Interagency Expanded Site Investigation

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

FY 96 Report

July 1997

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

INTERAGENCY EXPANDED SITE INVESTIGATION: EVALUATION OF WHITE PHOSPHORUS CONTAMINATION AND POTENTIAL TREATABILITY AT EAGLE RIVER FLATS, ALASKA

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CONTRIBUTORS

M.E. Walsh, C. Racine, C. Collins, M.R. Walsh, Maj. M. Meeks, R. Bailey
U.S. Army Cold Regions Research and Engineering Laboratory

J. Cummings, R. Johnson, K. Gruver, P. Pochop, J. Davis
U.S. Department of Agriculture, National Wildlife Research Center, Fort Collins, CO

C. Rossi
U.S. Department of Agriculture, Animal Damage Control Center, Palmer, AK

W. Eldridge
U.S. Fish and Wildlife Service, Division of Migratory Bird Management, Anchorage, AK

L. Reitsma, B. Steele, S. Burson, III
New England Institute for Landscape Ecology, Canaan, NH

Points of Contact:

W.A. Gossweiler
Director of Public Works
600 Richardson Drive #6500
ATTN: APVR-PW-ENV
Fort Richardson, Alaska 99505
(907) 384-3017
(907) 384-3047 Fax

Charles M. Collins
CRREL
72 Lyme Road
Hanover, NH 03755
(907) 353-5180
(907) 353- 5142 Fax

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I. EXECUTIVE SUMMARY

INTRODUCTION

This is the seventh annual report (1990–1996) describing the results of white phosphorus contamination studies in Eagle River Flats (ERF), a 865-ha estuarine salt marsh artillery impact range on Ft. Richardson, Alaska. Waterfowl mortality occurs here as a result of ingestion of white phosphorus (WP) particles from artillery smoke rounds. ERF is the first documented case of WP poisoning on a US Army training area, although since then other artillery range training areas have been found to be contaminated with WP. In 1991 and 1992 efforts were focused on determining the nature and extent of WP contamination in ERF and on the monitoring of waterfowl mortality. In 1992 it was determined that although WP has a reputation for being easily oxidized, it is very stable as a solid particle underwater and in saturated sediments where waterfowl feed. In 1993 more detailed studies of the problem were initiated including WP toxicology, invertebrate and fish studies, and radiotelemetry of waterfowl, shorebirds, and eagles to monitor movement and mortality. Investigations of the physical system processes occurring in ERF began in 1992 and continued through 1995. Waterfowl censusing by aerial survey began in 1989 and have continued to the present. The use of ground based transects to determine waterfowl mortality, originally started in 1991, was reduced in 1996 due to safety concerns. Conversely, the use of radiotelemetry of waterfowl as a method of determining exposure risk and an indicator of rates of mortality was expanded in 1996.

Treatability studies were a major focus of the 1996 work and included remote-controlled dredging, pond draining, and natural attenuation. The ERF spatial database continued to be updated and a QA/QC audit was conducted prior to its tranfer to a private contractor, CH2MHill. The spatal database is being used by CH2MHill to help in the preparation of CERCLA documentation for ERF.

II-1. WATERBIRD UTILIZATION OF EAGLE RIVER FLATS AND UPPER COOK INLET: APRIL–OCTOBER 1996

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

Thirty-four aerial surveys of Eagle River Flats (ERF) were conducted during spring, summer and fall of 1996 as part of ongoing waterfowl mortality studies sponsored by the U.S. Army. Generally spring was late in 1996, so ERF received less use by ducks and swans than in previous years. Use by geese was similar to other years. The summer was very dry in 1996, but some permanent ponds retained water and several broods of ducks and geese were observed. Fall tides flooded most of ERF in late August. The fall was generally mild, which allowed waterfowl to move through the region at a leisurely pace and there were no large build-ups in waterfowl populations. Numbers of swans on ERF in fall were lower in 1996 than in previous years. Numbers of ducks and geese were higher than in previous years, possibly due to the decreased human activity and hazing in 1996. Swans used Areas A and B the most during fall. Geese used Coastal East and West the most, and ducks were more evenly distributed in fall, utilizing Coastal West and Area B slightly more than the other areas.

II-2. WATERFOWL MORTALITY ON EAGLE RIVER FLATS

Benjamin B. Steele, Leonard R. Reitsma and Sherman L. Burson, III
New England Institute for Landscape Ecology

New safety regulations precluded walking on permanent mortality transects in 1996. Counts of ducks from Cole Point indicated duck populations similar to other years. Duck use of Bread Truck Pond was substantially reduced but not eliminated by the excavation of a drainage ditch. Canoe surveys of Racine Island and Area A indicated that mortality is still occurring in these areas.

II-3. MOVEMENT, DISTRIBUTION, AND RELATIVE RISK OF MALLARDS AND BALD EAGLES USING EAGLE RIVER FLATS: 1996

John L. Cummings, Richard E. Johnson, Kenneth S. Gruver, Patricia A. Pochop, and James E. Davis
Denver Wildlife Research Center
Charles H. Racine
U.S. Army Cold Regions Research and Engineering Laboratory

We determined spatial distribution, movements, turnover rate, and mortality of mallards using Eagle River Flats, Fort Richardson, Alaska, during fall migration, August 3 to October 15, 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. Tracking data indicated that transmitters did not appear to inhibit movements or activities of either ducks. Mallard movements and distribution indicate 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 mortality 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%, respectively). During 1994 and 1995, 10 and 14 bald eagles were fitted with satellite transmitters. As of December 1996, only one transmitter remains active. That eagle is near Cordova, Alaska. No eagle mortality has been documented from instrumented birds, even though eagles scavenge dead ducks (including instrumented ducks). Indications from the 1996 data, compared to 1993 and 1995 mallard data, are that hazing is having a positive effect on the redistribution of waterfowl to uncontaminated areas on ERF.

III-1. REPORT OF USDA–APHIS–ANIMAL DAMAGE CONTROL FOR THE U.S. ARMY AT EAGLE RIVER FLATS, APRIL–OCTOBER 1996

Corey Rossi
Alaska District, USDA-APHIS-Animal Damage Control

From April 15 to May 31, 1996 USDA–APHIS–Animal Damage Control (ADC) continued efforts to keep migratory waterfowl from being poisoned by white phosphorus in the Eagle River Flats (ERF) Impact Area at Ft. Richardson, Alaska. With only minor exceptions, ADC employed the same techniques that have proven to be successful in previous seasons. Hazing methods included propane cannons and visual scare devices such as scarecrows and mylar tape. Additional static devices included eagle effigies and an electronic guard. However, ADC 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. Two ADC personnel walked or canoed through the areas of concern 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. From April 15 to May 31 a total of 253 staff hours were expended in the field hazing a total of 1575 ducks and 10 Canada geese. There were no waterfowl moralities found by ADC personnel during the spring of 1996.

In the fall, hazing was delayed until September 23 to allow researchers to monitor duck movements, marsh use, and mortality independent of hazing activities. Due to the more stringent safety requirements, all access into ERF for hazing was to be done by hovercraft. However, by the time the hazing operation was to begin, only one of the four hovercraft available was even partially functional. Because of the lack of functional hovercraft from September 23 to October 26, no waterfowl were hazed by ADC personnel. In excess of 100 staff hours and considerable funds were expended repairing hovercrafts.

III-2. DEMONSTRATION OF SAMPLE COMPOSITING METHODS TO DETECT WHITE PHOSPHORUS PARTICLES

Marianne E. Walsh, Charles M. Collins and Ronald N. Bailey
U.S. Army Cold Regions Research and Engineering Laboratory

White phosphorus is a difficult contaminant to characterize in the environment. Spatial heterogeneity of concentration estimates is extreme, varying over many orders of magnitude for closely spaced discrete samples. Therefore, any attempt to determine remediation success at ERF based on concentrations found in sediment samples would be costly due to the enormous number of samples required to make an informed decision. Because the goal of remediation at Eagle River Flats is to reduce waterfowl mortality, we developed a composite sampling method designed specifically to determine the presence of white phosphorus particles (the form responsible for acute poisoning of waterfowl at ERF), and we demonstrated the feasibility of this approach in a contaminated pond in Area C.

To form each composite, many small samples were pooled and passed through a 0.59-mm mesh to remove the fine-grain material. The material left on the mesh was examined for white phosphorus particles. The samples were collected on square and triangular grids, and the distance between samples was based on the assumption that most of the available white phosphorus is located in hot spots with radii of approximately 1 m. Unless the number of hot spots is large, the distance between samples must be on the order of 2 m to maintain a low risk of not hitting a single hot spot. The area we sampled was highly contaminated, and white phosphorus particles are still abundant within the top 9 cm of sediment.

For this study we also collected and analyzed individual discrete samples. The concentrations found in these samples showed that sites with high white phosphorus concentration and containing solid pieces of white phosphorus are indeed located within small areas (hot spots) punctuating a much larger area containing low concentrations of white phosphorus. This spatial heterogeneity necessitates closely spaced sampling, which in turn requires compositing to reduce analytical costs.

We believe composite sampling will provide cost-effective data upon which decisions may be made as to whether an area remains contaminated with white phosphorus particles.

III-3. POND DRAINING TREATABILITY STUDY: 1996 STUDIES—THE DRAINING OF BREAD TRUCK POND

Charles M. Collins, Maj. Michael T. Meeks, Marianne E. Walsh, and Ronald N. Bailey
U.S. Army Cold Regions Research and Engineering Laboratory

On 30 April 1996 the Army conducted an operation to excavate a drainage ditch to drain a pond within Eagle River Flats using explosives. The pond was contaminated with white phosphorus from smoke munitions previously fired into the area. Because of a possibility of encountering unexploded ordnance (UXO) if the ditch was excavated using standard mechanical techniques, the ditch was excavated using military explosives. The operation was conducted by personnel of the 23rd Engineer Co., Ft. Richardson, as a training exercise, with the operation planned and coordinated by CRREL. The ditch was excavated in two stages. Seventeen 40-lb shaped charges were used to punch a series of 1-ft-diameter pilot holes straight down into the frozen ground and ice of the BT pond and the adjacent land to a depth of 1.5–2.4 m. The total amount of explosives detonated in this first explosion was approximately 320 kg (700 lb). For the second stage, a 40-lb cratering charge was placed in each of the pilot holes created by the shaped charges. The cratering charges were linked together with detonation cord and then detonated. The total amount of explosives detonated in this second explosion was also approximately 320 kg (700 lb). The evenly spaced cratering charges produced a series of overlapping craters forming a ditch approximately 1.5 m deep, 3–4.5 m wide and 90 m long. Several short sections of blockages in the ditch prevented full flow through the ditch until a series of flooding high tides later in the spring eroded them out. Full flow through the ditch and drainage of the pond started on 22 May. By 21 June the BT pond water level was 30 cm below the normal water level and occupied less than 10% of the original pond surface area. Prior to the next series of flooding tides starting 1 July, the exposed pond bottom had started to dry out and the surface cracked. Dataloggers continued to monitor water levels, soil temperature, and soil moisture conditions throughout the summer and fall.

III-4. MONITORING OF THE DREDGING PROGRAM AT EAGLE RIVER FLATS, ALASKA

Michael R. Walsh and Charles M. Collins
U.S. Army Cold Regions Research and Engineering Laboratory

Investigations into the fate and persistence of white phosphorus (WP) at Eagle River Flats (ERF), Alaska, indicate that WP is persistent in the permanently ponded areas of ERF. Several remediation strategies for these WP-contaminated areas were initiated or implemented in the 1994–1996 field seasons encompassing a range of methodologies including covering contaminated areas, designing equipment for the draining of large contiguous ponds, enhancing natural attenuation in intermittently flooded areas, pond draining through explosive trenching, and dredging. The objective of this project is to monitor the commercial implementation of a small, remote-controlled dredge designed to remove sediments from contaminated ponded areas and to continue an efficacy study of the treatment of the spoils in an open retention basin. The treatment method will be the natural attenuation of the white phosphorus, once conditions of the sediments in the basin are conducive to sublimation.

Dredging was chosen as a method of remediation because of the positive removal of the contaminated material and the ability to treat the material in a controlled environment. By using a small remote-controlled dredge, limited areas could be dredged, and transport of the contaminated material (spoils) to a retention basin for treatment can be quickly and efficiently conducted. Environmental impact to the salt marsh system, although not negligible, can be minimized through a careful dredging strategy. Because of the presence of unexploded ordnance, a non-manned system was required.

This is the third year of the dredging project at Eagle River Flats. The first year primarily involved processing a contract for the dredge equipment; designing, constructing, and testing a spoils retention basin; integrating specialized equipment to the dredge; getting the leased equipment operational; and test dredging a small area at the Flats. During 1995 three tasks were undertaken: continued investigation of the hydrological properties of the retention basin; dredge operations; and initiation of the attenuation study in the Basin. This year, 1996, the operation of the equipment was turned over to a local contractor. An area was designated for dredging, and technical assistance was provided for the initial setup and operation of the equipment.

Although all sampling and testing was originally cut from the project proposal, limited sampling and testing were conducted in the basin and on the spoils entering the basin. Datalogger stations were re-installed in the basin to monitor such parameters as air and soil temperature, soil moisture, and water level. Prior to the initiation of dredging, two percolation tests were performed in the basin. Both tests indicated a percolation rate above the acceptable level of 10^{-6} cm/s. The higher percolation rates are probably due to the reduction in liner density due to the severe freeze–thaw cycling that occurred over the previous winter, when lack of snow exposed the liner to solar and temperature variations. The lack of funds for improving the liner, as well as the proximity of the test results to acceptable levels, resulted in the use of the basin in the condition found.

In December 1995 a list of possible improvements to the equipment was given to the contractor. A few of these changes were implemented prior to dredging and more during dredging as the contractor saw the need for them after familiarization with the equipment and operation. The primary change to the equipment was the placement of the auger drive behind the augerhead, rather than on its side. This change was not implemented as recommended, however, and the 3-in. protrusion on the side of the augerhead enclosing the drive continues to be problematic. Stress on the augerhead cutter resulted in the breakage of one auger assembly, which was quickly replaced by the contractor using one of the spare units on hand. Some improvements to the system were made by the contractor, and the system continues to work fairly well. A patent application has been submitted for this device.

Anchoring points continue to be problematic. The contractor was convinced shortly after startup that the lateral winch system was not feasible in the Flats environment, and a manually adjustable system was devised using telephone pole anchors, similar to the anchoring system used last season. This eliminated the need for helicopter support, thereby saving a substantial sum of money and logistical effort. Further work on this system is required. Improvements to the spoils transfer line eliminated any blow-outs like those experienced last year. The contractor is currently looking into a radio-control package to improve reliability of the dredge control system.

In September, funding was received to enable a trip to collect and analyze bottom samples and to survey the area dredged. Survey data indicate that the dredged depth is around 51 cm, significantly less than the 90 cm specified. The area dredged is approximately 0.29 hectares. Results of the spoils line sample analyses indicate that contaminated material continues to be transferred from the Flats to the retention basin. Of 12 spoils samples analyzed, three were contaminated with white phosphorous. One of five water samples taken from the outflow line was slightly contaminated (<1 μg/L). The small number of samples taken limits the conclusions that can be drawn from the data, although results are similar to the larger sampling program conducted in 1995.

IV-1. FY96 EAGLE RIVER FLATS GIS DATABASE

Charles H. Racine
U.S. Army Cold Regions Research and Engineering Laboratory

In 1996 the ERF spatial database was transferred to CH2MHILL for use in the preparation of the Remedial Investigation (RI) report, an important CERCLA document. As part of this transfer, an audit and QA/QC procedures were conducted on the database. In the RI document the GIS database was analyzed extensively to conduct an ecological risk assessment and thereby identify areas in ERF of highest risk to waterfowl. Of major importance to these conclusions were coverages developed and updated in 1996, including the Waterfowl Database, consisting of mortality transect data, telemetry data, and some census data from past years. The WP Database was also critical to this document and now contains about 2700 samples collected in ERF and analyzed for WP. Finally, the Landcover Database, showing crater density and the locations and distributions of ponds used by waterfowl, was critical to identifying high-risk sites. Other accomplishments in 1996 include transfer of the database to the USARAK GIS project, telemetry data analysis, and future planning of a remediation monitoring and evaluation database.

II-1. WATERBIRD UTILIZATION OF EAGLE RIVER FLATS AND UPPER COOK INLET: APRIL–OCTOBER 1996

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

INTRODUCTION

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

Weekly waterbird surveys of other Upper Cook Inlet (UCI) marshes, conducted during fall by the F&WS and sponsored by Elmendorf Air Force Base, U.S. Air Force, will be referenced in this report.

STUDY AREA

Eagle River Flats is a salt marsh complex comprising approximately 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 CRREL (1995). The UCI marshes surveyed during fall as part of the Air Force study in-

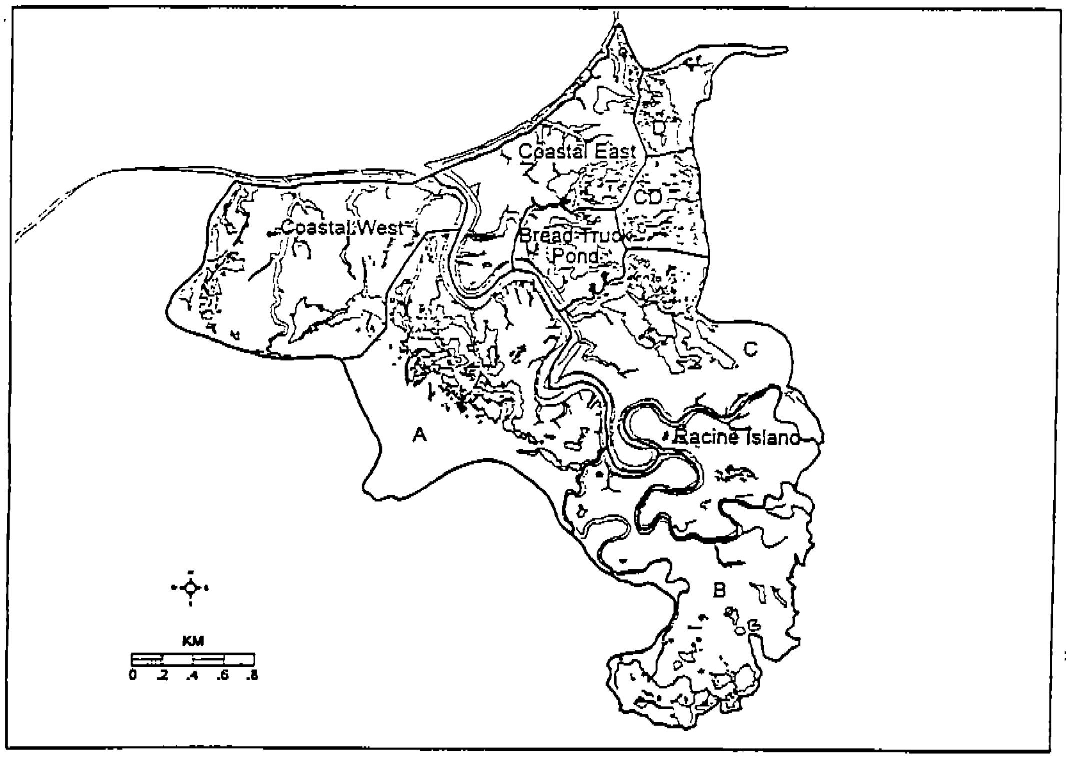

Figure II-1-1. Standardized ERF study areas surveyed for waterfowl.

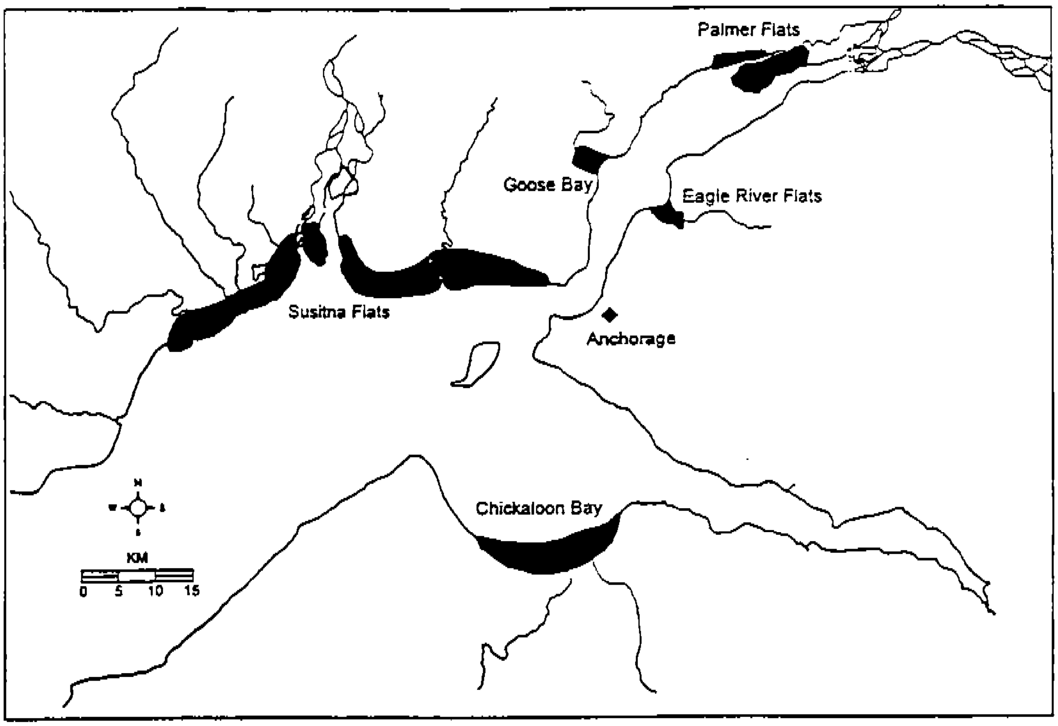

Figure II-1-2. Upper Cook Inlet marshes surveyed for waterfowl in 1996.

cluded Palmer Hay Flats, Goose Bay, Susitna Flats, and Chickaloon Flats (Fig. II-1-2). Trading and Redoubt Bays, surveyed in 1995, were not surveyed this year.

METHODS

Aerial surveys of ERF were flown from April through mid-October, 1996. 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. 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 study areas recently standardized for researchers (Fig. II-1-1). In addition, separate counts were recorded by ponds within the study areas to better define bird use. Areas of study ponds were obtained from digitized maps provided by CRREL and used to convert bird numbers to densities.

Aerial surveys of UCI marshes conducted for the Air Force used the same aircraft, observer and methodologies as used for ERF.

RESULTS AND DISCUSSION

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 100% of ERF on 9 April and gradually diminished through the month. Snow and ice cover diminished from 15% on 1 May to less than 5% on 9 May. Late May, June and July were dry months in UCI and on ERF. Major portions of ERF were drying by the end of May when high tides flooded the area. ERF dried rapidly and remained dry through June, re-flooded with tides in early July, then dried quickly. Water levels were altered dramatically in the Bread Truck Pond when a ditch was blasted from the pond to a tide gully extending from Eagle River. From that time on, it was filled only with high tides. Water levels in ERF fluctuated in August depending on tides and rain. By 11 October 90% of ERF ponds were covered by skim ice. By 15 October, 100% of ERF ponds were solidly frozen, and only rivers and tide gullies were open.

Abundance and distribution of waterbirds on ERF

Thirty-four surveys of ERF were conducted in 1996. Numbers of birds by species or species group are listed by survey date in Table II-1-1 and Fig. II-1-3 for ERF. 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 (*Columbus columbianus*) and trumpeter swans (*C. buccinator*) was minimal during spring 1996 (Table II-1-2), with a maximum count of 27 on 29 April. The mean spring count of 5.9 birds/survey is significantly below the 1998–1995 mean of 38. The majority of swans were observed in Areas A (38%) and B (32%) (Fig. II-1-4). Area D, used most during spring of 1995, was iced over much of the spring in 1996.

In fall, swan numbers peaked in mid-September at 297, earlier than other years. The mean number of swans in the fall, 50.3 birds/survey, was also significantly less than the 1988-1995 mean of 213. Swans remained on ERF in moderate numbers until the first week in October, then most departed. Swans used Areas D (49%) and B (36%) the most, similar to other years. The highest densities of swans, based on areas of intermittent and permanent ponds within each study area, also occurred on Areas D and B (Fig. II-1-4).

Geese

Peak aerial counts of geese in spring occurred during the last week of April. Numbers were similar to other years when snow geese (*Chen caerulescens*) were present (Fig. II-1-3). Snow geese comprised 84% of the total geese counted in spring, followed by Canada geese (*Branta canadensis*). Small numbers of Pacific white-fronted 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 Area B (Table II-1-1, Fig. II-1-5), unlike 1995 when Area C had the highest number. The difference was probably due to the availability of food sources for snow geese. Canada geese used ERF in small numbers during summer, similar to other years. Broods were observed in Areas C, CD, and B. In summer Canada geese used Areas A (24%), Racine Island (19%) and Area C (17%) the most (Fig. II-1-5). Geese began to use Bread Truck Pond more than previous years in 1996, although it was mostly dry during the summer.

Fall goose migration phenology was earlier than other years, peaking during mid- to late September (Fig. II-1-3). Tule white-fronted geese comprised 2% of the fall count, and no snow geese were observed in fall. Generally numbers of geese were higher in 1996 in fall, possibly reflecting decreased human disturbance. The Coastal West (43%) and East (30%) study areas had the highest percentage use of all areas, and the highest densities (Fig. II-1-5).

Ducks

Duck species utilizing ERF in 1996 were similar to previous years (Table II-1-1). The majority of ducks were counted on ponds during all seasons (Table II-1-3). Dabbling ducks comprised more than 95% of the ducks counted by species. Mallards (*Anas platyrhnchos*), 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 1991–1996 (Fig. II-1-6).

In spring, numbers of ducks peaked in late April and early May after a late but rapid movement into UCI on 20 April. Mean num-

Table II-1-1. Numbers of birds, by species or species group, observed during aerial surveys of ERF in 1996.

	4/09	4/22	4/26	4/29	5/01	5/5	5/09	5/17	5/22	5/27	6/03	6/12	6/19	6/26	7/03	7/11	7/18	7/30	8/06
Swans	0	0	22	27	0	0	0	0	3	1	2	0	0	0	0	0	0	0	0
Geese																			
Greater white-fronted	0	0	0	0	5	11	0	0	0	0	0	0	0	3	0	0	0	0	6
Lesser snow	0	2000	1385	2785	405	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Canada	0	395	213	119	64	4	2	25	20	0	21	25	41	24	0	0	0	10	27
Subtotal geese	0	2395	1598	2904	474	15	2	25	20	0	21	25	41	27	0	0	0	10	33
Ducks																			
Green-winged teal	0	61	15	0	69	136	164	22	25	15	44	3	0	4	0	3	0	18	80
Mallard	0	69	37	4	10	18	16	20	33	15	28	29	35	21	6	24	6	17	54
Northern pintail	0	97	0	0	33	96	46	4	13	13	0	10	0	5	0	3	8	27	262
Blue-winged teal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northern shoveler	0	0	0	0	0	38	30	20	31	10	14	2	0	26	0	1	0	0	0
American wigeon	0	2	82	0	0	124	86	19	78	55	107	135	71	49	5	68	19	8	125
Scaup	0	0	0	0	0	4	0	5	0	0	0	0	0	0	0	0	0	0	0
Goldeneye	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bufflehead	0	0	2	8	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Merganser	0	2	0	8	0	4	0	0	1	0	0	0	0	0	0	0	0	0	0
Unidentified duck	0	5	0	0	0	5	0	17	0	6	0	0	0	8	22	29	56	21	0
Subtotal ducks	0	238	136	20	114	425	342	107	181	114	193	179	106	113	33	128	89	91	521
Other birds																			
Red-necked grebe	0	0	5	5	8	11	15	0	0	0	0	0	0	0	0	0	0	0	0
Bald eagle	0	4	4	4	4	2	2	0	0	0	0	0	0	0	0	1	0	0	0
Sandhill crane	0	2	2	2	33	7	11	11	2	1	11	4	0	2	2	7	0	0	4
Shorebird	0	0	0	0	1	127	147	685	271	18	34	69	43	319	77	142	76	20	2
Gull	0	40	32	46	66	252	87	27	70	82	82	80	34	73	47	36	27	3	13
Arctic tern	0	0	0	1	14	5	29	8	10	22	21	37	33	21	17	14	6	0	0

Table II-1-1. Continued.

	8/20	8/27	8/31	9/03	9/06	9/09	9/12	9/16	9/19	9/23	9/26	9/30	10/04	10/08	10/11	10/16
Swans	0	5	2	12	18	6	2	297	114	125	58	34	78	25	22	4
Geese																
Greater white-fronted	70	8	36	100	92	0	11	12	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
Canada	365	519	460	1003	132	135	650	636	775	415	235	174	0	0	0	0
Subtotal geese	435	527	496	1103	224	135	661	648	775	415	235	174	0	0	0	0
Ducks																
Green-winged teal	248	198	62	20	66	385	420	343	271	0	75	121	45	28	49	9
Mallard	267	352	35	125	87	100	420	289	328	67	47	214	944	239	593	5
Northern pintail	197	330	560	0	50	4	130	0	65	12	0	10	55	33	8	0
Blue-winged teal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northern shoveler	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
American wigeon	99	2	280	250	0	18	150	0	0	0	100	0	0	1	0	0
Scaup	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Goldeneye	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bufflehead	0	0	0	0	0	0	0	0	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
Unidentified duck	212	1080	900	660	1527	734	800	1678	1571	710	565	55	0	208	50	0
Subtotal ducks	1028	1962	1837	1055	1730	1241	1920	2310	2235	789	787	400	1044	509	700	14
Other birds																
Red-necked grebe	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bald eagle	1	0	3	0	0	0	0	0	4	2	1	0	0	4	3	0
Sandhill crane	4	15	38	5	9	3	40	27	0	0	0	0	0	0	0	0
Shorebird	70	23	200	0	5	0	100	0	30	0	0	0	0	50	0	0
Gull	3	3	0	0	0	0	0	0	0	0	9	0	0	0	0	0
Arctic tern	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

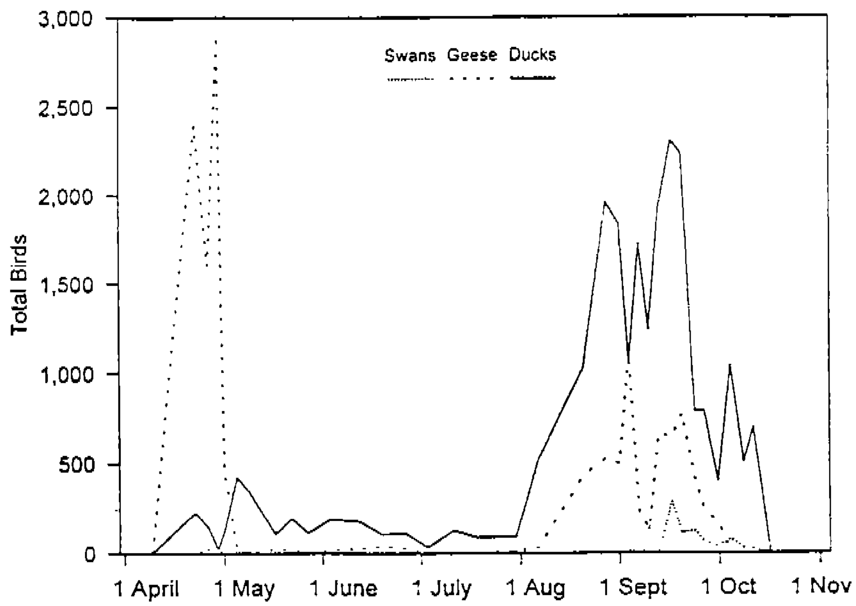

Figure II-1-3. Numbers of ducks, geese, and swans counted on ERF during aerial surveys in 1996.

Table II-1-2. Mean numbers of waterfowl groups on ERF study areas in 1996 by season. The number of complete surveys used to classify observations by area, for spring, summer and fall, were 9, 9, and 15, respectively.

	Coastal West	*A*	*B*	*Racine Island*	*C*	*CD*	*Bread Truck Pond*	*Coastal East*	*D*
					Spring				
Swans	0.2	2.2	1.9	0.6	0.4	0.6	0.0	0.0	0.0
Geese	84.1	51.7	555.0	0.9	74.4	0.0	4.7	48.9	5.0
Greater white-fronted	0.0	0.0	1.2	0.0	0.6	0.0	0.0	0.0	0.0
Lesser snow	70.6	37.8	533.3	0.0	61.1	0.0	0.0	27.8	0.0
Canada	13.6	13.9	20.4	0.9	12.8	0.0	4.7	21.1	5.0
Ducks	18.2	56.3	19.6	2.8	46.9	9.6	7.9	23.6	4.3
					Summer				
Swans	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Geese	1.3	4.3	2.1	3.3	3.0	0.3	1.3	1.7	0.0
Greater white-fronted	0.0	0.7	0.0	0.0	0.0	0.3	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	1.3	3.7	2.1	3.3	3.0	0.0	1.3	1.7	0.0
Ducks	4.0	55.6	10.2	3.8	19.9	33.2	0.1	7.3	27.3
					Fall				
Swans	0.0	3.1	19.5	0.0	0.3	1.8	0.0	2.3	26.4
Geese	167.5	48.5	13.5	2.7	27.9	0.0	12.1	116.3	0.0
Greater white-fronted	3.7	2.7	2.5	2.7	8.8	0.0	1.3	0.3	0.0
Lesser snow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Canada	163.8	45.9	11.0	0.0	19.1	0.0	10.8	116.0	0.0
Ducks	296.1	177.5	243.7	2.9	127.3	120.1	9.2	188.7	138.7

Table II-1-3. Percent duck use of major landform types by season on ERF in 1996. The total number of ducks counted in each season is in parentheses.

