.53 4.53	a	2,500	48	b,a	8-Oct-99

Table III-2-A-1 (cont'd). 1999 Composite samples.

Pond	Sample type	Collector	Unique ID	Date collected	WP conc. (µg/g)	East (m)	North (m)	Elevation (m)	Type of subsample	Mass of composite (g)	Number of subsamples in com-posite	Analysis method	Date analyzed
75	Grid	MEW-RNB-CMC	CD-4	15-Sept.-99	0.0288	354,780.50 354,777.12 354,760.78 354,763.81	6,802,077.75 6,802,073.27 6,802,085.09 6,802,089.69	4.57 4.54 4.54 4.46	a	2,400	48	b,a	8-Oct-99
78	Grid	MEW-RNB-CMC	CD-5	15-Sept.-99	not detected	354,776.31 354,773.53 354,756.40 354,759.37	6,802,040.87 6,802,035.91 6,802,046.41 6,802,051.23	4.59 4.56 4.57 4.57	a	2,100	48	b,a	8-Oct-99
no #	Grid	MEW-RNB-CMC	CD-6	15-Sept.-99	not detected	354,761.87 354,760.93 354,780.76 354,781.50	6,802,028.97 6,802,023.51 6,802,020.60 6,802,026.03	4.58 4.59 4.56 4.58	a	2,100	48	b	8-Oct-99
76	Grid	MEW-RNB-CMC	CD-7	15-Sept.-99	not detected	354,706.98 354,706.83 354,686.73 354,686.76	6,802,053.61 6,802,047.94 6,802,048.61 6,802,054.05	4.51 4.60 4.58 4.39	a	2,100	48	b	8-Oct-99
no #	Grid	MEW-RNB-CMC	CD-8	16-Sept.-99	not detected	354,735.75 354,739.74 354,753.32 354,748.76	6,802,011.21 6,802,015.06 6,801,999.05 6,801,995.86	4.51 4.54 4.54 4.52	a	2,100	48	b	8-Oct-99
no #	Grid	MEW-RNB-CMC	CD-9	16-Sept.-99	not detected	354,782.61 354,786.31 354,772.76 354,768.76	6,801,971.77 6,801,967.75 6,801,952.88 6,801,956.74	4.58 4.57 4.58 4.53	a	2,100	48	b,a	8-Oct-99
no #	Grid	MEW-RNB-CMC	CD-10	16-Sept.-99	not detected	354,756.75 354,762.06 354,757.30 354,751.72	6,801,946.30 6,801,944.85 6,801,925.35 6,801,926.67	4.61 4.61 4.60 4.58	a	2,000	48	b	8-Oct-99
no #	Grid	MEW-RNB-CMC	CD-11	16-Sept.-99	not detected	354,747.60 354,745.60 354,727.17 354,729.40	6,801,914.78 6,801,909.57 6,801,917.55 6,801,922.62	4.56 4.61 4.68 4.54	a	2,100	48	b	8-Oct-99
no #	Grid	MEW-RNB-CMC	CD-12	16-Sept.-99	not detected	354,682.54 354,680.35 354,661.87 354,664.24	6,801,926.22 6,801,921.06 6,801,929.06 6,801,934.05	4.54 4.64 4.67 4.61	a	2,100	48	b	8-Oct-99
87	Grid	MEW-RNB-CMC	CD-13	16-Sept.-99	not detected	354,677.63 354,673.54 354,659.15 354,663.19	6,801,940.76 6,801,936.81 6,801,950.93 6,801,954.92	4.67 4.71 4.67 4.66	a	2,100	48	b	8-Oct-99

Table III-2-A-1 (cont'd). 1999 Composite samples.

Pond	Sample type	Collector	Unique ID	Date collected	WP conc. (µg/g)	East (m)	North (m)	Elevation (m)	Type of subsample	Mass of composite (g)	Number of subsamples in com-posite	Analysis method	Date analyzed
85	Grid	MEW-RNB-CMC	85-1	22-Sept.-99	not detected	354,929.27 354,932.46 354,949.41 354,945.89	6,801,884.30 6,801,888.95 6,801,877.11 6,801,872.94	4.28 4.34 4.35 4.32	a	2,800	48	b	8-Oct-99
85	Grid	MEW-RNB-CMC	85-2	22-Sept.-99	not detected	354,952.21 354,951.14 354,970.28 354,971.80	6,801,893.84 6,801,899.09 6,801,905.41 6,801,900.13	4.34 4.40 4.37 4.32	a	2,400	48	b	8-Oct-99
730	Line	MEW-RNB-CMC	730SW -Stinky Ditch	15-Sept.-99	not detected	354,875.14 354,826.48	6,801,801.92 6,801,790.61	4.08 4.18	a	2,700	52	b	8-Oct-99
112	Line	MEW-RNB-CMC	112	22-Sept.-99	not detected	355,039.87 355,104.62	6,801,909.12 6,801,944.53	4.23 4.23	scoop-shovel	1,900	38	b	8-Oct-99
Racine Island													
680	Grid	MEW-RNB-CMC	RI 1	22-Sept.-99	not detected	355,197.58 355,194.78 355,212.45 355,216.23	6,800,021.44 6,800,026.21 6,800,035.87 6,800,032.15	4.74 4.70 4.73 4.63	a	2,500	48	b	8-Oct-99
680	Grid	MEW-RNB-CMC	RI 2	22-Sept.-99	not detected	355,225.22 355,215.83 355,220.67 355,230.33	6,800,031.72 6,800,049.04 6,800,052.11 6,800,034.44	4.62 4.65 4.66 4.55	a	2,400	48	b	8-Oct-99
680	Grid	MEW-RNB-CMC	RI 3	22-Sept.-99	not detected	355,236.22 355,241.80 355,243.06 355,237.44	6,800,022.80 6,800,023.48 6,800,003.51 6,800,003.20	4.59 4.63 4.66 4.66	a	2,300	48	b	8-Oct-99
680	Grid	MEW-RNB-CMC	RI 4	22-Sept.-99	not detected	355,222.49 355,223.64 355,205.58 355,204.57	6,799,988.79 6,799,983.24 6,799,979.87 6,799,985.32	4.64 4.65 4.68 4.63	a	1,700	44	b	8-Oct-99
680	Grid	MEW-RNB-CMC	RI 5	22-Sept.-99	not detected	355,221.19 355,221.51 355,201.51 355,201.14	6,800,010.40 6,800,004.75 6,800,003.33 6,800,008.92	4.63 4.67 4.67 4.67	a	2,000	48	b	8-Oct-99

Type of Subsample: a) Discrete Core (Oakfield); b)Discrete Core (50 cc syringe)
Analysis Method: a) Solvent Extraction and GC; b) SPME and GC

Table III-2-A-2. 1999 Discrete samples and subsurface samples.

Pond	Sample type	Collector	Unique ID		Date collected	WP conc. (µg/g)	East (m)	North (m)	Elevation (m)	Date analyzed
Area C										
183	Discrete	MEW-RNB	R4C1	Pen 5	22-Sept.-99	not detected	355,034.80	6,801,299.00		14-Oct-99
183	Discrete	MEW-RNB	R4C2	Pen 5	22-Sept.-99	0.00042	355,036.00	6,801,300.50		14-Oct-99
183	Discrete	MEW-RNB	R4C3	Pen 5	22-Sept.-99	not detected	355,037.30	6,801,301.50		14-Oct-99
183	Discrete	MEW-RNB	R4C4	Pen 5	22-Sept.-99	not detected	355,038.50	6,801,303.00		14-Oct-99
183	Discrete	MEW-RNB	R5C1	Pen 5	22-Sept.-99	not detected	355,033.60	6,801,300.50		14-Oct-99
183	Discrete	MEW-RNB	R5C2	Pen 5	22-Sept.-99	0.00061	355,034.80	6,801,301.50		14-Oct-99
183	Discrete	MEW-RNB	R5C3	Pen 5	22-Sept.-99	0.00103	355,036.00	6,801,303.00		14-Oct-99
183	Discrete	MEW-RNB	R5C4	Pen 5	22-Sept.-99	not detected	355,037.30	6,801,304.50		14-Oct-99
183	Discrete	MEW-RNB	R6C1	Pen 5	22-Sept.-99	not detected	355,032.30	6,801,301.50		14-Oct-99
183	Discrete	MEW-RNB	R6C2	Pen 5	22-Sept.-99	not detected	355,033.60	6,801,303.00		14-Oct-99
183	Discrete	MEW-RNB	R6C3	Pen 5	22-Sept.-99	not detected	355,034.80	6,801,304.50		14-Oct-99
183	Discrete	MEW-RNB	R6C4	Pen 5	22-Sept.-99	not detected	355,036.00	6,801,305.50		14-Oct-99
183	Discrete	MEW-RNB	R7C1	Pen 5	22-Sept.-99	0.0024	355,031.09	6,801,303.00		14-Oct-99
183	Discrete	MEW-RNB	R7C2	Pen 5	22-Sept.-99	not detected	355,032.30	6,801,304.50		14-Oct-99
183	Discrete	MEW-RNB	R7C3	Pen 5	22-Sept.-99	not detected	355,033.60	6,801,305.50		14-Oct-99
183	Discrete	MEW-RNB	R7C4	Pen 5	22-Sept.-99	0.035	355,034.80	6,801,307.00		14-Oct-99
183	Discrete	MEW-RNB	R8C1	Pen 5	22-Sept.-99	0.00238	355,029.90	6,801,304.50		14-Oct-99
183	Discrete	MEW-RNB	R8C2	Pen 5	22-Sept.-99	not detected	355,031.10	6,801,305.50		14-Oct-99
183	Discrete	MEW-RNB	R8C3	Pen 5	22-Sept.-99	not detected	355,032.30	6,801,307.00		14-Oct-99
183	Discrete	MEW-RNB	R8C4	Pen 5	22-Sept.-99	0.0093	355,033.60	6,801,308.50		14-Oct-99
183	Discrete	MEW-RNB	R9C1	Pen 5	22-Sept.-99	not detected	355,028.60	6,801,305.50		14-Oct-99
183	Discrete	MEW-RNB	R9C2	Pen 5	22-Sept.-99	not detected	355,029.90	6,801,307.00		14-Oct-99
183	Discrete	MEW-RNB	R9C3	Pen 5	22-Sept.-99	not detected	355,031.10	6,801,308.50		14-Oct-99
183	Discrete	MEW-RNB	R9C4	Pen 5	22-Sept.-99	not detected	355,032.30	6,801,309.50		14-Oct-99
183	Discrete	MEW-RNB	R10C1	Pen 5	22-Sept.-99	not detected	355,027.40	6,801,307.00		14-Oct-99
183	Discrete	MEW-RNB	R10C2	Pen 5	22-Sept.-99	0.0029	355,028.60	6,801,308.50		14-Oct-99
183	Discrete	MEW-RNB	R10C3	Pen 5	22-Sept.-99	0.0363	355,029.90	6,801,309.50		14-Oct-99
183	Discrete	MEW-RNB	R10C4	Pen 5	22-Sept.-99	0.00033	355,031.10	6,801,311.00		14-Oct-99
183	Discrete	MEW-RNB	R11C1	Pen 5	22-Sept.-99	0.00018	355,026.20	6,801,308.50		14-Oct-99
183	Discrete	MEW-RNB	R11C2	Pen 5	22-Sept.-99	not detected	355,027.40	6,801,309.50		14-Oct-99
183	Discrete	MEW-RNB	R11C3	Pen 5	22-Sept.-99	0.00798	355,028.60	6,801,311.00		14-Oct-99
183	Discrete	MEW-RNB	R11C4	Pen 5	22-Sept.-99	not detected	355,029.90	6,801,312.50		14-Oct-99
183	Discrete	MEW-RNB	R12C1	Pen 5	22-Sept.-99	0.00087	355,024.90	6,801,309.50	4.64	14-Oct-99
183	Discrete	MEW-RNB	R12C2	Pen 5	22-Sept.-99	not detected	355,026.20	6,801,311.00		14-Oct-99
183	Discrete	MEW-RNB	R12C3	Pen 5	22-Sept.-99	not detected	355,027.40	6,801,312.50		14-Oct-99
183	Discrete	MEW-RNB	R12C4	Pen 5	22-Sept.-99	not detected	355,028.60	6,801,313.50	4.63	14-Oct-99
164	Oakfield core to 20 cm depth	MEW-RNB	Miller's Hole Core 1 Top Half		22-Sept.-99	0.00084	355,066.90	6,801,176.50	4.45	13-Oct-99
164	Oakfield core to 20 cm depth	MEW-RNB	Miller's Hole Core 1 Bottom Half		22-Sept.-99	0.00119	355,066.90	6,801,176.50	4.45	13-Oct-99
164	Oakfield core to 20 cm depth	MEW-RNB	Miller's Hole Core 2 Top Half		22-Sept.-99	0.00027	355,066.90	6,801,176.50	4.45	13-Oct-99
164	Oakfield core to 20 cm depth	MEW-RNB	Miller's Hole Core 2 Bottom Half		22-Sept.-99	0.00157	355,066.90	6,801,176.50	4.45	13-Oct-99
146	Subsurface	RNB-MEW	53	Surface	9-June-99	1.43	355,329.90	6,801,173.90		15-Jun-99
146	Subsurface	RNB-MEW	53	5 cm	9-June-99	1.16				15-Jun-99
146	Subsurface	RNB-MEW	53	10 cm	9-June-99	0.003				15-Jun-99

Table III-2-A-2 (cont'd). 1999 Discrete samples and subsurface samples.

Pond	Sample type	Collector	Unique ID		Date collected	WP conc. (µg/g)	East (m)	North (m)	Elevation (m)	Date analyzed
146	Subsurface	RNB-MEW	53	15 cm	9-June-99	0.020				15-Jun-99
146	Subsurface	RNB-MEW	53	20 cm	9-June-99	0.116				15-Jun-99
146	Subsurface	RNB-MEW	53	25 cm	9-June-99	0.015				15-Jun-99
146	Subsurface	RNB-MEW	53	30 cm	9-June-99	0.016				15-Jun-99
146	Subsurface	RNB-MEW	53	0 to 30 cm	9-June-99	9.6				15-Jun-99
183	Subsurface	RNB-MEW	240	Surface	9-June-99	not detected	354,999.40	6,801,322.38	4.55	15-Jun-99
183	Subsurface	RNB-MEW	240	5 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	240	10 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	240	15 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	240	20 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	240	25 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	240	30 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	240	0 to 30 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	549	Surface	9-June-99	not detected	355,021.39	6,801,365.68	4.65	15-Jun-99
183	Subsurface	RNB-MEW	549	5 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	549	10 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	549	15 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	549	20 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	549	25 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	549	30 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	549	0 to 30 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	381	Surface	9-June-99	not detected	355,050.00	6,801,393.89	4.68	15-Jun-99
183	Subsurface	RNB-MEW	381	5 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	381	10 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	381	15 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	381	20 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	381	25 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	381	30 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	381	0 to 30 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	547	Surface	9-June-99	not detected	355,088.80	6,801,363.00		15-Jun-99
183	Subsurface	RNB-MEW	547	5 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	547	10 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	547	15 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	547	20 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	547	25 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	547	30 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	547	0 to 30 cm	9-June-99	not detected				
183	Subsurface	RNB-MEW	230	Surface	9-June-99	not detected	355,152.90	6,801,380.70	4.65	15-Jun-99
183	Subsurface	RNB-MEW	230	5 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	230	10 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	230	15 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	230	20 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	230	25 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	230	30 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	230	0 to 30 cm	9-June-99	not detected				15-Jun-99

Table III-2-A-2 (cont'd). 1999 Discrete samples and subsurface samples.

