Annex A: The Development of the DEW Line Cleanup Criteria

When the Environmental Sciences Group began the environmental study of the North Warning System (NWS, the modernized form of the DEW Line) in 1989, there were no environmental criteria specific to the Canadian Arctic. One of the most comprehensive sets of environmental quality indicators were those produced by the Québec government (MENVIQ 1988). These were therefore employed during the initial interpretation of data obtained from the study of the first ten NWS Long Range Radar and DEW Line sites.

During the course of the NWS Study, the Canadian Council of Ministers of the Environment Interim Environmental Quality Criteria for Contaminated Sites were prepared (CCME 1991). In anticipation that there would be considerable interest in applying *national* criteria to the NWS sites, cleanup recommendations for the NWS sites were reviewed in the context of the new CCME criteria and included in the *North Warning System Environmental Study* (Volumes One - Three, ESG 1991).

Vegetation samples were analyzed in order to determine potential uptake of contaminants into the food chain, and the results of these analyses were correlated with soil results and used to determine the concentrations of contaminants in soil which caused an impact on the food chain. The consideration of results obtained from these analyses of Arctic vegetation and the tendency of certain contaminants (lead and PCBs) to undergo aerial transport indicated a need to combine features of the Québec and the CCME criteria. This combination was designated the DEW Line Cleanup Criteria, DCC.

The DCC Level II Criteria (or DCC-II) and CCME Residential/Parkland Criteria (or CCME R/P) are identical to each other for inorganic element and PCB concentrations in soils. The DCC-II and CCME R/P Criteria are also identical to Québec "B" Criteria (MENVIQ, 1988) for those substances included in the DCC. The DEW Line Cleanup Criteria, however, dictate a more rigorous trigger for the removal of two substances from the Arctic environment: lead and PCBs. Previous research by the ESG, as well as other scientific studies, led to the inclusion of another tier of soil criteria for these two contaminants, the DCC Level I (or DCC-I). Both lead and PCBs, unlike many other contaminants, tend to migrate from a source to surrounding areas (including the surfaces of plant leaves) through the air. Both substances are also known to exert chronic (long term) - as opposed to acute (short term) - toxicological effects on animals in association

with long-term bioaccumulation (in the case of lead) or food-chain related biomagnification (in the case of PCBs).

Annex B: The Use of Plants as Environmental Indicators

The same concentration of a contaminant in soil can display very different effects under different circumstances, depending on the soil type and depth, ecosystem features etc. It is therefore necessary to determine the impact of contaminants on a site-specific basis, which means that site-specific criteria must be established. Mathematical models can be used to estimate exposures/dose and the results are then combined with toxicological information to obtain site-specific risk. This methodology has some inherent difficulties such as applying the procedures correctly, having all the toxicological information, and defining acceptable risk levels.

An alternative to the modeling method of generating site-specific criteria is to modify criteria-based assessments by taking into account relative, or site-specific, factors. This can be achieved by directly measuring the entry of contaminants into the food chain, resulting in a measured rather than modeled estimate of risk. Samples of vegetation were therefore collected at the same locations as some of the soil samples. The species collected were those which have importance in the food chain: willows (*Salix* sp.) and oleasters (*Shepherdia* sp.). Willow, for example, demonstrates the ability to accumulate and, in some cases, concentrate one or more of the parameters analyzed from the soil or sediment (North Warning System Environmental Study, Volume One, Chapter VI; see also ESG, 1993 and 1994). The results of the analysis of plant samples are not intended to preclude the interpretation of soil and water data, since the DCC for some substances in soils appear to be reasonable indicators of ecosystem impact at northern sites based on previous vegetation studies (Reimer et al., 1993). Instead, plants provide a different perspective on the environmental status of the site, help to identify substances with particular biological activity and assist in the selection of remedial options.

Plants vary greatly in their ability to accumulate contaminants; some naturally accumulate substances that, in excessive amounts, can be toxic. The specific concentrations of these substances (such as inorganic elements and PCBs) in plants that pose a threat to the ecosystem are unknown. The impact of contaminants on the ecosystem is therefore measured by a comparison of the analytical results for samples collected from impacted areas with the results for samples collected from non-impacted areas (background samples). Thus, background plant and soil samples were collected from areas that were representative of the terrain on the island but removed from the immediate influence of previous station activities. Where possible, plant species common to the

various geographical areas of the site were collected from the background locations. Since the geographical areas of the site do not all contain the same types of plants, the results have been pooled together.