	(n)	*Ponds*	*Knik shoreline*	*Eagle River*	*Tideguts*
Spring	(1,694)	84	2	13	1
Summer	(1,453)	91	3	6	0
Fall	(19,561)	72	23	3	1
Total	(22,708)	74	20	4	2

ber of ducks in spring (189) was significantly lower than the 1988–1995 mean of 394, possibly due to the late spring. Most ducks were observed on Areas A (30%) and C (25%) in spring.

Numbers of ducks in summer were lower than 1995, probably due to dry conditions, but similar to the 1988–1995 average. Male wigeons preparing for molt were most common in summer. Most ducks were observed in Areas A (34%) and CD (21%) in summer. Several broods of American wigeons, mallards, northern pintail, and green-winged teal were observed on ERF during summer.

Migration phenology for ducks in fall was similar to other years, with numbers peaking from mid- to late September. The mean numbers of ducks observed on fall surveys was significantly higher (1304) than the 1988–1995 mean (869). While duck numbers were higher than previous years in fall, the early freeze-

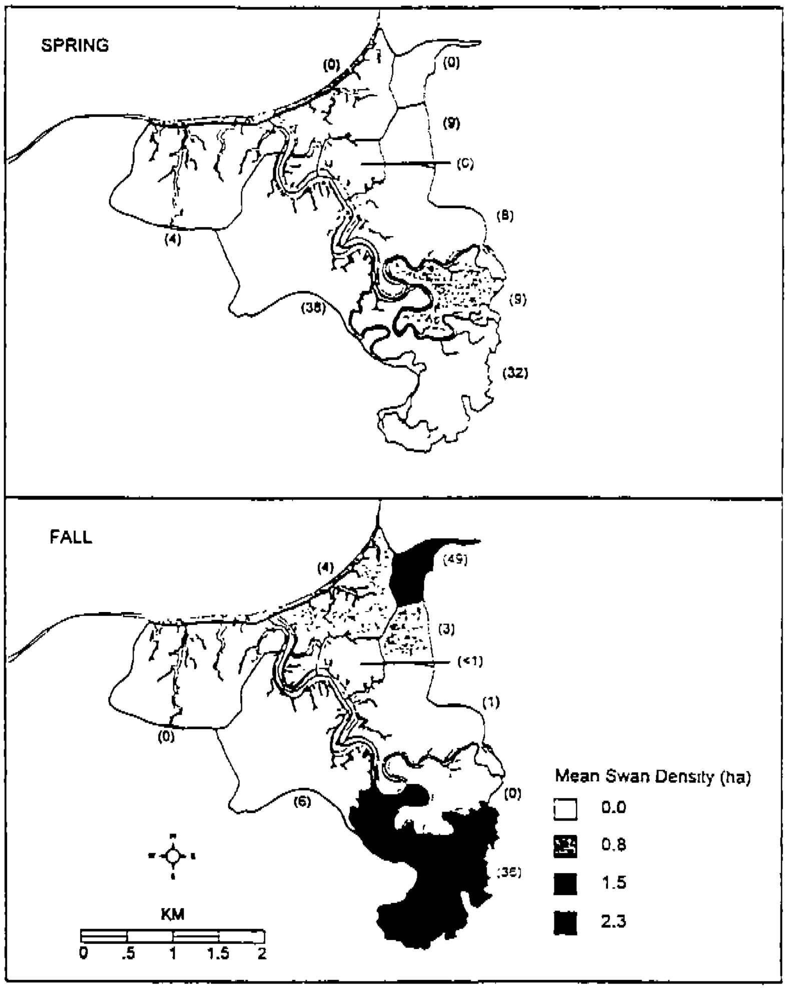

Figure II-1-4. Mean densities of swans on ERF study areas in spring and fall 1996. Numbers in parentheses are the percent of total swans observed on ERF in each areas. The area (ha) of permanent and intermittent ponds in each area were used to calculate densities.

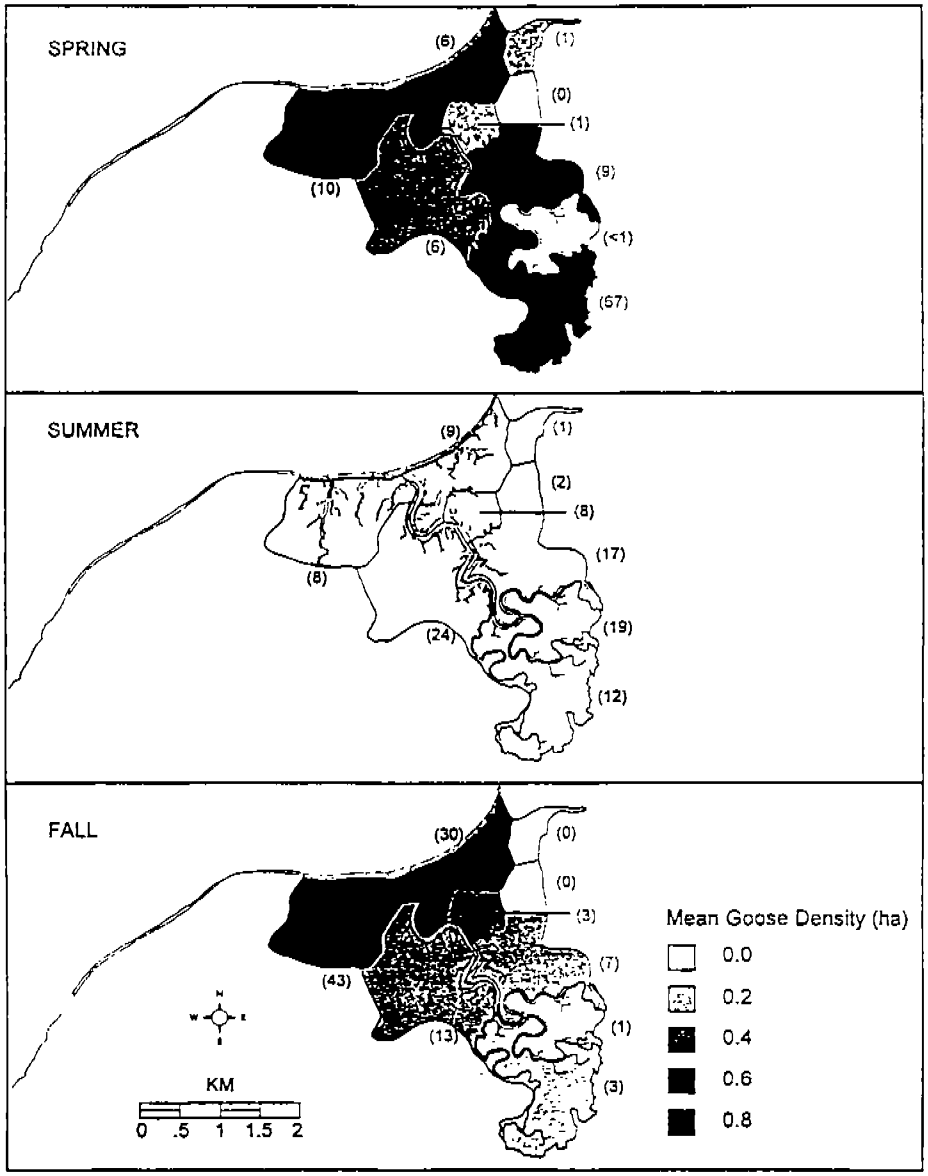

Figure II-1-5. Mean densities of geese on ERF study areas in spring, summer, and fall in 1996. The numbers in parentheses are the percent of total geese on ERF observed in each area.

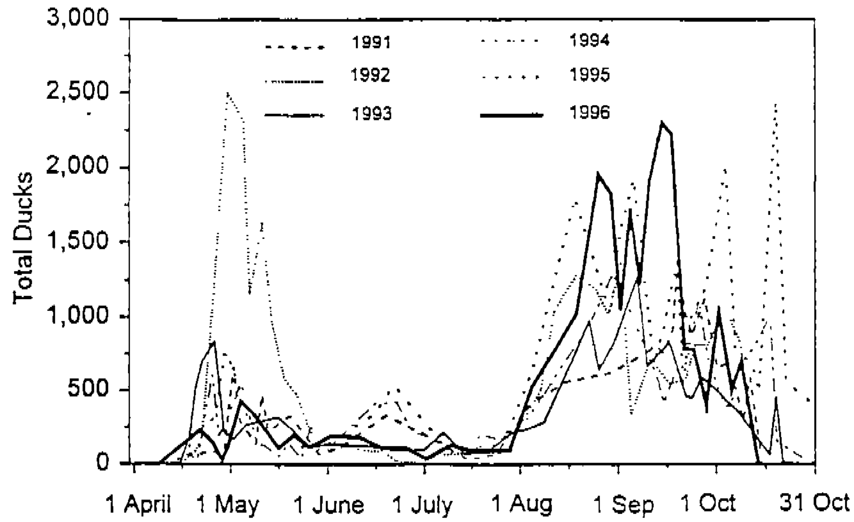

Figure II-1-6. Numbers of ducks observed on aerial surveys of ERF, 1991-1992.

up resulted in a shortened season. The increase could be a result of decreased hazing and human disturbance on ERF in 1996. In 1996, ducks were more evenly distributed across ERF relative to other years: Coastal West (22%), Area B (19%), Coastal East (15%), Area A (14%), Area D (11%), Area C (10%), CD (9%). In 1995 Areas A (20%) and D (20%) were the most utilized. Highest densities of ducks in 1996 were found on Areas B, CD, and Coastal East (Fig. II-1-7). Approximately 60% of all fall observations of ducks on the Coastal East and West areas occurred on the mudflats along the tideline in Knik Arm. Because these ducks usually appear to be resting, density or percentage use figures may give a disproportionate importance to these areas as potential sources of white phosphorus. The Bread Truck Pond, drained in 1996, comprised only 1% of duck use in fall. The mean number of birds using the Bread Truck Pond in fall dropped from 51 birds per survey in 1995 to 9 in 1996. Water conditions and lack of human disturbance are likely factors in the changed distribution from 1995.

In addition to the standard aerial survey where observations of birds were assigned to an area, duck and swan observations were also assigned to individual ponds with the use of a pond numbering system maintained in a CRREL geological database. While it was not possible to separate small ponds in complex areas from the plane, many ponds could be distinguished. Thirteen ponds comprised 75% of fall observations of ducks that were recorded on ponds. The large pond in Area D and ponds in Area B had some of the highest use (Fig. II-1-8).

Bald eagles

Numbers of bald eagles (*Halcatecus leucocephalus*) were low, similar to 1995. While specific shoreline surveys for eagles were not conducted, higher concentrations of eagles typical of earlier years would have been noticed.

Shorebirds

Numbers of shorebirds were combined for all species since individual species were not identified from the air (Table II-1-1). Numbers of shorebirds were lower than earlier years. Common species on ERF include least (*Calidris minutilla*), semipalmated (*C. pusilla*) and 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.*

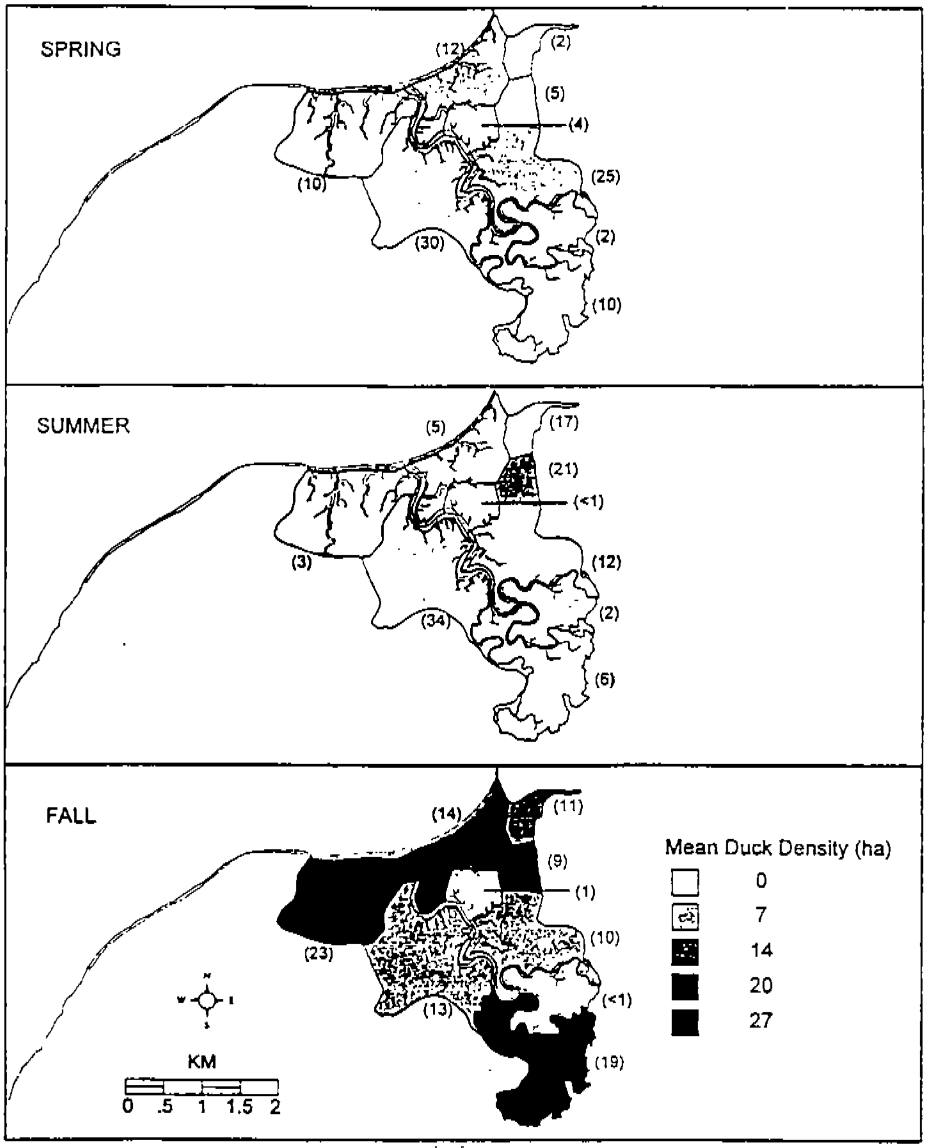

Figure II-1-7. Mean densities of ducks on ERF study areas in spring, summer, and fall 1996. The numbers in parentheses are the percent of total ducks on ERF observed in each study area. The area (ha) of permanent and intermittant ponds in each study area were used to calculate densities.

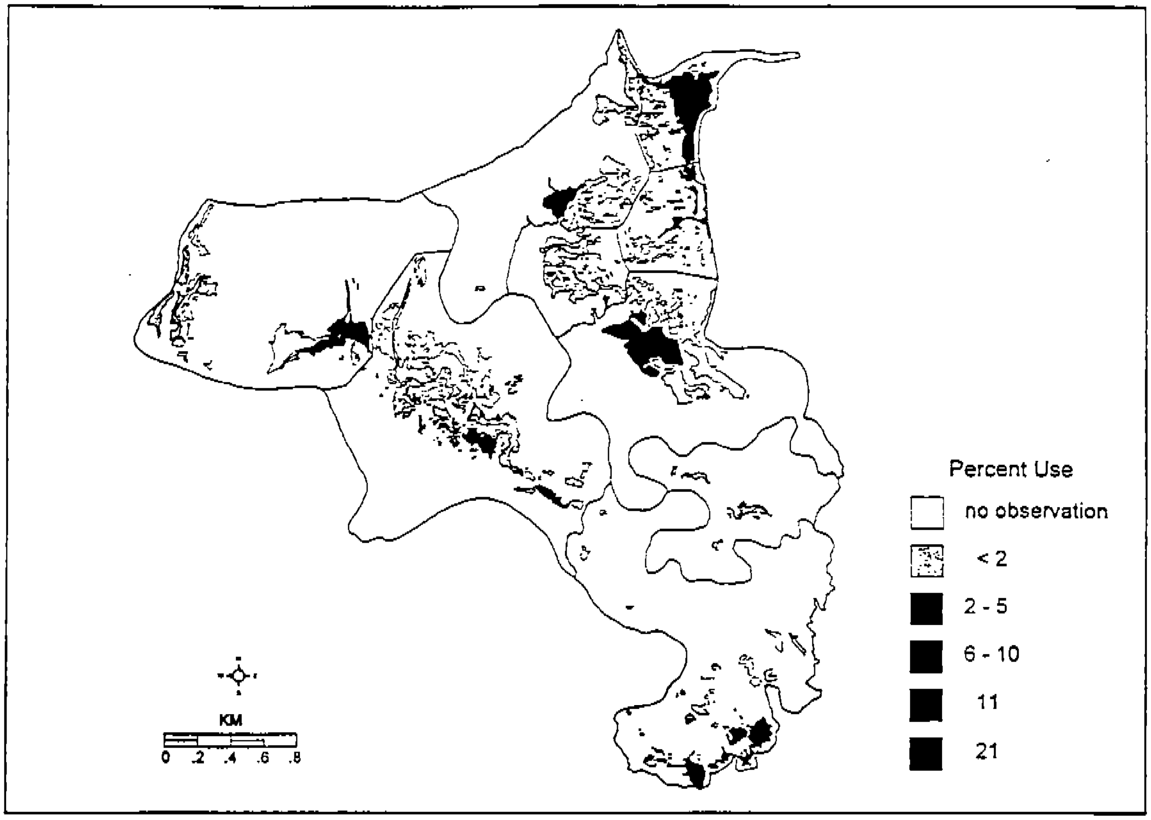

Figure II-1-8. Percent use of ponds by ducks observed on ponds in fall, 1996.

glausescens) and herring gulls (*L. argentatus*). Arctic terns (*Sterna paradisaea*) were common into July. The mew gull colony in Area D appears to be decreasing in size.

Limitations and potential biases in data

The limitations and biases in the kind of aerial survey used for this study were discussed in CRREL (1996) and are applicable to this year's effort. Sources of variablity, including observer, survey platform, and weather conditions, are minimized by standardizing. Timing of the survey in relation to tide or time of day is not possible on ERF due to difficulty in obtaining permission to use military airspace when desired, or obtaining pilots and aircraft.

A study to determine correction factors for birds on the area but not visible or identifiable from the air was planned for 1996 but was not conducted because ground crews were not permitted on ERF due to safety concerns. The data, however, are comparable to previous years. Similar to previous years, it was possible to miss major movements of waterbirds through ERF because surveys were conducted on a twice weekly basis, at most.

A major difference between 1996 and recent years was the amount of human disturbance and hazing. Due to safety and funding concerns, considerably less disturbance occurred on ERF in 1996. Therefore, distribution and numbers of birds on ERF might be considered more natural than other years.

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Racine, C., and D. Cate (1996) Interagency expanded site investigation: Evaluation of white phosphorus contamination and potential treatability at Eagle River Flats, Alaska. FY 95 Final Report. U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire.

II-2. WATERFOWL MORTALITY ON EAGLE RIVER FLATS

Benjamin B. Steele, Leonard R. Reitsma, and Sherman L. Burson, III
New England Institute for Landscape Ecology

INTRODUCTION

The 1996 field investigation was designed to measure mortality rate in Areas A, C, Bread Truck Pond, and other areas of Eagle River Flats. However, field investigations were curtailed by a change in safety regulations. No foot traffic was allowed onto ERF so transect counts of carcasses were not possible. We were able to obtain a general sense of the number of ducks present and the level of mortality.

METHODS

New England Institute for Landscape Ecology personnel were at ERF from Aug. 19 to Sept. 7, and Sept. 20 to Sept. 23, 1996. On each morning, between dawn and 1000, censuses of all ducks visible were made from Cole Point observation tower. Separate counts were made of each area within ERF and counts were also made of Canada Geese, Sandhill Cranes, Common Ravens, Bald Eagles, and Gulls (including Herring and Mew Gulls). Area A and Racine Island were searched for carcasses by canoe on August 21 and September 23. Other areas were searched from the edge of ERF when possible.

RESULTS

The total number of ducks visible from Cole Point in 1996 was similar to that in previous years (Fig. II-2-1). In general, counts were intermediate between those made in 1994 and 1995. During spring 1996 a channel was dug

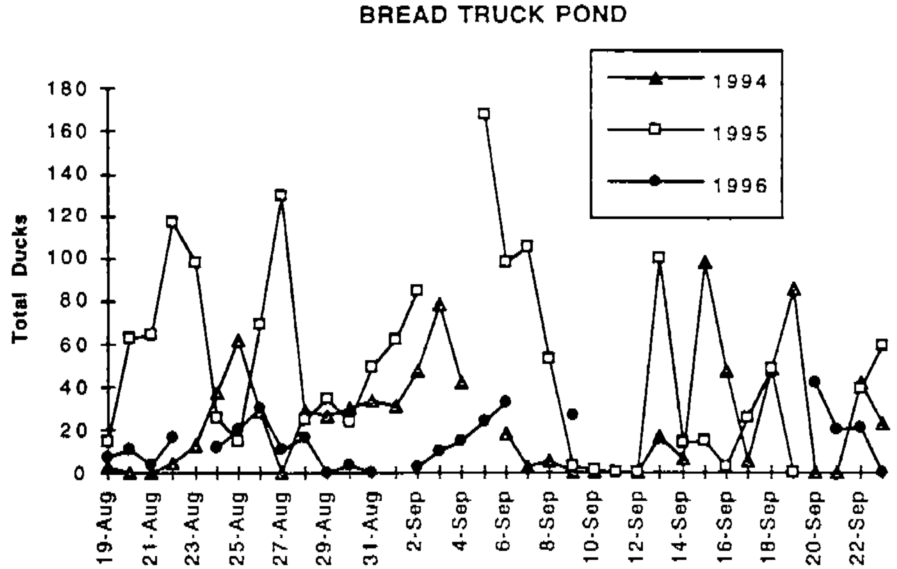

Figure II-2-1. Total number of ducks observed from Cole Point in the fall of 1994, 1995 and 1996.

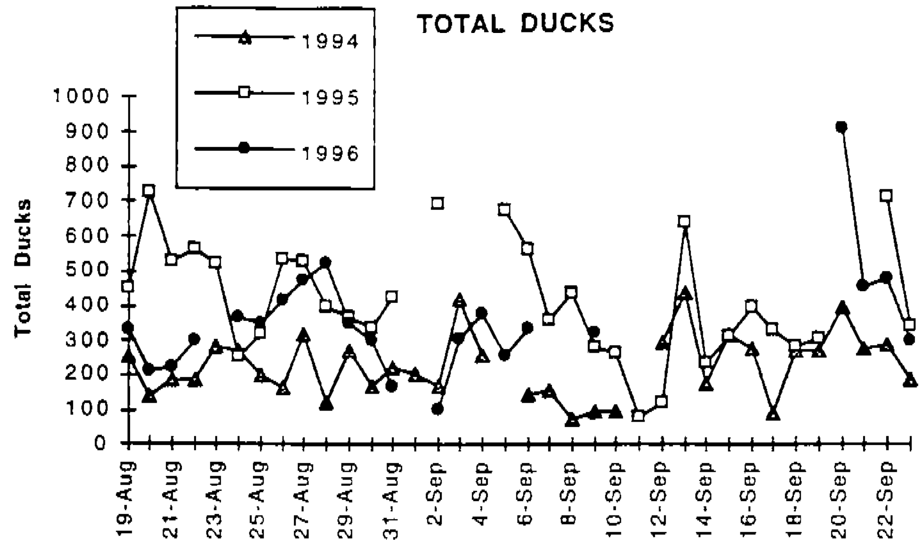

Figure II-2-2. Ducks observes at Bread Truck Pond in the fall of 1994 and 1995 (previous to excavation of the drainage ditch) and in 1996.

with explosives between the Bread Truck Pond and the closest gully to drain the pond. It was expected that a lack of water in this highly contaminated site would attract fewer ducks and result in lower mortality. It was also expected that the drained pond will allow sediments to dry out, oxidizing white phosphorus. Counts from Cole point show that the number of ducks using Bread Truck Pond was lower that in previous years, but ducks still used that area (Fig. II-2-2).

On August 21, 25 carcasses were found along the edges of Racine Island, including 11 mallards, 7 pintail and 7 green-winged teal. Five duck carcasses were found in Area A on the same date. On 23 September, 4 mallard carcasses were found at Racine Island and none at Area A, for a total count of 34 carcasses. These counts indicate that mortality is still occurring in these areas, but comparisons with previous years are not possible because of the much reduced sampling effort. It was impossible to obtain access to Bread Truck Pond and Area C.

DISCUSSION

Although quantitative comparisons with other years are not possible, it is evident that waterfowl mortality is still occurring at ERF. The draining of Bread Truck Pond was successful at reducing but not eliminating duck use of that area. The few ducks still using that pond are probably still exposed to white phosphorus and mortality may continue to occur until drying of sediments reduces the number of particles of white phosphorus.

II-3. MOVEMENT, DISTRIBUTION, AND RELATIVE RISK OF MALLARDS AND BALD EAGLES USING EAGLE RIVER FLATS: 1996

John L. Cummings, Richard E. Johnson, Kenneth S. Gruver, Patricia A. Pochop, and James E. Davis
Denver Wildlife Research Center

Charles H. Racine
U.S. Army Cold Regions Research and Engineering Laboratory

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 (WP). By February 1991, it was concluded that WP 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 WP 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 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 transi-

ACKNOWLEDGMENTS

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tion 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 eagles 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 for 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, we continued to focus on issues outlined under the CERCLA process for ERF. In the conceptual 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 WP 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 were:

- Determine the daily and seasonal movements and distribution, turnover and mortality rates of mallards at ERF;
- Determine the hazards that mallards poisoned by white phosphorus pose to bald eagles at ERF; and
- Establish baseline data for waterfowl, specifically mallards and bald eagles with respect to proposed remediation actions.

METHODS

Beginning August 3, 1996, we captured ducks, specifically mallards, on ERF with swim-in traps, mist nets, or net guns. Swim-in traps were placed in traditional locations, 1 in Area B, 3 in Area A, 1 in Area C/D, and 1 in Area D (Fig. II-3-1). Mist nets were used in the area surrounding the EOD pad (Fig. II-3-1). Duck captures with the net gun were at random from all areas on ERF. Ducks were individually banded with U.S. Fish and Wildlife Service bands. We color-marked ducks on the right wing with a 2.5- × 7.5-cm orange patagial tag (Armorlite, Codey, Inc., Pawtucket, R.I.). The capture and release locations and date, band number, age and sex were recorded for each bird. In addition, all ducks were fitted with radio transmitters (standard or mortality) weighing 9.1 g. The first 50 mallards captured were fitted with standard transmitters, which provided daily movement and distribution data. The remaining mallards and pintails were fitted with mortality transmitters, which only activated when the duck died. These transmitters were used to determine only mortality. Each transmitter was positioned on the upper back of each bird and attached with a Teflon ribbon harness (Cummings et al. 1993).

Bald eagles were captured, marked, and radioed in 1994 and 1995 (Cummings et al. 1994, 1995). The satellite transmitters were expected to last about 18–24 months, or until about January 1997.

Mallards and bald eagles were tracked from fixed telemetry towers located on opposite sides of ERF. 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 two fixed tracking towers and/or one mobile unit. The birds were assumed to be near the point where the bearings crossed, and each bearing location was entered onto a radio tracking form. Birds were also tracked on foot, from hovercraft or National Guard helicopter to

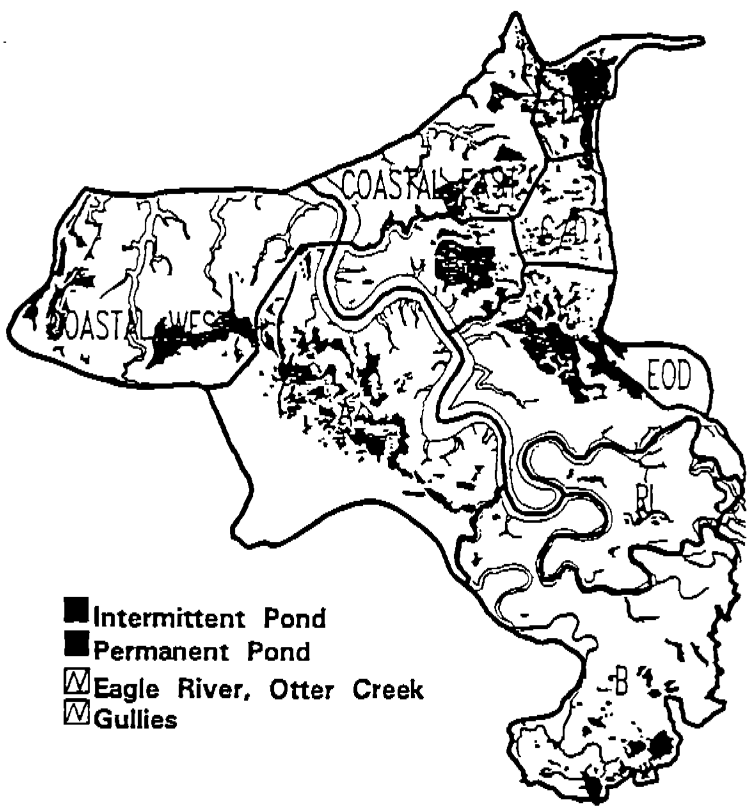


Figure II-3-1. Geographic information system map depicting Eagle River Flats.

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, or remains were collected to determine the cause of death and a location recorded.

Data from mallards were compiled using Locate II (Pacer, Truro, Nova Scotia, Canada) and mapped using GIS ARC/INFO and/or ARC/VIEW. Data from eagles fitted with satellite transmitters were compiled by the Argos Data Collection system, which is a cooperative venture between CNES, the French Space Agency, NASA, and NOAA. The Argos data collection receiver is simultaneously carried on two TIROS-family NOAA satellites, which are in 85-km circular orbits. The eagle satellite transmitters, or platform transmitter terminals (PPT), are programmed to turn on for 8 hr every 96 hr and will send a message every 60 s. The PTTs differentiated from each other by a unique code built in by the manufacturer. The received messages are recorded and retransmitted to ground stations at Fairbanks, Ak.; Wallops Island, Va.; and Lannion, France. The messages are relayed to Suitland, Md., processed and the data made available to users (DWRC).

In 1995, ERF was divided into ten areas representing sites that waterfowl used for foraging and loafing (Fig. II-3-1). Since that time, telemetry data have been plotted and analyzed based on these ten areas. The areas were synonymous with areas used by the U.S. Army to identify specific areas on ERF. The ten areas are A, B, RI (Racine Island), C, C/D, D, BT (Bread Truck), EOD, Coastal West, and Coastal East. Areas A, RI, C, and BT have documented high levels of white phosphorus. In 1996, activity on 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 from radio-instrumented birds were used to address concerns about the relative risk to respective species and to establish baseline data with respect to proposed remediation actions.

The daily turnover rate of instrumented birds 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 WP 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.

RESULTS

Waterfowl

From August 3 to 23, 1996, 107 mallards and 51 pintails were captured, banded, and released on ERF (Table II-3-1). Of the mallards, 2 were captured with the mist nets, 8 with swim-in traps, and 97 with the net gun/helicopter. We used 25 hours of helicopter time to capture 97 mallards; 9 of those hours we only captured 2 mallards due to the inexperience of pilots. The best capture was 21 mallards in 2 hours. All pintails were captured in Area A with swim-in traps. Of the 107 mallards, 53 were fitted with standard transmitters. In addition, 54 mallards and 29 pintails were fitted with mortality transmitters (Table II-3-2). The movement of instrumented ducks following release indicated that transmitters did not appear to inhibit movements or activities. Observations indicated that the behavior of instrumented ducks 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 12% of the instrumented mallards were in final stages of molt when captured. These ducks were noted to remain in the capture/

Table II-3-1. Waterfowl, dowitchers and bald eagles fitted with radio transmitters on Eagle River Flats, Fort Richardson, Alaska.

	1993	*1994*	*1995*	*1996*
Mallards	12	27	17	107
Northern pintails	11	1	16	29
Green-winged teal	11	4	21	0
Bald eagles	0	10	14	0
Dowitcher	0	20	0	0
Banded only	28	2	28	22
Total	62	64	96	158

release areas longer than the same species that had completed molt. Of the 13 mallards in molt, 7 were captured on Racine Island.

