TABLE 5. RESPONSE FACTORS AND DETECTION LIMITS
FOR [redacted] ND [redacted] OF 2,4-D
AND 2,4,5-T

		Methyl Esters	Butyl Esters
2,4-D	Response factor	1.667 x 10^{-6} µg/area	3.29 x 10^{-6} µg/area
	Lower limit of detection	0.1 µg/l	0.32 µg/sample
	Lower limit of quantitation	0.25 µg/l	0.5 µg/sample
2,4,5-T	Response factor	5.263 x 10^{-7} µg/area	8.000 x 10^{-7} µg/area
	Lower limit of detection	0.1 µg/l	0.26 µg/sample
	Lower limit of quantitation	0.25 µg/l	0.5 µg/sample

GC conditions were established and optimized for each of the esters with the following parameters:

- A 6 ft x 2 mm ID glass column was used, packed with 1.50 percent OV-17/1.95 percent QF-1 on 80-100 mesh Chromosorb W-HP
- A 10 percent methane/argon carrier gas
- And the following instrument operating conditions

	Methyl Esters	Butyl Esters
Flow Rate	15 ml/min	25 ml/min
Column Temp.	185 C	190 C
Injector Temp.	260 C	260 C
Detector Temp.	300 C	300 C
Retention Times		
2,4-D	2.26 mins.	2.89 mins.
2,4,5-T	3.75 mins.	4.68 mins.

These rather low flow rates were found to improve the detector sensitivity while not altering resolution. For example, the 2,4,5-T area response increased by a factor of 2.5 in changing from a 50 ml/min. to 20 ml/min. flow rate at 170 C. Also, no unduly rapid fouling of the detector was observed at these flow rates.

A check was made for interferences or impurities in the various solvents used. One liter of each solvent was reduced in volume to 1 ml and injected into the GC. The distilled water was extracted with 3 x 100 ml ether which was reduced to 1.0 ml. Although some impurities were found especially in the distilled water, none was of sufficient concentration or rentention time to interfere with the analysis.

3.2.5.3.1 Land Based Monitoring - Water Samples

The water samples examined in the study were prepared using the following method:

- Sample Preparation
  - Measure sample volume and quantitatively transfer 1 liter to a 2 liter separatory funnel. (If sample volume is less than 1 liter, then make-up sample difference with distilled water.)
  - Acidify to approximately pH 2 with concentrated sulfuric acid.
- Extraction
  - Add 150 ml of ethyl ether to the sample in the separatory funnel and shake vigorously for 1 minute.
  - Allow contents to separate for at least 10 min. after layers have separated, drain the water layer into a 1 liter Erlenmeyer flask. Transfer the organic solvent layer into a 250 ml ground glass boiling flask containing 2 ml of 37 percent aqueous potassium hydroxide.
  - Transfer the water in the 1 liter Erlenmeyer flask to the 2 liter separatory funnel. Rinse flask with an aliquot of 50 ml ethyl ether and transfer to separatory funnel and complete the extraction procedure a second time.
  - Perform a third extraction in the same manner.
- Hydrolysis
  - Add 10 ml of distilled water and a glass bead to the flask containing the ethyl ether.

- Fit the flask with a 3-ball Snyder column and place on a steam bath. Evaporate the ethyl ether and continue heating for a total of 60 minutes.

- Transfer the concentrate to a 60 ml separatory funnel. Extract the solution 2 times with 20 ml of ethyl ether and discard the ether layers. (The herbicides remain in the aqueous phase since they are in the salt form).

- Acidify the contents of the separatory funnel by adding 2 ml of cold (4 C) 25 percent sulfuric acid. (This changes the herbicides from the salt to the acid form.)

- Extract the herbicides once with 20 ml of ethyl ether and twice with 10 ml of ethyl ether. Collect the extracts in a stoppered 125 ml Erlenmeyer flask containing about 0.5 grams of acidified anhydrous sodium sulfate.

- Allow the extract to remain in contact with the sodium sulfate for approximately 2 hours.

- Sample is ready for methylation. Follow Boron-trifluoride esterification procedure.

Boron-trifluoride Esterification

- Transfer the ether extract, through a funnel plugged with glass wool, into a 125 ml Kuderna-Danish flask equipped with a 1.0 ml graduated ampul. Use liberal washings of ether in the transfer.

- Add 0.5 ml benzene to a Snyder column and evaporate to about 2 ml on a steam bath.

- Remove ampul from flask and add small snyder column and further concentrate the extract to 0.4 ml.

- After the benzene solution in the ampul has cooled, add 0.5 ml of boron-trifluoride-methanol reagent. Cover ampul tightly with solvent-rinsed aluminum foil and hold the contents of the ampul at 50 C for 30 minutes on the steam bath.

- Cool, and add about 4.5 ml of a neutral 5 percent aqueous sodium sulfate solution and transfer to a 20 ml concentrator tube. Rinse 1 ml ampul with 2.0 ml benzene and add rinse to 20 ml concentrator tube.

- Mix on Vortex mixer and allow layers to separate. Remove benzene layer to a 15 ml conical test tube using capillary pipet. Repeat twice more.

- Concentrate benzene extract to 0.5 ml.

- Proceed with Florisil micro-column cleanup.

Micro-Column Cleanup Procedure

- Wash micro-column with 5 ml of hexane and discard washings.

- Place a clean 15 ml tube below the column for collection.

- Quantitatively transfer extract to column. Wash sample test tube with three 0.5 ml of hexane and transfer washing to column.

- Fraction A: Add Eluate a (20 percent methylene chloride in henane) to the column and elute until 10 ml are collected.

- Fraction B: Place a new test tube under the column and start eluting with Eluate B (50 percent methylene chloride-0.35 percent acetonitrile - 49.65 percent hexane) until 10 ml are collected.

- Evaporate Fraction B down to 0.5 ml. Add 0.5 ml of iso-octane and continue evaporation to 0.4 ml. Make up to 10 ml with iso-octane.

- Sample is ready for gas chromatography. (Place in freezer if samples are not chromatographed when ready.)

<u>Fraction B</u>

2,4-D Methyl Ester
2,4,5-T Methyl Ester

Samples were processed in groups of four with a distilled water blank being included after approximately every tenth sample. A typical chromatogram is shown in Figure 26. All reagents were freshly prepared each week.

Recovery studies were conducted before each dedrum operation and the averaged value used in calculating results for water samples analyzed during that period. These studies consisted of processing distilled water samples spiked with varying amounts of 2,4-D and 2,4,5-T. (See Table 111-26.) Recovery percentages for 2,4-D and 2,4,5-T were 47.4 percent and 54.5 percent, respectively, with an average value of 50.9 percent.

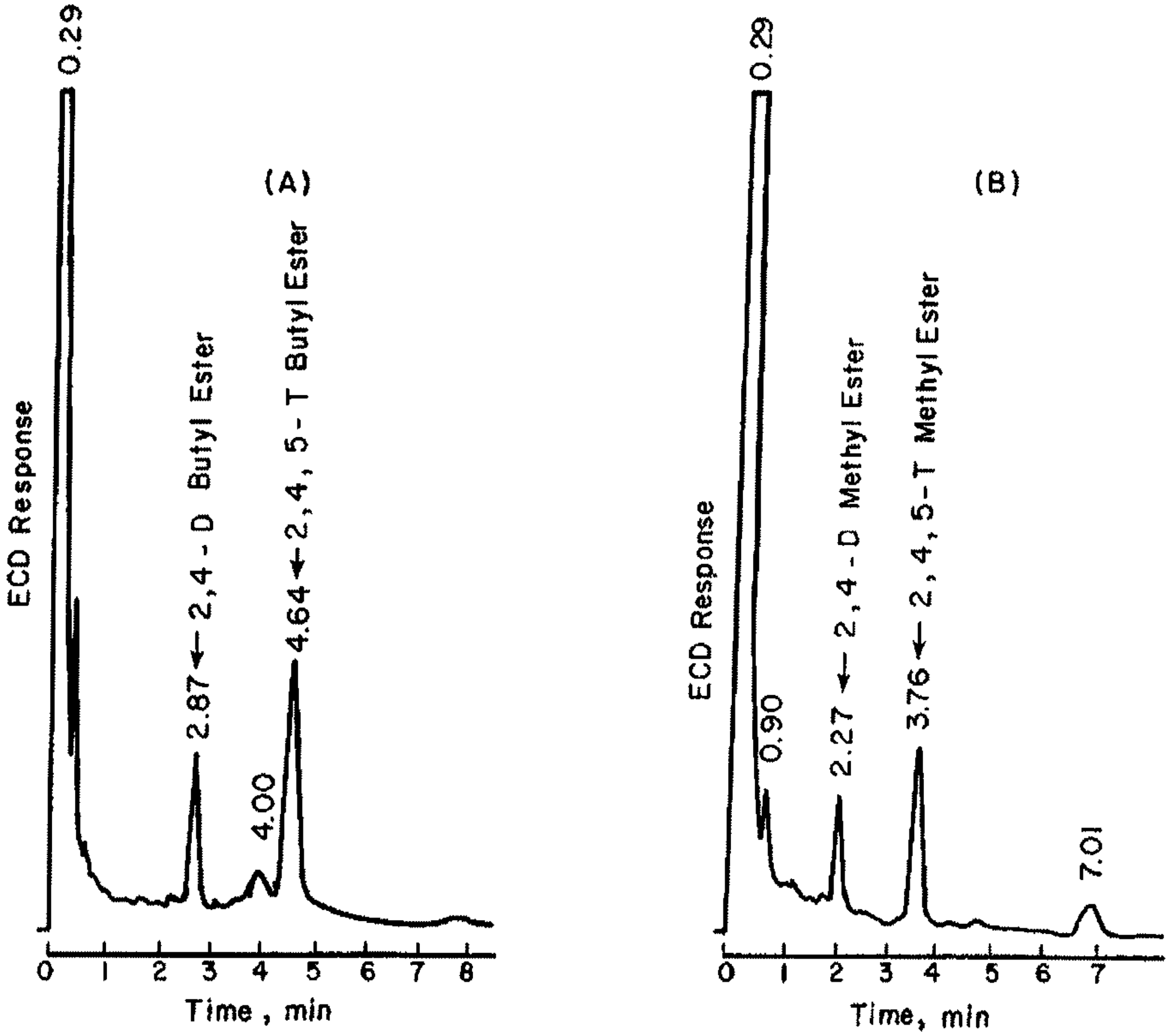

FIGURE 26. GC CHROMATOGRAMS OF (A) CHROMOSORB SAMPLE CD 29Y707J AND (B) WATER SAMPLE WS 30Y700J

Although there appeared to be some differences in the recovery of 2,4-D as compared with 2,4,5-T, these differences were much smaller than the deviation from sample to sample and a single average "correction factor" was used for both esters. This factor was entered into the "firmware" of the GC microprocessor and the data generated directly in units of concentration. These recovery studies were updated periodically and the "correction factor" was adjusted accordingly.

Chromosorb Samples. The chromosorb samples examined in this study were processed as follows:

- Chemical and Materials
  - Chromosorb 102, 60/80 mesh, Johns Manville Corporation.
  - Hexane and acetone of pesticide residue analysis quality.
  - Soxhlet extractors with 250 ml flask.
  - Alundum Soxhlet thimbles.
  - Standards
  - Chromosorb 102 tubes
- Gas Chromatography (Same as water sample procedures)
- Procedure
  - Remove adsorbent and glass wool plug from the collector tube and place in an alundum Soxhlet thimble.
  - Add 150 ml of hexane to the 250 ml Soxhlet extractor flask and extract adsorbent for 1 hour (50 cycles).
  - Concentrate extract to 1 ml and make up to 4 ml with iso-octane for gas chromatography.
- Reports
  - Report concentrations of each n-Butyl ester in micrograms per sample.

The cellulose Soxhlet extraction thimbles were extracted and examined for interferences. As a great many electron-capturing species were observed in the chromatograms of the blank thimble extracts, thimbles were routinely soaked in hexane in a dessicator overnight which was found to be sufficient for removal of these interferences. A typical chromatography of these chromosorb samples is shown in Figure 26.

3.2.5.3.2 Drum Rinse Samples

The analysis of diesel fuel rinse samples was conducted using the following procedure:

- The contents of a sample bottle was agitated by hand for 5 seconds. Using a 0.5 ml volumetric pipet, 0.5 ml of the diesel fuel rinse was transfered to a 5.0 ml volumetric flask.
- The flask was made up to 5.0 ml with pesticide grade benzene and the contents agitated 5 seconds. (Any large rust particles were allowed to settle.)
- Using a 0.2 ml calibrated pipet, 0.1 ml of the above benzene solution was transfered to a 10.0 ml volumetric flask. The flask was made up to 10.0 ml with pesticide-grade iso-octane (2,24-trimethylpentane) and agitated 5 seconds.
- Using a second 0.2 ml calibrated pipet, 0.1 ml of the above iso-octrane solution was transfered to a 10.0 ml volumetric flask. The flask was made up to 10.0 ml with pesticide-grade iso-octane and agitated 5 seconds.
- Approximately 2 ml of the final iso-octane solution was placed in each of two GC sample vials labeled with the proper lab code number and the final dilution ratio (1:100,000). The vials were tightly capped. One of the vials was used for analysis of total 2,4-D and 2,4,5-T by GC-ECD. The second vial was archived.

The data collected from the drum rinse samples were presented in both tabular and graphic form. Control charts (see Figures 15 and 16) were constructed to graphically monitor the drum rinse procedure and provide an early warning of possible changes in the efficiency of this operation.

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During the dedrum operation, drum rinse samples were obtained approximately once every hundredth drum. Samples were processed and analyzed within 8 hours of their receipt. Chromosorb samples were processed in groups of 12 per day beginning in the afternoon and processing the samples pulled from the morning shift and the previous night shift. Water samples were processed at a rate of 4-5 per day depending upon whether a blank was included or not, and performed on the water samples collected the previous day. To avoid possible conflicts, the water samples were begun at 0530 and required 10 hours for completion such that when the chromosorb sample prep was begun at 1400 hours, the water task was being completed.

3.2.5.3.3 Glassware Cleanup

One of the most crucial steps in any routine trace analytical procedure is the glassware cleanup procedure. In an effort to avoid the small traces of impurities which could ruin the analytical method, a rigorous and thorough glassware washing was employed as follows:

- Separate racks were used for "clean" and "dirty" glassware.
- "Dirty" glassware was not allowed to dry before washing.
- "Dirty" glassware was placed one rack at a time in the chromic acid bath, which was prepared fresh every 10 days.
- Glassware was then rinsed thoroughly with tap water and placed in detergent bath.
- Glassware was scrubbed in a detergent bath, rinsed, and placed in the rinse bath.
- Glassware was rinsed again with tap water and then with distilled water.
- Glassware was placed on "clean" glassware rack and transfered to 150 C oven.
- Glassware was removed from the oven after 1/2 hour, cooled, rinsed with acetone, and stored in closed cabinets.

It should be noted that the use of the cleaned glassware with reagent blanks demonstrated that this glassware cleaning regime was successful.

All rinse and detergent baths were changed after each rack was processed.

3.2.5.3.4 Ship Samples

In addition to the samples collected during the land-based monitoring effort, a number of benzene impinger, trace line rinse, chromosorb, wipe, and drinking water samples were collected on board the incineration ship M/V Vulcanus and analyzed for 2,4-D and 2,4,5-T at the Pacer HO Analytical Lab. These samples were received upon arrival of the M/V Vulcanus at the end of each burn and were processed and analyzed on a first-priority basis.

Impinger samples were collected in benzene-acetone impingers while trace line rinse samples were taken from the heated trace lines leading from the stack to the impingers as a part of the shipboard incinerator stack gas monitoring program. The analysis procedure for these samples follows:

- Each sample was measured volumetrically.
- The sample was then shaken thoroughly and 1 ml aliquots were withdrawn for GC analysis.
- The remainder of the sample was archived at 4 C.

Many of the impinger samples contained several milliters of a non-miscible green liquid which was believed to have resulted from aqueous HCl generated during the combustion of the halogen-containing herbicide. Severe corrosion of some of the stainless steel trace lines was observed by ship personnel and the resultant metal salts might account for the green color of this liquid. These samples proved to be quite corrosive to the vial caps and septa, and the GC injection syringes. Several syringes were destroyed as a result of corrosion of the plunger in the needle barrel.

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Also severe contamination of the detector was observed after several injections which might be expected from the injection of highly concentrated halogen-containing samples. This required thermal and solvent cleaning before any further analyses could be performed.

Chromosorb, water and wipe samples were collected at different stations within the ship in an effort to monitor its environment for Orange Herbicide contamination. These samples were prepared and analyzed using a procedure similar to that described for the land-based chromosorb and water samples. In addition, a wipe sample recovery study was conducted using standard solutions of the butyl esters of 2,4-D and 2,4,5-T in the following manner:

- Filter paper discs (11.0 and 15.0 cm) were pre-extracted by soaking in hexane overnight and then soaked an additional hour in fresh hexane and air dried.
- These filter discs were then impregnated with measured amounts of butyl ester standards and allowed to dry.
- Each disc was then placed in a Soxhlet extractor and extracted for 2 hours (50 cycles) using 100 ml hexane.
- The extract was then diluted to 100 ml and analyzed by GC.

The results of these recovery studies are given in Table III-27, and show average recovery as ranging from 154 percent at low concentrations to 108 percent at high concentrations. Some interferring compounds were present in these samples, probably originating from the filter paper discs. However, as evident from Table III-27, these interferences presented a serious problem only at very low levels since many of the wipe samples analyzed contained considerably in excess of 10 μg, further refinement of this procedure was not considered to be warranted.

At the completion of the dedrum and loading operation, the refueling vehicles were rinsed to remove all waste material associated with the disposal operation. Wipe samples were taken from the inside of each refueling vehicle and analyzed as described above. Also, during the incineration of the dunnage material, high volume impingers were operated and the filter discs were analyzed as described for the wipe samples.

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3.2.6 Spill Prevention and Countermeasure Plan

Personnel involved with the project on Johnston Island were briefed on spill prevention, countermeasures, and personnel safety (see below) on July 23, 1977. The following equipment was inspected and pre-positioned in the event of use:

(A) 10,000 and 50,000 gallon bladders at dock.

(B) Submersible pump with hoses in Building 303, adjacent to dock. This building was always open for easy entry.

(C) One pallet in the dedrumming area containing:

  (1) One electric pump (10 GPM) with 25 ft hose.

  (2) One portable electric generator for electrical power.

  (3) 25-30 Sand bags.

  (4) 3 Shovels.

  (5) 3 Squeegees.

  (6) 2 Bags of absorbent material.

  (7) 2 Rolls of plastic (100 ft x 20 ft each).

  (8) 2 Instant foam kits.

(D) One PMU-27 in the dedrumming facility next to the above pallet.

As at Gulfport, the dock pumps were positioned inside a sandbagged area lined with plastic ground cloth in order to "pool" any spilled herbicide.

3.2.7 Safety Plan

(1) All personnel working inside the dedruming facility were supplied with coveralls, rubber gloves, splash aprons, rubber boots, face shields, and respirators. Use of this protective equipment was mandatory throughout the entire operation (Plate 13).

(2) The change room was located on the ground floor of Building 250. Workmen were to shower and change into clean clothing at this location before leaving to enter the mess hall or other buildings on the island. The contaminated coveralls were laundered daily.

(3) Smoking was prohibited inside of or near the dedrumming site. Breaks were to be taken at one of the two rest areas provided, either at the Fox Plant 200 yards southwest of the facility or in the area of the clerk's offices nearby to the northeast. Gatorade and fresh fruits were provided for refreshment.

(4) Because Herbicide Orange has an oily texture and splashing onto the smooth, concrete floor of the facility was unavoidable, a cleaning solvent was utilized so that spills could be immediately washed into the drainage gutter.

(5) In order to provide adequate ventilation for the dedrumming facility, the walls remained rolled opened, thus taking advantage of the island's near constant 15 MPH trade winds.