Annex C: Dew Line Clean Up Protocol

The DEW Line Clean Up (DLCU) Protocol was originally endorsed by various government agencies including Environment Canada, Indian and Northern Affairs, Government of the Northwest Territories and Fisheries and Oceans at a meeting in Victoria, BC in October 1991. This revised version (April 1994) has been slightly modified as a result of:

- Presentations (1992, 1993, 1994) to the Legislative Assembly of the Northwest Territories;
- Community consultations at ten northern communities in 1992 and twelve in 1993;
- Further scientific studies including analytical field testing, leachate testing and barrel sampling;
- Engineering designs for a landfill leachate control system and a contaminated soil containment facility in permafrost;
- Continuing discussions with regulatory agencies, including a second major workshop held in March 1993; and,
- Changes in staffing requirements at the North Warning System sites.

The DLCU Protocol, which is divided into three main areas, provides a strategy for dealing with chemical contamination and physical debris at the DEW Line sites.

1. Contaminated Soils

Remediation is to be applied to soils and sediments where inorganic elements and/or PCBs have been found to be present at concentrations in excess of the DEW Line Cleanup Criteria (DCC); this includes soils contaminated by sewage in outfall areas and

lagoons. The DCC (Table 1) are a combination of the CCME R/P[2] and Quebec B[3] criteria and were determined, on the basis of site specific investigations, to be protective of the Arctic ecosystem.

Table 1: DEW Line Cleanup Criteria

Substance	Units	DCC Tier I	DCC Tier II
Arsenic	ppm	-	30
Cadmium	ppm	-	5.0
Chromium	ppm	-	250
Cobalt	ppm	-	50
Copper	ppm	-	100
Lead	ppm	200	500
Mercury	ppm	-	2.0
Nickel	ppm	-	100
Zinc	ppm	-	500
PCBs	ppm	1.0	5.0

- Soils containing contaminants above the DCC Tier II level should be excavated and removed to a Northern Disposal Facility.
- Soils containing PCBs and lead at concentrations between the DCC Tier I and Tier II levels may be placed in an on-site engineered landfill.
- Special attention should be given to soils that act as sources of contaminants to nearby aquatic environments - even if the concentrations of contaminants are below the DCC criteria.

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[2] Interim Canadian Environmental Quality Criteria for Contaminated Sites as of 1991 produced for the Canadian Council of Ministers for the Environment (CCME).

[3] Quebec Soil Contamination Guidelines as of 1991.

- Soils containing PCBs above the 50 ppm level in contravention of the Canadian Environmental Protection Act (CEPA) must be treated as per the regulation.

- Confirmatory testing will be limited to known, but unstained, contaminated areas and will be to DCC Tier II criteria; visibly stained soils will be excavated to a distance extending a minimum of 0.5m beyond the boundary of the stain.

2. Landfills

These fall into one of three categories:

- Those located in an unstable, high erosion area must be relocated. Contents should be treated as per the procedures for contaminated soils and physical debris.

- Those located in a suitable location with no evidence of contaminated leachate may remain as is; additional granular fill may be required to ensure erosion protection and proper drainage.

- Those located in a suitable location but which are acting as a source of contaminated leachate must be stabilized by the installation of a suitably engineered containment system.

3. Physical Debris

Visible debris should be sorted into hazardous and non-hazardous components. This includes all unburied material and debris resulting from building demolition.

- Hazardous debris should be dealt with according to appropriate regulations.

- Non-hazardous materials should be buried in an engineered landfill on-site provided that there is a suitable location and sufficient gravel is available.

Hazardous debris may include but not necessarily be limited to: radioactive materials, batteries, wastes containing toxic chemicals at potentially harmful levels, and ash produced by

the combustion of waste material - such materials should be shipped south for disposal. Asbestos can be suitably wrapped and buried in an on-site engineered landfill.

POL tank sludge, waste oil, petroleum products, antifreezing agents, solvents and barrels are treated as per the DLCU Barrel Protocol.

III. SITE ASSESSMENT

A. Sampling and Analytical Programs

1 Sampling Program

The main sampling program at Radio Island was carried out from 7-10 August 1996. During the program 82 soil samples, 12 plant samples, 8 water samples, 2 paint samples and 2 samples for asbestos analyses were collected from various locations on the island. These locations included areas around buildings, their drainage pathways, the beach area, and dumps. For comparison purposes, samples were also collected from areas well removed from the site (background samples). The sampling locations were selected on the basis of evidence of former activities as well as previous ESG experience with patterns of contamination and disposal. The number of samples collected was intended to provide enough information that all potential areas of concern would be identified.

Each sample was identified by a number code in the form of 84XX. The exact location of samples are indicated on Map III-1, III-2, and III-3.

2. Analytical Program

There is a lack of reliable information concerning the total range of materials used at the site over its period of operation. Therefore, a screen for a wide range of Environment Canada priority pollutants was conducted on a select number of samples. These included PCBs, inorganic elements, PAHs, and pesticides.

