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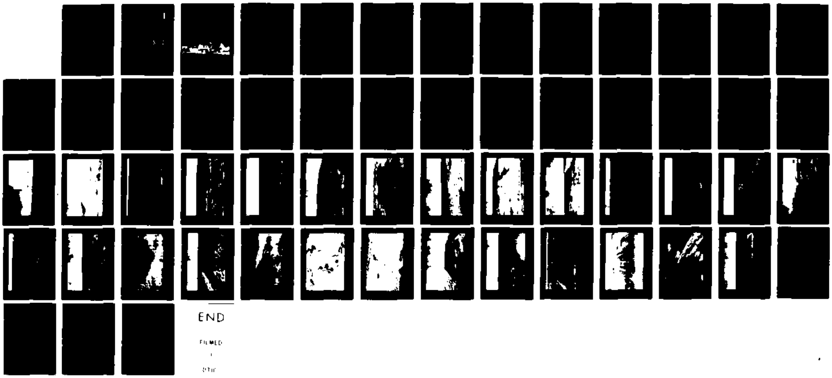

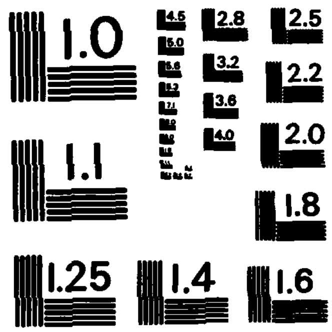
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MATERIALS EVALUATION FOR AIRCRAFT BLAST AND HELICOPTER DOWNWASH PROTECTION

by

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U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

June 1975

Final Report

Prepared for Office, Chief of Engineers, U. S. Army
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This investigation was conducted to evaluate materials and develop construction techniques for the rapid protection of airfield and heliport shoulders and overrun areas against hot engine blast and rotor downwash with ground air velocities up to 125 mph using existing materials. The objective was accomplished by a series of jet engine exhaust blasts impinging on a number of treated test areas.

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PREFACE

The authorization for this investigation is contained in Research and Development Project 4A762719AT31-02, "Research for Lines of Communication Facilities in Theater of Operations." This investigation was performed under sponsorship of the Directorate of Military Engineering, Office, Chief of Engineers, U. S. Army.

The data reported herein were obtained by personnel of the U. S. Army Engineer Waterways Experiment Station (WES), Soils and Pavements Laboratory, under the general supervision of Messrs. J. P. Sale, Chief, Soils and Pavements Laboratory, and A. H. Joseph, and under the immediate supervision of Mr. G. W. Leese. This report was prepared by Messrs. Leese and J. W. Carr.

Directors of WES during the conduct of this investigation and preparation and publication of this report were BG E. D. Peixotto, CE, and COL G. H. Hilt, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
inches	2.54	centimetres
feet	0.3048	metres
square feet	0.09290304	square metres
square yards	0.8361274	square metres
ounces (mass)	28.34952	grams
pounds (mass)	0.4535924	kilograms
pounds (force) per square inch	6894.757	pascals
feet per minute	0.3048	metres per minute
miles per hour	1.609344	kilometres per hour
degrees (angle)	0.01745329	radians
Fahrenheit degrees	5/9	Celsius degrees or Kelvins*

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use: $K = (5/9)(F - 32) + 273.15$.

MATERIALS EVALUATION FOR AIRCRAFT BLAST AND HELICOPTER DOWNWASH PROTECTION

PART I: INTRODUCTION

Background

1. Rapidly prepared runway and heliport surfaces in forward areas are usually constructed with prefabricated landing mat panels and/or membrane ground covers. These items are placed on a prepared smooth subgrade, fastened together, and anchored to provide a continuous surface. Grading operations preparatory for the surfacing and to provide proper clearances leave unprotected soil surfaces on the runway and heliport shoulders which are subjected to the exhaust and/or rotor blast of aircraft operating from these areas. This blast on the unprotected soil surfaces creates dust and soil erosion which is detrimental to both the aircraft and surrounding personnel and equipment.

Purpose and Scope

2. The purpose of this investigation was to evaluate materials and techniques for the rapid protection of airfield and heliport shoulders and overrun areas against hot engine blast and rotor downwash with ground air velocities up to 125 mph* using existing materials. The objective was accomplished by a series of jet engine exhaust blasts impinging on a number of treated test areas in the Surface Blast Effects Research Facility (SBERF) at the U. S. Army Engineer Waterways Experiment Station (WES).

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* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 4.

PART II: PREVIOUS STUDIES

3. To fully define the limits of the problem of aircraft blast effects on soil surfaces, a review was made of previous studies pertaining to aircraft blast velocity patterns on the ground surface, soil particle movement caused by aircraft blast, and materials used to alleviate the detrimental effects of aircraft blast.

Blast Characteristics

4. Blast characteristic data for fixed-wing transport-type aircraft (Reference 1) indicate that the C-130 aircraft produces a maximum blast velocity of 70 mph in a zone 75 to 110 ft behind the propellers. Velocities of sufficient magnitudes to cause dust extend to 325 ft behind the propellers. Maximum blast velocity created by the jet engines on the C-141 aircraft was 120 mph in a zone 130 to 180 ft behind the inboard engine. Blast velocites sufficient to cause dust extended 570 ft behind the engine. The maximum exhaust blast velocity of the C-5A aircraft was 130 mph in a zone 150 to 200 ft behind the inboard engine. Blast velocities sufficient to create dust clouds behind the C-5A during takeoff extended 1400 to 1500 ft behind the aircraft.

5. Groundwash data obtained beneath various Army helicopters (Reference 2) indicate dust conditions may extend outward from the center of the rotor up to 230 ft. These data are shown below.

Helicopter Designation	Gross Weight lb	Rotor Height Above Ground, ft	Maximum Ground Velocity mph	Dusting Radius ft
OH-58A	3,000	10	47	75
OH-6A	1,800	10	53	40
AH-1G	9,500	14	75	145
UH-1H	9,500	14	66 = 97ft	135
UH-1M	9,500	14	76	135
CH-47	36,000	15	90	220
CH-54	27,400	80	74	175
CH-54	28,600	40	73	175
CH-54	29,400	22	77	165
CH-54	38,000	40	99	230

(Continued)

Helicopter Designation	Gross Weight lb	Rotor Height Above Ground, ft	Maximum Ground Velocity mph	Dusting Radius ft
CH-54	38,000	80	88	225
CH-54	39,800	22	84	200
CH-54	45,000	80	74	175
CH-54	47,000	40	87	185

The maximum groundwash velocities shown in the above tabulation are within 0.3 ft of the ground surface and are not necessarily the maximum blast velocities reported elsewhere.

6. Groundwash velocities exceeding 1800 fpm (20.4 mph) will cause dusting of particles of lean clay while groundwash velocities exceeding 1200 fpm (14.7 mph) will cause fine dry sand to move along the surface (Reference 3). It should be noted that the highest velocity some distance above the ground surface is greater than that immediately adjacent to the ground surface. Thus, as a dust particle tumbles and bounces, it is picked up by the greater velocity and becomes airborne.

Dust and Soil Erosion Alleviators

7. Materials previously tested were studied to determine their ability to withstand the blast and downwash conditions described above. Several of the materials, described in Reference 4, appeared feasible for this study.

8. Data obtained by contacting 119 manufacturing firms indicated 28 materials that appeared to have the ability to sustain the 125-mph blast of the jet engine exhaust.

PART III: LABORATORY SCREENING TESTS

9. The materials selected for screening tests are listed in Table 1.

10. The laboratory screening tests were made to determine curing properties of the material, its compatibility with soils, its resistance to impact, and its fire resistance.

11. These tests were made by placing 0.94 lb/sq ft of the material on a 1-ft by 1-ft by 4-in.-deep specimen of loose sand and lean clay and allowing the material to cure for 24 hours. The material was then visually inspected to observe the cure and penetration into the sand and lean clay. To simulate the impact of a person's foot traffic, the specimen was subjected to a drop-ball test. This test involved dropping a 1-lb, 3-oz steel ball from a height of 31-1/2 in. and observing its penetration into the surface of the specimen. Observations were made to determine if the cured material sustained the impact or if it cracked, allowing the ball to penetrate into the loose sand or lean clay.

12. Materials withstanding the impact test were then tested for water resistance. The materials were not required to waterproof the soil, but were required to retain their strength and integrity in the presence of free water. This determination was made by ponding water on the surface and noting whether the material softened, swelled, dissolved, or held firm. Also, the material was to withstand JP4 fuels. To determine this, a small quantity of JP4 was ponded on the surface and allowed to stand for a period of time. If it appeared to have no softening or dissolving effect on the material, the fuel was then ignited to determine if the material was self-extinguishing.

13. From these screening tests, materials which showed the greatest potential were selected for further testing under field conditions. These materials were:

<u>a</u>. Petroset SB - Phillips Chemical Corp.

<u>b</u>. Rhoplex AC-33 - Rohm and Haas Corp.

<u>c</u>. DCA 1295 - Union Carbide Corp.

d. Aerospray 70 - American Cyanamid Co.

e. Lytron 112 - Monsanto Corp.

f. Stickvel P65 - Velsicol Chemical Corp.

g. Stickvel W617 - Velsicol Chemical Corp.

h. XB 2391 - 3M Co.

All of the above materials are water base emulsions with the exception of XB 2391, which is a polyurethane resin. Also selected for tests were the T-16 and XW-18 neoprene-coated nylon membranes, which were 1.15 and 4.62 lb/sq yd in weight.

PART IV: FULL-SCALE BLAST TESTS

Jet Engine Test Facility

14. The portable jet engine test facility used in the full-scale tests of the runway shoulder protection materials consisted of a trailer-mounted J35 jet engine and its necessary operating equipment (Photo 1). For these tests, the jet engine was mounted with its exhaust tail cone center 5 ft above the ground surface and with the engine center line tilted 4 deg tail down. The engine was calibrated in this position to determine the power setting necessary to produce the required blast velocities on the ground surface.

15. Test conditions were chosen to duplicate the C-130 and the C-5A aircraft blast parameters and slightly exceed the predicted heavy-lift helicopter's (HLH) groundwash velocities as follows:

Ground Velocity mph	Exposure Time min	Exposure Temp °F	Aircraft Blast Velocity Simulated
72	1	200	C-130
106	1	250	
125	1	275	C-5A
155	3	300	Predicted HLH

16. The velocities and temperatures were determined by placing velocity sensors and thermocouples in the blast impingement area of the jet engine and varying the power setting of the engine. A velocity contour of the blast impingement area for the 125-mph test sequence is shown in Plate 1.

Blast Test Area

17. The blast test area was located at the WES where the natural soil is a lean clay (CL). An area was graded to provide four sections, each 40 by 70 ft. Two of these sections were covered with mortar sand to a depth of 6 in.

18. The areas were prepared for material application by blading off the surface of the lean clay to provide a relatively smooth area. The sand areas were prepared by dragging a garden-type rubber hose over the surface to provide a smooth surface. No water was added prior to material application. As the areas were reused for testing the various materials, all previously tested material was completely removed by blading and new sand added, if necessary, before new materials were placed for testing.

Material Application

19. The material was applied over the test areas using a gasoline-driven centrifugal pump. The pumping system utilized a controlled by-pass which allowed partial recirculation of the material through the mixing tank. This prevented settlement or separation of the materials during application. The material was pumped under 40-psi pressure to a hand-held spray nozzle where it was applied at a rate of about 7 lb/sq yd total mixture. Cure time for all materials was 24 hours.

20. Five test areas were resurfaced with a fiber glass woven scrim material weighing 1.6 oz/sq yd with a 10- by 10-in. thread count. The scrim was 6 ft wide, and overlaps of 12 in. were used to provide the total area coverage desired. These tests involved:

Scrim with Rhoplex AC-33 on lean clay

Scrim with DCA 1295 on sand

Scrim with DCA 1295 on lean clay with edges anchored

Scrim with DCA 1295 on lean clay without edges anchored

Scrim with XB 2391 on lean clay

PART V: BLAST TEST RESULTS

Petroset SB

21. Petroset SB, as received, contained 48 percent solids. It was diluted with equal parts of water and appeared as 24 percent solids at a total application rate of 7 lb/sq yd, or 1.68 lb of solids/sq yd, on both the lean clay and sand test areas and was allowed to cure for 24 hours.

Lean clay test section

22. The lean clay section treated with Petroset SB withstood the 72- and 106-mph blasts; however, erosion of the section commenced at the beginning of the 125-mph cycle, with failure occurring after 1 minute of 155-mph velocity exposure (Plate 2). Photo 2 shows the type failure experienced by the Petroset SB material.

Sand test section

23. The sand section treated with Petroset SB sustained the 1-minute 72-mph blast of the jet engine but failed during the increase to the 106-mph phase of the test. Photo 3 shows the failed area after exposure to the jet engine blast test.