(6) The access road between the dedrumming operations area and wharf was graded and adequately marked to insure safe passage of the R-5 refuelers.

(7) During the loading and unloading of the R-5 refuelers a ground wire was attached between the truck and pump. A fire truck was also stationed on the wharf throughout operations.

(8) Key personnel of the Air Force, [redacted] b6 and [redacted] b6 TRW, and Battelle were equipped with two-way radios for the purpose of immediate notification in the event of accidents, spills, or procedural deviations.

4. ENVIRONMENTAL IMPACTS OF LAND-BASED OPERATIONS

4.1 HO Impacts on Natural Environment of Johnston Island

4.1.1 Land

The only land impacts associated with the disposal area were the commitment land for storage of the crushed drums, and an area of slightly contaminated soil around the dedrumming facility and the drum crusher.

The dedrumming activities made the land previously used as a drumyard available for other uses. However, the land is contaminated with HO, not due to the disposal operation. The Air Force is monitoring the soil contamination (see Section 6.6).

4.1.2 Air

A total of 156 chromosorb tube air samples were drawn before, during, and after the operations at Johnston Atoll. Figures 17, 18, and 19 present the locations of the fixed samplers. The concentration data for all samples are presented in the Level III report. It is seen from these data that the maximum concentrations observed at any station were 40.3 and 22.5 $\mu g/m^3$, for the 2,4-D and 2.4.5-T isomers, respectively, several orders of magnitude below the OSHA* TWA's of 10,000 $\mu g/m^3$.

A summary table of all observed air concentrations is presented as Table 6. These data are discussed further below.

4.1.2.1 Weather Station (CM)

This site was established as a background station, located as far as possible upwind of all of the HO activities. Yet low 2,4-D and 2,4,5-T concentrations (averaging 0.24 and 0.05 $\mu g/m^3$, respectively) were

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* The OSHA-ACGIH TWA values are allowable exposures for an 8 hour time weighted average. The TWA values are for 2,4-D and 2,4,5-T acids, and are explicitly stated for either as 10 mg/m^3. There are no ambient air quality standards for the esters of 2,4-D or 2,4,5-T.

TABLE 6. SUMMARY OF ALL CONCENTRATIONS AT AMBIENT AIR MONITORING SITES (Ug/m3)

Site	Interval	No. of Samples	2,4,5-T Mean	2,4,5-T Stand. Dev.	2,4-D Mean	2,4-D Stand. Dev.	*Percent Below Quantitative Detection Limit	
							2,4,5-T	2,4-D
Weather station (CM)	Pre-operational	3	0	0	0	0	100	100
	First load	11	0	0	0.25	0.39	100	64
	Interim	3	0	0	0	0	100	100
	Second load	11	0.10	0.34	0.23	0.77	91	91
	Post-operational	4	0	0	0	0	100	100
Wharf station (CW)	Pre-operational	3	0	0	0	0	100	100
	First load	11	0	0	0.29	0.42	100	64
	Interim	1	0	0	0	0	100	100
	Second load	7	0	0	0	0	100	100
	Post-operational	4	0	0	0	0	100	100
Downwind station (CD)	Pre-operational	3	0.08	0.13	0.49	0.85	67	67
	First load	15	2.11	1.0[illegible]	4.60	2.27	0	0
	Interim	2	2.49	0.73	5.91	1.92	0	0
	Second load	11	4.50	2.01	10.74	3.96	0	0
	Post-operational	5	4.55	1.86	10.39	4.52	0	0
CS (Southwest corner of facility)	Pre-operational	1	0.57	0	1.60	0	0	0
	First load	3	8.12	1.05	14.84	1.77	0	0
	Interim	0	--	--	--	--	--	--
	Second load	1	7.35	0	18.78	0	0	0
	Post-operational	4	2.61	0.88	7.80	2.10	0	0
CN (Northwest corner of facility)	Pre-operational	1	0	0	0	0	100	100
	First load	3	4.58	3.24	9.99	7.30	0	0
	Interim	0	--	--	--	--	--	--
	Second load	1	2.27	0	6.60	0	0	0
	Post-operational	5	2.85	0.80	7.13	1.57	0	0
CP (Center of eastern wall of facility)	Pre-operational	1	0.75	0	1.87	0	0	0
	First load	3	0	0	1.0[illegible]	1.37	100	33
	Interim	0	--	--	--	--	--	--
	Second load	0	--	--	--	--	--	--
	Post-operational	0	--	--	--	--	--	--

* 0 was used for non-detectable in averaging concentrations.

found during the two dedrumming periods. The possibility of these concentrations being due to lab contamination is discounted because of the correlation of observations to dedrumming activities. Had lab contamination existed, it would.

Contamination is virtually ruled out by the complete absence of measurable concentrations during the interim and the pre- and postoperation intervals. Furthermore, the rainwater collected at the weather station was contaminated slightly with 2,4-D and 2,4,5-T, further substantiating the measured air concentrations.

The most logical explaination of the observed concentrations, given the constancy of the wind direction, is that of upper air recirculation. While no data were taken on upper air winds, cloud observations occasionally indicated the possibility.

Furthermore, the atoll area is a heat island, and does have microscale impacts on weather. Perhaps the heat island effect is responsible for recirculation. At any rate, the observed concentrations were exceedingly low (averaging 20.5 and 3.8 parts per trillion), and no adverse impacts were observed.

4.1.2.2 Wharf

The wharf site (Plate 14) was situated to measure any 2,4-D and 2,4,5-T air concentrations resulting from ship loading which could impinge on the island. The site was located west and as far north as possible on the wharf, as the wind direction was from the east and south. Frequently, the R-5's were parked close to and upwind of the sampler. Furthermore, the R-5's had to pass upwind of the samplers to travel to and from the ship loading point. For these reasons, it was expected that the wharf sampler might measure HO concentrations.

In fact, nearly all of the samples taken at the wharf during dedrumming activities showed trace, but non-quantifiable (below about 0.8 μg/m^3, but dependent on sample volume) quantities. Several of the samples for the first dedrumming were quantifiable, yielding average concentrations for the first dedrumming period of 0.29 and 0.42 μg/m^3 for 2,4-D and 2,4,5-T, respectively. The peak 2,4-D concentration was 1.09 μg/m^3, comparing favorably to the OSHA TWA of 10,000 μg/m^3.

The tomato plants located ∿ 30 meters west of the site did not suffer HO damage, which would be expected at long term exposures to greater than 10 parts per trillion.

4.1.2.3 Downwind Station

This station, being partially downwind of the drums, was expected to have preoperational concentrations of HO. Furthermore, being directly downwind of the dedrumming facility, the site could be expected to react to dedrumming activities. In fact, both phenomena occurred.

Figure 27 was prepared to help visualize the causes of the observed concentrations. In addition to the plotted concentrations, the trend lines for the two dedrumming periods (least squares fit) are attached.

The initial concentrations were trace amounts. On the 26th of July, measurable concentrations were found: during that day dedrumming activities were demonstrated to the dedrumming staff.

From the 27th July to the 4th August, concentrations at the downwind site continued to climb. A noticeable drop occurred on the night of the 31st July following the dedrumming activities pause on the 30th July.

On these days, as in the second dedrumming period, concentrations during the day were noticably higher than at night. Several conditions could have accounted for this, as noted below:

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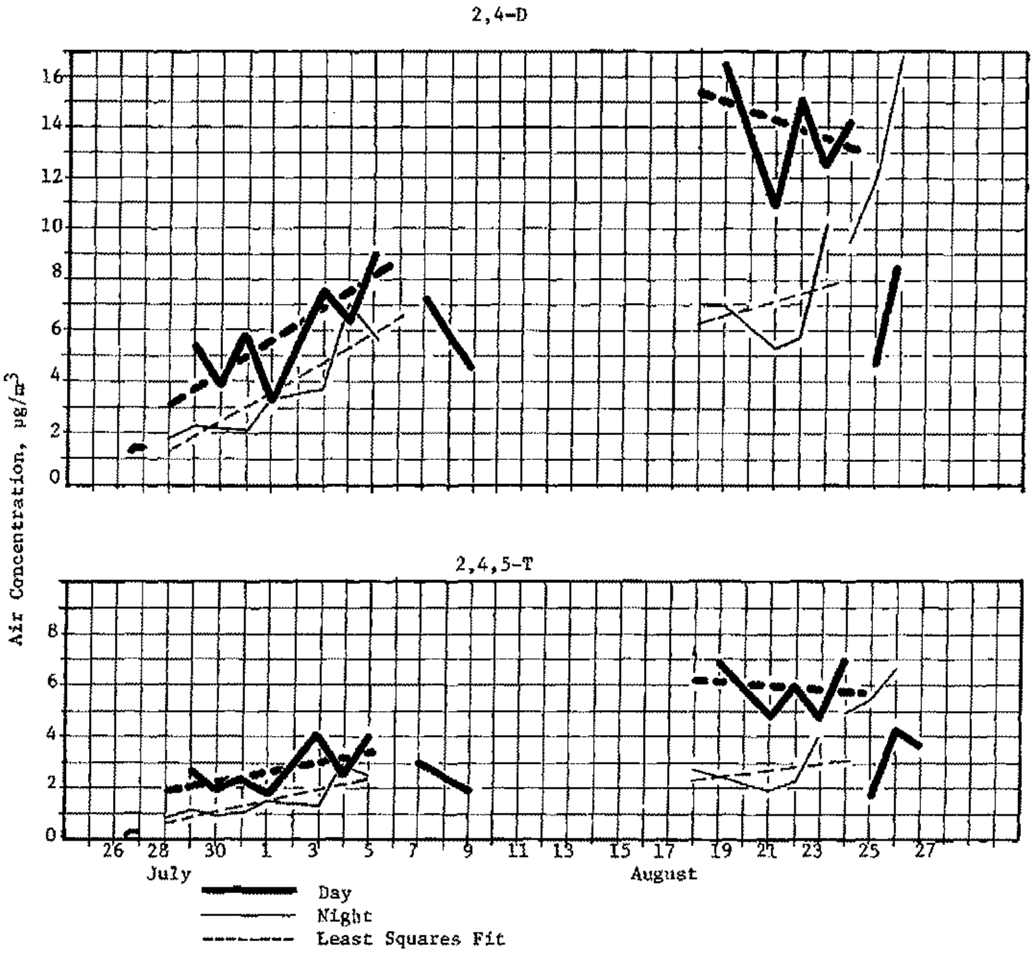

FIGURE 27. CONCENTRATIONS MEASURED AT DOWNWIND STATION

(a) The dispersion capabilities of the air. However, there was no quantifiable difference in wind speeds between morning and night, the most probable cause in dispersion differences.

(b) Differences in operating personnel. There were observable differences in the job performance of the dedrumming staff between day and night shifts. However, when the trend line is considered, the carry-over of contaminants between shifts would obscure shift differences.

(c) Insolation. Incoming solar radiation (and conversely, nighttime earth radiation) caused the land surface to suffer temperature extremes in excess of the ambient air temperature.

Reference (40) shows that the evaporation rates are approximately related to the logarithm of the temperature, and that the rate may double or even triple between 60 F and 80 F. This factor is sufficient to explain the differences between observed day and night concentrations.

The increasing concentrations are interesting. The most likely explanation of these is that, in removing barrels for dedrumming, the ground underneath the barrels, which in many cases had absorbed HO, was freshly exposed to the elements. The ever increasing area thus allowed more and more evaporation to take place, increasing observed concentrations.

If this explanation were correct, it would be expected that concentrations would decrease when dedrumming activities ceased. This is in fact observed in the first days after completion of the first dedrumming.

Concentrations during the second dedrumming period were noticeably higher than the first, but no general trend statement can be made with statistical confidence. Again, daytime concentrations were higher than nighttime concentrations.

During the post-operational phase, the start times for the night sample moved from 1900 to 1700 to 1600. Whereas the day time sample reflects the expected drop in concentrations, the nighttime sample actually increases. This would be consistent with the previously expressed belief that solar insolation/air temperatures are the predominant effect in the evaporation rate of the HO.

Further observations in the postoperative period were invalidated by the discovery of interfering contaminants on the chromosorb tubes used. Table 7 illustrates the mean values of 2,4-D and 2,4,5-T concentrations during intervals of interest at the downwind station.

TABLE 7. CONCENTRATION AVERAGES AT DOWNWIND STATION

Interval	Concentration, µg/m^3		
	2,4-D	2,4,5-T	/No. Samples
Pre-operational (day)	0.49	0.08	3
First load (day)	5.5	2.6	7
First load (night)	3.4	1.3	8
First load (combined)	4.6	2.1	15
Interim (day)	5.9	2.5	2
Second load (day)	14.1	5.3	5
Second load (night)	5.8	2.0	6
Second load (combined)	10.7	4.5	11
Post-operational (day)	6.6	2.8	2
Post-operational (mixed)	12.9	5.7	3
Post-operational (combined)	10.4	4.6	5

4.1.2.4 Dedrum Facility

Fixed monitors were located on the perimeter of the dedrum facility (Plate 14) to measure air concentrations at the facility boundaries. Site CP was essentially on the upwind side of the building: concentrations there being low during preoperations and first load, measurements at the site were discontinued.

Concentrations on the downwind corners of the building were also monitored. Table 8 presents their composited measurements.

TABLE 8. CONCENTRATION AVERAGES AT DEDRUM FACILITY

Interval/Measurement, $\mu g/m^3$	2,4-D	2,4,5-T	No. Samples
Pre-operational	0.8	0.3	2
First load	12.4	6.4	6
Second load	12.7	4.8	2
Post-operational	7.4	2.7	9

These concentrations demonstrate the expected pattern of high values during dedrumming and lesser values before and after. There was no demonstrated chronological trend in the post-operational measurements. However, daytime concentrations during loading (14.9 and 6.7 $\mu g/m^3$ for 2,4-D and 2,4,5-T) were higher than nighttime concentrations (10.0 and 5.3 $\mu g/m^3$, respectively) as was experienced at the downwind site. All values were well below OSHA TWA of 10,000 $\mu g/m^3$.

4.1.2.5 Tomato Plant Bioassay

The tomato plant bioassay was developed to provide a real-time monitoring system for detecting the presence of HO in the air of Johnston Island. As stated earlier, the sensitivity of tomato plants to HO is on the order of a few parts per trillion and at this or higher concentrations a response is generally seen within a matter of a few hours.

Tomato plants were placed at the 14 biomonitoring stations on Sunday, July 24, and observations were made for the next three days to establish a baseline with respect to tomato plant injury. The dedrumming operation began on Wednesday, July 27, and was completed on August 23. However, there was an interruption in the dedrumming operation between August 5, and August 17 while the M/V Vulcanus was performing the second burn.

Near the end of the study, three days prior to the completion of the dedrumming operation, six additional tomato plant stations were established in an effort to more closely delineate the area of highest herbicide concentration. Five of the six stations were located downwind of the dedrumming facility while the remaining station was located about 20 feet upwind of the facility (Figures 18 and 24). Four of the five additional downwind stations (D-5 through D-8) were located on a transect about 100 feet from the dedrumming facility. The fifth downwind station was located between stations D-2 and D-3.

A rating system was devised to evaluate plant damage Photographs showing the actual damage are presented in Plates 15 through 18.

The results of the tomato plant bioassay are shown in Table 9. The 3 days of preoperational observations indicated that concentrations of HO sufficient to cause severe injury to tomato plants existed in the vicinity of stations D-2 and D-3. These two stations were located about 500 feet downwind of the dedrumming facility (Figure 24). No injury was observed in the two remaining downwind stations or the 10 upwind stations.

Tomato plant observations which were made during the period July 28 through August 24 indicated that relatively high concentrations of the herbicide existed not only in the vicinity of stations D-2 and D-3 but also on occasion at stations D-1 and D-4. Severe injury was observed at stations D-2 and D-3 consistently except for three days. Herbicide injury was not observed in any of the 10 upwind stations during this period except for the two instances of slight injury observed on August 15 and 16 at station U-1 with unknown cause.

TABLE 9. SUMMARY OF DATA OBTAINED FROM TOMATO PLANT BIOASSAY CONDUCTED ON JOHNSTON ISLAND DURING DEDRUMMING OPERATIONS OF PROJECT PACER HO

Station Identification	July							August																										
	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
	Pre Op			Dedrumming Operation									Second Burn											Dedrumming Op								Post Op		
Downwind Stations																																		
D-1	1	1	1	2	1	1	1	1	1	1	1	1	2	4	4	4	4	4	4	4	4	4	4	4	4	4	1	1	1	2	2	1	2	3
D-2	3	3	4	4	4	4	4	4	4	2	4	4	4	4	4	4	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	2	3	4
D-3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2	3	4
D-4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	3	4	4	4	1	1	1	1	2	1	1	1
D-5																													4	4	4	2	2	3
D-6																													4	4	4	2	3	4
D-7																													4	4	4	2	3	4
D-8																													4	4	4	2	3	4
D-9																													4	4	4	2	3	4
Upwind Stations																																		
U-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1	1	1	1	1	1
U-2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
U-3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
U-4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
U-5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
U-6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
U-7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
U-8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
U-9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
U-10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
U-11																													4	4	4	2	4	4

Note: The data has been coded as follows: 1 = no injury--no epinastic growth; 2 = slight injury--epinastic growth limited to leaf tips and blades; 3 = moderate injury--epinastic growth involves leaf tips, blades and petioles; 4 = severe injury--epinastic growth involves entire apical portion of plant.

Sites identified on Figures 23 and 24.

The degree of tomato plant injury observed during the 3-day post-operational period was similar to that observed prior to the start of the disposal operation. Severe injury was observed at stations D-2 and D-3. A lesser degree of injury occurred at D-1 while injury was absent at station D-4.

The degree of tomato plant injury observed at the six additional stations was consistant with that observed at the original stations. Severe injury occurred at the five downwind stations as well as the one upwind station.

The results of the tomato plant bioassay indicate that during the dedrumming operation concentrations of HO above the sensitivity of tomato plants did not occur upwind of the dedrumming/storage facility on Johnston Island. However, significant concentrations of the Herbicide did occur directly downwind of this facility and on occasion extended laterally to the two outlying tomato plant stations. It is interesting to note that significant concentrations of HO occurred in this area prior to the start of of the disposal operation.

4.1.2.6 TCDD

The benzene impinger samples were sent to the Air Force for analysis by another contractor. As of this writing, a total of 20 samples from all locations had been analyzed. No TCDD was found in any sample. Minimum detectable concentrations ranged from 6.64 to 20.34 nanograms per cubic meter.

4.1.3 Water

The water environment acts as a transport medium for pollutants. Water quality measures environmental effects that may or may not have impacts associated with them. Whether a given level of a pollutant results in an impact depends on the subsequent biological response. Insofar as response measured in static bioassay testing may not be representative of environmental conditions, assignments of impacts via water concentrations are subject to error.

Data obtained during the operational and postoperational phases of the assessment are presented for each of the six water sampling sites and compared to baseline levels to determine if any statistically significant changes occurred. The data are further compared against applicable water quality criteria and/or standards. Water data summaries are shown in Tables 10, 11, and 12. Figures 20, 21, 22, and 23 define the water sampling locations.

4.1.3.1 Dedrum Area Offshore (Site WD)

Samples taken offshore of the dedrum area before, during, and after Operation Pacer HO showed no 2,4-D and traces (0.1-0.2 ppb) of 2,4,5-T in two of three operational or postoperational samples. Baseline samples taken by the Air Force showed quantifiable or trace levels in over 53 percent of the samples taken in this area between 1973 and 1977. Trace levels of 2,4,5-T were also found in the baseline sample taken by BCL on July 24.

It is therefore concluded that HO dedrum and transfer operations did not have adverse effects on the water environment offshore from the drum storage yard. Measurable concentrations of herbicide due to contaminated soils and interchange of shallow groundwater with offshore water will continue to produce occasional instances of HO contamination. The trace levels observed by BCL did not exceed established water quality criteria of 0.3-5 ppm and are considered negligible.

