OU-C 32308

Interagency Expanded Site Investigation

Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska

FY 97 Report

August 1998

Prepared for

U.S. ARMY, ALASKA
DIRECTORATE OF PUBLIC WORKS
William A. Gossweiler, Project Manager

Prepared by

U.S. ARMY COLD REGIONS RESEARCH AND
ENGINEERING LABORATORY
Charles M. Collins and David W. Cate, Report Editors

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I. EXECUTIVE SUMMARY

INTRODUCTION

This is the eighth annual contract report prepared by researchers from CRREL and other Federal agencies for USACE-Alaska and USARAK Directorate of Public Works describing the results of white phosphorus contamination studies in Eagle River Flats, an 865-ha estuarine salt marsh on Fort Richardson, Alaska. Eagle River Flats is designated as part of Operable Unit C (OU-C) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Documents produced under CERCLA, such as the Ecological Risk Assessment, Remedial Investigation, and Feasibility Study, have used the research results first published in this series of annual contract reports.

The use of Eagle River Flats on Ft. Richardson, Alaska, as an impact area has resulted in the contamination of large areas with the smoke munition component white phosphorus (WP). White phosphorus is a manufactured form of elemental phosphorus that does not naturally occur in the environment. It is unstable at moderate temperatures and will sublimate and oxidize if exposed to the atmosphere. It will auto-ignite if exposed to air at temperatures above approximately 30°C. However, it is quite stable if stored under water.

This year's report focuses on treatability studies of remediation procedures for the white phosphorus contamination. Of special note is the treatability study using a remote-controlled pump to temporarily drain a contaminated pond and keep it drained for an extended period during the summer. The treatability study, using a 2000-gpm pump in Pond 183 in Area C, was highly successful, exceeding our most optimistic expectation. We were able to pump the pond out, allowing the pond bottom sediments to dry and the white phosphorus to sublimate and oxidize. Pre- and post-treatment composite sampling of the pond bottom sediments showed reduction of over 85% in the average white phosphorus concentration levels. Pond pumping has been selected as the preferred remediation alternative in the Proposed Plan published in February 1998. Other studies reported on in this year's report are the permanent pond draining of Pond 270 on Racine Island, waterfowl use and mortality studies, the monitoring of reduction of white phosphorus contamination in the various treatability study areas, and the management of all the data collected for Eagle River Flats in the ERF GIS database.

II-1. WATERBIRD UTILIZATION OF EAGLE RIVER FLATS: APRIL–OCTOBER 1997

William D. Eldridge and Donna G. Robertson

Waterbird utilization of Eagle River Flats (ERF) was monitored during spring, summer and fall 1997, with 36 aerial observations. Numbers of waterbirds, identified to species or species group, were recorded by study area and pond number within the study area, and by four major habitat types. ERF became snow and ice free earlier than in 1996, experienced extremely dry conditions during summer, and experienced normal water levels in fall with a relatively early freeze-up. Numbers of swans in spring and fall were similar to 1996 but considerably lower than the 1988–95 average. Numbers of geese were similar to recent years. Duck utilization of ERF was minimal in spring 1997, but normal for summer, despite the low water levels. Duck migration in fall, 1997 exhibited a strong peak in early September rather than the protracted series of peaks normally observed, but the mean number for fall was similar to the 1988–95 average. Ducks preferred areas Areas B, C, and CD most in fall, with highest densities in Areas B and CD.

A comparison of air and ground counts on the same survey dates in fall was made to develop a correction factor for birds missed from the air, and to obtain a more accurate species composition of ducks. There were no statistical differences between counts of geese and swans from the air and ground, but there was a statistical difference between duck counts. Biases associated with the air/ground comparison probably make the counts unreliable for air/ground corrections. The ground counts do provide reliable counts for species composition.

II-2. MOVEMENTS, DISTRIBUTION AND RELATIVE RISK OF WATERFOWL AND BALD EAGLES USING EAGLE RIVER FLATS: 1997

John L. Cummings, Richard E. Johnson, Kenneth S. Gruver, Patricia A. Pochop, James F. Foley, James E. Davis, Jean B. Bourassa, and Charles H. Racine

We determined spatial distribution, movements, turnover rate, and mortality of mallards using Eagle River Flats, Fort Richardson, Alaska, during fall migration, August 2 to October 22, 1996. One hundred thirty-six mallards were randomly captured between August 2 and 12 on ERF using a net-gun from a Bell UH1 helicopter. Each mallard was banded and fitted with a 9.1-g backpack transmitter and released at its capture site. Of the 136 mallards, 55 were fitted with standard transmitters and 82 mallards were fitted with mortality transmitters. 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 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). However, mallards were only located 6 of 144 times in Racine pond and 2 of 21 times in Bread Truck pond. 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 October 7 to 16, when 52% of the mallards departed ERF. The mortality of instrumented mallards that used ERF from August 2 to October 22 was 35. Of that, 21 were attributed to white phosphorus ingestion. The greatest mortality occurred in Area BT, 5 of 21 (24%); Area A, 5 of 21 (24%); and Areas C/D and C, 7 of 21 (33%). Overall, these areas accounted for 81% of the mallard mortality on ERF. No mallard mortality was noted from capture, handling, or the transmitter. We recovered 15 whole duck bodies from the 21 white phosphorus mortalities. Analysis is planned. 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 August 3 to October 16. Dabblers peaked at 2333 individuals between September 13 and 16. The overall mortality that occurred on ERF was 655 dabblers. In 1997, 6063 individual dabblers used ERF from August 2 to October 22. Dabblers peaked at 4398 individuals between September 9 and 10. The overall mortality that occurred on ERF was 240 dabblers. These data represent a minimum number of mortalities on ERF during the fall migration. In conclusion, we feel that the baseline data collected in 1996 and 1997 can be used to measure the effects of future remediation actions.

III-1. REPORT OF USDA-APHIS-WILDLIFE SERVICES FOR THE U.S. ARMY AT EAGLE RIVER FLATS: APRIL–OCTOBER 1997

Corey Rossi

During 1997 USDA-APHIS-Wildlife Services (WS), formerly Animal Damage Control, continued efforts to keep migratory waterfowl from being poisoned by white phosphorus in Eagle River Flats Impact Area. From April 21 to May 31, 1997, a total of 945 ducks and 30 Canada geese were hazed at Eagle River Flats by five WS personnel. A total of 613 staff hours were expended in the field over 41 days of hazing. There were no waterfowl mortalities found by WS personnel during the spring of 1997. Several standard hazing methods were, including propane cannons , visual scare devices such as scarecrows and mylar tape, eagle effigies were used in Area A, Racine Island, C Pond, Lawson's Pond, and Bread Truck Pond to deter waterfowl from using the area. To augment the effectiveness of these static devices, WS personnel used 15-mm pyrotechnics, shell crackers, and 20-in. skyrockets to frighten birds from areas of concern.

During the fall of 1997, WS personnel essentially remained on standby, monitoring swan activity in the hot areas and assisting USDA-APHIS National Wildlife Research Center researchers with hovercraft support to recover transmitters from duck mortalities. Very few static deterrent devices were deployed in fall 1997. Late in the fall a few propane cannons were deployed in Area A, when two swan mortalities were discovered there. From September 23 to October 26, 1996, in excess of 280 staff hours were expended monitoring the hot areas for swan activity, as well as transferring and repairing hovercrafts. Two swan mortalities were recovered by WS personnel during the fall of 1997.

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

We monitored the effectiveness of pond draining on the remediation of white-phosphorus-contaminated sediments. Transects were established in Area C (ponds 164 and 183), which was drained by pumping, and in the

Bread Truck Pond (ponds 99 and 109), which was drained by breaching. The 200-m-long transects extended from what was intermittent pond on the west side to what was permanent pond on the east side. At 100-m intervals, dataloggers recorded the output of sediment moisture and temperature sensors, and the attenuation of planted white phosphorus particles was measured. At 50-m intervals, composite samples were collected from gridded areas extending 20 m north and south of the west–east transects.

Pumping was very successful at drying the surface sediments of Area C. Breaching of the Bread Truck Pond has resulted in some drying of the surface sediment, but a topography characterized by swales and craters that do not drain and a lower tidal flooding threshold slow the potential attenuation rates.

Sublimation/oxidation conditions were favorable for removal of some white phosphorus from the surface sediments of Area C and the Bread Truck Pond. An approximately 50% decline in mass, from 5.56 to 2.8 ± 0.9 mg, was found for white phosphorus particles planted in the surface sediments of Area C and the Bread Truck Pond. Composite samples taken in June from Area C and the Bread Truck Pond showed that most of the contamination was located at the midpoint of transects running west to east from intermittent to permanently flooded ponds. Resampling in September showed significant declines (>80%) in white phosphorus concentrations in Area C and the south side of Bread Truck Pond. Because the mass of white phosphorus found in the composite samples is the sum of a range of particle sizes, from colloidal to macroscopic, and because small particles take less time to attenuate, we see greater loss for those composite samples that had particles smaller then the manufactured particles. The composite sample taken in September from the north side of the Bread Truck Pond, where drying conditions were variable and white phosphorus particles were large, did not show a detectable change in concentration from the June sample.

Additional composite samples were taken from Pond 40 of Area C/D. No white phosphorus was detected by composite sampling, indicating that this pond is not a serious threat to waterfowl.

Finally, monitoring of the dredge spoils continued. The dredge spoils were air-dried in the retention basin during 1997, and no white phosphorus residue was found from particles planted in 1995.

III-3. DRAINING OF RACINE ISLAND POND BY EXPLOSIVE DEMOLITION OF A DRAINAGE DITCH

Charles M. Collins, MAJ Michael T. Meeks, and Marianne E. Walsh

In April 1997 we successfully conducted an operation to permanently drain a pond in Eagle River Flats contaminated with white phosphorus. This pond, located in the center of Racine Island, was one of the most highly contaminated in Eagle River Flats, with measured concentrations of white phosphorus of up to 3071 mg/g. We drained the pond by using explosives to excavate a drainage ditch connecting the pond with a nearby tidal drainage gully leading to Eagle River. This year's operation built on the success of a similar operation last year to drain Bread Truck Pond (Collins et al. 1997). Using explosives to excavate drainage ditches is an efficient and cost-effective method to permanently drain a pond where the potential dangers posed by unexploded ordnance (UXOs) preclude the use of conventional excavation equipment.

III-4. IMPLEMENTATION OF A REMOTE PUMPING SYSTEM FOR WHITE PHOSPHORUS REMEDIATION IN POND 183

Michael R. Walsh, Charles M. Collins, and Dennis J. Lambert

In 1997, funds became available for the feasibility study of pond pumping for remediation. A pump system, consisting of an 80-kW generator set, a separate 7.56-m^3/min (2000 gpm) pump, and 335 m of 20-cm-diameter discharge line, was available for this study. Originally planned for use in Pond 109, the decision was made to try to treat Pond 183 (C Pond) with this system. Pond 183 is not as isolated as Pond 109 and is much larger. It is also interconnected with a large number of adjacent ponds, including Pond 146, where dredging had been conducted, and Pond 155 (Lawson's Pond), another highly contaminated pond. Recharge from Clunie Creek and seeps along the shore of Ponds 146 and 40 were also thought to be problematic.

The overall performance of the pumping system was much better than expected. The system easily addressed the target area and influenced a wide area surrounding it as well. Improvements to the system increased its reliability and decreased the amount of human intervention required to keep the system operational. A second pump system, incorporating most of the features developed during deployment and operation of the first system, was ordered, received, and operational within two days. It has been run in and will be ready for deployment when needed, after some minor modifications.

The results from the sampling study indicate that remediation may be possible over the course of three good drying years (>60 core days without heavy rainfall). Based on composite sampling results, over 84% of the white phosphorus was remediated over the summer, and approximately 55% of planted particles' mass (5.56 mg original mass) attenuated over the same time span. For areas that may dry more slowly or flood more often, the term may be closer to the five years predicted by CH2M Hill. Sumps are ready for pump deployment in Ponds 155 and 290, and a route has been marked for clearance and access to Pond 146 next year. With pumps in Ponds 146, 155, and 183, drawdown should be much more rapid than this season's, perhaps less than 24 hours.

The pumped drainage of permanently ponded areas and their associated intermittent ponds is an almost ideal solution to the problem of white phosphorus contamination in Eagle River Flats. The relatively low costs and mild environmental impact of this remediation method make it a very viable option where it can be applied. It may even negate the need for bentonite coverage of most targeted areas. It should be considered in as many contaminated areas as feasible.

IV-1. MAPPING AND CLASSIFICATION OF INTERMITTENT AND PERMANENT PONDS ON EAGLE RIVER FLATS

Charles Racine, Brian Tracy, and Peter Berger

If ponds with sediments that become desaturated in some years can be identified, it is cost effective to allow natural attenuation of white phosphorus to occur in these ponds, rather than actively dredge, pump, or drain. In 1993, about 350 ponds covering 125 ha were photointerpreted from orthophotos and digitized into a GIS database (ARC/INFO). Each pond was classified as permanent (ponds that do not dry out in any year) or intermittent (ponds that dry up in some years and where white phosphorus could potentially sublimate). In mid-July1997 we conducted a field accuracy assessment of this classification by visiting 35 mapped ponds during a "dry period" (i.e. 60+ days without a flooding tide) and determined how much of the surface was flooded as well as other pond characteristics. The results showed an 86% accuracy in the original classification, well within the FGDC level of acceptance. In addition, we tested the use of digital multispectral video (DMSV) images for automated mapping of permanent and intermittent ponds and for monitoring pond drying and other conditions. Classified DMSV imagery was also used successfully to monitor both headward and lateral gully erosion between 1993 and 1997.

IV-2. GIS REMEDIATION DATABASE FOR EAGLE RIVER FLATS

Charles Racine and Peter Berger

As the remediation of white phosphorus in ponds proceeds over the next several years, the GIS database will centralize the data needed to evaluate the success of the effort and monitor changes in the environment on ERF. The database design is described and diagrammed. Ongoing analysis of radiotelemetry data will help analyze movements and mortality. New coverages for remediation actions, white phosphorus composite sampling, and planted particles were added during FY97. New remote sensing methods for determining which ponds have drained and for monitoring gully advancement are described in another section of this report.

II-1. WATERBIRD UTILIZATION OF EAGLE RIVER FLATS: APRIL–OCTOBER 1997

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

Donna G. Robertson
WEST, Inc.

INTRODUCTION

Aerial surveys to monitor waterbird use of Eagle River Flats (ERF) during the spring, summer, and fall of 1997 were conducted by the U.S. Fish and Wildlife Service as part of the ongoing mortality studies of ERF sponsored by the U.S. Army. The purpose, history, and status of these investigations have been presented elsewhere (Racine and Cate 1996).

STUDY AREA

Eagle River Flats is a salt marsh complex comprising 870 ha located on the southern 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 mid-October 1997. Surveys were conducted twice per week during spring and fall and once per week during summer, except when weather or air space restrictions did not permit flights. Surveys were flown using fixed-wing aircraft at an airspeed of 100–120 km/hr and at an altitude of 50–75 m. Total coverage of ERF was obtained by overlapping transects. The numbers of waterbirds were counted or estimated and recorded by species or species groups with a cassette tape recorder. Waterfowl numbers were classified by location on ERF using standardized study areas (Fig. II-1-1). In addition, separate bird counts were recorded by ponds within the study areas to better define bird use. Areas (ha) of study ponds were obtained from digitized maps provided by CRREL and used to convert bird numbers to densities.

In addition to aerial surveys, ground counts were conducted during selected fall aerial surveys to develop a correction factor of missed birds for application to aerial counts and to obtain more accurate species composition data. Ground counts were conducted from three observation towers: CD, Cole Point, and Swan Hotel (Fig. II-1-2). Aerial surveys were always flown during ground surveys. Areas surveyed by ground and air observers were standardized to compare results (Fig. II-1-2).

RESULTS AND DISCUSSION

Aerial survey data from previous years that are referenced in the following discussion can be found in Racine and Cate (1996).

Moisture conditions

Snow and ice covered 80% of ERF on 8 April, and most of the ice in ponds had sunk. On a similar date in 1996 there was 100% snow and ice cover, and most of the ice was still exposed on pond surfaces. By 16 April ERF was

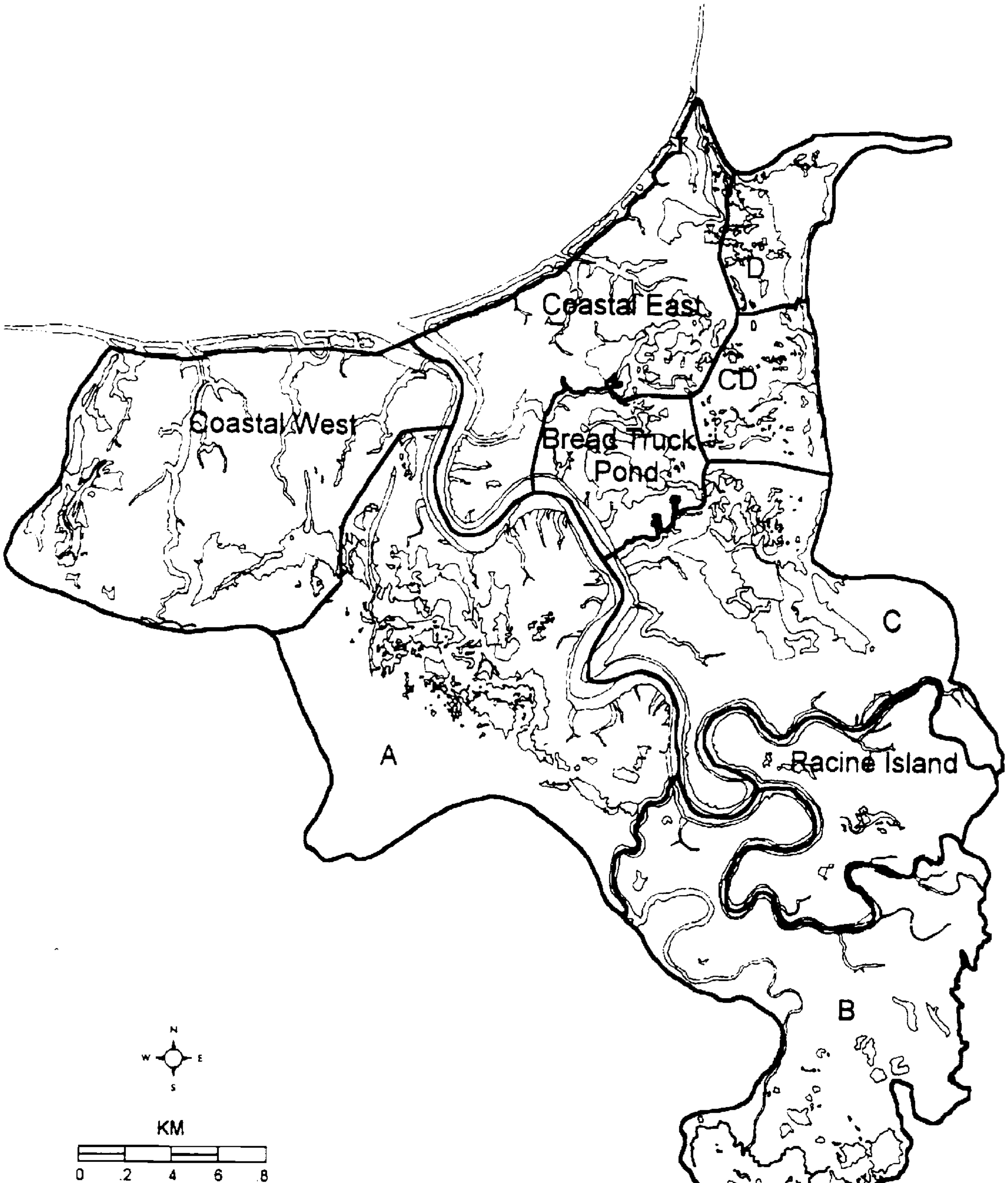

Figure II-1-1. Standardized ERF study areas surveyed for waterfowl.

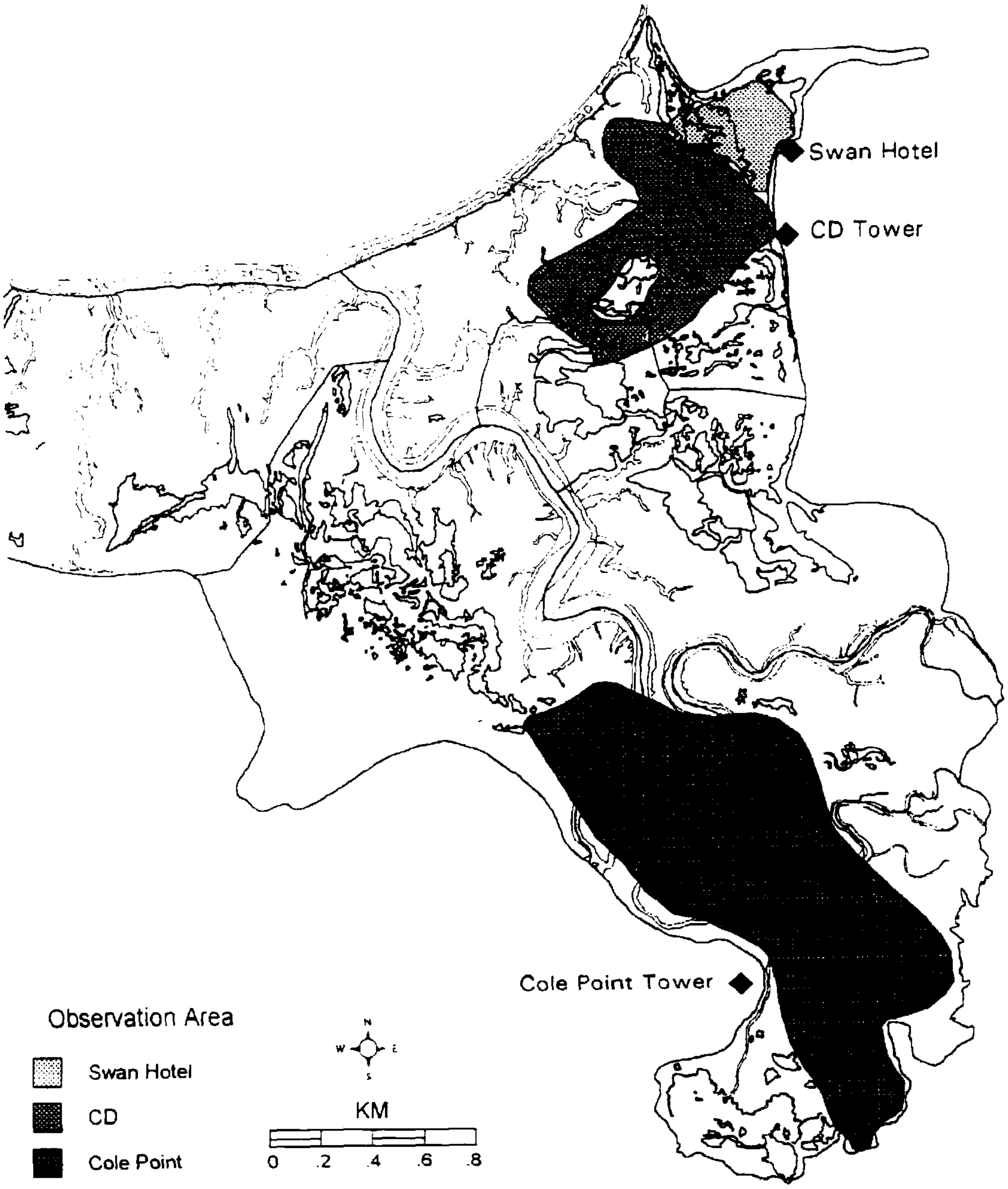

Figure II-1-2. Observation towers (CD, Cole Point, and Swan Hotel) and areas surveyed during ground counts of waterbirds on ERF, fall 1997.

75% open, considerably earlier than in recent years. Area B was still 85% ice covered at that time. By the end of April the entire ERF was open, with Area B the last to melt. May, June, July, and August were some of the driest months on record, and much of ERF was dry through the summer. Only the deepest, permanent ponds retained water until flooding high tides in August and September replenished the water levels. Water levels in one Racine Island pond were altered by blasting a ditch to a tidal creek. ERF froze early in October in 1997, and by 16 October the only open water was found in tidal creeks.

Abundance and distribution of waterbirds on ERF from aerial surveys

Thirty-six aerial surveys were conducted in 1997. Numbers of birds by species or species groups are listed by survey date in Table II-1-1 and Figure II-1-3. 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 major species or species groups is presented below.

Swans

Utilization of ERF by tundra swans (*Columbus columbianus*) and trumpeter swans (*C. buccinator*) was minimal during spring 1997 (Table II-1-1), similar to 1996, with a maximum count of 19 on 24 April. The mean spring count of three birds per survey is the lowest recorded since surveys began in 1988 and considerably below the 1988–1995 mean of 38. Swans used permanent ponds of Areas B and A most in spring 1997 (Table II-1-2, Fig. II-1-4).

In fall, swan numbers peaked during the first few days of October at 130 birds, fewer than in recent years. The mean fall count of 36 birds per survey was the lowest recorded since 1988 and considerably below the 1988–1995 mean of 213. Swans were not recorded on ERF after 9 October. Swans used areas D and B the most during fall 1997 (Table II-1-2, Fig. II-1-4), similar to other years. Swan use of Coastal West was higher than in recent years, primarily due to two survey dates when most of ERF was flooded from very high tides and swans had either been disturbed to this area or were utilizing food sources not available to them at normal water levels.

Geese

Peak aerial counts of geese occurred during the third week of April, due primarily to lesser snow geese (*Chen caerulescens caerulescens*) (Table II-1-1). Snow geese comprised 54% of the total geese counted in spring, followed by Canada geese (*Branta canadensis*). Small numbers of Pacific geese (*Anser albifrons frontalis*) and tule white-fronted geese (*A. a. gambelli*) were observed in low numbers, similar to other years. Mean spring numbers and densities of combined species of geese were highest in the Coastal West area, followed by Area A and Coastal East (Table II-1-2, Fig. II-1-5).

Canada geese used ERF only rarely in summer, probably due to the extremely low water levels. A few Canada goose broods were observed on ERF in late June.

Fall goose migration phenology was earlier than in other recent years, peaking in early September (Fig. II-1-3). Tule white-fronted geese comprised 7% of the fall count. Snow and Pacific white-fronted geese rarely migrate through Cook Inlet during fall and were not observed on ERF. Coastal West was the most important area for geese in fall (Table II-1-2, Fig. II-1-5).

Ducks

Duck species utilizing ERF in 1997 were similar to previous years (Table II-1-1). Of the four major habitat types used in classification, the majority of ducks were counted on ponds through the season (Table II-1-3). Dabbling ducks comprised 99% of the ducks counted from the air (97% from the ground). Mallards (*Anas platyrhynchos*), American wigeon (*A. americana*), green-winged teal (*A. crecca*), northern pintail (*A. acuta*), and northern shoveler (*A. clypeata*) were the most common species observed. Numbers of all species of ducks combined are presented for 1991–1997 (Fig. II-1-6).

In spring, numbers of ducks peaked in early May. The mean number of ducks in spring

Table II-1-1. Numbers of birds, by species or species group, observed during aerial surveys of ERF in 1997.

	4/8	*4/16*	*4/22*	*4/24*	*4/28*	*5/2*	*5/9*	*5/13*	*5/19*	*5/28*	*6/6*	*6/13*	*6/23*	*6/30*	*7/12*	*7/22*	*7/30*	*8/4*
Swans	0	0	0	19	12	0	0	0	0	0	0	0	0	0	0	0	0	0
Geese																		
Greater white-fronted	0	0	0	8	10	20	0	3	0	2	0	0	0	0	0	0	0	0
Lesser snow	0	83	2325	884	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Canada	0	660	982	950	98	54	8	6	15	2	5	7	31	0	0	0	0	3
Subtotal geese	0	743	3307	1842	108	74	8	9	15	4	5	7	31	0	0	0	0	3
Ducks																		
Green-winged teal	0	0	0	33	52	140	24	21	47	17	13	17	105	0	44	13	86	55
Mallard	8	71	90	23	4	30	22	8	18	24	4	65	3	33	38	0	66	145
Northern pintail	0	28	6	58	163	162	43	5	6	7	0	19	8	0	0	8	0	33
Northern shoveler	0	0	0	0	2	0	28	10	26	0	15	0	0	0	0	0	0	0
American wigeon	0	123	0	18	33	25	144	31	39	85	101	311	13	130	0	4	3	33
Canvasback	0	0	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0
Scaup	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bufflehead	0	0	0	0	0	2	4	0	0	0	0	0	0	0	0	0	0	0
Merganser	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Unidentified duck	0	5	0	0	0	0	40	0	0	0	71	45		67	20		58	
Subtotal ducks	8	227	96	132	254	359	305	75	151	135	204	457	129	230	102	25	213	266
Other birds																		
Loon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Bald eagle	1	0	1	1	1	0	0	0	0	0	2	0	0	0	0	0	0	0
Northern harrier	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0
Sandhill crane	0	0	0	2	2	21	0	2	4	13	4	1	4	9	0	1	0	6
Shorebird	0	0	2	0	2	69	49	592	232	134	36	0	432	104	27	111	34	3
Gull	0	46	0	20	86	234	58	109	60	40	50	0	51	33	0	15	3	5
Arctic tern	0	0	0	0	3	7	1	19	12	18	10	0	10	10	23	17	0	2

Table II-1-1. Continued.

	8/18	8/21	8/26	8/28	9/2	9/3	9/8	9/10	9/16	9/18	9/23	9/25	9/30	10/2	10/6	10/9	10/16	10/22
Swans	0	0	0	0	7	8	12	14	15	47	63	57	128	130	95	56	0	0
Geese																		
Greater white-fronted	225	42	50	55	115	80	27	103	0	3	0	10	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	350	248	145	895	395	1083	660	735	200	574	180	422	190	208	5	0	0	0
Subtotal geese	575	290	195	950	510	1163	687	838	200	577	180	432	190	208	5	0	0	0
Ducks																		
Green-winged teal	52	32	150	53	170	245	255	155	31	16	10	66	5	88	85	6	0	0
Mallard	177	60	305	163	265	148	647	240	72	6	243	238	25	650	90	157	18	6
Northern pintail	34	31	120	5	20	75	233	90	0	5	23	20	0	0	0	0	0	0
Northern shoveler	0	10	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
American wigeon	55	0	65	15	30	90	0	15	20	6	0	0	0	0	3	0	0	0
Canvasback	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scaup	0	0	0	0	10	0	0	0	15	0	0	0	0	0	5	0	0	0
Bufflehead	0	0	0	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0
Merganser	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unidentified duck	75	181	120	462	390	655	943	3169	202	366	296	280	1168	410	293	186	0	0
Subtotal ducks	393	314	780	698	885	1213	2078	3669	340	414	572	604	1198	1148	476	349	18	6
Other birds																		
Loon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bald eagle	0	0	3	1	2	1	6	0	0	0	0	2	2	0	10	2	0	0
Northern harrier	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Sandhill crane	7	17	13	19	38	45	26	17	33	27	13	0	0	0	0	0	0	0
Shorebird	0	0	0	0	0	0	6	10	0	0	15	0	0	0	0	0	0	0
Gull	0	0	10	0	0	0	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	0	0	0	0

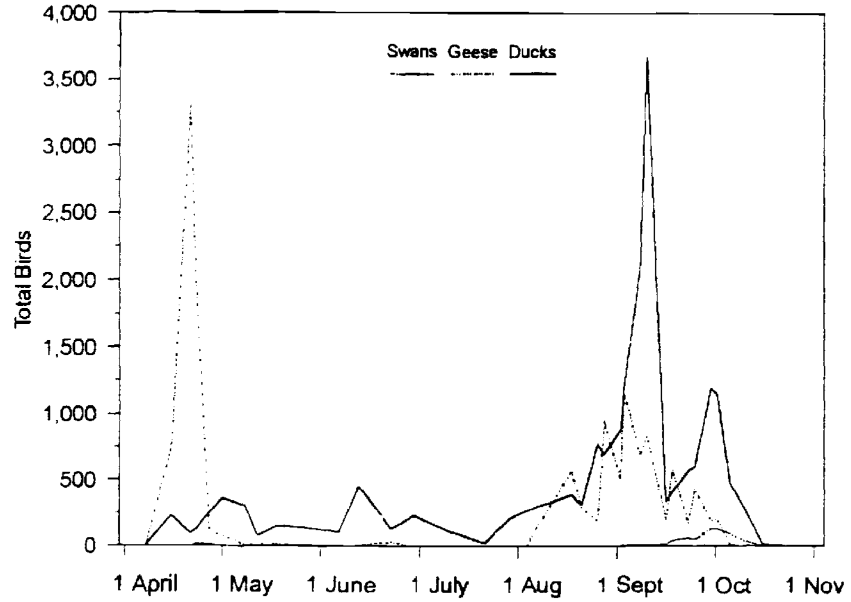

Figure II-1-3. Numbers of swans, geese, and ducks counted on ERF during aerial surveys in 1997.

Table II-1-2. Mean numbers of waterfowl groups in 1997 by season. The number of complete surveys used to classify observations by area, for spring, summer, and fall were 10, 9, and 16, respectively.

	Coastal West	*A*	*B*	*Racine Island*	*C*	*CD*	*Bread Truck Pond*	*Coastal East*	*D*
				Spring					
Swans	0.1	0.8	1.6	0.0	0.0	0.0	0.0	0.0	0.6
Geese	185.6	127.0	89.3	5.0	57.2	0.0	21.7	125.2	0.0
Greater white-fronted	0.0	1.4	2.3	0.0	0.6	0.0	0.0	0.0	0.0
Lesser snow	20.8	79.4	77.0	0.0	50.0	0.0	20.0	82.0	0.0
Canada	164.8	46.2	10.0	5.0	6.6	0.0	1.7	43.2	0.0
Ducks	34.9	60.3	20.1	1.4	18.3	7.0	6.3	9.6	16.3
				Summer					
Swans	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Geese	3.7	25.3	4.2	0.0	28.1	0.0	0.0	39.9	0.0
Greater white-fronted	0.0	25.3	3.4	0.0	0.9	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	3.7	0.0	0.8	0.0	27.2	0.0	0.0	39.9	0.0
Ducks	25.2	42.2	60.4	1.3	28.7	26.2	1.7	11.4	62.0
				Fall					
Swans	7.1	5.2	9.9	0.0	0.0	3.5	0.0	0.6	13.3
Geese	188.8	50.9	50.1	0.0	11.3	3.8	0.0	78.1	0.5
Greater white-fronted	9.6	5.9	5.0	0.0	1.7	2.5	0.0	2.5	0.5
Lesser snow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Canada	179.3	45.0	45.1	0.0	9.6	1.3	0.0	75.6	0.0
Ducks	91.9	127.1	225.0	5.5	160.9	103.0	11.4	82.0	96.3

Table II-1-3. Percent duck use of major habitat types by season on ERF in 1997. The total number of ducks counted in each season is in parentheses.

	(n)	Ponds	Knik Shoreline	Eagle River	Tideguts
Spring	(1,728)	93	1	6	0
Summer	(2,333)	92	4	4	<1
Fall	(14,443)	68	11	22	<1
Total	(18,504)	73	9	18	<1

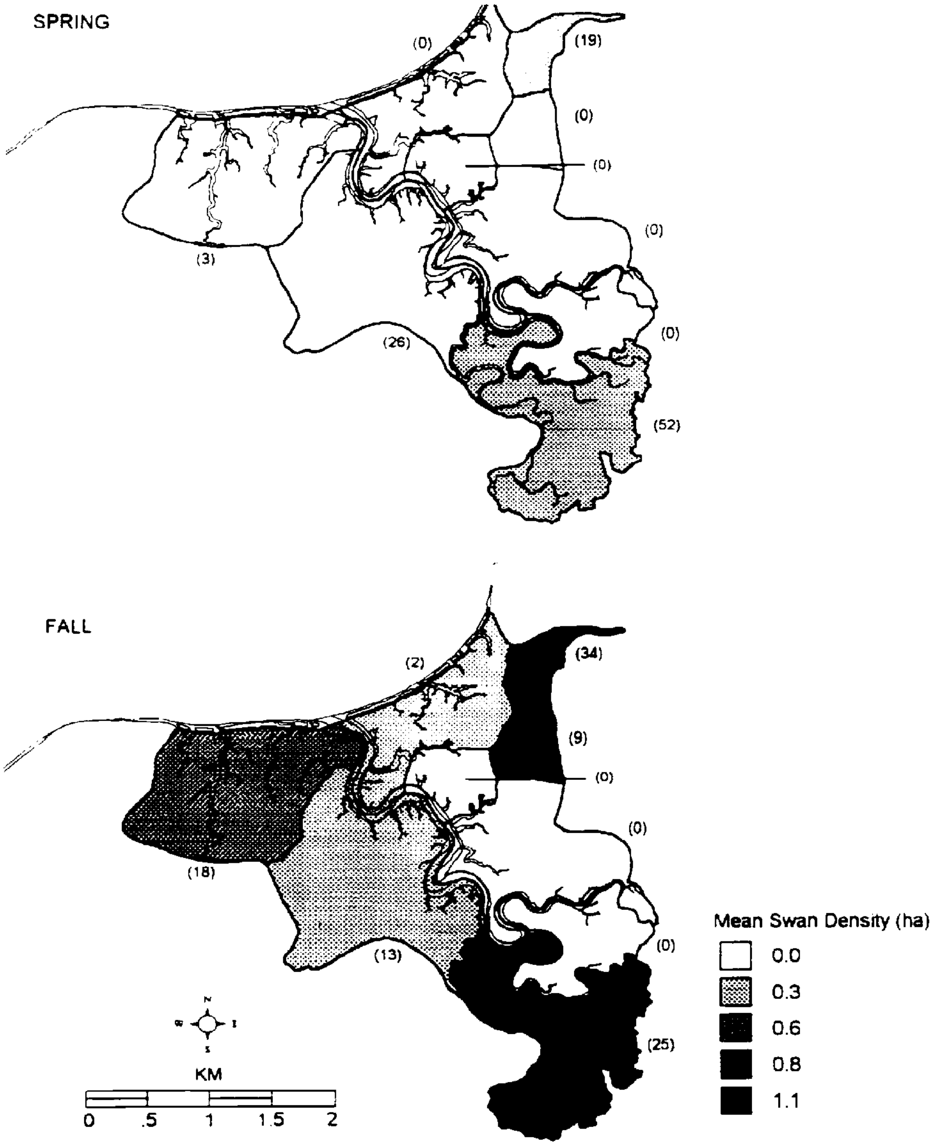

Figure II-1-4. Mean densities of swans on ERF study areas in spring and fall 1997. Numbers in parentheses are the percent of total swans observed in each area. The area (ha) of permanent and intermittent ponds in each area was used to calculate densities.

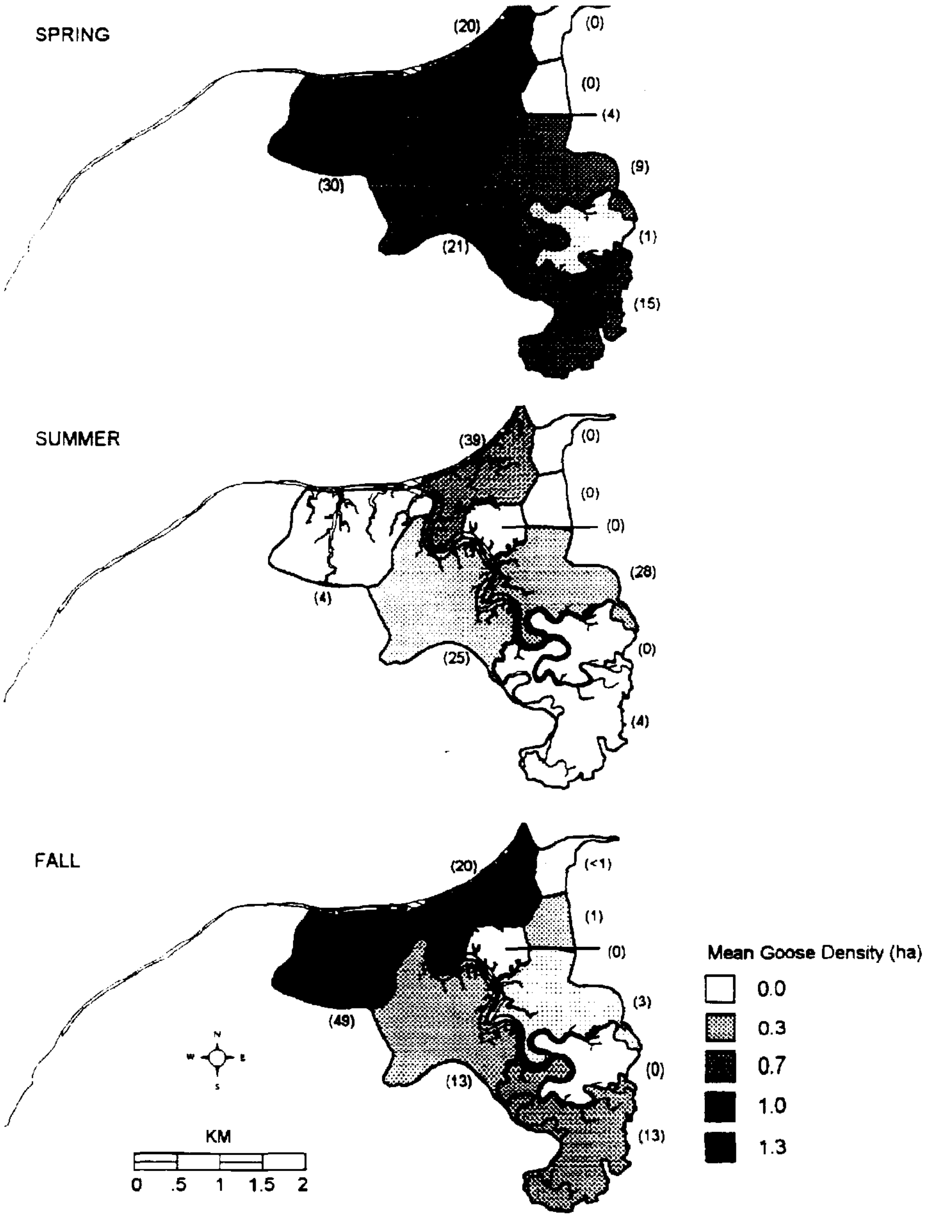

Figure II-1-5. Mean densities of geese on ERF study areas in spring, summer, and fall 1997. The numbers in parentheses are the percent of total geese observed in each area.