PCBs and inorganic elements have been found to be the main contaminants of concern at former government installations in Northern Canada. Therefore, all soil samples were analyzed for inorganic elements, and half were analyzed for PCBs. Three soil samples were analyzed for polyaromatic hydrocarbons (PAHs) - these samples were deemed most likely to contain PAHs if they were indeed present at the site. Similarly, four soil samples were analyzed for pesticides. These samples were chosen from locations around the site where it was likely that pesticides would have been used. All plant and water samples were analyzed for inorganic elements, while one water and two plant samples were analyzed for PCBs. Table III-1 summarizes the sampling and analytical program.

Table III-1: Sampling and Analytical Program at Radio Island

Type	Total Samples Collected[a]	Number of Samples Analyzed							
		PCBs	Inorganic Elements	Pesticide	PAH	TPH	Asbestos	Chlorinated Hydrocarbon	Leachate Test
Background	6 (1)	5	5	1	-	-	-	-	-
Main Site	48 (3)	24	48	3	2	5	-	-	3
Generator Building	17 (2)	8	17	-	1	11	-	1	5
Beach	11 (1)	4	11	-	-	-	-	-	-
Total soil	**82 (7)**	**41**	**81**	**4**	**3**	**16**	**-**	**1**	**8**
Water	8 (4)	1	4	-				-	-
Plant	12[b]	2	12	-			-	-	-
Paint	2	2	-	-		-	-	-	-
Other	2	-	-	-	-	-	2	-	-

a: Number in brackets indicates the number of field duplicates.
b: Two samples were separated into roots and shoots for a total of twelve samples.

B. Results

1. Background Samples

Background samples were collected from areas well removed from the influence of site activities. These background or baseline values were used to compare results from samples collected at the site. Five locations were selected; one to the north east of the site on Radio Island (8476), one to the north of the site on Boatswain Island (8480), one to the east of the site on Resolution Island (8477 and 8478), one to the north east of the site on Resolution Island (8479) and one to the west of the site on Entry Islands (8481). A water sample was collected from a small lake near sample 8476. Plant samples were collected at three of the background location (8477, 8479 and 8480). The background locations are indicated on Map I-2 in Chapter I.

Five of the six background soil samples were analyzed for PCBs by high resolution gas chromatography. All values were below the analytical detection limits. The highest detection limit was 11 ppb, which is well below the CCME Assessment Criteria for PCBs (100 ppb). The one water sample collected at the background location on Radio Island (FW8406) was found to contain PCBs in excess of the CCME Assessment Criteria for water, although PCBs were not detected in the soil sample collected from the same location (8476). There are no CCME Remediation Criteria for PCBs in water but the measured value of 0.4 ppb is well below the Canadian drinking water standard (3 ppb). This elevated result is most likely due to the proximity of the site to the BAF-5 radar site on Resolution Island, where there is known PCB contamination. Aerial transport of PCBs

is known (Bright *et. al.* 1995). None of the background plant samples were analyzed for PCBs.

Five of the six background soil samples were analyzed for inorganic elements. Nickel, cobalt, and chromium concentrations were above the CCME Assessment Criteria. However, it is believed that these are naturally occurring since all background samples contained elevated levels of these elements. The water sample collected at the background location (FW8406) was found to contain copper in excess of the CCME Assessment Criteria for water. Three plant samples were analyzed for inorganic elements, and of the eight elements analyzed, five were detected: copper, nickel, cadmium, zinc, and chromium.

The average results for background samples are shown in Table III-2.

Table III-2: Average Results for Background Soil, Water and Plant samples

Sample Type	Analytical parameter (ppm)								
	PCBs	Cu	Ni	Co	Cd	Pb	Zn	Cr	As
Soil Average (5 samples)	<0.025	24	42	12.7	<1.0	<10.0	42	46	0.98
CCME Assessment Criteria	**0.10**	**30**	**20**	**10**	**0.5**	**25**	**60**	**20**	**5**
Water (1 sample)	0.0004	0.028	<0.010	<0.010	<0.010	<0.010	0.020	<0.010	<0.001
CCME Assessment Criteria	**0.0001**	**0.025**	**0.010**	**0.010**	**0.001**	**0.010**	**0.050**	**0.015**	**0.005**
Plant Average (3 samples)	-	10.3	26	<5.0	1.2	<15	188	23	<0.2

2. *Area A: Main Site*

The main site is located on the western side of Radio Island. It comprises two intact buildings, a winch shed and main house (Photographs III-1 and III-2), and the foundations of two other structures. One foundation consists of eight concrete supports (Photograph III-3) and the other now houses a recent helipad (Photograph III-4 and III-5). All four structures are in close proximity and have common drainage pathways. These structures are shown on Map III-1.