Pond	Sample type	Collector	Unique ID		Date collected	WP conc. (µg/g)	East (m)	North (m)	Elevation (m)	Date analyzed
183	Subsurface	RNB-MEW	615	Surface	9-June-99	not detected	355,204.98	6,801,314.37	4.55	15-Jun-99
183	Subsurface	RNB-MEW	615	5 cm	9-June-99	0.00084				15-Jun-99
183	Subsurface	RNB-MEW	615	10 cm	9-June-99	0.00301				15-Jun-99
183	Subsurface	RNB-MEW	615	15 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	615	20 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	615	25 cm	9-June-99	0.00177				15-Jun-99
183	Subsurface	RNB-MEW	615	30 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	547 - 20 m W	Surface	9-June-99	not detected	355,068.77	6,801,362.92	4.66	15-Jun-99
183	Subsurface	RNB-MEW	547 - 20 m W	5 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	547 - 20 m W	10 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	547 - 20 m W	15 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	547 - 20 m W	20 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	547 - 20 m W	25 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	547 - 20 m W	30 cm	9-June-99	not detected				15-Jun-99
183	Subsurface	RNB-MEW	547 - 20 m W	0 to 30 cm	9-June-99	not detected				15-Jun-99
BT Pond										
BT Gully	Discrete	RNB-MEW	West Lobe	1	7-June-99	not detected	354,551.29	6,801,811.17	4.46	16-Jun-99
BT Gully	Discrete	RNB-MEW	SE Lobe	2	7-June-99	not detected	354,570.00	6,801,807.51	4.40	16-Jun-99
BT Gully	Discrete	RNB-MEW	East Lobe	3	7-June-99	not detected	354,590.68	6,801,833.32	4.60	16-Jun-99
BT Gully	Discrete	Sherri Butters	Smoke	0 (next to round)	9-June-99	67.6	354,590.00	6,801,834.50		16-Jun-99
BT Gully	Discrete	RNB-MEW	Smoke	1	9-June-99	0.041	354,585.00	6,801,834.50		16-Jun-99
BT Gully	Discrete	RNB-MEW	Smoke	2	9-June-99	0.0027	354,580.00	6,801,834.50		16-Jun-99
BT Gully	Discrete	RNB-MEW	Smoke	3	9-June-99	0.0007	354,575.00	6,801,834.50		16-Jun-99
BT Gully	Discrete	RNB-MEW	Smoke	4 (main ditch)	9-June-99	not detected	354,572.96	6,801,837.35		16-Jun-99

III-3. COMPOSITE SAMPLING AND ANALYSIS FOR WHITE PHOSPHORUS IN UNTREATED PONDS

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INTRODUCTION

During the initial effort (1990–1992) to locate white phosphorus contaminated ponds at ERF, sediment sampling was integrated with a waterfowl observation study. Avian ecologists watched for early signs of white phosphorus poisoning among flocks of dabbling ducks. With this approach, Area C (Ponds 183 and 146) and the Bread Truck Pond were quickly recognized as principal sources of poisoning (Fig. III-3-1). In these two frequently used waterfowl feeding areas, predation rates, carcass counts, and crater densities were high, and white phosphorus was found in many of the sediment samples collected. High carcass counts, crater densities, and white phosphorus concentrations were also co-located in Ponds 293 and 297 on Racine Island. Although these small ponds were never recognized as prime waterfowl feeding locations, the concentrations of white phosphorus were so high that most birds that fed here were probably poisoned. Because of the certain relationship between high white phosphorus concentrations and high rates of waterfowl poisonings, Area C was drained by pumping and Racine Island and Bread Truck pond were drained by ditching.

The significance of Areas A and C/D (Fig. III-3-1, III-3-2) as sources of waterfowl poisoning is less clear. White phosphorus has been detected in the permanent ponds of both areas, but concentrations and detection frequencies have been low. Both areas contain extensive bulrush marsh that makes each area very attractive to waterfowl. The clues that led us to hot spots in Area C, the Bread Truck Pond, and Racine Island are absent in Areas A and C/D. In Area A, crater density is highest on

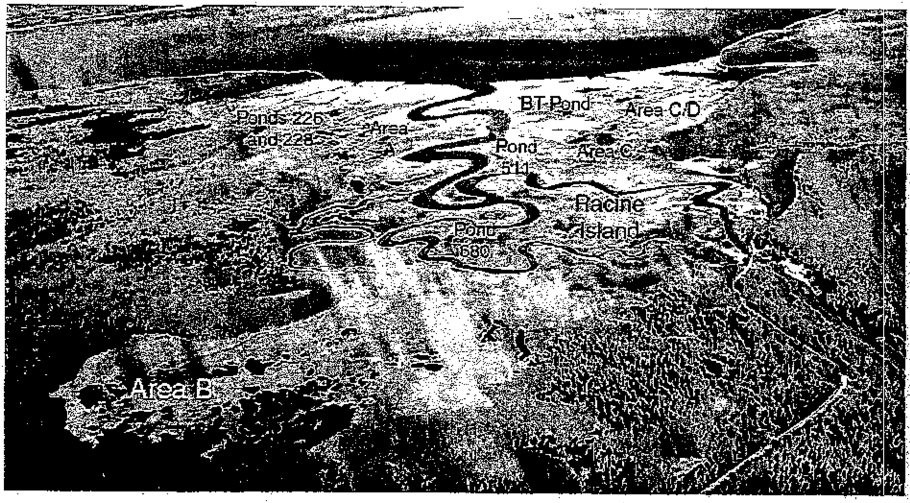

Figure III-3-1. Aerial oblique color-infrared photo looking N of Eagle River Flats, 17 August 1999.

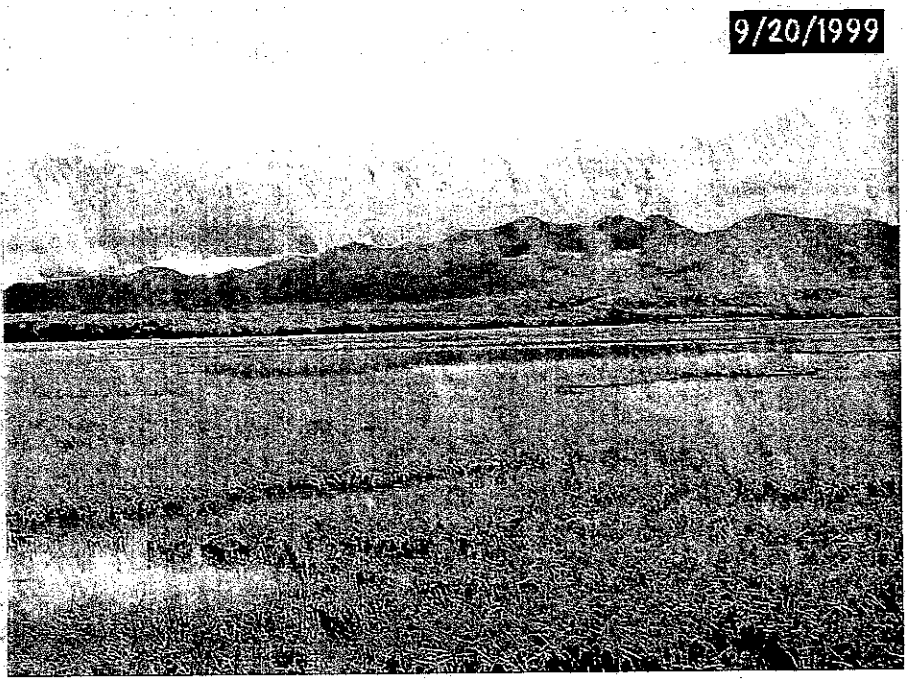

Figure III-3-2. Looking across to Pond 226 from west showing pond marsh complex in Northern Area A.

the mudflat and in the intermittent ponds that are to the east of the permanent ponds. Area C/D, which is in the buffer zone of the impact area, has low crater density. However, even if the permanent ponds were not bombarded by white phosphorus shells, isolated hotspots may be present because of the proximity of the permanent ponds to neighboring heavily impacted areas. Mortality of telemetry birds with confirmed white phosphorus in their gizzards indicates that such hotspots may exist in Area C/D and possibly Area A.

METHODS

We collected composite samples consisting of 31-mL subsamples taken at the nodes of a 1.82-m square grid. Each composite was made up of a maximum of 48 subsamples that we collected to a depth of 10 cm using an Oakfield corer. The outside dimensions of each gridded area was 5.46 m wide and up to 20.02 m long. The spacing between composite samples was governed by the shapes of the ponds.

C/D and Coastal East

Most of the ponds of Area C/D are not well defined (Fig. III-3-3). The ponds are located within a marsh complex and the boundaries of the ponds have changed since they were first mapped in 1996. Part of this change may be attributable to altered hydrology resulting from the ditch in the Bread Truck Pond to the west. Vegetation growth and beaver activity have also altered the pond dimensions.

We collected 13 composite samples in open water habitats north and west of Pond 730 (Fig. III-3-3) in a previously unsampled area. We reasoned that locations closer to the Bread Truck Pond and target would more likely be contaminated than locations closer to the shore (buffer zone). Most of the samples were not within previously mapped ponds.

We also collected samples from Ponds 85 and 112, both of which were designated as hot ponds in the *Remedial Investigation Report* (CH2MHill 1997). The open water area of Pond 85 has decreased markedly since the pond was mapped in 1996. Most of what was mapped as open water in 1996 is now vegeta-

Figure III-3-3. Aerial color-infrared photo of Area C/D (17 August 1999), showing locations of composite samples taken in 1999.

tion. We were able to collect two 5.46- × 20.02-m grid composites from this pond. Pond 112 was too deep to sample with the Oakfield corer. We sampled from the pond edge using the 250-mL long-handled scoop originally designed for the post-dredge sampling (M.R. Walsh and Collins 1997).

Pond 511 (C Swale)

Pond 511 is located on the west side of Area C (Fig. III-3-1, III-3-4, and III-3-5) near the Eagle River. Although this pond is not permanently flooded, white phosphorus contamination was found within the pond in 1992 (sample 1095, 0.14 µg/g). We sampled here because we observed ducks using this pond and we wanted to determine if white phosphorus was still detectable. We collected four composite samples, each containing 48 subsamples.

Pond 680 (Racine Island)

Pond 680 is located on Racine Island (Fig. III-3-1 and III-3-6) and was not previously sampled. The pond's location on Racine Island, where severely contaminated ponds were found, prompted us to sample there. Five composite samples, each composed of 48 subsamples, were collected.

Pond 226 and 228 (Northern A)

Ponds 226 (0.54 ha) and 228 (0.74 ha) (Fig. III-3-1 and III-3-7) were both designated as hot ponds in the *Remedial Investigation Report* (CH2MHill 1997). Because white phosphorus was detected previously in discrete samples in Pond 226, we intensively sampled this pond (23 composite samples) in an effort to find hotspots.

Pond 228 was not sampled previously, probably because water depth was too great to allow access on foot. Pumping of ponds in Area A to the south appeared to draw down the water to allow us to collect nine composite samples.

RESULTS AND DISCUSSION

C/D and Coastal East

Of the 13 composite samples we collected to the north and west of Pond 730, only one

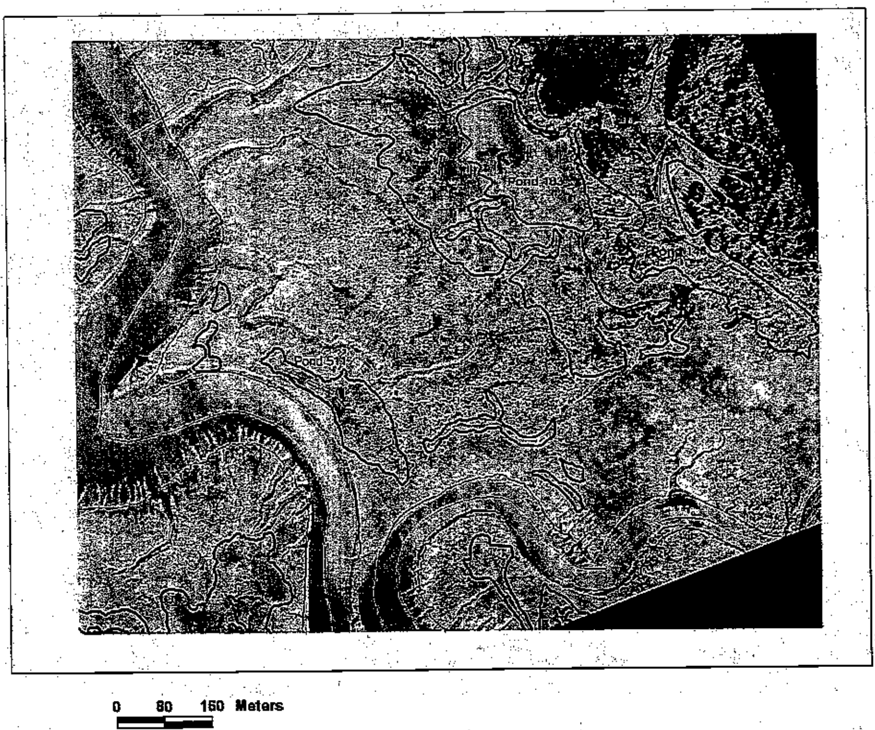

Figure III-3-4. Aerial color-infrared photo of Area C, showing locations of composite samples 1997 to 1999.

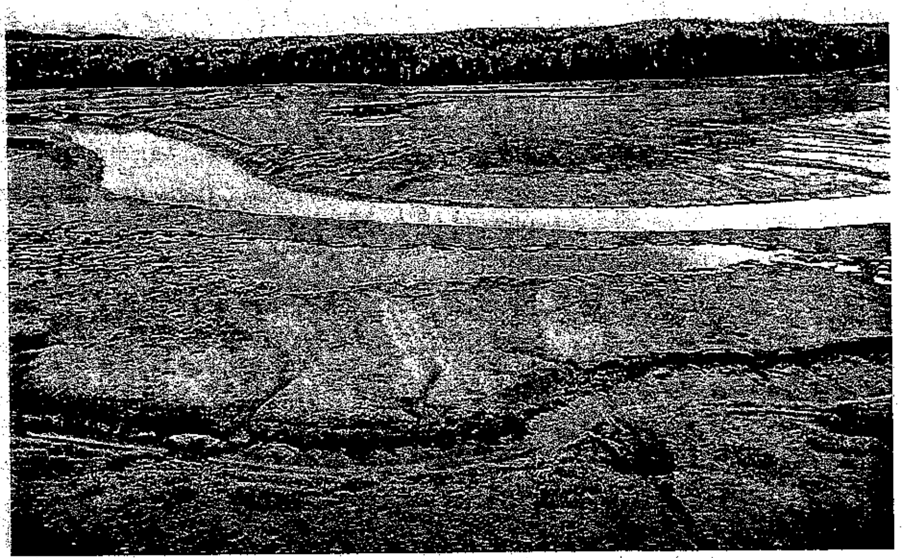

Figure III-3-5. Aerial oblique view of Pond 511 looking west. B-Gully is in the foreground, roughly paralleling Pond 511 and the Eagle River. Area A is in the background.