The GIS system produced two types of maps for each mallard. The first map showed mallard telemetry points pre- and post-September 5 (Fig. II-3-2 is an actual example). This division is based on previous hazing start-up dates. These data will be used to compare 1996 with previous years. The second map depicts the last 5–10 telemetry locations before the mallard died (Fig. II-3-3 is an actual example). These maps (n = 16) were useful in determining a general area that mallards could have been exposed to WP. Exact locations, and on occasions even the general location, of where the duck might have ingested the WP were difficult to discern because telemetry data points were missing. Missing telemetry points were attributed to lack of a good cross from each telemetry tower or because telemetry personnel did not work on the weekends.

Mallard (n = 53) movements and distribution on ERF during the fall indicate that they spent the majority of their time from August 3 to October 15 in Areas A, B, C, and C/D

Table II-3-2. Radio transmitters fitted to waterfowl on Eagle River Flats, Fort Richardson, Alaska, August 3 to October 15, 1996.

	Standard	*Mortality*	*Banded only*
Mallards	53	54	0
Northern pintails	0	29	22

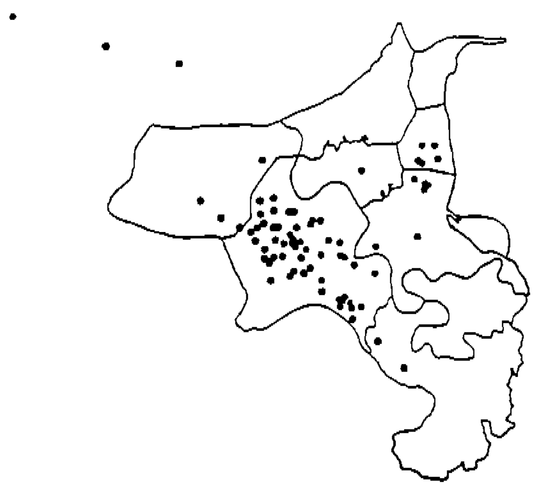


Figure II-3-2. Example of radio-telemetry results on Eagle River Flats, Fort Richardson, Alaska. Movement patterns of a mallard from August 3 to October 15, 1996. Dark dots represent movements from August 3 to September 5 and light dots represent movements from September 6 to October 15. One dot may represent several telemetry locations.

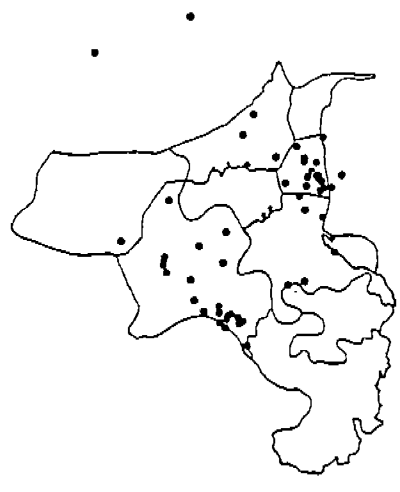


Figure II-3-3. Example of a geographic information system map depicting a radio-telemetry result of a mallard that died from ingesting white phosphorus. Light dots show the last days of movements prior to mortality.

(Table II-3-3). Use of these areas represented about 91% of the time mallards spent on ERF (Table II-3-3). Several mallards were documented moving to various locations near ERF, such as Gwen, Otter, and Six Mile Lakes, Palmer Hay Flats, and Susitna Flats. Mallards spent about 83% of their time in Areas A, BT, C, C/D, EOD, and RI, which are areas that are considered contaminated (Table II-3-3).

To evaluate the effects of hazing on mallards, we compared mallard movements and distribution from 1996 (non-hazed year) to 1995 (hazed year). During 1995 hazing began on September 5. 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-3-4). In areas that were actively hazed, Area 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 (Fig. II-3-4). In 1996, mallards spent 33% of their time in Areas A, C, C/D, and BT prior to September 5 and 46% of their time in the same areas after September 5.

The average number of days spent on ERF by mallards (n = 53) was 47, range 1–71. At the conclusion of the study, October 15, 3 mallards remained on ERF. These birds were using the Eagle River because all other areas on ERF were covered with snow and/or ice. The average daily turnover rate for mallards was about 1.4%. The greatest turnover for mallards occurred from October 1 to 15, where 62% of the mallards departed ERF (Fig. II-3-5). Over 20% of the mallards departed between August 16 and 31 (Fig. II-3-5). Turnover prior to September 5 of 1995 and 1996 for mallards was 47% and 26%, respectively.

The mortality of mallards using ERF from August 3 to October 15 was 37 (C.L. 26–44), or about 35% (Table II-3-4). Mallards found dead during this period were on the Flats from 4 to 68 days. The average exposure before mortality was 29 days. The greatest mortality occurred in Areas C, 13 of 37 (35%); A, 8 of 37 (22%); and C/D and RI both accounted for 6 of 37 (16%). Overall, these areas accounted for 89% of the mallard mortality on ERF (Table II-3-5). Three other mallards found dead were attributed to mink. The carcasses and transmitter of each bird was recovered from mink burrows. No mallard mortality was noted from capture, handling or the transmitter. Carcasses were collected and frozen for residue analysis.

Table II-3-3. Distribution of mallards on Eagle River Flats (ERF), Fort Richardson, Alaska, August 3 to October 15, 1996.

	Telemetry points		
ERF area	*(no.)*	*(%)*	*Mortality*
A	1215	62	8
B	213	11	2
C	204	10	13
C/D	167	8	6
CW	63	3	0
RI	40	2	6
CE	27	1	0
D	18	<1	0
EOD	16	<1	0
BT	13	<1	2
Total	1976	100	37

Bald eagles

During 1994 and 1995, 10 and 14 bald eagles were captured on ERF and each fitted with backpack transmitters, respectively. In 1995, two of those were breeding adults from two nest sites surrounding ERF. Telemetry and observational data (see Cummings et al., 1995 ERF report) of instrumented eagles, excluding the two nesting birds, indicated that eagles spent an average of 1.2 days (range 1–25) on the Flats during the spring and an average of 0.2 days (range 1–50) on the Flats during the fall. Instrumented eagles were only located in Areas A, C, and C/D during the spring and Areas A and C/D during the fall. Most of the time was spent in the wooded areas surrounding ERF. Eagles (satellite) that did not nest in the woods surrounding ERF were located with 300 km radius of the Flats.

As of December 1996, only one satellite transmitter remained active. That eagle is near Cordova, Alaska. During the study no eagle mortality occurred.

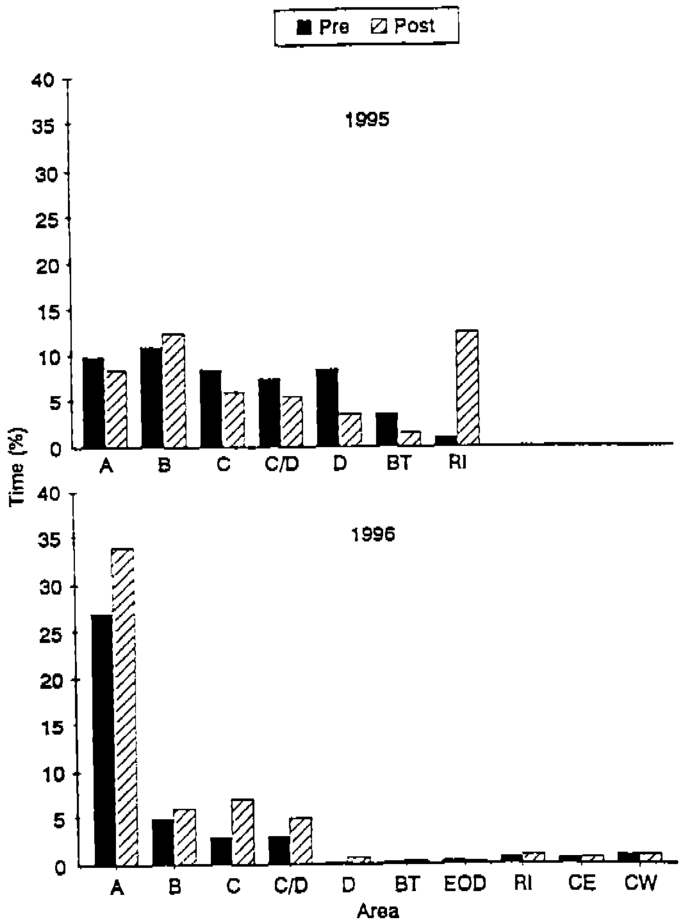


Figure II-3-4. Distribution of mallards on Eagle River Flats pre and post September 5 in 1995 and 1996. Hazing was conducted during the post period in 1995.

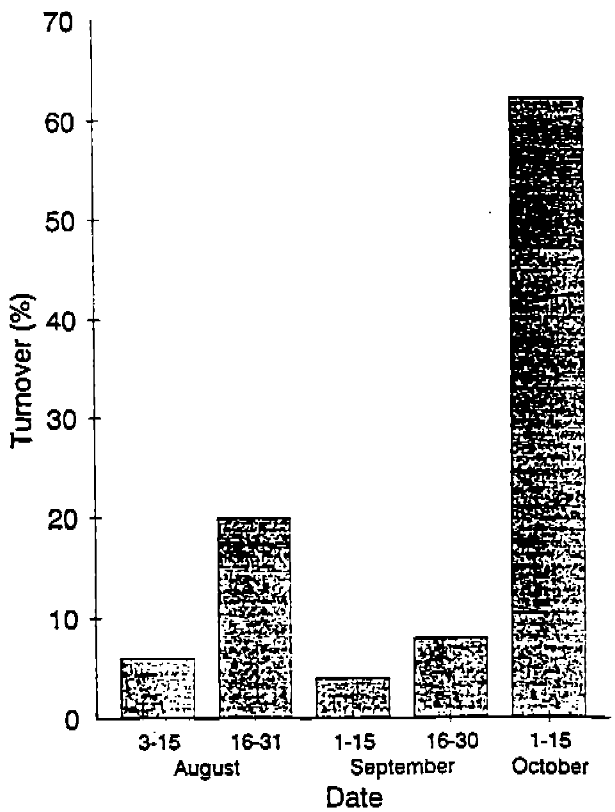


Figure II-3-5. Turnover of mallards on Eagle River Flats, Fort Richardson, Alaska from August 3 to October 15, 1996.

Table II-3-4. Mallard mortality from white phosphorus on Eagle River Flats, Fort Richardson, Alaska.

	Captured (no.)	*Mortalities (no.)*	*White phosphorus mortalities (%)*
1996	107	37	35
1995	17	4	24
1994	27	5	19
1993	12	2	17

Table II-3-5. Mortality of mallards on Eagle River Flats, Fort Richardson, Alaska, August 3 to October 15, 1996.

	Area								
Transmitter	*A*	*B*	*C*	*D*	*BT*	*C/D*	*RI*	*CE/CW*	*Total*
Standard	3	2	3	0	1	2	4	0	15
Mortality	5	0	10	0	1	4	2	0	22
Total	8	2	13	0	2	6	6	0	37

DISCUSSION

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

Mallards highly preferred Area A in 1996, followed by Areas B, C, and C/D. Mallards distribution data collected during the fall migration period in 1993 and 1995 indicate that mallards 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. Indications from 1996 data are that hazing is having a positive effect on redistributing waterfowl to uncontaminated areas. For example, mallards showed a significant redistribution from non-hazed periods to hazed periods. A comparison of 1995 to 1996 shows that mallards spent about equal time in Areas A, C, C/D, and BT prior to September 5. Following this period, use of these areas decreased 32% in 1995 (hazing) while increasing 40% in 1996 (non-hazing). In addition, the average number of days mallards spent on ERF in 1995 was 40, whereas it was 47 in 1996. Also, the average daily turnover rate was 3.8% in 1995 and 1.4% in 1996. Both of these factors indicate that without hazing, mallards resided longer on ERF and departed the Flats at a slower rate.

Mallards mortality during 1996 (n = 37) was 35%. In 1995 it was 23% (4 of 17) and 16% (2 of 12) in 1993. Mortality in 1996 probably increased because mallards use of contaminated areas increased.

In conclusion, we feel that the baseline data collected in 1996 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 the reduction in waterfowl mortality. To measure this endpoint, we suggest that mallards continue to be used as the indicator species for ERF and telemetry be used to monitor their activities. 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.

Of importance is being able to determine if remediation actions reduce mortality. Because waterfowl use the entire ERF, remediation of one area doesn't necessarily mean that mortality will decrease. Waterfowl might redistribute themselves 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 telemetry data be integrated into the risk assessment process, that future remediation actions be assessed with telemetry birds, that mortality on ERF be assessed by instrumenting more than 100 waterfowl with mortality transmitters, and that eagles fitted with satellite transmitters continue to be monitored.

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. In addition, it is considered a standard method for projects of this type.

REFERENCES

Cummings, J.L. (1993) U.S. Army Eagle River Flats: Protecting waterfowl from ingesting white phosphorus. Den. Wildl. Res. Ctr. Final Report 94-1. 78 p.

Cummings, J.L. (1994) U.S. Army Eagle River Flats: Protecting waterfowl from ingesting white phosphorus. Den. Wildl. Res. Ctr. Final Report 94-2. 69 p.

Cummings, J.L. (1995) U.S. Army Eagle River Flats: Protecting waterfowl from ingesting white phosphorus. Den. Wildl. Res. Ctr. Final Report 95-1. 101 p.

III-1. REPORT OF USDA–APHIS–ANIMAL DAMAGE CONTROL FOR THE U.S. ARMY AT EAGLE RIVER FLATS, APRIL–OCTOBER 1996

Corey Rossi
Alaska District, USDA-APHIS-Animal Damage Control

During parts of April and May 1996, under Agreement #96-73-02-21 58 (formerly agreement #1 2-34-73-2158), USDA–APHIS–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, ADC 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 attractive to ducks. This season, as in 1995, mylar tape was deployed to a lesser degree than in previous seasons, primarily due to its limited long-term efficiency 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 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-min. intervals to deter waterfowl during hours of darkness.

To augment the effectiveness of these static devices, two ADC 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 1996 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 15 to May 31, 1996, a total of 1575 ducks and 10 Canada geese were hazed at Eagle River Flats, by four ADC personnel. A total of 253 staff hours were expended in the field over 45 days of hazing. There were no waterfowl moralities found by ADC personnel during the spring of 1996.

Fall

From September 23 to October 26, 1996, no waterfowl were hazed by ADC personnel at Eagle River Flats. In excess of 100 staff hours were expended transferring and repairing hovercrafts.

DISCUSSION

The spring 1996 total of "ducks hazed" reveals a dramatic decrease over the same period in 1995 (3406 in 1995 vs. 1575 in 1996). This is due, at least in part, to a very unusual 1995–1996 winter. Because the marsh experienced virtually no snow cover until February 1996, the frost reached much deeper into the soil than usual. As a result much of the sediment in the ponds remained frozen long after the exposed surface water had melted. Much of the permanently ponded area had some frozen sediment well into May 1996. The frozen sediments made it difficult to impossible for foraging ducks to consume the white phosphorus particles within the sediment. Although ducks still attempted to utilize the open water areas, they were quite easy to deter, as the ponds were less attractive without foraging opportunities. Overall duck use of the permanently ponded areas appeared to be much less in spring 1995 than in previous years.

The fall 1996 season presented some unexpected circumstances. During discussions with researchers from DWRC, it was determined that a four-week cessation in hazing (at the beginning of the fall migration) would be of value to researchers. ADC adjusted its proposed startup date accordingly to September 23, 1996. The purpose of the delay was to allow researchers to monitor duck movements, marsh use, and mortality, independent of hazing activities. Aside from some incidental hazing by other research groups, the plan worked well. However, by the time the hazing operation was to begin, the cache of functional hovercraft had been exhausted. In fact, of the four hovercraft in supply, only one was even partially functional.

It has been ADC's intention to use the hovercraft whenever possible to assist in hazing operations and thus limit ADC personnel's potential exposure to unexploded ordnance. This season the hovercraft's role became even more important due to stricter rules regarding human access to the Eagle River Flats Impact Area. The new rules made it exceedingly difficult to operate in the Flats without helicopter or hovercraft support.

Due to the more stringent safety requirements, any personnel whose duties required them to deviate from established paths must have helicopter or hovercraft support. Most of ADC's daily activities fall under this category. A number of the other groups were similarity affected. In addition, if the hovercraft was used, a second hovercraft (with a trained operator) was required to be immediately available. These developments have made it *critical* to maintain at least two functional hovercraft at all times. This is especially true now that funding cuts have made hovercraft support a more reasonable option than helicopter support in many cases.

Unfortunately the hovercraft's increased popularity did not come without a cost. ADC spent several thousand dollars of their operating budget repairing hovercrafts after the spring 1996 season concluded. In addition, ADC 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,

As ADC stated in last year's report, "The hovercraft operation manual describes it as an aircraft, rather than a boat. And in its purest sense, that is exactly what it is. The steering mechanism of a hovercraft is more closely related to that of a helicopter than that of a boat. By establishing designated paths through the Flats and emphasizing thorough operator training, ADC plans to overcome the craft's weak points and make it an indispensable tool for hazing and personnel/equipment transit."

ADC is still busy completing the necessary repairs to ready the hovercrafts for use in the spring of 1997. Perhaps this season's experience will provide a valuable lesson in the development of future hovercraft use policies.

During the periods of hazing cessation in 1994, ADC was still present at ERF assisting other groups and remaining on standby in the event that hazing might need to be initiated immediately to protect waterfowl. This procedure was not implemented in 1995 or 1996, and its absence may have contributed to increased waterfowl mortality. If hazing cessations are implemented in the 1997 season, it would seem prudent to have a hazing crew standing by and assisting other groups as in the past.

Although ADC's original hazing schedule outlined a tentative completion date of October 26, 1996, a contingency provision in our 1996 proposal allowed ADC to continue operations until all contaminated areas had frozen over. This policy would have been beneficial to the fall 1996 hazing effort (had it occurred) and should be continued in coming seasons.

There were no "new" tools/procedures involved in ADC's 1996 hazing operations. With only minor exceptions, ADC employed the same techniques that have proven to be successful in previous seasons. However, ADC 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 the most essential component in a successful waterfowl deterrent operation.

CONCLUSION

In spite of the mechanical problems encountered in the spring season, ADC believes the 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 a "late spring"). While the fall season was essentially unproductive in terms of waterfowl deterrence, it may serve as the impetus to establish more stringent hovercraft operation policies. As in previous seasons, ADC observations and waterfowl surveys by USF&WS indicated a dramatic decrease in waterfowl numbers in ADC-protected areas when compared to those in established sanctuary areas. The effective protection of waterfowl was further enhanced by a contingency provision initiated in the 1994 proposal which allowed ADC'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 1997 season.

III-2. DEMONSTRATION OF SAMPLE COMPOSITING METHODS TO DETECT WHITE PHOSPHORUS PARTICLES

Marianne E. Walsh, Charles M. Collins, and Ronald N. Bailey
U.S. Army Cold Regions Research and Engineering Laboratory

INTRODUCTION

As remediation at ERF progresses by active or natural methods, remediation success (i.e., reduction in the amount of white phosphorus available to waterfowl) will need to be measured. Without taking an unrealistically large number of samples, simple measurement of white phosphorus concentrations in discrete samples will not provide reliable data for this determination. Although white phosphorus concentrations can provide useful data when the objective of sampling is to determine if an area is contaminated, measurement of concentration changes is more difficult due to sample heterogeneity. One alternative to measuring white phosphorus concentrations is to employ a sampling strategy designed to determine the availability of lethal quantities of white phosphorus.

From 1990 to 1993, analysis of surface sediment samples taken at approximately 25-m intervals along transects through sections of Eagle River Flats allowed us to identify which areas were contaminated with white phosphorus. Three areas—Area C, the Bread Truck Pond, and Racine Island—had the highest rates of detection and samples with the highest concentrations. In these areas white phosphorus concentrations varied widely (Table III-2-1), with relatively few samples having concentrations large enough to present an acute lethal dose of white phosphorus to a duck. When samples were taken at close intervals (1–5 m) around sample points with high white phosphorus concentration, we again observed extreme heterogeneity, with non-detectable concentrations within a few meters of high concentration samples (over 100 µg/g). This pattern of contamination led us to believe that most of the white phosphorus was located in "hot spots," probably at the point of impact of a white-phosphorus-containing projectile. Microscopic examination of high concentration samples revealed the presence of solid pieces of white phosphorus, some up to 6 mm long and weighing over 100 mg. These particles could easily be selected by dabbling ducks and swans searching for food or grit. The very low concentrations detected in most samples is probably due to colloidal, dissolved, or molecular white phosphorus sorbed to sediment surfaces. We hypothesize that only sample sites with solid chunks of white phosphorus present a risk to waterfowl, given the unrealistically large amount of sediment a duck would need to process to obtain an acute lethal dose when concentrations are less than 1 µg/g, and no clear mechanism by which waterfowl could extract white phosphorus from low concen-

Table III-2-1. White phosphorus concentrations found in field samples collected from ERF (Racine 1995)

Concentration range (µg/g)	*Number of samples*	*Percent of samples*
Not Detected	1281	66
Detection limit to 0.00099	79	4
0.001 to 0.0099	203	11
0.01 to 0.099	185	10
0.1 to 0.99	72	4
1.0 to 9.99	43	2
10 to 99.99	38	2
100 to 999.9	16	1
1000 to 9,999.9	6	0.3

tration sediments (Racine 1995). This hypothesis is supported by the mortality observed in the DWRC pen studies.

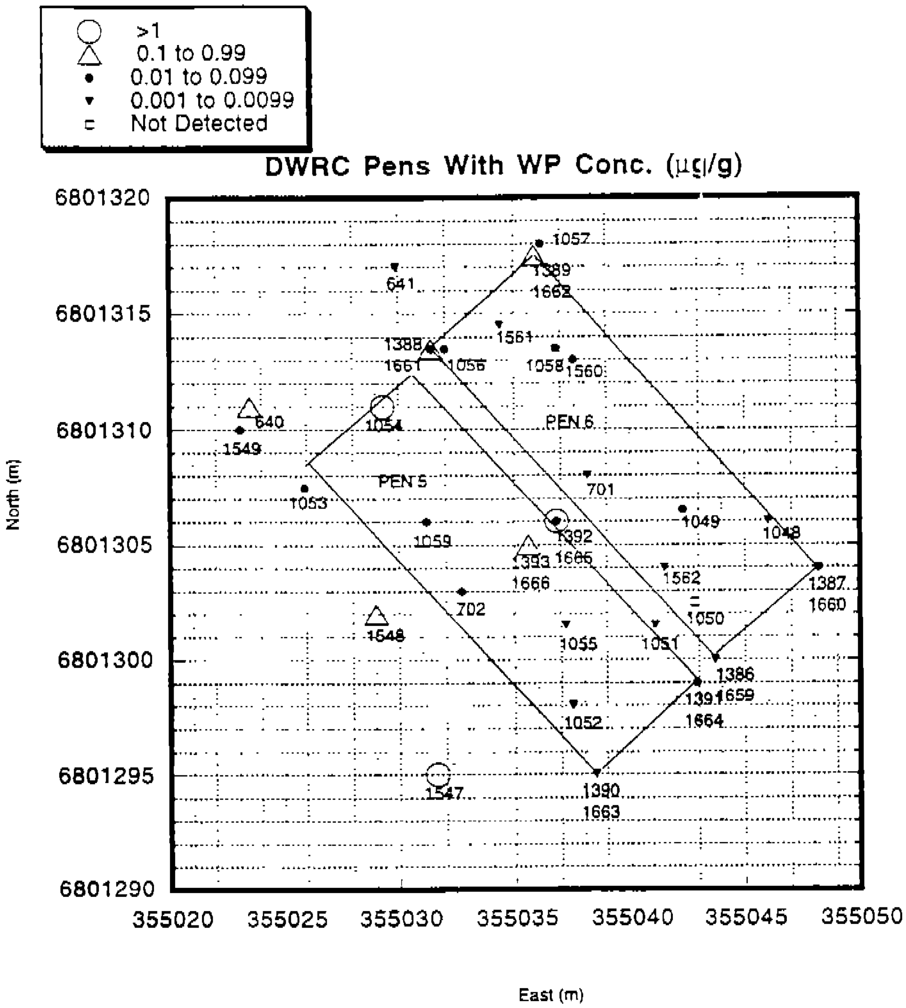
From 1992 to 1994, DWRC conducted studies to test the chemical bird repellent methyl anthranilate (Clark and Cummings 1994). A component of this study during 1992–1993 involved exposure of mallards to contaminated ERF sediment by confining mallards within six pens located in the northwest of the main pool in Area C. The pens were located in an area where white phosphorus was detected in 1991 (Racine et al. 1993), and additional samples were obtained by DWRC in 1992 to 1994 to confirm the presence of white phosphorus (Racine and Brouillette 1995). For each study, six mallards were placed within these pens for various lengths of time, and feeding behavior and mortality monitored. From 1992 to 1993, 282 mallards were exposed, of which 32% appeared to die of white phosphorus poisoning. Waterfowl mortality occurred within each pen (Table III-2-2).

One confounding factor in this study was the inability to quantify white phosphorus exposure of the mallards within each pen. Because of the heterogeneous distribution of white phosphorus and the wide range of concentrations found in discrete samples, average white phosphorus concentration estimates are not meaningful for estimating exposure. Almost all the surface samples collected from the pens had measurable amounts of white phosphorus (Racine and Brouillette 1995) (Fig. III-2-1), but most birds exposed to these contaminated sediments were not

Table III-2-2. Number of mallards appearing to die from white phosphorus poisoning while exposed to contaminated sediments within DWRC pens in Area C of ERF. (Data courtesy of Patty Pochop.)

Season and year of exposure	*Hours of exposure per day*	*Total exposure (hrs)*	*Number of penned mallards dying from WP poisoning*						
			Pen 1	*Pen 2*	*Pen 3*	*Pen 4*	*Pen 5*	*Pen 6*	*Total*
Spring 1992	3	12	1	0	1	2	1	0	5
Spring 1992	3	12	0	1	2	1	3	0	7
Fall 1992	3	12	Not used	1	0	0	0	Not used	1
Fall 1992	3	12	1	0	Not used	Not used	3	0	4
Fall 1992	3	9	1	1	1	0	1	1	5
Fall 1992	24	168	Not used	2	Not used	Not used	Not used	5	7
Spring 1993	3	15	0	0	0	1	3	0	4
Summer 1993	24	264	6	4	5	6	6	3	30
Summer 1993	24	168	Not used	Not used	Not used	Not used	6	Not used	6
Fall 1993	24	168	2	5	2	5	6	2	22
Total mortality			11	14	11	15	29	11	91
Number mallards exposed			42	54	42	42	54	48	282
Percentage mortality			26%	26%	26%	36%	54%	23%	32%

Season and year of exposure	*Average death rate (deaths/hour exposure)*					
	Pen 1	*Pen 2*	*Pen 3*	*Pen 4*	*Pen 5*	*Pen 6*
Spring 1992	0.056	0.000	0.056	0.111	0.056	0.000
Spring 1992	0.000	0.028	0.083	0.056	0.057	0.000
Fall 1992	Not used	0.019	0.000	0.000	0.000	Not used
Fall 1992	0.014	0.000	Not used	Not used	0.097	0.000
Fall 1992	0.028	0.056	0.019	0.000	0.028	0.056
Fall 1992	Not used	0.014	Not used	Not used	Not used	0.020
Spring 1993	0.000	0.000	0.000	0.014	0.039	0.000
Summer 1993	0.018	0.007	0.014	0.007	0.023	0.006
Summer 1993	Not used	Not used	Not used	Not used	0.008	Not used
Fall 1993	0.004	0.020	0.003	0.009	0.027	0.003
mean	0.017	0.016	0.025	0.028	0.037	0.011
Ave. time (hour) to death	59	63	40	36	27	95



UTM Coordinates for Pen 5		
Corner	East	North
SW	355038.5	6801295.0
SE	355042.9	6801299.2
NW	355026.2	6801308.5
NE	355030.6	6801312.6

Figure III-2-1. Map of DWRC Pens 5 and 6 showing white phosphorus concentration ranges and sample numbers for discrete samples taken 1991–1994.

acutely poisoned. To see if chronic poisoning was occurring, in 1992, gizzard contents and fat samples were taken from birds that did not die from acute poisoning during exposure to contaminated sediments. These samples were analyzed, and white phosphorus was not detected on any of the samples, suggesting that chronic poisoning was not occurring. Instead, acute poisoning following the ingestion of a single lethal dose of white phosphorus appeared to be the more likely scenario. Considering that the LD_{50} for mallards is estimated to be 3–4 mg/kg of body weight (Sparling et al. 1995), and the waterfowl at most risk at ERF weigh between 0.25 kg (teal) and 1 kg (mallards), a lethal dose is provided by the ingestion of milligram-size particles of solid white phosphorus, not the nanogram to microgram quantities associated with most of the sediment samples.

If we accept that we may focus on high concentration samples in our sampling strategy to determine if white phosphorus is available to waterfowl, the size difference between typical ERF sediments and milligram white phosphorus particles presents us with an opportunity to collect numerous point samples, which can be composited and then reduced in volume by sieving through an appropriate size mesh. White phosphorus particles, if present, are retained on the mesh and can be detected by various methods. This approach is similar to the way ducks feed and allows us to determine if white phosphorus is available to dabbling ducks and swans, the receptors at most risk.

STUDY OVERVIEW

Objective of sampling

The objective was to determine if lethal quantities of white phosphorus are available to waterfowl in a given area.

Assumptions

1. Waterfowl at Eagle River Flats are being acutely poisoned by the ingestion of white phosphorus.
2. An acutely lethal dose of white phosphorus is in the form of at least one solid particle with a mass greater than one milligram.
3. The bulk of the solid particles at ERF reside in localized "hot spots" with radii on the order of 1 m.

Approach

1. Collect samples systematically using a two-dimensional grid designed to detect a single hot spot, if one exists, with probability of missing the hot spot of 10, 20, and 40%.
2. Composite the samples and isolate the fraction that potentially contains milligram particles of white phosphorus (i.e. fraction retained on 0.59 mm mesh sieve).
3. Determine if white phosphorus particles are present in the composite sample.

METHODS

Field tasks

Samples were collected based on the methods described by Gilbert (1987) for locating hot spots with a chosen level of confidence that hot spots will not be missed. These methods require the following conditions:
The hot spot is circular or elliptical.

- Samples are taken on a square, rectangular, or triangular grid.
- The distance between grid points is much larger than the area sampled at the grid points. (If a large portion of the area is sampled, the probability of hitting a hot spot will be greater than indicated by the model used here.)
- The definition of "hot spot" is clear.
- No errors are made in detecting a hot spot.

Also implied is that the area of the hot spot is small compared to the total area of interest, analogous to a needle in a haystack.

For the most part these conditions are valid at ERF for the following reasons:

- The hot spots at ERF are most likely due to the point of detonation of white phosphorus containing projectiles, which produce circular patterns of contamination.
- Samples were taken on square and triangular grids.
- Equal volumes of sediment were obtained at each sample point using a graduated coring device that had a diameter of only 2.65 cm, whereas the grid spacing used in this study varied from 0.91 to 2.44 m.
- We define a hot spot as a localized area containing solid white phosphorus particles.
- If white phosphorus particles are abundant within each hot spot, detection errors should be minimal. However, we do not expect the particles to be distributed evenly throughout the hot spot. Rather, the hot spots at ERF are likely to have "fuzzy edges," meaning that white phosphorus particles are expected to be less numerous towards the edges of the hot spots. There-

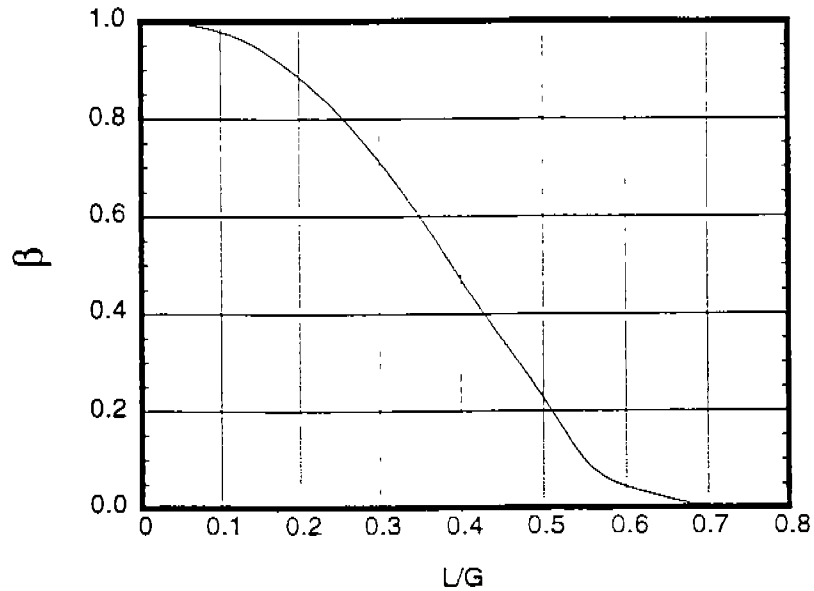


Figure III-2-2. Curve relating L/G, the ratio of the radius of a circular hot spot to spacing on a square grid, to risk, β, of not finding a hot spot. (From Gilbert 1987.)

fore, the number of particles found cannot be used to estimate the number of hot spots, if more than one hot spot exists.

