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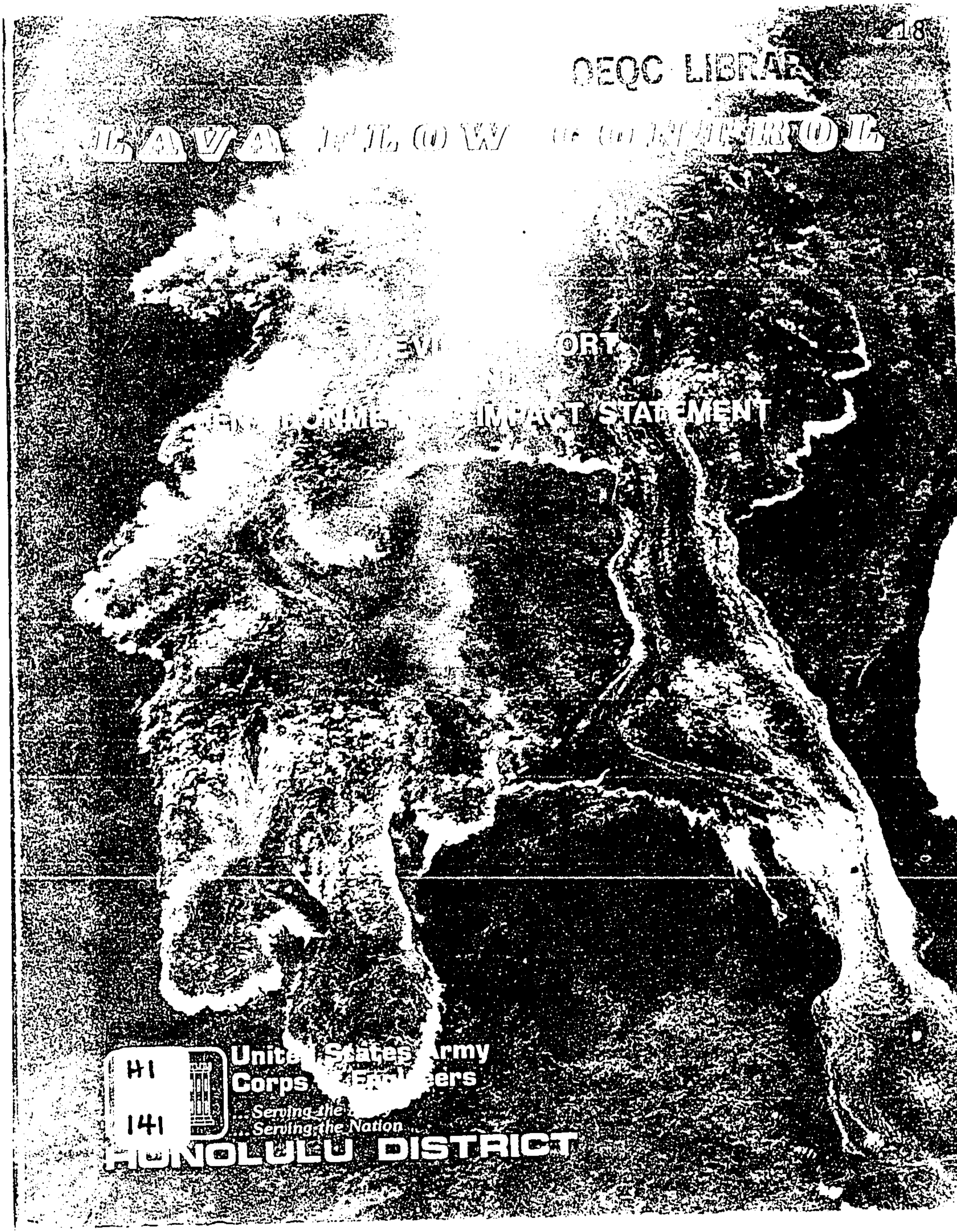
LAVA FLOW CONTROL

REVIEW REPORT
AND
ENVIRONMENTAL IMPACT STATEMENT



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DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON, D.C. 20314

REPLY TO ATTENTION OF:

DAEN-CWP-A

12 March 1981

TO INTERESTED PARTIES

Inclosed for your information is a copy of the Final Environmental Impact Statement (EIS) on the Lava Flow Control, Island of Hawaii, Hawaii, project. The EIS is being filed with the Environmental Protection Agency pursuant to the National Environmental Policy Act of 1969 (NEPA) and regulations of the President's Council on Environmental Quality for implementing NEPA (40 CFR Parts 1500-1508).

Also inclosed is a copy of the report of the Board of Engineers for Rivers and Harbors and the proposed report of the Chief of Engineers. The Final EIS addresses the action proposed by the Chief of Engineers. These documents are currently under review by the heads of Federal agencies and the Governor of the State of Hawaii. Upon receipt of their comments, the report of the Chief of Engineers will be completed and submitted to the Secretary of the Army for transmittal to Congress.

Any questions on the Final EIS should be directed to the Office of the Chief of Engineers, ATTN: DAEN-CWP, Washington, D.C. 20314, within 30 days.

Forrest T. Gay III

FORREST T. GAY, III
Colonel, Corps of Engineers
Executive Director, Engineer Staff

3 Incl
1. FEIS
2. BERH Rpt
3. Proposed Chief's Rpt

DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON, D.C. 20314

REPLY TO
ATTENTION OF:

DAEN-CWP-A

SUBJECT: Lava Flow Control, Island of Hawaii, Hawaii

THE SECRETARY OF THE ARMY

1. I submit for transmission to Congress my report on Lava Flow Control, Island of Hawaii, Hawaii. It is accompanied by the reports of the Board of Engineers for Rivers and Harbors and the District and Division Engineers. These reports are in response to a resolution adopted 14 November 1975 by the United States Senate Committee on Public Works. The Committee requested the Board of Engineers for Rivers and Harbors to review the report of the Chief of Engineers for lava flow control, Island of Hawaii, so that long-term solutions and a more detailed plan for combating lawa flows can be developed.

2. The District and Division Engineers recommend a reaction plan to be carried out only if a volcanic eruption occurs and the consequent lava flows threaten lives and property. The plan provides for construction of up to nine miles of earth diversion barriers to direct lava flows into a flow corridor and away from inhabited areas which could be destroyed. Diversion barriers would be constructed in segments with total length dependent upon location of the eruption and direction of flow. The plan would become an integral part of the State's emergency plan which would be put into effect by the Governor of Hawaii. The reporting officers also recommend that authorization be obtained for the Chief of Engineers to implement the Corps reaction plan by amending the Flood Control Act approved 18 August 1941 (33 U.S.C. 701). Based on 1979 price levels and construction of the maximum length of diversion structures, first cost to carry out the recommended plan is estimated at $3,560,000. Using a 50-year period for economic analysis and a 7-1/8 percent interest rate, total average annual charges are estimated at $320,000. Average annual benefits are estimated at $2,750,000, and the benefit-cost ratio is 8.6.

DAEN-CWP-A
SUBJECT: Lava Flow Control, Island of Hawaii, Hawaii

3. The Board of Engineers for Rivers and Harbors concurs in the emergency plan of reaction recommended by the reporting officers for lava flow control on the Island of Hawaii. However, since lava flow is not a widespread problem throughout the United States, but has been limited to the Island of Hawaii, the Board is of the opinion that authority to resolve localized problems should be obtained through legislation specific to these problems and solutions, and not through generic changes to existing laws. Accordingly, the Board recommends that Corps emergency assistance for lava flow control in the State of Hawaii be authorized for implementation, at the request of the Governor of Hawaii, generally in accordance with the plan of the District Engineer with funds available to the Chief of Engineers, under direction of the Secretary of the Army, and with such advance preparation and modification thereof as is in the discretion of the Chief of Engineers may be advisable.

4. Based on October 1980 price levels the first cost of the project is estimated at $3,993,000. Applying the current interest rate of 7-3/8 percent, and a 50-year period for economic analysis, annual charges are estimated to be $368,000. Average annual benefits are estimated at $3,371,000. The benefit-cost ratio is 9.2.

5. I concur in the findings, conclusions, and recommendations of the Board.

J. K. BRATTON
Lieutenant General, USA
Chief of Engineers

DEPARTMENT OF THE ARMY
BOARD OF ENGINEERS FOR RIVERS AND HARBORS
KINGMAN BUILDING
FORT BELVOIR, VIRGINIA 22060

REPLY TO ATTENTION OF:

15 DEC 1980

BERH-PLN

SUBJECT: Lava Flow Control, Island of Hawaii, Hawaii

Chief of Engineers
Department of the Army
Washington, DC 20314

Summary of Board Action

The Board believes that the plan of action to provide emergency lava flow control for the Island of Hawaii, State of Hawaii, is needed, is economically justified, and is environmentally acceptable. The Board concurs with the reporting officers' plan to construct a diversion barrier under emergency conditions to direct overland lava flows away from the City of Hilo. The Board also believes that such Federal emergency assistance for lava flow control should be authorized for implementation at the request of the Governor of Hawaii with funds available to the Chief of Engineers under direction of the Secretary of the Army. Total length of barriers could range from 1 to 9 miles. Estimated cost to implement the plan is $3,993,000, of which $348,000 would be non-Federal. The benefit-cost ratio is 9.2.

Summary of Report Under Review

1. Authority. This report is in response to a resolution adopted 14 November 1975 by the United States Senate Committee on Public Works. The Committee requested the Board of Engineers for Rivers and Harbors to review the report of the Chief of Engineers for lava flow control, Island of Hawaii, so that long-term solutions and a more detailed plan for combating lava flows can be developed. The resolution is quoted in the District Engineer's report.

2. Description of the study area. The study area includes the northeast slope of the active volcanic mountain Mauna Loa and the City of Hilo on the Island of Hawaii. The mountain is a shield volcano, with a broad, gently sloping dome. The Mauna Loa dome covers an area of about 2,035 square miles and has a summit elevation of 13,679 feet above mean sea level. A rift line extends northeast along the slope of Mauna Loa toward the City of Hilo. Lava flows generally originate from points along the rift, either on the slopes or in the summit crater.

3. Economic development. Hilo is the principal urban area on the Island of Hawaii and the second largest city in the State. The Hilo area population in 1977 was approximately 50,000, or about 64 percent of the Island's total population. The mainstays of the Island's economy through the first half of the 20th century were the pineapple and sugar industries, supplemented in the last two decades by an increase in diversified farming and manufacturing. However, the largest component of the Island's economic base is now the tourist industry.

4. Existing improvements. There are no existing Federal or non-Federal lava flow control improvements on the Island. In late 1977, the State of Hawaii coordinated and developed an emergency plan for the protection of Hilo if lava flow from Mauna Loa posed potential danger to the City. The State Emergency Plan includes a series of coordinated reaction activities to be carried out by various local, State, and Federal agencies. The U.S. Army Corps of Engineers role in that plan would be limited to an advisory capacity until a Presidential Declaration of Emergency is made and the Federal Emergency Management Administration assigns the Corps the task to carry out a plan on a reimbursable basis.

5. Problems and needs. Mauna Loa has been among the world's most active volcanoes. Since 1843, there have been seven major eruptions in Mauna Loa's northeast rift zone, extruding from 100 million to 300 million cubic yards of molten lava. Lava from four of these eruptions advanced to within 7 miles of Hilo, and lava from one eruption advanced to within 1-1/2 miles of Hilo Bay. Most historic eruptions have generated lava flows varying in length from 2 to 20 miles with widths up to 2 miles. Any lava flows originating along the northeast rift below the 11,500-foot elevation would move down the broad valley toward Hilo, thereby creating a potential for extensive property damage to the City if uncontrolled. There is a need to provide protection to the City of Hilo from the damaging effects of volcanic eruptions and the attendant flow of lava. Since time of reaction is critical to success of any emergency reaction plan, it is believed that a clear division of responsibilty with authority to implement that plan without institutional and financial constraints should be established.

6. Improvements desired. Local interests, including the Governor of Hawaii, desire a plan to protect the City of Hilo from lava flows.

7. Alternatives considered. The District Engineer considered various nonstructural and structural plans to reduce or to prevent damage to the City of Hilo from lava flows. Nonstructural measures included evacuation, relocation, and zoning. Such

measures would prevent loss of life, but would do very little to reduce property damage. Structural measures included water cooling of the lava flow front, use of explosives, and diversion barriers. Of the structural measures considered, the diversion of lava flows was found to be the most practical solution.

8. Plan of improvement. The District Engineer recommends a reaction plan to be carried out only if a volcanic eruption occurs and the consequent lava flows threaten lives and property. The plan would become an integral part of the State's emergency plan which would be put into effect by the Governor of Hawaii. The plan provides for construction of earthen diversion barriers to direct lava flows into a flow corridor and away from inhabited areas which could be destroyed. Diversion barriers would be constructed in segments with total length depending upon location of the eruption and direction of the flow. Estimated maximum total length of the diversion barriers is about 9 miles.

9. Economic evaluation. Based on 1979 price levels and construction of the maximum length of diversion structures, the reporting officers estimate the first cost to carry out the recommended plan at $3,560,000. Using a 50-year period for economic analysis and a 7-1/8 percent interest rate, total average annual charges are estimated at $320,000. Average annual benefits are estimated at $2,750,000, and the benefit-cost ratio is 8.6.

10. Project effects. The proposed emergency plan of reaction would reduce or prevent damage from lava flow resulting from volcanic eruptions. The District Engineer indicates that since it is not possible to anticipate the time or location of a volcanic eruption, the precise environmental impacts of implementing the barrier diversion plan cannot be predicted. However, efforts were made to establish flow corridors to minimize adverse effects.

11. Recommendation of the reporting officers. The District Engineer recommends that authorization be obtained for the Chief of Engineers to react to threatening lava flow situations in accordance with the plan in his report by amending the Flood Control Act approved 18 August 1941 (33 U.S.C. 701). Section 5 of the Act would be amended by inserting at the end thereof the following:

"The Chief of Engineers is also authorized to undertake such measures with emergency funds that in his discretion are necessary to assist local and state efforts in the provision of emergency work for control of lava flow in order to prevent loss of life and serious damages to improved property from such volcanic activity, when it has been determined that there exists an imminent danger to such life or improved property."

The Division Engineer concurs.

Review by the Board of Engineers for Rivers and Harbors

12. General. The scope of the Board's review encompassed the overall technical, economic, social, environmental, and policy aspects involved in the emergency plan proposed by the reporting officers. The Board considered the report's conformance with the essential elements of the Water Resources Council's Principles and Standards for Planning Water and Related Land Resources. The Board also considered the views of local interests, as well as Federal, State, and local agencies.

13. Response to the Division Engineer's public notice. The Division Engineer issued a public notice on 31 May 1980 stating the findings and recommendation of the reporting officers and offering interested parties an opportunity to present additional information to the Board. No letters were received in response to the public notice.

14. Findings and conclusions. The reporting officers recommend that Section 5 of the Flood Control Act, approved 18 August 1941 (Public Law 99), be amended by requesting general authority to permit the Chief of Engineers to undertake such measures with emergency funds that in his discretion are necessary to assist local and State interests in the control of lava flows. Their recommendation would constitute a basic change to existing general legislation and would be applicable throughout the entire United States. The Board notes that damage from lava flows is not a widespread problem in the United States, but has been limited to the Island of Hawaii. Therefore, the Board believes it should confine its recommendation to the specific problem of lava flow on the Island, and authority to resolve localized problems should be obtained through legislation specific to those problems and solutions rather than through generic changes to existing laws. The Board recognizes, however, that because of other natural disaster potentials from volcanic eruptions, mudslides, and earthquakes, the Chief of Engineers may wish to consider the need for general legislation to enable him to provide timely emergency assistance for those types of natural disasters similar to that provided by Section 5 of the Flood Control Act, approved 18 August 1941 (Public Law 99).

15. The reporting officers considered several alternatives to provide protection from lava flows, including water cooling,

permanent diversion barriers, and emergency diversion barriers. Each of the final alternatives was found to be economically justified; however, the emergency diversion barrier plan was the least costly and most cost-effective. Due to the unpredictable nature of eruptions and direction of resultant lava flow, it is not possible to provide permanent diversion works which would ensure complete protection to the City of Hilo. The reporting officers found that implementation of an emergency diversion barrier plan was the most practical solution to prevent damage to the City of Hilo from lava flows. The Board concurs in that finding.

16. Under existing regulations, the U.S. Army Corps of Engineers cannot construct diversion barriers to control lava flow until a Presidential Declaration of Emergency and the Federal Emergency Management Administration assigns the task to the Corps. Since immediate reaction is critical to successful implementation of the proposed emergency plan, the Board believes procedures need to be established to permit Corps implementation of emergency measures immediately in response to a direct request to the Corps by the Governor of Hawaii. Such implementation would be with funds available to the Chief of Engineers, under direction of the Secretary of the Army.

17. Success of the proposed emergency plan depends on diversion of lava flow from its natural path. Therefore, there is the possibility that lava could be directed onto lands or properties that may not have been affected without the proposed project. This could result in destruction of property and reduction in productivity of those covered lands. Consequently, civil damage suits could be brought against the agency carrying out the emergency plan. Accordingly, the reporting officers have requested the State of Hawaii to agree to assume responsibility for any litigation arising out of or from implementation of the emergency plan. The State has complied with that request, and the Board believes that requirement is appropriate.

18. The Board of Engineers for Rivers and Harbors concurs in the emergency plan of reaction recommended by the reporting officers for lava flow control on the Island of Hawaii. The plan is economically justified, is engineeringly and environmentally acceptable, and the requirements of local cooperation are generally appropriate. The Board believes the District Engineer's proposed plan will reduce or eliminate damage to developed property from uncontrolled lava flow on the Island of Hawaii and will make a significant contribution to the regional economy and the Hilo community's social well-being. Based on October 1980 price levels, the first cost of the plan is estimated at $3,993,000.

15 DEC 1980

Applying the current interest rate of 7-3/8 percent and a 50-year period for economic analysis, annual charges are estimated to be $368,000. Average annual benefits are estimated at $3,371,000. The benefit-cost ratio is 9.2.

19. Recommendations. Accordingly, the Board recommends that Corps emergency assistance for lava flow control in the State of Hawaii be authorized for implementation, at the request of the Governor of Hawaii, generally in accordance with the plans of the District Engineer with funds available to the Chief of Engineers, under direction of the Secretary of the Army, and with such advance preparation and modification thereof as in the discretion of the Chief of Engineers may be advisable. The estimated implementation cost to the United States for each event is $3,645,000. This recommendation is made with the provision that, prior to implementation, State and local interests will, in addition to the general requirements of law, agree to comply with the following requirements:

a. Provide without cost to the United States all lands, easements, and rights-of-way necessary for the construction of barriers, related diversion facilities, and flow corridors under emergency lava flow situations;

b. Hold and save the United States free from any damages or injuries due to, resulting from, or as a consequence of, lava barrier construction and resulting lava flows, except damages due to the negligence of the United States or its contractors;

c. Assume responsibility for the maintenance or removal of protection measures after their purpose has been served;

d. Assume responsibility for any litigation arising out of or from the implementation of the plan; and

e. Publicize volcanic eruption information in the area concerned and provide this information to zoning and other regulatory agencies for their guidance and leadership in preventing unwise future development in areas subject to damage from lava flows and in adopting such regulations as may be necessary to ensure compatibility between future development and protection provided by the project.

FOR THE BOARD:

William R. Wray
WILLIAM R. WRAY
Major General, USA
Chairman

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LAVA FLOW CONTROL
ISLAND OF HAWAII

REVIEW REPORT
AND
ENVIRONMENTAL IMPACT STATEMENT

US Army Engineer District
Honolulu
May 1980

The cover photograph is the advancing front of the lava flow extruded by the 1950 eruption in the southwest rift zone of Mauna Loa. This eruption produced over 600 million cubic yards of lava, one of the most voluminous eruptions ever of Mauna Loa. The eruption lasted 23 days, and the lava entered the ocean at three locations. (See Table 1, page 11, and Figure 2 in Appendix E.)

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SUMMARY

The genesis of this study was the 5 July 1975 summit eruption of Mauna Loa that ended a 25-year period of quiescence. Ensuing seismic tremors suggested that this might be the beginning of another period of frequent volcanic activities of Mauna Loa paralleling the highly active period that extended from 1843 to 1950. Immediately after the 1975 eruption, the seismic activities shifted from the summit down to the northeast rift zone and became stationary around the 10,000-foot elevation area. The sense of urgency is conveyed in the Governor's letter dated 29 July 1975, which requested the Corps provide federal assistance to protect property from lava flows. Presently, inflation has subsided, few seismic tremors are occurring, and the likelihood of a flank eruption along the northeast rift zone is less now than was earlier predicted. However, the probability still exists that a flank eruption will take place in the future, consistent with the general cyclical interval of eruptions at Mauna Loa.

Areas of the island of Hawaii have been threatened by inundation from lava since prehistoric times. The area now included in the city of Hilo is one of these threatened locations. The northeast rift zone of Mauna Loa points directly at Hilo, and since 1843, Mauna Loa has been one of the most active volcanoes in the world. Historical documents reviewed by the late Dr. Gordon A. MacDonald indicated the apprehension with which Hilo residents watched the advance of the lava flows of 1852 and 1855. In 1881, the concern was even greater when lava reach the vicinity of Hilo. Since the 1930's, much has been written on the subject of a lava barrier to protect Hilo. Other methods which have been attempted on a small scale in Hawaii to control or divert lava include aerial bombing and water cooling.

The problems and needs embraced in this study are numerous and varied. The many factors considered include: the diversity of public views on how resources can be or should be utilized; the socioeconomic effects of the alternative plans on the existing and future development; the probable impacts on the environment due to the broad range of alternatives, from advance construction measures to emergency actions; and the institutional structure which involves many federal, state, and local participating agencies. The study involved the appraisal of past and present analyses of protective measures against the possible hazards of lava flow, the evaluation of opportunities to reduce the danger of destruction of Hilo by future lava flows. Studies by the military on the use of ordnance for lava diversion are being conducted independently. As a basic objective, the study attempts to formulate a long-range protective plan for combating lava flows.

Various solutions to the stated problems and needs were analyzed. While nonstructural measures such as evacuation and land use zoning are desirable components of any long-term plan, the results of the study show that structural measures have the greatest chance of protecting urban Hilo, an area that is estimated to represent more than $700 million in investments.

Implementation of a rapidly constructed diversion barrier during eruption would defer protection investment until the time of need. The study results show that under certain conditions, the most practical plan to meet potential volcanic flow threats is an emergency barrier plan. This plan, including details on project implementations, will add substantively to the overall State Emergency Plan. Conditions noted during the study defined as critical to the sucess of the plan include continued field operational evaluations and an expanded administrative effort by all concerned to minimize the reaction time.

The District Engineer recommends an addition to Public Law 84-99, the Corps legislative authority for assistance in flood and coastal storm emergencies, to include emergencies of a volcanic nature. This change would give the Chief of Engineers authority to provide direct assistance during lava flow situations to any state upon request of the governor of the affected state.

SECTION I

INTRODUCTION

SCOPE OF THE STUDY

The island of Hawaii is the largest and youngest of the Hawaiian Islands archipelago. The island is the result of the coalescence of the lava flows of five volcanoes. The oldest, Kohala, has not erupted in the last 50,000 years; the two youngest, Mauna Loa and Kilauea, are very active, both erupting in the 1970's. Most eruptions of Mauna Loa and Kilauea occur either at the summits or in rift zones, areas of fissures and cracks penetrating deep into the mountains.

Kilauea is located on the southeast flank of Mauna Loa, and flows from the two volcanoes probably interfinger extensively at depth. During the 1935-1951 interval there were five eruptions of Mauna Loa, while Kilauea remained completely inactive. In 1952, Kilauea returned to activity after a quiescence of 18 years. Since then, Kilauea has erupted 33 times, but Mauna Loa was quiet until 1975. The most damaging of the recorded eruptions of Kilauea was the 1960 eruption. That eruption destroyed 87 buildings in the village of Kapoho and approximately 400 acres of cultivated lands in the Puna District of east Hawaii. The most recent Kilauea eruption in November 1979 lasted only 24 hours and caused virtually no damage.

Mauna Loa has two well-defined rift zones: the southwest rift zone and the northeast rift zone. A third area, the north rift zone, is much less developed. Hilo, the county capital, lies on the flank of Mauna Loa and almost in direct line with the northeast rift. Earlier lava flows from this rift zone have built a broad ridge that also trends toward Hilo. Hilo Bay lies at the intersection of the slopes of Mauna Loa and Mauna Kea, and the Wailuku River follows the line of that inter-section. Any lava flows that originate in Mauna Loa's northeast rift zone below an elevation of approximately 11,500 feet would move toward Hilo down the broad valley bordered by the lava ridge and the Wailuku River. Lava originating from the rift zone above this elevation would probably flow north and northwest, away from Hilo.

The study area is the elongated zone extending from the 11,500-foot elevation on Mauna Loa to Hilo shown on Figure 1. The study focused on the evaluation of lava flows that could threaten Hilo, development of alternative solutions for protecting the city of Hilo or reducing damages, determination of the economic feasibility and environmental impacts associated with these measures, and selection of a plan that would effectively solve the lava flow and related problems.

STUDY AUTHORITY

This review study was conducted in compliance with a Congressional Committee resolution adopted 14 November 1975:

> "Resolved by the Committee on Public Works of the United States Senate, that the Board of Engineers for Rivers and Harbors be, and is hereby, requested to make a formal review and update of the report of the Chief of Engineers, dated 3 January 1966, for lava flow control, Island of Hawaii, State of Hawaii, so that long-term solutions and a more detailed plan for combating lava flows can be developed."

Previous studies were conducted in compliance with the Flood Control Act of 1960 and a Congressional Committee resolution:

Section 208 of the Flood Control Act of 1960:

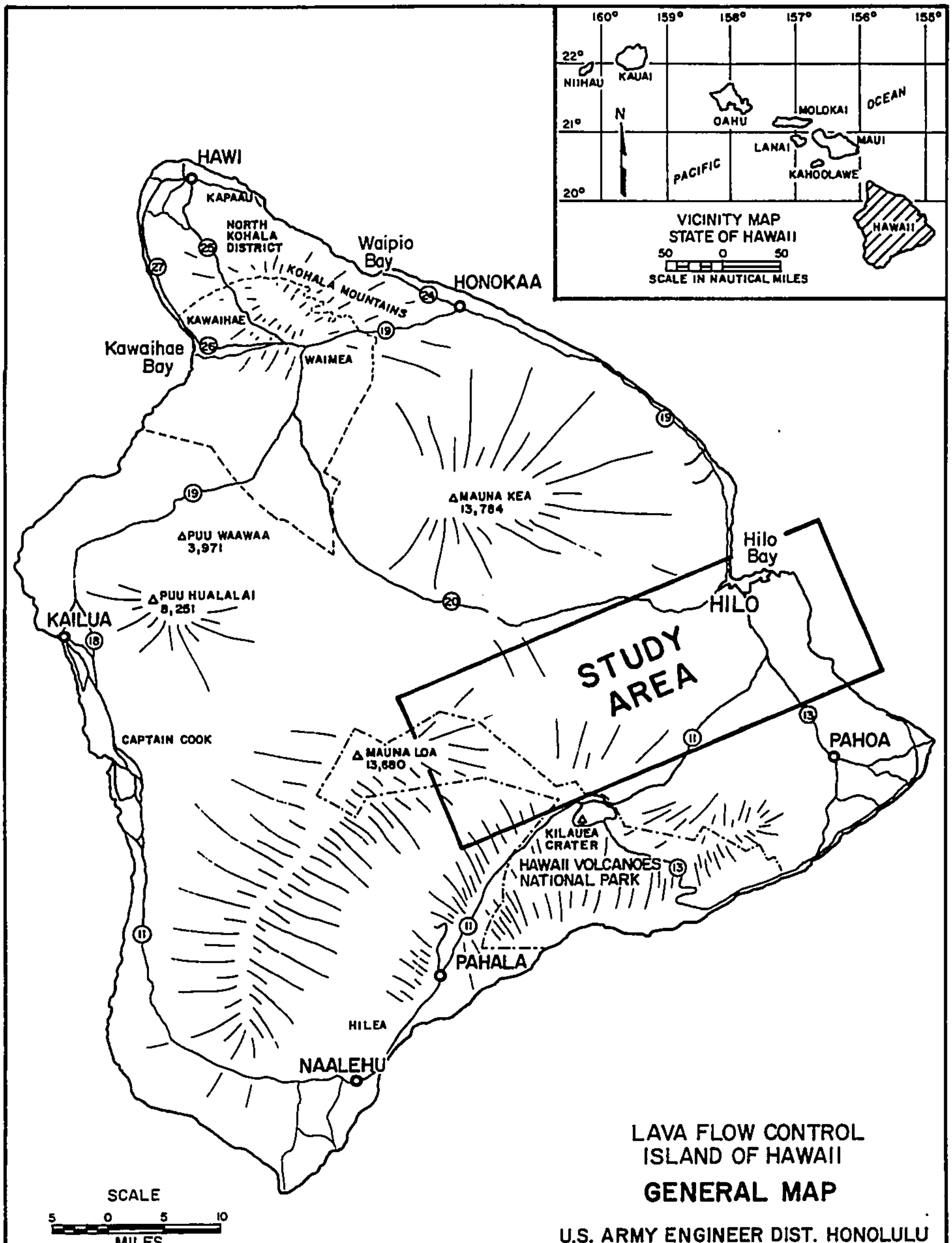
> "The Secretary of the Army is hereby authorized and directed to cause surveys...to be made under the direction of the Chief of Engineers, in drainage areas of the United States and its territorial possessions, which include the following-named localities...Island of Hawaii, State of Hawaii, construction of dikes, barriers, or walls to protect lives and property from lava flows resulting from volcanic eruption."

Resolution adopted 27 September 1951:

> "Resolved by the Committee on Public Works of the House of Representatives, United States, That the Board of Engineers for Rivers and Harbors be, and is hereby, requested to review the reports on Hilo Harbor, Hawaii, submitted to Congress on March 26, 1941, with a view to determining whether it is advisable at this time to provide a lava barrier for the protection of Hilo Harbor, Hawaii."

PRIOR STUDIES AND REPORTS

With respect to the need for protection for Hilo, the barrier approach was first advocated in 1937 by Dr. T. A. Jaggar, founder of the Hawaii Volcano Observatory. Following preliminary studies by the Hawaii Volcano Observatory staff, Dr. Jaggar proposed a system of three



VICINITY MAP
STATE OF HAWAII
SCALE IN NAUTICAL MILES
NIIHAU
KAUAI
OAHU
MOLOKAI
LANAI
MAUI
KAHOOLAWE
HAWAII
PACIFIC
OCEAN
HAWI
KAPAAU
NORTH KOHALA DISTRICT
KOHALA MOUNTAINS
Waipio Bay
HONOKAA
KAWAIHAE
Kawaihae Bay
WAIMEA
MAUNA KEA 13,784
PUU WAAWAA 3,971
PUU HUALALAI 8,251
KAILUA
Hilo Bay
HILO
STUDY AREA
PAHOA
CAPTAIN COOK
MAUNA LOA 13,680
KILAUEA CRATER
HAWAII VOLCANOES NATIONAL PARK
PAHALA
HILEA
NAALEHU
SCALE
MILES
LAVA FLOW CONTROL
ISLAND OF HAWAII
GENERAL MAP
U.S. ARMY ENGINEER DIST. HONOLULU

FIGURE I

barriers on the lower slopes of Mauna Loa to deflect flows from Hilo and its immediate vicinity. This proposal was published in "Protection of Hilo from Coming Lava Flows," Volcano Letter Number 443.

In 1938, the U.S. Engineer Department (now U.S. Army Corps of Engineers) investigated the feasibility of constructing lava barriers. The official report dated Janury 1940 stated: "The District Engineer believes it is possible to protect the harbor and city by a properly located and constructed barrier." However, based on economic reasons, the District Engineer recommended that the lava diversion barrier not be constructed at that time, and the Board of Engineers for Rivers and Harbor further stated that the construction of the barrier was considered not a justifiable function of the War Department.

In accordance with the Congressional Resolution adopted 27 September 1951 and Section 208 of the Flood Control Act of 1960, the Corps of Engineers completed a Review Report on Survey for Lava Flow Control in 1966. In his determination of the engineering and economic feasibility of providing a federal project to divert and control the lava flows, the District Engineer concluded that the preparation of a pre-emergency planning program and the implementation of this program during the first hours of eruption, should effectively reduce damages. He therefore recommended that no action be taken to authorize a federal project.

By letter of 29 July 1975, Governor George Ariyoshi requested that the U.S. Army Corps of Engineers review and update the above mentioned 1966 report. This request was the result of the Mauna Loa summit eruption on 5 July 1975. Although the eruption activities subsided the next day, scientists at the Hawaii Volcano Observatory predicted at that time that a follow-up eruption from the northeast rift zone would probably occur within the next 30 months. In recognition of the threat to the city of Hilo, local, state and federal agencies, including the military forces in Hawaii, participated in the development of an emergency action plan.

Because of its previous study of lava barriers, the Honolulu Engineer District was asked to develop the barrier plan which would be incorporated with other protective measures in the overall emergency plan for Hilo. The report "Lava Barrier System for the Protection of Hilo, Island of Hawaii," December 1975, was the result of Corps investigation and emergency planning. The recommended plan in the report provides for a basic range of barriers from which only those barrier segment(s) needed to guide the flows away from the city of Hilo would be selected for emergency construction.

Under a Memorandum of Agreement between the State of Hawaii and the Honolulu Engineer District, seven test-barrier sections were constructed on the upper slopes of Mauna Loa in March 1977. The work was funded by the State and accomplished under Corps of Engineers supervision. Investigation results are discussed in the report "Lava Barrier Construction Evaluation," Corps of Engineers, Pacific Ocean Division, April 1977.

Other reports and studies pertinent to this study include:

"Bomb Cratering Tests in Hawaiian Lava," HQ Pacific Air Forces, 1976 (Reference 44).

"Mauna Loa Threatening," American Geological Institute, 1976 (Reference 19).

"The August and October 1968 East Rift Eruptions of Kilauea Volcano, Hawaii," USGS, 1975 (Reference 15).

"The Battle of Heimaey," 1975 (Reference 35).

"Natural Hazards on the Island of Hawaii," USGS, 1975 (Reference 49).

"Man Against Volcano: The Eruption of Heimaey, Vestmann Islands, Iceland," USGS, 1975 (Reference 48).

"Volcanic Hazards of the Island of Hawaii," USGS, 1974 (Reference 25).

"Cooling of the Lava Fields," 1973 (Reference 36).

"Dynamic Mixing of Water and Lava," 1973 (Reference 7).

"Lava Cooling on Heimaey--Methods and Procedures," 1974 (Reference 17).

"Surveillance of Volcanic Activity in Iceland as Illustrated by the Heimaey, 1973 Eruption," 1973 (Reference 42).

"The Viscosity of Basaltic Magma, 1968 (Reference 33).

"The 1959 and 1960 Eruptions of Kilauea Volcano, Hawaii, and the Construction of Walls to Restrict the Spread of the Lava Flows," 1962 (Reference 21).

"Feasibility of a Lava-Diverting Barrier at Hilo, Hawaii," 1961 (Reference 55).

"Barrier to Protect Hilo from Lava Flows," 1958 (Reference 20).

"Protection of Harbors from Lava Flow," 1945 (Reference 16).

THE REPORT AND THE STUDY PROCESS

REPORT FORMAT

The report is divided into two components: the main report, which includes the Environmental Impact Statement (EIS), and the supporting appendices. The main report, essentially a summary of the study process, contains the planning logic and conclusions reached during the study. The format of the EIS follows recently adopted guidelines of the Council on Environmental Quality (CEQ). Detailed information in the EIS is summarized or referenced elsewhere in the main report when relevant to the discussion.

Because of the nature of the study, the material that would normally be presented in a plan formulation appendix is in the Plan Formulation section of the main report. The appendices attached to this report are listed below.

APPENDIX	TITLE
A	Property Value Study
B	Technical and Cost Analyses
C	Public Views and Responses
D	Aerial Photo Maps
E	Fish and Wildlife Service Planning Aid Report
F	Formal Biological Opinion, Endangered Species Office, Fish and Wildlife Service

STUDY PROCESS

The Lava Flow Control study followed the planning requirements of the Water Resources Council (WRC) and the guidelines of the U.S. Army Corps of Engineers for conducting feasibility studies for water and related land resources. The WRC planning requirements are presented in

"Principles and Standards for Planning Water and Related Land Resources" (P&S) (38FR 24778-24869, 10 September 1973). The guidelines of the Corps of Engineers are presented in "Water Resources Council Principles and Standards, National Environmental Policy Act, and Related Policies--Guidelines for Conducting Feasibility Studies for Water and Related Land Resources; Final Rules" (43FR 30222-30254, 13 July 1978).

These guidelines specify that feasibility studies be conducted in a three-phase process:

Stage 1 - Reconnaissance
Stage 2 - Intermediate Plan Development
Stage 3 - Detailed Plan Development

The four iterative tasks of problem indentification development, formulation of alternatives, impact assessment, and evaluation are performed at each stage, but with different emphasis for each stage. Separation of plan development into stages allows the development of more reliable and more precise plans throughout the study. Figure 2 is a generalized representation of the planning process followed in Corps of Engineers feasibility studies.

In the initial stage, the four tasks were performed at a limited level sufficient to define the scope and character of the study. The purposes were to determine the need for additional study and to establish a tentative schedule for performing the additional studies, if needed. The product of this stage was "Plan of Study, Hilo Lava Flow Control, Island of Hawaii," completed in May 1977.

In the second stage, the emphasis was on identifying and analyzing the full range of alternative measures. The emphasis in the final stage was on impact assessment and evaluation of alternative plans. The initial product of the final stage was the Draft Report and Draft EIS, distributed for public and agency review in July 1979. Comments on the Draft Report and Draft EIS, those received both at public hearings and through the mail, have been incorporated into this Review Report and Environmental Impact Statement.

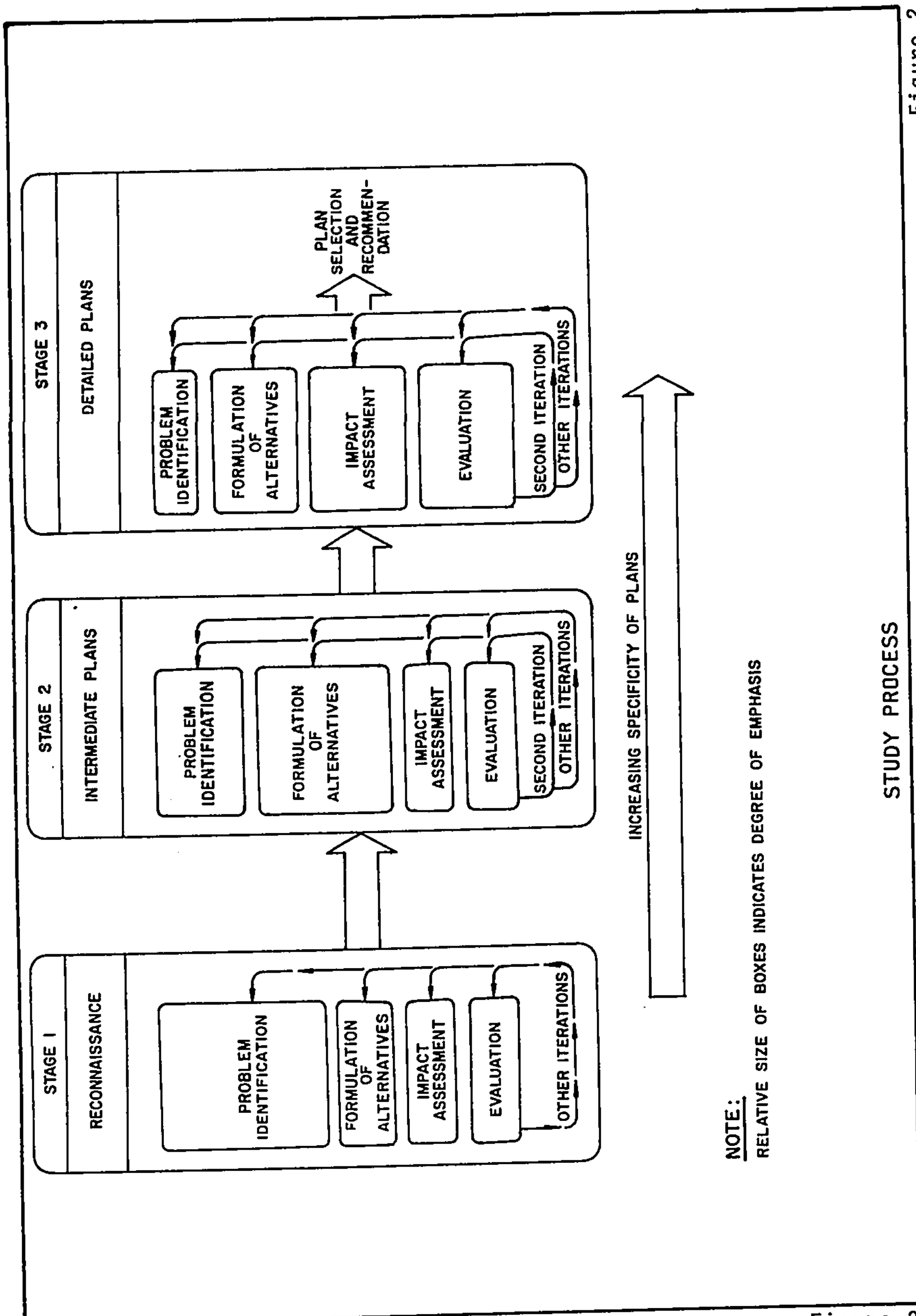


Figure 2

Figure 2

SECTION II

PROBLEM IDENTIFICATION

As shown in Figure 2, Problem Identification is the first step in the planning process. This task is performed in all three study stages, interacting with the accomplishment of the other planning tasks. Although problem identification forms the major task of stage 1, and is mostly completed in stage 1, the identification task continues and the results changed and refined throughout the study.

The activities performed as part of the Problem Identification task are outlined below.

1. Identify public concerns
2. Analyze resource management problems
3. Define the study area
4. Describe the existing condition
5. Project future conditions
6. Establish planning objectives

These activities are summarized in the sections that follow.

The activities were not conducted independently, but each drew on the results of the others. In particular, the planning objectives were formulated to address the problems and needs uncovered by the other activities. In turn, the planning objectives formed the basis for the formulation of plans in the next step of the planning process.

NATIONAL OBJECTIVES

The Water Resources Council's Principles and Standards (P&S) require that planning for development of water and water-related land resources must be directed toward achieving two equal national objectives: National Economic Development (NED) and Environmental Quality (EQ). The NED objective is achieved by a plan with results that increase the nation's output of goods and services and improve the national economic efficiency. The EQ objective is achieved by the management, conservation, preservation, creation, restoration, or improvement of the quality of certain natural and cultural resources and ecological systems.

As an aid to decision making and plan selection, the P&S require that an NED plan (the plan that maximizes benefits to the economy) and an EQ plan (the plan with the maximum contribution to the environment) be designated. If no plan can be formulated that is economically justified, the investigation is ended. If no plan can be formulated with net environmental benefits, the plan least damaging to the environment must be noted.

EXISTING CONDITION

The volcanoes of the island of Hawaii have been active almost continuously throughout recorded time. The two volcanoes now active, Kilauea and Mauna Loa, lie in close proximity to each other, their main vents being just over twenty miles apart. Combined, these two volcanoes have erupted over 80 times since the 1820's, when records first began to be made. The last eruption of a volcano other than Kilauea or Mauna Loa was the 1801 eruption of Hualalai, on the west side of Hawaii. The most recent eruptions of Kilauea are described in Section 1 of this report. The last eruption of Mauna Loa was a short, one-day summit eruption in 1975. Table 1 lists the recorded activity of Mauna Loa.

A rift line extends roughly northeast-southwest through Mokuaweoweo crater, Mauna Loa's summit caldera. A shorter, less developed rift extends north from the summit crater. Lava flows generally originate from points along these rifts, either on the slopes or in the summit crater. Mauna Loa is flanked by Mauna Kea on the north, Hualalai on the northwest, and by Kilauea on the immediate southwest. The mountain is a classic example of a shield volcano, with a broad, gently sloping dome. The Mauna Loa dome covers an area of about 2,035 square miles, more than half the area of the island of Hawaii. Mauna Loa (Long Mountain) is the largest single mountain on earth.

Hilo is the principal urban area of the island of Hawaii and the second largest city in the state. The area on which the present city is located has been inhabited for centuries and is mentioned repeatedly in Hawaiian historic chants and legends. Hilo Bay is the only sheltered bay along the eastern coast, and the city extends to the southwest of the harbor area. The topography is dominated by the twin peaks of Mauna Loa (13,679 feet) and Mauna Kea (13,784 feet). From Hilo, the ground slopes gradually and rather uniformly to those summits, rising up to the Mauna Loa summit in about 38 miles.

The total state resident population in 1977 was 894,700, with 78,100 living on the island of Hawaii. The Hilo area population was approximately 50,000, about 64 percent of the island's population. In 1978, the labor force of Hawaii County, which includes only the island of Hawaii, was 35,600. With an unemployment rate of 10.2 percent, the total

Table 1.* ERUPTIONS OF MAUNA LOA[a]

Date of outbreak	Approx. duration (days) Summit	Flank	Location	Altitude (feet)	Area (sq. mi.)	Approx. volume (million cy)
1832 Jun 20	21	(?)	SW rift	8,200(?)	6.8(?)	90
1843 Jan 9	5	90	NE rift	9,800	20.2	250
1849 May	15	-	Caldera	13,000[d]	-	-
1851 Aug 8	21	(?)	Caldera & SW rift	13,300	6.9	90
1852 Feb 17	1	20	NE rift	8,400	11.0	140
1855 Aug 11	-	450	NE rift	10,500(?)	12.2[b]	150
1859 Jan 23	1	300	NW flank	9,200	32.7[c]	600[c]
1865 Dec 30	120	-	Caldera	13,000	-	-
1868 Mar 27	1	15[e]	SW rift	3,000	9.1[c]	190[c]
1872 Aug 10	60[f]	-	Caldera	13,000	-	-
1873 Jan 6	2	-	Caldera	13,000	-	-
1873 Apr 20	547	-	Caldera	13,000	-	-
1875 Jan 10	30	-	Caldera	13,000	-	-
1875 Aug 11	7	-	Caldera	13,000	-	-
1876 Feb 13	Short	-	Caldera	13,000	-	-
1877 Feb 14	10	1[g]	W flank	-180±	-	-
1880 May 1	6	-	Caldera	13,000	-	-
1880 Nov 1	-	280	NE rift	10,400	24.0	300
1887 Jan 16	-	10	SW rift	5,700	11.3[c]	300[c]
1892 Nov 30	3	-	Caldera	13,000	-	-
1896 Apr 21	16	-	Caldera	13,000	-	-
1899 Jul 4	4	19	NE rift	10,700	16.2	200
1903 Oct 6	60	-	Caldera	13,000	-	-
1907 Jan 9	1	15	SW rift	6,200	8.1	100
1914 Nov 25	48	-	Caldera	13,000	-	-
1916 May 19	-	14	SW rift	7,400	6.6	80
1919 Sep 29	Short	42	SW rift	7,700	9.2[c]	350[c]
1926 Apr 10	Short	14	SW rift	7,600	13.4[h]	150[c]
1933 Dec 2	17	1	Caldera & SW rift	13,000	2.0	100
1935 Nov 21	1	42	NE rift	12,000	13.8[i]	160
1940 Apr 7	133	1	Caldera & SW rift	13,000	3.9[j]	100
1942 Apr 26	2	13	NE rift	9,200	10.6[k]	100
1949 Jan 6	146	2	Caldera	13,000	5.8	75
1950 Jun 1	1	23	SW rift	12,000[l]	15.6[c]	600[c]
1975 Jul 5	1	-	Caldera	13,000	-	35

* Taken from Stearns and Macdonald, Geology and Ground Water Resources of the Island of Hawaii, USGS, 1946 and Mullineaux and Peterson, Volcanic Hazards on the Island of Hawaii, USGS, 1974 (except for data on 1975 flow).

NOTES

a - The duration for most of the eruptions prior to 1899 is only approximate. Heavy columns of fume at Mokuaweoweo, apparently copious gas release accompanied with little or no lava discharge, were observed in January 1870, December 1887, March 1921, November 1943, and August 1944. They are not indicated on the table.

b - Upper end of the flow cannot be identified with certainty.

c - Area above sea level. The volumes below sea level are unknown, but estimates are included in the volumes given in the table.

d - All eruptions in the caldera are listed as 13,000-foot elevation, although many were a little lower.

e - Flank eruption started April 7.

f - Activity in the summit caldera may have been essentially continuous from August 1872 to February 1877 with only the most violent actviity visible from Hilo.

g - Submarine eruption off Kealakekua on the west coast of Hawaii.

h - 2.5 square miles of this is the thin flow near the summit. An unknown area lies below sea level.

i - About 0.5 square miles is the thin flank flow above the main cone and 0.8 square miles is in the caldera.

j - 2.8 square miles in Mokuaweoweo Caldera and 1.1 square miles outside the caldera.

k - 2.8 square miles is the thin flank flow near the summit and 0.5 square miles is in the caldera.

l - Source varied from 9,000 feet to 12,800 feet over a series of vents.

number employed was 31,900. Fifty-four percent of the labor force was employed in service industries, 19 percent in agriculture, 19 percent in trade, and 8 percent in manufacturing. The total personal income in 1976 in the county amounted to $445 million, an increase of 6.4 percent over 1975. The 1976 per capita income was $5,812, more than double the 1966 figure. The number of housing units in the county in 1970 was about 18,200. By 1977 this had grown to 25,300, showing an average annual increase of 4.2 percent.

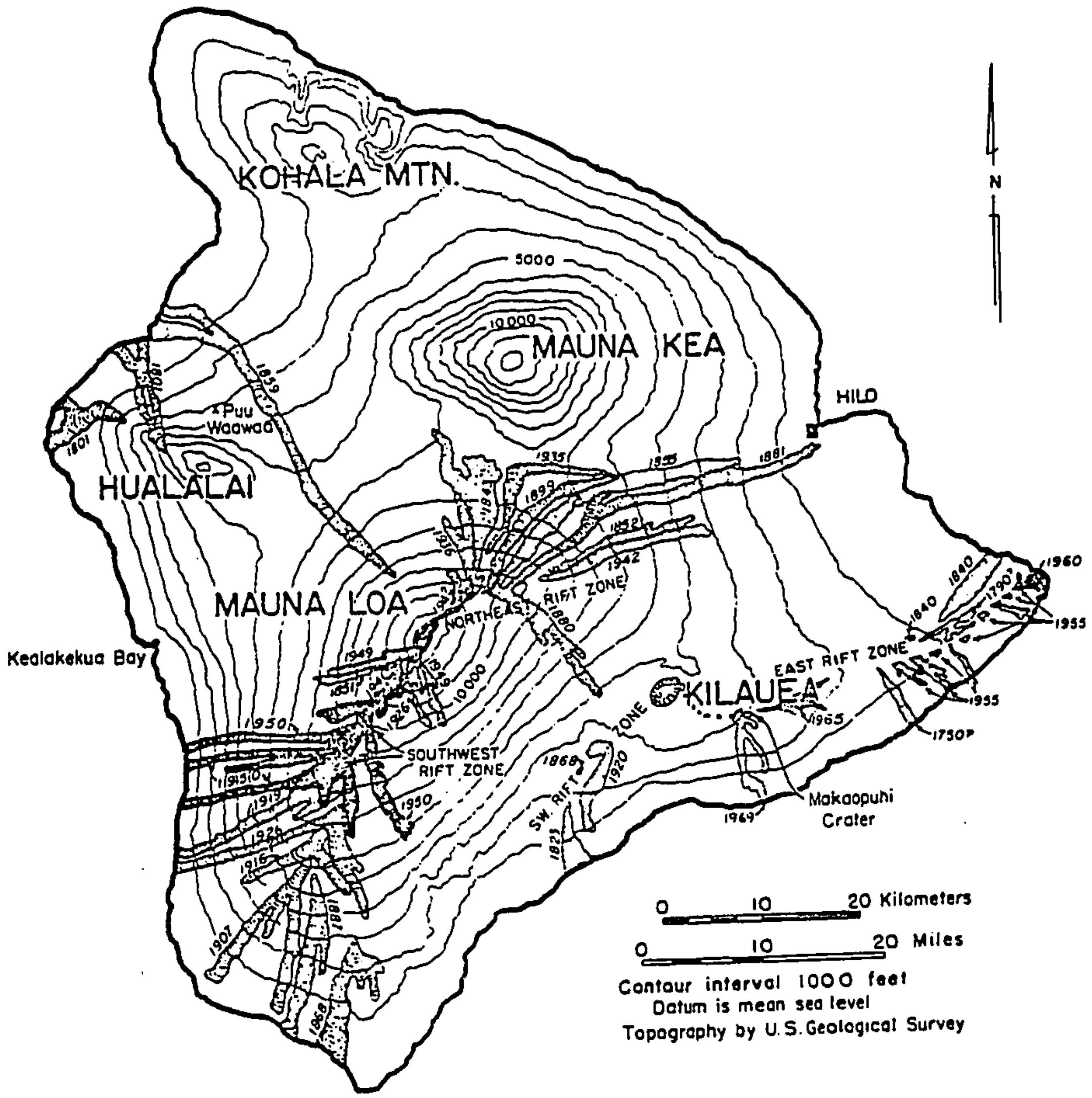
The island's economy has traditionally been based on agriculture and fishing. The mainstays of the island economy through the first half of the twentieth century were the pineapple and sugar industries, supplemented in the last two decades by an increase in diversified agriculture and manufacturing. However, the largest component of the island's economic base is now the tourist industry.

The island of Hawaii has a semi-tropical climate, but has wide variations across the island in temperature and rainfall. Temperatures range from 58 to 90 degrees (minimum-maximum) along the coastal plain to sub-freezing minimums in the mountains. Mauna Kea (White Mountain) often has a mantle of snow during the winter months. Rainfall varies from over 300 inches annually near the 3,000-foot elevation on the windward side to about 5 inches on the northwest coast. Hilo has an average annual precipitation of about 140 inches. Relatively uniform tradewinds prevail offshore, but disruption by the high land masses make inland winds very complex.

The island exhibits all stages of ecological succession from bare lava flows to dense rain forests. The low elevation forest from Hilo to Kalapana is interrupted by exotic plantations, mixed exotic forests, and expanding urban development. Between the 3,500- to 6000-foot elevations a nearly uninterrupted band of rain forest, dominated by ohia lehua, extends from Kilauea to Kohala. The study area is characterized by a complex forest, dominated on shallow soils by ohia lehua and elsewhere by koa. The extensively forested land within the study area provides habitat for a diverse group of plants and animals, including endangered species. For most, the area is only a small portion of their known range.

The study area encompasses or borders on identified area of biological significance that must be taken into consideration. These areas include:

State Forest Reserves
Waiakea 1942 Lava Flow Natural Area
Other Natural Area Reserves under consideration
Kipuka Ainahou Nene Sanctuary
Known habitat of endangered birds and plants
Hawaii Volcanoes National Park



VOLCANOES AND HISTORIC LAVA FLOWS ON THE ISLAND OF HAWAII

Taken from <u>Volcanoes in the Sea</u>, MacDonald and Abbott (Reference 22).

Cultural and historical areas of significance may also be affected by implementation of a project. These significant areas are treated in detail in the sections of the Environmental Impact Statement (EIS) that evaluate the impacts of lava flows and diversion alternatives.

A major concern expressed during this study was that any interference with the natural processes of the volanoes is contrary to traditional Hawaiian cultural beliefs. Some residents view any construction, such as diversion barriers, or aerial bombing as a confrontation with Pele, the Hawaiian volcano goddess, and oppose any overt action against an approaching flow.

WITHOUT CONDITION

The potential danger to the city of Hilo from lava flows originating in the northeast rift zone of Mauna Loa has been recognized for more than a century. The city should continue to follow existing growth trends with or without lava flow protective measures unless future eruptions threaten populated areas or unless zoning restrictions relating to the lava flow hazard are imposed in the future.

The population of the County of Hawaii was projected through the year 2000 by the Hawaii State Department of Planning and Economic Development (DPED). These projections, the latest from DPED, are designated by them as "series 11-F." DPED has requested that series 11-F projections be used by all agencies involved in population projections to promote uniformity and consistency. The population through the year 2035 was estimated by the Corps by extrapolating the population chart of the series 11-F projections (Table 2). The armed forces population on the island varied from 100 in 1976 to 200 in 1977 and is not a significant portion of the population compared to the civilian portion.

Table 2. Projected Population of Hawaii County

1975	75,000
1980	84,700
1985	95,200
1990	105,100
1995	115,000
2000	123,300

The forecasting horizon in the series 11-F projections extends to the year 2000. Basic assumption of these projections include:

A middle fertility level of 2.1 lifetime births per woman.

Visitor arrival growth rates of 7 percent for 1977-1979, 5 percent for 1980-1985, 4 percent for 1986-1990, 3 percent for 1991-1995, and 1 percent for 1996-2000.

An increase in defense expenditures of 2 percent annually.

Sugar and pineapple production remaining contant and a growth rate for other exports of 2 percent annually.

An increase in earnings per worker of 3 percent annually until 1985 and 2-1/2 percent after that date.

Per capita disposable personal income was projected in the series 11-F projections from year 1980 to year 2000 for the State of Hawaii. These projections were extended by using 2.49 percent per annum, the projected rate of growth of per capital income for non-Standard Metropolitan Statistical Areas of Hawaii. Table 3 tabulates the projected disposable and total per capita income for Hawaii County inflated to 1978 dollar value. The total per capita income was estimated from disposable per capita income based on a 16-year (1960-1975) average ratio of 1.19.

Table 3. Hawaii County Per Capita Income
(1978 dollar)

Year	Disposal	Total
1980	6,031	7,182
1985	6,824	8,127
1990	7,670	9,134
2000	9,526	11,345
2010	12,182	14,508
2020	15,579	18,553
2030	19,924	23,727
2035	22,531	26,832

The population growth in Hawaii is directly related to the growth of tourism. In 1977, the hotel employment in Hawaii County was 3,200; this figure should nearly triple to 9,100 by the year 2000. Most of the new hotels and resorts will be in the Kona and Kohala areas, resulting in greater population growth in these areas than in the rest of the island, including Hilo. The increase in tourism and hotel emploment will either directly or indirectly create jobs in other sectors (Table 4)

The number of hotel rooms in Hilo was fairly constant at about 36 percent of the island total during the 1970's, but the occupancy rate in Hilo has been lower than the overall island average since 1974. Hotels in Hilo experienced a 53 percent occupancy rate in 1977, much lower than the overall island average of 61 percent. Future outlook for tourism development in the Hilo area is not as attractive as for other areas. The State Tourism study shows that only about 25 percent of the future hotel units on the island will be built in Hilo.

Hilo Harbor is the island's largest and most developed deep draft port, handling the majority of imports and exports. The outshipped general cargo tonnage at Hilo Harbor has been gradually declining, partially due to increased shipments from Kawaihae Harbor. Shipments from Kawaihae have stabilized, and this declining trend may not continue.

Sugar and molasses are the leading export goods from Hilo, comprising about 80 percent of total outshipments. Significant expansion of export activity is not expected for Hilo since there is no sign of future development in the island's sugar and molasses industry. There is a possibility that about 70,000 tons of manganese product may be outshipped annually if the nodule processing plant is constructed at Puna. However, the development of manganese nodule mining and processing is very uncertain at this time.

Table 4. Employment Projections by Section for Hawaii County (Thousands of Jobs)

	1980	1985	1990	1995	2000
Primary Industries					
Sugar Field	1.5	1.4	1.3	1.2	1.1
Sugar Processing	1.4	1.3	1.1	1.0	.9
Pineapple Field	0	0	0	0	0
Pineapple Processing	0	0	0	0	0
Other Agriculture	1.3	1.5	1.6	1.6	1.6
Food processing	.7	.8	.9	1.0	1.0
Hotels	4.8	6.1	7.3	8.4	9.1
Government					
State-Local Government	6.0	6.9	7.8	8.7	9.5
Federal Government	.3	.3	.3	.3	.4
Construction	1.7	1.9	2.0	2.0	2.0
Other Industries					
Misc. Industries	.7	.7	.6	.6	.6
Transportation	1.2	1.3	1.5	1.6	1.7
Community/Utilities	.7	.8	.9	.9	1.0
Trade	5.7	6.6	7.4	8.2	8.8
Eating-Drinking	2.0	2.4	2.8	3.1	3.3
Banking/Finance/RE	1.2	1.5	1.8	2.2	2.5
Services	3.1	3.8	4.6	5.3	6.1
Jobs by Sector	32.3	37.3	42.0	46.2	49.6
Self-Employed	4.2	4.0	3.8	3.6	3.5
Total Civilian Jobs	36.5	41.2	45.7	49.8	53.1

Source: State of Hawaii Series 11-F Projections

Inshipped general cargo at Hilo grew from about 207,000 tons in 1959 to about 436,000 tons in 1977. Projections show that the volume of general cargo inshipped at Hilo should continue to grow through the year 2035.

All petroleum products used in the state originally come in by water transportation. From 1958 to 1977, an average of 93 percent of the petroleum cargoes brought into the island of Hawaii moved through Hilo Harbor. Growth in the Hilo area is expected to proceed at a slower rate than in the rest of the island, and the percentage of petroleum products handled at Hilo is expected to decrease. Because of continuing growth, the total tonnage of petroleum products inshipped to Hilo should continue to grow slowly.

The ambitious energy self-sufficiency program of Hawaii County may lead to the development of a comparatively inexpensive source of power that could attract processing or manufacturing industries to the island. There is the distinct possibility that the island could become the location for a manganese nodule processing plant if a clean, abundant, inexpensive energy source becomes available.

If the industry does establish on the island, an investment of over $500 million would be required for construction of the processing plant and the associated infrastructure. In addition, over $20 million would be required for the construction of the required power generating facilities. During the three-year construction period the Gross State Product would increase by about $202 million annually. Over 6,000 new jobs would be created statewide, with 5,000 in Hawaii County including 3,000 in the construction industry. If the plant were to become fully operational at the projected processing level of 3 million tons per year, it would increase the Gross State Product by $335 million.

The two major geographical districts within the study area are South Hilo and Puna. Figure 3 shows the state's land use districts for these regions. The four land use classifications are urban, rural, agricultural, and conservation. The urban classification is generally defined as lands in urban use with sufficient reserve to accommodate foreseeable growth. Rural lands are defined as those lands primarily comprised of small farms and low density residential lots with a minimum lot size of one-half acre. The agriculture district includes lands under cultivation or intended for cultivation. The conservation district consists primarily of those lands in the existing forest and water reserve zones.

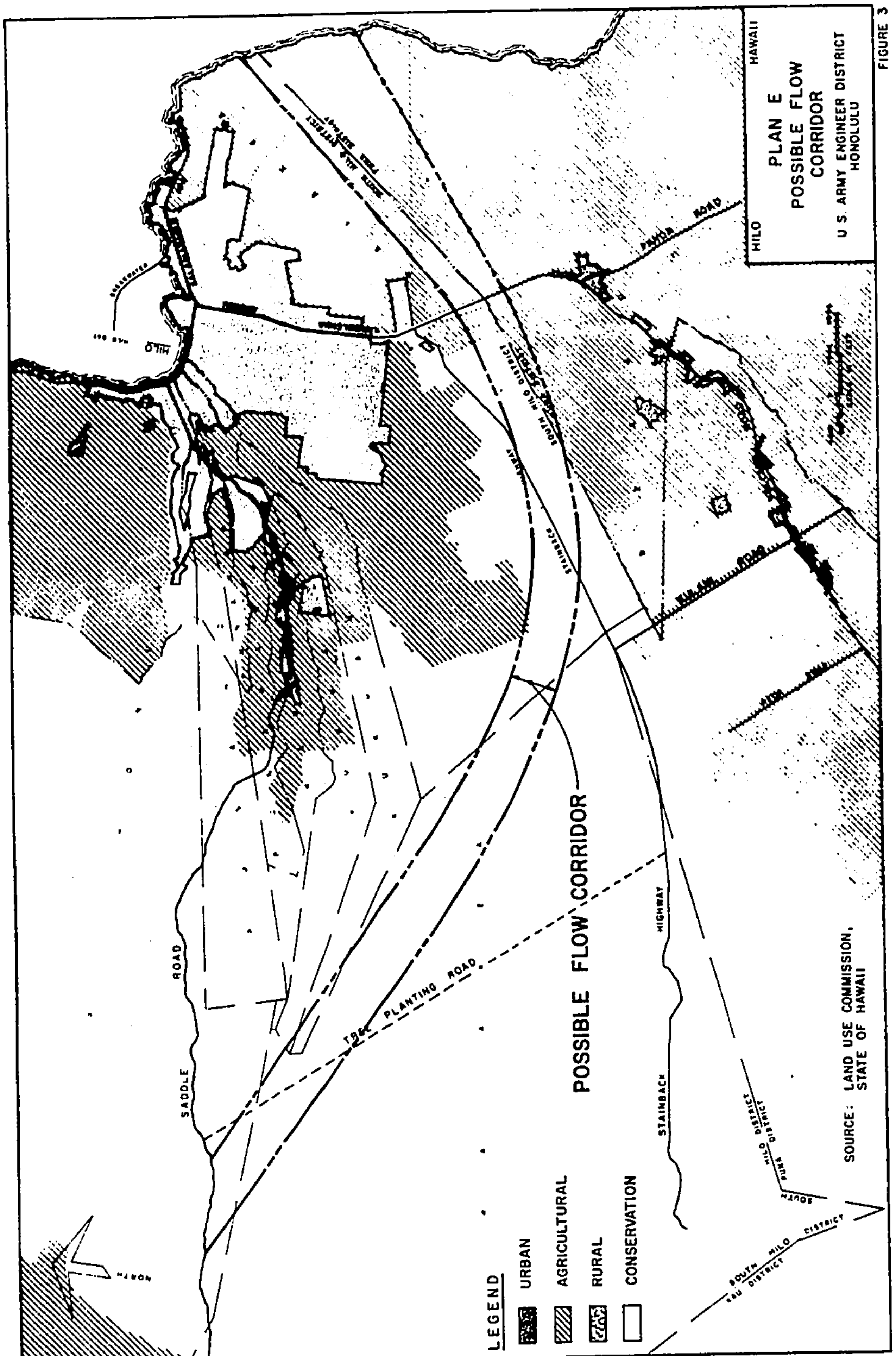

HILO HAWAII
PLAN E
POSSIBLE FLOW
CORRIDOR
U.S. ARMY ENGINEER DISTRICT
HONOLULU
FIGURE 3
POSSIBLE FLOW CORRIDOR
LEGEND
URBAN
AGRICULTURAL
RURAL
CONSERVATION
SADDLE ROAD
TREE PLANTING ROAD
STAINBACK HIGHWAY
PAHOA ROAD
NORTH
SOURCE: LAND USE COMMISSION,
STATE OF HAWAII

FIGURE 3

PROBLEMS AND NEEDS

Mauna Loa has been among the world's most active volcanoes. Most of the city of Hilo is built on geologically recent (about 1,400 years) Mauna Loa lava, and Hilo Bay is formed by Leleiwi Point, a protrusion of a broad lobe of Mauna Loa lava into the ocean.

Since 1843 there have been seven major eruptions in Mauna Loa's northeast rift zone, each producing a lava flow containing at least 100 million cubic yards of lava. Of the seven flows, four advanced within seven miles of the city. Lava from the 1880 eruption came within 1-1/2 miles of the harbor, and portions of Hilo are on the area covered by this flow. Table 5 lists the duration and approximate volume of lava of these seven eruptions.