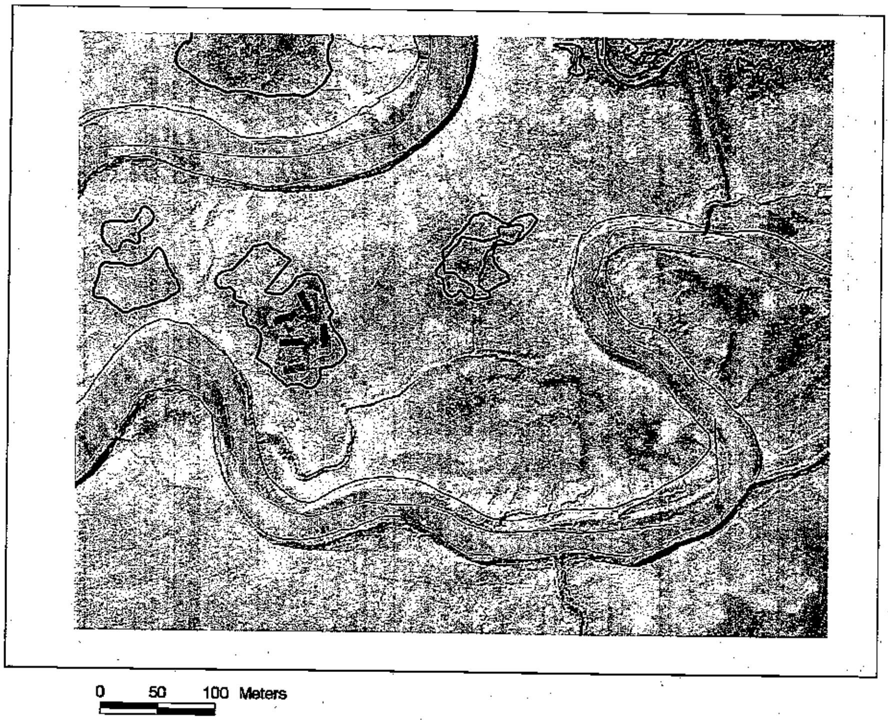

Figure III-3-6. Aerial color-infrared photo of the west side of Racine Island, showing location of composite samples (shown as dark rectangles) in Pond 680 (left side of photo). The drainage ditch is on the right of the photo. Outlines of mapped ponds are shown as dark lines.

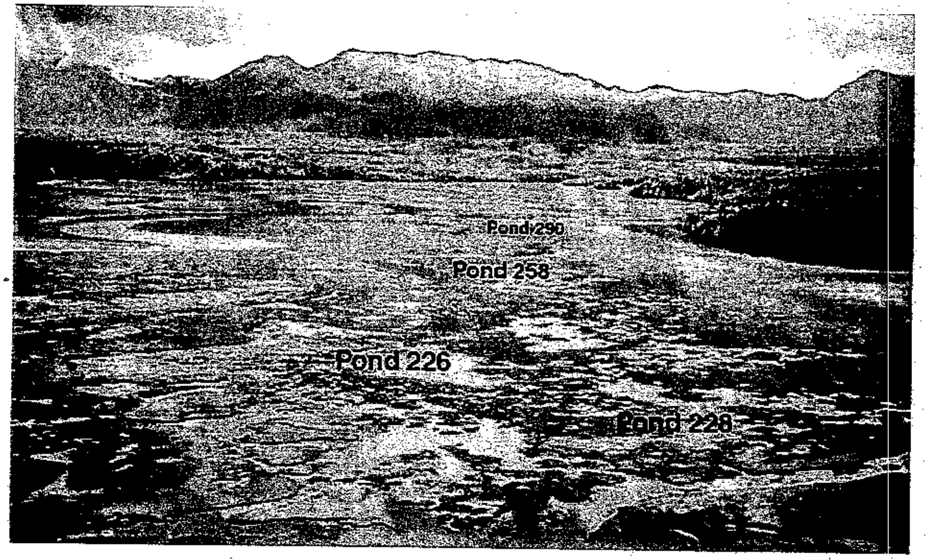

Figure III-3-7. Aerial view (September 1999) of Area A, looking south, showing ponds 226 and 228 in foreground.

was positive. Sample CD4 (Fig. III-3-3 and III-3-8) was located within Pond 75 and the concentration was sufficiently high to be of concern. Maximum possible concentration for a subsample within a composite sample can be calculated by multiplying the composite sample concentration by the number of subsamples making up the composite. Given that the composite concentration was 0.03 µg/g and that there were 48 subsamples, the maximum possible concentration in a subsample would be 1.4 µg/g. Previously, we have observed that sediment samples with white phosphorus concentrations above 1 µg/g frequently contain macroscopic white phosphorus particles, the form lethal to waterfowl.

Further sampling of the C/D area appears to be necessary, on the basis of the number of telemetry mallard mortalities in this area that had white phosphorus in their gizzards. Sampling and remediation of C/D are difficult, owing to the non-contiguous pattern of both open water and contamination.

Pond 511 (C Swale)

Waterfowl were using Pond 511 as we approached to sample the sediment. The pond was so shallow that the surface sediment was grooved where ducks had slid along on their undersides.

The open water area of this pond was also less than what was originally mapped. We collected four grid composites along the long axis bisecting present open water area. None of the composites had detectable white phosphorus.

Pond 680 (Racine Island)

Pond 680 is also a shallow pond (Fig. III-3-6 and III-3-9), and the sediment was consolidated, leading us to believe that the pond dries out periodically. White phosphorus was not detected in any of the five composite samples collected.

Pond 226 and 228 (Northern A)

Ponds 226 and 228 were both difficult to sample because of unconsolidated sediment and deep water (up to 50 cm). White phosphorus was previously detected in discrete samples taken from Pond 226 and, while we were sampling, we discovered three waterfowl skeletons in the vegetation surrounding

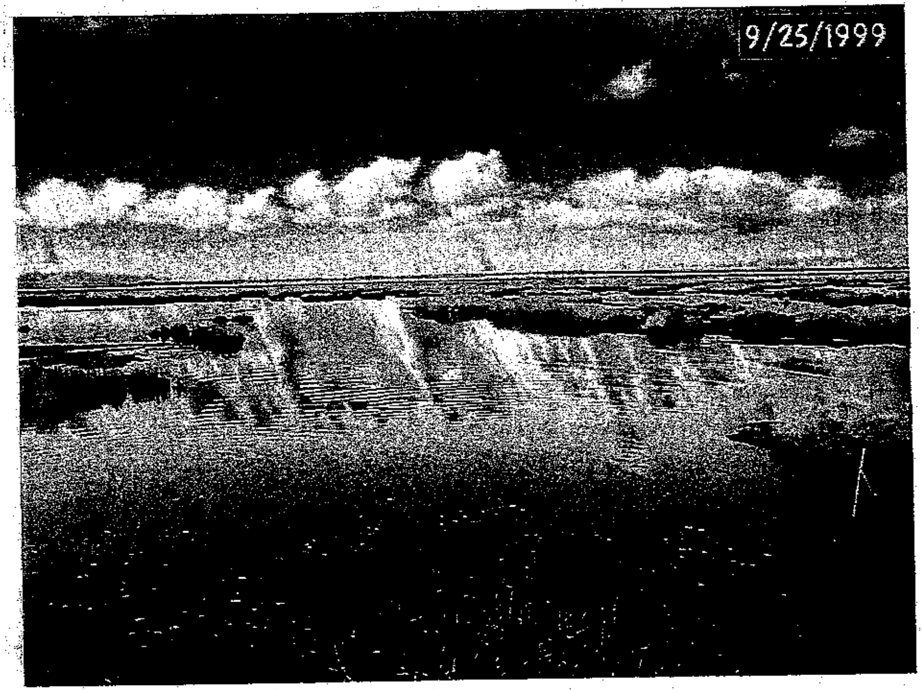

Figure III-3-8. Ground view of Pond 75, from which a positive (0.03 µg/g) composite sample was collected in Area C/D–Coastal East.

9/20/1999

Figure III-3-9. Ground view of Pond 680 on Racine Island with Sherri Butters clearing of ordnance.

the ponds. Of the 23 composite samples we collected from Pond 226, one was positive in the middle of the pond (0.006 µg/g) (Fig. III-3-10). None of the samples in Pond 228 were positive.

The pattern of contamination in these two ponds was typical of what we have found in the permanent ponds of Area A: white phosphorus is sporadically found at low concentrations.

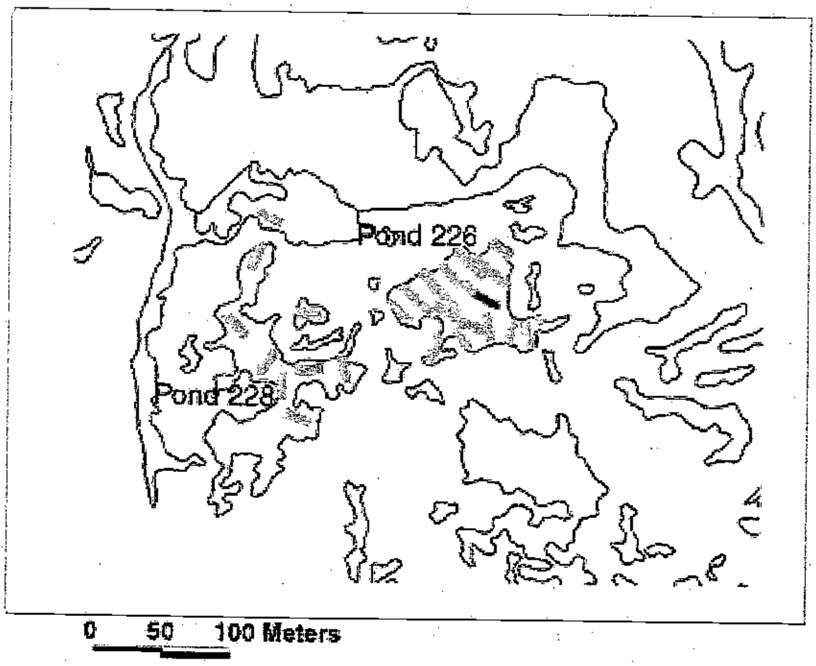

Figure III-3-10. Map of Northern Area A Ponds 226 and 228, showing composite samples taken in 1999. Only one sample had detectable white phosphorus (location shown as red or darker rectangle in Pond 226).

CONCLUSIONS

At many remediation projects, the residual contamination that remains after the bulk has been removed is often the most difficult to address. At Eagle River Flats, we have located and are treating areas where contamination was severe and widespread. However, isolated pockets of contamination may still be present in relatively clean areas. Ducks that are obligated to feed in the sediment unfortunately may encounter these hotspots.

Our composite sampling in Areas A and C/D show that contamination is present but sporadic. Only two samples were positive. One positive sample was in Pond 75 and the other was in Pond 226 (Area A). Because significant mortality of telemetry mallards appears to be linked to Area C/D and the bulrush marsh of northern C, future sampling efforts will concentrate in these areas. Future sampling locations in Area A are harder to determine.

REFERENCES

CH2MHill (1997) Operable Unit C, Final Remedial Investigation Report, Fort Richardson, Alaska. Prepared for U.S. Army Alaska, Directorate of Public Works.

III-4. 1999 WEATHER DATA FOR EAGLE RIVER FLATS

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INTRODUCTION

Weather is one of the two main driving forces affecting almost all physical and biological processes in Eagle River Flats, the other being the tides. Both phenomena determine how effective cleanup procedures will be that depend on natural drying of pond bottom sediments. To quantify local weather conditions in Eagle River Flats and determine their effect on potential remediation strategies, a meteorological data station was installed at the edge of the EOD pad in May 1994 (Haugen 1995) and air temperature, radiation, precipitation, and evaporation data have been collected every summer since then. In 1998 the meteorological station was revamped with a new, higher 4-m tower and updated sensors and data collection procedures (Collins 1999). We wanted to automate the data collection procedure so that timely meteorological data were made available to all the personnel conducting research in ERF. Via a cell phone connection, the data were downloaded automatically each day to a computer at CRREL-Hanover. Additionally, dataloggers installed in several of the ponds being treated in ERF were linked to the meteorological station by radio telemetry so that soil moisture conditions could also be monitored remotely. The data from the four remote sites were transmitted to the meteorological station, stored, and then transmitted daily along with the meteorological data. The daily meteorological data and the data from the treated ponds were displayed on the Eagle River Flats Web Page, linked to the CRREL Public Web site (Collins 1999).

METEOROLOGICAL STATION

The meteorological station is located on a small gravel pad extending into the salt marsh off the edge of the EOD pad. A 4-m tower allows the wind speed and direction instrumentation to be placed high enough to be above any effects caused by the edge of the nearby EOD pad. The 4-m guyed tower has a wind anemometer that records wind direction and speed mounted on top, air temperature and relative humidity sensors located at 2- and 0.5-m heights, and incoming and reflected radiation sensors. A white fiberglass enclosure contains the Campbell Scientific CR10 datalogger and storage module, a modem, a radio receiver, and a cell phone. The radio receiver allowed communications between the station and four remote datalogger sites located in treated ponds. The modem and the cell phone allowed the meteorological data to be downloaded daily from the datalogger and transferred to a computer server at CRREL-Hanover. The antenna for the radio receiver linking the remote dataloggers at the sediment monitoring sites is attached to the top of the 4-m tower, along with an antenna for the cell phone. A precipitation gage is located on a separate stand, 3 m to the east of the tower. A standard 1.22-m (48-in.) diameter evaporation pan is located 3 m to the west of the tower. A Druck pressure transducer

Table III-4-1. Summary of meteorological station instruments and the parameters measured.

Instrument	*Parameter measured*
R.M. Young Wind Anemometer, 4 m height	Average wind speed (m/s) Average wind direction (m/s) Peak wind speed (m/s) Time of peak wind speed
(2) Air temperature sensors, 2 m & 0.5 m heights	Average 2 m temperature (°C) Maximum 2 m temperature (°C) Minimum 2 m temperature (°C) Average 0.5 m temperature (°C) Maximum 0.5 m temperature (°C) Minimum 0.5 m temperature (°C)
(2) Relative Humidity sensors, 2 m & 0.5 m heights	Average 2 m relative humidity (%) Maximum 2 m relative humidity (%) Minimum 2 m relative humidity (%) Average 0.5 m relative humidity (%) Maximum 0.5 m relative humidity (%) Minimum 0.5 m relative humidity (%)
(2) Epply radiation (0.3-3 μm) sensors, incident & reflected	Average short wave incident radiation (W/m^2) Average short wave reflected radiation (W/m^2)
Tipping bucket rain gage	Tipping bucket 15-min precipitation (mm) Tipping bucket total daily precipitation (mm)
Druck 357/D pressure transducer	Evaporation pan water level 15-min sample Evaporation pan water level 15-min average

mounted on the bottom of the evaporation pan measures water depth. A 12-V deep cycle lead–acid battery powers the station and a solar panel mounted on the tower keeps the battery charged. The instruments of the meteorological station are summarized in Table III-4-1.

RESULTS

The meteorological station was restarted for the summer season on 5 June 1999. We would have liked to start it a little earlier in the season, by mid-May, but were unable to because of time constraints and other, higher priorities. Although the station ran the entire summer until 17 September, several technical problems prevented the timely transmitting and posting of the data to the Eagle River Flats Web page. Various problems with the cell phone connection in the field and problems with the database program on the computer server and the Web site in Hanover all contributed to preventing the system from providing the timely data for which we were hoping. Even though the meteorological and soil moisture data were not displayed on the Web site, all data collected were stored in the storage modules of the data loggers and manually retrieved later.

Another problem that developed was not noticed until late in the season. Spiders infested the precipitation sensor, spinning webs that choked it and prevented it from accurately measuring precipitation. The precipitation that was measured greatly underreported the actual rainfall (Table III-4-2). To present a more accurate picture of rainfall this summer, the precipitation record from July onward was reconstructed using the evaporation pan data. The 48-in. evaporation pan recorded water levels hourly and precipitation caused an increase in water level. The reconstructed precipitation record, while not exact, compares favorably with other records from the Anchorage Bowl area, such as Merrill Field, International Airport, and Elmendorf.