A large pond (400 m^2) is located in the center of the structures and probably served as a fresh water source. The pond is dammed on the west side. A metal debris dump is located to the west of the helipad. and debris is scattered around the site in numerous ravines (Photograph III-6). Approximately 75 rusty empty barrels were found in 3 caches. All of the barrels were empty. Four piles of coal were found at the site.

In total, 48 assessment soil samples, including five field duplicates, were collected from the vicinity of the main site and its drainage.

All forty-eight samples were analyzed for inorganic elements. Copper, lead and zinc were the prevalent contaminants found at concentrations exceeding the DEW Line Cleanup Criteria (DCC) Tier II (100, 500 and 500 ppm respectively), and were detected above these levels in 26 separate locations. The mean copper concentration (106 ppm) was 1.1 times the criterion, and the maximum concentration detected (580 ppm) was 5.8 times the criterion. The mean lead concentration (2100 ppm) was 4.2 times the criterion, and the maximum concentration detected (41400 ppm) was 83 times the criterion. The mean zinc concentration (1980 ppm) was 4 times the criterion, and the maximum concentration detected (26640 ppm) was 53 times the criterion.

Nickel, cadmium, cobalt, and arsenic were the only other inorganic elements detected at concentrations exceeding the DCC. Nickel contamination was found in three of the assessment samples collected at the main site. The maximum nickel concentration (142 ppm) was 1.4 times the criterion. Cadmium contamination was found in six of the assessment samples collected at the main site. The maximum cadmium concentration (21 ppm) was four times the criterion. Cobalt contamination was found in one of the assessment samples collected at the main site. The maximum cobalt concentration (90 ppm) was 1.8 times the criterion. Arsenic contamination was found in two of the assessment samples collected at the main site. The maximum arsenic concentration (53 ppm) was 1.8 times the criterion.

Leachate tests were conducted on three of the samples: a sample (8402) containing copper, cadmium, lead and zinc (251, 10.5, 13840, and 5480 ppm respectively), a sample (8418) containing copper, lead and zinc (580, 6060, 6640 ppm respectively), and a sample (8441) containing cadmium, lead and zinc (6.5, 41400, 26640 ppm respectively). Leachate from one sample (8441) contained a lead concentration of 41 ppm, exceeding both the Ontario leachate criteria and the British Columbia leachate criteria for lead. Leachate values for the remaining two samples were below the criteria.

Five vegetation samples were analyzed for inorganic elements. All samples showed elevated levels of zinc (mean=1120 ppm). Two samples showed elevated levels of copper (mean=22 ppm); four samples showed elevated levels of cadmium (mean=4.9 ppm); and three samples showed elevated levels of lead (mean=37 ppm).

Twenty-four soil samples were analyzed for PCBs. All values were well below DCC Tier I. The highest level of PCBs detected was 490 ppb. Two plant samples (one root and one shoot) were analyzed for PCBs. Aroclor 1260 was detected in both samples (mean=1.8 ppb).

Two soil samples (8405 and 8436) were analyzed for PAHs. Both samples were well below the CCME Remediation criteria for soil.

Three soil samples were analyzed for pesticides (8410, 8450 and 8470). All levels were well below the applicable criteria.

Five soil samples were analyzed for total petroleum hydrocarbon (TPH). Three samples showed TPH values greater than 1100 ppm with the highest value at 18800 ppm. The average TPH value was 4940 ppm.

Three water samples were analyzed for inorganic elements. One sample (WF8402) contained a concentration of zinc (0.3 ppm) that was 6 times the CCME Assessment criterion for water (0.05 ppm).

Two paint samples were analyzed for PCBs and lead. No PCBs were detected, but very high levels of lead were detected in both samples (mean=78450 ppm). Two samples were collected that were suspected to contain asbestos. Asbestos was found in one of the samples - a tile sample collected from inside the main house. Asbestos was not detected in the other sample collected from the chimney south of the main house.

3. *Area B: Generator Building Foundation*

The generator building foundation is located approximately 35m to the south west of the main site. The foundation is 12 m by 6 m and contains the remains of 3 generators and one boiler. Twenty-six empty barrels are located within the foundation. Other visible debris includes: metal cable, charred wood, insulator caps, filing cabinets, coal, and crushed batteries. The entire generator building area is stained (Photograph III-7) and at the time of the site visit, a hydrocarbon odour was detectable. The drainage from the

foundation is to the west and south east of the foundation (Photograph III-8 and III-9). The drainage to the west reaches the sea at approximately 30 m while the drainage to the southeast drains to the interior of the island. These features are shown on Map III-2.

In total, seventeen samples, including two field duplicates, were collected around the generator building foundation and in its drainage.