Rhoplex AC-33

24. Rhoplex AC-33, as received, contained 46 percent solids. After dilution with equal parts of water, it was applied as 23 percent solids at a total weight of 7 lb/sq yd, or 1.61 lb/sq yd of solids, on both the lean clay and sand sections and allowed to cure for 24 hours. Photo 4 shows the Rhoplex AC-33 on the sand test area before the blast tests.

Lean clay test section

25. The lean clay test section sustained the full blast test sequence without failure. Close examination revealed two holes about 1-1/2 in. in diameter which appeared to have been caused by the heat and blast.

Sand test section

26. The sand area treated with Rhoplex AC-33 failed after

2 minutes and 40 seconds of exposure to the 155-mph blast of the jet engine. The failed area appeared to have softened from heat and excessive "stretching" caused pocketing just prior to failure. Photo 5 shows the sand test area after failure.

Rhoplex AC-33 with reinforcement

27. One test section using Rhoplex AC-33 with scrim reinforcement was prepared on lean clay. After placement of the scrim reinforcement, 4.8 lb/sq yd (1.15 lb solids/sq yd) was applied and allowed to cure for 24 hours. This section sustained a total of five blast sequences without any detrimental effects over a 3-month period. Each blast sequence consisted of all of the velocities and times listed in paragraph 15 and as portrayed by Plate 2.

DCA 1295

28. DCA 1295, as received, contained 60 percent solids. After dilution with one part of water to two parts of material, it was applied as 40 percent solids at a total weight of 7 lb/sq yd on both the lean clay and sand test areas. This material after application required 7 days to cure sufficiently for the blast tests.

Lean clay test section

29. The DCA 1295 material on lean clay sustained 1 minute of 72-mph blast but failed after 30 seconds of exposure to the 106-mph blast. Failure appeared to be caused by heat (250°F) softening the material just prior to failure (Photo 6).

Sand test section

30. The DCA 1295 material on sand sustained the 72-mph blast but failed as the jet engine was being increased to the 106-mph blast sequence (Plate 2). Again, heat softened the material causing it to stretch with failure resulting (Photo 7). It was noted that the DCA 1295 material had not cured within the sand as samples taken after testing would cure when exposed to the air.

DCA 1295 with scrim reinforcement

31. Three test sections were constructed using scrim

reinforcement and DCA 1295, one on sand and two on lean clay. The sand test section and one clay test section had a 6-in.-deep ditch around their outer perimeter to anchor the scrim in place. The remaining lean clay section was bladed flat.

32. Sand section. After the scrim was placed, the section was sprayed with 10-1/2 lb/sq yd (4.2 lb solids/sq yd) and the anchor ditch was filled, compacted, and sprayed (Photo 8). After curing for 24 hours, the reinforced DCA 1295 material sustained blast velocities up to 125 mph with no noticeable detrimental effects. As the jet engine was being increased to the 155-mph blast sequence, it was noted that the coated scrim separated from the sand section but it did not fail during a 3-minute exposure to this blast (Plate 2).

33. Clay Sections. One lean clay test section was prepared by ditching the perimeter for scrim anchorage and spraying it with 7-1/2 lb/sq yd (3.0 lb solids/sq yd) of DCA 1295 (Photo 9). The other test section on lean clay was prepared by blading flat and applying 4-1/2 lb/sq yd (1.8 lb solids/sq yd) over the scrim; no anchor ditch was used on this area (Photo 10).

34. The 7-1/2-lb/sq yd reinforced DCA 1295 test section sustained jet engine exhaust blast forces of 155 mph with no detrimental effects. However, the test section with the 4-1/2-lb/sq yd DCA 1295 reinforced with scrim separated from the lean clay soil at the beginning of the 155-mph blast sequence. It was noted that the reinforced material remained adhered to the soil around its unanchored edges, which indicated that the ditches were not needed. Though the material separated from the test section in the blast impingement area, it continued to protect the soil and prevent dusting. Surface appearance did not change during these blast exposures.

Aerospray 70

35. Aerospray 70, as received, contained 60 percent solids. After dilution with one part water to two parts material, it was applied as 40 percent solids at a total weight of 7 lb/sq yd

(2.8 lb solids/sq yd) on both the lean clay and sand test sections and allowed to cure for 24 hours. Photos 11 and 12 show the treated lean clay and sand test sections, respectively.

Lean clay test section

36. The Aerospray 70 treated lean clay test section sustained the jet engine blast velocities through 125 mph but failed after 24 seconds of exposure to the 155-mph blast velocity (Photo 13).

Sand test section

37. The Aerospray 70 treated sand test section sustained the 1-minute exposure of the 72-mph blast velocities but failed after a 1-minute exposure to the 106-mph blast.

Lytron 112

38. Lytron 112, as received, contained 40 percent solids, and after mixing with equal parts of water, it was applied as 20 percent solids at a total weight of 7 lb/sq yd on both sand and lean clay (1.4 lb solids/sq yd).

Lean clay test section

39. The Lytron 112 sustained the blast sequences through 125 mph but failed after 20 seconds of 155-mph blast velocity. Some erosion was noted prior to failure. Photo 14 shows the failure occurring during testing.

Sand test section

40. The Lytron 112 treated sand sustained the 106-mph blast exposure but failed after 20 seconds of 125-mph blast exposure (Photo 15).

Stickvel P65

41. Stickvel P65, as received, contained 62 percent solids. It was reduced by equal parts of water to 31 percent solids and applied to the test sections at the rate of 7 lb/sq yd (2.17 lb solids/sq yd).

Lean clay test section

42. Erosion was noted after 25-second exposure to the 155-mph blast, with failure occuring after 1-1/2 minutes at this test sequence (Plate 2 and Photo 16).

Sand test section

43. The Stickvel P65 treated sand sustained the 72-mph blast velocity but failed after 30 seconds of exposure to the 106-mph exhaust blast (Photo 17).

Stickvel W617

44. Stickvel W617, as received, contained 50 percent solids. After dilution with equal parts of water to 25 percent solids, it was applied to the test sections at the rate of 7 lb/sq yd (1.75 lb solids/sq yd).

Lean clay test section

45. The Stickvel W617 treated clay test area withstood the blast sequence exposure through 125 mph but failed as the jet engine was being increased to produce the 155-mph blast (Photo 18).

Sand test section

46. The sand test section treated with Stickvel W617 withstood blast velocities through 106 mph but failed after 10-second exposure to the 125-mph blast (Photo 19).

XB 2391

47. The XB 2391 material differs from those discussed previously herein in that it is a polyurethane solvent carried material rather than a water emulsion. The material depends on solvent evaporation and moisture for its curing. As this material appeared to have properties not possessed by the other materials tested, it was subjected to additional tests which included a lean clay scarified test area and a scrim reinforced test area on lean clay, and the standard tests on bladed lean clay and sand areas. Curing time with temperatures above 70°F was

about 2 hours; higher temperatures and high humidity accelerated curing. The material was applied to the test sections undiluted, containing 65 percent solids. Rate of application was 5 lb/sq yd (3.25 lb solids/sq yd) on the lean clay, lean clay scarified, and sand test sections, and 3 lb/sq yd (1.9 lb solids/sq yd) on the scrim reinforced test area on lean clay.

Lean clay test section

48. The lean clay test section treated with XB 2391 withstood the full blast sequence through 155-mph blast velocities. However, weathering for 3 days caused drying shrinkage cracks to develop in the lean clay soil. These shrinkage cracks are believed to have triggered the failure of the XB 2391 material during the second blast retest.

Scarified lean clay test section

49. The lean clay section was scarified to a depth of 1 in. to allow penetration of the XB 2391, which was applied at a rate of 5 lb/sq yd (3.25 lb solids/sq yd). The cured section, when tested within 24 hours after placing, withstood the entire blast sequence. However, after allowing the test section to set for a day, large shrinkage cracks occurred (Photo 20) and the test section failed early in the blast sequence during blast retest (Photo 21).

Lean clay reinforcement

50. To overcome the detrimental shrinkage in clay soils, scrim material was placed over the test area and coated with 3 lb/sq yd (1.9 lb solids/sq yd). During a 3-month period, this area withstood a total of seven blast sequence tests without failure (Photo 22). However, the clay soil did shrink and crack during dry weather, and softened during wet weather, but the scrim material provided the strength necessary to prevent soil erosion and dusting that would have been caused by the blast of the jet engine.

Sand test section

51. The XB 2391 protected sand section withstood five complete blast test sequences over a 5-month period (Photo 23). The area failed during the sixth exposure to the 155-mph blast. However, the test area surface had been damaged by foot traffic which caused heel-holes that

allowed sufficient blast to penetrate beneath the "crust" to blow it out. Shrinkage cracks did occur early in the tests but were easily repaired; none occurred after the first repairs. Crust thickness varied between 1 and 1-1/2 in.

Membranes

52. Two membrane ground covers were tested in the blast impingement area of the jet engine exhaust. Basic construction of the membranes was neoprene-coated nylon fabric with factory-made joints. The lighter T-16 membrane (1.15 lb/sq yd) was a single-ply membrane while the heavier XW-18 membrane (4.62 lb/sq yd) was a two-ply fabrication. Both membranes were placed on the test sections and configured to have a field-constructed joint transverse to the direction of blast (see Plate 3). The edges of the membrane were placed in ditches about 12 to 16 in. deep; large anchor "tacks" were uniformly spaced in the ditches through the membrane edges to anchor them; and the ditches were then backfilled. The joint across the area was made by overlapping and using special adhesive made for the purpose. The large anchor tacks were placed through the overlap at each factory-made joint, and covered with a 3-ft wide strip of membrane material adhered so as to cover the joint and tack heads. The ends of this cover strip were buried in the ditches also. Photo 24 shows the lightweight membrane section before tests, and Photo 25 shows the heavy membrane section before tests.

T-16 membrane

53. This lightweight membrane withstood the blast sequence through the 125-mph velocities and 2 minutes of the 155-mph velocity exposure before the overlap field joint partially pulled loose. However, this membrane did successfully complete the full blast sequence. Partial seam failure was caused by heat softening the adhesive, but the seam did remain waterproof throughout the test. Photo 26 shows the damage caused by blast to the overlap field joint of the T-16 membrane.

XW-18 membrane

54. The heavy XW-18 membrane withstood blast sequences through

the 106-mph velocities with seam failure occurring after 15 seconds of the 125-mph exposure. The failed seam was a prefabricated (factory-constructed) seam and was to one side of the test area. Just after blast velocity was increased to 155 mph, the overlap field joint protective strip began peeling loose and the overlap joint failed after 2-1/2 minutes of the 155-mph blast (Photo 27). From observations of this test and study of movies, it is believed the weight of this membrane was a contributing factor to its failure. The flapping caused by the blast generated such momentum that it literally tore the overlap seam apart and pulled the anchors out of the ground.

PART VI: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

55. Based on the test results reported herein, it is concluded that the following materials will provide rapid protection of airfield and heliport clay and sand shoulders against hot engine exhaust blast and rotor downwash with ground air velocities up to 125 mph.

- a. Rhoplex AC-33.
- b. DCA 1295 with reinforcement.
- c. XB 2391 with reinforcement.

Recommendations

56. It is recommended that further study be made using the urethane materials (XB 2391) as an admix in both soils and sand to provide not only a blast-resistant surface but also a load-bearing and wear surface.

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Table 1

Materials Selected for Screening Tests

Trade Name	Manufacturer
Aerospray 70	American Cyanamid Co.
Aquaprime	LMF Research Center, Inc.
Asphalt RS2C	Globe Asphalt Co.
Asphalt SS-1	Globe Asphalt Co.
Coherex	WITCO Chemical Co.
Corezyn-1665	Interplastics Corp.
Kymine 557	Hercules Inc.
Lytron 112	Monsanto Corp.
Petroset AT	Phillips Chemical Corp.
Petroset AX-1	Phillips Chemical Corp.
Petroset RB	Phillips Chemical Corp.
Petroset SB	Phillips Chemical Corp.
Petroset SB-2	Phillips Chemical Corp.
Semipave	WITCO Chemical Co.
Soil Bond HP401	Hunt Process Co.
Soil Gard	Alco Chemical Co.
Stickvel P65	Velsicol Chemical Corp.
Stickvel W617	Velsicol Chemical Corp.
Varnish IS 41	Isochem Resins
40-350	Reichhold Chemical Co.
40-311	Reichhold Chemical Co.
Reactor Wash Water	Reichhold Chemical Co.
Rhoplex AC-33	Rohm and Haas Corp.
Rezsol	E. F. Houghton Co.
XA 2391	3M Co.
XB 2391	3M Co.
XB 2386	3M Co.
Penemulsion	ARMARK
DCA 1295	Union Carbide Corp.