Table 5. Major Eruptions of Mauna Loa Since 1843 (Northeast Rift)

Date	Duration (days)	Volume (1,000,000 cy)
January 1843	90	250
February 1852	20	140
August 1855	450	150
November 1880	280	300
July 1899	19	200
November 1935	42	160
April 1942	13	100

The greatest danger from Hawaiian lava flows is to property. Lava flows at a distance from the source vents generally move so slowly that they can be avoided, but they do cover large areas of land and can engulf and destroy structures. After cooling, the lava hardens into solid rock that is difficult to remove, severely limiting any future use of the land.

Lava extruded during an eruption moves downslope from the point of extrusion. The length of the flow depends on the slope, the rate of eruption, the duration of eruption, and the volume of lava extruded. Most historic eruptions have generated flows varying in length from 2 to 20 miles with widths up to 2 miles. The 1859 flow from the northwest flank of Mauna Loa, which had an approximate volume of 600 million cubic yards, reaches 35 miles from the point of eruption to where the flow enters the sea. In comparison, the vents of the 1942 and 1880-1881 flows are, respectively, about 28 and 30 miles from Hilo Harbor. If either of these eruptions had produced a flow equal in volume to the 1859 flow or to the 1950 flow from the southwest rift zone, which had a volume comparable to the 1859 flow, the lava most likely would have reached the city and entered Hilo Bay.

Other dangers associated with eruptions are rock fragments and gas clouds produced during explosive eruptions. Rocks and rock fragments can be ejected with great force from a volcano during a violent eruption, but the hazard is localized around the immediate area of the eruption. Gases and clouds containing mixtures of gases and fine particles can be emitted and drift downslope and downwind. Most Hawaiian eruptions are mild, rarely producing the explosions that eject rock fragments, gases, and gas-and-particle clouds. The danger does exist, however and should be recognized.

Figure 4 shows composite areas of risk from volcanic causes on the island of Hawaii. Risks included are lava flow, falling volcanic fragments, earthquakes, and gases. The areas are rated in terms of relative risk from A through F, with A the area of least hazard and F the areas of greatest hazard. These most hazardous areas (F) are the rift zones of Mauna Loa and Kilauea. Area E, which includes Hilo, are those downslope areas of Mauna Loa and Kilauea that are subject to being covered by lava should an eruption of those volcanoes occur.

Dr. T. A. Jaggar authored several papers in the 1930's addressing the dangers of lava flows and proposing a method of protection (Reference 16). The U.S. Army Corps of Engineers has examined the problem on several occasions (discussed on pages 2 to 4, Prior Studies and Reports). The results of these past studies indicated barriers to divert lava as a feasible solution from an engineering standpoint. The extreme unpredictability of eruptions makes it impossible to forecast exactly where and when an eruption will occur and what the volume of lava from an eruption would be. However, below the 11,500-foot elevation, eruptions from Mauna Loa's northeast rift will be influenced by the existing topography to flow generally within a six-mile wide belt directly oriented towards Hilo.

If a flow with the volume of the 1880-1881 flow were to follow the path of that flow, about 70 residential and public structures in the Kaumana section of Hilo would be damaged. Should a similar flow occur today and reach the central area of Hilo, millions of dollars of property damage would result. The current fair market value of all properties in Hilo, including contents and improvements, exceeds $700 million. The extent of damage from a lava flow would depend on the path of the flow and the width of the flow front.

PLANNING OBJECTIVES

Based on an analysis of social, economic, and environmental aspects of the study area, as well as the identification of problems, needs and desires, the following planning objectives were developed to guide the formulation and evaluation of alternative plans to protect the city of Hilo from lava flows:

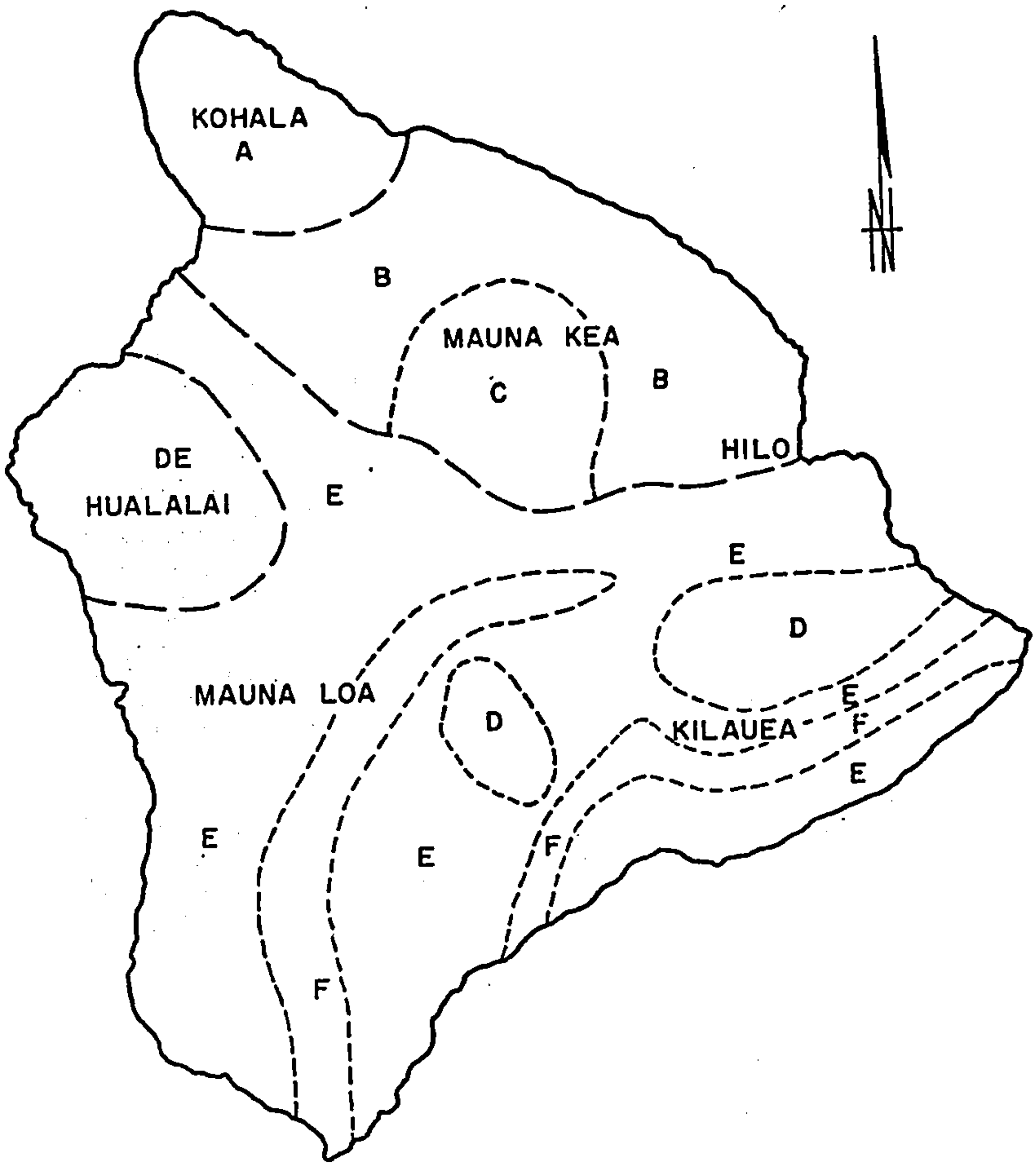


FIGURE 4. AREAS OF RELATIVE RISK FROM VOLCANIC HAZARD.

ADAPTED FROM "NATURAL HAZARDS ON THE ISLAND OF HAWAII", USGS: INF-75-18

Contribute to lava flow control, for the protection of private and public properties and the general well-being of the populace in the Hilo area against future Mauna Loa lava flows.

Protection of valuable cultural or biological resources in the Hilo area and in the slopes above Hilo likely to be adversely affected by lava flows from the northeast rift of Mauna Loa.

SECTION III

FORMULATION OF PRELIMINARY PLANS

MANAGEMENT MEASURES

Based on existing records of Mauna Loa eruptions, future lava extrusions can be expected to vary from brief to long-lived eruptions producing lava at varying rates. At the present state of knowledge and technology, an accurate prediction of location, frequency, duration, and volume of lava produced is not possible. Further, there is no practical way to stop or to slow an eruption. In contrast, it may be possible to alter or divert the path of flowing lava to minimize the damage that would otherwise have resulted. Lava diversion measures which have been employed in Hawaii and elsewhere include:

> The use of ordnance to disrupt the supply of lava at or near the source.
>
> Use of water to cool the approaching front to slow and divert the oncoming flow.
>
> The use of rock and earth barriers to divert the lava flow.

Additional measures that could be implemented to lessen the damages caused by lava include:

> Evacuation
> Relocation
> Land use restrictions

These measures all have potential to contribute to the effort to minimize damages caused by lava flows. Even though the effectiveness and reliability of diversion measures cannot be precisely determined, these measures should be considered separately and in combination with applicable nonstructural measures in the development of feasible solutions for prevention of lava flow damage.

PLAN FORMULATION RATIONALE

The primary objective of this study was to develop an acceptable and economically feasible solution for reducing damages should an eruption of Mauna Loa produce a lava flow of sufficient volume and duration to threaten the city of Hilo and Hilo Harbor. Implicit in the formulation of plans was the realization that the path, duration, and volume of future flows from the northeast rift zone would be similar to earlier flows from that rift zone.

The uncertainty of future eruptions, volume of flow, and probable frequency of hazard is partially shown by the historical record. As shown on Table 5, the duration of recorded eruptions (1843-1942) in the northeast rift zone has varied from 13 to 450 days and the volume of extruded lava from 100 to over 300 million cubic yards. Eruptions in other parts of the mountain (Table 1) have lasted as long as 547 days and produced lava in excess of 600 million cubic yards. This figure of 547 days may be inaccurate. The summit of Mauna Loa was in very frequent eruption between 1872 and 1876. Direct observations of the summit were much less common, and the exact length of eruptive phases cannot be established exactly. Between 1832 and 1950, the interval between eruptions of Mauna Loa were irregular, but averaged just over three years. However, no eruptions occurred in the 25 years between 1950 and 1975.

Summit eruptions such as the July 1975 event, with only one exception between 1832 and 1950, were followed within three years by a flank eruption. The pattern generally was two summit eruptions followed by a flank eruption. The time between the two summit eruptions was 2 to 3 years with the flank eruption following the second within a few days. Mauna Loa has been quiet since the 1975 eruption even though indications at the time led scientists at the Hawaiian Volcano Observatory to predict that a flank eruption would occur within three years. However, these indications and forecasts from the observatory have changed. Through early 1980, reports from the observatory revealed that an ongoing count of earthquakes at the summit is low; and that inflation and deflation of the summit and northeast rift zone, which show movement of magma into and out of an area, continued at only a slight level.

PLANS OF OTHERS

Although proposals for barriers to protect Hilo were made as early as 1937, there are no existing definite plans for the construction of barriers or for any other protective structures in advance of volcanic eruptions. The State of Hawaii does have an emergency plan for the protection of Hilo in the event of a threatening flow. The concept and responsibilities of the State of Hawaii Emergency Plan to protect Hilo from a lava flow are discussed briefly in the paragraphs that follow.

STATE OF HAWAII EMERGENCY PLAN TO PROTECT HILO FROM A LAVA FLOW

CONCEPT

The plan establishes the coordinated actions to be implemented by federal, state and county agencies assisted by the Hilo Contractors' Association to slow and/or divert a lava flow that threatens the Hilo area. Under this plan, the state government takes the leading role with the support and cooperation of all levels of government and the community.

Upon determination that a major eruption has occurred that could affect the Hilo area, a state control point will be established to direct and coordinate lava flow control operations. Based on flow data evaluated by the Hawaiian Volcano Obaservatory, a series of progressive actions will be implemented. Military ordnance may be directed at flow formations, and emergency barriers may be constructed at strategic locations. Water cooling of lava near Hilo and evacuation would be implemented should diversion measures be insufficient.

The seven support systems of the plan are:

Use of Military Ordnance for Lava Flow Control

Lava Barrier System for the Protection of Hilo, Island of Hawaii

Emergency Communications

Public Affairs

Logistics

Lava Flow Evacuation Plan for City of Hilo

CINCPAC Concept Plan (CONPLAN)

INSTITUTIONAL ARRANGEMENTS AND RESPONSIBILITIES

Hawaiian Volcano Observatory (HVO). The observatory would provide scientific and technical information, advice, and guidance for lava diversion operations relative to the use of techniques such as explosives, barriers, and other methods of control. The HVO would continue to monitor the situation and advise the Mayor of Hawaii County and the Director of Civil Defense.

State Civil Defense Agency. This agency is responsible for implementing the state emergency plan. In cooperation with the local government, the State Civil Defense Agency would arrange for the mobilization of equipment, materials, and manpower necessary for the emergency operations. The State Director of Civil Defense assumes direction and coordination of operation activities and makes recommendations to the Governor for state responses and actions, such as requests for military ordnance, technical assistance to construct emergency barriers, and presidential declaration of emergency.

Hawaii County Civil Defense Agency. This agency would activate the Hawaii County Emergency Operations Center. It would also provide cooperation with respect to the use of local facilities, services, and communication equipment as required and would direct county emergency support teams. This agency would also be responsible for any necessary evacuation.

Federal Emergency Management Administration (FEMA). The FEMA would evaluate requests for federal disaster assistance and direct and coordinate overall relief efforts. Upon a presidential declaration of emergency, FEMA would task the U.S. Army Corps o Engineers to provide direct federal assistance in barrier construction.

Commander in Chief, Pacific (CINCPAC). Pacific Air Force (PACAF) and U.S. Army Western Command (WESTCOM) would provide military assistance and resources of U.S. Department of Defense components, including the use of explosives.

U.S. Army Corps of Engineers. Under the existing State Emergency Plan, the Honolulu Engineer District would furnish engineering and technical assistance associated with emergency barrier work. The alignment of these barriers would be as shown in the State Emergency Plan. (The Corps of Engineers developed this alignment in 1975 (Reference 46) at the state's request.) A Memorandum of Agreement between the Corps of Engineers and the State Civil Defense provides for Corps assistance when requested by the state agency and for repayment of expenses incurred by the Corps in providing that assistance. Upon a presidential declaration of emergency and task assignment by FEMA, the Corps would provide direct federal assistance and assume overall direction for barrier construction.

If the results of this study are approved and immediate direct federal assistance is authorized, the State's Emergency Plan for diversion barrier implementation and the Corps role under that plan would change. The emergency barrier plan would be updated to reflect the current study, and Corps assistance would be available on request of the Governor.

Other State Agencies. The plan also requires all State of Hawaii departments to provide support upon request of the State Director of Civil Defense. The Hawaii Department of the Attorney General will advise and assist on all legal matters, while the Department of Land and Natural Resources will handle the problems in the area of environmental resources.

PRELIMINARY PLAN DESCRIPTION AND ASSESSMENT

The various measures identified as available to divert lava flows or to reduce damages from lava flows are listed under Management Measures in an earlier part of this section. The following paragraphs are a short discussion of each of these measures.

EVACUATION

There has been no recorded loss of life due to Hawaiian lava flows in recent history, so planning measures relating to protection of life were not evaluated in this study. If future eruptions resemble those of the past, the speed of a lava flow approaching Hilo will allow sufficient time for evacuation; and removal of some contents of buildings in the flow path would reduce loss. The State's Emergency Plan includes an evacuation plan developed by the County of Hawaii Civil Defense Agency.

While evacuation would prevent loss of life and reduce damages, major damage would still occur to property that cannot readily be moved. Community disruption could be severe as an indefinite amount of time would be required before people could return to the affected area.

RELOCATION

This alternative would require remove removal of damageable property and conversion of land to uses compatible with lava flow risk. Economic and social impacts of this alternative would be very high. The city of Hilo is intimately tied to its major transportation facilities (harbor and airport). Relocation to another site would severely disrupt the flow of goods and services, at a cost that may approach or exceed probable damages from future flows. It would require acquisition and development of new land. It is very likely that relocation would not be socially acceptable to most residents, particularly in view of the uncertainty of risk due to lava flow damage.

ZONING/LAVA INSURANCE

Restriction of future development in areas likely to be affected by future lava flows would confine economic losses to existing structures and unmovable contents. In order to actually reduce losses, authority would be required to limit repair or replacement of existing property as it deteriorates. Such restriction would create its own adverse economic and social impacts and would be unacceptable to the resident population. A federally funded lava insurance program, similar to existing flood insurance programs, could result with the passage of legislative acts in the future. Evaluation of insurance possibilities would involve lava hazard studies and more precise lava flow delineation on a technical and geological basis. Should such studies be undertaken in the future, it is likely that any lava insurance program would be established within the Federal Emergency Management Agency (FEMA), which has a similar program in flood insurance. Both zoning and lava insurance programs could be considered by other agencies that have responsibilities of this nature.

WATER COOLING

Large volumes of water solidifying the approaching lava front could be used to check the advance of a flow margin. In view of the proximity of Hilo to the ocean, sea water cooling is a potential measure. Freshwater cooling with water from the Wailuku River is less practical due to the limited quantity of water available during periods of low flow. Demonstrated success of seawater cooling on a 1973 lava flow in Heimaey, Iceland, increased interest in this method to protect Hilo[1/]. Icelandic officials, on the advice of geologists and geophysicists decided to cool and harden lava by spraying seawater on the advancing front. The cooling process increased the lava's viscosity and caused it to slow and thicken. The Iceland effort represents the most ambitious attempt by man to control lava flows to date. More than 19 miles of pipe and 43 pumps were eventually used in the cooling process. During a five-month period more than 26 million gallons of seawater were sprayed onto the lava flows. Water cooling on a small scale was used during the 1960 Kilauea eruption (Reference 21). Although the attempt accomplished little, the small amounts of water used did slow the movement of lava temporarily.

AERIAL BOMBING

The use of high explosives to disrupt lava supply channels has been attempted in Hawaii. During the northeast rift eruptions of Mauna Loa in 1935 and 1942, aerial bombing of flows met with apparent success in slowing and diverting the progress of the flows. Volcanologists suggest the explosives could again be used as the first line of defense high on the slopes of Mauna Loa. Three lava formations have been suggested as targets: lava tubes, lava channels, and spatter cones. During the late 1975 and early 1976, in corroboration with members of the Hawaiian Volcano Observatory, the Pacific Air Force conducted a series of three tests to investigate the effects of bombing on lava formations (Reference 44). The results of these tests on the northern slope of Mauna Loa confirm their preliminary conclusions that aerial bombing can disrupt lava flow, although the action would affect spatter cones, channel levees and tubes in different ways. Whether or not this methodology will eliminate the need for diversion actions at lower elevation will depend upon the location, magnitude, and duration of the eruption as well as the immediate availability of suitable aircraft and ordnance. Weather conditions and visibility during times of eruption are other factors which may limit the use of this technique. The use of military ordnance is identified as the first line of defense in the State Emergency Plan.

1/ References 17, 35, 36, 42, 48 and 56.

DIVERSION BARRIERS OR LEVEES

Diversion barriers to protect Hilo from lava flow were first proposed more than 40 years ago (Reference 16). Following preliminary studies by volcanologists, the Corps began an early investigation of lava barrier feasibility in 1938 and concluded that it would be possible to protect the harbor and city by a properly located and constructed barrier. The feasibility of the concept has been debated in the scientific literature since the early studies (Reference 20, 55). Barriers have been tried on a small scale on Hawaiian flows under emergency conditions with very little success. Attempts to control lava flows in Hawaii by barriers were made during the 1955 and 1960 eruptions of the Kilauea Volcano. These barriers were not effective due to (1) insufficient slope of the ground surface to provide a reasonable flow gradient, (2) barrier placement was essentially perpendicular to the line of flows, and (3) lack of heavy material in the vicinities requiring use of predominantly light-weight cinder. In the proposed work area, the natural ground slope will provide a sufficient flow gradient for diversion barrier; and, heavy material is readily available for effective barrier construction.

CONCLUSIONS

Though the nonstructural concepts of relocation and land use restrictions do represent measures with potential to reduce the overall damages that would occur in the event of a lava flow encroaching into Hilo, these measures are not considered to be in accordance with the objectives of this study, and they were eliminated from detailed examination. Both aerial bombing and evacuation are integral parts of the State Emergency Plan and could be implemented by the state should the need arise. Consequently, the detailed plan assessment and evaluation phase of the study was limited to examination of diversion barriers and water cooling measures, both for construction in advance of an eruption and for implementation under emergency conditions only. In this examination of the structural concepts of barriers and water cooling, five alternative plans were developed. These five plans are discussed in detail in the next section of this report.

SECTION IV

ASSESSMENT AND EVALUATION OF DETAILED PLANS

From the array of conceptual plans discussed in the previous section, five specific alternatives were determined to be compatible with planning objectives and feasible from engineering and economic standpoints (Figure 5, 6 and 7). Three of the plans (alternatives A, B, and D) would involve construction of diversion structures in advance of eruption. Alternative D would include freshwater cooling in addition to barrier construction. Alternative C involves seawater cooling only and at a lower elevation than the other plans. The fifth plan, alternative E, is an emergency action plan, with actual construction of barriers to begin only in the event of a threatening flow. The two fixed alignment barrier alternatives A and B provide the upper and lower limits of a corridor for flow diversion. Alignment A reflects the uppermost limit where effective diversion can be developed. Alignment B reflects the lowest limit (in elevation) where maximum protection to Hilo developments can be obtained. Plan E utilizes an alignment which would provide easy access and quick plan implementation under emergency conditions, recognizing that response time after eruption may be very short. Significant environmental impacts are anticipated, particularly from the actual earthwork construction of the barrier alternatives. Each of the five alternative plans would also result in residual economic losses due to lava flow diversion, should diversion be required. The type, severity, and duration of impacts would vary with individual plans. On the effectiveness of barriers, it should be noted that any subsequent diversion would be less effective than the initial diversion unless restoration work or corrective measures are accomplished through a maintenance program. Likewise, those alternatives (barriers) constructed prior to an emergency would be larger structures and more engineeringly capable of diverting lava flows since time is not a factor as in an emergency condition. The tabulation below provides a comparison of dimensions and costs between barrier construction in advance of the eruption and under emergency construction. Barrier design is discussed in Appendix B, Technical and Cost Analyses.

Barrier Section & Cost	Advance Construction	Emergency Construction
Height, ft.	30	12 - 15
Side slope	1 on 1-1/2 - 2	1 on 2 - 3-1/2
Crest, ft.	20	5 - 10
Approx fill, cy per mi	385,000	132,000
Approx cost per mi	$760,000	$360,000

DESCRIPTION OF ALTERNATIVE PLANS

ALTERNATIVE A

This plan involves construction of a fixed structure extending from about elevation 600 feet to about elevation 5,700 feet (Figure 5). The structure would be in two sections and would have a total length of about 22 miles. The structure would be approximately 30 feet high with a crest width of about 20 feet to allow for truck access during emergency operations. The structure base would vary up to 150 feet with the alignment sited at a maximum of 45 degrees from the direction of expected lava flow. A cleared flow path about 500 feet upstream of and parallel to the diversion structure would be provided as a part of this plan. Suitable material obtained by ripping or excavation within the cleared flow path would be used for the barrier embankment. Below elevation 600 feet, a flow easement varying up to 2,000 feet wide would be acquired for control purposes. The estimated first cost of this plan is $16.6 million, exclusive of land requirements estimated at $450,000.

ALTERNATIVE B

This alternative (Figure 6) involves construction of approximately 19 miles of barrier, comparable in sectional dimensions to alternative A. The major portion of the diversion structure would be located between elevation 200 and 3,600 feet. The upper section (3.4 miles) is identical to the uppermost structure of alternative A, which is designed to divert lava flows away from the Wailuku River basin. The lower 15.4 miles of barrier would be located below the 3,600-foot elevation. A 500-foot wide cleared flow path, as in alternative A, is also included in this plan. Below Highway 11 (Hilo - Olaa), a flow easement varying up to 2,000 feet in width would extend to the coast. The alignment of the barrier in this alternative is considered to be at the lowest possible elevation to preclude significant damage to Hilo from lava flows. Implementation would cost approximately $14.7 million, exclusive of land costs estimated at $370,000.

ALTERNATIVE C (Seawater Cooling)

This alternative (Figure 5) would involve the use of seawater pumped from Hilo Bay to cool the lava flow front to impede or divert flows from the high value areas of Hilo. A pumphouse with intakes in Hilo Bay would initially be constructed to be utilized for pumping seawater to an elevation of about 800 feet, the lowest elevation considered possible for effective employment of this technique. An extensive site survey would be required to establish the alignment to be used during actual lava flow conditions. A system of concrete thrust blocks that would hold the pipes in place during pumping would be installed along the selected alignment. A complete inventory of hardware, including pipes, pumps, valves, and miscellaneous fittings, would also be required. For the purposes of this investigation, it is estimated that equipment required would include three high head 1,100 gpm turbo pumps,. 24-inch cast iron pipes with a valve system for a feeder line to the flow front area, and 4-inch distribution lines with valves to provide water at the front. A minimum of 5 to 7 days lead time would be necessary for implementation of the initial phase of this alternative. Existing roads and cleared areas would provide access and alignments for the water lines. Cost of this alternative is estimated at $6 million, exclusive of $250,000 for lands and other costs for storage of materials in Hilo prior to use during conditions of threatening flows.

ALTERNATIVE D (River Pickup and Barrier)

This alternative, shown on Figure 6, combines barrier construction and fresh water cooling along the alternative B alignment. Initial construction would require placement of about 7 miles of 20 to 30-foot high structure on the upper levels. The structures in the lower 12 miles would be constructed to a height of only 10 to 15 feet. The cleared

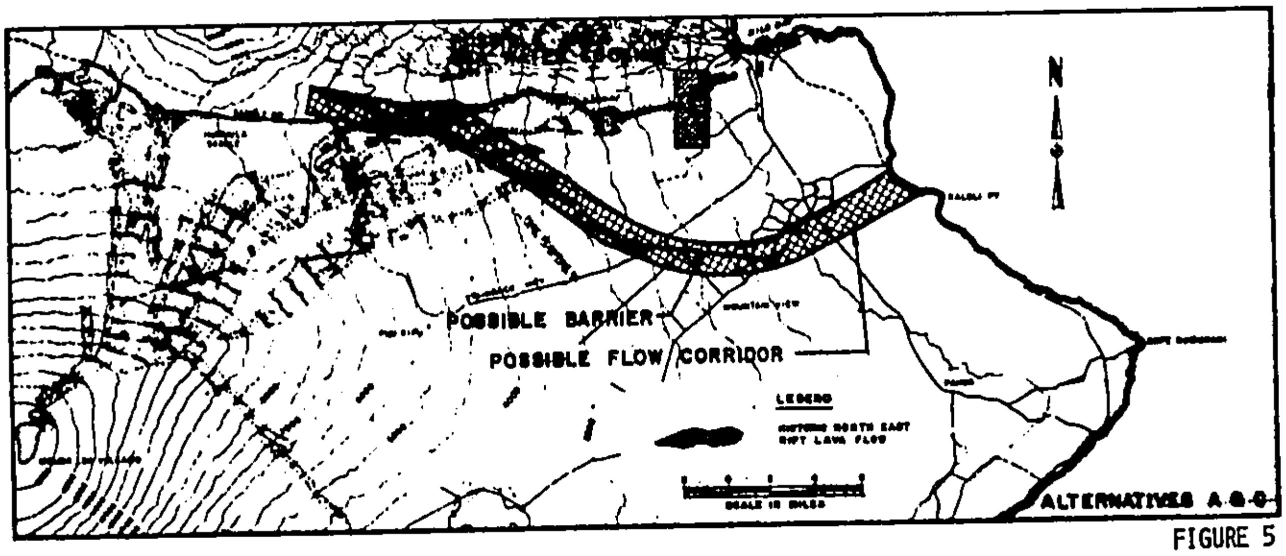


FIGURE 5

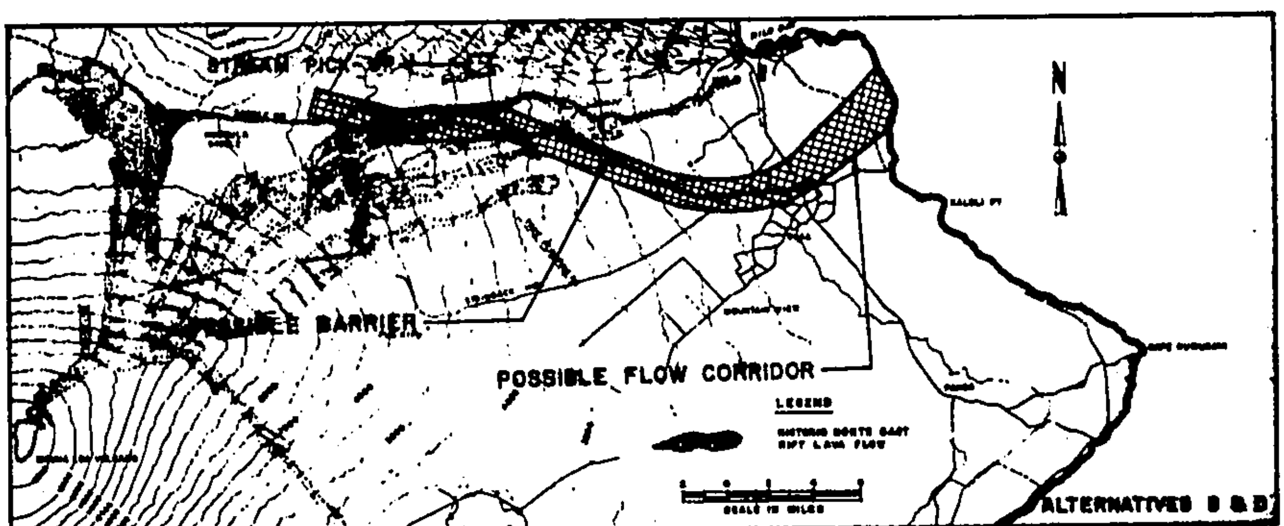


FIGURE 6

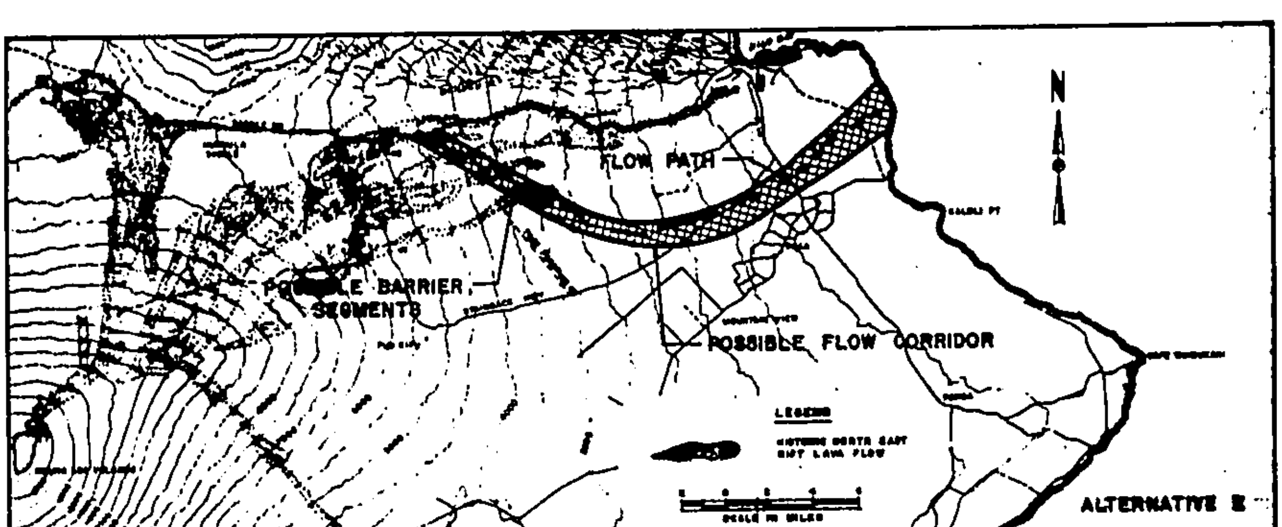


FIGURE 7

flowpath and flowage easement would be identical to alternative B. A stream pickup in the Wailuku River yielding approximately 10 mgd would be used to supplement the diversion barriers. A system of 24-inch cast iron pipes fitted with valves and stub-outs would supply water along the barrier alignment. A pump would not be needed if the pickup point were selected to utilize gravity flow. The cost for this alternative is estimated at $23.6 million, exclusive of land costs estimated at $370,000.

ALTERNATIVE E (Emergency Operation)

This alternative involves advance planning for lava diversion barriers to be constructed only in the event of an imminent, threatening lava flow. The alignment of barrier segments shown on Figure 7 illustrates approximately the locations under maximum diversion conditions. The size, length, number and locations of the barrier segments will be determined by the natural flow path, field conditions, and diversion efficiency. However, all diversion structures and diverted flows are anticipated to be confined in the corridor as shown on Figure 7. Appendix D contains aerial photo maps of the possible flow corridor and adjacent areas. Based on a maximum condition, the construction of about nine miles of diversion structures would be required, along with a 23-mile cleared flow path and flowage easement. The cost of this alternative is estimated to range up to $3.25 million exclusive of $310,000 for lands. The total federal cost of this emergency action would be determined by the duration, volume, and path taken by the actual flow and by the size and extent of the barriers needed to successfully divert the oncoming flow.

BENEFIT ANALYSIS.

Historic Mauna Loa lava flows are shown in Table 1 on page 11. Based on the events of eruptions on the northeast rift and north flank, two statistical (graphical) plots were made of volume-probability, using plotting points and procedures explained in "Statistical Methods in Hydrology" by Leo R. Beard. The first graphical analysis shows six eruptions that occurred on the northeast rift and flowed towards Hilo; the second includes an additional, more voluminous, north flank eruption and the 1843 northeast rift eruption which moved towards northwest. The methodology employed in determining the frequency, magnitude and duration for a volcanic eruption is not based on scientific findings. Volcanic eruptions are a result of numerous parameters that include, but are not limited to, tectonic movements, degree of gas saturation of the magma, and geologic setting. Any or all of the numerous parameters may have a significant effect on the occurrence, including rate of extrusion, magnitude, duration, and volumes of volcanic eruptions. Based on a series of papers by R. Wickman entitled "Repose Periods Patterns of Volcanoes" (1965) no set model or statistical distribution has been identified as being more reliable than another in describing the occurrence of this natural phenomenon. Therefore, the "median plotting" procedure developed by Leo R. Beard in "Statistical Methods in Hydrology" was considered appropriate. The expected probability adjustment, which assumes a certain unreliability of statistics due to the shortness of records, and an adjustment for the "non-zero" years of record were employed in developing the volume-frequency curves shown in Figure 8.

If probable future flow volumes were based only on past flows moved towards Hilo, Curve A would be applicable. However, if the more voluminous north flank flows and the 1843 northeast rift were included, then Curve B would be appropriate. Table 6 provides a comparative tabulation of Exceedance Frequency versus Flow Volume for these two possibilities. These two conditions indicate the wide variation in flow volumes that result from different assumptions, including statistical methods.

TABLE 6. COMPARATIVE FLOW TABULATION

EXCEEDANCE FREQUENCIES	FLOW VOLUME X 10^6 CUBIC YARDS CURVE A	CURVE B
50 years	160	220
100 years	215	360
300 years	350	720
500 years	420	960

Statistical analysis of six northeast rift eruptions included in Curve A revealed a linear relationship between the logarithmic values of the areal coverage of lava and the logarithmic value of the probability of occurrence. This relationship can be approximated by the following equation:

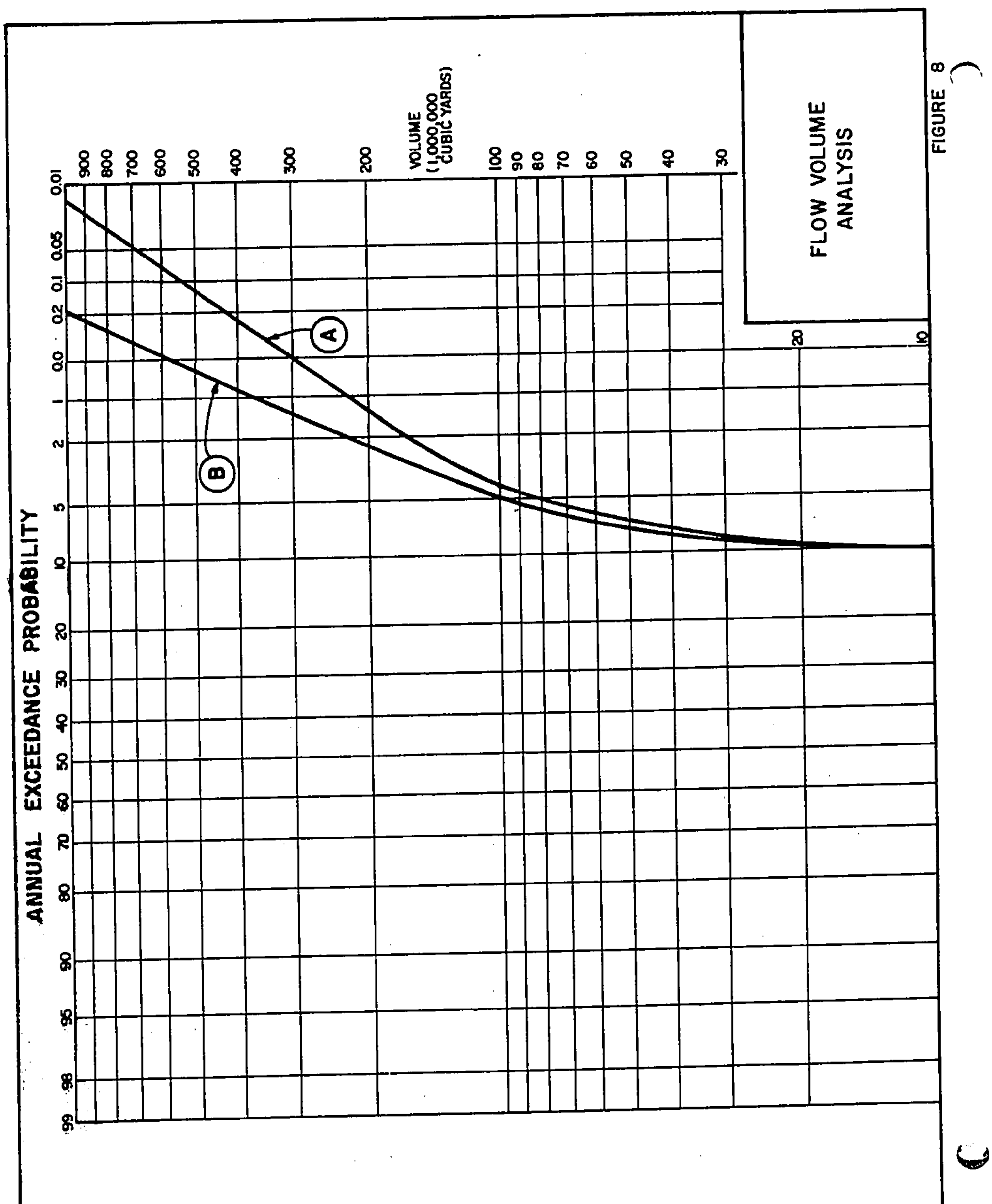
$$P = 7.81\ A^{-2.18},\ A \geq 10$$

Where A is the lava flow area in square miles and P is the annual probability of eruption of a lava flow with an area equalling or exceeding A. The frequency and extent of future eruptions can be estimated, assuming they follow the historical trend.

Expected Average Annual Benefits Under Existing Conditions.

Lava from the 1880-1881 eruption had an areal coverage of 24 square miles and reached within 1.5 miles of Hilo Harbor. The probability for this eruption to occur in any given year is 0.0067 or once every 150 years on the average. A comparable flow under existing conditions would cause severe damages to about 70 residential and public structures, roads, water systems, and other utility systems in the Kaumana section of Hilo. The market value of these structures and their contents, roads, and utilities is estimated at $7,800,000.

An inundation of lava greater in area than the 1881 flow in approximately the same location would affect urban areas of Hilo. For a 200-year return period, the lava coverage would be approximately 27 square miles. Due to the uncertainty of lava flow patterns, the land area covered cannot be accurately predicted. In a 1978 inventory and analysis of Hilo properties, the total current fair market value of damageable properties was estimated at $706 million (Table 7). The net damageable property value, excluding Kaumana section, is about $698 million. Based on this total property value of the 14 square miles of urban area and the assumption that the chances for damaging any part of Hilo are the same, the expected resultant damage for a 200-year event would be about $150 million.



ANNUAL EXCEEDANCE PROBABILITY
0.01
0.05
0.1
0.2
0.0
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
VOLUME
(1,000,000 CUBIC YARDS)
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
A
B
FLOW VOLUME
ANALYSIS
FIGURE 8

FIGURE 8

Any larger eruption would cause more damage, but some of the discharge would probably flow into the sea. No recorded northeast rift eruptions reached the coast in historic time, but about one-half the volume of eruptions occurring on the north flank and southwest rift flowed into the sea. Since these eruptions occur at somewhat lower altitude than northeast rift eruptions, it is assumed that, with a suffficiently long and large northeast rift eruption, about one-third of the lava volume could flow into the sea. Based on this assumption, it was estimated that an equivalent total lava flow with areal coverage of 55 square miles could cover a major portion of Hilo. The chance of this happening in any year is 0.0011. In other words, this event is expected to occur once in every 900 years. An event of this magnitude could conceivably destroy more than $700 million of damageable property in Hilo and would fill the shipping channel. The dredging cost for a new harbor is estimated at $40 million.

With any flow having a probable frequency of less than the 100-year event, no damage is expected to occur in the urban Hilo area. The lava flow size/damage relationship is tabulated below:

RETURN PERIOD (Years)	PROBABILITY OF OCCURRENCE	VOLUME (106 Cubic Yards)	COVERAGE (Sq. Mi.)	ESTIMATED DAMAGE ($Million)
100	0.01	215	19.9	Negligible
150	0.0067	250	24.4	8
200	0.005	300	27.4	150
900	0.0011	520	54.9	746

Effectiveness of the five alternatives discussed in this study cannot be determined with reasonable accuracy. It is conceivable that these alternatives might not fully protect the properties and some residual damages would occur. For the purpose of estimating the expected project benefits, it is assumed that there will be a 15% residual damages due to possible engineering inadequacy of the protective measures. Under the current conditions, the expected average annual benefit resulting from alternative A, estimated from a damage frequency curve (Figure 9), and an assumed 15% residual damages is $2.33 million. Alternatives B and D would not provide complete protection for the upper Waiakea Homestead area as would be provided by plan A. Accordingly, the expected average annual benefit is reduced to $2.27 million for each. As alternative C would not protect the Kaumana development and part of the Waiakea Homestead development, the expected average annual benefit for this plan is estimated to be $2.20 million.

TABLE 7. TOTAL PROPERTY VALUES IN HILO

ITEM	TOTAL DEPRECIATED REPLACEMENT VALUES	TOTAL DEPRECIATED REPLACEMENT VALUES ADJUSTED FOR EVACUATION
Commercial/Industrial	$302,604,000	$181,928,000
Single Family Dwellings	230,814,000	230,814,000
Multi-family Dwellings	81,478,000	81,478,000
Hotels	34,373,000	34,373,000
Agriculture	1,398,000	1,398,000
Public Facilities	183,684,000	143,433,000
Public Utilities	44,920,000	33,074,000
TOTAL	$879,271,000	$706,498,000

Information furnished by the Hawaiian Volcano Observatory indicates that in west Hilo, the maximum width of any single flow is approximately two kilometers and could possibly be as much as six kilometers wide in the east Hilo area. Also, based on present knowledge, geologist at the observatory estimate that it may have been more than one thousand years since lava flow entered Hilo Bay. Lava inundation would reduce land value, but this damage is insignificant compared to damages to improved properties and facilities. Diversion plans under consideration would divert the lava flow to the ocean along a cleared flow path that would be located, as much as possible, on undeveloped and uncultivated land.

The potential flow paths for alternatives A, B, D, and E consist primarily of conservation and agricultural lands which have limited structural development. Flow paths for alternatives B, D, and E are about the same in alignment, and these alignments are likely to affect the macadamia nut orchards. Alternative A is likely to cause damage to sugarcane crops with flow diversion, and based on the maximum requirement for lands and easements (plan A - 3,530 acres), the maximum assessed value for the affected areas would be $1.3 million. Furthermore, if the attempt to confine lava to underdeveloped land is not successful, damages estimated at up to about $9 million could occur to agricultural products and improvements. However, netting these estimated implementation damages would not significantly affect project feasibility.

Alternative B is closer to urbanized areas than the other barrier alternatives, and there are some sparsely scattered residential property at or near the conceptual alignment. Among the alternatives, plan A is most distant from Hilo City. Its alignment is on agriculture and conservation lands with the exception of some small urban districts near the lower end. However, a carefully selected layout could avoid relocation. Alternative C is on urban and agriculture lands. Under lava cooling or diversion conditions, this plan would be expected to have more undesirable social-economic impacts than other alternatives. This is due to the emergency nature of water cooling, which would be a last ditch effort to provide protection near the urbanized area.

There is only one recorded (1859) historic eruption along the north flank of Mauna Loa. This flow had an approximate volume of 600 million cubic yards with an areal coverage of 32.7 square miles, more voluminous than any

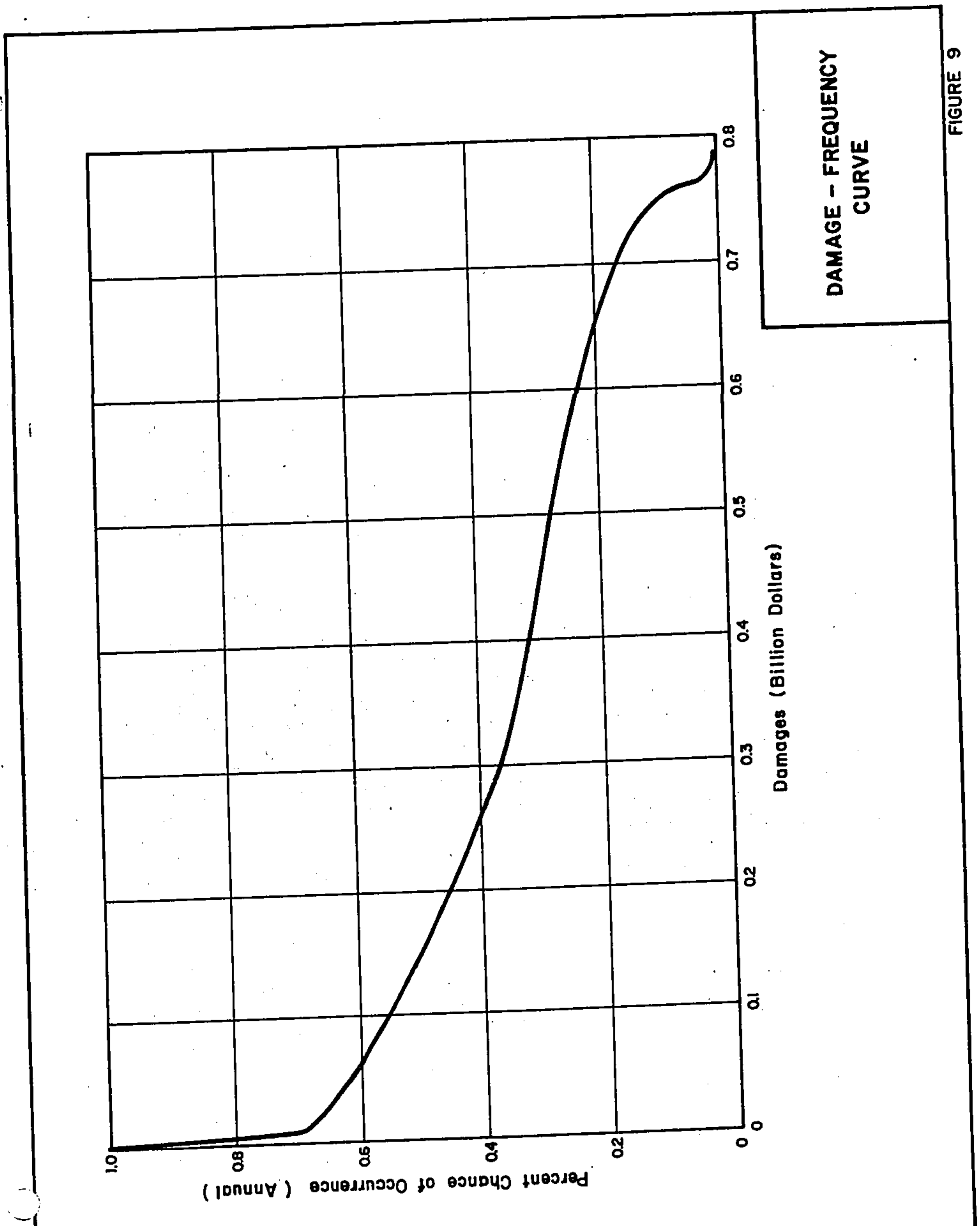

DAMAGE – FREQUENCY CURVE
FIGURE 9
Damages (Billion Dollars)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Percent Chance of Occurrence (Annual)
1.0
0.8
0.6
0.4
0.2
0

FIGURE 9

recorded northeast rift eruption. The 1950 flow from the southwest rift zone had a similar volume. If either of the 1881 or 1942 northeast rift eruptions had produced a flow with a volume equal to that of the 1859 or 1950 flows, the lava almost certainly would have covered much of the present day Hilo and entered Hilo Bay. Inclusion of the north flank event and the 1843 northeast rift flow in the statistical analysis would significantly increase the potential damages to Hilo, resulting in an estimated average annual benefit of about $5.5 million. However, since these two eruptions were not directed towards Hilo, the lower average annual benefit of $2.33 million, based on the analysis of six historical northeast rift eruptions, was adopted for this study. Based on the analysis of annual benefits under existing conditions and annual costs amortized from a discount rate of 7-1/8 percent, estimated benefit-to-cost ratios over a 50-year period of analysis are 1.6 for alternative A, 1.8 for alternative B, 3.4 for alternative C, and 1.1 for alternative D.

Under the emergency operation plan (Alternative E), the construction costs incurred for different lava eruptions would depend on vent location, volume, and rate of extrusion. Benefits resulting from protective actions would also vary according to conditions. As a minimum, it is possible that a flow could stop short of diversion barriers, and the expenditures for emergency actions will result in no damage prevention. Conversely, it is possible that extensive damageable properties in Hilo could be protected. For the purpose of comparison, based on probable maximum annual benefits and charges, the benefit-to-cost ratio is 7.3.

Expected Average Annual Benefits Under Projected Future Conditions.

As discussed in Section II, the population growth on the island of Hawaii is directly related to the growth of tourism. Since only about 25 percent of the future hotel units on the island will be built in Hilo, it is assumed that only 25 percent of the islandwide population growth will be in the Hilo area. Based on this assumption and the latest State of Hawaii Series II-F population projection for the island, the annual rate of population growth in the Hilo area was calculated to be 0.8 percent. It is further assumed that the damageable properties in the Hilo area will increase at the same rate as population growth. The damageable property values in the year 2028 were then estimated to be $1.111 billion, which is $365 million over the 1978 estimate of $746 million. Including these damageable properties from future development, the expected average annual benefits will be increased by a factor of 13.1 percent.

The residential content value will also grow corresponding to the steadily increasing per capita personal income and personal consumption expenditures. Currently, the content to housing structure value ratios for single family dwellings and multifamily dwellings in Hilo are 50 percent and 45 percent, respectively. From the State of Hawaii Series II-F projections discussed in Section II, the annual rate of growth of per capita income in Hawaii County was calculated to be 2.3 percent. Assuming that the residential content values will also grow at an annual rate of 2.3 percent, then it will take 18 years for single family content to reach the maximum of 75 percent, allowed under ER 1105-2-351, of the structure value and 22 years for the multifamily content. To account for the effect of net growth of residential content values, the expected average annual benefits will be increased by a factor of 4.3 percent.

The expected average annual benefits, considering the projected future development and an affluence factor benefit for upgrading of residential contents are $2.75 x 106 for alternative A, $2.68 x 106 for alternatives B and D, and $2.6 x 106 for alternative C. The benefit to cost ratios over a 50-year period of analysis are 1.9 for alternative A, 2.1 for alternative B, 4.0 for alternative C, 1.3 for alternative D, and 8.6 for alternative E.

IMPACT ASSESSMENT

Lava flows are viewed as venting of anger by Pele among many people, especially Hawaiians, and that the legends of Pele and spiritual values are important to them from the social and cultural standpoints. Although opposition to lava flow interference is strongest for bombing measures, any form of flow diversion efforts will upset some people while others might be skeptical. The general opinion is that when Pele is doing no harm to human activities, do nothing to anger Pele. During the 1977 Kilauea eruption and lava flow in the Kalapana area, public opposition prevented experimental waterbombing by the military. The purpose of waterbombing was to determine the effects diversion had on an actual lava flow. It should be noted, however, that this particular flow did not impact on an urban area. In the event of a large flow from the northeast rift of Mauna Loa approaching Hilo, it is likely that public acceptance to protective measures will increase significantly.

The economic, social, and environmental affects of the alternative plans were assessed, evaluated, and summarized and are shown in the Summary Comparison of Alternative Plans (Table 8). The table displays the significant contributions, beneficial and adverse effects, and the extent to which the planning objectives and evaluation criteria are met by each plan. In assessing the evaluation criteria (Table 8, Item C3), it is recognized that a probability of diversion failure exists for each of the five alternatives, due primarily to the different parameters regarding lava flow characteristics. A detailed environmental impact assessment for each alternative is presented in the Environmental Impact Statement.

TABLE 8. SUMMARY COMPARISON OF ALTERNATIVE PLANS
(BASE CONDITION: YEAR 1990)

		WITH CONDITION PLANS				
	WITHOUT CONDITION	BARRIER "A" PLAN A	BARRIER "B" PLAN B	SEAWATER COOLING PLAN C	RIVER PICKUP AND BARRIER PLAN D	EMERGENCY BARRIER PLAN E
A. PLAN DESCRIPTION						
1. STRUCTURAL FEATURES	NO ADVANCE OR PREPLANNED DIVERSION BARRIER CONSTRUCTION.	22-MILE BARRIER	19-MILE BARRIER	PUMPHOUSE, PIPING	19 MILE BARRIER	UP TO 9 MILES OF BARRIER SEGMENTS
2. NON-STRUCTURAL FEATURES	LOCAL EMERGENCY OPERATIONS.	31-MILE FLOWPATH	30-MILE FLOWPATH	EMERGENCY PIPELINE	30-MILE FLOWPATH	UP TO 23-MILE FLOWPATH
3. LAND REQUIREMENTS (STRUCTURES)	NONE	400 ACRES	350 ACRES	5 ACRES	350 ACRES	UP TO 150 ACRES
CLEARED CORRIDOR	NONE	1,390 ACRES	1,450 ACRES	NONE	1,450 ACRES	UP TO 1,070 ACRES
FLOWAGE EASEMENT	NONE	1,740 ACRES	1,240 ACRES	NONE	1,240 ACRES	UP TO 1,280 ACRES
TOTAL LANDS	NONE	3,530 ACRES	3,040 ACRES	5 ACRES	3,040 ACRES	UP TO 2,500 ACRES
B. IMPACTS ASSESSMENT						
1. SOCIAL WB, & REGIONAL DEVELOPMENT						
a. HEALTH, SAFETY & COMMUNITY WELL-BEING	IF FLOW OCCURS. IMPACT WILL VARY WITH DIRECTION & EXTENT OF FLOW. UNTIL FLOW OCCURS LACK OF PROTECTIVE MEASURES MAY CREATE APPREHENSION AMONG THOSE LIVING IN PROBABLE FLOWPATH. CONCERN WILL INCREASE WITH EACH ERUPTION.	PROTECTION IN HILO-KEAAU. REDIRECTION OF FLOW TO MOUNT VIEW AREA, STAINBACK HIGHWAY.	MORE UNPROTECTED AREAS THAN PLAN A.	GREATER RISK THAT CONTROL WILL BE UNSUCCESSFUL THAN OTHER PLANS.	SIMILAR TO PLAN B	WITHOUT ACCOMPANYING LAND USE CONTROLS, PEOPLE MAY DISCOUNT LONG-TERM RISK AND OCCUPY HIGH RISK AREAS. THIS WOULD STIMULATE SHORT-TERM BENEFITS TO COMMUNITY GROWTH BUT COULD INCREASE PROBABILITY OF FUTURE DISPLACEMENT OF STRUCTURES FOR DIVERTED LAVA FLOW. HEALTH, SAFETY AND COMMUNITY WELL-BEING BE MORE ADVERSELY AFFECTED WHEN LAVA FLOW OCCURS, BUT SHORT-TERM SENSE OF SECURITY WOULD PREVAIL.

		WITH CONDITION PLANS				
	WITHOUT CONDITION	BARRIER "A" PLAN A	BARRIER "B" PLAN B	COOLING PLAN C	RIVER PICKUP AND BARRIER PLAN D	EMERGENCY BARRIER PLAN E
b. DISPLACEMENT OF PEOPLE	POTENTIAL EXISTS TO DISPLACE NEARLY ENTIRE POPULATION, BUT AT LOW HEALTH AND SAFETY RISK DUE TO SLOW MOVEMENT OF FLOW. LONG-TERM GROWTH OF HILO COULD BE REVERSED IF FLOW MODIFIES HILO HARBOR.	MINIMAL DISPLACEMENT ALONG STAINBACK, MOUNT VIEW-OLAA AREA. DIVERTED FLOW WOULD TEMPORARILY AFFECT ACCESS TO AND FROM HILO.	GREATER DISPLACEMENT IN WAIAKEA SUBDIVISION, KEAAU AREAS. ACCESS TO HILO AFFECTED AS IN PLAN A.	ALIGNMENT CAN BE ADJUSTED TO MINIMIZE DISPLACEMENT.	SIMILAR TO PLAN B.	POSSIBLE TEMPORARY DISPLACEMENT DURING EMERGENCY OPERATIONS. ACCESS TO AND FROM HILO AFFECTED IF DIVERTED FLOW REACHES HIGHWAY.
c. NOISE	HIGH NOISE LEVELS DURING FLOW	SIGNIFICANT INCREASE IN NOISE DURING CONSTRUCTION.	SAME AS IN PLAN A.	MINIMAL IMPACT.	SIMILAR TO PLAN B.	SAME AS PLAN A, BUT SHORTER DURATION.
d. AESTHETIC VALUES	POTENTIAL TO DESTROY MUCH OF EXISTING LANDSCAPE.	EXTENSIVE FOREST DESTRUCTION.	FOREST DESTRUCTION AT LOWER ELEVATION THAN PLAN B.	MINIMAL IMPACT.	SIMILAR TO PLAN B.	REDUCES FOREST DESTRUCTION TO MINIMUM COMPARED TO PLANS A, B, AND D.
e. COMMUNITY COHESION AND GROWTH	GROWTH IN LAVA-PRONE AREAS MAY BE RETARDED BY LAND USE CONTROLS OR APPREHENSION DUE TO LACK OF PROTECTION.	ADVERSE IMPACT DUE TO ARBITRARY PROTECTION OF SOME PROPERTIES: SOME ACCELERATION OF GROWTH IN HILO DUE TO PROTECTION.	SAME AS PLAN A.	PROBABLY LITTLE EFFECT, VIEWED BY MOST AS LAST DITCH ALTERNATIVE.	SIMILAR TO PLAN A.	ENHANCE GROWTH BEHIND KNOWN LINE OF DEFENSE.
2. ECONOMIC						
a. PROPERTY VALUES	NO CHANGE. MAY DECLINE OR GROW MORE SLOWLY IN VULNERABLE AREAS, PARTICULARLY, IF ZONING OCCURS.	INCREASES VALUE FOR PROTECTED AREA.	SAME AS PLAN A.	SIMILAR TO PLAN A; SMALLER PROTECTION	SIMILAR TO PLAN B.	PROBABLY NO EFFECT ON NATURAL INCREASE.
b. TAX REVENUE	NO CHANGE.	NET INCREASE.	SAME AS PLAN A.	INSIGNIFICANT CHANGE.	SAME AS PLAN B.	NO CHANGE.
c. PUBLIC FACILITIES	NORMAL GROWTH	ENHANCEMENT.	SAME AS PLAN A.	LESS ENHANCEMENT THAN PLAN A.	SAME AS PLAN B.	INSIGNIFICANT.
d. DESIRED REGIONAL GROWTH	MAY RESTRICT DESIRED GROWTH IN VULNERABLE AREAS.	ENHANCEMENT.	SAME AS PLAN A.	LESS ENHANCEMENT THAN PLAN A.	SAME AS PLAN B.	INSIGNIFICANT.
e. EMPLOYMENT/LABOR FORCE	NO CHANGE.	ENHANCES BASE DURING CONSTRUCTION.	SAME AS PLAN A.	SAME AS PLAN A.	SAME AS PLAN B.	INCREASED DURING CONSTRUCTION ONLY.

	WITHOUT CONDITION	WITH CONDITION PLANS: BARRIER "A" PLAN A	BARRIER "B" PLAN B	SEAWATER COOLING PLAN C	RIVER PICKUP AND BARRIER PLAN D	EMERGENCY BARRIER PLAN E
f. BUSINESS/INDUSTRIAL ACTIVITIES	MAY RESTRICT GROWTH IN VULNERABLE AREAS.	MINIMAL IMPACT.	SAME AS PLAN A.	SAME AS PLAN A.	SAME AS PLAN A.	INCREASED DURING CONSTRUCTION.
g. FARM DISPLACEMENT	NONE	ELIMINATES SOME AGRICULTURAL LANDS BELOW HIGHWAY 11. PROTECTS LANDS BEHIND BARRIER.	SAME AS PLAN A.	NONE	SAME AS PLAN B.	DIVERSION MAY EFFECT SOME LAND BELOW HIGHWAY 11. PROTECTS LANDS BEHIND BARRIER.
3. ENVIRONMENTAL						
a. ARCHAEOLOGICAL/HISTORICAL	NO EFFECT UNLESS FLOW OCCURS. IMPACT WILL VARY WITH DIRECTION AND EXTENT OF FLOW. MAY EFFECT UNIDENTIFIED SITES.	INSUFFICIENT DATA; POSSIBLE CONSTRUCTION IMPACTS ON UNIDENTIFIED SITES AND ONE KNOWN SITE. WILL PROTECT SITES BEHIND BARRIER.	SAME AS PLAN A, EXCEPT ONLY UNIDENTIFIED SITES POSSIBLY AFFECTED.	NO KNOWN SITES ALONG ALIGNMENT.	INSUFFICIENT DATA; SIMILAR TO PLAN B.	SIMILAR TO PLAN B. ALTHOUGH REDUCED IMPACT DUE TO SMALLER SIZE AND LENGTH OF STRUCTURES. FLOWS IN DIRECTION OF HILO WILL DESTROY MORE ARCHAEOLOGICAL/HISTORICAL SITES THAN IF DIVERTED
b. FLORA AND FAUNA	NO EFFECT UNLESS FLOW OCCURS. GREATEST IMPACT ON PRISTINE FOREST WILL OCCUR BETWEEN 3,000- TO 7,000 FEET. SIZE AND LOCATION OF FLOW WILL DETERMINE SEVERITY OF IMPACT OF ENDANGERED SPECIES.	EXTENSIVE IMPACT ON NATIVE FOREST; ENDANGERED SPECIES HABITAT INVASION OF EXOTIC PLANTS. IMPACT ON NATURAL AREA RESERVE. PROTECTS LESS VALUABLE HABITAT BEHIND BARRIER..	SERIOUS IMPACT ON NATIVE FOREST ABOVE 3,000 FEET, LESS BELOW. DISPERSAL OF EXOTIC PLANTS. PROTECTS LESS VALUABLE HABITAT BEHIND BARRIER.	MINIMAL IMPACT ON FLORA AND FAUNA; SOME ALTERATION OF EXOTIC FOREST. PERMITS FLOW TO DESTROY HABITAT OTHERWISE PROTECTED BY BARRIERS IN PLANS A, B, & D.	SIMILAR TO PLAN B.	SIMILAR TO PLAN B. IMPACT VARIES WITH SELECTION OF BARRIER SITES IN REACTION TO APPROACHING FLOW. BARRIERS WILL PROTECT LOWER ELEVATION HABITAT FROM FLOWS.
c. WATER AND AIR QUALITY	NO EFFECT UNLESS FLOW OCCURS. WILL ALTER NATURAL DRAINAGE PATTERNS. COULD DEGRADE WATER SUPPLY IF LAVA FLOW REACHES WAILUKU RIVER. AIR QUALITY WILL DETERIORATE DURING FLOW DUE TO GASES PRODUCED.	LOCALIZED CONSTRUCTION IMPACTS ON DRAINAGE; SOME AIR POLLUTION DURING CONSTRUCTION.	SAME AS PLAN A; INCREASED SENSITIVITY OF PEOPLE DUE TO PROXIMITY.	LOCALIZED EFFECT OF COOLING ON DRAINAGE PATTERNS. MINIMAL IMPACT.	IMPACT TO WATER SUPPLY ONLY DURING COOLING; LOCALIZED AIR AND WATER POLLUTION ALONG ALIGNMENT.	SIMILAR TO PLAN B, ALTHOUGH WILL HAVE LESS IMPACT IN DRAINAGE DUE TO LACK OF CONTINUOUS BARRIER AND SMALLER TOTAL LENGTH. DRAINAGE WOULD BE ALTERED BY FLOW ANYWAY. REDUCES ADVERSE IMPACTS OF FLOW IN POPULATED AREAS.