All seventeen samples were analyzed for inorganic elements. Copper, lead and zinc were the prevalent contaminants found at concentrations exceeding DCC II (100, 500 and 500 ppm respectively), and were detected above these levels in 13 separate locations. The mean copper concentration (487 ppm) was 4.9 times the criterion, and the maximum concentration detected (2160 ppm) was 21.6 times the criterion. The mean lead concentration (5280 ppm) was 10.6 times the criterion, and the maximum concentration detected (18860 ppm) was 38 times the criterion. The mean zinc concentration (4160 ppm) was 8.3 times the criterion, and the maximum concentration detected (20820 ppm) was 42 times the criterion.

Nickel and cadmium were the only other inorganic elements detected at concentrations exceeding the DCC. Nickel contamination was found in two of the assessment samples. The maximum nickel concentration (840 ppm) was 8.4 times the criterion. Cadmium contamination was found in six of the assessment samples collected at the generator building. The maximum cobalt concentration (116 ppm) was 2.3 times the criterion.

Five samples from the vicinity of the generator building contained very high concentrations of various inorganic elements, and therefore were subjected to leachate tests: Two samples (8458 and 8463) exceeded both the Ontario leachate criteria and the British Columbia leachate criteria for lead (5.1 and 7.4 ppm respectively). Leachate values for the remaining three samples were all below the criteria.

Four vegetation samples were analyzed for inorganic elements. Three samples showed elevated levels of zinc (mean=780 ppm); three showed elevated levels of copper (mean=117 ppm); one showed elevated levels of cadmium (mean=11.5 ppm); and three showed elevated levels of lead (mean=124 ppm).

Eight samples were analyzed for PCBs. All concentrations were below the DCC, with the highest level at 85 ppb. No plant samples were analyzed for PCBs.

One soil sample (8466) was analyzed for PAHs. It contained detectable levels of phenanthrene, fluroanthene, pyrene, benzo(a)anthracene and chrysene. The level of chrysene (1100 ppb) was above the criteria for Managing Contaminated Sites in British Columbia.

One soil sample (8466) was analyzed for chlorinated hydrocarbons. None were detected.

Eleven samples were analyzed for total petroleum hydrocarbon (TPH). Seven samples showed TPH values greater than 1100 ppm with the highest value at 36150 ppm. The average TPH value was 4925 ppm.

4. Area C: Beach

The beach area at Radio Island drains into Acadia Cove to the north. The beach is a fairly small area (1800 m^2) receiving drainage from the main site. Located on the east side of the beach are the remains of a burnt out house (Photograph III-10). A large pile of coal (anthracite), a suspected dump, two barrel piles consisting of empty rusted barrels are also present at the beach area. These features are shown on Map III-3.

In total, eleven assessment soil samples, including one field duplicate, were collected from the beach area. No vegetation samples were collected as only moss was growing in the area.

All eleven samples were anlayzed for inorganic elements. Lead was the main contaminant found at concentrations exceeding DCC II (500 ppm), and was detected in two separate locations. The maximum lead concentration detected (2900 ppm) was 5.8 times the criterion.