Photo 1. Jet Engine Mobile Test Facility

Photo 2. Blast Damage of Petroset SB on Clay

Photo 3. Blast Damage of Petroset SB on Sand

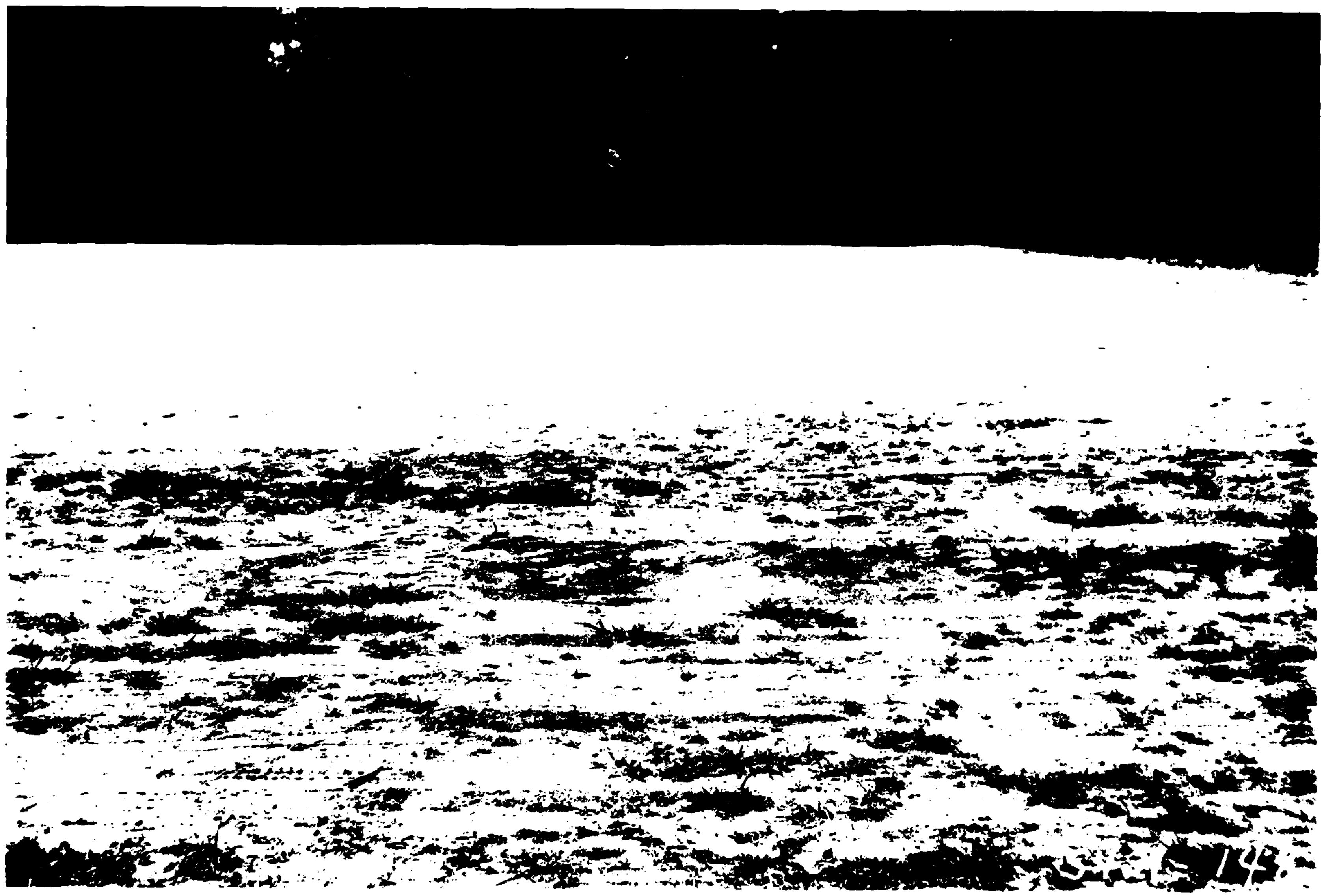


Photo 4. Rhoplex AC33 on Sand Before Test

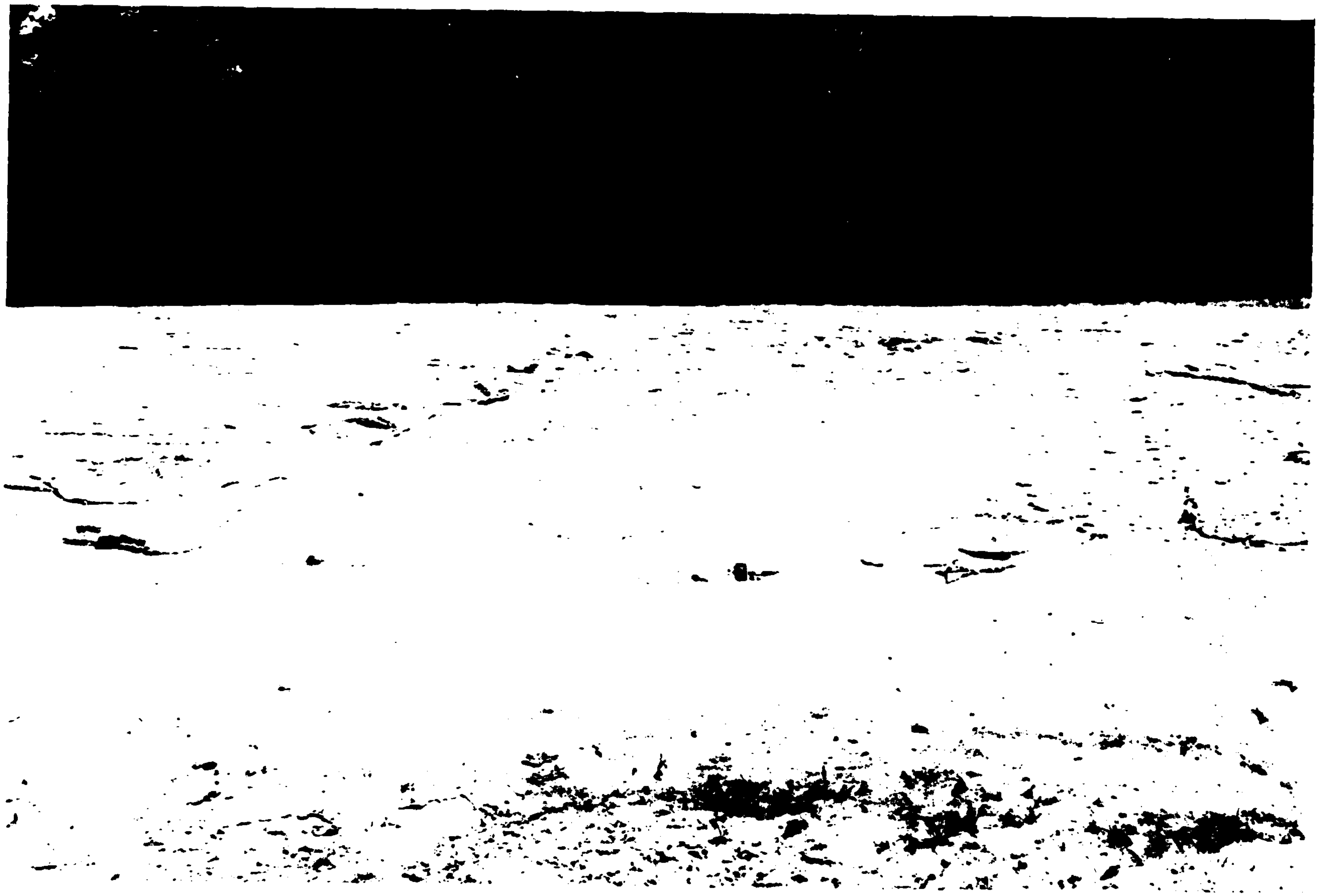


Photo 5. Blast Damage of Rhoplex AC33 on Sand

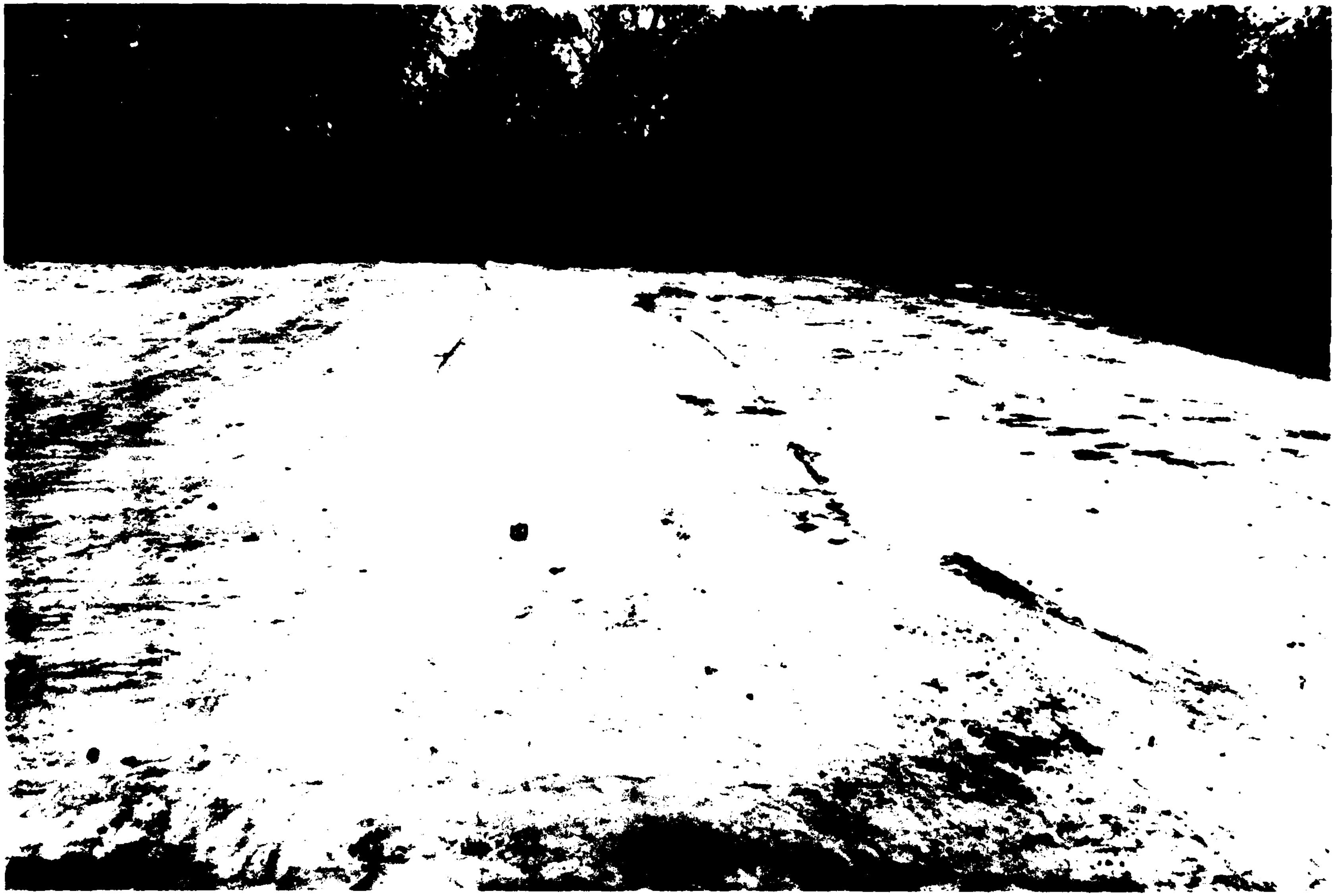


Photo 6. Blast Damage of DCA 1295 on Clay

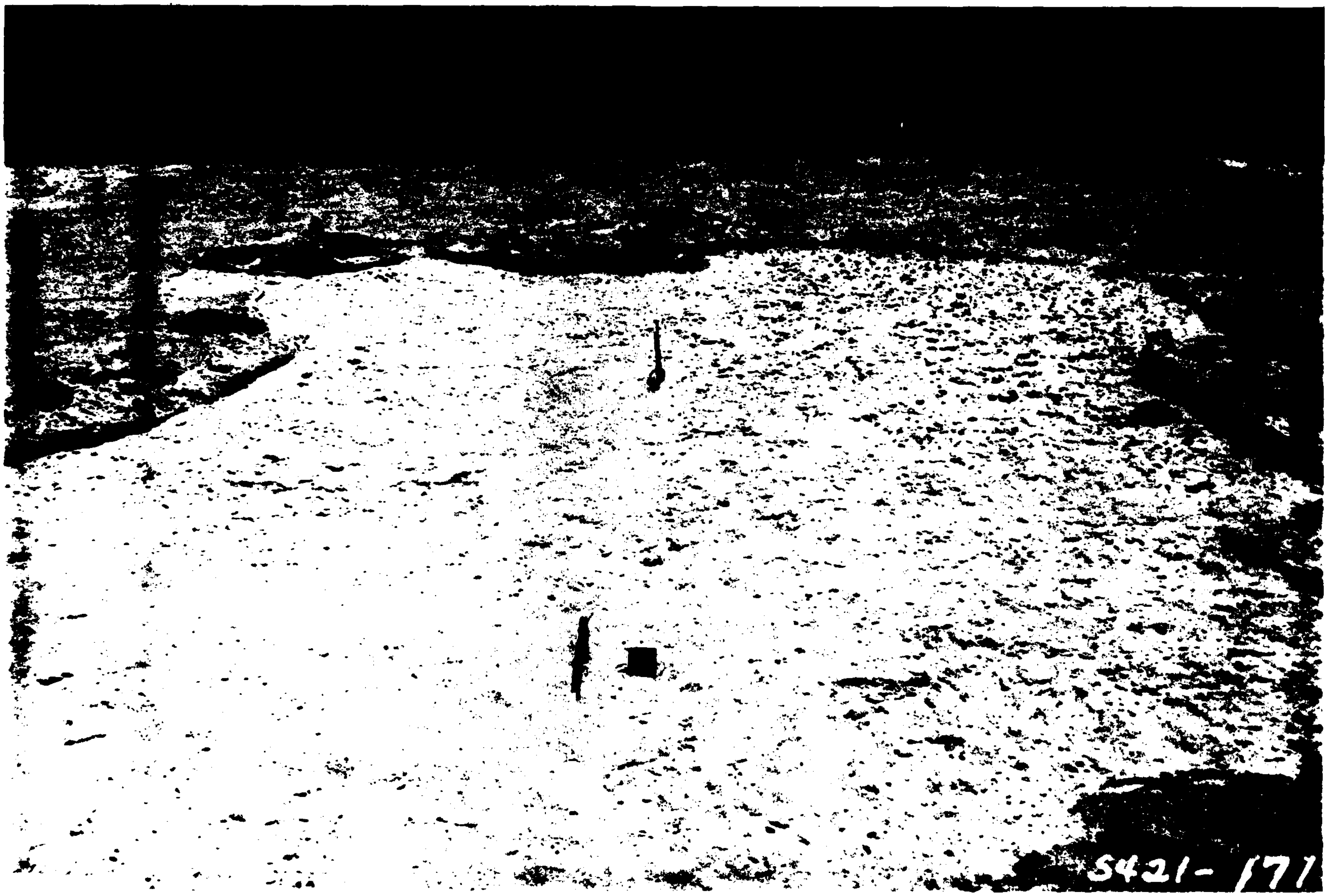


Photo 7. Blast Damage of DCA 1295 on Sand

Photo 8. Scrim Reinforced DCA 1295 on Sand