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TABLE 10. WATER DATA SUMMARY
OPERATIONAL

Location	No. Samples	Maximum in PPB D	Maximum in PPB T	Minimum in PPB D	Minimum in PPB T	Positive Average in PPB D	Positive Average in PPB T	Percent Positive D	Percent Positive T	Percent Trace D	Percent Trace T	Percent N.D. D	Percent N.D. T
WS saltwater intake	15	2.11	1.32	<.1	<.1	1.05	.60	29	36	29	50	43	14
WF wharf	17	4698.1	3418.5	<.1	<.1	791.3	496.4	38	44	25	31	38	25
WO wastewater outfall	7	<.1	Trace	<.1	<.1	--	--	0	0	0	43	100	57
WD downwind dedrum	2	<.1	<.1	<.1	<.1	--	--	0	0	0	0	100	100
P1&P2 potable water	16	<.1	Trace	<.1	<.1	--	--	0	0	0	80	100	20
SE1&SE2 sewage	9	65.63	72.15	8.93	11.77	32.08	32.42	100	100	0	0	0	0
RW rainwater	1	<.1	Trace	<.1	<.1	--	--	0	0	0	100	100	0

TABLE 11. WATER DATA SUMMARY
INTERIM

Location	No. Samples	Maximum in PPB		Minimum in PPB		Positive Average in PPB		Percent Positive		Percent Trace		Percent N.D.	
		D	T	D	T	D	T	D	T	D	T	D	T
WS saltwater intake	3	Trace	Trace	<.1	<.1	--	--	0	0	33	66	66	33
WF wharf	3	.38	.36	<.1	Trace	.38	.32	33	66	33	33	33	0
WO wastewater outfall	0	--	--	--	--	--	--	--	--	--	--	--	--
WD downwind dedrum	0	--	--	--	--	--	--	--	--	--	--	--	--
P1&P2 potable water	3	<.1	Trace	<.1	<.1	--	--	0	0	0	33	100	66
SE1&SE2 sewage	9	20.35	21.76	12.26	13.59	16.30	17.67	100	100	0	0	0	0
RW rainwater	1	<.1	<.1	<.1	<.1	--	--	0	0	0	0	100	100

TABLE 12. WATER DATA SUMMARY
POST OPERATIONAL

Location	No. Samples Taken	Maximum in PPB		Minimum in PPB		Positive Average in PPB		Percent Positive		Percent Trace		Percent N.D.	
		D	T	D	T	D	T	D	T	D	T	D	T
WS saltwater intake	3	<0.1	T	<0.1	<0.1	0	0	0	0	0	33	100	67
WF wharf	3	<0.1	T	<0.1	<0.1	0	0	0	0	0	33	100	67
WD dedrum offshore	1	<0.1	T	<0.1	T	--	--	0	0	0	100	100	0
WO wastewater outfall	1	<0.1	<0.1	<0.1	<0.1	--	--	0	0	0	0	100	100
P1&P2 potable water	3	<0.1	<0.1	<0.1	<0.1	0	0	0	0	0	0	100	100
SE1&SE2 sewage	2	3.88	2.83	1.42	0.89	2.65	1.86	100	100	0	0	0	0
RW rainwater	0	--	--	--	--	--	--	--	--	--	--	--	--

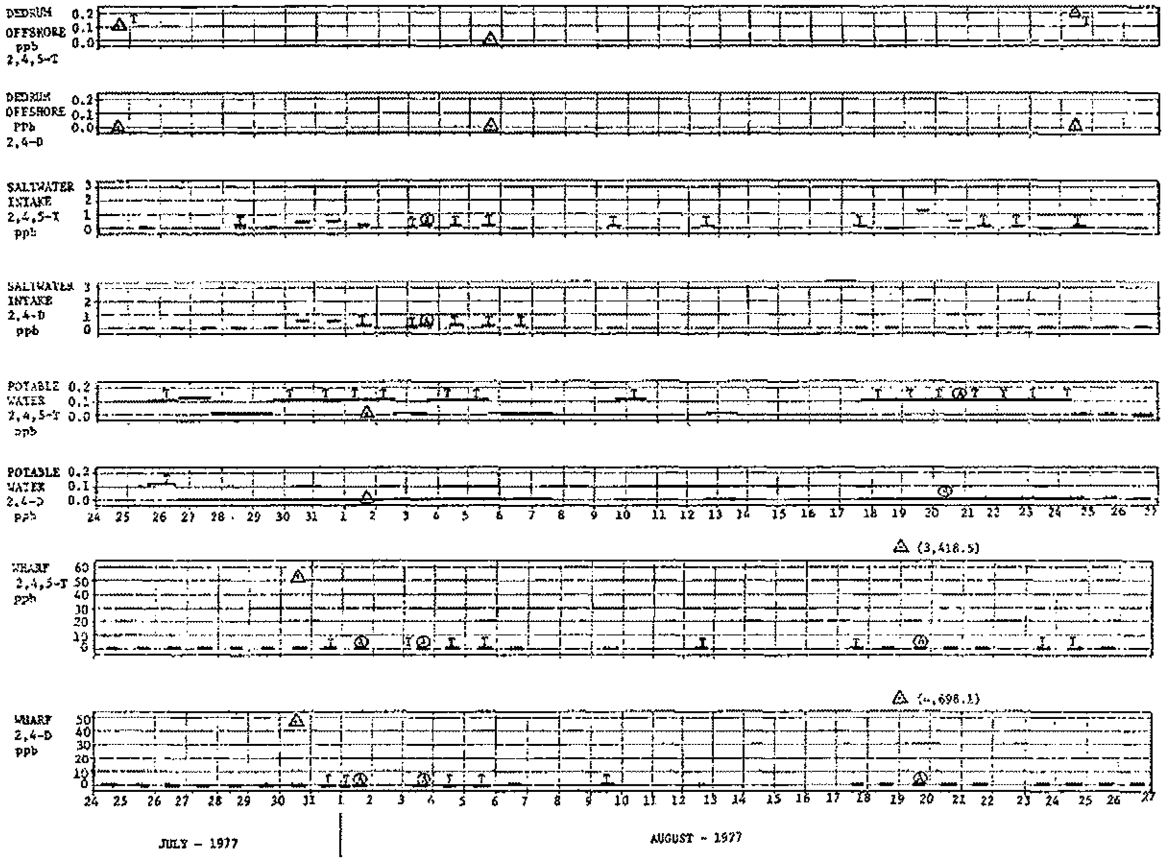

FIGURE 28. CHRONOLOGICAL PROFILE OF WATER CONCENTRATIONS CONTRASTED WITH THE DEDRUMMING ACTIVITIES

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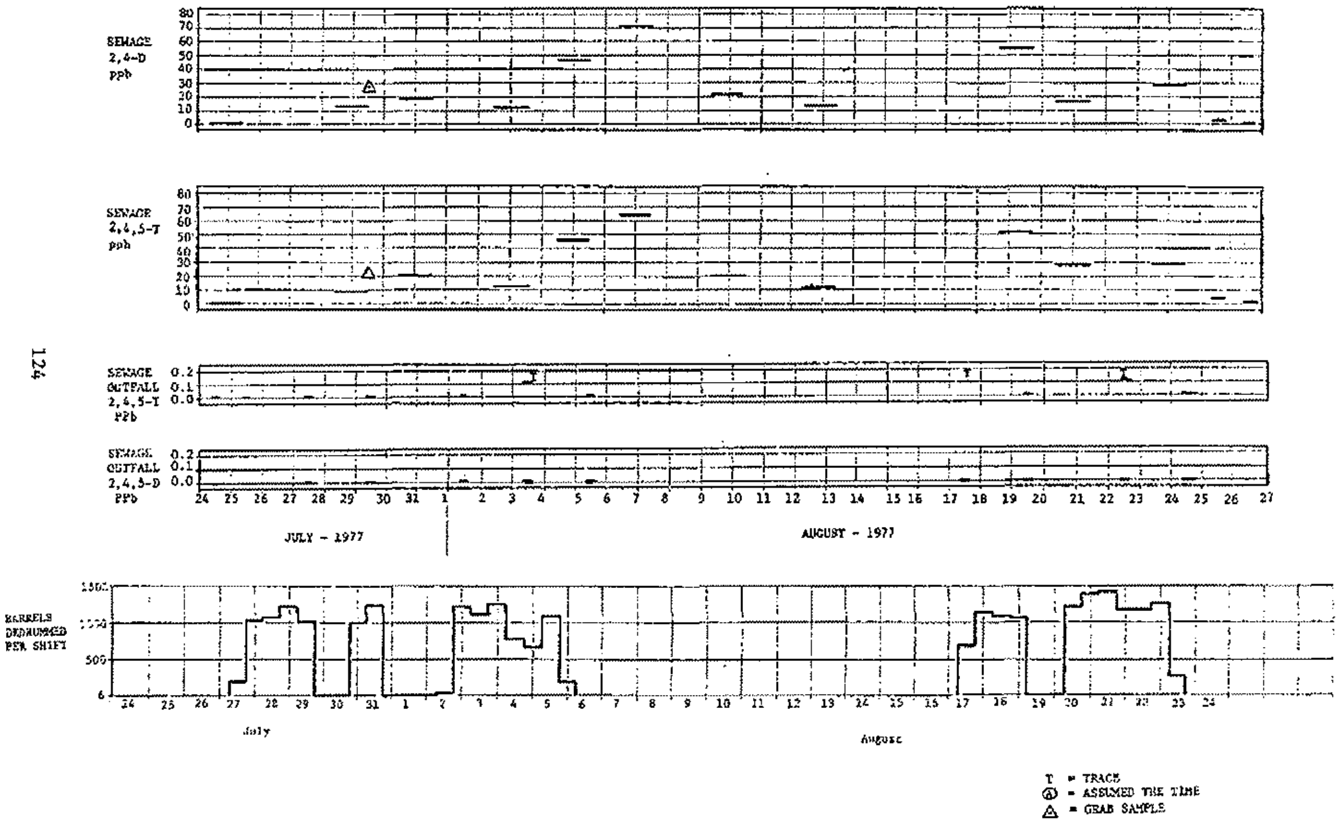

FIGURE 28. (Continued)

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4.1.3.2 Wharf (Site WF)

A total of 17 operational, three interim, and three postoperational samples were analyzed and showed positive averages for 2,4-D of 791.3 ppb, 0.38 ppb, and <0.1 ppb for the above periods, respectively. Corresponding results for 2,4,5-T were 496.4 ppb, 0.32 ppb, and a trace. The highest values observed were related to the two 24-hour deballasting periods during which bilge water contaminated with Orange Herbicide was pumped from the M/T Vulcanus into the lagoon water.

The first of these events occurred on July 31. At 1100 hours, a patch of orange-hued water was observed along the port side of the ship just astern of the deballast pump discharge. A sample of this water was taken from about one meter depth contained 47.57 ppb of 2,4-D and 54.14 ppb of 2,4,5-T. By 1400 hours the area affected by the deballast discharge had increased to include the entire port side of the ship and about 5 meters forward of the bow and 5 meters aft of the stern. At 1800 hours the plume was noticably less distinct and presumable had sunk and/or dispersed. Since the concentrations were at the low end of the toxicity range and did not persist for more than 8 hours, it is reasonable to conclude that no adverse impacts occurred. Furthermore, the relatively small area involved would not preclude fish from avoiding the area altogether for this short period. No distress effects were noted in any fish or other aquatic life and concentrations in the composited wharf sample taken over a larger area were 0.45 ppb 2,4-D and 0.41 ppb 2,4,5-T well below published toxic concentrations of 0.3-5 ppm. No biological specimens were collected.

A similar situation existed during the second deballast period on the 19th of August. A sample taken of the water about 10 feet (3 meters) astern of the discharge at 1000 hours showed 4698.1 ppb of 2,4-D and 3418.5 ppb of 2,4.5-T. At this time, the plume extended approximately 20 feet (6.1 meters) in both directions between the ship's hull and the wharf. The total volume of water discharged on this date was 1500 m^3 (396,000 gallons; 1.5 x 10^6 ℓ).(38) A "worst case" scenario would be that the concentrations as measured in the lagoon were invariant during this time period. A conservative dilution factor of 10 was estimated in which case 155 lb (70.7 kg) of 2,4-D and 113 lb (51 kg) of 2,4,5-T were released to the marine environment. Put in perspective, this means that, at 10.7 lb per gallon, approximately 25 gallons of pure herbicide was released. This corresponds to about 1/2 drum as an absolute maximum.

In both instances, the plume edges were sharp and distinct, and the plume was confined to near the ship, in spite of wharf currents. The rapid disappearance of the plume is attributed to the fact that HO, heavier than water, and immiscible in water, sinks. It is expected that the discharged HO sank to the bottom of the ship channel and then spread out. Concentrations observed at the saltwater intake support this belief. These concentrations demonstrated that the HO rapidly dispersed to insignificant concentrations.

The resulting concentrations were above the suggested aquatic life criteria. However, in view of the fact that the area of impact was limited and the exposure time relatively short, it is believed that the adverse impacts, if any, were minor. No visible signs of distress were noted in fish swimming near the wharf. The concentrations in the composite wharf sample for August 19 were 0.33 ppb 2,4-D and 0.25 ppb 2,4,5-T, and on August 20 were 1.02 and 0.88 ppb, well below the suggested quality criteria of 0.3-5 ppm. Values of 0.38 ppb 2,4-D and 0.36 ppb 2,4,5-T noted on August 6 were probably due to wash down of the decks following final sampling of the ship's tank just prior to departure. These concentrations posed no danger to the aquatic life.

The median concentration for all operational samples taken at the wharf was $\leq$ 0.2 ppb.

Measurable concentrations of Orange Herbicide have been found at this location on three occasions in the past by the Air Force.(16) The maximum concentrations were 0.54 ppb 2,4-D and 0.29 ppb 2,4,5-T and the positive average concentrations were 0.31 ppb and 0.22 ppb. The median concentration for 52 samples was $\leq$ 0.2 ppb.

Samples taken by BCL during the baseline period showed no detectable levels of HO.

It is concluded that concentrations of herbicide significantly exceeded baseline concentrations on three occasions during the assessment. on one of these occasions the concentrations exceeded the upper aquatic life criterion of 5 ppm by at least 60 percent. Acute impacts were not directly observed.

4.1.3.3 Saltwater Intake (Site WS)

As mentioned previously (Section 2.1.3.2), the local circulation during certain tidal movements allows the water mass to move from the vicinity of the main wharf to the intake for the island's water system. At a speed of one knot, a parcel of water at the wharf could be easily transported the short distance to (480 meters) to the intake in a short period of time.

Baseline samples taken by BCL showed no detectable Orange Herbicide. Baseline samples taken by the Air Force between 1973 and 1977 had quantifiable or trace levels of 2,4-D six times and of 2,4,5-T 10 times. The maximum concentrations of 2,4-D and 2,4,5-T were 2.31 and 0.65 ppb, respectively.

Fifteen operational samples taken by BCL showed maximum concentrations of 2.11 ppb 2,4-D and 1.32 ppb 2,4,5-T. Twenty-nine percent of the samples were in excess of 0.2 ppb 2,4-D and 36 percent were above 0.2 ppb for 2,4,5-T. The value of 0.2 ppb is the limit of quantitation of the analytical method. No samples were in violation of currently accepted drinking water standards of 100 ppb 2,4-D even when applied to the intake side of the system and were never greater than 50 percent of the more stringent no-effect level for 2,4-D (4.4 ppb). The maximum concentration of 1.32 ppb 2,4,5-T is an even lower percentage of the no-effect level of 35 ppb.

The chronological profile of concentrations of herbicide at the various sites is contrasted in Figure 28 with the number of barrels dedrummed per shift during the operation period. Quantifiable levels of Orange Herbicide observed during the assessment period are well correlated with activities at the wharf leading to the conclusion that the M/V Vulcanus was the source of the contamination (see previous discussion in Section 4.1.3.2 above). All concentrations were well below the suggested aquatic life criteria.

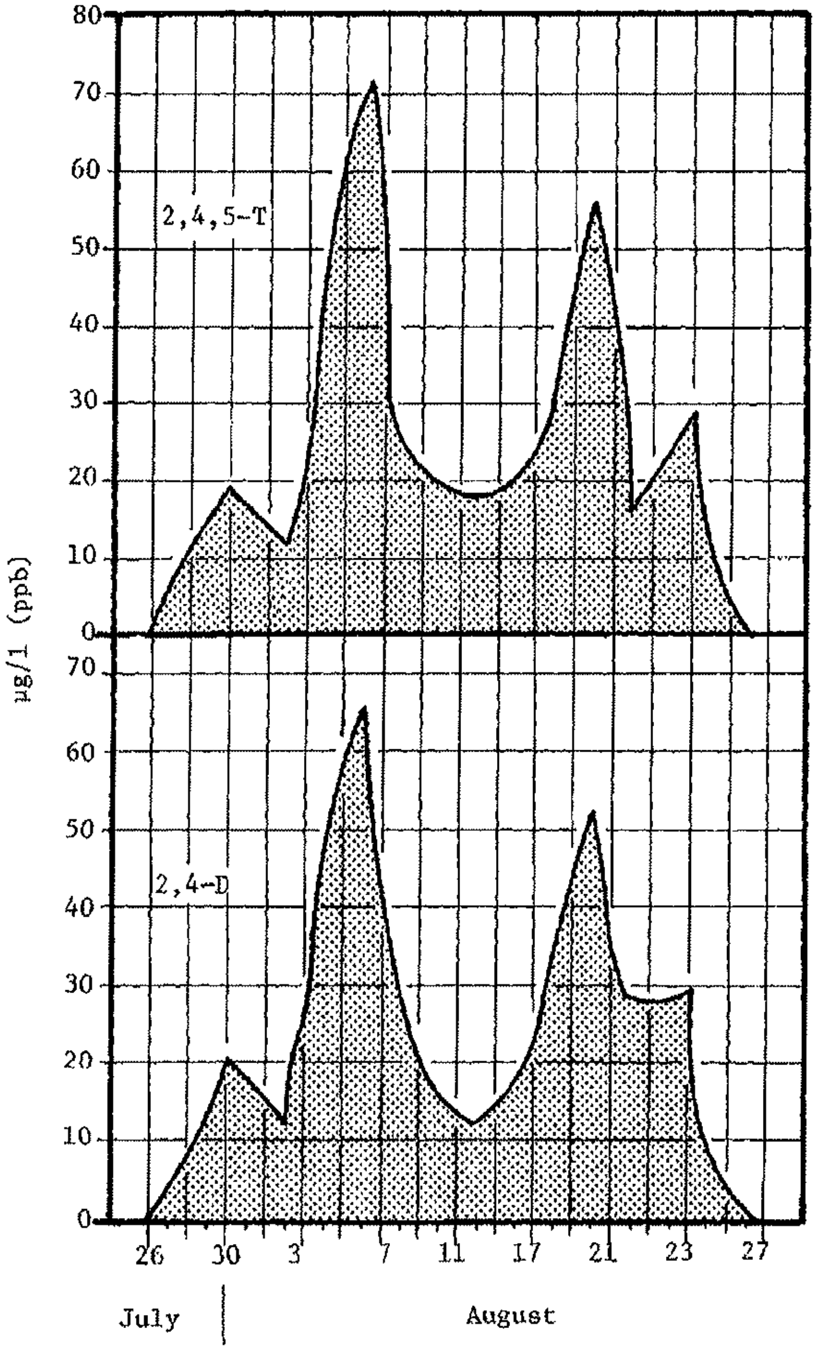

FIGURE 29. SEWAGE SYSTEM DISCHARGES OF 2,4-D AND 2,4,5-T TO THE OFFSHORE AREA SOUTH OF JOHNSTON ISLAND

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One grab sample taken at noon on July 29, was analyzed and exhibited 2,4-D concentrations about 10 percent higher than the corresponding 24-hour average. Similarly, the grab sample showed 43 percent higher 2,4,5-T levels than the composite. July 29 was in the peak dedrumming activity period for the first loading operation.