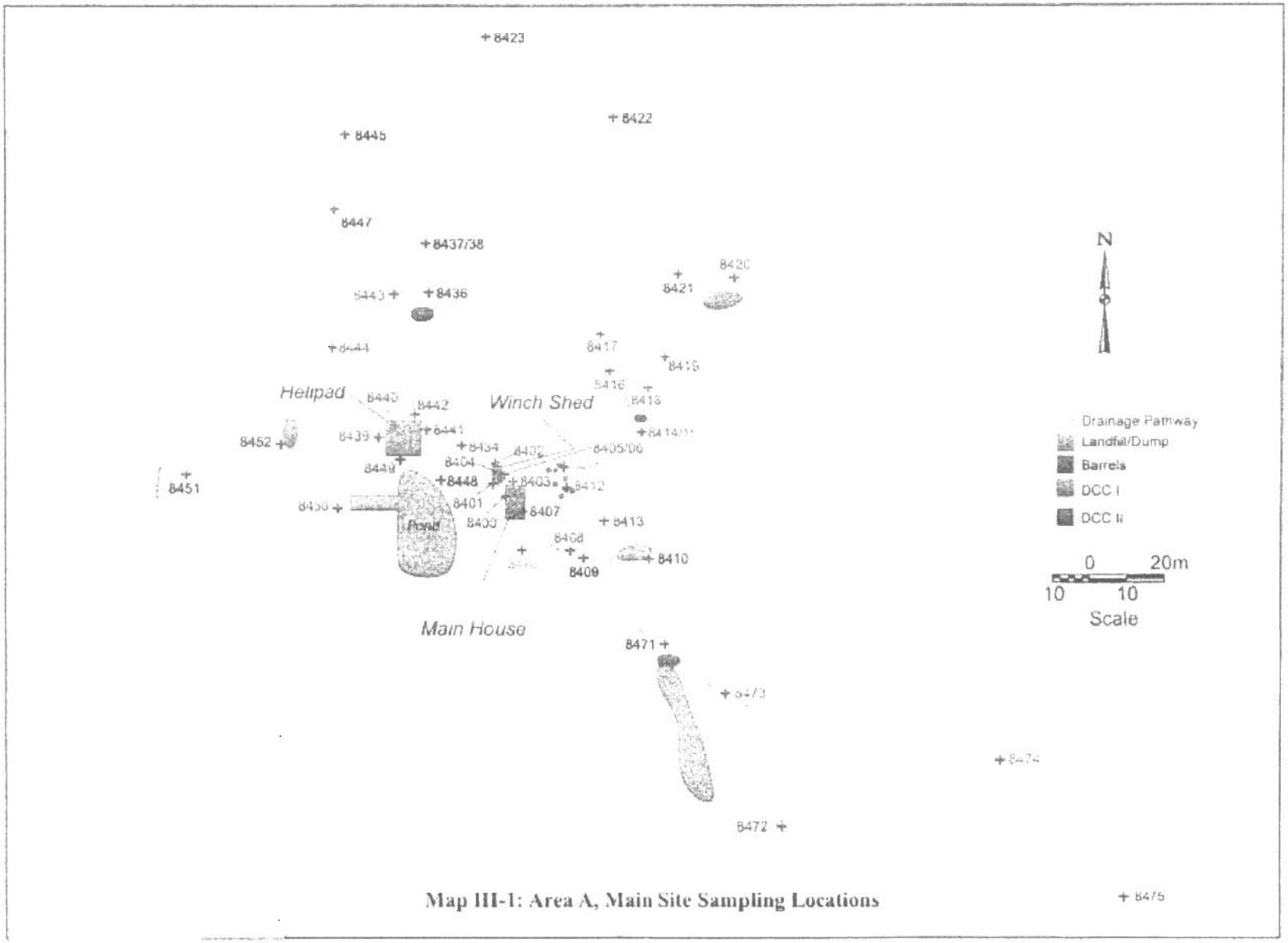
Zinc and cadmium were also found at concentrations exceeding the DCC. Zinc contamination was found in one of the samples collected at the beach area. The zinc concentration (3300 ppm) was 6.6 times the criterion. Cadmium contamination was found at one sample location at the beach area. The cadmium concentration (50 ppm) was 10 times the criterion.

Four soil samples were analyzed for PCBs. All samples were below DCC I. The highest level of PCBs detected was 360 ppb.