	WITHOUT CONDITION	WITH CONDITION PLANS: BARRIER "A" PLAN A	BARRIER "B" PLAN B	SEAWATER COOLING PLAN C	RIVER PICKUP AND BARRIER PLAN D	EMERGENCY BARRIER PLAN E
d. RECREATION	A NEW FLOW WOULD DESTROY HUNTING AREA EQUAL TO SIZE OF FLOW, BUT COULD INCREASE ACCESS TO REMOTE AREAS. WILL PROVIDE SOURCE OF VISITOR INTEREST AND SITE FOR RESEARCH.	INCREASED PUBLIC ACCESS ALONG ALIGNMENT FOR HUNTING AND NATURE STUDY.	SAME AS PLAN A.	NO IMPACT.	SIMILAR TO PLAN B.	SIMILAR TO PLAN A, ALTHOUGH EXTENT OF ADDITIONAL ACCESS WILL BE REDUCED. FLOW ITSELF WILL PROVIDE SOME SITE INTEREST.
c. PLAN EVALUATION						
1. CONTRIBUTIONS TO PLANNING OBJECTIVES						
a. REDUCTION OF LAVA FLOW DAMAGE	NO	YES	YES	YES	YES	YES
b. MAINTAIN VISUAL AND OPEN SPACE QUALITY	YES	NO	NO	YES	NO	YES, UP TO PLAN IMPLEMENTATION.
2. RELATIONSHIP TO:						
a. NED ACCOUNT						
CONSTRUCTION COST 1/	0	$16,600,000	$14,700,000	$6,000,000	$23,600,000	UP TO $3,250,000
LAND COST	0	450,000	370,000	250,000	370,000	UP TO 310,000
TOTAL COST	0	17,050,000	15,070,000	6,250,000	23,970,000	3,560,000
ANNUAL COST 2/	NONE	1,430,000	1,260,000	640,000	2,000,000	UP TO 320,000
ANNUAL NED BENEFIT	NOT APPLICABLE	2,750,000	2,680,000	2,600,000	2,680,000	UP TO 2,750,000
B/C RATIO	-	1.9	2.1	4.0	1.3	8.6 3/
b. EQ ACCOUNT	NO EFFECT ON ENVIRONMENT.	SIGNIFICANT ADVERSE IMPACT.	SIMILAR TO PLAN A.	MINIMAL IMPACT.	SAME AS PLAN B.	ADVERSE IMPACT DURING EMERGENCY OPERATIONS.
c. SWB ACCOUNT		(SEE ITEM B-3 FOR DETAILED ASSESSMENT)				
d. RD		(NOT SEPARABLE FROM NED, DETAILED ANALYSIS NOT PERFORMED)				
3. RESPONSE TO EVALUATION CRITERIA						
a. ACCEPTABILITY	LACKS OVERALL ACCEPTABILITY.	LOW	LOW	LOW	LOW	MORE ACCEPTABLE THAN OTHER PLANS
b. EFFECTIVENESS	NOT EFFECTIVE	PARTIAL	PARTIAL	LEAST EFFECTIVE	PARTIAL	PARTIAL
c. EFFICIENCY	NO PROTECTION OUTPUT.			APPROACHES LEAST COST FOR IMMEDIATE OUTPUT.	HIGHEST COST FOR OUTPUT.	LOWEST COST FOR OUTPUT.
d. STABILITY		LOW	LOW	MEDIUM	LOW	HIGH

	WITHOUT CONDITION	WITH CONDITION PLANS				
		BARRIER "A" PLAN A	BARRIER "B" PLAN B	SEAWATER COOLING PLAN C	RIVER PICKUP AND BARRIER PLAN D	EMERGENCY BARRIER PLAN E
e. COMPLETENESS	NOT REQUIRED	NOT APPLICABLE, SUBJECT TO LOCAL COOPERATION PRIOR TO PROJECT IMPLEMENTATION FOR PLANS A THROUGH D; LOCAL REQUESTS PLUS EMERGENCY FUNDS FOR PLAN E.				
f. CERTAINTY	NO	PARTIAL-MODERATE	PARTIAL-MODERATE	PARTIAL-LOW	PARTIAL-HIGH	HIGH, IF CONSTRUCTION TIME ADEQUATE
g. REVERSIBILITY		NOT LIKELY	NOT LIKELY	POSSIBLE	NOT LIKELY	NOT LIKELY AFTER INITIAL IMPLEMENTATION
h. GEOGRAPHICAL SCOPE	NOT APPLICABLE	HILO-KEAAU AREA	HILO AREA	HILO TOWN	HILO AREA	HILO AREA
4. RANKING OF PLAN CONTRIBUTIONS						
a. NED		4	3	2	5	1
b. EQ		5	3	2	4	1
c. SWB		3	5	4	2	1
d. RD		3	5	4	2	1
D. IMPLEMENTATION RESPONSIBILITY						
1. CORPS OF ENGINEERS		X	X	X	X	X
2. OTHER FEDERAL		X	X	X	X	X
3. STATE		X	X	X	X	X
4. COUNTY		X	X	X	X	X

1/ INCLUDES ENGINEERING, DESIGN, SUPERVISION, AND ADMINSTRATION COSTS.
2/ INCLUDES MAINTENANCE COSTS.
3/ BASED ON PROBABLE MAXIMUM ANNUAL BENEFIT AND COST.

SECTION V

COMPARISON OF DETAILED PLANS

All of the alternatives considered displayed benefit-cost-ratios greater than unity. The estimated implementation costs ranged from $3,560,000 for alternative E to $23,970,000 for alternative D. Land requirements range from five acres for alternative C to 3,530 acres for alternative A, including the flowage easement requirements. Costs for land acquisition are estimated to be from $250,000 for alternative D to $450,000 for alternative A, all based on tax assessed valuations. Land required only for construction of structures ranges from five for alternative C to 400 acres for alternative A. There is no advance land acquisition requirement for the emergency action plan, alternative E.

Each of the alternative plans have significant environmental impacts associated with construction and operation. Alternative A includes the longest structure and would incur more construction-related impacts. Alternative E would require no construction prior to an emergency and would have no impacts until the eruption occurred. If an eruption with a flow covering an area larger than that covered during the 1880-1881 eruption were to occur, adverse impacts caused by construction of any alternative would be much less significant than impacts of the actual flow.

Alternative E, with equipment and related resources during emergency operations, has the potential for providing the greatest efficiency in the most cost effective manner. There are about 60 bulldozers in the Hilo area (about 30 with rated horsepower of more than 275) which could be activated in response to emergency operation. Present access difficulties due to extremely poor road conditions and boggy areas can be readily improved using material and equipment readily available in Hilo. Additional equipment and resources, if needed, could be air-lifted or barged from Honolulu. Barrier segments would be constructed as dictated by field conditions and only in locations critical to the protection of the Hilo area. The barrier alternatives (Plan A, B, and D), because the barrier locations are fixed and initial investment is considerably higher, provide protection in a less cost-effective manner. Alternative C, seawater cooling, has a greater risk of being unsuccessful due to its location at a lower elevation. An item-by-item comparison of the alternative plans is shown in Table 8, "Summary Comparison of Alternative Plans," found at the end of the preceeding section.

DESIGNATION OF NED PLAN

A National Economic Development (NED) plan addresses the planning objectives in the way which maximizes net economic benefits. Alternative E has the lowest construction costs and potentially has the greatest net benefits in lava flow damage reduction for the city of Hilo. Based on maximum average annual benefits and costs, the net annual benefits for Plan E are $2,430,000. In comparison, Plan C is second in net benefits, with only $1,960,000 net annual benefits. Based on this, alternative E is designated the NED plan.

DESIGNATION OF EQ PLAN

The Environmental Quality (EQ) plan should address planning objectives in a way which emphasizes aesthetic, ecological or cultural contributions. Beneficial EQ contributions are made by preserving, maintaining or enhancing significant cultural and natural environmental attributes of the study area. Extensive public input has played an important role in the subjective placement of values on the environmental contributions of alternative plans. Of the alternatives considered, the designated EQ plan should be the one which contributes to or is most harmonious with environmental objectives. If no plan makes net positive environmental contributions, the plan least damaging to the environment should be selected. In this study, alternative E has been selected as the least environmentally damaging plan. It would involve no substantial adverse impacts until a threatening flow actually occurred, at which time project related impacts would be far surpassed by the impacts of the flow itself and mitigated by the protection of forested and urban lands that the plan would provide.

PLAN SELECTION

The selection of the most desirable plan of improvement involved comparison and tradeoffs among the alternative plans. Ranking the alternative plans was made on the basis of (1) beneficial and adverse effects of each alternative, (2) relative contribution to the planning objectives, and (3) response to other criteria such as tests of acceptability, effectiveness, efficiency, stability, completeness, and certainty. The analysis require subjective judgments and evaluation of public opinion and input. As summarized in Table 8, all the alternative plans have significant environmental impacts if implemented. However, Plans A, B, and D would result in extensive pre-emergency construction, while Plan E would defer construction impacts until actual lava eruptions have occurred. Adverse impact at that time would be supplemental to impacts of the eruption and lava flows. With respect to adverse economic effects, the greatest difference between plans is the higher project costs for fixed-alignment barrier alternatives as compared with the emergency plan due primarily to the longer length of the structures. The fixed-alignment work would extend over a longer but normal period of construction, rather than a compressed emergency construction schedule. The work areas for the fixed-alignment barrier alternatives also extend to higher elevations where on-site construction material is more difficult to obtain due to the hardness of pahoehoe lava, which is more common at those elevations. Because of the long pipeline required, water cooling facilities would add substantially to the total cost so that the barrier-water cooling alternative (Plan D) was found to be the most costly of all the plans.

The seawater cooling alternative (Plan C) would have limited direct impact on the environment. During actual plan implementation, residual chlorides resulting from the use of sewater would affect the productivity of the immediate area. This impact, however, is expected to be short- term due to the rapid leaching of the chlorides. However, due to its close proximity to Hilo, there is an inherent greater risk of diversion or cooling effort being unsuccessful. Also, because the cooling process is dependent on labor-intensive efforts and equipment efficiency, this alternative is likely to be less efficient than the fixed barrier alternatives. Because of their fixed-locations, Plans A through D are considered less efficient (flexible) in meeting the diversion needs compared to Plan E since eruption and flow locations cannot be predicted with any degree of accuracy. These uncertainties, plus the potentially great adverse environmental impacts were the primary reasons the public considered fixed alternatives to be less acceptable than Plan E.

Based on comments received during coordination with Federal, State and County agencies, community groups and interested citizens, Plan E was identified as the most desirable plan. This plan provides the best balance of physical, environmental, and socioeconomic factors since it will retain the natural environment with no commitment of natural resources prior to a threatening flow. Plan E was therefore discussed as the tentatively selected plan in the draft report and during the final public meeting held on 10 October 1979. Based on letters of comment and views expressed at the public meeting, this plan was reaffirmed as the selected plan.

In compliance with Executive Order 11988 on floodplain management, an assessment was made of the proposed site. The site is not in the base floodplain as shown on the Federal Insurance Administrative Flood Hazard Boundary Map for the area. The selected plan, therefore, fully complies with the intent of the Executive Order,

In accordance with Section 404 of the Clean Water Act of 1977, the disposal of fill material into the nation's waters is administered by the Corps in compliance with the guidelines of the Environmental Protection Agency. Construction of diversion barriers under the selected plan does not constitute "discharge of dredged or fill materials" as defined. Consequently, implementation of the selected plan will not conflict with the provisons of this Act.

SECTION VI

DESCRIPTION AND COST ESTIMATES OF THE SELECTED PLAN

PLAN DESCRIPTION

Technical details of the selected plan are discussed in Appendix B. In summary, the selected plan provides for barrier construction under emergency conditions. The plan defines a flow corridor (Plates B-1 and B-2 and Appendix D) into which lava flows would be diverted or guided by a system of barrier segments. For purposes of illustration and probable areas of operation, the most likely maximum number of diversion barrier segments and areas of construction activities are shown in Plates B-1 and B-2. Should a flow move downslope along the southern end of the historic lava flow belt, it is conceivable that the need for barrier construction would be minimal. As with all alternatives investigated, the work areas and diversion facilities shown for alternative E are approximations of locations and routes. As such, the estimated costs are shown to establish an order of magnitude.

Barrier segments would be constructed on an "as needed" basis. Depending on the flow location, their combined total length may range from a mile to approximately 9 miles. The excavated material for barrier construction would be obtained primarily from the adjacent upslope lands. The average design flow along the upper segments above elevation 3,500 feet would be approximately 20 feet thick; a flow against the lower segments below the 3,500-foot elevation would average about 15 feet. Estimated material required per mile of barrier for the upper and lower areas are 200,000 and 160,000 cubic yards, respectively. To minimize the length of barrier segments, and to take advantage of natural topography such as drainageways and ridges, connecting cleared flow paths between barrier segments would be provided by bulldozers to guide the diverted flows from segment to segment.

Six areas have been identified as staging areas to support construction operations. The selection of these sites is based on their accessibility and proximity to the potential work areas. To accommodate equipment repairs, refueling, and other operations, it is estimated that one to two acres at each site would be required.

The areal extent to be impacted by barrier construction and related activities would vary depending on the flow location. Based on an approximately 600-foot wide strip for barrier construction, cleared flow paths and clearing of 1 to 2 acres for each staging area, the land involved would range from a minimum of 410 to 1,220 acres for lands above Highway 11. Should diversion work be extended below Highway 11, an additional 1,280 acres would be affected.

COST ESTIMATES

The estimated first cost of the selected plan, based on maximum diversion facilities and July 1979 prices, is summarized in the following table. The estimates include a contingency allowance of 30 percent. The indirect cost, which includes operating costs during an emergency, is estimated at 16 percent of the land and construction cost. Details of the construction by barrier segments are presented in Appendix B.

Summary of First Costs

Item	Cost
Lands and Easements	$ 310,000
Construction	2,750,000
Subtotal	3,060,000
Indirect Cost	500,000
Estimated First Cost	$3,560,000

The average annual costs of the selected plan include interest and amortization of the first cost and an estimated maintenance cost. The maintenance cost includes restoration and corrective work necessary to maintain the completed structures for subsequent diversion needs. Based on a 7-1/8 percent interest rate and a 50-year period of analysis, the annual costs are as follows:

Interest and Amortization	$262,000
Estimated Maintenance	58,000
Total Average Annual Cost	$320,000

DIVISION OF RESPONSIBILTIES

The responsibilities of federal and non-federal interests for the possible implementation of the selected plan include emergency preparedness planning, construction, maintenance, and liability. Figure 10 illustrates the resulting institutional arrangements for the emergency diversion plan.

COST ALLOCATION

The selected plan is single purpose (prevention of damage from lava flows), and no allocation of costs is required.

EMERGENCY PLAN

PROBABLE INSTITUTIONAL ARRANGEMENTS

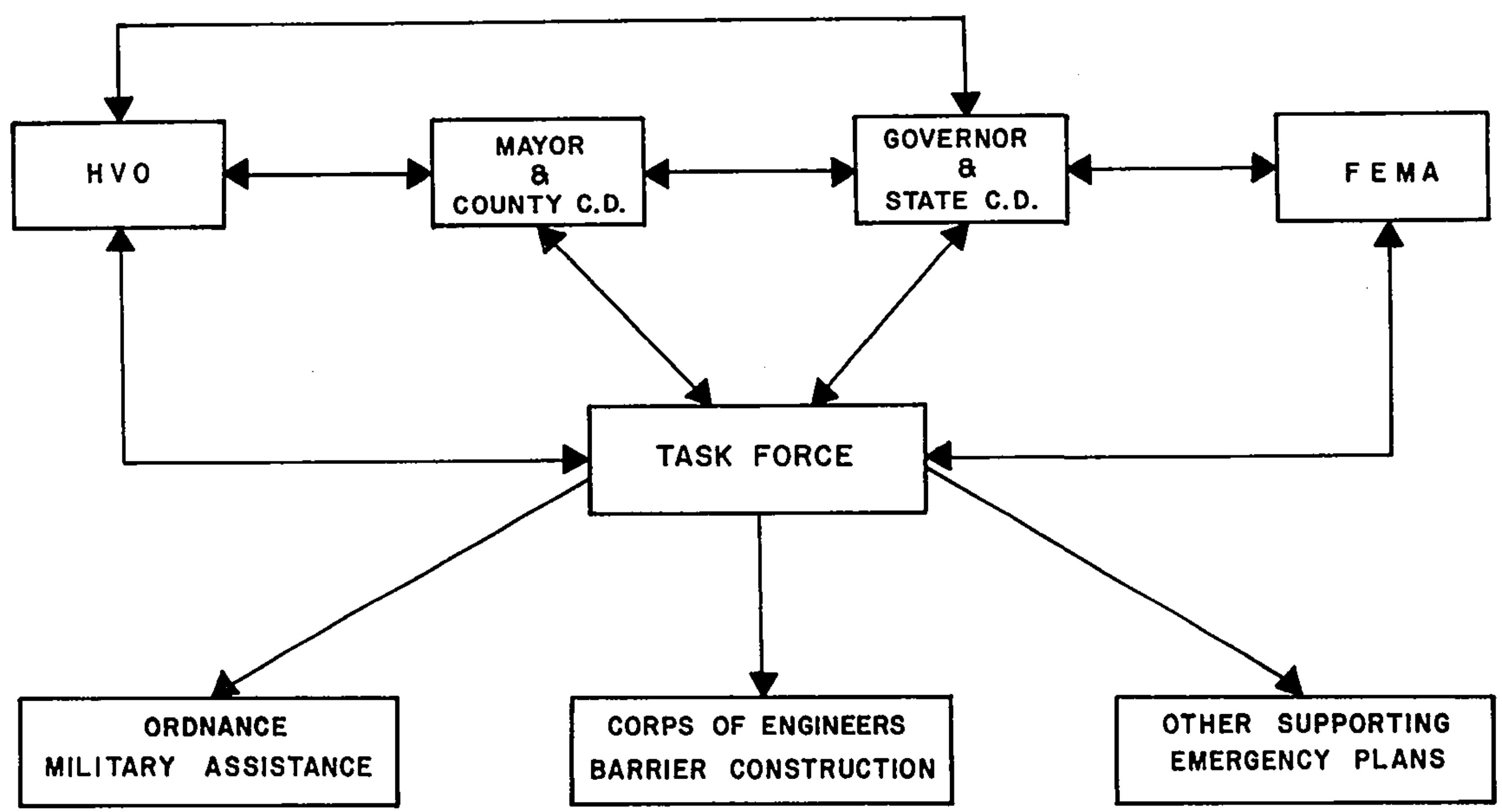


FIGURE 10

FIGURE 10

FEDERAL RESPONSIBILITIES

The Federal Government (Corps of Engineers) would prepare a detailed plan-of-action based on the recommended plan. This plan of action would become part of the Pacific Ocean Division's planning for natural disaster in accordance with ER 500-1-1, Emergency Employment of Army and Other Resources. Construction of the various plan elements would be undertaken only in response to a request from the Governor of Hawaii for assistance.

NON-FEDERAL RESPONSIBILITIES

Local interests would provide the necessary land easements, and rights-of-way to construct the project elements and would assume liability for litigation resulting from emergency operations. Maintaining or removing the completed structures would also be the responsibility of the local interests.

SECTION VII

CONCLUSIONS

STATEMENT OF FINDINGS

In light of the overall interest, the District Engineer has evaluated the pertinent information and the stated views of the other interested Government agencies and the concerned public on the various practical alternatives for alleviating the lava flow problem for Hilo, Island of Hawaii. The alternatives considered were each examined for environmental, social, and economic consequences and for engineering feasibility. Other factors considered were the specifically stated desires of local government officials and citizens.

During the course of the study, on-site investigations were made independently and in cooperation with others; and discussions were held with scientists at the Hawaiian Volcano Observatory, state and county officials, and interested groups or citizens. A wide variety of alternative measures exist to meet the problems of lava flow. These measures include structural, nonstructural, and combination of categories for possible implementation prior to or during eruption conditions. Among the measures known to have been used to control or divert lava flows, all have been attempted in Hawaii at least on a small scale. These measures are aerial bombing, diversion barriers and lava cooling by dousing the flow front with water. Initial consideration was also given to the possibility of nonstructural measures such as relocation, land-use zoning, and evacuation.

In conjunction with this survey investigation, the State of Hawaii, through its Department of Defense, developed a cooperative emergency plan entitled "State of Hawaii Emergency Plan to Protect Hilo From a Lava Flow." Methods noted in the State Plan as potential protective solutions are military ordnance, emergency barriers, water cooling, and evacuation. Since a multi-agency participation is expected in the event of a lava flow emergency, the Corps of Engineers efforts were directed to the structural and water cooling measures. The study scope was also consistent with the authorizing Senate Resolution of 14 November 1975, which directed that "....long term solutions and a more detailed plan for combating lava flow...." be developed.

Five plans emphasizing barriers and water cooling concepts were examined in detail: two barrier plans consisting of fixed alignment barriers constructed in advance of an eruption, a plan for seawater cooling only, a fixed alignment barrier plan with river water cooling, and a barrier plan to be implemented only in the event of a threatening lava flow. The alternative plans and their physical, socioeconomic, and environmental impacts were coordinated with other federal, state and county agencies, and the concerned public. Public meetings were held in Hilo in March 1977 and October 1979. A public workshop was held in June 1978, also in Hilo. Other meetings were held throughout the period of study with state, county, and federal agencies to coordinate and to facilitate the conduct of the study. A series of informal meetings with various interest groups held before the final public meeting helped to acquaint these segments of the public with the preliminary results of the study. The less structured atmosphere of these meetings encouraged questions about the results, more so than would have been experienced in a formal public meeting. The report was distributed to various governmental agencies and offices, especially to elicit responses from state and local agencies, and to organizations and individuals that attended meetings or requested reports.

The large number of responses to the draft report from agencies, organizations and individuals reflected the interest and the degree of public involvement attained. The comments were both supportive and critical, with criticisms on both technical and social aspects of the report. Appendix C, Public Views and Responses, contains copies of all pertinent correspondence received and answers to that correspondence received and answers to that correspondence.

Based on evaluation of acceptability and feasibility of the alternative plans and public opinions and comments received, the fixed alignment barrier plans were not selected. In addition to being high in costs and low in flexibility to respond to changes in flow locations and characteristics, these plans would have the most adverse impacts on the environment, particularly the native forest. The addition of river water cooling to a fixed barrier was found to be most costly. The seawater cooling plan, with its location near urban Hilo and greater risk that control by this means may not work, was considered least effective in meeting the planning objectives. The post-eruption plan or emergency plan has the potential for providing protection at the lowest cost of the five alternatives and requires no advance construction. This plan also has the advantage of causing very little environmental damage until implementation is necessitated by a threatening lava flow. For these reasons, this plan was designated as the NED Plan as well as the Least Environmentally Damaging (LED) plan.

Based on the above and on review comments received during coordination of this study that it provides for the best balancing of the physical, environmental, and socioeconomic factors pertinent to lava flow protection, the emergency plan was selected to be the most desirable plan. The adverse impacts associated with this plan are primarily related to construction impacts additive and much less than those resulting from the eruption and the natural lava flow. The construction impacts are not considered to be sufficiently detrimental to preclude proceeding with obtaining the necessary authorization at this time.

The District Engineer believes that all necessary investigation commensurate with the scope of the survey study of lava flows problems have been made, and sufficient information on the engineering, economic, and environmental aspects of the alternatives considered have been reviewed to facilitate making a sound decision. The District Engineer concludes that implementation of the selected plan under emergency conditions in conjunction with existing local emergency plans for lava flow situations is the most logical course of action. A significant point is that the selected plan does not commit natural resources in anticipating the possible needs. Rather, resources will be used effectively and selectively in time of emergency. Based on these study findings, the District Engineer further concludes that the overall public interest would be best served by a change to Public Law 84-99, providing the Chief of Engineers authority for direct assistance to any state during lava flow situations upon request of the governor of the affected state.

SECTION VIII

RECOMMENDATIONS

The District Engineer recommends that authorization be obtained for the Chief of Engineers to react to threatening lava flow situations by amending the Flood Control Act approved 18 August 1941, (33 U.S.C. 701) as follows: Section 5 is amended by inserting at the end thereof the following:

"The Chief of Engineer is also authorized to undertake such measures with emergency funds that in his discretion are necessary to assist local and state efforts in the provision of emergency work for control of lava flow in order to prevent loss of life and serious damages to improved property from such volcanic activity, when it has been determined that there exists an imminent danger to such life or improved property."

Furthermore, the District Engineer proposes that Alternative E, as presented herein, be used as a basis for selecting a final emergency reaction plan to control lava flows that threaten life and property on the Island of Hawaii. Such plan to be implemented at the request of the Governor of Hawaii in time of emergency subject to the following conditions of local corporation:

a. Provide without cost to the United States all lands, easements, and rights-of-way necessary for the construction of barriers and related diversion facilities under emergency lava flow situations.

b. Hold and save the United States free from any damages or injuries due to or resulting from or as a consequence of lava barrier construction, except damages due to negligence of the United States or its contractors.

c. Assume discretionary responsibility for the removal of the protective measures after their purpose has been served.

d. Assume responsibility for any litigation arising out of or from the implementation of the plan.

B. R. SCHLAPAK
Colonel, Corps of Engineers
District Engineer

ENVIRONMENTAL IMPACT STATEMENT

LAVA CONTROL STUDY

ENVIRONMENTAL IMPACT STATEMENT

LAVA FLOW CONTROL STUDY
HILO, HAWAII

Responsible lead agency· U.S. Army Corps of Engineers, Honolulu District

Responsible coordination agency: U.S. Fish and Wildlife Service

Abstract: In July 1975, the State of Hawaii requested the U.S. Army Corps of Engineers to review and update earlier studies relating to protection of Hilo, Hawaii from lava flows. Both nonstructural and structural measures were evaluated during the present study. Five alternative plans were determined to meet the planning objectives of the study and were evaluated in detail. Three of the plans involve diversion barrier construction prior to actual emergency; one of these plans incorporates additional freshwater cooling along a barrier alignment. An additional plan involves seawater cooling only. The fifth alternative is an emergency operation plan involving construction of barrier segments only in the event of an actual eruption causing flows that threaten Hilo. This final plan is the Corps' recommended alternative.

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SUMMARY

1.01 Major Conclusions and Findings:

Each of the five major alternatives for lava control evaluated in this statement are anticipated to result in significant environmental impacts if implemented. Each of the diversion barrier plans would result in adverse impacts on pristine native forest ecosystems, within which several species of rare and endangered plants and animals are found. It is anticipated that large portions of forested lands above 3,000 feet in elevation will be eventually designated as critical habitat for endangered species and thereby derive greater protection against disturbance. Adverse impacts on these species and their habitats could be mitigated by limiting or eliminating the use of diversion structures in higher elevation forest or by aligning barriers to avoid localized areas of high value and to divert lava flows away from such areas.

This statement also evaluates other anticipated impacts on other physical and human resources. The most significant impacts involving water supply and water quality would result from alternative plans involving use of water cooling to divert lava. Noise and air quality impacts would be greatest for alternatives requiring barrier construction. Anticipated impacts on recreational opportunity and aesthetics are also considered but are predicted with less certainty. Remnants of rich Hawaiian culture are found in the Hilo area and surrounding lands, with less archaeological or historical evidence known to be from higher elevation lands that would be directly affected by the alternative plans under consideration. Diversion structures and diverted flows may directly impact unidentified cultural resources in their path, although successful diversion of approaching flows would protect resources concentrated in the Hilo area, and along pathways of undiverted flows.

An important distinction is made in this statement between those alternatives (A, B, C, D) that would involve extensive pre-emergency site preparation or construction and the final alternative (E) that would not be implemented unless an actual eruption produced a flow believed to threaten Hilo. A decision to implement a pre-emergency alternative would be based on an assumption that a potentially damaging flow is likely to occur within the foreseeable future; however, the evidence at this time supporting this assumption is the subject of considerable debate. It is important to note that the impacts associated with these pre-emergency alternatives would occur whether or not the anticipated flow actually does occur but that the benefits, both economic and environmental, associated with protection of Hilo from such a flow would accrue only if and when a flow does occur and if it is successfully diverted. In the case of the emergency alternative (Plan E), any construction impacts would be supplemental to impacts associated with the flow itself, and would be weighed against the benefits of protection if the diversion barriers are successful. For these reasons, the emergency alternative (Plan E) was chosen by the Corps as the NED (National Economic Development) Plan. None of the alternatives would result in a positive environmental contribution, so an EQ (Environmental Quality) Plan was not chosen. However, the emergency plan (Plan E) is believed to be the least environmentally damaging plan. For these reasons, the Corps recommends Plan E at this time.

1.02 Area of Controversy and Unresolved Issues.

The Lava Control Study continues to be a source of considerable public controversy and has been debated at several public meetings and workshops. Primary controversy centers around the questionable threat of damaging lava flow and the uncertainty that proposed diversion alternatives will actually be effective. Another area of controversy is the more basic spiritual question regarding the advisability of attempting to interfere with this natural phenomenon. Lava flows traditionally represent the venting of anger by Pele, the legendary and still feared volcano goddess. Other controversial issues that have arisen include the advisability of seriously considering various other nonstructural or administrative alternatives and the potentially significant legal and economic ramifications of diverting a natural lava flow in a manner that shifts the area of impact from one location to another. Although these issues are treated in the Environmental Impact Statement and elsewhere in the study report, the controversy is by no means resolved.

It is also apparent that a decision to implement one or more alternative lava control plans will necessitate inevitable environmental tradeoffs. Current environmental protection laws, most specifically the Endangered Species Act of 1973, prohibits a federal agency from authorizing, funding or undertaking an action which jeopardizes the continued existence of endangered species or their critical habitats. In formal consultation, the Fish & Wildlife Service has determined that the Corps' recommended alternative (Plan E) would jeopardize the continued existence of three endangered bird species. It should be recognized that Plan E would be implemented only during actual lava flow situations upon determination that an emergency exists. This law does provide for a review process leading to possible exemption of certain projects but other reasonable alternatives must be ruled out before such an exemption would be considered seriously.

1.03 Relationship to Environmental Requirements.

Table 8 (page 42) presents a brief outline of the relationship of the five different alternative plans to pertinent statutes and regulations affecting the study. Detailed discussion of problems and needs, development of planning objectives, engineering solutions and economic costs and benefits are provided in earlier sections of this report and in the appendices.

2. PROBLEMS AND OBJECTIVES

2.01 Study Authority.

This study was conducted in compliance with the 14 November 1975 resolution of the U.S. Senate Public Works Committee. Earlier studies were conducted in compliance with the Flood Control Act of 1960 and a 27 September 1951 resolution of the Public Works Committee of the U.S. House of Representatives. These authorities are given in detail in Section I of this report.

2.02 Public Concerns:

Since 1843, northeast rift zone eruptions on Mauna Loa have occurred on the average of once every 20 years. The town of Hilo lies at the base of the slope below this northeast rift zone. Lava flows which originate below 11,500 feet in this portion of the mountain are directed by slope toward Hilo. Four of the seven flows since 1843 that advanced towards Hilo actually came within seven miles of the city proper. Lava from the 1880-1881 eruption, with a volume of approximately 300 million cubic yards, reached within 1.5 miles of Hilo Bay. Part of the present city of Hilo is built on that flow.

A flow today, comparable to that resulting from the 1880-1881 eruption, would cause nearly $8 million in damage to structures and contents, roads, and utilities. Damage to lands would be similar in economic loss. Although it is not possible to predict exactly what lands would be covered by a future flow of greater magnitude than the 1880-1881 event, potential damageable losses within Hilo exceed $700 million (see Appendix A). It is the magnitude of these potential economic losses in the Hilo area which has prompted this study of potential means to divert future lava flows.

2.03 Planning Objectives:

Based on an analysis of social, economic, and environmental aspects of the study area, as well as the identification of problems, needs and desire, the following planning objectives were developed to guide the formulation and evaluation of alternative plans to protect the city of Hilo from lava flows:

Contribute to lava flow control, for the protection of private and public properties and the general well-being of the populace in the Hilo area against future Mauna Loa lava flows.

Protection of valuable cultural or biological resources in the Hilo area and in the slopes above Hilo likely to be adversely affected by lava flows from the northeast rift of Mauna Loa.

3. ALTERNATIVES CONSIDERED

Both the preliminary concepts considered early in the study and the five alternatives considered in depth in this statement are described in Section III and Section IV of this report. An evaluation of anticipated environmental impacts of the five alternative plans is presented in Section 7 of this statement.

4. AFFECTED ENVIRONMENT

4.01 Introduction

The lava control study area is located on the eastern portion of the island of Hawaii (Fig. 1). It includes an elongated lava flow zone extending from about 7,000 feet in elevation on the northeastern slope of Mauna Loa to the coastline near Hilo. The limits of the study area relate to the location of historic lava flows which have approached towards Hilo. The study also includes lands and waters that may be affected if a threatening flow is diverted to avoid Hilo.

4.02 Geology

The island of Hawaii was formed by five independent lava sources: Mauna Loa, Mauna Kea, Kilauea, Hualalai and Kohala. Mauna Loa is a shield-shaped dome about 60 miles long and 30 miles wide. Lava flows that threaten the Hilo area originate from a rift line extending north and south through Mokuaweoweo Crater. This caldera resulted from collapse and is growing broader through coalescence with adjacent pit craters. A typical eruption on Mauna Loa begins in Mokuaweoweo and extends down one of the rift zones (Ref. 39). Large volumes of fluid pahoehoe lava are poured out at the beginning, and may initially flow downslope at speeds up to 25 miles per hour. The pahoehoe usually changes to aa lava a short distance from the fountains. The pahoehoe lava is relatively smooth and ropy on the surface while the surface of aa flows is extremely rough, consisting of clinker and loose basalt pieces. Dense, hard basalt underlies the surface layer. Flows near the origin are generally less than 3 feet thick, but increase to 10-15 feet downslope or as much as 50 feet or more where they pool in flats. Tubes created by pahoehoe lava that crust over at the cooler surface may feed surface flows several miles down the mountain. A pahoehoe flow may advance over older aa flows and the areas where recent flows have contacted older flows are often characterized by great surface irregularities.

4.03 Hydrology

a. Characteristics of streams are determined in large part by surface geology and topography. Hawaii is the youngest island of the archipelago, and its relatively unweathered lava flows are far more porous than those of the older islands. No perennial streams reach the coastline along three fourths of the coastline of Hawaii, as water in high elevation drainages infiltrates the ground before reaching the sea. Only the northeast slope of the Kohala and Mauna Kea volcanoes are traversed by extensive perennial streams and rivers. The Wailuku River, the most southern of the Mauna Kea drainages, forms the northern border of the study area. Extremes of flows in this river vary from less than one cubic foot per second (cfs) in summer lows to a maximum of 64,000 cfs recorded at the Piihonua gage. Average discharge over the last 45 years is 286 cfs. Other streams north of the area include Honolii, Kapue, Kawainui, Kolekole, Hakalau, Umauma, and Ponakupuka. In aggregate, the average stream flow into the ocean is estimated at approximately 2,000 mgd (million gallons per day), mostly unused since the practice of fluming cane stalks to mills has been discontinued. Surface water in the study area originates from fog drip and direct precipitation.

b. On poorly drained soils, particularly where depressed areas have been created by lava flow patterns, saturated soil conditions may persist. However, porous lava generally absorbs water quickly, and runoff onto lower elevation lands is confined, for the most part, to major drainages (i.e., Wailuku River). Excessive water in poorly drained areas is believed to play a contributory role in "dieback" of ohia forests within the study area. Groundwater occurs as basal water, perched water, and, most likely, as dike-impounded water deep in the rift flow.

c. Large quantities of basal groundwater flow into the ocean at or near the shore along the Hamakua coast. The flow is largest in the area between Hilo and Laupahoehoe. The average pumpage of basal groundwater in the area is 3 to 4 mgd, most of it from shafts in Ookala and Paauilo for sugarcane cultivation and processing. The total basal-water discharge from Mauna Kea lavas between Hilo and Laupahoehoe is estimated at roughly 750 mgd or 38 mgd per shoreline mile. Most basal water at the shore is brackish because of mixing with seawater. Salinity decreases with distance inland, but the decrease is irregular.

d. Dikes in the interior parts of Mauna Kea, Mauna Loa, and Kilauea probably impound a great volume of water, but no valleys are deep enough to intersect these water bodies. The depths to dike-impounded water are great enough to preclude development at reasonable cost. Perched-water bodies are numerous along the slopes of Mauna Kea; however, total flow is small in relation to basal and surface water flows. Seawater sources are unlimited along the coastline.

e. Since the discontinuance of the practice of fluming cane stalks from fields to mills, the use of surface water has been limited to domestic use and for mill use. In the south Hilo area, water from Kahoama Stream, a tributary of Wailuku River, supplies an average of 3.8 mgd of domestic water to the Hilo water system, and the Waiakea Stream supplies about 0.15 mgd. The total water available at the intake is deficient during drought periods. Hilo Electric Company diverts an average of 48 mgd from Wailuku River for the generation of hydro-electric power.

4.04 Water Quality

a. The Wailuku River is fed by several perennial tributaries originating at the 5,000-6,000-foot elevation. Prior to recent adoption of new State Water Quality Standards, streams in the Wailuku-Alenaio watershed were designated as Class 2 waters, except Wailuku River tributaries, which provide Hilo's water supply, which were Class 1. The river experiences periodic significant increases in turbidity during storm runoff. Recent studies conducted by the U.S. Geological Survey (USGS) indicate that virtually all sediment discharged by Wailuku River is transported during less than 2 percent of the entire year. Water quality data gathered by USGS indicate that most dissolved solids are at background levels, dissolved oxygen is close to saturation, and fecal coliforms show a pattern of decreasing value with elevation.

b. Hilo Bay and adjacent coastal waters were classified as Class A under past State Water Quality Standards, although a limited area next to the pier facilities was in Class B. Recent studies indicate that nutrient levels in the harbor generally exceed the former State Water Quality Standards for total phosphorus and total nitrogen for Class A and B waters (Refs. 40, 41). The nutrient levels in Hilo Bay exhibit an apparent seasonal variation, probably related to surface runoff. However, nutrient levels are generally high enough so that they are not likely to be a factor limiting phytoplankton growth rate. Suspended solids and turbidity measurements show the large influences of seasonally high surface runoff and the more localized effects of shore erosion. Dissolved oxygen levels indicate locally excessive organic loading, probably the combined result of organic materials in stream discharges and waste discharge from domestic, industrial and agricultural sources. Bacteriological analyses show highest levels of fecal coliform and fecal strep in areas influenced by discharges from Wailuku River, Wailoa River, and Reeds Bay. Generally, low coliform levels recorded in recent studies, when compared to earlier data recorded prior to discontinuance of many point discharges in the bay, substantiate a significant decrease in coliform levels.

c. Section 208 of the Federal Water Pollution Control Act Amendments of 1972 authorized the Areawide Waste Treatment Management Study in Hawaii. One of the objectives of this ongoing study has been to recommend technical revisions to the State's water quality standards based on an ecologically sound classification of State waters. New water quality standards were approved by the Governor in September 1979. Under these standards, the Wailuku River was placed in Class 1.b (inland water in the protective subzones designated by Regulation 4 of the Board of Land and Natural Resources). New standards for embayments place the entire Hilo Bay (inside the breakwater) into Class A. Additional categories are designated for specific bottom types, including marine pools and nearshore reef flats. In the Hilo area, the marine pools and nearshore reef flats (Blonde Reef) are rated Class II.

4.05 Air Quality

Existing air pollution within the study area is confined to the urban and suburban areas of Hilo and associated communities. Cane burning activities in low elevation land create temporary, but significant, sources of objectionable air pollution, particularly under conditions of low wind. Exhaust pollution, particularly that produced by large trucks is aggravated on the Saddle Road by increasing grade. However, the impact of this pollution is localized and quickly dissipated. The State Air Quality Monitoring Station on the island is located within Hilo. This station monitors particulates and sulfur dioxide. During the period January 1976 to March 1977, State Air Quality Standards were not exceeded for either parameter.

4.06 Noise

Natural noise levels in the lava barrier project area are generated by stream flow, waves, wind in foliage, and wildlife. Man-generated noise is highest within the urbanized Hilo area, along the Saddle Road, along Stainback Highway, and along the Hilo-Volcano Road. Traffic levels are greatest within Hilo and along the Hilo-Volcano Road. However, the gradual increase in elevation for vehicles traveling west on the Saddle Road increases ambient noise levels appreciably, particularly as a result of the large trucks (cattle, produce, military) that traverse this road and the poor condition of the pavement. Limited additional man-induced noise is created by 4-wheel drive vehicles traveling on the three major jeep roads that traverse the Waiakea Forest Reserve (Tree Planting Road, Powerline Road, Olaa Flume Road). It is doubtful that highway-associated noise contributes significantly to ambient noise levels at distances greater than 1,000-2,000 feet from the highways and access roads. Hunters within the project area create additional noise with firearms although this is restricted, for the most part, to readily accessible forest along access roads. The eastern edge of the study area is close to Pohakuloa Training Area. It is likely that noise associated with artillery and bombing is detectable at the eastern limit of the study area. However, the sound absorptive qualities of the forest and lava, together with the distances involved, probably reduce the decibel level of military ordnance in the study area to a point far below that offensive to man or wildlife.

4.07 Terrestrial Biota.

a. The island of Hawaii is the largest, highest, youngest, and most complex of the islands in the Hawaiian archipelago. Altitudinal zonation and variability in climate have set the scene for evolutionary development of a highly diverse flora, exhibiting all stages of ecological succession from bare lava flows to dense rain forest. Recent introductions of plants and alteration of forest have changed flora significantly and, in so doing, have also altered the vulnerability of the natural environment to future man-induced change.

b. It is likely that a mixed lowland forest once formed a continuous belt along the entire windward coast and volcanic slopes although much of the lower elevations were in grassland by the time the first European explorers arrived. From Hilo to Waipio Valley, sugarcane has replaced the lowland forest and grassland to an elevation of 1,500-1,800 feet, except within deep gulches forested with a variety of exotic trees. The low elevation forest from Hilo to Kalapana is interrupted by barren lava, exotic plantations (sugarcane, macadamia nut), mixed exotic forest, and expanding urban development.

Ohia (Metrosideros) is the dominant tree species in native forest from sea level to 4,000 feet except in the Olaa flume road area, Kaumana, and Honomu, where koa (Acacia) is dominant. Between 4,000-6,500 feet, koa is the dominant species except on shallow soils, where ohia dominates. On Mauna Kea, an extensive mamane (Sophora) and naio (Myoporum) forest extends to tree line above the koa forest.

c. The lava control study area is characterized by a complex forest, dominated at upper elevations by ohia. The substrate originates from the northeast rift of Mauna Loa and consists primarily of relatively unweathered aa or pahoehoe lava. The exposed flows range from very recent (1942) to probably not much more than 1,000 years. Soil varies in depth from less than an inch to more than 6 feet.

d. As a result of extensive variation in age and type of substrate, many varied stages of ecological succession are represented within the study area. The primary tree colonist is ohia, preceded only in the earliest pioneer stages on barren lava flows by ferns, lichens and mosses. Where soil is sufficiently moist, larger ferns (Sadleria, Dicranopterus) have invaded and form a dense understory. In more advanced stages, large tree ferns (Cibotium) and a variety of shrubs and epiphytes have invaded. Where the forest is drier, a variety of scrubby plants (Dodonaea, Vaccinium, Styphelia) cover the ground surface, and ohia trees are generally more dispersed.

e. For the purposes of discussion of vegetation, the study area under consideration is confined on the east by the Hilo-Volcano Highway, on the south by Stainback Highway, on the west by Powerline Road, and on the north by the Wailuku River. The southeastern portion of this area is dominated by agricultural lands, interspersed with mixed exotic-native forest. The density of the ohia forest and associated ground cover tends to increase with elevation to approximately 4,000 feet or above, but this pattern is interrupted by the presence of recent lava flows, some of which are barren or display the earliest stages of ecological succession. The drier forest above the peak rainfall area is often more sparse, with less understory and widely dispersed trees. Pockets of forest in advanced stages, called kipuka, are "islands" of land left untouched by lava flows. They are found throughout the project area. The lower elevation lands and forested areas bordering roads within the study area are characterized by a greater abundance and diversity of exotic plants than are the more isolated areas of forest.

f. Most of the forest within the study area is experiencing extensive "ohia-dieback." Some investigators have predicted that at the present rate of decline, the ohia forest within this area will be virtually eliminated within 15-25 years. Although the actual causes of decline are not fully understood, the results of recent studies suggest that "dieback" may actually be a natural process that permits regeneration of the ohia forest through exposure of shade intolerant seedlings to sunlight (Ref. 24).

g. Although only five species of Hawaiian plants have been officially listed on the Federal list of Endangered and Threatened Species, approximately 900 Hawaiian plants known to be rare or possibly extinct had been proposed for the formal list. The "proposed" list was formally withdrawn from consideration in November 1979, but it is likely that several species from the original list will be proposed again in the near future. Biological surveys conducted since 1977 by the Fish and Wildlife Service (FWS) within the lava control study area have documented the presence of several plant species formerly on the "proposed" list, although the status of many of these is uncertain due to the limited area surveyed (Ref. 27). Transects followed on the survey, designed primarily to record distribution of forest birds, are illustrated in Figure 13. Most of the rare plants observed on survey were seen on transects north and south of the lava control study area. It was noted in reporting results that the portion of Mauna Loa between transects 24 and 28 "is sufficiently youthful geologically that most of the vegetation has not developed successionally to the point where the communities are diverse enough to contain many rare plant species. Exceptions are found in the oldest of the numerous kipuka, most of which lie between transect lines" (Ref. 54). It was also noted that many of the kipuka are severely damaged by feral pigs. Those rare plant species identified along or near transects 24-28 include the following (Ref. 54):

#24 : None
#25 : Stenogyne scrophularioides Benth. var. remyi Sherff (1950-2700')
#26 : Argyroxiphium kauense (Rock & Neal) Deg. & Deg. (5250')
#27 : None
#28: Joinvillea ascendens Brongn. & Gris. subsp. ascendens (2150' - 3800')
Cyanea tritomantha Gray var. tritomantha (3000' - 3900')
Labordia hedyosmifolia Baill. var. robusta Sherff (3300')

h. Extensive forested lands within the lava barrier project area provide habitat for a diverse group of animals. For most of these species, the lava control study area provides only a small portion of their known range on the island or in the state. Until recently, the terrestrial fauna of remote forested lands within the Upper Waiakea Forest Reserve was poorly investigated. Studies by FWS biologists provide the most current data, particularly on birdlife. Analysis of these data is not yet complete, but preliminary data on distribution of rare birds has been made available to the Corps for the Lava Control Study through the fish and wildlife coordination process (Ref. 51). Additional information was provided by the FWS through the formal consultation process, pursuant to the Endangered Species Act of 1973, as amended (Appendix F).

i. Thirty-six species of birds were recorded during the 1977 FWS survey that ranged from Hamakua to Olaa Forest Reserve, principally between 2,000-6,000 feet. This list included 16 native and 20 exotic species. A review of preliminary data indicated that at least 85 percent of these species were found within the lava control study area. None were restricted in distribution to this area. The range of many exotic species observed on this survey extends into low elevation land including the exotic forest, agricultural lands, and developed areas near Hilo. Ten of the exotic bird species recorded on the FWS survey are game species. In addition, several species of waterbirds (endemic, indigenous, exotic, and migratory) inhabit wetlands in the Hilo and Kapoho areas.

j. Six birds observed on FWS transect surveys (Figure 13) within the lava control study area are presently on the state and federal lists of endangered species: Hawaiian goose (Branta sandvicensis), Hawaiian hawk (Buteo solitarius), Hawaii creeper (Loxops maculata mana), Hawaii 'akepa (Loxops coccinea coccinea), 'akiapola'au (Hemignathus wilson), and 'o'u (Psittirostra psittacea). An additional bird species, the Newell's shearwater (Puffinus puffinus newelli), is on the federal list of threatened species. Although not recorded within the study area, the Newell's shearwater or 'a'o was recorded from Hawaii Volcanoes National Park and from the Hamakua Forest north of the study area. It is likely that the species may nest undetected in the forest at the 2,000-3,000-foot elevation in the study area. Distribution maps for the other five species, based on FWS surveys, are portrayed in Figures 14 to 18 for the immediate area within and adjacent to the lava control study area. It is important to note that most of these species are also found elsewhere on the island of Hawaii, as portrayed in a combined distribution map, Figure 19. The Hawaiian goose, or nene, occupies only a remnant of its former range. The population, now estimated at approximately 750 individuals on Hawaii, occurs primarily between 5,000 and 8,000 feet. The Hawaii creeper appears to be restricted to native forest above 4,000 feet. The Hawaii 'akepa is comparatively rare, reported from the eastern slopes of Mauna Loa and southwestern slopes of Hualalai. FWS survey data indicates they are most concentrated in the Waiakea

Forest Reserve and Keauhou Ranch. The 'akiapola'au is locally common on the eastern slopes and high elevations of Mauna Loa and rare on Mauna Kea. Waiakea Forest Reserve is also an important habitat for this species. The 'o'u has been reported from the Olaa Tract and adjacent forest and in limited distribution within the upper Waiakea and Hilo forest reserves. The Hawaiian hawk or 'io is widely distributed over the entire island, but is not considered to be common in any district. One additional endangered species from the study area is the Hawaiian coot (Fulica americana alai), but it is confined in this area to wetlands near Hilo.

k. The only terrestrial mammal endemic to the islands is the Hawaiian bat (Lasiurus cinereus semotus), and it is most common on the island of Hawaii. Bats were observed within the Upper Waiakea and Olaa forest reserves and in northern Hamakua forests during FWS studies. They have also been recorded regularly from the Hilo bay area, where they seek food. The species has also been recorded on Kauai, Oahu and Maui. The Hawaiian bat is listed by state and federal law as "endangered" because of its apparent low numbers, but little is known of its biology.

l. All four species of introduced rodents (black rat, Norway rat, Polynesian rat, and house mouse) are known from the study area and throughout the islands. Of these the black rat and the house mouse are best adapted to higher elevation forests, but all four species are found in lower elevation exotic forests, agricultural lands and urban areas.

m. Game mammals on the island of Hawaii include feral pig, feral goat, feral sheep, and mouflon sheep. If the Tree Planting Road is used as the western limit of the study area, then both species of sheep are excluded from consideration by their restricted distribution to higher elevation lands on Mauna Kea; and in the case of the feral sheep, also on Hualalai and the west slope of Mauna Loa. Feral goats, on the other hand, are common on Mauna Loa, Hualalai, and the southwest slopes of Mauna Kea, and extend their range in the east saddle region into the study area at the higher elevation limit. Goats are rarely found in the study area below 5,000 feet and for the most part, well south of the saddle road at this elevation. Feral pigs are well distributed throughout the study area and elsewhere within forests of the island of Hawaii. Ohia-tree fern rain forest supports the greatest number of pigs of any habitat type on the island, particularly between 3,000-5,000 feet (Ref. 10). Population density of pigs within the forest varies considerably with hunter pressure, as evidenced by comparatively low numbers of pigs in habitats along forest access roads within the study area. Pig densities within the remote portions of the Upper Waiakea Forest

Reserve have been estimated as high as 1 pig/12 acres (Ref. 10). In these areas, damage to forest vegetation is frequently severe. High populations of pigs can prevent regeneration of canopy and understory species through extensive rooting in the forest floor.

n. Other mammals known in the study area include the mongoose, feral dog, and feral cat. The mongoose has been reported as high as 10,000 feet in elevation, but is most common in low elevation lands altered by human use, including urban areas. Rain forests of higher elevations in the project area provide only marginal habitat for feral dogs and cats.

o. It is estimated that nearly 10,000 species of insects occur in Hawaii, of which about 90 percent are found only in these islands. This entire fauna appears to have evolved from as few as 150 colonist species. In addition, more than 1,000 species of land snails have evolved from an estimated 25 original immigrant species. The native rain forests provide habitat for the greatest percentage of these unique invertebrates. Undisturbed habitat is critical to the survival of these species, particularly those inhabiting only a small range. Remote forests within the study area are recognized by invertebrate zoologists as important areas for study. Of particular significance is the relatively high number of lava tubes created by recent lava flows within the study area. In recent years, the evolution of unique dark zone ecosystems, dominated by insects, has been discovered within these lava tubes.

4.08 Aquatic Biota

a. The Wailuku River is the largest stream in the State by drainage area, length, and mean annual discharge. From its headwaters at 6,500 feet, the Wailuku flows 19 miles through the Hilo Forest Reserve to the sea. Waters of the Wailuku River are characteristically soft (conductivity ranges between 20-42 umhos) and slightly acid (pH range is between 6.4-7.6). Stream temperatures range between 16°-22°C. In general, physicochemical parameters show altitudinal gradients.

b. Despite the large size of the river, few aquatic species are found in the Wailuku River (Ref. 52). The stream community is dominated by exotic species of fishes and invertebrates which have been introduced since the turn of the century. No reference to stream biota prior to 1940 can be found in historic record. It is possible that these introductions have led to the elimination of many endemic species. Perhaps the most conspicuous exotic is a small caddis fly which was introduced as food for trout in the late 1950's. Its aquatic larvae are found under rocks throughout the stream course.

Other exotic species abundant in the Wailuku include the Louisiana crayfish, a guppy, and the loach or "dojo." Two amphibians, the giant toad and bull frog, are exotic omnivores present in Wailuku River. A number of Tahitian prawns were observed in lower Wailuku as early as 1968. The State Division of Fish and Game observed numerous small endemic gobies in the lower and middle reaches of the stream in 1969. However, the most recent reconnaissance survey conducted by FWS did not discover any gobiid fishes (Ref. 52). The most abundant native species found throughout the stream is the mountain opae. Large populations were recently observed at mid-stream stations by the FWS.

c. At present, there are no aquatic species officially listed as threatened or endangered by the Department of the Interior. Although an endemic goby has been recommended for inclusion on the federal list, no populations of the species have been identified in the Wailuku drainage.

4.09 Marine Biota

a. Nearshore areas of sandy substrate in Hilo Bay appear to be poor in species number due to periodic inundation with freshwater, siltation, and wave scour. Sediments in the central harbor may not present a suitable habitat for many of the more common nearshore benthic organisms.

b. Phyto- and zooplankton levels within the harbor are high, however. Some live corals appear to thrive along the inner edges of the breakwater and Blonde Reef. In contrast, deteriorating water quality has been blamed for the death of large coral colonies along the shoreward portion of the eastern harbor.

c. Recent studies have concluded that the bay is not as productive in terms of pelagic fishery resources as other areas of east Hawaii. The commercial baitfish (nehu) catch has declined in recent years despite a relatively stable fishing effort (Ref. 41). Overharvesting, removal of juveniles by bait fishermen, pollution from sugar mills, and inadequate enforcement of existing fishing regulations are blamed for declining fishery resources in the Bay.

d. The coastline between Hilo and Kaloli Point, to the southeast, is characterized by rugged lava subject to the direct effect of tradewind generated surf and swells. Coastal waters in this area support a high diversity of marine fishes and invertebrates. Shallow inshore areas exposed to heavy wave action may be low in coral cover near the coast as a result of scouring.

4.10 Dedicated Use Areas (Figure 11)

The study area encompasses or borders upon identified areas of biological significance that must be taken into consideration in land use planning. These areas are included here within the discussion of environmental setting, and treated in further detail within sections of this report evaluating impacts of lava flows and diversion alternatives.

a. State Forest Reserves (FR). The lava barrier project area includes portions of three state forest reserves (Upper Waiakea FR, Waiakea FR, and Hilo FR). These reserves were established by executive order (Chapter 183, H.R.S.) for watershed protection, forest products, forest recreation, protection of native plants and maintenance of fish and wildlife habitat.

b. Natural Areas Reserve (NAR) System - Waiakea 1942 Lava Flow Natural Area Reserve. An area of 640 acres was designated as the Waiakea 1942 lava flow NAR on 16 November 1973 by the Board of Land and Natural Resources. The reserve was established pursuant to Regulation No. 6 (DLNR). The purpose of the reserves system is to protect and preserve areas of unique natural resources. Regulation 6 outlines specific restrictions and control regarding human use of this reserve. Although uses of reserves are confined principally to education and research, public hunting is allowed within the Waiakea 1942 lava flow NAR.

c. Other Natural Area Reserves. An additional seven areas on the island of Hawaii were formally designated as Natural Area Reserves in 1978. Two of these (Puna, Pu'u Makaala) areas are at the southern limit of the study areas, but are not likely to be affected by any project alternatives. The proposed Piihonua NAR contains 10,000 acres and is aligned east-west, parallel to the Wailuku River. Recent evidence of previous disturbance in the lower elevation portion of this area has prompted discussion of possible lateral expansion of the proposed boundaries to include some forested lands south of the saddle road. The revised area has not been formally proposed as yet.

d. Kipuka Ainahou Nene Sanctuary. By Regulation 37 of the State Division of Fish and Game (adopted 8 February 1974), the Kipuka Ainahou Nene Sanctuary was established on lands bordering the upper elevation limit of the Upper Waiakea Forest Reserve on the island of Hawaii. The area is approximately 38,400 acres in size and contains a diversity of nene habitat including several stages of forest succession from bare flows to dense forest. Regulation 37 describes the restrictions and permitted uses of this area. The purpose of the regulation is to provide habitat for recovery of the endangered Hawaiian goose, or nene. Three other large sanctuaries exist on the island as well.

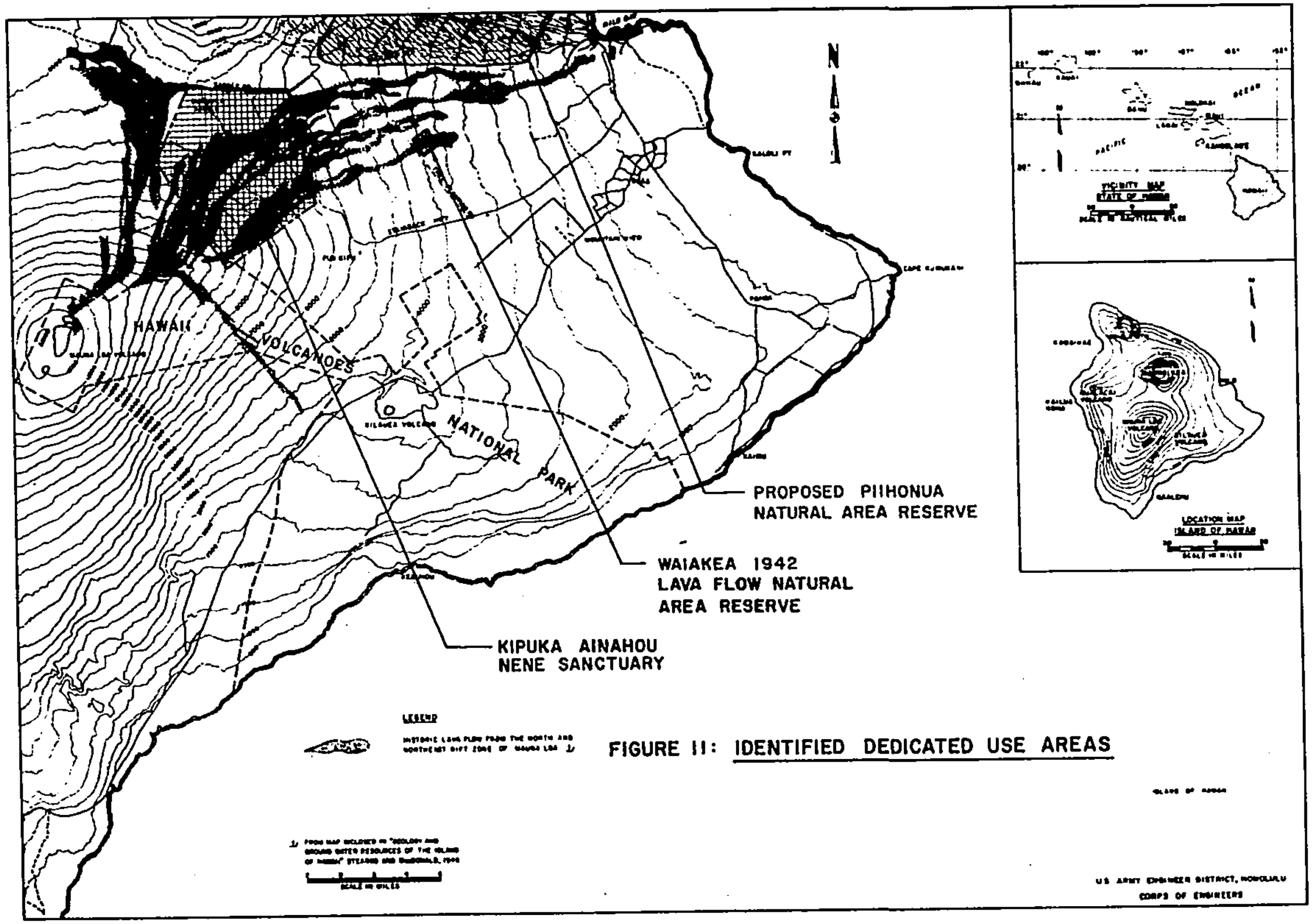


FIGURE 11: IDENTIFIED DEDICATED USE AREAS

e. Endangered Species Critical Habitat. Surveys by FWS biologists of forested lands in the State of Hawaii are being conducted to determine the abundance and distribution of endangered bird species. With sufficient field survey data, it will be possible to delineate boundaries of "critical habitat" as specified in the Endangered Species Act of 1973, as amended. This legislation provides regulatory authority to minimize adverse impact on species and their habitat. The law is particularly explicit with respect to the actions of federal agencies that affect endangered species and their formally designated "critical habitat." As a result of FWS surveys beginning in 1977, it is anticipated that a large area of forest on the island of Hawaii between 3,000-6,000 feet will eventually be recommended as critical habitat for one or more of the several endangered bird species known to inhabit the forest. A portion of this forested land lies within the higher elevation portion of the lava control study area. Rare plants known within the project area may also be listed as endangered within the near future, and critical habitat designations for these species may also be forthcoming. Coordination with the Endangered Species Office of the U.S. Fish and Wildlife Service has been continuing, and formal consultation, pursuant to the Endangered Species Act, has been completed. Should any additional studies be made concerning the biological aspects of the area, consultation would be reinitiated.

4.11 Education/Research

a. The extremely varied habitat within the lava control study area provides a rich opportunity for educational and research pursuits. Relatively undisturbed nearshore coastal areas east of Hilo contrast significantly with the radically altered harbor area. Several recent studies of the marine environment have been useful in documenting the impact of human disturbance (Refs. 6, 13, 40, 41, & 52). Research in nearshore wetlands in the study area have focused on rare waterbirds, wetland plants and unique fauna of anchialine pools and natural lakes (Refs. 9, 31). Research in the stream drainages in the lava control study area has been directed towards a descriptive evaluation of aquatic fauna, geomorphology, and water quality (Refs. 50, 52).

b. Primary terrestrial research has focused on forested slopes in the center of the lava control study area. Interest in this area relates to the diversity of habitat, documented age of the substrate and growing concern regarding the adverse impact of natural and man-related factors on forest ecosystems. In addition, the distribution of forested land- bound islands (kipuka) isolated by historic lava flows provides a rare opportunity for evolutionary studies. Access roads traversing the Waiakea and Upper Waiakea Forest Reserve facilitate continuing studies.

c. The most intensive research in the forested lands of the study area has been the 1977 bird surveys and plant studies conducted by FWS. The lava control study area was the central portion of a larger area investigated as part of the International Biological Program and reported in 1977 (Ref. 24). State Fish and Game biologists and researchers from the University of Hawaii have also studied the effects of feral mammals on forest habitat in the area (Ref. 10, 23). Ongoing studies in the area by U.S. Forest Service and FWS biologists are contributing data on the relationship between bird distribution and habitat type. The role of isolated forest kipuka in avian evolution is also being documented by field research. Invertebrate zoologists have found the study area particularly interesting due to the contrasting condition of forest habitat and the density of unique lava tube ecosystems in the area. Perhaps the most prolonged research interest in the area has focused on the problem of "onia-decline" (Ref. 4, 24).

4.12 Recreation

a. Hilo is the primary business and transportation center for the island of Hawaii. More than 50 percent of the district's population is found in Hilo, creating considerable demand on nearby recreational resources. Expected growth in population and tourism will also influence demand on these resources. Shoreline recreation is limited due to rugged coastlines and limitations on access across private lands. Comparatively few sandy beaches are available. Twenty-three parks are within 15 minutes of Hilo and 18 of these are inland parks. Wailoa and Wailuku Rivers, Waiakea Pond, Waialama Canal and Hilo Bay attract recreational fishermen. Scenic recreational resources along Wailuku River (Rainbow Falls, Boiling Pots) attract residents and visitors.

b. The primary recreational use of upland areas within the study area is public hunting. Access to forest reserves north of Wailuku River is complicated by difficulties in access across private lands; thus, forested land with access from the Saddle Road attracts considerable hunting pressure. Portions of the Waiakea and Upper Waiakea Forest Reserve and Hilo Forest Reserve are most pertinent to this study. The most abundant game animal on Hawaii, and particularly within the study area is the feral pig. However, hunting pressure is concentrated in forests within a relatively short distance of available access roads (Saddle Road, Stainback Highway, Tree Planting Road, Powerline Road, Olaa Flume Road). Hunting success (ratio of pigs per hunter) in forests within the study area is generally greater than in other pig hunting areas on Hawaii. However, these areas typically account for fewer than 30 percent of the annual hunter trips on the island due to the wide distribution of hunters and the availability of other, more sought-after game (i.e. feral sheep). Public hunting of game birds is concentrated on the saddle region and elsewhere in dry forest or grassland of Mauna Kea and Mauna Loa. Lava control study area lands do not provide a significant game bird resource.

c. Most of the study area lands do not at the present time provide other significant recreational resources due to difficulties in access, characteristics of the terrain, and lack of developed facilities.

4.13 Archeological/Historical Resources

a. The district of Hilo has an important part in Hawaiian myth and legend. It was in a cave behind Rainbow Falls that beautiful Hina made her home, the woman who bore the demigod Maui for the island's traditional founder, Hawaii Loa. Pele herself is said to have shaped the area of Hilo by sending fingers of lava down the slopes of Mauna Kea and Mauna Loa. In more recent times, Kamehameha I spent part of his youth in the district and there, moved and overturned the Naha Stone, an omen of his later rise to power when he would rule a united island kingdom. It was in 1882 that the great Chiefess Ruth came in the midst of night to erect an altar about a mile above Hilo Harbor to make sacrifice to the ancient Hawaiian gods so that a threatening flood of lava would not destroy Hilo. She was apparently successful, for the next day the lava flow stopped.

b. As part of a recent cultural resource study by the Bishop Museum, contracted by the Corps, the Lava Control Study area was divided into five zones of Hawaiian settlement and land use (Figure 12). The discussion which follows is excerpted from the report of this study. The purpose of this effort was to provide a sound basis for predicting the probability of significant historic or archeological sites in the study area. The five zones used are the coastal settlement, upland agriculture, lower forest, rain forest, and subalpine. The highest number of people in the early historic period, and subsequently the highest site probabilities, are found in the coastal settlement zone. Population centers were concentrated around Hilo Bay and in six villages along the Puna Coast to Cape Kumukahi. Suitable soils, water sources, access to the ocean, and ponds or streams for aquaculture served as concentrating influences. Reports relating to the upland agricultural zone confirm an expanse of unwooded grasslands roughly corresponding to the distribution of ash soils. Scattered huts with garden plots and groves of economically beneficial tree species dotted this expanse to 1,500 feet in elevation, where the forest began. Major trails passed through the grassland zone. Prehistoric Hawaiian land use, including frequent burning, created and maintained this open landscape. Two examples of large extensive lava tubes containing evidence of probable prehistoric Hawaiian activities transverse portions of this zone.