Table III-4-2. Monthly summary of temperatures and precipitation for Eagle River Flats and Anchorage showing the 1999 monthly (or partial monthly) average temperatures for both sites, the normal average temperatures for Anchorage, the monthly total measured and reconstructed precipitation for ERF, and the monthly total and normal average precipitation for Anchorage.

	Temperature (°C)			*Rainfall (mm)*			
	Anch. normal	*Anch. 1999*	*ERF 1999*	*Anch. normal*	*Anch. 1999*	*ERF 1999 measured*	*ERF 1999 reconstructed*
May	8.1	7.7	—	18.5	23.6	—	—
5–30 June	—	13.3	13.2		18.0	24.0	24
June	12.4	13.0	—	29.0	25.1	—	—
July	14.7	14.7	13.8	43.4	54.4	24.4	57
August	13.5	13.9	12.3	62.0	120.1	22.9	125
1–17 Sept	10.4	10.9	9.1	38.9	61.0	0.3	41
September	9.1	9.4	—	68.6	82.3	—	—

CLIMATE SUMMARY

The summer of 1999 had normal to slightly above-normal temperatures from June through September. Precipitation was below normal in June, slightly above normal in July, and considerably above normal in August and the first half of September. Table III-4-2 shows the June through September monthly total rainfall for Eagle River Flats and for the National Weather Service (NWS) station at Anchorage, the normal monthly rainfall for Anchorage, the monthly average temperatures for ERF and Anchorage, and the normal monthly temperatures for Anchorage. The NWS Anchorage data are presented along with the Eagle River Flats data since we do not have a long-term average for the Eagle River Flats climatic site.

May and June are normally the driest months of the core drying season needed for treatment of contaminated pond bottom sediments. The cooler weather and flooding tides of May eliminated any effective drying that month, but June and the first week of July provided near ideal drying conditions. Figure III-4-1 is a plot of the maximum, minimum, and average air temperatures for the summer. There were 30 days during the summer with maximum temperatures of 20°C or more. This compares to only 18 days during the entire summer of 1998.

Precipitation in August was also well above normal. Figure III-4-2 is a plot of precipitation and net evaporation for the summer of 1999 in Eagle River Flats. The evaporation plot shows the very dry conditions during June and the first part of July. After 9 July, the net evaporation rate decreased dramatically because of the increased rainfall, more complete cloud cover, and resulting decreased evaporation. Several large rainfall events occurred in August with 25 mm (1 in.) falling on 13 August.

The daily climate data for the entire summer season are summarized in Table III-4-3. The more detailed climatic data that include all the 15-minute observations and additional measured parameters are available from CRREL in an Excel spreadsheet format if needed.

Problems with the Web site have been worked out and an improved radio modem link to a phone line, replacing the problem-

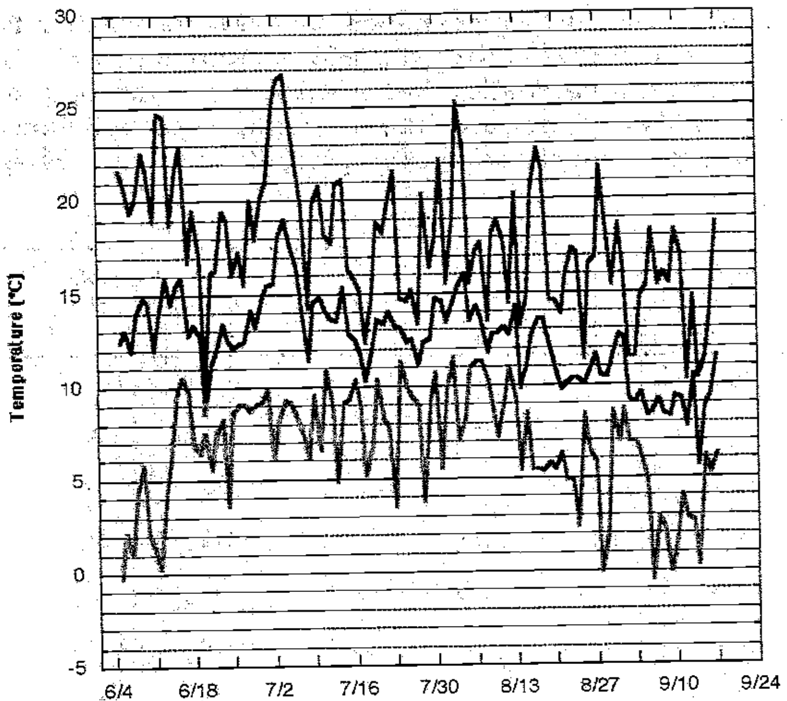

Figure III-4-1. Plot of maximum, minimum, and average daily air temperature for Eagle River Flats. There were 30 days during the summer of 1999 with maximum temperatures of 20°C and over. This compares to only 18 days during the summer of 1998.

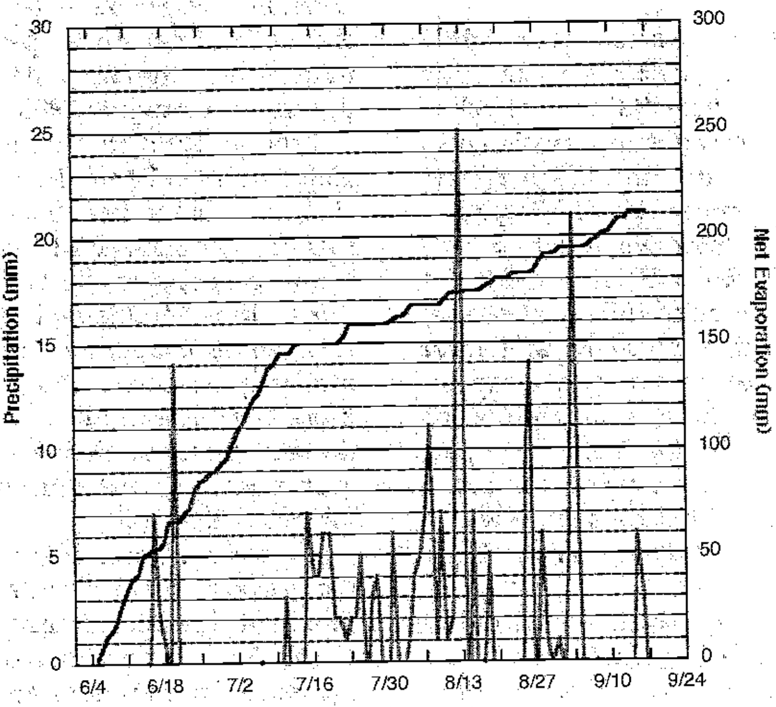

Figure III-4-2. Plot of precipitation and net evaporation for the summer of 1999 in Eagle River Flats. The evaporation plot shows the very dry conditions during the first part of the summer and the increased rainfall and decreased evaporation after 9 July.

Table III-4-3. Daily climatic data for the Eagle River Flats meteorological station during June–September 1999.

Date	*Air temp. maximum* (°C)	*Air temp. average* (°C)	*Air temp. minimum* (°C)	*RH average* (%)	*Wind speed average* (m/s)	*Wind speed maximum* (m/s)	*Radiation (0.3 to 3 µm)* *Incident* (W/m²)	*Reflected* (W/m²)
5-Jun	21.6	12.4	-0.3	49	1.96	6.15	343.40	40.20
6-Jun	20.9	13.0	2.1	51	1.77	6.34	336.10	39.50
7-Jun	19.3	11.9	1.0	59	1.56	4.81	243.14	28.15
8-Jun	20.0	13.9	4.3	56	1.73	4.69	306.43	36.38
9-Jun	22.6	14.8	5.8	54	2.06	9.79	283.85	34.98
10-Jun	21.6	14.5	2.2	47	2.11	5.86	345.55	42.56
11-Jun	18.9	12.0	1.2	59	1.84	6.10	344.92	43.08
12-Jun	24.7	13.8	0.3	60	1.20	4.54	330.10	40.55
13-Jun	24.5	15.9	4.4	54	2.33	9.61	333.98	41.38
14-Jun	18.7	14.4	6.2	65	1.41	4.48	203.22	22.78
15-Jun	21.7	15.5	9.7	70	1.28	4.62	224.41	25.24
16-Jun	22.9	15.8	10.5	73	1.18	7.18	197.26	22.18
17-Jun	16.7	12.8	9.7	83	1.30	4.37	162.08	19.09
18-Jun	19.5	13.3	6.8	73	1.32	5.13	275.95	34.04
19-Jun	17.1	12.8	6.4	75	1.16	8.91	152.22	16.91
20-Jun	9.9	8.6	7.4	88	1.43	1.38	66.64	7.19
21-Jun	16.1	11.2	5.5	72	1.11	4.68	215.99	26.20
22-Jun	16.3	11.9	7.4	76	1.00	4.68	143.17	17.48
23-Jun	19.4	13.4	8.2	69	1.73	4.70	300.06	38.57
24-Jun	19.0	12.5	3.6	70	1.41	6.10	209.02	25.58
25-Jun	16.0	12.1	8.5	73	1.25	5.36	148.44	19.05
26-Jun	17.2	12.3	9.0	73	1.29	4.66	200.01	26.40
27-Jun	15.5	12.4	9.0	74	0.95	3.90	107.73	12.64
28-Jun	20.0	14.1	8.7	65	1.99	8.59	315.50	40.52
29-Jun	17.9	13.2	9.0	72	1.32	15.39	191.76	24.14
30-Jun	20.2	14.7	9.2	64	1.45	5.64	312.99	41.22
1-Jul	21.0	15.4	9.8	70	1.62	5.73	286.34	38.58
2-Jul	25.0	15.6	6.1	68	1.42	4.70	323.92	42.76
3-Jul	26.4	18.0	8.1	66	1.34	4.24	339.07	42.59
4-Jul	26.8	19.0	9.3	65	1.15	3.69	259.96	35.11
5-Jul	24.6	17.6	9.1	63	1.18	4.38	217.85	29.29
6-Jul	21.8	16.4	8.2	59	1.51	6.39	255.94	33.94
7-Jul	19.7	13.9	7.5	73	1.92	5.97	286.32	40.05
8-Jul	14.2	11.4	6.1	83	1.06	4.00	80.16	9.74
9-Jul	19.9	14.5	9.5	69	1.17	4.68	221.45	29.42
10-Jul	20.7	14.8	6.6	69	1.44	4.64	237.88	32.71
11-Jul	18.1	14.0	10.9	82	1.01	4.38	124.87	15.25
12-Jul	17.7	13.6	9.0	75	1.59	4.06	178.80	23.08
13-Jul	20.8	13.5	4.8	69	1.50	4.45	292.35	38.92
14-Jul	21.1	15.3	9.1	73	1.11	4.90	197.32	25.51
15-Jul	16.3	12.9	9.3	90	1.25	4.23	74.23	8.49
16-Jul	15.7	12.4	10.3	86	1.12	4.30	120.77	14.91
17-Jul	15.1	11.7	9.0	88	0.73	3.94	98.85	12.07
18-Jul	12.3	10.2	5.2	91	0.87	3.68	83.36	9.36
19-Jul	14.7	11.9	6.6	88	0.86	3.86	98.63	11.85
20-Jul	18.8	13.6	10.3	79	1.42	6.26	101.84	13.55
21-Jul	18.2	13.3	8.1	65	2.53	10.14	207.52	28.07
22-Jul	19.7	14.0	7.8	63	1.36	4.56	283.05	38.23
23-Jul	21.5	13.2	3.5	68	1.32	4.51	223.54	29.05
24-Jul	14.7	13.1	11.3	87	0.94	4.01	61.42	6.30
25-Jul	14.5	12.3	9.9	90	0.74	3.50	62.03	6.67
26-Jul	15.1	12.5	9.4	87	0.88	4.26	108.68	13.11
27-Jul	13.3	11.1	8.9	86	1.24	5.29	80.59	9.64
28-Jul	20.3	12.3	3.8	76	0.99	3.98	234.13	30.63
29-Jul	16.4	12.5	9.1	84	1.22	8.38	41.28	4.13
30-Jul	17.8	14.7	10.7	77	1.28	10.31	74.48	7.97
31-Jul	22.1	14.5	5.5	75	1.30	4.26	251.52	32.51

Table III-4-3 (cont'd). Daily climatic data for Eagle River Flats meteorological station during June–September 1999.

Date	*Air temp. maximum* (°C)	*Air temp. average* (°C)	*Air temp. minimum* (°C)	*RH average* (%)	*Wind speed average* (m/s)	*Wind speed maximum* (m/s)	*Radiation (0.3 to 3 µm)* *Incident* (W/m²)	*Radiation (0.3 to 3 µm)* *Reflected* (W/m²)
1-Aug	15.5	13.4	9.7	88	0.84	3.80	66.89	7.31
2-Aug	18.9	14.5	11.5	90	0.97	3.66	103.65	12.88
3-Aug	25.2	15.3	7.0	77	1.16	6.04	195.84	25.72
4-Aug	22.7	16.0	8.1	67	1.34	5.70	184.78	22.48
5-Aug	15.5	13.5	10.9	92	0.70	3.04	66.66	6.71
6-Aug	17.2	14.3	11.3	90	0.57	3.89	86.12	9.58
7-Aug	17.7	13.5	11.3	91	1.00	4.13	101.25	12.39
8-Aug	13.5	11.7	10.2	90	0.89	3.28	49.28	5.28
9-Aug	18.1	12.8	8.8	85	0.88	4.39	160.73	19.88
10-Aug	18.9	12.8	7.2	77	1.23	5.17	198.01	26.05
11-Aug	17.8	13.1	9.1	80	1.17	4.90	159.80	20.15
12-Aug	14.4	12.7	10.9	94	0.95	4.26	35.81	3.12
13-Aug	20.3	14.3	9.2	83	1.10	4.83	201.06	27.19
14-Aug	13.2	9.8	5.4	88	0.67	3.32	52.57	5.76
15-Aug	14.7	11.1	8.5	91	0.70	3.06	96.82	10.56
16-Aug	20.5	12.8	5.4	83	1.21	4.63	218.97	29.90
17-Aug	22.7	13.6	5.4	78	1.04	3.55	230.79	29.81
18-Aug	21.6	13.6	5.3	77	1.23	6.12	205.91	29.59
19-Aug	14.5	12.1	5.8	87	0.94	5.55	61.04	6.98
20-Aug	14.5	10.9	5.4	84	0.88	6.16	76.22	8.42
21-Aug	13.8	9.7	6.3	87	0.58	2.72	71.38	7.97
22-Aug	15.9	10.1	4.8	84	0.92	3.69	120.36	14.66
23-Aug	17.3	10.3	4.8	83	1.01	5.98	146.76	18.72
24-Aug	17.1	10.3	2.4	80	1.04	4.84	196.24	25.58
25-Aug	11.4	10.0	8.4	93	0.71	3.18	37.85	3.45
26-Aug	16.5	10.7	6.4	83	0.75	3.81	153.60	21.12
27-Aug	16.9	11.6	5.7	81	0.95	4.06	174.86	24.56
28-Aug	21.7	10.5	-0.1	73	1.24	6.55	202.63	28.72
29-Aug	18.1	10.4	1.8	75	0.96	4.50	157.89	21.07
30-Aug	15.3	11.5	8.6	84	0.84	3.82	86.10	9.47
31-Aug	18.6	12.7	6.9	71	1.86	8.74	163.13	22.18
1-Sep	16.4	12.5	8.7	74	2.14	10.77	53.01	5.50
2-Sep	11.5	9.2	6.9	93	0.75	3.56	20.21	1.41
3-Sep	11.5	9.0	6.9	84	2.95	8.79	66.13	8.10
4-Sep	14.7	9.5	6.1	75	1.14	4.49	131.67	17.74
5-Sep	15.3	8.3	4.6	85	0.91	3.64	133.64	19.40
6-Sep	18.3	8.5	-0.5	78	0.70	3.18	177.16	25.03
7-Sep	15.3	9.2	2.8	82	0.77	3.56	127.09	17.27
8-Sep	16.0	8.4	2.3	85	0.73	3.61	141.67	20.30
9-Sep	15.4	8.2	-0.1	84	0.70	3.21	126.98	16.55
10-Sep	18.3	9.4	1.0	73	1.26	7.00	166.84	24.08
11-Sep	16.9	9.2	4.0	79	0.84	3.45	136.14	18.76
12-Sep	10.2	7.7	2.8	92	0.66	3.13	28.07	2.74
13-Sep	14.7	10.5	2.6	78	1.63	11.78	61.40	6.80
14-Sep	10.3	5.6	0.3	91	0.69	2.97	41.68	4.42
15-Sep	11.4	8.8	6.1	91	1.51	4.68	39.72	3.82
16-Sep	13.7	9.4	5.2	84	0.81	3.65	80.86	8.58
17-Sep	18.6	11.5	6.2	67	2.13	10.72	63.61	7.60

atic cell phone connection, will be put into place next spring. We are looking forward to a much smoother running meteorological station next season that will allow the weather data to be posted daily to the Eagle River Flats Web site.