To determine the grid spacing (G), the length (L) of the semimajor axis (radius for a circle) of the smallest hot spot must be known. Previous studies indicate that L is around 0.5 to 1 m for the hot spots in ERF. Then the acceptable probability (β) of not finding a single hot spot if one exists must be specified. A nomogram (Fig. III-2-2) is then used to compute grid spacing (Gilbert 1987). For this study, composite samples were collected for β equal to 10, 20, and 40%. Grid spacing ranged from 0.91 to 2.33 m for the square grid and 2.00 to 2.44 m for the triangular grid (Table III-2-3).

Table III-2-3. Grid shapes and spacing that were used to collect a composite sample from 7- × 20-m area including DWRC Pen 5. Also shown are the number of samples that made up a composite sample and the total volume of sediment that was collected prior to sieving through a #30 mesh.

	Grid shape	*Beta (%)*	*Grid spacing (m)*	*No. samples*	*Total vol. (mL)*
L=1	Square	10	1.82	48	2,400
L=1		20	1.96	44	2,200
L=1		40	2.33	36	1,800
L=1	Triangular	10	2.00	48	2,400
L=1		20	2.17	39	1,950
L=1		40	2.44	30	1,500
L=0.5	Square	10	0.91	184	9,200

L = one-half length of long axis (m).
Beta = Risk of missing a single hot spot.

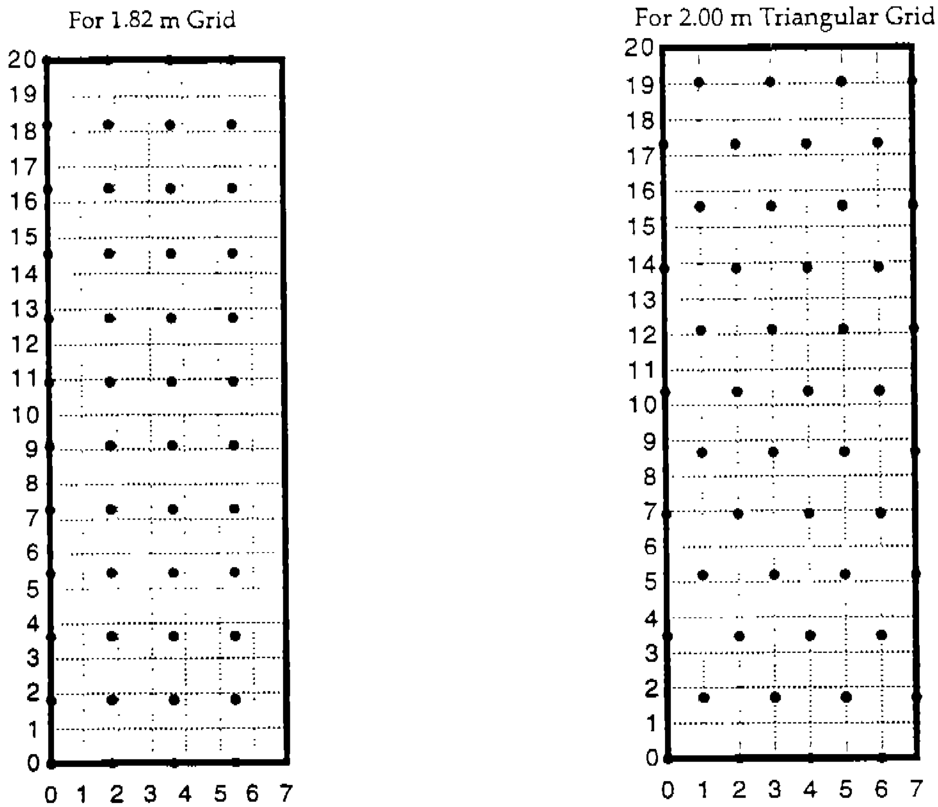


Figure III-2-3. Examples of grid shapes and spacing that were used under the assumption that L = 1 m and setting β to 10% in a 7- × 20-m area.

Also, discrete samples were collected on a 1.82-m-square grid, which corresponds to β of 10% for locating a circular hot spot with a radius of 1 m.

Composite samples

Because of the tight grid spacing required to detect a hot spot, numerous samples must be taken, adding up to a large volume of sediment. Because the objective of this sampling is to detect milligram-size white phosphorus particles, and the sediment at ERF is fine silt and clay, white phosphorus particles were separated from the bulk of the sediment by passing the samples through a 30-mesh (0.59 mm) sieve. To reduce the number of samples submitted for analysis, samples were composited as described below.

The corners of Pen #5 used in the DWRC studies were relocated by surveying (Fig. III-2-1). An area 7 × 20 m encompassing the pen was marked with survey lath. Prior to any activity, the area was checked for UXOs. A visual inspection of the surface was made prior to walking in the immediate vicinity to prevent suspending sediment and limiting visibility. Additionally, a hand-held magnetometer, a Heliflux Model GA-52C Magnetic Locator, was used to scan the area to detect any buried ferrous metal objects. Three spots produced a signal, and these spots were marked with orange flagging and avoided. Samples were taken on square and triangular grid patterns based on the assumptions that the contaminated hot spots are circular with radii of 1.0 m (Fig. III-2-3). Additional samples were collected based on the assumption that the hot spot radius was 0.5 m and β equals 10%. To maintain proper grid spacing, quadrates and triangles were constructed from 3/4-in. i.d. CPVC pipe and fittings.

At the grid nodes, a measured volume (50 mL) of sediment was collected using a syringe corer (2.65 cm i.d., 9 cm length) and samples combined in a wash bucket equipped with a #30 mesh sieve (Forestry Supply, Jackson, MS, Part No. 77255) to produce one composite sample for the 7 × 20 m pen. The wash bucket was held underwater, and the sediment stirred to wash away the fine-grained sediment and reduce the volume of the sample. Previously, when ERF sediments were sieved in this manner, the volume was reduced by a factor of about 100, depending on the amount of organic matter present. Each composite sample was placed in a glass jar equipped with a septum cap and refrigerated in the dark until analysis. Duplicate samples were taken for each grid shape and spacing.

Discrete samples

To relate the results of this field compositing protocol to white phosphorus concentration and to determine the distribution of white phosphorus within the pen, discrete 120-mL discrete samples were obtained using a 1.82-m-square grid spacing for a total of 48 samples. In addition, replicate samples were taken from five randomly chosen sites.

Laboratory tasks

Composite samples

To detect the presence of white phosphorus, the composite samples were warmed to room temperature, and headspace solid-phase microextraction (SPME) followed by gas chromatography performed (Walsh et al. 1996). When the SPME method indicated that white phosphorus was present, the sample was examined using a dissecting scope, and white phosphorus particles were picked out and measured with a micrometer. When no more particles were observed by microscopic examination, 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. Particles greater than 0.3 mm in diameter (26 µg) can be detected using this method (Walsh et al. 1995). The number of particles detected using each grid spacing and shape was tabulated.

Discrete samples

The 53 discrete samples from the 1.82-m-square grid were analyzed in duplicate using the standard method of analysis for white phosphorus in sediment (USEPA 1995). For this method, white phosphorus is solvent-extracted from 40-g subsamples, and the solvent analyzed by gas chromatography (GC). This method determines the total mass of white phosphorus present in a sample, and results are expressed in concentration units (µg/g). Following subsampling for the GC analysis, approximately 80 mL or 120 g of sample remained, and this sediment was examined for white phosphorus particles by spreading the sample on aluminum plate and heating as described above. These samples were not sieved because the amount of sediment was small.

RESULTS

Composite samples

The area sampled is within a pond that is only partially vegetated. Despite the large amount of sediment collected to form the composite samples (Table III-2-3), once sieved, the volume in all cases was reduced to less than 100 mL. This volume of sediment can be analyzed without subsampling in the laboratory using headspace SPME. The SPME analysis indicated a large amount of white phosphorus in each of the composite samples collected.

In our original work plan, we proposed to count white phosphorus particles by spreading the composite sample on a pan, heating, and counting flames. This approach was used for the first sample examined (2.33-m-square grid, Rep. 1) (Table III-2-4). However, so many particles were present in this sample that, once heated, it resembled the grand finale of a fireworks display. With so many particles undergoing simultaneous ignition and the residue of adjacent particles merging, accurate counting of the particles was difficult. For the re-

Table III-2-4. Numbers of particles retained on a 0.59-mm mesh from composite samples made up of 50-mL sediment samples collected at the nodes of regular two-dimensional grids.

Grid size (m)	Grid shape	Number sample sites	Number of particles		
			Rep1	Rep 2	Total
0.91	Square	184	75	50	125
1.82	Square	48	21	34	55
1.96	Square	44	14	12	26
2.33	Square	36	28	43	71
2.00	Triangle	48	7	8	15
2.17	Triangle	39	29	9	38
2.44	Triangle	30	6	3	9

maining samples, we used microscopic examination first as described above in Methods.

White phosphorus particles were detected using each of the grid sizes and shapes we tested (Table III-2-4). The greatest number of particles was found using the smallest (0.91 m) grid where the most samples were composited; however, number of samples in each composite was not correlated with numbers of particles detected.

The particle sizes were typical of what we had observed previously in samples collected from permanently flooded areas. Of the 208 particles that were found by microscopic examination, most were between 0.59 mm (the size of the mesh used for sieving) and 2 mm in their longest dimension (Fig. III-2-4), which is equivalent to 0.2 to 7.6 mg for spherical particles. The largest particle found measured

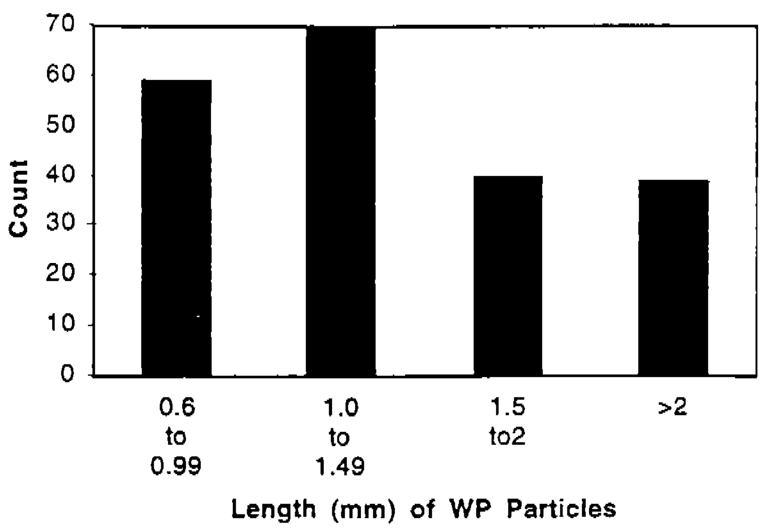


Figure III-2-4. Size distribution of white phosphorus particles retained on a 0.59-mm mesh from composite samples taken from DWRC Pen #5.

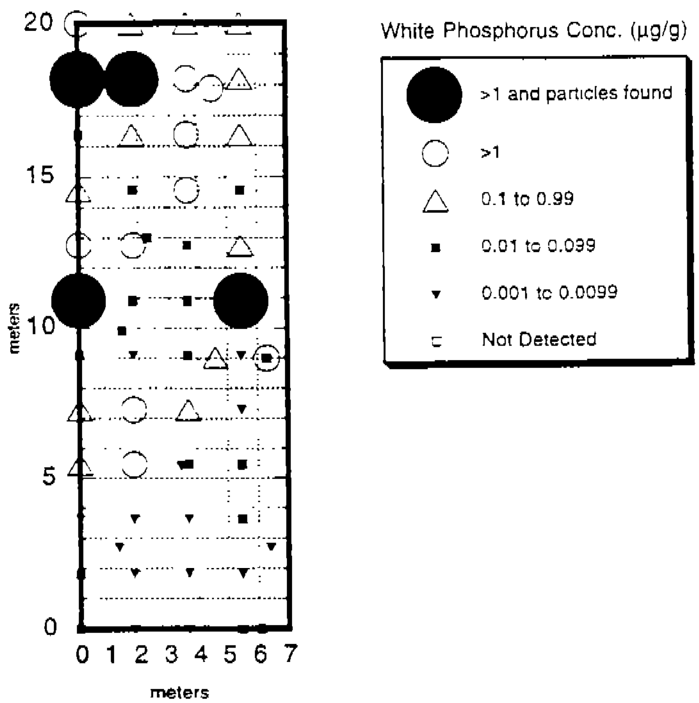


Figure III-2-5. Plot of white phosphorus concentrations found on a 1.82-m-square grid in 1996 and in samples taken by DWRC, 1992–1994. The large black circles indicate discrete samples where white phosphorus particles were found, and the diameter of the circle is proportional to the assumed hot spot diameter.

7.4 × 3.7 × 3.0 mm and weighed approximately 150 mg.

Discrete samples

White phosphorus was detectable by solvent extraction and gas chromatography in every discrete sample taken on the 1.82-m-square grid, and concentrations ranged from 0.002 to 421 µg/g. Particles were observed at only four sample sites (Fig. III-2-5, Table III-2-5), all of which had concentrations over 3 µg/g. The largest number of particles (102 particles in 117 g of sediment) was found at the sample site with the highest concentrations, which were 421 and 393 µg/g for the duplicate analyses.

DISCUSSION

From 1991 to 1993, sampling along transects through large areas of ERF allowed us to determine which areas are contaminated with white phosphorus. Samples were collected at 25-m intervals based on the area estimated to contain most of the fallout from the kinds of smoke projectiles that were commonly fired into ERF during training exercises (Shin 1985). Most of the samples from these transects contained low or undetectable concentrations of white phosphorus. Sporadically a sample was collected that had high white phosphorus concentrations and contained solid pieces of white phosphorus (Racine and Brouillette 1995). Further work examining the distribution of white phosphorus from point-detonating 81-mm mortar smoke rounds at an upland site showed that most of the residual white phosphorus was located within 2 m of the point of impact and white phosphorus concentrations decreased exponentially out to 22.5 m away (Walsh and Collins 1993). Extrapolating these results to the pattern of contamination at ERF, any detection

Table III-2-5. White phosphorus concentrations and numbers of particles found in discrete samples taken from the nodes of a 1.82-m square grid (See Figure III-2-5).

Row	Column	x (m)	y (m)	WP conc. (µg/g wet weight)		Mean	Dups†		Part-icles††	Sample mass (g) †††
1	1	0	0	0.0489	0.0137	0.0313			0	125
1	2	1.82	0	0.0050	0.0043	0.0047			0	115
1	3	3.64	0	0.0025	0.0027	0.0026			0	119
1	4	5.46	0	0.0181	0.0161	0.0171			0	115
2	1	0	1.82	0.0222	0.0247	0.0234			0	126
2	2	1.82	1.82	0.0024	0.0030	0.0027			0	122
2	3	3.64	1.82	0.0029	0.0038	0.0033	0.0035	0.0081	0	108
2	4	5.46	1.82	0.0029	0.0039	0.0034			0	122
3	1	0	3.64	0.0081	0.0079	0.0080			0	131
3	2	1.82	3.64	0.0037	0.0046	0.0042			0	123
3	3	3.64	3.64	0.0083	0.0091	0.0087			0	129
3	4	5.46	3.64	0.0162	0.0096	0.0129			0	127
4	1	0	5.46	0.1018	0.1075	0.1046			0	134
4	2	1.82	5.46	4.30	4.02	4.16			0	105
4	3	3.64	5.46	0.0319	0.0165	0.0242	0.0441	0.0383	0	104
4	4	5.46	5.46	0.0117	0.0132	0.0125			0	123
5	1	0	7.28	0.135	0.153	0.144			0	117
5	2	1.82	7.28	5.38	4.92	5.15			0	118
5	3	3.64	7.28	0.551	0.642	0.597			0	132
5	4	5.46	7.28	0.0096	0.0118	0.0107			0	116
6	1	0	9.1	0.0289	0.0410	0.0350			0	128
6	2	1.82	9.1	0.0087	0.0149	0.0118			0	130
6	3	3.64	9.1	0.0757	0.1111	0.0934			0	134
6	4	5.46	9.1	0.0076	0.0069	0.0073	0.0333	0.0310	0	115
7	1	0	10.9	22.9	237	130			9	137
7	2	1.82	10.9	0.0391	0.0347	0.0369			0	127
7	3	3.64	10.9	0.0577	0.0597	0.0587	0.102	0.114	0	111
7	4	5.46	10.9	25.3	45.5	35.4			6	126
8	1	0	12.7	8.52	5.47	7.00			0	117
8	2	1.82	12.7	6.01	5.92	5.97			0	120
8	3	3.64	12.7	0.0148	0.0149	0.0148			0	125
8	4	5.46	12.7	0.760	0.773	0.767	0.431	0.525	0	125
9	1	0	14.6	0.129	0.152	0.140			0	129
9	2	1.82	14.6	0.0610	0.0652	0.0631			0	130
9	3	3.64	14.6	1.73	1.68	1.71			0	121
9	4	5.46	14.6	0.0626	0.0502	0.0564			0	127
10	1	0	16.4	0.0336	0.0384	0.0360			0	110
10	2	1.82	16.4	0.112	0.102	0.107			0	108
10	3	3.64	16.4	19.7	30.4	25.0			0	104
10	4	5.46	16.4	0.279	0.287	0.283			0	107
11	1	0	18.2	421	393	407			102	117
11	2	1.82	18.2	3.63	4.62	4.12			5	105
11	3	3.64	18.2	1.28	0.516	0.900			0	108
11	4	5.46	18.2	0.691	0.513	0.602			0	101
12	1	0	20	5.24	0.265	2.75			0	112
12	2	1.82	20	0.616	0.475	0.546			0	121
12	3	3.64	20	0.320	0.349	0.335			0	104
12	4	5.46	20	0.337	0.414	0.376			0	118

†Separate sample; ††Found using hot plate; †††Mass of sediment examined for particles

Table III-2-5 (Continued).

	Subsample 1	*Subsample 2*	*Mean of subsamples*
All Rows			
mean	11.0	15.4	13.2
s	60.7	65.6	61.3
max	421	393	407
min	0.0024	0.0027	0.0026
median	0.069	0.084	0.078
Geo Mean	0.140	0.138	0.145
n	48	48	48
Rows 1 to 3			
mean	0.0118	0.0086	0.0102
s	0.0135	0.0067	0.0093
max	0.0489	0.0247	0.0313
min	0.0024	0.0027	0.0026
median	0.0066	0.0062	0.0063
Geo Mean	0.0072	0.0067	0.0071
n	12	12	12
Rows 4 to 6			
mean	0.89	0.84	0.86
s	1.87	1.72	1.79
max	5.38	4.92	5.15
min	0.0076	0.0069	0.0073
median	0.0538	0.074	0.064
Geo Mean	0.082	0.089	0.086
n	12	12	12
Rows 7 to 9			
mean	5.47	24.7	15.1
s	9.14	68	37.5
max	25.3	237	130
min	0.0148	0.0149	0.0148
median	0.445	0.463	0.454
Geo Mean	0.542	0.66	0.63
n	12	12	12
Rows 10 to 12			
mean	37.8	35.9	36.9
s	121	113	117
max	421	393	407
min	0.0336	0.0384	0.0360
median	0.65	0.445	0.574
Geo Mean	1.21	0.90	1.14
n	12	12	12

of white phosphorus at a sampling point, no matter how low the concentration, indicated that white phosphorus munitions had been fired nearby; thus there was potentially a localized hot spot within 20 m corresponding to the point of detonation of the white phosphorus round.

The term "hot spot" typically refers to a highly contaminated localized area (Gilbert 1987). Hadley and Sedman (1992) argued that not only must the contaminant concentration be elevated relative to the surrounding area, it must also pose a potential threat to public health. At ERF the white phosphorus contamination is distributed over broad areas, such as Area C, the Bread Truck Pond, and Racine Island, but the bulk of the contaminant that is available to feeding waterfowl is confined to very small areas (1- to 2-m diameter), punctuating the much larger areas containing little or no white phosphorus. These small areas are what we refer to in this report as hot spots. To find these hot spots using traditional discrete samples would require the collection and analysis of an unrealistically large number of samples. In this study we demonstrate that compositing of samples may be used to test areas for hot spots.

For this study we chose to sample an area that was known to contain white phosphorus that was available to feeding waterfowl, the DWRC pen #5 that was used for chemical bird repellent studies. This pen is located near the northwestern edge of the permanently flooded main pond in Area C, and since 1990, when we began our studies, has always been covered with water. Within this 7- × 20-m area a total of 54 mallards, in groups of six, were penned for various lengths of time. Of these 54 mallards, 29 appeared to die of white phosphorus poisoning. In the studies where the mallards were confined continuously for one week or more, all the birds died (Table III-2-2). This pattern of mortality seemed to indicate that if the mallards took enough "samples" from the sediments within the pen, they eventually would hit a hot spot. Modeling our sampling approach after the ducks, we also took numerous samples; however, we chose the sample points systematically so that we would have some idea of our risk of missing a hot spot.

We collected composite samples from the nodes of square and triangular grids with grid spacing chosen to find circular hot spots with a radius of 0.5 to 1 m and risk of not finding a single hot spot of 10, 20, or 40%. Each of the grid sizes and shapes was adequate for finding particles in this particular pen (Table III-2-4). For the square grids the largest number of particles was detected using the 0.91-m grid, followed by the 2.33 m, then the 1.82 m, and the fewest were found on the 1.96-m grid. The ranking was true for replicate 1 and for replicate 2, and the total number of particles found, although the agreement between replicate 1 and replicate 2 was not very good in some cases. This poor agreement between replicates reflects the heterogeneity in the distribution of particles within a hot spot where we expect fewer particles towards the edge.

The results from the individual discrete samples taken on a 1.82-m-square grid indicates that the particles within this pen were indeed localized in "hot spots" (Fig. III-2-5). The assumption that the radii of the hot spots are around 1 m appears to be valid. One sample site had over 100 particles in 80 mL (117 g) of sediment. A duck dabbling at this site could not avoid ingesting a lethal quantity of white phosphorus. In previous years, white phosphorus particles were never found in samples with concentrations less than 1 µg/g (Racine 1996). This trend was true in these samples as well. The white phosphorus concentrations in these samples with visible particles ranged from 3.6 to 421 µg/g. However, there were eight sites where at least one duplicate gas chromatographic analysis of a 40-g subsample yielded a concentration greater than 1 µg/g, yet no particles were observed in the remaining sample. Particles in these samples must have been less than 0.3 mm diameter (0.026 mg), the smallest particle that produces a noticeable flame and leaves an orange residue (the method used to count particles). Only two of these small particles in a 40 g subsample would produce a concentration greater than 1 µg/g (Table III-2-6). We know that the toxicological properties of white phosphorus are not significantly changed by the form of the white phosphorus (dissolved in oil, small particles, or large particles) (Roebuck and Nam 1995). Yet we do not know if a duck will actually ingest very small (<0.5 mm diameter) particles while dabbling. For now, 1 µg/g can conservatively be used as a threshold concentration where there are potentially ingestible white phosphorus particles.

Table III-2-6. Relationship between white phosphorus concentration found by solvent extraction of a 40-g sediment sample and the size of a single spherical white phosphorus particle, the presence of which, could result in that concentration.

White phosphorus conc. (µg/g)	*White phosphorus mass (mg)*	*Diameter of white phosphorus particle (mm)*
1	0.04	0.35
5	0.2	0.59
10	0.4	0.75
50	2.0	1.28
100	4.0	1.61

The results of discrete samples on the 1.82-m-square grid indicate that four of the sample sites were within hot spots. Were these hot spots sampled using the other grids? Because we do not know the exact center of these hot spots, a definitive answer is not possible. However, by overlaying each grid on a map with the four hot spots centered on the 1.82-m grid system (Fig. III-2-5), we can estimate that the smallest grid (the 0.91-m square) hit each hot spot multiple times, the 1.96-m square and 2.00-m triangle hit them all once, and the 2.33-m square and 2.17-m triangle hit three of the four hot spots. Only the 2.44-m triangle does not have a node that falls within hot spots centered on the 1.82-m grid. Although few in number, particles were found using this grid so at least one hot spot was sampled.

For future applications of this compositing method, what size grid would we recommend? The size of the grid depends on the acceptable risk of missing a single hot spot

(β), if one exists. In all likelihood, more than one hot spot exists in highly contaminated areas of ERF, as we found in the area sampled for this study. If more than one hot spot exists, and we are still interested in finding only single hot spot with a probability of 90%, how might the grid size be changed? If we know the number of hot spots (H), we may use a binomial distribution to compute the grid spacing needed to find a certain number (h) of these hot spots at an acceptable risk (Gilbert 1982):

Probability of hitting exactly h of H hot spots

$$= \left(\frac{H!}{h!(H-h)!} \right) (1-\beta)^h \beta^{(H-h)}$$

Unfortunately we have no idea how many hot spots exist in ERF. Gilbert (1982) presents two options when this knowledge is unavailable. The first is to guess a likely number of hot spots, based on historical information and use the binomial distribution as shown above. The second is more complicated, and involves choosing an a priori Poisson distribution and using a compound binomial distribution. We lack sufficient information for either approach. However, we can determine the extremes of grid spacing by systematically increasing the number of hot spots in our calculation and seeing how grid size may increase while maintaining an acceptable risk of missing hot spots. For example, we set the probability of hitting zero of H hot spots to 10% (or some other acceptable risk) and the binomial distribution simplifies to:

Probability of hitting exactly 0 of H hot spots = 0.1 = β^H for H = 1, 2, 3 ....

Then solving for β:

$$\beta = (0.1)^{(1/H)}.$$

Going back to the operating curve relating L/G to risk β (Fig. III-2-2), we can calculate G, the grid spacing needed to maintain a 90% chance of hitting *at least* one hot spot. Results of this calculation for H = 1, 2, 3, ...15 (Fig. III-2-6) shows that the grid spacing needs to be

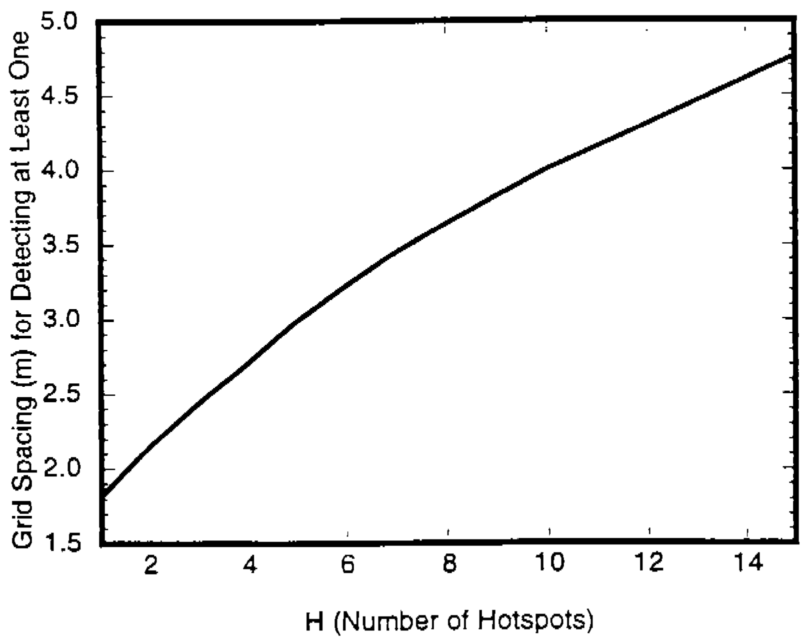


Figure III-2-6. Effect of the number of hot spots on the grid size designed to detect at least one hot spot while maintaining a 10% risk of not hitting any hot spots.

on the order of a few meters to find at least one hot spot with a radius (L) of 1 m, unless the number of hot spots is large. Even if 100 hot spots exist, the grid spacing can be no larger than 10 m to find at least one hot spot 90% of the time. This requirement for such tight grid spacing brings out the importance of compositing samples to reduce the total number of samples submitted for analysis. Because a single hot spot can contain enough white phosphorus to poison hundreds of ducks, the prudent approach would be to keep the grid spacing small (approximately 2 m), and sample along transects through the area of interest.

The triangular grid system is more efficient (i.e., requires fewer samples) (Parkhurst 1984, Singer 1975); however, we found that consistent grid spacing and alignment was easier to maintain using the square grid. The quadrate of the square grid was laid down in one corner of the pen and samples taken at each apex, then the quadrate was flipped end over end, and another four samples taken. In this way, two rows were sampled simultaneously. One could envision sampling a transect through a much larger area using this approach.

A logical follow-up would be to collect composite samples on a grid pattern from the other pens. Waterfowl mortality occurred within each of these pens, so white phosphorus was available. If we could demonstrate the success of this compositing approach within these pens, our confidence would increase for use elsewhere within ERF. After we obtained our samples from Pen 5 in mid-May 1996, safety regulations changed at ERF, and walking through water-covered areas was prohibited for the first time since we began our investigations in 1990. Future sampling in water-covered areas may need to be accomplished from a boat (which would be a challenge in windy conditions) or a remotely controlled sampling device.

One potential application of composite sampling is in the drained Bread Truck Pond. Since this area is no longer covered with water, sampling may be done without violating safety regulations. Based on the predicted tidal cycle for 1997, there will potentially be a 10- to 14-week interval between tidal flooding (May 9 to July 20 or May 7 to Aug. 18) (Haugen 1996, p. 128-129). If weather conditions are favorable for drying, large sections of the Bread Truck pond may decontaminate. We have the opportunity to have "before" and "after" measurements if samples are taken early May and August 1997.

CONCLUSION

A sampling protocol designed to detect the presence of white phosphorus particles was demonstrated in a heavily contaminated area of ERF, the site of the DWRC pen studies (Racine 1994). Because ducks are the main receptors at risk, a sampling protocol was modeled after the way ducks feed. Specifically, many small samples were composited and passed through a 0.59-mm mesh to remove the fine-grain material. The material left on the mesh was examined for white phosphorus particles. The distance between each sample was based on the assumption that most of the available white phosphorus is located in hot spots with radii of approximately 1 m. Unless the number of hot spots is large, the distance between samples must be on the order of 2 m to maintain a low risk of not hitting a single hot spot.

Results from the analysis of individual discrete samples showed that sample sites with high white phosphorus concentration and containing solid pieces of white phosphorus are indeed located within small areas punctuating a much larger area containing low concentrations of white phosphorus. The area we sampled was highly contaminated, and white phosphorus particles are still abundant within the top 9 cm of sediment even though six years have passed since white phosphorus munitions were used at ERF.

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III-3. POND DRAINING TREATABILITY STUDY: 1996 STUDIES—THE DRAINING OF BREAD TRUCK POND

Charles M. Collins, Maj. Michael T. Meeks, Marianne E. Walsh, and Ronald N. Bailey

U.S. Army Cold Regions Research and Engineering Laboratory

INTRODUCTION

Since the identification of white phosphorus (WP) contamination in Eagle River Flats in 1990 (Racine et al 1991, 1992b), considerable work has been conducted both to characterize the nature and extent of WP contamination and to develop possible treatment options (Racine et al 1992a, 1993, Racine and Cate 1994, 1995). Treatment options being studied include dredging, covering, and pond draining.

Work by M.E. Walsh (Walsh and Collins 1995, Walsh et al. 1995, 1996) has shown that if pond sediments contaminated with WP dry below saturation, the WP particles within the sediment will begin to sublime if soil temperatures are above about 15°C. The unsaturated condition of the sediment allows the WP vapors to disseminate through the soil pores away from the WP particle and oxidize into P_4O_{10}, a nontoxic compound. For this sublimation and oxidation process to proceed, the contaminated pond bottom sediments need to be subaerially exposed long enough for the sediments to dry to below saturation. This occurs normally in the intermittently flooded shallow ponds during periodic long intervals between flooding tides when the ponds dry up due to evaporation. Because of this in-situ natural attenuation of WP contamination when pond sediments dry, pond draining has been considered as one treatment option. The contaminated pond bottom sediments could be subaerially exposed, either through temporary draining of the ponds by pumping or through permanent draining by ditching.

Initial treatability studies were conducted to ascertain if either temporary or permanent pond draining was a viable option (Collins 1994, 1995, Collins et al. 1996). The feasibility of using pond draining as a treatability option depends on several factors, including location, local surface topography, and hydrology. The pond would have to be hydrologically isolated enough from other nearby ponds or extensive wetland areas so that draining would not materially affect the other areas. If we attempted to drain too large a hydrologically connected area, there would not be sufficient time to both drain the area and allow the newly exposed sediments to dry prior to the area being refilled by a flooding high tide. In addition, limiting draining to just isolated pond areas would limit the environmental impact and loss of habitat that more widespread draining would cause.

The Bread Truck (BT) Pond, an isolated, shallow, highly contaminated pond northwest of Area C and west of C/D area, appeared to lend itself to a pond draining treatment based on surveys and initial studies (Collins 1995).