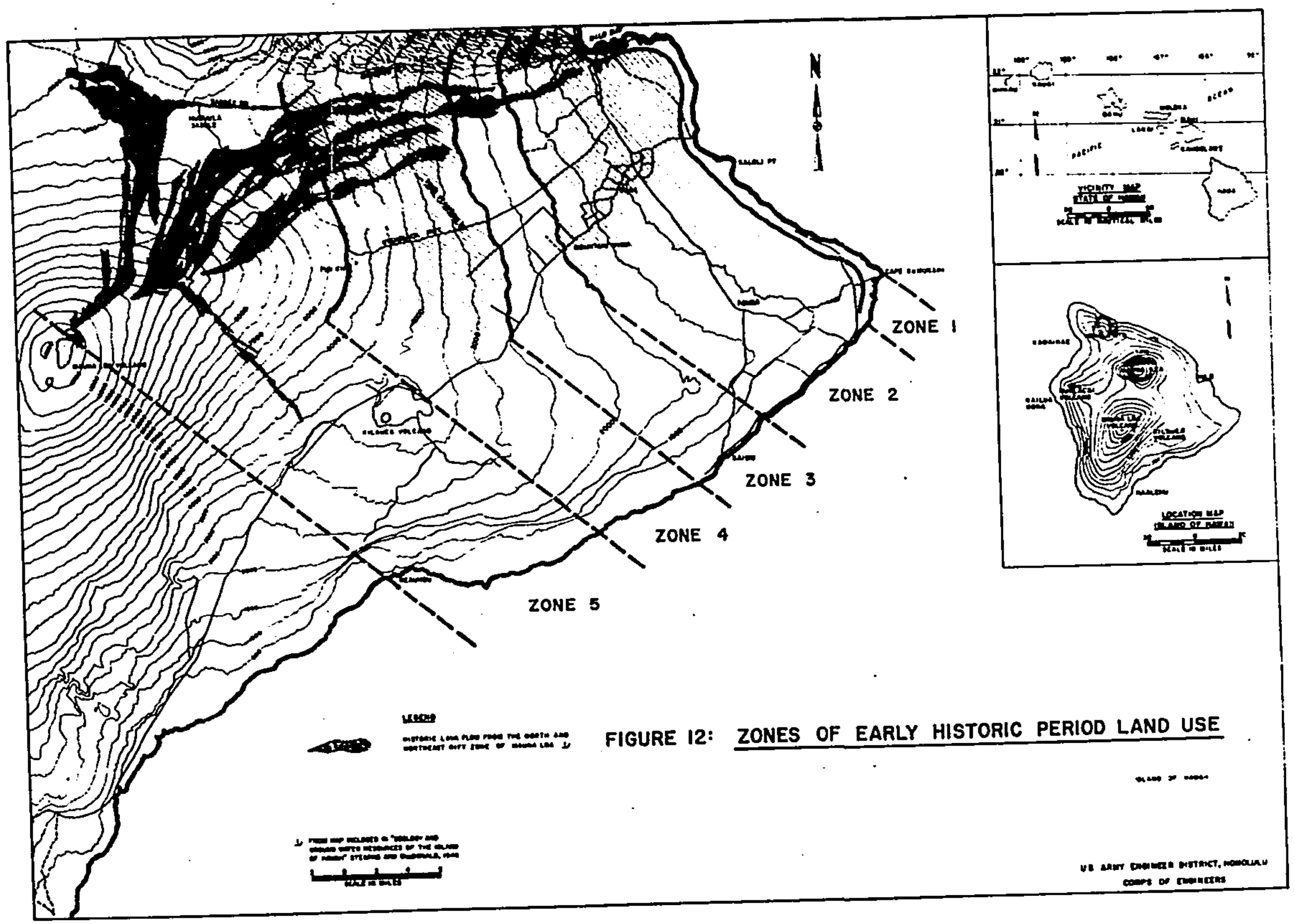


FIGURE 12: ZONES OF EARLY HISTORIC PERIOD LAND USE

c. Use of the lower forest zone, from roughly 1,500-2,500 feet in elevation, revolved around the gathering of forest resources, including wood, fiber, bird feathers and food crops from small forest clearings and along streams. Historic accounts suggest clusters of small huts, small religious shrines and numerous paths were found in this zone, but the probability of finding structural or artifactual evidence is low due to the temporary nature of structures and rapid regrowth of ground cover. The upper limit of this zone corresponds to early historic and present distribution of known Hawaiian cultigens and koa.

d. Available evidence suggests the rain forest zone (2,500-5,500 feet) was visited only infrequently in prehistoric times due to the increasing distance from population centers, reduced accessibility due to dense vegetation, habitat, references of valued plant species and discomforts of increasing rainfall and lower temperatures. Exceptions include possible use of the area by bird catchers and use of at least one major inter-district trail that crosses the zone. The exact location of this trail is nearly impossible to determine. Use of major trails probably dominated the utilization of the subalpine zone as well. Resources were limited to birds and valued hardwoods of dry forests.

e. The cultural resources study identified 331 sites in the lava study area of which only four are currently listed on the National Register of Historic Places: the Hilo District Court House and Police Station, the U.S. Post Office and Office Building, the Wyman House, and the Shipman Residence, all in the Hilo vicinity. Most of the identified sites are within the coastal settlement and upland agricultural zones (below 1,500 feet). The significance of fewer than 60 percent of the identified sites has been determined and little of the upper three zones has been surveyed for sites. Some of the upper areas in need of further research include the Puu-Oo-Volcano Trail along which lie Waiakea Camp, Solomon's Water Hole and Keawewai Camp; the Waiakea-Uka Springs; the Middle Flume Spring; portions of Stainback Highway and Hilo-Kona Road; Olaa Flume Road; and Kukui Camp.

4.14 Aesthetics

a. The landscape of the Big Island as seen from the air or from the island's highways provides a vista unique in the State: large, gradually sloping volcanoes, characteristic of young islands. From the air, one perspective can include from the rocky shoreline, up the forest slopes, past timberline to the snow-capped tops of Mauna Kea and Mauna Loa. In the saddle region, sloping down towards Hilo, this visual perspective is already marred by the extensive "ohia dieback" that appears as a blight on the land, but the aesthetics of the sweeping, essentially unbroken forest above 3,000 feet is a recognized natural value.

b. There are few places along the Saddle Road above Hilo where one can view more than the immediate vicinity of the road. The view here is dominated by ohia forest on lava flows, with variable stages of forest development dependent on the age of the flow at this location on the island. Although the type of view from this road is not unique, it is largely undisturbed by human intrusion into the natural environment above 1,000 feet in elevation.

c. In contrast, the land bordering the Hilo-Volcano Road, at the western edge of the study area, has been highly altered by human use. The primary vista includes agricultural lands with intermittent human development along the route.

5. ENVIRONMENTAL CONSEQUENCES

5.01 Introduction

a. Revised Council on Environmental Quality guidelines for implementation of the National Environmental Policy Act stress the need for a thorough evaluation of environmental impacts of various project alternatives. This discussion should include the direct and indirect effects of the alternatives, and the significance of these effects. In addition, the discussion should identify: 1) adverse effects which cannot be avoided, 2) the relationship between short-term uses of man's environment and the maintenance and enhancement of long-term productivity, and 3) any anticipated irreversible or irretrievable commitments of resources. Finally, means to mitigate adverse environmental impacts should be identified.

b. The comparison of alternatives under consideration in the lava control study is complicated by the different circumstances under which each plan would be implemented. For each alternative, some pre-emergency work would occur. In the case of Alternatives A, B, and D, most of the proposed construction work would occur prior to the actual occurrence of a threatening flow. In the case of Alternative C, pre-emergency work would involve selection of a water cooling alignment, placement of an onshore pumphouse, and possibly preparation of concrete thrust blocks along the selected alignment. For Alternative E, pre-emergency work on site would be limited to identification of potential barrier alignments and possibly some preparation of staging areas. Actual construction would not occur until authorities determined that an approaching flow was likely to threaten Hilo if not successfully diverted.

c. In view of the fact that at least two of the considered alternatives would not be fully implemented unless a flow actually occurs, it is reasonable to compare the anticipated environmental impact of an undiverted lava flow to the effects of measures taken to divert that flow. This is followed by a discussion of anticipated project impacts.

6. ENVIRONMENTAL CONSEQUENCES OF A LAVA FLOW WITHIN THE STUDY AREA

6.01 Geology

As indicated earlier, seven distinct flows from the northeast rift zone of Mauna Loa have entered the study area since 1843. Alteration of surface topography with each flow has varied considerably with the size and depth of flow, characteristics of lava, and the specific path followed. These parameters are essentially unpredictable for a future flow, as is the impact on existing geology. The most significant geological changes would occur if a future flow reached the developed lands of the Hilo area and these human alterations to the natural landscape are obliterated.

6.02 Hydrology and Water Quality

A new flow in the study area would alter surface drainage patterns in ways that will vary considerably with the source and path of the flow, and the thickness and geological characteristics of the lava. The most significant direct impact on hydrology of water quality resulting from a new flow would occur only if the flow made contact with the Wailuku River. The water in the river might serve to cool and divert the flow, while conversely, the flow would heat the river water and possibly divert the river. Molten lava in the stream drainage would alter downstream water chemistry until the flow had solidified. It is not likely that a lava flow similar to other flows in recent history would produce a detectable effect on either basal water quality or supply beyond the immediate area of the flow. At lower elevation, such a flow could alter drainage systems established for human habitation and agriculture. If a new flow reaches the sea, it seems apparent that the localized and temporary impact on marine water quality would be far exceeded by the adverse impacts on agriculture and developed lands.

6.03 Air Quality

Although several gases are released during a typical eruption, concentrations of SO^2 (sulfur dioxide) are the most offensive to humans. Additional emission of mercury creates the most significant air quality health hazard associated with volcanic activity. Localized areas of the Big Island (i.e., Puna, Volcano) are continually producing gases, in some cases above recommended health safety levels. A new flow above Hilo would not increase the long-term production of offensive gases near inhabited areas, but it would temporarily affect air quality, particularly as a result of forest fires and steam.

6.04 Noise

Active lava flows are characterized by high levels of sound, in part dependent on the nature of the flowing lava and the terrain over which it passes. Sounds of exploding trees, burning ground cover, and shifting substrate are all typical of moving lava. The sound levels quickly die down with cooling of the lava. Although noise levels may be offensive to some, the other associated damage caused by a flow in or near human habitation far outweighs the noise impacts.

6.05 Terrestrial Biota

a. Lava penetrating forested lands in Hawaii is certainly a natural phenomenon that continues today only on the island of Hawaii. Isolation of islands of forest (kipuka) by flowing lava has played an important role in the evolution of unique life forms and has been the subject of considerable scientific study.

b. Vegetation within the lava barrier project area illustrates the impacts of lava flows and the gradual process of plant invasion and succession after each flow. The rate and pattern of succession depends upon the extent of forest destruction (depth and type of lava, temperatures), as well as the climate conditions and proximity and diversity of potential colonist plant species. If trunk and root structures are left protruding from the flow, invasion and succession may be accelerated. The primary colonist tree species is ohia (Metrosideros), preceded only by early pioneer stages of algae, ferns, lichens, and mosses.

c. Although lava flows are a natural phenomenon to which Hawaii's flora has adapted, the pattern of reinvasion and reestablishment of forest after a flow has changed somewhat since the introduction of exotic plants and animals to the islands. Studies have documented the early invasion of lava flows by exotic herbaceous seed plants, grasses, and forbs (Ref. 37). However, since there are relatively few native species in this life-form group of plants, direct competition is minimized. Presumably, future succession on new flows will be characterized by an increasing component of exotic plants, although there is little evidence to suggest that these species will outcompete or interfere with natural invasion and development of native plants.

d. It is likely that a new flow would destroy remaining pockets of rare plants in its path. The long term adverse impact of this loss on the perpetuation of these species is aggravated by the loss of habitat elsewhere and the combined influence of other man-related adverse factors (feral mammals, exotic plants, etc.).

e. Depending upon the direction and extent of travel, a new lava flow at lower elevations near Hilo would also penetrate small blocks of exotic planted forest and extensive acreage of agricultural lands (cane, macadamia nuts, truck crops).

f. A new lava flow following the pattern of recent flows in the saddle region would eliminate large blocks of important native wildlife habitat, some of which may be crucial to the survival of endangered forest birds. As is the case for rare plants, this natural phenomenon would adversely affect populations of rare birds more seriously than did earlier flows due to presently low numbers and already patchy distribution. Major loss of forest between 3,000-6,000 feet would be particularly significant to these species. The impact on wildlife would be aggravated by the ongoing apparent degeneration of native forest in this area as a result of "ohia dieback." Although some investigators believe this dieback is part a long term natural process, it is clear that affected forest supports far less native wildlife than unaffected forest and diminished populations may not be able to with stand a long-term, albeit cyclic, degradation of habitat.

6.06 Aquatic/Marine Biota

A flow reaching Wailuku River would adversely impact upon stream fauna, although the native species component is low and no listed endangered species are involved. Wetlands in the Hilo area could be inundated but none are critical to the survival of any endangered waterbirds. Lava entering Hilo Bay would have significant impacts on relatively undisturbed reef area only if the entire harbor was affected, a very unlikely phenomenon. Depending upon the path of the flow, other coastal marine resources could be adversely affected by a flow reaching the ocean.

6.07 Dedicated Use Areas

Impact of a new flow in the study area on identified dedicated use areas would depend upon its precise alignment. It is very likely that high elevation wildlife habitat in the Kipuka Ainahou Nene Sanctuary would be affected by loss of vegetative cover. The Waiakea 1942 Lava Flow Natural Area Reserve could be inundated, as could portions of the pending Piihonua NAR. Forested habitat for endangered birds under consideration for possible candidate critical habitat status would be adversely impacted by any lava flows that travel far enough to threaten Hilo.

6.08 Education/Research

A new lava flow within the study area may alter or obliterate areas now under study by research biologists. However, such a flow would provide an opportunity to evaluate impacts on the forested lands and to document the pattern of vegetational succession in an area where several flows can be accurately dated. Botanical and zoological studies recently completed in the area would provide an interesting baseline for subsequent studies.

6.09 Recreation

Impact of a new flow on recreation would be confined largely to hunting opportunity at higher elevations, but could alter or eliminate recreational resource areas at the upland edge or within Hilo if the flow progressed this far. Some feral pig habitat would be destroyed in a saddle area flow, although the extent of impact would vary significantly with the size and alignment of the flow. The flow would also affect access to existing hunting areas. Impacts on recreational resources within Hilo, should the flow reach that far, are thought to be insignificant by comparison to other losses.

6.10 Archeological/Historical Resources

Inundation of Hilo could destroy four National Register sites and conceivably many other sites of potential register eligibility that have not been evaluated sufficiently to date or even identified. Based on historical data, it is reasonable to assume that most future flows would not extend below the lower forest zone (1,500 feet). The lack of survey data from the elevations above this zone make it impossible to accurately assess the impacts of flows on cultural resources. Based on the analysis of probable prehistoric and historic land use in the area, and known historic sites in this upper area, it is likely that relatively few prehistoric cultural resources would be destroyed by lava flows in comparison with areas lower in elevation. On the other hand, as many as ten historic sites could be destroyed, depending on the direction and magnitude of flows.

6.11 Aesthetics

Lava flows of variable age are part of the natural visual environment on the island of Hawaii and to this extent are aesthetically valuable. These resources are a major visual attraction within Hawaii Volcanoes National Park. There is even reason to believe that another natural flow would be of equal interest, particularly during the stage of peak volcanic activity. Such a flow would adversely impact aesthetics as it approached or penetrated developed areas at lower elevation, but other impacts would generally be considered more significant.

6.12 Social Behavior

a. There are predictable social or cultural behavioral responses associated with volcanic activity in Hawaii. These often involve appeals to the supernatural, mainly Pele, the volcano goddess. Many people, especially Hawaiians, make offerings of liquor, candy, tobacco, flowers, food, and ti leaves to Madame Pele. Furtner, many believe it is possible to pray to dead relatives who have been dedicated to Pele to intercede with the goddess to direct a lava flow away from a particular piece of land. Pele beliefs also play a part in behavior associated with evacuation on the part of old Hawaiians. Such people may designate a flow as being Pele who "can take anything she wants when she will," and when a lava flow approaches their property, they will do nothing, believing that to take any action would anger the goddess. During the 1955 eruption in Puna district, an old Hawaiian man refused to move his belongings, including a new television set and refrigerator, because of his beliefs. During the recent volcanic eruption and lava flow in the Kalapana area of south Puna in 1977, there was widespread local opposition to any form of experimental waterbombing by the Army to determine the effects on the flow of lava. The degree of opposition finally led the Mayor of Hawaii County and the Governor of the State to informally request federal authorities to stop their experimentation.

b. Empirical studies conducted in Puna district to measure the perception and evaluation of volcanic hazards and the evaluation and adoption of adjustments to these hazards, (i.e. ignoring eruptions, propitiating spirits, evacuating orderly or panicking), show that experience, as reflected by age, length of residence in the area, and personal encounters with the hazard are most important variables. Factors relating to socioeconomic status or characterization of people and where people lived were significant in Puna where there is much absentee-ownership of land. In areas such as the South Hilo district, location may become more important in determining one's behavior during threatening volcanic activity. Variations according to ethnic background may also be important. Knowledge of these social and other variables may aid disaster planners in learning to cope with potential victims before, during, and even after the event and could aid in forecasting how potential victims would react to success or failure of the array of alternative plans to divert future lava flows.

7. ENVIRONMENTAL CONSEQUENCES OF ALTERNATIVE LAVA CONTROL PLANS

7.01 Geology

ALTERNATIVE A

Construction of a diversion barrier would radically alter surface geology the entire length of the barrier and over the width of a cleared flow channel. Excavation of material to create the barrier would significantly alter the existing geological characteristics. Successful diversion of a flow would prevent alteration of geology downslope, but the path of the diverted flow would include areas that would not be affected if there were no project.

ALTERNATIVE B

Same as "A" although the primary area of construction impact would be shifted downslope. The total amount of surface alteration would be less due to a shorter barrier requirement.

ALTERNATIVE C

Use of the sea water cooling alternative at the lower elevation alignment would accelerate soil runoff below the site, but the lasting geological impact of this activity is not expected to approach the significance of flow itself in this area. If the cooling were unsuccessful in diverting the flow, impacts to geology would not be appreciably different than if no action were taken.

ALTERNATIVE D

The impact of this alternative on surface geology would be similar to "B," although the requirement for less fill for a narrower barrier at low elevation would reduce geological impact. Use of Wailuku River cooling water along the alignment would have a localized effect on soil, but this effect would not occur unless a flow approached and the flow itself would have greater adverse geological impact.

ALTERNATIVE E

This plan would involve considerably less barrier construction and, consequently, less alteration to surface geology than would Plans A, B, or D because of the shorter length and smaller size of barrier involved. The exact location of the impact would not be certain until the probable flow path is determined.

7.02 Water Supply

ALTERNATIVE A

Indirect impact of this barrier on water supply may occur through alteration of drainage patterns. Diverted flows may also impact water supply routes to isolated areas in Puna distirct and in the vicinity of Olaa and Keaau. This, in turn, could adversely affect both rural home use of water and agricultural production.

ALTERNATIVE B

Impacts would be similar to Alternative A, although direct effects on human use of water may be more significant due to the proximity of the barrier to developed lands, particularly in the Kaumana area.

ALTERNATIVE C

Saline waters may enter Wailuku River and affect water supply, but the impact would be insignificant by comparison to impacts of the lava flow at this location.

ALTERNATIVE D

Diversion of Wailuku River water in the event of a lava flow would have temporary impact on domestic water supply, including reduction of existing hydroelectric use. The latter could have severe adverse secondary effects unless emergency power generation is made available. Emergency fire fighting needs should also be considered. Impacts on water supply of the diverted flow would be similar to Alternative B.

ALTERNATIVE E

The emergency operation could affect surface drainage but the uncertainty of specific location and length makes it impossible to predict degree of effect. Impacts on domestic and agricultural water supply by a diverted flow would vary considerably with the lava flow path.

7.03 Water Quality

ALTERNATIVE A

Alteration of drainage patterns due to barrier placement would affect water quality by altering the percolation of water into the substrate. Crushed aggregate used in barrier construction would generally be above silt size so there would be little increase in turbidity of runoff. Operation of heavy equipment and storage of fuel would create a source of petrochemical pollution in runoff, but is likely that most of this would be absorbed by barrier substrate. An exception to this would occur in depressed areas already deficient in drainage.

ALTERNATIVE B

Impacts would be similar to Alternative A, although greater proximity to developed lands may increase localized impacts and the extent to which area residents complain about water quality impacts.

ALTERNATIVE C

Use of salt water for cooling would affect drainage water quality in the immediate area through additional runoff and altered salinity. If salt water enters the Wailuku River, localized and temporary alteration of water quality would occur.

ALTERNATIVE D

Impacts of barrier construction on water quality would be similar to Alternative B. Minimal adverse impact on water quality would occur during construction of a diversion structure. Actual diversion of river water in the event of a lava flow would approximate drought conditions in lower parts of the river. Limited dilution or stagnation of water in pools within the river would degrade water quality. The significance of this impact on human use of this water would depend upon the duration of need for water diversion.

ALTERNATIVE E

Adverse impacts on water quality associated with barrier construction would be significantly less than other barrier alternatives due to the shorter length of barriers. Also, this impact would not occur unless an approaching flow dictated barrier construction.

7.04 Air Quality

ALTERNATIVE A

Use of heavy equipment on access roads and movement of fill would each create localized and temporarily significant increases in air pollution due to fugitive dust. However, most construction material in areas where the barrier crosses recent flows would be of great enough size to significantly limit the dust problem. At lower elevations where soil depths are greater, fugitive dust would be a locally serious problem requiring use of dust control techniques, particularly during low rainfall conditions. Blasting would contribute to the fugitive dust problem and also create locally significant smoke pollution. Any fires accidentally caused by construction activities would create smoke pollution as well. The severity of this problem would depend on number and size of vehicles, proximity to one another, and wind conditions. Air pollution at elevations close to human habitation would be most offensive. In the event a future flow is diverted, adverse impacts of the flow on air quality would be shifted from the densely populated Hilo area to the less populated rural areas in Puna.

ALTERNATIVE B

Degradation of air quality would be similar to Alternative A, although closer proximity to the Saddle Road and to low elevation habitation would magnify the problem. Barrier alignment would result in greater movement of wind borne dust and smoke into developed areas, increasing significance of the impact to humans. Significance to wildlife, particularly endangered species, would be less than Alternative A, due to the lower elevation alignment of Alternative B.

ALTERNATIVE C

Impacts due to fugitive dust and measures of hydrocarbon emission during road and thrust block placement would be minimal and temporary.

ALTERNATIVE D

Air quality impacts associated with barrier construction would be identical in type to Alternative B, but reduced in duration due to the reduced size of the barrier. Road construction and diversion structure placement in the Wailuku River would create minimal air quality impacts.

ALTERNATIVE E

Adverse impacts would be less than other barrier alternatives, both in duration and in distribution, due to smaller magnitude of construction activities. Such air quality impacts would be additive to natural emissions and forest fires resulting from the approaching flow. The adverse impacts of the diverted flow would shift from the Hilo area to less populated rural and agricultural lands of Puna.

7.05 Noise

ALTERNATIVE A

Construction of the proposed barrier would involve heavy motorized earth-moving and hauling equipment. The noise generated by this equipment would be significantly greater than present natural or man-related noise conditions. The sound of blasting to loosen lava for barrier construction would be evident for long distances. The actual impact of these noises would depend on weather conditions (wind, temperature, humidity) and in the case of blasting, on the size and location of the charge. Complaints by people in the area would be dependent upon frequency and time of day of blasting activities. Impacts on humans in the project area would be greatest at lower elevations, particularly near Waiakea Homestead and Kurtistown. People on the Saddle Road or on access roads into the upper project area may also find these noises offensive.

ALTERNATIVE B

Noise associated with this barrier alignment may be significantly reduced in comparison to Alternative A due to the greater amount of aa lava, requiring less use of blasting than pahoehoe lava. However, the closer proximity of this barrier to the Saddle Road and to rural or suburban developments would result in greater significance of this additional noise. Maintenance of the barrier after construction would involve little additional noise impacts.

ALTERNATIVE C

Additional noise associated with road construction and thrust block placement would be minimal and temporary.

ALTERNATIVE D

Noise impacts would be similar to Alternative B, although reduced in duration due to smaller size of barrier. Road construction and diversion structure placement at the Wailuku River would create some additional noise, yet this would be undetectable at the nearest residences.

ALTERNATIVE E

Noise impacts would vary with specific selected location for barrier construction, but would be reduced in duration due to emergency need. Blasting may be required to expedite barrier construction. Noise effects will be additive to effects of the approaching lava flow.

7.06 Terrestrial Biota (Flora)

ALTERNATIVE A

a. Alteration of intact native ecosystems: Barrier construction would involve loss of 1,790 acres of habitat. This includes the barrier, the cleared area above the barrier, and the cleared path between barrier segments. Approximately 75 percent of the barrier alignment would pass through tall-stature ohia forest. Slight shifts in alignment would affect, significantly, which kipuka are destroyed by barrier construction, or protected from future flows. Habitat would be destroyed by coverage with fill and by clearing and grubbing. A diverted flow would also adversely impace more pristine (less disturbed) native forest in the southeast portion of the Upper Waiakea Forest Preserve.

b. Invasion of exotic plants (i.e., Melastoma, Setaria, Psidium, Clidemia): Exotic pest plant invasion would be accelerated by movement of equipment into the site. Smaller (crushed) aggregate in the barrier would create more suitable substrate for exotic grasses (i.e. Andropogon), increasing the fire hazard. The impact would compare to road construction where pest plants invade the perimeter. The most significant exotic plant invasion would probably be Koster's Curse (Clidemia hirta), now known to be established at lower elevations along the barrier alignment.

c. Loss of rare or endangered plants: Intact ecosystems in the study area have been shown to contain species of rare plants, some believed to be in danger of extinction. At this point, it is impossible to estimate the full extent of project impacts on these species, but it is likely to be locally severe. This could be mitigated or avoided after detailed field study by aligning diversion barriers to avoid, and potentially protect, areas of rare plant concentrations. The proposed alignment of the barrier under Alternative A would protect known habitat of at least one species (see 4.07g) from a future lava flow.

d. Piling of forest debris - Increased threat of fire: Clearing activities would create piles of forest vegetation, increasing the threat of major fire and also creating additional problems with potential pest insects and rodents. Storage and transport of fuel and use of heavy equipment in the area would also increase fire threat.

e. Alteration of drainage patterns: Barrier construction would affect runoff patterns, particularly on land immediately adjacent to the alignment. This may result in localized pooling of water, and consequent impact on forest reproduction, as well as drought-related impacts below the barrier.

f. Additional hunting opportunity - reduced impact of pigs on flora: Access provided by barrier alignment would provide some additional opportunity for hunting. However, impact on pig populations would be minimal in the long term and focused only along alignment of barrier.

ALTERNATIVE B

Impacts would be similar to Alternative A, (approximately 1,800 acres habitat destroyed). Approximately 50 percent of the barrier above Olaa Flume Road would cross tall-stature open ohia forest. Most of the lower segment (below 3,000 feet) would penetrate previously disturbed forest, including some exotic tree plantations and sugarcane fields. Access of exotic plants to high elevation forest would be accelerated as in Alternative A. The proposed alignment of the barrier passes close to recently identified rare plants (see 4.07g), and slight adjustments in alignment would significantly affect overall impact on these plants and forest kipuka.

ALTERNATIVE C

This water cooling plan would involve road construction and thrust block placement within predominantly exotic forest, much of which is already highly disturbed by prior human use. There is little chance of significant impact on rare flora. Construction of roads would aggravate dispersal of exotic pest plants, yet with little long term impact on forest ecology. Use of salt water for cooling would cause excessive vegetation loss downslope of the alignment, but the water would not be used unless necessary, and the impact of the lava flow would be far more significant.

ALTERNATIVE D

Impacts would be similar to Alternative B, except that extent of clearing would be reduced somewhat in the lower portion to the alignment. Acceleration of exotic plant dispersal would be similar to Alternative B. Stream site alteration of vegetation would be minimal as project involves water diversion, not storage.

ALTERNATIVE E

Impact of this alternative on native flora would be less than would occur with other barrier alternatives due to the reduced size of the structure. Effects on rare plants would vary considerably with specific locations chosen for diversion. Barrier segments below the Tree Planting Road are expected to have significantly less impact on rare plants than would higher elevation barriers but this would need to be confirmed. The necessity to restrict emergency activity to easily accessible areas (close to roads) would minimize direct effects on the most remote forest. Although this would result in less indirect impact by providing less opportunity of invasion to pristine areas by exotic plants, it would not significantly increase hunters' accessibility to remote forests in which pig populations are virtually unchecked.

7.07 Terrestrial Biota (Fauna)

ALTERNATIVE A

a. Loss of wildlife habitat for game and nongame species: Habitat would be lost or severely altered by destruction of vegetation and by associated impacts on the forest. Also, division of existing forest by the barrier would further isolate populations of rare species, limiting dispersal and contributing to possible extinction of critically endangered species. As indicated in Figures 14 to 16, nene, akiapola'au and Hawaii creeper would be more affected by this diversion barrier than the other endangered species in the study area. Diversion of flows would not necessarily reduce or increase the impact of the flows on these species. It is unlikely that individuals of rare species forced to move as a result of this alternative would successfully colonize adjacent lands. Introduced exotic plants would create adverse impacts on wildlife cover, food supply, nesting habitat, etc.

b. Increased hunting opportunity: Additional access to previously inaccessible forest would create limited additional pig hunting opportunity, with localized positive impact on forest ecology.

c. Dispersal of exotic wildlife: The barrier would provide a convenient means of dispersal for exotic insects, molluscs, rodents, and other wildlife, with potential long term adverse impacts on native species.

d. *Disturbance of resident wildlife*: Construction activities and barrier maintenance (or road use) would create continuing disturbance of wildlife in previously isolated areas. Impacts would involve visual disturbance, excessive noise, air pollution, and others.

ALTERNATIVE B

General types and severity of impact on fauna would be similar to Alternative A, particularly along the upper segment. The lower two barrier segments would not penetrate into the known range of the five endangered species shown in Figures 14 to 18. Below 1,600-1,800 feet, wildlife habitat disturbance is already excessive and these lands support few species of wildlife, virtually all of which are foreign to Hawaii. In the event of a lava flow, the barrier would shift the area of impact but there are insufficient data to determine whether this would diminish or increase the threat to rare species of wildlife.

ALTERNATIVE C

This alignment is below the lower elevation distribution of most native species of wildlife. If diversion were successful, endangered waterbirds in the wetlands may be protected but no forest species will be affected by diversion efforts at this low elevation. Several species of exotic birds and mammals inhabit the area, but this alternative would not have long term impact on populations of these species. If salt water is used for cooling, some localized loss of wildlife habitat would occur. However, impact of this activity would be far less significant than habitat loss due to lava flow at this location.

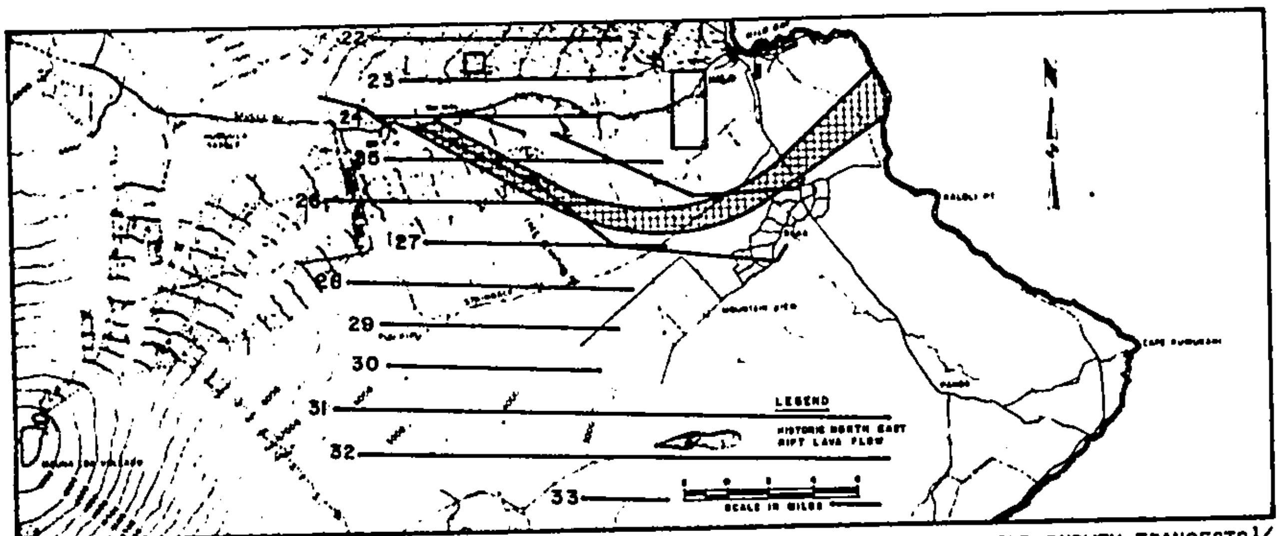


FIGURE 13. US FISH AND WILDLIFE SERVICE FIELD SURVEY TRANSECTS[1/]

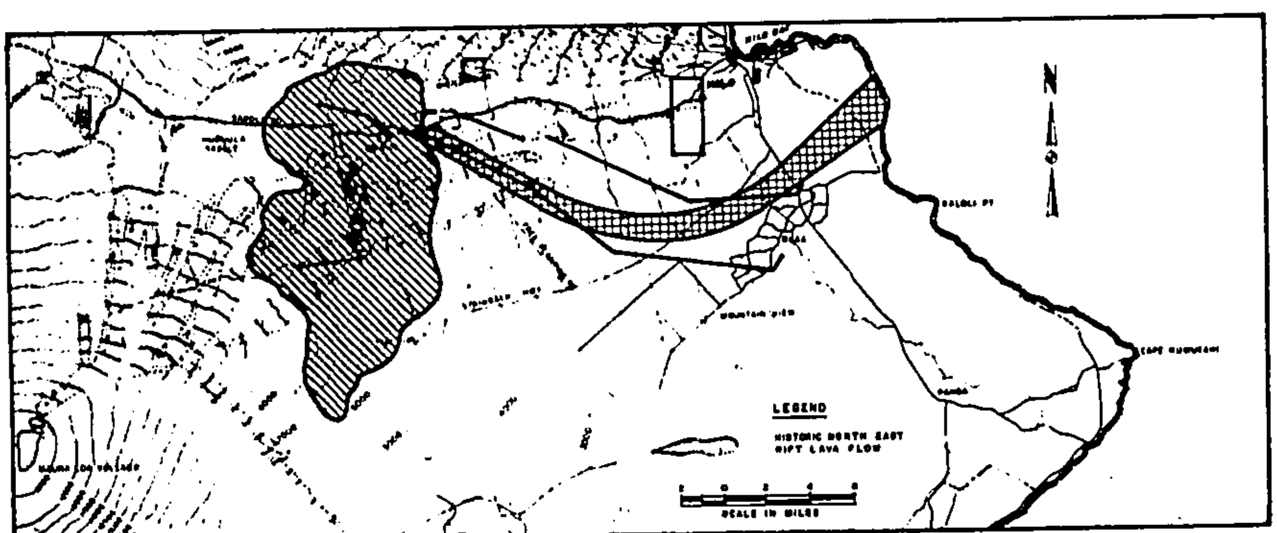
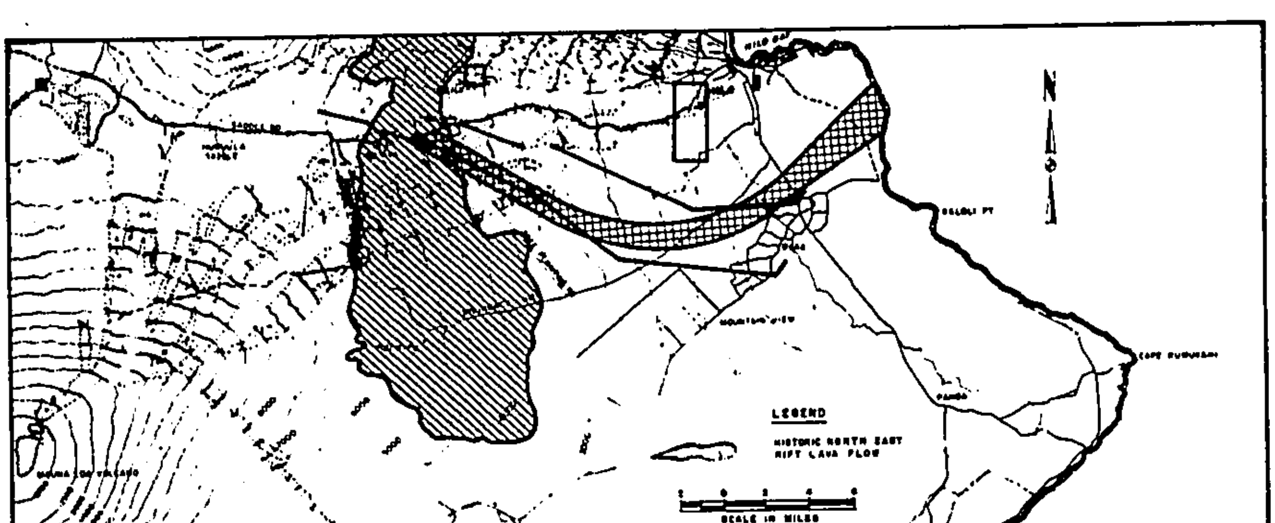


FIGURE 14. NENE DISTRIBUTION IN STUDY AREA[1/]



1/SOURCE: UNPUBLISHED USF&WL DATA

FIGURE 15. AKIAPOLA'AU DISTRIBUTION IN STUDY AREA[1/]

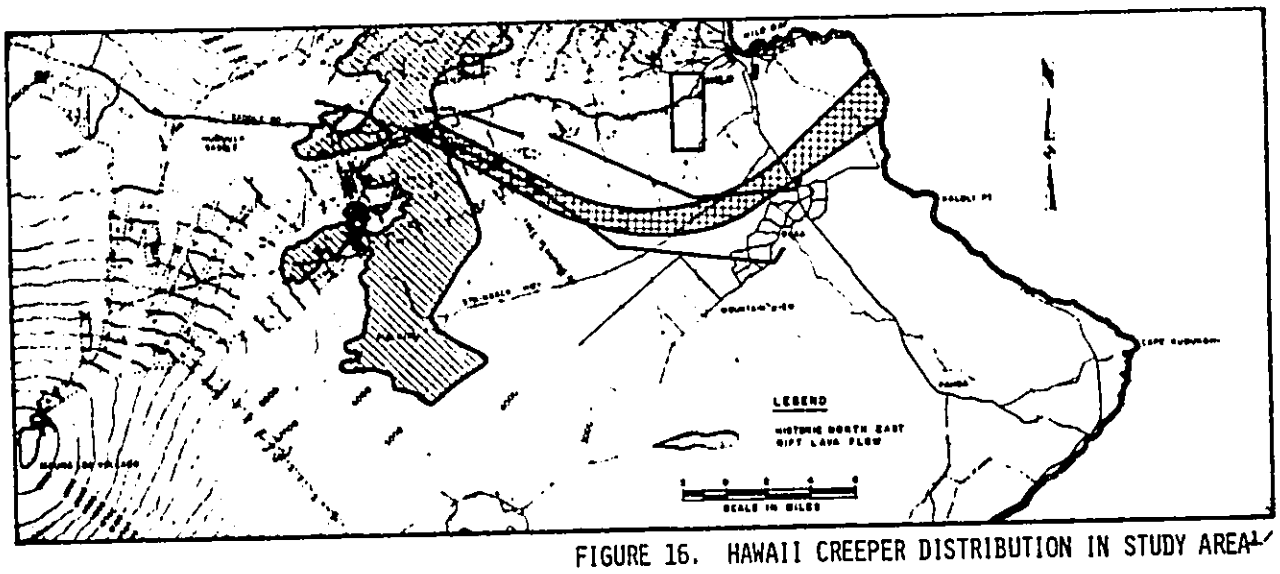


FIGURE 16. HAWAII CREEPER DISTRIBUTION IN STUDY AREA1/

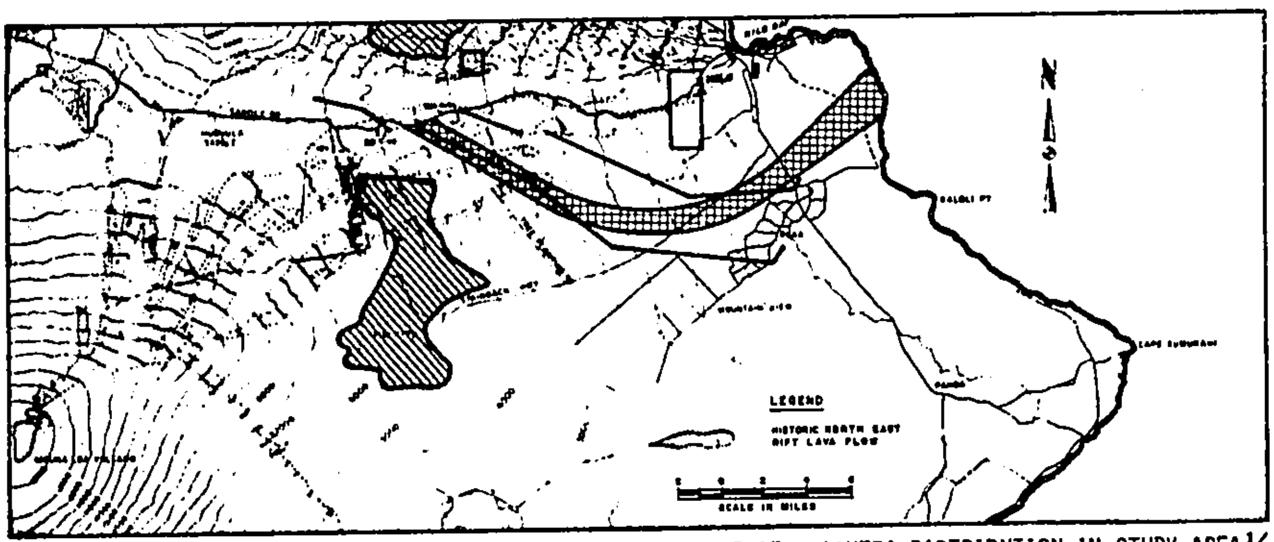
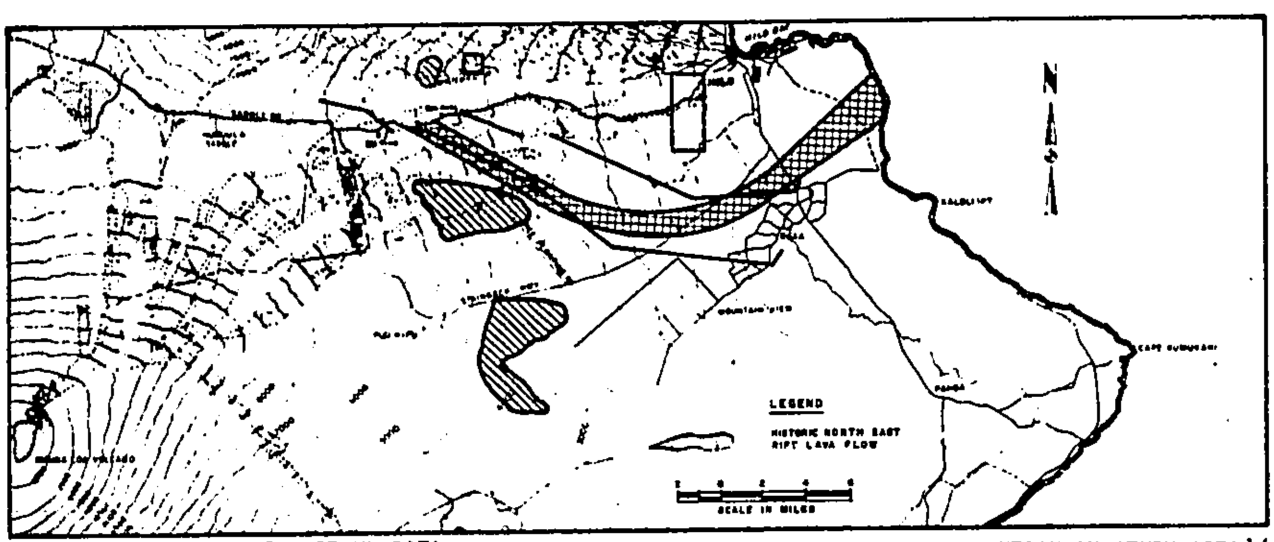
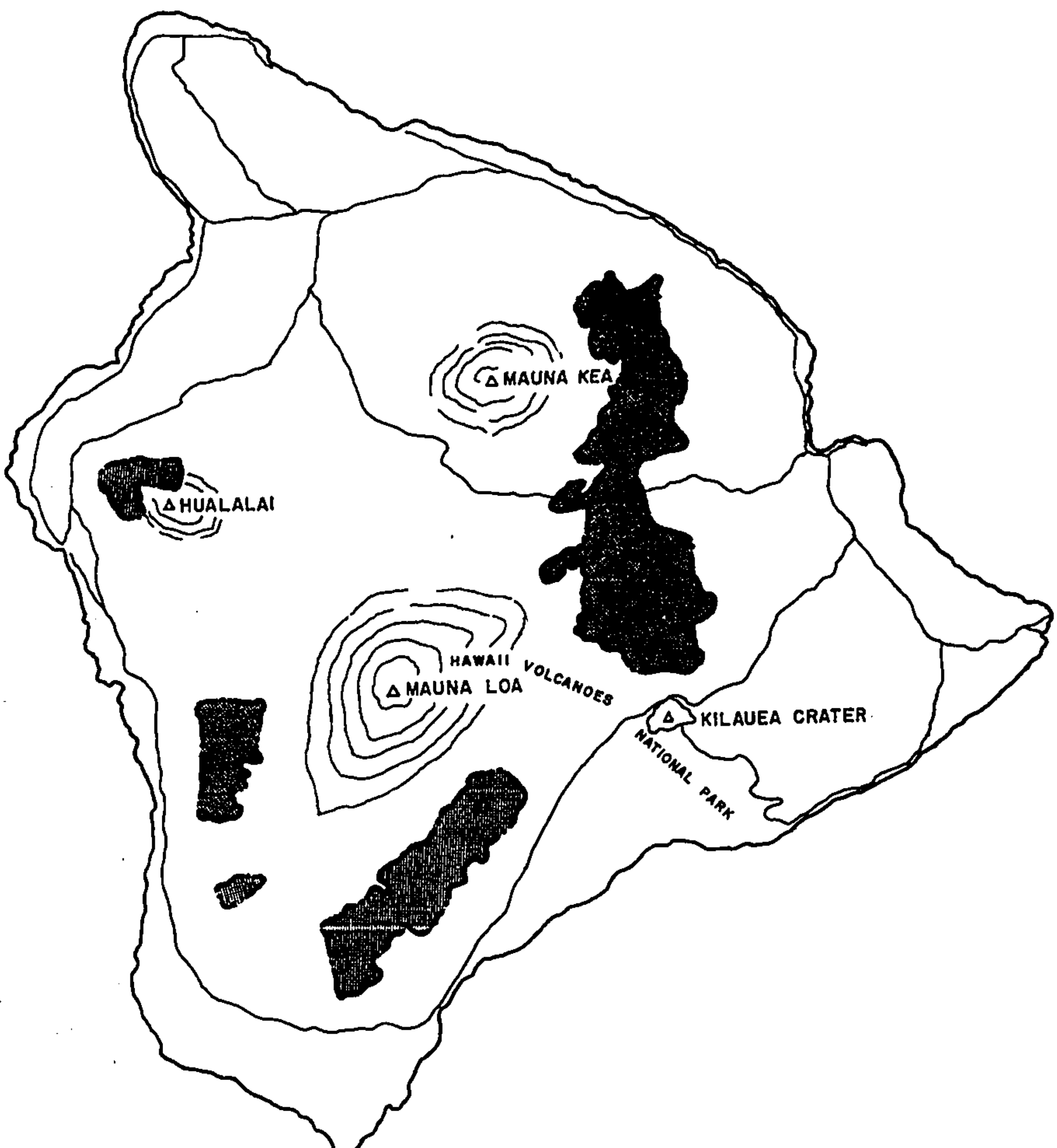


FIGURE 17. 'AKEPA DISTRIBUTION IN STUDY AREA1/



1/SOURCE: UNPUBLISHED USF&WL DATA

FIGURE 18. 'O'U DISTRIBUTION IN STUDY AREA1/



COMBINED DISTRIBUTION OF HAWAII CREEPER, HAWAII 'AKEPA, AKIAPOLA'AU, AND'O'U

FIGURE 19

ALTERNATIVE D

Adverse impacts on terrestrial fauna would not be appreciably different with this plan than as a result of Alternative B. Some additional wildlife habitat loss would occur through road construction to a stream diversion site.

ALTERNATIVE E

The adverse impacts on terrestrial fauna associated with this alternative relate directly to the alteration of forest described previously. Even though the "corridor" for this plan penetrates the known range of rare bird species (Figures 14, 15, 16), the Corps feels that it is doubtful that endangered wildlife would be significantly impacted as all construction above Tree Planting Road would probably occur in the immediate vicinity of existing access. Also these impacts would be additive to the direct and more significant impact of an approaching flow. Both the barrier construction and the flow would increase accessibility of more remote areas, potentially resulting in reduction of pig populations by expanded hunting at a later date.

Pursuant to the Endangered Species Act of 1973, as amended, formal consultation was initiated with the Fish and Wildlife Service to evaluate potential impact of the recommended alternative plan (Plan E) and to investigate measures to avoid or minimize adverse impacts. The FWS concluded, in a letter of 15 November 1979 (see Appendix F), that Plan E is likely to jeopardize the continued existence of the 'akepa, 'o'u and 'akiapola'au. The FWS noted that, in their opinion, implementation of Plan E would not likely jeopardize the continued existence of the Hawaii creeper, Hawaiian hawk, Hawaiian goose, Newell's shearwater or Hawaiian hoary bat due to their more dispersed distribution and population concentrations outside the project area. The FWS recommended "reasonable and prudent alternatives" to avoid jeopardy as a result of Plan E implementation. These recommendations included (1) consideration of a "corridor" through less environmentally sensitive areas in the Upper Waiakea Forest Reserve, (2) placement of barriers to protect prime forest bird habitat and (3) use of barrier construction material obtained from unforested portions of the study area.

7.08 Aquatic Biota

ALTERNATIVES A, B, C, & E

No effect is anticipated unless the diversion barrier or cooling prevented a lava flow from reaching the Wailuku River.

ALTERNATIVE D

Direct stream pickup of water for use in lava cooling may cause the reduction of aquatic populations within the Wailuku River both above and below the point of dewaterment if only low or base flows are available for export. If water is taken out of the stream at a deep pool, little entrainment of aquatic organisms is expected unless the intake point is at the bottom of the pool. Primary adverse effects of this alternative would occur through the reduction in surface flow downstream of the withdrawal point. As the water levels decreased, invertebrate drift may be expected to increase, and individual animals would be forced to move within the water column or risk dessication. Many stream species are sessile invertebrates which are by and large incapable of escaping such a stress. Other impacts associated with water diversion include increase in stream temperatures, reduction in available habitat, alteration of trophic structure, reduction of nutrient input to receiving waters and diminished fishery resources. It is assumed that dewaterment in case of lava flows might be sustained for a period of a day to one week maximum to achieve adequate cooling of the lava front. The effects of such stress will increase with the duration of pumping and reduced stream discharge. At worst, populations of stream fauna could be eliminated from the lower reaches of the Wailuku River. Since the native species actively migrate throughout the stream, populations above the diversion point may be expected to dwindle. Should the effect be short-lived, sufficient numbers of organisms would survive to recolonize those areas which were dewatered.

7.09 <u>Marine Biota</u>

ALTERNATIVES A, B, D, & E

No effect on marine biota is anticipated unless a lava flow occurs and is successfully diverted fom the Hilo Bay area, in which case the marine ecosystem in this area would be protected. However, depending upon the magnitude and duration of the eruption, the diverted flow may reach the ocean at a point east of Hilo, and would adversely impact coastal marine biota. Studies of recolonization of lava flows in the Kapoho area indicate that a period of 15 years or more would be required before the coastal invertebrate and fish fauna would approximate the condition before the flow (Refs. 11, 12, 45). The Hawaii coastline has been subjected to repeated growth by lava flows even in the present century, so this is a natural phenomenon to which marine species have adapted.

ALTERNATIVE C

It is unlikely that pumping of water from Hilo Bay would have a significant impact upon the marine environment. Plankton would undoubtedly become entrained in the water intake systems. Important constituents of the zooplankton communities in Hilo Bay are the eggs and larvae of fishes, bivalves, gastropods, and crustaceans. The volume of seawater required for control of lava flows, if pumped from the bay, would reduce localized populations of marine fauna which have planktonic larvae. A few species of macrofauna may be expected to become entrained in the pump intake system unless water is drawn from the surface layers of the sea. No other impacts are anticipated assuming seawater, as surface runoff from the cooling lava flow, does not enter Wailuku River. Should this occur, some stream fauna may be lost through alterations in water quality; however, these impacts would be short term in nature and the dilution effect of the stream would limit the area of impact to a very small area. Many of the native stream species are capable of withstanding increased salinities for brief periods.

7.10 Dedicated Use Areas

ALTERNATIVE A

a. The barrier alignment passes through the northeast corner of Waiakea 1942 Lava Flow Natural Area Reserve, and would directly impact on this site. Even adjustment of the alignment a short distance from the NAR would degrade the quality of this area through acceleration of exotic plant dispersal and associated human disturbance. However, if this barrier is successful in diverting an approaching flow, large areas of native forest, including the proposed Piihonua NAR, would be protected from inundation by the flow.

b. Although "critical" habitat has not yet been formally designated for endangered birds or plants in the project area, it is very likely that recently obtained scientific data will be used to justify critical habitat boundaries that will include much of the Upper Waiákea Forest Reserve. Major portions of the Alternative A barrier alignment above the Tree Planting Road are almost certain to be within these boundaries. Under present regulations, when areas are formally designated as critical habitat, projects with federal government involvement will not be permitted if they adversely impact upon the "critical" habitat of the endangered birds or plants within.

ALTERNATIVE B

This alignment avoids any existing or proposed natural area reserves and wildlife sanctuaries, although additional areas may be proposed in the future. With the exception of the upper segment, this barrier alignment is below the lower elevation limit of most endangered forest birds. It is unlikely that any land below 3,000 feet will be included within proposed "critical" habitat of endangered birds, but some rare plant habitat may be protected below that elevation (see 4.07g). Diverted flows will not directly impact any dedicated use areas.

ALTERNATIVE C

There are no identified natural areas, sanctuaries or other sensitive areas along this alignment. Successful diversion would protect valuable wetland habitat within and adjacent to Hilo

ALTERNATIVE D

The anticipated stream diversion would be within the proposed Piihonua Natural Area Reserve. It is uncertain whether or not diversion of the stream would be compatible with NAR regulations. Impacts of the barrier on potential endangered species critical habitat would be similar to Alternative B, and would not be reduced significantly by use of a smaller barrier.

ALTERNATIVE E

This alternative is not anticipated to adversely impact any dedicated use areas, with the possible exception of potential critical habitat for endangered species in forested lands above the Tree Planting Road. However, precise barrier alignments are uncertain until a flow occurs. The most likely sites for barrier construction are adjacent to access roads. It should also be noted that barriers would not be built unless a lava flow was advancing towards the area, in which case the adverse effects of barriers would be additive to the adverse effects of the lava flow.

7.11 Education/Research

ALTERNATIVES A, B, & D

Barrier construction within Upper Waiakea Forest Reserve would have mixed effects on existing or future educational and research use of the area. With the subsequent adverse impacts on native forest ecosystems the opportunity for research in undisturbed areas would diminish. As populations of some species diminish or go extinct, research opportunity would be affected. However, access to remote locations would be improved by barrier and adjacent road construction, facilitating potential studies that are hampered by logistical constraints. Improved control of feral pigs in some remote areas would reduce ongoing forest degradation on a localized basis. Observation and study of the response of flows to diversion structures would provide important data for future efforts to protect inhabited areas from flows.

ALTERNATIVE C

Efforts to divert a flow on an emergency basis would provide an important area for research into the efficiency and methodology of emergency diversion by water cooling. No other effects are anticipated.

ALTERNATIVE E

Effects of barrier construction on research/education opportunities would be similar to Alternatives A, B and D, but reduced in scope by the smaller comparative size. Also, effects would be additive to effect of the lava flow. Some additional access to remote areas would be provided by creation of staging areas in preparation for emergency action.

7.12 Recreation

ALTERNATIVE A

Assuming public access was permitted along barrier roads after construction, increased opportunity for recreation would result. Hunting would be possible in formerly inaccessible areas, as would other non-consumptive uses of the natural environment. Some people would be attracted to view the barrier. Within the short period of time, the quality of hunting would drop to a level similar to that in the proximity of present access roads. Disturbance of habitat and wildlife in the area during construction would limit some forms of recreational use of the area. Successful diversion of lava flows would protect existing recreational opportunity in lower elevation forest.

ALTERNATIVE B

Impacts would be similar to Alternative A, although this barrier would not significantly increase access to game species for hunting, except along the upper alignment. Game populations in this area are already low by comparison to more remote forest areas. Proximity to the Saddle Road may encourage development of other forms of recreational opportunity associated with the barrier.

ALTERNATIVE C

Road and thrust block placement may involve some alteration of existing sites (i.e. Boiling Pots) depending upon chosen alignment and proximity to Wailuku River. No other impacts on recreation are anticipated.

ALTERNATIVE D

Impacts of the barrier on recreational opportunity are identical to Alternative B. Access to Wailuku River at the diversion site may increase localized recreational opportunity. It is unlikely that temporary impact on recreational opportunity by diversion of water in Wailuku River will be viewed as significant when the threat of a lava flow approaching Hilo is imminent.

ALTERNATIVE E

Construction or improvement of roads and development of staging areas would provide additional access for recreational use. If a flow occurs, localized lava diversion structures and roads would improve access of hunters to forested areas, but this effect would be additive to the effects of the flow itself. Like the other alternatives, successful diversion of a flow would protect downslope sites of current recreational significance.

7.13 Archeological/Historical Resources

a. Currently available data are inadequate to fully assess the consequences of the diversion alternatives, although the results of recent Corps contracted studies suggest that principal impacts will occur in the coastal settlement zone and upland agricultural zone below 1,500 feet (Figure 12). Field surveys for archeological remains and existing historic structures performed along the proposed alignment and diversion corridor would provide data that could be used in siting barriers to divert flows in a manner to protect areas of particular significance.

b. No sites known to be eligible for, nominated to, or listed on the National Register of Historic Places would be directly affected by construction activities. Surveys within the likely affected diversion corridor prior to implementing Alternative E would be used to identify possible sites, and to avoid or mitigate anticipated impacts of diversion. Sites of undetermined significance along the Hilo-Volcano Road at lower elevations in the coastal region could be affected by the diversion of flows away from the Hilo area. Sites in the Hilo area would be protected if flows were successfully diverted.

7.14 Aesthetics

ALTERNATIVE A

Construction activities would create an adverse impact on aesthetics of the area for the duration of the project. Some would view the long barrier through the forested slopes above Hilo as an impressive man-made addition to a monotonous landscape. Others would consider it an offensive intrusion into the natural environment that destroys a once-beautiful undisturbed vista. From the ground, this proposed barrier would be visible from points along the Saddle Road and Hilo-Volcano Road. Much of the barrier path would be visible from Hilo area as well. The view from a road paralleling the barrier would be unattractive by comparison to undisturbed forest, and the rows of cleared trees and shrubs would also be an undesirable visual impact on a natural scene. Over time, much of the barrier would vegetate. To the extent that this would not conflict with the diversion purpose, it could be accelerated by planting of desirable species.

ALTERNATIVE B

Impacts on aesthetics would be similar to Alternative A, but increased significantly by the closer proximity of this alignment to Hilo and to rural areas around the town. It is likely that the number of those who viewed the barrier as an attractive addition to the environment would be far outweighed by those who were offended or angered by its impact on the aesthetics of the area.

ALTERNATIVE C

This alternative would not create any significant adverse or positive impact on aesthetics. Several small roads penetrate the forest around this elevation on the Saddle Road, so it is not likely that a new road would degrade the aesthetics of the area in any way.

ALTERNATIVE D

Impacts of this alternative are similar to Alternative B, but reduced somewhat due to use of a lower barrier involving a narrower swath through the forest. A diversion structure at Wailuku River would not necessarily create adverse aesthetic impact and an access road would create additional opportunity to view the area.

ALTERNATIVE E

Significant alteration of natural aesthetics would not occur unless it was considered necessary to divert an approaching flow. For this reason, the aesthetic effects of the barrier and flow would be additive. One is a natural part of the landscape while the other is a man-made intrusion.

7.15 Socioeconomic Effects

a. It is clear from the public response to this study that the planning process itself has created significant social impacts. Differences in the perception of the lava threat to Hilo as well as even stronger differences of opinion regarding the advisability of interfering with natural phenonmena have clearly surfaced in the public review process. Serious concern regarding the actual feasibility of diversion and the anticipated impact of diversion structures on native forest ecosystems has been expressed, and this concern will not be eliminated altogether through more intensive study. Although the proposed alternatives are intended to minimize economic losses and social disruption in the Hilo area in the event of a flow, it is also clear that this cannot be accomplished without shifting the anticipated impacts to other locations. Those most likely to be affected by such diversion are understandably among those most opposed to the diversion concept in general, and the recommended plan in particular.

b. If the plan is approved and the emergency diversion plan is incorporated into the State's emergency plan, the "sense of security" that is likely to result will have both direct and indirect effects on future land use in the Hilo-Puna area. The debatable presumption that land below the diversion corridor will thereafter be protected from lava damage could stimulate development and further urbanization. This presumption of adequate protection may also lead to the perception that hazard zoning and lava insurance programs are still not needed to direct future growth away from lava-prone areas. The opposite would be true for areas within the proposed diversion corridor which, by virtue of the emergency plan, would then become more hazardous lands to develop. This contrasting scenario would only be changed if there is wide public perception of the fact that the emergency diversion plan is not fool-proof, and the risk of emergency barrier failure is sufficient justification to pursue restrictive zoning alternatives simultaneously.

c. It is clear that a decision to approve the recommended emergency operation plan and to proceed will not be completely acceptable to all. A decision to avoid physical manipulation of the path of an approaching flow would satisfy some people who have strongly expressed the spiritual belief that such manipulation is doomed to failure. Underlying this concern is the belief that violence (in the form of barrier construction) will offend the volcano goddess Pele, who will have her revenge. Concern regarding the violence of diversion measures has been most strongly expressed in response to the bombing alternatives.

d. Selection of Alternative E as an implementable plan will generate support (or at least reduce opposition) from those who feel that the lava flow risk is minimal and those who feel that barrier construction before the need arises would result in unnecessary environmental and economic costs. On the other hand, Alternative E will generate opposition from those who feel that the risk of flow damage is great and from those who feel that the emergency diversion will not work due to the unpredictability of the flow path and the limited time to react. Additional engineering, economic and environmental studies would improve the data base necessary to effectively react to a threatening flow, but would not settle the debate regarding the lava flow risk or satisfy concern that the emergency diversion may fail.

e. The potential economic savings that would result from successful flow diversion outside of the Hilo area has been documented in the survey report and in Appendix A. Anticipated economic impacts of the diverted flows resulting from any of the barrier alternatives (A, B, D, E) would differ significantly from each other and would be far outweighed by losses created by an undiverted flow into the Hilo area. In each case, primary economic impacts of diversion would involve losses to production of agricultural lands and disruption of commerce and transportation between outlying communities at Volcano and in Puna and the urban center in Hilo. It is important to note in review of economic impacts associated with diversion of flows along various barrier alternatives that the precise location of structures is by no means definite. Major adjustments are likely to be made to insure effective diversion in the least damaging manner.

8. PUBLIC INVOLVEMENT

8.01 Public Involvement Program

The results of these public meetings, workshops, and public involvement activities are summarized in Appendix C. Many of the concerns raised during these activities remain unchanged from those voiced during previous investigations of the feasibility of lava flow diversion. A list of agencies, groups and individuals receiving copies of the draft report and EIS is also included, along with comments and responses, in Appendix C.

8.02 Required Coordination

a. Historical coordination: Preliminary studies were conducted by the Bishop Museum, on contract to the Corps, to identify historical or archeological sites on the state or national registers within the areas to be affected by alternative lava control plans. The Bishop

Museum study also led to preparation of a research plan for possible additional archeological/historical studies. Coordination will be continued with the State Historic Preservation Officer through distribution of the study report and environmental statement.

b. US Fish and Wildlife Service: The Corps transferred funds to the Ecological Services Division of the U.S. Fish and Wildlife Service in FY 78 to prepare an assessment of anticipated project impacts on fish and wildlife resources. A report of this effort was submitted to the Corps in December 1978, and data from the report was incorporated into this statement. The Corps has continued coordination with the Ecological Services Division as the array of alternatives has changed in the study process.

c. Endangered Species Office: Coordination was maintained with the Endangered Species Office of the U.S. Fish and Wildlife Services beginning in early 1978 with a request for research data generated during extensive FWS studies in the project area. The Corps was provided with preliminary data at that time and informed that all the pertinent data would be fully analyzed before the end of calendar year 1978. Although other priorities have prevented completion of the data analysis, the FWS did provide the Corps with additional data on plant and bird distribution in the study area during Fall 1979. In addition, the Corps initiated formal consultation pursuant to the Endangered Species Act, as amended, by letter of 20 August 1979. The FWS responded, by letter of 15 November 1979 (Appendix F), with a formal biological opinion on the anticipated impacts of the emergency alternative plan (Alternative E) on the threatened or endangered bird and mammal species in the study area. It was concluded in this biological opinion that Alternative E would be likely to jeopardize the continued existence of three of eight listed bird and mammal species known to inhabit the area. The FWS opinion also provided specific recommendations to avoid jeopardy to these species.

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APPENDIXES

LAVA FLOW CONTROL STUDY
ISLAND OF HAWAII

PROPERTY VALUE STUDY

APPENDIX A

PROPERTY VALUE STUDY

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PROPERTY VALUE STUDY

SUMMARY

1. A study of total damageable property values in Hilo, Hawaii, has been conducted. Included in this study are structure and content values for: Commercial, industrial, and agricultural establishments; single and multi-family dwellings; and public facilities and utilities. Values for content losses, in the event of lava flow, were also calculated for this study.

2. A summary of total structure on content values (less depreciation) and a summary of total damageable property (less depreciation) of the Hilo study area are as follows:

Item	Total Depreciated Replacement Values	Total Depreciated Replacement Values Adjusted for Evacuation
Commercial/Industrial	$302,604,000	$181,928,000
Single Family Dwellings	230,814,000	230,814,000
Multi-family Dwellings	81,478,000	81,478,000
Hotels	34,373,000	34,373,000
Agriculture	1,398,000	1,398,000
Public Facilities	183,684,000	143,433,000
Public Utilities	44,920,000	33,074,000
Total	$879,271,000	$706,498,000

3. The total property value (less depreciation) of the Hilo area is estimated at $879,000,000. Total damageable property (after evacuation) is estimated at $706,000,000.

INTRODUCTION

4. The purpose of this study was to acquire and analyze data in order to arrive at a total property values, that are subject to damage in the event of lava eruption, in the Hilo area. The study area encompassed tax zone 2, sections 1-5 and plates 1-8 of section 6, in the third taxation district of the State of Hawaii (plate A-1).

5. The Hilo area damageable property valuation was made by surveying significant commercial/industrial establishments, agricultural, residential and public facilities' structure and content values. Total values were estimated by relating the ratio of content to structure values calculated in the surveys to total structure values in the study area.

6. The study consisted of four surveys. First two were conducted in August 1977 to inventory the property values and uses in Hilo. The remaining surveys were done in March 1978 to conclude the damageable property values estimation:

a. A sample of 60 homes were surveyed in order to value the home contents and to relate the content value to the structure value. Home contents were determined by on-site inspections and interviews. Valuation of the contents was done as a separate task and involved the analysis of retail prices in Hilo. Structure values were determined by using State Tax Office structure assessed values (as of 8 Jul 77) and adjusting the assessed values to market values with the factor used by the State Department of Taxation.

b. Each commercial and industrial establishment in the study area was given an on-site inspection in order to assign a tax map key code by parcel number and to assign a Standard Industrial Classification (SIC) code by type of business.

c. The structure value of each commercial/industrial and agricultural establishment chosen for the survey was determined by using State of Hawaii tax office assessed structure values. Interviews were then conducted with management of the establishments in order to acquire inventory and content values.

d. Content values and replacement costs of all public facilities and utilities were gathered by interviews with appropriate department personnel.

7. The following paragraphs discuss the method of approach used in the field surveys and their results; the assumptions used in the analysis of total area valuation, and a summary of total Hilo area damageable property value.

METHOD OF APPROACH

RESIDENTIAL SURVEY

8. The initial step in the residential survey was the design of the inventory form to be used in the field research. The form was designed by surveying a substantial home in Honolulu and noting all the contents. Additional items not present were added to complete the form. The form was designed with three columns for each item. Labeled X, Y, Z on the form, they were used to denote the quality of the items inventoried during the field survey. Low quality was indicated in the X column; standard quality in the Y column; and high quality in the Z column.

9. The next phase began in Hilo. The Mayor of Hawaii County, Honorable Herbert Matayoshi, was visited to enlist his aid in setting up the interviews for the home content inventory. At this point in the project, it was felt that the field surveyors might meet with resistance when calling on the homes. The Mayor agreed to sign a letter that would be mailed to the homes to be inventoried.

10. Following the meeting with the Mayor, real property assessors from the State Department of Taxation were interviewed to identify different types of neighborhoods in the study area.

11. Once the neighborhoods were identified, a field survey was made to choose 100 homes for mailing of the Mayor's letter. It was important to visually select the homes in each neighborhood so that a representative sample could be chosen and large dogs avoided. As each home was chosen, its address was noted. The survey was also done so that the interviewers would be familiar with the Hilo area before starting the home content inventories.

12. With the addresses from the initial neighborhood inspection, the Tax Map Key (TMK) code for each address selected was researched using the Hawaii County Building Department's tax maps. The tax maps in the Building Department were used because they assign all addresses and are kept up-to-date.

13. Using the TMK codes, the names of the owners and the assessed structure values were researched at the State Department of Taxation. With this information, the Mayor's letter to each home was posted.