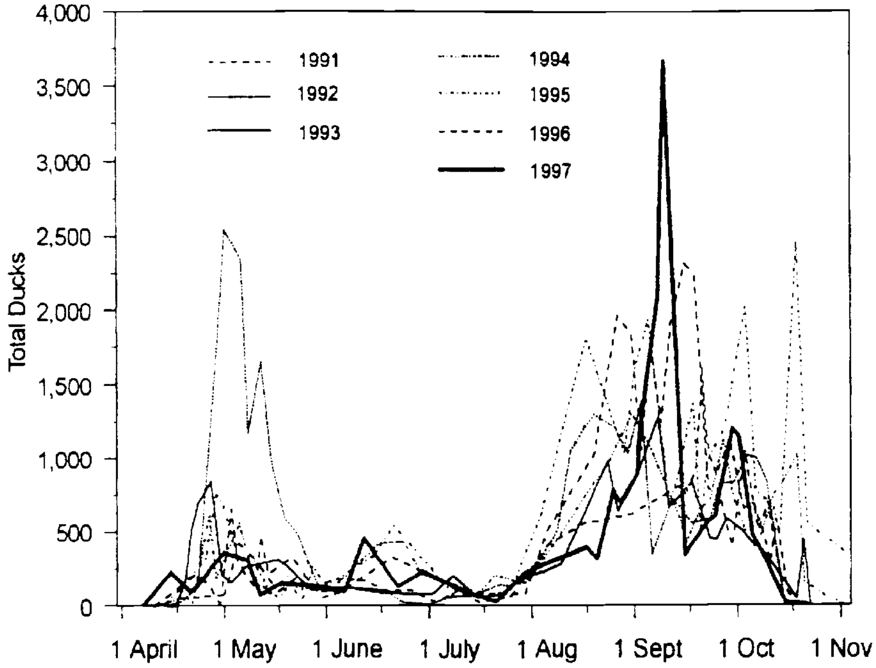

Figure II-1-6. Numbers of ducks observed during aerial surveys of ERF, 1991–1997.

(173) was considerably lower than the 1988–1995 mean of 394 and was the lowest recorded since 1988. Ducks utilized Area A most in the spring in 1997 (Table II-1-2, Fig. II-1-7).

Numbers of ducks in summer were similar to the 1988–1995 mean of 259, even though water levels were extremely low. Ducks concentrated on Areas B and D during summer (Table II-1-2, Fig. II-1-7). A few broods of American wigeons and mallards were observed on ERF during summer but less than in recent years.

Migration phenology for ducks in fall 1997 was different than in other years. Numbers of ducks peaked strongly in early September and dropped sharply, rather than exhibiting a protracted series of peaks throughout fall as in other years (Fig. II-1-6). However, the mean number of ducks observed on fall surveys was 903, similar to the 1988–1995 average of 869. Similar to 1996, the 1997 fall season was shortened by an early freeze-up. Ducks used Areas B, C, CD, and D most in fall, with highest densities recorded on Areas B and CD (Table II-1-2, Fig. II-1-7).

In addition to the standard aerial survey where observations of ducks were assigned to a study area, duck and swan observations were also assigned to individual ponds within a study area using a pond numbering system maintained in a CRREL geographical database (Fig. II-1-8). While it was not possible to separate small ponds in complex areas from the plane, important ponds were distinguished. Nine ponds comprised 75% of fall observations of ducks that were recorded on ponds.

Bald eagles

Numbers of bald eagles (*Haliaeetus leucocephalus*) were low, similar to recent years. While specific shoreline surveys for eagles were not conducted, higher concentrations of eagles typical of earlier years would have been noticed. Lower numbers of eagles in recent years could be due to decreased mortality of ducks on ERF.

Shorebirds

Numbers of shorebirds were combined for

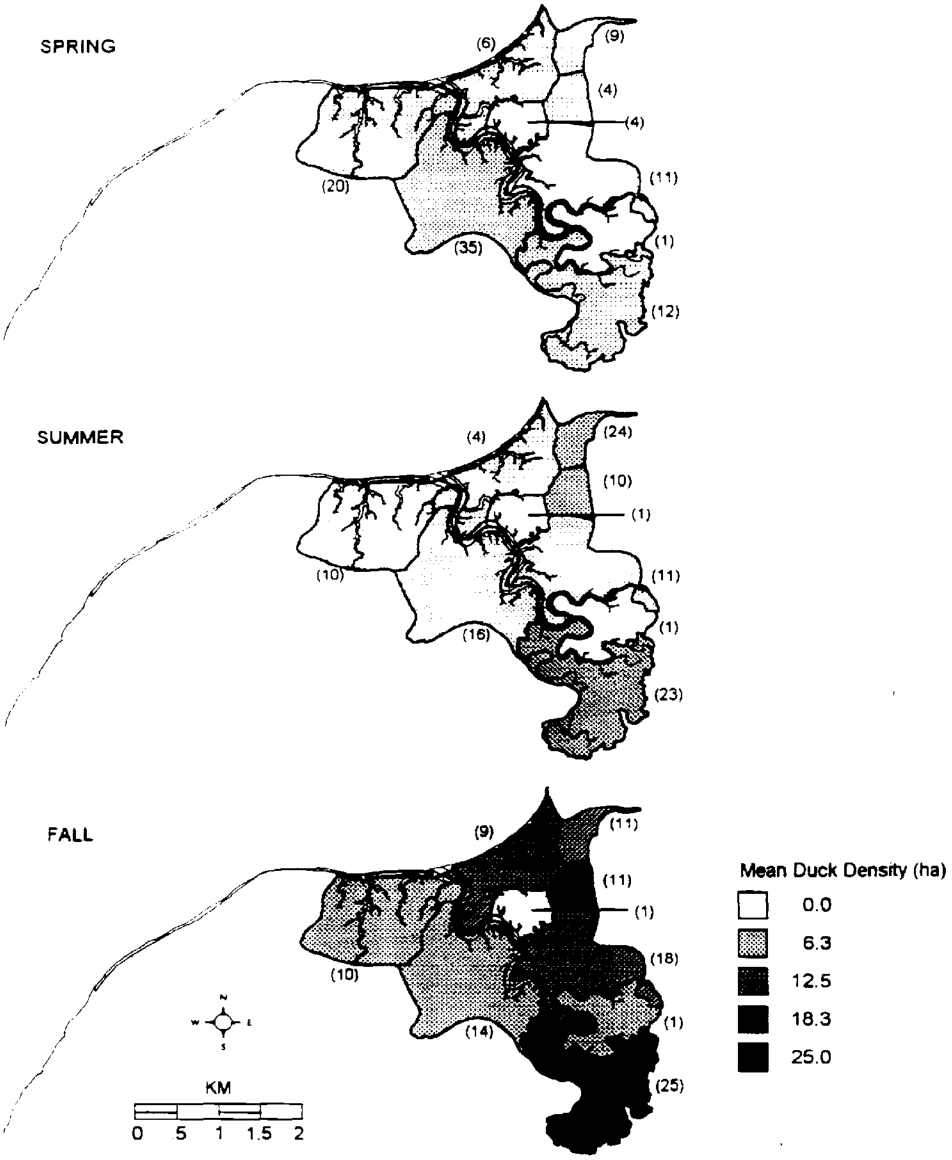

Figure II-1-7. Mean densities of ducks on ERF study areas in spring, summer, and fall 1997. The numbers in parentheses are the percent of total ducks observed in each area. The area (ha) of permanent and intermittent ponds in each study area was used to calculate densities.

all species, since individual species were not identified from the air (Table II-1-1). Numbers of shorebirds were lower than in recent years, particularly in fall. Common species on ERF include least sandpipers (*Calidris minutilla*), semipalmated sandpipers (*C. pusilla*), western sandpipers (*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.*

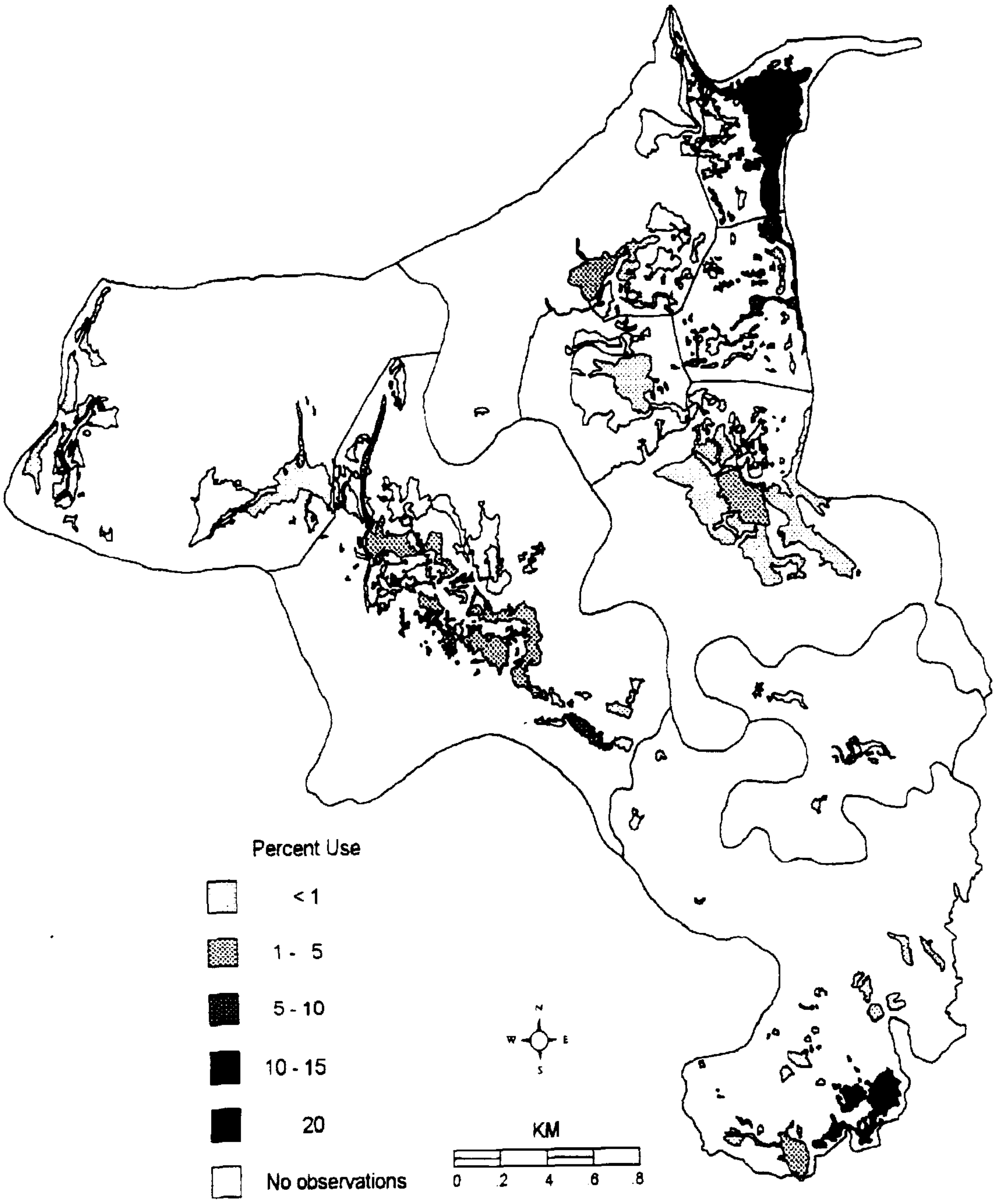

Figure II-1-8. Percent use of ponds by ducks observed on ponds during aerial surveys in fall, 1997.

glaucescens) and herring gulls (*L. argentatus*). Arctic terns (*Sterna paradisaea*) were common into July.

Sandhill cranes

Sandhill cranes (*Grus canadensis*) were observed on ERF throughout the study in small numbers. One sandhill crane chick was observed with adults in mid-summer. Cranes appear to prefer the upland areas of Area B.

Comparison of ground and aerial surveys

Coordinated air and ground surveys were conducted on nine survey dates in the fall, resulting in 26 useable comparisons. During surveys, all swans, geese, and ducks were counted by the ground observer and air observer in the designated areas. The results of the ground survey counts are listed in Table II-1-4. Results of air/ground comparisons by species or species group are presented in Table II-1-5.

No statistical differences were apparent in ground/air comparisons of swans ($P = 0.18$) and geese ($P = 0.45$). However, there was a statistical difference in duck counts ($P = 0.02$). The mean number of ducks counted from the air was 63% of the mean counted from the ground. Several biases with the survey techniques are likely to have contributed to this difference. The comparable air/ground survey areas (Fig. II-1-2) are probably not representative of ERF as a whole. Tidal creeks, most riverbanks, and coastal mudflats, all areas of good visibility from the air, could not be seen from the ground towers, so observations from these areas were not included. Inclusion of these areas would decrease the difference between ground and air counts.

Also, while aerial surveys always occurred during ground counts, it was not possible to synchronize air/ground counts as well as desired due to logistics of scheduling airspace and aircraft. Ground counts of the three study areas took several hours to complete, whereas air counts took less than one-half hour. During the time after the aerial survey was complete, and while the ground count was ongoing, movement of birds could occur, and probably did, so that the air and ground counts may included different populations. Examples of probable biases from bird movements during counts are:

- On 6 October, 23 swans were counted from the air in Swan Hotel (Fig. II-1-2), and 79 were counted from the ground.
- On 28 August, 123 Canada geese were counted from the ground at Cole Point, but none were seen from the air.
- On 16 September, 33 ducks were counted from the air on the CD study area, and 389 were counted on the ground.

It is highly unlikely that easily observable swans and large numbers of geese and ducks were missed from the air.

Finally, although every attempt was made to determine the boundaries of the survey areas by the ground and air observers, permanent markers were not available and some mistakes may have been made, particularly with ducks along the borders. Emergent vegetation complicated border identification and visibility of ducks for both air and ground observers.

Due to these potential biases, we do not believe it is appropriate to use the 63% air/ground ratio to correct for the number of ducks seen from the air. We believe the biases were serious enough that the 63% air/ground ratio is a worst-case scenario. Based on years of aerial survey experience, the senior author predicts that a more realistic air/ground figure for the entire ERF would be near 75% or higher. Air/ground visibility correction factors for breeding pairs elsewhere in Alaska are generally two or more times the number of ducks counted on the ground, but these are determined when birds are in pairs in spring, not flocks during migration such as found on ERF. It is well known that flocked birds are much easier to see than scattered pairs.

It should be noted that the ground counts listed in Table II-1-2 provide an accurate measure of species composition during the fall. Species composition from the air during fall is difficult to obtain because ducks are in eclipse plumage and occur in mixed-species groups. Ground counts can be used to correct the number of unidentified dabblers counted during aerial surveys.

Table II-1-4. Numbers of birds, by species or species group, observed during ground surveys of ERF, fall 1997. Birds were counted from CD tower, Cole Point tower, and the roof blind of Swan Hotel. Aerial surveys were conducted over the same areas.

	8/28			*9/3*			*9/8*			*9/10*			*9/16*		
	CD	*Cole Pt*	*Swan*	*CD*	*Cole Pt*	*Swan*	*CD*	*Cole Pt*	*Swan*	*CD*	*Cole Pt*	*Swan*[a]	*CD*	*Cole Pt*	*Swan*
Swans	0	0	0	0	0	9	13	0	13	8	0	nc	14	0	13
Geese															
Greater white-fronted	0	50	0	0	78	0	0	23	0	0	7	nc	0	0	0
Canada	0	73	0	0	61	0	0	99	0	0	88	nc	0	0	0
Subtotal geese	0	123	0	0	139	0	0	122	0	0	95		0	0	0
Ducks															
Green-winged teal	14	22	8	128	8	17	151	4	78	60	3	nc	83	21	22
Mallard	13	26	42	1	14	46	36	151	81	45	201	nc	54	164	72
Northern pintail	6	0	27	8	0	42	83	0	114	1	0	nc	116	3	48
Northern shoveler	0	0	4	2	0	1	3	0	11	0	0	nc	0	0	0
American wigeon	15	3	27	3	7	45	62	10	109	22	19	nc	131	32	80
Gadwall	0	0	0	0	0	0	0	0	5	0	0	nc	0	0	0
Scaup	0	0	0	0	0	0	0	24	33	0	25	nc	0	5	16
Goldeneye	0	0	0	0	0	0	0	0	0	0	0	nc	0	0	0
Bufflehead	0	0	0	0	0	0	0	0	0	0	0	nc	0	0	2
Merganser	0	0	0	0	0	0	0	0	0	0	0	nc	0	0	0
Unidentified duck	0	64	0	25	36	6	12	122	18	300	67	nc	5	0	5
Subtotal ducks	48	115	108	167	65	157	347	311	449	428	315		389	225	245
Other birds															
Bald eagle	0	0	0	0	0	2	0	0	0	0	0	nc	0	0	0
Great blue heron	0	0	0	0	0	0	0	0	0	0	0	nc	0	0	0
Sandhill crane	2	17	0	0	6	0	0	23	0	0	36	nc	0	15	0
Yellowlegs	10	0	5	4	0	2	0	0	6	0	0	nc	0	0	0
Other shorebird	0	0	0	0	0	0	20	0	53	44	6	nc	9	0	1
Raven	0	0	0	0	0	0	0	0	0	0	0	nc	0	0	0

a—no count was conducted from Swan Hotel on 9/10/97.
b—all areas observable from CD tower were frozen on 10/9/97.

Table II-1-4. Continued.

	9/18			9/23			10/6			10/9		
	CD	*Cole Pt*	*Swan*	*CD*	*Cole Pt*	*Swan*	*CD*	*Cole Pt*	*Swan*	*CD*[b]	*Cole Pt*	*Swan*
Swans	0	4	0	0	0	2	0	19	79	0	26	5
Geese												
Greater white-fronted	0	0	0	7	0	0	0	0	0	0	0	0
Canada	0	279	0	80	0	0	0	0	0	0	0	0
Subtotal geese	0	279	0	87	0	0	0	0	0	0	0	0
Ducks												
Green-winged teal	8	23		38	0	0	0	11	14	0	0	18
Mallard	6	395	4	41	214	69	0	50	159	0	196	74
Northern pintail	0	21	0	145	0	51	13	1	28	0	0	1
Northern shoveler	0	0	0	11	0	9	0	0	1	0	0	0
American wigeon	2	40	17	193	0	93	2	0	32	0	17	3
Gadwall	0	0	0	1	0	0	0	0	0	0	0	0
Scaup	0	4	20	0	0	9	0	0	0	0	0	0
Goldeneye	0	0	0	0	0	2	0	0	6	0	0	0
Bufflehead	0	0	2	0	0	3	0	0	0	0	0	0
Merganser	0	0	0	0	0	0	0	0	2	0	0	1
Unidentified duck	0	9	0	154	0	30	0	0	0	0	0	0
Subtotal ducks	16	492	43	583	214	266	15	62	242	0	213	97
Other birds												
Bald eagle	0	0	0	0	0	0	1	0	0	0	0	0
Great blue heron	0	0	0	1	0	1	0	0	0	0	0	0
Sandhill crane	0	58	0	0	5	0	0	0	0	0	0	0
Yellowlegs	0	0	0	5	0	1	0	0	3	0	0	0
Other shorebird	0	0	0	9	0	0	0	0	0	0	0	0
Raven	0	0	0	0	0	0	10	0	0	0	0	0

a—no count was conducted from Swan Hotel on 9/10/97.

b—all areas observable from CD tower were frozen on 10/9/97.

Table II-1-5. Comparison of aerial surveys to ground counts of major waterfowl groups on ERF, fall 1997. Ground counts were conducted from CD, Cole Point, and Swan Hotel towers. Aerial surveys counted birds in the same areas as ground surveys. Means were calculated from a sample size of 26 (9 surveys, 3 counts/survey, excluding one count from Swan Hotel). A Student's *T*-test for paired observations was used to test whether air and ground counts were different. Significant negative numbers indicate that the ground observer counted more birds than the air observer. Percent air/ground ratios were calculated by dividing the mean number of birds counted during aerial surveys by the mean counted during ground surveys.

	Mean		*Paired T-test*		*Percent air/ground ratio*
	Air	*Ground*	*T*	*P*	
Swans	4.5	7.9	-1.42	0.1673	57
Geese	27.4	32.8	-0.77	0.4459	84
Ducks	134.7	215.8	-2.43	0.0225	63

RECOMMENDATIONS

1. Continue to monitor waterbird populations on ERF with aerial surveys. If mallards continue to be monitored with radio transmitters for mortality studies, then a better effort can be made to determine mallard composition from the air.

2. Due to logistical problems of operating on ERF, ground/air comparisons will be difficult to make. A larger number of surveys, encompassing a larger and more representative area, with greater synchrony are needed but will be difficult to accomplish. A helicopter/fixed-wing comparison may be more useful.

REFERENCES

Racine, C.H. and D. 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.

II-2. MOVEMENTS, DISTRIBUTION, AND RELATIVE RISK OF WATERFOWL AND BALD EAGLES USING EAGLE RIVER FLATS: 1997

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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 February 8, 1990, the Army temporarily suspended firing into Eagle River Flats due to the suspected correlation between explosives and duck deaths (Quirk 1991). 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 (CRREL 1991).

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.

During fall migration, August to September 1993, movement, distribution, turnover rate, and site-specific exposure of waterfowl species most susceptible to white phosphorus poisoning was determined at Eagle River Flats, Fort Richardson, Alaska (Cummings et al. 1994). Sixty-two ducks of five species were captured, mainly in areas C, C/D, and Bread Truck, with mist nets and swim-in traps. Of those, radio transmitters were attached to 12 mallards, 11 pintails, and 11 green-winged teal. Tracking data indicated that during August (pre-hazing) telemetry species ranged

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ACKNOWLEDGMENTS

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over the entire Flats. Mallards tended to concentrate in Areas A and B, Racine Island and the C/D transition area. Pintails used Area C and Bread Truck. Green-winged teal used the C/D transition area and shallow pools in Areas A and C. Post-hazing, most waterfowl concentrated in Areas B and the C/D transition area. The average daily turnover rate of waterfowl species using the Flats during August and September was about 3%. Using this turnover rate and the data from ERF aerial waterfowl surveys, it is estimated that about 5400 ducks used the Flats during fall migration (August to October). Waterfowl most susceptible to white phosphorus represent about 3900. Eight telemetry ducks were found dead (23%) on ERF: Racine Island (1), Area A (3), Area C (2) and the C/D transition area (2).

During spring migration, April–May 1994, 34 ducks, 20 dowitchers, and 10 bald eagles were captured on ERF using various capture techniques. All birds were fitted with radio transmitters. This included 27 mallards, 4 green-winged teal and 1 northern pintail. Of the 10 eagles, 3 were fitted with satellite transmitters. All eagle transmitters are expected to last two years. Tracking data indicated that mallards and teal averaged 6.8 days (range 1–17 days) on the Flats. Average daily turnover for waterfowl was about 5%. Waterfowl mortality during the spring migration period was about 12%. Waterfowl, mallards, and teal tended to concentrate in Areas C, C/D and D. Waterfowl spent more time in Areas B and D and off the Flats post-hazing. Bald eagles spent an average of 2.9 days on the Flats. Most of the telemetry contacts with eagles were in the wooded areas bordering ERF. Transmitters from three scavenged ducks were found in trees surrounding ERF and at an eagle nest site on the Flats. Eagles fitted with satellite transmitters moved to Kodiak Island and Cordova, Alaska, in late November. No eagle mortality has been documented as of December 1996. Dowitchers spent an average of 6.8 days on the Flats and mainly foraged in highly contaminated areas without any mortality (Cummings et al. 1995).

In 1995, daily waterfowl movements during August, September, and October indicated that all species moved among areas quite readily. However, each species showed a preference for certain areas on ERF. Mallards preferred Area B; pintails, Area C; and teal, Area D. All species had in common Area A. Teal preferred ponds that were shallow (<8 cm) or areas that had extensive mudflats. Distribution data indicated that ducks, as in previous years, used a larger portion of ERF in August than in September. This was attributed to the start of the hazing program on September 5. However, pintail use patterns post-hazing indicated an increase in the use of Area C. Mortality during 1995 ($n = 5$) was 9%, or about half the number of ducks that died during fall migration in 1993. Finally, the turnover rate (3.8%) for 1995 was lower than 1993 or 1994. The average number of days spent on ERF by mallards was 40 days; pintails, 46 days; and teal, 27 days.

In 1996, one hundred fifty-eight ducks were captured on ERF using various capture techniques. 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 October 1 to October 15, when 62% of the mallards departed ERF. The number of mortalities of instrumented mallards using ERF from August 3 to October 15 was 37, or about 35%. The greatest mortality occurred in Area C (35%), Area A (22%), and Areas C/D and RI (16%). Indications from the 1996 data, compared to the 1993, 1994, and 1995 mallard data, are that hazing had a positive effect on the redistribution of waterfowl to uncontaminated areas on ERF.

In 1997, we continued to focus on issues outlined under the CERCLA process for ERF. In the conceptional site model, waterfowl and bald eagles are listed as receptors to the exposure and effects of white phosphorus. On

ERF, mallards have been selected as the indicator species to evaluate the effects of white phosphorus on waterfowl. Bald eagles are considered the top avian scavengers of waterfowl poisoned by white phosphorus. In this case, both mallards and bald eagles are considered to be prime species in the ERF food chain that would have direct exposure to white phosphorus and be a significant part of the Ecological Risk Assessment. The objectives, as outlined below, of this study are designed to contribute to remedial decisions concerning ERF.

The objectives for 1997 were to:

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

METHODS

Beginning August 2, 1997, we randomly captured mallards on ERF using a net-gun from a Bell UH1 helicopter. Mallards were captured from random locations on ERF. Ducks were individually banded with U.S. Fish and Wildlife Service bands. The capture and release location and date, band number, age, and sex were recorded for each bird. All ducks were also fitted with a radio transmitter (standard or mortality) weighing 9.1 g. The first 55 mallards captured were fitted with standard transmitters that provided daily movement and distribution data. The remaining mallards were fitted with mortality transmitters that only activated when the duck died. These transmitters were used to determine mortality only. Each transmitter was positioned on the upper back of the duck and attached with a Teflon ribbon harness (Cummings et al. 1993).

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. Birds were located simultaneously from each tracking towers. 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 that 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 was 14,400 m^2 and 8,159 m^2. The data set was transferred from LOCATE to EXCEL and mapped using GIS ARC/INFO and/or ARC/VIEW.

Birds were also tracked on foot or from hovercraft or National Guard helicopter to determine their status. Towers could receive radioed birds up to 25 km from the Flats. Helicopters were used to track birds up to 90 km from the Flats in areas such as the Susitna Flats, Palmer Hay Flats, and Chickaloon Flats.

Telemetry locations were determined daily between 0700 to 1000 and 1500 to 2000 h during August, September, and October. Birds that could not be detected as moving or did not move more than 10° in 2–3 days were visually located to determine their status. Mortality radios were recovered once they activated. Dead birds were recovered to determine the cause of death, and the location of each 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 the same as the 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

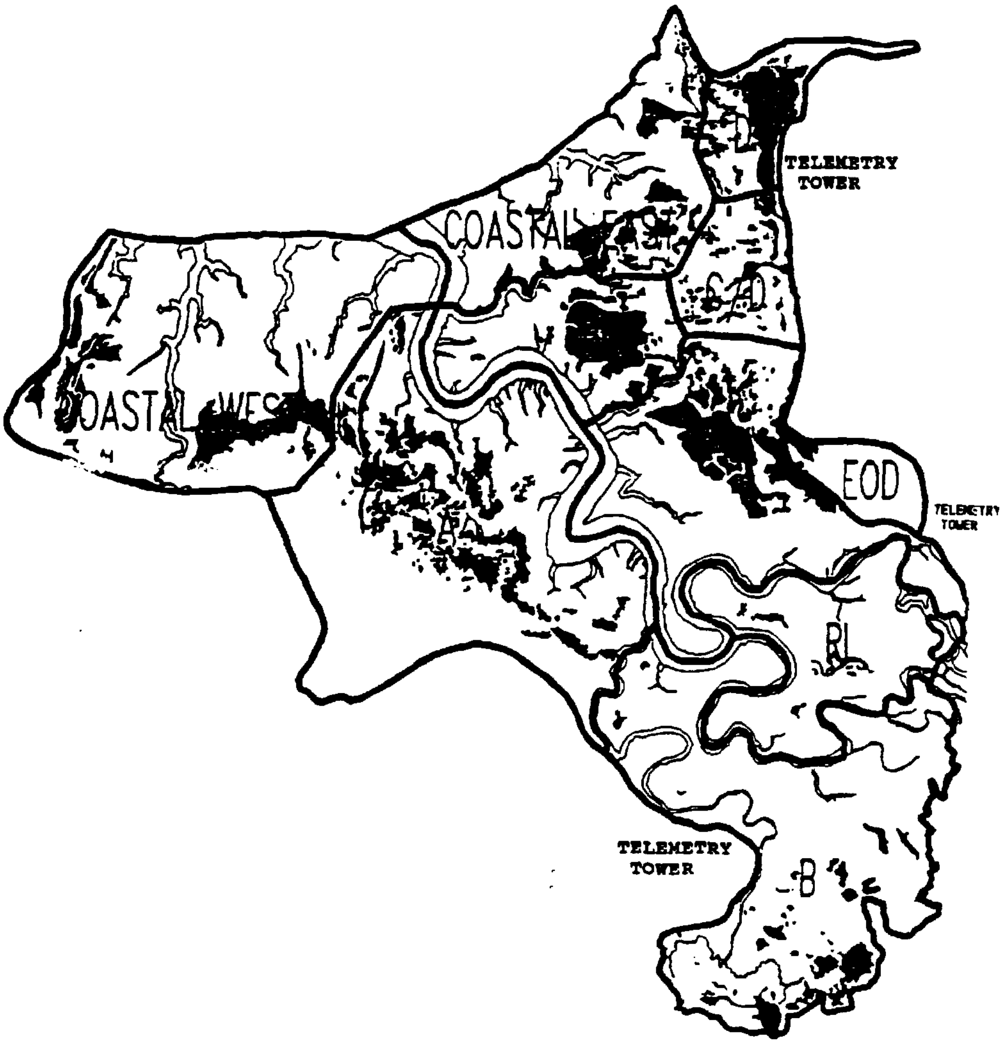

Figure II-2-1. Geographic information system map depicting Eagle River Flats.

documented high levels of white phosphorus.

In 1997, 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 was developed for ERF to determine the number of dabbling ducks that die from ingesting white phosphorus during the fall migration period. Duck census data (Eldridge 1996, 1997, unpubl. data) and telemetry, turnover, and mortality data from 1996 and 1997 were used in the model. The model formula is:

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

where A1 = number of dabblers surveyed
A2 = actual number of dabblers using ERF
D = number of dabblers departing ERF
M = number of dabbler mortalities
R = number of radioed ducks.

RESULTS

From August 2–12, 1997, 136 mallards were randomly captured on ERF using a net-gun from a Bell UH1 helicopter. We used 41 hours of helicopter time to capture the mallards. The best capture was 27 mallards in two hours. Each mallard was banded and fitted with a 9.1-g backpack transmitter and released at its capture site. Of the 136 mallards, 55 were fitted with standard transmitters and 82 mallards were fitted with mortality transmitters (Table II-2-1). The movement of instrumented mallards following release indicated that transmitters did not appear to inhibit movements or activities. Observations indicated 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. However, about 7% of the instrumented mallards were in the final stages of molt when captured. These ducks were noted to remain in the capture/release areas longer than the same species that had completed molt.

The GIS system produced two types of maps for each mallard. The first map showed mallard telemetry points before and after September 5 (Fig. II-2-2). This division is based on previous hazing start-up dates in 1995. The data from 1997 will be compared with previous years. The second map depicts the last five to ten telemetry locations of mallards that died from white phosphorus (Fig. II-2-3). These maps (n = 8) were useful in determining a general area that mallards could have been exposed to white phosphorus. Exact locations, and on occasions even the general location, of where the duck might have ingested white phosphorus was difficult to discern because the death of a duck occurred on the weekend when personnel did not work.

Mallard (n = 55) movements and distribution on ERF during the fall indicate that they spent the majority (88%) of their time from August 2 to October 22 in Areas A, B, C, and C/D (Table II-2-2). In addition, mallards spent about 69% of their time in areas that are considered to be contaminated (A, BT, C, C/D, and RI). However, mallards were only located 6 of 144 times in the actual Racine pond and 2 of 21 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.

To evaluate the effects of hazing on mallards, we compared mallard movements and distribution from 1996 and 1997 (non-hazed year) to 1995 (hazed year). During 1995, hazing began on September 6. In that year mallards (n = 17) spent the majority of their time from August 1 to September 5 (non-hazing period) in Areas A, B, and D. Use of these areas represented about 60% of the time mallards spent on ERF (Fig. II-2-4). In areas that were actively hazed (Areas A, C, C/D, and BT), mallards spent about 31% of their time in these areas during the non-hazed period and 21% of their time during the hazed period

Table II-2-1. Radio transmitters fitted to mallards since 1993 on Eagle River Flats, Fort Richardson, Alaska.

	Std	*Mort*	*Total*
1993	12	0	12
1994	27	0	27
1995	17	0	17
1996	53	54	107
1997	55	81	136

STD = standard transmitter.
MORT = mortality transmitter.

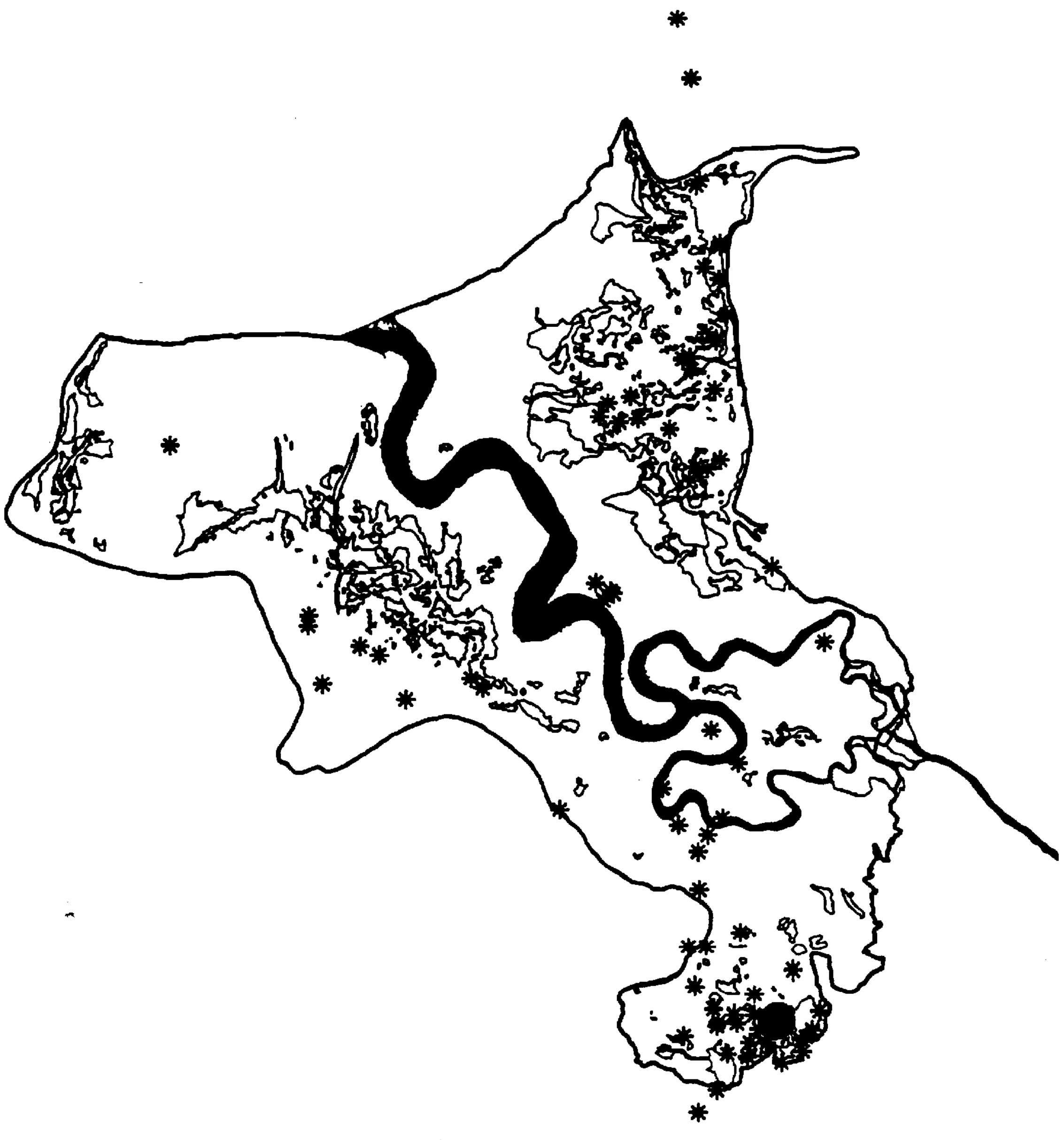

Figure II-2-2. Example of a GIS map of radiotelemetry results on Eagle River Flats showing the movement patterns of a mallard from August 2 to October 22, 1997. Dark stars represent movements from August 2 to September 5, and light stars represent movements from September 6 to October 22. One star may represent several telemetry locations.

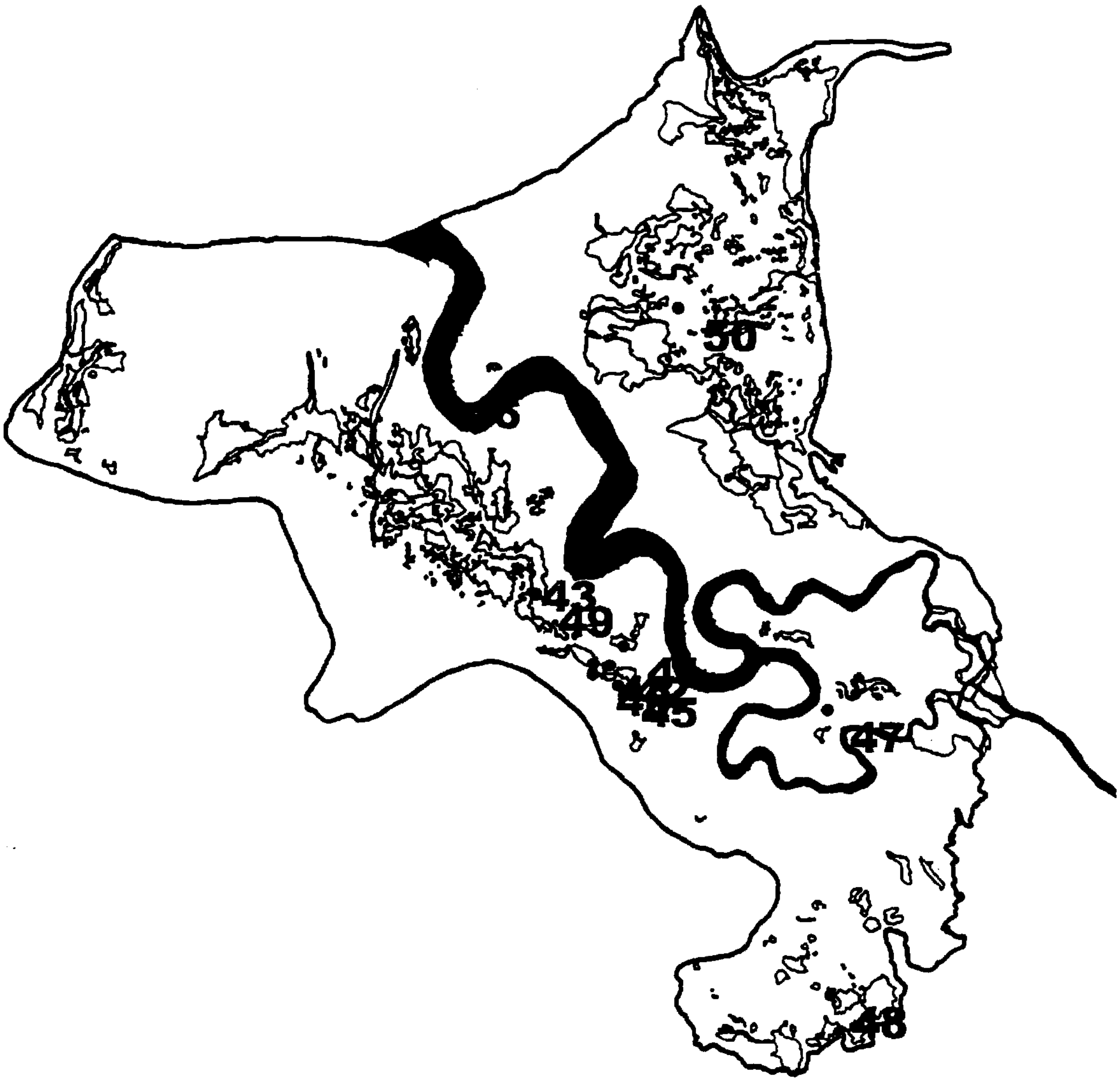

Figure II-2-3. Example of a GIS map depicting a radiotelemetry result of a mallard that died from ingesting white phosphorus. Dots (no. 40–48) show the last five days of movements prior to mortality (no. 49 died and 50 carcass recovered).

Table II-2-2. Distribution of radioed mallards on Eagle River Flats (ERF) during August, September, and October, 1996 and 1997.

	Telemetry points					
	No.		*Percent*		*Mortality*	
ERF area	*1996*	*1997*[a]	*1996*	*1997*	*1996*	*1997*
A	1215	1054	62	39	8	5
B	213	672	11	25	2	2
BT	13	21	<1	<1	2	5
C	204	213	10	8	13	3[b]
C/D	167	414	8	15	6	4
CE	27	5	1	<1	0	0
CW	63	79	3	3	0	0
D	18	84	<1	3	0	0
EOD	16	13	<1	<1	0	0
RI	[illegible]	143	2	5	6	2[c]
Total	1976	2698	100	100	37	21

[a] Standard transmittered duck locations for capture (C) and recovery (R) were removed from certain areas to make 1997 data equivalent to 1996 data (Area A - 27 C, 3 R; Area B - 12 C, 2 R; Area BT - 2 R; Area C/D - 16 C, 2 R; Area RI - 1 R).

[b] Mallard carcasses from Area C were recovered from areas other than the main pond that was drained (i.e. Lawson's pond, near Clunie creek, or ponded area near EOD pad).

[c] In 1997, mallard carcasses from RI were recovered from the river channel (the main ponds on RI were drained or treated with AquaBlok), whereas in 1996, carcasses were recovered from the large pond.

(Fig. II-2-4). In 1996, mallards spent 33% of their time in Areas A, C, C/D, and BT prior to September 6 and 46% of their time in the same areas after September 6 (Fig. II-2-4). In 1997, mallards spent 39% of their time in Areas A, C, C/D and BT prior to September 6 and 23% [illegible] ber 6 (Fig. II-2-4).

The average and median number of days mallards ($n = 55$) spent on ERF was 42 and 53, respectively. The range was from 1 to 74 days. At the conclusion of the study, October 22, 8 mallards remained on ERF. These birds were confined to using the Eagle River and some open water in Area B because all other areas on ERF were covered with snow and/or ice. The average daily turnover rate for mallards was about 1.1%. The greatest turnover of mallards occurred from October 7 to 16, whereas 71 (52%) of the mallards departed ERF during this time period (Table II-2-6). In addition, 14% of the mallards departed between August 4 and 18 (Table II-2-6).