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IV-1. POND PUMPING–DITCHING AND HABITAT CHANGE ON EAGLE RIVER FLATS

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INTRODUCTION

ERF is a small sample of several salt marshes on Cook Inlet that provide important habitat to migrating geese, ducks, and swans, in addition to a broad range of other species. During the spring and fall migration, thousands of dabbling ducks, shorebirds, and 30–100 swans use the limited pond habitat on ERF (15% of saltmarsh) for feeding and resting. In the ponds, waterfowl feed on plant seeds, rhizomes, and invertebrates in the bottom sediments. In addition, emergent vegetation in these ponds provides cover and protection from abundant predators (eagles and other raptors).

Because the bottom sediments of some permanent ponds have become contaminated with highly toxic particles of white phosphorus, both dabbling ducks and swans are poisoned. To remediate this problem (cause the sublimation of these particles), several permanent ponds have been drained over the past 4 years, using either drainage ditches constructed with explosives or large floating pumps installed in a sump hole blasted into the pond bottom. A total of nine permanent ponds have been treated by pumping or ditching between 1996 and 1999. These ponds cover an area of about 17 ha and represent one-third of the permanent pond area on ERF (55 ha).

Two ponds were ditched using explosives in April 1996 (Bread Truck Pond, Pond 109 in Fig. IV-1-1) and April 1997 (Racine Island Pond, which is not shown in Fig. IV-1-1), respectively. Large centrifugal pumps have been installed in blasted sump holes in seven different ponds and operated for one to three summers beginning in spring (May) and ending in September or October. Four of these ponds are shown in Figure IV-1-1 treated by pumping for 1 year (Pond 730), 2 years (Ponds 155 and 146) and 3 years (Pond 183). The pond water is pumped through a large hose running from the pump to the heads of nearby tidal creek gullies. In addition smaller drainage lines were dug or blasted through ponds to more effectively move water to the sump holes. Tide gates were also installed at the heads of several narrow tidal gullies to help prevent water movement into the ponds during high tides.

One effect of pond pumping and draining is the loss of flooded pond habitat, at least during part of the year in the case of pumping. In addition, pond dewatering has altered the flooding regime, soil moisture conditions, and hydroperiod in treated ponds. The water table under and adjacent to the drained ponds has also changed (since salt marsh plant species are presumably controlled by soil conditions, including waterlogging and salinity [Snow and Vince 1984]), changes in species composition might be expected to occur as a result of pond drainage. Responses could include:

- No change in the vegetation in or adjacent to the drained ponds.
- Invasion–colonization of the exposed pond bottom by species adapted to drier conditions.
- Loss of aquatic or emergent vegetation, or both.

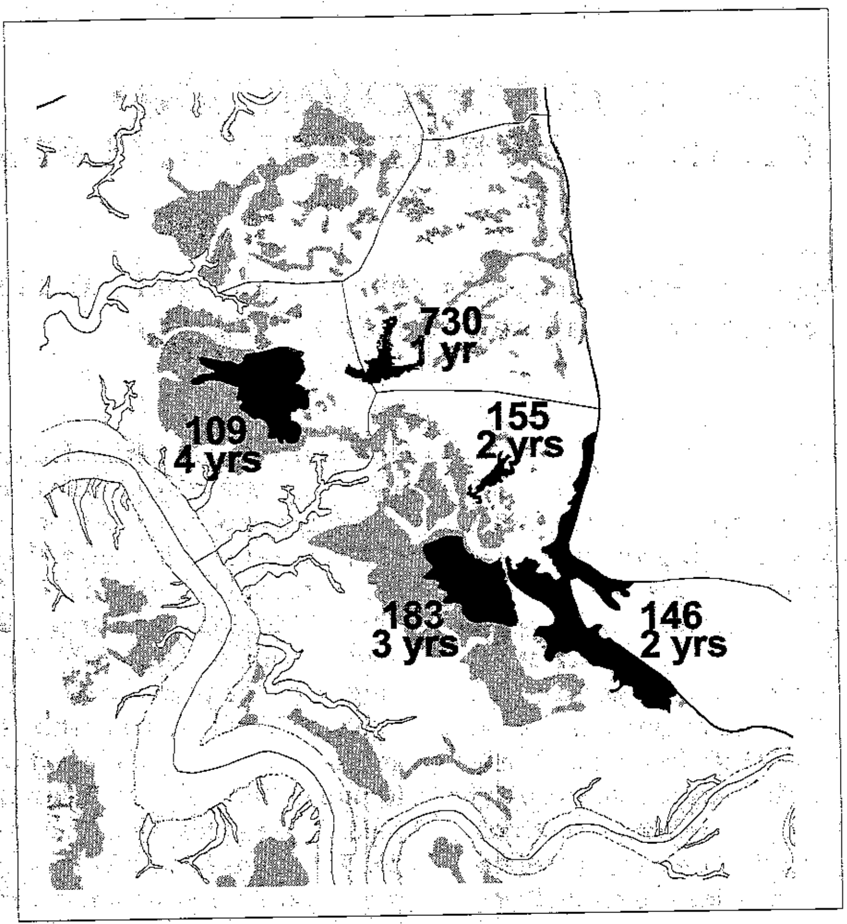


Figure IV-1-1. Map of the study area on the east side of Eagle River Flats, showing ponds treated (shaded black with id) and number of years over which treatment has been applied.

Because vegetation is a major component of habitat and plays a major role in capturing sediments, we focus on changes in vegetation cover and species that have occurred in and in the vicinity of the five ponds that have been treated between 1995 and 1999 (Fig. IV-1-1).

This study will help answer the question of how much and in what direction habitat–vegetation change is occurring because of the remediation effort and whether it is minor, major, or lasting in its effect. This information is necessary as part of the *Final Remediation Plan* and as an aid in restoring the wetland habitat once remediation is complete. This is the second year of this effort, although the work is related directly to the earlier development of a GIS database for Eagle River Flats, initiated in 1991. Other salt marsh change analyses have been conducted for various types of disturbances, including goose overgrazing in arctic salt marshes (Jano et al. 1998), structural marsh management and water control structures in Louisiana (Kuhn et al. 1999), and mosquito control drainage projects in the 1950s in New England (Barrett and Niering 1993).

BACKGROUND ON STUDY AREA

Zonation is a well-known phenomenon in salt marshes and is presumably related to changes in salinity, flooding frequency, and sedimentation, all of which change back from the coast and river in the case of an estuarine salt marsh such as ERF. The zonation pattern

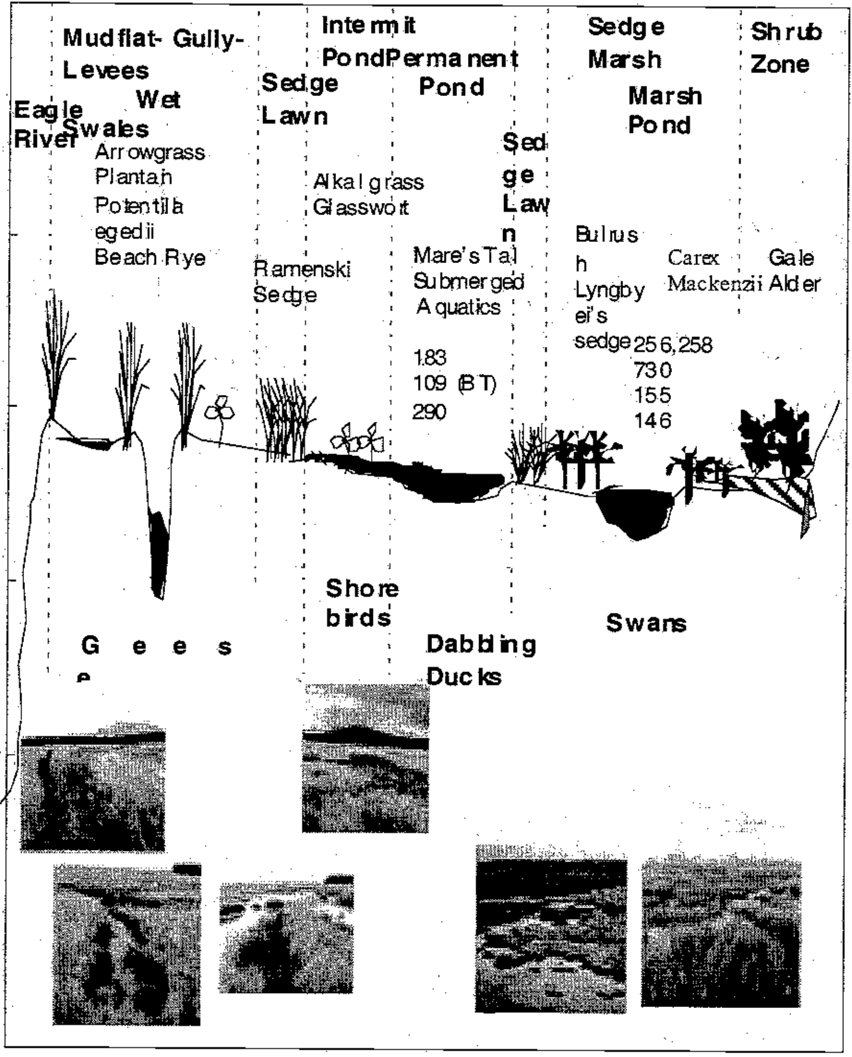


Figure IV-1-2. Idealized cross section from Eagle River inland, showing vegetation and waterfowl zonation.

in ERF is shown in Figure IV-1-2. A mudflat-distributary zone is located closest to the river and coast and is replaced inland by a narrow sedge meadow and intermittent ponds, and permanent pond, sedge marsh, and pond zones. Treated ponds are located in the permanent pond, sedge marsh, and pond zones.

METHODS

The methods for analyzing both vegetation and erosional changes were developed in 1998 (Racine et al. 1999) and applied more extensively in this effort. The main area of change analysis for 1999 is shown in Figure IV-1-1, where five different ponds have been treated over the past 4 years since spring 1996. Vegetation change was analyzed in and adjacent to these treated ponds, and erosional change was analyzed for the four tidal creek channels that feed water into and drain these ponds (Fig. IV-1-1).

Vegetation change was monitored using both field sampling and permanent plots, as well as remote sensing methods.

Plot methods

In 1992 before active remediation of the site began, we established over 400 sample points for measurement of vegetation cover, sedimentation–erosion, etc. Each point was surveyed, as were the UTM easting and westing coordinates and elevation. Vegetation composition and cover were estimated in 1- × 1-m plots at each of these points and a vertical photo of the plot was obtained. Wooden lathe stakes were used to mark the position of these plots, but over the past 7 years they have been lost or destroyed by ice movement, particularly in the ponds. In 1999 we used real-time differential GPS (Trimble Pathfinder XR) to relocate or navigate to about 24 of these points (Fig. IV-1-3) in the vicinity of the five treated ponds in Figure IV-1-1. We then resampled and rephotographed these points to assess change during the past 7 years.

Remote sensing

We conducted a computer-based spectral analysis of digital multispectral video (DMSV) images from 1995, 1997, and 1999. DMSV images were obtained by Aeromap, Inc. (Anchorage, AK), with four video cameras mounted on an airplane, each with a different filter recording reflected light from the surface (in 1.5- × 1.5-m pixels) at four different wavelengths: 1) blue—450 nm, 2) green—550 nm, 3) red—650 nm, and 4) near infrared—770 nm—or infrared—990 nm. These last two infrared bands are particularly sensitive to vegetation cover and health.

A "greenness index" was calculated for each pixel in the registered August 1995 and August 1999 DMSV images, based on the re-

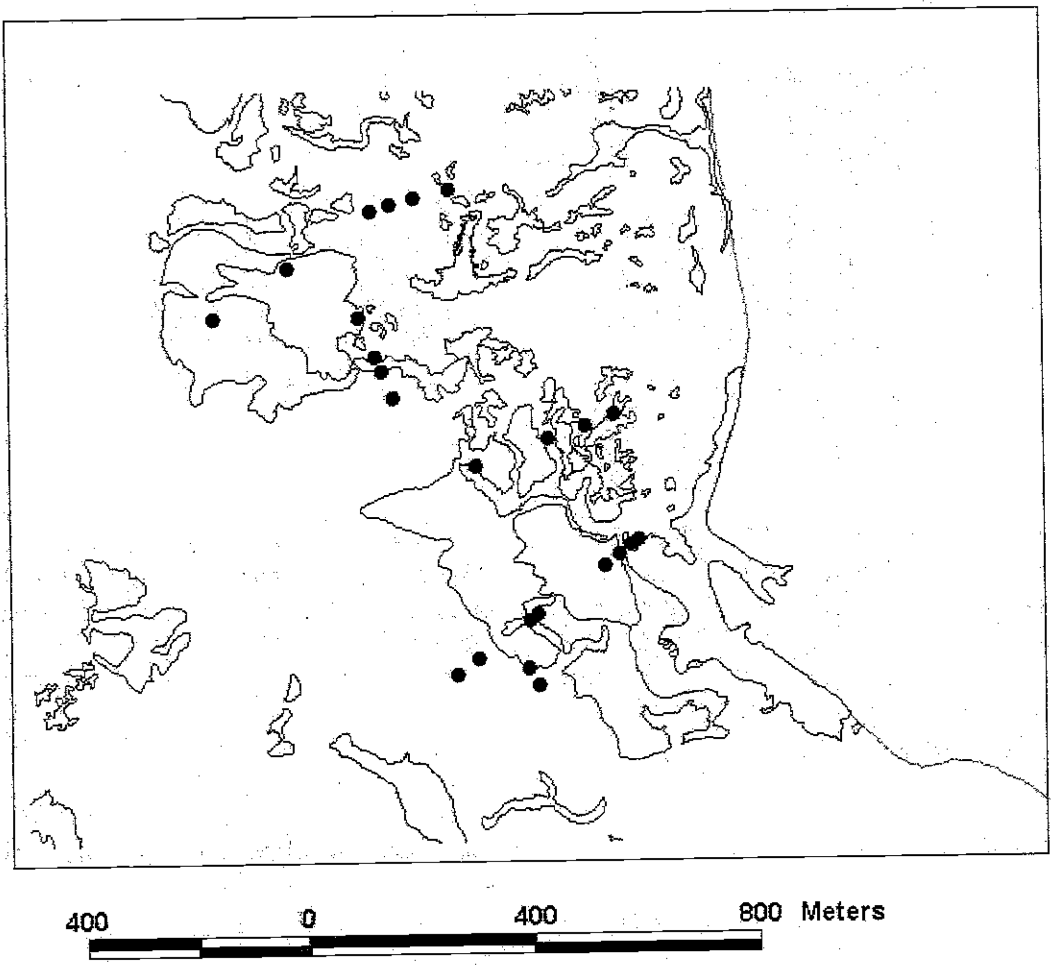


Figure IV-1-3. Location of points and vegetation plots sampled in 1992, relocated, and sampled again in 1999 to determine habitat change.

flectance of solar radiation in the near infrared (NIR) (770 nm) and red chlorophyll-absorbing bands (RED) (650 nm). This "normalized difference vegetation index or NDVI" is calculated as NDVI = (NIR – RED)/(NIR + RED). The NDVI is calculated for each pixel of the image for a given year and then any difference in the NDVI value from one year to the next is seen as an increase or decrease in vegetation cover. A low NDVI value indicates low vegetation cover and appears as dark on the images, while a high value is bright white.