14. The next phase of the research involved the actual survey and inventory of 60 of the 100 homes selected to receive the Mayor's letter. The method used to inventory the homes was as follows:

a. A neighborhood was visited and each of the chosen homes contacted to see if someone was at home. When one of the parents of the family was home, he/she was shown a copy of the Mayor's letter and told the purpose of the inventory in detail. With the person, the home was then inspected room by room and the contents noted in the appropriate column on the survey form. While in certain rooms, the person was queried as to items that may have been present but were not visible--china, silver, crystal, power tools, toasters, etc. Any special items not on the survey form were noted and, when possible, an estimate of value was made by the owner.

b. Following each day's interviews, the location of each home surveyed was noted on a map (see plate A-1 for location of the areas interviewed). After the survey was approximately two thirds complete, it became apparent that certain neighborhoods were unrepresented by letters mailed from the Mayor's office. These neighborhoods were visited and a house-to-house survey made using a plain copy of the Mayor's letter. Although a sufficient number of homes were surveyed, this method was not as satisfactory as calling on the homes to which a letter had been mailed.

c. Table A-3 shows the total content values for the 60 homes surveyed.

RETAIL PRICE SURVEY

15. The retail price survey was initiated in Honolulu before the field trip to Hilo. A catalog from Sears was obtained so that the residential interviewers could familiarize themselves with prices and quality before arriving in Hilo.

16. In Hilo, retail prices were surveyed during and following the period that home contents were being inventoried. When special items not on the survey form were found, they were noted so that prices could be researched at a later date.

17. Retail prices were surveyed by visual inspection in the stores visited. When an item was found in more than one store, the prices were listed for each store. Also, a price range was established for each store when possible. Following the retail price research, values were assigned to items found in the home content inventories and total values were calculated.

18. A list of content retail price sources can be seen in table A-1. Content retail prices for each store surveyed are shown in table A-2. The prices used for the content valuation have been underlined for each item in table A-2. A scatter diagram showing the relationship of content values to structure market values can be seen in figure A-1.

COMMERCIAL/INDUSTRIAL ESTABLISHMENTS CLASSIFICATION

19. The commercial/industrial (C/I) establishments inventory and classification was initiated in Honolulu. A copy of the computer printout containing all commercial and industrial zoned properties in the study area was obtained from the State Department of Taxation, Real Property Division. This information was organized by Tax Map Key (TMK): 2-1-1 through 2-6-8. Also, a list of all three digit SIC codes was prepared.

20. In Hilo, the survey of C/I establishments was conducted by walking and driving through the study area. In concentrated C/I establishment sections, the surveyor made his visual inspection on foot, noting the name and address (when available) of each establishment and assigning a TMK code from a set of plat maps obtained in Hilo. As the establishment was inspected, the business type was noted on the work sheets, when necessary, for future SIC code assignment.

21. Following the walk-through phase, an inspection of all outlying sections was made by automobile. This inspection was made by two surveyors, one driving and one using the plat maps to assign TMK codes. Once all readily visible establishments had been surveyed, the assigned TMK codes were compared with the prepared list of C/I zoned parcels to discover those that had been missed. The parcels that did not have establishments listed from the first survey were noted on the plat maps and visually inspected. They were found to be primarily vacant lots, residences, alleys, churches, and schools.

22. The next phase of the research involved the assignment of SIC codes to all surveyed establishments. The prepared list of three digit codes was used, as well as a copy of the SIC manual for those businesses not found on the list and for those whose business type was uncertain (see reference 1).

23. The final effort of this research section involved checking all TMK codes with the County of Hawaii Planning Department. Where discrepancies were found, additional on-site inspections were made for clarification. Also, schools were noted and assigned TMK parcel codes although they were not all found on C/I zones' parcels. The information was obtained as the visual inspections were made.

COMMERCIAL/INDUSTRIAL ESTABLISHMENTS VALUATION

24. The initial step in the C/I valuation was to choose about 50 significant establishments in the study area. The establishments were chosen for the survey according to their SIC codes so as to get a sample of each major type of business. Two or more establishments were picked from each classification in order to develop as complete a sample as possible. The establishments to be surveyed were then listed with corresponding addresses and tax map identification. Also a structure and content survey form was designed for use during the field research (see page A-7).

25. Step two involved Hawaii County Mayor, Honorable Herbert Matayoshi, who was contacted to secure his aid in setting up the interviews necessary for the study. It was felt that the Mayor's assistance would provide surveyor credibility for the interview process. The Mayor agreed to have a letter sent to the business establishments selected earlier. Before the letters were posted, a visual survey of the establishments was conducted to ascertain their significance within the study area. Accordingly, some were deleted from a master list and new establishments were added. Letters were then posted to the establishments on the revised list. Maps were used during the selection of the establishments to assure adequate coverage of the study area and to avoid concentration in any particular section of Hilo.

26. While the letters were in the mail, the assessed structure values were researched at the State Department of Taxation. At the same time, the value of all structures in each section of Hilo was identified (see reference 2).

27. The last phase of the research involved the interviewing of the establishments' management personnel. In all cases the interviews were held with a responsible person of the firm (president, vice-president, owner, office manager, or controller). The method used for the interviews was as follows:

a. An establishment was visited without an appointement. During the initial visit, if a responsible person was not available, a specific appointment for the future was made. If a responsible person was available, he was shown a copy of the letter from the Mayor's office and given an explanation of the purpose of the study, and its confidentiality. With most of the smaller establishments, the content field survey form was discussed and filled out at that time. In some instances with the larger firms, the form would be discussed and then filled out after the necessary information had been collected.

b. During each interview the question was asked as to how much of the contents of the firm would be removed in case of an evacuation. Four days were given as the amount of time available for the removal of property.

28. The resulting adjusted replacement content values were used during the analysis phase of the project to calculate the adjusted replacement content value to structure value ratio for the C/I establishments to determine estimated total adjusted replacement content values for the study area.

WORK SHEET

Inventory and Analysis of the Value of Damageable Property
Hilo, Hawaii

ESTABLISHMENT ______________________ Date Interviewed __________

SIC & Industry Heading ________________

TAX MAP KEY ______________ Address ____________________

1. Inventory Value ____________________

2. Building improvements not included in structure value ____________________

3. Office equipment ____________________

4. Other fixed assets ____________________

5. Other assets that would be affected by potential lava flow (parking lots, driveways, etc.) ____________________

6. Adjusted asset value ____________________

7. Structure value (if in office building, est. sq. ft. floor space) ____________________

8. Type building construction ____________________

Replacement costs ____________________

less depreciation ____________________

TOTAL ____________________

RESIDENTIAL ESTABLISHMENTS VALUATION

29. Total Hilo residential structure values were researched at the State Department of Taxation (see reference 2). The content-structure value ratio derived from the sample survey was applied to total structure values, in the next section (Hilo Area Damageable Property Valuation) of this appendix, to estimate total residential content values in the Hilo area.

30. Multi-family dwelling structure values was researched at the Department of Taxation (see reference 2). A content-structure value ratio was estimated based on content-structure value ratio for single family dwellings. This ratio was applied to the total multi-family dwelling structure values in the next section.

AGRICULTURAL ESTABLISHMENTS VALUATION

31. As in the C/I survey, letters from the Mayor's office were posted to the agricultural establishments. Interviews with responsible persons were held following delivery of the letters. The survey form contained a request for total value of crops (or flowers) under cultivation as well as the same information that was requested in the C/I survey. Total agriculture zoned land and structure values within the study area were researched at the State Department of Taxation.

32. The value of structures, structure contents and crops under cultivation were estimated for all establishments in the survey area because of the limited number of establishments. This analysis can be seen in the next section.

PUBLIC FACILITIES AND UTILITIES VALUATION

33. A list of public facilities that would need to be analyzed for structure and content value was drawn up. During the survey process in Hilo, other facilities were found to be significant and were added to the list. These include all utilities--gas, power, telephone, and all public facilities--administration, protection, education, recreation, water, sewer, and transportation. To gather the content values and facility replacement costs, responsible personnel in each area were interviewed. A copy of the Mayor's letter was shown to insure full cooperation from the respondents. In most cases it was necessary to pick up the required information after it had been compiled by department staff. Structure values were researched at the State Department of Taxation. This information has been used in the next section with the total area values for commercial, industrial, residential, and agricultural properties to estimate the total value of structures and contents in the Hilo area.

HILO AREA DAMAGEABLE PROPERTY VALUATION

TOTAL VALUATION OF THE HILO AREA

34. The following is a summary of estimated total depreciated replacement values and total depreciated replacement values adjusted for evacuation for the Hilo study area.

Item	Total Depreciated Replacement Values	Total Depreciated Replacement Values Adjusted for Evacuation
Commercial/Industrial 1/	$302,604,000	$181,928,000
Single Family Dwellings	230,814,000	230,814,000
Multi-family Dwellings	81,478,000	81,478,000
Hotels	34,373,000	34,373,000
Agriculture	1,398,000	1,398,000
Public Facilities 2/	183,684,000	143,433,000
Public Utilities 2/	44,920,000	33,074,000
Total	$879,271,000	$706,498,000

The total value of the Hilo study area (less depreciation) is estimated at $879,000,000. The value of total damageable property (less depreciation) of the Hilo study area is estimated at $706,000,000.

COMMERCIAL/INDUSTRIAL PROPERTY VALUATION

35. Table A-4 contains the results of the survey of C/I establishments in the Hilo study area. This table shows the ratio of replacement content value to total structure value for the firms surveyed. Applying this ratio to the total structure value of all C/I establishments in the

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1/ Public facility and utility structure values have been subtracted from the total structure value of the tax office Pitt Code categories Commercial and Industrial to avoid double counting (see paragraph 46).

2/ For total replacement values for each type facility, see tables A-9 through A-24.

study area results in an estimate of total content value. Combining total content value and total structure value yields an estimate of total property value (not including land) for C/I firms in Hilo. Following is an explanation of the headings used in tables A-4 through A-8.

36. Structure Assessed Value. The State Department of Taxation assesses the value of all structures in the County of Hawaii. When a structure is built, its construction cost is used as the market value.

37. Over time, structure value is depreciated on a straight line basis. Any appreciation in property market value (land and building) is attributed to the land. This has resulted in a declining structure value and an increasing land value for most properties in the State.

38. Structure Market Value. Structure market value is the assessed value divided by 59 percent.

39. Replacement Content Value. During the survey process, it was found that the firms interviewed gave either current replacement cost estimates or book value for their assets. In order to be consistent in the calculation of total content value, it was necessary to estimate the replacement cost, less depreciation, for all depreciable assets. If the current replacement cost of assets was given during the interview, an estimate of depreciation was made based upon usable life remaining and IRS depreciation guidelines (see reference 3). If book value was given (original cost less depreciation) for the assets, the book value was inflated to current replacement value using the consumer price index for Hawaii (see reference 4). Inventories were assumed to be at replacement value for all the firms surveyed.

40. The asset guideline period for the majority of the contents surveyed was 10 years. The consumer price index for the past 10 years rose 70.5 percent. If the establishment was less than 10 years old, the appropriate consumer price index was used in the calculations. Total replacement content value was calculated as the content value, less inventory, multiplied by the consumer price index (when applicable), with the inventory then added back on.

41. Replacement Content Value to Structure Market Value Ratio. The ratio of C/I replacement content value to total structure market value of the establishments surveyed has been calculated as follows:

Total replacement content values of establishments surveyed	$20,066,000
Total structure market values of establishments surveyed	$ 8,681,000
Replacement content value to structure value ratio	231%

42. Adjusted Replacement Content Value. Adjusted replacement content values are total content values less an amount assumed to be removed during evacuation, and then inflated to replacement costs (when applicable).

43. To derive a factor to be used in the adjusted replacement content value to structure market value ratio, several assumptions about future events in the case of evacuation have been made.

a. Equipment would be available to transport the contents during the evacuation.

b. There would be storage areas (under cover with security) for the contents being removed.

c. Items needing constant refrigeration would be considered a total loss.

d. Inventory that was bulk stored would be considered a total loss (gas, bulk sugar, etc.).

44. Adjusted replacement content values have been calculated by subtracting an estimated amount of contents that would be saved during evacuation from the total content values. As in replacement content values, the adjusted replacement content values have been calculated at replacement cost.

45. Adjusted Replacement Content Value to Structure Market Value Ratio. The ratio of C/I adjusted replacement content value to total structure market value of the establishments surveyed has been calculated as follows:

Total adjusted replacement content value of establishments surveyed	$8,563,000
Total structure market value of establishments surveyed	$8,681,000
Total adjusted replacement content value to total structure market value ratio	99%

46. Adjusted Replacement Content Value to Replacement Content Value Ratio. The ratio of C/I adjusted replacement content value to C/I replacement content value of the establishments surveyed has been calculated as follows:

Total adjusted replacement content value of establishments surveyed	$8,563,000
Total replacement content value of establishments surveyed	$20,066,000
Total adjusted replacement content value to total replacement content value ratio	43%

47. Total Hilo Commercial/Industrial Establishment Valuation. Total C/I structure values for the Hilo study area have been researched at the State of Hawaii Department of Taxation. The value of structures, by TMK section, are categorized by gross, exempt, and net. Gross value represents total value of all structures classified as C/I. The exemption category includes amounts not counted for tax purposes. This study has used the gross category in its valuation of total Hilo area. Public facility and utility structure values, shown in paragraphs 56-59 have been subtracted from total C/I structure values to avoid double counting.

Total Hilo area commercial/industrial structure market values 1/	$143,459,266
Public facility and utility structure market value	$52,038,000
Net Hilo area commercial/industrial structure market values	$91,421,266
Replacement content value to structure market value ratio (page 15 of this report)	231%
Total estimated replacement content value	$211,183,124
Total Hilo area estimated commercial/industrial replacement content and structure value	$302,604,390

RESIDENTIAL

48. Single Family Dwellings. Total residential structure market value in the Hilo area is $153,875,637 (see reference 2). From table A-3, the average content to structure value ratio for single family dwellings was 50

1/ Includes structure values of public facilities and utilities.

percent. Unlike the survey of commercial/industrial establishments, this study did not estimate the amount of contents that would be saved during evacuation. However, because the major content items were large and difficult to move--kitchen appliances and furniture--and because of the lack of available transportation, it has been assumed for this analysis that all contents would be lost.

49. The calculation of the total Hilo area value of single family housing structures and contents is as follows:

Total single family housing structure value	$153,876,637
Content to housing structure value ratio	50%
Total estimated content value	$76,938,000
Total Hilo area single family dwelling structure and content value	$230,814,000

50. Multi-family Dwellings. Total multi-family dwelling structure market value in the Hilo area is $56,192,000. Total multi-family dwelling structure values were researched at the State Department of Taxation (see reference 2). The total market value for this category, hotels/apartments (multi-family dwellings)/resorts, is $84,640,967. To derive the total for multi-family dwellings (apartments), the total value of hotels/resorts was subtracted from this category total (see table A-8). Content value was estimated at 45 percent. This estimate allowed for the absences of outdoor type furniture and equipment found at single-family dwellings. It has been assumed for this analysis that all contents would be lost in the event of lava flow.

51. The calculation of the total Hilo area value of multi-family housing structures and contents is as follows:

Total multi-family housing structure value	$56,192,000
Estimate content to housing structure value ratio	45%
Total estimate content value	$25,287,000
Total Hilo area estimated multi-family dwelling structure and content value	$81,478,000

AGRICULTURE

52. Because of the type of information available, it was necessary to estimate total agricultural value (not counting land) differently from the method used for the C/I establishments.

53. During the research for total structure values at the State Department of Taxation, it was found that County and State park facilities' values were included in the agricultural category. It was not possible to separate total agricultural use structure values from park structure values. Also, no value of plantings was included in the State Tax Office values.

54. Each of the agricultural enterprises was visited, surveyed, and interviewed. As several owners of the firms were not willing to release any information, the value of their plantings and structures was estimated using information gained from other completed interviews and their area under cultivation.

55. The following is a list of agricultural enterprises in the Hilo study area. The estimate of total value for each establishment is shown. Total planting value is the estimated value of all the plants in the ground. Planting value would be a total loss in case of lava flow damages. Agricultural structures are in use for the packing and screening of plants. As such, they contain minimal content value. Of the establishments interviewed, two were tropical garden type for viewing; four were orchid growers for export; and one was an anthurium nursery for export. The growers for export have their gardens located on the same property as their homes.

Sample No.	Total Structure Value	Total Plant Value	Total Value
1.	$ 1,000	$ 500,000	$ 501,000
2.	1,000	83,000	84,000
3.	10,000	100,000	110,000
4.	3,000	400,000	403,000
5.	5,000	120,000	125,000
6.	2,000	70,000	72,000
7.	3,000	100,000	103,000
Total Value	$25,000	$1,373,000	$1,398,000

PUBLIC FACILITIES AND UTILITIES

56. The total value of all public facility and utility structures and assets was determined through interviews with responsible employees of each department or enterprise. This was done because total structure values for these facilities were not available at the State Department of Taxation. They were included with C/I total structure values. Values were calculated to replacement cost, less depreciation (see paragraphs 39, 40, 42, 43, & 44). A 50 percent depreciation rate was used where replacement values were given (unless otherwise indicated).

57. Public Facilities. Public facilities include both administration buildings and special use facilities. Table A-9 shows the total value for County, State, and Federal office buildings. Tables A-10 through A-21 show the total value for each special facility. A summary of total public facility values is shown below:

Facility	Total Value	Total Depreciated Replacement Values	Total Depreciated Replacement Values Adjusted for Evacuation
Federal/State/County Office Buildings	$ 33,055,000	$ 33,055,000	$ 18,920,000
Parks & Recreation	15,370,000	15,370,000	14,646,000
Streets & Roads	22,039,000	11,149,000	10,890,000
Water System	40,832,000	20,807,000	20,025,000
Sewer System	18,198,000	9,119,000	9,080,000
Police Department	5,593,000	4,720,000	4,364,000
Fire Department	2,174,000	1,755,000	1,303,000
Hawaii National Guard	13,222,000	13,222,000	833,000
Schools	36,510,000	36,510,000	30,815,000
Library	4,534,000	4,534,000	2,245,000
General Lyman Field	38,000,000	21,800,000	18,645,000
Hilo Harbor 1/	10,645.000	9,425,000	9,408,000
Lyman Museum	2,218,000	2,218,000	2,218,000
Total Value	$242,750,000	$183,684,000	$143,433,000

1/ Onshore facilities only.

58. Public Utilities. A summary of public utility total values is given below. Tables A-22 through A-24 show the total value analyses for the individual utilities.

Facility	Total Value	Total Depreciated Replacement Values	Total Depreciated Replacement Values Adjusted for Evacuation
Gas Co.	$13,461,000	$ 6,890,000	$ 6,743,000
Hawaiian Elec. Light	25,564,000	17,269,000	14,079,000
Hawaiian Telephone	20,802,000	20,761,000	12,252,000
Total Value	$59,827,000	$44,920,000	$33,074,000

59. Public Facilities and Utilities Summary. The following is a summary of public facility and utility values for the Hilo area.

Facility	Total Value	Total Depreciated Replacement Values	Total Depreciated Replacement Values Adjusted for Evacuation
Public Facilities	$242,750,000	$183,684,000	$143,433,000
Public Utilities	59,827,000	44,920,000	33,074,000
Total Value	$302,577,000	$228,604,000	$176,507,000

LIST OF REFERENCES

1. United States, Office of Management and Budget, Statistical Policy Division, Standard Industrial Classification Manual, 1972 ed.

2. State of Hawaii, Department of Taxation, Real Property Assessment, 11 April 1977.

3. United States, Department of the Treasury, Internal Revenue Division, Publication 534, Tax Information of Depreciation, 1978.

4. State of Hawaii, Department of Planning and Economic Development, _The State of Hawaii Data Book, A Statistical Abstract_, 1977.

TABLE A-1

INVENTORY OF PROPERTY VALUES & USES
HILO, HAWAII
CONTENT RETAIL PRICE SOURCES
AUGUST 1977

Letter Code	Source
A.	B. J. Furniture
B.	Western Auto Family Store
C.	Koehnen's
D.	Sears' Catalog
E.	Sears Appliance Store
F.	J. C. Penney
G.	Agasa Furniture
H.	Yamada's Furniture
I.	Bob McRae's Piano Mart
J.	Honsport
K.	Taka's Appliance
L.	Hilo Radio Appliance
M.	Typewriter Center, Inc.
N.	S. H. Kress & Co.
O.	The Singer Co.
P.	Bernina Sewing Centers
Q.	Shair Water Beds
R.	Owner/ECMI

Note: The above letter codes are used to identify the source of the retail prices shown in Table A-2.

Source: Environment Capital Managers, Inc.

TABLE A-2

INVENTORY OF PROPERTY VALUES & USES
HILO, HAWAII
CONTENT RETAIL PRICES
AUGUST 1977

Item	Letter Code	Inexpensive	Regular	Expensive
Living Room:				
Sofa: Punee	D		110	
Hide-A-Way	A	300	500	650
	C			650
	D	250		
Regular	A	300		
	B		400	
	C			600
	D	170		
Modular	C		1300	1600
Sofa & Love Seat	B		500	900
	D	350		
Sofa & Easy Chair	D		250	
Chairs: Easy	B	50		
	C			325
	D	130	240	
Rockers	C		155	300
	D	110	170	210
Recliners	A	200	250	300
	B	150		
	C		300	500
	D		210	
Television	A	150	500	800
	B	390	550	800
	E	130	560	780
	F	100		
Stereo	E	320	450	1200

TABLE A-2 (Cont)

Item	Letter Code	Inexpensive	Regular	Expensive
Living Room: (Cont)				
Reel-to-Reel Tape Deck	H		400	1200
Radio	A			100
	E	20	45	
End Tables	A	50	100	150
	C	25	125	200
Coffee Tables	A	100	250	
	B	50		
	C	150	300	400
Table Lamps	A	50	75	100
	B	25	40	50
	C	50	100	150
	F	15	50	
Overhead Lamps	A		50	100
	B	30	50	
	D	30	50	100
Floor Lamps	G	50	70	100
Pictures	H	10	50	100
NicNacs	R	20	50	100
Plants	R	10	35	75
Carpet - 9 X 12	F	50	100	140
Drapes - 84 X 96 (Pair)	B	15		
	D		50	70
Piano	I	1000	1500	2500
Organ	I	1200	2500	5000
Wall Units	A	80		
	B		120	
	D			460

TABLE A-2 (Cont)

Item	Letter Code	Inexpensive	Regular	Expensive
Dining Room:				
Dinner Table & Chairs	A		600	800
	B	350	750	
	C	900	1200	2400
	D	270		
Light Fixtures	D	15	50	70
Buffet	C			900
	D	160		
	G		450	
China Cabinet	C			720
China	C		225	325
Silver	C		1600	3000
Crystal - Per Item	C		10	20
Chests	D	50		
	C		175	325
Kitchen:				
Refrigerator	A	350	750	1500
	B	360	450	610
	D	280	580	750
	E	600	800	1150
Stove/Oven	A	350	470	850
	B	280	400	480
	D	340	600	780
	E		500	600
Deep Freeze	A			500
	B	225	400	
	D	200	240	370
	E			510
Dishwasher	A		560	700
	D	230	300	330
	E	280	380	
Compactor	B		300	

TABLE A-2 (Cont)

Item	Letter Code	Inexpensive	Regular	Expensive
Kitchen: (Cont)				
Microwave Oven	A	350	450	620
	B	310	460	
	D	300	490	
	E		550	
Dishes - 8 Places	F	15	50	60
Flat Ware - 8 Places	D	10	50	
	F	40	55	
Pots and Pans	D	10	35	125
	F		50	150
Utensils	F	15	25	50
Electric Aids:				
Can Opener	A	15	20	
	B	10	20	
	D	15		
	F	15		
Blender	A	10	20	
	B		20	
	F		20	40
Mixer	A	40	60	80
	B	15	20	
	D		20	80
Grinder	D			60
	F		40	
Juicer	D			80
	F		20	
Toaster	A			40
	F		20	
Toaster Oven	A	40	50	60
	D		45	
	F	35	50	
Rice Cooker	A	30	35	

TABLE A-2 (Cont)

Item	Letter Code	Inexpensive	Regular	Expensive
Kitchen: (Cont)				
Mr. Coffee	D	30		
	F		40	
Kitchenette	A	75	175	250
	B		150	180
	C	220	650	1140
	D	150	260	290
Stools	A	30		
	D	40	50	80
	C			80
Laundry:				
Washing Machine	A	350	400	600
	D	275	370	
	E	240	300	330
Dryer	A	250	300	450
	D	150	200	230
	E	190		
Iron	A	15	25	35
	D		20	
	F	10	25	
Ironing Board	D		25	
	N	10		
Vacuum	A	60	125	250
	E	70		
	F		110	
Sewing Machine	Ø	110	240	
	P			600
Sewing Machine & Table	D	130	180	
	Ø		360	660
Bathrooms:				
Sink & Counter Top	E		80	
Mirrors	C		80	125
Light Fixtures	D	15	50	70

TABLE A-2 (Cont)

Item	Letter Code	Inexpensive	Regular	Expensive
Bathrooms: (Cont)				
Carpet	F		50	
Vanity	G	100	250	900
Furo	R		200	
Bedrooms:				
Beds: Twin Regular	A			320
	C	90	260	
	D	80	150	
Double Regular	A			360
	B		220	
	C	110	320	
	D	80	200	
Queen Regular	A			430
	C	180	380	
King Regular	A			620
	C	240	540	
Double - Water			350	1000
Queen - Water			350	1000
Night Tables	B	25		
	C		100	125
Dressers	A		250	
	C	200	300	600
	D	75	100	
Drapes - 84 X 48 (Pair)	D	5	20	30
Carpet - Per Room	F	50	100	140
Crib	H	80	100	120
Den:				
Tables	C		250	500
	D	100		
Desks	C	170	300	530
	D	140		

TABLE A-2 (Cont)

Item	Letter Code	Inexpensive	Regular	Expensive
Den: (Cont)				
Bookcases	A	80		
	D	90	120	450
Bookshelves	D	20	50	70
File Cabinet	B		70	
Bar	D		300	
Books - $10 Each	R	250	500	1000
Encyclopedia	R		360	
Guns	J		250	
Samurai Swords	R		250	
Pool Table	J		300	1200
Typewriters	M	320	360	450
Miscellaneous:				
Tools: Table Saw	E		475	
Hand Saw - Power	E		75	
	F	25	75	
Saber Saw	E		50	70
Drill Press	E		415	
Hand Drill - Power	E	30	50	75
	F	20	50	
Sander - Power	E		50	
Power Mower	D	120	150	230
	E		220	250
	F	150	190	
Lawn Furniture: Chaise Lounge	C		190	
Table & Chairs	C			450
	H		185	

TABLE A-2 (Cont)

Item	Letter Code	Inexpensive	Regular	Expensive
Miscellaneous: (Cont)				
Barbecue	E		180	
Vases	R		50	100
Buddhist Shrines	R		50	150
Japanese Dolls	R		25	50

TABLE A-3

INVENTORY OF PROPERTY VALUES & USES
HILO, HAWAII
RESIDENTIAL CONTENT VALUE TO STRUCTURE MARKET VALUE RATIO
AUGUST 1977

Sample No.	Structure Value Market 1/	Content Value 2/	Content Value to Structure Market Value Ratio - %
1.	$13,200	$10,000	76
2.	5,700	7,400	130
3.	7,300	9,500	130
4.	4,400	9,500	216
5.	9,400	8,700	93
6.	3,600	8,100	225
7.	6,900	9,200	133
8.	9,800	8,800	90
9.	34,800	20,100	58
10.	30,200	12,200	40
11.	10,100	15,100	150
12.	7,000	18,900	270
13.	5,900	7,300	124
14.	18,800	13,300	71
15.	28,600	18,100	63
16.	8,600	10,600	123
17.	4,300	10,200	237
18.	11,500	10,000	84
19.	73,800	17,100	23
20.	70,000	31,200	45
21.	25,200	15,500	53
22.	28,700	8,500	30
23.	29,300	15,400	53
24.	25,400	7,300	29
25.	19,200	8,600	45
26.	28,000	24,500	88

TABLE A-3 (Cont)

Sample No.	Structure Value Market 1/	Content Value 2/	Content Value to Structure Market Value Ratio - %
27.	$18,100	$ 7,500	42
28.	29,700	17,700	60
29.	40,900	19,600	48
30.	40,800	16,500	40
31.	40,600	11,800	29
32.	37,000	16,500	45
33.	54,400	12,800	24
34.	58,700	22,100	38
35.	75,600	20,300	27
36.	47,200	10,200	22
37.	79,000	21,400	27
38.	17,400	11,600	67
39.	40,800	11,500	28
40.	49,000	18,100	37
41.	29,700	18,100	37
42.	28,200	17,600	63
43.	28,800	6,700	23
44.	31,300	11,600	37
45.	26,500	7,600	29
46.	16,400	14,300	87
47.	23,700	16,800	71
48.	23,200	9,200	40
49.	28,100	13,100	47
50.	53,300	17,000	32
51.	50,100	15,600	31
52.	50,100	18,200	36
53.	49,900	16,800	34
54.	50,100	15,600	31
55.	29,600	41,400	140

TABLE A-3 (Cont)

Sample No.	Structure Value Market 1/	Content Value 2/	Content Value to Structure Market Value Ratio - %
56.	18,500	28,800	156
57.	82,400	42,000	51
58.	20,700	13,100	63
59.	6,300	17,500	277
60.	19,500	19,600	100

1/ Structure market value is calculated from structure assessed value based on the ratio: Assessed Value = 59% of Market Value. This ratio was determined by the: Hawaii's Assessment-Sales Ratio Study of Non-Agricultural Properties, 1976, State of Hawaii Department of Taxation, Property Technical Office, January, 1976.

2/ Content Values are as of August 1977. Content Value equals undepreciated replacement cost. Sixty percent of this value would be the average depreciated replacement cost.

TABLE A-4

INVENTORY AND ANALYSIS OF THE VALUE OF DAMAGEABLE PROPERTY
HILO, HAWAII
COMMERCIAL/INDUSTRIAL REPLACEMENT CONTENT VALUE TO STRUCTURE MARKET VALUE RATIO
MARCH 1978

Sample No.	Structure Market Value 1/	Replacement Content Value	Replacement Content Value To Structure Market Value Ratio - %
1.	$ 64,000	$ 33,000	52
2.	245,000	481,000	196
3.	30,000	35,000	116
4.	13,000	11,000	85
5.	150,000	219,000	146
6.	368,000	254,000	69
7.	685,000	2,741,000	400
8.	13,000	37,000	281
9.	33,000	150,000	455
10.	193,000	2,360,000	1223
11.	15,000	74,000	493
12.	38,000	119,000	313
13.	135,000	259,000	192
14.	156,000	846,000	542
15.	439,000	2,559,000	583
16.	41,000	253,000	617
17.	95,000	369,000	388
18.	63,000	290,000	460
19.	668,000	608,000	91
20.	191,000	712,000	373
21.	127,000	386,000	304
22.	874,000	2,847,000	326
23.	206,000	427,000	207
24.	66,000	388,000	588

TABLE A-4 (Cont)

Sample No.	Structure Market Value 1/	Replacement Content Value	Replacement Content Value To Structure Market Value Ratio - %
25.	$ 63,000	$ 56,000	88
26.	264,000	461,000	175
27.	39,000	86,000	220
28.	50,000	125,000	250
29.	71,000	88,000	124
30.	21,000	30,000	143
31.	202,000	223,000	110
32.	52,000	25,000	48
33.	312,000	85,000	27
34.	273,000	131,000	48
35.	125,000	100,000	80
36.	12,000	4,000	33
37.	17,000	13,000	76
38.	61,000	15,000	25
39.	1,081,000	1,750,000	162
40.	1,094,000	286,000	26
41.	13,000	62,000	477
42.	3,000	12,000	400
43.	20,000	56,000	280
TOTAL	$8,681,000	$20,066,000	231%

1/ Structure market value is calculated from structure assessed value based on the ratio: Assessed Value = 59% of market value. This ratio was determined by the: Hawaii's Assessment-Sales Ratio Study of Non-Agricultural Properties, 1976, State of Hawaii Department of Taxation, Property Technical Office, January, 1976.

Source: Environment Capital Managers, Inc., Honolulu, Hawaii.

TABLE A-5

INVENTORY AND ANALYSIS OF THE VALUE OF DAMAGEABLE PROPERTY
HILO, HAWAII
COMMERCIAL/INDUSTRIAL ADJUSTED REPLACEMENT CONTENT VALUE TO STRUCTURE MARKET VALUE RATIO
MARCH 1978

Sample No.	Structure Market Value 1/	Adjusted Replacement Content Value	Adjusted Replacement Content Value to Structure Market Value Ratio - %
1.	$ 64,000	$ 0	0
2.	245,000	404,000	165
3.	30,000	5,000	17
4.	13,000	0	0
5.	150,000	219,000	146
6.	368,000	121,000	33
7.	685,000	2,679,000	391
8.	13,000	1,000	8
9.	33,000	146,000	442
10.	193,000	171,000	87
11.	15,000	0	0
12.	38,000	24,000	63
13.	135,000	105,000	77
14.	156,000	212,000	136
15.	439,000	604,000	146
16.	41,000	3,000	7
17.	95,000	184,000	194
18.	63,000	239,000	379
19.	668,000	144,000	21
20.	191,000	552,000	289
21.	127,000	318,000	250
22.	847,000	90,000	10
23.	206,000	8,000	4
24.	66,000	72,000	109

TABLE A-5 (Cont)

Sample No.	Structure Market Value 1/	Adjusted Replacement Content Value	Adjusted Replacement Content Value to Structure Market Value Ratio - %
25.	$ 63,000	$ 25,000	40
26.	264,000	70,000	27
27.	39,000	0	0
28.	50,000	1,000	2
29.	71,000	2,000	3
30.	21,000	30,000	143
31.	202,000	10,000	5
32.	52,000	5,000	10
33.	312,000	68,000	22
34.	273,000	97,000	36
35.	125,000	50,000	40
36.	12,000	2,000	17
37.	17,000	2,000	12
38.	61,000	7,000	11
39.	1,081,000	1,750,000	162
40.	1,094,000	78,000	7
41.	13,000	26,000	200
42.	3,000	3,000	100
43.	20,000	0	0
TOTAL	$8,681,000	$8,563,000	99%

1/ Structure market value is calculated from structure assessed value based on the ratio: Assessed Value = 59% of Market Value. This ratio was determined by the: Hawaii's Assessment-Sales Ratio Study of Non-Agricultural Properties, 1976, State of Hawaii Department of Taxation, Property Technical Office, January, 1976.

Source: Environment Capital Managers, Inc., Honolulu, Hawaii.

TABLE A-6

INVENTORY AND ANALYSIS OF THE VALUE OF DAMAGEABLE PROPERTY
HILO, HAWAII
COMMERCIAL/INDUSTRIAL ADJUSTED REPLACEMENT CONTENT VALUE TO REPLACEMENT CONTENT VALUE RATIO
MARCH 1978

Sample No.	Replacement Content Value	Adjusted Replacement Content Value	Adjusted Replacement Content Value to Replacement Content Value Ratio - %
1.	$ 33,000	$ 0	0
2.	481,000	404,000	84
3.	35,000	5,000	14
4.	11,000	0	0
5.	219,000	219,000	100
6.	254,000	121,000	48
7.	2,741,000	2,679,000	98
8.	37,000	1,000	3
9.	150,000	146,000	97
10.	2,360,000	171,000	7
11.	74,000	0	0
12.	119,000	24,000	20
13.	259,000	105,000	41
14.	846,000	212,000	25
15.	2,559,000	640,000	25
16.	253,000	3,000	1
17.	369,000	184,000	50
18.	290,000	239,000	82
19.	608,000	144,000	24
20.	712,000	552,000	78
21.	386,000	318,000	82
22.	2,847,000	90,000	3
23.	427,000	8,000	2
24.	388,000	72,000	19
25.	56,000	25,000	45

TABLE A-6 (Cont)

Sample No.		Replacement Content Value	Adjusted Replacement Content Value	Adjusted Replacement Content Value to Replacement Content Value Ratio - %
26.		$ 461,000	$ 70,000	15
27.		86,000	0	0
28.		125,000	1,000	1
29.		88,000	3,000	3
30.		30,000	30,000	100
31.		223,000	10,000	4
32.		25,000	5,000	20
33.		85,000	68,000	80
34.		131,000	97,000	74
35.		100,000	50,000	50
36.		4,000	2,000	50
37.		13,000	2,000	15
38.		15,000	7,000	47
39.		1,750,000	1,750,000	100
40.		286,000	78,000	27
41.		62,000	26,000	42
42.		12,000	3,000	25
43.		56,000	0	0
	TOTAL	$20,066,000	$8,563,000	43%

Source: Environment Capital Managers, Inc., Honolulu, Hawaii.

TABLE A-7

INVENTORY AND ANALYSIS OF THE VALUE OF DAMAGEABLE PROPERTY
HILO, HAWAII
COMMERCIAL/INDUSTRIAL REPLACEMENT CONTENT VALUE AND ADJUSTED REPLACEMENT CONTENT VALUE
MARCH 1978

Sample No.	Inventory	Office Equipment	Other Fixed Assets	Total Contents	Amount Removed During Evacuation	Remaining Content Value	Replacement Total Content Value	Adjusted Replacement Content Value
1.	$ 15,000	$ 1,000	$ 10,000	$ 26,000	$ 26,000	$ 0	$ 33,000	$ 0
2.	300,000	8,000	98,000	406,000	45,000	361,000	481,000	404,000
3.	10,000	3,000	12,000	25,000	22,000	3,000	35,000	5,000
4.	5,000	2,000	2,000	9,000	9,000	0	11,000	0
5.	100,000	40,000	30,000	170,000	0	170,000	219,000	219,000
6.	116,000	1,000	80,000	197,000	78,000	119,000	254,000	121,000
7.	98,000	50,000	1,500,000	1,648,000	36,000	1,612,000	2,741,000	2,679,000
8.	17,000	1,000	11,000	29,000	28,500	500	37,000	1,000
9.	20,000	1,000	75,000	96,000	2,000	94,000	150,000	146,000
10.	5,000	30,000	1,351,000	1,386,000	1,286,000	100,000	2,360,000	171,000
11.	50,000	2,000	45,000	97,000	97,000	0	74,000	0
12.	88,000	3,000	15,000	106,000	85,000	21,000	119,000	24,000
13.	150,000	10,000	55,000	215,000	110,000	105,000	259,000	105,000
14.	265,000	20,000	321,000	606,000	456,000	150,000	846,000	212,000
15.	1,200,000	55,000	742,000	1,997,000	1,498,000	499,000	2,559,000	640,000
16.	250,000	2,000		252,000	250,000	2,000	253,000	3,000
17.	270,000	20,000	38,000	328,000	164,000	164,000	369,000	184,000
18.	250,000	5,000	19,000	274,000	40,000	234,000	290,000	239,000
19.	464,000		95,000	559,000	464,000	95,000	608,000	144,000
20.	600,000	25,000	200,000	825,000	171,000	654,000	712,000	552,000

TABLE A-7 (Cont)

Sample No.	Inventory	Office Equipment	Other Fixed Assets	Total Contents	Amount Removed During Evacuation	Remaining Content Value	Replacement Total Content Value	Adjusted Replacement Content Value
21.	250,000	10,000	257,000	517,000	70,000	447,000	386,000	318,000
22.	2,300,000	111,000	210,000	2,621,000	2,569,000	52,000	2,847,000	90,000
23.	263,000	21,000	75,000	359,000	354,000	5,000	427,000	8,000
24.	156,000	16,000	120,000	292,000	250,000	42,000	388,000	72,000
25.	30,000	500	15,000	45,500	20,500	25,000	56,000	25,000
26.	195,000	32,000	124,000	351,000	281,000	70,000	461,000	70,000
27.	50,000	3,000	18,000	71,000	71,000	0	86,000	0
28.	116,000	4,000	10,000	130,000	129,000	1,000	125,000	1,000
29.	75,000	2,000	5,000	82,000	80,000	2,000	88,000	3,000
30.	6,000	3,000	25,000	34,000	0	34,000	30,000	30,000
31.	200,000	5,000	40,000	245,000	225,000	20,000	223,000	10,000
32.	20,000	5,000	5,000	30,000	20,000	10,000	25,000	5,000
33.		50,000		50,000	10,000	40,000	85,000	68,000
34.		56,000	21,000	77,000	20,000	57,000	131,000	97,000
35.		200,000		200,000	100,000	100,000	100,000	50,000
36.		2,000	1,000	3,000	2,000	1,000	4,000	2,000
37.	1,000		25,000	26,000	22,000	4,000	13,000	2,000
38.	2,000	2,000	5,000	9,000	5,000	4,000	15,000	7,000
39.	2,000	1,000	1,025,000	1,028,000	0	1,028,000	1,750,000	1,750,000
40.	150,000	14,000	78,000	242,000	189,000	53,000	286,000	78,000
41.	2,000	5,000	30,000	37,000	22,000	15,000	62,000	26,000
42.	5,000	4,000		9,000	7,000	2,000	12,000	3,000
43.		3,000	30,000	33,000	33,000	0	56,000	0
TOTAL	$8,096,000	$828,500	$6,818,000	$15,742,500	$9,347,000	$6,395,500	$20,066,000	$8,563,000

TABLE A-8

INVENTORY AND ANALYSIS OF THE VALUE OF DAMAGEABLE PROPERTY
HILO, HAWAII
HOTEL CONTENT VALUE TO STRUCTURE MARKET VALUE RATIO
MARCH 1978

Sample No.	Structure Market Value 1/	Content Value	Content Value To Structure Market Value Ratio - %
1.	$10,219,000	$2,250,000	22
2.	10,457,000	2,143,000	20
3.	268,000	56,000	21
4.	2,867,000	602,000	21
5.	1,066,000	224,000	21
6.	1,956,000	411,000	21
7.	1,116,000	255,000	21
8.	400,000	84,000	21
TOTAL	$28,349,000	$6,025,000	21%

Adjusted Replacement Content Value - $6,025,000 2/

Total Depreciated Replacement Value - $34,373,000

1/ Structure market value is calculated from structure assessed value based on the ratio: Assessed Value = 59% of Market Value. This ratio was determined by the: Hawaii's Assessment-Sales Ratio Study of Non-Agricultural Properties, 1976, State of Hawaii, Department of Taxation, Property Technical Office, January 1976.

2/ It was indicated, during the interview process, that nothing would be evacuated.

Source: Environment Capital Managers, Inc.

TABLE A-9

INVENTORY AND ANALYSIS OF THE VALUE OF DAMAGEABLE PROPERTY
HILO, HAWAII
FEDERAL/STATE/COUNTY BUILDING AND CONTENT VALUES 1/
MARCH 1978

Item	
State:	
Building	$ 4,311,385
Contents	18,104,000
County:	
Building	2,458,505
Contents	5,840,000
Federal:	
Building	1,488,210
Contents	852,500
TOTAL	$33,054,600

Adjusted Replacement Content Value - $10,662,000

Total Depreciated Replacement Value - $33,055,000

1/ State of Hawaii, Department of General Services and Accounting

TABLE A-10

INVENTORY AND ANALYSIS OF THE VALUE OF DAMAGEABLE PROPERTY
HILO, HAWAII
REPLACEMENT COST FOR PARKS AND RECREATION 1/
MARCH 1978

Item	Amount	Total Amount
Beach Park	94 Acres @ $15,000 per 10 Acres	$ 1,410,000
Playground Park	18 Acres each @ $85,700	1,542,600
Community Park	27 Acres eacg @ $83,300	2,249,100
Neighborhood Park	7 Acres each @ $106,300	744,100
Regional Park (Hoolulu)		5,000,000
Tennis Court (Lincoln)		100,000
Gyms	4 Each @ $400,000	1,600,000
Municipal Golf Course		2,000,000
Baseyard:		
Vehicle and Heavy Equipment	$716,000	
Tools	8,525	724,525
	TOTAL	$15,370,325

Adjusted Replacement Content Value - $000

Total Depreciated Replacement Value - $15,370,000

1/ State of Hawaii, Department of Parks & Recreation, County of Hawaii

TABLE A-11

INVENTORY AND ANALYSIS OF THE VALUE OF DAMAGEABLE PROPERTY
HILO, HAWAII
REPLACEMENT COSTS FOR STREETS AND ROADS 1/
MARCH 1978

Item	Amount	Total Cost
Road: 36' Pavement, Curb, Gutter, Drainage, Sidewalk	25 Miles each at $316,000	$ 7,920,000
Road: 20' Pavement, 6' Shoulder	75 Miles each at $184,000	13,860,000
Baseyard:		
Heavy Equipment - $151,745		
Other Equipment - 107,415		259,160
	TOTAL	$22,039,160

Adjusted Replacement Content Value - $000

Total Depreciated Replacement Value - $11,149,000

1/ State of Hawaii, Department of Public Works, County of Hawaii

TABLE A-12

INVENTORY AND ANALYSIS OF THE VALUE OF DAMAGEABLE PROPERTY
HILO, HAWAII
REPLACEMENT COST FOR WATER SYSTEM 1/
MARCH 1978

Item		Amount	Total Cost
Reservoirs:	0.6 - 1.0-MG 2/	4 Each @ $450,000	$ 1,800,000
	0.3 - 0.5-MG	3 Each @ 350,000	1,050,000
	Below 0.3-MG	16 Each @ 125,000	2,000,000
Deep Wells		3 Each @ 400,000	1,200,000
Booster Pump Stations		10 Each @ 75,000	750,000
Telemetering			100,000
Pipelines:	16" and larger	10 Miles @ 160,000 per	1,600,000
	12"	10 Miles @ 130,000 per	1,300,000
	8" and smaller	300 Miles @ 100,000 per	30,000,000
Baseyard:			
Inventory - $100,000			
Equipment - 682,000			782,000
Control and Chlorinator Buildings		10 Each @ 25,000	250,000
		TOTAL	$40,832,000

Adjusted Replacement Content Value - $000

Total Depreciated Replacement Value - $20,807,000

1/ State of Hawaii, Department of Water Supply, County of Hawaii

2/ Million Gallons

TABLE A-13

INVENTORY AND ANALYSIS OF THE VALUE OF DAMAGEABLE PROPERTY
HILO, HAWAII
REPLACEMENT COST FOR SEWER SYSTEM
MARCH 1978

Item	Amount	Total Cost
Pipelines	38.05 Miles @ $343,000 per	$13,058,760
Booster Pump Station		600,000
Booster Pump Stations	4 Each @ 250,000	1,000,000
Sewage Treatment Plant		3,500,000
Baseyard:		
Equipment - $ 8,525		
Vehicles - 30,690		39,215
	TOTAL	$18,197,975

Adjusted Replacement Content Value - $000

Total Depreciated Replacement Value - $9,119,000

1/ State of Hawaii, Department of Sewage and Sanitation, County of Hawaii

TABLE A-14

INVENTORY AND ANALYSIS OF THE VALUE OF DAMAGEABLE PROPERTY
HILO, HAWAII
POLICE DEPARTMENT 1/
MARCH 1978

Item	Amount	Total Cost
Building (Police Headquarters)		$2,523,539 2/
Building (Public Safety)		1,500,000 3/
Office Equipment		400,000
Communication Equipment		300,000
Crime Lab		8,000
Police Cars	2 Each @ $3,000	6,000
Arsenal		100,000
Other		25,000
Jail		26,307 2/
Office Equipment		44,000
Additional Equipment		5,000
Vans	2 Each @ $3,000	6,000
Car		3,000
New Jail Facility		1,000,000 3/
	TOTAL	$5,952,846

Adjusted Replacement Content Value - $356,000 4/

Total Depreciated Replacement Value - $4,720,000 4/

1/ State of Hawaii, Police Department, County of Hawaii

2/ Market Value

3/ Construction Cost (currently under construction)
4/ Depreciated by 25%

TABLE A-15

INVENTORY AND ANALYSIS OF THE VALUE OF DAMAGEABLE PROPERTY
HILO, HAWAII
FIRE DEPARTMENT 1/
MARCH 1978

Item	Amount	Total Cost
Central Fire Station:		
Building	$418,000	
Engines - 2 Each @ $85,000	170,000	
Tanker	55,000	
Rescue	25,000	
Utilities - 3 Each @ $13,000	39,000	
Operational Equipment	20,000	
Total Central Fire Station		$727,000
Waiakea Fire Station:		
Building	$179,000	
Engines - 2 Each @ $85,000	170,000	
Rescue	25,000	
Rescue Boat	18,000	
Utility	13,000	
Salvage	25,000	
Operational Equipment	20,000	
Total Waiakea Fire Station		$450,000
Kawailani Fire Station:		
Building	$ 85,000	
Engine	85,000	
Rescue	25,000	
Operational Equipment	20,000	
Total Kawailani Fire Station		$215,000

1/ State of Hawaii, Fire Department, County of Hawaii

TABLE A-15 (Cont)

Item	Amount	Total Cost
Kaumana Fire Station:		
Building	$179,000	
Engine	85,000	
Rescue	25,000	
Utility	13,000	
Operational Equipment	20,000	
Total Kaumana Fire Station		$ 322,000
Annex Buildings:		
Repair Shop	$150,000	
Supply Warehouse	150,000	
Office	125,000	
Inventory	35,000	
Total Annex Buildings		$ 460,000
TOTAL HILO FIRE DEPARTMENT		$2,174,000

Adjusted Replacement Content Value - $17,000

Total Depreciated Replacement Value - $1,755,000

TABLE A-16

INVENTORY AND ANALYSIS OF THE VALUE OF DAMAGEABLE PROPERTY
HILO, HAWAII
HAWAII NATIONAL GUARD 1/
MARCH 1978

Item	Total Cost
Building	$ 830,000
Army:	
Total Inventory and Equipment	3,069,000
Air Force:	
Equipment	8,167,000
Vehicle	1,146,000
Office Equipment	7,000
TOTAL	$13,222,000 2/

Adjusted Replacement Content Value - $000

Total Depreciated Replacement Value - $13,222,000

1/ U.S. Armed Forces, Hawaii National Guard, County of Hawaii

2/ Values are depreciated replacement costs.

TABLE A-17

INVENTORY AND ANALYSIS OF THE VALUE OF DAMAGEABLE PROPERTY
HILO, HAWAII
SCHOOLS 1/
MARCH 1978

School	Buildings	Contents	Total Cost
Hilo High School	$ 4,088,000	$1,581,000	$ 5,669,000
Hilo Union High School	947,000	537,000	1,484,000
Hilo Intermediate	2,320,000	825,000	3,145,000
Ernest Besilva	1,044,000	251,000	1,295,000
Keaukaha	271,000	102,000	373,000
Latter Day Saints Preschool	46,000	17,000	63,000
Hilo Honpa Hongwanji	337,000	126,000	463,000
Kapiolani Elementary	307,000	116,000	423,000
Day Care Center	33,000	12,000	45,000
Hilo Baptist Kindergarten	158,000	60,000	218,000
Mauna Loa	208,000	78,000	286,000
Waiakea Elementary	2,856,000	1,071,000	3,927,000
St. Joseph High School	957,000	360,000	1,317,000
St. Joseph Elementary	556,000	208,000	764,000
Kaumana Baptist	163,000	61,000	224,000
University of Hawaii-Hilo	7,928,000	2,974,000	10,902,000
Hilo Community College	4,299,000	1,613,000	5,912,000
TOTAL	$26,518,000	$9,992,000	$36,510,000

Adjusted Replacement Content Value - $4,297,000

Total Depreciated Replacement Value - $36,510,000

1/ State of Hawaii, Department of General Services and Accounting

TABLE A-18

INVENTORY AND ANALYSIS OF THE VALUE OF DAMAGEABLE PROPERTY
HILO, HAWAII
LIBRARY 1/
MARCH 1978

Item		Total Cost
Building		$ 518,591
Books		1,961,000
Furniture and Equipment		2,054,000
	TOTAL	$4,533,591

Adjusted Replacement Content Value - $1,726,000

Total Depreciated Replacement Value - $4,534,000

1/ State of Hawaii, Department of General Services and Accounting

TABLE A-19

INVENTORY AND ANALYSIS OF THE VALUE OF DAMAGEABLE PROPERTY
HILO, HAWAII
GENERAL LYMAN FIELD 1/
MARCH 1978

Item	Total Cost
Buildings	$20,000,000
Fixed Assets	2,000,000
Terminal Equipment	1,000,000
Runway Replacement	15,000,000
	$38,000,000

Adjusted Replacement Content Value - $645,000

Total Depreciated Replacement Value - $21,800,000

1/ General Lyman Field, Airport Manager, County of Hawaii

TABLE A-20

INVENTORY AND ANALYSIS OF THE VALUE OF DAMAGEABLE PROPERTY
HILO, HAWAII
HARBOR FACILITIES 1/
MARCH 1978

Item	Total Cost
Buildings	$ 7,538,000
Pier 1	1,850,000 2/
Pier 2	1,042,000 2/
Pier 3	133,000 2/
Boathouse	53,000
Office Equipment	29,000
TOTAL	$10,645,000

Adjusted Replacement Content Value - $12,000

Total Depreciated Replacement Value - $9,425,000

1/ State of Hawaii, Department of Transportation, Harbors Division

2/ Fire Insurance values

TABLE A-21

INVENTORY AND ANALYSIS OF THE VALUE OF DAMAGEABLE PROPERTY
HILO, HAWAII
LYMAN HOUSE MEMORIAL MUSEUM 1/
MARCH 1978

Item	Total Cost
Building	$ 969,419 2/
Exhibits	1,000,000 3/
Showcases	76,000 3/
Lyman Missionary House 4/	73,000 3/
Equipment	100,000
TOTAL	$2,218,419

Most items on exhibit were considered too rare or irreplaceable to quote values, therefore insurance values were used. Adjusted replacement content values were not available as the Director of the Museum felt that a considerable amount of the exhibits would be damaged as soon as they were moved or in the process of moving and storing.

Adjusted Replacement Content Value - $1,176,000

Total Depreciated Replacement Value - $2,218,000

1/ Lyman House Memorial Museum, Hilo, Hawaii

2/ Market Value

3/ Insurance Value

4/ 144 Year old house of the first missionary family in the Hilo area

TABLE A-22

INVENTORY AND ANALYSIS OF THE VALUE OF DAMAGEABLE PROPERTY
HILO, HAWAII
REPLACEMENT COST FOR GASCO 1/
MARCH 1978

Item	Amount		Total Cost
Inventory:			
Appliances	150 Each @ $300.00 2/	$ 45,000	
Parts		50,000	
Gas	45,000 Gals @ $ .05 3/	225,000	$ 320,000
Buildings			200,000
Office Equipment			34,000
Low Pressure Sphere Tank			1,000,000
Storage Tanks	19 Each @ $40,000		760,000
Pressure Reducing Station	2 Each @ 5,000		15,000
Booster Pump Station	3 Each @ 8,000		24,000
Booster Pump Station			20,000
Pipelines	60 Miles @ $184,800 per mile		11,088,000
	TOTAL		$13,461,000

Adjusted Replacement Content Value - $240,000

Total Depreciated Replacement Value - $6,908,000

1/ Gasco, Hilo, Hawaii

2/ Average cost per appliance

3/ Average amount of gas on hand

TABLE A-23

INVENTORY AND ANALYSIS OF THE VALUE OF DAMAGEABLE PROPERTY
HILO, HAWAII
REPLACEMENT COST FOR HAWAII ELECTRIC LIGHT CO., INC. 1/
MARCH 1978

Item	Amount	Total Cost
Buildings		$ 1,369,000
Office Equipment		465,000
Other Fixed Assets		5,640,000
Inventory		1,500,000
Lines:		
Transmission	26 Miles Each @ $ 65,000	1,690,000
Distribution	450 Miles Each @ 30,000	13,500,000
Underground	7 Miles Each @ 200,000	1,400,000
	TOTAL	$25,564,000

Adjusted Replacement Content Value - $845,000

Total Depreciated Replacement Value - $17,269,000

1/ Hawaii Electric Light Company, Inc., Hilo, Hawaii

TABLE A-24

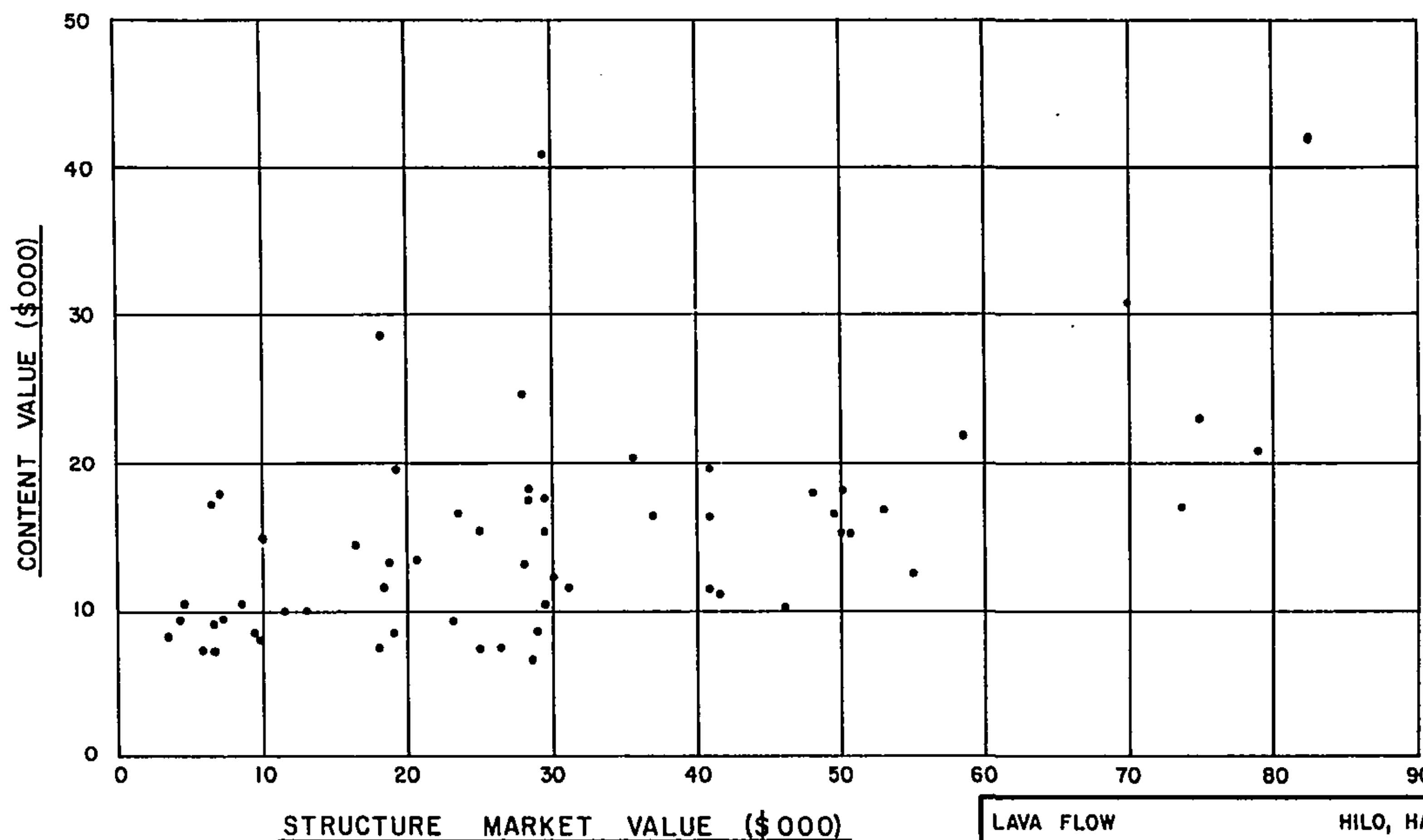
INVENTORY AND ANALYSIS OF THE VALUE OF DAMAGEABLE PROPERTY
HILO, HAWAII
HAWAIIAN TELEPHONE CO. 1/
MARCH 1978

Item	Amount	Total Cost
Facilities and Buildings		$20,725,360
Distribution Cable (Main)	70 Miles @ $1,096 per mile	76,000
	TOTAL	$20,802,132

Adjusted Replacement Content Value - $6,450,000

Total Depreciated Replacement Value - $20,761,000

1/ Hawaiian Telephone Company, Honolulu, Hawaii



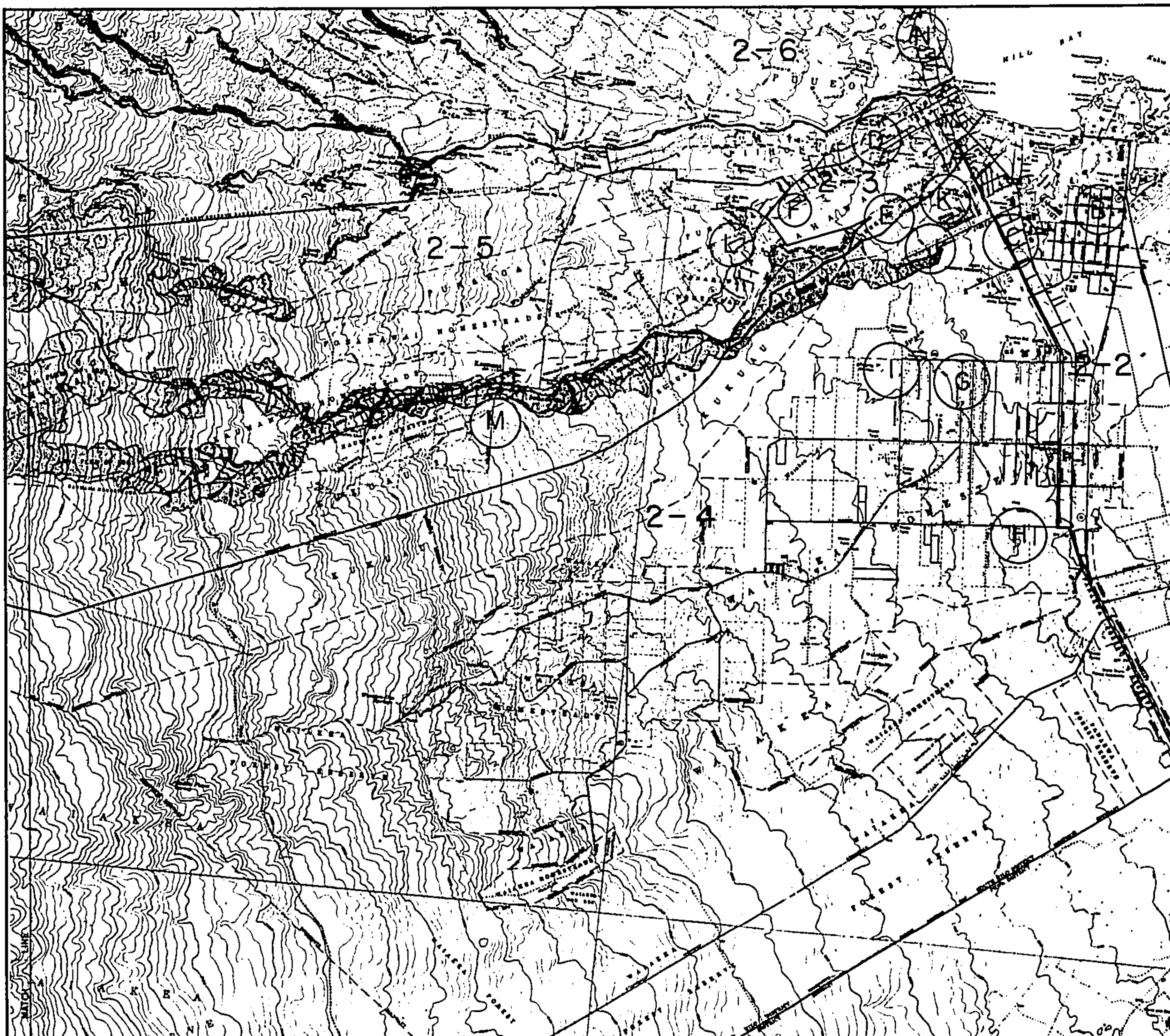
LAVA FLOW HILO, HAWAII

SCATTER DIAGRAM

RESIDENTIAL MARKET STRUCTURE VALUE
VERSUS
CONTENT VALUE

U.S. ARMY ENGINEER DISTRICT, HONOLULU

FIGURE A-1

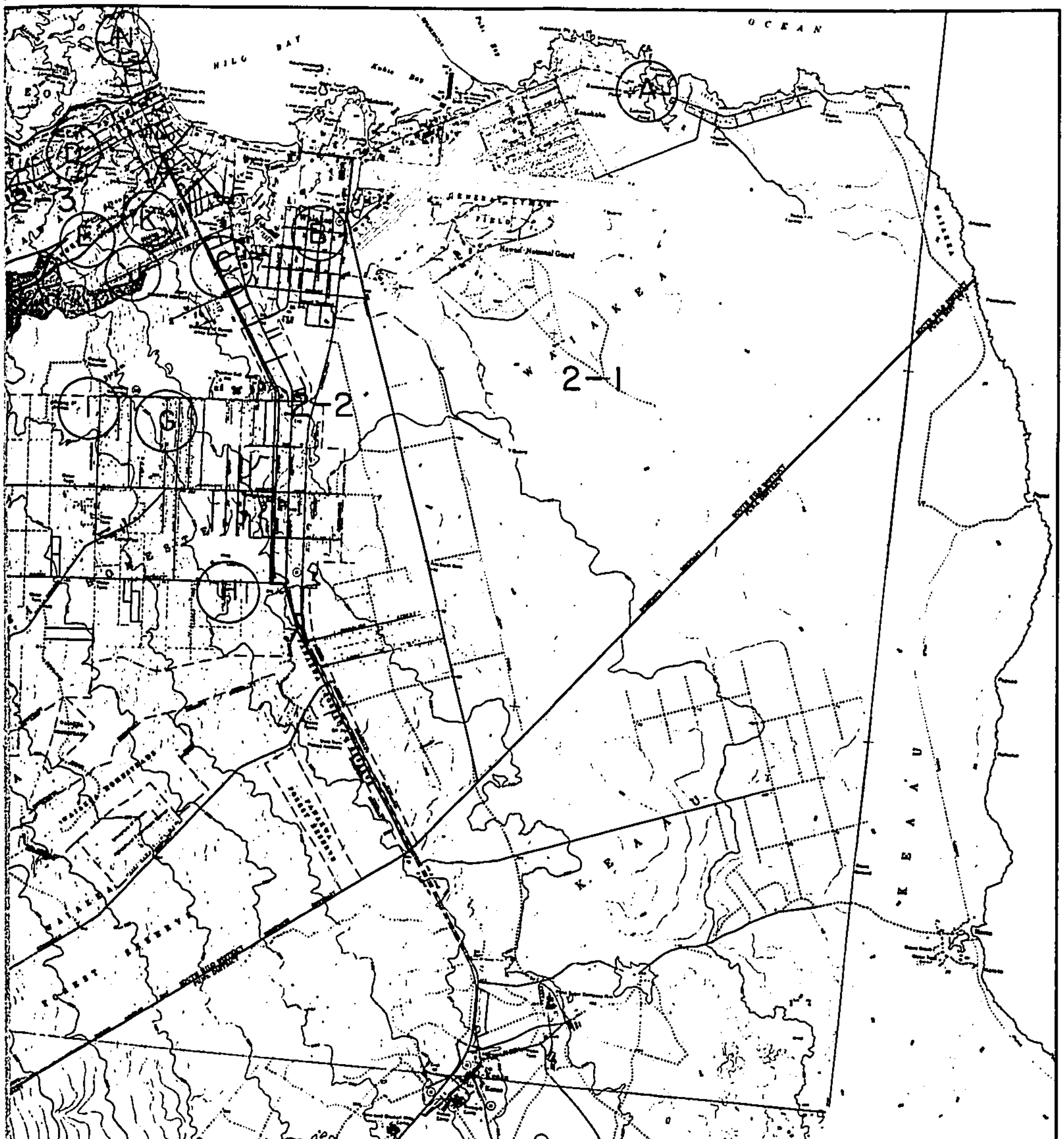


NOTE: MAP REPRODUCED FROM 1:24000 USGS QUADRANGLES
CONTOUR INTERVAL 20 FT.
SCALE 1:24000

LEGEND:

2-4 INDICATES ZONE NUMBER (2) AND SECTION NUMBER (4)

(B) INDICATES LOCATION OF RESIDENTIAL AREAS INTERVIEWED



ZONE NUMBER (2) AND
NUMBER (4)
LOCATION OF RESIDENTIAL
TERVIEWED

HILO LAVA PROTECTION STUDY
HILO, HAWAII, HAWAII

STUDY AREA

U. S. ARMY ENGINEER DISTRICT, HONOLULU
CORPS OF ENGINEERS

PLATE A-1

LAVA FLOW CONTROL STUDY
ISLAND OF HAWAII

TECHNICAL AND COST ANALYSES

APPENDIX B

TECHNICAL AND COST ANALYSIS

TABLE OF CONTENTS

PLATES

APPENDIX B

TECHNICAL AND COST ANALYSIS

1. This appendix covers preliminary details and costs associated with Alternative E, Emergency Plan. Numerous studies and evaluations of lava flows and diversion plans and experiences have been published by scientists specializing in the field of volcanology in Hawaii. (For references, see Prior Studies and Reports in Section I and the Reference List at the end of the Main Report.) Much of the details and concepts presented herein are developed based on work done by these scientists including the very basic diversion barrier concept. Structures and Flow corridors considered in this analysis are shown on Plates B-1 through B-3.