Thirty-five radio-instrumented mallards that used ERF died from August 3 to October 22 (Table II-2-3). Of those mallard deaths, 21 (15%) were attributed to white phosphorus, 7 were shot by hunters, 3 slipped due to molt, 2 were caught by falcons and 2 predated by [illegible] had used the Flats from 2 to 72 days. The average exposure before mortality was 35 days. The greatest mortality occurred in Areas BT, 5 of 21 (24%); A, 5 of 21 (24%); and C/D and C, 7 of 21 (33%) (Fig. II-2-5). Overall, these areas accounted for 81% of the mallard mortality on ERF (Table II-2-4). No mallards died in Bread Truck or Racine Island ponds. The carcasses and transmitter of suspected mink kills were recovered from mink burrows, but there were not enough remains to warrant analysis for white phosphorus. No mallard mortality was noted from capture, handling or the transmitter. We recovered 15 whole duck bodies from the 21 mortalities attributed to white phosphorus. They will be analyzed

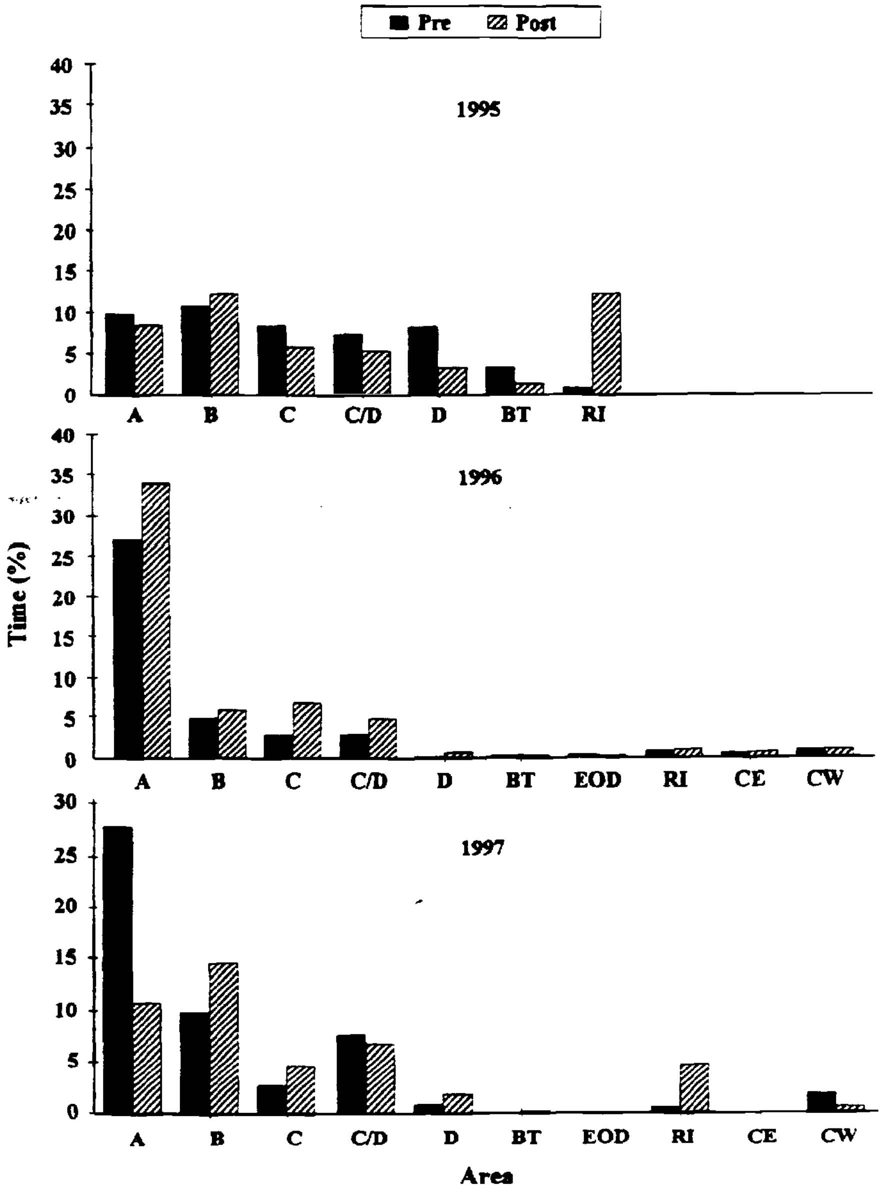

Figure II-2-4. Distribution of mallards on Eagle River Flats before and after September 6 in 1995, 1996, and 1997. Hazing was conducted after September 6 in 1995.

for white phosphorus residues at a later date.

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 duck mortalities on ERF during the fall migration period. We used the number of radioed mallards from 1996 and 1997, the 1996 and 1997 aerial census counts of waterfowl on ERF, and the number of 1996 and 1997 mallard mortalities on ERF in the mortality model. In 1996, 5413 individual dabblers used ERF from August 3 to October 16 (Table II-2-5). Dabblers peaked at 2333 individuals between Septem-

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

Year	Captured (no.)	Mortalities (no.)	White phosphorus mortalities (no.)
1993	12	2	2
1994	27	5	5
1995	17	4	4
1996	107	42	37
1997	136	35	21

ber 13 and 16. The overall mortality that occurred on ERF was 655 dabblers. In 1997, 6063 individual dabblers used ERF from August 2 to October 22 (Table II-2-6). Dabblers peaked at 4398 individuals between September 9 and 10. The overall mortality that occurred on ERF was 240 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 50% of the fall migration period (Cummings et al. 1994, 1995, 1996). Thus, overall mortality for 1996 was 983 dabblers and for 1997, 360 dabblers. Mortality decreased about 63% from 1996 to 1997. The decrease is attributed to the draining of BT and Racine Island ponds and the pumping of the C pond.

DISCUSSION

In 1996 and 1997, mallards were selected as the indicator species to measure the effects of any treatability studies or remediation actions on ERF. The 1996 and 1997 sample sizes of 107 and 136, respectively, radioed mallards were large enough to establish a baseline that can be used with confidence to detect future changes in mallard movements, distribution, turnover and mortality. Any comparison of the data from 1996 and 1997 with that of 1993, 1994, and 1995 must be carefully interpreted because of the small sample size of mallards captured in 1993, 1994, and 1995. Also, other activities on the Flats during those years, such as hazing, data collection, and movement of personnel, are all factors that may influence waterfowl behavior. However, we feel confident that data from 1996 and 1997 can be used to make decisions about future remediation actions.

Mallards highly preferred Area A in 1997, followed by Areas B, C/D, and C. These were the same areas that mallards preferred in 1996. Mallard distribution data collected during the fall migration period in 1993, 1994, and 1995 indicate that mallards slightly preferred Area B over other areas on ERF. The distribution of mallards in previous years showed a larger use of ERF in August than in September and October. Comparisons of the 1996 and 1997 data with 1993, 1994, and 1995 data indicated that hazing had a positive effect on redistributing waterfowl to uncontaminated areas. For example, mallard use of contaminated areas (A, C and C/D) remained fairly equal for the period before and after September 6. In some cases the use actually increased in contaminated areas. A comparison of 1995 with 1996 and 1997 data shows that mallards spent about equal time in Areas A, B, C and C/D. Following this period, use of these areas decreased in 1995 (hazing) while increasing in 1996 (non-hazing) and increasing in two areas in 1997 (non-hazing) but also decreasing in two areas. In addition, the average number of days mallards spent on ERF was 40 in 1995, 47 in 1996, and 42 in 1997. Also, the average daily turnover rate was 3.8% in 1995, 1.4% in 1996, and 1.1% in 1997. Mortality and turnover indicate that, without hazing, mallards resided longer on ERF and departed the Flats at a slower rate.

Mallard mortality was 16% in 1993, 23% in 1995, 35% in 1996, and 15% in 1997. The mortality model predicted 655 duck mortalities in the fall migration period in 1996 and 240 in 1997. The increase of mallard mortalities on ERF during 1996 can be attributed to the lack of a hazing program and other activities on the Flats that kept ducks from using contaminated sites and the increased use of contaminated areas by ducks on the Flats.

The mortality model for ERF is a more ac-

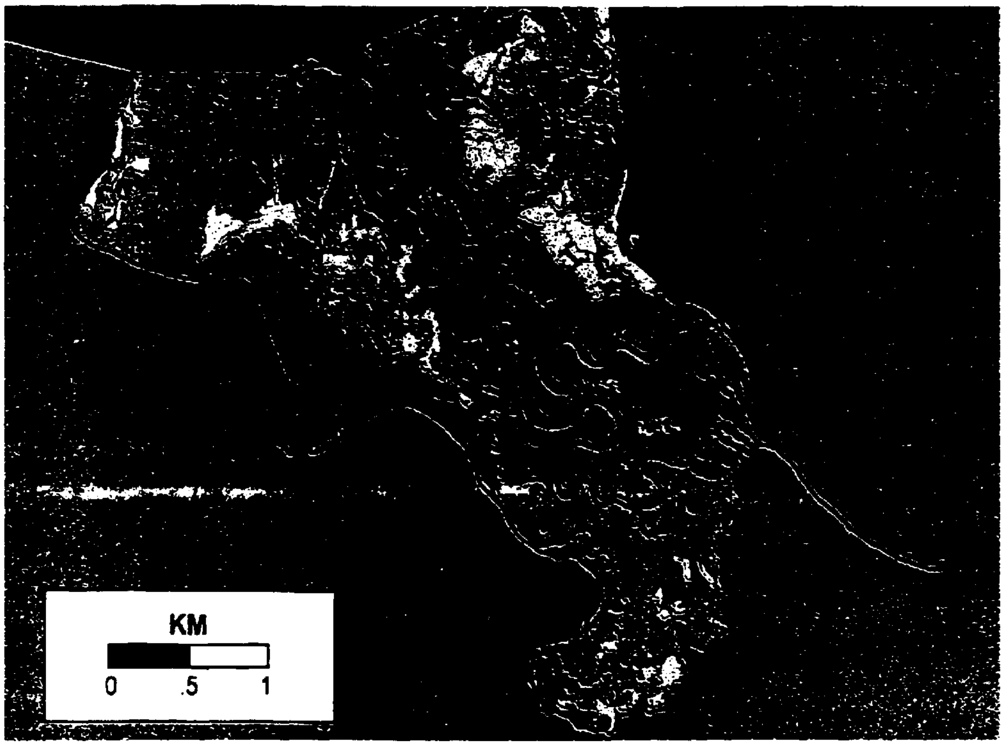

Figure II-2-5. Locations of mallards that died from ingesting white phosphorus on Eagle River Flats, August 2 to October 22, 1997.

Table II-2-4. Mallard mortalities from white phosphorus on Eagle River Flats, during August, September, and October, 1996 and 1997.

Transmitter	*A*	*B*	*BT*	*C*	*CE/C*	*C/D*	*D*	*RI*	*Total*[a]
					1996				
Standard	3	2	1	3	0	2	0	4	15
Mortality	5	0	1	10	0	4	0	2	22
Total	8	2	2	13	0	6	0	6	37
					1997				
Standard	2	0	2	0	0	2	0	1[b]	7[c]
Mortality	3	2	3	3	0	2	0	1[b]	14[c]
Total	5	2	5	3	0	4	0	2[b]	21[c]

[a] Total does not include ducks recovered by hunters (1 mallard), transmitters that slipped (1 mallard), or ducks that were taken by predators (3 mallards).

[b] Carcasses were recovered in the river channel not on the island.

[c] Total does not include ducks recovered by hunters (9 mallards), transmitters that slipped off (3 mallards), or ducks that were taken by predators (2 mallards).

curate predictor of the actual numbers of ducks that die from white phosphorus ingestions than trying to extrapolating the percent of telemetry mortalities to the ERF duck population. The model combines all the data from telemetry ducks, including 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 on a daily, weekly, or monthly bases. It is inaccurate to extrapolate the percent mortality from telemetry ducks to the ERF duck population because this percent 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.

In conclusion, we feel that the baseline data collected in 1996 and 1997 can be used to measure the effects of future remediation actions. Showing a significant effect will depend on having a sample size that exceeds 100 mallards captured in a relatively short period of time.

RECOMMENDATIONS

The biological assessment endpoint for ERF is a reduction in waterfowl mortality. To measure this endpoint, we suggest that mallards continue to be used as the indicator species for ERF and that telemetry be used to monitor their activities. Increasing the number of transmitters by 50 will only reduce the standard deviation about 2%. In addition, a mix of standard and mortality transmitters will allow a broad evaluation of factors affected by remediation actions.

It is important to be 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 that 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.

The use of telemetry:

- reduces human exposure to UXOs.
- supports measuring the assessment endpoints with relatively good confidence limits.
- generates excellent data on waterfowl distribution, movements, turnover, and mortality, which are all factors affecting remediation.
- costs less than $90,000 per year if 150 transmitters are used.
- has no impact on the behavior of radioed birds or other birds using ERF.
- is considered a standard method for projects of this type.

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Table II-2-5. Mortality model for Eagle River Flats, August 3 to October 16, 1996.

				Dabblers surveyed				
Date	*Radioed birds (no.)*	*Turnover (no.)*	*Mortality (no.)*	*Aerial counts (no.)*	*Unknown dabblers[1] (no.)*	*Total dabblers (no.)*	*Adjusted for turnover (no.)*	*Projected mortality[2] (no.)*
8/3–20	107	18	10	712	201	913	1,099	103
8/21–27	89	16	8	880	1,026	1,906	2,324	208
8/28–31	73	2	2	657	855	1,512	1,555	43
9/1–3	71	0	0	145	627	772	772	0
9/4–6	71	1	1	203	1,451	1,654	1,679	24
9/7–9	70	1	1	489	697	1,186	1,204	17
9/10–12	69	3	1	970	760	1,730	1,809	26
9/13–16	66	3	1	632	1,594	2,226	2,333	35
9/17–19	63	1	1	664	1,492	2,156	2,191	35
9/20–23	62	4	3	79	674	753	805	39
9/24–26	57	1	1	122	537	659	671	12
9/27–30	56	1	1	345	52	397	404	7
10/1–4	55	1	1	1,044	0	1,044	1,064	19
10/5–8	54	7	1	300	198	498	572	11
10/9–11	47	13	3	650	48	698	965	62
10/12–16	34	32	2	14	0	14	241	14
Total	107	104	37	7,906	10,212	18,118	19,688	655

[1] Dabblers represent 95% of unknown ducks.

[2] Minimum number of dabbler duck mortalities on ERF during fall migration, August 3 to October 16, 1996.

Table II-2-6. Mortality model for Eagle River Flats, August 4 to October 22, 1997.

				Dabblers surveyed				
Date	*Radioed birds (no.)*	*Turnover (no.)*	*Mortality (no.)*	*Aerial counts (no.)*	*Unknown dabblers[1] (no.)*	*Total dabblers (no.)*	*Adjusted for turnover (no.)*	*Projected mortality[2] (no.)*
8/4–18	136	19	4	302	71	373	516	15
8/19–21	117	3	3	126	172	298	484	12
8/22–26	114	1	1	627	114	741	862	8
8/27–28	113	1	1	223	431	654	1,095	10
8/29–9/2	112	3	1	470	371	841	1,246	11
9/3	109	2	0	530	622	1,152	1,185	0
9/4–8	107	0	0	1,082	896	1,978	2,591	0
9/9–10	107	0	0	492	3,010	3,502	4,398	0
9/11–16	107	7	2	131	192	323	3,569	67
9/17–18	100	2	2	45	348	393	597	12
9/19–23	98	2	2	262	281	543	910	19
9/24–25	96	5	0	308	266	574	903	0
9/26–30	91	11	1	26	1,110	1,136	1,595	18
10/1–2	80	0	0	702	389	1,091	1,101	0
10/3–6	80	7	2	174	278	452	1,700	42
10/7–9	73	28	1	155	177	332	1,170	16
10/10–16	45	43	1	17	0	17	425	10
10/17–22	42	2	0	8	0	8	8	0
Total	136	136	21	5,680	8,728	14,408	24,355	240

[1] Dabblers represent 95% of unknown ducks.

[2] Minimum number of dabbler duck mortalities on ERF during fall migration, August 4 to October 22, 1997.

III-1. REPORT OF USDA-APHIS-WILDLIFE SERVICES FOR THE U.S. ARMY AT EAGLE RIVER FLATS, APRIL–OCTOBER 1997

Corey Rossi
U.S. Department of Agriculture, APHIS-Wildlife Services

During parts of April and May of 1997 under Agreement #97-73-02-2158 (formerly agreement #12-34-73-2158), USDA-APHIS-Wildlife Services (WS-formerly Animal Damage Control, ADC) continued efforts to keep migratory waterfowl from being poisoned by white phosphorus in the U.S. Army's Eagle River Flats (ERF) Impact Area at Ft. Richardson, near Anchorage, Alaska. The work involved the use of a variety of traditional hazing methods over discrete, limited areas within ERF, with other less-contaminated areas remaining as undisturbed sanctuaries.

OPERATIONAL AREAS

The standard operational areas, i.e., Area A, Racine Island, C Pond, Lawson's Pond, and Bread Truck Pond, again received aggressive attempts to deter waterfowl from their use. Because the exact boundaries of the operational areas are not clearly defined, WS again established estimated boundaries and perimeter buffer zones, then sought to haze waterfowl from the area within the perimeter of the buffer zones. This has been a common practice in all of our operational areas. The significance of this approach is:

- The exact location of the source of the toxicity within the given area still has not been clearly identified, and
- Waterfowl present within the buffer zones surrounding an operational area tend to decoy additional waterfowl, which often land within the contaminated zones.

METHODS

Several standard hazing methods were used. Up to eight propane cannons were strategically located around the open water areas within the marsh. Efforts were made to vary firing intervals and collocate them with visual scare devices such as scarecrows and mylar tape. Scarecrows were of the traditional clothed-frame design. Mylar tape was strung in difficult-to-reach areas that appeared to be attractive to ducks. This season, as in 1996, mylar tape was deployed to a lesser degree than in previous seasons, primarily due to its limited long-term efficacy and the difficulty in gathering and disposing of it at the end of the season.

Additional static devices included eagle effigies and another device known as the electronic guard. Eagle effigies were of painted plywood construction and were built in a standing, as well as a suspended "in flight," configuration. The electronic guard consists of a siren and flashing strobe light, both of which activate automatically on 6- to 8-minute intervals to deter waterfowl during hours of darkness.

To augment the effectiveness of these static devices, two WS personnel walked or canoed through the marsh to service the devices and deter birds that had landed or were attempting to land in critical areas. Personnel used 15-mm pyrotechnics, shell crackers, and 20-in. skyrockets to frighten birds from areas of concern. A bird was considered successfully hazed if it responded to our stimuli and left the immediate area for another portion of the marsh. In 1997 we again intensified our hazing efforts to include all waterfowl within our operational areas. In past seasons we had often left grazing geese and loafing wigeons unmolested, but we have learned that these species often inadvertently decoy those species more susceptible to white phosphorus poisoning.

RESULTS

Spring

From April 21 to May 31, 1997, a total of 945 ducks and 30 Canada geese were hazed at Eagle River Flats by five WS personnel. A total of 613 staff hours were expended in the field over 41 days of hazing. There were no waterfowl mortalities found by WS personnel during the spring of 1997.

Fall

From September 23 to October 26, 1996, no waterfowl were hazed by WS personnel at Eagle River Flats. In excess of 280 staff hours were expended monitoring the hot areas for swan activity, as well as transferring and repairing hovercrafts. Two swan mortalities were recovered by WS personnel during the fall of 1997.

DISCUSSION

The spring 1997 total of "ducks hazed" reveals a decrease over the same periods in 1995 and 1996 (3406 in 1995, 1575 in 1996, and 945 in 1997). While the decrease from 1995 to 1996 may have been due, in part, to a very unusual 1995-96 winter (i.e. little snow, deep frost, and frozen pond sediments into May), the decrease in 1997 may have been caused by other factors.

One such factor may have been the reduction in available habitat due to pond drainage (Bread Truck, C Pond, and Racine Island). Another possible factor may have been the incidental deterrent effect produced by increased hovercraft use during the spring 1997 season. In addition, in spring 1997, WS personnel spent more than twice as many staff hours in the field than in spring 1996. All things considered, the decreased use of contaminated areas by waterfowl was probably the primary reason that WS personnel found no waterfowl mortalities during the spring of 1997.

During the fall 1997 season, WS hazing strategies changed considerably. During discussions with the ERF project manager and researchers from NWRC, it was determined that a cessation in waterfowl hazing (except for swans) would be of value to researchers. Constant hazing has the potential to greatly bias waterfowl movement and mortality studies. WS adjusted its proposed start-up date accordingly to September 23, 1997, to coincide with the return of the swans to ERF.

Researchers have determined that duck mortality rates are an important indicator of the relative success of the remediation efforts at ERF. This modified hazing cessation strategy allowed researchers to monitor duck movements, marsh use, and mortality, independent of hazing activities and without a major sacrifice of swans. Aside from some incidental hazing by research groups, the plan worked well.

The fall 1997 hazing cessation was very similar to the strategy used in the fall of 1996. The primary difference was that when the fall 1997 hazing began, it was designed specifically to protect swans. WS personnel patrolled the site primarily from the perimeter of the contaminated areas, in an effort to not disturb ducks (which may have biased the mortality research). During this time, WS personnel essentially remained on standby, monitoring swan activity in the hot areas and assisting NWRC researchers with hovercraft support to recover transmitters from duck mortalities. Very few static deterrent devices were deployed in fall 1997. Late in the fall a few propane cannons were deployed in Area A, when two swan mortalities were discovered there.

In 1997, WS again used the hovercraft whenever possible to assist in hazing operations and to transport researchers and their equipment. This procedure greatly reduced the need to walk through the marsh and thus limited WS personnel's potential exposure to unexploded ordnance. The hovercraft's role has become increasingly important due to stricter rules (implemented in 1996) regarding human access to the Eagle River Flats Impact Area. The new rules greatly restricted foot traffic in the marsh and made it exceed- [redacted]

Because of the more stringent safety requirements, any personnel whose duties required them to deviate from established paths must have had helicopter or hovercraft support. Most of WS's daily activities fell under this category. A number of the other groups were similarly affected. In addition, if the hovercraft was used, a second hovercraft (with a trained operator) was required to be immediately available. These developments made it critical to maintain at least two functional hovercraft at all times. This was especially important since funding cuts often made hovercraft support a more reasonable option than helicopter support.

Prior to 1997, WS faced some difficult challenges with the use of hovercraft at ERF. For example, in 1996, WS spent several thousand dollars of their operating budget repairing hovercrafts after the spring 1996 season concluded. In addition, WS spent most of their fall 1996 resources repairing hovercraft that had been rendered inoperable by mid-September 1996. Most of the repairs were directly related to the fragile nature of the craft. But many could easily have been avoided with routine maintenance and more thoroughly trained operators.

Hovercraft availability was greatly enhanced in the 1997 season by aggressive maintenance and the use of more thoroughly trained operators. This simple strategy helped WS to overcome the craft's weak points and make it an indispensable tool for hazing and transportation of personnel and equipment.

Although WS's original hazing schedules outline a tentative completion date, contingency provisions in our 1996 and 1997 proposals allowed WS to continue operations until all contaminated areas had frozen over. This policy is in the best interest of protecting swans and should be continued in coming seasons.

There were no "new" tools or procedures involved in WS's 1997 hazing operations. [redacted] successful in previous seasons. However, in 1997 (as in 1996) WS increased its emphasis on vigorously harassing the birds while they were still airborne over the protected areas. Waterfowl are more difficult to deter from an area after they have landed. At this time, field personnel armed with pyrotechnics are still the most important component in a successful waterfowl deterrent operation.

CONCLUSIONS

WS believes that the 1997 hazing operation was successful. The reduction in waterfowl use of contaminated areas, as well as the subsequent reduction in waterfowl mortality, was positive (even though it was at least partially due to pond drainage).

As in previous seasons, WS observations and waterfowl surveys by USF&WS indicated a dramatic decrease in waterfowl numbers in WS-protected areas when compared to those in established sanctuary areas.

In spite of the potential incidental hazing caused by hovercraft in the fall 1997 season, they were still a valuable tool when operated and maintained properly.

The effective protection of waterfowl was further enhanced by a contingency provision initiated in the 1994 proposal that allowed WS's operations to continue until all of the contaminated areas had frozen over (regardless of the date). This contingency provision will be proposed again for the 1998 season.

OU-C 32351

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

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INTRODUCTION

Pond draining by either pumping or breaching are two remedial alternatives for contaminated ponds at ERF (CH2MHill 1997). Draining allows the pond surface sediments to dry below water saturation, a condition necessary for in-situ attenuation of the solid white phosphorus particles (Walsh et al. 1995) that are the cause of the excessive waterfowl mortality at ERF. During the summer of 1997, monitoring was initiated to verify the success of these remedial alternatives. A component of the monitoring process is to confirm that the amount of white phosphorus in surface sediments is decreasing, thereby becoming less of a threat to waterfowl.

To monitor changes in white phosphorus concentrations using discrete sampling of the surface sediments requires the analysis of a multitude of samples. We have used iterative discrete sampling in one small intermittently dry part of Area C (site 883) and documented a decrease in white phosphorus contamination since 1992. To monitor changes over larger areas, an alternative to discrete sampling was needed. During the summer of 1996 we demonstrated that composite sampling could be used to detect the presence of hot spots containing solid white phosphorus particles. Composite samples can also be used to obtain an estimate of average white phosphorus concentrations (Walsh et al. 1997). During the summer of 1997 we performed composite sampling in Area C (ponds 164 and 183), which was drained by pumping, and the Bread Truck Pond (ponds 99 and 109) (CH2MHill 1997), which was drained by breaching, to evaluate spatial and temporal changes in the severity of white phosphorus contamination. We also monitored sediment temperature and moisture conditions and the attenuation of white phosphorus particles that we placed at various points in the drained ponds. We also used composite sampling to look for hot spots in pond 40 (CH2MHill 1997) of Area C/D.

Finally, we analyzed for white phosphorus residues in the dredge spoils that have dried in the retention basin located on the OB/OD pad (Walsh and Collins 1997).

METHODS

Discrete sampling— site 883, Miller's Hole

Since 1992 we have collected discrete sediment samples from two locations within the intermittent pond (Pond 164) of Area C with the objective to monitor changes in white phosphorus concentrations with time. Site 883 (UTM 354,981.6 E; 6,801,183.8 N) was resampled as was done in 1992, 1994, and 1995 by taking samples at 1-m intervals out to 5 m along eight axes around the center point. We also sampled Miller's Hole (UTM 355,066.9 E; 6,801,176.5 N), the crater produced when a WP mortar round was detonated in May 1992, by taking two cores from the center or deepest part of the crater. We obtained the cores to a depth of 20 cm using a 2-cm-i.d. Oakfield corer. The cores were divided into four sections representing 0- to 5-, 5- to 10-, 10- to 15-, and 15- to 20-cm depths. We also collected two samples, each comprising eight subsamples, from the crater rim.

Each discrete sample was analyzed for white phosphorus using solvent extraction and gas chromatography (SW-846 Method 7580) (U.S. EPA 1997).

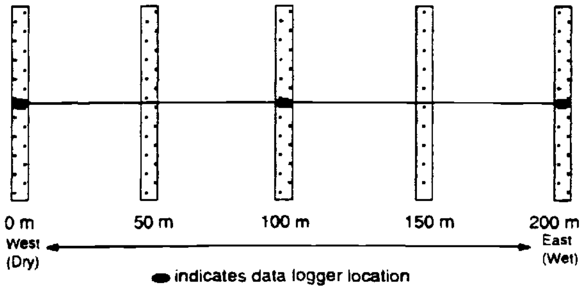
Transect layout in area C and BT Pond

We set up west–east transects in Area C and the Bread Truck Pond to monitor sublimation/oxidation conditions and for baseline and verification sediment sampling (Fig. III-2-1 and III-2-2). Each transect was 200 m in length and included areas that were mapped as intermittent and permanent ponds prior to draining. The intent of the transect layout was to represent a range of moisture conditions within each area from west to east. The west end of each transect was located at the highest elevation and as a result would be exposed to air longer than the rest of each corresponding transect (Fig. III-2-2). Three transects were established: one in Area C (ponds 164 and 183) and two in the Bread Truck Pond (ponds 99 and 109). Location UTMs and elevations were obtained by surveying.

Sublimation/oxidation conditions

Sensors were installed to monitor temperature and moisture conditions at 0, 100, and 200 m along each of the three transects. Sediment temperatures were monitored at 5- and 10-cm depths using Campbell Scientific (Logan, UT) 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.

On 31 May 1997 at each datalogger station we planted ten WP particles (1.8 mm diameter, 5.56 mg) that were made in the laboratory (Walsh and Collins 1995). Each particle was first inserted into a plug of saturated sedi-



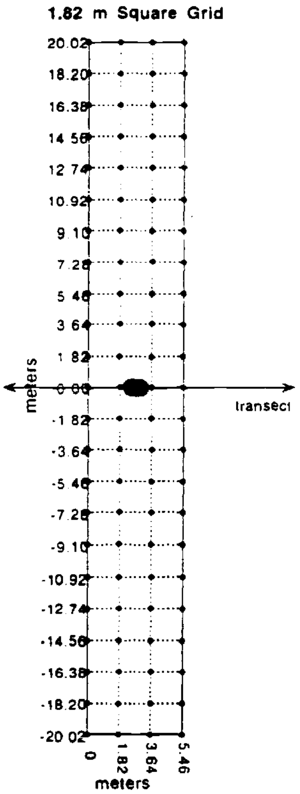


Figure III-2-1. Planned layout for a) west to east transects to monitor sublimation/oxidation conditions in Area C and the Bread Truck Pond. Baseline and verification sediment samples were collected as composites from grids extending 20 m north and south of the west-east transect. b) Detail of gridded area from which composite samples were collected. Cores were taken at grid nodes.

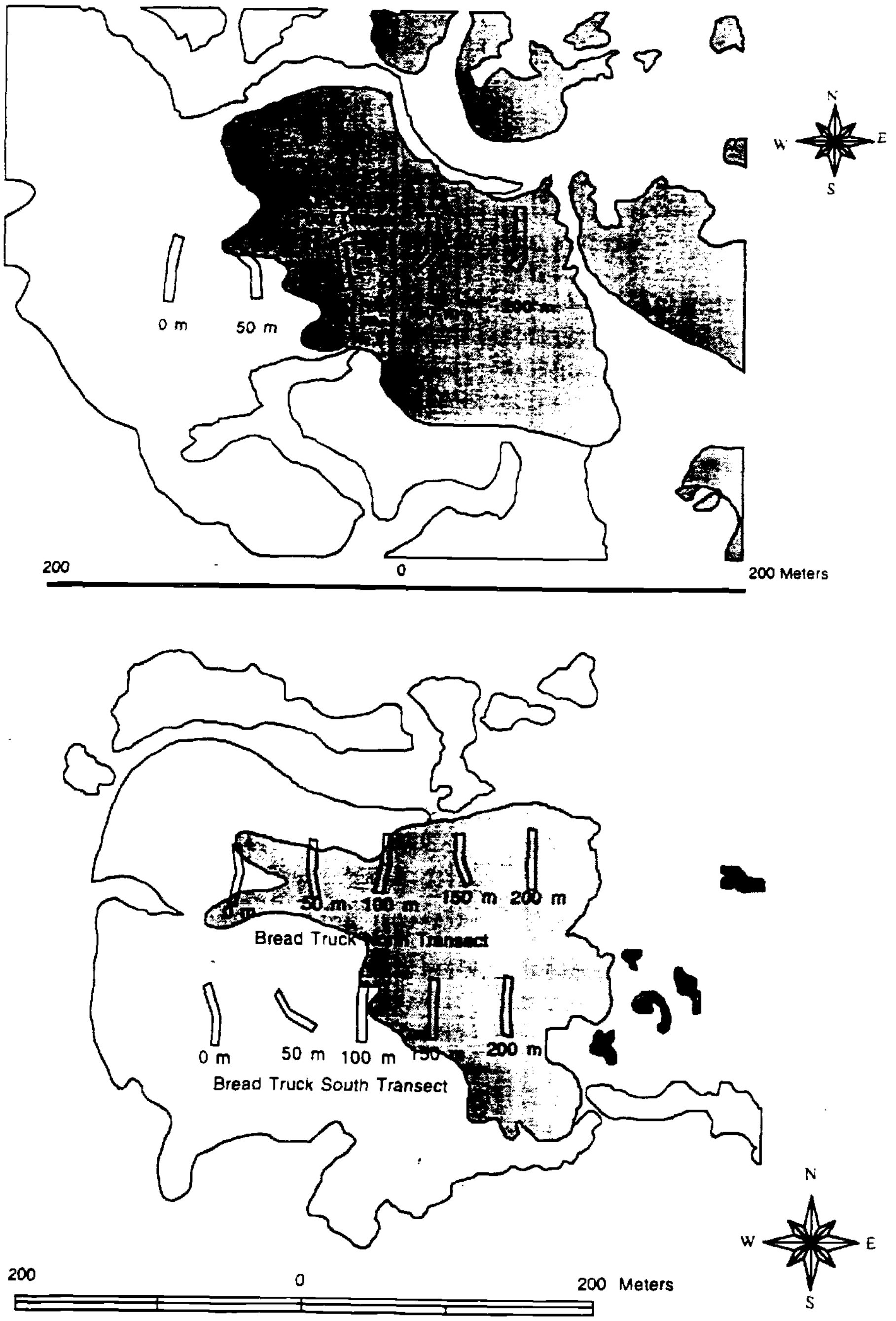


Figure III-2-2. Locations of transects in Area C and the Bread Truck pond. UTM coordinates and elevations are given in Table III-2-4.

ment, 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 these plugs from each station on 3–4 September 1997 to determine if WP mass had decreased. To determine if the WP particles had changed, the sediment samples containing particles were placed into isooctane to extract WP residue prior to analysis by gas chromatography.

Water depths of any standing water in the ponds were monitored using Druck pressure transducers at the 200-m station along each transect. The Druck transducers were placed so that the measurement port was at the sediment surface. The depth of any standing water in the pond would be detected by the transducer and the output recorded using Campbell CR10 dataloggers. The elevation of the port of the Druck transducer was determined by surveying, and from that elevation the water surface elevation of standing water was calculated.

A set of tensiometers was installed at 50-m intervals along each transect to provide another measure of near-surface sediment moisture. SoilMoisture® (SoilMoisture Equipment Corp., Santa Barbara, CA) Series 2725 tensiometers equipped with dial gauges were installed, one at 10-cm depth and another at 25-cm depth at most sites. At 5-cm depth we installed a SoilMoisture Model 2100F soil moisture probe at most sites. These tensiometers were read periodically by personnel from CH2MHill.

Baseline and verification sediment sampling

Along each west–east transect at 0, 50, 100, 150, and 200 m, composite samples were collected to determine if hot spots were present (Fig. III-2-1 and III-2-2). 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. Cores were taken to a depth of 9 cm. We collected a total of 1380 cores from the three west–east transects. In Area C, 50-mL samples were obtained using a plastic syringe corer (2.65 cm i.d., 9 cm length) as was done in 1996 (Walsh et al. 1997b). Because of sediment consolidation due to draining, insertion of the plastic corer into the sediment was very difficult. In the Bread Truck area, 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 9-cm-long core was taken, resulted in a 28-mL sediment sample.

In the laboratory each composite sample was thoroughly mixed by stirring and kneading. To obtain an estimate of average WP concentration, five 40-g subsamples were taken from each composite and analyzed using solvent extraction and gas chromatography. The remainder of each composite was rinsed through a 30-mesh sieve (0.59-mm sieve opening) to remove the fine-grain sediment. Material remaining on the sieve was placed in a septa jar and equilibrated at room temperature. To determine if WP particles had been retained on the sieve, we performed headspace solid-phase microextraction (SPME) followed by gas chromatography (Walsh et al. 1996). When the SPME method indicated that white phosphorus was present, the sample was spread in a thin layer on an aluminum pan and the sample 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.

Composite sampling in C/D

Composite samples were collected along four grid transects in Pond 40 of Area C/D (Fig. III-2-3). Water depths in parts of this pond are close to 1 m, so we used a canoe to traverse the pond during sampling. Sediment was collected at the nodes of a 2-m-square grid using an Oakfield corer to a depth sufficient to obtain an intact core. Each core was approximately 9 cm long, but because of the unconsolidated nature of the sediment, the sampling depth actually exceeded 9 cm at

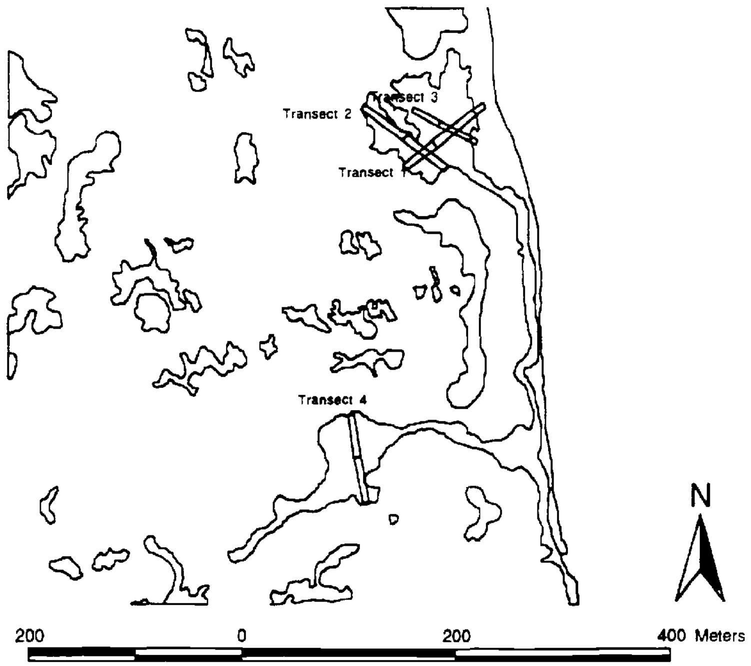


Figure III-2-3. Locations of grid-transects in pond 40 of Area C/D from which composite samples were taken. UTM coordinates are in Table III-2-4.

most locations. Each of the four grid transects was subdivided at the approximate half-way point so that a total of eight composites were collected, two from each grid transect. We recorded water depths as we sampled each transect.

The composite samples from Area C/D were analyzed for white phosphorus using the same procedure as for the composite samples from Area C and Bread Truck.

Retention basin

On 28 September 1995, M.R. Walsh and C.M. Collins planted six WP particles at four sites in the retention basin containing dredge spoils from pond 146. On 22 May 1996, prior to the onset of dredging in 1996, three samples containing WP particles residue were collected and analyzed, and variable amounts of WP were found (Walsh and Collins 1997). On 10 September 1997, the remaining three samples at three of the sites were collected for WP analysis.

RESULTS AND DISCUSSION

Discrete sampling— site 883, Miller's Hole

Site 883 was first sampled in May 1992 and had a white phosphorus concentration of over 200 µg/g. WP concentrations in samples taken at 1-m intervals radiating out from this site on 19 August, 1992, showed extreme spatial variability. Most of the 41 samples had measurable concentrations of WP (only 37% of the samples were less then 0.001 µg/g) (Table III-2-1, Fig. III-2-4a). Since August 1992, sediments in this part of Area C were desaturated during the summers of 1993 and 1994 and for a prolonged time in 1997. When sampled in September 1997 in the same pattern as was done in 1992, 1994, and 1995, 98% of the samples were less then 0.001 µg/g. Only three samples contained detectable WP. These samples were located 2 m E (0.0006 µg/g), 3 m E (0.068 µg/g), and 1 m SE (0.0007 µg/g) from the center point at site 883.

The decrease in WP contamination in the

Table III-2-1. Distribution of WP concentration ranges for 41 samples collected in an intermittent pond in Area C (Site 883).

	Percentage of samples			
Conc. (µg/g)	*On Aug. 19, 1992*	*On Aug. 19, 1994*	*On Sept. 17, 1995*	*On Sept. 3, 1997*
<0.001	37	59	68	98
0.001 to 0.099	41	29	29	2
0.1 to 9.9	12	10	2	0
>10	10	2	0	0

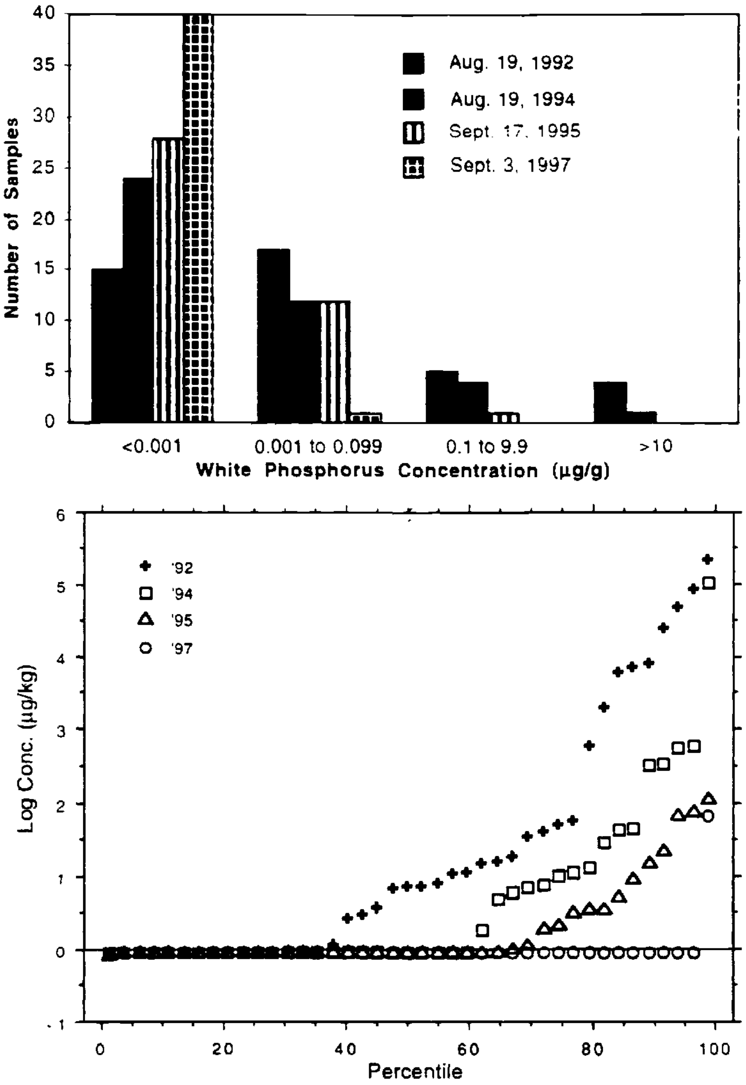


Figure III-2-4. a) Histogram showing number of samples in different concentration ranges in 1992, 1994, 1995 and 1997 around site 883 in an intermittent pond (#164) of Area C. b) Percentile plot of WP concentrations found.

surface sediments at this intermittently dry site is obvious when the data are presented as a percentile plot (Fig. III-2-4b). The y axis is log concentration (μg/kg) to show the wide range in concentrations detected. Zero on this log scale is equivalent to 1 μg/kg, or 0.001 μg/g. This plot shows the yearly decline in the percentage of samples that had concentrations greater than 0.001 μg/g, and a general decline in the maximum concentrations detected.

In the three samples that had detectable WP in 1997, the concentrations are too low to contain white phosphorus particles that could pose a threat to waterfowl. The surface sediments at this site can be considered remediated, and future resampling of the surface sediments is unnecessary (although some core samples of the underlying sediments may be useful to determine if residual contamination remains at depth).

While we do not know when site 883 was actually contaminated, we do know that eight summers have passed since the last time WP munitions were fired into ERF. This site was probably desaturated for part of those summers with at least eight weeks between flooding tides (1990, 1992, 1993, 1994, 1997), so five seasons were needed to essentially rid the surface sediments of white phosphorus.