The total mass of Orange Herbicide discharged to the marine environment from the wastewater system can be determined from Figure 29 and the estimate of sewage production. The total mass of 2,4-D released was approximately 0.46 lb (0.21 kg) and the total of 2,4,5-T released was 0.48 lb (0.22 kg). The sum of the two components on a volume basis represents less than 0.1 gallons of pure herbicide.

4.1.3.6 Wastewater Outfall (Site WO)

The pollution field which develops in a receiving water body can be modeled if certain velocity and flow components are known. The area and configuration of the field are functions of the

- Rate of discharge
- Diameter, direction, and submergence of the outfall pipe
- The velocity of receiving water currents.

The dilution effected at the top of a wastewater plume can be determined from the differences in density between the waste and the receiving water, the rate of discharge and the orifice diameter.

At Johnston Island, the sewage outfall consists of a simple, 10 inch (0.25 meter) open-ended, prestressed concrete pipe discharging at 25.6 feet (7.68 meters) from the surface. To calculate the rate of discharge, Q, it was assumed that all sewage flow occurred during the 14 daylight hours. At an estimated 75,000 gpd, the hourly pumpage was 5,367 gallons. Based on observation, the daytime pumping cycle was 5 minutes on, 15 minutes off or 1785 gallons per cycle for an estimated 360 gpm (0.797 cfs) discharge.

The dilution ratio $S = Q_o/Q$. Here Q_o is the volume flow rate of discharge after dilution with the receiving water.

The densimetric Froude number, $F = Q/0.25\ \pi d^2 (g'd)^{1/2}$, is used to determine the dilution factor where, d = Diameter of outfall pipe and $g' = g(\rho_s - \rho/\rho)$ is the apparent acceleration of orifice flow due to differences in density between the wastewater discharge and the receiving water. ρs, was taken as 1.025 g/cc for seawater at 26 C while ρ was taken as 0.9944 for freshwater at 34 C,(18) the mean temperature measured at Site SE.

The warmer, less dense freshwater plume should rise through the more dense saline receiving water. The dilution ratio was obtained from Reference 41 where F is plotted as a function of y_o/d and where:

y_o = depth above the top of the outlet

and d has its former meaning.

It is of interest to examine the relative areas of influence of the sewage and the herbicide. The sewage, having a very low dissolved oxygen content, creates an area in which fish and other higher life forms cannot exist. If it can be shown that this extends to or beyond the similar extent of the toxic herbicide concentrations, then it can reasonably be concluded that the discharge of herbicide has had no incremental impact.

To increase the dissolved oxygen in the sewage (0.9 mg O_2/ℓ) to 5.0 mg/ℓ by a simple mixing with receiving water and ignoring as a first approximation the oxygen demand rate and, oxygen transfer a dilution factor of at least 5.5 is required. A dilution factor for herbicide of about 4 is required assuming conservatively that the maximum peak concentrations reached during any 24-hour period were 50 percent greater than the highest average HO concentrations observed by BCL (0.130 ppm) and that the no-effect level is 50 percent of the lowest 48-hour TL_m (0.100 ppm).

The required dilution for dissolved oxygen at the head of the rising plume is achieved about 5.5 meters below the surface while the Herbicide concentration of 50 ppb is achieved more than 6 meters below the surface. A dilution factor of 30.7 at the surface was calculated so that neither pollutant affects the surface layers of water.

The impact area in the horizontal plane can be calculated in the presence of a steady velocity component, U, in the receiving water by determining the distance, x, at which the pollutant is dispersed by lateral diffusion to a concentration, c_x, from an initial concentration, c_o. Four assumptions are required to model the behavior of a conservative pollutant:

- The turbulent diffusion law is applicable
- The eddy diffusivity or turbulent transport coefficient, ε, is a function of (Z/Z_0) where Z is the plume width at a distance, x, from the discharge and Z_o is the width of the discharge at the orifice
- The value of Z/Z_o is a function of x but not z, and,
- Vertical mixing in the y direction and longitudinal mixing in the x direction is minimal.

Solutions to the resulting differential equations are plotted in Reference 41 as a function of $\beta x/Z_0$ and the dilution factor C_0/C_x, where $\beta = {}^{12\varepsilon_o}/UZ_o$. Since it is desired to know x, the graphical solutions can be used in reverse solving for x given the required dilution factor. In the analysis $\varepsilon/\varepsilon_0$ is assumed equal to $(Z/Z_0)^{4/3}$, after Brooks.(39)

Two situations were identified for Johnston Island. For Case I (easterly flow), the receiving water current is essentially parallel to the discharge direction and has a speed of 2.5 ft/sec (0.78 m/sec). The calculated value of x is then 774 ft (240 meters) for dissolved oxygen and 539 ft (167 meters) for Orange Herbicide. The area in the xy plane at or near the concentration c_x is approximately a trapezoid whose height is equal to x, whose base width is equal to Z_o and whose top width equals Z where $Z = Z_o \ (1 + 2/3\beta x/Z_o)^{3/2}$. For dissolved oxygen, the impact area is 2,334 ft^2 (259.3 m^2) and for herbicide it is 1170 ft^2 (130.1 m^2).

For Case II (westerly flow) the ambient current is nearly perpendicular to the discharge. As a first approximation, it is assumed that the velocity component perpendicular to the flow does not affect the dilution factor. The parallel velocity component is about 16 percent of the total (about 10°) or 0.4 ft/sec. The calculated value of x is then 124 ft (38.5 m) for dissolved oxygen and 86.5 ft (26.8 meters) for herbicide. The impact areas are 373.5 ft^2 (41.5 m^2) and 1,875 ft^2 (20.8 m^2), respectively.

In both cases, it is seen that the effects of low dissolved oxygen in the sewage are more serious than those from Orange Herbicide. Furthermore, the intermittent nature of the discharge (5 minutes of every 20) prevents a steady-state concentration from being achieved for very long, if at all.

None of the samples taken by BCL showed more than a trace of herbicide, attesting to the rapid dissipation of the herbicide in the receiving water body. It is concluded that the effects of this discharge were negligible.

4.1.3.7 TCDD

Water samples were sent by BCL to the Air Force for TCDD analysis by another contractor. As of this writing, a total of 11 samples from all sites had been analyzed. No TCDD was found in any sample. Minimum detectable limits ranged from 3.6 to 8.0 nanograms per liter.

4.1.4 Biota

The environmental impact of the HO land-based disposal operations upon the biotic portion of the natural environment of Johnston Atoll was evaluated with particular emphasis upon the vegetation of Johnston Island and the bird population of Sand Island.

4.1.4.1 Vegetation

The vegetation of Johnston Island as observed at the start of the operation can best be described as sparce, primarily because of the poor soil and climatic conditions found there. Only in areas where residents fertilize and water regularly was the vegetation in a healthy, rapidly growing state. The prominent species in the open areas of Johnston Island (or more specifically the man-made portion), were Fimbristylis cymosa, Lepturus repens and Pluchea carolinensis. The first two species were also prominent in the area immediately adjacent to the HO storage yard and dedrumming facility, occurring both upwind and downwind of this area. The vegetation occurring downwind consisted of only three species, Lepturus repens, Fimbristylis cymosa and Conyza bonariensos which occurred only in areas not disturbed by vehicular traffic (Plate 19).

Orange Herbicide is a 50:50 mixture of two phenoxy herbicides, 2,4-D and 2,4,5-T which are chemicals widely used to kill dicotyledonous weed species. Therefore, broadleaf vegetation was expected to be most susceptible to impact from the HO disposal operations. Because of their greater sensitivity to these two phenoxy herbicides, any dicotyledonous species in the area adjacent to the dedrumming facility, or perhaps adjacent to the areas where transport and transfer operations occurred, would be most susceptible to herbicide damage. Accordingly, four areas were chosen as the primary sites where vegetation would be examined on a weekly basis for signs of herbicide damage. These sites were (1) the dedrumming area, (2) along the roadway between the dedrumming facility and the main wharf, (3) the swimming pool and (4) the U.S. weather station. The major plants and especially the dicotyledonous plants, in these four areas were examined for symptoms of epinastic growth. A list of these species appear in Table 13.

No signs of epinastic growth were noted during the preoperational vegetation survey made on July 27. There were several Casliarina equisetifolia trees along the roadway adjacent to and upwind from the dedrumming facility which did not appear healthy, having fewer "needles" in comparison with other trees of the same species. There were, however, several trees of this species at the opposite end of the island in the area of the baseball field which were also very thin.

The vegetation surveys which were conducted during the dedrumming operation revealed only one instance of herbicide injury. In this instance one Conyza bonarunsis plant (Plate 20) from a total of about 10 located downwind of the dedrumming area showed the classic symptoms of epinastic growth. However, it is not known whether this HO injury was a result of the land-based HO disposal operations or whether it occurred prior to the start of the operation. In any event, this injury observed on one plant of one species is not a significant impact of the land-based HO disposal operation on the vegetation of Johnston Island.

TABLE 13. PLANT SPECIES OBSERVED ON JOHNSTON ATOLL

Calatropis gigantera	
Elusine indica	Goose Grass
Euphorbia hirta	Spurge
Fimbristylis cymosa	
Euphorbia prostrata	Spurge
Tridox procumbens	
Portulaca oleracea	Purslane
Pluchea carolinensis	
Musa sapientum	
Casaurina equisitifolia	Ironwood
Heliotropium ovalifolium	
Cyperus rotundus	Purple Nutsedge
Coccoloba uvifera	Sea Grape
Ipomoea pes-caprae	Beach Morning Glory
Cocos nucifera	Coconut Palm
Sesuvium portulacastrum	
Scaevola taccada	
Hibiscus rosa	
Cynodon dactylon	Bermuda Grass
Lepturus repens	Bunch Grass
Solanum melogena	Eggplant
Solanum lycopersicum	Tomato
Capsicum frutescens	Pepper
Plumeria rubra	
Conocarpus erecta	
Cenchrus echinatus	Sandbur
Nerium oleander	Oleander

The postoperational survey conducted on August 27, revealed no additional instances of epinastic growth. The vegetation of Johnston Island as well as that of the other three islands appeared not to be affected by the land-based HO disposal operations.

4.1.4.2 Birds

Except for man, birds and particularly sea birds, are ecologically the most important species on the four islands of Johnston Atoll. The original (eastern portion) of Sand Island is of major importance for its breeding population of Sooty Terns and of significant importance for breeding populations of Red-footed Boobies, Brown Noddies, Wedge-tailed Shearwaters and Great Frigatebirds. It is also significant as a wintering area for shorebirds, particularly the American Golden Plover and Ruddy Turnstone.

The sea bird population of Sand Island as observed at the start of the operation was found to be quite similar to previous descriptions with respect to the species observed, the nesting areas of each species and the stage in the breeding cycle of each species which was observed.(2) No attempt was made to monitor the numbers of each species present on Sand Island. Instead the weekly inspections were aimed at detecting abnormalities within behavior, distribution and mortality which might be indicative of an adverse impact of the HO disposal operations upon the sea bird population of Sand Island.

The preoperational bird survey of Sand Island conducted on July 26, revealed the bird population to be healthy except for a few individuals of several species which had sustained wing injuries as a result of striking guywires. There were numerous dead birds which were observed in various stages of decay. Dead birds in less advanced stages of decay were examined and broken wings and subsequent starvation was believed to be the major cause of death. A further indication of the general good health of the population was the fact that many very young chicks were observed, notably those of the Brown Noddy.

During the initial survey, and subsequent ones a total of 11 species was observed on Johnston Atoll (Table 14). Of these 11 species, seven comprised the breeding population of Sand Island. The distribution of six species on the original portion of Sand Island is shown in Figure 30. Brown Noddy, the most dominant of the six species, nested over most of the island particularly along the perimeter of the island. Many Brown Noddies could be seen either sitting on eggs or with very young chicks. Sooty Tern the second most dominant species, nested in a rather confined area southeast of the Loran antenna. Wedge-tailed Shearwater nested in burrows along both sides of the road leading to the antenna. Frigatebirds were limited to the southern shore and the southwest islet. Brown boobies were found on the hillside south and east of the antenna. Red-footed Boobies were found nesting on the Tournefortia bush northeast of the antenna. They could also be seen on the guywires northeast and southeast of the antenna. A seventh species of sea bird, Red-tailed tropicbird, was found nesting under low vegetation on the man-made portion of Sand Island. Several chicks of this species were seen at various stages of maturity.

During subsequent bird surveys conducted on August 1, 8, 15 and 22, while the HO disposal operation was proceeding or the postoperational bird survey of August 27, no abnormalities in behavior, distribution or incidence of dead birds were seen in the sea bird population of Sand Island or the avifaunal population of the other three islands of the Atoll.

4.2 Human Environment

4.2.1 Industrial Hygiene

In addition to the air monitoring program established inside the dedrumming facility, a comprehensive operations report including all accidents and injuries regardless of severity was compiled daily for each shift. In view of these reports, general observations of operational procedures, and concentrations of herbicide detected in the air of the working environment, the disposal program in effect on Johnston Island was reasonably safe. Problems associated with disposal operations were of a minor nature. Following is a summary of the industrial hygiene monitoring activities.

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TABLE 14. BIRD SPECIES OBSERVED ON JOHNSTON ATOLL

Scientific Name	Common Name
Anous stolidus	Brown Noddy
Sterna fuscata	Sooty Tern
Gygis alba	White Tern
Arenaria interpres	Ruddy Turnstone
Pluvialis domenica	American Golden Plover
Fregata minor	Great Frigatebird
Sula sula	Red-footed Booby
Sula leucogaster	Brown Booby
Phaethon rubricauda	Red-tailed Tropicbird
Phaethon lepturus	White-tailed Tropicbird
Puffinus pacificus	Wedge-tailed Shearwater

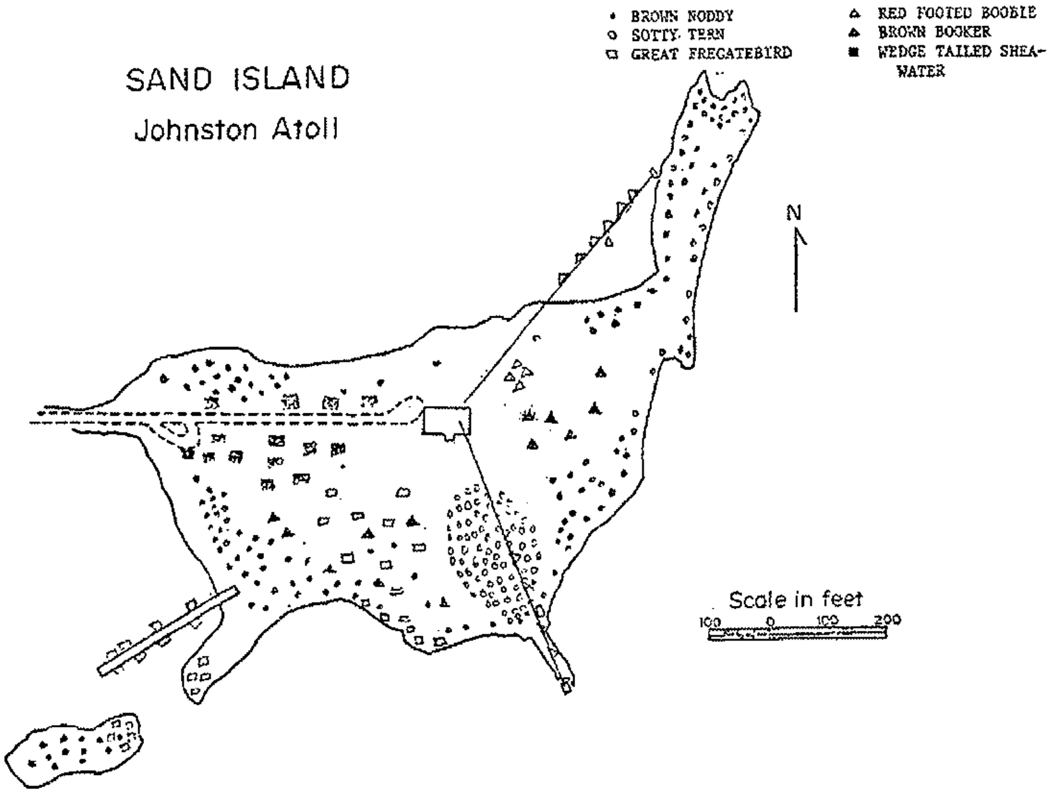

FIGURE 30. THE DISTRIBUTION OF SIX SEABIRD SPECIES ON THE ORIGINAL PORTION OF SAND ISLAND, JOHNSTON ATOLL, 1977

4.2.1.1 Industrial Hygiene Air Monitoring

The sampling of personnel breathing zones inside the dedrumming facility provided an accurate means of investigating individual exposures (see Section 3.2.3.1.). A total of nine areas inside the facility were differentiated in the personnel sampling code in order to determine the effects of different working assignments on herbicide exposure. These areas included the high (opening) and low (draining) positions on either side of the barrel rack for the four corner stations inside the facility, and also the pump operator.

Figure 19 presents the locations within the facility for personnel monitoring and their alphameric designations. Summary results for these locations are presented in Table 15. It is generally not possible to differentiate among the results, except that these breathing zone exposures are generally higher than at the fixed monitors at the edge of the facility.

This may be due to the mobility of personnel from one working position to another during a shift. Thus, monitored concentrations were representative of individual exposure, and not position exposure.

In exception to this, the pump operator usually stayed to the eastern (upwind) end of the facility. The five samples taken at this position show little difference from what was recorded for other personnel. The operator's close proximity to the herbicide sump beneath the pump may account for this.

The results of the personnel samples taken inside the dedrumming facility indicate levels of Orange Herbicide far below the Threshhold Limit Value (TLV) of 10 milligrams per cubic meter established by the American Conference of Governmental Industrial Hygienists. Concentrations ranged from 2.71 micrograms per cubic meter to 62.81 micrograms per cubic meter, with a mean of 30.66 and standard deviation of 13.71.* Levels were slightly higher during the second loading of the ship as compared to the first. This may be due to increased contamination of protective equipment near the breathing zone (splash aprons, face shields, and respirators) as well as

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* A statistical examination could not demonstrate with any confidence that any one location was different than the others. Therefore, the locations were grouped for averaging.

TABLE 15. SUMMARY TABLE OF AIR CONCENTRATIONS-PERSONNEL SAMPLERS

Site	Interval	No. of Samples	2,4,5-T Mean	2,4,5-T Stand. Dev.	2,4-D Mean	2,4-D Stand. Dev.	*Percent Below Quantitative Detection Limit	
							2,4,5-T	2,4-D
PP	First load	5	6.32	3.61	14.36	8.18	0	0
(Pump operator)	Second load	0	--	--	--	--	--	--
PX	First load	2	8.48	0.20	17.40	2.34	0	0
Outside rack	Second load	7	12.80	6.48	22.86	10.94	0	0
PV	First load	2	7.86	0.83	16.17	0.95	0	0
Inside rack	Second load	2	9.45	0.89	16.38	0.02	0	0
PU	First load	5	8.64	3.14	17.86	6.90	0	0
Inside rack	Second load	5	15.37	5.28	25.71	8.83	0	0
PT	First load	5	7.30	4.43	15.55	8.48	0	0
Outside rack	Second load	3	14.01	8.44	24.65	14.94	0	0
PY	First load	0	--	--	--	--	--	--
Outside rack	Second load	1	6.76	0	13.24	0	0	0
PZ	First load	2	13.30	0.42	25.35	0.92	0	0
Inside rack	Second load	0	--	--	--	--	--	--
PQ	First load	1	9.90	0	19.40	0	0	0
Inside rack	Second load	0	--	--	--	--	--	--
PR	First load	1	16.10	0	30.80	0	0	0
Outside rack	Second load	2	13.39	2.79	22.87	2.96	0	0

* All samples (either trace or non-detect) that were below the quantitative detection limit were taken to be zero for the calculations above. (All concentrations are in micrograms per cubic meter).

the dedrumming area in general. It is interesting to note that in all of the personnel samples the 2,4-D component exceeded the 2,4,5-T component by a ratio of about two to one. The increased volatility of the lower molecular weight 2,4-D accounts for this.