DESIGN FOR DIVERSION STRUCTURES

2. The standard viscosity equation for hydraulic flows is used as a design base for selection of heights of the structures. The equation is given in the form:

$$u = \frac{wD^2 \text{ Sin } A}{3v}$$

where u = coefficient of viscosity

w = specific weight of the "fluid"

D = average flow depth

A = slope angle in direction of flow

v = mean flow velocity

or $$D = \left(\frac{3v \times u}{w \text{ Sin } A}\right)^{\frac{1}{2}}$$

3. Based on the data available from the 1950 Honokua Flow (southwest rift zone flow of Mauna Loa), the average coefficient of viscosity of 2 x 10^5 poises (478.8 poises = lb. sec per ft^2) was computed and used as a typical design viscosity for this analysis. Slopes along the upper reaches average approximately 0.04 and are used as a design slope. A maximum velocity of 0.2 miles per hour (equivalent to 0.29 feet per second) has been observed in past Mauna Loa flows and is used as a design velocity for the upper reach and reduced to 0.1 miles per hour for the mid- and lower reaches.

An average specific weight of 125 pounds per cubic foot is assumed for flows from Mauna Loa. Computed flow depths, D, for the two velocity considerations are:

where V = 0.2 mph   D = 8.5 feet

V = 0.1 mph   D = 6.1 feet

4. The diverted flow is expected to take a roughly triangular flow section extending upslope from the diversion structures. The computed depths, D, are the average over the flow section giving a flow depth at the structure of approximately 17 feet and 12 feet for the two velocity considerations shown above.

5. Since the "embankment" would be constructed of material excavated and ripped primarily from the upslope areas of the "Lava Channel-way," excavations of 3 to 6 feet could be accomplished as part of the diversion plan. The excavated channels combined with 15-foot and 12-foot embankment heights would provide for effective diversion structures totaling about 20 feet and 15 feet along the prepared alignment.

6. The proposal to create diversion structures to redirect lava flow is based on the premise that the slow moving lava exerts minimal forces in the direction of flow; therefore, structural considerations of the diversion embankment are not significant aspects in their design. Experience in past Kilauea volcanic eruptions in the Kapoho area apparently confirms this consideration where flows were successfully diverted using loose materials excavated from the upslope sections of the terrain.

CLEARED FLOW PATH

7. Although there are no specific experience factors associated with extensive use of this concept, past minor clearing of flow paths associated with flows from the Kilauea volcanic series in the Kapoho area indicates that lava flows tend to seek a flow path of least resistance. Using this concept combined with the moderate natural slopes and topographic features of the area, lava flow corridors can be preselected. Clearing these corridors of vegetation and other obstructions would then induce the molten basalt to seek lower elevations within a predetermined alignment, basically parallel with the average topographic slopes.

8. Although flow widths of past historic Mauna Loa eruptions have taken paths more than a mile wide below elevation 4000, much of this wide path is attributed to the high resistance along the flow path created by obstructions including heavy trees and shrubs that prevail in the rain forest area. Widths of a few hundred feet have also been experienced; these result from a combination of low resistance along the

path and the high rate of extrusion from the vent source. The proposed plan to provide cleared flow paths downslope would effectively reduce the friction factor along the cleared alignment, thus confining flows to a relatviely narrow path. Cleared flow path widths, as proposed, would vary from 400 to 500 feet in the upper slopes and up to 2,000 feet at the extreme lower end seaward of Highway 11.

BASIS FOR EMBANKMENT, CONSTRUCTION, AND ESTIMATE OF COSTS

9. Test excavation and construction evaluation were completed in April 1977 along the Tree Planting Road in the vicinity of Sectors A and B of the proposed plan. Embankment heights up to 15 feet were constructed using Caterpillar D-9G bulldozers with rippers and blades. Details of the test results and section configurations are presented in a subsequent portion of this appendix.

10. Estimate of construction costs for the embankments are based on the findings of the test excavation work. An average rate of 200 cubic yards per hour per bulldozer was selected for purposes of this report. The cost estimates reflect emergency construction by contract.

11. Costs for lands are not included in this evaluation. It is assumed that the State and local interests will have the authority and requisition procedures to acquire needed lands for use in emergency situations and will assume liability for litigation resulting from emergency operations. Indirect costs, including planning, operations and logistic support are not included since costs for these items are highly variable and no experience factors are available associated with this type of operation.

12. An eruption could occur anywhere along the northeast rift zone, with the resulting lava flow taking a path determined by the location of the eruption. The five estimates shown in Table B-1 are based on different intersection locations of a lava flow with the diversion zone. Estimate I is based on a lava flow near the Saddle Road, the path taken by the 1855 flow. A flow such as this would require the greatest number of barrier segments for diversion. Estimate V is based on a lava flow intersecting the diversion zone near the Stainback Highway. A flow in this area would probably require no structures, but a cleared path only. The other estimates represent lava flows located between these two extremes. The probable diversion zone, the structure locations (sectors), and the cleared flow path are shown on Plates B-1 and B-2.

a. Estimate I: Intersection from Saddle Road south to the 1882 flow remnants.

b. Estimate II: Intersection from the 1882 flow south to the 1942 flow remnants.

c. Estimate III: Intersection from the 1942 flow south to Stainback Highway.

d. Estimate IV: Intersection of a flow parallel to and north of Stainback Highway.

e. Estimate V: Intersection of a flow parallel to and south of Stainback Highway.

TABLE B-1. CONSTRUCTION COST ESTIMATES

Estimate I (Maximum Cost Condition)

Item	Quantity	Cost
Diversion Structures A and B	13,000 ft	$ 286,000
Diversion Structures C, D, and E	26,500 ft	716,000
Diversion Structure F	9,000 ft	225,000
Clearing Flow Paths	2,500 Ac	910,000
Contract Overhead and Profit	-	613,000
Total Construction Cost Estimate I		$2,750,000

Estimate II

Item	Quantity	Cost
Diversion Structures C, D, & E	26,500 ft	$ 716,000
Diversion Structure F	9,000 ft	225,000
Clearing Flow Paths	2,090 Ac	780,000
Contract Overhead and Profit	-	519,000
Total Construction Cost Estimate II		$2,240,000

Estimate III

Item	Quantity	Cost
Diversion Structures D and E	11,500 ft	310,000
Diversion Structure F	9,000 ft	225,000
Clearing Flow Paths	2,040 Ac	765,000
Contract Overhead and Profit	-	390,000
Total Construction Estimate III		$1,690,000

Estimate IV

Item	Quantity	Cost
Diversion Structure F	9,000 ft	225,000
Clearing Flow Paths	1,990 Ac	751,000
Contract Overhead and Profit	-	294,000
Total Construction Estimate IV		$1,270,000

Estimate V

Item	Quantity	Cost
Clearing Flow Paths	1,690 Ac	665,000
Contract Overhead and Profit	-	205,000
Total Construction Estimate V		$ 870,000

LAVA BARRIER CONSTRUCTION EVALUATION

13. Following the July 1975 summit eruption of Mauna Loa and with a predicted threat of a flank eruption, a quick review was made of the problems and needs with appropriate agencies of the federal, state and local governments. The report "Lava Barrier System for the Protection of Hilo, Island of Hawaii, December 1975" was the result of Corps investigation and emergency planning. The required nominal surveys and experimental work was outlined in that report.

14. The feasibility of a barrier system depends on the rate of excavation of an unknown geologic condition. Thus, in accordance with the 29 October 1976 Memorandum of Agreement between the State of Hawaii and the U.S. Army Corps of Engineers, seven test-barrier sections were constructed on the upper slope of Mauna Loa by James W. Glover, Ltd., under the supervision of the Honolulu Engineer District during the period of 14 to 25 March 1977. The locations and layout of the test sites were surveyed for the Corps of Engineers by the R.M. Towill Corporation and are shown on Plate B-3.

PURPOSE

15. The seven separate test-barrier sections were made to investigate terrain conditions and measure the time to clear, strip, rip, and pile various kinds of lava basalt. Time measurements and geological engineering observations made during the experimental work provide the basis for construction planning to divert lava flows.

SCOPE

16. Two bidders responded from a total of 16 solicitations. An Equipment Rental Contract No. DACW84-77-C-0024 was made 3 March 1977 between the James W. Glover, Ltd., and the Corps of Engineers. Two Caterpiller D-9G bulldozers with hydraulically operated single tooth rippers and 14-foot dozer blades spent a total of 100 hours to make the seven test sections. A Joy trac-mounted percussion drill worked 19 hours using 3-1/2 inch diameter bits drilling 70 holes 8 to 12 feet deep to correlate rock qualities (based on drilling time) and probe for cavities and lava tubes.

LOCATION OF TEST SECTIONS

17. The upper test area is adjacent to the Powerline Road, approximately 6,500 feet south of the Saddle Road near Mile Post 21 from Hilo at about 5,700 feet elevation. The lower test area is located on both sides of the Tree Planting Road 14,000 feet south of the Saddle Road near Mile Post 16 from Hilo and at about 3,800-foot elevation.

DISCUSSION

18. Pahoehoe and Aa Lava Flows. Both pahoehoe and aa lava flows are common on the upper slopes of Mauna Loa with a preponderance of aa flows found at the lower elevations. Heavy "rain forest" vegetation with thick undergrowth covers and conceals the land surface between Stainback Highway and Saddle Road above Hilo. There are only three jeep trails across the 170-square-mile area and the terrain and geological conditions throughout the region are practically unknown. Areal distribution of the two-flow deposits is not known.

19. Because all flows are erupted first in the pahoehoe form, the upland parts near the fissure or crater exhibit a larger preponderance of pahoehoe. With distance down the flanks of Mauna Loa, pahoehoe flows become aa and a greater volume of aa can be expected in the lower parts of the region.

20. The contact of lava flows, one on another, is marked by great irregularity occasioned by the broken character of the pre-existing surface and by the chilling and increase in viscosity of the advancing lava. Pahoehoe flows are distinguished by relatively smooth, billowy, ropy, or entrail-like surfaces. When the viscosity of the molten lava increases and the slope of the terrain decreases, tumuli or pressure domes develop. Transition of pahoehoe to aa goes through a stage called slabby pahoehoe.

21. The surface of aa flows are extremely rough and almost impossible to traverse especially if covered by thick vegetation and the surface is hidden by moss, lichen, and ferns. The upper part of aa consists of clinker and loose scoriaceous basalt pieces which are generally weathered and produce a soil-rock mixture when excavated. The loose clastic surface layer of aa is open and porous and hence decay has created a residual sediment suitable for barrier construction. Dense, hard basalt underlies the clinker-scoriaceous, stripable layer in aa flows which requires ripping to excavate. The hard layer varies in depth below the surface anywhere from one to fifteen feet. No discernible surface feature was found in the brief testing period that would differentiate thick strippable clastic aa layers.

22. Upper Site. The surface rock in the upper site is pahoehoe lava flow of 1855 with relatively flat to gently rolling, hummocky (low tumuli) overlapping pahoehoe toes and lobes. The surface at the test site dips two degrees to the east. Scattered small brush and plants cover the black, shiny rock surface which is otherwise devoid of vegetation.

23. Based on topography and surface appearances, three representative areas were selected to test rock response to stripping, ripping, and piling. The term stripping is used to describe the material that can be excavated with the dozer blade and the minimum amount of ripping. Stripping is the quickest way to excavate and pile rock for barrier construction.

24. The barriers are all sharp crested ridges made by the piling action of the dozer. In the interest of time and speed, no attempt was made to shape the piles of loosely dozed rock rubble. Rock pieces in the three test piles were uniformly heavy averaging between 2.5 and 3.0 bulk specific gravity. The strippable surface layer generated the greater amount of light weight pieces around 2.5 specific gravity.

25. Pile one is in a comparatively smooth-surfaced, low relief area with hard and dense basalt. Ripping was required throughout the entire test. The strippable rock was limited to the top 12 inches. Excavation and piling ranged from 160 cubic yards per hour per bulldozer in the strippable layer near the test pile to 90 cubic yards per hour per bulldozer (cyhd) in harder rock over 100 feet from the pile. The final test pile measured 110 feet long by 82 feet wide and 12 feet high. Pile heights are limited to the natural angle of repose of rocky, blocky pieces (approximately 1H on 1V) and the ability of the dozer to climb over boulder-size pieces which range in size up to five tons. Ripping was slow in the dense, hard blocky rock below the thin strippable layer. Stripping the softer and lighter surface layer over greater distances away from the test pile is faster if the terrain and rock conditions are uniform and favorable. The square shape of the pile is the result of the bulldozers not being able to push the large blocky pieces (0.5 tons to 5.0 tons) up the slope of the pile. The width of the pile gradually increased to 82 feet instead of the anticipated width of about 30 feet with a 15-foot high barrier and a 1H on 1V side slope.

26. Test pile two was placed in a low tumuli or pressure dome which stood 20 feet above the surrounding flow rock. The purpose of the test was to measure rock excavatibility with elevated terrain features on the possibility that the dome rock would be weaker. The rock at test pile two was similar to test pile one having a foot or so of strippable material over hard basalt. Ripping the dome was slow because of the shape and variation in the slopes of the surface of the structure. The rock was harder the deeper the core of the dome was pentrated. Ten dozer hours were required to build test pile two at the rate of 120 cyhd. The shape of the pile was held to representative dimensions by increasing the length to 180 feet. The average pile height was 12 feet. Size of pieces again controlled the shape of the pile.

27. Test pile three was to measure changes in rock strength with a change in direction of stripping and ripping. The ripping and stripping was oriented in the direction of the flow as compared with test piles two and three which were ripped and stripped across the flow. The direction of excavation did not seem to influence the rate. The strippable surface layer measured one to three feet in thickness and the piling rate increased accordingly to 150 cyhd. The height of the pile was limited to 15 feet by the blocky pieces recovered below the strippable layer.

28. A Joy trac-mounted shot-hole percussion drill was used at the upper site to check the hardness of rock by timing the rate of drilling and

examining the rock cuttings. Test holes were drilled in the several types of pahoehoe found in the upper site. A total of 70 holes were drilled using 3-1/2-inch diameter carbide tipped bits. The holes were 8 to 12 feet deep and drilling rates ranged from one to four feet per minute, averaging 2.5 feet per minute. Three small cavities were found in the borrow area of Pile One. The largest was four feet found between five and nine feet below the surface. The other two cavities were only one foot in depth and were found between six and eight feet. The information and data gained from drilling at this site did not justify additional drilling and testing work at the lower site.

29. Lower Site. The terrain and surface conditions in the lower site are completely different from those found in the upper site. Rolling mounds and ridges of aa clinker and scoria are masked by thick growths of trees and rain forest. Vegetation clearing and trail building is rapid by a D-9 bulldozer with little resistance from the small diameter trees, ferns and other vegetation which are removed along with the loose strippable surface layer. An area was selected between stations 5+00 and 8+00 near the back of the lower site to take advantage of a natural hill, or mound of as near station 8+00 to tie one end of the barrier into. Two separate test sections were designated Pile 4 and Pile 5.

30. The foundation under Pile 4 was excavated to a depth of four feet to remove loose, porous clinker-scoria material to prevent molten lava from undermining and penetrating beneath the barrier. The borrow area (300 by 150 feet) north of the pile location (parallel to the surveyed access trail) was rapidly cleared of trees and vegetation prior to the start of stripping. No ripping was done. Loose strippable clinker-scoria was pushed by the dozers to make Pile 4. The piling rate was 250 cyhd. The depth of the strippable material varied from near the surface to five feet. Sufficient fine grain residual soil is present in the strippable layer to make shaping of the pile easy and give fairly smooth side slopes.

31. The northwest half of the area selected for testing was used to clear, strip, and pile the clastic residual surface layer of aa material without first removing the trees and vegetation. The rate of pile construction was 330 cyhd. The wider borrow area was chosen to provide room for the bulldozers to obtain material from the strippable layer without having to rip. The hard underlying basalt layer varied from near the surface to four feet below in the borrow area for Pile 5.

32. Two short trenches were excavated at the northwest side of the lower test site to measure the thickness of the strippable clinker-scoria layer at this location. Both trenches found between 10 and 15 feet of loose residual soil-rock material which could be excavated and piled at rates up to 600 cyhd. Two test pits were also dug in the access trail in the highest mounds found along the trail. The strippable layer was six feet thick in both pits.

33. These test trenches and pits indicate there is a wide variation in the thickness of strippable aa at least within the limits of the lower site. How great a variation there may be elsewhere on the slopes of Mauna Loa cannot be predicted.

CONCLUSIONS

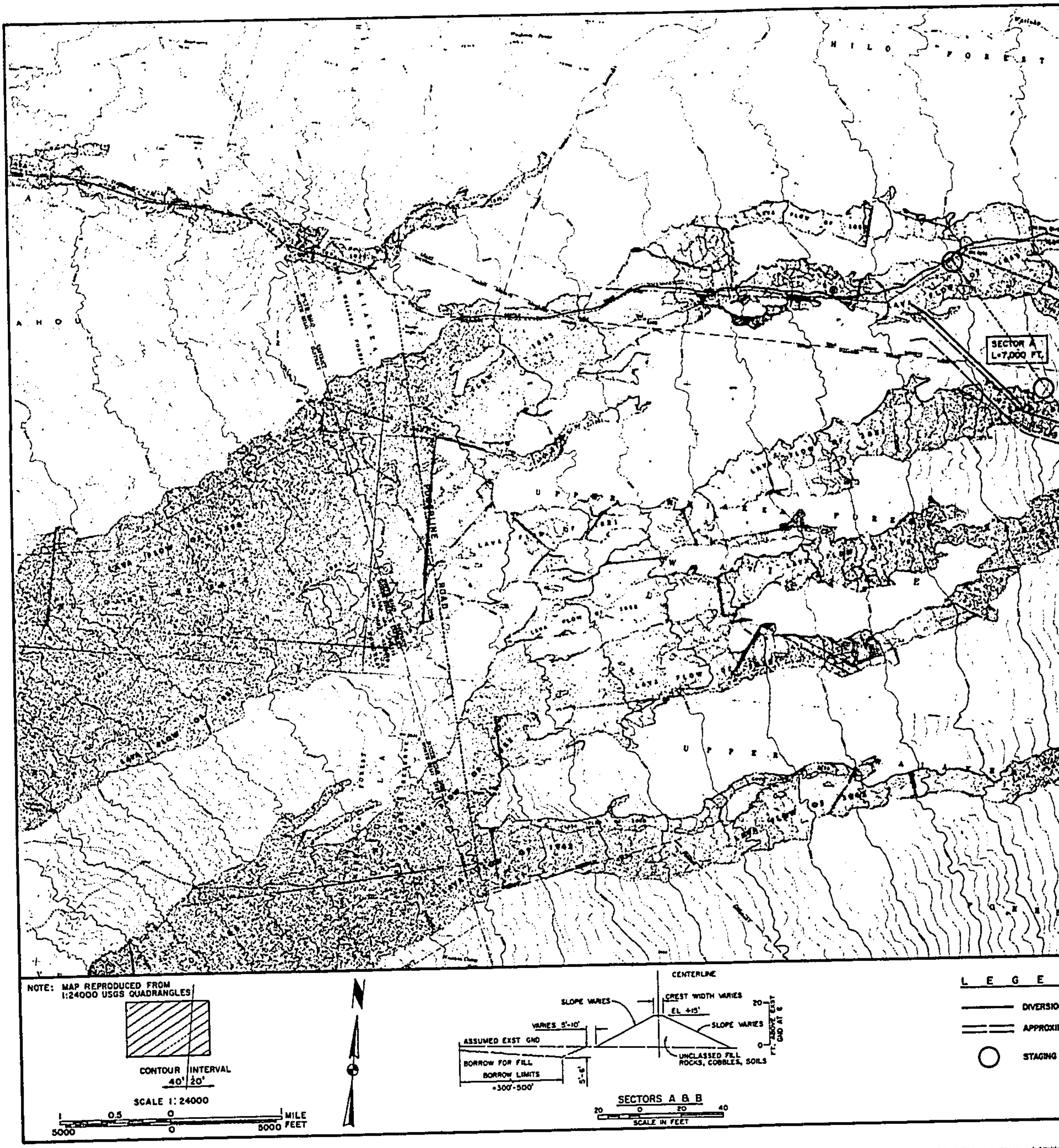
34. Both pahoehoe and aa lava flows were used to construct test sections with the aa material providing more satisfactory results. Pahoehoe flows are not ideal sources for barrier construction being limited to 100 lineal feet of barrier per day per dozer and barrier heights up to only 12 feet. Construction of barriers in pahoehoe flows in considerably more difficult and borrow sites may be necessary to yield a section which is 20 feet high.

35. Strippable surface layers of residual-clastic aa ranging from 1 to 15 feet will provide the best source of material for barrier construction on the upper slopes of Mauna Loa, averaging 200 lineal feet of barrier per day per dozer with heights up to 20 feet.

36. Clearing and stripping in aa can be done simultaneously on the upper slopes covered by small diameter trees. Tree diameters increase on the lower slopes and will require more effort to remove. Front-end loaders can work the strippable aa layer. Construction along all sites can proceed must faster if additional access is provided.

37. The shot-hole percussion drill confirmed the continuity of hard basalt with depth in pahoehoe flows, failed to locate any large tubes or cavities, and is not considered necessary for future investigations.

38. As noted in paragrpah 13, additional field investigations will be needed in the 170-square-mile virgin country above Hilo during the post-authorization study stage. Specific investigations would include biological, archaeological/historical, topographic surveys, test sources of construction material for barriers, and provisions for better vehicular access for emergency operations.


SECTOR A
L=7,000 FT.
NOTE: MAP REPRODUCED FROM 1:24000 USGS QUADRANGLES
CONTOUR INTERVAL 40' 20'
SCALE 1:24000
0.5 0 MILE
5000 0 5000 FEET
N
CENTERLINE
SLOPE VARIES
CREST WIDTH VARIES
EL +15'
VARIES 5'-10'
SLOPE VARIES
ASSUMED EXST GND
BORROW FOR FILL
BORROW LIMITS
+300'-500'
5'-6'
UNCLASSED FILL ROCKS, COBBLES, SOILS
FT. ABOVE EXST GND AT ℄
SECTORS A & B
SCALE IN FEET
L E G E
DIVERSIO
APPROXI
STAGING

L E G E N D

DIVERSION STRUCTURE ALIGNMENT FOR EMERGENCY OPERATIONS.

APPROXIMATE LIMITS OF CLEARED PATH FOR LAVA FLOW CONTROL.

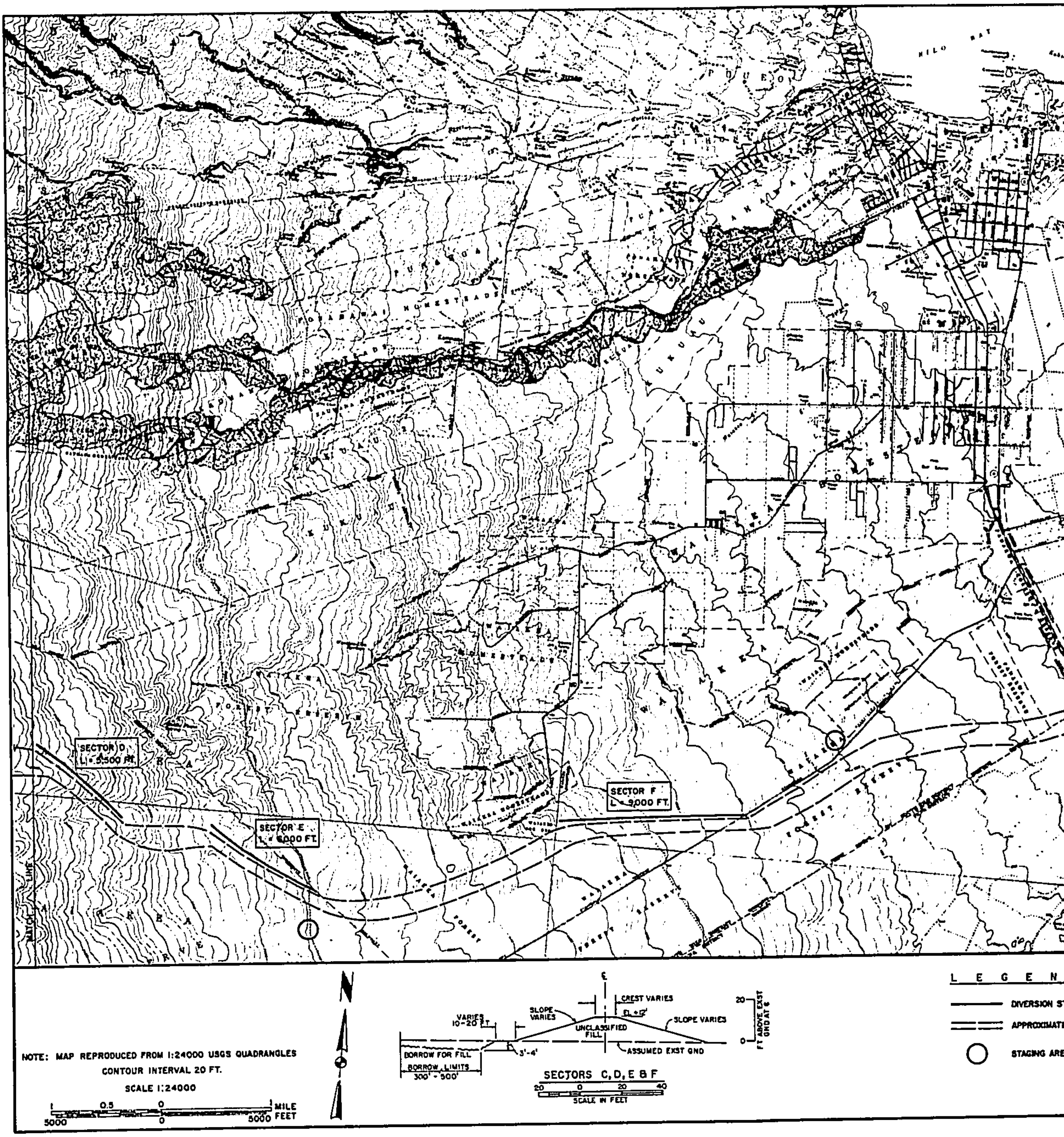
STAGING AREAS FOR EMERGENCY OPERATIONS USES.

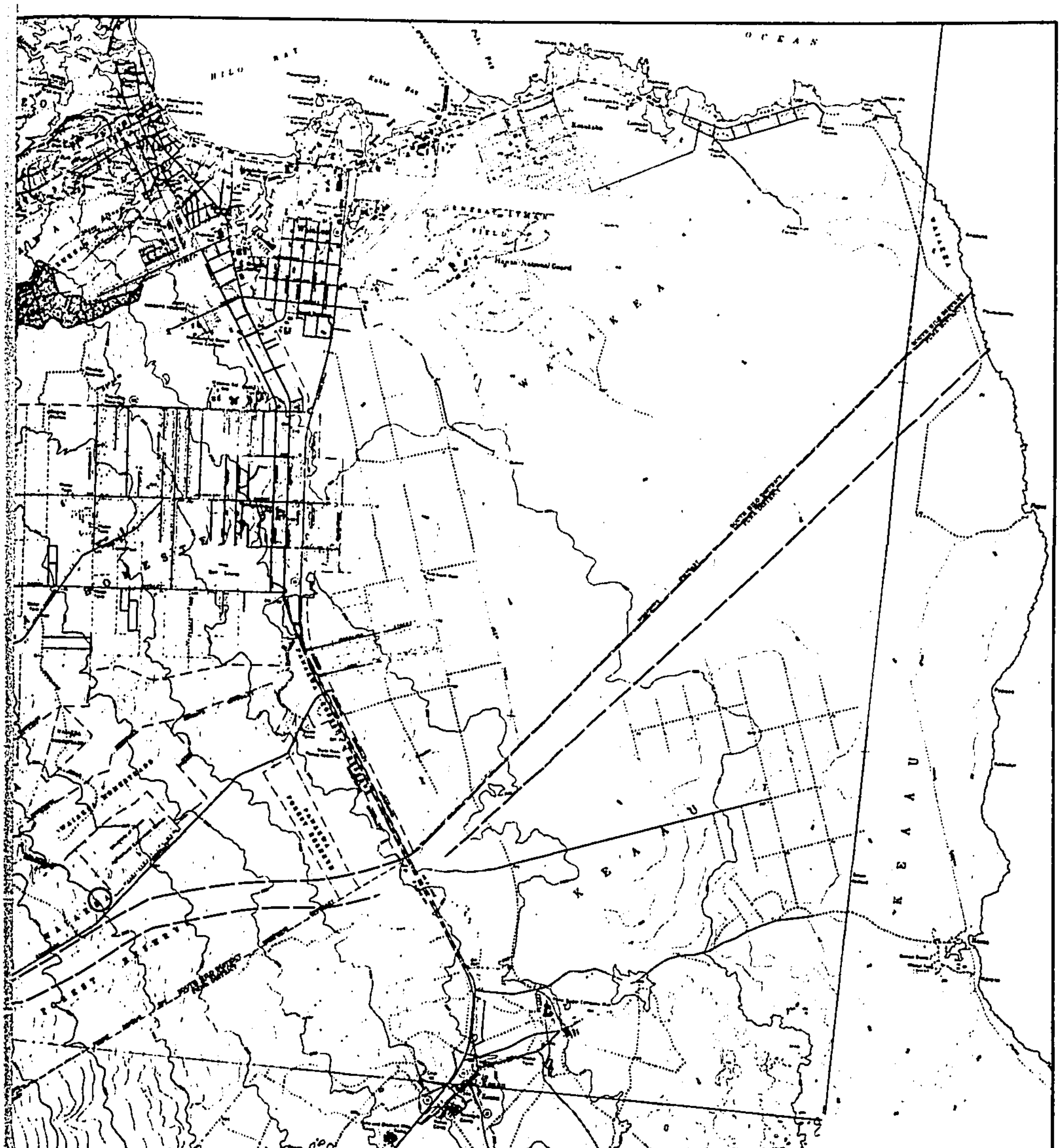
HILO LAVA PROTECTION STUDY
HILO, HAWAII, HAWAII

EMERGENCY PLAN

U. S. ARMY ENGINEER DISTRICT, HONOLULU
CORPS OF ENGINEERS

PLATE B-1


HILO BAY
SECTOR D
L = 5500 FT.
SECTOR E
L = 6000 FT.
SECTOR F
L = 9000 FT.
MATCH LINE
N
NOTE: MAP REPRODUCED FROM 1:24000 USGS QUADRANGLES
CONTOUR INTERVAL 20 FT.
SCALE 1:24000
0.5
0
MILE
5000
0
5000 FEET
CREST VARIES
EL +12'
SLOPE VARIES
SLOPE VARIES
VARIES 10-20 FT
UNCLASSIFIED FILL
ASSUMED EXST GND
3'-4'
BORROW FOR FILL
BORROW LIMITS
300' - 500'
20
0
FT ABOVE EXST GND AT ℄
SECTORS C, D, E & F
20 0 20 40
SCALE IN FEET
LEGEND
DIVERSION ST
APPROXIMATE
STAGING ARE



LEGEND

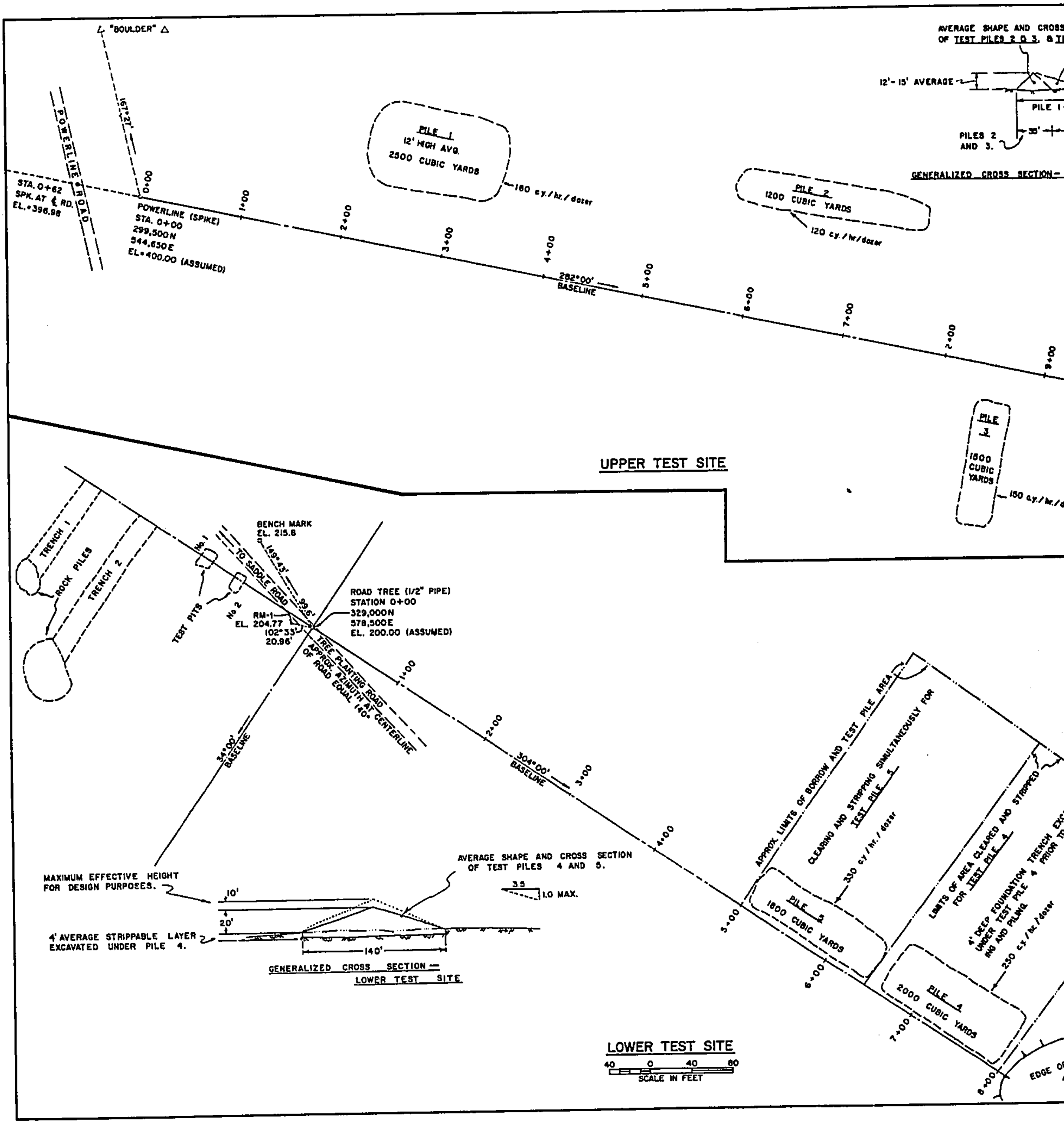
- DIVERSION STRUCTURE ALIGNMENT FOR EMERGENCY OPERATIONS.
- APPROXIMATE LIMITS OF CLEARED PATH FOR LAVA FLOW CONTROL.
- STAGING AREAS FOR EMERGENCY OPERATIONS USES.

HILO LAVA PROTECTION STUDY
HILO, HAWAII, HAWAII

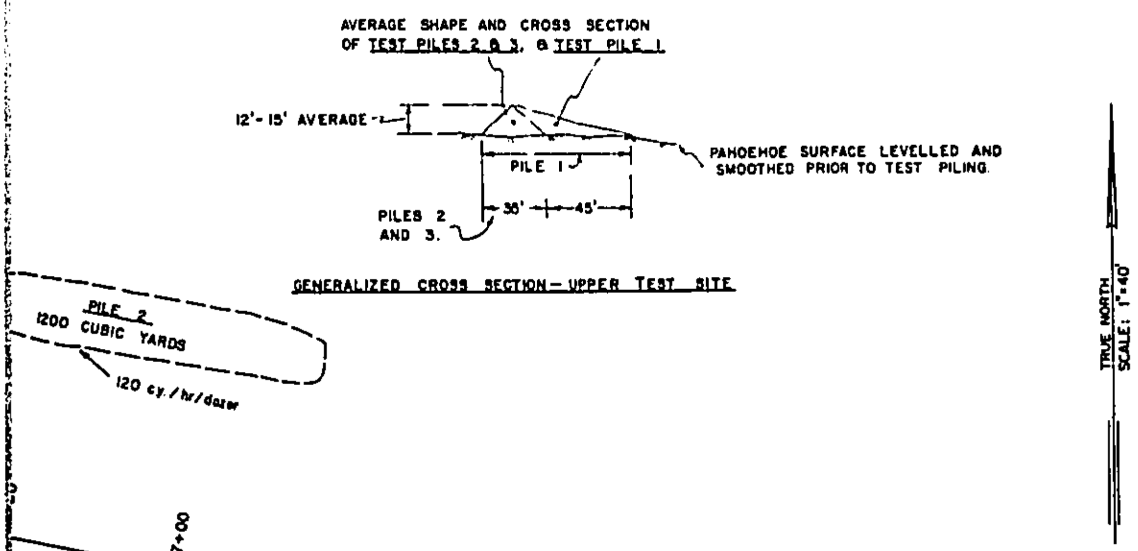
EMERGENCY PLAN

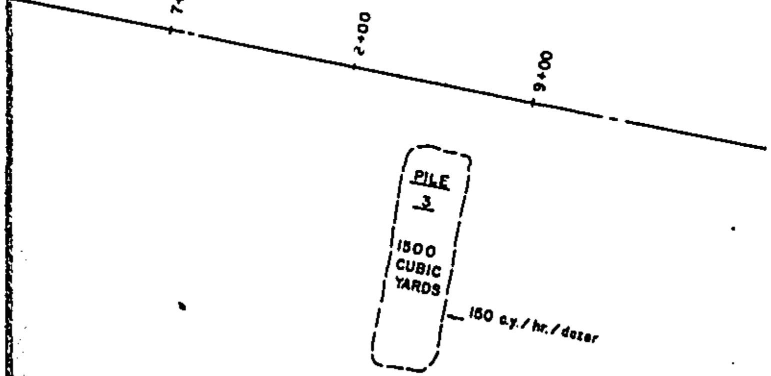
U. S. ARMY ENGINEER DISTRICT, HONOLULU
CORPS OF ENGINEERS

PLATE B-2



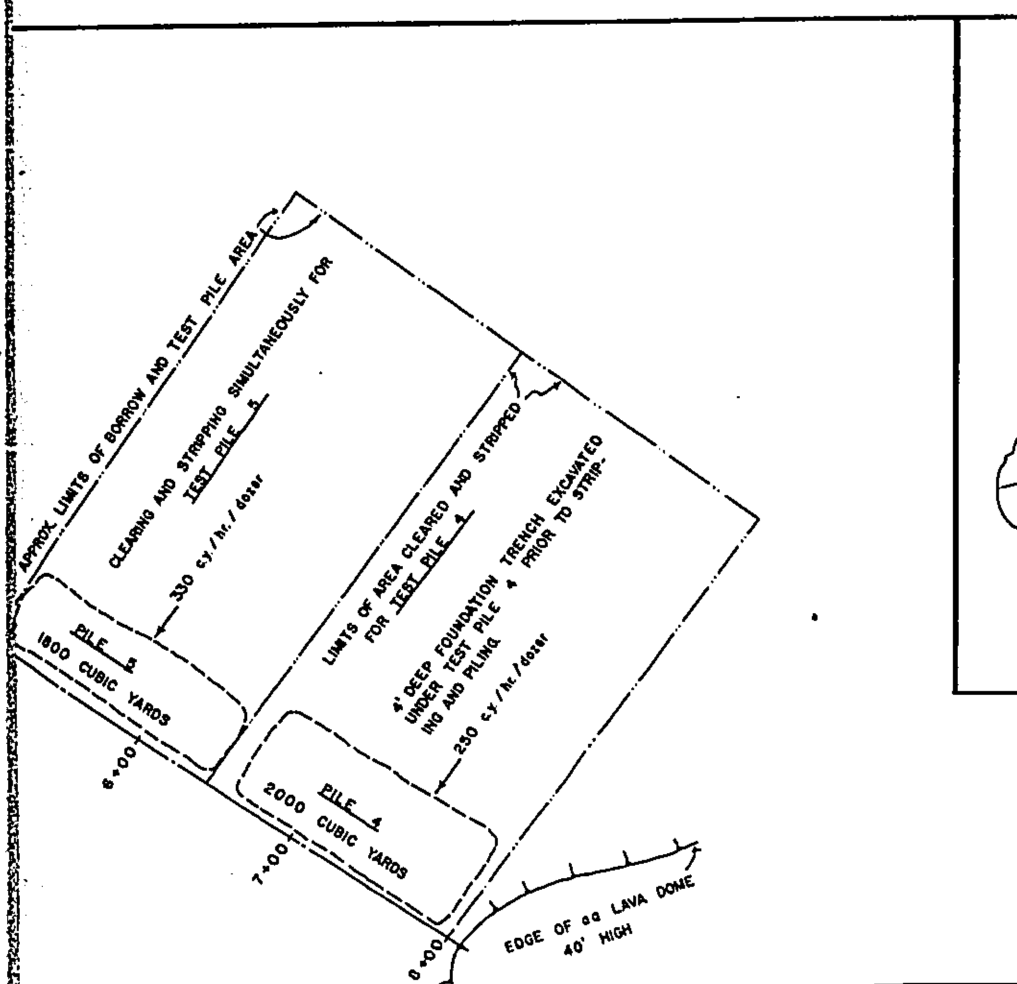
"BOULDER"
POWERLINE ROAD
STA. 0+62
SPK. AT ℄ RD.
EL.=396.98
POWERLINE (SPIKE)
STA. 0+00
299,500 N
544,650 E
EL.=400.00 (ASSUMED)
PILE 1
12' HIGH AVG.
2500 CUBIC YARDS
180 c.y./hr./dozer
PILE 2
1200 CUBIC YARDS
120 c.y./hr/dozer
282°00'
BASELINE
PILE 3
1500 CUBIC YARDS
AVERAGE SHAPE AND CROSS
12'-15' AVERAGE
PILES 2 AND 3.
GENERALIZED CROSS SECTION—
UPPER TEST SITE
TRENCH 1
TRENCH 2
ROCK PILES
TEST PITS
No. 1
No. 2
BENCH MARK
EL. 215.8
TO SADDLE ROAD
RM-1
EL. 204.77
102°33'
20.96'
ROAD TREE (1/2" PIPE)
STATION 0+00
329,000 N
578,500 E
EL. 200.00 (ASSUMED)
TREE PLANTING ROAD
APPROX. AZIMUTH AT CENTERLINE OF ROAD EQUAL 140°
34°00'
BASELINE
304°00'
BASELINE
APPROX. LIMITS OF BORROW AND TEST PILE AREA
CLEARING AND STRIPPING SIMULTANEOUSLY FOR TEST PILE 5
330 c.y./hr./dozer
PILE 5
1800 CUBIC YARDS
LIMITS OF AREA CLEARED AND STRIPPED FOR TEST PILE 4
4' DEEP FOUNDATION TRENCH UNDER TEST PILE 4
250 c.y./hr./dozer
PILE 4
2000 CUBIC YARDS
MAXIMUM EFFECTIVE HEIGHT FOR DESIGN PURPOSES.
AVERAGE SHAPE AND CROSS SECTION OF TEST PILES 4 AND 5.
10'
20'
3.5
1.0 MAX.
4' AVERAGE STRIPPABLE LAYER EXCAVATED UNDER PILE 4.
140'
GENERALIZED CROSS SECTION — LOWER TEST SITE
LOWER TEST SITE
40 0 40 80
SCALE IN FEET

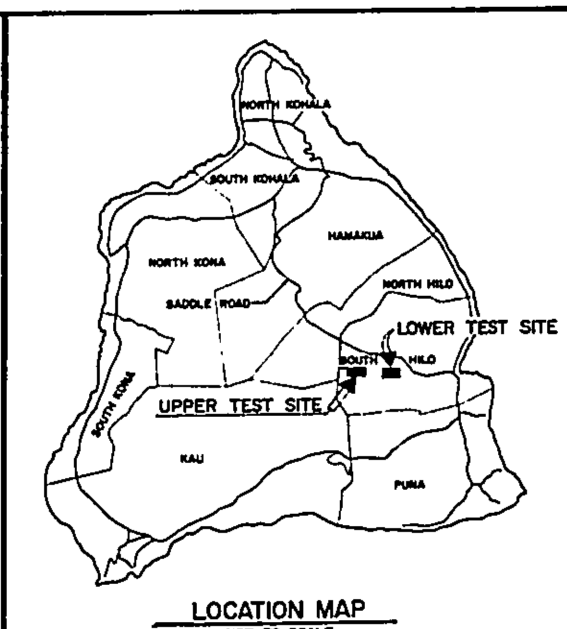




NOTES

1. TEST BARRIERS WERE MADE 14 TO 25 MARCH 1977 USING TWO D-9G BULLDOZERSTO CLEAR, STRIP, RIP AND PILE ROCK.
2. UPPER TEST SITE IS IN PAHOEHOE LAVA BASALT FLOWS.
3. LOWER TEST SITE IS IN aa LAVA BASALT FLOWS WITH THICK VEGETATION.
4. LARGE BLOCKY PIECES OBTAINED BY RIPPING CONTROLLED THE SHAPE AND CROSS SECTION OF PILE ONE.
5. TEST BARRIERS WERE BULLDOZED INTO IRREGULAR AND UNDRESSED SLOPES WITH VARYING SHAPES. DIMENSIONS AND QUANTITIES ARE APPROXIMATE.





LOCATION MAP
NOT TO SCALE

HILO LAVA PROTECTION STUDY
HILO, HAWAII, HAWAII

LAVA BARRIER CONSTRUCTION EVALUATION

U.S. ARMY ENGINEER DISTRICT, HONOLULU
CORPS OF ENGINEERS

PLATE B-3

LAVA FLOW CONTROL STUDY

ISLAND OF HAWAII

PUBLIC VIEWS AND RESPONSES

APPENDIX C

PUBLIC VIEWS AND RESPONSES

TABLE OF CONTENTS

APPENDIX C

PUBLIC VIEWS AND RESPONSES

PUBLIC INVOLVEMENT PROGRAM

1. Public participation was conceived and carried out as a key element of the lava flow control study. Since the 5 July 1975 summit eruption of Mauna Loa, the state, county, and federal agencies, including the military forces in Hawaii, conducted numerous field investigations and technical conferences on the feasibility of lava flow diversion plans. Representatives of the Pacific Ocean Division were actively involved as participants or as observers. Consistent with the continuing and interactive planning process, the public involvement program for this study was integrated with the three stages of the planning process:

   a. Development of a Plan of Study (POS);

   b. Development of Intermediate Plans; and

   c. Development of Detailed Plans.

2. During the Stage 1 (POS) period, the participating public consisted primarily of government agencies, and planning efforts concentrated on problme identification. The physical study area, nature of volcanic hazards, public concerns, and base and probable future conditions were identified, establishing the study approach. This identification work was accomplished by coordination and interaction with interested and affected agencies in the course of the POS preparation and during the initial public meeting conducted in Hilo on 28 March 1977. The Stage 1 effort resulted in a Plan of Study, which indicated the planning scope, the extent of the study area, planning objectives, applicable constraints and controls, and how subsequent planning action would be handled.

3. The Stage 2 (Development of Intermediate Plans) public involvement activities consisted of presenting a preliminary range of solutions for public reaction and comments. Special effort was made to maintain close interaction with the Hawaiian Volcano Observatory and the State and County Civil Defense agencies. This period of study culminated in a formulation stage public workshop in June 1978. Public comments and responses during Stage 2 served as a basis to explore the implications of each intermediate alternative in terms of engineering, environmental, social and cost preferences.

4. In the Stage 3 phase, efforts were directed to segments of the public likely to be affected by or interested in the study recommendations. The group includes local government officials, landowners, residents in the study area, and agencies or groups that have been involved in lava flow control/diversion matters. This approach was necessary to prevent major unresolved issues from surfacing prior to the late stage public meeting held near the conclusion of the study.

SUMMARY OF PUBLIC MEETINGS AND WORKSHOPS

5. On 28 March 1977, a public meeting held in Hilo provided the public with an opportunity to express their views on the subject of lava flow control. Protective measures, both construction in advance of eruption and planned emergency operations after an eruption, expressed were discussed. Total attendance was about 110 persons. Opinions varied from support for the study to skepticism on the effectiveness of various possible methods of controlling or diverting lava. Significant points and/or concerns voiced during the meeting are summarized below:

a. A position paper prepared by State Representative Herbert Segawa was read, in part: "... As a State Representative, I am especially concerned about the public safety of the city of Hilo. Every time an eruption gets into the populated section of the island, we talk about protective measures. But, after the crisis passes, the talk dies out and we forget about it until the next time...I support this Hilo lava flow study and stand ready to do whatever I can to assist your efforts..."

b. The Hawaii Audubon Society emphasized the importance in this study of looking at the environment, at proposed or alternate projects, and looking at the environmental impacts of any construction projects long in advance before they are actually needed.

c. Based on his experience at Kapoho in 1955 and 1960, a speaker suggested a deep channel to convey the lava because barriers or water cooling will not work. He further stated, "If you don't mess around with Pele, she won't mess around with you."

d. Questions were raised on property damages caused by the lava flow diversion and who would be responsible. (Response: There is no question that any disaster brings some suffering. In the past, the governments have done what they could to alleviate and take into account damages to private property).

e. A point was made in favor of manmade barriers as an emergency plan and even as a long-range solution because saving lives is as importaint as environmental preservation.

f. The feasibility of pumping water from Wailuku River was questioned. It was stated that at times, the river has very little water in it.

g. Mass evacuation is the best plan. (Response: That would certainly be part of the overall plan).

h. As a part of the study, it was suggested that the study consider the legends of Hawaii to learn how ancient Hawaiians dealt with eruptions.

6. Written communication received from those who were unable to attend the meeting is summarized as follows:

Number of Responses	Comments
26	Oppose flow diversion.
13	Support plans for public awareness, emergency action, and evacuation.
17	Support planning - no specific opion of measures.
16	Support diversionary concept.
11	Support bombings and water cooling.
3	Oppose bombing.
15	No comment.
101 Total Responses	

7. A public workshop held on 29 June 1978 presented the planning considerations and concepts of improvement. Approximately 70 persons attended. As in earlier lava flow control meetings, attendees expressed skepticism and differences of opinion regarding the advisability of diverting flows by manmade structures. The legends of Pele and spiritual values were of great importance to the majority at the workshop. Other views were as follows:

a. Inability to predict magnitude of eruption and path of flow makes damage prevention considerations guess work.

b. Experimental or observed data is insufficient to support degree of effectiveness of barriers or water cooling.

c. Some believe that aa flows would overtop barrier.

d. Adverse environmental impacts may result due to construction work in native forest. Therefore, Corps should not provide facilities in advance of volcanic eruptions.

e. Some form of federally funded lava damage insurance was suggested.

f. Focus should be on evacuation and disaster relief.

8. During the period of 12 to 14 September 1979, the Honolulu Engineer District personnel conducted a series of small informational sessions with various publics in Hilo. The purpose of the sessions was to meet with different interest groups who wished to discuss the subject study and their concerns. The meetings provided a forum for asking specific points which may not have been possible in the larger public meetings. The County Civil Defense Administrator assisted in making most of the meeting arrangements, including the use of the State Office Building Conference room. Table C-1 summarizes these information sessions.

9. On 10 October 1979, the final public meeting formally presented the detailed study information which led to the selection of the proposed emergency barrier plan. Notices of the meeting were sent to State and County officials and agencies, as well as to interested organizations and individuals. The U.S. Senators and Representatives from Hawaii and other federal agencies were invited to participate. Approximately 60 people attended this final meeting. Views expressed covered a broad range of attitudes, from full support for the emergency barrier plan to total opposition of any structural measures for flow diversion. Results were termed inconclusive, due in part to the indeterminable nature of lava flow. Potential damages to the Puna area and macadamia nut orchard were cited because of the diverted flows. The possibility of unnecessary destruction or degradation of the native wilderness due to barrier construction was also voiced. The question of liability for property and economic losses caused by the diversion was discussed briefly with a note that it needs to be further pursued. The proponents for the emergency barrier plan stressed efforts to protect property and investments threatened by a lava flow must be considered. Major comments made during the testimony are summarized as follows:

a. The study fails to identify the problems that will be created in the Puna area, if the emergency barrier diversion plan is implemented

b. Include answers to the many questions before final plans for lava flow control are adopted.

c. Due to the high value of macadamia nut production, the proposed flow path should be modified to bypass the orchards.

d. It was requested that provisions to indemnify property owners due to diversion losses be clarified.

e. Non-structural alternatives (bombing and lava flow insurance) should be added to report.

f. Against Corps' efforts to amend Public Law 84-99.

g. The contents of the State Emergency Plan should be addressed and summarized in report.

h. The report may be misleading in its emphasis that singles out Hilo as a target of Mauna Loa eruptions.

TABLE C-1. SUMMARY OF GROUP MEETINGS

DATE	GROUP	MAJOR COMMENTS
12 September 1979	County Agencies Office of the Corporation Counsel Planning Department Police Department Department of Public Works Civil Defense Agency Sierra Club, Hawaii Chapter	Decision to "destroy this to save that" is tough. Concept of obliteration of Hilo was an overstatement. There is a concern for liability caused by diverted flows. Include information on the State Civil Defense plan in report.
	Hawaiian Volcano Observatory	Institution arrangements need to be clearly defined. Aerial bombing at higher elevations should be employed to spread flows. Chance of Hilo being affected widely by lava was very small. Geologic mapping of the north flank of Mauna Loa completed; northeast flank and Hilo area mapping underway.
	U.S. Fish and Wildlife Service and Audubon Society	Bird and plant distribution maps under preparation. Relationship between the State Civil Defense emergency plan and the Corps study should be discussed in report. Other agencies participating in lava related studies should be noted. In report. Recent data regarding the age of pre-historic flows in the Hilo area may be very relevant to risk prediction. Additional studies should be clearly defined. Draft report implies Hilo is the only problem area.
	Congress of Hawaiian Peoples	Proposal to divert lava flows is a waste of taxpayers' money. Spiritual concerns are based on fear of reprisals from Madame Pele. People participating in bombing of the 1942 lava flow have since died in violent deaths. Older Hawaiians would laugh or object passively to an emergency diversion, but there may be violent opposition to bombing. Hawaiian community would be upset and skeptical regarding any diversion efforts. Work with nature rather than fight it--early Hawaiians moved when affected by lava flows.
13 September 1979	State Agencies Governor's Liaison Conservation Enforcement Department of Social Service and Housing Division of Land Management Division of Forestry Division of Parks Division of Fish and Game Department of Transportation	Specifics of the proposed plan and other protective measures were of great interest to the group. Consider channel excavation as opposed to barriers. Inability of the military to respond on time to bomb at the source is of concern. The liability issue for losses due to diverted flows.
	Mauna Loa Macadamia Nut Corporation	Concerns regarding feasibility of barriers for diversion and problems of liability. More scientific data needed in order to design effective barriers. Detailed engineering speculative in view of multiple uncertain variables.
	Business Interests Hawaii Island Chamber of Commerce Hilo Contractor's Association Downtown Improvement Association	Inequity in flow diversion. Rather collect from insurance company due to fire by lava than lose everything in protection attempts. Strongly recommended that some protective plan be adopted.
14 September 1979	Puna Sugar	Impacts of flow diversion would be minimal with respect to Puna Sugar activities.

i. The draft environmental statement lacks specific data on biological resources of the study area.

j. Construction of diversion barriers only in the event of a threatening lava flow is the most practical plan.

k. Opposition to any fixed barrier prior to eruption.

l. Should consider diversion into Wailuku River.

m. Study should include protection for other areas on the island.

10. These statements also reflect in general the type of views and comments received in written communications from the public. These letters and pertinent Corps of Engineers responses are included in the Section of this appendix titled "Report Comments and Responses."

DRAFT REPORT AND ENVIRONMENTAL STATEMENT REVIEW

11. The draft document was sent to the following agencies, groups, and individuals for review:

a. U.S. Government Agencies

Members of Congress, Hawaii
Advisory Council on Historic Preservation, Washington and Denver Offices
Department of Agriculture
  Office of the Secretary
  Soil Conservation Service
  Director, Forest Service
Department of Commerce
  Deputy Assistant Secretary for Environmental Affairs
  Regional Representative
  Economic Development Representative
Department of Defense
  Commander, USASCH
  Commander, Naval Base, Pearl Harbor, Hawaii
Environmental Protection Agency
  Regional Administrator
  Officer of Field Activities
Department of Health, Education and Welfare
  Regional Administrator
Department of Housing and Urban Development
  Assistant Secretary
  Regional Administrator
  Federal Housing Administration, Honolulu Office
Department of Transportation
  Federal Highway Administration
  Commander, 14th Coast Guard District

Department of the Interior
- Office of Environmental Project Review
- Interagency Archaeological Services
- Fish and Wildlife Service
- Ecological Services
- National Park Service
- Hawaiian Volcano Observatory, Geological Survey

b. State of Hawaii
- Governor of Hawaii
- Director of Civil Defense, Department of Defense
- Department of Transportation
- Department of Health
- Department of Land and Natural Resources
- University of Hawaii
- Deparmtent of Planning and Economic Development
- Department of Agriculture
- Environmental Center, University of Hawaii
- Water Resources Research Center, University of Hawaii
- Department of Hawaiian Home Lands
- State Historic Preservation Officer
- Office of Environmental Quality Control

c. County of Hawaii
- Mayor of Hawaii
- Hawaii County Council
- Department of Water Supply
- Civil Defense Agency
- Department of Public Works
- Department of Parks and Recreation
- Planning Department
- Department of Research and Development

d. Organizations and Private Interests
- Hawaii Audubon Society
- Hawaii Island Chamber of Commerce
- Hilo Contractor's Association
- Hawaii Tribune
- Hilo Community College

e. Individuals
- Dr. John P. Lockwood, Geologist
- Mr. Arthur G. Sylvester, Geologist
- Mr. Jay Sasan, Chairman, Big Island RC&D Council
- Mr. Michael Tulang, Director, Big Island RC&D Project
- Dr. Edwin Mookini, Chancellor, University of Hawaii at Hilo

REPORT COMMENTS AND RESPONSES

12. Pertinent correspondence received from government agencies, groups, and individuals are displayed in this section.

EXECUTIVE CHAMBERS

HONOLULU

GEORGE R. ARIYOSHI
GOVERNOR

February 22, 1980

Colonel B. R. Schlapak
Honolulu District Engineer
U. S. Army Corps of Engineers
Building 230
Fort Shafter, Hawaii 96858

Dear Colonel Schlapak:

Subject: Lava Flow Control Study, Island of Hawaii

The emergency plan for barrier construction, as described in the Draft Report and Environmental Impact Statement for Lava Flow Control, Island of Hawaii, provides a welcome supplement to the existing State Plan for emergency lava flow protection. The State of Hawaii supports this plan and is willing to provide the following assurances, when required:

a. Provide without cost to the United States all lands, easements, and rights-of-way necessary for the construction of barriers and related diversion facilities under emergency lava flow situations.

b. Hold and save the United States free from any damages or injuries due or resulting from or as a consequence of lava barrier construction, except damages due to negligence of the United States or its contractors.

c. Assume discretionary responsibility for the removal of the protective measures after their purpose has been served.

d. Assume responsibility for any litigation arising out of or from the implementation of the plan.

I appreciate the effort that has gone into this study and your assistance in providing for the well-being of the people of Hawaii.

With warm personal regards, I remain,

Yours very truly,

George R. Ariyoshi

DANIEL K. AKAKA
SECOND DISTRICT, HAWAII

COMMITTEES:
AGRICULTURE
MERCHANT MARINE AND FISHERIES
SELECT COMMITTEE ON POPULATION

Congress of the United States
House of Representatives
Washington, D.C. 20515

November 29, 1979

Lt. Colonel B.R. Schlapak
Deputy District Engineer
U.S. Army Engineer District
Fort Shafter, Hawaii 96858

Dear Colonel Schlapak:

This is in reference to a letter I recently received from my constituent, Mrs. Mele U. Spencer concerning the lava flow control study.

May I request that the final statement by the Army Corps of Engineers include answers to the questions raised in Mrs. Spencer's testimony. For your convenience, I have included a copy of Mrs. Spencer's statement.

Thank you for your assistance. If I may be of any assistance to you, please do not hesitate to contact me.

Aloha pumehana,

DANIEL K. AKAKA
Member of Congress

Enclosure

P. O. Box 1373
Hilo, HI 96720
November 18, 1979

Honorable Daniel Akaka
U.S. House of Representatives
Washington, D.C.

Dear Sir:

Enclosed is my testimony at the Lava Flow Control Study Meeting in Hilo.

My comments are self-explanatory in expressing my concern over the incompleteness of the study.

I would appreciate your assistance in seeing that my questions are answered by the Corps in their final impact statement. Thank you.

Respectfully submitted,

(Mrs.) Mele U. Spencer

The concern over the potential destruction of Hilo town is indeed a serious problem deserving of the study to minimize the liability to life and property. However, the Hilo lava flow control study is far from complete and fails to identify the problems that will be created, particularly as they will affect the people in the Puna area, if the emergency barrier diversion plan is implemented.

First, your impact statement identifies only the property loss to the town of Hilo. It does not identify the property loss to the North Hilo and Puna areas.

Secondly, how accurate is the diversion plan? Can the Corps accurately project the control of lava to the confines of the proposed flow corridors?

Thirdly, the diversion will cut all access to and from Hilo town for the Puna people. The study fails to show the economic loss to these people and even farther, the residents of Volcano and possibly Kau, due to loss wages for those working in Hilo and the agriculture production losses if these producers are unable to get their produce to market.

Fourthly, because the diversion plan will be "man-made", who is liable for the property and economic loss? The federal government? the State? the County? Is there a plan to assist people in getting to their jobs? Will the Federal Disaster Assistance Administration implement their programs even if the diversion is man-made? FDAA programs provide only low interest loans for physical and economic loss; not grants. Reduced property taxes and income tax write-offs are wholly inadequate.

There are approximately 8,000 people in the Puna area alone. Your flyers about this hearing were sent only to postal customers in the Hilo 96720 area. Why not the people in Puna? They are the ones that will feel the greatest adverse affects of the diversion.

Again, your study has failed to fully address the effects of the diversion plan and answer questions the people most adversely affected by this plan are entitled to have answered.

I urge you to expound on the study to include answers to the many questions still pending before any final plans for the lava flow control are adopted.

October 10, 1979

Mrs. Hele U. Spencer
P. O. Box 1373
Hilo, HI 96720
Phones: Res. 968-6216
Ofc. 961-5573

PODED-PJ 28 December 1979

Honorable Daniel K. Akaka
House of Representatives
415 Cannon House Office Building
Washington, D. C. 20515

Dear Mr. Akaka:

This is in reply to your letter of 29 November 1979 inclosing a copy of Ms. Mele U. Spencer's testimony at our 10 October 1979 Lava Flow Control Study public meeting. The following information is furnished in response to questions raised by Ms. Spencer.

a. The purpose of the damageable property survey in Hilo was to determine the order of magnitude of potential damages that can be prevented by protective measures. This determination is needed to establish the feasibility of various alternative plans in protecting the town of Hilo. The Puna District would be affected by lava diversion under the emergency barrier plan, through the agricultural area in northern Puna. Maximum damage due to the diversion works is estimated at about $9 million in north Puna. The estimated damage is discussed on page 29 of the draft report. North Hilo has not been affected by Mauna Loa eruptions in historic time and, therefore, was not a part of the study.

b. The extreme unpredictability of lava flow makes it impossible to determine accurately the effectiveness and reliability of the diversion. The barrier alignment and flow path would not be definitely known until the plan was implemented.

c. A major eruption of the northeast rift zone of Mauna Loa will likely divide Hilo town and the Puna District with or without diversion. Because of this with and without project condition, the economic losses were not investigated.

d. The proposed U.S. Army Corps of Engineers plan for emergency barrier construction would only be implemented at the request of the Governor as a component of the State of Hawaii Emergency Plan. The question of liability should the plan be implemented is being studied by the Corps and the State and will be addressed in the final report and EIS.

e. We are unaware of any plans for assisting people in getting to their jobs during an emergency. Request for assistance from the Federal Emergency Management Administration (formerly FDAA) is made by the Governor of Hawaii.

f. By letter dated 18 September 1979, 1,000 public notices were sent to the Postmaster at the Keaau Post Office. The letter of transmittal also noted that:

'Although the notices are for zip code of 96720, please distribute one notice to each postal customer with your zip code of 96749 by 25 September 1979.'

We are currently revising the subject report and environmental statement based on comments received. Additional information will also be incorporated to improve the clarity of the final report.

Your interest and concern in this study are appreciated.

Sincerely yours,

B. R. SCHLAPAK
Lt Col, Corps of Engineers
District Engineer

Copy Furnished:
Honorable Daniel K. Akaka
Representative in Congress
300 Ala Moana Blvd., Room 5104
Honolulu, Hawaii 96850

Ms. Mele U. Spencer
P.O. Box 1373
Hilo, Hawaii 96720

United States Department of the Interior
FISH AND WILDLIFE SERVICE
LLOYD 500 BUILDING, SUITE 1692
500 N.E. MULTNOMAH STREET
PORTLAND, OREGON 97232

November 15, 1979

In reply refer to
AFA-SE, #1-2-79-F-107

Mr. Kisuk Cheung
Chief, Engineering Division
Pacific Ocean Division
Corps of Engineers
Building 230
Fort Shafter, Hawaii 96858

Dear Mr. Cheung:

This responds to your letter of August 20, 1979, requesting formal consultation pursuant to Section 7 of the Endangered Species Act of 1973 and Amendments of 1978 (PL 95-632). It concerns the Hilo Lava Flow Control Study which attempts to develop a long-range plan for protecting the city of Hilo from lava flows. These listed species which may be affected by this project are: the endangered Hawaii creeper (Loxops maculata mana); Hawaii 'akepa (Loxops c. coccinea); 'akaipola'au (Hemignathus wilsoni); 'o'u (Psittirostra psittacea); 'io (Buteo solitarius); nene (Branta sandvicensis); Hawaiian hoary bat (Lasiurus cinereus semotus); and the threatened 'a'o (Puffinus puffinus newelli).

Project Description

The Corps draft interim report and environmental impact statement identifies a fully prepared emergency barrier plan as being the most desirable long term plan of protection. This plan is the tentatively selected Alternative E. The impacts of this plan, Alternative E, on endangered species will be addressed in this opinion.