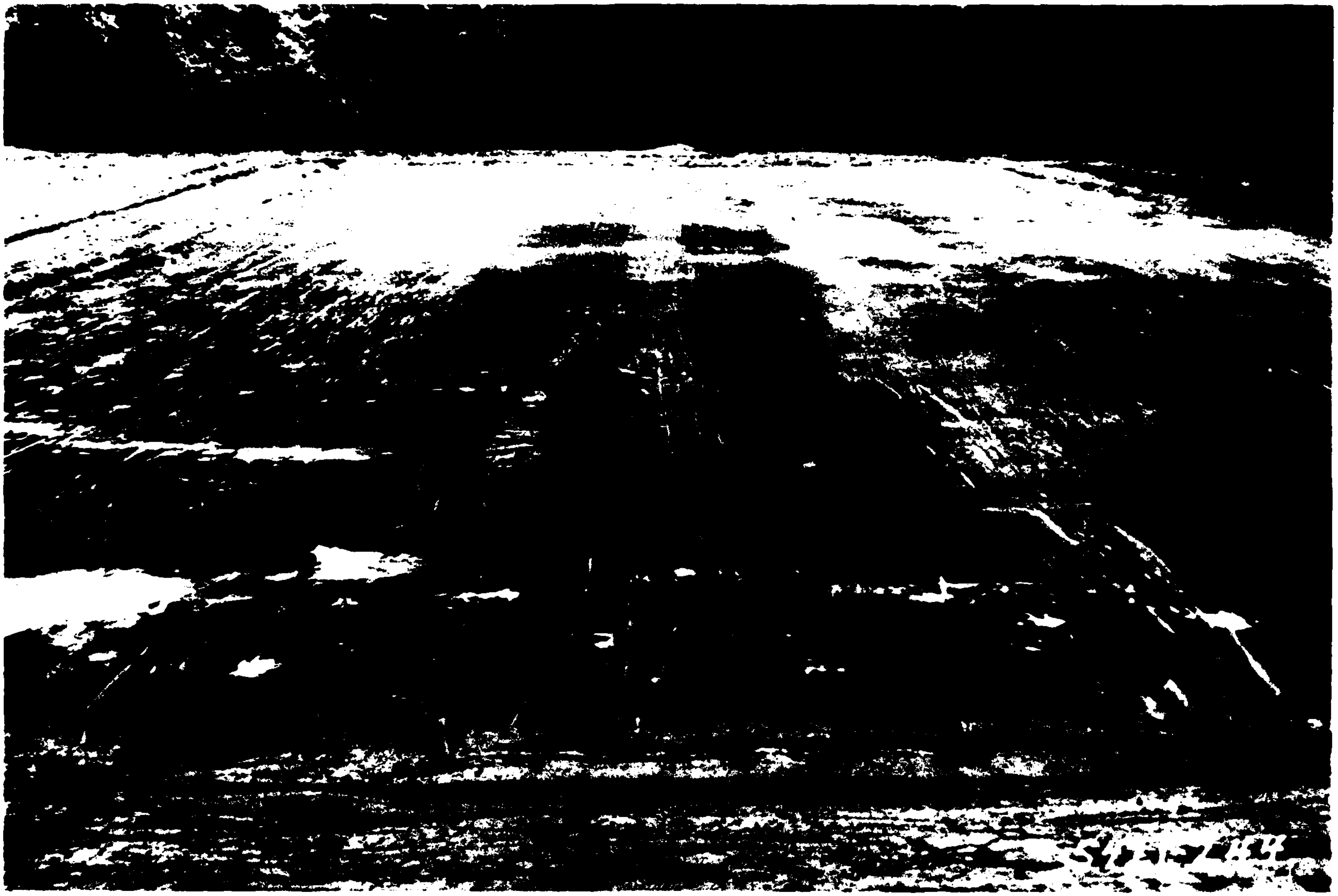


Photo 9. Scrim Reinforced DCA 1295 on Clay

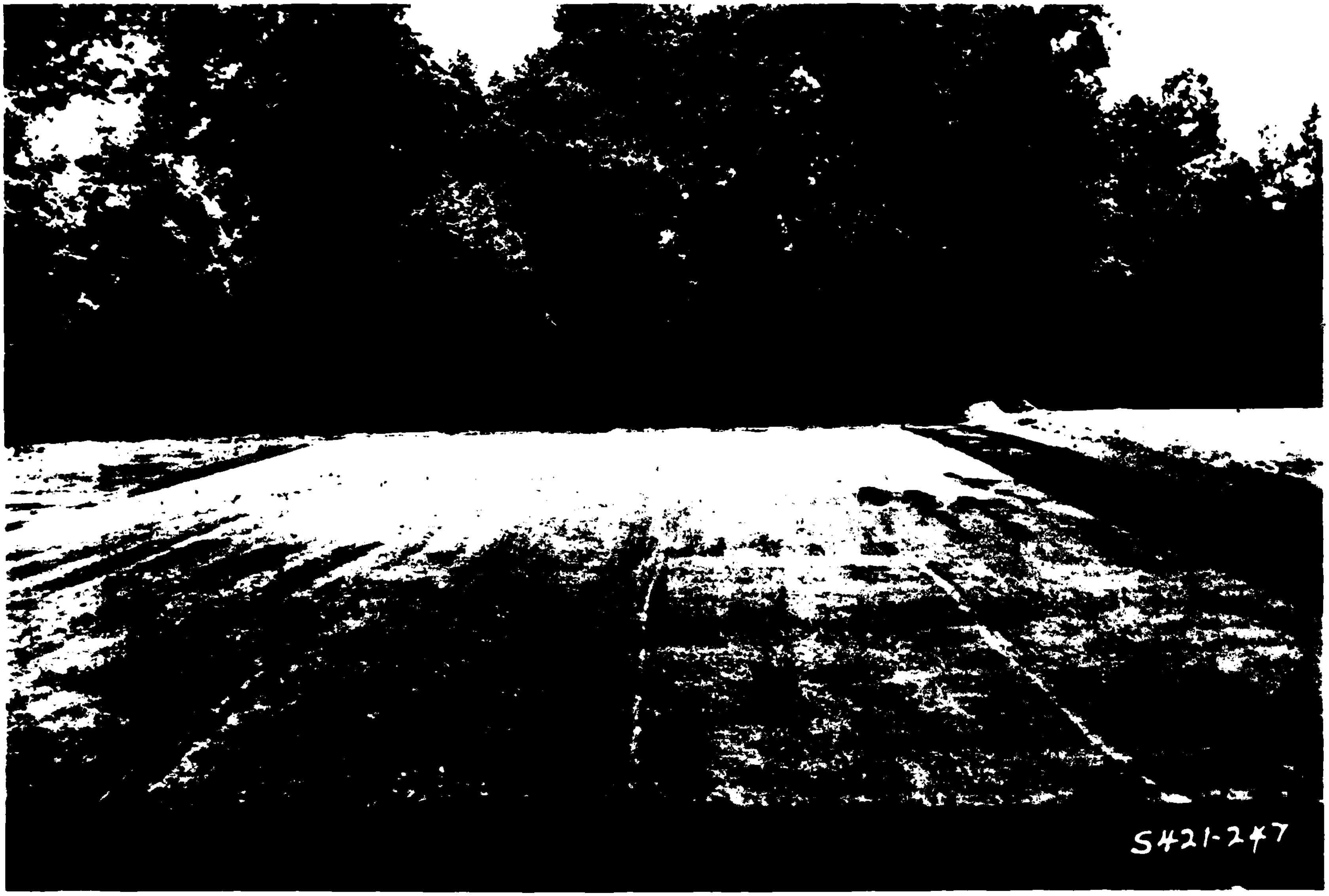


Photo 10. Unanchored Scrim Reinforced DCA 1295 on Clay

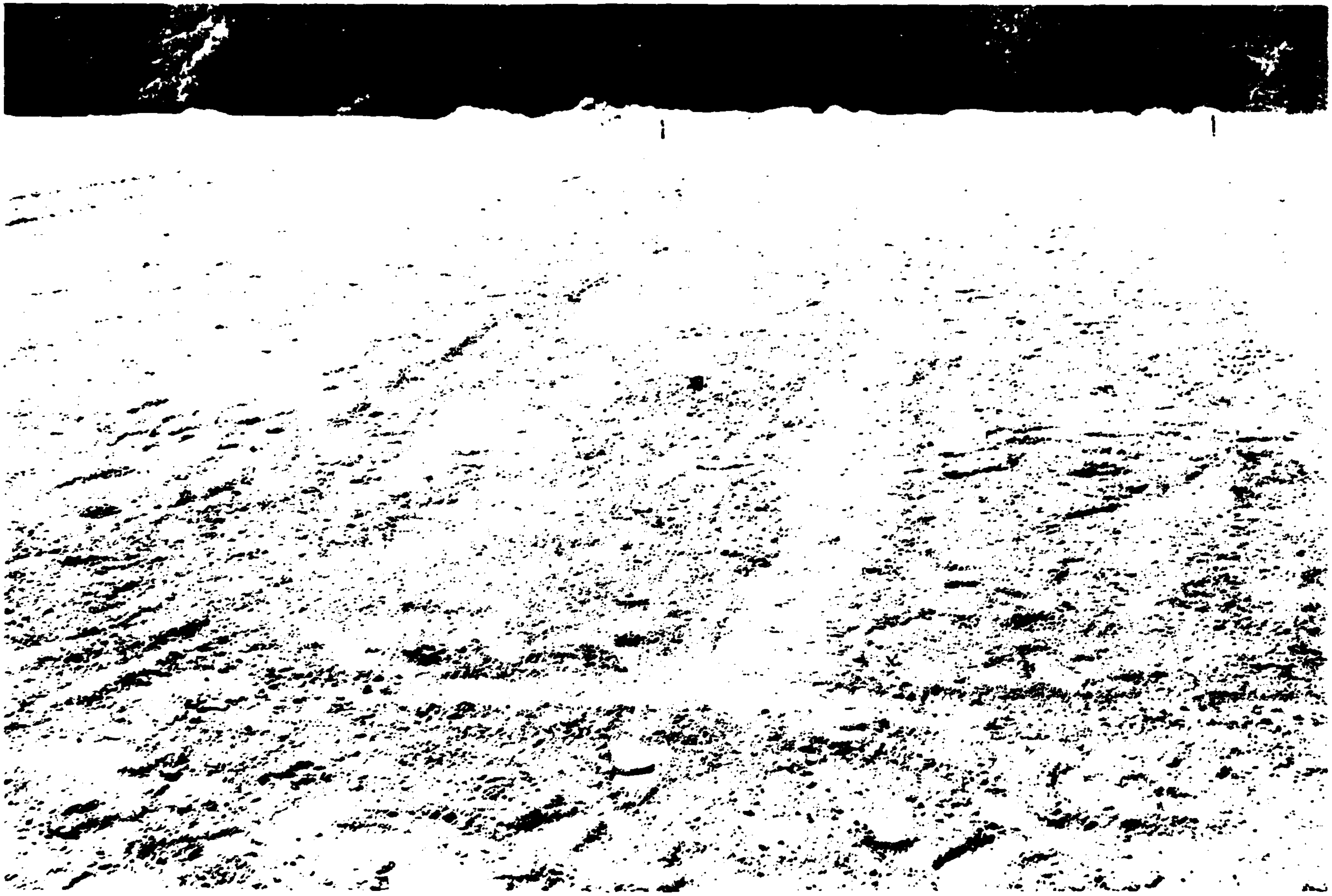


Photo 11. Aerospray 70 on Clay

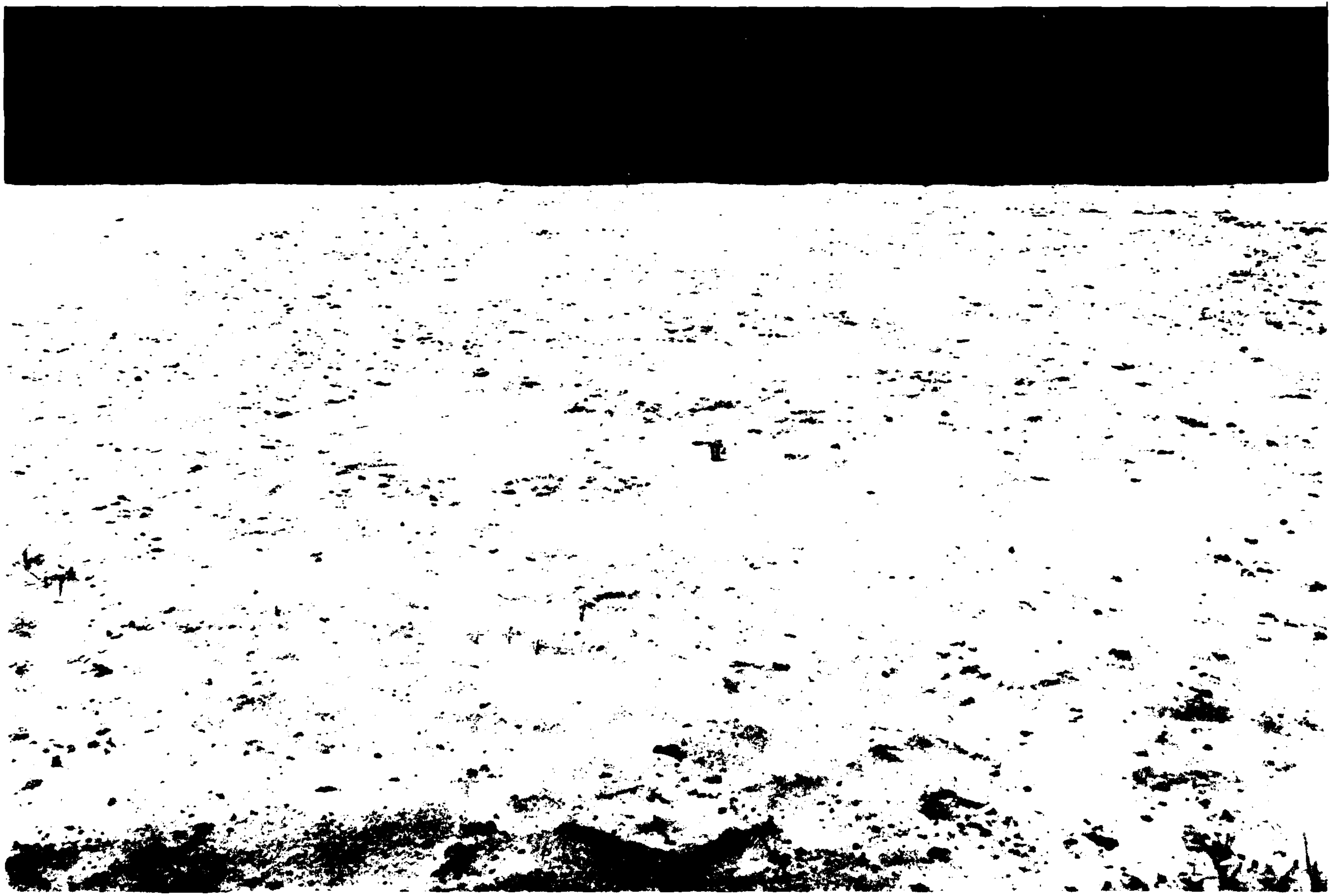


Photo 12. Aerospray 70 on Sand

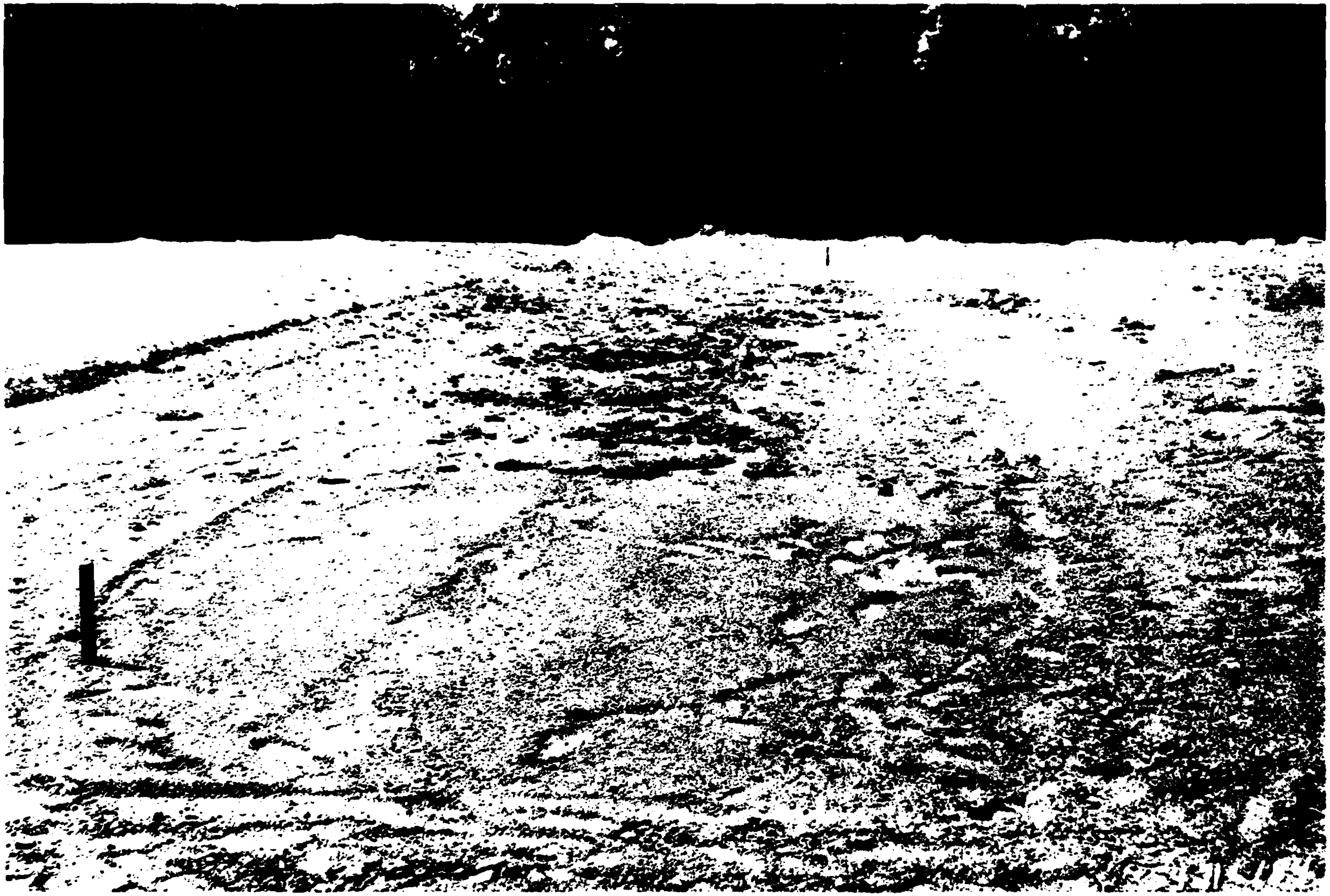


Photo 13. Blast Damage of Aerospray 70 on Clay

Photo 14. Blast Damage of Lytron 112 on Clay

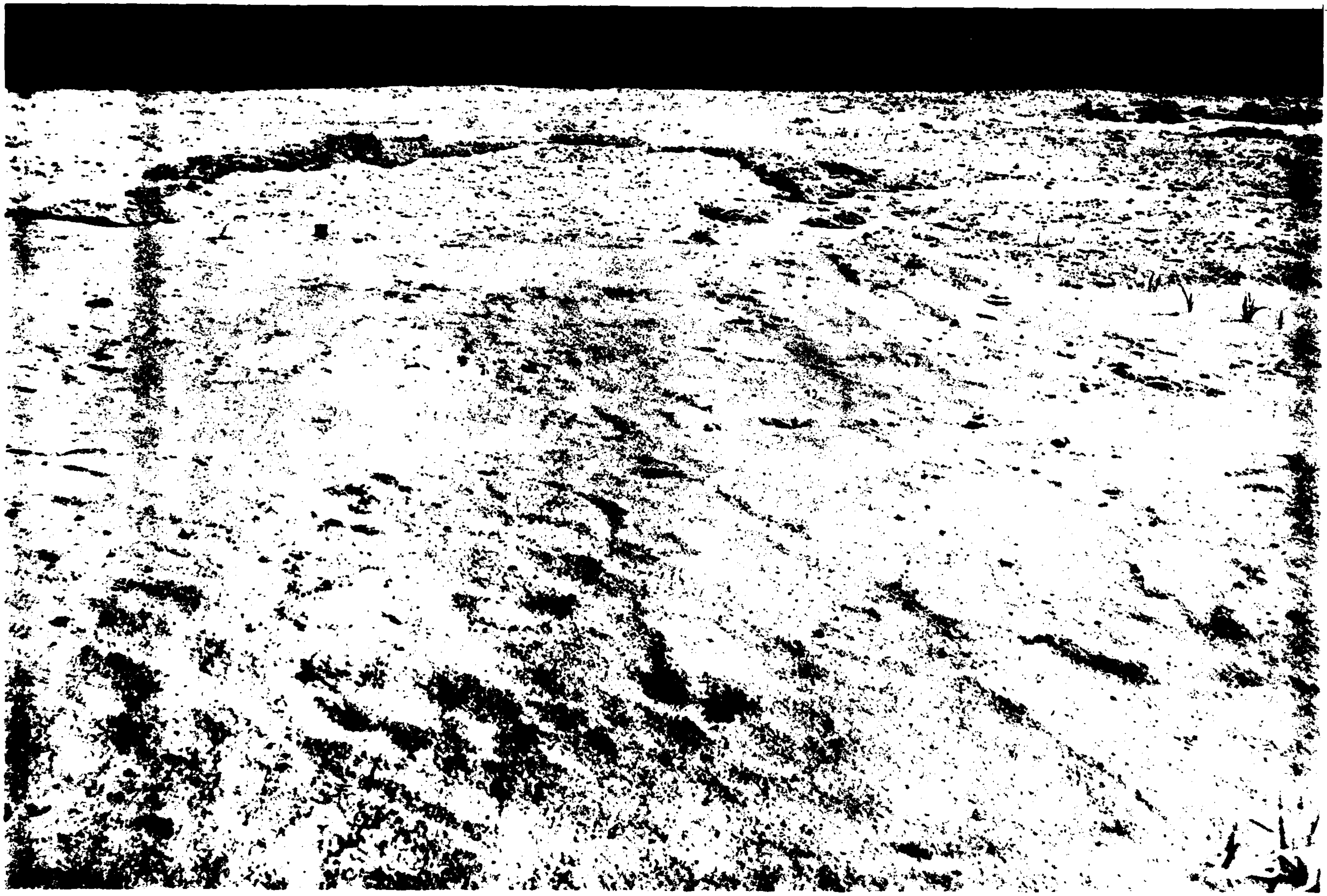