TCDD analyses form the benzene impinger at the southwest corner of the dedrumming facility were conducted by another contractor. No TCDD was detected in any of the samples analyzed. Minimum detectable concentrations ranged from 6.6 to 23.4 nanograms per cubic meter.

4.2.1.2 Accidents or Injuries

Very few accidents or injuries occurred as a result of the operations on Johnston Island. The following is a list of reported occurrences, all of them being minor in nature:

- Dust in eye of worker near drum crusher
- Herbicide in eye--three occurrences
- Nail puncture wound
- Workman slipped inside facility--two occurrences
- Groin injury from handle of floor brush
- Finger pinched between two drums.

In addition to the above list, ailments not necessarily related to operational activities included a workman with back pain (reported to dispensary during off-duty hours) and another with a cold with elevated temperature.

The problem of dust emanating from the crusher was resolved by the issuance of face shields to workers in that area. The cases of herbicide in the eye were immediately treated and affected workers were able to return to work. In some cases a pressure buildup inside the drum caused a spray to be released as the barrel was being opened from the top, a position frequently just below the workers breathing zone. Slippery floors within the dedrumming facility continued to be a problem despite the use of a cleaning solvent.

4.2.1.3 Miscellaneous

Several miscellaneous activities having potential implications for the industrial hygiene monitoring included the following:

- The heavy forklift and refueler traffic in the dedrumming area posed no ambient dust problem. The island's crushed coral composition accounts for this.
- The fact that the dedrumming facility was left open to prevailing trade winds allowed exposures of the herbicide to workmen to be minimized. This ventilation system also provided an excellent means of cooling the workmen, who were at the same time shaded from the intense afternoon sunshine.
- The effectiveness of the respirators was questioned by many of the workers. The replacement of filter cartridges in some cases failed to prevent herbicide odors from being experienced. The major problem was an improper and often uncomfortable fit around the face. Although the wearing of face masks in the dedrum facility were mandatory throughout the operations, violations of this policy were frequently noted.
- Some personnel were observed carrying smoking materials into the dedrumming facility. This practice can be dangerous because of the excellent absorbing tedencies of tobacco. Some workers were seen smoking only a few feet outside the facility in the area of the R-5 refuelers. The incident was immediately reported and the crews advised, whereupon the practice ceased.
- The impact of the disposal operation on regular island personnel caused no problems of significance. Housing and mess hall personnel were asked to work longer hours to accommodate those project personnel working on the island temporarily. The area from the wharf to the dedrumming area bounded by the sea to the north and the taxiway (R-5 access road) to the south was also placed off-limits to all personnel not directly involved with the project.

4.3 Non-HO Impacts

4.3.1 Temperature and Dissolved Oxygen

Non-HO water quality parameters monitored during the project included temperature and dissolved oxygen. Tables 16 and 17 are statistical summaries of these data. For each of the five locations monitored on a regular basis, the mean, standard deviation, and number of samples are given. No statistically significant differences between the baseline and operational or postoperational periods were noted.

Other non-HO impacts can only be described subjectively. These include increases in turbidity and discharges of oil and grease.

Turbidity plumes associated with the ship's deballasting operation were noted during both loading periods. These were composed primarily of water with suspended rust particles and dirt from the bilge. The compensation point for photosynthesis was certainly reduced by more than 10 percent. However, the area affected was between the hull of the ship and the wharf and was shaded by the ship. It is doubtful that this area is of high ecological value due to the extensive alteration of the substrate for construction and dredging in previous years. The turbidity created by the deballasting activities created no observable impact on the fish population observed swimming in the edges of the plume.

Small diesel fuel slicks or sheens were noted in the deballast discharge and in the exhaust from the landing craft used to obtain water samples. These were small enough and/or were spread over a large enough area to not cause the dissolved oxygen to fall below 5.0 mg/ℓ or to have caused toxic effects. The latter comment is based solely on observational evidence and on the high probability of rapid evaporation of the aromatic fractions which are the most toxic.

4.3.2 Operational Impacts

The most significant non-HO impact associated with the project is that of incremental air transportation, and its associated fuel consumption and effluents. It is estimated that the operation itself required about

TABLE 16. STATISTICAL SUMMARY OF NON-HO WATER DATA

Location		Baseline		Operational		Interim		Post-Operational	
		Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.
Wharf	$\bar{x}$	26.8	7.3	27.2	6.8	26.6	6.8	27.6	6.9
	s	1.8	0.4	1.0	0.4	1.7	0.4	0.6	0.2
	n	23.	24	79	83	24	24	18	18
Saltwater Intake	$\bar{x}$	26.1	7.7	26.9	7.0	26.6	7.1	27.3	7.1
	s	0.6	0.3	0.9	0.4	1.5	0.4	0.6	0.2
	n	24	24	89	89	24	24	18	18
Potable Water (Composite) only	$\bar{x}$	32.0	6.0	33.7	5.5	33.8	5.9	33.0	5.1
	D	1.7	0.3	1.1	0.4	2.0	1.1	1.0	0.2
	n	3	3	16	16	3	3	3	3
Sewage (Composite) only	$\bar{x}$	32.5	1.1	33.9	0.9	32.8	1.1	33.8	0.8
	s	2.1	0.2	1.1	0.4	1.3	1.1	0.8	0.4
	n	2	2	16	16	6	6	3	3
Waste Outfall	$\bar{x}$	26.4	6.9	27.3	6.6	--	--	27.5	6.7
	s	0.5	0.4	1.6	0.5	--	--	0.7	0.2
	n	6	6	13	13	0	0	2	2

Temp. in °C and D.O. in mg/ℓ.

TABLE 17. PERCENT DISSOLVED OXYGEN SATURATION FOR MEAN TEMPERATURE

	Baseline	Operational	Interim	Post-Operational
Wharf[a]	106	99	99	101
Saltwater intake[a]	108	101	103	103
Potable water	81	76	82	70
Sewage	15	13	15	11
Waste outfall[a]	99	96	--	99

(a) Assumed chloride concentration of 15 ppT.

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100 round trips to Johnston Island, and several pallet loads of air freight, all carried on scheduled air carriers. In addition, a special military flight was sent from Johnston Island to Wright-Patterson to carry samples for TCDD analysis.

4.3.3 Land-Based Incineration of Wood Dunnage

After the Battelle land based environmental monitoring program had concluded, U.S. EPA and U.S. ERDA agreed to permit the burning of wood dunnage on Johnston Island. This dunnage had been contaminated by leaking Orange Herbicide drums. Visual inspection of the wood indicated that less than a third of the wood was contaminated with the HO and was in a dry kindling state. It was estimated by the [redacted] and [redacted] engineers that the dunnage totalled 300 cubic yards. b6 b6

Air Force scientists and engineers on the island designed a temporary, but substantial, incinerator to dispose of the dunnage, plus lab aprons, gloves, tissues and a drum of solvents used to clean glassware (Plate 22). This incinerator was designed to collect the 10-15 knot trade winds common and constant on the extreme northwestern tip of the island. The winds were constricted and made more turbulant by funneling over baffling blocks that were placed into the air flow under the hearth or primary chambers of the incinerator. A steel plate was placed over this charging chamber to intensify the combustion temperatues and to increase the retention time in the chamber as the exhaust gases traversed the glowing steel plate into stack boxes in the rear of the incinerator. Twin stacks were designed to permit sufficient air flow rates and to enhance the draw and to reduce the potential of a snuffing or a temporary flame out during a charging operation. The effective height of the exhaust plume before dispersing in the trade winds was designed for approximately 20 feet of vertical rise before horizontal displacement and dispersion began.

The incinerator was located in an ideal, tip of the island at a downwind location. A meteorological station was located nearby to the incinerator. This facility was used to record wind speed and direction data. Battelle's analytical laboratory staff reported that the fire during the first 20 minutes permitted some gray particulate matter to emit. After the initial ignition the plume was reported to diminish to a light gray-white exhaust stream as the combustion temperature increased (Plate 23).

Due to the reported twisting and sagging of the steel incinerator roof plates, it is estimated that the temperatures were as high as 2500 F. The fire was continually batch loaded to maintain the temperature in the block and steel incinerator chamber.

The Air Force scientists placed high volume air particulate samplers in the near geographic area of the incinerator and the results are shown in Table 18. Hi-volume samplers ran for 3 hrs at indicated flow (nominal) rates.

TABLE 18. AIR FORCE HI-VOLUME SAMPLER RESULTS OF HO DUNNAGE BURN, SEPTEMBER 10, 1977

Sample Code No.	Location	2,4-D ng/m^3	2,4,5-T ng/m^3	Sampled Air m^3
SDW 09577	Outside Analytical Laboratory Bldg. 6	11.6*	11.3*	214
SDW 09577	100 yards downwind on beach terrace	8.5*	11.1*	178
SDW 09577	100 yards downwind on beach terrace	87.3	174.6	280

* These are within the range of normal background values for unextracted filter paper used with the hi-volume samplers.

The detection limit for 2,4-D and 2,4,5-T was 0.1 μg/sample. As can be seen by the data the concentrations of 2,4-D and 2,4,5-T associated with particulates are extremely low and such loadings should not have adversely impacted the seas west of Johnston Island.

The ash value suggests that the burn was successful in combusting the HO in the wood dunnage.

4.3.4 Social and Economic Impact

It was anticipated that the influx of the disposal staff might cause some dislocations with the island staff, due to competition for limited recreational facilities. This was not observed.

5. RELATIONSHIP BETWEEN LOCAL SHORT TERM USES OF JOHNSTON ISLAND TO LONG TERM IMPACTS

Had the US Air Force been unable to implement the at-sea incineration disposal action, other disposal methods and/or recontainerizing of the stored HO would have been necessary. Such alternative actions would have been implemented as a matter of Air Force environmental protection policy. The following discussion delineates the long term environmental impacts resulting from completion of the HO disposal operations.

5.1 Air

The removal of HO resulted in air emissions and, thus, detectable air concentrations of 2,4-D and 2,4,5-T at several sites. The most predominantly affected area was that of the drum storage yard where local concentrations were as high as 30-40 ug/m^3. In addition, smaller concentrations were measured at the wharf site, at the meteorological station, and in the change room. Furthermore, the tomato plants delineated a plume of HO vapors downwind of the drum storage yard. All of these concentrations, except downwind of the drum storage yard, were transient in nature with significant decreases observed when dedrumming operations ceased. The concentrations downwind of the barrel yard are expected to decrease with time as the HO contaminated soil weathers.

5.2 Water

Orange Herbicide dedrumming and transfer operations resulted in measurable short term concentrations of 2,4-D and 2,4,5-T at the wharf, saltwater intake, and in the sewage effluent. The highest concentrations were associated with the deballasting of the M/V Vulcanus and on at least one occasion resulted in herbicide concentrations in excess of recommended aquatic life criteria. All of the observed concentrations were transient. The thermal destruction of the herbicide stocks created conditions for the eventual return of the water environment to its prior state.

5.3 Land

Very little land in addition to the storage area was used for disposal purposes. Rather, approximately 120,000 square meters of land were evacuated of drums and, after reclamation, will be available for other uses.

A small part of the drumyard was used for storage of the crushed drums. The crushed drums have been removed from the island for recycling.

5.4 Biota

No adverse impacts on the biota of Johnston Atoll were noted as a result of the disposal operations. It is possible that, had the disposal operation not been completed, an accident of some kind may have caused the release of hazardous quantities of herbicide from the drum storage yard into the ecosystem of the Atoll.

5.5 Summary

The short term use of Johnston Island made use of existing facilities and equipment, and the largest impact was that of an accelerated release of HO into the Atoll environment. No consequences of that release, which was minimal, were observable or expected.

This impact must be compared to the alternative of no action. Had the at-sea or an alternative disposal operation not been conducted, the drums containing the HO could have continued to leak into the Atoll environment. Battelle estimates that about 6250 lbs of HO were released into the environment (mostly through volatilization) during the dedrumming activities. In comparison, drum leakage was causing as much as 49,000 lbs of HO to escape to the environmental each year.

6. MEASURES TO MITIGATE ENVIRONMENTAL IMPACTS

Since the whole thrust of project Pacer HO was to eliminate the stocks of HO in an environmentally safe manner, this section is somewhat redundant. Basically, the efforts to mitigate adverse environmental impacts of the land based operation occurred in several areas.

6.1 Drum Yard

The dedrumming crew was alerted to notice the existence of leaking drums. Fresh leakers were pulled out and dedrummed immediately. Where fresh spillage was noted, it was sorbed and surface soil was scraped and sealed.

6.2 Dedrumming Facility

The floors of the facility were frequently mopped with a solvent to prevent a buildup of HO on the concrete floor, and subsequent tracking into the barrel yard.

6.3 Change Building

The use of boots at the site and the use of the showers in the change facility prevented the spread of the HO over the island by the dedrumming crew. All the buses and the cleanup facility used by the dedrumming crew were decontaminated after the project.

6.4 HO Transfer

From the dedrumming facility, the HO was transferred into R-5 refuelers, transported to the ship, and pumped into the ship. At both transfer points, zero volume connectors and catchment basins avoided any spillage of HO. The pump at the dockside was located with a plastic lined sump constructed of sandbags, in case of catastrophic pump failure. The equipment was kept at the wharf in case of fires. The refueler pumps were bypassed to avoid contamination and deterioration of pump seals. Finally, the road used by the R-5's, the wharf, and the drum yard were closed to non-Pacer HO project personnel.

6.5 Cleanup

At the end of the project, all of the equipment, starting at the dedrumming facility, was flushed with diesel fuel, which was then loaded on the M/V Vulcanus. Thus, the island was left nearly clean of HO.

6.6 Site Reclamation

A monitoring program has been instituted by the Air Force to track the degradation of HO residue in the coral soil of the drumyard. Through time, it is anticipated that evapo-transpiration, weathering, and microbial action will work to reduce HO levels to biologically and ecologically safe levels. This program will monitor soil concentration until such levels are reached.

This monitoring program is in response to the leackage of drums over the years, and not to the minimal soil contamination which occurred as a result of Pacer HO.

7. UNAVOIDABLE ADVERSE ENVIRONMENTAL DEFECTS

The operations at Johnston Island were remarkable in that no acute impacts of HO releases from operations were noted, nor were concentrations high enough to produce observable ecological stresses. This section is presented to discuss those features of the operations which produced unavoidable effects on the air or water of Johnston Island.

7.1 Air

By far the largest release of HO occurred to the atmosphere. This was due to the large surface area of exposed HO, both within the dedrumming facility and in leak areas in the barrel yards. Battelle has estimated the total quantity released to the atmosphere to be around 6,000 lbs. Since much of this was from fresh exposure of old leakage and from crushing drums, the release was unavoidable.

7.2 Water

Approximately four-hundred and thirty grams of HO were discharged through the sewage system to the open ocean as an unavoidable consequence of the need to wash work clothing.

7.3 Land

The operations to remove HO from Johnston Island produced almost no spillage to land areas. Only the soil immediately surrounding the crusher and dedrum facilities were slightly and unavoidably contaminated.

8. SUMMARY AND CONCLUSIONS

8.1 General Summary

The disposal operations of dedrumming, hauling, and transferring the Orange Herbicide to the M/V Vulcanus had negligible impact upon the local marine and surface terrestrial environment of Johnston Island. This observation is specific to the herbicide disposal operations of July 27 through August 24, 1977.

8.2 Weather Observations

Weather conditions were such that the wind was consistently from the east at significant velocities (10 to 20 knots). With the dedrumming activities located on the west and north corner of the island, and the ship on the north side, the prevailing air currents carried released herbicide rapidly away from the atoll without exposing the biota on Johnston Island or on the three other islands of the atoll, which lie to the east.

8.3 Ambient Air Observations

In order to determine the impact of dedrumming and transfer operations on the air environment, four monitoring areas were chosen for sampling. These were the meteorology building (located 2 miles upwind for use as a background station), the wharf (300 feet downwind of the loading area), the dedrum facility (to determine occupational exposures), and as an absorbing medium were located at each site for the detection of TCDD. Chromosorb samples were also taken at each site for immediate analysis for 2,4-D and 2,4,5-T. The benzene samples were analyzed at Wright State University. No TCDD was detected in any analyzed samples. The chromosorb samples taken over the duration of dedrumming and transfer operations yielded the following observations:

- Concentrations in samples taken at the upwind meteorology building ranged from levels below detection to trace amounts (less than 1 microgram per cubic meter).
- There was little difference between data recorded at the meteorology building and that at the wharf. The impact on air due to the loading procedure at the wharf was negligible.
- Total herbicide* concentrations detected 310 feet downwind of the dedrum site ranged from 3 to 23 micrograms per cubic meter. Concentrations inside the dedrum facility were only slightly higher, from 7 to 27 micrograms per cubic meter. These concentrations produced negligible impacts.

8.4 Water Quality Observations

Six water sampling locations were utilized for environmental impact assessment throughout the operation. Four of these sampling sites were located immediately offshore of significant land-based activities. The location and analytical results of these sites are briefly summarized here. Levels of herbicide in water samples were generally at or below detectable limits. Of those samples analyzed for TCDD, none were found to contain any TCDD or trace of TCDD.

8.4.1 Saltwater Intake

The water in the vicinity of the intake for the desalination plant was monitored on a daily basis. The level of herbicide ranged from below detection limits (.1 ppb) to 3.43 ppb*. Over 60 percent of the samples analyzed had concentrations below the quantification limit of the analytical method 0.2 ppb. The measured concentrations, including the maximum observed concentration, were well below the applicable standards for human consumption or aquatic life propagation.

8.4.2 Potable Water

Samples taken before the operation showed no detectable concentrations. During the operation, herbicide concentrations* were found at

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* Concentration is reported as sum of 2,4-D and 2,4,5-T.

or below trace levels (below 0.2 ppb) in 100 percent of the samples. Measured concentrations were insignificant in comparison with current drinking water standards of 100 ppb.

8.4.3 Sewage Outfall

Water samples were taken on alternating days in proximity to the sewage outfall, which is approximately 550 feet offshore. Only trace levels of either 2,4-D or 2,4,5-T (less than 0.1 to 0.2 ppb) were detected in the samples analyzed. This was of no significance to the aquatic life because the area of adverse impact due to the sewage itself was larger than that of the herbicide.

8.4.4 Raw Sewage

The sewage samples, contaminated from the washing of work clothes showed concentrations of herbicide of from 20.7 ppb to 137.8 ppb*. A total of 0.94 lbs of herbicide was released into the sewage system. The effects of this release, if any, were mitigated by the intermittent nature of the discharge and by the dispersing effect of the currents.

8.4.5 Dedrum

Water samples were taken offshore and downwind of the dedrum facility four times during the operation. One sample contained trace levels of 2,4,5-T while all other samples analyzed had no detectable levels. These concentrations were insignificant.

8.4.6 Wharf

Water samples were taken on a daily basis in the vicinity of the wharf, which included special grab samples during the two deballasting periods

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* Concentration reported as sum of 2,4-D and 2,4,5-T.

from the M/V Vulcanus. The water in the immediate vicinity (10 feet) of the deballast discharge contained levels of herbicide* that ranged from below detection to 8,116.7 ppb. The concentrations of HO in the composited water samples at the wharf in the days following the deballasting substantiated an effective dilution process. The concentrations of herbicide dropped from 8,116.7 to 1.90 to 0.75 ppb in the 2 days following the second deballast period. Including the deballasting periods, the concentrations of both 2,4-D and 2,4,5-T stayed below 0.2 ppb (trace) in over 50 percent of the samples taken. Although some concentrations exceeded the upper water quality criterion of 5 ppm by a significant margin, the concentrations were transient and no acute toxic symptoms were noted.

8.5 Biological Observations

8.5.1 Tomato Plant Bioassay

Three days of preoperational observations indicated that concentrations of Orange Herbicide sufficient to cause injury to tomato plants (*Lycopersicon esculentum*), a species sensitive to herbicide at the low parts per trillion level, only at two of 14 stations. These two stations were approximately 500 feet from the dedrumming site and directly downwind. During the operation, these two stations experienced the most frequent and most severe injury. Occasional damage was experienced at two peripherally located downwind stations.