This alternative is basically an emergency reaction plan. Barriers would be built (using available material) only during a volcanic eruption and in response to the flow of lava that occurs. These unknown and uncontrollable natural phenomena will determine the location and extent of lava diversion barriers, as described in Alternative E. There may be direct impacts on endangered species through destruction of habitat when the lava diversion barriers are constructed and/or indirect impacts may result from diversion of lava flows onto habitats important to these species, destroying these forest habitats.

Species Account

All of the listed species in question were once abundant or common, either throughout or at specified locales on the Island of Hawaii (Perkins, 1903, Baldwin, 1945, Peale, 1848). A number of causative factors have played a role in the decline of one or more of the species. Among the factors are: 1) avian disease, particularly introduced pathogens; 2) competition with exotic birds and other animals; 3) indiscriminate collecting; 4) elimination or degradation of habitat by cultivation, lumbering, livestock grazing, and exotic plant and animal introductions; and 5) predation. Island species are particularly vulnerable to any such factors because of their frequently low numbers, restricted geographical distribution, and the susceptibility of their ecosystems to drastic changes from introduced plants and animals.

Present population baseline data for these species are generally lacking, though continued forest bird surveys and studies are providing new information. Current data has shown the Hawaii creeper to be restricted to native forests above the 4,000-foot elevation where they are considered rare. Known populations occur in the Kilauea Forest Reserve and Keauhou Ranch on the eastern slope of Mauna Loa.

The Hawaii 'akepa is comparatively rare, reported from the eastern slopes of Mauna Loa and southwestern slopes of Hualalai. They are mostly concentrated in the Waiakea Forest Reserve and Keauhou Ranch.

The 'akiapola'au is locally common on the eastern slopes and high elevation of Mauna Loa and rare on Mauna Kea (Scott, et al. 1978). Present data show this species restricted mainly to the Waiakea Forest Reserve.

The 'o'u has only recently been reported from the Olaa Tract and adjacent forest lands of the Puna District of Hawaii. During the Hamakua Forest Bird Survey, the 'o'u was observed in the upper Waiakea and Hilo Forest Reserves. It also occurs in small numbers within the Alakai Swamp on the Island of Kauai.

The 'io is widely distributed over the island, but is not considered common in any district.

The nene occupies a remnant of its former range. They occur primarily from 5,000 to 8,000 feet in elevation on the Island of Hawaii. Investigation of known nesting areas and observations of pen-reared nene released in the wild indicate a population of approximately 750 individuals, which is stable or slightly increasing.

The 'a'o was recently reported from the Hawaii Volcanoes National Park. Others were observed in the Hamakua Forest and may be nesting undetected on the forested slopes of Mauna Loa in the study area. However, the species mainly breeds on the Island of Kauai.

The Hawaiian hoary bat is considered rare and presently has a scattered population on Kauai, Oahu, Maui, and Hawaii due to their nonsocial behavior (Tomich, 1969).

Conclusion

Because of the inability to predict barrier placement and lava flows, it is also difficult to predict potential impacts to these endangered species. However, we do know that a particular placement of a barrier, or directing a lava flow through a specific area, can have severe detrimental effects on those species that have restricted distribution on the eastern side of Mauna Loa.

The 'akepa, 'o'u, and 'akiapola'au have such population characteristics. These species are comparatively rare and significant numbers have been censused in portions of the forested areas of the Upper Waiakea Forest Reserve between approximately 3,500 to 5,800 feet.

It is, therefore, our opinion that Alternative E of the Hilo Lava Flow Control Study, as discussed above, is likely to jeopardize the continued existence of the 'akepa, 'o'u, and 'akiapola'au, due to the restricted distribution and the potential for catastrophic results should the Corps place a barrier and/or direct a lava flow through their habitat. Further, we are of the opinion that the subject project is not likely to jeopardize the continued existence of the Hawaii creeper, 'io, nene, 'a'o, and Hawaiian hoary bat due to their more dispersed distribution or because their population concentrations are outside of the project area.

The 1978 amendments to the Endangered Species Act include a mandate that "reasonable and prudent alternatives" be provided when a Biological Opinion indicates jeopardy to a listed species. "Reasonable and prudent" refer to alternative courses of action open to the Federal agency with respect to an activity or program that are technically capable of being implemented and consistent with the intended primary purpose of the activity or program. We believe the following recommendations are consistent with the definition:

1. The possibility of a lava flow inundating the Upper Waiakea Forest Reserve should be considered, and a "corridor" through the less environmentally sensitive areas should be determined. This corridor might consist of recent flows which are barren, or those with vegetation in an early successional state.

2. Lava diversion barriers should be designed for placement to protect the prime forest bird habitat in the study area.

3. The material for constructing the lava diversion barriers should be obtained from unforested portions of this study area whenever feasible.

We would also like to emphasize that the Corps of Engineers has the opportunity to utilize this project authority to promote the conservation of these endangered and threatened species as outlined in Section 7(a) of the Endangered Species Act. To meet this mandate of the Act, the Corps of Engineers, in cooperation with this Service, should identify sensitive areas in the general study area and should initiate studies necessary to ensure maximum conservation of endangered species of flora and fauna.

This concludes our formal consultation on the Hilo Lava Flow Control Study. If a plan other than Alternative E is selected, and if project modification beyond those suggested as alternatives occur, or if new information on listed species becomes available, reinitiation of consultation will be appropriate. We would appreciate notification of your intent in light of this opinion.

Sincerely yours,

Bill Meyer

William H. Meyer
Acting Regional Director

United States Department of the Interior

FISH AND WILDLIFE SERVICE
LLOYD 500 BUILDING, SUITE 1692
500 N.E. MULTNOMAH STREET
PORTLAND, OREGON 97232

August 31, 1979

In reply refer to:
AFA-SE - 1-2-79-F-107

District Engineer
Pacific Ocean Division,
Corps of Engineers
Building 230
Fort Shafter, Hawaii 96858

Dear Sir:

This acknowledges the request of Kisuk Cheung, Chief, Engineering Division, dated August 20, 1979, for consultation relative to Section 7 of the Endangered Species Act (ESA) for the Hilo Lava Flow Control Study Area.

We received your draft EIS, dated July, 1979, accompanying your request as a "biological assessment", as required for construction project, by Section 7 (c) of the ESA. Please be advised that the statement did not discuss the Newell's manx shearwater, a listed species known to nest on the Island, and did not list the Hawaiian hoary bat as endangered. (Please include these corrections in the revised DEIS to be released in November, 1979). Thus, this activity could affect a total of eight species: Hawaiian goose, Hawaiian hawk, akiapola 'au, Hawaii akepa, Hawaiian creeper, Newell's manx shearwater, Ou and Hawaiian hoary bat.

Your request was received here on August 21, 1979, and is being designated as case number 1-2-79-F-107. Please refer to this case number on any further correspondence.

We are assigning field work for this consultation to our Administrator at the following address:

Dale T. Coggeshall
Pacific Islands Administrator
300 Ala Moana Blvd. Room 5302
P.O. Box 50167
Honolulu, Hawaii 96850
Phone: 546-5608

His staff will likely want to review the project with your staff, and may need additional information. We will notify you of our conclusion within 90 days as required by the recent amendments to the Endangered Species Act.

Sincerely yours,

for David B. Marshall

E. B. Chamberlain, Jr.
Assistant Regional Director
Federal Assistance

United States Department of the Interior
FISH AND WILDLIFE SERVICE
LLOYD 500 BUILDING, SUITE 1692
500 N.E. MULTNOMAH STREET
PORTLAND, OREGON 97232

August 28, 1979

In reply refer to:
AFA-SE

Kisuk Cheung, Chief
Engineering Division
U.S. Army Engineer District, Honolulu
Building 230
Fort Shafter, Hawaii 96858

Dear Mr. Cheung:

As requested by your letter of June 29, 1979, and puruant to Section 7 of the Endangered Species Act of 1973, as amended in 1978 (ESA), you will find attached a list of listed and proposed endangered and threatened species that may be present in the area of the Lava Flow Control Study Area. It fulfills the requirement of the Fish and Wildlife Service to provide a list of species under Section 7(c) of the ESA.

As you are aware, the 1978 amendments to the Act require Federal agencies that are planning construction projects to conduct a biological assessment for the purpose of identifying any proposed and/or listed endangered and threatened species which are likely to be affected by their projects. This process is initiated by the constructing agency in requesting a list of listed and proposed endangered and threatened species. The assessment should be completed within 180 days after initiation of the assessment, or within such time period as is mutually agreed to between us. No irreversible commitment of resources is to be made during the biological assessment process which would result in violation of your requirement under Section 7(a) of the ESA. Your agency may continue working on plans, design and perform administrative action; however, no construction may begin.

With regard to the biological assessment, your agency should conduct a comprehensive survey of the area to identify any listed species or species proposed to be listed which may be affected by the construction project, and should determine the nature and extent of impact that the proposed project may have on such species, and should conduct any studies necessary to make such determination. Biological assessments should include: 1) the results of the comprehensive survey of the area; 2) the results of any studies undertaken to

determine the nature and extent of any impacts on identified species; 3) the agency's consideration of cumulative effects on the species or its Critical Habitat; 4) the study methods used; 5) difficulties encountered in obtaining data and completing the proposed study; 6) conclusions of the agency including recommendations as to further studies; and 7) any other relevant information.

Upon completion of the biological assessment, should you determine that a listed species is likely to be affected (adversely or beneficially), then your agency should request formal Section 7 consultation through this office. If there are both listed and proposed species that may be affected, then, if requested, we will informally consult on the proposed species during the formal consultation. However, should the assessment reveal that only proposed species may be affected, then you should consider informal consultation with our Area Office at the following address:

Dale T. Coggeshall
Pacific Islands Administrator
300 Ala Moana Blvd., Room 5302
P.O. Box 50167
Honolulu, Hawaii 96850
Phone: (808) 546-5608

One of the benefits of informal consultation to the consulting agency is to provide the necessary planning alternatives should a proposed (or candidate) species become listed before completion of a project.

Should you have any additional questions regarding your responsibilities under the Act, please contact the Area Manager listed above. We thank you for your interest in endangered species, and we await your assessment.

Sincerely yours,

John A. Sayre

John . Sayre
Acting Regional Director

LISTED AND PROPOSED ENDANGERED AND THREATENED
SPECIES THAT MAY OCCUR WITHIN
THE LAVA FLOW CONTROL STUDY AREA

LISTED SPECIES

Hawaiian goose, Branta sandvicensis

Hawaiian hawk, Buteo solitarius

Akiapola'au, Hemignathus wilsoni

Hawaiian hoary bat, Lasiurus cinereus semotus

Hawaii akepa, Loxops coccinea coccinea

Hawaiian creeper, Loxops maculata mana

Ou, Psittirostra psittacea

Newell's manx shearwater, Puffinus puffinus newelli

PROPOSED SPECIES

Makou, Botrychium subbifoliatum Brack.

'oha, Clermontia hawaiiensis Rock var. hawaiiensis

'oha, Clermontia lindseyana Rock

'oha, Clermontia peleana Rock

'oha, Clermontia pyrularia Hbd.

haha, Cyanea tritomantha Gray

N.C.N., Delissea fallax Hbd.

Hilo ischaemum, Ischaemum byrone (Trin.) Hitchei

'ohe, Joinvillea ascendens Brongn. & Gris.

Kamakahala, Labordia baillonii St. John

N.C.N., Labordia hirtella var. microcalyx Hbd.

Newell's 'ohia-lehua, Metrosideros collina var. newellii Rock

'aiea, Nothocestum longifolium var. rufipilosum Stone

Mohihi, Stenogyne scrophularioides Benth. var. scrophularioides

'ohe, Tetra plasandra kavaiensis var. dipyrena Sherff

UNITED STATES DEPARTMENT OF COMMERCE
The Assistant Secretary for Science and Technology
Washington, D.C. 20230
(202) 377XXXX 4335

September 25, 1979

Mr. Kisuk Cheung
Chief, Engineering Division
U.S. Army Engineer District, Honolulu
Department of the Army
Building 230
Ft. Shafter, Hawaii 96858

Dear Mr. Cheung:

This is in reference to your draft environmental impact statement entitled, "Hilo Lava Flow Control, Hilo, Hawaii." The enclosed comments from the National Oceanic and Atmospheric Administration are forwarded for your consideration.

Thank you for giving us an opportunity to provide these comments, which we hope will be of assistance to you. We would appreciate receiving eight (8) copies of the final environmental impact statement.

Sincerely,

Sidney R. Galler
Deputy Assistant Secretary
for Environmental Affairs

Enclosure — Memo from: Mr. John R. Apel
Environmental Research
Laboratories - RD/RF28
NOAA

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
ENVIRONMENTAL RESEARCH LABORATORIES
Pacific Marine Environmental Laboratory
3711-15th Avenue N.E.
Seattle, WA 98105

September 14, 1979

TO: PP/EC - Richard L. Lehman

FROM: RD/RF28 - John R. Apel for

SUBJECT: DEIS 7908.24 - Hilo Lava Flow Control, Hilo, Hawaii

The attached draft comments are forwarded for your reference and use as you consider appropriate.

Atch: Comment

Rec'd PP/EC
SEP 18 1979

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Region
Western Pacific Program Office
P. O. Box 3830
Honolulu, Hawaii 96812

August 31, 1979 FSW1:JJN

Colonel Peter D. Stearns
District Engineer
U.S. Army Engineer
District, Honolulu
Building 230
Ft. Shafter, Hawaii 96858

Dear Colonel Stearns:

The National Marine Fisheries Service (NMFS) has reviewed the draft environmental impact statement (DOC DEIS #7908.24), Hilo Lava Flow Control, Hilo, Hawaii (CE).

In order to provide as timely a response to your request for comments as possible, we are submitted this comment letter to you directly, in parallel with its transmittal to the Department of Commerce for incorporation in the Departmental response. The views submitted represent those of the NMFS. The formal, consoliated views of the Department should reach you shortly.

Resources impacted by implementation of the various alternatives are under the jurisdiction of the U.S. Fish and Wildlife Service (FWS). These include a number of species listed under the Endangered Species Act of 1973. It is, therefore, imperative that consultation under Section 7 of the Act take place between the Corps and FWS concerning potential impacts from the project on the various terrestrial endangered species in the area.

The NMFS recommends implementation of Alternative E, which has been designated the "Least Environmentally Damaging Plan" in the DEIS. We concur with the concept set forth in this alternative; that construction of lava diversion barriers should occur only in the event of a threatening lava flow. We strongly recommend against implementation of Alternative D (direct stream pickup of water for use in lava cooling) and Alternative C (pumping of seawater from Hilo Bay for lava cooling).

We hope these comments will be of assistance to you in selecting the appropriate alternative. Please send us a copy of the final EIS as soon as it becomes available.

Sincerely yours,
for Doyle E. Gates
Administrator

cc: Gary Smith, FSW3
Office of Habitat Protection, F7(4 copies)

PODED-PJ 6 November 1979

Mr. Sidney R. Galler
Deputy Assistant Secretary
for Environmental Affairs
US Department of Commerce
Washington, DC 20230

Dear Mr. Galler:

Thank you for your comments on the draft Lava Flow Control Report and Environmental Statement.

With respect to comments from the National Oceanic and Atmospheric Administration and as evidenced by the discussion in the DEIS, the Corps is well aware of the endangered wildlife resources in the study area. We have been coordinating closely with the US Fish and Wildlife Service since initiation of the study, and are currently involved in the formal consultation process with the Endangered Species Office.

In regard to the comments from the Environmental Center, University of Hawaii, we have previously responded directly to the Center. A copy of that reply is inclosed.

Sincerely yours,

1 Incl
As stated

KISUK CHEUNG
Chief, Engineering Division

UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF THE SECRETARY
PACIFIC SOUTHWEST REGION
BOX 36098 • 450 GOLDEN GATE AVENUE
SAN FRANCISCO, CALIFORNIA 94102
(415) 556-8200

ER-79/794

District Engineer
Honolulu District, Corps of Engineers
Building 230
Fort Shafter, Hawaii 96858

Dear Sir:

The Department of the Interior has reviewed the draft environmental statement and Survey Report (Combined), Lava Flow Control Study, Hilo City, Hawaii Island, Hawaii, and offers the following comments.

Because of the high potential for discovery of more archeological sites in the study area, we urge the Corps to complete its survey work so that contingency plans for emergency barrier construction can take significant cultural resources into account. The Corps should also consult with the State Historic Preservation Officer to evaluate the remainder of the known cultural sites in the area for their eligibility to the National Register of Historic Places.

It appears that only the Keaau Quarry, operated by the Allied Aggregates Corporation, would be directly affected by any of the five alternatives. The proposal tentatively selected by the Corps of Engineers would defer threaten Hilo City. Thus, the impact on mineral resources is expected to be minimal.

Hawaii Volcanoes National Park should be listed as an area of biological significance within the study area (page 11).

Although the proposed construction does not directly affect the park, we are interested in the protection of the forest as part of the critical habitat for endangered bird species.

The documents are adequate in their treatment of fish and wildlife resources. We understand that additional information on endangered and threatened species will be incorporated as it becomes available.

We appreciate the opportunity to review and comment on this document.

If you have any questions regarding these comments, please contact my office.

Sincerely,

Patricia S. Port
Patricia Sanderson Port
Regional Environmental Officer

cc: Director, OEPR (w copy incoming)
Director, Fish and Wildlife Service
Director, Heritage Conservation & Recreation Service
Director, National Park Service
Director, Bureau of Mines
Director, Geological Survey
Director, Office of Surface Mining
SHPO
Regional Directors

PODED-PJ 6 November 1979

Ms Patricia Sanderson Port
Regional Environmental Officer
Office of the Secretary
US Department of the Interior
Box 36098
San Francisco, California 94102

Dear Ms Port:

Thank you for your comments on the draft Lava Flow Control Report and Environmental Statement.

Provided the recommendation for Alternative E is authorized by the US Congress, additional cultural investigations will be conducted in the post-authorization phase. Topographic data from ongoing photogrammetric mapping studies will aid in refining the alignment. This, in turn, will determine where intensive cultural resources studies will focus. Results of these studies will make it possible to determine eligibility of potentially affected sites and to develop suitable mitigation. We have received input regarding cultural resource studies from the State Historic Preservation Officer, and will continue this coordination.

Implementation of any barrier alternative would utilize available material to be generated by stripping and excavation adjacent to the barrier. Borrow from quarries would not be needed.

The report will be modified to include discussion of Hawaii Volcanoes National Park as an area of biological significance within the Lava Flow Control Study area. As noted, additional data gathered during US Fish and Wildlife Service studies will be incorporated in the discussion of biological resources and anticipated environmental impacts. We have continued coordination with FWS throughout the study, and are currently involved in formal consultation regarding threatened and endangered species.

Sincerely yours,

KISUK CHEUNG
Chief, Engineering Division

United States Department of Agriculture
Soil Conservation Service
P. O. Box 50004
Honolulu, Hawaii
96850

September 13, 1979

Mr. Kisuk Cheung
Chief, Engineering Division
U.S. Army Engineer District,
Honolulu
Building 230
Ft. Shafter, HI 96858

Dear Mr. Cheung:

Subject: Draft EIS for the Lava Flow Control Study, Hilo, Hawaii

We reviewed the subject draft EIS and have the following comment: Plates I, II, and IV showing alternatives A, B and D, and E respectively, show that the lava is being diverted to the rural community of Olaa. The consequences of this diversion is not addressed in the draft EIS.

Thank you for the opportunity to review this document.

Sincerely,

Wm H Mann ACTING
Jack P. Kanalz
State Conservationist

PODED-PJ

5 November 1979

Mr. Jack P. Kanalz
State Conservationist
Soil Conservation Service
U.S. Department of Agriculture
P.O. Box 50004
Honolulu, Hawaii 96850

Dear Mr. Kanalz:

Thank you for your comments on the draft Lava Flow Control Report and Environmental Impact Statement (EIS). The draft EIS will be revised to evaluate the anticipated impacts of diverted lava flows.

Sincerely yours,

KISUK CHEUNG
Chief, Engineering Division

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION
INSTITUTE OF PACIFIC ISLANDS FORESTRY
1151 PUNCHBOWL STREET, ROOM 323, HONOLULU, HAWAII 96813

1950-3
September 5, 1979

District Engineer
U. S. Army Engineer District, Honolulu
Building 230
Ft. Shafter, Hawaii 96858

Dear Sir:

Reference is made to your Draft Interim Report and Environmental Impact Statement, Hilo Lava Flow Control project.

Generally the EIS is adequate, but some inaccuracies should be flagged. They are:

Page 11: There is no such area as the "U. S. Forest Service Ecological Research Area". It would be better to describe this as the Kilauea-Keauhou Study Area (in which the University of Hawaii, the Fish & Wildlife Service, and the U. S. Forest Service are conducting long-term research in cooperation with Bishop Estate, the owners). If the area referred to is the Upper Waiakea Forest Reserve then this statement should be deleted. Also, change National Area Reserves to Natural Area Reserves.

Page 59, paragraph b: The earliest European explorers (Cooke) reported grasslands, not forest, extended from sea level to 1000 to 2000 feet all along the Hamakua Coast, except in the gullies. This is the area now occupied by sugar cane. We don't know if this was natural or caused by Hawaiian cultivation. Ohia is dominant in the native forest from sea level to 4000 feet except in three locations (Plume Road, Waiakea; Kaumana; Honomu), where koa is the dominant species. Between 4000 and 6500 feet koa is the dominant species, except on shallow soils where ohia is dominant.

Page 59, paragraph c: The location of the koa forest as described in this paragraph would be about 2000 feet too high.

Page 65, paragraph b: The Upper Waiakea Forest Reserve is not dedicated to long range ecological research. The U. S. Forest Service is presently conducting a study of vegetation changes associated with the ohia decline in this area, but has no long term claim to the area.

The environmental consequences described from page 76 onwards are clear statements of the effects of the various alternatives.

Sincerely,

ROGER G. SKOLMEN
Project Leader

Copies to:

Clayton, PIF
Chaffin, R-5
State Forester

PODED-PJ

5 November 1979

Dr. Charles Hodges, Director
Forest Service
U.S. Department of Agriculture
1151 Punchbowl Street, Room 323
Honolulu, Hawaii 96813

Dear Dr. Hodges:

Thank you for your views and comments on the draft Lava Flow Control Report and Environmental Impact Statement. In reference to your specific comments, we furnish the following:

Page 11 and 65. The reference in the DEIS to a Forest Service Ecological Research area was derived from a letter written to the U.S. Army Corps of Engineers by Mr. Robert Nelson on 3 March 1977 on the subject of the Lava Control Study. The research area was discussed in more detail on page 65 (Section 4.10) in the DEIS. It is apparent from your letter that this site is no longer of special significance to your agency, and the EIS will be changed to reflect this. The incorrect reference to "National Area Reserve" will also be changed.

Page 59. The discussion of forest ecosystems in Section 4.07 will be modified to reflect information included in your letter.

Sincerely yours,

KISUK CHEUNG
Chief, Engineering Division

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Big Island RC&D Area Office, P. O. Box 915, Hilo, HI 96720

September 10, 1979

Kisuk Cheung, Chief
Engineering Division
Department of the Army
U. S. Army Engineer District
Building 230
Ft. Shafter, HI 96858

Dear Sir:

Generally, the document shows that there has been considerable thought in its preparation. I have listed a few comments which I feel could improve the report. They are as follows:

1. Page 51, paragraph 1: Realizing that the summary should be concise and understandable. The last sentence is confusing - is the primary intent of the lava barriers being considered to protect people or endangered plants and animals?

2. Page 51, paragraph 2, last sentence: There is a direct implication that there are cultural resources. Before such an impact can be mentioned, shouldn't proof of existence be assertained? The implication here is that there are cultural resources.

3. Page 63 & 65 map: Proposed Piihonua Natural Area Reserve... Recommend to check status...it is not a primary consideration now, according to the State of Hawaii, Division of Forestry.

The following are general comments. Throughout the text, the reader is lead to believe that for each alternative that mentioned a barrier will be constructed along the entire alignment. I am sure that this is not the intent. This fact is described in Section V, comparison of detailed plans but it is after the reader has waded through almost 40 pages. In fact, I would strongly suggest that the point that barrier segments would be constructed on an "as needed basis" and that dependent upon the flow location a combined total length may range from a mile to approximately nine miles.

This would mean then for any barrier construction, the total cost would be in the neighborhood of about $2.7 to $6.5 million and NOT the $16.0 million in Alternative A, and the $13.6 million in Alternative B.

Although this intent is alluded to in the introductory paragraph on page 25, there is still the basic confusion whether or not the Draft Environmental Statement should be addressing barrier segments in Alignments A, B, and D.

I questioning whether the presentation should be approached in this matter because of public's confusion, and misunderstanding. This is resulting in some unnecessary concern locally and adverse feelings towards the plan and the Corp of Engineers.

I suggest that if you intend to stay with the present format of the statement, there should be a clear distinction between the pre-emergency plan and the emergency action plan. This should be covered in the summary or throughout the document to preclude any misunderstanding.

Thank you for the opportunity to comment on the Statement.

Sincerely,

Michael C. Tulang
RC&D Area Coordinator

MCTulang:ltp 9-10-79

PODED-PJ

1 November 1979

Mr. Michael C. Tulang
RC&D Area Coordinator
Soil Conservation Service
US Department of Agriculture
P. O. Box 915
Hilo, HI 96720

Dear Mr. Tulang:

Thank you for your review comments on the draft Lava Flow Control Report and Environmental Impact Statement. Responses to your specific comments follow:

a. Page 51, paragraph 1: The primary intent of lava diversion is to reduce property damage. However, in accomplishing this objective through barrier construction, significant environmental impacts are anticipated. The purpose of the EIS is to describe those impacts and to consider mitigation measures to reduce the severity of impacts. In this way, the public and elected officials reviewing the document have a clear picture of the environmental consequences of their decisions.

b. Page 51, paragraph 2, last sentence: Section 4.13 (pages 67-70) of the DEIS briefly describes available information on cultural resources in the study area. As stated in the summary (Section 1.01), available data suggest that the likelihood of significant cultural resources decreases with elevation in the study area, so it is doubtful that important cultural resources would be directly affected by barrier construction. Provided the recommendation for Alternative E is authorized by the US Congress, additional cultural investigations will be conducted in the post-authorization phase.

c. Pages 63 and 65. You are correct in the reference to the present status of the proposed Piihonua Natural Area Reserve. The proposal has been deferred because of recently obtained data on the distribution of exotic plants in the lower elevation portion of the proposed Natural Area Reserve. According to Mr. Robert Lee of the Natural Area Reserves System

Commission, this site will be reevaluated in 1980 with a view towards possible expansion of the upper elevation boundaries at the same time that disturbed portions in the lower elevation area may be excluded.

General comments on alternatives. Of the four barrier plans (Plans A, B, D, and E), three plans are fixed alignment alternatives (Plans A, B, and D) whereby barrier construction would be implemented in advance of eruption. Plan E, which we designate as the emergency plan, consists of barrier construction on an "as needed basis," and its estimated maximum length is up to nine miles. This point will be clarified in the revised report on page 25. Clear distinction between the pre-emergency plans and the emergency plan will also be made on table 8.

Sincerely,

KISUK CHEUNG
Chief, Engineering Division

APZV-EHE-E

SUBJECT: Draft Survey Report and Draft Environmental Impact Statement (DEIS) for Lava Flow Control Study, Hilo, HI

District Engineer
US Army Engineer District, Honolulu
ATTN: PODED-PJ
Building 230
Fort Shafter, Hawaii 96858

1. Subject report and statement have been reviewed and US Army Support Command, Hawaii (USASCH) concurs with the tentatively selected plan (Alternative E) as being the least environmentally damaging.

2. USASCH responsibilities on page 21 of the report have been noted. However, since all Army units in Hawaii are under control of the MACOM (i.e. WESTCOM), clarification of responsibilities is requested. Perhaps future planning should also involve coordination with appropriate WESTCOM personnel.

3. The opportunity to review this document is appreciated.

FOR THE COMMANDER:

PETER D. STEARNS
Colonel, CE
Director of Engineering and Housing

PODED-PJ (28 Sep 79) 1st Ind
SUBJECT: Draft Survey Report and Draft Environmental Impact Statement (DEIS) for Lava Flow Control Study, Hilo, HI

DA Honolulu District, Corps of Engineers, Building 230, Fort Shafter, Hawaii, 96858 4 October 1979

TO: Cdr, USASCH, Fort Shafter, Hawaii 96858

1. USASCH responsibilities noted on page 21 of subject report reflect the State of Hawaii Emergency Plans option whereby the Governor may request CINCPAC to employ PACAF and USASCH to deliver military ordnance against lava flow targets.

2. With the formation of WESTCOM, coordination for all emergency planning regarding Army support is being carried out with the office of the WESTCOM Engineer through our Emergency Planning Manager.

B. R. SCHLAPAK
LTC, Corps of Engineers
District Engineer

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
AREA OFFICE
300 ALA MOANA BLVD., RM. 3318, P.O. BOX 50007
HONOLULU, HAWAII 96850

REGION IX
450 Golden Gate Avenue
P.O. Box 36003
San Francisco, California 94102

September 6, 1979

IN REPLY REFER TO:
9.1SS (Johnson/546-5554)

Mr. Kisuk Cheung
Chief, Engineering Division
U. S. Army Engineer District, Honolulu
Building 230
Fort Shafter, Hawaii 96858

Dear Mr. Cheung:

We have reviewed your Draft Interim Report and Environmental Impact Statement for Hilo Lava Flow Control dated July 1979.

We concur with your tentative recommendation, Alternative E, (Emergency Operation) for the protection of the City of Hilo from lava flow inundation. Protecting communities from natural hazards is also one of HUD's concerns:

The final report should identify all the preconstruction work, including legal, administrative, coordination, etc. necessary to assure barrier construction upon short notice during an emergency.

Thank you for the opportunity to review and comment on the Draft Report and EIS.

Sincerely,

Alvin K. H. Pang
Area Manager

PODED-PJ

24 September 1979

Mr. Alvin K. H. Pang
Area Manager
Department of Housing and
Urban Development
PO Box 50007
Honolulu, Hawaii 96850

Dear Mr. Pang:

Thank you for your review comments on the draft Hilo Lava Flow Control Report and Environmental Statement. The additional information indicated in your letter for the preconstruction work activities, including any necessary legal, administrative, and coordination arrangements will be identified in the final report.

Sincerely yours,

KISUK CHEUNG
Chief, Engineering Division

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

HAWAIIAN VOLCANO OBSERVATORY

HAWAII NATIONAL PARK, HAWAII 96718

IN REPLY REFER TO

August 10, 1979

Mr. Kisuk Cheung, Chief
Engineering Division
Dept. of the Army
U.S. Army Engineer District, Honolulu
Building 230
Ft. Shafter, Hawaii 95858

Dear Mr. Cheung:

Thank you for sending me the Draft Environmental Statement concerning the Lava Flow Control Study for Hilo, Hawaii.

As you know, there is no agreement among volcanologists about the effectiveness of lava flow control techniques. Their views, like those on surgical techniques in medicine, range from advocates to skeptics. The medical analogy is perhaps useful, because in both cases - erupting volcanoes and emergency patients - everything depends on individual circumstances.

A realistic plan for rapid mobilization of heavy construction equipment and operators is extremely important. But even more important is the advance establishment of a small group of advisors and a "fire boss" who can direct a concerted effort and make rapid changes in plans as required.

I realize your statement is not specifically directed to this leadership problem, but I'm taking some liberty in my reply to emphasize the importance of this aspect of any Lava Flow Control Plan. Any advisory group should include two volcanologists - one an advocate, the other a skeptic of lava flow control - in order to give the "fire boss" a balanced view.

The best laid plans are bound to fail if effective leadership is not available when an emergency arises.

I have made some minor suggestions in the text of the summary. A xerox copy of these ~~are~~ is enclosed.

Sincerely,

Robert W. Decker
Scientist-in-charge

cc: John P. Lockwood

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
September 9, 1979

Cheung Kisuk, Chief
Engineering Division
U.S. Army Corps of Engineers
Bldg. 230, Fort Shafter
Honolulu, HI 96858

Dear Mr. Cheung:

Thank you for the copy of your Hilo Lava Flow Control draft interim report and EIS.

This report presents a wealth of important information on the need for and the effects of lava diversion above Hilo. The Report's title suggests a complete review of lava flow control problems, but in fact it focuses almost entirely on lava barrier construction along with the excellent discussion of the environmental and economic impact of diversion plans. Some attention is paid to application of seawater (Alternative C), but the use of explosives is almost completely ignored except for a paragraph on p. 23. Of course it is not within the scope of this Report to discuss the use of explosives high on Mauna Loa, as this is the Kuleana of CINCPAC, but the Report's title should perhaps be less inclusive so as to alert the reader that the report is focused on lava diversion by barrier construction. The lava barrier contingency planning is a critically important, integral part of any general plan to divert lava should that be deemed necessary and feasible by County and State authorities, but it is only a part of the overall strategy, and the report should make extensive reference to the State Civil Defense plan, which provides the overall framework in which COE, as well as other agencies must operate.

Some of the published record of Mauna Loa's eruptive activity has been found to be erroneous, and some of these errors have crept into the report. I have noted a number of geologic changes, most of them minor, which seem appropriate--I shall discuss these by page number:

1) p. 1, Summary: The first sentence is true, but you might as well slate the full uniqueness of the Hilo threat with a sentence like "The City of Hilo is the only urban community in the United States that has been threatened by a lava flow in historic time."

2) p. 15, last paragraph: We now know the eruption of 1843 was primarily a Northeast Rift Zone eruption, although one vent did occur on the north flank. Accordingly, the first sentence should read: "Since 1843 there have been seven major. . ." In the second sentence, you write that "Eight major flows have resulted." Where does the figure "eight" come from? I record only seven flows, although of course each has several branches.

3) p. 20, 2nd paragraph: "Volume of extruded lava" should read "100 to over 300 yds.^{3}"

The figure "457 days" is wrong, this apparently is a typographical error refering to the "547 days" in Table 6, but this figure too is questionable.* For "other parts of the mountain," the 300 days eruption of 1859 is the longest.

4) p. 28, 1st paragraph: In the second sentence, add "in historic time" after "reached the coast."

The reference to probability of a single flow large enough to cover all of Hilo seems inappropriate. Studies in progress by Jane Buchanan-Banks show that no single flow of such extent has ever buried the entire area of present Hilo. Maximum width of any single flow is perhaps less than a kilometer in west Hilo, but widens to perhaps two kilometers in Keaukaha.

This is not a fatal error though, as the 0.0011 annual probability of a flow reaching the coast works out pretty well, so far as our present knowledge of prehistoric eruptive frequency. The cost/benefit analysis needs to be adjusted to reflect the fact that a "900 year" flow might conceivably, at worst case, only destroy perhaps one-half the Hilo property value.

5) p. 30, Table 6: There are several errors in this table, but the only one that affects this Report is the suggestion that the 1873 eruption lasted for two years. In fact Mauna Loa's summit was in very frequent eruption between 1872 and 1876, but infrequent observation doesn't allow us to say how long any one phase lasted. In any event, the eruptions were in the summit, not the Southwest Rift Zone as indicated by the published table.

6) p. 71, 4th paragraph: The seven flows from the Northeast Rift have occured since 1843 (change 1850).

7) Appendix, p. B-9, item 36: I couldn't agree more that extensive additional field work is sorely needed to maximize the chances of success of lava barriers and to minimize adverse environmental impact. I do question if "cleared trails" are needed to effect this though. Adequate geological surveys can be made without trails. Without these surveys, however, I fear lack of information on local relief and sources of easily rippable material make success of barrier construction questionable. I feel this extensive geological investigation is the most critically needed "missing ingredient" in an otherwise generally well-thought-out COE plan.

I hope these brief comments are of use.

* See comment 5)

Sincerely,

John P. Lockwood, Geologist

CC: J. Buchanan-Banks, D. Cox
R. Decker, J. Halbig

PODED-PJ

26 September 1979

Dr. John P. Lockwood, Geologist
US Geological Survey
Hawaiian Volcano Observatory
Hawaii Volcanoes National Park
Hawaii 96718

Dear Dr. Lockwood:

Thank you for your review comments on the Draft Lava Flow Control Report and Environmental Statement.

While we agree with you that the report's title suggests a complete review of lava flow control measures, there is little we can do regarding a less inclusive title. Administratively, the study title was adopted in compliance with the study authority which is US Senate Resolution dated November 1975. We will include an explanation at the beginning of the final draft report, i.e., the syllabus to alert the reader of the primary study effort. Reference to the State Civil Defense Plan which provides the overall framework for lava flow emergency operations will be made in applicable sections of the report.

We are currently revising the subject report based on comments received. Please be assured that we will correct the erroneous published record of Mauna Loa's eruptive activity noted in your letter as well as other suggested changes to the report.

Sincerely yours,

KISUK CHEUNG
Chief, Engineering Division

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Hawaii Volcano Observatory
Hawaii Volcanoes National Park
Hawaii, 96718

September 19, 1979

Cheung Kisuk, Chief
Engineering Division
U.S. Army Coprs of Engineers
Bldg. 230, Fort Shafter
Honolulu, HI 96858

Dear Mr. Cheung:

I have read with interest the Hilo Lava Flow Control - Draft Interim Report and Environmental Impact Statement, and was impressed by the careful and thorough research that went into the report.

I have little to add to Jack Lockwood's September 9 letter of review as my geologic mapping in the Hilo 7½' topographic quadrangle has only recently begun. However, I would like to amend slightly Jack's estimates of flow widths into Hilo. Reconnaisance geology indicates that in west Hilo the maximum width of any single flow is approximately two kilometers and possibly as much as six kilometers in Keaukaha. More detailed geologic mapping will refine these estimates.

Also, Jack's comment 6) would also apply to p. 53, section 2.02, first paragraph.

On p. 66-68, Archeological/Historical Resources, the report quotes from "...a recent cultural resource study by the Bishop Museum...". I would be most interested in obtaining a copy of this report if an extra is available; it not, would it be possible to borrow or buy a copy? I believe it could be useful in my present project.

I hope these comments are of use and would appreciate being placed on your mailing list to receive further publications on this subject.

Very truly yours,

Jane Buchanan-Banks
Jane M. Buchanan-Banks
Geologist

cc: J.P. Lockwood
D. Cox
R. Decker
J. Halbig

PODED-PJ

26 September 1979

Ms. Jane M. Buchanan-Banks
Geologist, US Geological Survey
Hawaii Volcano Observatory
Hawaii Volcanoes National Park
Hawaii 96718

Dear Ms. Buchanan-Banks:

Thank you for your review and comments on the Draft Lava Flow Control Study and Environmental Statement. Your comments and amended estimates of flow widths into the Hilo area will be used in revising the draft report.

As requested, one copy each of the "Archaeological and Historical Literature Search and Research Design" and "Inventory of Archaeological and Historical Resources", resulting from the Bishop Museum study, are inclosed. Also your name will be added to our mailing list to receive future publications on this study.

Sincerely yyours,

KISUK CHEUNG
Chief, Engineering Division

2 Incl
As stated

UNITED STATES DEPARTMENT OF AGRICULTURE
FARMERS HOME ADMINISTRATION
345 Kekuanaoa Street
Hilo, Hawaii 96720

September 10, 1979

Department of the Army
Attn: Colonel Peter D. Stearns
U. S. Army Engineering District, Honolulu
Building 230
Ft. Shafter, Hawaii 96858

Dear Colonel Stearns:

Re: Hilo Lava Flow Control
Interim Report and Environmental
Impact Statement

We have reviewed a copy of the referenced report and find it very informative. FmHA's programs for financing homes, businesses, farms, and other community facilities in the Hilo area dictate a necessity for our agency to keep apprised of programs such as yours. Accordingly, we would like to be included on your mailing list for future publications.

We sincerely appreciate your assistance on this request.

Sincerely,

for Dorothy F. Jensen
MEGUMI KON
State Director

Farmers Home Administration is an Equal Opportunity Lender. Complaints of discrimination based on race, sex, religion, national origin or marital status should be sent to: Secretary of Agriculture, Washington, D. C. 20250

PODED-PJ

24 September 1979

Mr. Megumi Kon, State Director
Farmers Home Administration
U.S. Department of Agriculture
345 Kekuanaoa Street
Hilo, Hawaii 96720

Dear Mr. Kon:

Thank you for your letter of 10 September 1979 concerning your review 66 the Draft Hilo Lava Flow Control Report and Environmental Statement.

We will include your agency on our mailing list for future publications.

Sincerely yours,

KISUK CHEUNG
Chief, Engineering Division

United States Department of the Interior
NATIONAL PARK SERVICE
HAWAII VOLCANOES NATIONAL PARK
HAWAII 96718

IN REPLY REFER TO:
L7619

August 24, 1979

Mr. Kisuk Cheung
Chief, Engineering Division
Department of the Army
U.S. Army Engineer District, Honolulu
Building 230
Ft. Shafter, Hawaii 96858

Dear Sir:

I have read with interest your Draft Interim Report and Draft Environmental Impact Statement for the Hilo Lava Flow Control. As the plan does not propose any direct control methods within the boundaries of Hawaii Volcanoes National Park, I have no comments relative to the national park. If, in the future, any plans or discussions involve operations of any sort within the national park, National Park Service State Director Robert Barrel and I should both be involved.

As the National Park Service is interested in maintaining the forest habitat outside of the national park for the benefits that accrue to endangered bird species within the national park, we are concerned that all alternatives, except Alternative E, would have major negative impacts.

One change we would like to make is that throughout the plan, such as on Page 11, Hawaii Volcanoes National Park is not listed as an identified area of biological significance and that must be taken into consideration.

Thank you very much for the opportunity to review the Hilo Lava Flow Control Plan.

Sincerely,

David B. Ames
Superintendent

HEADQUARTERS
NAVAL BASE PEARL HARBOR
BOX 110
PEARL HARBOR, HAWAII 96860

IN REPLY REFER TO:
002A:JWC:njp
Ser 1743

20 AUG 1979

From: Commander Naval Base, Pearl Harbor
To: District Engineer, U. S. Army Engineer District, Honolulu

Subj: Draft Survey Report and Environmental Impact Statement, Hilo Lava Flow Control

Ref: (a) DISTENGR HONO ltr PODED-PJ of 1 Aug 1979

1. The Draft Survey Report with Draft Environmental Impact Statement forwarded by reference (a) has been reviewed. The Navy has no comments to offer.

2. The opportunity to review the EIS is appreciated.

J. W. CARL
By direction

Copy to:
COMPACNAVFACENGCOM

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
215 Fremont Street
San Francisco, Ca. 94105

AUG 30 1979

Project #D-COE-K91000-CA

Mr. Kisuk Cheung
Pacific Ocean Division
Corps of Engineers
Building 230
Ft. Shafter HI 96855

Dear Mr. Cheung:

The Environmental Protection Agency (EPA) has received and reviewed the draft environmental impact statement (DEIS) titled HILO LAVA FLOW CONTROL.

The EPA's comments on the DEIS have been classified as Category LO-1. Definitions of the categories are provided on the enclosure. The classification and the date of the EPA's comments will be published in the Federal Register in accordance with our responsibility to inform the public of our views on proposed Federal actions under Section 309 of the Clean Air Act. Our procedure is to categorize our comments on both the environmental consequences of the proposed action and the adequacy of the environmental statement.

The EPA appreciates the opportunity to comment on this draft environmental impact statement and requests three copies of the final environmental impact statement when available.

If you have any questions regarding our comments, please contact Susan Sakaki, Acting EIS Coordinator, at (415) 556-6695.

Sincerely yours,

Carl C. Kohnert, Jr.
Carl C. Kohnert, Jr., Director
Surveillance and Analysis Division

Enclosure

EIS CATEGORY CODES

Environmental Impact of the Action

LO--Lack of Objections

EPA has no objection to the proposed action as described in the draft impact statement; or suggests only minor changes in the proposed action.

ER--Environmental Reservations

EPA has reservations concerning the environmental effects of certain aspects of the proposed action. EPA believes that further study of suggested alternatives or modifications is required and has asked the originating Federal agency to reassess these aspects.

EU--Environmentally Unsatisfactory

EPA believes that the proposed action is unsatisfactory because of its potentially harmful effect on the environment. Furthermore, the Agency believes that the potential safeguards which might be utilized may not adequately protect the environment from hazards arising from this action. The Agency recommends that alternatives to the action be analyzed further (including the possibility of no action at all).

Adequacy of the Impact Statement

Category 1--Adequate

The draft impact statement adequately sets forth the environmental impact of the proposed project or action as well as alternatives reasonably available to the project or action.

Category 2--Insufficient Information

EPA believes that the draft impact statement does not contain sufficient information to assess fully the environmental impact of the proposed project or action. However, from the information submitted, the Agency is able to make a preliminary determination of the impact on the environment. EPA has requested that the originator provide the information that was not included in the draft statement.

Category 3--Inadequate

EPA believes that the draft impact statement does not adequately assess the environmental impact of the proposed project or action, or that the statement inadequately analyzes reasonably available alternatives. The Agency has requested more information and analysis concerning the potential environmental hazards and has asked that substantial revision be made to the impact statement.

If a draft impact statement is assigned a Category 3, no rating will be made of the project or action, since a basis does not generally exist on which to make such a determination.

DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

COMMANDER
Fourteenth Coast Guard District
Prince Kalanianaole Federal Bldg.
300 Ala Moana Blvd.
Honolulu, Hawaii 96850

16450
Series 529
16 AUG 1979

Mr. Kisuk Cheung
Chief, Engineering Division
Department of the Army
U. S. Army Engineer District, Honolulu
Building 230
Fort Shafter, Hawaii 96858

Dear Mr. Cheung:

The Coast Guard has reviewed the Draft Environmental Statement for the Lava Flow Control Study, Hilo, Hawaii and has no objection to the plan or constructive comments to offer at the present time.

Sincerely,

J. F. OTRANTO
Commander, U. S. Coast Guard
District Planning Officer
Fourteenth Coast Guard District
By Direction of the District Commander

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
REGION NINE
Hawaii Division
Box 50206
Honolulu, Hawaii 96850

August 10, 1979

IN REPLY REFER TO
HEC-HI

Mr. Kisuk Cheung, Chief
Engineering Division
Department of the Army
U.S. Army Engineer District, Honolulu
Building 230
Fort Shafter, Hawaii 96858

Dear Mr. Cheung:

Subject: Hilo Lava Flow Control Study

Your letter of August 1, 1979 transmitted the Draft Survey Report and Environmental Impact Statement for the Corps of Engineers' Lava Flow Control Study, Hilo, Hawaii.

We have no comment concerning the Survey Report and EIS.

Thank you for the opportunity of reviewing the document.

Sincerely yours,

Ralph T. Segawa
Division Administrator

GEORGE R. ARIYOSHI
GOVERNOR

STATE OF HAWAII
OFFICE OF ENVIRONMENTAL QUALITY CONTROL
OFFICE OF THE GOVERNOR
550 HALEKAUWILA ST
ROOM 301
HONOLULU, HAWAII 96813

RICHARD O'CONNELL
DIRECTOR

TELEPHONE NO.
548-6915

November 15, 1979

Mr. Kisuk Cheung, Chief
Engineering Division
U.S. Army Engineer District
Honolulu
Building 230
Fort Shafter, Hawaii 96858

SUBJECT: Draft Lava Flow Control Report and Environmental Statement

Dear Mr. Cheung,

This refers to your response dated November 6, 1978, to our comments on the subject statement. We have reviewed these responses and find that they do not fully satisfy our concerns.

The potential impacts after the lava has been diverted successfully need further consideration. When the diverted lava hardens, it will cause a change in the terrain, thereby altering drainage patterns which in turn, may lead to severe flooding. Also, though the barriers may divert lava successfully, any subsequent lava flow may pose a greater threat to Hilo. These points should be given greater consideration.

If you should have any questions regarding this matter, please do not hesitate to contact us.

Sincerely,

Richard L. O'Connell
Director

PODED-PJ

27 December 1979

Ms. Mae E. Mull
Island of Hawaii Representative
Hawaii Audubon Society
P.O. Box 275
Volcano, Hawaii 96785

Dear Ms. Mull:

In response to your specific comments on the Draft Hilo Lava Flow Control Report and Environmental Statement, we offer the following:

a. In regard to the items in paragraph (1) of your letter, the deployment of aerial explosives was addressed on page 24 of our report. Results of the bomb cratering tests conducted by the U.S. Air Force and details on bombing lava will be added to the final report. Concerning the item of a government-subsidized insurance plan, the scope of this study was directed in response to the authorizing legislation for investigation of reducing the potential damage in Hilo due to lava flows. The implementation of an insurance plan is not within the scope of the study or the authority of the U.S. Army Corps of Engineers.

b. We concur with you regarding the manifold uncertainties of future Mauna Loa eruptions. For this reason, we concluded (page 39) that the first four alternatives involving advance construction would be less efficient and have greater risk of being unsuccessful than the emergency plan (Plan E). With regard to Public Law 84-99, amending the law as envisioned would provide the Corps authority to react in the event of a threatening lava flow. Authority for advance construction of diversion barriers of other structures in not being sought.

c. Regarding the State's Emergency Plan—first of all, we wish to correct the misconception that "The Corps was intimately involved in the development of the plan..." Although the State plan considers emergency barriers as a part of the overall protective plan, the contents and results of that plan were achieved by the State Civil Defense Agency in coordination with many State, County and federal agencies, one of which was the Corps. Our contribution to the present State plan is limited to the emergency barrier system developed in 1975 for the State

PODED-PJ

26 November 1979

Mr. Richard L. O'Connell, Director
Office of Environmental Quality Control
State of Hawaii
550 Halekauwila Street, Room 301
Honolulu, Hawaii 96813

Dear Mr. O'Connell:

This is in reply to your letter of 15 November 1979 restating your concerns on the Draft Lava Flow Control Report. Specifically, you noted greater consideration should be given to the potential impacts after the lava has been diverted successfully.

In the draft EIS, we noted that each of the five alternatives would result in significant adverse environmental impacts if implemented. These include impacts due to construction as well as flow diversion on both the physical and human resources. Because of the greater overall environmental impacts associated with the pre-emergency alternatives, the emergency plan (Plan E) has been designated as the most appropriate plan for implementation since barriers would not be constructed before the need arises. With respect to the diverted flow changing the terrain and drainage patterns, we fully agree with you that there will be changes in the surface drainage characteristics. It is important to note however, that drainage patterns will also alter due to the effects of natural lava flows. Intensification of the drainage changes would be supplemental to impacts associated with the natural flow itself. In assessing the difference in impact, it is extremely difficult to ascertain the significance of these supplemental changes. Within the probable lava flow corridor, there is no major perennial stream and general flooding in the Hilo area is attributed to the lack of defined stream channels in most cases. Given the possible variations in emergency barrier location and the uncertainties of drainage characteristics in that area, we have no basis to believe implementing Plan E will lead to severe flooding at this time. Should Plan E be authorized by the US Congress, additional engineering studies will be conducted to determine means to mitigate the flood potential if needed.

The implication of a greater threat to Hilo by subsequent lava flows is questionable since barriers would be constructed to guide the flow away from Hilo. It is expected also that subsequent lava flows will again necessitate emergency reaction by the concerned agencies.

Sincerely yours,

KISUK CHEUNG
Chief, Engineering Division

GEORGE R. ARIYOSHI
GOVERNOR

STATE OF HAWAII
OFFICE OF ENVIRONMENTAL QUALITY CONTROL
OFFICE OF THE GOVERNOR
550 HALEKAUWILA ST.
ROOM 301
HONOLULU, HAWAII 96813

RICHARD O'CONNELL
DIRECTOR

TELEPHONE NO.
548-6915

September 14, 1979

Kisuk Cheung, Chief
Engineering Division
Department of the Army
U.S. Army Engineer District
Honolulu
Building 230
Fort Shafter, Hawaii 96858

SUBJECT: Draft Interim Report and Environmental Impact Statement for Hilo Lava Flow Control

Dear Mr. Cheung,

We have reviewed the subject document and offer the following comments for your consideration:

1. Page 16

The document states, "If either of these eruptions had produced a flow equal in volume to the 1859 flow or the 1950 flow from the southwest rift zone, which had a volume comparable to the 1859 flow, the lava most likely would have covered most of the city and entered Hilo Bay". It should be noted that the southwest rift is steeper which increases the spread of the lava flow whereas the same flow on the northeastern rift would neither be as fast nor cover the same distance. Therefore, in making the cited statement, it should be recognized that the comparison is not based on similar topographical conditions.

2. Liability

The EIS lacks discussion about the legal liability of diverting lava flow. Who is liable for damages once the lava is diverted?

3. Diverted Lava Flow

It is important to discuss the possible route of lava flows once it has been diverted. Although a smaller population may be affected, the diverted lava will have an impact. Therefore, we recommend that discussion be given on the probable routes of the diverted and the resulting impacts. With this information, one can more thoroughly analyze the impacts of the five alternatives.

4. Lava Barrier

The possibility of the existing lava regaining heat and molting with the fresh flowing lava should be considered. If this does occur, how effective would the lava barrier be?

5. Page 75

Although in the appendices, Alternative E is more detailed, the text should reflect a more detailed description of the alternatives. For example, the description in the text does not indicate whether the barrier will be bulldozed or how high it will be.

6. Alternatives

Alternatives A & B seem to be short-sighted, "one-shot" mitigating measures. Although the diversion may work once, consideration must be given to subsequent lava flows in the same path. Would more barriers be required? Is the proposed action creating more problems to solve later? For example, when the lava hardens the change in terrain caused by the barriers may affect drainage patterns which could lead to severe flooding. The barriers may divert lava flows successfully the first time, but the second time it may pose a greater threat to Hilo. It is important to consider the long range impact of the proposed action.

Kisuk Cheung, Chief
DOA USAED
EIS Hilo Lava Flow Control
Page 3-

We are transmitting copies of the comments we have received on the subject EIS. We would like to request twenty-two copies of the final EIS when it becomes available.

We trust that out comments will be helpful to you in preparing the final document and look forward to the final EIS.

Sincerely,

Richard L. O'Connell
Director

Attachment

PODED-PJ

6 November 1979

Mr. Richard L. O'Connell, Director
Office of Environmental Quality Control
Office of the Governor
State of Hawaii
550 Halekauwila Street, Room 301
Honolulu, Hawaii 96813

Dear Mr. O'Connell:

Thank you for your views and comments on the Draft Lava Flow Control Report and Environmental Statement. Responses to your comments are as follows:

a. Page 16. In your statement, do you mean "speed" rather than "spread" as typed? The document statement reflects a hypothetical flow of 600 million cubic yards of lava along the 1880-1881 or 1942 lava flow alignment. Since the estimated volumes were 300 and 100 million cubic yards for the 1880-1881 and 1942 flows, respectively, superimposing 600 million cubic yards of lava to either flow by extension would result in lava flow reaching the ocean. As noted on page 15, the 1880-1881 flow with 300 million cubic yards came within 1-1/2 miles of the harbor. The steeper slope of the southwest rift is not a factor in this comparison of volumes.

b. Liability. Federal and non-federal responsibilities, including legal liability of diverting flows are discussed on page 41. This information will be expanded in the final report and summarized in the environmental impact statement.

c. Diverted Lava Flow. Section 7 (Environmental Consequences) of the environmental impact statement will be expanded to more thoroughly address the anticipated impacts of diverted flows. However, it should be noted that prediction of such impacts is largely speculative in view of the uncertainties of the natural flow characteristics as well as the duration and magnitude of diverted flows.

d. Lava Barrier. Information from the Hawaiian Volcano Observatory indicated that it is not possible for existing lava to regain sufficient heat to become fluid when in contact with fresh flowing lava. Regarding the effectiveness of the barrier, it is considered that subsequent diversions would be less effective than the initial diversion unless restoration work and corrective measures are accomplished through an operation and maintenance program. Maintaining the effectiveness of the barrier for subsequent diversions will be added in the revised report.

e. Page 75. Could your comments on alternatives have been made with reference to page 25? More detailed description of the alternatives will be included.

f. Alternatives. Our planning process provides for an approach to formulation in which an array of plans is developed to address the planning objectives. Alternatives A and B were formulated on the basis of barrier construction in advance of lava flow situations. Restoration work under the maintenance program for these fixed alignment alternatives to maintain the integrity as well as the effectiveness of the structure explained in item d above. On the probability scale, our analysis of the historic flow records indicated (page 27) that a flow which could affect Hilo such as the 1880-1881 flow, would occur once in 150 years. Some flows in the future may not reach the positioned barrier at all. Therefore, the maintenance work would most likely to be infrequent and limited to the barrier section located in the higher elevations closer to the source vent. In our evaluation and comparison of the detailed alternatives, it it is our conclusion that Plan E represents the best overall plan in that it is cost effective, and its long range adverse impact is less than the other alternative plans.

Sincerely yours,

KISUK CHEUNG
Chief, Engineering Division

GEORGE R. ARIYOSHI
GOVERNOR OF HAWAII

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
P. O. BOX 621
HONOLULU, HAWAII 96809

SUSUMU ONO, CHAIRMAN
BOARD OF LAND & NATURAL RESOURCES

EDGAR A. HAMASU
DEPUTY TO THE CHAIRMAN

DIVISIONS:
CONSERVATION AND RESOURCES ENFORCEMENT
CONVEYANCES
FISH AND GAME
FORESTRY
LAND MANAGEMENT
STATE PARKS
WATER AND LAND DEVELOPMENT

September 25, 1979

REF. NO.: APO-949
YOUR REF. NO.: PODED-PJ

Mr. Kisuk Cheung
U. S. Army Corps of Engineers
Building 230
Ft. Shafter, HI 96858

Dear Mr. Cheung:

We have reviewed the draft EIS for the lava control project.

We find that all alternatives have adverse environmental effects, but believe these to be secondary in importance to protection of Hilo.

In this light, we prefer alternative E which defers finalizing action until a threat is clearly posed. We encourage further study of this alternative in terms of detail. In addition it may be worthwhile to evaluate limitations in the effectiveness of the alternative.

Thank you for the chance to review this important study.

Very truly yours,

SUSUMU ONO, Chairman
Board of Land and Natural Resources

LAND A HAND TO CLEAN OUR LAND · STATE OF HAWAII

PODED-PJ

6 November 1979

Mr. Susumu Ono
State Historic Preservation Officer
Department of Land and Natural Resources
State of Hawaii
PO Box 621
Honolulu, Hawaii 96809

Dear Mr. Ono:

Thank you for your review comments on the draft Lava Flow Control Environmental Statement.

Provided the recommendation for Alternative E is authorized by the US Congress, additional engineering studies will be conducted during the post-authorization phase.

Sincerely yours,

KISUK CHEUNG
Chief, Engineering Division

GEORGE R. ARIYOSHI
GOVERNOR

STATE OF HAWAII
DEPARTMENT OF TRANSPORTATION
869 PUNCHBOWL STREET
HONOLULU, HAWAII 96813

RYOKICHI HIGASHIONNA, PH.D.
DIRECTOR

DEPUTY DIRECTORS
CHARLES O. SWANSON
JAMES R. CARRAS
DOUGLAS S. SAKAMOTO
JACK K. SUWA

IN REPLY REFER TO
HWY-PA
2.53340

September 27, 1979

Mr. Kisuk Cheung
Chief Engineering Division
Department of the Army
U.S. Army Engineering
District, Honolulu
Building 230
Fort Shafter, Hawaii 96858

Dear Mr. Cheung:

Subject: Hilo Lava Flow Control

This is in response to your letter dated August 1, 1979, requesting our comments on the "Draft Interim Report and Environmental Impact Statement" for this project.

We have noted that Alternatives A and B of this project have proposed the construction of barriers across two major routes, FAP 11 and FAS 200. In the interests of this department and the general public, we strongly recommend that barriers be terminated prior to reaching the highway facilities. Also, we suggest that a combination of Alternatives A, B, and E be investigated, whereby an upper segment of a barrier could be initially constructed, and during the time of flow, Alternative E could be implemented as neccessary.

We sincerely apologize for this late reply. If we may be of further assistance to you, please feel free to contact us at your earliest convenience.

Very truly yours,

T. Harano

T. HARANO
Chief
Highways Division

PODED-PJ

2 November 1979

Mr. Tetsuo Harano, Chief
Highways Division
Department of Transportation
869 Punchbowl Street
Honolulu, Hawaii 96813

Dear Mr. Harano:

Thank you for your comments on the draft Lava Flow Control Report and Environmental Statement. Based on our evaluation of the alterative plan and public input, Alternative E (emergency barrier plan) appear to be the most appropriate plan for implementation purposes.

In view of the uncertainties of lava flow and adverse environmental impacts associated with pre-emergency construction work, alternatives involving any construction in advance of damaging lava flows are considered less desirable than an emergency reaction plan.

Sincerely yours,

KISUK CHEUNG
Chief, Engineering Division

GEORGE R. ARIYOSHI
GOVERNOR OF HAWAII

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
P. O. BOX 621
HONOLULU, HAWAII 96809

SUSUMU ONO, CHAIRMAN
BOARD OF LAND & NATURAL RESOURCES

EDGAR A. HAMASU
DEPUTY TO THE CHAIRMAN

DIVISIONS:
CONSERVATION AND RESOURCES ENFORCEMENT
CONVEYANCES
FISH AND GAME
FORESTRY
LAND MANAGEMENT
STATE PARKS
WATER AND LAND DEVELOPMENT

September 21, 1979

Mr. Kisuk Cheung, Chief
Engineering Division
Department of the Army
Building 230
Fort Shafter, Hawaii 96858

Dear Mr. Cheung:

Subject: Lava Flow Control Study
Hilo, Hawaii - Draft EIS

Thank you for the opportunity to review and comment on the above named Draft EIS.

Although the Draft EIS has addressed the question as to whether any historical or archaeological sites within the area of impact are listed on the Hawaii or National Registers of Historic Places, they have not addressed whether any of the sites located in the archaeological survey contracted by them for this study are eligible for listing in the National Register in accordance with 36 CFR 800 nor have all areas under consideration been surveyed to locate potentially endangered sites.

Additionally, the EIS should address possible mitigative measures that will be applied to sites on the Hawaii or National Register of Historic Places or those sites eligible for the National Register which will be directly or indirectly impacted.

The completed survey and proposed mitigative measures would need to be completed prior to implementation of any of the proposed alternatives that would adversely effect any registered or eligible to be registered sites.

Sincerely yours,

Susumu Ono
State Historic Preservation
Officer

PODED-PJ

5 November 1979

Mr. Susumu Ono
State Historic Preservation Officer
Department of Land and Natural Resources
State of Hawaii
PO Box 621
Honolulu, Hawaii 96809

Dear Mr. Ono:

Thank you for your letter commenting on the draft Lava Flow Control Environmental Statement which was transmitted to us by the Office of Environmental Quality Control.

As noted in Section 7.13 of the DEIS (page 88), the US Army Corps of Engineers contract study identified no sites known to be eligible for, nominated to, or listed on the National Register of Historic Places that would be directly affected by construction activities. However, the study was based on a literature survey, interviews and field experience of the principal investigator. No field work was conducted specifically for this study. The contract study did note that two historic sites (Hawaii Consolidated Railway, 'Ola's Flume) and three historic trails (Hilo-to-Puna, Hilo-to-Volcano, Hilo-to-Pu'u 'O'o) cross the diversion corridor identified for Alternative E, but the significance of these resources has not yet been determined. Other unrecorded sites may also be found in this corridor, provided the recommendation for Alternative E is authorized by the US Congress, additional archaeological/historical investigations will be conducted in the post-authorization phase.

One aspect of the contracted cultural study focused on development of a suitable research methodology for future field studies. Topographical data to be obtained from recently contracted aerial mapping will assist in refining the probable alignment for diversion barrier construction and will also aid in predicting the path of diverted flows. Cultural field studies during the post-authorization phase would focus on the alignment under consideration and provide the data necessary to determine site eligibility and to evaluate mitigative measures.

Sincerely yours,

KISUK CHEUNG
Chief, Engineering Division

University of Hawaii at Manoa

Environmental Center
Crawford 317 • 2550 Campus Road
Honolulu, Hawaii 96822
Telephone (808) 948-7361

Office of the Director

September 13, 1979

RE:0287

Mr. Kisuk Cheung, Chief
Engineering Division
U.S. Army Engineer District, Honolulu
Building 230
Fort Shafter, Hawaii 96858

Dear Mr. Cheung:

HILO LAVA FLOW CONTROL

Introduction

We appreciate the opportunity to review the "Draft Interim Report and Environmental Impact Statement, Hilo Lava Flow Control." Comments incorporated in this review have been submitted by Doak C. Cox, Environmental Center; Joseph B. Halbig, Hilo College; and John Sorensen, Geography. Jack Lockwood, an affiliate of Hilo College has seen and criticized a draft of the review but will be submitting his comments as a member of the staff of the Hawaiian Volcano Observatory.

The hazard whose reduction is proposed in the report is the hazard to Hilo from Mauna Loa lava flows. The report discusses five alternative barrier schemes to reduce this hazard. Estimates of average annual damages without the barrier protection (or average annual benefits of the barriers) are presented in the report, and from these the costs of the barriers and the cost benefit ratios of most the schemes are calculated.

In this review we:

i) identify certain parameters whose identification is incomplete in the report and call attention to some variables influencing the probabilities of lava flows affecting Hilo that seem not to have been taken into account in the reported study and some possible additional evidences of these probabilities,

ii) discuss the form of the probability-size distribution for the lava flows;

iii) call attention to a factor that should have been taken into account in estimating the benefits of the barrier schemes that might well reduce the estimates by a factor on the order of 2;

iv) discuss the adequacy of impact assessment; and

v) call attention to the alternatives of lava-flow diversion through the use of explosives that has been quite inadequately evaluated in the report, and other alternatives that are not addressed in the report.

AN EQUAL OPPORTUNITY EMPLOYER

Estimation of annual lava-flow damages

In the reported study, certain relationships between lava-flow size and probabilities of occurence were derived. Lava flow sizes were then related to the damages they would cause in Hilo and the damages related to probabilities by way of their mutual relationships to size. Annual damages were then estimated from the damages expectable with various probabilities.

In the estimation of damages, only lava flows from the northeast rift of the Mauna Loa were considered, but probability-size relationships are presented in the report not only for those lava flows alone, but for the combination of those and north flank lava flows.

Probability-size distributions

The report states (p. 27, para. 2) that "Statistical analysis of the northeast rift eruptions reveals that a linear relationship exists between the logarithmic values of the area coverage of lava and the probability of occurrence." This linear relationship is not documented in the report, and a plot of log areas of lava flows vs. exceedence probabilities computed from the data in Table 6 (p. 30) relating to historical northeast-rift lava flows would indicate a decidedly curvilinear relationship. In the uppermost part of report Figure 4 (p. 33), log volumes erupted are plotted against what seems to be the log of the log of exceedence probabilities. (The numbers related to the latter are apparently percent probability per year, although this is not indicated in the figure.) One plot relates to the record of northeast-rift eruptions alone, the other to the record of northeast-rift and north-flank eruptions together. Both plots are curvilinear.

Plots of log areas covered and of log volumes erupted against log probabilities (Figure A attached to this memo), indicates that approximately linear relationships exist between these parameters. These relationships would seem to be a more satisfactory base for the further statistical analysis than either an assumed linear relationship between log areas and probabilities or the volume relationship plotted in report Figure 4. It is of interest to note, however, that extrapolation suggests an exceedence probability of about 0.0011 per year for a lava flow covering 55 square miles, a probability that is given for this area in the report (p. 28, para. 1). Hence, it is possible that no significant error has been introduced through the assumption of an invalid relationship.

The log-log relationship indicated in the case of northeast-rift lava-flow areas is equivalent approximately to:

$$P = 6.42\,A^{-2.16}$$

where A = lava flow area in square miles

P = annual probability of eruption of a lava flow with an area equalling or exceeding A.

Probabilities of lava flows affecting Hilo

The proposed barriers would provide protection from Mauna Loa flows alone. Of such flows, those erupted on the northeast rift present the greatest hazard to Hilo. The hazard is evaluated in the report by considering the historic record of Mauna Loa northeast-rift eruptions alone. The lava flows considered are historic members of the Kau volcanic series.