Photo 15. Blast Damage of Lytron 112 on Sand

Photo 16. Blast Damage of Strickvel P65 on Clay

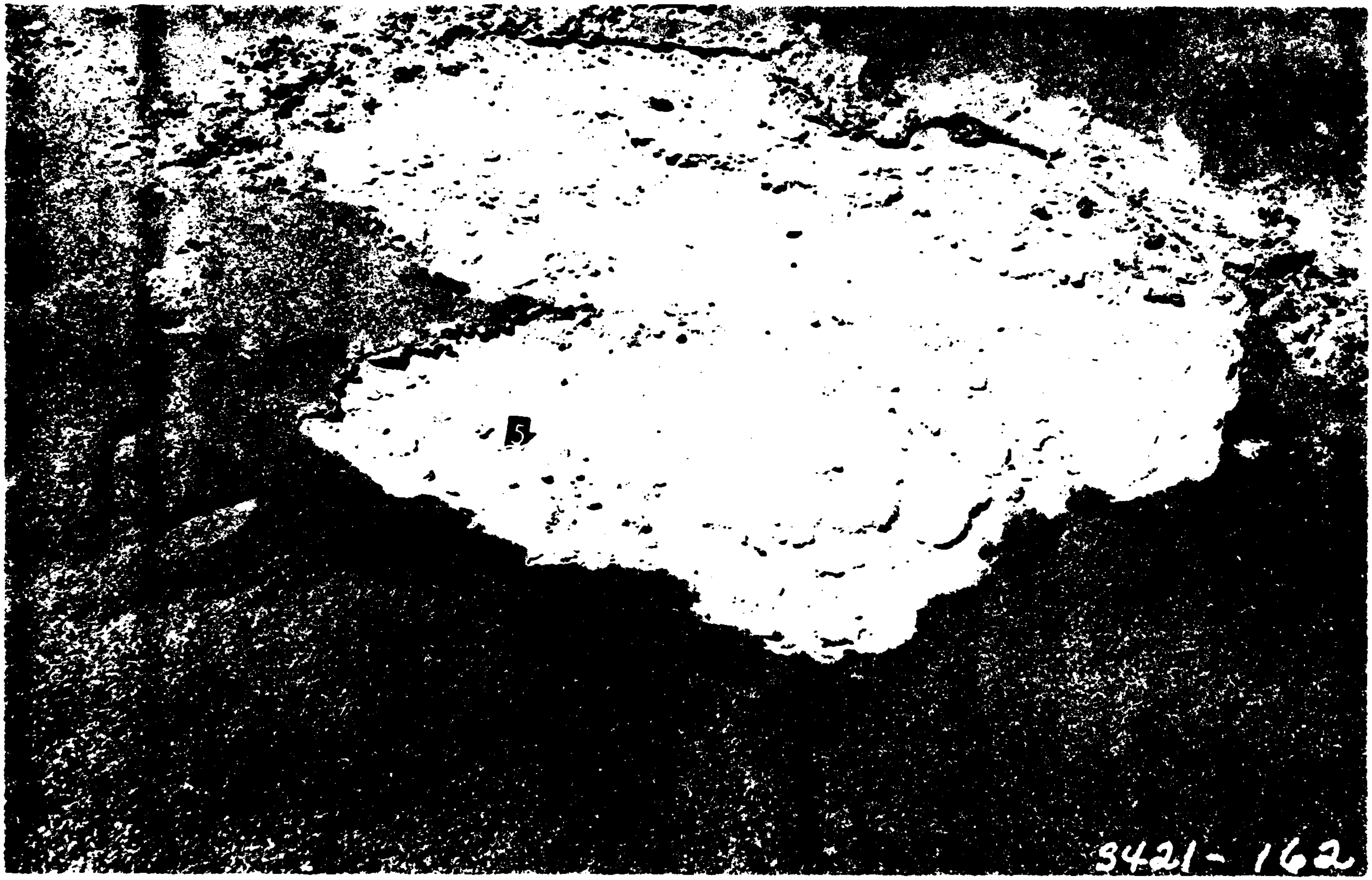


Photo 17. Blast Damage of Stickvel P65 on Sand

Photo 18. Blast Damage of Stickvel W617 on Clay

Photo 19. Blast Damage of Stickvel W617 on Sand

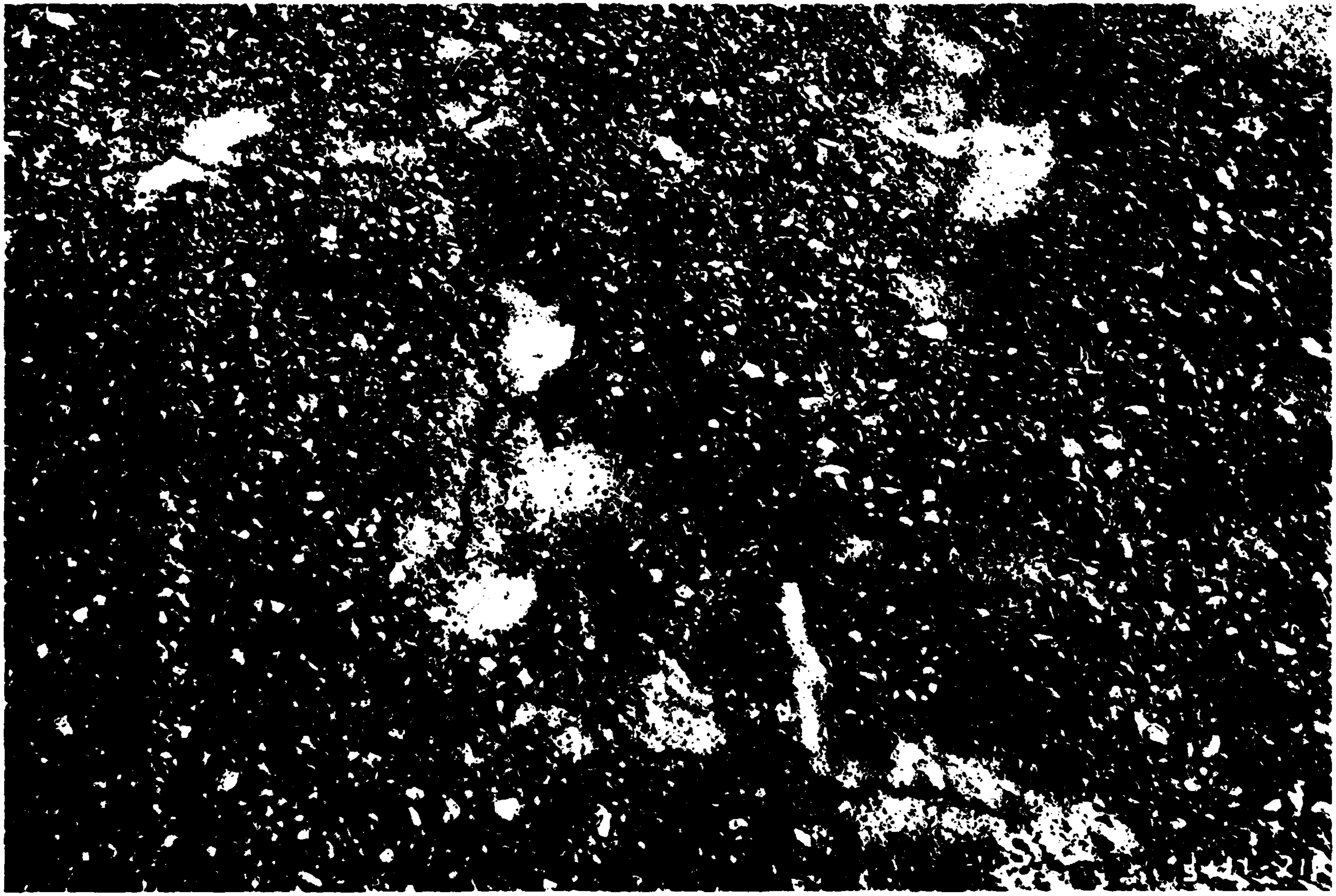


Photo 20. XB2391 Clay Section Shrinkage Cracks

Photo 21. Blast Damage of XB2391 on Clay

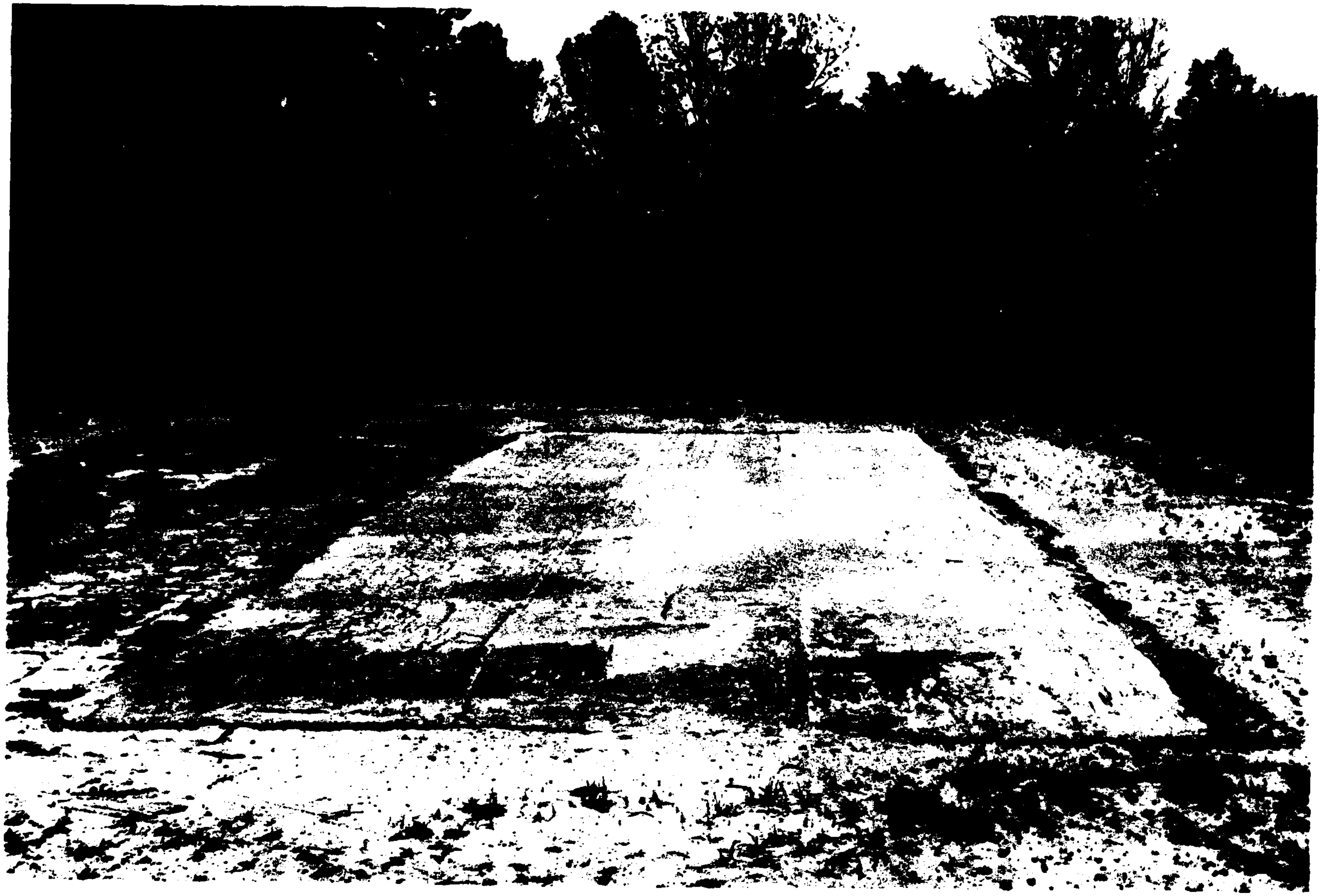


Photo 22. Scrim Reinforced XB2391 on Clay After Seven Blast Exposures