We do know when Miller's Hole was contaminated. In May 1992 a UXO WP mortar round was found and deliberately detonated. Because the high explosive charge used to destroy the UXO was placed on top of the mortar round, the force of the explosion drove much of the WP filler into the soft sediment and created a crater that is 30 cm deep. The explosion also dispersed WP at least as far as the observation tower in Area C, which was located 74 m from the detonation, farther then would be typical of a WP round that exploded on impact. Miller's Hole is located 85 m east of site 883, but the rim is the same elevation as site 883, so exposure times have probably been comparable. The white phosphorus concentrations in the rim of the crater decreased markedly during the first summer of exposure, and WP has been undetectable in the rim during those years when a dry period preceded sampling (Table III-2-2). The crater bottom, because of its lower elevation, has experienced much shorter drying times then the rim. Nonetheless, concentrations in the surface sediments of the crater bottom have generally declined with time. The apparent increase in concentration when the crater was underwater during all of 1995 (and in some spring sampling [Walsh et al. 1995]) suggested to us that the underlying sediments might still contain high concentrations of WP. This year, we took core samples and confirmed that high concentrations still exist at depths greater than 10 cm (Table III-2-3). This reservoir of WP will decline with time, but decontamination will be slower because of shorter periods below water saturation and greater sediment consolidation.

Table III-2-2. WP concentrations found at Miller's Hole, a crater produced by the detonation of a WP UXO.

Sampled	*Days since explosion*	*WP concentration (μg/g)*	
		Center	*Rim*
5/20/92	0	2,394	979
8/21/92†	93	184	0.00427
8/27/93†	464	81.5	0.00177
8/30/94	832	9.5	not detected
9/17/95††	1215	166	0.0006
9/3/97	1932	1.6	not detected

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

Transects in Areas C and BT

Transect layout

We sought to establish 200-m-long transects west to east through C Pond and the

Table III-2-3. WP concentrations found in duplicate core samples collected from Miller's Hole on 3 September 1997.

Depth (cm)	*WP concentration (μg/g)*	
	Core 1	*Core 2*
0 to 5	1.59	0.03
5 to 10	2.5	0.048
10 to 15	1300	330
15 to 20	48	1728

Table III-2-4. UTMs and elevations for monitoring stations and composite sample grids.

C Pond

	East *(m)*	*North* *(m)*	*Elevation* *(m)*
0 m			
Midpoint[1]	354,928.26	6,801,293.32	4.73
N extreme	354,929.48	6,801,314.62	4.77
S extreme	354,928.81	6,801,273.16	4.77
50 m			
Midpoint	354,974.79	6,801,297.37	4.66
N extreme	354,961.91	6,801,313.53	4.71
S extreme	354,973.44	6,801,276.21	4.75
100 m			
Midpoint[1]	355,023.66	6,801,303.20	4.65
N extreme	355,036.51	6,801,318.08	4.62
S extreme	355,024.18	6,801,282.47	4.72
150 m			
Midpoint	355,073.85	6,801,308.34	4.58
N extreme	355,071.58	6,801,329.45	4.62
S extreme	355,064.37	6,801,292.99	4.65
200 m			
Midpoint[1]	355,123.40	6,801,314.15	4.54
N extreme	355,119.89	6,801,334.18	4.59
S extreme	355,120.65	6,801,294.97	4.61

Bread Truck North

	East *(m)*	*North* *(m)*	*Elevation* *(m)*
0 m			
Midpoint[1]	354,437.05	6,801,818.64	4.76
N extreme	354,431.12	6,801,838.75	4.76
S extreme	354,433.93	6,801,796.58	4.73
50 m			
Midpoint	354,487.31	6,801,821.78	4.71
N extreme	354,485.00	6,801,842.27	4.77
S extreme	354,486.80	6,801,801.40	4.71
100 m			
Midpoint[1]	354,536.98	6,801,826.74	4.76
N extreme	354,534.32	6,801,846.02	4.78
S extreme	354,534.55	6,801,804.90	4.70
150 m			
Midpoint	354,587.18	6,801,827.87	4.71
N extreme	354,590.65	6,801,848.21	4.75
S extreme	354,590.82	6,801,811.44	4.73
200 m			
Midpoint[1]	354,636.85	6,801,831.08	4.69
N extreme	354,634.29	6,801,851.46	4.77
S extreme	354,634.28	6,801,809.88	4.73

Bread Truck South

	East *(m)*	*North* *(m)*	*Elevation* *(m)*
0 m			
Midpoint[1]	354,421.25	6,801,721.99	4.83
N extreme	354,416.84	6,801,742.05	4.87
S extreme	354,423.40	6,801,699.86	4.82
50 m			
Midpoint	354,471.57	6,801,722.69	4.77
N extreme			
S extreme	354,487.81	6,801,709.54	4.77
100 m			
Midpoint[1]	354,521.08	6,801,724.34	4.76
N extreme	354,519.86	6,801,743.96	4.73
S extreme	354,524.35	6,801,702.92	4.80
150 m			
Midpoint	354,571.53	6,801,726.09	4.65
N extreme	354,568.31	6,801,746.83	4.64
S extreme	354,567.18	6,801,706.04	4.70
200 m			
Midpoint[1]	354,621.50	6,801,727.84	4.68
N extreme	354,618.89	6,801,749.37	4.67
S extreme	354,623.98	6,801,708.01	4.69

[1] Location of planted white phosphorus particles and data-logger with sediment moisture and temperature sensors.

Pond 40 in C/D

	East *(m)*	*North* *(m)*	*Elevation* *(m)*
Transect 1			
Midpoint	355,219.09	6,802,326.62	4.59
N extreme	355,260.41	6,802,365.82	4.80
S extreme	355,189.42	6,802,306.89	4.79
Transect 2			
Midpoint	355,190.73	6,802,336.81	4.35
N extreme	355,149.70	6,802,364.45	4.53
S extreme	355,225.70	6,802,305.65	4.72
Transect 3			
Midpoint	355,220.21	6,802,344.62	4.38
N extreme	355,196.34	6,802,361.02	4.29
S extreme	355,254.06	6,802,329.07	4.25
Transect 4			
Midpoint	355,146.91	6,802,054.48	4.32
N extreme	355,139.99	6,802,092.23	4.23
S extreme	355,149.10	6,802,011.06	4.48

Table III-2-5. Range and average elevation of gridded areas from which composite samples were collected in Area C and Bread Truck Pond.

	Elevation (m)	
	Range	Average
C Pond		
0 m	4.69 to 4.79	4.75
50 m	4.66 to 4.78	4.74
100 m	4.60 to 4.72	4.65
150 m	4.58 to 4.65	4.62
200 m	4.54 to 4.66	4.60
Bread Truck South		
0 m	4.80 to 4.87	4.84
50 m	4.74 to 4.81	4.77
100 m	4.69 to 4.80	4.75
150 m	4.64 to 4.76	4.70
200 m	4.64 to 4.70	4.68
Bread Truck North		
0 m	4.73 to 4.85	4.77
50 m	4.71 to 4.77	4.74
100 m	4.69 to 4.79	4.75
150 m	4.71 to 4.79	4.74
200 m	4.69 to 4.78	4.74

Bread Truck Pond that would represent the range of sediment moisture conditions within each area. North and south of each transect, we gridded an area (40 m × 5.46 m) (Fig. III-2-1b) from which we collected composite samples. As we set up the grids north and south, we tried to maintain the same elevation as the intersection point on the west–east transect (Table III-2-4). As depicted on the maps (Fig. III-2-2), the grids were angled at some locations in an attempt minimize the range of elevations sampled for each composite.

The transect through C Pond declined in average elevation from west to east (4.75 to 4.60 m) (Table III-2-5). However, topography north and south of the transect varied in elevation, with the south extreme generally at a higher elevation then the north extreme for those grids located in what was permanent pond prior to draining (Table III-2-4).

The elevation of the transect through the south portion of Bread Truck Pond varied from a high of 4.87 m on the west to a low of 4.64 m (Table III-2-5). Both the 150-m and 200-m stations were within a swale that pooled rain or tidal water.

The transect through the north portion of Bread Truck Pond was essentially flat from west to east based on average elevation (Table III-2-5), but there was considerable elevation variation within the gridded areas due to craters, swales, and hummocks. The numerous depressions do not drain after a flooding event, and drying relied on evaporation. Because of this wide variation in local topography, moisture conditions were variable, which would lead to variable rates of attenuation of white phosphorus particles.

Sublimation/oxidation conditions

To rid ERF sediments of white phosphorus particles, the sediments must be desaturated (Walsh et al. 1995). Temperature is important because high temperatures will hasten the loss of white phosphorus but is secondary to desaturation. Based on the output of the soil moisture probes and tensiometers we placed in drained ponds in Area C and Bread Truck Pond, we found sediments in both areas experienced desaturated conditions. We estimated the number of days (Table III-2-6) that the sediments were desaturated at 5- and 10-cm depths based on the graphs of moisture probe resistance, where drying periods are indicated by a sharp rise in resistance (Fig. III-2-5) and in tension (Fig. III-2-6).

Pumping of Area C resulted in a total of 38–40 days during which the sediments were desaturated. After the initiation of pumping at the end of May, the sediments at 5-cm depth along the instrumented transect were desaturated by June 12, even at the C Pond 200-m station that was located well within the permanent pond. Sediments continued to dry until a heavy rain event on June 19–20 (Table III-2-7). By June 23, sediments were again desaturated until July 11, when another heavy rain resaturated the sediments. Another brief period of drying (July 17–20) preceded the flooding tide on July 21. Sediments were desaturated for the final time during the first week of August. Then heavy rains and flooding tides ended the drying season for 1997.

Table III-2-6. Length of time and temperatures during which sediments were unsaturated at 5- and 10-cm depths between 6 June and 4 September 1997.

Station	*Number days unsaturated*	*Number days unsaturated and >20° C*	*Average temp (°C) while unsaturated*	*Maximum temp (°C) while unsaturated*	*Dates unsaturated*	*Average temp (°C) July 5 to 10*
a) At 5 cm depth						
C Pond						
0 m	38	13	18.73	22.77	June 11-19, June 23-July 10, July 16-20, Aug. 2-5, Aug. 7-8	19.85
100 m	38	5	17.53	21.72	June 11-19, June 23 - July 10, July 17-21, Aug. 3-9	18.98
200 m	40	3	17.10	21.53	June 12-19, June 22-July 10, July 16-21, Aug. 3-9	18.27
BT South						
0 m	41	27	21.24	26.97	June 11-19, June 22-July 10, July 16-20, Aug 2-9	22.31
100 m	12	7	19.71	22.22	June 19, July 2-10, July 19, Aug. 11	20.73
200 m	8	2	19.48	20.62	July 3-10	19.54
BT North						
0 m	6	5	21.16	22.65	July 5-10	21.16
100 m	18	9	19.13	21.67	July 2-10, Aug. 2-9, Aug 11	20.40
200 m	26	5	18.03	20.88	June 14-19, June 28-July 10, July 17-19, Aug. 5-8	19.63
b) At 10 cm depth						
C Pond						
0 m	35	11	18.27	22.13	June 10-19, June 22-July 10, July 16-July 21	19.76
100 m	41	2	16.96	20.59	June 10-19, June 21-July 10, July 17-21, Aug. 4-9	18.45
200 m	33	2	16.90	20.37	June 14-20, June 23-July 10, July 17-20, Aug. 5-8	17.98
BT South						
0 m	34	19	21.05	25.87	June 15-June 19, June 22-July 10, July 16-20, Aug 5-9	21.81
100 m	11	6	19.38	21.68	June 19, July 3-10, July 19, Aug. 11	20.55
200 m	9	1	19.32	20.25	July 2-10	19.30
BT North						
0 m		No data	No data	No data		
100 m	11	5	18.60	21.46	July 4-10, Aug 8-12	20.44
200 m	12	0	18.75	19.85	June 19, June 30-July 10	19.14

The degree to which the intermittent and permanent ponds in Area C dried this summer while the drainage pump was in operation far exceeded what we have observed in previous years under natural conditions. The highest tension measured in an intermittent pond during 1994, the last summer with an extended time between flooding tides, was 30 cbars. In July 1997, peak tensiometer readings exceeded 70 cbars (Table III-2-8), even in what was the permanent pond of Area C.

Less drying occurred in the Bread Truck Pond. Breaching has lowered the flooding threshold, and sediments were rewetted more frequently by tides than in Area C. Nonetheless, sediments were desaturated during the

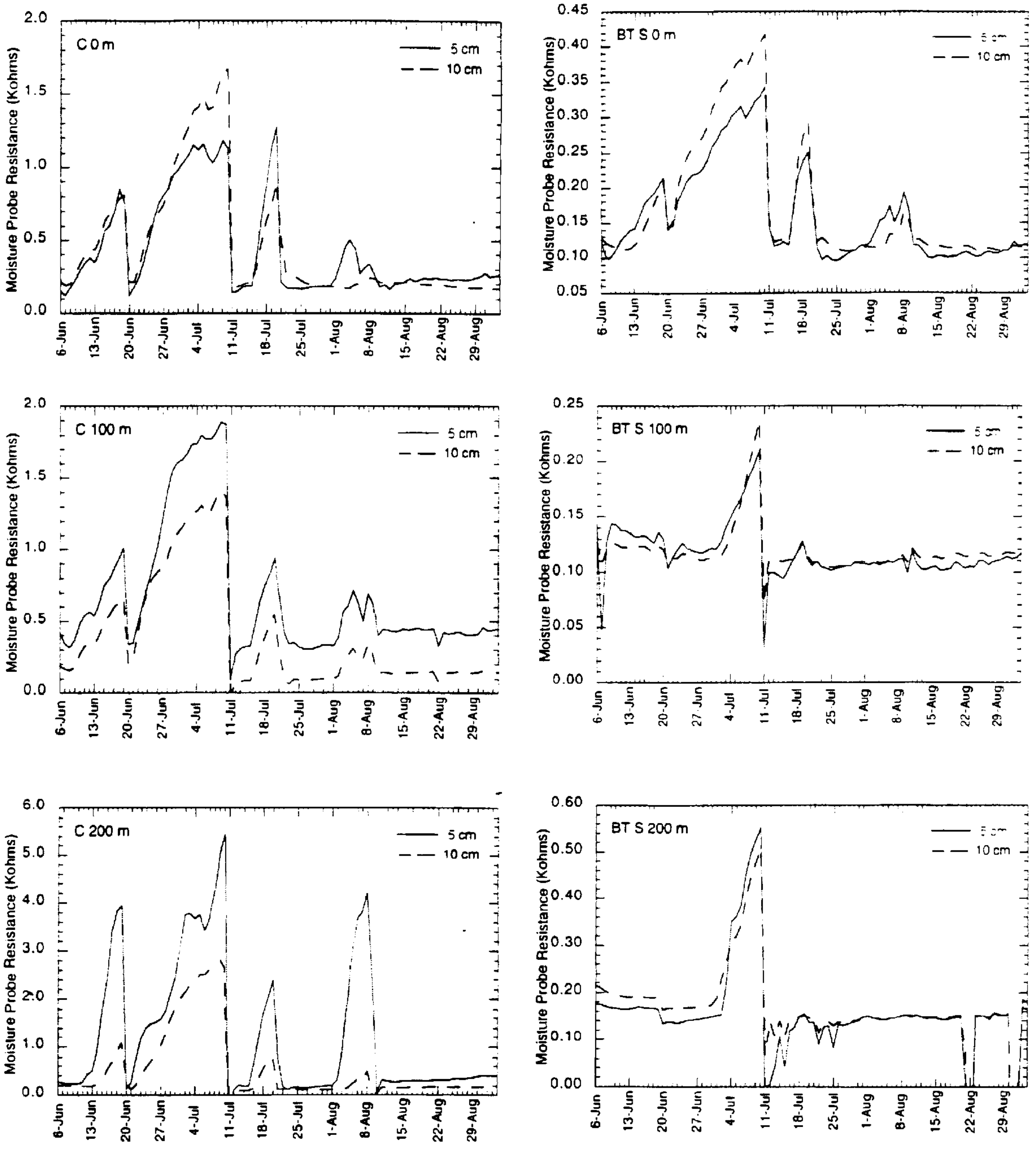


Figure III-2-5. Moisture probe resistance at datalogger stations. An increase in resistance inidcates drying.

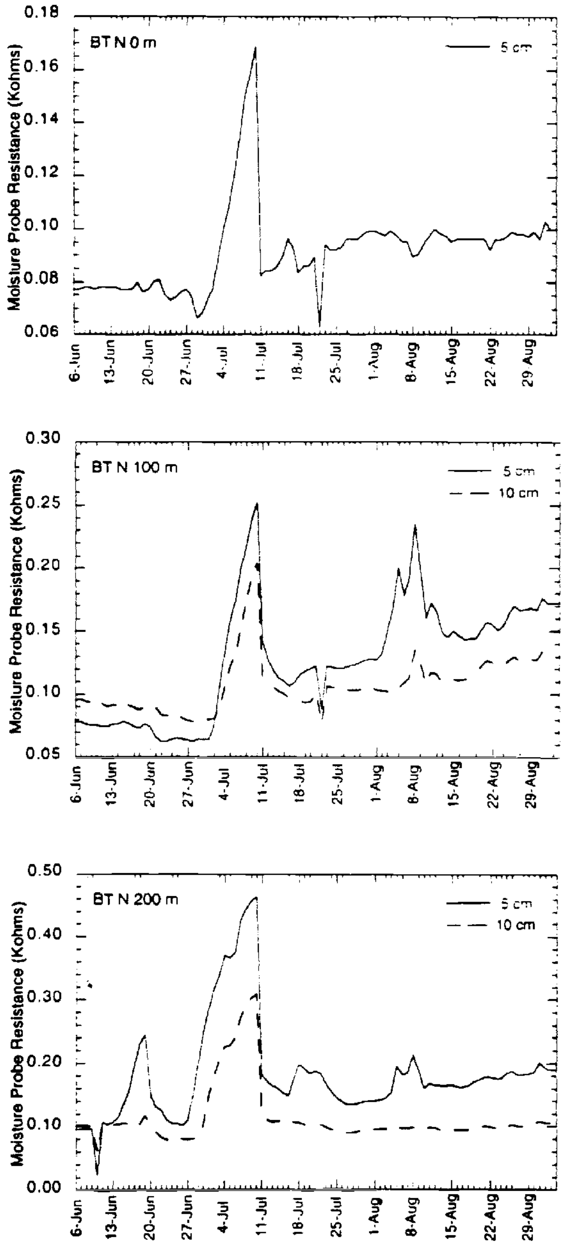


Figure III-2-5 (cont'd). Moisture probe resistance at datalogger stations. An increase in resistance inidcates drying.

first part of July at the six datalogger locations.

Average and maximum sediment temperatures during periods of desaturation were highest in the westernmost stations (stations at 0 m) along all three transects compared to stations at 100 m and 200 m east (Table III-2-6, Fig. III-2-7). The westernmost stations were located in what was intermittent pond versus permanent pond to the east. In general, sediment temperatures were slightly higher in the Bread Truck Pond compared to Area C. In all cases, sediment temperatures were sufficiently high to expect attenuation of white phosphorus particles.

An approximately 50% decline in mass was found for WP particles planted in the top 5 cm of sediment from 31 May to 3–4 September 1997 (Table III-2-9). The means of the residual masses of the for five replicates from each of the nine monitoring stations were remarkably similar, considering the variation in the lengths of time that the stations were desaturated. The loss in C Pond was consistent with that expected due solely to sublimation of white phosphorus particles in saturated sediments (Fig. III-2-8). Oxidation, which is likely to occur at temperatures above 20°C, will accelerate loss and may explain the comparable loss in the Bread Truck Pond, where desaturated conditions were of shorter duration then in Area C. The particles we planted were larger than the average particles we have found in ERF sediments and will take longer to diminish. While differences in particles sizes, sediment moisture contents, and temperatures make predictions difficult, the loss observed for the planted particles indicates that smaller WP particles (<1 mg) would have attenuated to near completion.

Baseline and verification sediment sampling

Baseline sampling was done in June by collecting composite samples on a grid system extending 20 m north and south of the west-to-east transects at 0, 50, 100, 150, and 200 m along the west–east transects. Along all three transects, white phosphorus concentrations were highest in the 100-m composites (Table III-2-10). In addition, white phos-

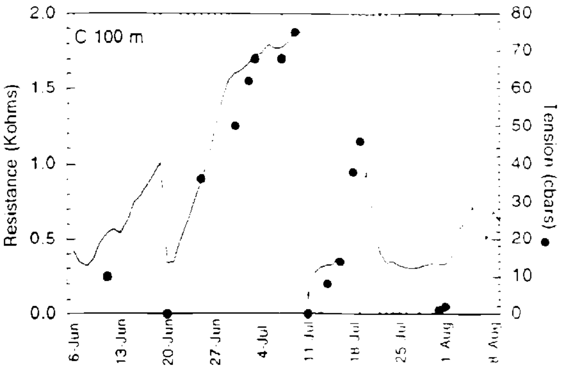


Figure III-2-6. Unsaturated conditions, as indicated by increasing moisture probe resistances, were verified by periodic tensiometer readings. High resistance coincides with high tension, confirming that sediments were desaturated.

phorus particles were found only in the 100-m composite samples.

The highest mean concentration (61.2 µg/kg) was found in June in the Area C composite sample that includes part of the DWRC pens. Located within the permanent pond, this highly contaminated area was exposed by pumping for the first time since it was originally identified as contaminated in 1991. When resampled in September, the mean concentration for the composite sample was 6.89 µg/kg, an 89% decline from June 1997 (Table III-2-11). In addition, no white phosphorus particles were isolated from the September sample.

The transect through the north portion of the Bread Truck Pond also had significant WP contamination for the 100-m composite. The June composite sample contained multiple white phosphorus particles, one of which burned for over five minutes (an indication of considerable size). The composite sample collected in September still had white phosphorus particles. The gridded area from which composites were taken is heavily cratered (Fig. III-2-9) and did not readily drain after flooding. As a result, drying conditions were not uniform across the sampled area and were not sufficient to decontaminate the entire area.

Table III-2-7. Precipitation measured at Anchorage International Airport (NOAA 1997) for June, July and August 1997.

Month	*Day*	*Precipitation (cm)*
June	5	0.10
	6	0.43
	7	0.03
	13	0.10
	14	0.15
	15	0.05
	19	0.20
	20	0.41
	22	0.05
June Total		1.52
July	10	0.23
	11	1.90
	12	0.13
	13	0.46
	14	0.30
	15	0.20
	20	0.03
	24	0.13
	30	0.08
July Total		3.45
August	6	0.10
	9	1.04
	10	0.28
	11	0.89
	12	1.12
	13	0.89
	15	0.25
	16	0.61
	20	0.15
	21	7.01
	22	0.15
	25	0.15
	26	1.45
	27	0.76
	30	0.03
	31	6.37
August Total		21.24

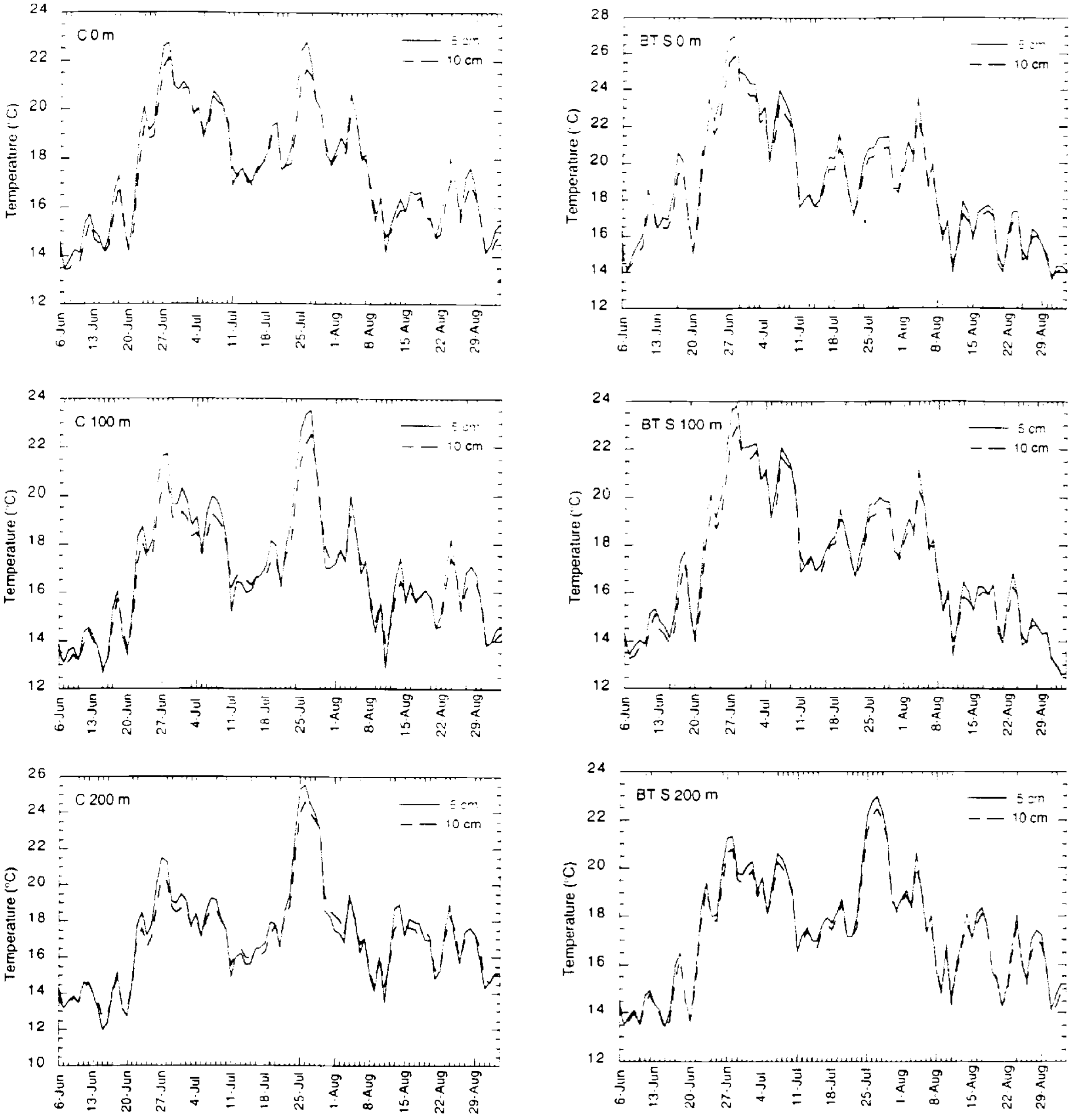
The transect through the south side of the Bread Truck Pond was the least contaminated of the three transects. The 100-m composite collected in June did have one small white phosphorus particle. Concentrations appeared to decline between June and September from a mean of 4.9 µg/kg to 0.87 µg/kg (an 82% decline), and no white phosphorus particles were found in September.

Table III-2-8. Tensiometer readings.

		Tension (cbars)[†]														
		June				July										August
Station	Depth (cm)	11	20	25	30	2	3	7	9	11	14	16	18	19	31	1
a) C Pond																
0 m	5	15	2	44	19	n/a	n/a	n/a	24	0	8	12	32	36	3	4
	10	15	3	49	50	56	52	60	57	6	8	12	23	40	2	4
	20	14	12	40	48	50	50	54	55	13	10	12	24	32	2	4
50 m	10	11	4	42	50	56	55	62	65	6	7	10	4	42	2	4
	20	11	8	38	48	52	52	58	62	10	8	11	54	37	4	5
100 m	5	10	0	36	50	62	68	68	75	0	8	14	38	46	1	2
	10	9	1	35	46	52	49		50	6	7	12	52	44	1	2
	20	4	0	29	40	46		52	64	6	5	8	40	37	0	0
	10[*]	12	4	42	50	58	54	66	80	6	12	17	64	55	4	6
150 m	10	5	0	7	10	10	10			0	1	12	38	46	0	0
	20	2	2	32	48	68	72	76	78	0	5	9	30	29	0	2
200 m	5	3	0	31	54	58	61	60	65	0	3	6	41	28	0	0
	10	4	4	28	37	41	42	48	50	6	8	8	39	5	4	4
	20	2	4	24	30	n/a	36	42	47	6	5	6	29	2	0	0
b) Bread Truck South																
0 m	5	7	1	15	—	—	—	26	—	—	—	9	—	—	2	—
	10	0	0	0	—	—	—	0	—	—	—	0	—	—	6	—
	20	0	0	7	—	—	—	16	—	—	—	0	—	—	0	—
50 m	10	0	0	6	—	—	—	18	—	—	—	4	—	—	0	—
	20	0	2	6	—	—	—	16	—	—	—	4	—	—	0	—
100 m	5	0	2	2	—	—	—	8	—	—	—	4	—	—	1	—
	10	1	4	4	—	—	—	10	—	—	—	6	—	—	2	—
	20	2	4	4	—	—	—	10	—	—	—	6	—	—	3	—
150 m	10	0	0	0	—	—	—	30	—	—	—	4	—	—	0	—
	20	0	6	3	—	—	—	20	—	—	—	6	—	—	0	—
200 m	5	0	0	0	—	—	—	12	—	—	—	3	—	—	0	—
	10	0	0	0	—	—	—	10	—	—	—	0	—	—	0	—
c) Bread Truck North																
0 m	10	2	4	5	—	—	—	13	—	—	—	4	—	—	4	—
	20	4	6	7	—	—	—	15	—	—	—	6	—	—	6	—
50 m	10	0	0	0	—	—	—	10	—	—	—	3	—	—	3	—
	20	0	0	0	—	—	—	0	—	—	—	0	—	—	0	—
100 m	10	1	2	2	—	—	—	10	—	—	—	2	—	—	4	—
	20	2	2	2	—	—	—	10	—	—	—	2	—	—	2	—
150 m	10	7	2	4	—	—	—	13	—	—	—	6	—	—	9	—
	20	6	3	4	—	—	—	0	—	—	—	0	—	—	7	—
200 m	10	0	0	0	—	—	—	15	—	—	—	4	—	—	2	—

[†] Tensiometer were read by Patrick Lemay of CH2MHill.

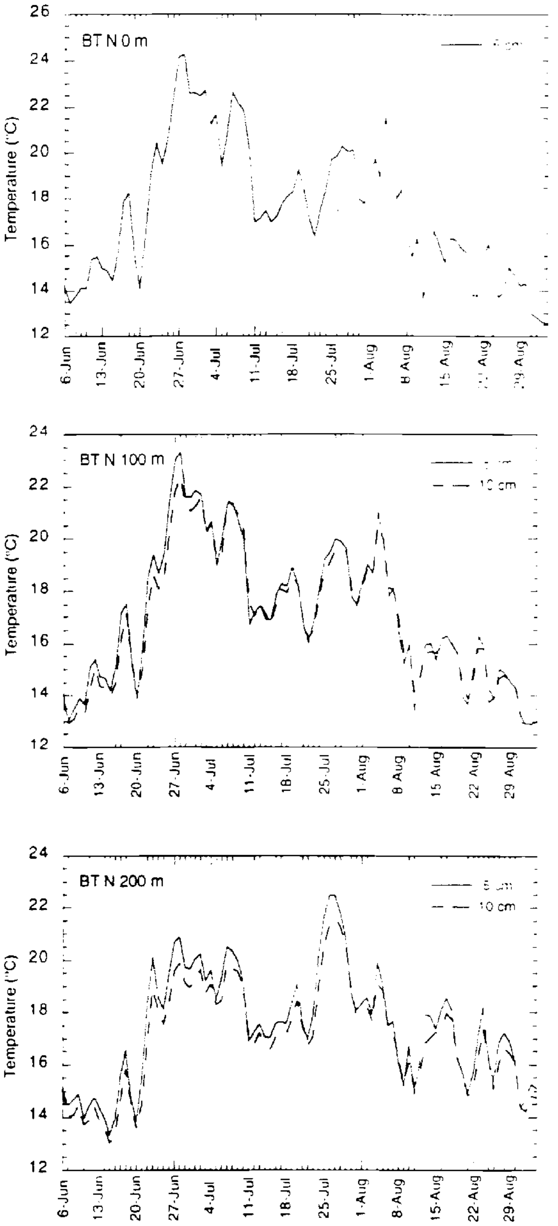
[*] Duplicate measurement.



a. Area C.

b. Bread Truck South.

Figure III-2-7. Sediment temperature (24-hr averages) at datalogger stations in Area C and the Bread Truck Pond.



c. Bread Truck North.

Figure III-2-7 (cont'd). Sediment temperature (24 hr averages) at datalogger stations in Area C and the Bread Truck Pond.

Table III-2-9. Mass remaining from WP particles incubated in the top 5 cm of sediment from 31 May to 3–4 September 1997. The initial mass of each particle was 5.56 mg.

	Residual WP mass (mg)		
Replicate	*0 m*	*100 m*	*200 m*
C Pond			
A	2.95	1.57	0.88
B	3.02	2.82	2.87
C	3.08	2.87	2.96
D	3.20	2.90	3.06
E	3.40	3.03	3.09
mean	3.13	2.64	2.57
BT South			
A	2.81	0.00029	2.82
B	2.86	1.19	2.89
C	3.01	2.66	2.94
D	3.40	3.91	3.82
E	4.05	4.43	3.88
mean	3.23	2.44	3.27
BT North			
A	2.64	1.10	0.17
B	2.74	2.84	2.40
C	2.75	3.20	2.81
D	2.85	3.65	2.92
E	2.87	4.44	3.08
mean	2.77	3.05	2.28

Composite sampling in C/D

No white phosphorus was found in the composite samples collected from pond 40 in Area C/D (Table III-2-12), confirming that this ponded area does not have widespread contamination like that in the Bread Truck Pond and Area C. In addition, water depths for much of the pond were greater than 40 cm, the maximum depth of suitable feeding habitat for mallards (Low et al. 1970 in Pain 1991) (Table III-2-13). The profile of transect 2 (Fig. III-2-10) was typical of the other three transects. The shallowest depths correspond to clumps of bulrush, and the deepest depth is in a beaver channel.

Four other ponds (49, 93, 85, and 112) within Area C/D have been designated as hot ponds (CH2MHill) but have not been sampled. The two ponds farthest west (85 and 112) should be sampled due their proximity to the Bread Truck Pond.

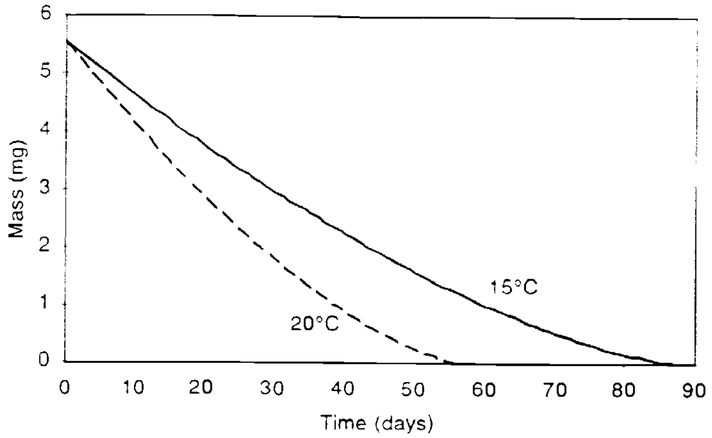


Figure III-2-8. Simulation of decrease in mass due to sublimation of a spherical white phosphorus particle with an initial diameter of 1.8 mm (mass 5.56 mg) in near saturated sediment at 15 and 20°C (Walsh 1993).

Table III-2-10. WP concentrations found in composite samples collected June 2-4, 1997.

	White phosphorus conc. (µg/kg)				
	0 m	*50 m*	*100 m*	*150 m*	*200 m*
Area C					
	not detected	0.32	18.5	2.73	0.37
	not detected	0.49	61.0	3.46	0.42
	not detected	0.61	68.5	3.95	0.47
	not detected	0.70	73.2	4.14	0.67
	not detected	0.76	84.7	4.93	0.83
mean	not detected	0.58	61.2	3.84	0.55
BT South					
	not detected	0.67	3.0	1.4	0.39
	not detected	0.70	3.3	1.8	0.49
	not detected	0.87	4.0	2.7	0.49
	not detected	0.93	6.1	3.7	0.59
	not detected	1.12	7.9	20.0	0.71
mean	not detected	0.86	4.9	6.0	0.53
BT North					
	0.63	0.57	3.9	0.69	not detected
	0.63	0.71	8.1	0.79	not detected
	0.75	0.79	12.0	0.82	not detected
	0.85	0.98	12.4	1.02	not detected
	1.00	0.99	21.2	1.18	not detected
mean	0.77	0.81	11.5	0.90	not detected

Table III-2-11. WP concentrations found in composite samples collected at 100 m along west–east transects on Sept. 3–4, 1997.

	Area C	*BT South*	*BT North*
	5.35	0.56	4.9
	6.26	0.71	5.1
	6.27	0.86	5.6
	6.46	1.05	16
	10.1	1.17	3097
mean	6.89	0.87	**

**Mean not valid due to one high concentration.

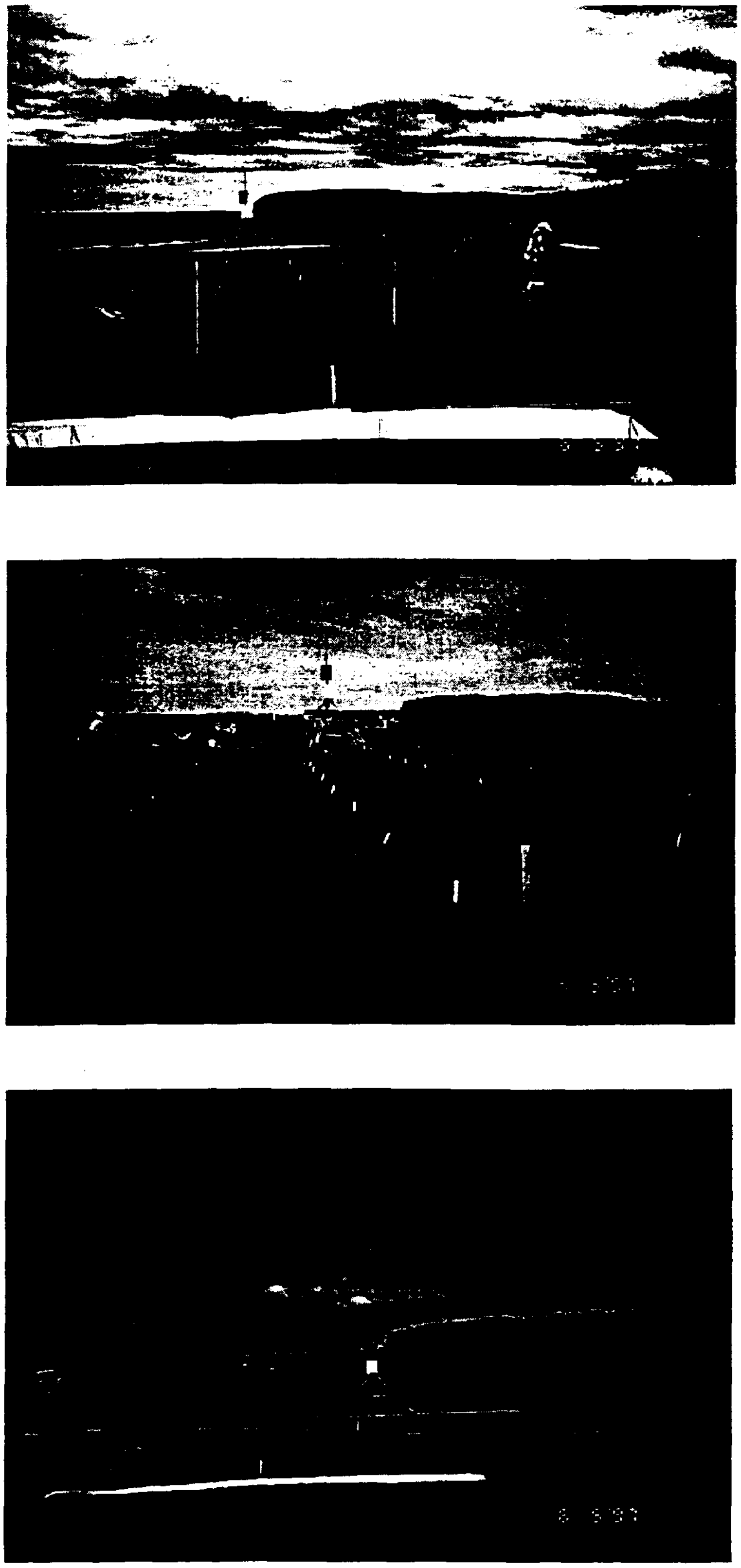


Figure III-2-9. Ground views of the 100 m stations. All views are from the south end of the gridded area looking north on June 5, 1997. a) C Pond b) Bread Truck South c) Bread Truck North.

Table III-2-12. Composite samples collected from Pond 40 in Area C/D (Fig. III-2-3).

	White phosphorus concentration (μg/g) based on wet weight							
Rep.	*Trans. 1-SW*	*Trans. 1-NE*	*Trans. 2-SE*	*Trans. 2-NW*	*Trans. 3-SE*	*Trans. 3-NW*	*Trans. 4-S*	*Trans. 4-N*
A	<d	<d	<d	<d	<d	<d	<d	<d
B	<d	<d	<d	<d	<d	<d	<d	<d
C	<d	<d	<d	<d	<d	<d	<d	<d
D	<d	<d	<d	<d	<d	<d	<d	<d
E	<d	<d	<d	<d	<d	<d	<d	<d
Number subsamples in composite	68	76	96	88	51	45	76	72
Date composite collected	5 Sep 97	5 Sep 97	6 Sep 97	6 Sep 97	8 Sep 97	8 Sep 97	8 Sep 97	8 Sep 97
Mass (g) of composite	2657	3160	4040	3550	2268	1889	3755	3435

Table III-2-13. Average water depths measured while collecting composite samples in Area C/D s. Transect locations are shown in Figure III-2-3.

	Water depth (cm)			
	Transect 1	*Transect 2*	*Transect 3*	*Transect 4*
Average	41	45	41	44
Std. dev.	12	14	12	9
Maximum	90	94	90	71
Minimum	19	10	18	23
Date	5 Sept. 1997	6 Sept. 1997	8 Sept. 1997	8 Sept. 1997

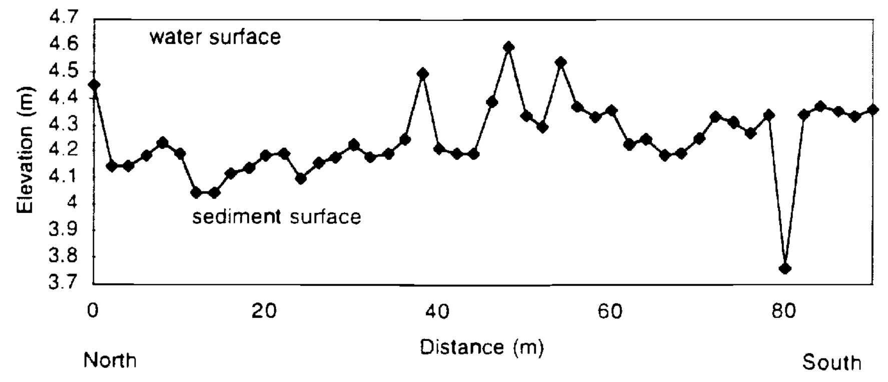


Figure III-2-10. Sediment surface elevation profile along Transect 2 in Area C/D (Figure III-2-3).