Temporary pond draining would involve the use of a large-capacity pump to pump the pond basin dry. The pumping would have to be repeated periodically, either as the basin started to refill from groundwater inflow and flow from the surrounding areas, or after one of the recurrent monthly flooding high tides. Because of the requirements to subaerially expose the pond bottom sediments as long as possible to allow them to dry below saturation, a pump system would have to be large enough to drain the pond as quickly as possible and keep it dry as long as possible throughout the summer. The other advantage of temporary pond draining was that it was easily reversible. Once the pond bottom sediments underwent drying and natural attenuation, the pond environment could be restored simply by removing the pump and allowing the natural periodic flooding to refill the basin. A pump system to temporarily drain small ponds was designed, ordered, and received in 1995. It was not placed in service that season because of the lateness of the delivery of equipment (Collins et al. 1996).

Permanent pond draining would involve the excavation of a drainage ditch connecting the pond to a nearby distribution gully. Permanent draining had the advantages of less labor costs and much less operational costs than temporary pond draining after the initial excavation. However, reversing the process would be much more difficult. Because of time and funding constraints during 1996, permanent pond draining was deemed a less expensive, more expedient treatment method than temporary draining, and the decision was made to permanently drain the BT Pond through the excavation of a drainage ditch connecting the pond with a nearby distributary gully leading into Eagle River. Because of the possibility of encountering unexploded ordnance, conventional excavation of a drainage ditch using heavy equipment was not practical. Instead, plans were made to use military explosives to excavate the drainage ditch.

SITE DESCRIPTION

The Bread Truck (BT) pond is an isolated pond located east of Eagle River and northwest of the Area C pond complex (Fig. III-3-1). The BT Pond consists of an inner permanently flooded pond with an area of 33,000

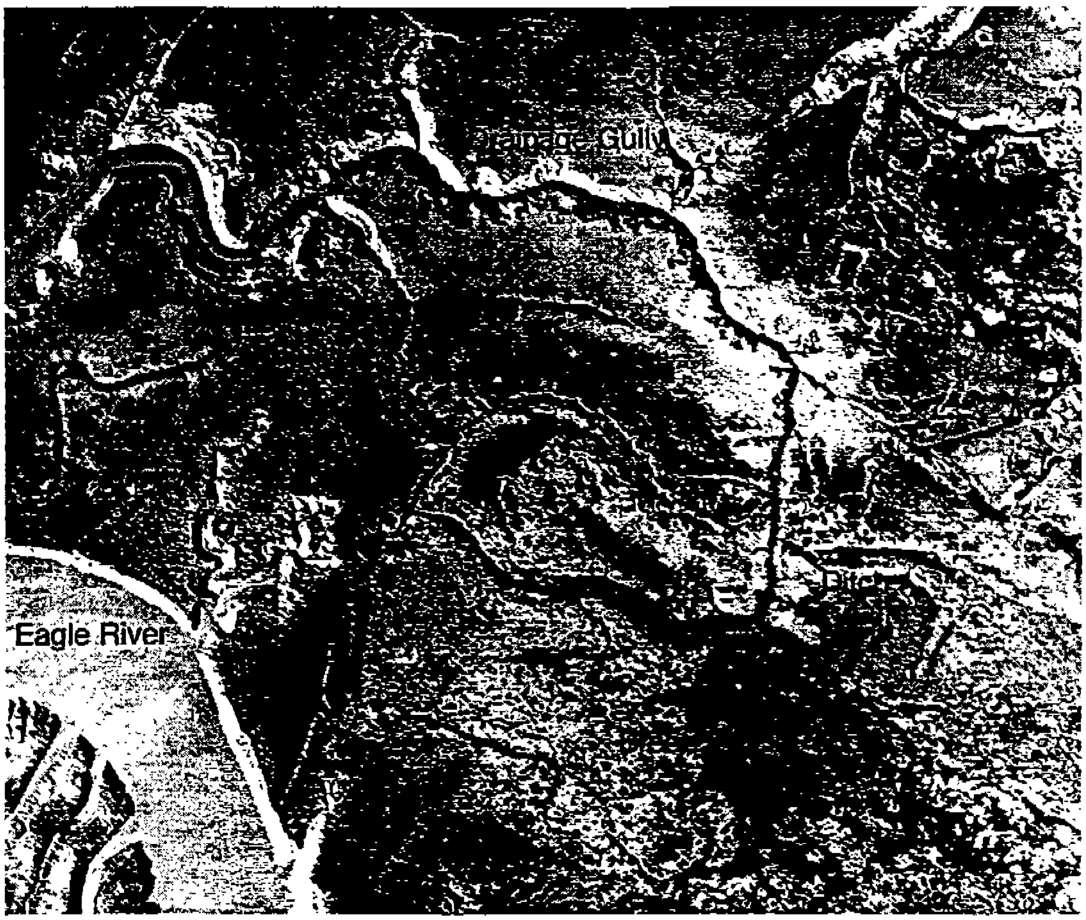

Figure II-3-1. Aerial view of region of Bread Truck Pond within Eagle River Flats.

m^2 (3.3 ha). An outer intermittently flooded pond area of 5.4 ha surrounds the permanent pond, mainly on the west and south. Additional adjacent and connected intermittently flooded ponds on the north total another 1.0 ha. The pond area is surrounded on three sides by higher, vegetated mudflats (Racine et al. 1993). On the fourth side, to the east, the pond is bounded by a sedge and bulrush marsh complex called the C/D area. The elevation on this side of the BT Pond is lower than the other three sides, allowing some flow between the BT Pond and the C/D area at certain water levels. To the east of the C/D area is an upland bluff marking the eastern boundary of Eagle River Flats.

Distributary channels or gullies leading to Eagle River are located on the south and north side of the BT Pond (Fig. III-3-1). These allow tidal inflow into the pond during flooding high tides and provide drainageways for the area during the tidal ebb. The gullies are undergoing headward erosion and are projected to eventually intercept and permanent drain the BT Pond. The gully just to the northwest of the BT Pond has exhibited net headwall recession rates of up to 3.5 m per year during 1993 and 1994 (Lawson et al. 1994, 1995). Erosion increased dramatically during 1995 with headward erosion of 15 m or more (Lawson et al. 1996). If such headward erosion rates continue, erosion would cause natural drainage of the pond within 2–5 years rather than the 10–15 years predicted previously.

The BT Pond basin is subject to periodic refilling under certain 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. Some years will have only one or two series of flooding high tides during the summer. Other years, such as 1991 and 1996, had a flooding series of high tides every month of the summer. Prior to the excavation of the drainage ditch, monthly peak high tides, if above about 31 ft Anchorage tidal datum (or about 4.79 m MSL), would spill over a threshold into the pond basin from the nearby distributary gully, refilling the pond basin. Depending on the height of the flooding high tide, the water will fill the intermittently flooded pond areas up to a water surface elevation of about 4.95 m. The water level in the pond will then slowly drop as water flows out of the pond through the distributary channels. Additional drops in the water level below the threshold elevation occur as evaporation reduces the amount of water in the pond and possible groundwater flow out of the pond.

Minimum pond bottom elevations within the permanent pond are about 4.40 m, giving a maximum depth following filling by a flooding high tide of about 0.55 m. Minimum elevations for the intermittently flooded pond area range from 4.75 to about 4.95 m, giving a maximum depth following filling by a flooding high tide of 0–0.15 m (Collins 1995)

METHODS

Planning the explosive excavation of the ditch

Because Eagle River Flats is an artillery impact range, there is a possibility 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 the BT Pond with the nearby gully. Military engineer units train to use explosives to excavate tank trap ditches, breaches across roadbeds, etc., as part of their combat engineering mission (U.S. Army 1987, 1992). The mission to explosively excavate a ditch in ERF was presented to the 23rd Engineer Co., Ft. Richardson, as a unique 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 exercise.

The plan was to conduct the mission in early spring, prior to thawing of the ice covering the pond and the surrounding area. The ice cover would facilitate access in the area, keeping personnel from wading through water as they placed explosive charges. The ice cover would also decrease the possibility of personnel encountering UXOs while working in the area.

A review of the literature was done to try to determine the type of explosives to use and optimum spacing of explosive charges. A review of guidelines given in the Engineer Field Manual (U.S. Army 1992) indicated that a series of 40-lb cratering charges set off in a line, producing a series of overlapping craters, would be the optimum method for excavating the ditch. To produce the optimum size crater for the amount of explosive, the cratering charge needs to be placed at depth in a 30-cm-diameter borehole in the ground. Standard procedures call for either using a drill rig to auger the boreholes or using standoff shaped-charge explosives to explosively excavate the boreholes. The cratering charges are then placed in the boreholes and detonated, producing the final crater. Again, because of the possibility of encountering UXOs in ERF, the boreholes we needed for the cratering charges would have to be excavated using shaped charges.

The field conditions we would encounter during the operations would affect the diameter and depth of the craters formed by the cratering charges. Thus the spacing used for the charges needed to be adjusted for the field conditions. The conditions we would encounter would vary over the length of the planned ditch. Approximately 55% of the planned 90-m length of the planned ditch would be located on an area of vegetated mudflat between the north edge of the pond and the southern end of the nearby gully. The vegetated mudflat area consists of fine-grained (mostly clay with some silt) cohesive soil with sparse to dense low-sedge vegetation. The ground would be seasonally frozen to some unknown depth, probably about 60 cm. The soil beneath the frozen layer would be fairly dense but saturated. The northern end would be frozen deeper, because of the exposure of the headwall of the gully. Depending on the year, there may be a superimposed ice layer on top of the ground surface (Taylor et al. 1994, Collins and Calkins 1995). Within the pond, normal water depths would vary from 0 to 30 cm, with the ice frozen to bottom by spring. Beneath the ice, sediment may be frozen to some unknown depth or may be unfrozen and saturated.

A review of literature on the use of explosives to excavate craters in frozen ground gave some information on expected size of craters from a given charge size. 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 center line 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 the spacing to as large as practical, yet still producing craters that would overlap to some degree, thus forming a connected ditch. Erosion from flooding and ebbing tidal water would erode out and widen any material left in the ditch. Increasing the spacing would allow us to use as small an amount of explosives as possible. This was a major consideration due both to the cost of the explosives and the desire to keep the size of the blast as small as possible. Ft. Richardson is adjacent to the community of Eagle River, and noise from range use was a concern to the Army Command.

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 (Mellor 1986a) 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 equations presented in Mellor (1986a, 1989).

The 40-lb cratering charge is a watertight,

Table III-3-1. Predicted apparent scaled radius (m/kg$^{1/3}$) at optimum charge depth.

	Moist clayey soil[1]	Frozen silt[1]	Ice[2]
R_a	0.9	0.9–1.1	0.71
Opt. depth	0.5	0.7–0.8	—

Radius and depths of craters in m.
[1]Mellor (1989).
[2]Mellor (1986a).

Table III-3-2. Demolition munitions requested.

Type	Quantity
M3A1 40-lb shaped demolition charge	17 each
M7 nonelectric blasting caps	10 each
Detonating cord	1000 ft
M700 time fuse	100 ft
40-lb cratering charges	17 each
C4, 1.25-lb blocks	40 each
TNT, 1-lb blocks	40 each
M60 fuse igniter	10 each

cylindrical metal container with approximately 13.6 kg (30 lb) of ammonium-nitrate-base explosive and 4.5 kg (10 lb) of TNT explosive booster (U.S. Army 1992) for a total of 18.1 kg of explosives. Using the equations of 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 size 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 we decided to place our cratering charges at 5-m intervals along the planned line of the ditch.

Both 15-lb, M2A4 and 40-lb, M3A1 shaped demolition charges are available for the explosive excavation of boreholes. Work by Smith (1982) showed that the 15-lb shaped charge did not consistently give a wide enough diameter borehole in frozen sediment to enable placement of the 8-in. diameter cratering charge. Because of this we planned to use the larger 40-lb shaped charge for the borehole excavations. The M3A1 shaped charge contains a 0.05-kg booster of Composition A3 (91% RDX, 9% wax) and a 13.4-kg main charge of Composition B (60% RDX, 40% TNT) (U.S. Army 1992)

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).

Excavating the ditch

Due to unavoidable delays in securing permission to draw the required munitions from Army stores and the time required to get approvals to carry out the demolition mission, 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 late April, spring thaw had already started in ERF. The snow cover within ERF was already mostly gone, and meltwater pools covered portions of the ice surface of the ponds. The ice cover on the BT Pond was still in place, though covered in water in some areas. The ice cover would still decrease the possibility of personnel encountering UXOs while working in the area.

The mission was finally set for 30 April 1996. The date was weather dependent, with the mission to be delayed if there was a low cloud cover. The presence of a low cloud cover would reflect and intensify the sound of the explosive blasts, disturbing civilian areas off post. The weather on the morning of 30 April was clear, so the operation proceeded as planned.

The munitions were drawn from the Ammo Supply Point the previous day by the 23rd Eng. Co. (Table III-3-3). They were stored in a secured area overnight and brought down to the EOD (OB/OD) Pad the morning of 30 April. The EOD Pad along the edge of ERF was used as the base of operations for the mission. The munitions were unpacked, sorted, and prepared by the soldiers of the 23rd Eng. Co. A UH-1H helicopter of the Army National Guard was used to ferry the soldiers and the munitions out to the BT Pond demolition site, 1300 m to the northwest.

Prior to commencement of operation, the area of the planned ditch was examined by EOD personnel from the 176th EOD Detachment to ensure that there are no UXOs exposed on the surface in the immediate vicinity that may have posed hazards to the personnel carrying out the operation.

The ditch was excavated in two stages. The beginning and endpoints of the planned ditch were located and flagged. The beginning point was at the head of the gully system north of the pond. The end point would be within the BT Pond 90 m to the south–southeast. The first stage used seventeen 40-lb shaped charges to form boreholes into the sediment. Nominal 1-× 2-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 down. The charges were spaced every 5 m along the centerline of the planned ditch. A block of C4 explosive was molded into the top 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 block of C4 on top of the shaped charge. The line main detonation cord connected all 17 shaped charges together. A dual detonating firing system consisting of two fuse igniters, two lengths of time fuse cut to 7-minute lengths, and two blasting caps was used.

Once all branch lines were secured to the line main, all but three personnel departed the area, returning to the EOD pad 1300 m away. This was outside the minimum safety zone of 900 m. The OIC and two EOD personnel remained on site. OIC notified Range Control that area was about to go hot (10-minute advance notice). When approval was received from Range Control, the time 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 1-ft-diameter hole straight down into the ground. The total amount of explosives detonated in this first explosion was approximately 320 kg (700 lb). The detonation of the shaped charges produced a very loud, sharp explosive noise. After the blast the helicopter returned to the area, landing away from explosive blast area. The EOD personnel then again inspected the area for any possible newly exposed UXOs.

The inspection of the area following the first blast revealed that there was one shaped charge that did not detonate. This dud was located at the third planned borehole from the north end of the ditch. The C4 charge at the top of the shaped charge went off, but the shaped charge itself 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. 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. All the holes were filled with meltwater. Once the area was cleared, the rest of the personnel were ferried in by helicopter, and set up for the cratering charges began.

The second stage of the explosive excavation was then set up. In each of the 16 bore holes created by the shaped charges, the soldiers placed a 40-lb cratering charge with an attached 1-lb block of TNT. The charges were wired together in a similar matter to the shaped charges. The original plan was to tamp or stem the holes with sandbags once the charges were placed. The water-filled holes negated having to use all the sand bags we originally planned. Stemming by water provides satisfactory results with crater charges (Knudson et al. 1972). The one extra cratering charge (due to the missing borehole) was added to the cratering charge in the adjacent borehole. The cratering charges were connected in a similar manner to the shaped charges. Detonation cord was cut into 12-ft branch lines and tied with a Uli knot to the detonation cord line main and attached to block of TNT on the cratering charge. A dual detonating firing system consisting of two fuse igniters, two lengths of time fuse cut to 7-minute lengths, and two blasting caps was used to detonate the explosion.

Figure II-3-2. Cratering charge blast.

Once all branch lines are secured to the line main, all but three personnel departed the area via helicopter, returning to the EOD pad. The OIC gave 10-minute advance notice to Range Control that the area was about to go hot. When approval was received from Range Control, the time fuse igniters were pulled and the remaining personnel boarded the waiting helicopter and departed the area. The total amount of explosives detonated in this second explosion was also approximately 320 kg (700 lb). The detonation of the cratering charges (Fig. III-3-2) produced a very loud, deep, rumbling explosive noise that shook the ground and a shock wave that could be felt several thousand meters away.

Personnel

Officer-In-Charge (OIC)
 Maj. Michael Meeks, CRREL
Demolition Team, 23rd Eng. Co.
 2LT Shannon M. Cecchini
 SSG Clinton Brown
 SSG Carl O. Wilson
 SSG Luke Wong
 SGT Michael A. Boozer
 SGT Peter Wilson
 SPC Louis D. Keemer
 SPC Brad Spallino
 PFC Sharpherfy L. Davis
 PFC Thoris L. Rutledge
176th Explosive Ordnance Detachment
 CPT Michael Hicks, CO
 SGT Jessy Eismann
Surveying, Photography, Initial Planning, and Project Coordination
 Charles M. Collins, CRREL.

Instrumentation

Three instrumented sites were installed in the BT Pond in May to monitor environmental conditions in the pond bottom sediments. The sites were located in a transect from the northern edge of the pond, through the shallower, intermittently flooded pond area, to the deeper, permanently flooded pond area. Sites ranged in elevation from 4.79 to 4.43 m. UTM coordinates and elevations for the three instrumented sites and a data sampling summary are given in Table III-3-4. These three sites were three of the seven sites instrumented in 1995 (Collins et al. 1996)

Prior to any activity occurring at a site, the area around each site, as well as the path between sites, was checked for UXOs. A visual inspection of the surface was made prior to

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

	BT Pond Site BT-2	*BT Pond Site BT-4*	*BT Pond Site BT-6*
Location, East	354,513.7	354,519.03	354,529.0
North	6,801,856.5	6,801,830.3	6,801,791.3
Elevation	4.79 m	4.77 m	4.43m
Type of site	Intermittent pond	Intermittent pond	Permanently flooded
Water surface level	—	—	Continuously
Air temperature	—	—	Continuously
Sediment temperature	Continuously	Continuously	Continuously
Sediment moisture	Continuously	Continuously	Continuously
Tensiometer	Continuously	Continuously	Continuously

walking in the immediate vicinity to prevent sediment from being stirred up in the shallow standing water and limiting visibility. A hand-held magnetometer, a Heliflux Model GA-52C magnetic locator, was then used to scan the area to detect any buried ferrous metal objects. If nothing was detected, then we proceeded with sensor installation at the site. If a signal was detected, the spot was marked, flagged, and avoided, and another site selected.

The three sites were instrumented using electronic dataloggers to monitor sediment moisture levels and sediment temperatures on a continuous basis. Site BT-6, located in the deepest portion of the pond, was also instrumented to monitor pond water levels on a continuous basis.

The dataloggers used for the three sites are the 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 in turn 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-3-3).

Measurement of pond water level

Pond water levels were monitored at one location within the BT Pond (Site BT-6) using a CSI SR50 Sonic Ranging Sensor. The depth gage is attached to the end of a bracket arm that is in turn attached to the center mast of the tripod. The sensor is suspended on the bracket arm approximately 2.5 m above the water surface (Fig. III-3-3). 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 transmission 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 gage 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 gage sensor for the setup we used is ±1 cm.

The elevation of the bottom of the depth gage sensor was established by surveying from the Bread Truck 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 at Site BT-6. A measurement was taken every ten minutes and averaged every hour.

Sediment temperatures were measured

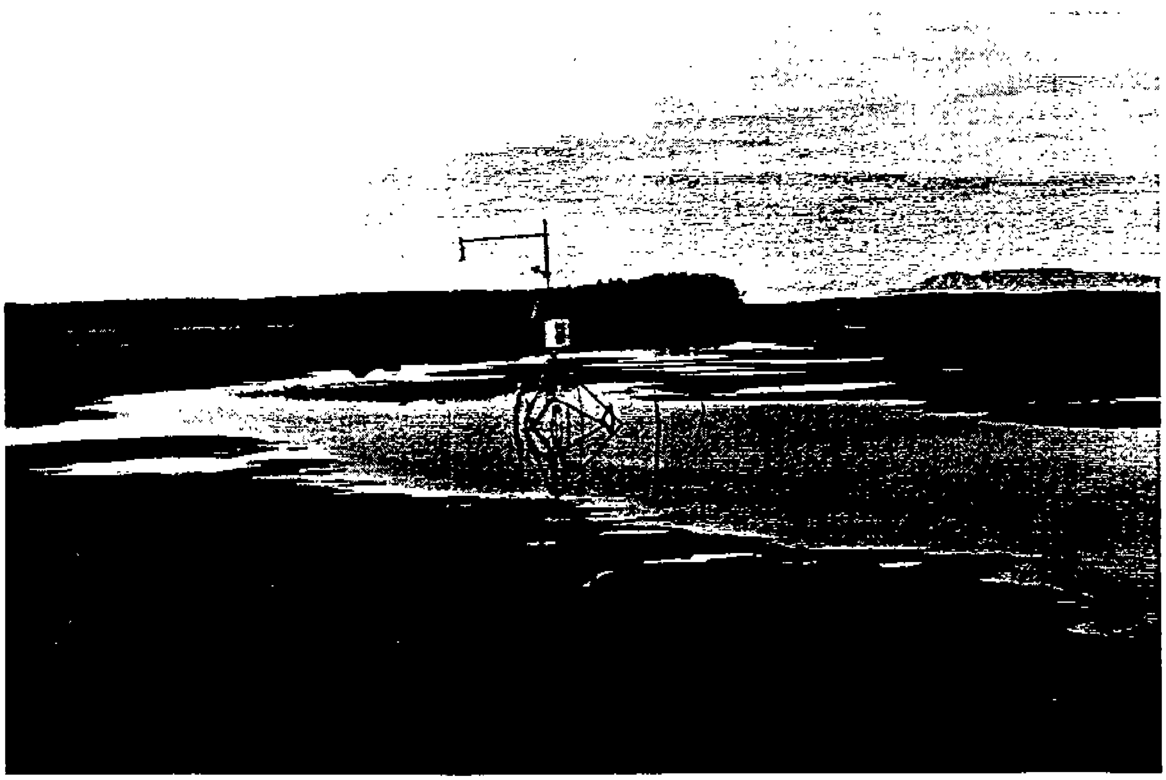

Figure II-3-3. Site BT-6 located in a remnant of Bread Truck Pond following draining. A depth gage is suspended on the bracket arm at the top of the tower above the datalogger enclosure.

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 at each of the three locations in the BT Pond. Soil temperature probes were installed by attaching sensors to a wooden lath at the proper spacing. The lath was pushed into the sediment until the sensors were at the proper depths. The leads for the two sensors were then wired into the wiring panel of the datalogger. 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 to 2 bars. The output from the sensors is the ratio of excitation voltage to 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 at the three locations. They were installed by attaching sensors to a wooden lath at the proper spacing. The lath was pushed into the sediment until the sensors were at the proper depths. The leads for the two sensors were then wired into the wiring panel of the datalogger. The sensor resistance is measured by the datalogger and stored in memory. The datalogger measured the resistance once every ten minutes, averaged the measurements once an hour, and stored the averaged measurement in memory.

Bulk sediment samples obtained from Sites BT-2 and BT-4 were used to develop a calibration curve for the soil moisture probe sensors. A known mass (2.5 kg) of dried soil was placed in a large container. Water was added to bring the soil moisture of the sediment up to 60% moisture content by dry weight. Three probes were placed in the sediment and allowed to come to equilibrium. The probes were connected to a CR10 datalogger, and periodic measurements of the sensors were made. Periodic soil moisture content measurements of the container of soil were also made. A plot of the soil resistance measurements versus gravimetric sediment moisture content are given in Figure III-3-4. At approximately 47% soil moisture, the BT Pond sediments start to become unsaturated, as indicated by the sharp rise in resistance as measured by the soil moisture probe.

A single SoilMoisture Model 2100F soil moisture probe tensiometer equipped with a Model 5301 current transducer instead of the dial gauge was installed at the 5-cm depth at each of the three sites to assist in monitoring near-surface sediment moisture. The current transducer converted soil moisture tension measurements into a digital output, which was recorded on the datalogger.

Organic content and drying potential

The drying potential of the sediments of the BT Pond was estimated by characterizing samples of sediment from the BT Pond. A bulk composite sample, approximately 20 kg, was taken of the bottom sediment in the area of BT-2 and BT-4. A portion of the sample was used to determine the organic content of the sediment [ASTM Standard D2974-88] (ASTM 1988). The sediment was oven dried at 105°C for 24 hr. The sediment was pulverized and mixed, and a series of subsamples was taken. The subsamples were placed in pre-weighed crucibles, weighed, and heated at 550°C for 16 hr to burn off organic material. The subsamples were cooled in a desiccator and re-weighed to determine percentage organic content by dry weight.

Air-entry value

Using a standard Tempe pressure cell (SoilMoisture Equipment Corp., Santa Barbara, CA), a moisture retention curve (Hillel 1982) for the BT Pond sediment was determined. This curve was used to estimate the air entry value, which gives an indication of how far the water table must drop before surface sediments become unsaturated. It also gives an estimate of the tensiometer reading corresponding to the onset of unsaturated conditions as sediments dry. To generate the curve, air pressure was applied to a core of saturated sediment placed on a porous ceramic plate in the Tempe pressure cell. Air

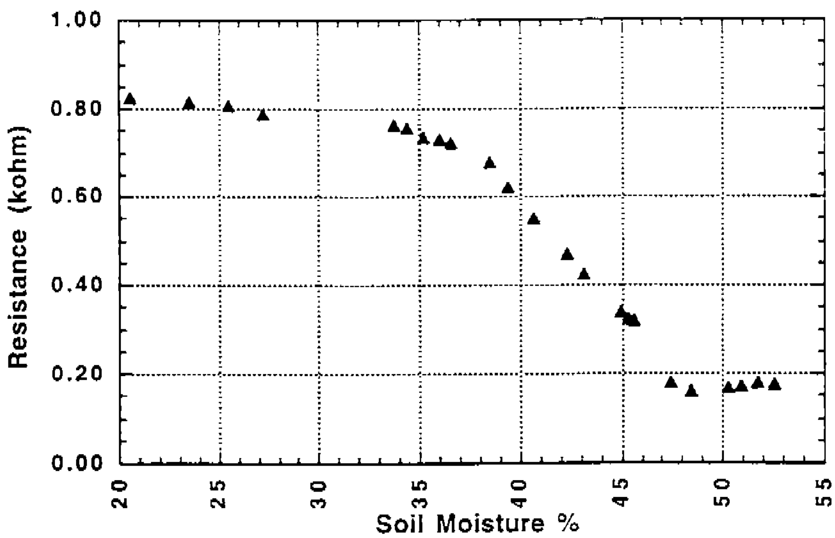

Figure II-3-4. Soil moisture probe resistance versus percent soil moisture by dry weight for a bulk sample of sediment from Bread Truck Pond.

pressure was incrementally increased, and the amount of water forced out of the sediment was recorded. The air entry value corresponds to the pressure at which capillary forces are overcome and air begins to penetrate the sediment matrix.

Surveying

We conducted a detailed survey to determine horizontal coordinates and elevations of instrumented sites in the BT Pond in May. We also surveyed the perimeter of the drainage ditch in May. In September the perimeter survey was done by C. Hunter and D.E. Lawson. 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 used a benchmark (Bread Truck BM) near the north shore of the BT Pond, which had been previously surveyed. Universal Transverse Mercator (UTM) horizontal coordinates and the elevation are known for the BM.

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 the Bread Truck BM, this was the Ruth Point BM on the upland bluff to the northeast. The two-person party moved to each location to be surveyed and the prism rod placed on the ground at each site. To achieve uniformity in surveying elevations, 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 down into the soft surface. The triple prism was sighted on by 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 drainage ditch

The explosion of the cratering charges produced a series of overlapping craters forming a ditch 90-m long. Craters were up to 2 m deep and varied from 3 to 5 m wide. The craters within the slightly higher vegetated mudflat area near the northern end were the smallest in diameter. The ground here was more deeply frozen, and the explosive charges may not have been as efficient in removing material. There were several small blockages of less than a meter wide in the ditch where there was incomplete overlap of craters. Because of the one dud shaped charge, a gap in the crater coverage occurred between the planned second and fourth crater hole near the northern end. This resulted in an almost 3-m wide blockage of nearly undisturbed material between the two adjacent craters. Craters formed along the southern half of the ditch line, within the pond area proper, were larger and had more overlap, forming a continuously connected ditch. The softer pond bottom sediment beneath the ice cover appeared to allow more efficient removal of material by the explosions.

The incomplete connection of the craters forming the ditch caused by the one large and the several smaller blockages prevented any initial flow through the ditch. Following the spring thawing of the pond ice and the surrounding seasonally frozen ground, a series of flooding high tides in late May eroded out the blockages and initiated draining of the pond on 19 May (Fig. III-3-5). A survey of the perimeter of the ditch (Fig. III-3-6) was conducted on 21 May 1996, soon after water initially began flowing through the ditch. The perimeter of the ditch was resurveyed at the end of the season on 27 September. The two surveys show the increase in size as each monthly series of flooding tides through the summer widened and lengthened the ditch through erosion. In September the ditch averaged nearly 10 m in width. It was nearly 15 m wide near the northern end, at the site of the earlier 3-m-wide blockage. The ditch had extended southeastward into the pond an-

Figure II-3-5. Drainage ditch in early summer, after initial drainage and erosion of blockages within the ditch.

other 10 m, bifurcating into several short branches at the head. A side gully, 11 m long, had formed on the west side of the ditch. The branches at the head of the ditch had steep headwalls with a plunge pool at the base (Fig. III-3-7). Figure III-3-8 is an oblique aerial view of the BT Pond in June following draining. There are pockets of standing water still present in deeper areas of pond basin. Most of these areas dried up due to evaporation by late June. Figure III-3-9 shows a closer oblique aerial view of the drainage ditch on 1 October. The pond basin had just recently been refilled by a flooding high tide and water is flowing back out the drainage ditch.

Data collection

Pond water surface levels

Water surface elevations were continuously recorded within the BT Pond by the data-logger at Site BT-6. A plot of the record (Fig. III-3-10) shows the sharp drop in water level in the pond following the start of draining through the ditch on 19 May from the normal water level of approximately 4.70 m. Water levels dropped down to about 4.57 m through mid-June. Water levels dropped again down to the 4.42-m level during late June due to evaporation during a warm dry period. By 21 June the BT Pond water level was 30 cm below the normal water level and occupied less than 10% of the original pond surface area. Prior to the next series of flooding tides starting 1 July, the exposed pond bottom had started to dry out and the surface cracked. Water levels rose rapidly with the series of flooding tides in early July, then dropped off as water drained. Water levels repeated this cycle through three additional series of flooding high tides.

Even though the tidal peaks were higher for each of the successive tidal cycles from July through September, the maximum pond water level following each of the individual flooding tides was lower for each of the cycles. This reflects the increase in the size of the

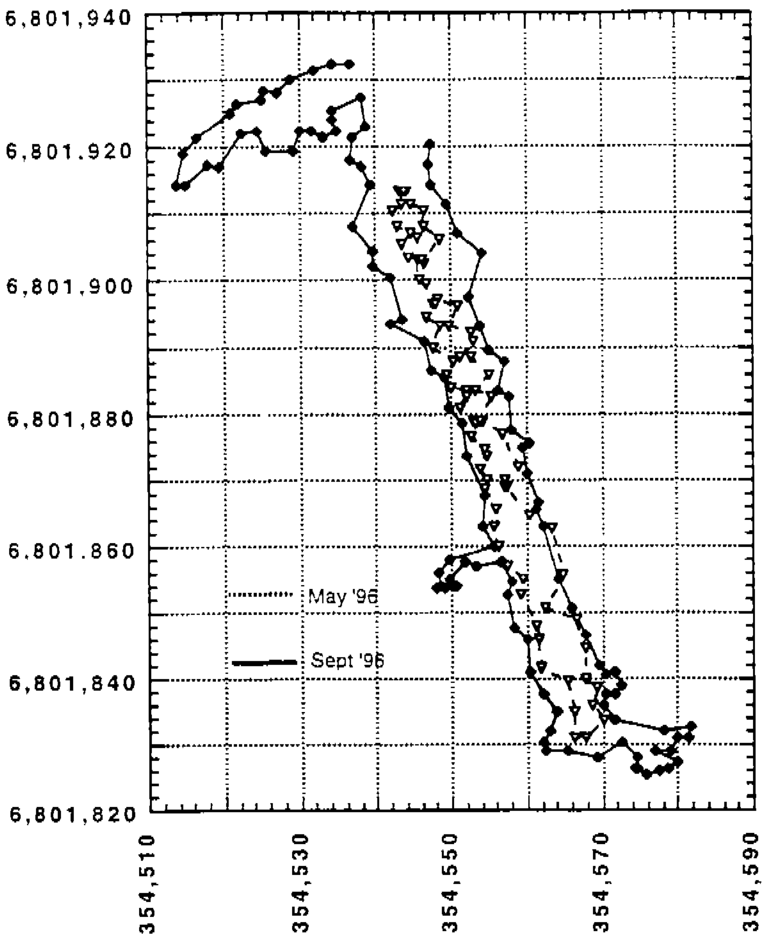

Figure II-3-6. Perimeter of the drainage ditch on 5/21/96 and 9/27/96 showing both the widening of the ditch and the headward erosion and bifircation of the head of the ditch. (Sept. 96 survey data courtesy of L. Hunter and D. Lawson.)