8.5.2 Vegetation Survey

During this study, no significant physical or morphological changes were noted in any indigenous plant species on Johnston Island which could be attributed to the effects of Orange Herbicide.

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* Concentration reported as sum of 2,4-D and 2,4,5-T.

8.5.3 Bird Survey

Observations were made of the bird population on Sand Island both before and during the operation. These observations indicated that there were no effects upon the bird population which could be attributed to the Orange Herbicide disposal operations.

8.6 Industrial Hygiene Observations

The analytical results on air samples for Orange Herbicide (2,4-D and 2,4,5-T) show that personnel exposures were two to three orders of magnitude below the TLV for the acid (10 mg/cubic meter).

The Holmes and Narver, Inc. log of injuries is in agreement with the Air Force record on potentially significant injuries as follows:

- HO in eye - 2
- Cut finger - picket knife - 1
- Slip while cleaning dedrum area - 2
- Finger caught between empty drums - 1
- Walked into brush handle (groin) - 1.

There was one dermatitis case diagnosed as nonoccupational.

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PLATE 2. VIEW OF EMPTY DRUMYARD SHOWING OBSERVATION WELL

PLATE 1. AERIAL VIEW OF JOHNSTON ISLAND, SHOWING INCOMPLETE REEF

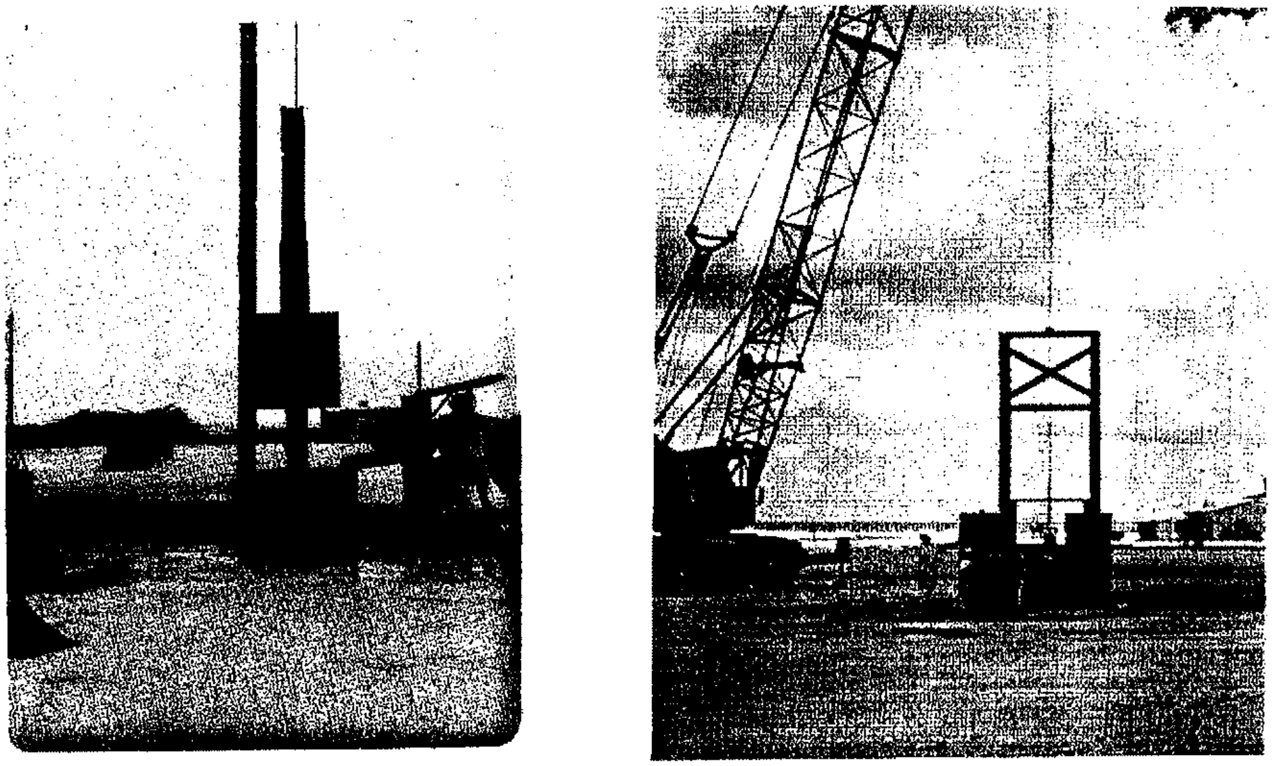

PLATE 3. TWO VIEWS OF DRUM CRUSHER. LEFT HAND VIEW SHOWS STANDING WATER IMMEDIATELY AFTER SHOWER, AND STAIN FROM RESIDUAL DIESEL FUEL EXPELLED FROM DRUMS

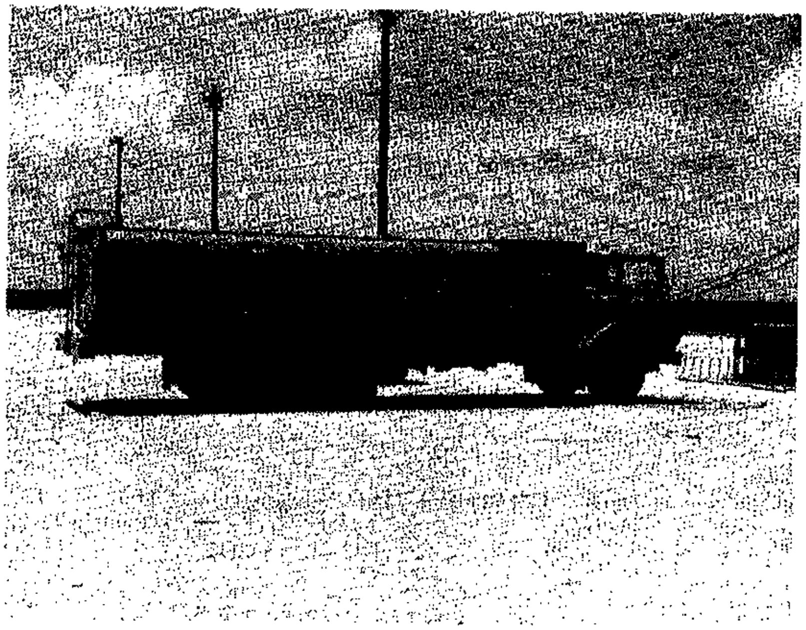

PLATE 4. R-5 REFUELER. NOTICE HO IDENTIFICATION ON TANK

PLATE 5. DIKED AREA. SPILLS OF SEVERAL HUNDRED GALLONS COULD BE CONTAINED WITHIN THE PLASTIC LINED AREA

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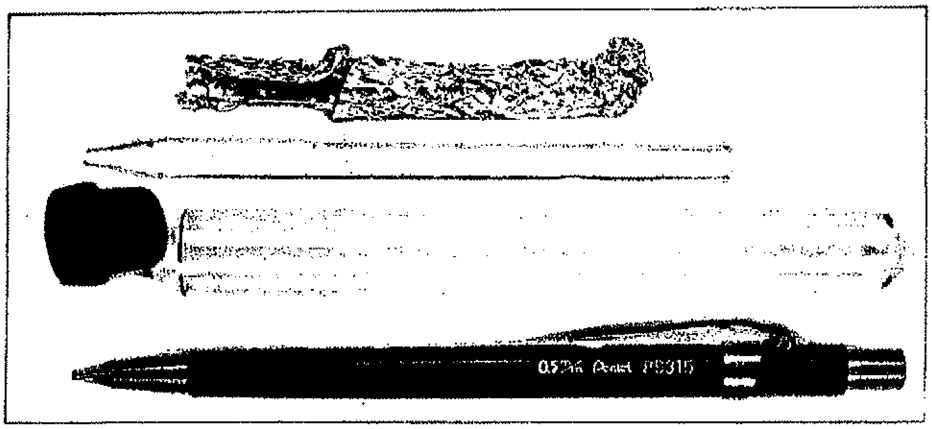


PLATE 6. CHROMOSORB TUBE, ALUMINUM FOIL WRAP, AND STORAGE TUBE. PENCIL ADDED FOR SCALE. CHROMOSORB MATERIAL IN LEFT 1/3 OF TUBE

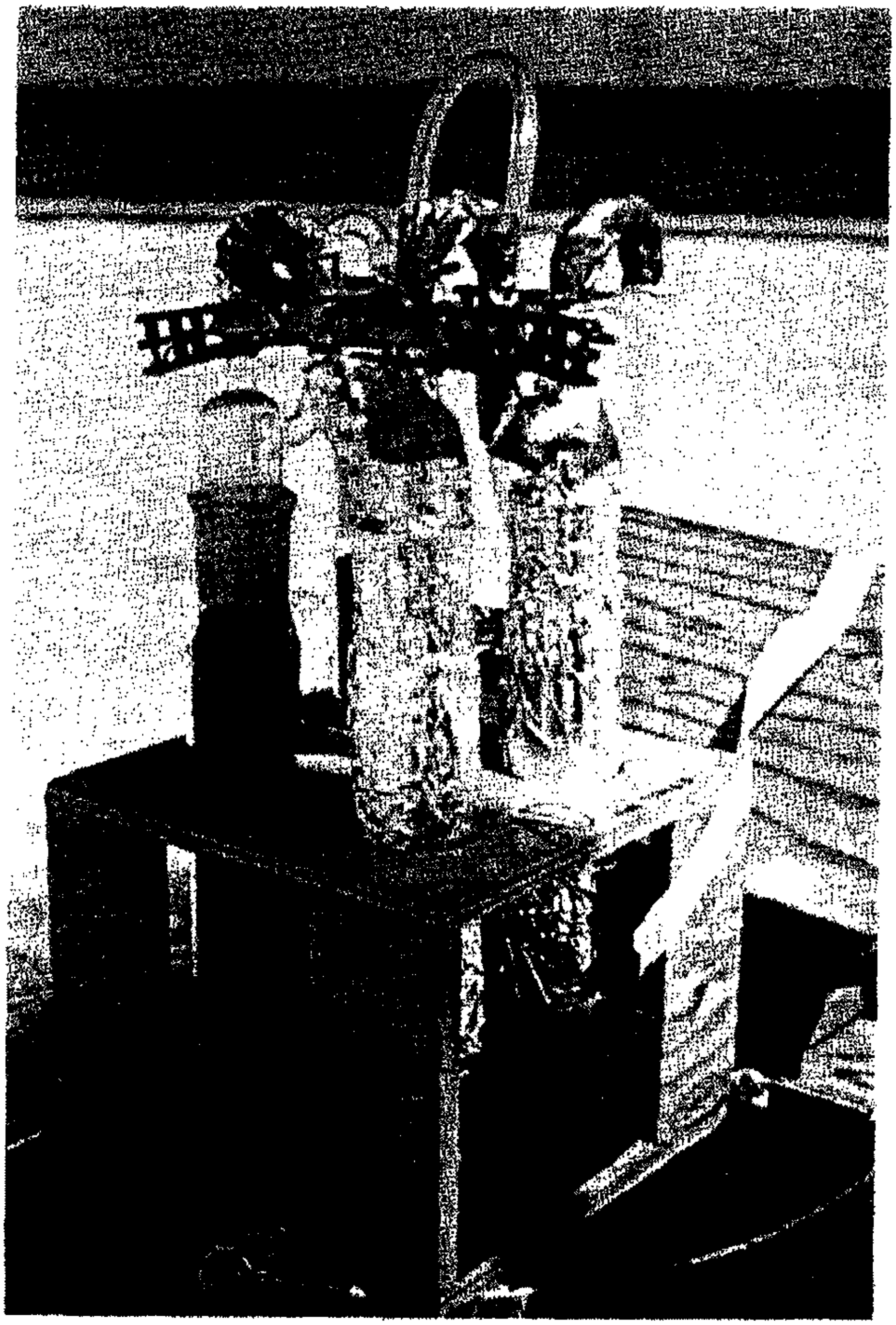


PLATE 7. BENZENE IMPINGER SETUP. BENZENE FLASKS ARE WRAPPED IN ALUMINUM FOIL TO PREVENT PHOTO-DECOMPOSITION OF TRAPPED SPECIES

PLATE 8. WATER SAMPLING LOCATION OFF SHIP BOW. ANOTHER SITE WAS LOCATED APPROXIMATELY 10 METERS OFF THE BOW

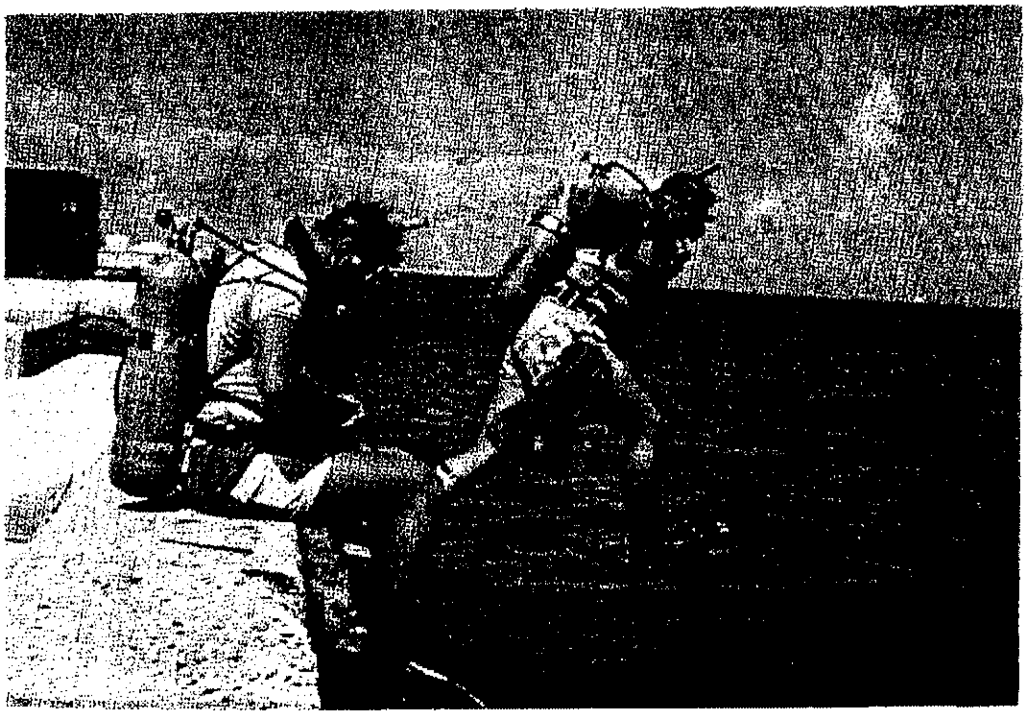
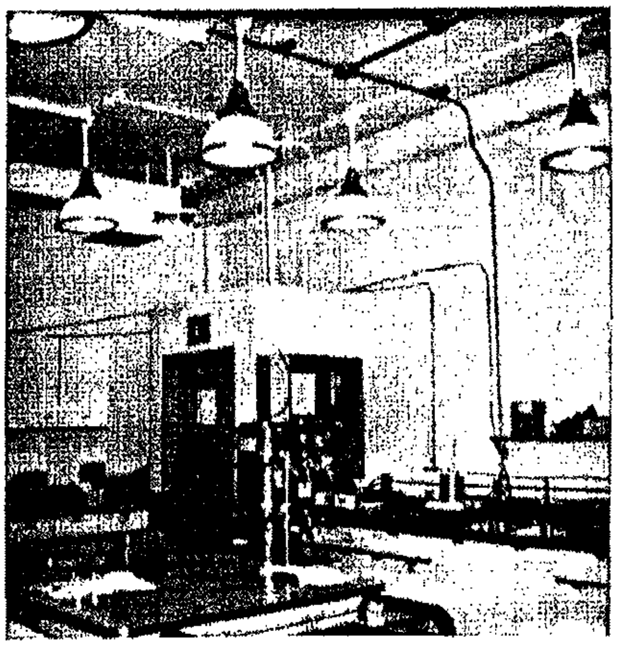


PLATE 9. SEDIMENT SAMPLING. SCUBA GEAR REQUIRED BECAUSE OF DEPTH. OBSERVATION OF DIVERS LED TO UNDERSTANDING OF SURSURFACE CURRENTS



PLATES 10, 11, 12. WATER AND CHROMOSORB
PREPARATION LABORATORY

PLATE 13. SAFETY EQUIPMENT. TAKEN IN DEDRUM FACILITY, SHOWING RESPIRATOR, FACE SHIELD, GLOVES AND APRON

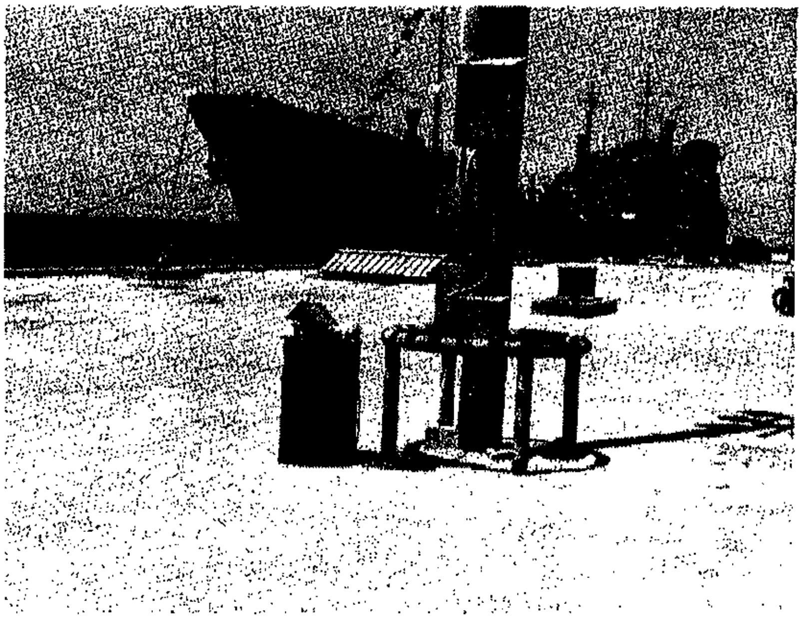


PLATE 14. WHARF AIR SAMPLE SITE. WIND DIRECTION, QUARTERING BOW, EVIDENT FROM FLAGS

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PLATE 17. TOMATO PLANTS WITH LEVEL 2
INJURY (TIP CURLING)

PLATE 18. TOMATO PLANT WITH LEVEL 3
INJURY (STEM CURLING)

PLATE 19. TOMATO PLANT WITH LEVEL 4
INJURY (SEVERE CURLING)

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PLATE 20. NATIVE FLORA DOWNWIND OF DRUMYARD. TOMATO PLANT LOCATION IN BACKGROUND

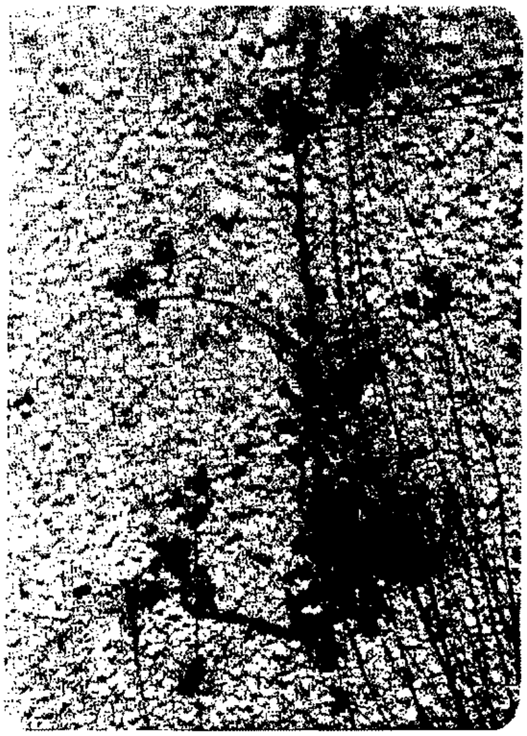

PLATE 21. EPINASTIC GROWTH IN NATIVE FLORA (OBSERVED PRIOR TO PACER HO PROJECT)