Photo 23. XB2391 on Sand After Five Blast Exposures

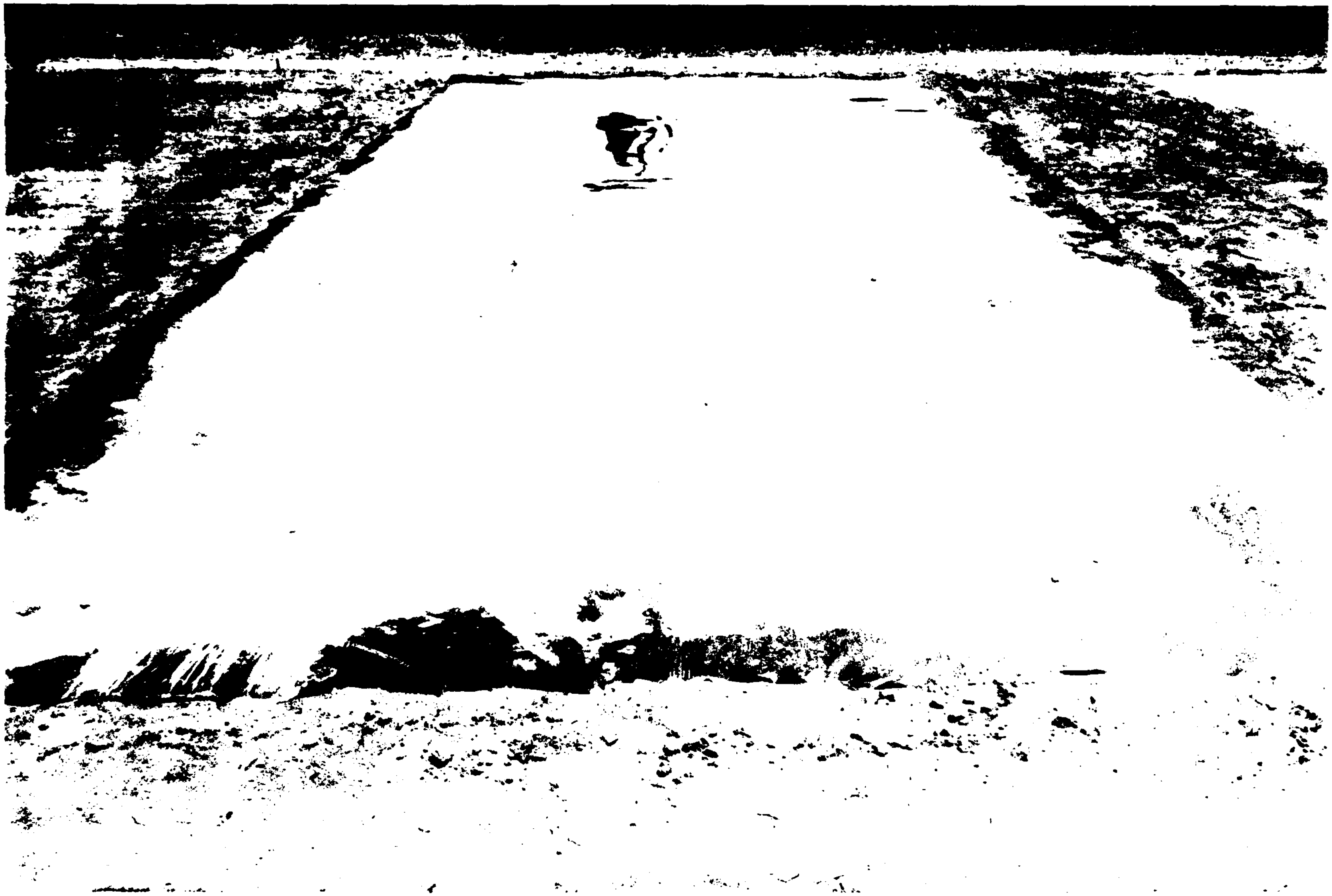


Photo 24. T-16 Membrane Section Before Blast Test

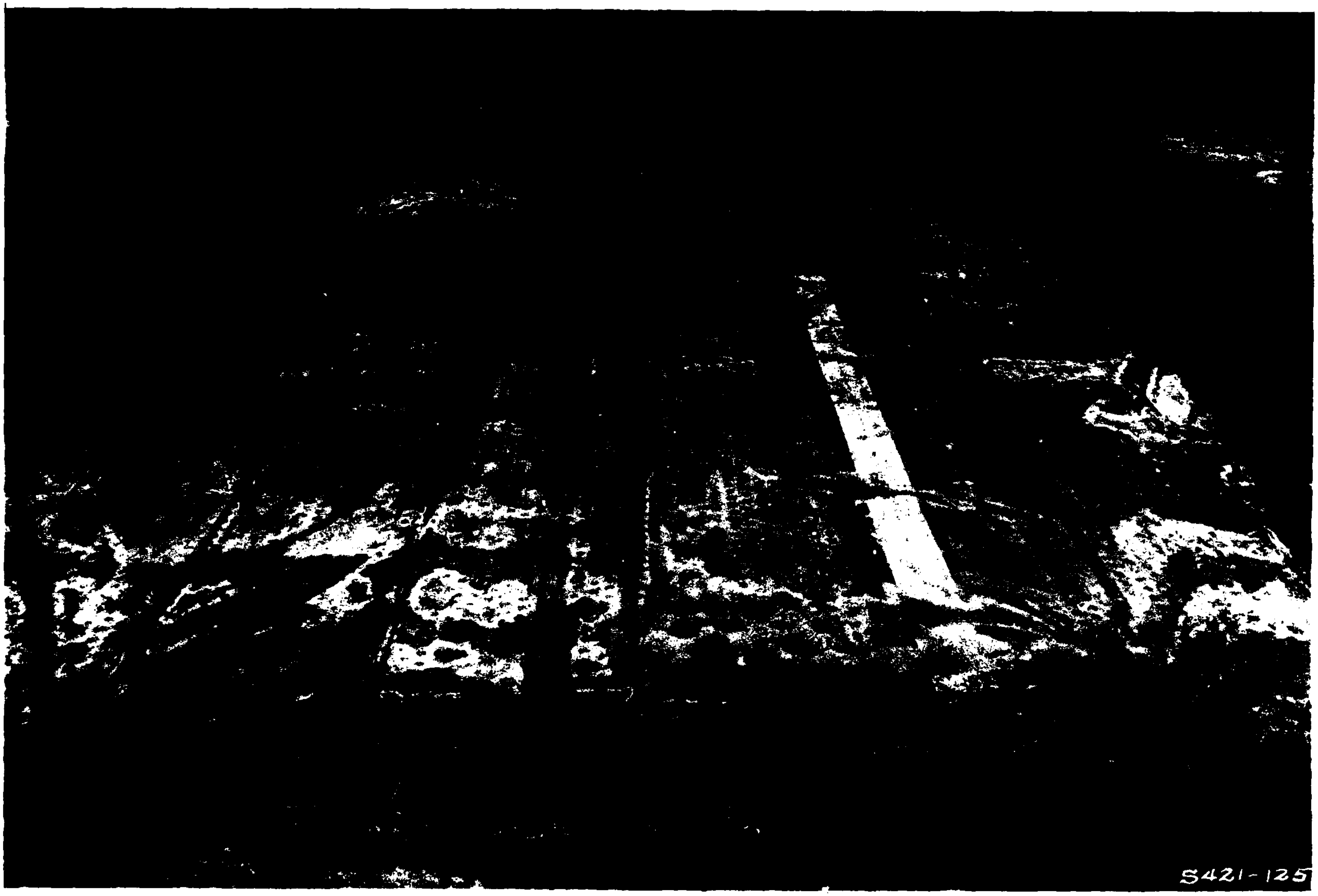


Photo 25. XW-18 Membrane Section Before Blast Test

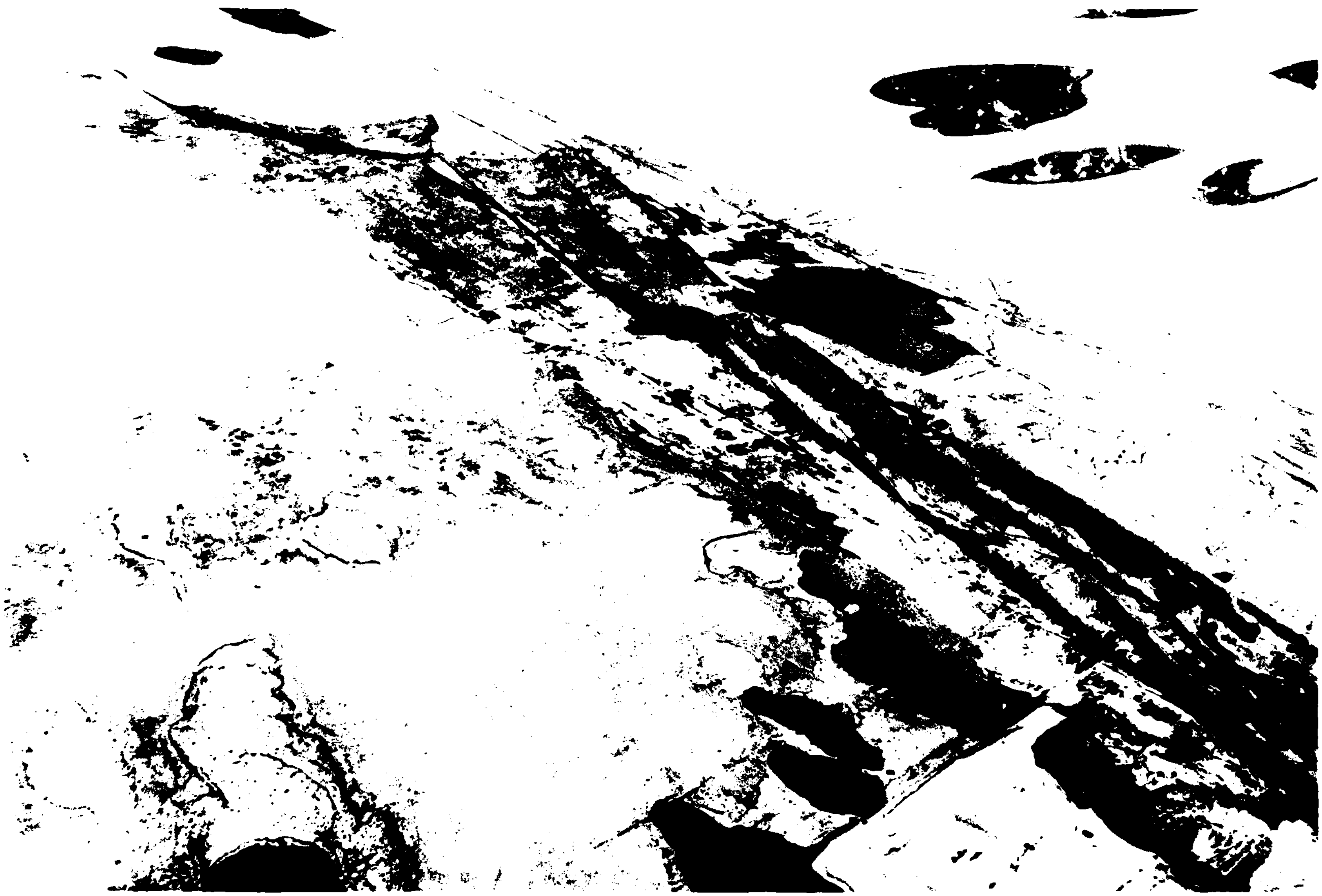


Photo 26. Blast Damage to T-16 Membrane Overlap Seam

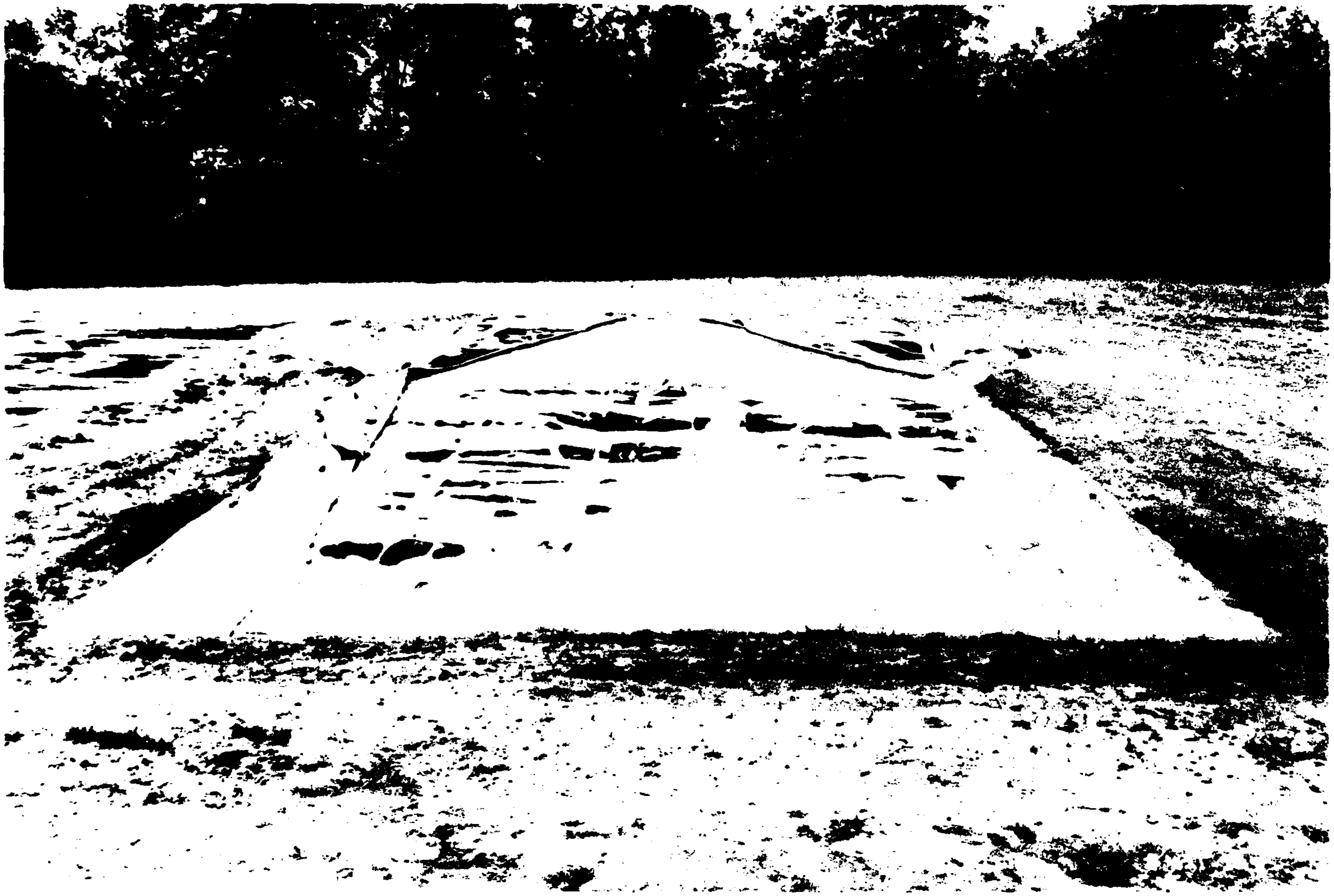
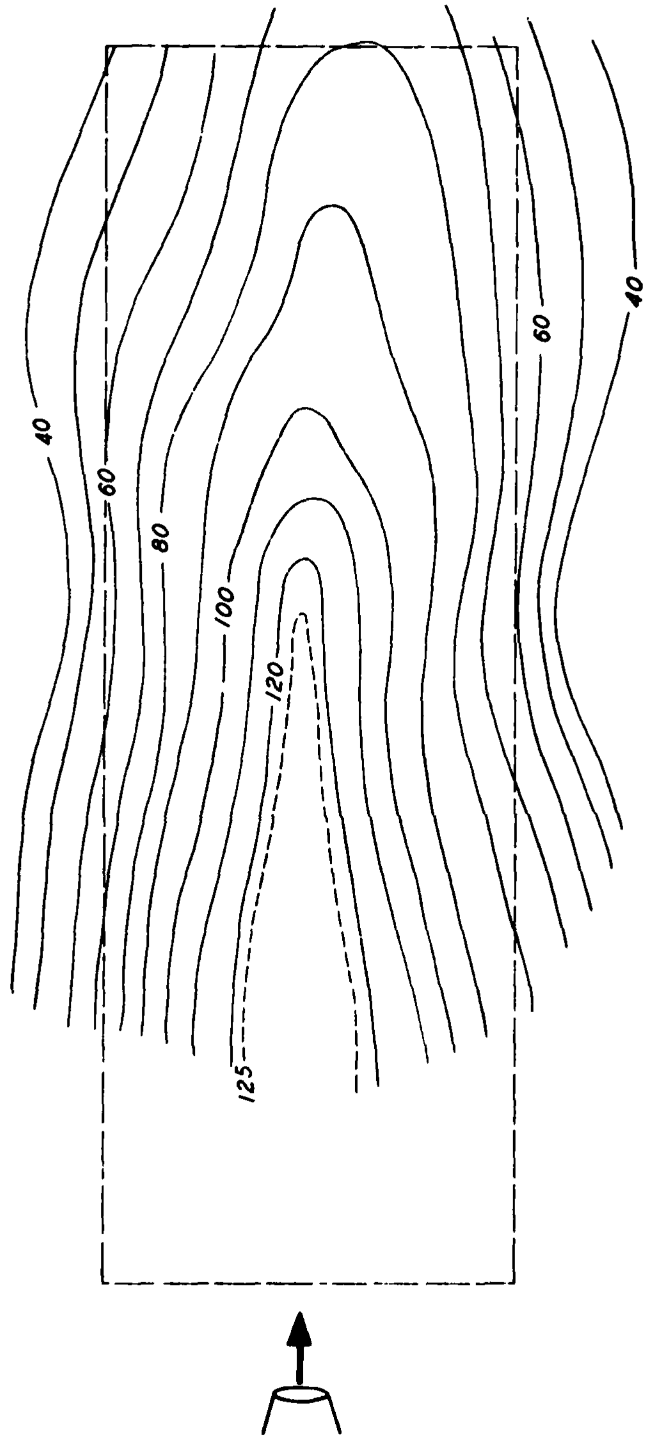
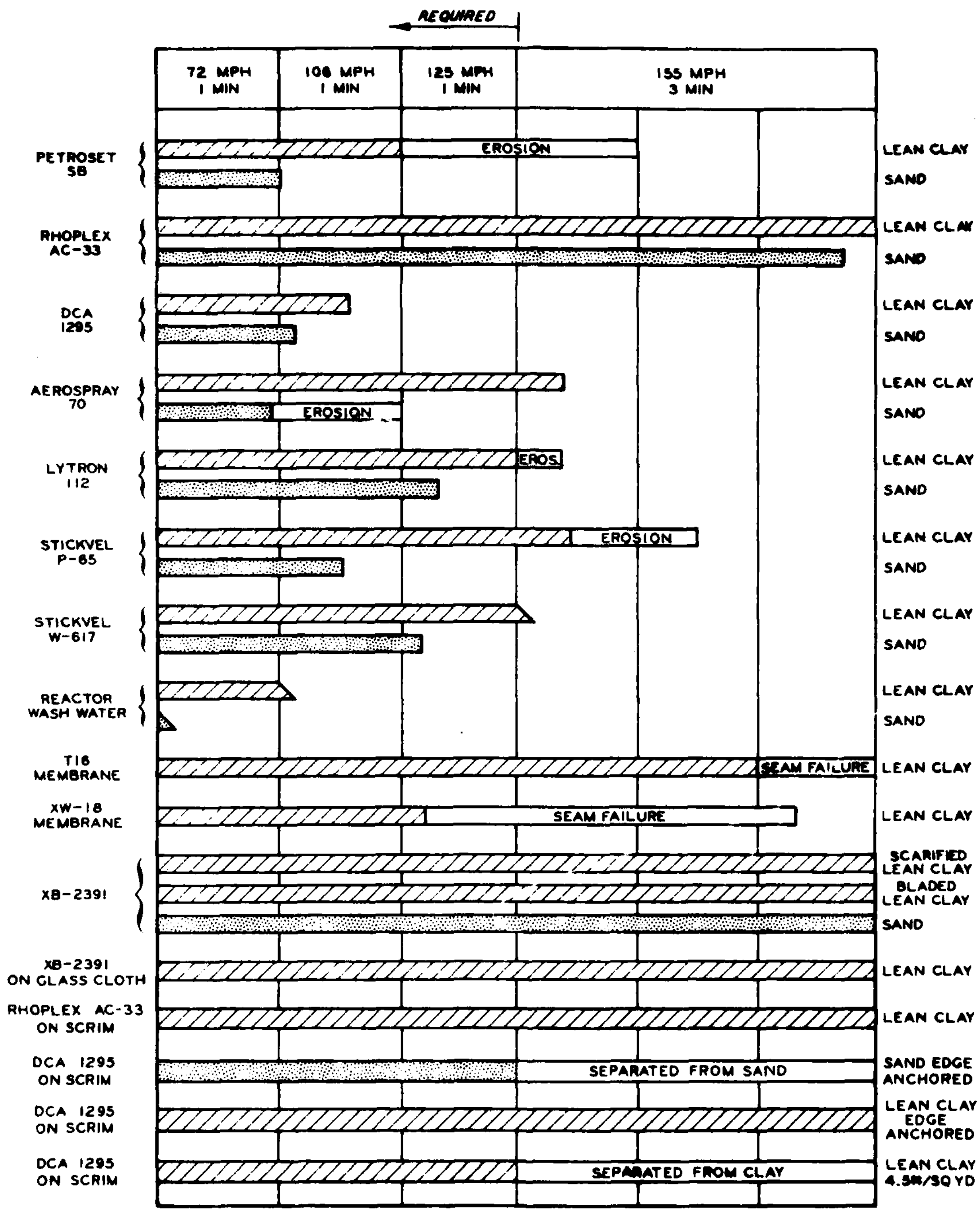


Photo 27. Blast Damage to XW-18 Membrane