Figure II-3-7. Drainage ditch on 27 September following a flooding high tide.

Figure II-3-8. Oblique aerial view of Bread Truck Pond in mid-June, after draining of pond was initiated. Standing water is still present in deeper areas of pond basin. Most of these areas dried up due to evaporation by late June.

Figure II-3-9. Oblique aerial view of the drainage ditch. The pond has been recently refilled by a flooding high tide. The yellow bread truck is above the ditch to the right. The line of instrument tripods is above the truck, parallel to the ditch.

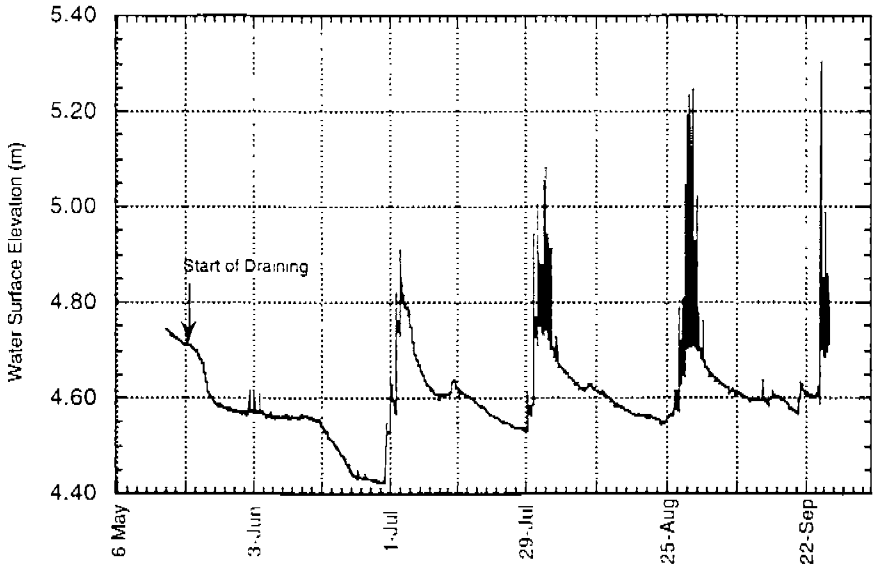

Figure II-3-10. Water surface elevation record for Bread Truck Pond (Site BT-6).

drainage ditch due to continued erosion, and its capacity to more quickly drain away water following a high tide.

The present threshold controlling drainage and the maximum static water surface level in the pond appears to be 4.53 m. This will decrease as the ditch continues to erode headward into the deepest part of the remaining pond basin next season. This means that the size of the remnant permanent pond will continue to decrease also, down to only a small percentage of its original size. There is 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 of course almost immediately flow out of the pond basin through the drainage ditch, but the exposed pond bottom sediments will be periodically rewetted, slowing down the process of natural attenuation of WP contamination that occurs when the sediments dry below saturation.

Sediment temperature and moisture conditions

The sediment at Site BT-6, at an elevation of 4.43 m the lowest of the three instrumented sites, was covered with water throughout the summer except for a short period during late June. Site BT-4, at an elevation of 4.694 m, was exposed for a much longer time during the summer, only being covered during periods of flooding tides (Fig. III-3-11). Soil tension measurements from the tensiometer at a 5-cm depth indicated that the sediment dried during the late June period and began to become unsaturated (soil tension above about 15 kbars). Sediment dried to a lesser degree during late July.

The sediment moisture probe at the 5-cm level at BT-4 changed slightly in late June and again in late July (Fig. III-3-12), also indicating that the sediment started to dry out during those short time periods. Each time, the site was inundated by a series of flooding high tides and the sediments resaturated. The amount of sediment drying indicated by the tensiometer and the moisture probes is not enough to significantly affect sublimation of any WP contamination present (Walsh et al. 1995). If the period between flooding tides in June and July had been longer, the drying of sediment may have been much more significant and may have materially affected the sublimation rate of WP contamination. During the summer of 1997 the periods between flooding tides are predicted to be much longer, thus holding forth the possibility of signifi-

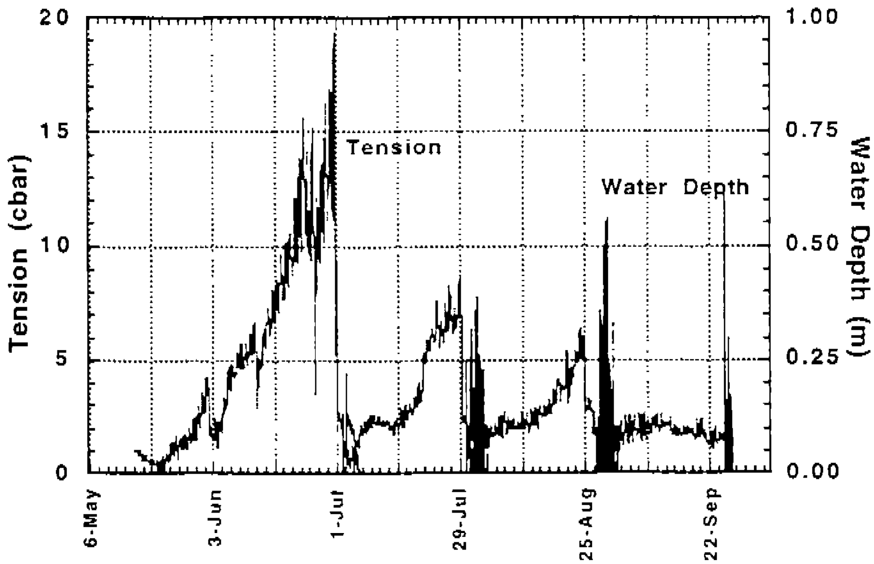

Figure II-3-11. Soil tension and water depths at site BT-4, showing the rise in soil tension following draining of the pond in June. The tension data indicate that soil moisture conditions just started to become unsaturated before the site was inundated by flooding tides and the sediments resaturated.

cant natural intrinsic remediation within BT Pond.

The sediment moisture probe at the 5-cm level at BT-2 did not change significantly through the summer (Fig. III-3-13). Although BT-2 is just slightly higher than BT-4, 4.70 m versus 4.69 m, the site sits in a slight hollow that kept the sediments saturated throughout the summer.

The minimum, maximum, and mean sediment temperatures measured for the three instrumented sites in the BT Pond are summarized in Table III-3-5. Maximum measured hourly sediment temperature at the 5-cm level

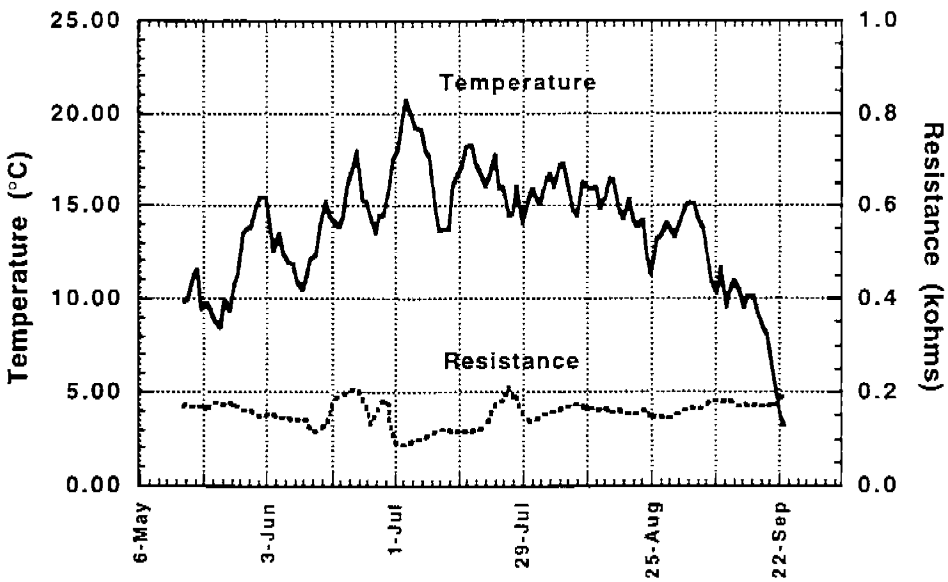

Figure II-3-12. Daily (24-hour average) temperature and moisture probe resistance at the 5-cm depth, Site BT-4.

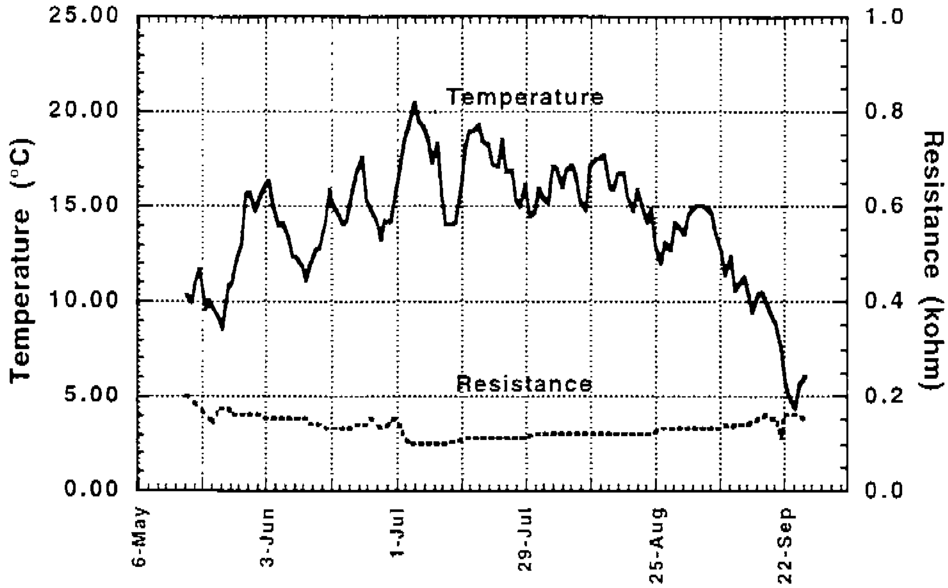

Figure II-3-13. Daily (24-hour average) temperature and moisture probe resistance at the 5-cm depth, Site BT-2.

was 24.81°C for both BT-4 and BT-6. The mean temperature for all sites was 14.3°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

Nine subsamples of sediment from the BT Pond were obtained, weighed, and heated at 550°C for 16 hr to burn off organic material. The subsamples were cooled in a desiccator and re-weighed to determine percent organic content by dry weight. The samples ranged from 2.0 to 5.3% organic material by dry weight, with the mean of the nine samples being 3.7%. 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).

Air-entry value

No data are available yet.

Data assessment

Many of the criteria for fully assessing the implementability of this treatment option are not yet available. Other parameters are available. The various parameters are summarized below, with known parameters given and unknown parameters identified.

Cost

The cost of treatment will be calculated per unit area of pond treated for one season. The cost will include:

- The cost of the explosive munitions used in the demolition operation: $9,000.00 for a 90-m-long ditch. In this instance, the explosives were drawn from Army stores slated to be withdrawn from service due to age. Because of this there were no charges to the project for the munitions. Future operation may have to fully refund the Ammunition Supply Point for any munitions used.
- The operating cost, including labor of a dozen soldiers to install munitions, and helicopter time to ferry personnel and equipment to site. The operation was carried out as a training mission for personnel of the 23rd Engineer Co. There were no costs to the project for their time. The mission was seen as such a great training opportunity that there will be little problem for getting additional

troops to participate in any future operations. An additional approx. $10,000 was required for the initial planning and coordination effort. The cost of the helicopter flight time was paid by Directorate of Public Works in support of the project. It involved approximately 3 hr of UH1-H helicopter time at $800/hr. An estimated 24 man-hours (3 people × 8 hr) were required to set up monitoring equipment in the BT Pond and to survey the initial ditch in May. Another estimated 24 man-hours (3 people × 8 hr) were required to pull monitoring equipment and to survey the ditch in September. Approximately 3 hr of UH1-H helicopter time at $800/hr were required to ferry in and out the monitoring equipment.

The total cost per year to treat the pond divided by the total area of the pond (8.7 ha) gives us a cost per hectare per year:

1st year:

$9,000	for explosive munitions
$12,500	for planning and conducting operation
$5,500	for setting up monitoring operations.
$27,000	total direct costs.

The total cost of $27,000 to treat 8.7 ha equals $3,100/ha. These costs DO NOT include the costs of the troops that carried out the mission. Nor do they include costs to analyze data from monitoring and preparation of reports.

Effectiveness

The effectiveness of the treatment will depend on the following factors:

- Frequency of flooding tides during the summer season,
- Average pond water levels throughout season,
- Percent decrease in pond surface area following draining,
- Total time pond bottom remains subaerially exposed,
- Estimated rate of WP removal in exposed pond bottom sediments.

Several years may be required before significant WP removal in exposed pond bottom sediments occurs.

Implementability

Excavation of drainage ditch is permanent but may be reversible in the future once significant WP removal in exposed pond bottom sediments has occurred.

Explosive excavation technology uses conventional military equipment and components. Military personnel are trained in this type of operation but rarely get a chance to put their training to use.

Applicability of explosive excavation of drainage ditches to other sites within Eagle River Flats needs to be more fully assessed based upon the results of the test in the BT Pond. The assessment of other potential sites would include a list of site data needed for an such as elevational data, pond area and volume estimates, access concerns, surface water hydrology of surrounding area, and projected tidal flooding events. Of primary concern is the presence of either the river or a drainage gully near enough to the site to allow a ditch to connect. Ditch lengths much greater than the 90 m excavated for the BT Pond may have to be excavated in two or more stages. This would avoid excessively large explosions that could potential affect off-post areas.

Initial surveying and measurements (Lawson et al. 1996) indicate that the contaminated pond in the center of Racine Island may be amenable to draining as a treatment option. The elevation of this site is lower than the BT Pond. Because of more frequent periodic rewetting due to flooding tides, there is some question as to whether the sediments would dry enough to allow sublimation of WP. We might only be removing this area as waterfowl habitat and thus breaking the pathway between the WP contamination present and the feeding waterfowl.

Implementability (monitoring):

- Non-intrusive
- Measurements using conventional sensors and equipment.

On-site activity requirements (monitoring):

- Dataloggers installed on three instrument tripods at beginning of season. Instrument tripods had been installed at seven sites in pond the previous year.

- Sensors installed in sediment and interfaced to datalogger
- Dataloggers and sensors removed at end of season. Tripods left in place for future use.

Frequency of monitoring:

- Data collected hourly throughout season by datalogger. Data downloaded periodically and at end of season.
- Drainage ditch perimeter surveyed at beginning and end of season. Instrumentation locations and elevations surveyed at beginning of season.
- No monitoring of changes in WP was done this season due to funding constraints.

CONCLUSIONS AND RECOMMENDATIONS

The explosively excavated drainage ditch was successful in greatly lowering average water surface levels in Bread Truck Pond. It also greatly reduced the average size of the pond, with only the deepest part of the pond containing standing water throughout most of the summer.

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 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 explosive training skills in a mission that was much larger than they would ever have a chance to participate in during normal peace-time training. It was also a real-world mission solving an environmental problem. Both of these opportunities were greatly appreciated by the soldiers.

Future use of explosively excavated drainage ditches to drain isolated WP-contaminated ponds in ERF appears feasible. Selection of specific sites for treatment will mainly depend on the nearness to a drainage gully of the river. The training opportunity provided by the large-scale use of military explosive munitions nearly guarantees that military troops will be available to carry the operation as a training mission at little cost to the project.

We recommend a slightly smaller spacing than the 5 m we used between cratering charges for future ditching operations. A spacing of 4 m between cratering charges would provide slightly more overlap of craters and ensure a continuously connected ditch system. Ditches longer than the one excavated for this treatability study will require proportionally more explosives for the excavation. Because of the concerns about noise affecting the surrounding communities, any future explosive excavation may have to be carried out in multiple stages to keep the explosions at or under the 320-kg level that we used for this test. Thus a long ditch may require two or more separate blasts using shaped charges to form the boreholes and two or more separate blasts using cratering charges to form the ditch. 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.

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III-4. MONITORING OF CONTRACT DREDGE OPERATIONS AT EAGLE RIVER FLATS, ALASKA

Michael R. Walsh and Charles M. Collins
U.S. Army Cold Regions Research and Engineering Laboratory

INTRODUCTION

Investigations into the fate and persistence of white phosphorus (WP) at Eagle River Flats, Alaska (Fig. III-4-1) indicate that WP is persistent in the permanently ponded areas of the Flats (Racine et al. 1993, Walsh et al. 1995). Several remediation strategies for these WP-contaminated areas were investigated, initiated, or implemented in the 1994–1996 field seasons, encompassing a range of methodologies including covering contaminated areas, designing equipment for the draining of large contiguous ponds, enhancing natural attenuation in intermittently flooded areas, monitoring natural erosion and cover deposition, pond draining through explosive trenching, and dredging. The objective of this

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

project is to monitor the commercial implementation of a small, remote-controlled dredge designed to remove sediments from contaminated ponded areas and to continue an efficiency study of the treatment of the sediment in an open retention basin. The treatment method will be the natural attenuation of the white phosphorus, once conditions of the sediments in the basin are conducive to sublimation.

BACKGROUND

Since the late 1940s, Eagle River Flats has been used as an impact area by the military. Among the many munitions fired into the Flats were white phosphorus rounds. The Flats are an estuarine salt marsh and, as such, contain many permanent and periodically flooded areas. The area is also intensively used by migrating waterfowl as a feeding and resting stop. When white phosphorus rounds were fired into the Flats, incompletely combusted particles of WP were either driven into the mud through impact detonation or deposited in flooded areas. In both cases the lack of oxygen terminated the particle combustion. In wet, cool mud or on the bottom of permanently flooded areas, the particles can persist for decades. When dabbling waterfowl such as swans and some duck species sieve bottom sediments for food items or gizzard material, these particles are taken up. Very small quantities of white phosphorus, on the order of a milligram, are sufficient to kill a small duck. It has been estimated that, prior to the initiation of remediation efforts at the Flats, mortality among the various species of dabbling waterfowl exceeded 2000 birds per year (Racine et al. 1993).

In 1994 the restoration project managers for Eagle River Flats (ERF) approached CRREL about the feasibility of small-scale dredging at the Flats. Dredging was chosen as a method of remediation because of the positive removal of the contaminated material and the ability to treat the material in a controlled environment. By using a small remote-controlled dredge (Fig. III-4-2), limited areas

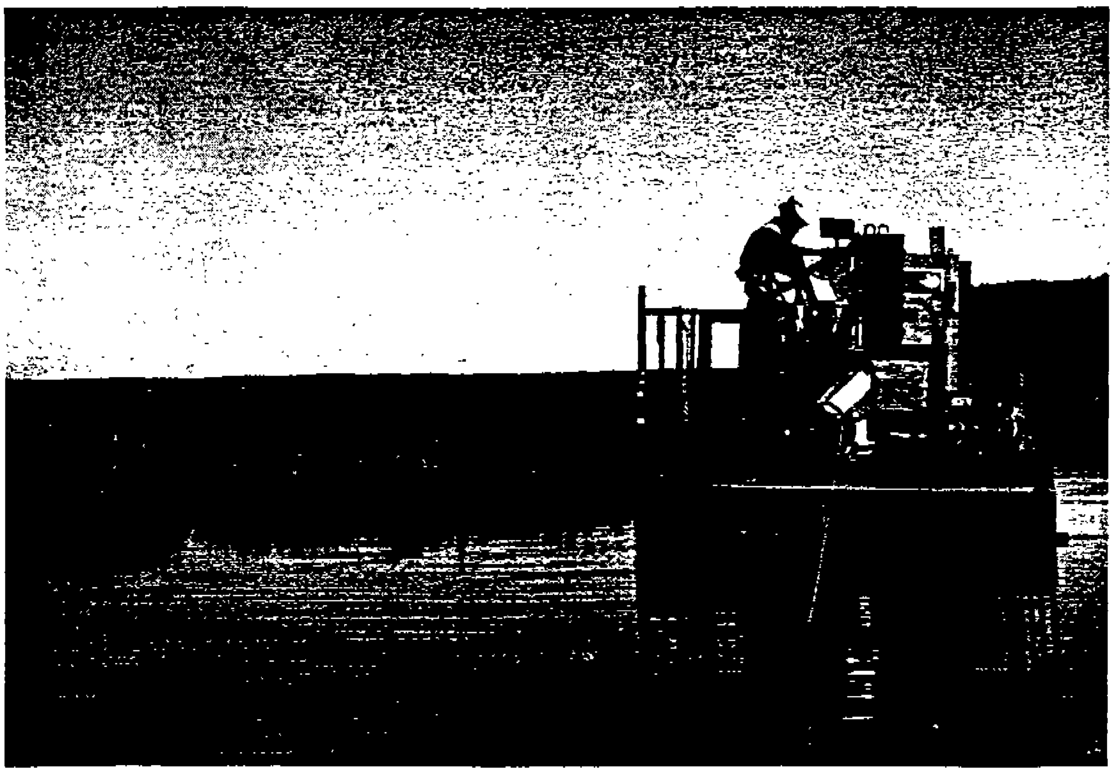


Figure III-4-2. Dredge deployed at Eagle River Flats (1996).

could be dredged and transport of the contaminated material (spoils) to a retention basin for treatment can be quickly and efficiently conducted. Environmental impact to the salt marsh system, although not negligible, can be minimized through a careful dredging strategy. Because of the presence of unexploded ordnance, a non-manned system would be required.

The decision to pursue a dredging strategy is based on several previous studies. Primary among these is the work conducted by Marianne Walsh on natural attenuation of WP both at the Flats and under controlled laboratory conditions (Walsh, M.E., et al. 1995, 1996). It was found in lab studies that certain conditions of temperature and soil moisture had to be met before natural attenuation could occur. A model of the attenuation process was developed and verified in field experiments conducted over the 1993–1995 field seasons at ERF. These studies indicate that permanently ponded areas will remain dangerous to waterfowl due to the persistence of white phosphorus over a very long period of time. This has been demonstrated by the continuation of mortality of swans and ducks in ponded areas even though no WP has been fired into the Flats since 1991.

This is the third year of the dredging project at Eagle River Flats. The first year primarily involved processing a contract for the dredge equipment; designing, constructing, and testing a spoils retention basin; integrating specialized equipment to the dredge; getting the leased equipment operational; and test dredging a small area at the Flats. During 1995 three tasks were undertaken: continued investigation of the hydrological properties of the retention basin; dredge operations; and initiation of the attenuation study in the Basin (Racine and Cate 1996). This year, 1996, the operation of the equipment was turned over to a local contractor. An area was designated for dredging, and technical assistance was provided for the initial setup and operation of the equipment.

Dredging activities were conducted in parts of ERF known as Area C, Clunie Creek, and the EOD Pad (Racine et al. 1992, 1993, 1994, Walsh, M.R. et al. 1996) (Fig. III-4-3). Area C is a large area composed of interconnected

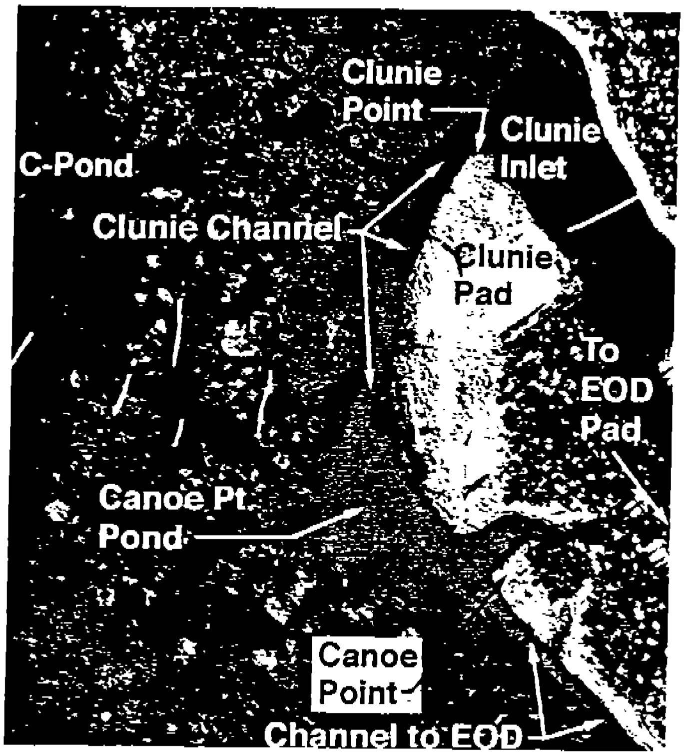


Figure III-4-3. Area of ERF involved in the dredging project.

permanent ponds, mudflats, heavily vegetated areas, and channels (Fig. III-4-3). This area has large sections that are permanently flooded due to their topography. These areas are not amenable to other remediation strategies such as draining because they are not isolated but rather interconnected over large areas. There is also an influx of fresh water to the area from either Clunie Creek or infiltration through the ground. This makes the water in the area less brackish than in other areas in the Flats and thus slows settling rates of suspended solids.

Area C is subject to periodic flooding under certain high-tide conditions. How often the area and its associated ponds are flooded during the summer depends on the maximum height of the monthly series of peak high tides. Some years, such as 1990, will have only a few monthly series of flooding high tides during the summer. Other years, such as 1995, will have a flooding high tide every month of the summer. The monthly peak high tides, if above about 31 ft Anchorage tidal datum (or about 4.79 m MSL), will spill over a threshold into the pond basin from the nearby distributary gullies, refilling the ponds. Depending on the height of the flooding high tide, the water will fill the intermittently flooded pond areas. The water level in the area will then slowly drop as water flows out of the ponds through the distributary channels. Additional drops in the water level below the threshold elevation occur as evaporation reduces the amount of water in the pond.

PROJECT OBJECTIVES

The main objective of this project is to monitor the removal of sediments in a large, permanently flooded area that contains lethal amounts of the contaminant white phosphorus in the bottom sediments. Another important objective is to monitor the fate of the contaminated spoils sediments in the retention basin built specifically for this project for settlement, decantation, and natural remediation. Measurements of WP concentrations in the spoils line prior to deposition in the retention basin as well as in the decanted sediment in the basin will give an indication of the extent of contaminant being removed from the dredged areas. Post-remediation sampling within the basin will determine the efficiency of natural remediation on the sediment within the basin. In addition, CRREL engineers were tasked with assisting the contractor in equipment deployment, operations instruction, and guidance during the initial phase of operation.

Although all sampling and testing was originally cut from the project proposal, limited sampling and testing were conducted in the basin and on the spoils entering the basin. Datalogger stations were reinstalled in the basin to monitor such parameters as air and soil temperature, soil moisture, and water level. Prior to the initiation of dredging, two percolation tests were performed in the basin. Soil moisture analyses were also conducted on the basin sediment and liners prior to the resumption of dredging. The study of the natural attenuation of planted particles in the basin was continued in a limited scope, and some pre-dredging sediment thicknesses in the basin were measured. All these tasks had been cut from the original work. Restoration of some funds after the completion of the dredging operations enabled us to sample the dredged area and have the samples analyzed for white phosphorus. In addition, the area dredged was surveyed, salinity measurements at various locations taken, organic contents of the basin liner and sediments measured, two samples of the basin sediment were collected and analyzed for white phosphorus, and an overflight of the Flats scheduled with AeroMap. All these tasks we felt were critical to the continuity of data for the evaluation of the dredging as well as other programs at the Flats.

The work on the Explosive Ordnance Disposal (EOD) pad wells, installed late in the season in 1995, was cut altogether from this year's planned work. We did, however, survey in the locations of the wells, measure depths and water levels, and install a datalogger in one of the wells. Time constraints prevented any further instrumentation of the wells for monitoring the effect on groundwater level due to use of the retention basin, as originally proposed. In addition, several hours were spent in consultation with the Alaska District, Corps of Engineers, on information transfer for the sampling wells that were to be installed on the EOD Pad by a contract firm.

TECHNICAL ASSISTANCE

An important task in this year's work plan was to train the contract employees on how to deploy and operate the dredge equipment. Fortunately the equipment operators were quite familiar with the equipment from the past two dredging seasons. We therefore concentrated on assisting with equipment setup, improving the equipment based on the last two years' experience, and training the operators on how best to utilize the equipment. A total of four trips were made by the two principals, with one of us (Collins) making four more short trips to check on progress. A total of about one month was spent with the contractor by either one or both of us.

In December 1995, following dredging operations that year, a list of possible improvements to the equipment was given to the contractor. A few of these changes were implemented prior to dredging, and more during dredging as the contractor saw the need for them after increased familiarization with the equipment and operation. The primary change to the equipment was the placement of the auger drive behind the augerhead, rather than on its side. This change was not implemented as recommended, however, and a 3-in. protrusion on the side of the augerhead enclosing the drive continues to be problematic.

Stress on the augerhead cutter resulted in the breakage of one auger assembly, which was quickly replaced by the contractor using one of the spare units on hand. Some improvements to the augerhead cutter and grate system developed by CRREL were made by the contractor, and the system continues to work fairly well. A patent application has been submitted for this device.

One area of concern for both the contractor and the CRREL engineers is the difficulty in moving the dredge during dredging operations. This is due to the firmness of the consolidated bottom sediments as well as the large amount of debris found in the area, especially in vegetated areas adjacent to the permanently ponded areas. The use of the cutter and grate system has greatly improved the dredge performance, but problems still persist. The use of additional extended cutters on the auger may help alleviate traversing through consolidated sediment by further breaking up the material. The hydraulic system may have to be modified to enable more power to be delivered to the auger drive motor.

Related to the traversing difficulties, anchoring points continue to be problematic. The contractor was convinced shortly after startup that the lateral winch system was not feasible in the Flats environment, and a manually adjustable system was devised using telephone pole anchors, similar to the anchoring system used last season. This eliminated the need for helicopter support, thereby saving a substantial sum of money and logistical effort. Further work on this system is required. Improvements to the spoils transfer line eliminated any blow-outs like those experienced last year. The contractor is currently looking into a radio-control package to improve reliability of the dredge control system, as recommended in December 1995.

In addition to equipment modification and troubleshooting, several other services were provided. The video system and pressure feedback sensors were re-installed and calibrated prior to dredging. The area to be dredged was delineated and the contractor given a map. Assistance with layout of the spoils line was given, and pre- and post-dredging helicopter support was arranged. This year saw the introduction of a contract health and safety officer, and she was briefed by us as to the special considerations necessary during the dredging operations. After the conclusion of the dredging season, all government property items were removed from the equipment. Arrangements were made for removal of the equipment from the Flats for storage on base.

BASIN INVESTIGATIONS

A number of tests and measurements of retention basin parameters were made prior to and after dredging. These tests, although cut from the work plan, were thought to be important enough that they were funded, for the most part, with unrelated money. The retention basin sits on an EPA-designated Solid Waste Management Unit (SWMU), and as such, we felt it critical that we monitor as many critical parameters as possible to avoid future difficulties. The investigations performed on the basin are outlined below.

Basin percolation tests

Prior to resumption of dredging, a percolation test was performed on the basin to ensure its integrity and suitability for reuse. Two percolation barrels were set in the basin liner, one in an area of low sedimentation near Instrumentation Station #4 and one in a deep sedimentation area adjacent to Instrumentation Station #3. Both tests indicated a percolation rate above the acceptable level of 10^{-6} cm/s (Table III-4-1 and Fig. III-4-4). It should be noted that these were not rigorous percolation tests (no bentonite sealer was used) and thus only give a rough indication as to the condition of the liner. The higher percolation rates are probably caused by a reduction in liner density due to the severe freeze–thaw cycling that occurred over the previous win-

Table III-4-1. Basin percolation barrel tests data.