C. Conclusions

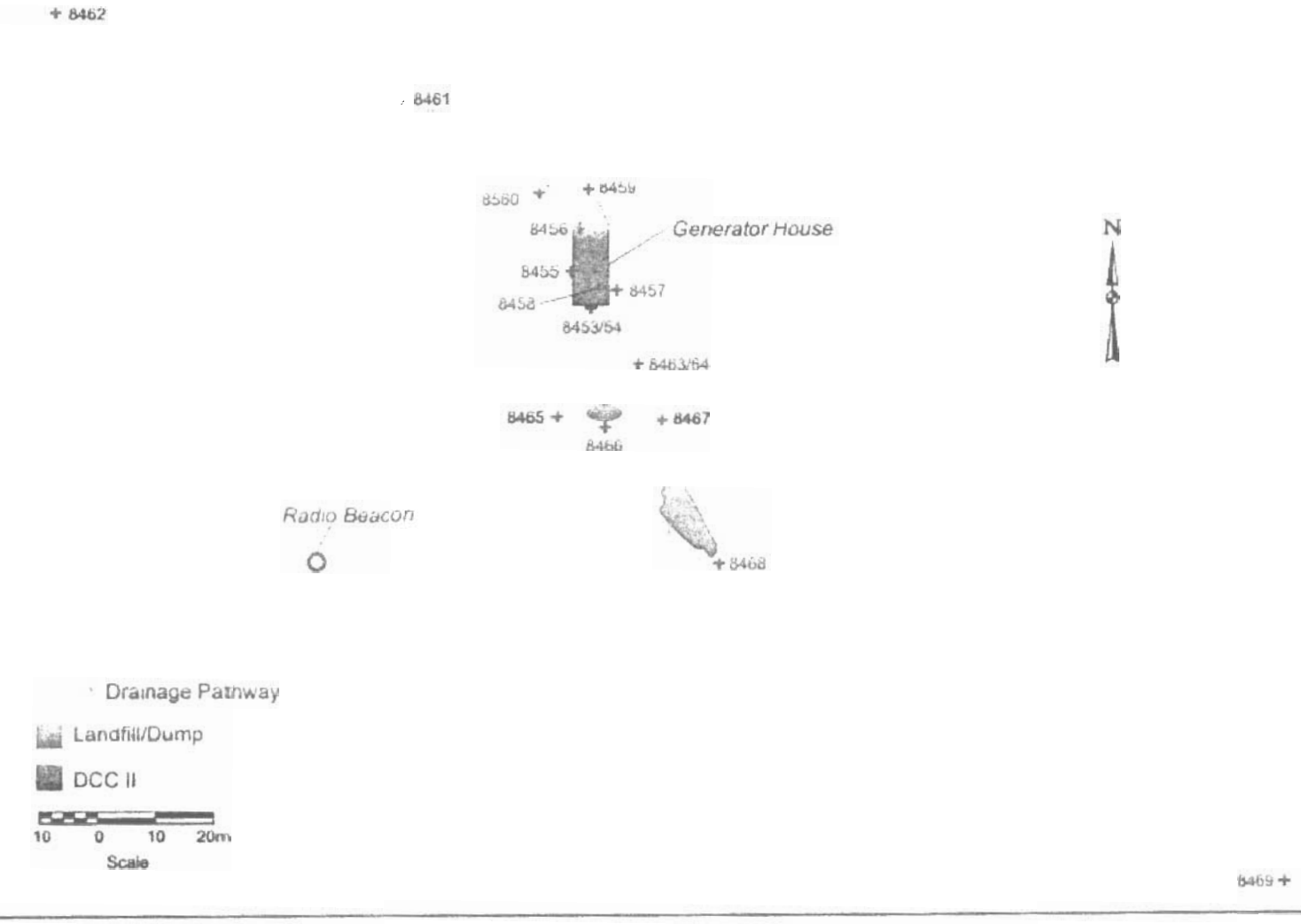
Overall, four areas at Radio Island were found to contain at least one contaminant at a concentration exceeding the DEW Line Cleanup or other applicable criteria. Contaminated areas include the main house and winch shed, the helipad, the generator building foundation and a small area at the beach. Copper, lead and zinc were the most prevalent contaminants found at concentrations exceeding the DCC in soil and plant samples. Nickel, cobalt, cadmium and arsenic were also detected at elevated concentrations in many soil and plant samples from the site.

These results of plant samples indicate that contamination in soil at Radio Island is entering the food chain and therefore having an impact on the local terrestrial ecosystem. Fortunately, the relatively low abundance of vegetation minimizes the overall potential for impact. Results from soil samples collected in drainage courses show that contaminants are not reaching the marine environment, and therefore there is no impact on the marine ecosystem.