Retention basin

No white phosphorus residue was detectable from particles planted in dredge spoils in the retention basin. Dredging in 1996 resulted in the burial of some of these samples with several feet of highly organic material. No dredging occurred in 1997, so the spoils air-dried under field conditions throughout 1997 and were wetted only by rain events.

CONCLUSIONS

Pumping was very successful in drying the surface sediments of Area C. Breaching of the Bread Truck Pond has resulted in some drying of the surface sediment, but topography characterized by swales and craters that do not drain and a lower tidal flooding threshold slow the potential attenuation rates. A tide gate designed to reduce the frequency of flooding would greatly enhance decontamination of the sediments, especially at depth. If the Bread Truck Pond were to be used as an impact area again during summer, decontamination of white phosphorus at depth is crucial.

Sublimation/oxidation conditions were favorable for removal of some white phosphorus from the surface sediments. An approximately 50% decline in mass, from 5.56 to 2.8 ± 0.9 mg, to was found for white phosphorus particles planted in the surface sediments of Area C and the Bread Truck Pond. Composite samples taken in June from Area C and the Bread Truck Pond showed that most of the contamination was located at the midpoint of transects running west to east from intermittent to permanently flooded ponds. Resampling in September showed significant declines (>80%) in white phosphorus concentrations in Area C and the south side of Bread Truck Pond. The mass of WP found in the composite samples is the sum of a range of particle sizes, from colloidal to macroscopic, and because small particles take less time to attenuate, we see greater loss for those composite samples that had particles smaller then the planted particles. The composite sample taken in September from the north side of the Bread Truck Pond, where drying conditions were variable and WP particles were large, did not show a detectable change in concentration from June sample.

No white phosphorus was detected by composite sampling in Pond 40 of Area C/D, indicating that this pond is not a serious threat to waterfowl.

The dredge spoils were air-dried in the retention basin during 1997, and no white phosphorus residue was found from particles planted in 1995.

The composite sampling approach was useful for discerning spatial trends in concentrations across a large area. When a highly contaminated area was found, temporal changes could be monitored. To gain confidence that temporal changes are significant, replicate composites will be taken during future sampling events.

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III-3. DRAINING OF RACINE ISLAND POND BY EXPLOSIVE DEMOLITION OF A DRAINAGE DITCH

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INTRODUCTION

Two distinctly different approaches to pond draining have been studied for use in ERF for treating WP-contaminated sediment. Each approach has its own advantages and disadvantages. Temporary pond draining involves the use of a large-capacity pump to pump a pond basin dry (Walsh, M.R. et al., this vol.). The pumping has to be repeated periodically, either as the basin starts to refill from surface water and groundwater inflow from the surrounding areas, or after one of the periodic flooding high tides. Because of the requirements to subaerially expose the contaminated pond bottom sediments as long as possible to allow them to dry below saturation and thus to allow the white phosphorus to sublimate and oxidize (Walsh and Collins 1995, Walsh et al. 1995, 1996), a pump system has to be large enough to drain the pond as quickly as possible and keep it dry as long as possible throughout the summer. These requirements require using a large pump with associated generator set requiring large capitol costs. The advantage of temporary pond draining is that it is easily reversible. Once the pond bottom sediments have undergone sufficient drying so that the WP has sublimated and oxidized, the pond environment can be restored simply by removing the pump and allowing the natural periodic flooding to refill the basin.

Permanent pond draining involves the excavation of a drainage ditch connecting the pond to a nearby tidal distribution gully or the river. Because of the possibility of encountering unexploded ordnance, conventional excavation of a drainage ditch using heavy equipment is not practical in ERF. Instead, military explosives have been used to explosively excavate the ditch. Permanent draining has the advantages over temporary pond draining of less capitol and labor costs and little or no operational costs after the initial excavation. However, reversing the drainage process and restoring the pond habitat later will be much more difficult. In addition, excavating a drainage ditch into a pond basin lowers the threshold of the basin, allowing lower high tides to flood the basin. This increases the frequency of tidal flooding and increases the time required for pond bottom sediments to undergo sufficient drying for the WP contamination to sublimate and oxidize.

In April 1996 we successfully conducted the first operation to permanently drain a pond in Eagle River Flats contaminated with white phosphorus. This pond, Bread Truck Pond, located to the northwest of Area C, was one of the most highly contaminated in Eagle River Flats, with large numbers of observed waterfowl deaths each year. We drained the pond by using explosives to excavate a 70-m-long drainage ditch connecting the pond with a nearby tidal drainage gully leading to Eagle River (Collins et al. 1997). Using explosives to excavate drainage ditches is an efficient and cost-effective method to permanently drain a pond where the potential dangers posed by unexploded ordnance (UXOs) preclude the use of conventional excavation equipment. Based on our experiences with last year's operation in Bread Truck Pond, we developed recommendations on improvements to the method and the applicability of explosive excavation to other locations in ERF

Following the removal of the Bread Truck pond as a major source of waterfowl mortality, attention turned to the large pond on Racine Island. Several factors caused the Remedial Project Managers to consider this pond a candidate for permanent pond draining. The pond (Pond 293 in the ERF GIS database) was a major source of waterfowl mortality. Sediment samples containing the highest measured concentration of WP found in ERF (3071 µg/g) were collected here. Access to the pond is limited because of its location in the center of a large island between two channels of Eagle River. Pond 293 and its surrounding sedge marsh are of limited extent, so only a relatively small amount of waterfowl habitat would be lost if the pond was permanently drained. Because of these considerations, as well as the lower costs involved, the decision was made to permanently drain Pond 293 by ditching rather than by trying to temporarily drain by repeated pumping.

SITE DESCRIPTION

Pond 293 is an isolated pond located within the south-central portion of Racine Island in the southern half of Eagle River Flats (Fig. III-3-1). Racine Island is formed by the bifurcation of Eagle River just downstream of the Route Bravo bridge. The right channel flows north and then west while the left channel flows northwest and then north to rejoin the right channel, forming a 54-ha island. Pond 293 is a long narrow S-shaped pond that appears to be part of a former meander channel. The pond area is 1.0 ha. Within the pond, normal water depths vary from 0 to 50 cm. It is surrounded by 6.4 ha of sedge marsh with bulrush up to 40 cm tall and standing water. Within the sedge marsh are scattered small open-water ponds. This low area of pond and

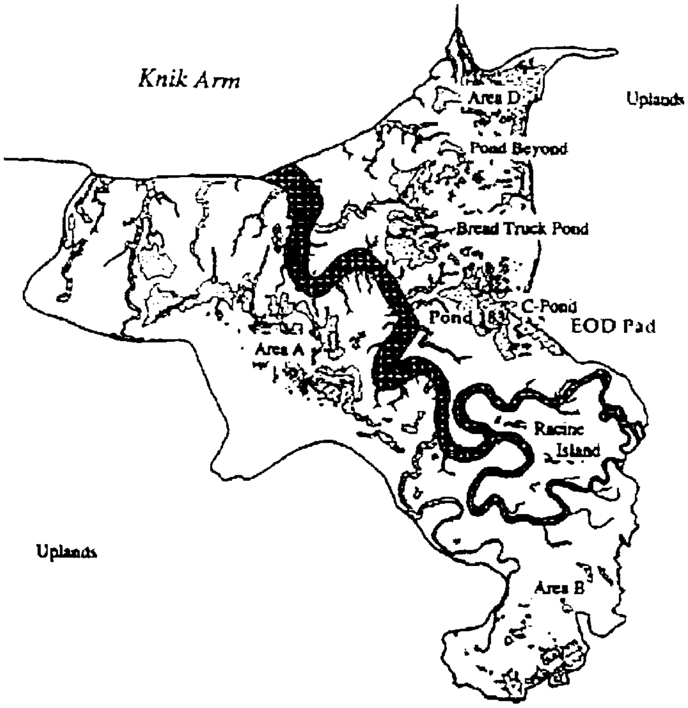

Figure III-3-1. General location of Racine Island and Pond 293 within the southern portion Eagle River Flats.

sedge marsh is in turn surrounded by a higher-elevation vegetated mudflat area (*Ramenski* sedge meadow [Racine et al. 1994]). This *Ramenski* sedge meadow consists of fine-grained cohesive soil (mostly clay with some silt) with sparse to dense low sedge vegetation.

Tidal distributary gullies leading to Eagle River are located on both the north and south sides of Pond 293 (Fig. III-3-2). These allow tidal inflow into the interior of Racine Island and the pond during flooding high tides and provide drainageways for the area during the tidal ebb. Neither gully has had major headward erosion over the last several years, unlike other gullies in ERF (Lawson et al. 1995, 1996). The nearest gully to the pond, the gully to the south, is approximately 120 m due south of the deepest part of the pond located in the center of the S. The left channel of the river comes to within 90 m of the western end of Pond 293. However, the pond is shallow at this end, and the sedge meadow between the river and the pond is higher here than anywhere else on the island. This made this a less attractive route for a drainage ditch than the longer route from the center of the pond to the gully to the south.

The Racine Island pond basin and associated sedge marsh are subject to periodic refilling under flooding high tide conditions. How often the pond is flooded and refilled during the summer depends on the maximum height of the monthly series of peak high tides and the stage of the river at the time of the tide. Prior to the excavation of the drainage ditch, the maximum water level in the pond when the pond basin is full is about 4.79 m MSL. This is the threshold elevation controlling water flowing in and out of the pond system. High tides above this level will flood and fill the pond basin. Depending on the height of the flooding high tide, the water will also fill the surrounding sedge marsh area up to a water surface elevation of about 4.95 m. The water level in the pond and surrounding marsh will then slowly drop as water flows out of the pond through the distributary chan-

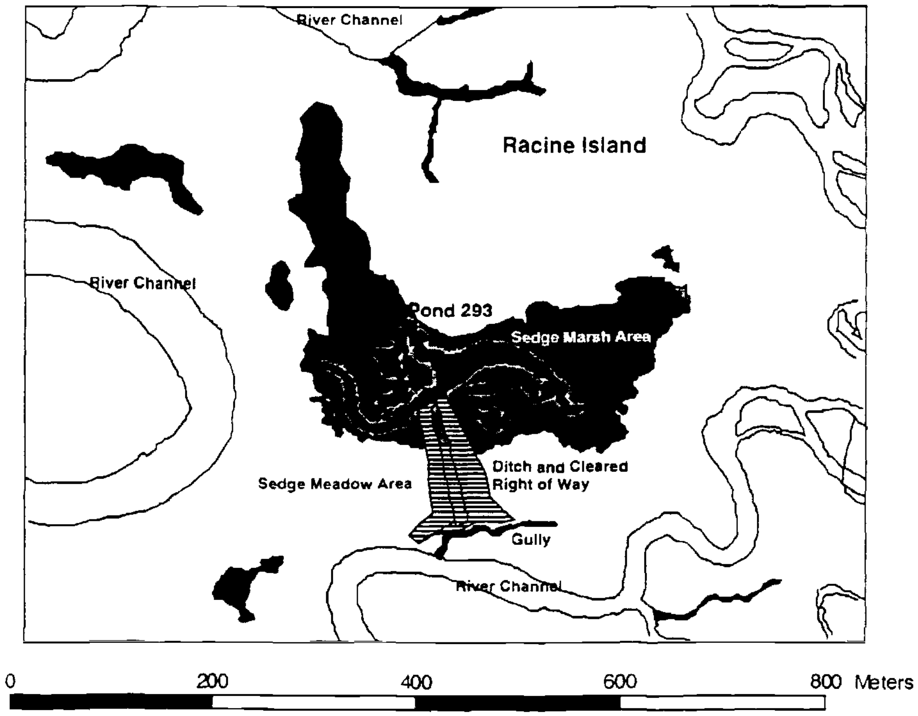

Figure III-3-2. Location of Pond 293, surrounding saltmarsh, drainage ditch, and tidal gullies within the south-central portion of Racine Island in Eagle River Flats.

nels. Additional drops in the water level below the threshold elevation occur as evaporation reduces the amount of water in the pond.

METHODS

Explosive excavation of ditch

Because Eagle River Flats is an artillery impact range, there is a potential of encountering unexploded ordnance (UXO) if digging or ditching is done using standard mechanical excavation equipment. To minimize the risk from UXOs, we planned to use explosives to excavate the drainage ditch connecting Pond 293 with the nearby gully. This would be similar to the method used last year for the Bread Truck Pond ditch excavation (Collins et al. 1997). The mission to explosively excavate the ditch was again presented to the 23rd Engineer Co., Ft. Richardson as a training opportunity. The operation was planned and coordinated by CRREL, with personnel of the 23rd Engineer Company to carry out the task as a training mission.

We reviewed the results of last spring's operation and adjusted our plans accordingly. One of the lessons we learned from that operation was that the spacing we used (5 m) was slightly too long, resulting in a couple of craters not overlapping. This produced narrow berms or barriers across the newly excavated ditch that did not allow flow out of the ditch until a flooding tide later in the spring eroded out the berm. The other lesson was that the cratering charges were not fully tamped despite the holes being filled with water, resulting in part of the explosive force going upward instead of being used to most effectively excavate material. This resulted in several craters not being excavated to the expected diameter, again resulting in several narrow berms or barrier across the newly excavated ditch.

The basic procedure used last year would again be used to carry out the excavation on Racine Island. As outlined in the guidelines given in the Engineer Field Manual and the Explosives and Demolitions Field Manual (US Army 1987, 1992), a series of 40-lb cratering charges set off in a line, producing a series of overlapping craters, is the optimum method for excavating a ditch. To produce the optimum size of crater for the amount of explosives, the cratering charge needs to be placed at depth in a 30-cm-diameter borehole in the ground. The cratering charges are then placed in the boreholes and detonated, producing the final crater. Because of the possibility of encountering UXOs in ERF, the boreholes needed for the cratering charges are explosively excavated using standoff shaped-charge explosives.

A review of literature on the use of explosives to excavate craters in frozen ground gave some information on the expected size of craters from a given size of charge. The guidance given in FM5-34 and FM5-250 on spacing of cratering charges is very conservative, resulting in placing of charges close together and multiple overlapping craters. For normal soils, 40-lb cratering charges placed every 5 ft (1.5 m) along the centerline of the ditch at 4-ft (1.2-m) depths would result in a ditch 20 ft (6 m) wide and 6 ft (1.8 m) deep. We wanted to increase this spacing to as large as practical yet still produce overlapping craters that would form a continuous ditch. Increasing the spacing would allow us to use as small an amount of explosives as possible. This was required due to limitations on the size of explosions allowed on the range.

Several authors have looked at the effects of explosions in ice and snow (Livingston 1960, Mellor 1965), in frozen ground (Livingston 1956,1959, Mellor and Sellmann 1970), and in and under floating ice sheets (Mellor 1982, 1986a, 1986b). The traditional analysis for determining the apparent scaled radius (R_a) and scaled depth (D_a) of craters formed by explosions uses cube-root scaling to remove the effect of charge size (all linear dimensions are divided by the cube root of charge mass), allowing comparisons of craters formed by various sizes of explosive charges. For explosions at the optimum charge depth, the predictions in Table III-3-1 can be made for the size of craters formed in moist clayey soil, frozen silt, and ice using the

Table III-3-1. Predicted apparent scaled radius at optimum charge depth.

	Moist clayey soil[1]	*Frozen silt*[1]	*Ice*[2]
R_a	0.9 $m/kg^{1/3}$	0.9–1.1 $m/kg^{1/3}$	0.71 $m/kg^{1/3}$
Opt. Depth	0.5 $m/kg^{1/3}$	0.7–0.8 $m/kg^{1/3}$	—

Radius and depths of craters in m.

[1] Mellor (1989)

[2] Mellor (1986a)

equations presented in Mellor (1986a, 1989).

The 40-lb cratering charge is a water-tight, cylindrical metal container with approximately 13.6 kg (30 lb) of ammonium-nitrate-base explosive and 4.5 kg (9.9 lb) of TNT explosive booster (US Army 1992) for a total of 18.1 kg of explosives. According to the equations in Table III-3-1, a single cratering charge placed at the optimum charge depth of 1.3 m in moist clayey soil should produce a crater with an apparent radius of 2.4 m, or an apparent diameter of 4.8 m. In frozen silt the same charge placed at the optimum charge depth of 1.85 m should produce a crater with an apparent radius of 2.6 m, or an apparent diameter of 5.2 m. Based on these numbers and the experiences from last year, we placed our cratering charges at 3.5-m intervals along the planned line of the ditch.

We planned to use the larger 40-lb M3A1 Shaped Demolition Charge rather than the 15-lb M2A4 Shaped Demolition Charge to form the boreholes because studies (Smith 1982) have shown that the 15-lb shaped charge did not consistently give a wide enough diameter borehole in frozen sediment to enable placement of the 20-cm- (8-in-) diameter cratering charge. The M3A1 Shaped Charge contains a 0.05-kg (0.11-lb) booster of Composition A3 (91% RDX, 9% wax) and a 13.4-kg (29.5-lb) main charge of Composition B (60% RDX, 40% TNT) (US Army 1992). The bottom of the charge contains an inverted metal cone that channels the resulting explosion into a downwards focused plasma jet that will explosively excavate a borehole into the ground. Based on the planned spacing of charges and the planned length of ditch to be excavated, a list of required munitions was put together and a request submitted to the Ammunition Supply Point, Ft. Richardson (Table III-3-2).

Because of the time required to get approvals to carry out the demolition mission and to draw the required munitions from Army stores, we were not able to conduct the mission in late March as we originally envisioned. By the time we received all the required approvals in April, spring thaw was well underway in ERF. The snow cover within ERF was mostly gone, as was the ice in the ponds. Pond 293 was free of ice. The ground surface of the sedge meadow was thawed to at least 20 cm.

On 21 April the area of the planned ditch was inspected and cleared by two UXO technicians (Sherry Butters and Arlan Pierce) from Explosive Disposal Engineering and Technology (EDET), the UXO contractor. The ground was visually inspected and also swept with magnetometers by the UXO technicians. Any positive anomalies were inspected and identified. All positive anomalies proved to be expended ordnance. No UXOs were found during the sweep. A right-of-way for the ditch, 5 m either side of the centerline, was marked and cleared. Along the centerline of the ditch, the planned location for each of the charges was marked every 3.5 m. Two additional charge locations were marked at either end

Table III-3-2. Demolition munitions requested.

Type	*Quantity*
M3A1 40-lb shaped demolition charge	40 each
M7 nonelectric blasting caps	60 each
Detonating cord	4000 ft
M700 time fuse	400 ft
40-lb cratering charges	40 each
C4, 1.25 lb blocks	100 each
M60 fuse igniter	20 each

to ensure that either end of the ditch was opened up by the explosives. The southern endpoint of the ditch was at the edge of the gully system south of the pond. The northern endpoint would be within the pond 120 m away. A large helicopter landing zone, capable of handling two UH-1H helicopters simultaneously, was marked out and cleared to the west of the ditch centerline.

The gravel pit to the southwest of ERF, off Otter Lake Road, was used as the staging area and base of operations for the mission on 22 April 1997. The munitions were drawn from the Ammo Supply on the morning of the 22nd by the 23rd Eng. Co. and brought to the staging area. The munitions were unpacked, sorted, and prepared by the soldiers of the 23 Eng. Co. Two UH-1H helicopters of the Alaska Army National Guard were used to ferry the soldiers and the munitions out to the demolition site, 1800 m to the northeast. A list of the personnel involved in this operation is given in Table III-3-3.

The ditch was excavated in three blasting operations, the first two to blast the boreholes and the third to excavate the ditch. Because of the required length of the planned ditch and the amount of required explosives, there was concern that if all forty shaped charges were set off at once there would be excessive noise created that would affect areas off the military reservation. Since the shaped charges are placed above the ground surface, they create a very loud sharp noise and a considerable shock wave when they are exploded. Because of this concern the blasting of the boreholes was done in two stages, using twenty 40-lb shaped charges each time. Nominal 1- by 3-in. wooden boards were duct-taped to the shaped charges, forming a stand to hold the shaped charge 2 ft above the surface with the charge pointing downward. The charges were spaced at the previously marked locations every 3.5 m along the centerline of the planned ditch (Fig. III-3-3), with the boreholes for the south half of the planned ditch being

Table III-3-3. Personnel involved in carrying out the demolition mission on 21-22 April 1997 and in the later documentation and instrumentation of the site.

Officer-In-Charge (OIC)
  MAJ Michael Meeks, CRREL

Surveying, Photography, Initial Planning, and Project Coordination
  Charles M. Collins, CRREL

Demolition Team, 23rd Eng. Co.
  2LT Troy Creason
  SSG Carl O. Wilson
  SGT Peter Wilson
  SGT Richard Niemritz
  SGT Ismael Barnes
  SGT Terrence Goens
  SGT Ramon Castro
  SGT David Martel
  SPC Thoris Rutledge
  SPC Joseph Poydack
  SPC Timothy Piercy
  SPC Deron Trumbette
  SPC Sharpherfy Davis
  SPC Ryan Thompson
  SPC Jimmie Roberson
  SPC James Wilson
  PFC Tymon Konieska
  PFC Sylvester Clark
  PFC Thomas Arce
  PFC Michael Flory
  PV2 Albert Jones
  PV2 Rondell Hilliard
  PV2 James Byrd
  PV2 Eugene Abramshe
  PV2 Jeffrey Green
  PVT JoshuaAlexander
  PVT Leonel Medina

EDET UXO Technicians
  Ms Sherry Butters
  Mr. Arlan Pierce

Project Support and Coordination
  Mr. William Gossweiler, DPW
  Ms. Laurie Angell, DPW
  Mr. Bill Smith, DPW

Later Instrumentation, Surveying , and Documentation of Results
  Charles M. Collins
  Ron Bailey, CRREL
  Marianne E. Walsh, CRREL
  Dennis Lambert, CRREL

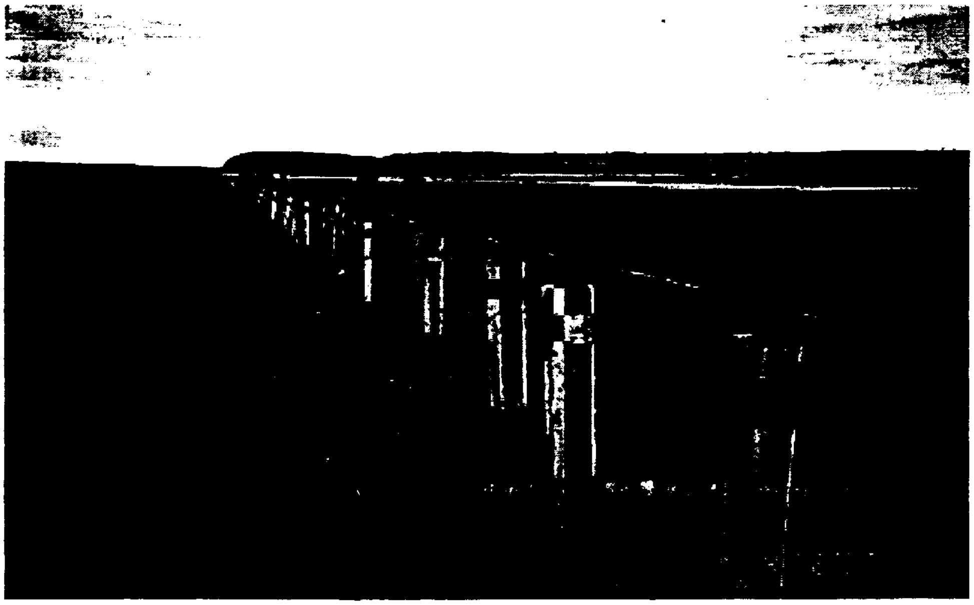

Figure III-3-3. Shape charge munitions being set up along the centerline of the planned ditch by soldiers of the 23rd Engineer Company.

excavated in the first blast and the boreholes for the north half of the planned ditch being excavated in the second blast.

Each of the first two blasts was conducted similarly. A blasting cap and a block of C4 explosive were molded into the top of each of the shaped charge. Detonation cord was cut into 12-ft branch lines and tied with a Uli knot to the detonation cord line main and then attached to the block of C4 on top of the shaped charge. The line main detonation cord connected all 20 shaped charges together. The dual detonating firing system consisted of two time-blasting fuse igniters, two lengths of time-blasting fuse cut to seven-minute lengths, and two non-electric blasting caps. Once all branch lines were secured to the line main, all but three personnel departed the area via helicopter. The fuse igniters were pulled, and the remaining personnel boarded the waiting helicopter and departed the area. The helicopter stayed airborne, outside the safety zone, until after the blast.

When detonated, the shaped charge produced a plasma jet that punched a 30-cm-diameter hole straight down into the ground. The total amount of explosives detonated in this first explosion was approximately 320 kg (700 lb). After the blast the helicopter returned to the area, landing away from the explosive blast area. The UXO technicians then again inspected the area for any possible newly exposed UXOs. The procedure was repeated for the second series of 20 shaped charges along the northern half of the planned ditch centerline.

The inspection of the area following the second blast revealed that there were two shaped charges that did not detonate. These duds were located near the north end of the ditch. The C4 charges at the top of the shaped charges went off, but the shaped charges themselves failed to detonate. The lack of a borehole at this location was a concern in that we may not end up with craters completely overlapping in this section of the ditch, as had occurred last year. All the other shaped charges worked as expected. The boreholes were all 0.3–0.45 m in diameter and at least 1.8 m deep (Fig. III-3-4). Once the UXO technicians had cleared the area, the rest of the personnel were ferried in by helicopter, and

Figure III-3-4. Borehole formed by 40-lb shaped charge.

the set up for the cratering charges began.

In each of the 38 bore holes created by the shaped charges, the soldiers placed a 40-lb cratering charge with attached block of C-4 (Fig. III-3-5). The charges were wired together in a similar matter to the shaped charges. Each of the cratering charges was tamped or stemmed with four to five sandbags. The two extra cratering charges (due to the two missing boreholes) were laid on the ground at the appropriate locations and sandbags piled on top. All of the cratering charges were con-

Figure III-3-5. Soldier placing a 40-lb cratering charge with attached block of C-4 into a previously blasted borehole.

Table III-3-4. Instrumented site characteristics and sampling summary.

	Pond 293, Racine Island
Location, east	355,548.89
north	6,800,247.92
Elevation	4.38m
Type site	Permanently flooded pond
Water surface level	Continuously
Air temperature	Continuously
Sediment temperature	Continuously at 5 and 10 cm depths
Sediment moisture	Continuously at 5 and 10 cm depths

nected similarly to the shaped charges. The total amount of explosives detonated in this explosion was approximately 750 kg (1650 lb).

Instrumentation

We installed one instrumented site in the Pond 293 on 16 May to monitor the environmental conditions in the pond bottom sediments. The site was within the narrow western limb of the pond at a pond bottom elevation of 4.38 m. UTM coordinates and a data sampling summary for the site are given in Table III-3-4. Prior to any activity occurring at a site, access paths and the area around the site were checked for UXOs by the UXO contractor.

The site was instrumented using an electronic datalogger to monitor sediment moisture levels, sediment temperatures, air temperature, and pond water levels on a continuous basis. The datalogger used was a Model CR10 datalogger system manufactured by Campbell Scientific, Inc. (CSI), PO Box 551, Logan Utah 84321. This system consists of the CR10 measurement and control module, the CR10 wiring panel, the PS12 12-V power supply and charging regulator, and the SM716 storage module. All of the components are housed in a weather-resistant fiberglass-reinforced polyester enclosure that is attached to the central mast of a galvanized steel tripod, consisting of three adjustable legs and a central mast with a total height of 3 m (Fig. III-3-6).

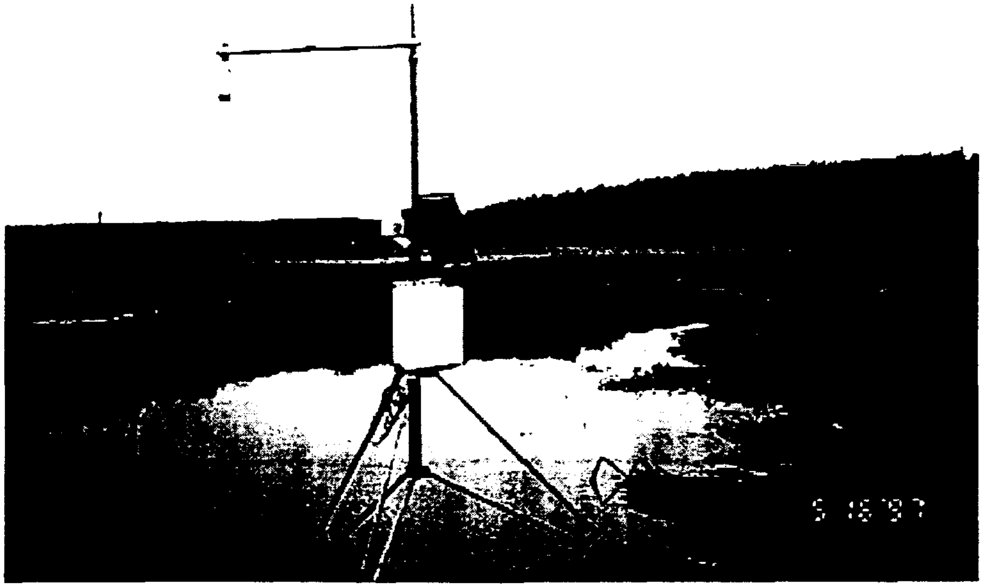

Figure III-3-6. Campbell CR10 datalogger mounted on 3-m-tall tripod. A sensor for determining water surface elevation is mounted on the bracket arm extending from the mast above the datalogger.

Measurement of pond water level

Pond water levels were measured using a CSI SR50 sonic ranging sensor. The sensor was attached to the end of a bracket arm that was in turn attached to the center mast of the tripod. The sensor was suspended on the bracket arm approximately 2.5 m above the water surface (Fig. III-3-5). The sensor measures the distance from the bottom of the sensor to a surface by bouncing an ultrasonic pulse off the surface, listening for the return echo. The distance to the surface is determined from the time from transmit to the return of the echo. The speed of sound in air depends on the air temperature, so air temperature is also measured by the datalogger at the same time. The signal from the depth gauge sensor is processed by the datalogger, corrected for the air temperature, and stored. Readings were taken by the datalogger every ten minutes and averaged every hour. The accuracy of the depth gauge sensor for the setup we used is ±0.5 cm. The elevation of the bottom of the depth gauge sensor was established by surveying from the Racine Island BM. Water surface elevations were then determined by subtracting the measured distance from the water surface to the sensor bottom from the surveyed elevation of the sensor bottom.

Measurement of temperature and sediment moisture

Air temperature was measured using a CSI Model 107 air temperature thermistor probe inside a six-plate gill radiation shield mounted on the center mast of the 3-m tripod. A measurement was taken every ten minutes and averaged every hour. Sediment temperatures were measured using CSI Model 107B soil/water thermistor probes that use the Fenwal Electronics UUT51J1 thermistor probe, which has an accuracy of <±0.2°C over the range of 0°C to +60°C. Soil temperature probes were placed at 5- and 10-cm depths within the pond bottom sediment. Measurements on each of the two sensors were taken every ten minutes and averaged every hour.

In-situ sediment moisture conditions were monitored using CSI Model 257 (Watermark 200) soil moisture probes, which estimate soil water potential in the range of 0–2 bar. The output from the sensors is the ratio of the excitation voltage to the signal voltage, from which resistance is calculated. Resistance is functionally related to soil water potential. A sensor in saturated sediment will give a resistance near zero, and as sediment dries, resistance increases. These sensors have internal gypsum tablets that reduce the error associated with changing salinity (Campbell Scientific 1994). The soil moisture probes were placed at depths of 5 and 10 cm within the sediment. Measurements were taken every ten minutes and averaged every hour.

Because of an error in hooking up soil temperature and moisture instrumentation to the datalogger, no data were collected for these parameters prior to 11 June. Air temperature and water surface elevations, on the other hand, were collected continuously from 13 May.

Surveying

We surveyed the instrument location in Pond 293 in May to determine the horizontal coordinates and the elevation of the site. We also surveyed the perimeter of the drainage ditch in May. Surveying was done using a Leitz SET4C electronic total station and a triple reflective prism mounted on a 1.45-m-tall prism rod. One person ran the total station while another person occupied each site to be surveyed with the prism rod. We established a new benchmark (Racine Is-97 BM) near the southern edge of Racine Island, just west of the south end of the drainage ditch. The benchmark was shot in from Crane BM, located on the edge of the EOD pad. Universal Transverse Mercator (UTM) horizontal coordinates and the elevation were then calculated for the new benchmark.

To conduct these surveys the electronic total station was set up over the BM and the instrument back sighted to the reference azimuth mark. For Racine Is-97 BM this was Crane BM. The person carrying the prism rod moved to each location to be surveyed and placed the prism rod on the ground at each site. For pond bottom measurements where there was a soft bottom, the tip of the prism rod was placed on a flat metal plate, which was in turn placed on the pond bottom surface. This provided a uniform bearing surface for the rod tip, keeping it from sinking into the soft surface. The triple prism was sighted with the total station, and the horizontal angle and distance and the vertical distance from the total station to the triple prism were then measured and recorded. Based on the horizontal angle and distance from the control point, the vertical distance between the total station and the triple prism, the height of the total station above the control point, and the height of the prism above the survey point, a set of UTM horizontal coordinates and an elevation for each survey point were then later calculated.

RESULTS

Explosive excavation of the drainage ditch

The explosion of all 40 of the cratering charges produced a large explosion (750 kg of explosives) that threw material several hundred meters into the air (Fig. III-3-7). The explosion formed a nearly straight 120-m-long ditch, 2 m deep and 4.7–5 m wide, leading from the pond to the gully (Fig. III-3-8). The problems we encountered last year with the BT Pond ditch (Collins et al. 1997) with various sizes of craters and with some craters not overlapping were completely avoided. The closer spacing of cratering charges and the tamping of the boreholes containing the cratering charges with a half dozen sandbags each produced a more constrained explosion and a more consistent excavation of ground material.

Where we were forced to place two cratering charges on the surface due to the two dud shaped charges, the resulting explosion excavated the ditch to nearly the same width and depth as the adjacent areas of the ditch formed by the emplaced cratering charges. Our spacings for the charges proved to be close enough so that the adjacent cratering charges in the boreholes plus the sandbagged cratering charges on the surface provided sufficient explosive force to fully excavate the ditch.

Immediately following the blast, water started flowing into the newly excavated ditch from Pond 293. The first crater at the north end of the ditch was 1.5 m deeper than the

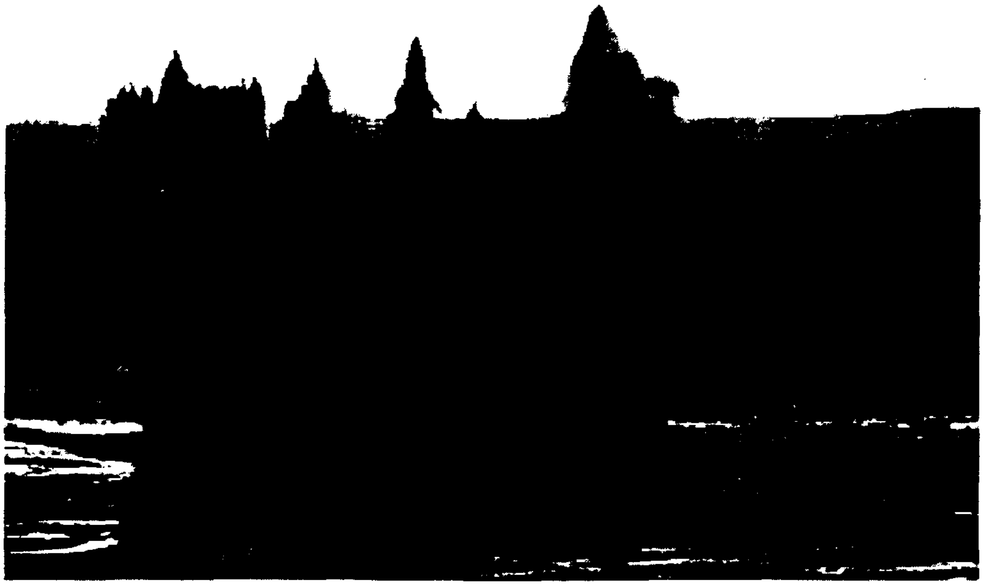

Figure III-3-7. Explosion of all forty 40-lb cratering charges.

Figure III-3-8. Aerial view of the newly excavated drainage ditch.

pond that it was located in, resulting in a cascade of water down into the crater (Fig. III-3-9). Water continued to flow into and fill the ditch for about 20 minutes. After the ditch filled with water, it began to erode the dirt berm thrown up around the last crater at the end of the ditch and flow out of the south end of ditch. Water flowed from the ditch into the ice-filled gully and hence into the river. Water continued to flow out of Pond 293 and

Figure III-3-9. Aerial view of water from the pond flowing into the newly excavated drainage ditch.

the surrounding sedge marsh for several weeks.

Data collection

Pond water surface levels

Water surface elevations were continuously recorded from 15 May within the western limb of Pond 293 by the installed datalogger. Water levels in the eastern limb of the pond were drained almost immediately by the ditch The pond bottom sediments, at an average elevation of about 4.25 m, were almost entirely exposed (Fig. III-3-10). Minor amounts of water continued to drain out of the surrounding sedge marsh into and through the eastern limb of the pond for several weeks. Water levels in the smaller western limb of the pond also dropped but initially remained much higher than in the eastern limb due to a natural constriction blocking unimpeded flow between the western limb and the head of the drainage ditch (Fig. III-3-11). A plot of the water surface elevation record (Fig. III-3-12) shows the initial drop in water level from 4.79 m at the time of the blasting of the ditch to 4.58 m when the datalogger was started. This marks the overall draining of the pond basin down to the elevation level where the constriction starts impeding flow from the western limb of the pond. The water level in the pond continued to drop as the narrow channel through the constriction eroded deeper. The water levels eventually dropped down to an elevation of 4.35 m. At that point the western limb of the pond was essentially empty except for standing water in low spots. The water surface elevation record also shows the periodic inundations by flooding tides that occurred throughout the summer. The first series of five flooding tide peaks started on the 4th of June. The record shows a rapid rise in water levels with each of the flooding tides and similarly rapid drop as water flowed back out the drainage ditch on the ebb tide. Five additional sets of flooding tides occurred in late June, early July, late July, late August, and early September. Based on the maximum recorded heights, the two sets of flooding tides in late June and early July probably would not have flooded into the pond without the presence of the drainage ditch. The threshold elevation of the lip of the ditch is now at the same elevation as the bottom of the pond in the east-

Figure III-3-10. Looking east at the exposed pond bottom in Pond 293.

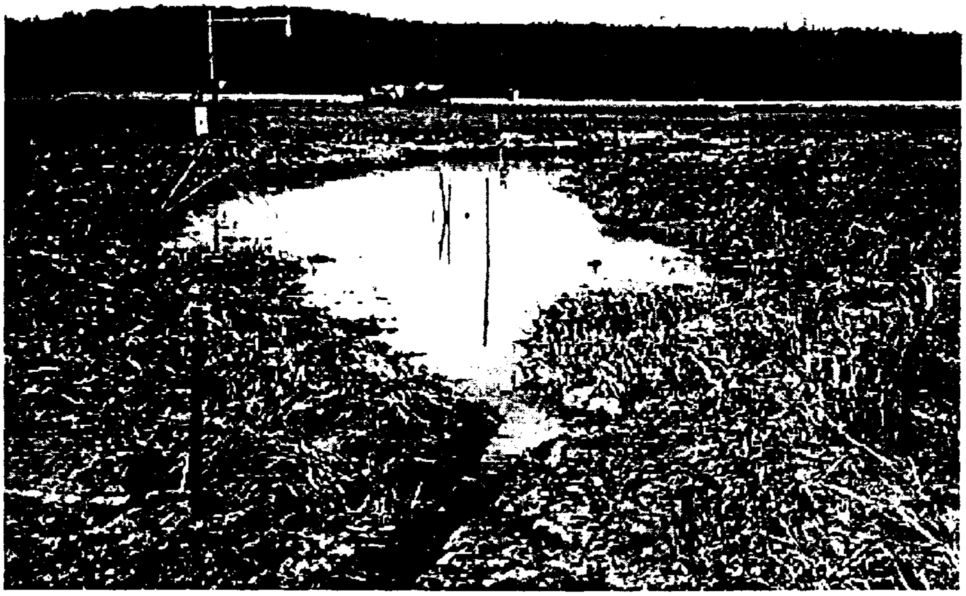

Figure III-3-11. Constriction blocking unimpeded flow from the western limb of Pond 293 and the head of the drainage ditch.

ern limb—4.22 m. There is a tradeoff with a lower threshold leading into the pond basin. Lower high tides that were previously excluded by the original higher threshold will now flow into the pond basin. Water from these lower high tides will almost immediately flow out of the pond basin again through the drainage ditch, but the exposed pond bottom sediments will be periodically rewetted, slowing the process of natural attenuation of

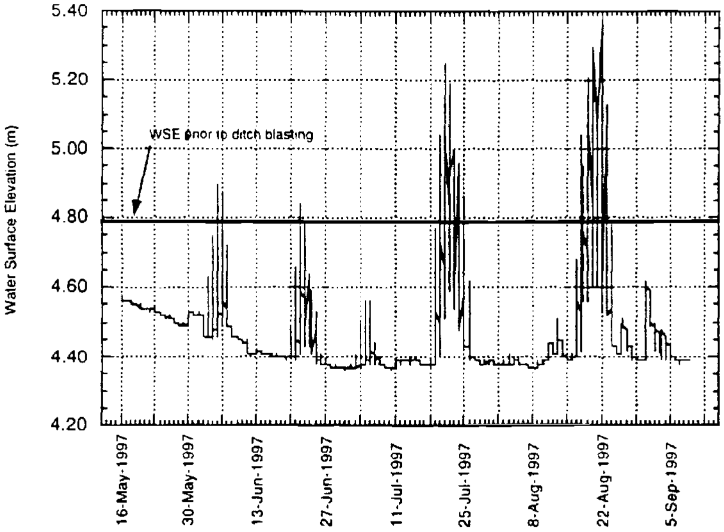

Figure III-3-12. Water surface elevation plot for the western limb of Pond 293.

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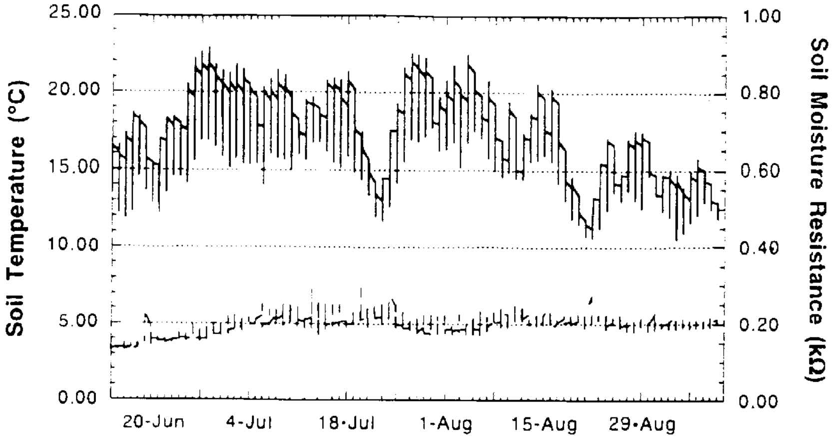

Figure III-3-13. Soil temperature and soil moisture resistance for the 5-cm depth in the pond bottom sediment in Pond 293.