	Barrel S-3*				Barrel S-4*			
Date	Time	Elapsed time (min)	Head drop (cm)	Percolation rate (cm/s)	Time	Elapsed time (min)	Head drop (cm)	Percolation rate (cm/s)
6/10	9:30	0	0.0	—	9:38	0	0.0	—
	9:45	15	10.0	1.39 E-02	9:53	15	7.0	9.00 E-03
	10:00	15	4.0	4.81 E-03	10:08	15	3.5	4.17 E-03
	10:15	15	2.8	3.28 E-03	10:23	15	2.8	3.28 E-03
	10:30	15	2.5	2.91 E-03	10:38	15	2.6	3.04 E-03
	10:45	15	1.2	1.36 E-03	10:53	15	2.3	2.67 E-03
	11:00	15	1.2	1.36 E-03	11:08	15	2.0	2.31 E-03
	11:35	35	3.3	1.68 E-03	11:38	30	3.7	2.21 E-03
	13:15	100	7.0	1.35 E-03	13:18	100	9.3	1.90 E-03
	13:45	30	1.8	1.03 E-03	13:48	30	2.3	1.34 E-03
	14:15	30	1.4	7.99 E-04	14:18	30	2.6	1.52 E-03
	14:45	30	1.4	7.99 E-04	14:48	30	2.1	1.21 E-03
	15:23	38	2.0	9.11 E-04	15:25	37	3.1	1.48 E-03
	15:50	27	1.2	7.58 E-04	15:52	27	2.0	1.28 E-03
	16:20	30	1.2	6.82 E-04	16:23	31	2.2	1.23 E-03
	16:56	36	1.2	5.68 E-04	16:58	35	2.1	1.04 E-03
6/11	8:30	934	27.0	—	8:30	932	27.0	—
	10:38	128	7.5	1.14 E-03	10:40	130	2.6	3.50 E-04
	11:12	34	0.3	1.48 E-04	11:15	35	1.9	9.38 E-04
	14:51	219	4.5	3.75 E-04	14:50	215	10.7	1.06 E-03
	15:30	39	0.6	2.59 E-04	15:33	43	2.2	8.89 E-04
6/12	9:51	1,101	20.2	5.64 E-04	9:49	1,096	27	—
	10:22	31	0.5	2.71 E-04	10:19	30	1.8	1.03 E-03
	10:52	30	0.3	1.68 E-04	10:49	30	1.2	6.82 E-04
	11:25	33	0.3	1.52 E-04	11:22	33	1.2	6.20 E-04

*Barrels 39.3 cm ø with 27 cm water when full.
Material thickness—Barrel S-3: 34 cm; Barrel S-4: 13.5 cm.

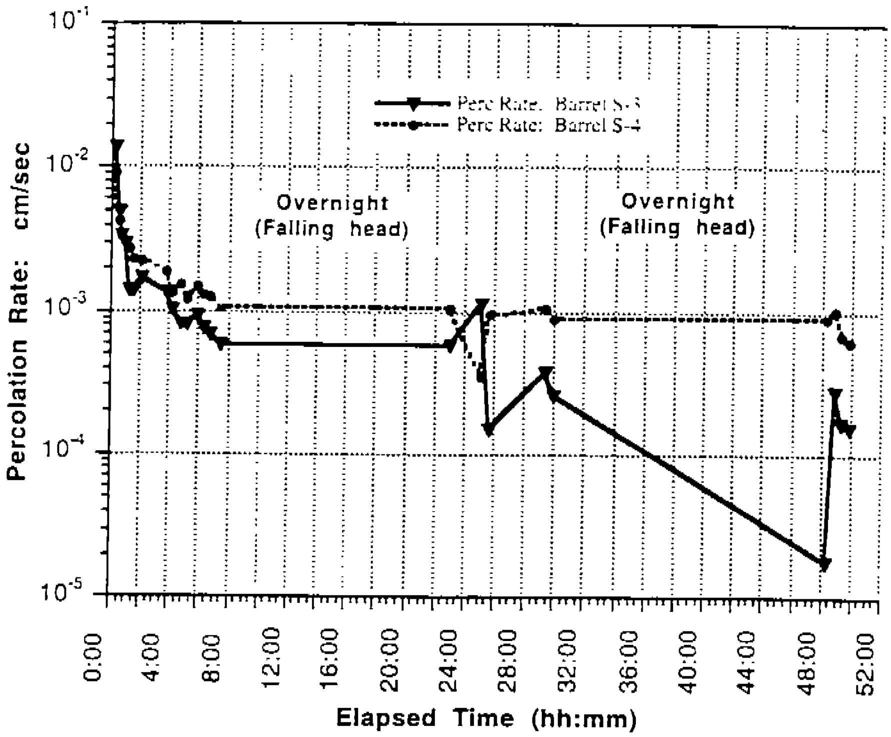


Figure III-4-4. Results of basin percolation tests.

ter, when lack of snow exposed the liner to repeated temperature fluctuations. The lack of funds for improving the liner as well as the proximity of the test results to acceptable levels resulted in the use of the basin in the condition found. For reference, work done in 1994 by Chamberlain and Walsh (Racine et al. 1995) showed that percolation rates of Flats water through the gravel base below the basin was on the order of 10^{-2} cm/s.

In addition to the percolation tests, a limited number of sediment moisture content tests were conducted. These will be discussed in the section on attenuation studies later in this report. Unfortunately, time and funding considerations prohibited conducting moisture and density tests of the basin liner. This information would have been quite useful in determining the cause of the sharp increase in hydraulic conductivity of the liner.

Sample sites were surveyed and the sediment thickness was measured within the basin prior to the onset of dredging in July. Post-dredging sediment profiles in the basin were surveyed in early October (see Attenuation Study, later in this report). Although the results of the survey indicate that the basin capacity should be sufficient for at least two more seasons at its current rate of deposition, problems once again occurred during dredging due to long settling times caused by the low salinity of the supernatant and the lack of particulate flocculation.

Salinity measurements

Salinity measurements were taken on June 7 from several locations around the area to be dredged. This was four days after a 31.8-ft flooding tide, a minor flooding event and the first flooding tide since March 21. These measurements indicate trouble for settlement times (Table III-4-2). Although Praudic (1970) stated the flocculation increases from salinity levels of 2 to 6 parts per thousand (ppt), our experience has shown that, for the extremely fine particles dredged from the Flats, the higher salinity levels are necessary to ensure workable settlement times of less than 12 hours. Work done last year showed that when incomplete settlement of the spoils occurs prior to decantation, total suspended solids of the supernatant are comparable to those

Table III-4-2. Salinity measurements in the dredge area.

Location	*Salinity (ppt NaCl)*	*Temperature (°C)*
Clunie Pad Ramp	3.1	19.8
Clunie Point	2.9	19.1
Canoe Point (N)	4.0	20.1
Off Canoe Point Boardwalk	3.4	20.0
Off EOD (EOD Pond)	7.0	21.2

found during flooding tides at the Flats (200 to 1600 mg/L vs. 1000 to 3000 mg/L, four samples). Particle size is also very small: less than 1% is retained by a #200 sieve (0.075 mm diameter particle diameter).

Settling times

The low salinities in the area to be dredged did in fact cause problems with decanting the supernatant from the retention basin. The supernatant remained quite cloudy for days after dredging was temporarily halted. Attempts to utilized the geotextile fabric for screening out the suspended solids resulted in minimal decantation due to fabric clogging. This also occurred last season. The problem was exacerbated this year as the contractor concentrated their dredging efforts during periods of high tides, with their associated influx of low salinity water.

Using the model for sediment settling times developed by Walsh and Chamberlain (Racine et al. 1995), extended settling times are necessary just for the median-sized particles. This model is based on Stoke's Law:

$$v = g(\rho_1 - \rho)d^2/18\mu \qquad \text{(III-4-1)}$$

where

v = particle settling velocity (cm/s: fresh water)

g = gravitational constant (980 cm/s^2)

ρ_1 = particle density (g/cm^3)

ρ = fluid density (g/cm^3)

d = particle diameter (cm)

μ = fluid viscosity (dyne-s/cm^2).

The Reynolds Number:

$$R = vrd/\mu \text{ (dimensionless)} \qquad \text{(III-4-2)}$$

is used to determine if settling is laminar or turbulent. Table III-4-3 depicts the results for settling of particles up to the median particle size. Note that the WP particles take longer to settle than the mineral sediments. This is due to a difference in density.

As mentioned above, one more attempt was made to utilize the geotextile filter fabric used as a secondary containment and decontamination structure in the basin drop inlet structure. Again, the fine particles quickly clogged the fabric, and repeated scraping of the fabric surface increased flow through the fabric only marginally. The fabric did work well as a secondary backup, holding well over a meter of supernatant back before we slowly lowered the top edge for decantation (Fig. III-4-5).

Basin monitoring instrumentation

During the initial trip to the Flats, when new safety concerns prevented the deployment of the dredge and time was available, the datalogger instrumentation stations were reinstalled in the retention basin. These sta-

Table III-4-3. Settling times for spoils in fresh water.

Retention pond size (ha)	*Particle size (cm)*	*Settling vel.: silt (cm/s)*	*Settling vel.: WP (cm/s)*	*Pond depth (cm)*	*Silt settling time (hr)*	*WP settling time (hr)*	*Dredge cycle (days)**
0.75	0.01	7.0E-1	3.6E-1	40.53	0.02	0.03	0.3
0.75	0.001	7.0E-3	3.6E-3	40.53	1.61	3.14	0.5
0.75	0.0003†	6.3E-4	3.2E-4	40.53	17.89	34.88	1.8

*8-hr dredging plus retention time. No decanting time included.
†Median particle size (Lawson and Brockett).

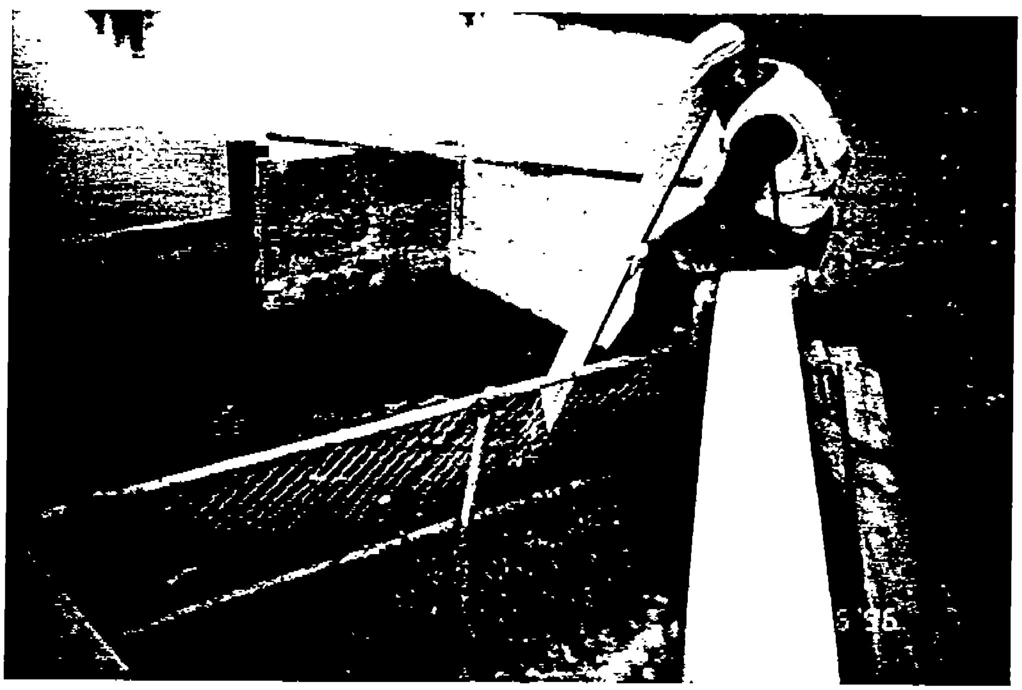


Figure III-4-5. Manually decanting supernatant over clogged filter fabric.

tions autonomously monitor sediment moisture and temperature, air temperature, and water levels in the basin. These parameters can be used in the natural attenuation studies, to determine the basin performance, and to monitoring dredging activities. The dataloggers used for the four sites are 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 in turn 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.

The most pertinent parameter available from the basin datalogger stations for the retention basin performance is the supernatant levels. As mentioned above, the long settling times of the extremely fine suspended particles in the supernatant combined with the slow decantation rates due to clogging of the geofilter fabric resulted in long retention times in the basin. This also resulted in high heads. These factors, plus the reduction in the performance of the basin liner, led to increased percolation of supernatant through the liner into the EOD Pad below. The drop in surface level of the supernatant, seen in Figure III-4-6, demonstrates this. The 500-mm drop, due to infiltration as well as passage through the geotextile fabric, occurred over the course of 81 hours. This translates to a percolation rate of about 1.6×10^{-4} cm/s. This is a "falling head" rate and assumes all loss is through the basin liner. Rates near the start and end of this period are 2.1×10^{-4} and 8×10^{-5}, respectively, over a 3-hr period. At the end of the dredging-season, the falling head percolation rate with over 1 m of spoils in the basin was 8.8×10^{-5} cm/s, with start and stop three-hour rates of 1.6×10^{-4} cm/s and 5.5×10^{-5} cm/s, respectively. Unfortunately, we were unable to monitor the effects on the water table below the EOD Pad surface due to the elimination of the EOD Pad monitoring well project in the FY 96 budget.

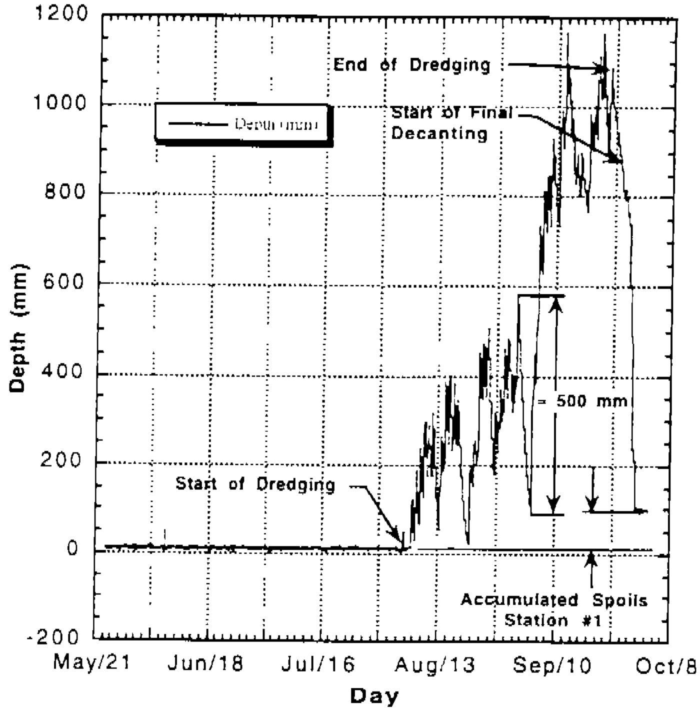


Figure III-4-6. Basin supernatant levels.

Liner organic content

One final test was performed to determine the basin liner characteristics. This was an organic carbon content analysis of the peaty-silt liner. Organic content will help determine the ability of the liner to densify and will affect the hydraulic conductivity. It also will affect the frost susceptibility of the liner; higher organic content means that more moisture may be held in the material, leading to frost deconsolidation of the liner. Table III-4-7, in the Attenuation Studies section, shows that the organic carbon content of the liner is over twice that of the sediments commonly found in the Flats. The average of the six samples is 11%, with a median value of 10.9% and standard deviation of ±1.5. This high organic content may well have contributed to the increase in hydraulic conductivity experienced over the winter of 1995–96.

DREDGE MONITORING

The actual dredge monitoring segment of the work plan was scaled back to include only occasional visits by one of us (Collins) to the site to determine if the contractor was addressing the areas originally delineated. Although funding for this segment of the work plan was never received, we did continue this work using funds from an unrelated source. In addition, some spoils and supernatant sampling and analysis were conducted during dredging operations, even though this was also eliminated from the work plan. In September, some funding was restored, and a trip to the Flats was made to sample the dredged area for white phosphorus contamination. As funds were limited, a new method of composite sampling, developed by M.E. Walsh of CRREL (See Section III-2), was used to maximize the area sampled while minimizing the number of analyses performed. Although not included in the task list, the dredged area was surveyed, as was the sediment delta in the retention basin. Again, the survey work will be discussed later in this report. Finally, Aeromap, Inc., was contracted to collect 1 in. = 600 ft vertical aerial photos of the Flats. We felt this was important for documenting several ongoing projects at ERF, including the pond draining study, dredging, natural attenuation, and physical systems dynamics.

Spoils line and supernatant sampling and analysis

Table III-4-4 depicts the results of the limited sampling conducted during dredging operations at the Flats. These samples were taken on 13, 21, and 28 August by Collins and analyzed at CRREL by M.E. Walsh and S.I. Nam. Of 12 spoils samples analyzed, three were contaminated with white phosphorus for a 25% contamination rate. One of five water samples taken from the outflow line was slightly contaminated (<1 µg/L). The small number of samples taken limits the conclusions that can be drawn from the data, although results are similar to those found during the larger sampling program conducted in 1995. In that year, 19% of the 137 sediment samples were contaminated, with a range of 0.22–66.00 µg/kg and an average contamination of 6.16 µg/kg. Only one of 23 superna-

Table III-4-4. Results of sampling during dredging activities.

Sample #	*Component*	*Sample site*	*Mass/vol. (g/mL)*	*WP Conc.*
813.01	Sediment	Spoils line	40.73	—
	Water		25.00	—
813.02	Sediment	Spoils line	40.26	—
	Water		25.00	—
813.03	Sediment	Spoils line	40.42	0.008 µg/g
	Water		25.00	0.0801 µg/L
813.04	Sediment	Spoils line	40.71	0.0241 µg/g
	Water		25.00	3.996 µg/L
813.05	Sediment	Spoils line	40.75	7.394 µg/g
	Water		25.00	0.546 µg/L
813.06	Sediment	Spoils line	40.32	—
	Water		25.00	—

Notes: Subsampled on 8-30-96.
Analyzed and re-analyzed with SPME on 9-3-96.
SPME positives extracted in isooctane overnight and analyzed with a GC.

Sample #	*Component*	*Sample site*	*Mass/vol. (g/mL)*	*WP Conc.*
821.01	Water	Outflow pipe	25.00	0.115 µg/L
821.02	Sediment	Spoils line	40.39	—
	Water		25.00	—
821.03	Sediment	Spoils line	40.67	—
	Water		25.00	—
821.04	Sediment	Spoils line	40.92	—
	Water		25.00	—
821.05	Sediment	Spoils line	40.25	—
	Water		25.00	—
821.06	Sediment	Spoils line	13.41	—
	Water		25.00	—

Notes: Subsampled on 8-30-96 and 9-3-96.
Analyzed and re-analyzed with SPME on 9-3-96.

Sample #	*Component*	*Sample site*	*Mass/vol. (g/mL)*	*WP Conc.*
821.01	Water	Outflow pipe	25.00	0.115 µg/L
828.01	Water	Outflow pipe	25.00	—
828.02	Water	Outflow pipe	25.00	—
828.03	Water	Basin, inside	25.00	—
828.04	Sediment	Spoils line	40.31	—
	Water		25.00	—
828.05	Water	Outflow pipe	25.00	—

Notes: Subsampled on 9-3-96.
Analyzed with SPME on 9-3-96.

tant samples was contaminated at a concentration of 4 µg/kg. Dredging this year took place in an area known to be more highly contaminated than the previous two years, which may account for the differences in positive results. Results of the spoils line sample analyses indicate that contaminated material continues to be transferred from the Flats to the retention basin.

Post-dredging sampling

Post-dredging sampling occurred in early October. Because the area had been swept by an unexploded ordnance detection contractor, bottom surface grab sampling was possible. Sampling occurred over transects oriented perpendicular to the dredge path in all areas except the Clunie Inlet area (Fig. III-4-3). Sampling in this area and in an area along Clunie Point dredged over the last two seasons was done for reference. Sampling transects were spaced approximately every 10 m. The transects were surveyed in after completion of sampling (Fig. III-4-7). An aerial photo of the area depicting the sites is shown in Figure III-4-8.

Sampling data for the dredged area are depicted in Table III-4-5. Samples were collected by Collins and M.R. Walsh and analyzed at CRREL by M.E. Walsh using solid phase microextraction-gas chromatography (SPME-GC). Samples testing positive were then re-analyzed using GC following solvent extraction of the entire sample. All samples are sieved composite samples, using a Wildco 190-E20 541-µm sieve bucket (S/N 0594). Subsample points are located every 2 m along each transect, where possible. Subsamples were taken from at least three locations along each transect line (Fig. III-4-8). Each location was sampled once with a specially designed 250-mL long-handled scoop. Subsamples were deposited in the bucket that was hung over the edge of the canoe from which sam-

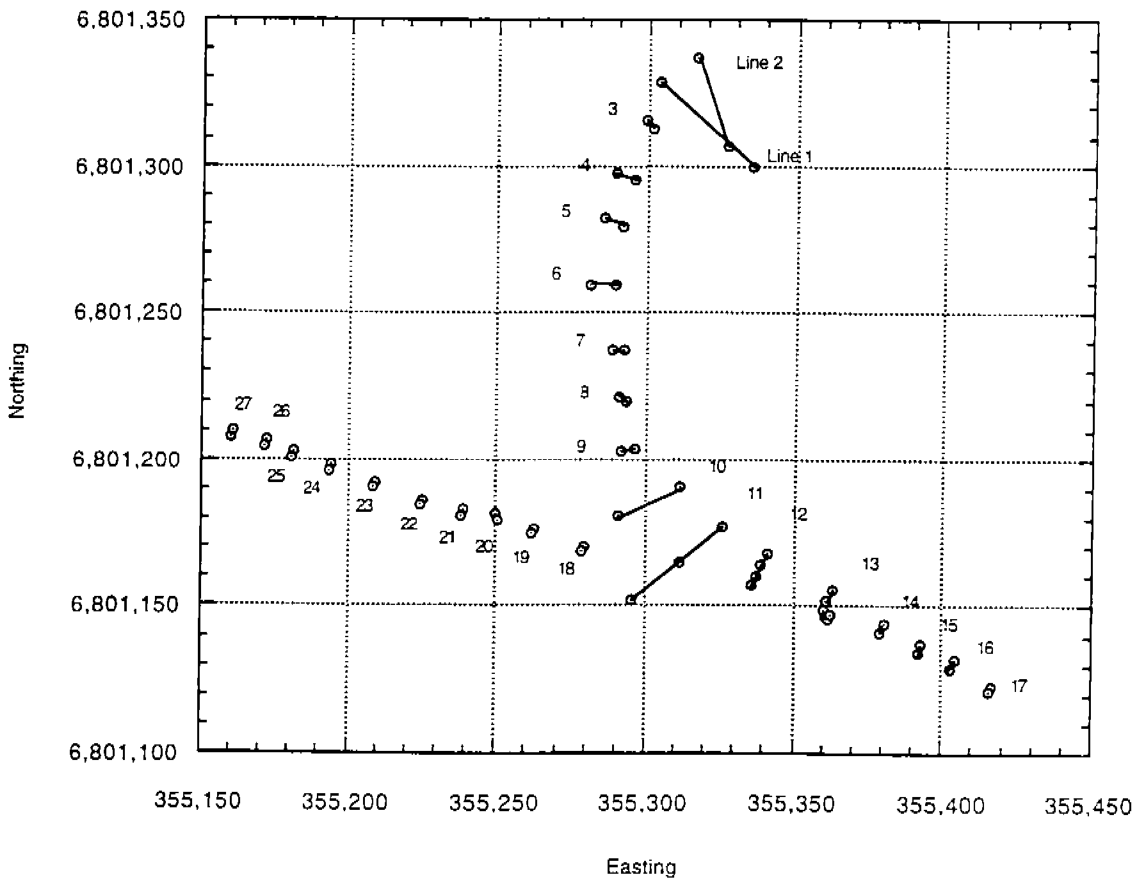


Figure III-4-7. Sampling transects in dredged area.

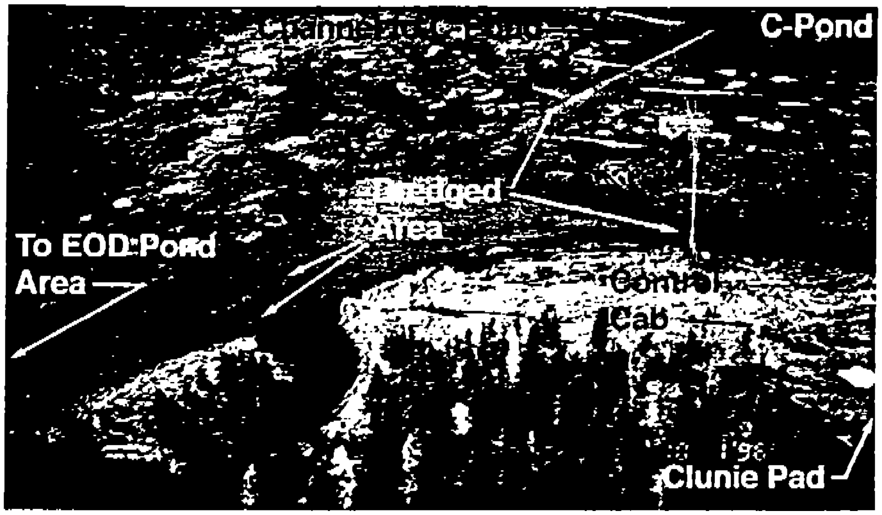


Figure III-4-8. Aerial view of dredged area.

Table III-4-5. Post-dredging sample data.

Line	*Site*	*Number of subsamples*	*WP mass found (µg)*	*Wet sample mass (g)*	*Concentration WP (µg/g)**
1a†	Clunie Pond	22	not detectable	534	–
1b†	Clunie Pond	–	not detectable	521	–
2a†	Clunie Pond	17	not detectable	502	–
2b†	Clunie Pond	–	not detectable	478	–
3	Clunie Channel	3	not detectable	513	–
4	Clunie Channel	4	not detectable	573	–
5	Clunie Channel	4	not detectable	526	–
6	Clunie Channel	5	not detectable	504	–
7	Clunie Channel	3	not detectable	527	–
8	Clunie Channel	3	not detectable	505	–
9	Clunie Channel	4	not detectable	487	–
10a†	Canoe Pt. Pond	12	40.4	531	0.076
10b†	Canoe Pt. Pond	–	151.0	538	0.281
11a	Canoe Pt. Pond	11	not detectable	542	–
11b	Canoe Pt. Pond	10	2055.0	540	3.800
12	Canoe Pt. Pond	7	not detectable	653	–
13	Canoe Pt. Pond	6	not detectable	545	–
14	Canoe Pt. Pond	3	not detectable	522	–
15	Channel to EOD	3	not detectable	520	–
16	Channel to EOD	3	not detectable	525	–
17	Channel to EOD	3	not detectable	569	–
18	Channel to EOD	3	not detectable	539	–
19	Channel to C-Pond	3	not detectable	553	–
20	Channel to C-Pond	3	not detectable	448	–
21	Channel to C-Pond	3	not detectable	405	–
22	Channel to C-Pond	3	not detectable	503	–
23	Channel to C-Pond	3	not detectable	495	–
24	Channel to C-Pond	3	not detectable	516	–
25	Channel to C-Pond	3	not detectable	330	–
26	Channel to C-Pond	3	not detectable	182	–
27	Channel to C-Pond	3	not detectable	191	–
–	Basin 1	1	2.82	619	0.005
–	Basin 2	1	162	607	0.267

Notes: *Samples analyzed at CRREL using SPME-GC by M.E. Walsh. Hits reanalyzed using GC following solvent extraction of the entire sample. Concentrations are from composite samples preconcentrated by sieving. Do not compare these concentrations to discrete sample results. †Duplicate samples.

pling was conducted. At the end of the transect, the bucket was agitated and the fines allowed to wash out. Clumps were broken up with a spoon. When the material was fully sieved, a 500-mL sample was taken of the remains. On long sample transects, two samples were taken from the bucket for analysis. These are denoted by the "a" and "b" suffixes on the line numbers in the table. The exception is line 11, where two separate samples were taken along the line, one from the East edge to the middle (11a) and one from the middle to the West edge (11b).

Composite sampling was used for post-dredging sampling for several reasons. Primary among these was that a larger area could be sampled more quickly and the samples analyzed more economically. Because of the heterogeneous distribution of the contaminant (WP), determining if an area is clean is more difficult. Composite sampling gives better coverage because many more points are sampled. Discrete sampling is much more likely to miss possible contamination due to the lower number of samples generally taken as compared to sieve compositing. Discrete sampling is thus more likely to produce a false negative result for contamination for a given number of samples.

Analysis of the dredged area sampling indicates that a small amount of contamination remains after dredging. The likely source of the contamination is material slumped from the edges of the dredge channel. Two out of 30 samples were contaminated, for a composite detection rate of less than 7%. This compares to discrete sample detection rates of between 50% and 80% and composite sample detection rates approaching 100% for areas known to be contaminated, based on past investigations at the Flats (Racine in Racine and Cate, 1996).

The concentration and number of contaminated samples for the compositing technique can not be directly compared to data obtained from discrete sampling, as the composite samples are composed of several discrete subsamples that are preconcentrated by sieving. This will overstate the presence of WP in comparison to a series of discrete samples. In our case, over 150 total discrete subsamples went into the 28 composite samples analyzed. The two composite samples testing positive—Line 10 (a and b) and Line 11b—each contained at least 10 subsamples. The small number of detections and wide variation in concentration, two orders of magnitude, makes any statistical analysis of the data difficult, if not meaningless. It should be used for comparison to other areas of known contamination which, as stated above, normally have detection rates approaching 100% using the sieved composite sampling method.

In addition to the spoils line and dredged area sampling, two sediment samples were analyzed from the retention basin. These samples were obtained near the spoils outfall pad, where sedimentation is thickest and drying time is longest (See Attenuation section). Both samples, taken from material from the same 20-cm depth, were contaminated. Results are shown in Table III-4-5 under "Basin."

Analysis of the dredged area sampling indicates that a small area is still slightly contaminated. Three out of 31 samples were contaminated, for a contamination rate of less than 10%. This compares to a contamination rate of about 20% for areas known to be contaminated, based on past experience of several investigators at the Flats. The small number of hits and wide variation in concentration (two orders of magnitude) makes any additional statistical analysis of the data difficult, if not meaningless.

Survey methods

A detailed survey was conducted to determine horizontal coordinates and elevations of sample locations and boundaries in the dredged area during October 1996. Surveying was done using a Leitz SET4B electronic total station and a triple reflective prism mounted on a 1.45-m-tall prism rod. One person ran the total station while the other person occupied each site to be surveyed with the prism rod. For the dredge area survey, we used two benchmarks (Canoe Point BM and Clunie BM) along the shore that had been previously surveyed. For the retention basin we used two benchmarks (Berm and Crane) lo-

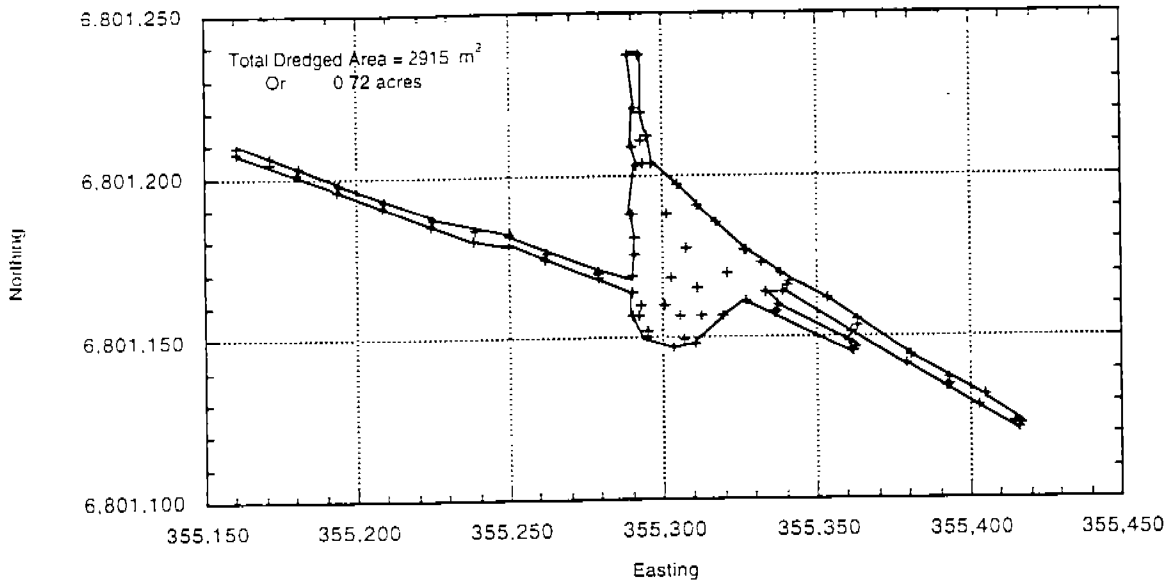


Figure III-4-9. Survey map of dredged area. (+ denotes surveyed point.)

cated on the EOD Pad. Universal Transverse Mercator (UTM) horizontal coordinates and the elevation were known for each of the BMs.

To conduct these surveys the electronic total station was set up over the BM and the instrument back-sighted to the reference azimuth mark. The prism rod was placed on the ground or pond bottom surface at each site to be surveyed. For the dredged area survey, a 20-cm-diameter flat plate was attached to the tip of the prism rod. This provided a uniform bearing surface for the rod tip, keeping it from sinking down into the pond bottom sediment. The triple prism was sighted on by 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.