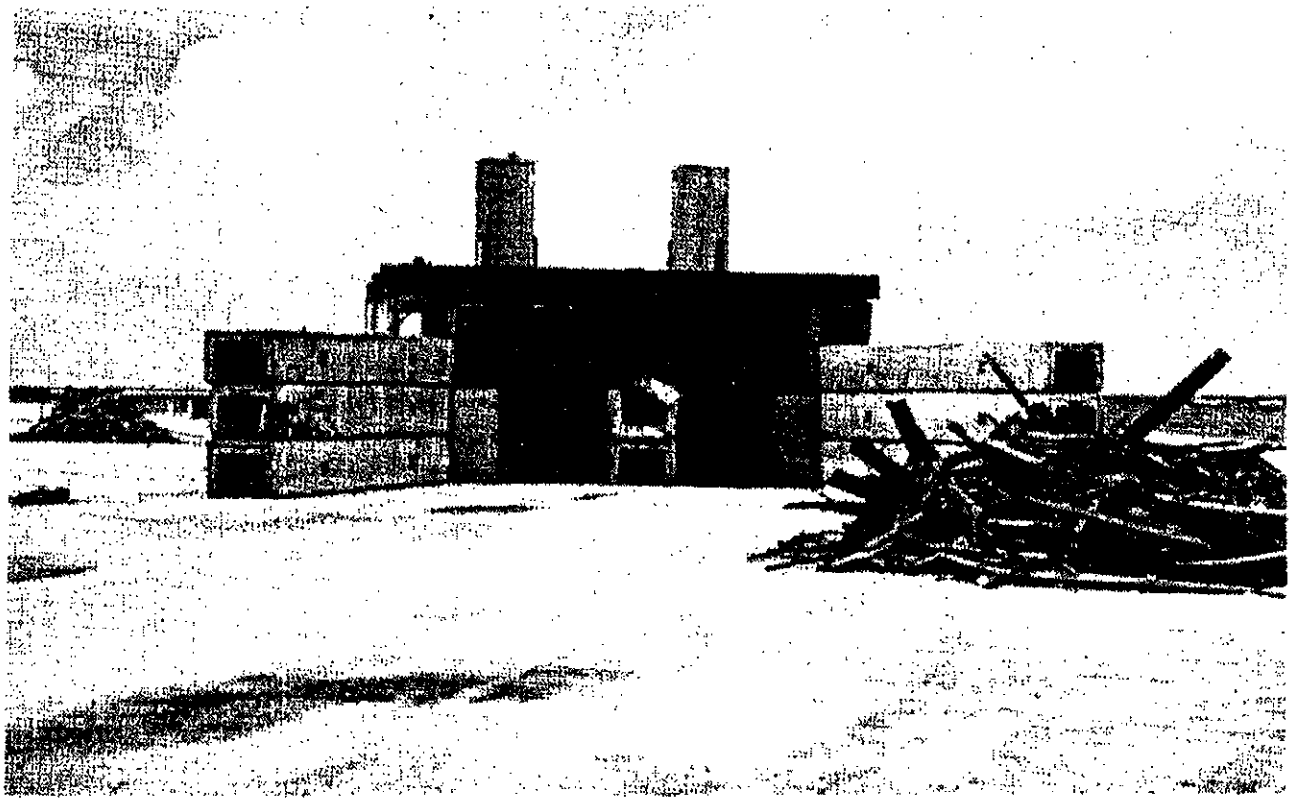

PLATE 22. INCINERATOR FOR WOOD DUNNAGE

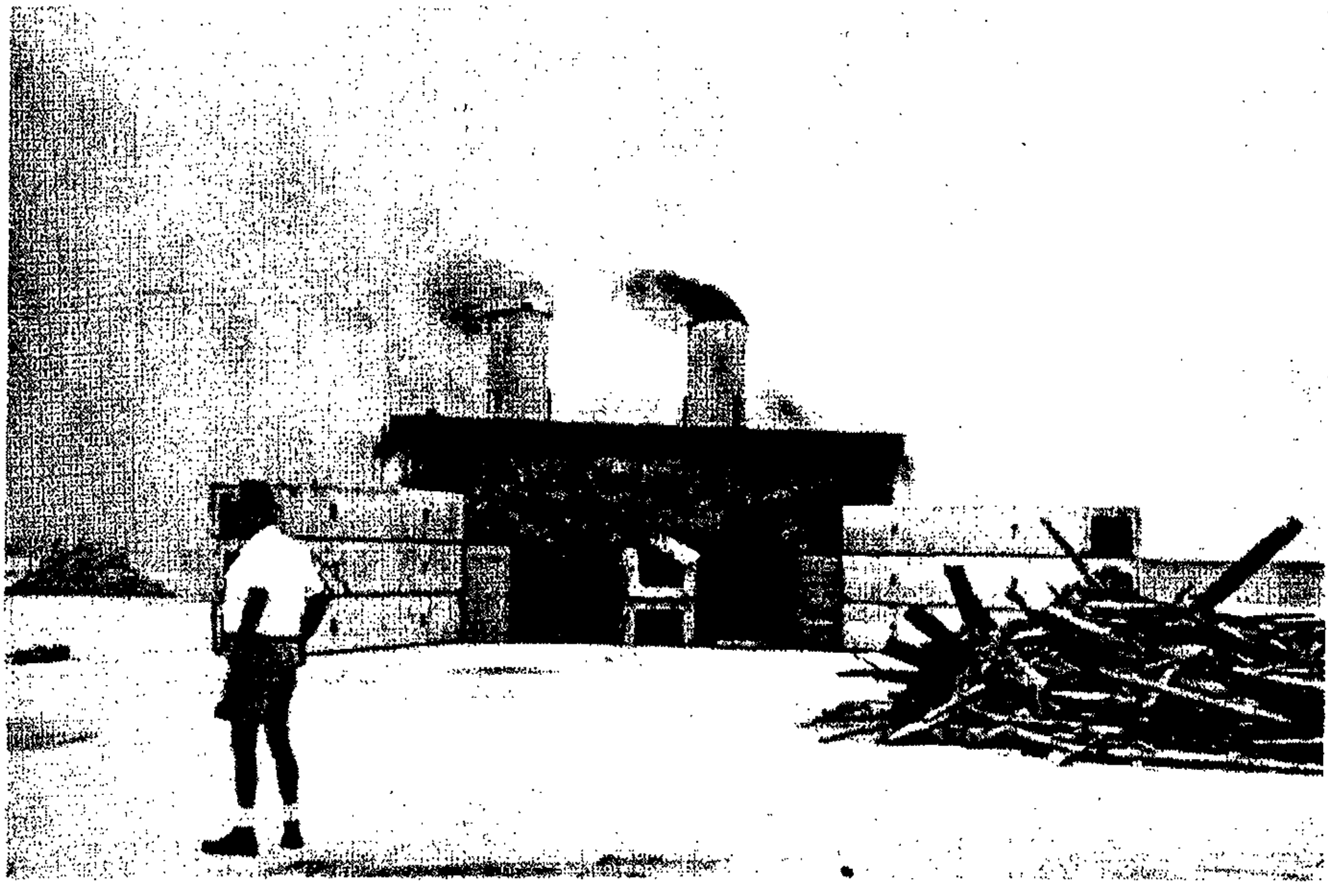

PLATE 23. TYPICAL OPERATION OF INCINERATOR

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USAF CEEDO TR-78-38

FINAL REPORT

on

LAND BASED ENVIRONMENTAL MONITORING AT JOHNSTON ATOLL - DISPOSAL OF HERBICIDE ORANGE

to

U.S. AIR FORCE OCCUPATIONAL AND
ENVIRONMENTAL HEALTH LABORATORY

September, 1978

PART III

by

[redacted] 66

U.S. Air Force Project Officer: [redacted] Maj., USAF

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Columbus, Ohio 43201

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DETAILED ENVIRONMENTAL ANALYSIS OF PROJECT PACER HO

1. INTRODUCTION

This report is part III of a 3-part report on the environmental consequences of a project conducted on Johnston Island, labeled Project Pacer HO, designed to remove and incinerate the stocks of Herbicide Orange stored on Johnston Island since 1972. The three parts to the report are as follows:

Part I	Executive Summary
Part II	Detailed Environmental Analysis
Part III	Supporting Raw Data

The Part III report is concerned only with the reporting of raw data and substantiating evidence collected at the site. No interpretation of results is provided within this report. The report is organized as follows:

1. Introduction
2. Air Monitoring Data
3. Water Monitoring Data
4. Biota Data
5. Analysis

Detailed data in each area are provided below.

2. AIR

Air samples were collected and analyzed by Battelle for the period July 24, 1977 through August 26, 1977. Both Chromosorb tubes and benzene impinger samples were collected, with the intention being for the analysis of 2,4-D and 2,4,5-T concentrations by Battelle Laboratory of the Chromosorb samples and the analysis of the benzene samples by another laboratory for 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). Tables 1 through 5 present all of the air samples

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TABLE 1. AIR SAMPLES DURING THE PREOPERATIONAL PERIOD

Sample Number (Code)	Time on (Min)	Flow (Lit/Min)	Volume Sampled (Liters)	Concentration of 2,4-D ($\mu g/m^3$)	Concentration of 2,4,5-T ($\mu g/m^3$)
AM24Y709W	265	1.0	265		
CM24Y709J	355	0.50	117.5	ND	ND
AW24Y709W	265	1.0	265		
CW24Y709J	355	0.50	117.5	ND	ND
AD24Y709W	230	1.0	230		
CD24Y709J	330	0.50	165	Trace	Trace
AB24Y709W	270	1.0	270		
AM25Y709W	275	1.0	275		
CM25Y709J	285	0.50	142.5	ND	ND
AW25Y709W	265	1.0	265		
CW25Y709J	310	0.50	155	ND	Trace
CC25Y709J	310	0.50	155	ND	ND
AB25Y709W	260	1.0	260		
AD25Y709W	265	1.0	265		
CD25Y709J	260	0.50	130	Trace	Trace
AM26Y709W	250	1.0	250		
CM26Y709J	325	0.50	162.5	ND	Trace
AW26Y709W	320	1.0	320		
CW26Y709J	320	0.50	160	ND	ND
AD26Y709W	240	1.0	240		
CD26Y709J	240	0.50	120	0.23	1.48
AB26Y709W	235	1.0	235		
CN26Y709J	185	0.50	92.5	Trace	Trace
CS26Y709J	185	0.50	92.5	0.57	1.60
CP26Y709J	185	0.50	92.5	0.75	1.87
CP27Y707J	500	0.50	250		
CS27Y707J	488	0.50	244		
CN27Y707J	479	0.50	239.5		
CD27Y708J	482	0.50	241		
CW27Y708J	483	0.50	241.5		
AW27Y708W	166	1.0	166		
CM27Y708J	465	0.50	232.5		
AM27Y708W	250	1.0	250		
AM27Y719W	300	1.0	300		

TABLE 2. AIR SAMPLES DURING FIRST LOAD

Sample Number (Code)	Time on (Min)	Flow (Lit/Min)	Volume Sampled (Liters)	Concentration of 2,4-D (μg/m^3)	Concentration of 2,4,5-T (μg/m^3)
CM27Y719J	480	0.50	240	--	Trace
AW27Y719W	295	1.0	295		
CW27Y719J	470	0.50	235	--	Trace
AD27Y719W	325	1.0	325		
CD27Y719J	590	0.50	295	0.82	1.92
AB27Y719W	310	1.0	310		
CS27Y719J	580	0.50	290	6.92	12.80
CN27Y719J	580	0.50	290	2.26	4.79
CP27Y719J	570	0.50	285	Trace	0.50
CM28Y707J	231	0.50	115.5	--	Trace
AM28Y707W	222	1.0	222		
CW28Y708J	234	0.50	117	--	Trace
AW28Y708W	182	1.0	182		
CD28Y709J	288	0.50	144	2.78	5.42
AD28Y709W	274	1.0	274		
CS28Y709J	255	0.50	127.5	8.60	16.00
AB28Y709W	248	1.0	248		
CN28Y710J	252	0.50	126	8.28	18.33
CP28Y710J	247	0.50	123.5	--	--
AM28Y719W	295	1.0	295		
CM28Y719J	435	0.50	217.5	--	Trace
AW28Y719W	285	1.0	285		
CW28Y719J	425	0.50	212.5	--	Trace
AD28Y719W	300	1.0	300		
CD28Y719J	525	0.50	262.5	1.17	2.36
AB28Y719W	305	1.0	305		
CN28Y719J	510	0.50	255	3.19	6.84
CS28Y719J	510	0.50	255	8.84	15.72
CP28Y719J	510	0.50	255	--	2.58
PP29Y707J	268	0.50	134	4.18	9.23
PV29Y707J	265	0.50	132.5	8.44	16.84
PX29Y707J	263	0.50	131.5	8.62	15.74
AB29Y707W	278	1.0	278		

TABLE 2. (Continued)

Sample Number (Code)	Time on (Min)	Flow (Lit/Min)	Volume Sampled (Liters)	Concentration of 2,4-D (μg/m³)	Concentration of 2,4,5-T (μg/m³)
CD29Y707J	235	0.50	117.5	1.98	2.89
AD29Y707W	230	1.0	230		
CW29Y708J	298	0.50	149	Trace	Trace
AW29Y708W	282	1.0	282		
CM29Y708J	287	0.50	143.5	---	--
AM29Y708W	283	1.0	283		
AD29Y722W	240	1.0	240		
CD29Y722J	240	0.50	120	0.91	2.18
AD30Y708W	304	1.0	304		
CD30Y708J	301	0.50	150.5	2.39	5.89
AD30Y719W	280	1.0	280		
CD30Y719J	585	0.50	292.5	1.02	2.14
AB30Y719W	275	1.0	275		
PP30Y719J	225	0.50	112.5	2.43	6.11
PT30Y719J	240	0.50	120	0.57	2.14
PU30Y719J	240	0.50	120	11.77	26.03
AW31Y701W	280	1.0	280		
CW31Y701J	280	0.50	140	ND	0.73
AM31Y701W	285	1.0	285		
CM31Y701J	285	0.50	142.5	ND	0.39
AW31Y708W	232	1.0	232		
CW31Y708J	230	0.50	115	ND	0.67
AM31Y708W	269	1.0	269		
CM31Y708J	267	0.5	133.5	ND	0.67
AB31Y707W	291	1.0	291		
PP31Y707J	259	0.50	129.5	5.09	11.81
PT31Y707J	247	0.50	123.5	12.33	23.29
PU31Y707J	250	0.50	125	3.79	7.64
AD31Y707W	252	1.0	252		
CD31Y707J	251	0.50	125.5	1.71	3.24
AD31Y719W	290	1.0	290		
CD31Y719J	290	0.50	145	1.48	3.37
CD02T709J	262	0.50	131	4.14	7.58

TABLE 2. (Continued)

Sample Number (Code)	Time on (Min)	Flow (Lit/Min)	Volume Sampled (Liters)	Concentration of 2,4-D ($\mu g/m^3$)	Concentration of 2,4,5-T ($\mu g/m^3$)
AD02T709J	187	1.0	187		
AD02T719W	285	1.0	285		
CD02T719J	285	0.50	142.5	1.33	3.79
AB02T719W	275	1.0	275		
PP02T719J	230	0.50	115	11.48	26.78
PT02T719J	210	0.50	105	9.71	20.57
PU02T719J	210	0.50	105	11.05	22.00
AM03T701W	290	1.0	290		
CM03T701J	290	0.50	145	ND	0.62
AW03T701W	290	1.0	290		
CW03T701J	290	0.50	145	ND	0.69
PP03T707J	245	0.50	122.5	8.41	17.88
PU03T707J	239	0.50	119.5	8.20	16.90
PT03T707J	233	0.50	116.5	6.01	12.53
CD03T707J	241	0.50	120.5	2.57	6.31
AD03T707W	199	1.0	199		
AB03T707W	256	1.0	256		
CW03T708J	294	0.50	147	ND	1.09
AW03T708W	290	1.0	290		
AM03T708W	289	1.0	289		
CM03T708J	286	0.50	143	ND	1.12
				ND	ND
AD03T719W	265	1.0	265		
CD03T719J	265	0.50	132.5	2.87	7.02
AB03T719W	265	1.0	265		
PZ03T719J	200	0.50	100	13.00	24.70
PQ03T719J	200	0.50	100	9.90	19.40
AM04T701W	270	1.0	270		
CM04T701J	270	0.50	135	ND	Trace
AW04T701W	270	1.0	270		
CW04T701J	270	0.50	135	ND	Trace
PX04T707J	211	0.50	105.5	8.34	19.05
PV04T707J	209	0.50	104.5	7.27	15.50
AB04T707W	253	1.0	253		

TABLE 2. (Continued)

Sample Number (Code)	Time on (Min)	Flow (Lit/Min)	Volume Sampled (Liters)	Concentration of 2,4-D ($\mu g/m^3$)	Concentration of 2,4,5-T ($\mu g/m^3$)
AD04T707W	241	1.0	241		
CD04T707J	241	1.0	120.5	3.98	9.05
AW04T708W	278	1.0	278		
CW04T708J	276	0.50	138	ND	Trace
AM04T708W	195	1.0	195		
CM04T708J	272	0.50	136	ND	Trace
AD04T719W	255	1.0	255		
CD04T719J	255	0.50	127.5	2.51	5.80
AB04T719W	255	1.0	255		
PZ04T719J	200	0.50	100	13.60	26.00
PR04T719J	200	0.50	100	16.10	30.80
AW05T701W	260	1.0	260		
CW05T701J	260	0.50	130	ND	Trace
AM05T701W	265	1.0	265		
CM05T701J	265	0.50	132.5	ND	Trace
AB05T707W	252	1.0	252		
PU05T707J	227	0.50	113.5	8.37	16.74
PT05T707J	226	0.50	113	7.88	19.20
CD05T707J	230	0.50	115	ND	ND
AD05T707W	230	1.0	230		
CW05T708J	289	0.50	144.5	Trace	Trace
AW05T708W	287	1.0	287		
CM05T708J	286	0.50	143	5.03	8.46
AM05T708W	283	1.0	283		

TABLE 3. AIR SAMPLES DURING INTERIM

Sample Number (Code)	Time on (Min)	Flow (Lit/Min)	Volume Sampled (Liters)	Concentration of 2,4-D ($\mu g/m^3$)	Concentration of 2,4,5-T ($\mu g/m^3$)
AD06T708W	253	1.0	253		
CD06T708J	253	0.50	126.5	3.00	7.27
AM06T708W	258	1.0	258		
CM06T708J	258	0.50	129	ND	ND
AD08T708W	264	1.0	264		
CD08T708J	264	0.50	132	1.97	4.55
AM08T708J	271	1.0	271		
CM08T708J	271	0.50	135.5	ND	ND
AM11T708W	259	1.0	259		
CM11T708J	259	0.50	129.5	ND	ND
AW11T708W	253	1.0	253		
CW11T708J	253	0.50	126.5	ND	ND
				ND	ND