WP contamination that occurs when the sediments dry below saturation.

Sediment temperature and moisture conditions

The sediment at the instrumented site, at an elevation of 4.38 m, was saturated throughout the summer. The sediment moisture probe at the 5-cm level did not change significantly throughout the summer (Fig. III-3-13). Even after water levels had dropped enough by early July to exposed most of the pond bottom sediment in this area, the site was inundated by repeated flooding high tides such that the sediments remained saturated. If the period between flooding tides in June and July had been longer, the drying of sediment may have been significant and materially affected the sublimation rate of WP contamination. During the summer of 1998 the periods between flooding tides are predicted to be much longer, holding forth the possibility of some natural intrinsic remediation within Pond 293. More detailed monitoring is planned in 1998, along the lines of the monitoring carried out in 1997 in Ponds 143 and 109 (Walsh et al., this volume), to verify rates of natural intrinsic remediation.

The minimum, maximum, and mean sediment temperatures measured for the site in Pond 293 are summarized in Table III-3-5. Maximum measured hourly sediment temperature at the 5-cm level was 22.87°C with a mean temperature of 16.22°C. Sediment temperatures at the 5-cm level reached levels that were warm enough to have allowed significant sublimation rates of WP if soil moisture conditions had been conducive.

Organic content and drying potential

Previous sampling and analysis of sediment from Pond 293 (Bouwkamp 1994, 1995) indicate that the total organic content of the sediment ranges from 4.1 to 6% by dry weight. Soils with an organic material content between 2 and 4% are considered to have moderate organic content. Soils containing greater than 4% organic material content are considered to have a high organic material content (Soil Conservation Service 1971). The range of organic content of the sediment is similar to other areas of Eagle River Flats, such as Pond 183 (4.7–8.0%) and Pond 109 (2.0–6.9%) (Bouwkamp 1994, 1995, Collins et al. 1997),

Table III-3-5. Maximum, minimum, and average air temperatures and soil temperatures (hourly) at the 5-cm depths for the instrumented site in Pond 293.

	Air temp. 5/13-9/9	*Soil temp. 5 cm* 6/12-9/9
Maximum temp. (°C)	28.17	22.87
Minimum temp. (°C)	–0.08	10.58
Average temp. (°C)	14.21	16.22

where sediment drying appears to be a viable method of natural intrinsic remediation of white phosphorus contamination.

CONCLUSIONS AND RECOMMENDATIONS

The explosively excavated drainage ditch was successful in almost immediately draining most of Pond 293 and the surrounding sedge marsh. The smaller western limb drained more slowly than the rest of the pond because of a constriction between it and the head of the drainage ditch. Over the summer as a channel eroded through the constriction, the western limb also drained, with the pond bottom sediments being exposed by early July. Periodic reflooding by tides prevented the pond bottom sediments from drying out to any significant degree.

The spacing of 3.5 m we used for this mission proved to be effective in completely excavating the drainage ditch. We also used five to six sandbags on top of each cratering charge to make sure that the charge was fully tamped. The combination of closer spacing and fully tamped charges provided a much more effective explosive excavation of the ditch than we achieved during the 1996 operation to excavate a ditch into Bread Truck Pond.

Ditches longer than the one excavated for Pond 293 will require proportionally more explosives for the excavation. We conducted two separate blasts using shaped charges to form the boreholes and one blast for the cratering charges operation. Because of the concerns about noise affecting the surrounding communities, any future explosive excavation requiring similar or larger amounts of explosives will also have to be carried out in multiple stages to keep the explosions at or under the level that we used for this operation. Thus a longer ditch may require two or more separate blasts for both the shaped charges and the cratering charges. Having multiple blasts will complicate the logistics and safety issues for the operation but should not preclude being able to carry out such a mission.

The use of explosives to excavate the drainage ditch was a viable method that has application to other areas of ERF. The method was very cost effective compared to other, alternative ways to drain the pond, especially when military explosives were used in conjunction with military troops conducting a training mission. The troops of the 23rd Engineer Company were able to use their explosives training skills in a mission that was much larger than they would ever have a chance to participate in during normal peacetime training. It was also a real-world mission solving an environmental problem. Both of these opportunities were greatly appreciated by the soldiers. The training opportunity provided by the large-scale use of military explosive munitions nearly guarantees that military troops will be available to carry out such operations in the future as a training mission at little cost to the project.

The future use of explosively excavated drainage ditches to permanently drain isolated WP-contaminated ponds in ERF must be evaluated carefully. The selection of specific sites for treatment will mainly depend on the nearness to a drainage gully of the river. It will also depend on other factors, such as the value of the targeted pond as waterfowl habitat and whether the removal of the pond as a potential source of white phosphorus poisoning outweighs the loss of the pond as waterfowl habitat. Reversing the process by blocking or filling the drainage ditch will be difficult, considering the soil conditions and the limitations placed on the use of heavy equipment by the presence of UXOs. All these factors would have to be carefully weighed before proceeding with additional permanent pond draining.

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III-4. IMPLEMENTATION OF A REMOTE PUMPING SYSTEM FOR WHITE PHOSPHORUS REMEDIATION IN POND 183

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INTRODUCTION

The use of Eagle River Flats on Ft. Richardson, Alaska, as an impact area has resulted in the contamination of large areas with the smoke munition component white phosphorus (WP). White phosphorus is a manufactured form of elemental phosphorus that does not naturally occur in the environment. It is unstable at moderate temperatures and will sublimate and oxidize if exposed to the atmosphere. It will auto-ignite if exposed to air at temperatures above approximately 30°C. However, it is quite stable if stored under water.

At Eagle River Flats (Fig. III-4-1), permanently ponded areas have been shown to be ideal locations for deposition of WP particles that have not oxidized during the detonation of WP munitions. These particles, found on or in the saturated, cool sediments of these ponds, have persisted since the cessation of firing of WP into the Flats in 1989. Models indicate that, under conditions found in these ponds at the Flats, these particles may persist for many decades (Walsh 1993, Walsh et al. 1995).

Eagle River Flats (ERF) is an important waterfowl staging area in the upper Cook Inlet region. During spring and fall migrations, thousands of birds pass through the Flats, many feeding in the area's shallow ponds. The sediments that make up the upper layers of Eagle River Flats are composed primarily of fine glacial silts and clays. The seeds and other food items that dabbling ducks and swans prefer are easily sieved from these fine sediments but, unfortunately, so are residual white phosphorus particles (Racine et al. 1992).

The ingestion of residual white phosphorus particles is deadly to waterfowl. Over the years of the ERF investigations, thousands of birds have been found dead or observed dying from WP poisoning. Food chain repercussions have also been observed, with the presence of many predators and scavengers threatening to involve other species. In 1994, after several years of studying the problem and its ramifications, feasibility studies were initiated to determine the most effective methods for remediating the problem (Racine and Cate 1994, 1995, 1996; Collins and Cate 1997).

REMEDIATION OPTIONS

Studies conducted as part of the Eagle River Flats investigation have determined that if white phosphorus is exposed to air at temperatures above 15°C, sublimation will occur and the contaminant will attenuate. Atmospheric exposure need not be direct, as in the removal of the contaminant from the environment. If the sediment can be desaturated such that pores within the matrix will allow exposure of the particles to the atmosphere, attenuation can occur. The higher the sediment temperature, the more efficient this process will be. Thus, if sediments can be desaturated during the relatively warm summer months at ERF, contaminated areas can be remediated in situ.

Because of the interconnectedness of the ponds within the Flats and the occurrence of flooding tides throughout the summer season,

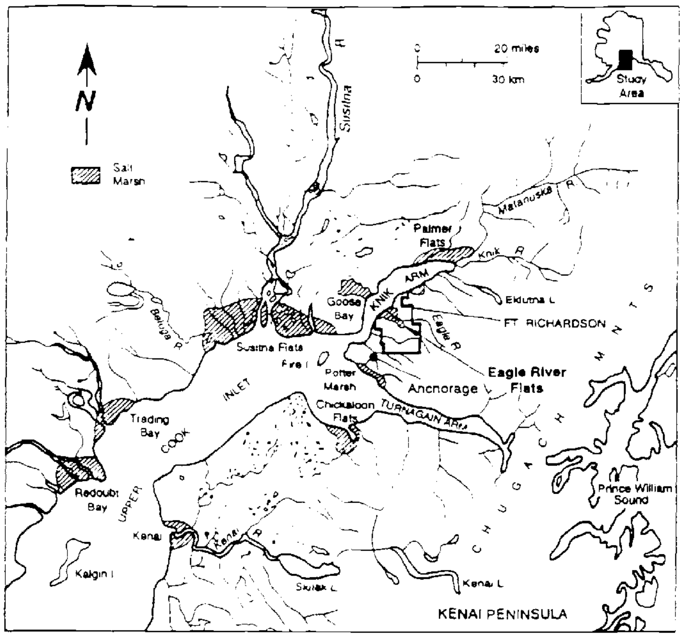


Figure III-4-1. Location of Eagle River Flats.

pond drainage as a method of remediation was not originally considered feasible. Other methods were considered for reducing or eliminating the contaminant exposure to the waterfowl. These methodologies followed three distinct strategies: removal of the contaminant from the environment, breaking the contaminant uptake pathway using physical or chemical barriers, and denying contaminant access to waterfowl through hazing. All three strategies were tried at the Flats as part of the feasibility study from 1994 to 1996, with varying results.

Removal of the contaminant was accomplished by dredging contaminated ponds (Walsh, M.R. 1996, Walsh, M.R., et al. 1996, Walsh and Collins 1997). This method, although effective, is extremely expensive and slow and has been shown to subject workers to a higher-than-expected exposure to unexploded ordnance (UXOs). A remotely controlled dredge system was deployed in the years 1994–1996 in Pond 146 adjacent to Clunie and Canoe Points. An area of approximately 0.5 ha was dredged to a minimum depth of 43 cm, and the spoils were transported to a retention basin on the EOD Pad for treatment. Attenuation studies of the basin sediments indicate that natural attenuation of the contaminant occurred over the course of a year, with complete attenuation of planted particles (Walsh and Collins 1997, Walsh, M.E., this volume). The areas dredged, once among the deadliest on the Flats, are now safe for waterfowl, and no dead birds have been found in the area since 1995. However, the environment has been altered such that it is no longer useable for feeding by dabbling ducks.

Barrier technologies are effective in preventing access to the contaminant in the environment but do not address the underlying problem of contamination. Chemical barriers are expensive and not permanent because of the tidal fluctuations, biological degradation, and movement of surface sediments by ice plucking (Clark and Cummings 1994). Permanent barriers such as geotextiles are also subject to influence by ice, and problems have occurred with uplifting due to trapped gasses (Henry 1994, 1995). When they can be permanently anchored or designed specifically for this environment, however, they can be effective. Sediment accumulation will bury the fabric after a few years, and its presence is nonintrusive.

Any capping material, such as gravel or a gravel–bentonite material, is also subject to erosion and degradation due to tidal and ice action. To prevent this and to assure sufficient coverage during application, a thick (15- to 30- cm) layer must be applied, thus altering the environment. Vegetation quickly reclaims most of the surface areas where a capping material is applied, but the use of the area may be permanently altered (Pochop et al. 1995, 1996). All three strategies also pose a degree of risk because the workers involved are exposed to UXOs.

Waterfowl hazing has been an effective interim method for disrupting the contaminant pathway in the Flats. Stricter adherence to safety measures in 1996, however, greatly limited the ability of the hazers to accomplish this mission. The use of automated hazing systems, such as propane cannons and flashers, as well as effigies, has only a limited influence on birds and is not as effective as human intervention. Thus, the use of hazing as a remediation method, transitory to begin with, has become less effective with decreased implementability.

In 1995, specifications were developed for a remote pump system to be deployed in the Bread Truck Pond (Pond 109) for a treatability study to determine if pond pumping was feasible. The pump system was ordered but not received in time to deploy in the field that season. In 1996, because of limited funding and continuing uncertainty over the feasibility of pumping, the treatability study was not undertaken. Instead the decision was made to concentrate the limited funds on blasting a ditch to "extend" the closest drainage channel into Pond 109. The use of the remote pump system was put on hold.

In April 1996 a ditch was successfully created between Pond 109 and its closest drainage gully using military explosives (Collins et al. 1997). This resulted in the drainage of the majority of the pond, removing it from dabbling waterfowl feeding habitat. The immediate result was a virtual cessation of deaths in this area, which was one of the worst areas for waterfowl mortality at the Flats. However, it also lowered the flooding threshold level for the pond, resulting in more frequent, almost periodic flooding. The increased flooding results in more frequent wetting of the sediments and thus a reduction in the rate of attenuation of the contaminant as shown by tensiometer, soil moisture, water level, and sampling data. Although reductions in contaminant levels are occurring, a definite improvement over the previous situation, the rate is slow (Walsh, M.E. et al., this volume). The other problem is the permanent alteration of the environment. By blasting a connecting ditch to the drainage gully, Pond 109 has ceased to exist. When the contaminant has attenuated to safe levels, the area will still not be useable by dabblers unless significant restoration occurs. This requires the construction of a permanent barrier structure in the blasted ditch. A strategy has been devised for this that minimizes both cost and exposure, but it will be experimental and there is no guarantee of success.

A second pond group, Ponds 293 and 297 on Racine Island, was drained by explosive excavation of a ditch in the spring of 1997 (Collins et al., this volume). A preliminary assessment of this action indicates that restoration will not be feasible because of both the size of the ditch and the pond's value as wildlife habitat. Additional ditching operations have been postponed pending the outcome of the pumping study. With a small amount of additional work in the spring of 1998, complete drainage of this pond system will be accomplished, removing this highly contaminated pond group from the Flats environment.

In 1997, funds became available for the feasibility study of pond pumping for remediation. The pump that was specified, ordered, and received in September 1995 was available for deployment. Originally planned for use in Pond 109, the decision was made to try to treat Pond 183 (C Pond) with this system. Pond 183 is not as isolated as Pond 109 and is much larger. It is also interconnected with a large number of adjacent ponds, including Pond 146, where dredging had been conducted, and Pond 155 (Lawson's Pond),

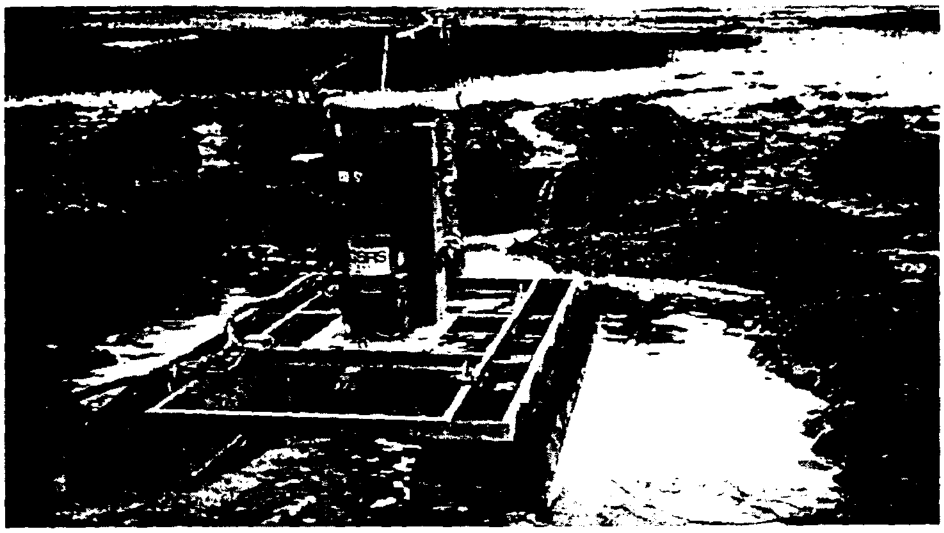


Figure III-4-2. Floating pump system.

another highly contaminated pond. Recharge from Clunie Creek and seeps along the shore of Ponds 146 and 40 were also thought to be problematic.

The plan was that, with the system deployed, at least a portion of the pond could be pumped out, allowing the exposed pond bottom sediment to dry enough to decontaminate. Any portion of the pond that could not be pumped out and dried would eventually be capped with a bentonite–gravel mixture. By treating the pond by pumping and drying vs. completely capping or permanently draining, enough of the pond habitat would be saved to make it a viable post-treatment subecosystem for dabbling ducks.

DESCRIPTION OF THE PUMP SYSTEM

Original calculations of the volume of water in a static Pond 109 indicated that a-7.56 m^3/min (2000 gpm) system is required to drain that area within two days, the target time set to assure sufficient drying time between monthly flooding tides for the exposed sediments to desaturate and significant sublimation of the WP to occur. Because of the possibility of detonation of an ingested UXO, the power source for the pump, a diesel powered genset, is to be located approximately 70 m from the pump. Both the pump and genset are mounted on floating platforms to compensate for rising waters during flooding tides. The pump was originally equipped with two reed switches that triggered pump start and shutoff sequences, depending on water level. The pump was to be placed in the lowest section of the pond, and it was assumed that the flow of water would create a small sump sufficient for the operation of the pump without cavitation. The system is designed to operate continuously for 48 hours without refueling.

The pump is a 15-cm (6-in.) discharge open-impeller centrifugal pump powered by a 45-kW (60-hp) three-phase 460 VAC electric motor. It is mounted on a 1.42-m-wide by 2.2-m-long frame, which in turn is mounted on top of two polyethylene segmented floats approximately 0.6 m in diameter (Fig. III-4-2). The original water level sensors were hinged magnetic reed switches mounted to a rod extending vertically from the frame towards the base of the pump. These switches could be individually adjusted to set trip points at various water levels. The switches were hard-wired into a waterproof (NEMA 4) junction box mounted to the pump platform frame. A single four-conductor instrumentation cord with waterproof military-

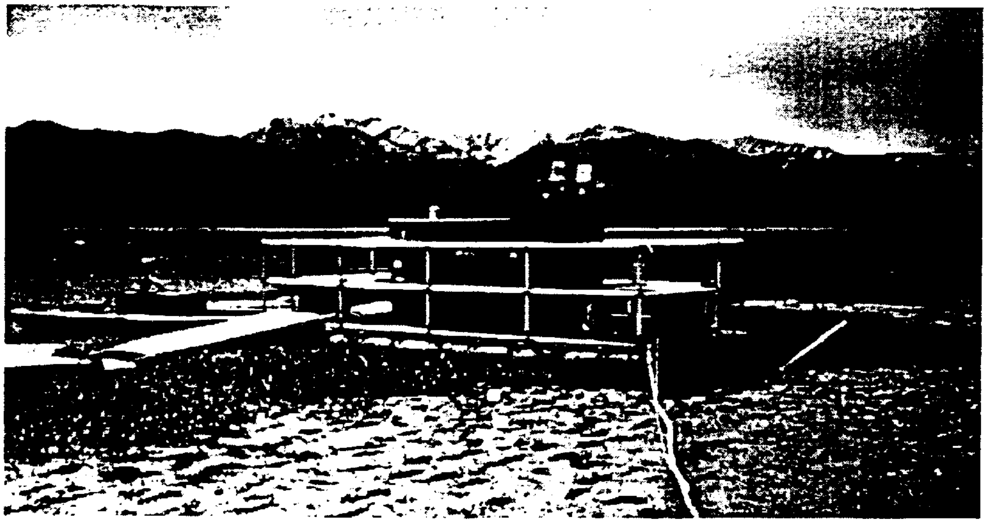


Figure III-4-3. Generator set module on the floating platform.

grade (mil) connectors linked the switches to the control circuitry on the genset.

The discharge line attaches to a 20-cm (8-in.) male nipple on the pump unit above the waterline. It consists of 20-cm-diameter SDR26 Schedule 40 polyethylene pipe in sections of 1.5-, 3-, and 6-m lengths and 20-cm-diameter rubber hose in 3- and 30-m lengths. Both types of discharge lines have galvanized steel quick disconnects with annular seals on either end. The total weight of a 6-m section of SDRC26 pipe is approximately 38 kg. The hose is about 20% heavier per unit length.

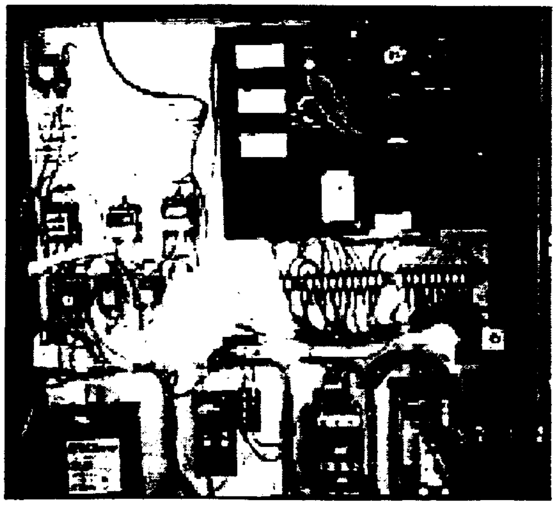


Figure III-4-4. Control panel on the genset showing automatic controls .

The generator set module, or genset, consists of an 80-kW (100-kVA) Onan generator, a control panel enclosed in a NEMA 3R enclosure, two 415-L fuel tanks, an expanded grate platform, and rails, all attached to a 2.4- × 6.6-m frame, mounted on 60-cm-diameter segmented floats running along all four sides (Fig. III-4-3). The genset is powered by a Cummins 100-kW six-cylinder diesel engine. Automatic controls on the control panel (Fig. III-4-4) include a start and stop delay potentiometer for control reset and engine cool-down cycles, automatic shutdown, and fault indicator lights for low oil pressure, high engine temperature, overspeed and overcrank, and low fuel. There are also gauges for voltage, amperage, output frequency, and engine speed. A meter is also provided for engine run time. A 70-m-long, 2-ga., four-conductor SO power cord carries power from the genset to the pump.

PRE-DEPLOYMENT TESTS AND MODIFICATIONS

Upon receipt of the equipment from the manufacturer in September 1995, some initial testing and run-in of the equipment was con-

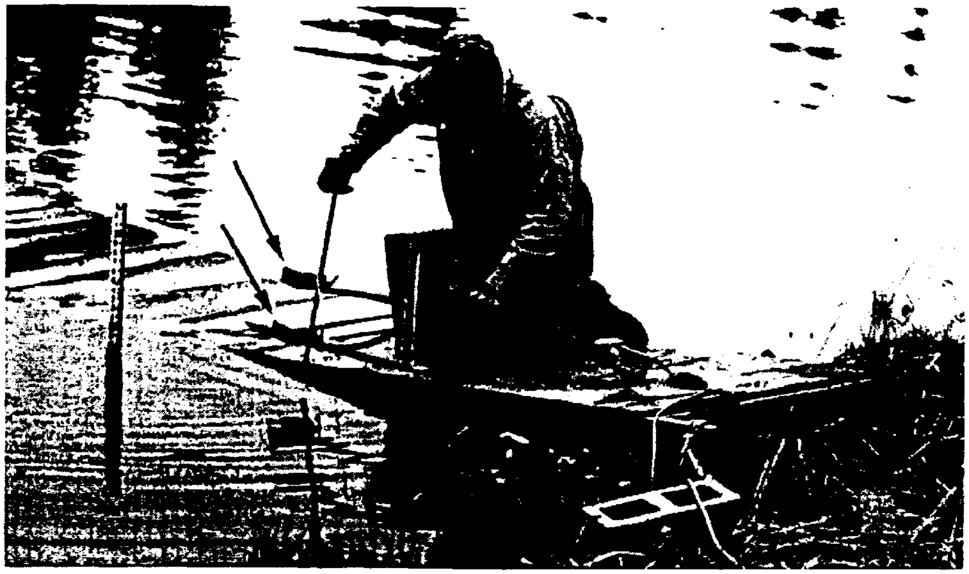


Figure III-4-5. Testing of the problematic original reed switches.

ducted. Following this work the equipment was placed in storage at Ft. Richardson until the spring of 1997. At that time the equipment was brought down to the Flats by DPW-Roads and Grounds personnel, and additional testing and run-in of the equipment was performed. Both in 1995 and in the spring of 1997 the pump system was set up for testing on Clunie Point. The pump was lifted into Clunie Creek by crane, and the genset was placed on the adjacent gravel pad. Some initial wiring problems were straightened out before testing could begin. In 1995 about 150 m of hose and pipe were run along Goose Road, and the water was pumped back into Pond 146 near the EOD Pad, while in 1997 the water was pumped back into Clunie Creek about 30 m from the pump. Most of the troubleshooting and testing were done in May 1997 because of the late arrival of the equipment in 1995.

Problems with the reed switches used to detect water levels were evident from the outset. These were tested by manually lifting and lowering them into the water and noting the reaction of the genset (Fig. III-4-5). The switches would consistently stick and not trigger. A light tap would loosen them enough to function. We remounted them on the pump, hoping that the vibration of the operating pump would help trigger them.

To assist in remotely monitoring the system operation, a strobe light was mounted to the top of the genset control cabinet. This strobe, which can be seen from several kilometers in daylight, indicates if the genset is operating. With the equipment now operational, the system was ready for deployment in Pond 183.

DEPLOYMENT PREPARATIONS

Two criteria were used to determine the placement of the pump system in Pond 183. The first was access to the deepest point in the pond. Pumping from the deepest point would help ensure water draining into the sump where the pump was located. The second criterion was proximity to the dredged channel between Ponds 146 and 183. This factor was driven by the need to try to economize by refueling the genset by water from Clunie Point rather than airlifting fuel with a UH-60 Blackhawk helicopter (approximately $2300/hr). This required that the genset be near enough to the end of the channel to allow fueling operations by a transfer skiff paddled from shore. We also hoped that we

Figure III-4-6. Blasting of the sump using two 40-lb cratering charges.

could paddle the genset out to its deployment location, thereby saving additional helicopter time.

The constraining factor on pump location was the length of the power cord between the genset and pump. The maximum distance between the two is 70 m. Using this figure, we determined the deepest point within that radius and marked it for pump placement. As this was not the deepest point in the pond, a sump would need to be created for the pond to drain into it. Fortunately we had discussed this possibility beforehand and had planned to create a sump with military explosives.

On 14 May, personnel form the 23rd Engineering Company, under the direction of MAJ Mike Meeks of CRREL, blasted an 8-m-diameter by 2.5-m-deep sump at the location marked for the pump placement. Two 18-kg shape charges were detonated to create 40-cm boreholes 4 m apart. Two 18-kg cratering charges, tamped with five 20-kg sandbags each, were then placed in the boreholes and set off (Fig. III-4-6), forming an 8-m-diameter crater. Inspection of the crater after the blast revealed that the rim of the crater had created a berm, preventing water from flowing into the sump and resulting in a dry hole (Fig. III-4-7). Two kilograms of C4 explosive were used to breach the rim, and several other breaches and channels were formed after the area was cleared, allowing free flow of pond water into the sump.

The 335-m length of the right-of-way for the discharge line to the nearest drainage gully and channel was marked and cleared by Arlan Pierce and Sherry Butters, two technicians from the UXO contractor, Explosive Ordnance Disposal Technology, Inc. (EDET). The approximate number of 6-m sections of 20-cm pipe needed for the discharge line were then airlifted in bundles to various points along this marked right-of-way using a UH1-H helicopter. The 30-m hose sections were then airlifted to either end of the right-of-way. The outlet for the discharge line was to be placed at least 15 m beyond the gully headwall to prevent accelerated erosion from occurring at the headwall.

Prior to airlifting the equipment into place, the power and instrumentation cable were evenly loaded onto the genset platform. A 3-m section of flexible hose was attached to the pump outlet to ease installation after placement in the sump. A datalogger station was assembled for installation near the pump to record water level and air temperature. The system was then ready for deployment.

Figure III-4-7. Crater after the blast.

SYSTEM DEPLOYMENT

On 15 May the pump and genset were airlifted into place using a UH-60 Blackhawk helicopter (Fig. III-4-8). Some difficulties were experienced during the genset airlift because of the short sling used, resulting in impaired visibility caused by rotor wash kicking up water from the surrounding ponded area. With the pump and generator in place, the equipment was connected via the power and instrumentation cords (Fig. III-4-9).

Assembling the pipe and hose was straightforward. The line was placed along the cleared right-of-way adjacent to the drainage slough that leads to the nearest drainage gully, designated B Gully. This was to reduce any impediments to post-flooding drainage

Figure III-4-8. Airlifting the genset into place using a UH-60 Blackhawk helicopter.

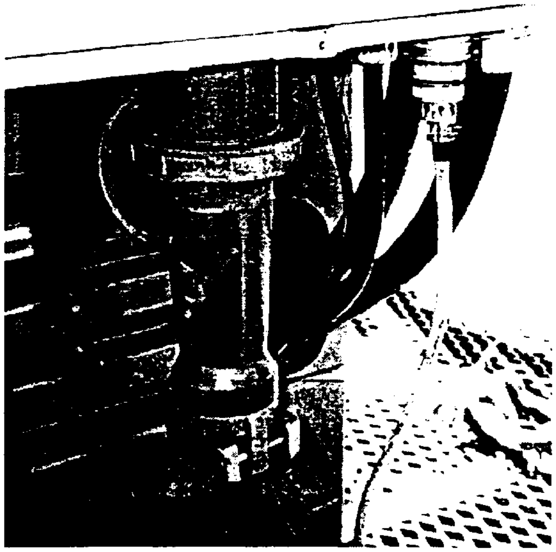


Figure III-4-9. Power and instrumentation cords connecting the pump with the genset.

of the ponds through the slough due to the discharge line. The outlet to the drainage line was located 15 m beyond the headwall at the gully edge. The line was connected to the pump using hose to ensure flexibility during starting, pump down, and stopping, when the pump moves about in the sump. Finally, sandbags were placed next to and on top of the pipe approximately every 30 m to prevent movement of the line during flooding events.

With all connections made, in-situ testing began on May 16. The system was fired up and pumping began at 1125 hr. Flow through the pipe (Fig. III-4-10) was less than originally specified but still significant. We estimated it at between 90 and 110 L/s; below the 125 L/s specified but, with twice the output line run of the original configuration, not unexpected. At 1700 hr the pond had been drawn down enough so that the water entering the sump was starting to flow in the ditches formed for drainage. At 2000 hr a member of the Hazing Team checked on the pump and reported that it was still operating smoothly.

On the morning of 17 May the pond had drained enough so that the water flow was completely restricted to the ditches, and the pump was slowly drawing down the sump. Shortly after we arrived, the pump drained the sump. Because of the failure of the water level switches to trigger, the pump continued running and had to be manually shut off from the genset controls. We allowed the sump to refill (approximately 3 minutes) and reactivated the system, which started immediately. Further ditch work to improve drainage allowed the pump to operate most of the day.

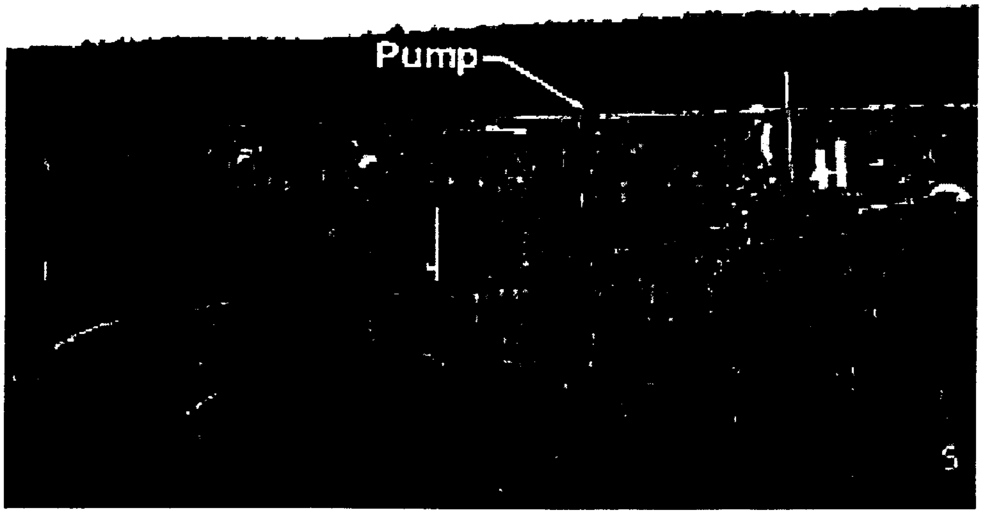


Figure III-4-10. Discharge into the gully from the 335-m-long hose and pipe system.

However, the switches remained problematic, and we were not able to operate the equipment overnight unmanned.

By the next morning Pond 183 had refilled substantially. We restarted the pump system around 0900 hr and had pumped the pond down by 1415 hr, much quicker than we thought possible. It was evident that recharge from groundwater sources was not going to be as much of a factor as originally thought and that the connection with Pond 146 was not as extensive as we expected.

On the 19th, drawdown of the sump first occurred at 1215 hr, an improvement over the previous day. It was obvious at this time that the switches and their associated circuitry would have to be changed. A plan of attack was developed, wherein the magnetic reed switches originally installed would be replaced with more robust float switches. A circuit was also installed that would cause a delay between the triggering of the upper float switch and the commencement of the genset startup cycle. This allows the sump to completely refill before pumping restarts, a problem when both switches are mounted on the pump. Finally, an additional strobe was installed to indicate that pumping was occurring.

A new float switch was installed, replacing the upper limit switch. Corrections were made to the wiring on the pump strobe light, and the system was successfully tested. At this time the lower limit switch, which was also not operating properly, stopped working altogether, and a circuit was developed to replace the normally closed reed switch with a normally open float switch. During this period we continued pumping Pond 183 down whenever the equipment could be made operational.

The following day the lower limit switch was replaced, and the associated circuitry was modified and tested successfully. Adjustments to the delay duration were made throughout the day to compensate for the lower flow into the sump. The system was allowed to operate unattended overnight. On the morning of 22 May, Pond 183 was essentially pumped out, with very little water flowing into the sump. Pools of water still existed at low points in the pond, but these would need to be dried by evaporation. There was some concern about the location of the lower float switch, and later it would have to be raised to keep it from contacting the soft mud into which the pump platform pontoons were sinking when the pump sucked the sump down. At this point the system was autonomously operational. Monitoring of the pump system was turned over to technicians from CH2M Hill.

SYSTEM IMPROVEMENTS

Although the system was now operational, there were improvements that could be made. One situation for which we had no automatic solution was the case of a flooding tide. As configured, when an incoming flooding tide triggered the upper float switch, the pump would turn on, resulting in the system trying to pump against the flooding tide. A second situation occurs when a heavy rain event floods the Flats. The sudden influx of water will trigger a pump cycle, but if the time delay circuit has been set for a dry climatic condition, the water will not be pumped out expeditiously.

To compensate for the flooding tide, a method of automatically shutting the system down while the Flats is flooded needed to be installed. The solution implemented for the pump system includes a third float switch and added circuitry. The switch, mounted away from the pump (Fig. III-4-11), will trigger when water reaches a "flooded" height. This is any height above the normal full pond level. The switch, when activated, opens the high- and low-water-level float switch circuits, forcing the control into a low-water-level mode and shutting down the system. When the natural draining of the pond after a flooding event is almost complete and the water level drops back to the normal full pond level, the flood switch opens and the controls revert to normal operation, triggering a pumping cycle. This control algorithm circuitry (Fig. III-4-12) was installed and successfully tested during

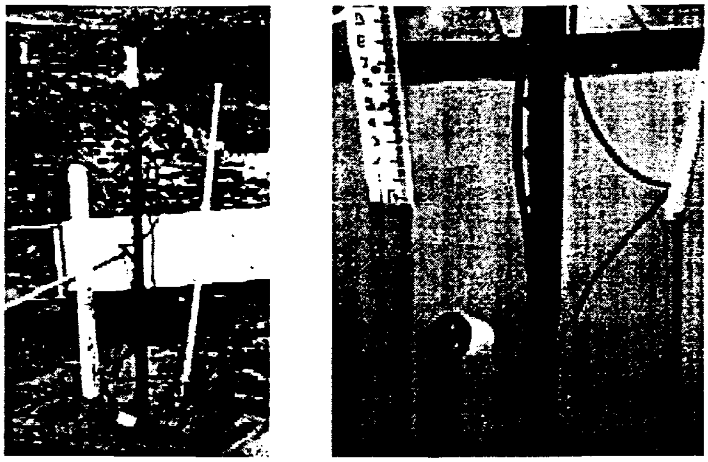
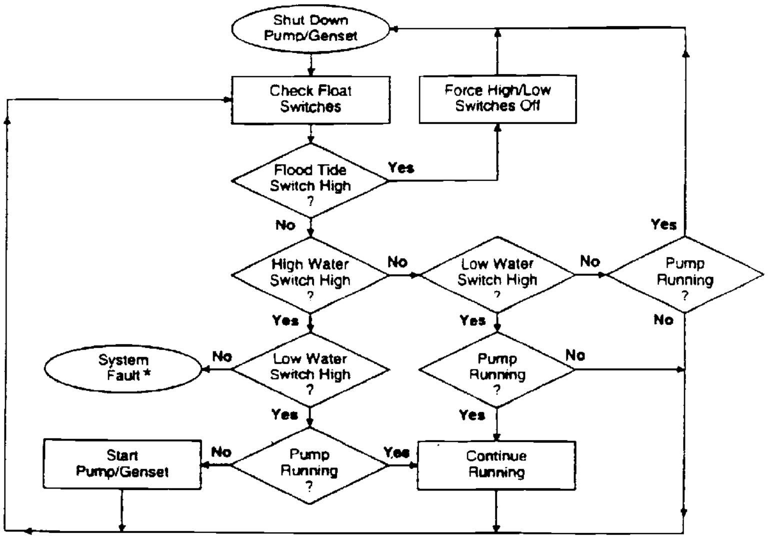


Figure III-4-11. Third float switch set up to turn the system off during a flooding tide.

the July flooding event at the Flats.

Problems with the setting of the start delay duration were solved using lessons learned from the flood switch. In this case the high-water-level switch was dismounted from the pump platform and mounted to a stake placed in a drainage channel feeding into the sump. When the sump fills and the water backs up into the drainage channel, the pump start cycle is initiated. The start delay can now be set for a minimal time period and need not be reset.

During this trip a window was installed in the control cabinet door to facilitate reading the elapsed time meter, warning lights, and control gauges for the genset. An hour meter was also installed in the door that directly reads elapsed time of pump operation.



* System Faults include faulty switches or logic elements. Field service required to rectify.

Figure III-4-12. Simplified logic diagram for the pump switch circuitry.

Figure III-4-13. Tide gate installed in the channel leading to B gully. A one-way gate prevents minor flooding from backing up the channel but allows flow back down the channel.

At this time, plans were made for installing a tide gate in the drainage channel leading out from the pond to B gully. This gate, which acts like a check valve for minor flooding tides that back up through B Gully and into the pond, will prevent nuisance flooding of the pond when flooding events are below 31.4 ft. This will extend the effective drying periods, in some cases eliminating complete flooding events if the concept is successful. If flooding does occur or the pond is in the process of draining, the gate will swing open during draining, minimizing impediment of the natural outflow process. This gate was installed in the channel leading to B Gully in September (Fig. III-4-13) and successfully prevented flooding during a 31.1-ft tide on 15 September.

One problem that occurs every time the sump is pumped down and the pump shuts off is back-draining of the outlet line into the sump. With a long run, such as installed at the Pond 183 site, this flow, up to 10,000 L (2,650 gal.), can fill a significant portion of the sump. To prevent this, a check valve for the 20-cm line was designed and fabricated at CRREL. Prior to removing the equipment from the pond in mid-September, the valve was installed in the line and successfully tested. By preventing back flow, cycle times will be stretched, resulting in less fuel consumption and fewer refueling operations, an important cost consideration for the more remote pump locations proposed for next year.

SYSTEM OPERATION

The modified system is now fully operational, requiring human intervention only for refueling and routine maintenance. All contingencies encountered over the 1997 season have been compensated for, including flooding events. During the high flooding tides (>33 ft) and record rainfalls (>10 cm) of late August, the genset drifted out of the channel and settled unevenly. Not knowing how badly it was tilted, the personnel from CH2M Hill monitoring the equipment were instructed to shut it down until the next CRREL field deployment in early September. At that time the system was restarted to pump out Pond 183 and facilitate retrograde of the equipment.

Drainage times for the pond after the initial drawdown in May and consolidation of

Table III-4-1. Summary of ponds affected by pond pumping in Pond 183.

Ponds	*Type*	*Area*
Directly affected		
Pond 183	Permanent	2.9 ha
Pond 164	Intermittent	5.48
Pond 205	Intermittent	3.32
Pond 158	Intermittent	0.72
Indirectly affected		
Pond 155	Permanent	0.3 ha
Pond 146	Permanent	5.5 ha

the sediments approached the 36 hours that was our target. Initial drawdown was slow because of the large volume of water incorporated in the soft bottom sediments, which drained slowly. After the initial drawdown and drying period, these bottom sediments became consolidated. Following subsequent flooding events, drawdown was much more rapid as the water, for the most part, was sitting on the surface of the consolidated sediments and drained freely. For more information on sediment moistures and the effects of reflooding, see M.E. Walsh et al. (this volume).

The area affected by the pump was quite large. It included Pond 183, several contiguous intermittent ponds, and adjacent intermittent and permanently ponded areas (Table III-4-1). The influence of Pond 146 was not as pronounced as we expected it would be, especially through the dredged channel. In fact, a small ditch was dug between the end of the dredge channel and the sump to draw down Pond 146 more than necessary to reduce the effect of storm water influx from this area. The effect on Pond 155 was peripheral in that water surface levels in the pond and surrounding area were drawn down but the pond was not drained. However, evaporation of the remaining water could begin at a lower level than normal. This same process affected adjacent intermittent ponded areas.

The initiation of cracking is indicative of consolidation and shrinkage of the sediments as the drying progressed down through the soil column. After flooding events the sediments did not easily resaturate due to the consolidation and densification of the material. This is evident in the soil moisture measurements (Walsh, M.E., et al., this volume). Physical evidence of this could be found after draining of the ponded area following a flooding event. Large desiccation cracks in the pond bottom still remained following tides in July and August that refilled the pond basin (Fig. III-4-14). The top few millimeters of sediment

Figure III-4-14. Large desiccation cracks in the pond bottom still visible following flooding tides in July and August that refilled the pond basin.

had resaturated such that they were slippery to walk on, but the remainder of the sediments were still firm enough to support a 100-kg person without penetration.

Some operational problems, inevitable when working with a prototype system, prevented this season from being as successful as it could have been. Two record rainfalls in August prevented sediments from thoroughly drying that month, and the inadequate anchoring of the genset prevented much draining after the August high tides. However, data from planted particle tests conducted in the previously permanently ponded area of Pond 183 indicate that attenuation of greater than 50% in mass of the particles had occurred over the summer season. Composite sampling of surface sediments in 183 showed greater than 85% decrease in WP concentrations (Walsh, M.E., et al., this volume)

A Doppler flowmeter was purchased with the second pump system, received in September. This was attached to both Pump System #1 installed in Pond 183 (with 335 m of line) and the new pump system, Pump System #2, when it was set up for initial tests in Pond 146 with the line running out and connecting with the existing discharge line of Pump #1 (506 m of line). Flow rates measured were 112 and 95 L/s, respectively. The rates for both systems were greater than expected and quite good considering the long discharge lines.