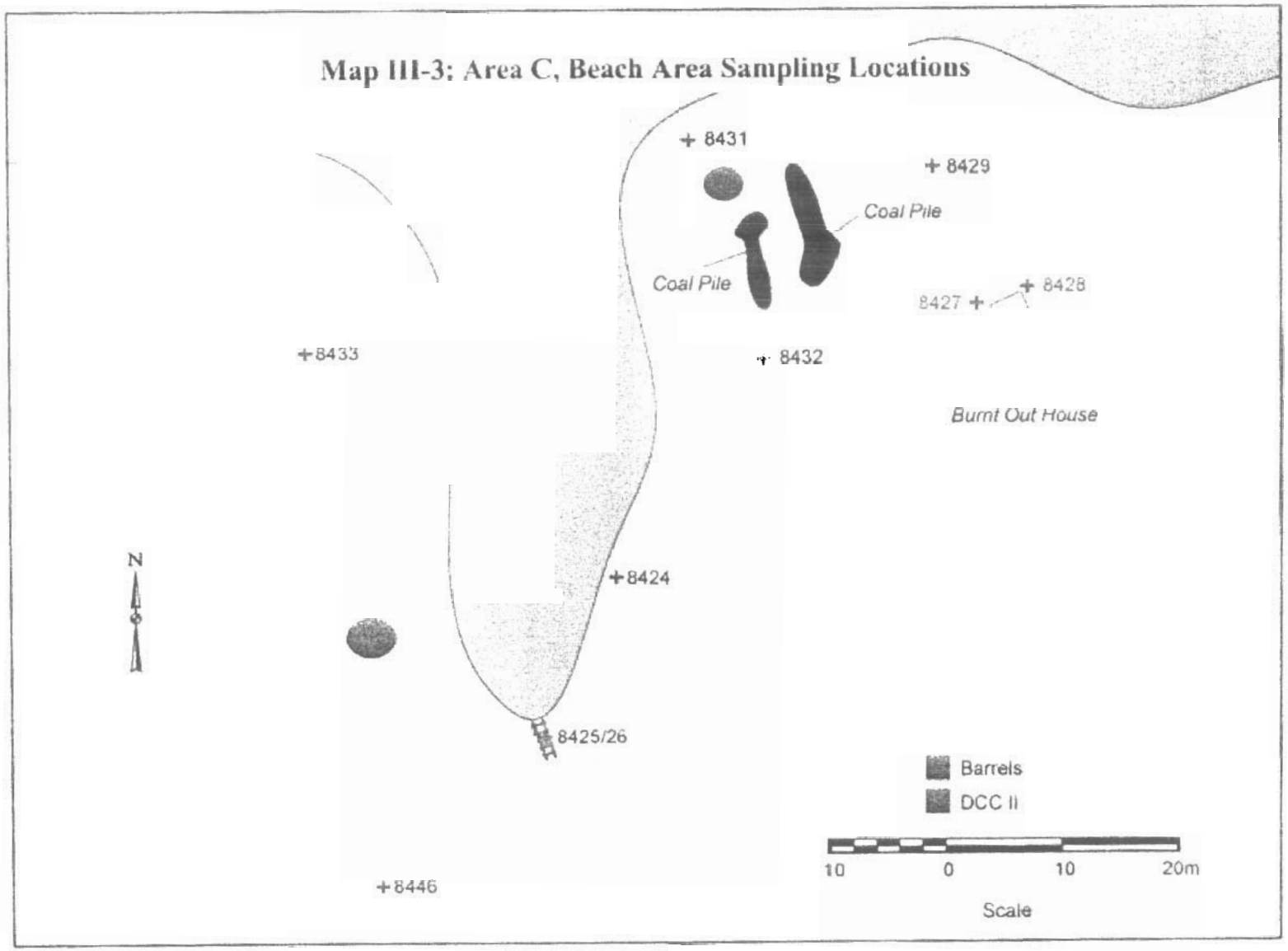


Map III-1: Area A, Main Site Sampling Locations

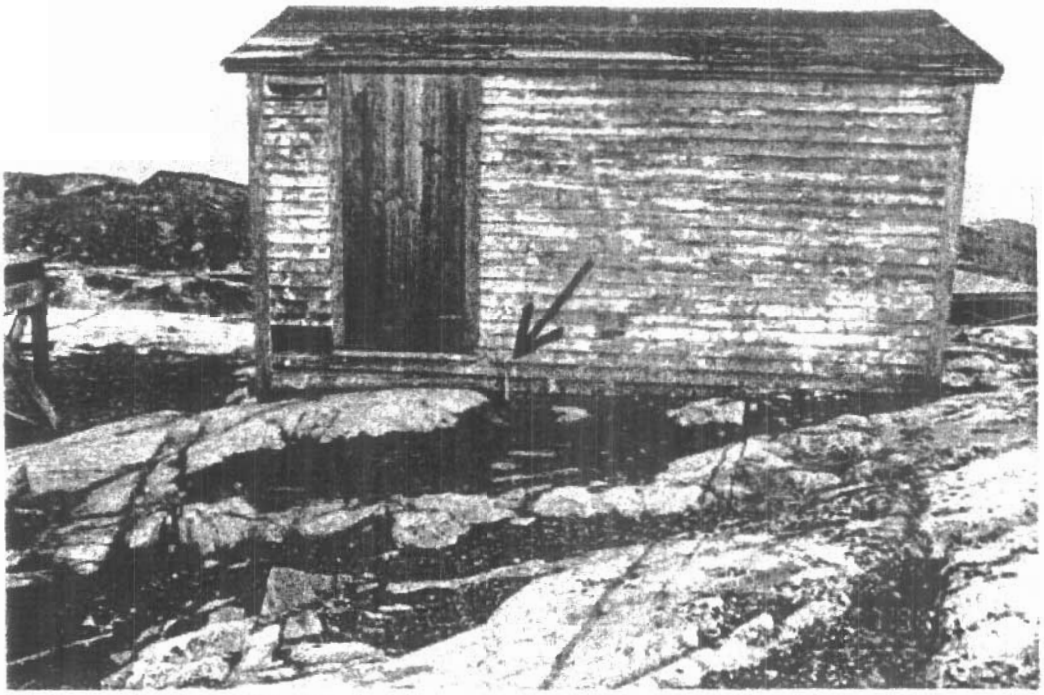
Map III-2: Area B, Generator Building Sampling Locations



Map III-3; Area C, Beach Area Sampling Locations



Photograph III-1: The Main House at Radio Island as seen from the southeast. Sampling locations 8408 and 8409 are indicated in the foreground.



Photograph III-2: The Winch Shed at Radio Island as seen from the east. Sampling location 8405 is indicated by the arrow.