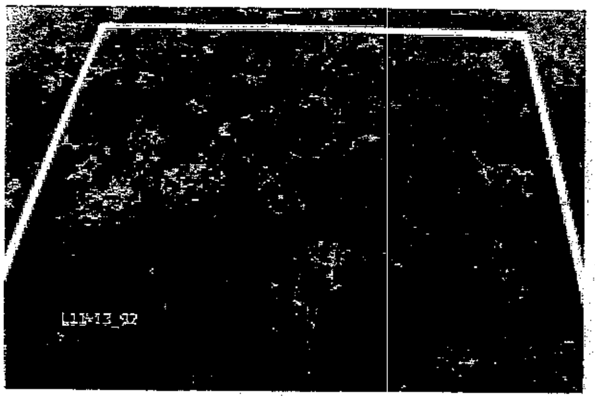
RESULTS

When the plot data are analyzed, it is clear that the vegetation in some plots has changed dramatically, while there has been little or no change in other sites from 1992 to the present. We can recognize which species are expanding, declining, or remaining stable following pond pumping or draining. Most of the changes in species abundance within the drained ponds can be related to changes in the flooding or soil moisture regime attributable to pumping or ditching.

It is difficult to relate changes in species abundance in intermittent pond areas on the outer edge of the drained ponds to pumping and ditching in the adjacent permanent pond. The bottoms of intermittent ponds are usually devoid of vegetation other than the emergent arrowweed. However, in some summers, large populations of annual species such as the bright red glasswort (*Salicornia europea*) and spurry (*Spergularia canadensis*) may develop on the bare sediments of these ponds and on the adjacent mudflats. During August 1999, both spurry and glasswort were particularly abundant along the outer intermittent pond edges of C Pond (Pond 183 in Fig. IV-1-1). Although we would expect these annuals to invade the exposed bottoms of drained permanent ponds, there is little evidence that this is occurring.

In permanently flooded pond centers and edges, the aquatic submerged species such as *Zannichellia palustris, Potomogeton pectinatus,* and *Ruppia spiralis* are completely dependant on continuous submergence, and they disappear almost immediately following pond drainage (Fig. IV-1-4). The circular colonies of the emergent mare's tail (*Hippuris tetraphylla*) also found in permanently flooded ponds decline more slowly, but have been completely eliminated from C Pond where this species was abundant before pumping in 1996 (Fig. IV-1-5). In the Bread Truck Pond 109, ditched in spring 1996, mare's tail has persisted in some places but in very poor condition (Fig. IV-1-6). This pond continues to periodically reflood from the ditch.

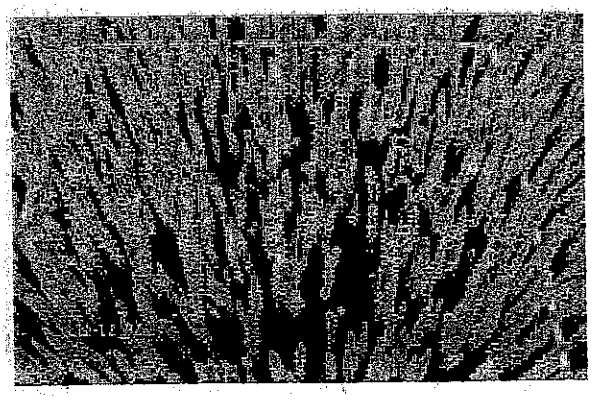
Ramenski's sedge (*Carex ramenskii*) forms tall, thick, almost pure sedge meadows as small clumps and in places continuous borders in the permanent ponds that have been drained (Fig. IV-1-7). Examination of photos



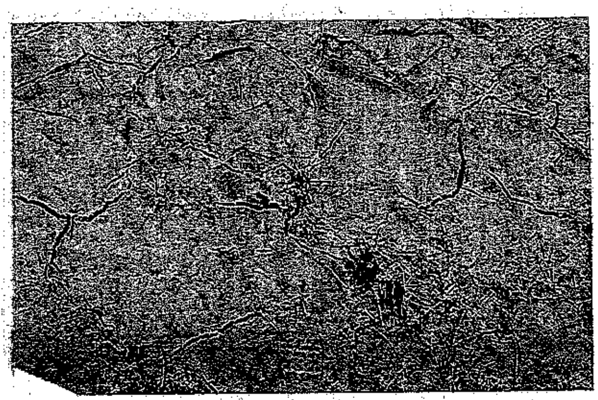
Line 11-13 1992

Line 11-13 1999

Figure IV-1-4. Comparison of a 1992 plot and the same plot in 1999. Loss of submerged aquatic species is almost immediate following pond drainage.

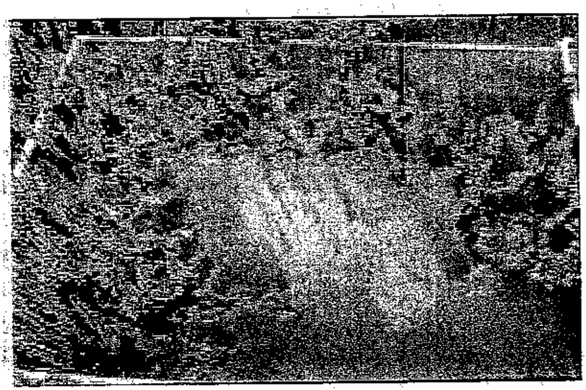


Line 11-12 1992

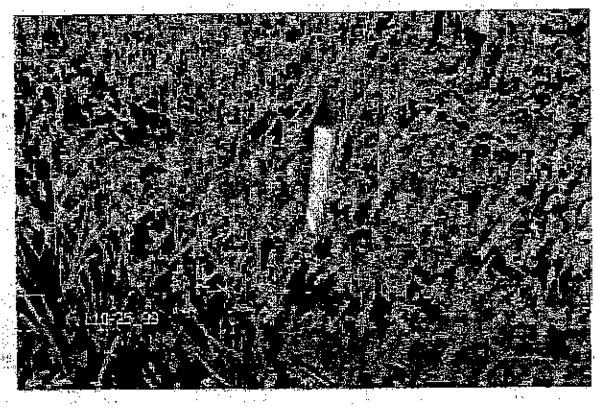


Line 11-12 1992

Figure IV-1-5. Loss of Hippurus tetraphylla *vegetation from 1992 to 1999 in a 1-×1-m quadrant placed in a pond drained by summer pumping in 1997, 1998, and 1999.*



Line 10-25 1992



Line 10-25 1999

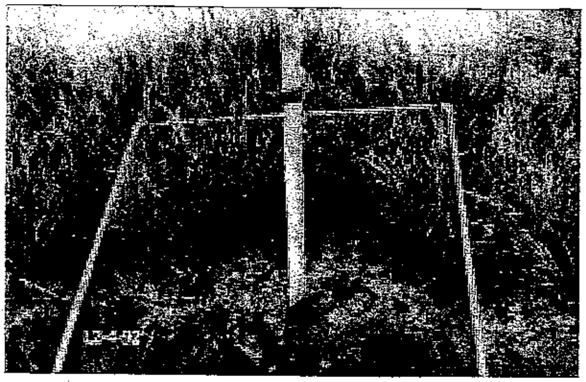
Figure IV-1-6. Persistence of Hippurus tetraphylla *in a poor condition in the Bread Truck Pond, which was ditched rather than pumped and, therefore, floods during occasional high tides.*

from 1992 and 1999 indicate that the species appears to be very stable and able to withstand the changes in flooding and soil moisture associated with pond drainage, at least during the 3 to 5 years the ponds have been drained (Fig. IV-1-7). Additional evidence for its persistence is observed in some intermittent ponds, where patches of Ramenski's sedge occur, surrounded by dried and cracked sediments (Fig. IV-1-8).

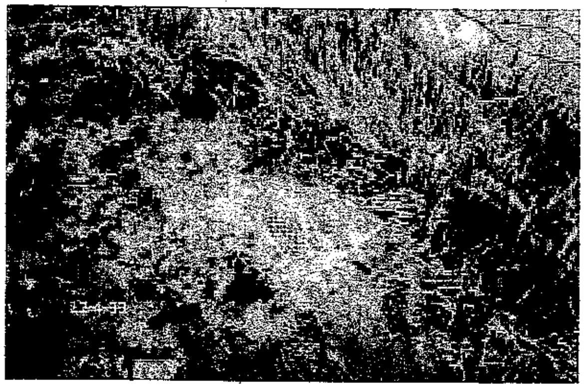
There is evidence for the expansion of two sedges onto the organic sediment surface of drained ponds such as 146 (Fig. IV-1-9). Both Mackenzi's sedge (*Carex mackenzii*) and Lyngbyei's sedge (*C. Lyngbyei*) appear to be invading the dewatered pond and have spread in both 1998 and 1999, during which time this pond was pumped.

It is difficult to detect changes in the almost mono-specific large areas of bulrush (*Scirpus paludosus*) marsh bordering the inner side of the Bread Truck and C Ponds. The few plots established in 1992 in this zone did not show major change (Fig. IV-1-10). Surviving vegetation in Pond 730, pumped for the first time in spring 1999, suggests that the tall green bulrush (*Scirpus validus*) was able to resprout by late August, but it has been greatly reduced in abundance.

Although it was difficult to detect loss of bulrush vegetation, remote sensing analysis in 1995, 1998, and 1999 suggested a decline in



Line 2-4 1992



Line 2-4 1992

Figure IV-1-7. Plots in ponds with Carex Ramenskii, *showing persistence of this species after 4 years of pumping.*

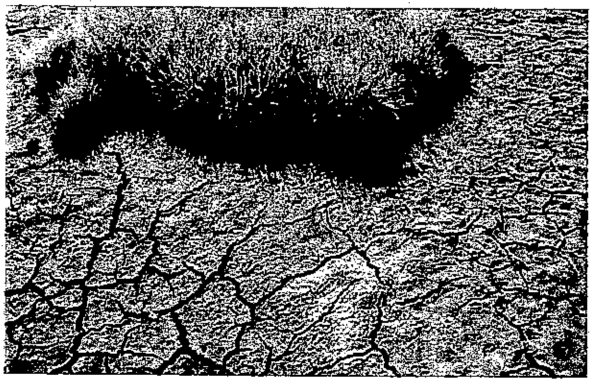
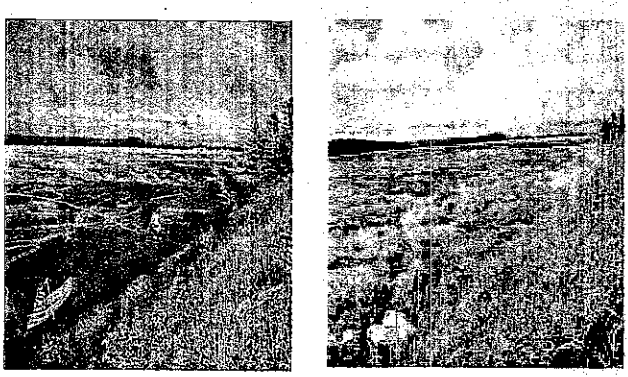
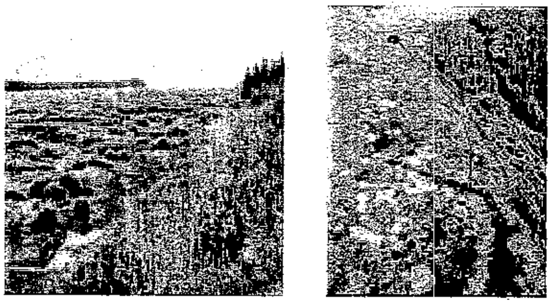


Figure IV-1-8. Ramenskii's sedge persists in an intermittent pond that has dried and cracked.



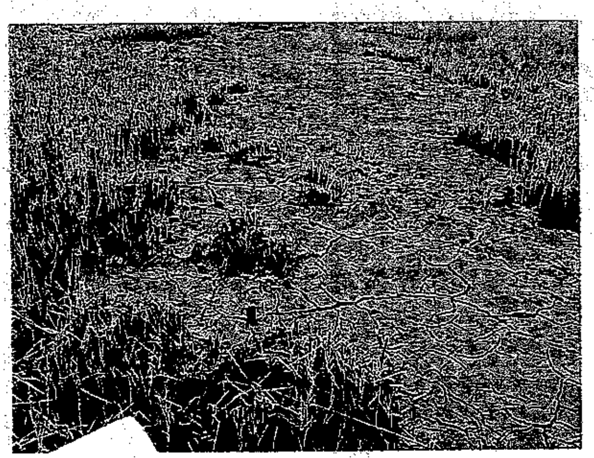
August 1991 August 1998



August 1999

Figure IV-1-9. Photos of Pond 146 before pumping during 1998 and 1999 and in August 1999, showing expansion of sedges.

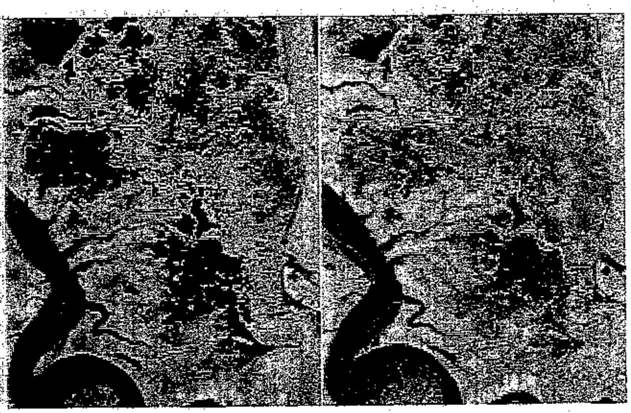
Line 5-17 1992



Line 5-17 1999

Figure IV-1-10. Photos of a plot in 1992 and 1999 of bulrush following only one summer of pond pumping between Ponds 146 and 183. Little change in bulrush vegetation is apparent here.

vegetation cover in these marshes bordering the east side of C Pond and Bread Truck Pond (Fig. IV-1-11). Some of this change may have been ascribable to the loss of mare's tail, which also forms colonies within the bulrush marsh. The overall condition of bulrush vegetation may also be declining because of pond draining.



August 1995 August 1999

Figure IV-1-11. NDVI analysis of DMSV images covering the study area of Eagle River Flats in August 1995 and mid-August 1999. Darker areas suggest a loss or reduced vigor of the vegetation.

DISCUSSION AND CONCLUSIONS

Some of the observed changes in vegetation and habitat are summarized in Table IV-1-1. While some species such as the submerged aquatics and mare's tail are fairly quickly eliminated by pumping, others, such as Ramenski's and Lyngbyei's sedges, persist. Ramenski's sedge, in particular, is an important source of forage for grazing geese. In addition, Mackenzii's and Lyngbyei's sedges appear to be expanding onto moister sediments exposed in the bottoms of some pumped marsh ponds.