TABLE 4. AIR SAMPLES DURING SECOND LOAD

Sample Number (Code)	Time on (Min)	Flow (Lit/Min)	Volume Sampled (Liters)	Concentration of 2,4-D ($\mu g/m^3$)	Concentration of 2,4,5-T ($\mu g/m^3$)
PT17T713J	184	0.50	92	16.63	27.83
PU17T713J	188	0.50	94	17.77	30.11
AB17T713W	205	1.0	205		
AD17T713W	195	1.0	195		
CD17T713J	195	0.50	97.5	7.08	13.23
AM17T713W	210	1.0	210		
CM17T713J	210	0.43	90	ND	ND
AD17T719W	225	1.0	225		
CD17T719J	285	0.50	142.5	2.74	7.09
AB17T719W	225	1.0	225		
PT17T719J	195	0.50	97.5	20.82	37.74
PX17T719J	195	0.50	97.5	9.44	16.10
AM17T720W	230	1.0	230		
CM17T720J	230	0.50	115	ND	ND
AM18T707W	240	1.0	240		
CM18T707J	240	0.50	120	ND	ND
CD18T707J	475	0.50	237.5	6.95	16.51
PU18T707J	180	0.50	90	15.89	25.56
PX18T707J	171	0.50	85.5	22.22	35.91
AB18T707W	200	1.0	200		
AD18T719W	280	1.0	280		
CD18T719J	280	0.50	140	2.43	7.00
AB18T719W	260	1.0	260		
PX18T719J	225	0.50	112.5	6.49	12.62
PV18T719J	220	0.50	110	8.82	16.36
AM18T720W	315	1.0	315		
CM18T720J	315	0.50	157.5	ND	ND
AB20T707W	300	1.0	300		
PX20T707J	229	0.50	114.5	10.92	17.73
PV20T707J	238	0.50	119.0	10.08	16.39
AD20T707W	300	1.0	300		
CD20T707J	302	0.50	151	4.77	10.99
AM20T708W	317	1.0	317		
CM20T708J	323	0.50	161.5	ND	Trace

TABLE 4. (Continued)

Sample Number (Code)	Time on (Min)	Flow (Lit/Min)	Volume Sampled (Liters)	Concentration of 2,4-D ($\mu g/m^3$)	Concentration of 2,4,5-T ($\mu g/m^3$)
AW20T708W	336	1.0	336		
CW20T708J	336	0.50	168	ND	Trace
AD20T719W	285	1.0	285		
CD20T719J	285	0.50	142.5	1.89	5.33
AB20T719W	290	1.0	290		
PU20T719J	190	0.50	95	22.53	38.00
PR20T719J	205	0.50	102.5	11.41	20.78
AM20T720W	315	1.0	315		
CM20T720J	315	0.50	157.5	1.14	2.54
AW20T720W	270	1.0	270		
CW20T720J	330	0.50	165	Trace	Trace
				ND	ND
AB21T707W	301	1.0	301		
AM21T707W	300	1.0	300		
AW21T707W	300	1.0	300		
AD21T707W	300	1.0	300		
CM21T707J	329	0.50	164.5	ND	ND
PU21T707J	218	0.50	109	9.08	15.96
PX21T707J	159	0.50	79.5	12.70	22.77
CD21T707J	300	0.50	150	5.87	15.27
CW21T707J	300	0.50	150	ND	Trace
AD21T719W	280	1.0	280		
CD21T719J	280	0.50	140	2.21	5.79
AB21T719W	280	1.0	280		
PT21T719J	210	0.50	105	4.57	8.38
PY21T719J	210	0.50	105	6.76	13.24
AW21T720W	295	1.0	295		
CW21T720J	295	0.50	147.5	ND	ND
AM21T720W	295	1.0	295		
CM21T720J	295	0.50	147.5	ND	ND
AB22T707W	300	1.0	300		
AD22T707W	300	1.0	300		

TABLE 4. (Continued)

Sample Number (Code)	Time on (Min)	Flow (Lit/Min)	Volume Sampled (Liters)	Concentration of 2,4-D ($\mu g/m^3$)	Concentration of 2,4,5-T ($\mu g/m^3$)
AW22T707W	300	1.0	300		
AM22T707W	303	1.0	303		
CD22T707J	300	0.50	150	4.67	12.53
CM22T707J	303	0.50	151.5	ND	Trace
CW22T707J	300	0.50	150	ND	Trace
PU22T707J	237	0.50	118.5	11.56	18.90
PX22T707J	216	0.50	108	21.20	40.28
AD22T719W	280	1.0	280		
CD22T719J	280	0.50	140	3.93	10.14
AB22T719W	280	1.0	280		
PX22T719J	190	0.50	95	6.63	14.63
PR22T719J	250	0.50	125	15.36	24.96
AW22T720W	285	1.0	285		
CW22T720J	285	0.50	142.5	Trace	Trace
AM22T720W	280	1.0	280		
CM22T720J	280	0.50	140	Trace	Trace
AB23T707W	98	1.0	98		
AD23T707W	307	1.0	307		
AW23T707W	300	1.0	300		
AM23T707W	300	1.0	300		
CS23T707J	98	0.50	49	7.35	18.78
CN23T707J	97	0.50	48.5	2.27	6.60
CD23T707J	307	0.50	153.5	6.91	14.27
CW23T708J	300	0.50	150	ND	Trace
CM23T708J	246	0.50	123	ND	Trace

TABLE 5. AIR SAMPLES DURING POSTOPERATIONS

Sample Number (Code)	Time on (Min)	Flow (Lit/Min)	Volume Sampled (Liters)	Concentration of 2,4-D (μg/m^3)	Concentration of 2,4,5-T (μg/m^3)
AB23T717W	305	1.0	305		
CS23T717J	305	0.50	152.5	2.96	8.26
CN23T717J	305	0.50	152.5	3.41	8.13
AD23T717W	300	1.0	300		
CD23T717J	300	0.50	150	4.93	9.53
AW23T717W	285	1.0	285		
CW23T717J	285	0.50	142.5	ND	Trace
AM23T717W	290	1.0	290		
CM23T717J	290	0.50	145	Trace	Trace
AB24T707W	300	1.0	300		
AD24T707W	300	1.0	300		
AW24T707W	131	1.0	131		
AM24T707W	300	1.0	300		
CS24T707J	300	0.50	150	1.33	5.00
CN24T707J	300	0.50	150	3.33	8.53
CD24T707J	300	0.50	150	1.60	4.80
CW24T707J	313	0.50	156.5	ND	Trace
CM24T707J	300	0.50	150	ND	Trace
AB24T716W	300	1.0	300		
CS24T716J	300	0.50	150	3.33	10.07
CN24T716J	300	0.50	150	3.27	7.40
AD24T716W	300	1.0	300		
CD24T716J	300	0.50	150	5.40	12.20
AW24T716W	295	1.0	295		
CW24T716J	295	0.50	147.5	Trace	Trace
AM24T716W	295	1.0	295		
CM24T716J	295	0.50	147.5	ND	Trace
AB25T707W	307	1.0	307		
AD25T707W	303	1.0	303		
AW25T707W	300	1.0	300		
AM25T707W	297	1.0	297		
CS25T707J	307	0.50	153.5	2.80	7.88
CN25T707J	305	0.50	152.5	2.75	7.08

TABLE 5. (Continued)

Sample Number (Code)	Time on (Min)	Flow (Lit/Min)	Volume Sampled (Liters	Concentration of 2,4-D (µg/m³)	Concentration of 2,4,5-T (µg/m³)
CD25T707J	303	0.50	151.5	4.22	8.51
CW25T707J	300	0.50	150	ND	ND
CM25T707J	297	0.50	148.5	ND	ND
AB25T716W	300	1.0	300		
CS25T716J	300	0.50	150	*3.20	14.20
CN25T716J	300	0.50	150	*3.60	13.13
AD25T716W	300	1.0	300		
CD25T716J	300	0.50	150	6.60	16.93
AW25T716W	300	1.0	300		
CW25T716J	300	0.50	150	*ND	4.47
CM25T716J	300	0.50	150	*ND	2.93
AB26T707W	294	1.0	294		
AD26T707W	292	1.0	292		
AW26T707W	288	1.0	288		
AM26T711W	300	1.0	300		
CS26T707J	294	0.50	147	*1.43	8.10
CN26T707J	293	0.50	146.5	1.50	4.51
CD26T707J	292	0.50	146	*3.56	23.63
CW26T709J	300	0.50	150	*ND	3.53
CM26T707J	338	0.50	169	*ND	9.88
AW26T716W	305	1.0	305		
CW26T716J	305	0.50	152.5	*ND	3.34
AM26T716W	300	1.0	300		
CM26T716J	300	0.50	150	*ND	4.13

taken, and the results to date, for the preoperational, first load, interim, second load, and postoperational periods.

The code provided for sample identification is straight forward, as discussed below:

First Two Digits

AM	Benzine Impinger at Meteorology Building
AB	Benzine Impinger at Dedrum Downwind Corner
AW	Benzine Impinger at Clock Site
AD	Benzine Impinger Downwind of Dedrum Site
CM	Chromosorb Tube at Meteorology Building
CW	Chromosorb Tube at Dock Site
CC	Chromosorb Tube in Clothing Change Building
CD	Chromosorb Tube Downwind of Dedrum Activities
CN	Chromosorb Tube at Northwest Corner of Dedrum
CS	Chromosorb Tube at Southwest Corner of Dedrum
CP	Chromosorb Tube at East Wall of Dedrum
PP	Personal Sampler on Pump Operator
PR	Personal Sampler on Spray Operator
PX	Personal Sampler on Spray Operator
PY	Personal Sampler on Spray Operator
PU	Personal Sampler on Drum Puncturers
PV	Personal Sampler on Drum Puncturers
PQ	Personal Sampler on Drum Puncturers
PZ	Personal Sampler on Drum Puncturers

Third & Fourth Digits: Day of Month

Fifth Digit: Y July

T August

Sixth & Seventh Digits: Sample Start Time, 24-Hour Local

Eighth Digit: Person Taking Sample

3. METEOROLOGY

The meteorological conditions observed during the project are summarized in Figure 1.

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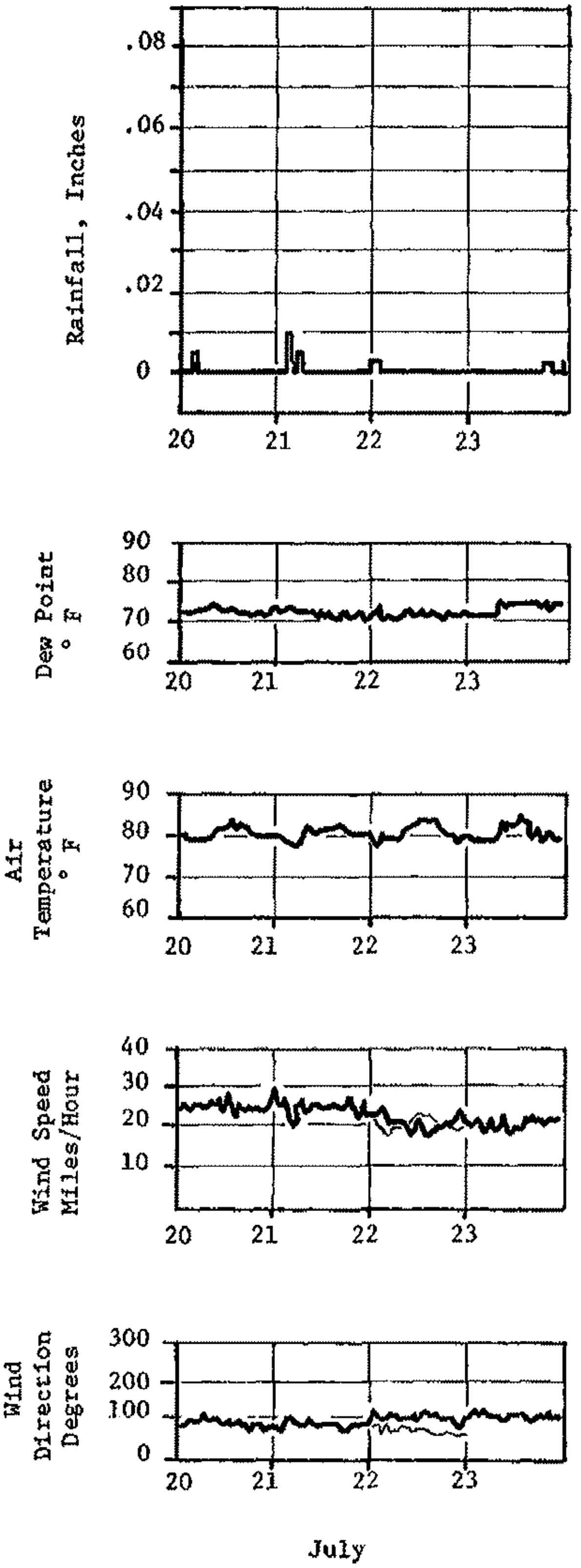

FIGURE 1. WEATHER OBSERVATIONS AT NOAA STATION, 1977

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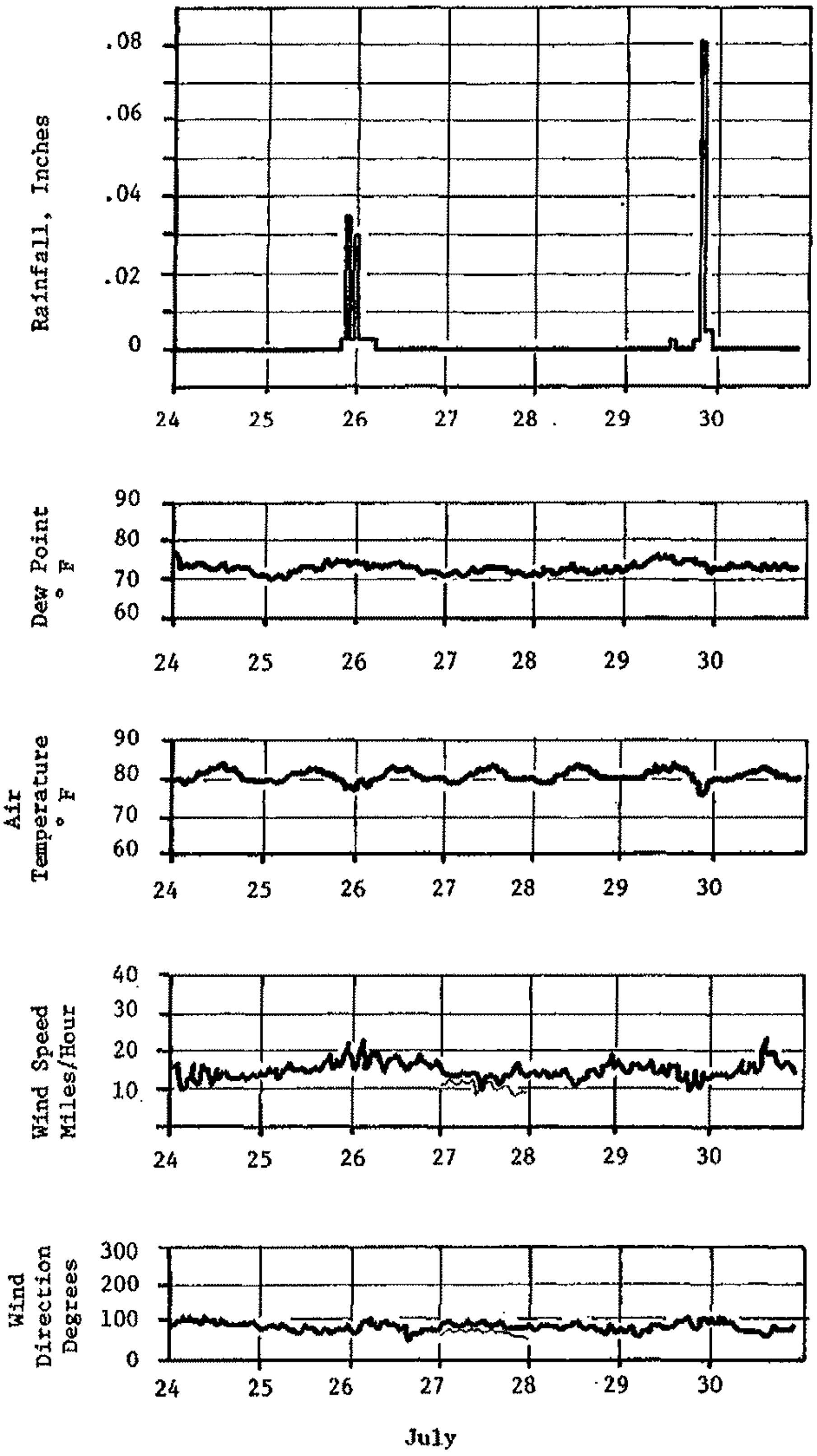

FIGURE 1. (Continued)

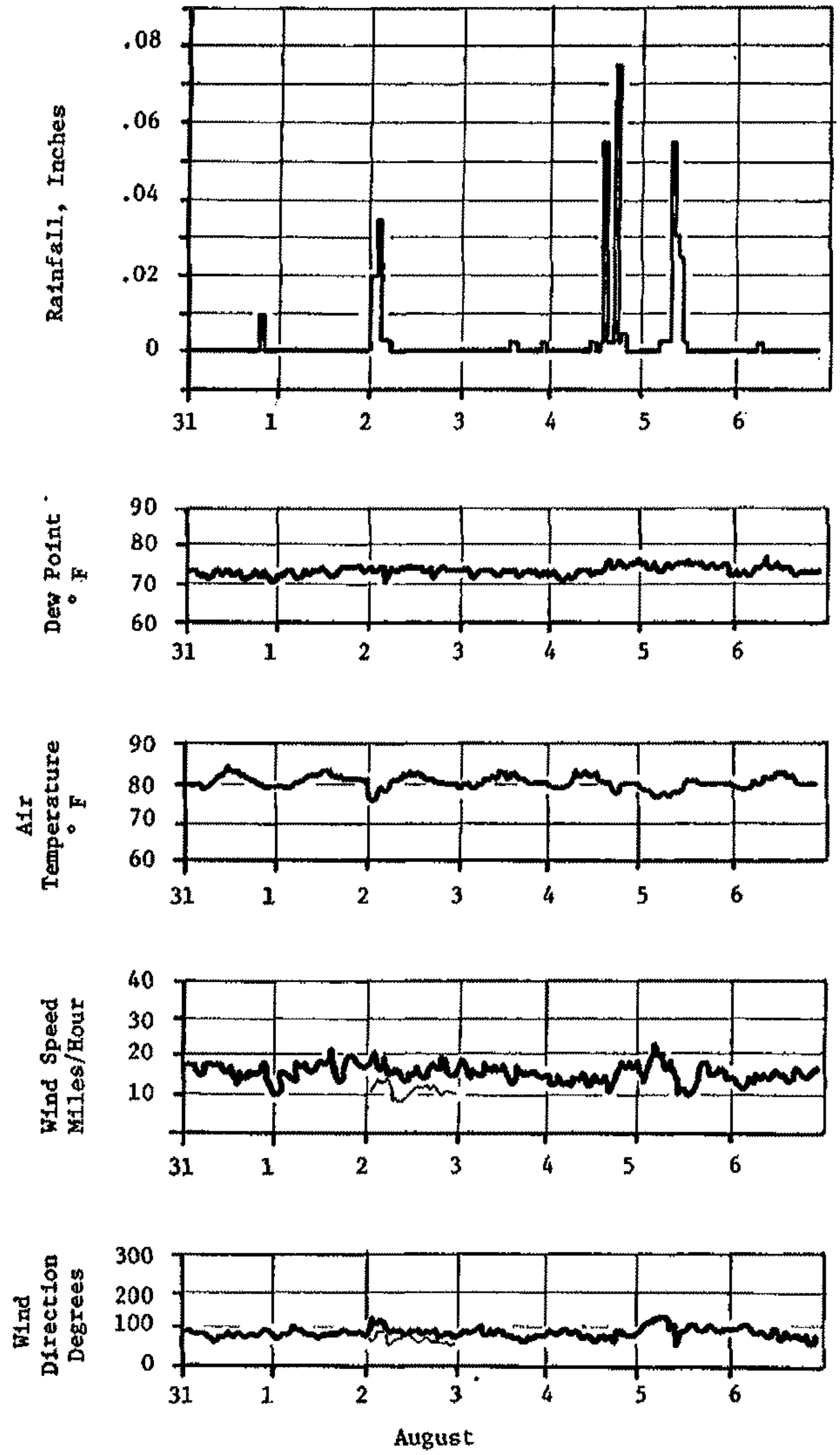

FIGURE 1. (Continued)

2300