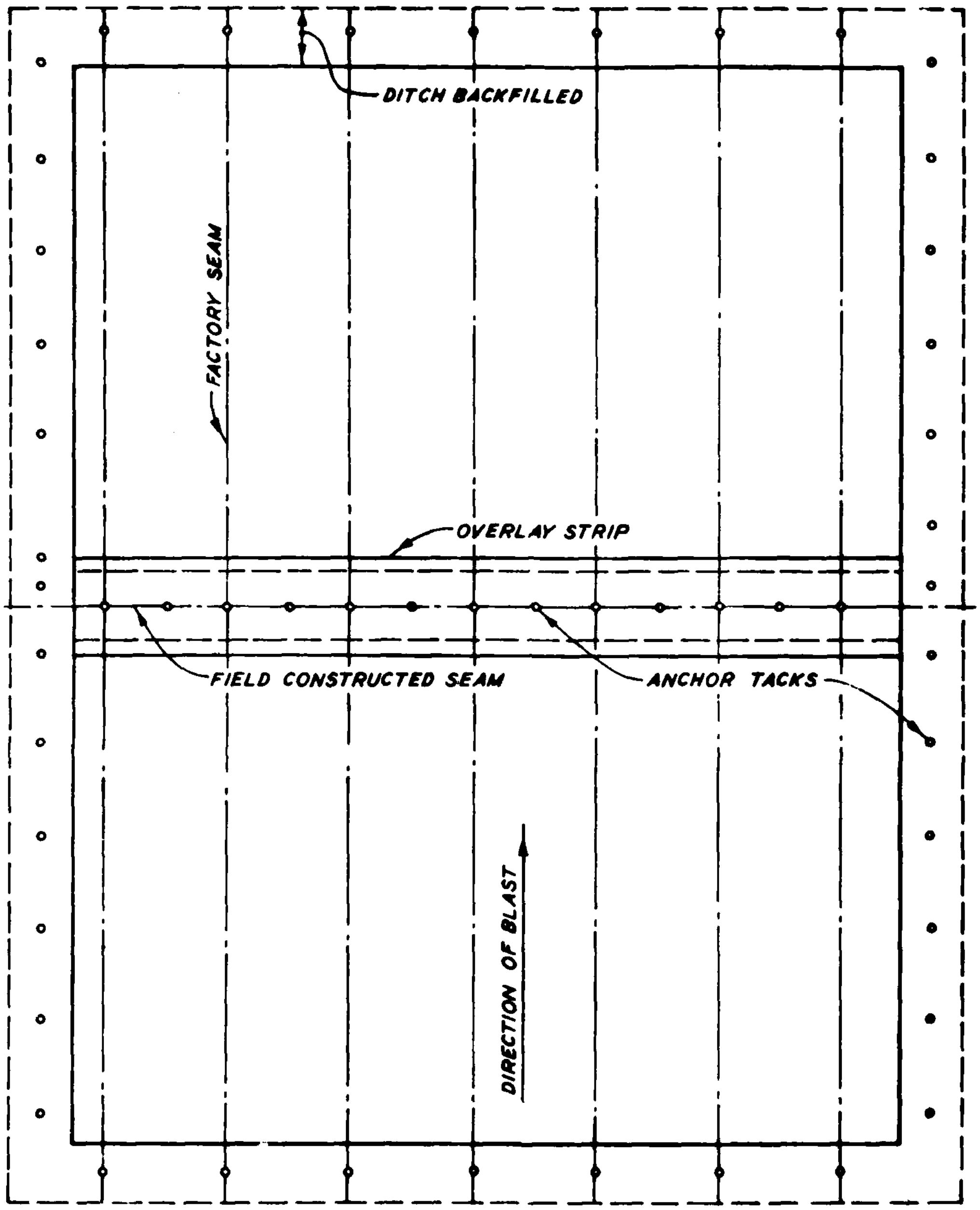
J-35 JET ENGINE EXHAUST
GROUNDWASH VELOCITY PATTERN

PLATE 1



RESULTS OF
BLAST TESTED MATERIAL

PLATE 2



SCHEMATIC
MEMBRANE PLACEMENT

PLATE 3

In accordance with ER 70-2-3, paragraph 6c(1)(b), dated 15 February 1973, a facsimile catalog card in Library of Congress format is reproduced below.

Leese, Grady W

Materials evaluation for aircraft blast and helicopter downwash protection, by Grady W. Leese [and] James W. Carr. Vicksburg, U. S. Army Engineer Waterways Experiment Station, 1975.

1 v. (various pagings) illus. 27 cm. (U. S. Waterways Experiment Station. Miscellaneous paper S-75-19)

Prepared for Office, Chief of Engineers, U. S. Army, Washington, D. C., under Project 4A762719AT31-02.

1. Aircraft blast. 2. Airfield construction. 3. Helicopter downwash. 4. Jet engine exhaust. I. Carr, James W., joint author. II. U. S. Army. Corps of Engineers. III. Title. (Series: U. S. Waterways Experiment Station, Vicksburg, Miss. Miscellaneous paper S-75-19)

TA7.W34m no.S-75-19