Dredge area survey

A survey was conducted to determine the perimeter of the area dredged in 1996 as well as spot measurements of dredge depths within the dredged area. A map of the dredged area is shown in Figure III-4-9. The total area dredged this year was approximately 2915 m^2, or about 0.72 acres. This is only about half the area that the contractor estimated that he had dredged. The average dredged depths along the sample transect lines and at additional spots within the dredge area are given in Appendix III-4-C. The average depth for the area dredged in 1996 was 63 cm (25 in.). Certain areas, such the channel from Canoe Pt. Pond out to C pond, were much shallower, averaging 45 cm (18 in.). Only a few areas within the center of the dredged area came close to the called-for dredge depth of 90 cm (36 in.). The minimum depth for breaking the contaminant pathway to feeding mallards, the largest of the dabbling ducks, is 40 cm (Low et al. 1970).

ATTENUATION STUDY

The natural attenuation project and the ongoing contaminant attenuation study being conducted in the retention basin were both cut from the program this year. Again, we felt these studies were extremely important in evaluating the efficacy of various remediation studies being conducted at the Flats, so we used funds from other sources to continue this work on a very limited basis. Due to restrictions on working in the Flats, we concentrated on the parameters affecting the sublimation of white phosphorus in the basin sediments.

Soil moistures

In early June a series of soil moisture measurements were made in the sediments of the previous years' dredging activities. Two-centimeter-diameter soil cores were taken down to liner depth at ten locations in the basin. Four of these locations corresponded to areas where plugs containing WP particles had been planted the previous fall, when the basin attenuation study was initialized. The other six locations follow the tapering sediment delta between the corner of the fencing around the North spoils splash pad and Instrument Station #1, both locations of particle plugs (Fig. III-4-10). The other two plug locations are at Instrumentation Station #3 and between the berm and splash pad, adjacent to the inlet pipe.

The data indicate that the sediment in most locations and depths is still nearly saturated (Table III-4-6). The exceptions are those sample points near Station #1 where sediment thickness is least. The sediment in these areas is also mostly mineral, with very little organic

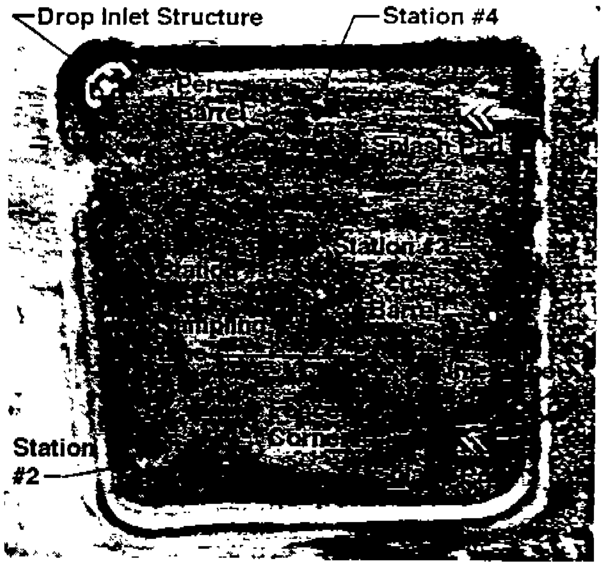


Figure III-4-10. Retention basin.

material evident. This results in quicker drying times. For sublimation to occur, moisture content levels must be below approximately 45%.

Organic contents

As the organic content of the sediments directly affects the drying rate, two samples were obtained from the basin near the spoils splash pad and analyzed for organics at CRREL by A. Hewitt. The samples were first dried in an oven at 105°C until the moisture was driven off. Portions of the sample were sieved with a #30 sieve prior to analysis. Samples were analyzed in a Leco CR-12 furnace using the methods as outlined in Merry and Spouncer (1988). Analyses included both the sieved and unsieved portions of the original sample. Replicates of both the sieved and unsieved analyses were run. Weights of two samples were measured to verify the ranges of the carbon contents. Data and results are found in Table III-4-7.

The organic contents of the sieved and unsieved basin sediment samples are in the same range as those found by Bouwkamp (in Racine et al. 1995). The average for the five samples done in these analyses is 4.3%, the median 4.4%, and the standard deviation ±0.3. In Bouwkamp, 36 of 42 samples analyzed had organic carbon contents in the 2.2–6.8% range. The overall average was 5.4%, the median 5.0%, and the standard deviation ±2.2. Eliminating the outliers brings the average to 4.6%, the median to 4.8%, and the standard deviation to ±0.98. Organic content has a great impact on drying times of the sediments and sorption of colloidal white phosphorus. Unfortunately no organic content analyses were performed on sediments farther from the splash pad. It is postulated that the values will reflect those of the sediment removed at the greater dredged depths and should be quite low.

WP particle plug attenuation

On 28 September 1995, after draining the retention basin, manufactured particles of white phosphorus (Walsh et al. 1995) were planted in the dredge sediments at four loca-

Table III-4-6. Moisture contents of basin sediment samples (June 1996).

Location	Sample number	Depth (cm)	Soil + tare: Wet (g)	Soil + tare: Dry (g)	Water wt. (g)	Soil wt. (g)	Soil moisture† content (%)
Inlet	P-00:10	0 to 10	49.27	30.37	18.90	21.23	89.02
Pipe	P-10:20	10 to 20	41.75	26.02	15.73	16.56	94.99
	P-20:30	20 to 30	39.31	23.99	15.32	14.51	105.58
	P-30:40	30 to 40	46.73	29.66	17.07	20.47	83.39
	P-40:45	40 to 45	28.90	20.40	8.50	11.34	74.96
Fence	F-00:10	0 to 10	51.33	33.39	17.94	24.31	73.80
Corner	F-10:20	10 to 20	44.08	28.03	16.05	18.58	86.38
	F-20:30	20 to 30	46.02	28.61	17.41	19.51	89.24
	F-30:37	30 to 37	33.75	22.99	10.76	13.83	77.80
5 m Out*	5-00:10	0 to 10	50.24	33.37	16.87	24.01	70.26
	5-10:20	10 to 20	38.68	25.72	12.96	16.31	79.46
	5-20:30	20 to 30	48.94	31.02	17.92	21.90	81.83
	5-30:33	30 to 33	21.31	16.43	4.88	7.13	68.44
10 m Out*	10-00:10	0 to 10	41.73	28.65	13.08	19.45	67.25
	10-10:20	10 to 20	41.50	26.67	14.83	17.21	86.17
	10-20:24	20 to 24	34.04	24.60	9.44	15.54	60.75
15 m Out*	15-00:10	0 to 10	45.59	30.06	15.53	20.67	75.13
	15-10:20	10 to 20	42.93	28.59	14.34	19.27	74.42
	15-20:28	20 to 28	41.23	29.59	11.64	20.14	57.80
20 m Out*	20-00:10	0 to 10	44.47	31.48	12.99	22.20	58.51
	20-10:18	10 to 18	40.42	28.41	12.01	18.95	63.38
25 m Out*	25-00:10	0 to 10	48.44	36.59	11.85	27.23	43.52
	25-10:13	10 to 13	23.54	19.08	4.46	9.74	45.79
30 m Out*	30-00:10	0 to 10	32.30	28.44	3.86	19.14	20.17
Station 1	S1-00:05	0 to 5	25.14	23.67	1.47	14.25	10.32
Station 3	S3-00.10	0 to 10	54.28	38.16	16.12	28.70	56.17
	S3-10:16	10 to 13	27.65	20.44	7.21	10.99	65.61

*Distance from fence corner on splash pad to Station 1.
†As a percentage of dry weight.

Table III-4-7. Organic carbon content analyses.

Run #	Source	Condition	Carbon content (%)	Target content (%)	Calibration error (%)
1	Standard	—	71.5	71.1	0.6
2	Liner	Sieved	9.8	—	—
3	Liner	Sieved	11.9	—	—
4	Liner	Sieved	12.3	—	—
5	Standard	—	10.7	12	10.8
6	Liner	Unsieved	9.3	—	—
7	Liner	Unsieved	9.8	—	—
8	Basin	Sieved	4.2	—	—
9	Standard	—	12.2	12	1.7
10	Basin	Sieved	4.5	—	—
11	Basin	Sieved	4.4	—	—
12	Liner	Sieved	12.8	—	—
13	Basin	Unsieved	4.5	—	—
14	Basin	Unsieved	3.9	—	—

tions in the basin to monitor attenuation of a known quantity of WP in the basin sediments over time. A single manufactured WP particle, approximately 2 mm in diameter, was inserted in a plug of sediment contained within a nylon mesh bag. Six plugs were planted at each of the four locations. Using other data such as sediment moisture content, organic content, and temperature, the efficacy of using the basin for natural remediation of white phosphorus contaminated sediments can be determined.

In May 1996, prior to resumption of dredging, three plugs from each of the four locations was pulled by M.E. Walsh for analysis at CRREL. At the time the sediments were still partially frozen and temperatures were averaging below 7°C, going below 0°C at night. Very little of the warm drying conditions necessary for the initiation of the sublimation process was seen between the end of September 1995 and the end of May 1996. Table III-4-8, the results of the analyses on the plugs, reflects this.

Analysis of another set of plugs extracted in early August 1996 would have been very useful but was not done due to lack of funding. These results are very similar to the results of the studies conducted in intermittent pond areas of ERF (Walsh, M.E. et al. 1995). As the sediments approach saturation, individual particles will start to sublimate as pathways through the soil structure become available. Variations in the availability of pathways through the soil account for the wide variability in the amount of WP mass remaining.

Basin contamination

Prior to dredging in 1996, a series of samples were collected from the retention basin for analysis for white phosphorus. Although not funded, we felt this would be an important indicator for roughly determining how well the natural attenuation of the contaminate was progressing. Sample points corresponded with the locations chosen for the soil moisture samples (Table III-4-7). As can be seen from Table III-4-10, no white phosphorus was detected at any of the sample points. This does not prove that the contaminant has completely disappeared from the basin (Table III-4-9), only that the contaminant is not widespread and that in the areas that were sampled, it has either disappeared through natural attenuation or was never deposited there. More intensive sampling of the basin would have given more reliable results, but time and funding considerations prevented this from occurring.

Within the Retention Basin, the locations

Table III-4-8. Analysis results for WP-spiked plugs in basin.

Site	*Rep*	*WP mass found (µg)**	*Percent remaining*
Station 1	a	Not detectable	0.00
	b	7.80	0.14
	c	Not detectable	0.00
Station 3	a	4400.0	80.59
	b	0.14	0.0026
	c	0.17	0.0031
MidInflow pipe	a	4690.0	85.90
	b	3308.0	60.60
	c	629.0	11.50
Fence corner	a	32.0	0.59
	b	0.2†	0.0037
	c	4402.0	80.60

*Samples analyzed by M.E. Walsh at CRREL using SPME and GC.
†Sample bag broke on extraction from basin.

Table III-4-9. Results of limited basin sampling.

Site ID	*WP mass found (µg)**
5 m	not detectable
10 m	not detectable
15 m	not detectable
20 m	not detectable
25 m	not detectable
30 m	not detectable
Station 1	not detectable
Station 3	not detectable
Fence corner	not detectable
Inflow pipe	not detectable

*Samples analyzed by M.E. Walsh at CRREL using SPME.

of the planted WP particle plugs (Table III-4-10) and sediment moisture sample points were surveyed (Table III-4-11). A profile of the sediment delta was surveyed to determine the distribution and depths of sediment built up in the Retention Basin (Table III-4-12) from this summer's dredging effort.

EOD PAD PIEZOMETER WELLS

Although the EOD Pad hydrology well work was completely cut in the 1996 budget, some work was done on the project when time was available. This included surveying in the wells (See Survey section), manually checking depths and water levels, and installating an autonomous data acquisition system at one of the sites. In addition, several hours of consulting work was done for the Alaska District in support of the sampling wells that were to be installed on the EOD Pad.

As previously mentioned, one of the primary purposes for the piezometer wells was to monitor how the basin infiltration affects the groundwater level below the EOD Pad. This year, groundwater level information was critical due to the deterioration of the basin liner and the high conductivity rates through the liner, especially early in the dredging season. The one well that was instrumented was done after the end of the dredging season and is located at the far corner of the EOD Pad.

Table III-4-10. WP particle plug locations.

Location	*Easting*	*Northing*	*Elevation (m)*
Fence corner	355,616.14	6,801,126.35	9.88
Pipe site	355,608.66	6,801,130.58	9.96
Sta #3 sample site	355,601.07	6,801,109.77	9.58
Sta #1 sample site	355,629.66	6,801,090.50	9.51

Table III-4-11. Sediment moisture sample points.

Location	*Easting*	*Northing*	*Elevation (m)*
Sample pt: 30 m out	355,627.13	6,801,098.26	9.56
Sample pt: 25 m out	355,625.66	6,801,102.62	9.53
Sample pt: 20 m out	355,623.55	6,801,107.75	9.62
Sample pt: 15 m out	355,621.54	6,801,112.84	9.61
Sample pt: 10 m out	355,619.85	6,801,117.68	9.68
Sample pt: 5 m out	355,617.85	6,801,122.46	9.81
Fence corner	355,616.14	6,801,126.35	9.88

Note: Surveyed 6/6/96.

Table III-4-12. 1996 Pre- and post-dredging sedimentation delta depths within Retention Basin.

Location	Depth (cm: 6/96)	Depth (cm: 10/96)
Inlet pipe near plugs	45	89
Fence corner near plugs	37	78
5 m out	33	59
10 m out	24	55
15 m out	28	61
20 m out	18	45
25 m out	13	38
30 m out	10	29
Inst. station #1 (37.8 m out)	4	16
40 m out	0	12
50 m out	0	11
Inst. station #3	16	44

Note: Surveyed on 6/6/96 and 10/2/96.

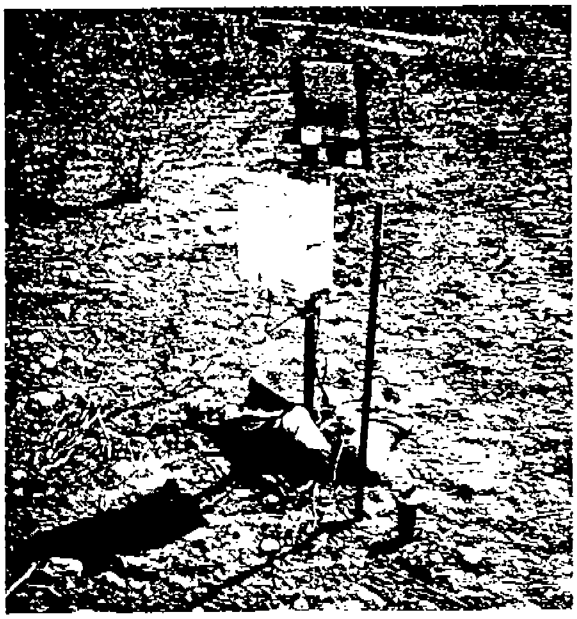
Water levels were significantly lower than last fall. In September 1995, all wells except C4, located along the northeast berm of the basin, contained water. In the spring, only four of the seven wells contained water. This was probably due to the dry spring as opposed to the wet fall of last year. Well C6, located in the east corner of the retention basin, contained the most water and thus was chosen

Table III-4-13. EOD Pad piezometer well UTM coordinates and elevation data.

Piezometer well #	Easting	Northing	Ground surface elevation*
C-1	355,809.79	6,800,934.79	9.41
C-2	355,698.04	6,800,953.48	8.22
C-3	355,571.43	6,801,022.76	7.86
C-4	355,640.93	6,801,147.46	10.39
C-5	355,728.46	6,801,148.81	11.45
C-6	355,860.01	6,801,136.20	12.37
C-7	355,712.58	6,801,047.02	9.93

Note: Surveyed 6/6/96.
*Ground surface elevation next to piezometer well casing. MSL = 0.

for instrumentation in mid-July (Fig. III-4-11). Bad probes and faulty wiring prevented automated collection of data until the end of September. The system will be allowed to collect data until at least December 1996 before it is removed. Data for the wells are found in Tables III-4-13 and III-4-14. Note that elevations are taken from mean sea level (MSL), which is not necessarily the surface level of the water in the Flats adjacent to the EOD Pad. The elevation of the EOD Pad at Pt. Crane, located at the west corner of the Pad, is 7.82



a. Instrumented well.

b. Close-up of wellhead.

Figure III-4-11. Piezometer instrumentation of well C-6.

Table III-4-14. Data for EOD Pad piezometer wells.

Date	Piezometer well #	Top of casing to well bottom (cm)	Top of casing to ground (cm)	Top of casing to water (cm)	Total well depth (cm)	Total water depth (cm)
6/10/96	C-1	616	21.5	609	594.5	7
	C-2	609	10.0	601	599.0	8
	C-3	613	10.5	569	602.5	44
	C-4	564	28.5	564	535.5	0
	C-5	621	15.0	621	606.0	0
	C-6	536	14.5	374	521.5	162
	C-7	619	0.0	619	619.0	0
7/18/96	C-6	536	14.5	390	521.5	146
8/8/96	C-6	536	14.5	396	521.5	140
9/30/96	C-6	—	—	—	—	167*

*Measurement obtained with Druck Pressure Transducer. Not checked manually.

m, but the water level adjacent to the pad is somewhere between 4.5 and 4.9 m (MSL).

Using 4.5 m for the approximate water level adjacent to the Pad, the distance from the surface of Pt. Crane to the theoretical water table will be about 3.3 m. Well C-3 is located adjacent to Pt. Crane, and the water level from the surface on 10 June was about 5.58 m, putting the water table at about 2.3 m. Even taking into account the prolonged period of time previous to the three minimal flooding tides in early June (March 22 to June 2, with tide heights of 31.5, 31.8, and 31.6 on 2–5 June), the 2-m difference cannot be explained at present. Further work may need to be done to "calibrate" the wells.

Figure III-4-12 depicts data gathered manually and with a pressure transducer for well

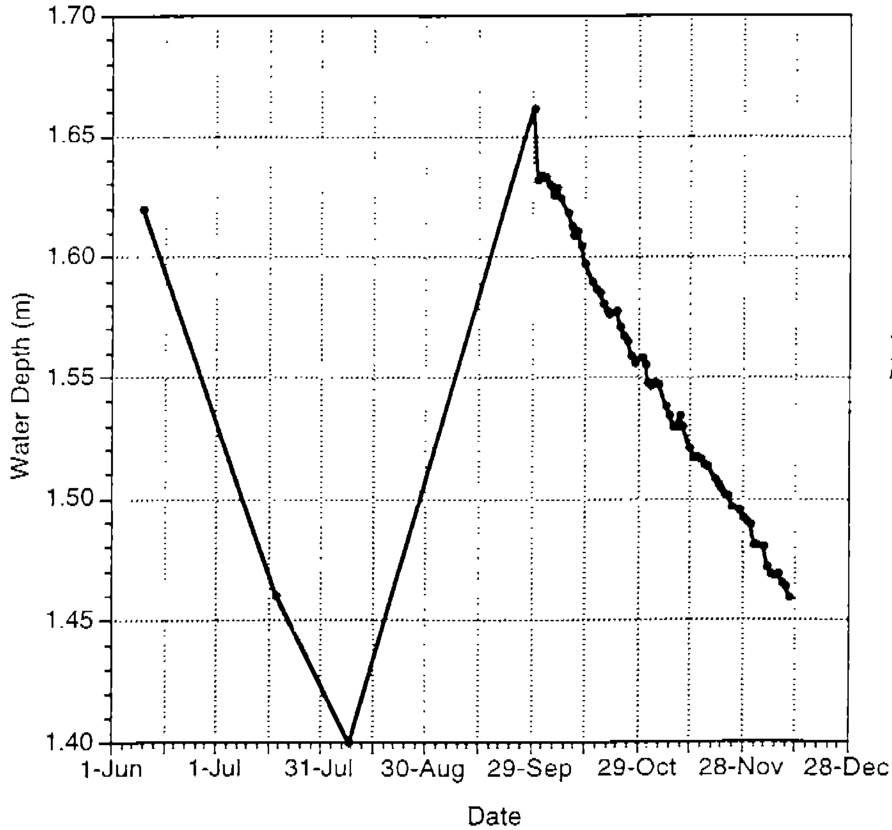


Figure III-4-12. Manual and piezometer data for well C-6.

C-6, located in the east corner of the Pad. This is our baseline groundwater well and shows the effects of seasonal variations in groundwater level in the far corner of the Pad. These data can be used as non-tidally-influenced groundwater data.

CONCLUSIONS

Technical assistance

- Further improvements have been made to the cutterhead to facilitate dredging.
- Contract personnel quickly came up to speed on dredge operation.
- Anchor points are still problematic. Anchor blocks were replaced by screw anchors, and lateral winches are no longer used. The anchoring and winching system still requires much manual work in the Flats. However, the revised system greatly reduces logistical effort. Helicopter support is no longer required for deploying winches.
- Some traversing problems still exist due to resistance of sediments to dredging (vegetation, extremely cohesive compacted sediments, debris).
- The use of helicopters has been virtually eliminated for near-shore operations, reducing support costs to overall program

Retention basin

- Retention basin hydraulic conductivity has increased to the point where it will not be useable next season without recompaction and probably should not have been used this season. The probable cause of deterioration is freeze–thaw cycling over the winter, caused by the retention of water in the highly organic liner material.
- Low salinities continue to plague flocculation and settlement of the suspended solids and negate the usefulness of the filter fabric in the drop inlet structure.
- Settling times are such that continuous dredging is not practical if TSS is to be below levels found in the Flats during flooding tides.
- The use of the instrumentation station for monitoring basin use is a good way of recording contractor performance at the Flats. It is also useful in determining rough percolation rates and thus basin performance. Soil temperature and moisture sensors should be useful if the attenuation study is continued. No analysis on this has been done to date.
- Basin sedimentation rates should allow for at least two more dredging seasons before it will be necessary to remove the sediments.

Dredge monitoring

- Spoils line sample analyses indicate that contaminant rates are comparable to those found in previous years.
- Some low-level amounts of WP contaminant is still being re-released into the Flats. However, this is most probably colloidal, not particulate, in form and should quickly be sorbed onto the vegetation in the area.
- Post-dredge sampling indicates that some contaminant is still being left behind after dredging, albeit at significantly lower occurrences than before dredging. Causes of contamination may be as follows:
    1.) Contamination may be coming from slumped banks on edge of dredged area.
    2.) Contamination may be occurring in areas that were not dredged to a full depth of 90 cm (36 in.), leaving contaminated sediments behind.
    3.) Some post-dredging sedimentation and recontamination may have occurred.
- Composite sampling techniques greatly facilitated our ability to sample the area dredged. They may be magnifying the problem in comparison to discrete sampling techniques, however, by consolidating the contaminant from a large number of samples along a sampling line into a single sample, thereby overemphasizing isolated hits and exaggerating

concentrations. Therefore, the results cannot be compared to discrete sampling method results due to the consolidation of subsamples.

- The presence of contaminant in basin from current-year dredge spoils confirms the transfer of contaminant to the basin.
- No dead ducks or swans were observed in or near the dredged areas and basin.
- The dredged area is about 3/4 acre (1966). Average depth is 25 in. (63 cm). This depth is sufficient to break the contamination pathway for mallards (40 cm), the largest and most vulnerable of the dabbling ducks.
- The dredged channel out to C-Pond will not be sufficient for the blast-and-drain remediation approach. It is located in a very shallow area of C-Pond and should have only a minimal effect on the surface hydrology of the system.
- The use of the contract UXO safety officer greatly facilitates the ability to operate at ERF.

Attenuation study

- Overwinter conditions are not conducive to drying of sediments. Sediment sample soil moisture contents averaged around 77% in June in areas where thickness exceeded 18 cm.
- Some attenuation of contaminant will occur even under less than ideal conditions. About 20% of the WP particles in planted plugs disappeared over the winter in moist areas, and all the WP was gone at the one dry area.
- The organic contents of sediments reflect those typical of the Flats in areas adjacent to the spoils line (≈ 4.5%). Sediments farther from the deposition delta appear to be inorganic.
- The organic content of sediment highly influences the attenuation of the contaminant.
- The results of limited basin sampling prior to 1996 dredging indicate that most of the contaminant is gone from the drier sediments.

EOD Pad piezometer wells

- Groundwater fluctuations of over 27 cm are evident at the control piezometer well located at the southeast corner of the EOD Pad.
- Effective wells may have to be up to 8 m in depth to compensate for seasonal groundwater fluctuations

RECOMMENDATIONS

The following recommendations are made based on this and previous years' work. They are listed to correspond to the order the subject matter is found in the main body of the report and not in order of importance or urgency.

- Further optimization of the dredge system will facilitate the dredging process. Refinement of the anchoring system, use of an r/c control system, additional extended cutter tines, and re-addressing the auger drive should all be considered.
- Further training of the contract operators will not be necessary.
- Retention basin hydraulic conductivity has increased to the point where it will be necessary to recompact the liner before reuse.
- The capacity of the basin is sufficient for at least two more seasons. It is not necessary to remove sediments at this time.
- The use of a coagulant such as aluminum sulfate (alum) or a polymer will facilitate the flocculation and settlement of suspended solids in the basin and should reduce the reintroduction of trace amounts of colloidal white phosphorus into ERF. Alum is effective for pH values of 5.5–8.0 (Corbit 1990), which covers the range of conditions found in ERF (Racine et al. 1993). Polymers have been used effectively to treat runoff at mine sites in Alaska such as the Usibeli Coal Mine.
- Basin investigations should be continued to ensure the viability of the system.
- Closer monitoring of the dredging operation by the Contract On-site Represen-

tative (COR) may be necessary to ensure the parameters of the contract are being met and progress is being correctly reported. We found the dredged area to be half what the contractor claimed, and the dredged depth was not to specifications.

- The attenuation study should be continued to monitor the efficiency of the natural attenuation process in the basin. Without this information, too many assumptions will need to be made in determining the treatment and remediation of the contaminated sediment. The basin is also a safe, representative area in which some controlled attenuation studies may be conducted.
- The absence of waterfowl mortality in the areas in and adjacent to the dredged areas, which were shown to be highly contaminated prior to dredging, indicates that dredging contaminated areas is contributing to the reduction of mortality at the Flats.
- Aerial photo overflights should continue to be done to document yearly changes in the topography of the Flats as well as monitoring dredged areas.
- Work should be restarted on the water table monitoring wells to determine the influence of basin infiltration, if any, and tides on the EOD Pad water table.
- Dredging should continue to be considered as a remediation strategy at the Flats.
- More work needs to be done to verify well surface and water levels.

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APPENDIX III-4-A. SPOILS SAMPLE COLLECTION, STORAGE, AND SHIPMENT SOP

Sample collection

Collection point: Spoils line, approximately 12 m upstream from crest of retention pond berm.

Sampling access: Open area accessible at all times. 13-mm pitless adapter on side of spoils line. Ball valve shutoff.

Sample strategy: Composite sample method. Samples are taken at 15-minute intervals by directing a stream of spoils from the spoils line through the pitless adapter, valve and 1 m of Tygon tubing into a 19-L PE bucket. After four 4.5-L samples have been taken, the bucket is covered and set aside for the sediment to separate from the supernatant, a minimum of two hours. After the sediment has settled, the supernatant is decanted by slowly tipping the barrel until only saturated solids remain. The solids are stirred and a 500-mL composite sample taken using a PE ladle. The sample container is a clear, wide-mouth 500-mL glass sample jar, level 2A clean (Eagle-Pitcher P/N 232-16C). Time, date, and approximate dredge location are noted. Sealing tape to be used. The bucket is then emptied, rinsed twice with distilled water, and finally dried for reuse. Decontamination procedure repeated for ladle.

Sample storage

Temperature: Temperature is not to exceed 15°C.

Location: Samples are not to be stored in direct sunlight. They will be stored in a cooler with an ice or frozen gel pack.

Documentation: All samples are to be labeled. Documentation will reside with samples whenever practicable. A duplicate set of documentation will be retained by the P.I. or sampler.

Sample shipment

Samples are to be shipped overnight or second-day air, whichever method is most practical. Samples are to be shipped to ensure temperature does not exceed 15°C. Adequate packing to ensure sample integrity will be used. Containers are to be sealed with a chain of custody document attached.

APPENDIX III-4-B. DECANTED SUPERNATANT COLLECTION, STORAGE, AND SHIPMENT SOP

Sample collection

Collection point: Drop inlet structure outlet pipe egress point.

Sampling access: Open area accessible at all times.

Sample strategy: Grab sample taken once to twice a day during decanting process. Samples taken by placing the mouth of a 1-L amber glass sample bottle, level 2A clean (Eagle-Picher P/N 223-32A), in the path of the outflow from the outlet pipe. Time and date are noted before obtaining sample. Sealing tape to be used.

Sample storage

Temperature: Temperature is not to exceed 15°C.

Location: Samples are not to be stored in direct sunlight. They will be stored in a cooler with an ice or frozen gel pack.

Documentation: All samples are to be labeled. Documentation will reside with samples whenever practicable. A duplicate set of documentation will be retained by the P.I. or sampler.

Sample shipment

Samples are to be shipped overnight or second-day air, whichever method is most practical. Samples are to be shipped to ensure temperature does not exceed 15°C. Adequate packing to ensure sample integrity will be used. Containers are to be sealed with a chain of custody document attached.

APPENDIX III-4-C: SURVEY DATA FOR DREDGED AREA AND SAMPLE POINTS

The following data were obtained from 30 September to 2 October as part of the sampling and evaluation tasks for the dredge project. Water depths are referenced to the water surface at the time of surveying. Flooding tides (10.1 m/33 ft max.) had occurred from 25 September to 1 October. Surveying was done using a Leitz SET4B electronic total station and a triple reflective prism mounted on a 1.45-m-tall prism rod.

Table III-4-C1. Dredged depths at survey point locations.

		*Avg depth**		*Starting coordinate*		*Ending coordinate*	
Transect	*Location*	*(m)*	*(in.)*	*Easting*	*Northing*	*Easting*	*Northing*
Line 1	Clunie Inlet	0.77	30	355,335.18	6,801,299 28	355,303.83	6,801,328.47
Line 2	Clunie Inlet	0.78	31	355,326.43	6,801,306.59	355,316.30	6,801,337.13
Line 3	Clunie Channel	0.75	30	355,301.42	6,801,313.17	355,298.91	6,801,316.19
Line 4	Clunie Channel	0.70	28	355,295.52	6,801,294.76	355,289.53	6,801,297.67
Line 5	Clunie Channel	0.74	29	355,291.54	6,801,279.73	355,285.73	6,801,281.78
Line 6	Clunie Channel	0.71	28	355,289.42	6,801,259.21	355,281.19	6,801,259.50
Line 7	Clunie Channel	0.47	19	355,292.41	6,801,237.20	355,288.83	6,801,236.90
Line 8	Clunie Channel	0.52	20	355,293.19	6,801,219.50	355,291.25	6,801,220.85
Line 9	Canoe Pt. Pond	0.60	24	355,296.45	6,801,203.88	355,291.38	6,801,203.23
Line 10	Canoe Pt. Pond	0.59	23	355,311.11	6,801,190.62	355,291.15	6,801,181.23
Line 11	Canoe Pt. Pond	0.73	29	355,326.26	6,801,177.17	355,295.25	6,801,152.00
Line 12	Canoe Pt. Pond	0.72	28	355,340.86	6,801,167.50	355,335.83	6,801,157.38
Line 13	Canoe Pt. Pond	0.73	29	355,363.18	6,801,155.62	355,361.12	6,801,146.36
Line 14	Ch. to EOD	0.75	30	355,380.38	6,801,144.34	355,379.52	6,801,141.43
Line 15	Ch. to EOD	0.75	30	355,393.18	6,801,137.71	355,392.33	6,801,134.46
Line 16	Ch. to EOD	0.71	28	355,404.67	6,801,131.94	355,403.01	6,801,128.82
Line 17	Ch. to EOD	0.64	25	355,416.88	6,801,122.81	355,415.83	6,801,121.40
Line 18	Ch. to C-Pond	0.52	20	355,279.21	6,801,170.52	355,278.87	6,801,168.46
Line 19	Ch. to C-Pond	0.60	24	355,262.69	6,801,176.53	355,261.66	6,801,174.64
Line 20	Ch. to C-Pond	0.37	15	355,249.83	6,801,181.32	355,250.25	6,801,178.99
Line 21	Ch. to C-Pond	0.41	16	355,238.83	6,801,183.37	355,238.27	6,801,180.45
Line 22	Ch. to C-Pond	0.38	15	355,225.38	6,801,186.64	355,224.33	6,801,184.92
Line 23	Ch. to C-Pond	0.36	14	355,209.22	6,801,192.47	355,208.47	6,801,190.57
Line 24	Ch. to C-Pond	0.42	17	355,194.39	6,801,197.80	355,193.80	6,801,195.94
Line 25	Ch. to C-Pond	0.41	16	355,181.21	6,801,202.92	355,180.76	6,801,200.84
Line 26	Ch. to C-Pond	0.50	20	355,171.80	6,801,206.30	355,171.26	6,801,204.29
Line 27	Ch. to C-Pond	0.61	24	355,160.24	6,801,207.34	355,160.70	6,801,209.40

*Based on a water surface elevation of 4.83 m at the time of survey on 10/2/96. Previous flooding high tide night of 30 September.