On 13 September the pump system was shut down and preparations made for the retrograde of the equipment. The pipe from the sump to B-Gully was disassembled and stacked ten to a pile for helicopter retrograde. Pipe between the two pump systems was retrograded by hand via the boardwalk. Helicopter retrograde of the pipe and hose took less than an hour, a considerable improvement over the deployment times.

The pump switches were removed from the pump and stored with other loose items in marked boxes. The signal cord was coiled on a spool and retrograded. The power cord was loosely coiled onto the genset platform. On 17 September, during a 33.4-ft flooding tide, the genset and pump were floated from their deployed positions and rowed back to Clunie Creek, where they were loaded by crane onto a flatbed truck for transport and storage at Ft. Richardson.

PUMP SYSTEM #2

Based on preliminary results of the deployed pump system at the Flats, a second system was requested by the project manager. Specifications from the first unit were modified to reflect changes made to the system over the course of testing and operation, and these specifications were used by CH2M Hill in developing a purchase order. The purchase order was awarded to SRS Crisafulli on a sole-source contract based on system compatibility and delivery.

In August, Dennis Lambert visited the manufacturer to inspect the equipment prior to shipment. Several faults were found, and assurances were given that corrections would be made prior to shipment to Alaska. In early September the equipment was delivered to Eagle River Flats, prior to our deployment that month.

Upon inspection it was obvious that many of the shortcomings on the system were not corrected prior to shipment. The most serious problem was that no float switches for the pump had been shipped. There was also no junction box on the pump. A "kit" had been shipped with some connectors and a non-waterproof box, but this was inadequate for the application. There was no fuel tank crossover valve to isolate the tanks during transport. Pinouts for the float switch cables were not consistent, not a critical fault but indicative of poor workmanship. Connectors were not correctly oriented, as male connectors were located on the live ends of the switch leads.

Inside the control cabinet the 110-VAC transformer had not been blocked prior to shipment and had broken from its mounts, crushing the back of the bulkhead connector for the switches. In addition, there was no guarding over the 460-VAC panel. The strobes specified had been replaced with blinking lights, totally inadequate for the application. There were also no caps for the float switch

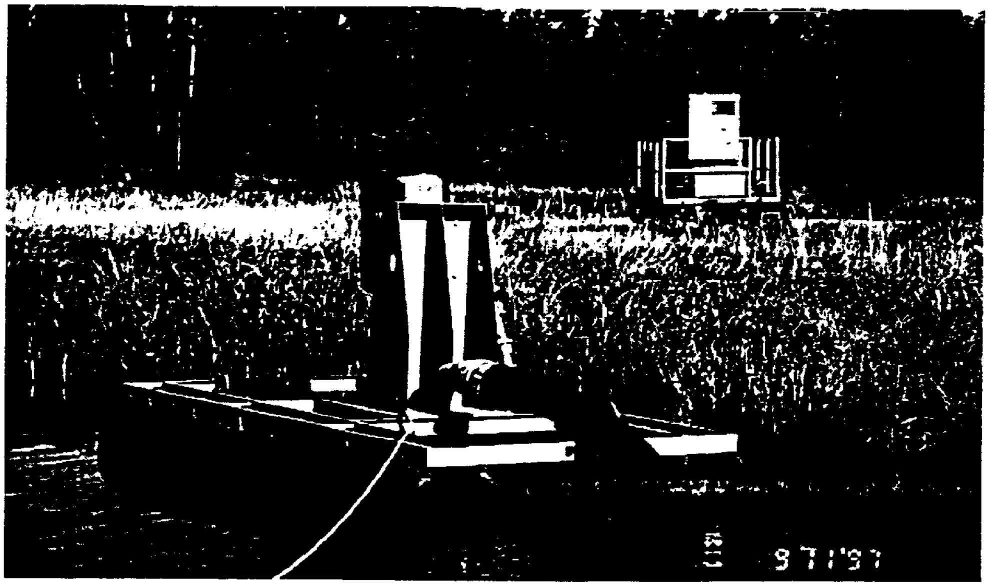


Figure III-4-15. Pump system #2 set up in Pond 146 near Clunie Pad.

connectors.

Repairs were made over the next two days to get the equipment operational. Upon firing the system up, it was noticed that it was not operating at the correct speed. The throttle was adjusted to lower the speed from 1830 rpm (61 Hz) to 1800 rpm (60 Hz). No locking mechanism was available on the throttle set screw, and overnight the screw would back off to the point where the low engine speed fault kicked in and disconnected the generator. When we shut the system down, there was no engine cool-down time. This had not been set in the controls. Consulting the genset manuals, we were able to find the potentiometer that controls cool-down time and reset it correctly.

The equipment was set up in Pond 146 near Clunie Pad and tested after repairs (Fig. III-4-15). The outlet was run along the boardwalk and attached to the line from Pump System #1 in Pond 183. The newly installed switches were tested, and the system worked fine. The system was run long enough to break it in (50 hours) and make it ready for deployment in 1998 if needed. Before deployment the lights should be replaced with strobes and the float switch connectors replaced with ones of the correct orientation.

RESULTS

The results of pumping can be measured in several ways. The most physically obvious is the amount of area exposed. Others include the pump-down time after a flooding tide, desaturation of the sediments, recovery after a heavy rain, and degree of autonomy in operation. Baseline and post-season sampling give a quantitative indication of the attenuation of the contaminant (Walsh, M.E., et al., this volume). Pump System #2 was received, repaired, and modified in early September and is almost ready for deployment.

Affected area

The area affected by pumping was not limited to Pond 183 and its contiguous intermittently ponded areas (164 and 205). The marsh area between Ponds 183 and 146 were partially drained, and Pond 146 was drawn down some as well, mainly through the ditch formed between the two ponds. The interconnectedness of Ponds 146 and 183 was not as great as was commonly assumed. Groundwater recharge from along the shore on Pond 146 and influx from Clunie Creek were also not problematic and were easily addressed by the pump.

Table III-4-2. Tensiometer data for Pond 183 Eagle River Flats, AK, collected by P. LeMay, CH2M Hill.

Station	*6/11/97*	*6/20/97*	*6/25/97*	*6/30/97*	*7/2/97*	*7/3/97*	*7/7/97*	*7/9/97*	*7/11/97*	*7/14/97*	*7/16/97*	*7/18/97*	*7/19/97*	*7/31/97***	*8/1/97*
	Clear	*Rain*	*Sun*	*Sun/ smoke*	*Sun*	*Sun*	*Sun*	*Sun*	*Heavy rain*	*Cloudy*	*Sun*	*Sprinkles/ Sun*	*Sun*	*Overcast*	*Overcast*
0 m															
5 cm	15	2	44	19	N/A	N/A	N/A	24	0	8	12	32	36	3	4
10 cm	15	3	49	50	56	52	60	57	6	8	12	23	40	2	4
20 cm	14	12	40	48	50	50	54	55	13	10	12	24	32	2	4
50 m															
10 cm	11	4	42	50	56	55	62	65	6	7	10	4	42	2	4
20 cm	11	8	38	48	52	52	58	62	10	8	11	54	37	4	5
100 m															
5 cm	10	0	36	50	62	68	68	75	0	8	14	38	46	1	2
10 cm	9	1	35	46	52	49		50	6	7	12	52	44	1	2
20 cm	4	0	29	40	46		52	64	6	5	8	40	37	0	0
10 cm*	12	4	42	50	58	54	66	80	6	12	17	64	55	4	6
150 m															
10 cm	5	0	7	10	10	10			0	1	12	38	46	0	0
20 cm	2	2	32	48	68	72	76	78	0	5	9	30	29	0	2
200 m															
5 cm	3	0	31	54	58	61	60	65	0	3	6	41	28	0	0
10 cm	4	4	28	37	41	42	48	50	6	8	8	39	5	4	4
20 cm	2	4	24	30	N/A	36	42	47	6	5	6	29	2	0	0

*Duplicate reading.

**Area C was flooded from 7/20/97 @7:53 A.M. with a 31.1 foot tide, the flooding tides lasted until 7/24/97 @11:00 A.M. After the last flooding tide the pump was started. The pond was pumped dry on 7/30/97. It took six days to get the pond dry.

On 7/29/97 the pump delay time was changed from 30 minutes to 1 minute. The reason behind this was that after the sump was filled and the water had tripped the upper float switch, the water coming from the dredge channel had 30 Minutes more of flow. This flow pushed the water back into Area C. Therefore, by adjusying the delay, Area C emptied out within a day and is starting to dry. The water from the dredge channel was still flowing on 8/1/97 at 10:00 A.M.

High Tides-July

	A.M.	FT.	P.M.	FT.
7/20/97	7:53	31.1	8:48	29.8
7/21/97	8:38	31.7	9:28	30.5
7/22/97	9:25	31.9	10:08	31.1
7/23/97	10:11	31.5	10:50	31.5
7/24/97	11:00	30.7	11:35	31.6

High Tides-August

	A.M.	FT.	P.M.	FT.
8/18/97	7:37	32	8:23	31.1
8/19/97	8:25	32.8	9:02	31.9
8/20/97	9:11	33.1	9:41	32.9
8/21/97	9:58	32.8	10:22	32.9
8/22/97	10:46	31.9	11:06	32.5
8/23/97	11:37	30.3	11:53	31.3

The area of Pond 183 is 2.9 ha. The two adjoining intermittent ponds have a combined area of 9.7 ha. These areas were directly affected by the pump. In addition, two adjacent intermittent ponds, with a combined area of 0.8 ha, were indirectly affected by drawing down their surface water, leaving less water to evaporate during the drying period. Ponds 155 (0.3 ha) and 146 (5.5 ha) were marginally affected, being drawn down by the pump but not enough to allow drying to occur other than at the edges.

Sediment desaturation

Sediments in Pond 183 both consolidated and dried over the course of the initial dry spell from late May to mid-July. Cracking, evident even from a helicopter, was extensive throughout the pond and adjacent areas. Rewetting during flooding and rain events resaturated only the top few millimeters of sediment, allowing rapid resumption of desaturation once the ponds were redrained. Soil moisture readings taken by Patrick LeMay of CH2M Hill confirm these observations (LeMay 1997) (Table IV-1-2). Additional information can be found in Walsh, M.E., et al. (this volume).

Recovery time

Initial drawdown of Pond 183 occurred intermittently over the period 16–21 May, although initial drawdown occurred in less than 24 hours. After flooding in July, drawdown took less than two days. Operational problems unrelated to the equipment resulted in a shutdown and only intermittent operation after the late August flooding tides. A record of the water levels in Pond 183 is shown in Figure III-4-16.

Operability

The equipment as originally deployed was not autonomous. No feedback mechanism for flooding tides was incorporated in the design, and the mounting of both water level switches on the pump platform resulted in unacceptably narrow cycle times. The addition of the time delay circuit, the flood switch, and related circuitry, and dismounting the upper-water-level switch from the pump platform, transformed the system. As

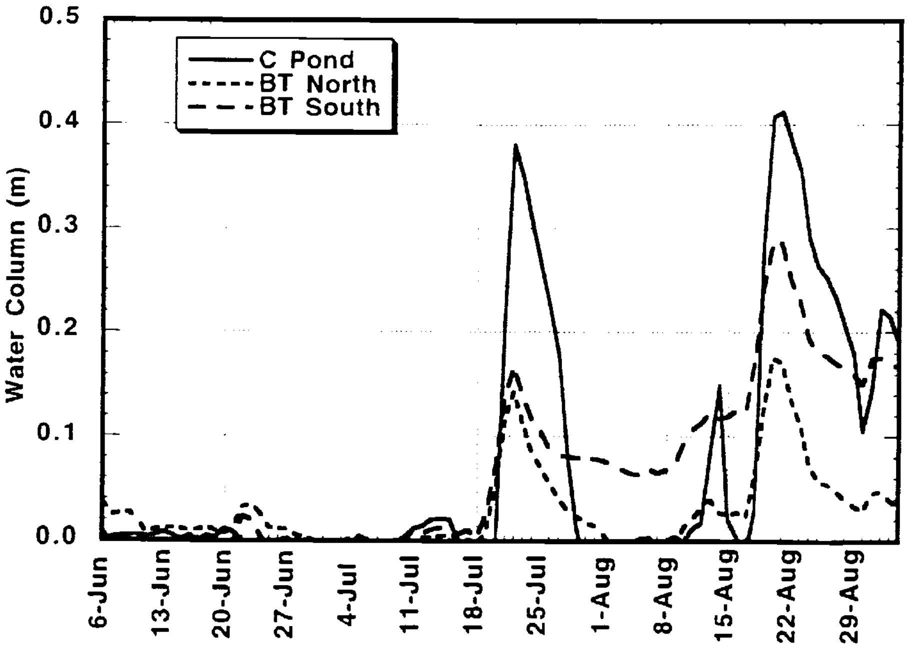


Figure III-4-16. Water levels from Pond 183 from May through August.

currently configured the two pump systems in inventory will require only refueling and routine maintenance and monitoring during deployment.

System #2

Pump System #2 was received in early September and tested for operability. Some damage was incurred during shipment but was easily repaired. Strobe lights will need to replace the blinking lights currently installed. A poorly designed switch junction box was replaced on the pump. Some connector changes will need to be made on the switch circuit prior to deployment. It is estimated that less than a day's work will be required.

CONCLUSIONS

Overall performance of the pumping system was much better than expected. The system easily addressed the target area and influenced a wide area surrounding it as well. Improvements to the system increased its reliability and decreased the amount of human intervention required to keep the system operational. The second pump system, incorporating most of the features developed during deployment and operation of the first system, was operational within two days. It has been run in and will be ready for deployment after some minor modifications.

Results from the sampling study indicate that remediation may be possible over the course of three good drying years (>60 core days without heavy rainfall). For areas that may dry more slowly or flood more often, the term may be closer to the five years predicted by CH2M Hill. Sumps are ready for pump deployment in Ponds 155 and 290, and a route has been marked for clearance and access to Pond 146 next year. With pumps in Ponds 146, 155, and 183, drawdown should be much more rapid than this season's, perhaps less than 24 hours.

The contracts with CH2M Hill and Explosive Disposal and Engineering Technology, Inc. (EDET) have proven crucial to our ability to do this work. Sherry Butters of EDET and Mey Wong and Patrick LeMay of CH2M Hill have contributed greatly, both directly and indirectly, to the success of this work. We recommend that this arrangement be continued in the future.

The pumped drainage of permanently ponded areas and their associated intermittent ponds is an almost ideal solution to the problem of white phosphorus contamination in Eagle River Flats. The relatively low costs and mild environmental impact of this remediation method make it a very viable option where it can be applied. It may even negate the need for bentonite coverage of most targeted areas. It should be considered in as many contaminated areas as feasible.

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IV-1. MAPPING AND CLASSIFICATION OF INTERMITTENT AND PERMANENT PONDS ON EAGLE RIVER FLATS

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INTRODUCTION

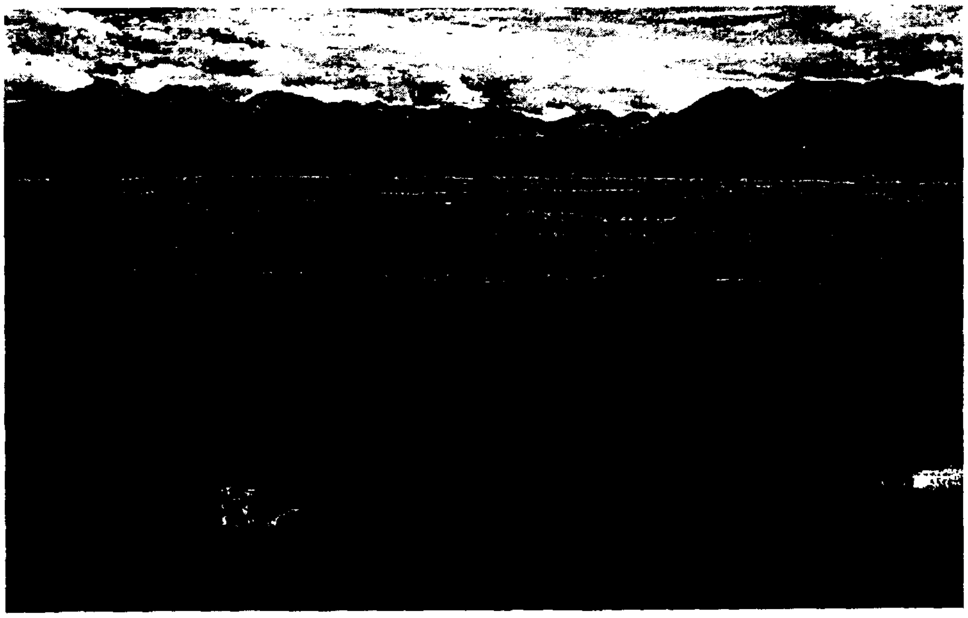
Walsh et al. (1996) showed that the particles of white phosphorus in the bottom sediments of ponds at Eagle River Flats undergo rapid sublimation (natural decontamination) once the bottom sediments have become subaerially exposed and then unsaturated. Methods to accomplish pond sediment drying include pond draining, pumping, and dredge-removal of the sediments to a drying basin. These are all expensive compared with the natural attenuation that can occur in some ponds on ERF during some summer dry periods, particularly when the monthly spring tide is "skipped" and evaporation is high over a period of 60–70 days (Walsh et al. 1996).

In 1993 about 350 ponds covering 125 ha were photointerpreted from orthophotos and digitized into a GIS (Arc/Info). Each pond was classified as permanent (228 ponds that do not dry out in any year) or intermittent (101 ponds that dry up in some years and where white phosphorus could potentially sublimate naturally) (Fig. IV-1-1). The objective of this study is to evaluate the accuracy of this original classification and to test the use of digital multispectral remote sensing techniques to further identify and map these two types of ponds, as well as soil moisture changes over a summer drying period. In addition, monitoring of the environment at Eagle River Flats using remote sensing is a priority to avoid risks associated with foot traffic and unexploded ordnance.

Since 1989, when the use of white phosphorus munitions in Eagle River Flats ceased, there have been two summers (1993 and 1997) when there were no flooding tides (above 31.1 ft) over a period of 60+ days between 8–9 May and 20–21 July. The original pond map and classification were based on orthophotos obtained on 8 July 1993; therefore, the summer of 1997 appeared to present an excellent opportunity to evaluate the original maps and conduct new studies of pond drying. The two objectives of the 1997 study therefore were to 1) conduct a field accuracy assessment of the original 1993 pond classification at the end of a similar summer drying period, and 2) obtain and evaluate the use of digital multispectral imagery to monitor pond drying and map ponds and other conditions in ERF.

STUDY AREA

Field observation of Eagle River Flats over several years revealed that during normal monthly spring tides over about 31 ft (based on published tide charts for Anchorage, Alaska), the entire 863-ha salt marsh floods. At this time all low ponded areas fill with water and then drain to reach an equilibrium level over a period of 2–3 days (Fig. IV-1-2a). Normally, this 30-day tidal cycle is too short for dewatering and drying of even shallow intermittent ponds to levels sufficient for WP sublimation (although unsaturated tensiometer readings of −10 cbars were reached in one pond on 12 June 1995, only 23 days after a flooding tide). However, the lowest soil moisture levels for the longest time intervals are reached during about two out of five summers when a monthly spring tide is "skipped" and evaporation is high over a period of 60–70 days. Relatively low heights of spring tides close to the summer solstice is a special fea-



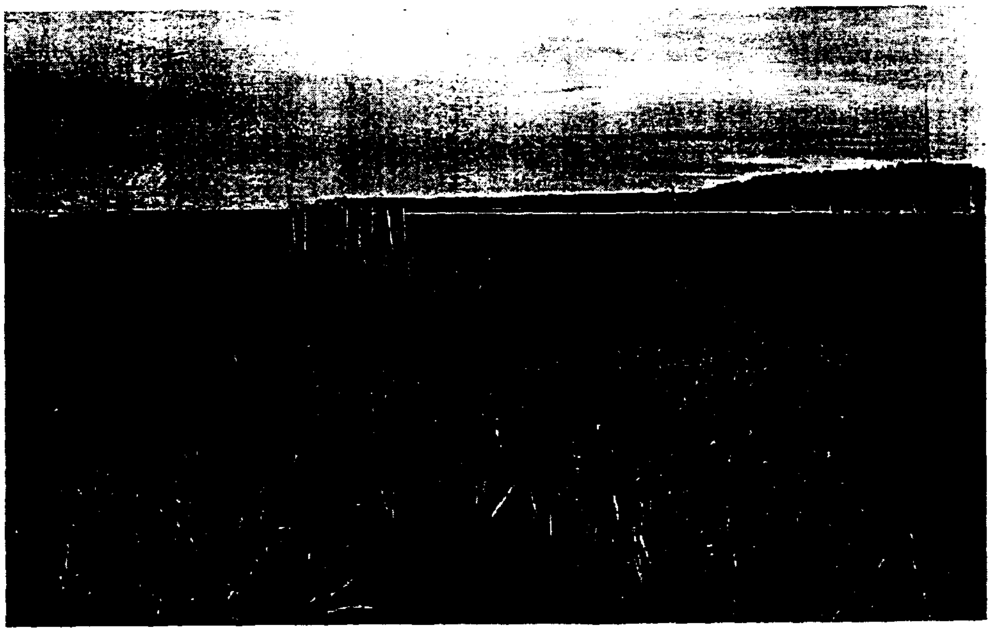
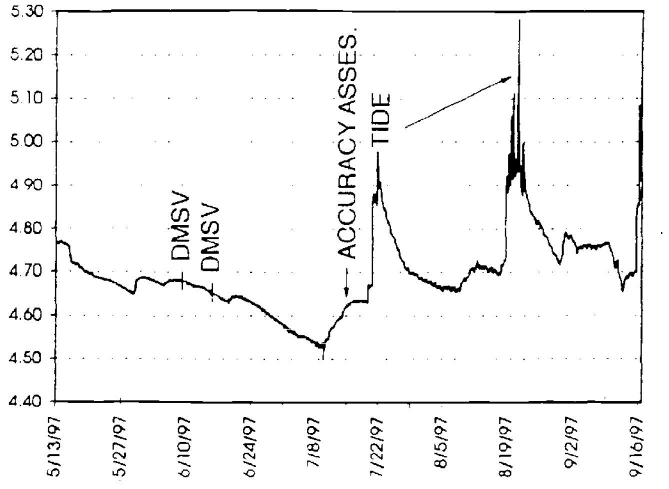
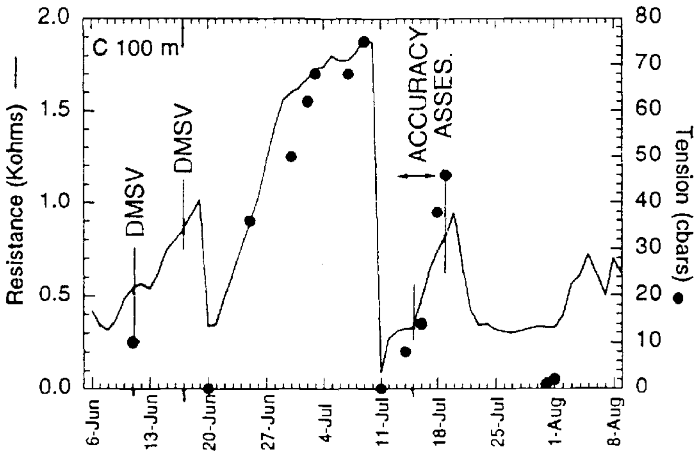


Figure IV-1-1. Intermittent (top) and permanent pond (bottom) on Eagle River Flats in mid-July 1997 after 60+ days without a flooding tide (8 May to 17 July). Note the network of surface cracks in intermittent pond and vegetation (Carex ramenskii)*. The vegetation in the permanent pond is bulrush* (Scirpus *sp.).*



a. Water surface elevations in Clunie Pond along the east edge of Eagle River Flats during summer 1997.



b. Tensiometer and clay block moisture probe electrical resistance in bottom sediments of C pond pumped area during summer 1997, showing decreasing soil moisture levels between 11 June and 17 June, the dates of DMSV image acquisition. (From M.E. Walsh and C.M. Collins.)

Figure IV-1-2. Moisture conditions in ERF during summer 1997.

ture of high-latitude salt marshes and has important consequences for soil moisture and salinity conditions (Srivastava and Jefferies 1995). In addition, ERF is located in a summer soil moisture deficit region [evaporation rates are greater than precipitation during the growing season (Patrick and Black 1968)]. The most rapid drying occurs when this tideless period occurs in June or coincides with the maximum solar input around 21 June. Optimum drying and usually lower rainfalls also occur at this time (Haugen 1995).

Various measurements of pond and ground water levels and sediment moisture (and temperature) levels have been made in ERF by Walsh and Collins during the summers of 1994, 1995, and 1997. In 1993, a very dry year, Collins measured soil moisture levels between 30–35% (dry weight basis) in the top 10 cm of exposed pond sediments. In 1994 an extensive study of soil moisture and water level conditions was conducted at 10 sites along a transect that included permanent (one site), intermittent (four sites), and mudflat-levee (five sites) areas. No tidal flooding above 31.1 ft occurred between late June and early Sept. (There were several 31.0-ft tides in July and August that apparently did not flood the study area.) After a flood event a combination of downward seepage and evaporative loss serve to dewater the pond surface and then dry the surface sediments. The elevation of the pond bottom site strongly determines when there is no more surface water and when the sediments can become unsaturated. Of the four intermittent pond sites the two highest sites (elevation 4.80 and 4.85 m) became unsaturated in June 1994, while the two lower sites (4.74 and 4.78 m, only 7–10 cm lower) did not become unsaturated until late July or early August. The permanent pond site at an elevation of 4.70 m remained flooded throughout the summer. At this pond site, ground water seepage also played a role in maintaining water levels and prevented drying by evaporation. Water levels during this year declined about 0.5 cm/day in mid-June just before a series of flooding tides beginning on 25 June.

During 1995, Haugen (1995) collected precipitation, relative humidity, solar radiation, pan evaporation, and air temperature data at ERF and calculated evapotranspiration. This was a particularly wet summer after 22 June, so that little or no additional drying took place after this date. In the summer of 1996, an evaporation pan was installed on ERF and showed a net loss of 21 cm in 60 days (22 May to 21 July). This agrees with measured pond level drops of 0.5 cm/day measured in previous years.

In 1997, soil moisture was monitored at 5- and 10-cm depths at 17 sites between 6 June and 4 September in the bottom sediments of two ponds by Walsh et al. (1998). Both ponds had been drained, one by pumping (C Pond) and the other (BT Pond) by constructing a drainage ditch. The surface sediments (at 5-cm depth) were unsaturated in the pumped C Pond from 11 June–19 June, 23 June–10 July, and 17–21 July at all three stations in C Pond, although the driest conditions occurred on 10 July prior to a 19-mm rainfall on 11 July (Fig. IV-1-2b). Monitoring of water elevations in a permanent pond along the east edge of ERF also showed that the pond water depth decreased by almost 25 cm from 4.75 m in mid-May to 4.52 m by 10 July (Fig. IV-1-2a). Water levels in this pond on 11 June and 17 June were 4.68 and 4.65 m, respectively, indicating a decrease of only 2–3 cm, or 0.5 cm/day. Between 11 June and 17 June only 2 mm of rain were recorded at the Anchorage Airport and a flooding tide had not occurred since 8 May.

METHODS

Pond mapping from aerial photos

In 1993, ponds were mapped and digitized into the ERF GIS using large-format black-and-white IR aerial orthophotos obtained on 8 July 1993, by Aeromap Inc. This date represented the end of a long drying period approximately 60 days after the previous flooding tide on 8 May. Mapping was done on acetate film placed over these large-format orthophotos. Interpreted and mapped landcover features included ponds, rivers, tidal creeks, mudbanks, and vegetation types. Two types of ponds were recognized and mapped, depending on the presence or absence of standing water on 8 July as compared with aerial photos taken only 15 days after a flooding tide. Since intermittent ponds contain no water and are barren of vegetation cover, they appear as bright objects on black-and-white IR prints. All of the landcover features mapped onto the acetate were then digitized into Arc/Info.

Accuracy assessment

In 1997 there was a period of suspended tidal flooding between 8 May and 21 July, very similar to the tidal pattern during the summer of 1993. This provided us with the opportunity to ground-truth the 1993 pond map by spot-checking ponds in mid-July to see if they were still flooded (permanent ponds) or

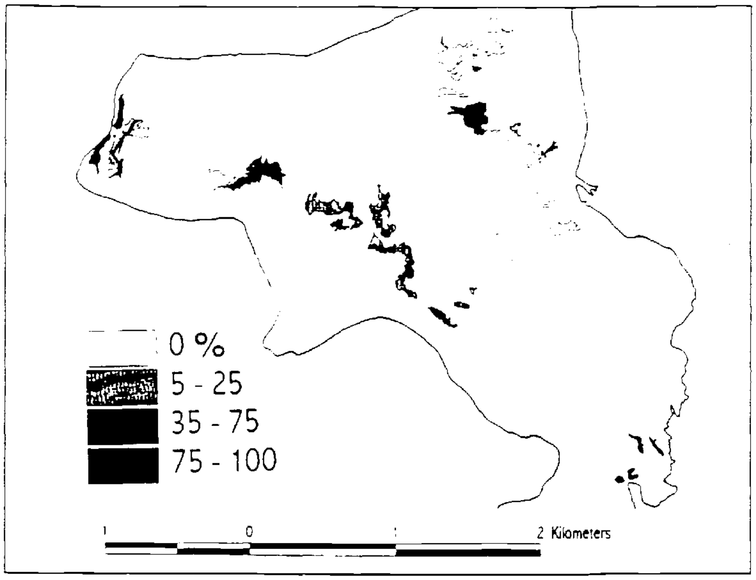


Figure IV-1-3. Outline map of ERF showing 35 ponds visited in mid-July to conduct an accuracy assessment of the pond GIS database. Here the percentage of standing water (by four classes) in mid-July 1997 in the 35 ponds is inventoried to evaluate the 1993 pond classification.

dewatered (intermittent ponds). Thirty five ponds were selected at random in all areas of ERF from the original GIS coverage (Fig. IV-1-3). Using an Arc/Info command, the midpoint of each of these ponds was determined. During the week of 12–17 July, we used a GPS unit (Trimble Pathfinder XR with Coast Guard beacon real-time GPS) to navigate to this midpoint in each pond. Standing and walking out from the selected point, we evaluated the following characteristics for the entire pond:

- Percent of the pond surface still flooded;
- If flooded, the water depth, conductivity and temperature (YSI 2500 water quality meter);
- Submerged and emergent vegetation cover;
- Surface features such as cracking, maximum width and depth of the cracks, and the presence of salt crusts and iron staining;
- Relative soil moisture levels on a scale from 1 to 5 evaluated subjectively by the feel and color of the sediments (1 = saturated; 5 = dry and cracked).

Pond mapping and monitoring using digital multispectral video

The work at ERF was focused on the use of digital multispectral video (DMSV) to detect and monitor pond dewatering, subaerial exposure, and drying of pond bottom sediments, a critical phase in white phosphorus remediation. The basic hypothesis is that drying of pond-bottom sediments will produce changes in the spectral reflectance of the pond bottom in one or more selected wavelengths. DMSV is a relatively new system with high spatial and spectral resolution made available by Aeromap Inc. Anchorage, Alaska. It has been used for customized applications and has a proven high capability in aquatic/wetland studies (Anderson et al. 1997).

Ground spectrographic measurements

In mid-July 1997 at the end of the 60+-day drying cycle, a spectrophotometer (Personal Spectrometer II by Analytical Spectral Devices) was used to measure surface reflectance at a range of wavelengths from 338 to 1050 nm. Since the emphasis here is on the use of multispectral imagery to monitor soil moisture conditions and change in ponds, exposed pond bottom sediments were measured at different soil moisture levels from shallowly flooded to dry. Reflectances from the bottoms of two adjacent intermittent ponds (158 and 159) at different soil moisture levels were measured on 17 July 1997. In addition three sites being monitored by M.E. Walsh and C.M. Collins in C Pond, dewatered in 1997 by pumping, were also measured.

Acquisition of DMSV images

Multispectral images were obtained at ERF in June 1997 using four video cameras mounted on an airplane and flown at an elevation of 7300 ft to produce pixel resolutions of 1.5 m. Each video camera contained a different filter to receive reflected radiation in 550 (green), 650 (red), 770 (IR), and 990 (IR) bands, each with a bandwidth of about 20 nm. To determine the ability of this technology to monitor pond drying, two images of ERF were obtained, one at noon on 11 June and the other at noon on 17 June 1997. On each date there were seven flight lines and several hundred images that were combined into a single georeferenced image of ERF by Aeromap Inc. using Erdas Imagine.

Analyses of the 11 June and 17 June images were conducted by Brian Tracy, (RS/GIS, CRREL) using image processing software (Erdas Imagine) to conduct both an unsupervised classification of each image and perform a change detection on selected areas of the image.

DMSV image classifications

Classification is the process of sorting pixels into a finite number of individual classes, or categories of data, based on their reflectance values in each of the four reflectance bands. If a pixel satisfies a certain set of criteria, then the pixel is assigned to the class that corresponds to that criteria. The classification resulted in the assignment of each pixel in the image (several thousand) to ten classes to produce groups or "clusters" of pixels with similar reflectances values in the four bands. The class that best represented the permanent (standing water) ponds and intermittent (drained) ponds was determined following the classification of each scene in Erdas Imagine.

Erdas Imagine uses the Isodata algorithm to perform an unsupervised classification. ISODATA stands for Iterative Self-Organizing Data Analysis Technique. It is iterative in that it repeatedly performs an entire classification (outputting a thematic raster layer) and recalculates statistics. "Self-Organizing" refers to the way in which it locates the clusters that are inherent in the data. The ISODATA clustering method uses the minimum spectral distance formula to form clusters. It begins with either arbitrary cluster means or means of an existing signature set, and each time the clustering repeats, the means of these clusters are shifted. The new cluster means are used for the next iteration. The ISODATA utility repeats the clustering of the image until either a maximum number of iterations has been performed or a maximum percentage of unchanged pixels has been reached between two iterations.

Change detection

Four areas (16–36 ha) with intermittent and permanent ponds were selected in four different areas of ERF (Pond C, Pond BT, Pond A, and Otter Creek Pond). Using band 2 (650 nm) of the two DMSV image scenes (11 June and 17 June), a new three-layer composite image of red, green, and blue was produced using the 17 June image for the red and the 11 June image for both the green and blue bands. Where change occurs in band 2 reflectance from the ponds due to pond water evaporation between 11 June and 17 June, the area would appear red, while no change in reflectance between the two dates would produce a gray shade (i.e. red, green, and blue would all have the same value). The new image produced with the three-layer composite was then classified by the above.

RESULTS

Pond accuracy assessment

Thirty-four ponds were visited and sampled during the week of 14–19 July following more than 60 days without a flooding

Table IV-1-1. Ponds visited and characteristics measured in accuracy assessment during July 15-18, 1997 at Eagle River Flats.

Pond id	*Type map*	*Water cover (%)*	*Max. crack width (cm)*	*Subm. veg (%)*	*Emergency vegetat (%)*	*Water depth (cm)*	*Pond area (ha)*	*STP*	*Moist rate*
36	int.	0	1.02	0	15	0	1.2	9	4
47	int	0	2.10	0	25	0	2.3	9	5
48	int	0	2.80	0	26	0	0.8	9	5
54	perm.	0	2.79	0	10	0	.0.5	9	5
69	int.	0	2.54	0	2	0	0.6	9	5
74	perm.	20	0.64	0	81	4	0.2	9	2
88	int.	0	1.78	0	9	0	0.7	9	4
97	int.	100	0.00	50	0	12	1.0	1	1
109	perm.	60	1.00	0	15	3	3.3	8	4
124	int.	15	1.50	0	0	5	0.3	1	2
127	perm.	95	0.00	20	0	8	1.0	1	1
128	int.	0	2.03	0	6	0	0.8	1	4
129	perm.	10	0.00	0	40	0	0.3	8	3
141	int.	0	1.91	0	20	0	0.6	8	4
148	int.	75	1.50	0	7	5	1.0	1	2
150	int.	0	2.54	0	40	0	0.8	1	4
155	perm.	100	0.00	25	5	7	0.3	8	1
158	int.	0	2.54	0	0	0	0.7	8	4
159	int.	0	1.27	0	1	0	0.2	8	3
168	int.	35	0.64	0	20	3	3.8	2	2
178	int.	0	2.03	0	31	0	3.5	1	3
199	int.	0	2.29	0	5	0	2.5	3	5
204	int.	7	1.27	20	1	0	2.9	3	4
205	int.	0	1.52	0	16	0	3.3	8	4
226	perm.	99	0.00	90	1	20	0.5	3	1
511	int.	0	3.20	0	3	0	1.6	8	5
243	int.	10	1.00	0	10	3	3.2	3	3
279	int.	5	3.18	0	26	0	0.2	4	4
288	int.	20	1.78	0	1	1	0.4	4	4
290	perm.	100	0.00	75	0	15	0.9	4	1
302	perm.	95	0.00	0	20	5	0.5	6	1
303	perm.	98	0.00	90	20	10	0.3	6	1
308	perm.	80	0.00	0	50	12	0.4	6	1
310	perm.	80	0.00	0	82	8	0.3	6	1

tide (Fig. IV-1-3). Of the 22 ponds originally mapped as intermittent, 14 had no standing water on 17 July and 6 had 5–35% water cover (outside of craters) with water depths less than 5 cm (Table IV-1-1). Two ponds originally mapped as intermittent had 75 and 100% water cover. Both of these ponds were located along the extreme northwest edge of ERF at the base of a steep slope where runoff or groundwater influences would be expected.

Twelve ponds originally mapped as permanent were visited. Three of them had less than 20% water cover, while the remaining nine had 60–100% water cover with depths ranging from 7 to 15 cm. The three misclassified ponds were small ponds (less than 0.5 ha) on the west side of ERF.

The overall accuracy was calculated at about 85%, well within the FGDC acceptable limit or error (Table IV-1-2).

Pond features

Surface cracks

As the bottoms of the intermittent ponds dry out, they develop mud cracks in a reticulate pattern. However, the pattern varied from a continuous network of larger cracks (up to 3.5 cm wide and 18 cm deep) forming discreet polygons about 20–30 cm in diameter to discontinuous crack patterns (less than 1 cm wide and 10 cm deep). In general the intermittent ponds with the lowest soil moisture levels have the largest and most continuous network of cracks. Other intermittent ponds

Table IV-1-2. Results of pond accuracy asssessment in which 34 ponds originally mapped as either permanent or intermittent based on July 8, 1993 orthophotos were revisited in July 1997 and water cover assessed.

Mapped July 8, 1997	*Ground intermittent*	*Ground permanent*	*Total*
Intermittent	20	2	22
Permanent	3	9	12
Total	23	11	34

at slightly lower elevations remain wetter with smaller discontinuous cracks. These cracks probably accelerate drying of the sediments, particularly next to the crack. During rain events, water flows into the cracks ,and in at least two ponds visited with standing water, there was a reticulate crack pattern, indicating that these ponds had been dry before flooding again with water.

Iron and salt crusts

Other intermittent pond surface characteristics evaluated include iron staining and salt crusts. About half of the 20 intermittent ponds contained iron staining covering at least 10% of the surface. This indicates that the soluble ferrous iron was oxidized to the insoluble ferric iron once the pond bottom became exposed. Many of these ponds with salt crusts also had windrows of dead stickleback fish, indicating that they may be flooded in most years but dry out only on the occasional dry summer. Salt crusts may also form as the mud surface dries out. This was observed to be less common than iron staining.

Water quality

In permanent ponds in mid-July, water depths were only in the 5- to 20-cm range, with high conductivities in the 15- to 34-ms/cm range. The average conductivity was 25 ms/cm (SD = ±7.4; *n* = 15). The highest conductivity (38 ms/cm) occurred in an intermittent pond with less than 20% standing water only 2 cm deep.

Vegetation

Pond vegetation includes plants growing in the middle and around the edge of the pond as well as the submerged aquatic species that occur only in permanent ponds. The pond vegetation plays an important role in pond waterfowl habitat, affecting both cover and food supply (seeds and corms), and provides the organic material that supports both sediment invertebrate and fish populations. All ponds were bordered by vegetation on at least one side, and the composition varied from a turf-banked Ramenski sedge border to bulrush. On the pond surface itself, the emergent vegetation cover varied from 0 to over 50% (Table IV-1-1). Submerged vegetation cover varied from 0 to 90%.

About 12 plant species were sampled and usually occurred in only one type of pond, i.e. intermittent or permanent. Species usually associated with permanent ponds include *Hippurus tetraphylla*, *Carex lyngbyaei*, *Carex mackenziana*, and submerged *Ruppia spiralis*, *Potomogeton pectinatus*, and *Zanichellia spiralis*. About two thirds of the permanent ponds sampled (7 of 12) had submerged vegetation. The bulrush *Scirpus validus* usually occurs in permanent ponds but is also present as dying populations on the edge of intermittent ponds. Species characteristic of intermittent ponds include *Triglochin maritima*, *Carex ramenskii*, *Puccinellia nutkaensis*, *Puccinellia phryganodes*, and species that invade pond bottoms following dewatering, such as *Salicornia europea* and *Chenopodium album*.

Digital multispectral video classification

All four spectral bands were used to conduct an unsupervised classification of the two DMSV images (11 June and 17 June 1997). This was done to determine if permanently flooded ponds and intermittent ponded areas could be mapped using DMSV images. Two of the ten landcover classes were identified from each image (Table IV-1-3) as flooded

Table IV-1-3. Classes representing different pond types produced by unsupervised classification of June 11 and June 17 DMSV images.

	June 11, 1997 image	*June 1, 19977 image*
Permanent ponds	Class 1-deep water Class 5-shallow water	Class 1-deep water
Intermittent ponds	Class 7-Bare silt, water along coast, tidal gullies	Class 6-Bare silt, river water, tidal creek banks
Remarks	High tide	Low tide

open water areas (i.e. permanent ponds) and bare-silty areas (intermittent ponds).