The habitat effects of reduced tidal flooding and inundation in salt marshes have been investigated in other coastal areas. In Alaska the 1964 earthquake resulted in an uplift of 1.8–3.4 m in Cooper River Delta salt marshes (Thilenius 1990). Areas that were previously intertidal became supratidal, and subtidal areas intertidal. Lyngbye sedge invaded much of the newly exposed intertidal areas, while shrubs, including alder (Alnus crispa) and sweetgale (Myrica gale), invaded the supratidal areas. Saltwater-intolerant species invaded some of the pond basins.

We can speculate as to whether the aquatic and emergent plant species (submerged macrophytes and mare's tail), lost following pond drainage, might recover or return once the ponds are reflooded (following 3 to 5 years and sublimation of the white phosphorus). We have observed the consolidation, hardening, and cracking of pond bottom sediments, probably associated with the loss of organic mat-

Table IV-1-1. Response of several salt marsh plant species to permanent pond drainage by habitat and response (loss/contraction, stable/no change, and expansion).

Dewatered habitat	*Loss/contraction*	*Stable/no change*	*Expansion*
Mudflats/Intermittent pond			Annuals ? Puccinellia nutkaensis?
Carex Ramenskii lawns		*Carex Ramenskii* *Carex Lyngbyei*	
Permanent ponds	Submerged aquatics and emergent Hippurus		
Sedge marsh		Seacoast bulrush (*Scirpus paludosus*) ?	
Deep marsh ponds	Submerged aquatics and Mare's tail		*Carex mackenzii* *Carex Lyngbyeii* *Scirpus americanus*

ter, increases in soil salinity, and reduced rates of sedimentation (Anisfeld and Benoit 1997). Such changes in the pond bottom sediment texture, hardness, chemistry, and structure may limit reestablishment of these species; however, we would expect that abundant seeds and possibly rhizomes or corms stored in the bottom sediments might germinate and grow following reflooding. However, we do not know how long the underground seeds, corms, or rhizomes of these species remain viable in the bottom sediments of the drained ponds.

The disturbances introduced to ERF by pumping and ditching must also be evaluated in relation to other natural and man-caused disturbances to which this area has been subject in the past (Table IV-1-2). Natural distur-

Table IV-1-2. Disturbances that cause habitat changes in the ERF saltmarsh.

Natural disturbances	*Effects*
1. Earthquakes, subsidence	Creation of new ponds, saltwater incursion
2. Volcanic ash deposition	Burial and sedimentation
3. High tidal amplitudes	High rates of erosion
4. High glacial sediment loads in flood tide	High rates of sedimentation
5. Ice shove along tidal creeks	Create dry ridges and levees
Anthropogenic disturbances	
1. Artillery craters, surface disturbances	Small pond creation
2. Permanent pond pump and drain	Vegetation loss
3. Old vehicle dumping	?
4. White phosphorus particles	Waterfowl mortality
5. Dredging and sump hole blasting	More flooding, deeper ponds
6. Ditch construction with explosives	Changed drainage patterns and erosion
7. Foot-trails	Exposed sediments
8. Boardwalks	?
9. Pump hoses	?

bances and forces include high tidal ranges (11 m) and associated flooding, high erosion rates in some tidal creeks (Lawson et al. 1996), high sedimentation rates, a subarctic coastal climate involving ice forces and an active tectonic setting (most recently from the 1964 earthquake, resulting in subsidence of 0.6 to 0.7 m). Past human disturbances at ERF include extensive surface cratering from explosives, introduction of white phosphorus particles, and dumping of derelict vehicles and other debris, all related to U.S. Army artillery training over the past 40 years.

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IV-2. UPDATED SPECIES LIST FOR EAGLE RIVER FLATS, ALASKA

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INTRODUCTION

As part of the extensive site investigation studies carried out in Eagle River Flats during 1990 through 1995 to evaluate white phosphorus distribution, persistence, and ecological risk, an ecological inventory was conducted to better characterize the ecosystem of this complex 865-ha estuarine salt marsh. Results of the inventory were described in Racine (1994), Racine and Brouillette (1995) and in *Operable Unit C, Final Remedial Investigation Report* (CH2M Hill 1997). The inventory included a list of vascular plant species observed in Eagle River Flats that was arranged by landform-vegetation class. A list of bird species seen in Eagle River Flats was given in Racine et al. (1993) and in the *Final Remedial Investigation Report* (CH2M Hill 1997). This was based on observations made by L. Reitsma and B. Steele while they conducted waterfowl mortality studies. Bouwkamp (1995) produced a list of invertebrate species for Eagle River Flats that were observed while water and sediment samples were collected for studies of the effects of white phosphorus on the aquatic ecosytem.

Here, we present an updated species list of birds (Table IV-2-1) and vascular plants (Table IV-2-2) for Eagle River Flats. As monitoring studies and remediation efforts have been carried out over the last several years, additional species have been added to each of the two lists. As of 1999 there have been 97 species of birds observed in or along the border of Eagle River Flats, indicating the rich diversity of this salt marsh complex and the important ecological role it plays in the Upper Cook Inlet Region. We have also included a revised listing of invertebrate species (Table IV-2-3), based on Carl Bouwkamp's observations (Bouwkamp 1995), as this remains the definitive list for this subset of the fauna of Eagle River Flats.

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Table IV-2-1. Birds observed in Eagle River Flats 1991–1999. Primary observations by B. Steele and L. Reitsma 1991–1994. Additional observations by C. M. Collins, M.E. Walsh, and M.R. Walsh 1995–1999. Bird species are listed in order of *The A. O. U. Checklist of North American Birds*, 7th Ed. The relative abundance of the species in ERF is based on a combination of observations in ERF, Armstrong's (1990) listing for the southcoastal region of Alaska, and the *Checklist of Alaska Birds* (Gibson 1993) (c = common, u = uncommon, r = rare, + = casual or accidental, usually only one individual has been seen in ERF. B = confirmed breeder in ERF, b = probable breeder in ERF). Habitat listed is where the species has been observed or generally can be expected to be seen in ERF. Contaminant effect lists which species have been most affected by white phosphorus contamination in ERF.

Species	*Abundance*	*Habitat*	*Contaminant effect*
Red-throated Loon	u	Permanent ponds	
Common Loon	u	Permanent ponds	
Horned Grebe	u	Permanent ponds	
Great Blue Heron	+		
Tundra Swan	u	Permanent ponds	Major
Trumpeter Swan	c	Permanent ponds	Major
Canada Goose	c	Vegetated mudflats	
Greater White-fronted Goose	u	Vegetated mudflats	
Snow Goose	c	Vegetated mudflats	
Brant	r	Vegetated mudflats	
Green-winged Teal	c, B	Permanent & temporary ponds	Major
Mallard	c, B	Bulrush marsh, Permanent ponds	Major
Northern Pintail	c	Permanent & temporary ponds	Major
Blue-winged Teal	r	Permanent & temporary ponds	Minor
Cinnamon Teal	+		
Northern Shoveler	c	Permanent & temporary ponds	Major
Eurasian Widgeon	r	Permanent & temporary ponds	
American Widgeon	c, B	Permanent & temporary ponds	Very minor
Ring-necked Duck	r	Permanent ponds	
Greater Scaup	r	Permanent ponds	
Lesser Scaup	r	Permanent ponds	
Common Goldeneye	r	Permanent ponds	
Bufflehead	r	Permanent ponds	
Oldsquaw	r	Permanent ponds	
Common Merganser	r	Permanent ponds	
Osprey	r	Marsh edge	
Bald Eagle	c, B	All habitats	Minor
Northern Harrier	u	All open habitats	
Sharp-shinned Hawk	u	Spruce forest border	
Northern Goshawk	u	Spruce forest border	
Red-tailed Hawk	u	All open habitats	
Rough-legged Hawk	r	All open habitats	
Golden Eagle	r	All open habitats	
Merlin	u	All open habitats	
American Kestrel	u	All open habitats	
Peregrine Falcon	r	All open habitats	
Spruce Grouse	c, B	Spruce forest border	
Sandhill Crane	c, B	Sedge or Bulrush Marsh	
Black-bellied Plover	r	Vegetated mudflat	
Lesser Golden Plover	r	Vegetated mudflat	
Semipalmated Plover	c	Temporary pond, pond edge, wet mudflat	
Killdeer	r	Vegetated mudflats	
Greater Yellowlegs	c	Temporary pond, pond edge, wet mudflat	
Lesser Yellowlegs	c, B	Temporary pond, pond edge, wet mudflat	
Solitary Sandpiper	u, b	Marsh Edge	
Wandering Tattler	+		
Spotted Sandpiper	u	Marsh Edge	
Whimbrel	u	Temporary pond, pond edge, wet mudflat	
Hudsonian Godwit	u	Temporary pond, pond edge, wet mudflat	

Table IV-2-1 *(cont'd).*

Species	*Abundance*	*Habitat*	*Contaminant effect*
Semipalmated Sandpiper	r	Temporary pond, pond edge, wet mudflat	
Western Sandpiper	u	Temporary pond, pond edge, wet mudflat	Minor
Least Sandpiper	c	Temporary pond, pond edge, wet mudflat	Minor
Baird's Sandpiper	r	Temporary pond, pond edge, wet mudflat	
Pectoral Sandpiper	c	Temporary pond, pond edge, wet mudflat	Minor
Sharp-tailed Sandpiper	+		
Dunlin	r	Temporary pond, pond edge, wet mudflat	
Short-billed Dowitcher	c	Temporary pond, pond edge, wet mudflat	Very minor
Long-billed Dowitcher	u	Temporary pond, pond edge, wet mudflat	
Common Snipe	u, b	Sedge or Bulrush marsh	
Wilson's Phalarope	+		
Red-necked Phalarope	c	Permanent & temporary ponds	
Bonaparte's Gull	u	Permanent ponds	
Mew Gull	c, B	Permanent ponds, vegetated mudflats	
Herring Gull	c, B	Permanent ponds, vegetated mudflats	
Glaucous-winged Gull	r	Permanent ponds, vegetated mudflats	
Arctic Tern	c, B	Permanent ponds, vegetated mudflats	
Belted Kingfisher	u, b	Permanent ponds, marsh edge	
Hairy Woodpecker	u	Spruce forest border	
Alder Flycatcher	u	EOD pad	
Violet-green Swallow	c	All open habitats	
N. Rough-winged Swallow	+		
Tree Swallow	c	All open habitats	
Bank Swallow	r	All open habitats	
Cliff Swallow	u	All open habitats	
Barn Swallow	c	All open habitats	
Black-billed Magpie	c	EOD pad	
Common Raven	c	All habitats	
Black-capped Chickadee	c	Spruce forest border	
Chestnut-backed Chickadee	c	Spruce forest border	
Red-breasted Nuthatch	u	Spruce forest border	
Swainson's Thrush	u	Birch forest border	
Hermit Thrush	u	Birch forest border	
American Robin	c	EOD pad, birch forest border	
Varied Thrush	u	Spruce forest border	
Ruby-crowned Kinglet	c	Spruce forest border	
Bohemian Waxwing	u	Marsh edge	
Northern Shrike	u	Spruce forest border	
Orange-crowned Warbler	u	Birch forest border	
Yellow Warbler	u	Birch forest border	
Yellow-rumped Warbler	c	Birch forest border	
Northern Waterthrush	r	Marsh edge	
Savannah Sparrow	c	Vegetated mudflat, marsh edge	
Lincoln's Sparrow	u	EOD pad	
White-crowned Sparrow	u	EOD pad	
Dark-eyed Junco	c	Spruce forest border	
Rusty Blackbird	u	Marsh edge	
Lapland Longspur	r	Vegetated mudflat	

Table IV-2-2. Vascular plant species sampled, observed, or collected by C.H. Racine in Eagle River Flats arranged by landform–vegetation class (1990–1998).

Species	*Riverine*	*Coastal*	*Mudflat*	*Ram Sedge*	*Pond-marsh*	*Border*	*Int. meadows*	*Ridges*
Forbs								
Achillea borealis								x
Angelica lucida								x
Atriplex patula			x	x				
Caltha palustris						x		
Chenopodium album			x	x				
Chrysanthemum album								
Chrysanthemum leucanthemum						x		
Cicuta virosa						x		
Conioselinum pacificum						x		x
Dodecatheon pulchellum								x
Equisetum arvense								x
Fritillaria kamchaticum								x
Gentiana amarella								x
Galium trifidum								x
Glaux maritima			x					x
Hippurus tetraphylla					x			
Iris setosa								x
Lathyrus palustris								x
Ligusticum scotium								x
Lysimachia thrysiflora						x		
Menyanthes trifolia						x		
Moehringia lateriflora							x	
Petasites sagitatus						x		
Plantago maritima			x	x				
Polygonum Fowleri								x
Potentilla egedii			x	x				
Potentilla palustris						x		
Ranunculus cymbalaria			x		x			
Rumex arcticus						x		
Rumex transitorius						x	x	
Salicornia europea			x		x			
Spergularia canadensis			x		x			
Stellaria humifusa				x			x	
Stellaria longifolia								x
Traraxacum sp.						x		x
Trientalis europea								x
Triglochin maritima	x	x	x	x	x		x	
Triglochin plaustris			x	x	x			
Sanguisorba canadensis								x
Trees								
Picea glauca								x
Graminoids								
Arctagrostis poaeoides							x	
Calamagrostis deschampsoides						x	x	
Calamagrostis sp.						x		
Carex aquatilis						x	x	x
Carex Lyngbyei	x				x	x	x	
Carex mackenzie					x	x		
Carex pluriflora			x			x		
Carex ramenskii			x	x	x			
Eleocharis kamtschatica					x	x		
Elymus mollis (=Leymus mollis)	x		x					
Hierchloe odorata							x	
Hordeum brachyantherum			x					x
Poa eminens							x	x

Table IV-2-2 (cont'd).

Species	*Riverine*	*Coastal*	*Mudflat*	*Ram Sedge*	*Pond-marsh*	*Border*	*Int. meadows*	*Ridges*
Puccinellia nutkaensis		x	x					
Puccinellia phryganodes			x		x			
Scirpus paludosus					x			
Scirpus validus					x			
Pondweeds								
Myriophylum spicatum						x		
Polygonum spicatum						x		
Potamogeton pectinatus					x			
Ruppia spiralis					x			
Zannichellia palustris					x			
Shrubs								
Myrica gale						x		
Rosa acicularis								x
Salix ovalifoli								x
Alnus crispa						x		
Salix fuscescens								x

Table IV-2-3. List of sediment invertebrates collected by Carl Bouwkamp in Eagle River Flats during the summer of 1993 and 1994 (Bouwkamp 1995). Edited and revised by C.H. Racine.