Intermittent ponds

The unsupervised classification of the June 17 DMSV images included a class that corresponded to areas of bare silt (class 6), which can be compared with 1993 manually interpreted intermittent ponds (Fig. IV-1-4). Although most areas mapped as intermittent ponds in 1993 are included in this class, many additional areas of bare silt outside intermit-

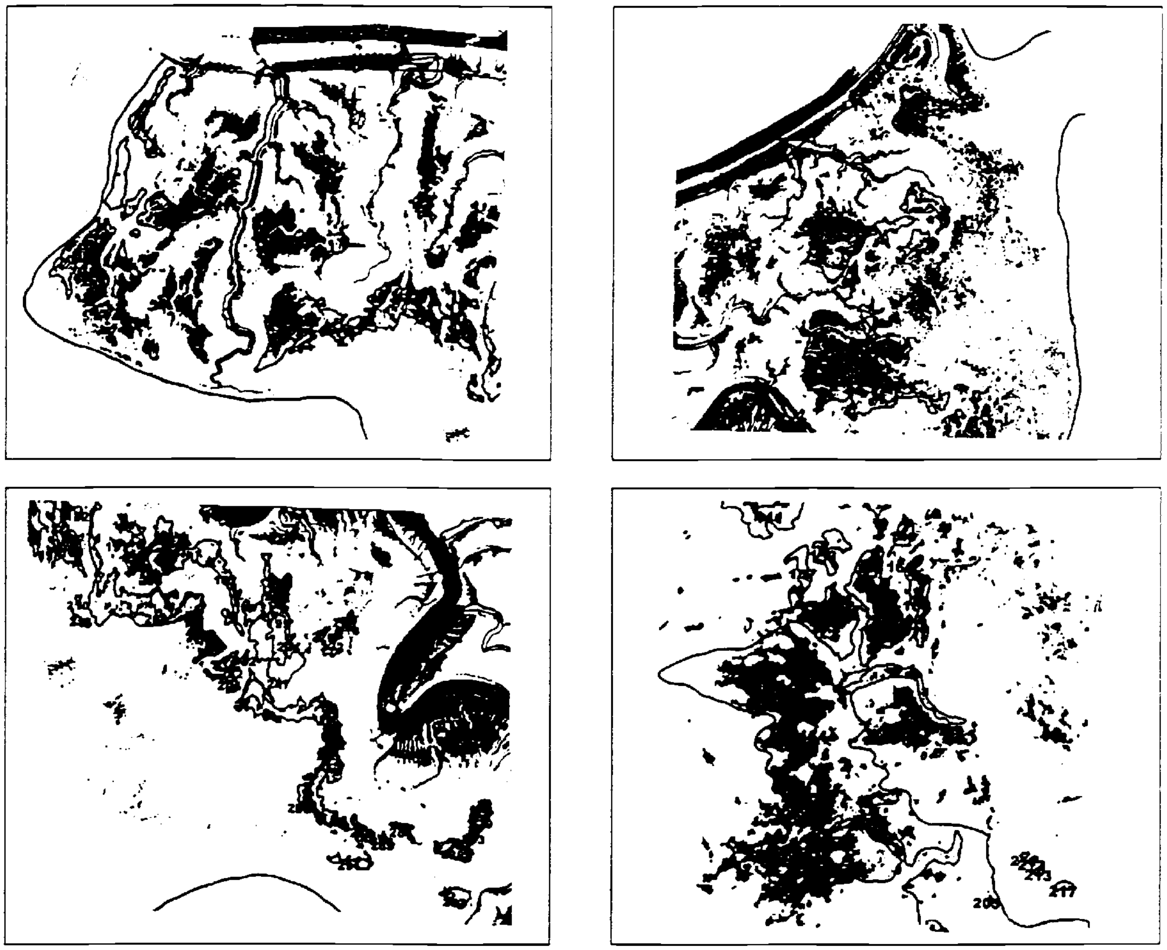


Figure IV-1-4. Maps comparing class 6 (shaded) from the unsupervised classification of 17 June 1997 DMSV image with 1993 manual photointerpretation (outline) of intermittent ponds for four areas of ERF. Note that class 6 represents mainly non-vegetated bare silt areas, including mudbanks and silty water.

tent ponds were also included. This encompasses non-vegetated mudflats, exposed river and tidal creek mudbanks, and even heavily silt-laden river water. These areas are all non-vegetated with exposed silty soils but do not necessarily hold water for any length of time following a flooding tide and should not be classified as intermittent ponds.

Permanent ponds

Classification of the 17 June image yielded one class that corresponded to areas of open standing water. Unlike the intermittent pond classification, which overestimated intermittent pond area, this classification underestimated the area of permanent ponds based on comparisons with the manual photointerpretation (Fig. IV-1-5). This occurred because the emergent and submerged vegetation that often occurs as patches in permanent ponds was not included in the open water class. This can be seen in Figure IV-1-5 comparing manual and automated permanent pond classifications, particularly in Area B, where tall bul-

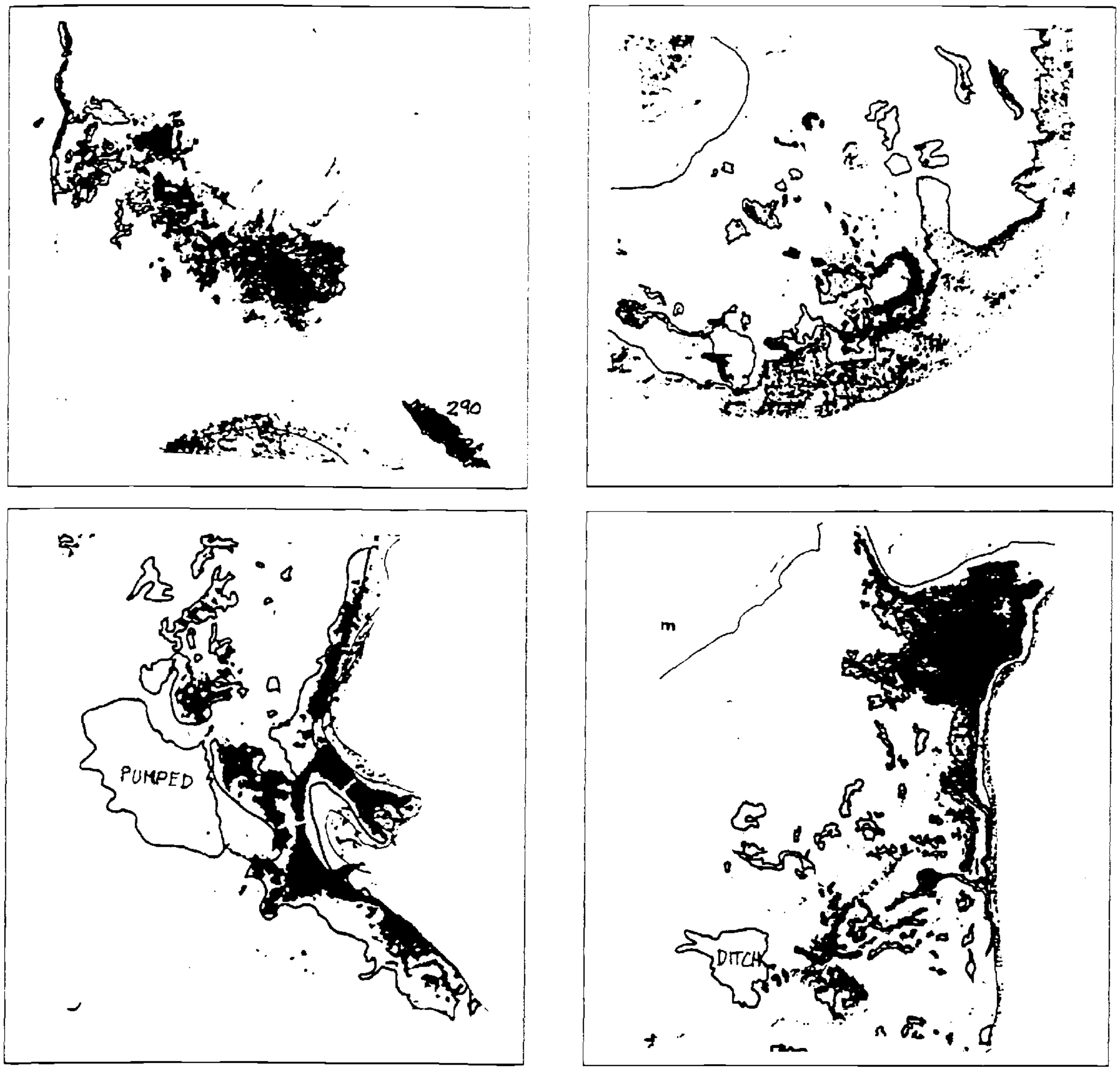


Figure IV-1-5. Maps of class 1 representing open water (shaded area) from the unsupervised classification of 17 June 1997 DMSV four-band image compared with manual photointerpreted permanent ponds (outlines) in Area A, Areas D and C/D, Area B, and Area C on Eagle River Flats.

rush is a common emergent species in the permanent ponds. The DMSV classification also showed that by 17 June neither of the permanent ponds that had been ditched (Bread Truck Pond; Fig. IV-1-5d) and pumped (C Pond; Fig. IV-1-5c) contained water.

Tidal creek erosion

To determine if DMSV classification could be used to monitor gully erosion, which can lead to natural pond drainage, we also overlaid the 17 June 1997 class 6 (bare silt) on the original 1993 coverage of eroded tidal creeks or gully channels. An example of this (Fig. IV-1-6) shows the bare silt extension of "Coastal 5" gully suggesting that it has eroded back almost 70 m since 1993. This agrees with field-measured rates of about 40 m from July 1993 to October 1995 (Lawson et al. 1996). Also shown are smaller areas of lateral erosion where the gully banks have been undercut, with resulting slump into the channel. This analysis suggests that DMSV may be a useful method for remote sensing of tidal creek erosion. The levees and area surrounding these tidal creeks are generally well vegetated, so any erosion and exposure of silt at the head or laterally along the gully walls will be easily detected by the image classification.

Spectrographic measurements

The spectral signature of the exposed sediments on the bottom of two intermittent ponds (158 and 159) were measured and the ratio between the raw radiance for pond 159/

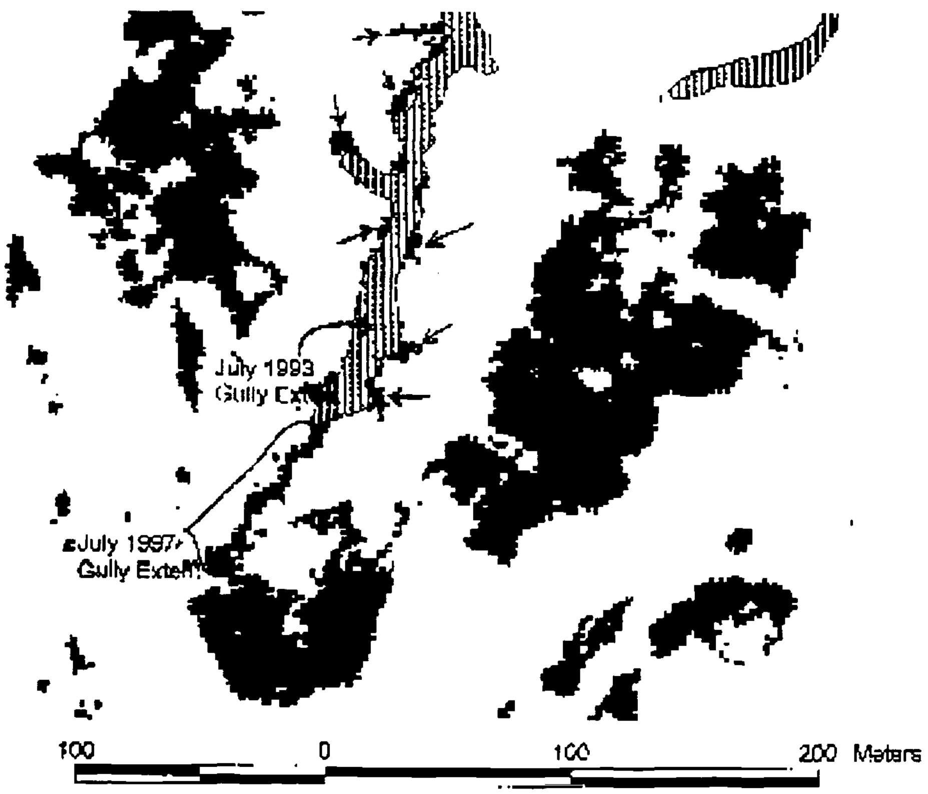


Figure IV-1-6. Mapped eroded tidal creek or gully areas on ERF in July 1993 (area with vertical lines) based on photointerpretation compared with class 6 of an unsupervised classification of a 17 June 1997 digital four-band multispectral video image (black areas). The arrows point to lateral erosion areas along the sides of gullies. Gully (coastal 5) showed headward erosion of almost 70 m between July 1993 and June 1997.

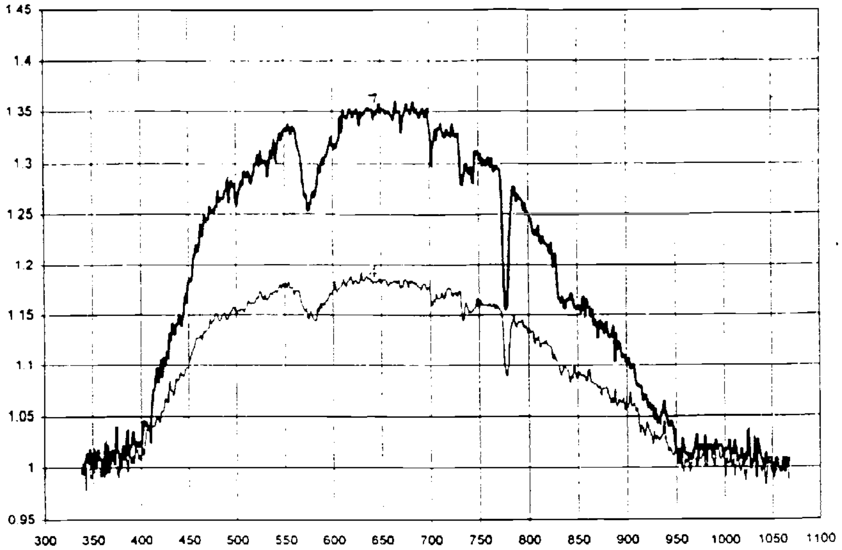


Figure IV-1-7. Ratio of surface radiance over wavelength bands from 350 to 1050 nm from the exposed silt bottom of two dewatered ponds (Pond 159/ Pond 158) on 12 June 1997 determined with an ASD Spectrometer held 1 m above the surface.

158 compared (Fig. IV-1-7). Soil moisture measurements with a tensiometer showed that at the time these measurements were made on 17 July 1997, Pond 158 was drier than pond 159 (–198 mbars in 158 vs. –63 mbars in 159). The largest difference or ratio between radiance of the two ponds was at 650 nm, or band 2 of the DMSV. It was therefore determined that this would be the best band to detect soil moisture differences and change.

Change detection

This study tested the use of DMSV to monitor pond dewatering and subaerial exposure of pond bottom sediments. The test was carried out by evaluating changes in the extent of standing water in specific ponds between 11 June and 17 June 1997, when the two images were obtained.

Changes in the exposure of bare silt due to drying between 11 June and 17 June could be detected for some intermittent pond areas by overlaying the bare silt classes for 11 June on the bare silt class for 17 June (Fig. IV-1-8). This showed that some areas of pond bottom on the west side of C Pond not exposed on 11 June had become exposed by 17 June.

Another change assessment technique involves producing a three-band color composite (red–green–blue) image consisting of using the same band (band 2, or 650 nm) for 17 June (red), 11 June (green) and 11 June (blue). If the reflectance of band 2 changed between the two dates due to change in water level and drying out of the bottom sediments, then that area will have a shade of red in the new image. If no change occurs (red = green = blue) the image remains a gray tone. The three-band image was classified, and the class representing the greatest change was identified. Figure IV-1-9 shows the extent of change in four intermittent ponds; the shaded area or class represents the part of the pond where the water level dropped to expose the bottom sediments between 11 June and 17 June. The striped area had standing water on 11 June but on 17 June was exposed silt. Two of these ponds (279 and 288) were visited in mid-July and still contained 5 and 20% water cover, respectively, similar to that in mid-June.

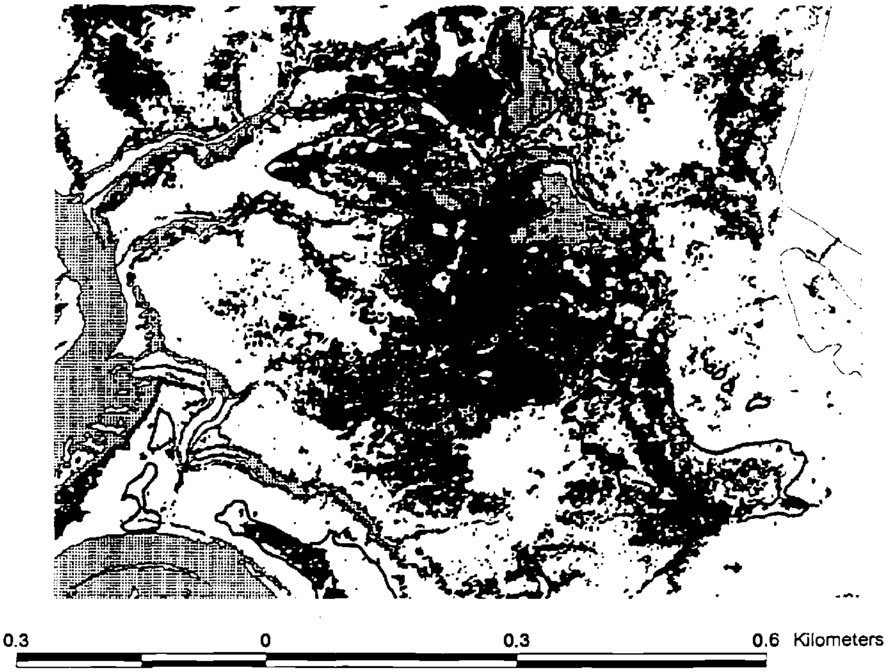


Figure IV-1-8. Overlay comparison between class 7 from the unsupervised classification of DMSV 11 June image representing bare silt or exposed pond sediments on top (dark shading) and class 6 from 17 June classification (stippled) representing new areas of exposed silt in the C Pond area.

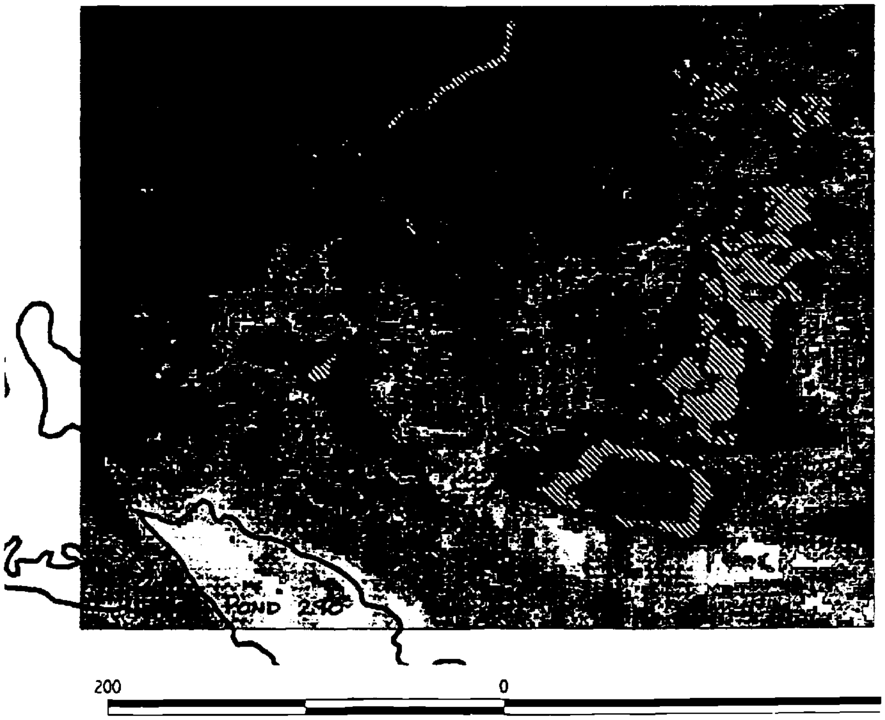


Figure IV-1-9. Change assessment for an area near Otter Creek Pond (290) (lower left). The striped area represents the class that had the greatest spectral change in band 2 between 11 June and 17 June 1997. Gray scales represent the other nine classes.

DISCUSSION AND CONCLUSIONS

The pond inventory in mid-July showed that the original pond classification produced by photointerpretation of July 1993 images is well within acceptable accuracy limits. The inventory also suggests that the entire surface of an intermittent ponds may not become exposed during a drying cycle due to irregularities in the surface topography. Pools and small areas of these intermittent ponds may remain flooded, even during very dry summers with skipped tides. The inventory also suggests that ponds form and then may drain by processes including gully erosion (Lawson et al. 1996).

Acquisition and analysis of digital imagery is a viable method for identifying bare silt areas, including pond bottoms that have become dewatered due to evaporation. This information is useful for monitoring and identifying ponds where natural remediation of white phosphorus is likely. Only those ponds without standing water can undergo further sediment drying necessary for sublimation. The DMSV was not used to detect actual surface soil moisture levels in different ponds, but we plan to conduct supervised classifications of the imagery to accomplish this in conjunction with spectrophotometer data. The classified imagery can also be used efficiently to monitor both the lateral and headward erosion of tidal creeks or gullies to predict possible pond drainage by gully capture.

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OU-C 32424

IV-2. GIS REMEDIATION DATABASE FOR EAGLE RIVER FLATS

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U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, NH

DATABASE DESIGN AND CONTENTS

The Eagle River Flats GIS acts as a centralized computerized storage of data in a spatial and historical context covering the entire project period from 1991 to 1997. The ERF GIS database has been constructed and refined over the past five years and now consists of over 100 coverages organized and catalogued according to Figure IV-2-1. The database design provides libraries in six major areas: 1) physical and biological features, 2) digital imagery, 3) waterfowl, 4) white phosphorus, 5) monitoring, and 6) remediation actions.

The *features and image libraries* include coverages for both Eagle River Flats and the surrounding region. Included are all natural features in ERF, such as ponds, tidal creeks, the Eagle River, mudbanks, upland and coastal boundaries, and vegetation. Artillery features include targets and crater densities. Accuracy assessments of some of these features are also included. The image library includes all of the digital imagery of ERF. Table IV-2-1 shows a comprehensive list of Eagle River Flats aerial photography and other imagery.

The *waterfowl library* includes census, mortality, and telemetry data. The aerial census coverages are still being developed, while mortality data along transects are stored in the database but are no longer being acquired. Telemetry data being acquired by the National Wildlife Research Center (Ft. Collins, CO) to monitor waterfowl movement and death are being input into the GIS, and movement patterns and mortality locations are being analyzed.

The white phosphorus library includes about 2700 point grab sediment and water samples collected in ERF and analyzed for white phosphorus since 1990. Two additions to this library were made in 1997: 1) a database for composite sampling by M.E. Walsh involving areas in which subsamples were collected and composited, and 2) a planted WP particle database with point locations where particles of known mass were planted in remediated ponds and harvested to determine change in mass over time.

The remediation library is also new in 1997 and includes coverages for pond remediation actions that have taken place. This includes draining through ditching, pumping, barriers on the bottoms of ponds, and dredging. The locations of these actions and the actual ditches, pump locations, and dredge areas are included, together with the dates on which these actions were initiated and the person responsible.

The monitoring library is under development but will include past and present studies dealing with changes and conditions in the physical, chemical, and biological environment on ERF, as well as survey data that have been obtained over the years. The survey data will be used to build an elevation model for the various ponds to be treated.

HARDWARE AND SOFTWARE

The ERF GIS database is stored as both Unix ARC/INFO and PC ARCVIEW files. The ARC/INFO database is stored on a Sun

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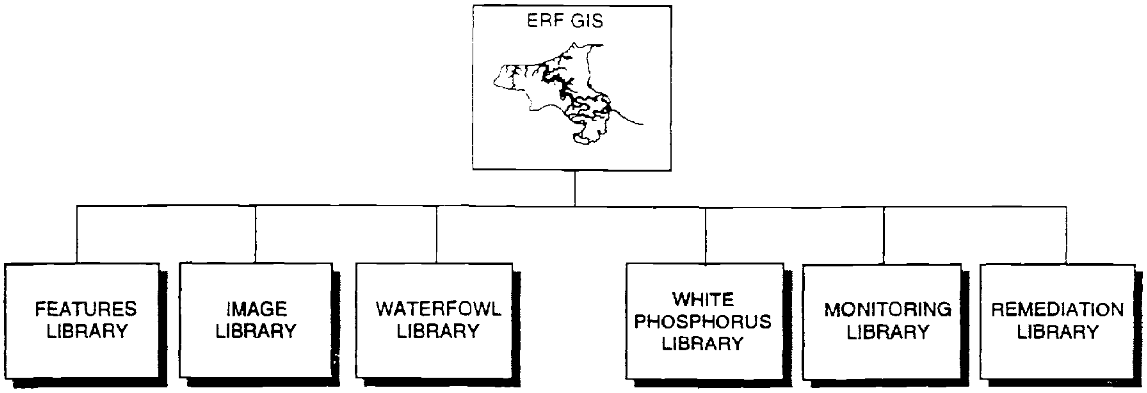
ERF GIS
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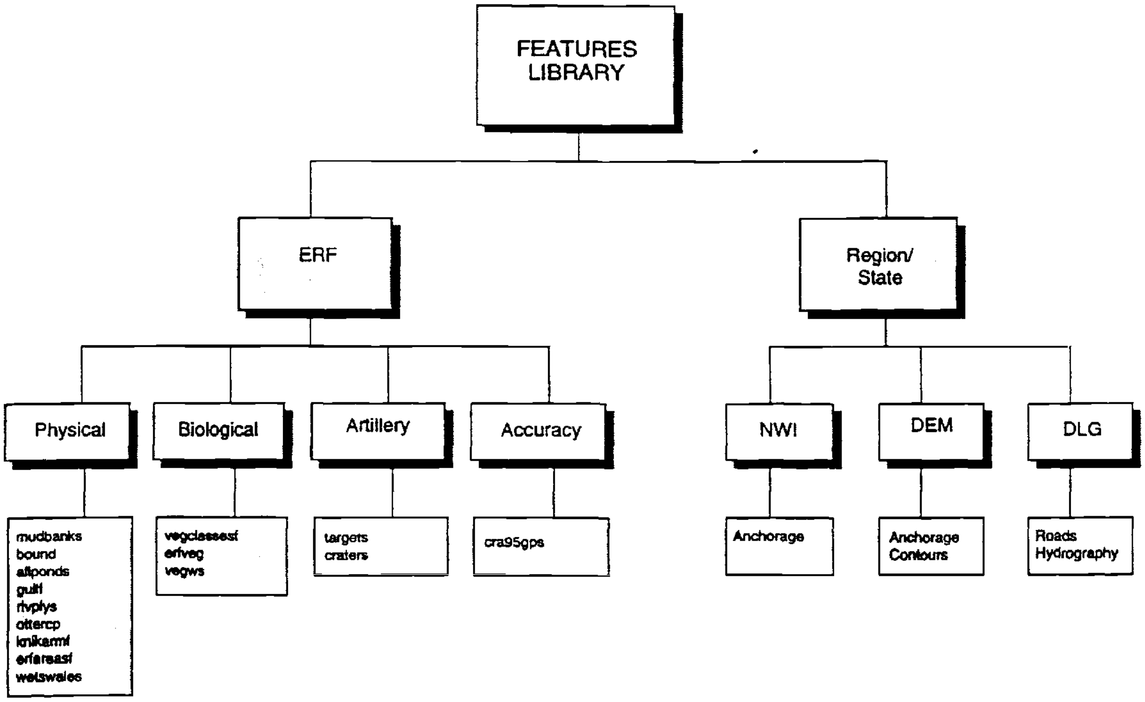
IMAGE LIBRARY
WATERFOWL LIBRARY
WHITE PHOSPHORUS LIBRARY
MONITORING LIBRARY
REMEDIATION LIBRARY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Region/ State
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Artillery
Accuracy
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DEM
DLG
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bound
allponds
gullf
rivplys
ottercp
knikarmf
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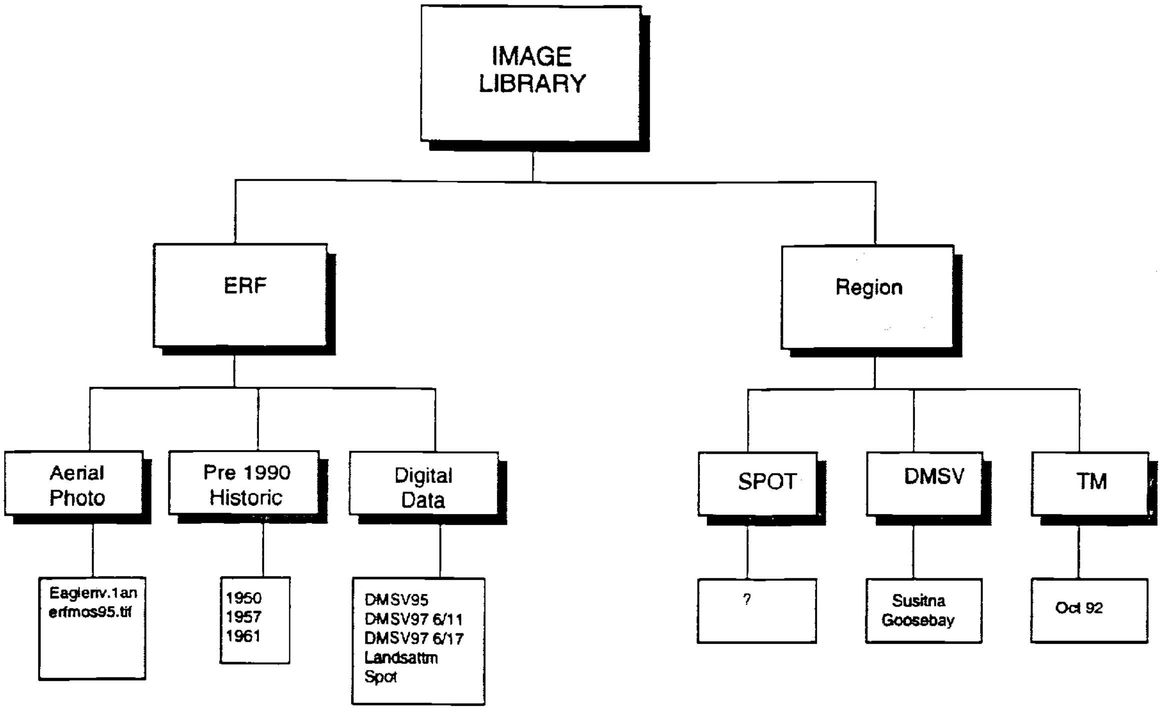
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ERF
Region
Aerial Photo
Pre 1990 Historic
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Landsattm
Spot
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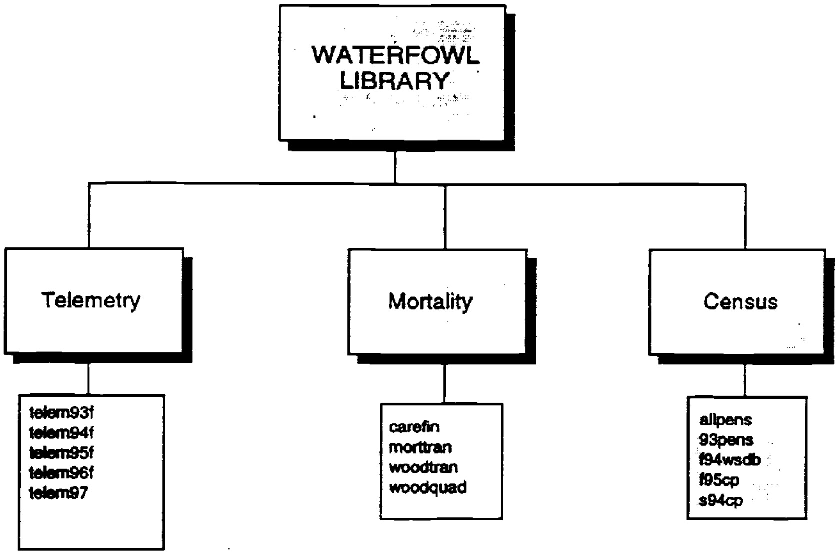
Susitna
Goosebay
Oct 92


WATERFOWL LIBRARY
Telemetry
Mortality
Census
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morttran
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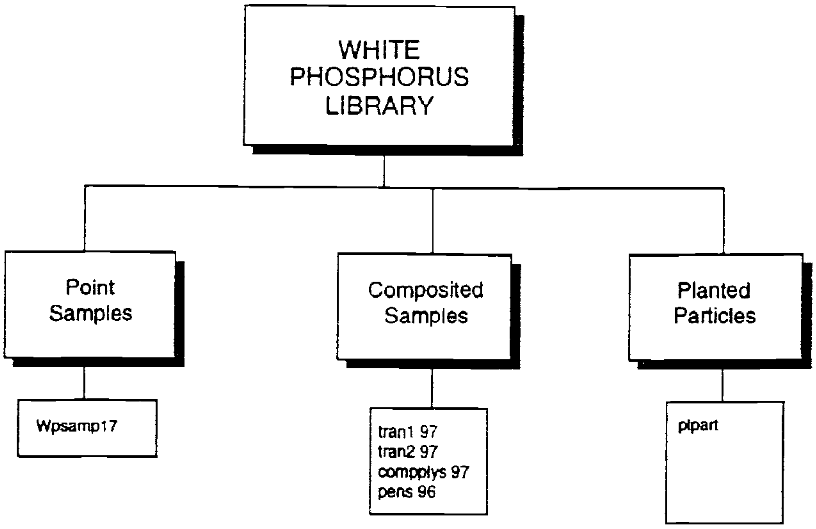
WHITE PHOSPHORUS LIBRARY
Point Samples
Composited Samples
Planted Particles
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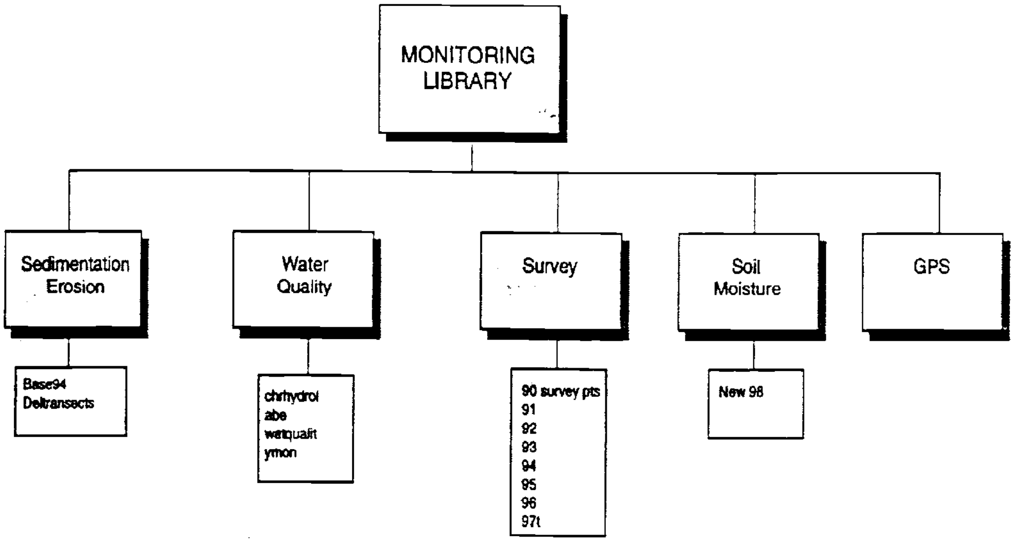
tran1 97
tran2 97
compplys 97
pens 96
plpart


MONITORING LIBRARY
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GPS
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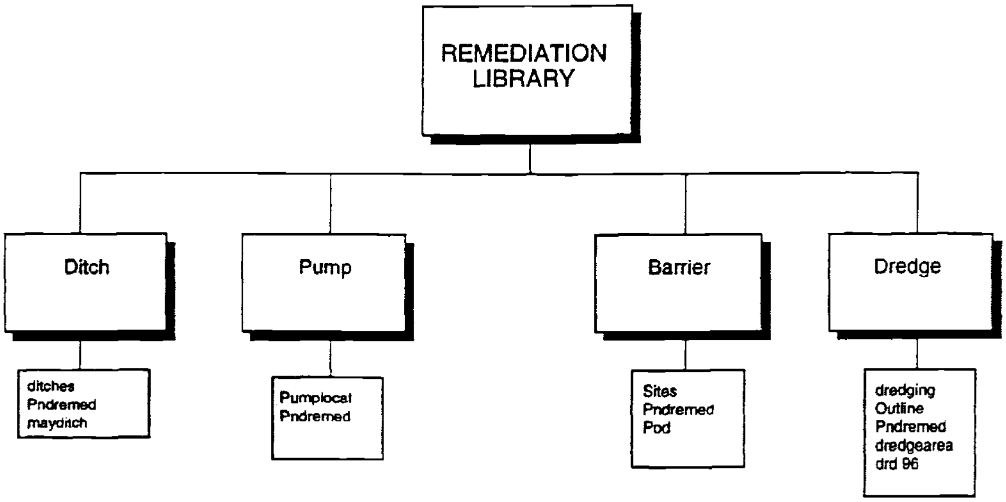
REMEDIATION LIBRARY
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Pump
Barrier
Dredge
ditches
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maydirch
Pumplocat
Pndremed
Sites
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Pod
dredging
Outline
Pndremed
dredgearea
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Table IV-2-1. Imagery of Eagle River Flats either archived as hard copy at CRREL or as digital images(*) in the ERF database. Lawson et al refers to photos printed in CRREL Reports 96-9.

Year	Photo date	Type	Scale	Date prev. tide*	Time since high tide	Other comments
1950	8 August	B-W	1" = 1500 ft	?		Lawson et al. 1996
1953	27 June	B-W	High alt	?		
1957	12 June	B-W		?	?	
1960	30 Aug	B-W	1 : 60000	10 Aug	20 days	
1962	17 May	B-W	1 : 6000	7 May	10	
1967	Unknown	B-W				Lawson et al. 1996
1972	? July	Cir				
1972	9 Aug	B-W		13 July	27	
1974	7 May	B-W	1" = 1000 ft	April ?		
1977	Unknown					
1978	? Aug					
1984	12 Aug	CIR	High alt	1 Aug	11	
1984	2 Sept	True color	1" = 1000 ft	31 Aug	2	
1986*	12 Sept	Landsat TM		7 Sept	5	
1986	5 Oct	True color	1" = 1000 ft	5 Oct	0	
1988	4 Aug	B-W	1" = 3000 ft	3 Aug	1	
1990	24 May	True color	1 : 21,000	24 May	0	
1991	21 June	Cir	1" = 600 ft	15 Jun	6	
1991*	21 June	CASI	2.5 m pixel	15 Jun	6	
1992	22 May	Cir	1" = 500 ft	7 May	15	Lawson et al. 1996
1992	2 Aug	Cir	1" = 1000 ft	2 Aug	0	
1993*	8 July	B-W orthoph		8 May	60	
1993	8 July	Cir		8 May	60	Lawson et al. 1996
1994	30 Aug	Cir	1" = 600 ft	11 Aug	19	
1994*	30 Aug	Digital cir orthophoto	1	11 Aug	19	
1995	16 Aug	Cir	1" = 600 ft	14 Aug	2	
1995*	11 Aug	DMSV	1.5 m pixels	11 Aug	0	450,550 650,770 nmbands
1995	9 Oct	True color	1" = 1200 ft	9 Oct	0	Lawson et al. 1996
1996	1 Oct	True color	1" = 500 ft	1 Oct	0	
1997*	June 11 June 17	DMSV	1.5 m pixels	May 8	34 40	550,650 770,950 nm bands
1997	July 27	True color	1" = 500 ft	July 23	4	
1997	May 24	True color	1" = 1000 ft	May 8	16	
1997	Aug 14	B-W	1" = 2500 ft	July 22	21	
1997*	May 6 May 12 Aug 12	B-W orthophoto	0.5 m pixels	May 6 May 9 July 25	0 3 18	Digital

Sparcstation 20 workstation connected to the local area Ethernet TCP/IP network at CRREL in Hanover, New Hampshire. The Sparcstation is configured with 32-MB random access memory (RAM), a 64-MB SIMM memory expansion chip, 4.0- and 1.0-GB internal drives, a 9 9-GB SCSI hard disc, a 5-GB, 8-mm tape drive, a CD-ROM drive, a SX 24-bit graphics card, and a 20-in.-high resolution monitor. Hardware accessible over the network includes scanners, printers, an Altek A31 digitizer, and an HP650C E-size plotter. The software includes a three-node ARC/INFO license from Environmental Systems Research Institute (ESRI).

ARCVIEW coverages are stored on both an

optical disk and a Jaz drive connected to two PCs. Software on these machines includes ARCVIEW (ESRI), Microsoft Excel for constructing spreadsheets, Trimble PFinder Office v.2.0 for collecting and processing geobased data, Trimble QuickPlan Version 1.2 for forecasting the availability of satellites for geopositioning, and Clark University's IDRISI Version 4.1 for handling raster-based image data. Two GPS units include a 12-channel Trimble Pathfinder Pro XR and an 8-channel Pro XL.

Personnel currently working on the ERF GIS include an ARC/INFO software technician (Peter Berger) and an ERF-GIS data manager, photointerpreter and director (C.H. Racine).

APPLICATION OF THE DATABASE

The major remediation objective at ERF is the reduction of dabbling duck mortality by reducing the WP exposure pathways or by reducing the amounts of WP. The database can be used to support this objective by helping to 1) identify clean up sites, 2) select an appropriate technology and track its use, and 3) evaluate success and habitat change resulting from the clean-up.

For example, to make the site selection of hot zones or high-risk areas for clean-up, several coverages are useful, including:

- Dabbling duck pond habitat identification,
- WP amounts and crater density surrogate,
- Location of past waterfowl mortality,
- Waterfowl usage-aerial census and telemetry.

To match technology and site conditions, the following coverages are useful:

- Pond type (natural attenuation for intermittent ponds vs. active clean-up in permanent ponds),
- Proximity to eroding gully, such as for natural or enforced drainage,
- Water depth and sediment organic content to evaluate drying potential,
- Pond size and access.

FY97 OBJECTIVES

The major objectives for the FY97 ERF GIS database work include:

- Maintain and update existing covers,
- Input and analyze 1997 radiotelemetry data for NWRC,
- Develop new databases for WP composite sampling, WP planted particles, and remediation pond sites.

RESULTS

Maintain and update existing databases

1. WP point samples added (WPSAMP17)
2. TELEMETRY DATABASE

- Past 5 years with 14,000 point locations of daily movements mostly mallards
- 1996 and 97 with 54 and 81 mort.trans.
- Analysis can provide information on:
  - —Use levels of certain areas, ponds, or habitats,
  - —Hazing and disturbance effects on movements,
  - —Possible WP poisoning locations.

Construction of new coverages

Remediation coverages

This new coverage consists of pond areas that have been or are being treated by any of the active technologies, not including dredging or drainage by pumping or ditching. The attributes of this coverage include pond ID, method, date of treatment, person responsible, and a lookup table for related databases such as white phosphorus sampling. Where a ditch, dredge, or pump action has occurred, these features are included in separate coverages to show the actual ditch, dredge area, or pump location.

White phosphorus

Composite samples. New techniques have been developed by Walsh et al. (1997) for composite sampling of sediments for white phosphorus contamination. These methods attempt to avoid the problem of extreme spatial heterogeneity in WP concentrations and the cost of collecting an unrealistically large numbers of discrete samples to evaluate cleanup success. During 1996 a method to sample and composite sediment samples on a grid pattern was developed and applied to several areas during 1997. The results of this sampling is contained in an area coverage representing the area composited along with the grid size, the number of subsamples pooled, and the resultant white phosphorus concentrations for replicates taken from these pooled subsamples for the composited area.

Planted particles. Another method for evaluating the success of pond sediment drying by natural attenuation, draining, or pumping is to plant particles of white phosphorus of known size and mass in the treated pond and then harvest these at intervals and determine their size and mass. During 1997 this method was used by M.E. Walsh in both the Bread Truck Pond and Pond C, which were ditched and pumped, respectively. The point coverage for planted particles provides the particle planting and harvest dates, original mass and size, and final size or mass, as well as percent attenuation.

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