Species	*Class*	*Order*
Chironomus plumosus	Insecta	Diptera
Chironomus salinarius	Insecta	Diptera
Cirolana	Crustacea	Isopoda
Coenagriidae	Insecta	Odonata
Crago nigrocauda	Crustacea	Decapoda
Cryptochironomus digitatus	Insecta	Diptera
Culicoides sp1	Insecta	Diptera
Culicoides sp2	Insecta	Diptera
Enallagma cyn	Insecta	Odonata
Ephydra sp.	Insecta	Diptera
Eukiefferiella	Insecta	Diptera
Gammarus lacustris	Crustacea	Amphipoda
Gnorimusphaenoma lutea	Crustacea	Isopoda
Gyraulus	Gastropoda	Planorbidae
Hydranea sp.	Insecta	Coleoptera
Hygrotus	Insecta	Coleoptera
Lanceimermis	Nematoda	Mermithidae
Libellula	Insecta	Odonata
Liga sp.	Crustacea	Isopoda
Limnophora sp.	Insecta	Diptera
Macoma nasuta	Bivalvia	Telluridae
Munna sp.	Crustacea	Isopoda
Nais variabilis	Annelida	Oligochaeta
Parachironomus	Insecta	Diptera
Phryganea sp	Trichoptera	Phryganeida
Physella gyrina	Gastropoda	Physidae
Rhamphamyia	Insecta	Diptera
Saduria entomon	Crustacea	Isopoda
Spharium sp.	Bivalvia	Sphaeridae
Stagnicolis arctica	Gastropoda	Physidae
Tanytarsus	Insecta	Diptera

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IV-3. TIDAL CREEK AND DRAINAGE DITCH EROSION AT EAGLE RIVER FLATS IN 1999

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INTRODUCTION

Active tidal creek and gully erosion has been identified by Lawson et al. (1996) as a major physical process in Eagle River Flats. The high tides and large volume of water that are drained by these gullies on the ebb tide result in large volumes of fast-moving water that can erode both lateral and headward walls of these gullies. This could result in pond drainage similar to that produced by blasting ditches. The erosion represents a loss of mudflat habitat and conversion to a tidal creek channel. These changes can also influence both the remediation success and our ability to restore the wetland habitat once remediation is completed. In addition, erosion can uncover buried munitions, resulting in exposure and possible transport. In summer 1999, headward erosion of the ditch constructed to drain the Bread Truck Pond in April 1996 resulted in the exposure of a white phosphorus round that released its contents. Lawson et al. (1996) measured headward erosion on some tidal creeks of up to 20 m/year, with localized lateral erosion rates of 5 m or less. In 1998, we developed a remote sensing technique (Racine et al. 1999) for monitoring gully erosion and applied it to one gully. This brief report extends some of this work by comparing erosional change from 1998 to 1999.

METHODS

Two methods were developed in 1998 and applied to the monitoring of gully erosion on the four gullies that drain the treated pond area east of Eagle River (Fig. IV-3-1).

GPS-GIS

Using a GPS (Trimble Pathfinder XR), we walked the edges of the four gullies in mid-August of both 1998 and 1999. Because the GPS received corrections from a Coast Guard beacon on Cook Inlet, we obtained real-time corrected line files (with an error of less than 1 m). This produced a map and GIS coverage of the gully edge in both 1998 and 1999 that can be compared each year to detect erosional change from one year to the next.

Remote sensing-GIS

In this method, color infrared aerial photos of the four tidal gullies (Bread Truck, Parachute, In-Between, and B-Gully) were obtained from 21 July 1991, 1995, 1998, and 1999, scanned at 600 dots per inch and georeferenced to each other. The outline of each of these gullies was then digitized into Arcview GIS. These outlines for each of the 3 years could then be overlayed and erosional change compared among the 3 years. Racine et al. (1999) showed that ground-based ero-

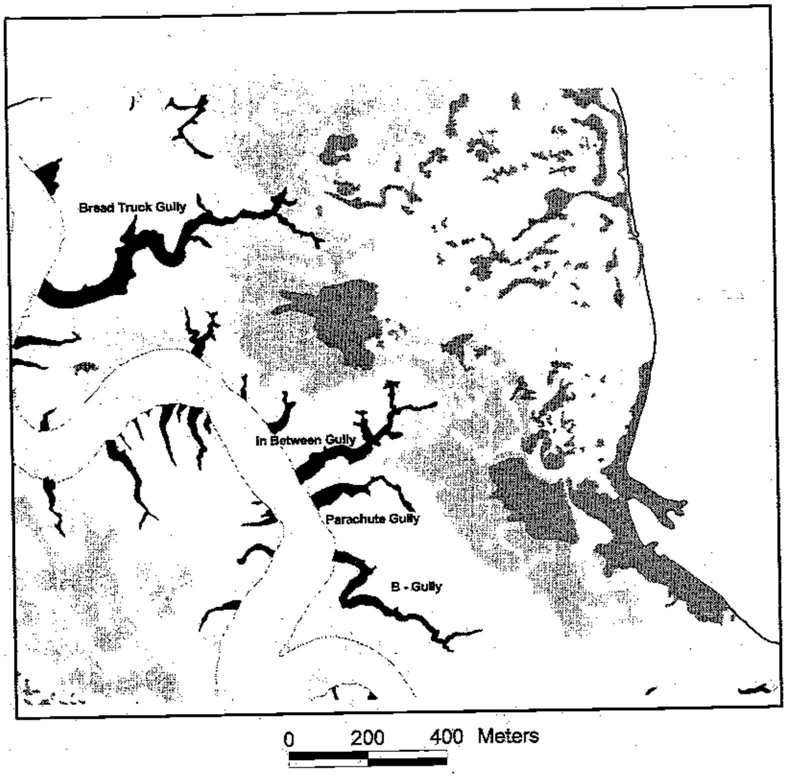

Figure IV-3-1. Map of the east side of Eagle River Flats, showing the study area and the location of the four tidal creeks or gullies where erosion is being monitored.

sion measurements and remote sensing-GIS based measurements showed close agreement.

RESULTS AND DISCUSSION

Figures IV-3-2, IV-3-3, and IV-3-4 show overlays of 1998 and 1999 GPS data mapping the scarp edge of B-Gully, and Parachute and In-Between Gullies. From these figures, it is apparent that there has been no additional headward erosion in these three gullies between August 1998 and August 1999. The apparent decrease in the width of Parachute and In-Between Gullies from 1998 to 1999 is attributable to a difference in the interpretation of the gully edge while mapping with the GPS. Vegetation had moved onto the slumped sediments of these two gully sides, so that in 1999 the bare sediments began lower on the slope.

Figure IV-3-5 shows the changes in the headwall and near-edge position of the Bread Truck ditch from August 1996, August 1997, August 1998, and August 1999. This ditch was blasted in April 1996 to drain the Bread Truck Pond. Between August 1996 and August 1997, the headwall formed two lobes, with one lobe extending south almost 25 m during this short period. From August 1997 to August 1998, this headwall eroded an additional 12 m, and from August 1998 to August 1999, it eroded an additional 5 m. Meanwhile, the other headwall lobe on the east eroded about 10 m during the past year. On the east side of this ditch, the lateral wall also eroded considerably from August 1997 to August 1998 and the east headwall lobe expanded about 8 m per year in both 1999 and 1998. It was in this lobe that the white phosphorus round was presumably exposed in June 1999.

There has been little new erosion of the headwalls of the three natural gullies draining the treated ponds on the east side of Eagle River Flats during the past year (August 1998 to August 1999). However, two lobes at the headwall of the constructed ditch in the Bread Truck Pond continue to erode on an average of about 8–10 m per year. These will eventually develop into two separate gullies, which may uncover additional ordinance buried by

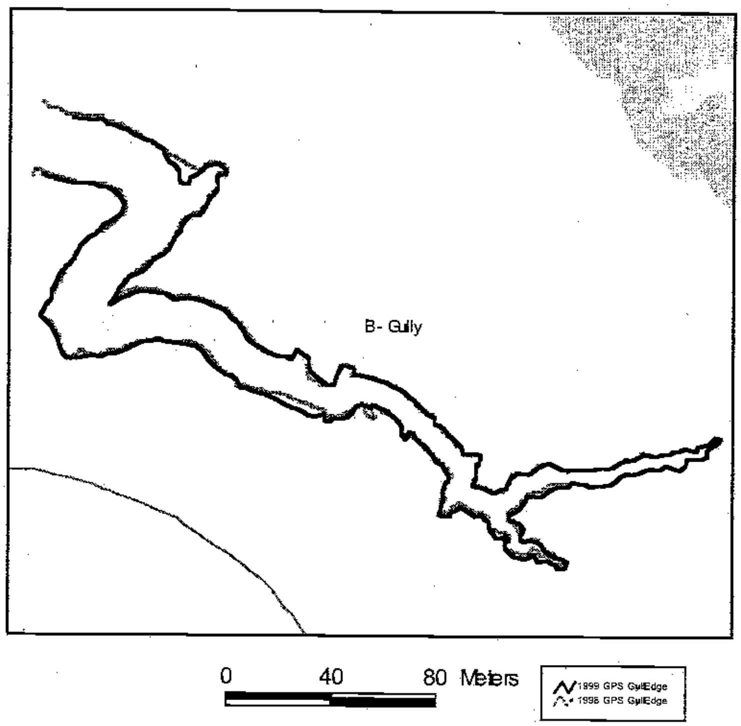

Figure IV-3-2. Close-up of a portion of B-Gully, showing the location of the gully edge in August 1998 and August 1999 as mapped with a differential GPS.

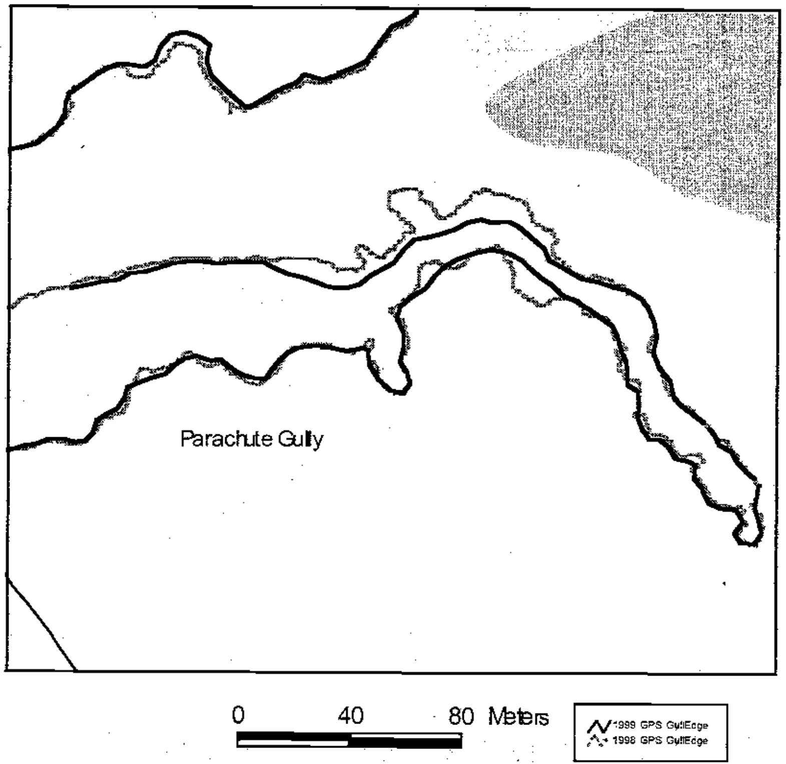

Figure IV-3-3. Close-up of a portion of Parachute Gully, showing the location of the gully edge in August 1998 and August 1999 as mapped with a differential GPS.

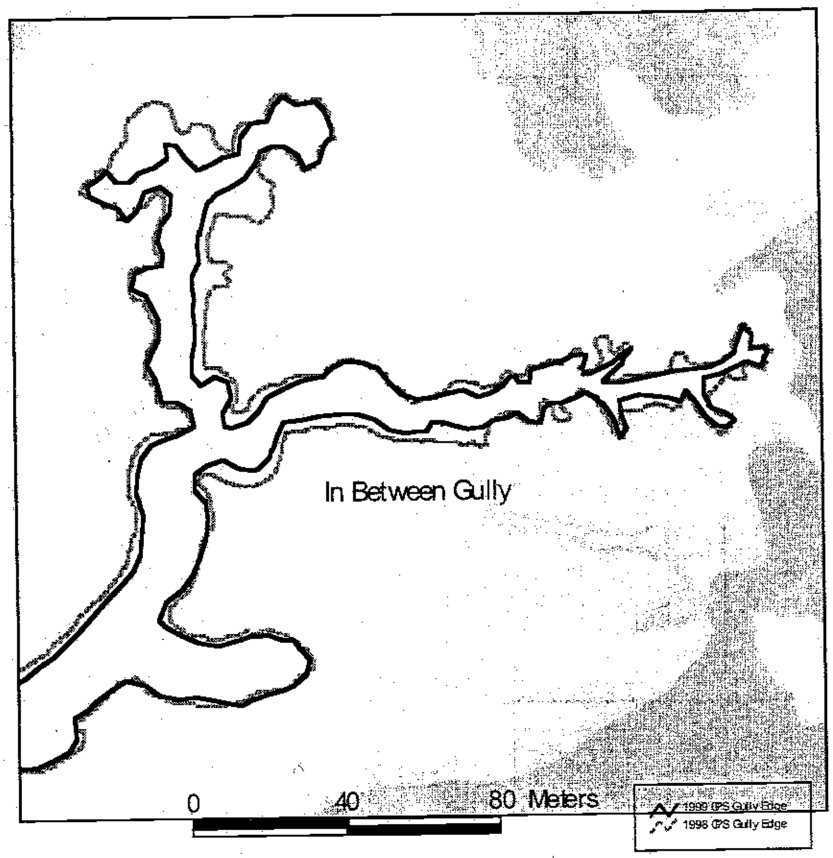

Figure IV-3-4. Close-up of a portion of In-Between Gully, showing the location of the gully edge in August 1998 and August 1999 as mapped with a differential GPS.

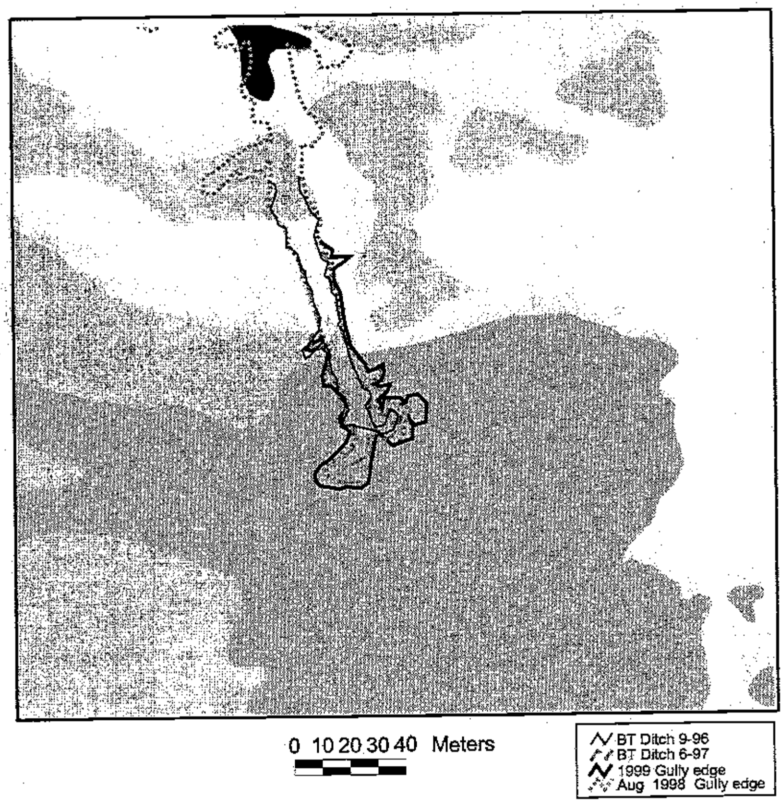

Figure IV-3-5. Close-up view of the blasted ditch constructed in April 1996 to drain the Bread Truck Pond, showing the edge of this ditch in September 1996, August 1997, August 1998, and August 1999.

sediments in the Bread Truck Pond as they erode. An effort may be required to stop this "runaway" erosion of the Bread Truck ditch, either by construction of a tide gate or by other means.

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