Not all Mauna Loa northeast-rift lava flows present hazards to Hilo. The 1935 eruption commenced on the uppermost part of this rift, one of the vents being on the edge of North Pit. If it had continued, one flow, leaving the rift zone about five mies northeast of North Pit, would passed west of the 1893 flow and been diverted in the Humuula Saddle toward North Kona rather than Hilo. The flow that ponded in the saddle and began to move toward Hilo emerged on the north flank, and apparently resulted from lava that was erupted originally on the northeast rift and poured into an open fissue from which it travelled underground to the north flank. One of the two flows of 1942 also originated at the summit, partly in North Pit and partly on the northeast rift. If the eruption on the upper part of the rift had continued, the flow from it, like that erupted highest in 1935, would have been diverted toward North Kona in the Humuula Saddle. A flow erupted as low on the northeast rift and as far south of the rift axis as Puu Kipu, a Kau series vent, even if it reached the sea, might miss Hilo, and if it did not would probably affect only the part of Hilo lying along the highway to Kilauea, the airport, and Keaukaha.

On the other hand, hazards to Hilo are presented by Mauna Loa flows other than those erupted on the northeast rift. The 1935 flow that reached the Humuula saddle and turned east emerged at the surface on the north flank, although the lava may have been erupted first on the northeast rift and then travelled underground in a pre-existing lava tube. If the vent of the north-flank flow of 1843 had been located half a mile east of its actual location, the flow would have followed about the same path as the lower 1935 lava flow.

Significant hazards to Hilo seem limited to flows originating on the northeast rift higher than Puu Kipu but lower than the 1935 rift vent, or on the north flank between the flow of 1843 and the northeast rift.

The extent of the hazard to Hilo of a lava flow originating thus would depend upon the vent location as well as on the size of the flow. To reach Hilo, a flow erupted above the 1899 vent would have to be larger than one erupted below the 1842 and 1942 vents. If flows from these two sources discharged equal volumes of lava into the sea, that from the lower source might affect Waiakea and areas to the south and east but not the old portion of Hilo proper, whereas that from the upper source vent might be channedled along the Wailuku River west of Puu Halai and destroy the old portion of Hilo but not areas to the south and east.

The historic record of northeast-rift eruptions and north-flank eruptions is so meager that considerable uncertainty must attach to any estimate of the probabilities of damage to Hilo from these eruptions based on that record alone. Some additional guidance might be provided by consideration of the size/probability distributions for the south rift and summit eruptions and the relationship between these distributions and that of the northeast

rift. We understand that additional information on the historic record of south rift eruptions is available from work at the Hawaiian Volcano Observatory by Peter Lipman.

The historic record of Mauna Loa eruptions begins in 1832. The 147 year period of record is extremely short for extrapolation to periods on the order of 900 years, which the report indicates is necessary for a satisfactory determination of the probabilities of lava-flow damage in Hilo. Approximate dates of pre-historic lava flows in Hilo established by the Hawaiian Volcano Observatory would provide very useful guidance to the estimation of probabilities of lava flows invading Hilo.

The risk to Hilo from lava flows originating on the north flank may approximately balance the lack of risk from lava flows from the uppermost and lowermost parts of the northeast rift, and it is possible that no substantial change in the damage probability estimates would result from detailed analysis of the vent-location effects, from the probability size relationships of lava flows originating in other parts of Mauna Loa, or from the dating of pre-historic lava flows. However, considering the importance of the estimation of the damage probabilities, it is disappointing to see in the report no evidence of extension of the analysis to include the effects of source vent locations, comparative statistics for different vent regions of Mauna Loa, or evidences of the dates of pre-historic lavas in Hilo.

Lava flow size-damage relationship

Details of the relationship assumed between the sizes of northeast-rift lava flows and the damages they would cause in Hilo are not indicated in either a table or figure in the report. However, three points on the area-damage curve are indicated by discussion in the report.

Appendix A presents a detailed property value study leading to an estimate of a total depreciated replacement value of $706 million after adjustment for evacuation. This estimate, and its components, appears also in Table 5 (p. 28) of the report. The destruction of Hilo Harbor is estimated in the report (p. 28, para. 1) as the cost of dredging a replacement, $40 million. It is assumed that the destruction of both all property in Hilo and Hilo Harbor, a total of $746 million, would result from a lava flow of 55 square miles. Damages of $150 million are estimated for a flow of 27 square miles (p. 27, para. 4), and $7.8 million for a flow of 24 square miles (p. 27, para. 3).

Probability-damage distribution as estimated in report

The probability-damage distribution estimated in the reported study is shown in the lower part of report Figure 4 (p. 33). The damage figures are identified as billion dollars, but the probabilities are identified only as percent chance of occurrence. It appears that the numbers relate to percent probability per year.

The probabilities associated with the damages estimated for lava flows of 24, 27, and 55 square miles, when combined with the formula for probability-size formula derived earlier, fall on the damage-frequency curve in report Figure 4. However, there is in the figure an unexplained increase in damages associated with very low probabilities, those less than about 0.0005 per year.

Integration of the probability-damage curve would apparently lead to an estimate of average annual damages of $2.74 million.

Benefit estimation

Barrier alternatives A through D

The report indicates that it was assumed in the study that the benefits of the proposed barriers will be identical to the damages that would result without protection in the areas to which protection is provided. The $150 million damages of a 200-year eruption (27 square mile lava flow area) and $746 million damages of a 900-year eruption (55 square mile area) are indicated (p. 28, para. 2) as benefits of alternative barrier schemes A, B, and D; and the $2.74 average annual damages estimate is indicated as the average annual benefit of the same schemes. The average annual benefit of $2.54 million for scheme C, which would not provide protection to Kaumana, appears to represent the total average annual damages without protection in the rest of Hilo.

The assumption that the benefits of protection would equal the total damages without protection would be valid only if it could be assumed appropriately that the barriers will be completely successful in diverting the lava flows from the areas they are intended to protect. There are good reasons for believing that complete success will be impossible.

Failures have occurred with previous barriers. They may result from overtopping or breaching. Yet there is in the report no discussion of either mechanism of possible failure; no comparison of the barriers proposed and the terrains in which they are proposed with the barriers and terrains in previous trials; no discussion of the probabilities of failures of the proposed barriers; and no reduction of the estimated benefits on account of these probabilities.

No matter how carefully a barrier may be located and designed, there must be some non-negligible probability that it will not divert a lava flow as intended, even if the flow is a simple one. The lava flows that result from extended eruptions characteristically include many flow units, some of which are overlapping and others of which follow different paths more or less parallel but distinct paths.

Tabulated below are the durations, areas covered by lava flows, and volumes of lava of the four largest eruptions of the north flank and northeast rift of Mauna Loa.

Eruption	Vent location	Duration days	Coverage sq. mi.	Volume million cu. yds.
1859	N flank	300	32.7	600
1880-81	NE rift	280	24.0	300
1843	N flank	90	20.6	250
1899	NE rift	16	16.2	200

The general occurrence of multiple flow units will be recognized from inspection of maps showing the coverage of these lava flows and other large ones.

Whether or not a lava flow arrives at a diversion barrier in one unit or multiple units and, if in multiple units, the relative location of the successive units, would seem to have considerable importance in determining whether the flow would be completely diverted by the barrier. If, at the elevation of the barrier, any lava flow included two units emplaced sequentially, there is at least a 50 percent chance that the second unit will meet the barrier atop or uphill from the first unit. Although the first unit may be diverted by the barrier, it may well pile up so high against the barrier as to that the second unit, even if it is ponded briefly, will overtop the barrier. If it is the later unit that flows the farthest and is capable of doing the most damage, the benefit of the barrier will be greatly reduced and may be nil. If more than two units of a lava flow reach a barrier, the chance of its being overtopped may be distinctly greater than 50 percent.

We suggest that the combined probabilities of failure in the case of a simple lava flow and of overtopping by a late unit of a complex lava flow may be on the order of 0.5. If so, the benefit cost ratios indicated in the report for alternatives A, B, C, and D should be reduced to about half the values indicated on the report (p. 27).

Barrier alternative E

Barrier alternative E, in which barrier construction would not be undertaken until after an eruption has begun and the probable path of the lava flow without diversion has been determined, is designated as the preferred alternative barrier scheme, without a clear statement of reasons. For reasons indicated (p. 29, para. 4), no estimates of benefits, costs, or the benefit-cost ratio are presented in the report other than a possible range of the ratio from 0 to 280. Bases for this range are not indicated.

It would appear that a reasonable estimate of the benefit-cost ratio for this alternative could be made for comparison with the ratios for the other alternative. The average annual benefits would be estimated in the same manner as in the case of alternatives A through D. In estimating the average annual costs, however, it would be necessary to estimate separately the probability that construction of each proposed barrier increment would be justified. These probabilities would be based on the size-probability relationships already developed, but even if the analysis did not include the variable of vent location would have to allow for differences in flow-path locations. Presumably the probability of a flow following a path more or less along the Wailuku River would be greater than other paths toward Hilo. The probability of a flow reaching a first barrier increment, being diverted by it, and approaching the site of a second barrier would then have to be estimated from the difference between the probability associated with the size of flow justifying the construction of the next barrier increment and the probability associated with the size of the flow justifying the construction of the first barrier increment alone. The probabilities of lava flows justifying the construction of third and succeeding barrier increments would have to be similarly estimated. The average annual costs for alternative E would be the sum of the products of costs and probabilities associated with the sum of all of the individual barrier increments. Environmental impacts of barrier alternative E are not described in the report, but impacts with various degrees of probability could be estimated, using the same method of probability estimation as in the case of costs and benefits.

No discussion is made of possible constraints to implementing Alternative E when a flow occurs. The report assumes that existing political social and economic are static and will not change in future years. Changes in political structure, individuals in key positions, public opinions or economic conditions could strengthen or weaken the ability to construct emergency barriers at some future date. For example, a party might file suit for a judge to issue a restraining order which would prevent the emergency barriers from being constructed. The suit could rest on a variety of grounds including possible damages from diverted flows, or on cultural or social grounds.

Environmental Impact Assessment

The need to assess the impacts of proposed barrier alternative E and means for the assessment have already been mentioned.

The report is not responsive to the social impact concerns raised by citizens as outlined in Appendix C. Furthermore community hearings are not a good means of measuring public preferences for this type of action. The report and EIS should go further in defining public values as they relate to this proposal.

Alternatives

Both State and Federal laws require that reasonable alternatives to a proposed project be examined in an environmental impact statement. Neither limits the requirement to the alternatives whose implementation happens to fall within the responsibility of the agency proposing the project. Yet the examination of alternatives in the report, other than barrier alternatives, are quite inadequately examined in the report, due presumably to the fact that implementation of the other alternatives is no within the purview of the Corps of Engineers.

Land-use restrictions

The report states that land use management "would be unacceptable to the resident population," yet no basis for making this statement is offered.

Insurance

Despite the disclaimer of ability offered on page 23, the probability and economic analysis in the report could provide a preliminary basis for estimating actuarial ratesd for lava-flow damage insurance. In fact, a county-sponsored (or state) self-insurance program with federal backing may provide an attractive alternative, particularly when tied into a plan to build emergency diversion barriers and land use planning to direct growth North of the Wailuku River.

Use of explosives

Although aerial bombing has been used to divert lava flows in Hawaii, the possibility of protecting Hilo by bombing is dismissed in the report (p. 23) with the comments that the effects of bombing would be different depending on whether it was a spatter cone, a lava channel levee, or a lava tube that was bombed, and that the success of bombing would depend on weather conditions and visibility. The report does not seem even to mention the possibility of producing the same results as those of bombing through shelling or through the manual emplacement of explosives next to a channel.

The failure to analyse the costs and probable effectiveness of bombing, shelling, and other means of emplacement of explosives and to compare the cost-benefit ratios with those of the proposed diversion barriers is a major weakness of the report.

As in the case of barrier effectiveness, it would be necessary to employ probability analysis. Although the probability of achieving the diversion of a lava flow by bombing at any one time may be small due to weather conditions, and the probability of diverting a lava flow by bombing, shelling or other means of emplacement at any one site may be small due to the lack of a weak natural retaining structure at site, the probability would seem substantial that a major, long-continuing lava flow unit could be diverted by bombing or shelling at some vulnerable site during the interval between the time diversion seemed warranted and the time when diversion would be necessary to avoid the advance of the flow-unit front into Hilo. Diversion of a flow by bombing or shelling will not eliminate the risk posed by that flow to Hilo, but if the supply of lava to the front of a first flow unit threatening Hilo is diverted, and the advance of that flow unit is halted, it may be weeks or months before the next flow unit threaten Hilo, its advance also may be halted by diversion by bombing. The process could be repeated of three or more times until the threat is ended by the natural termination of the eruption.

Combinations

The various alternatives are not all mutually exclusive. It would be possible, for example, to adopt a lava-flow hazard management scheme that combined barrier construction, land-use, restriction, and insurance. A particularly attractive combination is barrier construction in accordance with alternative E and the use of explosive, with or without land-use restrictions and insurance.

The choice between the construction of barriers, the use of explosives or both, the timing of barrier construction and/or explosive use, and the locations where barriers would be constructed or explosive of barrier construction and/or explosive use would be left, as in the case of barrier alternative E, until after an eruption started and a lava flow poses a significant hazard to Hilo. This combination shares with barrier alternative E the advantage that no costs (either monetary or environmental) would be incurred until the need arises and that the costs (of both kinds) would be more or less commensurate with the extent of risk. Whatever the benefit/cost ratio of barrier alternative E, the ratio of the combination could be no smaller and might be considerably greater.

<u>Summary</u>

The report contains a great deal of information that will be sueful in deciding on an appropriate lava-flow hazard management scheme for Hilo. However, some improvements should be made in the risk assessments presented, and the estimation of benefits and benefit/cost ratios presented in it do not take into account very significant probabilities that the barriers it proposes would fail. The discussion of alternatives other than barriers is superficial.

As it now stands, the report is an inadequate base on which to make a decision as to the most appropriate management scheme.

Yours very truly,

Doak C. Cox
Director

DCC/df

cc: Joseph B. Halbig
John Sorensen
Jack Lockwood
Office of Environmental Quality Control

PODED-PJ 2 October 1979

Dr. Doak Cox
Environmental Center
University of Hawaii
2550 Campus Road
Honolulu, Hawaii 96822

Dear Dr. Cox:

This is in reply to your letter of 13 September 1979 commenting on the draft Hilo Lava Flow Control Report and Environmental Statement.

As stated in the report, implicit in the formulation of plans was the realization that Mauna Loa eruptions follow no definite pattern and that frequency, location, duration, and volume of flow cannot be predicted with any degree of certainty. The uncertainty of probable damages to Hilo is also recognized. For the intended purpose of establishing the need for and authorization of participating in lava flow situations, we do feel the subject document has demonstrated the desirability of a protective barrier plan as a component of the State Civil Defense Emergency Plan. The following are our views and/or explanations to your comments:

a. Probabilities of lava flows affecting Hilo. The proposed barriers are viewed as one of the implementable protective measures. We did not state that the proposed barriers would provide protection from Mauna Loa flows alone as noted in your letter (first sentence, page 3). We agree with you that the historic record of northeast rift and north flank eruptions is meager. The relevancy of including the size/probability distributions for the south rift and the summit eruptions and correlation studies with those of the northeast rift were considered inappropriate in view of the differences in topographic and flow characteristics. However, the ongoing work being accomplished by Jack Lockwood and Jane Buchanan-Banks along the northeast rift and pre-historic lavas in Hilo will provide additional guidance for the damage probability estimates.

b. Probability-size distributions. Our analysis is based on a derived linear relationship between log areal coverage of lava and

log probability of occurrence which is exactly the same as what you noted. The intuition of the sentence (page 27, para 2), "Statistical analysis of the northeast rift eruptions reveals that a linear relationship exists between the logarithmic values of the areal coverage of lava and the probability of occurrence,' was to present this true linear relationship rather than the relationship between log area and probability of occurrence which is curvilinear. It will be clarified in the revised draft report.

c. Lava flow size-damage relationship. The relationship between the sizes of northeast rift lava flows and the estimated damages will be tabulated in the revised draft report.

d. Probability-damage distribution. The damage-frequency curve relates percent change of occurrence and the damages on an annual basis. Figure 4 will be clarified.

Damages resulting from less frequent eruptions should equal or exceed those of more frequent eruption. Increase in damages associated with very low probabilities as indicated on the damage-frequency curve is an estimation of additional damages to reflect less successful evacuation or possible higher harbor dredging cost for extremely destructive lava eruptions.

e. Benefit estimations.

(1) Barrier alternatives A through D: Probalities of failures of these alternatives are practically impossible to derive with reasonable accuracy. Based on the suggested 50 percent chance of failure, reduction of benefit to half will only render alternative D economically infeasible. However, the accuracy of this estimated probability of 0.5 is subject to debate.

(2) Barrier alternative E. Bases for a possible range of B/C ratio from 0 to 260 for alternative E are discussed on page 29. It is based on two possible extreme conditions.

(a) the expenditures for emergency actions will not generate any benefit; and

(b) all damageable properties ($746 million) in Hilo could be protected by emergency activities at a cost of about $2.65 million.

Average annual benefits and changes for alternative E were not estimated due to the wide range of possibilities. Due to implementation only in time of emergency and at a cost lower than other alternatives evaluated, Plan E was identified as the NED (National Economic Development) Plan as well as the LED (Least Environmentally Damaging) Plan. The tentative

PODED-PJ
Dr. Doak Cox

2 October 1979

recommendation of Plan E is based on this plan identification and further detailed analysis of B/C ratios would not alter the above stated conclusions.

Implementating alternative E, as a part of the overall State Civil Defense Emergency Plan will be made along with other possible protective measures by other involved agencies. The report assumes that emergency barriers will be implemented only on the request of local officials at that time.

f. Environmental Impact Assessment. Environmental impacts for alternatives "A" to "E," inclusive, were discussed in the draft Environmental Impact Statement on pages 76-90. Specific reference to the impacts of alternative E on geology, water supply, water quality, air quality, noise, flora, fauna, aquatic biota, marine biota, dedicated use areas, education/research, recreation, archaeological/historical resources, aesthetics, and socio-economic were included.

Discussion of socio-cultural aspects of lava flow and people's response to them are discussed on pages 75, and 89-90. In general, this discussion addresses the concerns raised by the public as documented in appendix C.

As a part of post-authorization, more intensive social and cultural studies will be undertaken including a study of Hawaiian "Pele" legends to learn more about how ancient Hawaiians perceived and coped with volcanic eruptions. The saliency and popularity of these beliefs among modern-day Hawaiians and other ethnic groups should also be further studied as one of many measures of defining public values as they relate to proposals to control or not control lava flows.

g. Alternatives. The alternative plans were developed on the basis of implementability, regardless of the implementation agency. It should be noted that we did not dismiss the use of explosives. On the contrary, we acknowledged its use under proper conditions on page 24. Regarding land use restrictions, the unacceptability is in reference to limiting repair or replacement of existing property as it deteriorates as discussed on page 22. On insurance, we took a positive responsibility to assure that the options are implementable. There is no county or state-sponsored self-insurance program with federal backing that we know of. Being the case, we do not wish to raise false expectations until this option can be transformed from concept to reality by the responsible agencies. Additional information relative to various protective measures will be incorporated to improve the clarity of the final report.

Sincerely yours,

KISUK CHEUNG
Chief, Engineering Division

DEPARTMENT OF PLANNING
AND ECONOMIC DEVELOPMENT

GEORGE R. ARIYOSHI
Governor

HIDETO KONO
Director

FRANK SKRIVANEK
Deputy Director

Kamamalu Building, 250 South King St., Honolulu, Hawaii • Mailing Address: P.O. Box 2359, Honolulu, Hawaii 96804

September 14, 1979

Ref. No. 9939

Mr. Kisuk Cheung
Chief, Engineering Division
Department of the Army
U.S. Army Engineer District, Honolulu
Building 230
Ft. Shafter, Hawaii 96858

Dear Mr. Cheung:

Subject: Hilo Lava Control Draft Interim Report and Environmental Impact Statement

We have reviewed the subject document and have the following comments to offer.

While we support in concept the thrust of the subject project to minimize loss to life and property resulting from future lava flows in the Hilo area, we do not have any detailed comments to offer at this time. Since the alternatives advanced in this report promise to impact on the objectives and policies of the Hawaii Coastal Zone Management Program, however, we would appreciate being kept abreast of any new developments in this important area of study.

Thank you for the opportunity to review this important document.

Sincerely,

Frank Skrivanek
for Hideto Kono

GEORGE R. ARIYOSHI
GOVERNOR

STATE OF HAWAII
DEPARTMENT OF AGRICULTURE
1428 SO. KING STREET
HONOLULU, HAWAII 96814

JOHN FARIAS, JR.
CHAIRMAN, BOARD OF AGRICULTURE

YUKIO KITAGAWA
DEPUTY TO THE CHAIRMAN

BOARD MEMBERS
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HAWAII MEMBER
JAMES E. NISHIDA
KAUAI MEMBER
Richard Caldito
MAUI MEMBER
Susumu Ono
EX OFFICIO MEMBER

August 21, 1979

Mr. Kisuk Cheung, Chief
Engineering Division
Department of the Army
U.S. Army Engineer District, Honolulu
Building 230, Ft. Shafter, HI 96858

Dear Mr. Cheung:

The Department of Agriculture has no comments to offer on the draft survey report with draft environmental statement for the Lava Flow Control Study, Hilo, Hawaii.

Thank you for the opportunity to comment.

Sincerely,

JOHN FARIAS, JR.
Chairman, Board of Agriculture

September 20, 1979

- ss

MEMORANDUM

To: Office of Environmental Quality Control

From: Deputy Director for Environmental Health

Subject: Environmental Impact Statement (EIS) for Hilo Lava Flow Control

Thank you for allowing us to review and comment on the subject EIS. On the basis that the project will comply with all applicable Public Health Regulations, please be informed that we have no objections to this project.

We realize that the statements are general in nature due to preliminary plans being the sole source of discussion. We, therefore, reserve the right to impose future environmental restrictions on the project at the time final plans are submitted to this office for review.

for JAMES S. KUMAGAI, Ph.D.

cc: Department of the Army ✓

GEORGE R. ARIYOSHI
GOVERNOR OF HAWAII

PROJECT OFFICES

WAIMEA OFFICE
P. O. BOX 125
KAMUELA, HAWAII 96743

KEAUKAHA OFFICE
P. O. BOX 833
HILO, HAWAII 96720

STATE OF HAWAII
DEPARTMENT OF HAWAIIAN HOME LANDS
P. O. BOX 1879
HONOLULU, HAWAII 96805

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MAUI OFFICE
P. O. BOX 22
KAHULUI, MAUI 96732

MOLOKAI OFFICE
P. O. BOX 198
HOOLEHUA, MOLOKAI 96729

KAUAI OFFICE
P. O. BOX 332
LIHUE, KAUAI 96766

August 30, 1979

Department of the Army
U.S. Army Engineer District,
Honolulu
Building 230
Fort Shafter, Honolulu, Hawaii
96858

Gentlemen:

SUBJECT: Hilo Lava Flow Control
Comments on EIS Draft

Reference is made to your letter of August 1, 1979, relative to the above subject project.

The Department of Hawaiian Home Lands has reviewed the draft report, and has no comments to make at this time.

Sincerely yours,

Georgiana K. Padeken
Chairman

GW:gay

STATE OF HAWAII
DEPARTMENT OF ACCOUNTING AND GENERAL SERVICES
DIVISION OF PUBLIC WORKS
P. O. BOX 119, HONOLULU, HAWAII 96810

HIDEO MURAKAMI
COMPTROLLER

MIKE N. TOKUNAGA
DEPUTY COMPTROLLER

LETTER NO. (P)1828.9

AUG 15 1979

Office of Environmental
Quality Control
550 Halekauwila Street
Room 301
Honolulu, Hawaii 96813

Gentlemen:

Subject: Hilo Lava Flow Control

Thank you for this opportunity to review and comment on the subject project.

The project will not have any adverse environmental effect on any existing or planned facilities serviced by our department.

Very truly yours,

RIKIO NISHIOKA
State Public Works Engineer

HI:dn

cc: U.S. Army Engineer District

COUNTY OF HAWAII

PLANNING DEPARTMENT

25 AUPUNI STREET • HILO, HAWAII 96720

HERBERT T. MATAYOSHI
Mayor

SIDNEY M. FUKE
Director

DUANE KANUHA
Deputy Director

September 19, 1979

Mr. Kisuk Cheung, Chief
Engineering Division
Department of the Army
Building 230
Fort Shafter, Hawaii 96858

Dear Mr. Cheung:

Draft Interim Report and EIS
Hilo Lava Flow Control,
July 1979

Thank you for sending the subject document to us for review. Please be informed that we concur with the selected "alternative E" which calls for no barrier structure to be constructed prior to the development of an actual lava flow hazard.

We do, however, have the following comments to offer. Please note that these comments reflect areas of concern which should be addressed and incorporated into the subject text.

1. It was noted within the subject text that no barrier structures were considered for location in the area north of the Saddle Road. The subject text has not addressed the possibility of a lava flow hazard occurring within the saddle area between Mauna Kea and Mauna Loa, and the subsequent extension of a flow hazard from the area north of the Saddle Road. Although this area is located outside of the indicated study area (figure 1 - page 3), the possible development of a lava flow hazard within this area should be addressed. It may be appropriate to expand the study area within the subject text to include the above mentioned area.

2. It was further noted within the subject text that the "cost-benefit" analysis of the proposed alternatives did not consider the actual loss of Agricultural values and lands resulting from the construction of the barrier structures or lava flow inundation resulting from the

barrier diversion. The "cost-benefit" analysis should be expanded within the subject text to include potential loss of Agricultural lands.

We apologize for this delayed response, and hope that our comments can still be considered for incorporation into the subject project. Mahalo.

Sincerely,

SIDNEY FUKE
Director

BS/VKG:ak

cc: Civil Defense

PODED-PJ 8 November 1979

Mr. Sidney Fuke, Director
Planning Department
County of Hawaii
25 Aupuni Street
Hilo, Hawaii 96720

Dear Mr. Fuke:

Thank you for your views and comments on the draft Lava Flow Control Report and Environmental Impact Statement.

Regarding possible barrier structures within the saddle area between Mauna Loa and Mauna Kea, our analysis of the historic flows from the northeast rift zone of Mauna Loa indicated that the Humuula Saddle area is not a high hazard flow area where lava may or may not flow from that point to Hilo. Lava flows reaching the saddle area could head toward North Kona rather than Hilo. As the greatest danger from the northeast flows is to property in Hilo, barriers in the saddle area were not considered. With respect to the barrier locations in the different alternatives as shown on plates 1, 2, and 4, diversion structures primarily south of the Saddle Road are viewed as more advantageous than north of the Saddle Road for the following reasons:

a. The structures would provide protection for the Saddle Road and areas north of the highway.

b. Since the diversion route is southwest of Hilo, the extent of diversion facilities and potential impact areas would be less than your suggested location. The above basis of analysis and barrier layout will be incorporated into the revised report.

As shown on page 37, necessary lands, easements, and rights-of-way have been included in the project cost for alternatives A, B, C, and D for the purpose of benefit-cost evaluation. For Alternative E, an estimate for the necessary lands will be added in the revised report. As stated

on page 29 for all alternatives, if the attempt to confine lava to undeveloped lands is not successful, damages estimated up to $9 million could occur. However, this residual damage is very small in comparison to the damage prevented and would have an insignificant impact on the overall feasibility.

Sincerely yours,

KISUK CHEUNG
Chief, Engineering Division

DEPARTMENT OF PUBLIC WORKS
COUNTY OF HAWAII · 25 AUPUNI STREET · HILO, HAWAII 96720 · TELEPHONE (808) 961-8321

HERBERT T. MATAYOSHI
Mayor
EDWARD K. HARADA
Chief Engineer
ARTHUR T. ISEMOTO
Deputy Chief Engineer

September 13, 1979

Mr. Kisuk Cheung
Chief, Engineering Division
U.S. Army Engineer District, Honolulu
Department of the Army
Building 230
Ft. Shafter, HI 96858

SUBJECT: DRAFT SURVEY REPORT WITH DRAFT ENVIRONMENTAL STATEMENT JULY, 1979

We have reviewed the subject document and have the following general comments.

1. Do we understand that the requirement to "assume liability for litigation resulting from emergency operations" by the local interest (State/County) (Page 41) is a general policy of the Army and/or the Federal government?

2. Do we need to maintain the completed structures even after the emergency is over?

3. The benefit analysis is based on present costs, but the time of eruption is futuristic. Should there be no development in the recommended Alternative Plan E area to minimize future damage cost?

4. What would be the benefit analysis should lava flow be diverted to Wailuku River? This would give another comparative evaluation.

Item 3 and 4 are questions raised at the September 12, 1979 informational meeting at the State Building Conference Room C.

EDWARD HARADA
Chief Engineer

PODED-PJ

28 September 1979

Mr. Edward Harada
Chief Engineer
Department of Public Works
County of Hawaii
25 Aupuni Street
Hilo, Hawaii 96720

Dear Mr. Harada:

Thank you for your views and comments on our Draft Lava Flow Control Report and Environmental Statement. The following is furnished in response to your comments:

a. Currently there is no authority for the Corps to provide emergency protective measures against lava flows. However, it is Corps policy under Public Law 84-99 (Flood Emergency Operations) that local assurances be obtained to (1) provide without cost to the United States all lands, easements, and rights-of-way necessary for the emergency work; (2) hold and save the United States free from damages due to the emergency work; and (3) maintain and operate all the rehabilitation work after its completion. The removal of emergency flood control works after their purpose has been served is also a local responsibility. In view of the similarities between flood and lava emergency operations, it is considered reasonable to tailor the conditions of local cooperation on terms comparable to existing policy.

b. The recommended Alternative Plan E would be implemented to meet an imminent lava flow threat. Its exact alignment will be determined based on field conditions such as the lava flow path, topographic features, and location and extent of development in the area at that time. Implementation criteria would be to provide maximum property protection in the least damaging way.

c. With regard to diversion into the Wailuku River, we did not perform a benefit analysis on this alternative in view of stated concerns on water supply and overall greater ecological impact.

PODED-PJ
Mr. Edward Harada

28 September 1979

As stated in b above, the alignment of any lava barrier in the time of emergency would be determined to provide maximum protection. Conditions at that time may be such that diversion into the Wailuku River would be the most logical course of action.

Sincerely yours,

KISUK CHEUNG
Chief, Engineering Division

DEPARTMENT OF WATER SUPPLY • COUNTY OF HAWAII
P. O. BOX 1820 • HILO, HAWAII 96720 • 25 AUPUNI STREET

August 23, 1979

Department of the Army
U. S. Army Engineer District, Honolulu
Building 230
Ft. Shafter, HI 96858

DRAFT SURVEY REPORT AND
ENVIRONMENTAL IMPACT STATEMENT
HILO LAVA FLOW CONTROL

Thank you for letting us review the above-mentioned report. We have no comments to offer. However, should the project affect any of our existing water sources, a separate study would be necessary.

Akira Fujimoto
Manager

CS

...Water brings progress...

INFORMATION COPY

For the Protection of Hawaii's Native Wildlife

HAWAII AUDUBON SOCIETY

P. O. Box 5032
Honolulu, Hawaii 96814
P. O. Box 275
Volcano, Hawaii 967

Comments on the Hilo Lava Flow Control Draft Interim Report and Environmental Impact Statement issued by the US Army Corps of Engineers for the public meeting held in Hilo, Hawaii, on October 10, 1979

The Hawaii Audubon Society presents the following comments in connection with its mission to protect remaining native wilderness from unnecessary destruction or degradation by mechanical operations and introduced foreign pest species of plants and animals.

1) The Lava Flow Control Report considers only structural alternatives. It would appear that costly construction schemes, including the emergency barrier plan, are the only possible choices in preparation for a Mauna Loa eruption aimed at Hilo. A careful evaluation of two non-structural alternatives should be added to the report. These are:

a) Deployment of aerial explosives high on the upper slopes of Mauna Loa to divert lava from spatter cones and underground lava tubes to the north slopes in the Saddle area.

b) A government-subsidized insurance plan to cover commercial and personal property losses as a result of lava inundation.

The 1975 US Senate Resolution authorizing the present study does not restrict the Corps of Engineers to a plan of construction. Alternatives that do not involve construction merit close scrutiny in the Corps' report -- from both economic and environmental viewpoints.

2) The first four structural schemes are in fact construction in advance of some future-time Mauna Loa eruption that may or may not threaten some part of Hilo. Serious consideration of advance construction measures appears to be inconsistent with the Corps' own published rules and regulations on natural disasters (Federal Register, January 9, 1978) which states:

> "(a) Volcanic eruptions. . . . . Advance measures, such as construction of lava deflection barriers or other structures, are not eligible under Pub. L. 84-99." page 1451

Considering the manifold uncertainties of future Mauna Loa eruptions and flows, this is a sound restriction on advance construction of lava diversion barriers. We oppose the Corps' efforts to amendment the regulation now so that advance construction will be permitted.

3) The State's Emergency Plan to Protect Hilo From a Lava Flow is alluded to in the Corps' report. The reader wonders what the State's plan is all about and how does the State's plan fit into the Corps' proposals for lava flow control. The contents of the State's plan should be addressed and summarized in the Corps' report to inform the public and decisionmakers of actions the County, State and federal agencies intend to take in the event of a threatening lava flow. The Corps' was intimately involved in the development of the plan and the Corps' present report should reflect that coordination.

The unbalanced concentration on construction projects can be corrected by expanding the report to cover the whole spectrum of potential measures. The people who live here need to see the whole picture presented in one document, along with an evaluation based on present knowledge of the relative success and failure of the various diversion schemes.

The State's Emergency Plan and expert volcanologists give first priority to the use of explosives to disrupt lava flows high on the northeast rift zone. In an article in the Hawaii Tribune-Herald (Hilo) on February 27, 1977, "Defense Against Lava Explored," Gordon P. Eaton and John P. Lockwood wrote:

> "The use of explosives high on the slopes of Mauna Loa is the first line of defense and the best method for the following reasons:
> 1) It is the least expensive method; 2) It is the most flexible method, since one can change one's response to changes in the volcanic threat in a matter of hours or even minutes; 3) Successful diversion would inundate Federal or State wastelands in the Humuula Saddle area rather than private lands; and 4) It would offer the best method for keeping lava out of the Hilo watershed." (p. D-18)

An article on a talk given by the late Dr. Gordon Macdonald in the Sunday Star-Bulletin & Advertiser (Honolulu) on June 19, 1977 reports that:

> "MacDonald identified explosives or aerial bombs as the most feasible way to control a flow. 'There are no guarantees' in predicting or trying to control eruptions, Macdonald said." (p. A-2)

The Corps' report should evaluate the relative merits and problems in lava diversion through the use of explosives.

4) The report may be misleading in its emphasis on Hilo as a target of Mauna Loa eruptions. Mauna Loa eruptions have a variety of possible flow paths, and the uncertainties and unknown factors which preclude advance predictions should be evenly presented to the public. In the last few hundred years Mauna Loa flows have reached the sea in Kailua town and elsewhere in the districts of North Kona, South Kona and Ka'u. Flows have covered parts of the northern slope in the Humuula Saddle as well as lava fingers that reached close to Hilo.

Based on present knowledge, geologists have informally estimated that it may be as long as 1400 years ago since a lava flow entered Hilo Bay.

Yet the report's detailed and exhaustive treatment of property values in Hilo town carries the implication that a lava flow would invade Hilo on a massive 1-2 mile wide front. Geological research would appear to indicate that such an event is highly improbable.

5) The Environmental Impact Statement (EIS) in the report is sorely lacking in specific data on the biological resources of the project study area and of the sites of the emergency barriers and the cleared lava flow paths. Information on vegetation types, ecological zones, native plant and animal components, and the presence, distribution and density of endangered birds and plants in the project area should be integrated into the final EIS. Anticipated impacts of land clearing and construction on native plant and animal communities need to be evaluated in explicit detail. I would appreciate a reply to these comments.

Submitted by: Mae E. Mull *Mae E. Mull*
Island of Hawaii Representative

PODED-PJ

27 December 1979

Ms. Mae E. Mull
Island of Hawaii Representative
Hawaii Audubon Society
P.O. Box 275
Volcano, Hawaii 96785

Dear Ms. Mull:

In response to your specific comments on the Draft Hilo Lava Flow Control Report and Environmental Statement, we offer the following:

a. In regard to the items in paragraph (1) of your letter, the deployment of aerial explosives was addressed on page 24 of our report. Results of the bomb cratering tests conducted by the U.S. Air Force and details on bombing lava will be added to the final report. Concerning the item of a government-subsidized insurance plan, the scope of this study was directed in response to the authorizing legislation for investigation of reducing the potential damage in Hilo due to lava flows. The implementation of an insurance plan is not within the scope of the study or the authority of the U.S. Army Corps of Engineers.

b. We concur with you regarding the manifold uncertainties of future Mauna Loa eruptions. For this reason, we concluded (page 39) that the first four alternatives involving advance construction would be less efficient and have greater risk of being unsuccessful than the emergency plan (Plan E). With regard to Public Law 84-99, amending the law as envisioned would provide the Corps authority to react in the event of a threatening lava flow. Authority for advance construction of diversion barriers of other structures in not being sought.

c. Regarding the State's Emergency Plan--first of all, we wish to correct the misconception that "The Corps was intimately involved in the development of the plan..." Although the State plan considers emergency barriers as a part of the overall protective plan, the contents and results of that plan were achieved by the State Civil Defense Agency in coordination with many State, County and federal agencies, one of which was the Corps. Our contribution to the present State plan is limited to the emergency barrier system developed in 1975 for the State

Civil Defense Agency as requested. In order to clarify this, we suggest that you discuss your particular concerns regarding the State plan directly with the State Civil Defense Division. The final study document will address the State Emergency Plan and clarify how the Corps fits into the State's plan.

d. As noted in your comments, the State Emergency Plan and volcanologists give first priority to the use of explosives as the first line of defense. We concur with this opinion, however, in view of the stated manifold uncertainties, the State plan also recognizes the need for other possible courses of action such as barriers and evacuation. It should be mentioned that, as in any natural disaster, many government agencies, groups, and individuals will respond to the occasion. In this regard, implementation of barriers or any other protective measures will be made by the State Director of Civil Defense in consultation with the Hawaiian Volcano Observatory staff and administrative officials. Since the characteristics of a particular lava flow cannot be predicted with certainty, the merits of lava diversion through the use of explosives cannot be determined meaningfully. If explosives or barriers are used successfully at the higher elevations, then other protective measures would not be needed. On the other hand, if explosives proved to be inadequate, other methods would necessarily be considered.

e. The adoption of Hilo as the target is related to the Governor's expressed concerns. While we are fully aware of other areas that might be affected by Mauna Loa eruptions, Hilo is the only urban community in the United States that has been threatened by a lava flow in historic time. The authorization we are seeking in response to lava flow situations is not limited to Hilo but the entire island of Hawaii. The report will be revised accordingly.

f. You may be interested to know that studies in progress by Ms. Jane Buchanan-Banks indicate that the maximum width of any single prehistoric flow is approximately two kilometers in west Hilo, and possibly as much as six kilometers in Keaukaha. On the probability scale, our analysis (page 28) of that historic flow records indicated that a massive flow which could affect Hilo would occur once in every 900 years.

g. Throughout this study, the Corps has maintained close coordination with the U.S. Fish & Wildlife Service (FWS) so that results of extensive FWS botanical studies and wildlife surveys in the area could be incorporated into the Corps' description of biological resources and comparative evaluation of alternative plans. Based on early information received from FWS, we anticipated these data would be fully analyzed and available for our use more than six months ago. Unfortunately, data analysis has taken significantly longer than anticipated so the Corps was forced to rely on preliminary study results in preparation of the Draft EIS. We anticipate, however, that the Corps' Final Report and FEIS will treat the discussion of biological resources in far more depth than the DEIS, as these data are incorporated.

h. Provided that the recommendation for Plan E is authorized, extensive site specific biological studies will focus on portions of the Alternative E diversion corridor within which probable barrier construction is shown to be feasible from an engineering standpoint. Results of these studies will enable the Corps to more critically evaluate anticipated impacts in a site specific manner and to identify feasible measures to mitigate or eliminate adverse impacts on biological resources. Our recognition of the significant impacts of fixed barrier construction on pristine native forest ecosystems is apparent in the Corps' strong recommendation to avoid higher elevation fixed barriers, as would occur with Alternatives A, B, and D.

We hope the above explanations are satisfactory to you. You will be kept informed of our planning activities, and your participation throughout the study is appreciated.

Sincerely yours,

KISUK CHEUNG
Chief, Engineering Division

CONSERVATION COUNCIL FOR HAWAII

State Board
P. O. Box 2923 - Honolulu, Hawaii 96802

Oahu Chapter
P. O. Box 2923 - Honolulu, Hawaii 96802

Hawaii Island Chapter
P.O. Box 1222 Hilo 96720

Maui Chapter
P. O. Box 416 - Haiku, Hawaii 96708

October 12, 1979

B.R. Schlapak
Lt. Col, Corps of Engineers
Deputy District Engineer
Department of the Army
Honolulu District, Corps of Engineers
Building 230. Ft. Shafter, Hawaii 96858

Dear Sir:

We wish to make the following comments on the Draft Interim Report and EIS for the Hilo Lava Control Study.

We are impressed by the scope of the problems addressed in this study. However, we feel that even after such a hard look at the feasibility and acceptability of lava flow diversion, the the Corps' recommendation to proceed with Alternative E, an emergency barrier program, is unacceptable due to serious questions relating to its effectiveness, cost, and impact on the native ecosystems. Our specific comments are as follows:

1. Effectiveness. We seriously doubt that the barrier system as proposed would be effective in diverting a lava flow as planned. First of all, as shown in Plates B-1 and B-2, the area for the proposed barrier construction is a linear mosaic of different aged lava flows running downslope. A topographic profile along the proposed barrier alignment shows a considerable degree of variability in the relative height of these different flows, i.e. each younger flow is higher than the older flow which it overrides. For example, in Barrier Sector C, the elevational change from the prehistoric pahoehoe lava flow onto the 1942 'a'a flow is over 20 ft! The result is a series of "natural flow barriers" which also run downslope. To construct a cross- or diagonal-slope barrier as planned would additionally involve excavating trenches up to 20 ft deep through thick flows such as the 1942.

Secondly, if a lava flow divides above the barrier, as most of the historic flows have done, the Puna-side lobe of the flow, even if diverted by a barrier, will most likely serve as an additional barrier for the Hamakua-side lobe, which could back up in this corner and eventually override the man-made barrier.

2. Cost. The $2.7M cost estimate for Alternative E is only for the actual constructuon phase of the plan. As noted in this document (p. B-3), it does not include additional costs for planning, logistics, land acquisition, and/or compensation resulting from litigation over property loss due to either the success or failure of the lava flow diversion. The real cost of this project will be the sum of all of these additional factors. Since a big point is made in this study regarding the cost-effevtiveness of the different plans in terms of potential property loss in Hilo, a truer estimate of the actual cost would give us a more realistic picture.

3. Impact on the native ecosystems. As stated in the EIS, the area for the proposed barrier construction for the most part does not include the distributional range of any officially listed endangered species. However, this a predominately native habitat, and further disturbance by extensive trail cutting for surveying the proposed barrier alignments, and the actual barrier construction with associated staging areas, will lead to the further degredation of the habitat, both directly, and indirectly by allowing new pathways for more exotic plant species into the area.

RECOMMENDATIONS

For the above reasons, we therefore recommend that the plan to spend so much money to attempt to divert lava flows away from Hilo by the construction of barriers, be abandoned. We feel that more promise is held with plans to divert the flows at higher elevations with ordnance. However, this approach still raises other questions on its feasibility, control of the direction of diverted flows, and general acceptability.

Let's face it, Hilo is built on the lava flows of one of the most active volcanoes in the world! Even if one attempt to divert a flow by one means or another, is successful, there will be countless other flows coming. We feel a more realistic approach would be to reevaluate the present land use zoning in all of our high-risk volcanic hazards areas (including Hilo, Puna, and South Kona) and direct major development away from them. For example, high-density residential zoning for the upper Kaumana area would seem to be ridiculous.

Further, the idea of lava flow damage compensation may be the most reasonable, and overall the least expensive way to deal with the hazards as they exist today.

We fully realize that the prospect of a lava flow coming into, and devastating a portion of Hilo, will directly or indirectly cause hardships to many people on the island of Hawaii. However, we must approach this possibility realistically, and we feel that the money and effort spent on attempting to divert the flows with barriers, will not give us the most realistic solution to the problem.

Sincerely,

James D. Jacobi
President
Hawaii Island Chapter CCH

PODED-PJ

15 January 1980

Mr. James D. Jacobi, President
Conservation Council for Hawaii
Hawaii Island Chapter
P.O. Box 1222
Hilo, Hawaii 96720

Dear Mr. Jacobi:

Thank you for your views and comments on the Draft Lava Flow Control Report and Environmental Impact Statement. The following is in response to your specific comments:

a. Effectiveness. We agree fully with you on the considerable degree of variability in the topography of the study area. As discussed in the report (page 40), we would like to emphasize that the proposed work areas and diversion facilities shown are intended only as approximations of locations for purposes of illustration. Barrier segments would be constructed on an "as needed" basis. Provided the recommendation for Alternative E is authorized by the U.S. Congress, additional topographic studies will be conducted during the post-authorization phase. This work would include the identification of natural features such as drainageways, ridges, and high-relief areas to minimize the need for diversion barriers and refine the basic plan. Regarding your point on a flow which divides above the proposed diversion area, we envision that attempts will be made to combine the flow units by means of ordnance (military) and/or short barrier segments.

b. Cost. For Alternative E, an estimate for lands, planning, operations and logistic support will be considered in the revised report. The compensation resulting from litigation over property loss due to the diversion is a legal matter which cannot be determined meaningfully for any of the alternative plans.

c. Impact on the Native Ecosystem. We recognize that selection of Alternative E does not eliminate the potential for direct and indirect adverse impacts on the native forest ecosystem. However, the risk of significant long term impact has been reduced by selection to the lowest

elevation corridor considered feasible from an engineering standpoint. In addition, post-authorization biological studies would emphasize the need to identify alignment that would minimize adverse impacts and possibly even protect areas of unique value. It is important to note that the impacts of barrier construction under Alternative E would be additive to the impacts of an actual lava flow at higher elevation. We do not anticipate that surveying work will require extensive cutting of vegetation in the pristine forest.

Your recommendations are appreciated. As in any natural disaster, many government agencies, groups, and individuals will respond to the occasion. In this respect, the decision to implement any protective plan will be made by the State Director of Civil Defense in consultation with the Hawaiian Volcano Observatory staff and administrative officials. We are hopeful that as a result of ongoing studies by the Air Force, high elevation bombing will prove to be a feasible method to successfully divert potentially threatening lava flows. In the event of such a flow, the proposed emergency barrier would not be constructed unless it was determined that an approaching flow was likely to reach Hilo. We are also supportive of a well conceived land use zoning effort to restrict or prevent urbanization of particularly lava-prone lands, but such a program would be under the jurisdiction of the local governments.

Sincerely yours,

KISUK CHEUNG
Chief, Engineering Division

November 6, 1979

Michael Tomich
P. O. Box 912
Capt. Cook, Hawai'i
96704

Honolulu District Corps of Engineers
Building 230
Fort Shafter, Hawai'i
96858

Lt. Col Schlapak:

I would like to go on record as being in favor of protecting from further encroachment by exotic species, the remaining tracts of native Hawaiian forest in the area of the proposed lava barrier construction.

Our fragile Hawaiian forest ecosystem containing many plant and animal species found nowhere else in the world has already been the victim of too many careless intrusions (by the human species and his accompanying weeds). Any excavation work for lava barriers would only serve to further deteriorate the quality of the native forest by exposing forest soil to various introduced plant pests, which once gaining a foot-hold are likely to spread over ever wider areas of native forests, occupying the ecological niches of rare Hawaiian plants, and eventually crowd them off the face of the earth (forever).

Even if Madame Pele should choose to cover this forested area with lava, the laws of nature (plant succession etc.) tend to favor reforestation of lava flows by native species thereby protecting the integrity of this unique island ecosystem.

Another aspect of these plans to control the direction of a lava flow raises a question which has not yet been answered to my satisfaction. Regarding the legal aspect, who would bear the burden of liability for ensuing property damage should a lava flow be diverted from Hilo lands to lands between Hilo and Ola'a?

Sincerely,

Michael Tomich
Concerned resident,
Hawai'i Island

PODED-PV

7 January 1980

Mr. Michael Tomich
P. O. Box 912
Captain Cook, HI 96704

Dear Mr. Tomich:

This is in response to your comments regarding the Lava Flow Control Study.

The potential adverse effect of barrier construction on native forest was addressed in the Draft Environmental Impact Statement (DEIS) and will be treated in more depth in the Final Environmental Impact Statement (FEIS). Recognition of the impact of exotic plant dispersal was a major consideration in the Corps' recommendation that no actual barrier construction should occur unless a threatening lava flow actually occurs. The objective of perpetuating the native forest ecosystem was also fundamental in selecting a diversion corridor that is situated, for the most part, adjacent to existing corridors (Saddle Road, Tree Planting Road) or below the range of elevation in which rare plants and wildlife are most common.

The proposed US Army Corps of Engineers plan for emergency barrier construction would only be implemented at the request of the Governor or as a component of the State of Hawaii Emergency Plan. The question of liability should the plan be implemented is being coordinated by the Corps with the State and will be addressed in the final EIS.

Thank you for your views on this study.

Sincerely,

KISUK CHEUNG
Chief, Engineering Division

Puna Realty Corp.

50 E. Puainako Street • Hilo, Hawaii 96720
KTA Shopping Center
Ph. (808) 959-5833

November 11, 1979

Lt. Col. B. R. Schlapak
Corps of Engineers
U.S. Army Engineer District, Honolulu
Building 230
Fort Shafter, HI 96858

Dear Sir:

I received a copy of your notice of public meeting to be held on October 10th, concerning the lava flow control study. Unfortunately for me, I was not able to attend; however, a question keeps coming to mind, so I thought I would bring it to your attention.

Has the government taken into consideration that if barricades are set up to divert the natural flow of lava, and the lava consequently flows over other private property, that the owners of the latter property will undoubtedly sue the government? Doesn't that take it out of the "act of God" category? I foresee tremendous liability on the part of the government (and taxpayers) if we alter nature's course. Please enlighten me.

Very truly yours,

Virginia C. Lee (Mrs.)
Principal Broker

cc: Mayor Herbert Matayoshi

MLS REALTOR®

PODED-PJ

21 November 1979

Mrs. Virginia C. Lee
Puna Realty Corporation
50 East Puainako Street
KTA Shopping Center
Hilo, Hawaii 96720

Dear Mrs. Lee:

This is in response to your letter of 11 November 1979 stating your questions concerning the lava flow control study.

For the purpose of reducing the potential damage in Hilo under lava flow conditions, our study demonstrates the desirability of an emergency barrier protective plan to be implemented as a component of the overall State Defense Emergency Plan for such an event. The State Plan also provides for the possible use of explosives by the military, and activation of the evacuation plan developed by the local governments. With respect to the liability question under emergency situations, we wish to quote the following from the State Plan:

"The State of Hawaii assumes liability for litigation resulting from the implementation of this plan. The Attorney General may use requisition procedures of Section 22, Chapter 128, HRS as amended, for private lands damaged by diverted lava flows. He will continue to advise and assist the Director of Civil Defense on all legal matters involved in the implementation of this plan."

Thank you for your interest in the lava flow control study.

Sincerely yours,

KISUK CHEUNG
Chief, Engineering Division

W. H. SHIPMAN, LTD.

P.O. BOX 950 · KEAAU, HAWAII 96749

October 15, 1979

U. S. Army Engineer District, Honolulu
Building 230
Fort Shafter, Hawaii 96858

Gentlemen:

Subject: Lava Flow Control Study

Since I was unable to attend the hearing in Hilo on October 10th, 1979 regarding the Lava Flow Control Study by the Army Corps of Engineers, I would like to put some of my thoughts in writing for the record on behalf of W. H. Shipman, Limited.

W. H. Shipman, Ltd. is one of the largest land holders in the Puna district with fee title to approximately 20,000 acres. Although we agree that Hilo should be protected from lava flows, we are absolutely opposed to any plan which would divert lava into the Puna District. After reviewing Emergency Barrier Plant Plate 1, it appears that a flow diverted into the Puna District could possibly wipe out Mauna Loa Macadamia Nut Orchard, Puna Sugar Co. Mill and Plantation and possibly Keaau town. In addition it would ruin valuable agricultural land to say nothing of many homes in its path. Such a diversion would result in millions of dollars being lost in the destruction of land, products and unemployment.

Although I'm no engineer I have seen many lava flows and was with Dr. Thomas Jaggar at Puu Oo Ranch in 1935-36 when the Mauna Loa flow was bombed. Rather than divert a flow and turn valuable land into waste land I would think it would be better to try and contain it on the upper slopes of the mountain. My thoughts on this would be curved barriers terraced down the side of the mountain. As the lava fills and overflows one barrier it would run into another and do the same...the net result would be delaying the flow and possibly stopping it in an area now considered waste.

Very truly yours,

W. H. SHIPMAN, LIMITED

Roy S. Blackshear

Roy S. Blackshear, President

RSB:bnm

POOED-PJ

20 November 1979

Mr. Roy S. Blackshear, President
W. H. Shipman, Limited
P.O. Box 550
Keaau, Hawaii 96749

Dear Mr. Blackshear:

Thank you for your letter of 19 October 1979 expressing your thoughts and concerns on the emergency lava flow control plan.

During the 10 October 1979 meeting, various protective measures to reduce the potential lava flow damage in Hilo were discussed. Among the measures noted were bombing, barriers, water cooling of lava, evacuation, relocation, and land use restrictions. As you know, such broad range of possibilities would necessitate the involvement of many federal, state, and local participating agencies. For example, the Pacific Air Force has been active in evaluating the effectiveness of aerial bombing, the local governments have developed an evacuation plan, and we have analyzed the potential of water cooling and protection by barrier(s). Because of this institutional structure and adverse environmental impacts associated with pre-emergency construction work, we find that a protective barrier plan to be implemented as a component of the overall State Civil Defense Emergency Plan as needed would be most desirable solution at this time. In addition to emergency barriers, the State Plan also provides for the use of explosives to be delivered by the military and implementation of the evacuation plan.

Regarding the tentative diverted flow alignment noted in our emergency barrier plan, we wish to emphasize that the route is approximate in location. While efforts have been made in our preliminary planning to minimize damages to agricultural lands in defining the probable corridor, aerial mapping is currently being accomplished so that further refinement can be made. For your information, a more detailed location map is inclosed. As shown, the flow path would be basically north of the Mauna Loa Macadamia Nut Orchard, although some newly planted areas could be affected.

PODED-PJ

Mr. Roy S. Blackshear

20 November 1979

Kaeau town is not within the flow corridor. In a discussion on 14 September 1979 between Mr. Harvey Young of my staff and Mr. John Humme of Puna Sugar, Mr. Humme stated that the probable diversion alignment would have minimal impact relative to Puna Sugar activities.

With respect to your thought on curved barriers in the upper slopes, we feel that diversion at the higher elevations may not be needed since the volume of lava may be insufficient to pose a threat to Hilo. Based on statiscal analysis of historic lava flows, the 1880 - 1881 flow is a 150 year event, which means a lava flow having a 0.67 percent chance of being equaled or exceeded in any given year.

Sincerely yours,

KISUK CHEUNG
Chief, Engineering Division

November 16, 1979

Department of the Army
Honolulu District Corps of Engineers
Lt. Col. B. R. Schlapak
Building 230
Fort Shafter, O'ahu
96858

Hannah Kihalani Springer
128 Hale Hani Street
Hilo, Hawai'i
96720

Aloha mai:

When any one of us has moved to the slopes of Mauna Loa, it has surely been with the knowlege that Mauna Loa is still classified as an active volcano.

It was just about 100 short (geologic time) years ago that Hilo was last threatened by a flow of lava from Mauna Loa. Considering the relative youth of Mauna Loa, many more lava flows will be generated in years to come as well.

I value the integrity of the native forests on the slopes of Mauna Loa (which are adapted to the geologic and climatic conditions of Hawai'i, ie. natural selection) which will be violated by the activities of lava barrier construction. All one has to do is follow a "bull-dozed" path across any of the slopes of Hawai'i to see the effects of introduced plants on native ecosystems. All manner of plant generating material (seeds etc.) are dispersed by "bull-dozers", imbeded in dirt on treads for example.

"One man's ceiling is another man's floor..." Who is to say whether the lands of so-and-so in Hilo are <u>really</u> more valuable than the lands of so-and-so in 'Ōla'a? If the lava barriers are constructed and lava is indeed diverted, the integrity of the event as natural (an act of god) is violated. Who will bear the responsibility (play god) for that violation? I am curious as to the economic and political aspects of the situation.

'Ino ka maha ō ka 'ōhi'a.	Laid to waste are the groves of 'ōhi'a.
Kūkepakepa ka maha ō ka lehua,	The clumps of lehua stand in torn fragments,
Ko'ohina i ka wela ō ke akua.	Burnt gray from the heat of the goddess.
'Uahi luna i ka 'oloke'a pōhaku.	Puna burns and smokes amidst rolling rocks.
Huna pe'a 'ia e ka wahine...	Reduced to ashes by the woman...

The verse is from "Kua Loloa Kea'au", a traditional chant of Hawai'i.
It has happened before...it will happen again...LET IT BE!

E mālama kākou i ka
'āina o Hawai'i,

Hannah Kihalani Springer

KUAOLA FARMS, LTD.
P. O. BOX 40[illegible]
HILO, HAWAII 96720

PH. (808) [illegible]

1 October 1979

B. R. Schlapak
Lt Col, Corps of Engineers
U. S. Army Engineer District, Honolulu
Building 230
Fort Shafter, Hawaii 96858

Dear Col Schlapak:

Reference is made to your notice announcing a public meeting to elicit response to various plans being considered to divert the flow of lava in Hilo.

Unfortunately, I will be out of town at the time of the scheduled meeting, so I will be unable to express my views in person. However, I would like to take this opportunity to make my opposition to your proposed Emergency Barrier Plan a matter of record.

The reasons for my opposition are as follows:

1. I doubt seriously that it will work:
   a. Damage is most likely to continue to occur in the main path of the flow.
   b. Damage will be spread outside of the path of the main flow, thereby causing destruction and possible death in areas that would not have been affected if the lava were allowed to follow the path of least resistance.
   c. Significant amounts of the taxpayers' money will be spent to little or no avail, and worse to attempt to select whose property is to be damaged and whose is not.

2. Interference with the forces of nature without a full understanding of all possible outcomes will more than likely result in greater loss of property and damage than allowing nature to take its course.

3. The use of the taxpayers' money to arbitrarily select those whose homes, farms, and places of business are expendable is unethical, immoral, and downright criminal.

4. Punishing those who have had the foresight to build their homes, farms, and places of business outside of the normal flows of lava; while at the same time protecting those who heedlessly rebuilt on top of relatively recent lava flows falls into the same category of immoral behavior.

After much careful consideration and study, we selected a relatively safe place to build our home and establish our farm and business which now employ twenty five people. One of the main bases of soliciting outside investment was the fact that the Panaewa area has been free of lava flows and other natural disasters for hundreds of years. Now, an agency of the Federal Government is recommending a plan which would penalize us for our foresight and diligence, by deliberately attempting to direct the flow of lava through our property.

Who will pay for the damage that is likely to occur to our property; the decimation of our home; the destruction of our means of livelihood and that of our employees? The damage will be the direct result of the emergency barrier plan, and not an act of God or nature. Will the Corps of Engineers pay? Who will determine the value of property, lives, and loss of income? What plans are being made to assign values to these items that are likely to be destroyed by your proposed plan? What happens to our Constitutional right of equal protection under the law?

We cannot support your plan because we believe it to be impractical, unproven, immoral, unethical, and criminal. We would prefer to put our fate in the hands of God, Pele, the Forces of Nature, and our own common sense in selecting an area free from such danger in recent times.

We urge you to abandon the proposed plan.

Respectfully submitted,

[signature]

J. J. Gervais

PODED-PJ

16 October 1979

Mr. J. J. Gervais
Kuaola Farms, Ltd.
P. O. Box 4038
Hilo, HI 96720

Dear Mr. Gervais:

This is in reply to your recent letter regarding the Corps of Engineers Lava Flow Study, Island of Hawaii. Your letter will be included as part of the 10 October 1979 official public meeting record. We regret that the opportunity did not present itself for us to speak personally with you about your concerns and objections.

We would like to emphasize that our study which was conducted in accordance with a Congressional directive was to consider a wide range of alternatives that could conceivably be implemented in the event of a major eruption that would threaten Hilo, Hawaii. Based on our findings and public input, the Alternative E, or emergency barrier construction when a major eruption is imminent or occurring, is the most appropriate plan for consideration should a need arise. The construction of such barriers would only be implemented at the request of the Governor of Hawaii.

The location of these barriers and the deflection of flow indicated in our plans are only illustrative, as the alignment and location of barriers and the size of the flow path would not be definitely known until the emergency plan was implemented by the responsible authority. I am sure that authority would consider very carefully at time of implementation the effects on private property and make every effort to minimize such damages. With regard to the liability of such actions, it would be classified by the Corps as an emergency action in response to a request for assistance by the State. As I mentioned at the meeting, Congress has immunized the Federal agencies from liability for any claim arising incident to rendering disaster relief assistance.

I share your concern about the possible damaging effect of controlling lava flows on you and your neighbors' properties. Hopefully, the need to implement such a contingency plan will never materialize.

Sincerely,

B. R. SCHLAPAK
Lt Col, Corps of Engineers
District Engineer

Hilo, Hawaii
October 8, 1979

B. R. Schlapak
Lt. Col, Corps of Engineers
Deputy District Engineer

Subject: Lava Flow Control Study

Dear Sir:

Reference to the feasibility study for the protection of Hilo against possible lava flow damages, will you please consider the following comments and objections.

As an employee during the last War with the U. S. Corps of Engineers here at Hilo and on the Big Island, I was assigned to the Engineering Division. While under this employment I assisted in engineering process doing research on the terrain and surveying of areas for Military projects. In the research on Volcanology I discovered that the eruptions that occured on the Big Island and prefereably at Mauna Loa and Kilauea were that of Flank eruptions, which means that while volcanologists can almost predict an eruption and where it might occur, the fact remains that they cannot accurately predict it. Eruptions can occur underground as well as on the immediate craters or on the surfaces of the mountains. To examplify the 1960 KAPOHO ERUPTION that destroyed the little town of Kapoho inspite of the barriers that were constructed. Lava flows are almost as similar as water flows, that is, it can undermine, bulldoze and overflow over any objects.

Earthquakes of the past and even recently show that it occured on the Kilauea area and also miles out of the coastline of Puna. The pressure of the MAGMA seldom is strengthened at Mauna Loa or any other part of the Island.

I object very much the construction of the barriers to protect the City of Hilo. What about the western side of the Island, Kona or Kawahae areas where the 1801 eruption occured and flowed from Hualalai to the sea.

It would be wasted the tremendous amount of taxpayer's money in trying to protect Hilo where we know that any destruction caused by Nature, men cannot fully control. It would be unwise to tamper with the wishes of God. HE performs miracles and actions in many mysterious ways. If such an eruption occurs, than let it be. DON'T TAMPER WITH GOD'S WORKS.

Instead of a plan for the construction of barriers, there should be an extensive Plan in educating the populace of the Big Island and prefereably the City of Hilo for mass evacuation. Preparedness and successfully carrying out of a plan for evacuation should be the first order of any study.

Hoping that you will consider this letter and contents pros and cons, I remain.

Sincerely,

Francis L Benevides, Sr.

Francis L Behevides, Sr.
P. O. Box 1877
Hilo, Hawaii 96720

Mauna Loa
Macadamia Nut Corp.

September 25, 1979

Mr. B. R. Schlapak
Lt. Col., Corps of Engineers
Deputy District Engineer
U. S. Army Engineer District, Honolulu
Building 230
Fort Shafter, Hawaii 96858

Dear Col. Schlapak:

MAUNA LOA MACADAMIA NUT CORP. plans to present a position statement at the October 10 public meeting called to review the tentative plan as contained in the Lava Flow Control Study, which the U. S. Army Corps of Engineers has prepared.

We are concerned with the present proposed flow path which, as presently planned, would cause extensive damage to the macadamia nut orchards owned and operated by MAUNA LOA MACADAMIA NUT CORP. in Keaau. Due to the high value of the product produced, the high initial investments being amortized and the potential loss of employment, we are requesting that the proposed flow path be modified to bypass the orchards.

Furthermore, we request clarification of provisions to indemnify property owners due to losses caused by the diversion and channelization of the lava flow.

Sincerely,

Paul G. Bennett

my

cc: A. Kugle, Corporate Counsel
J. Cykler, Engineering Director

MAUNA LOA MACADAMIA NUT CORP S P BOX 3 HILO, HAWAII 96720 PHONE (808) 966-9301

LAVA FLOW CONTROL STUDY
ISLAND OF HAWAII

AERIAL PHOTO MAPS

APPENDIX D

APPENDIX D

AERIAL PHOTO MAPS
(NOVEMBER 1979)

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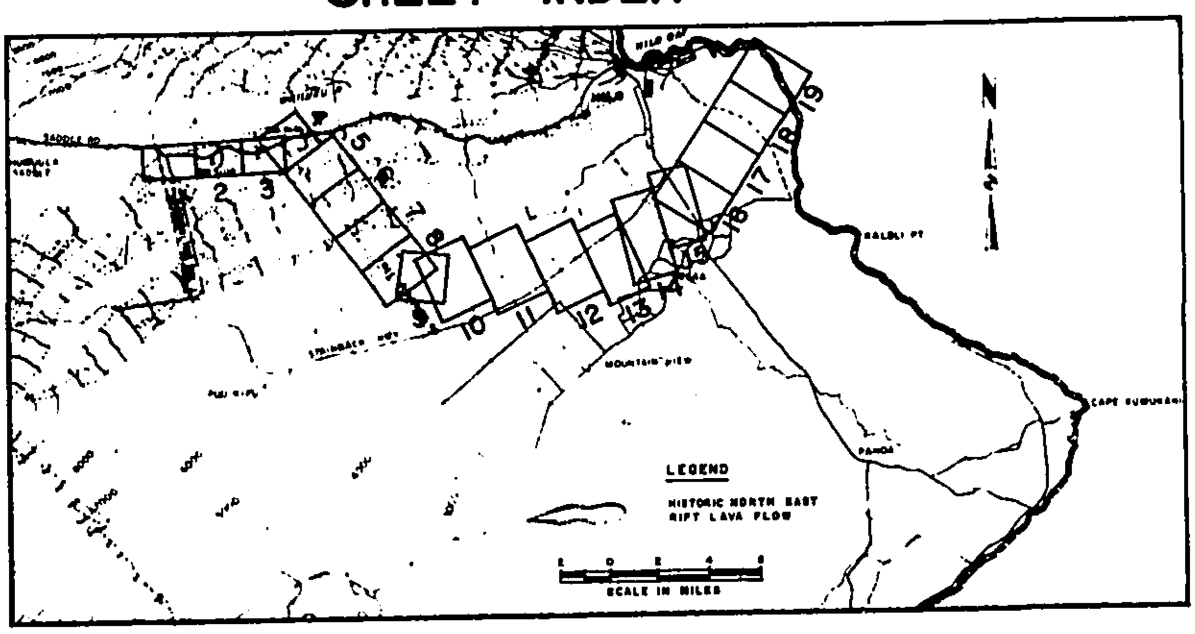

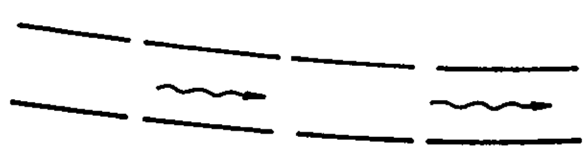

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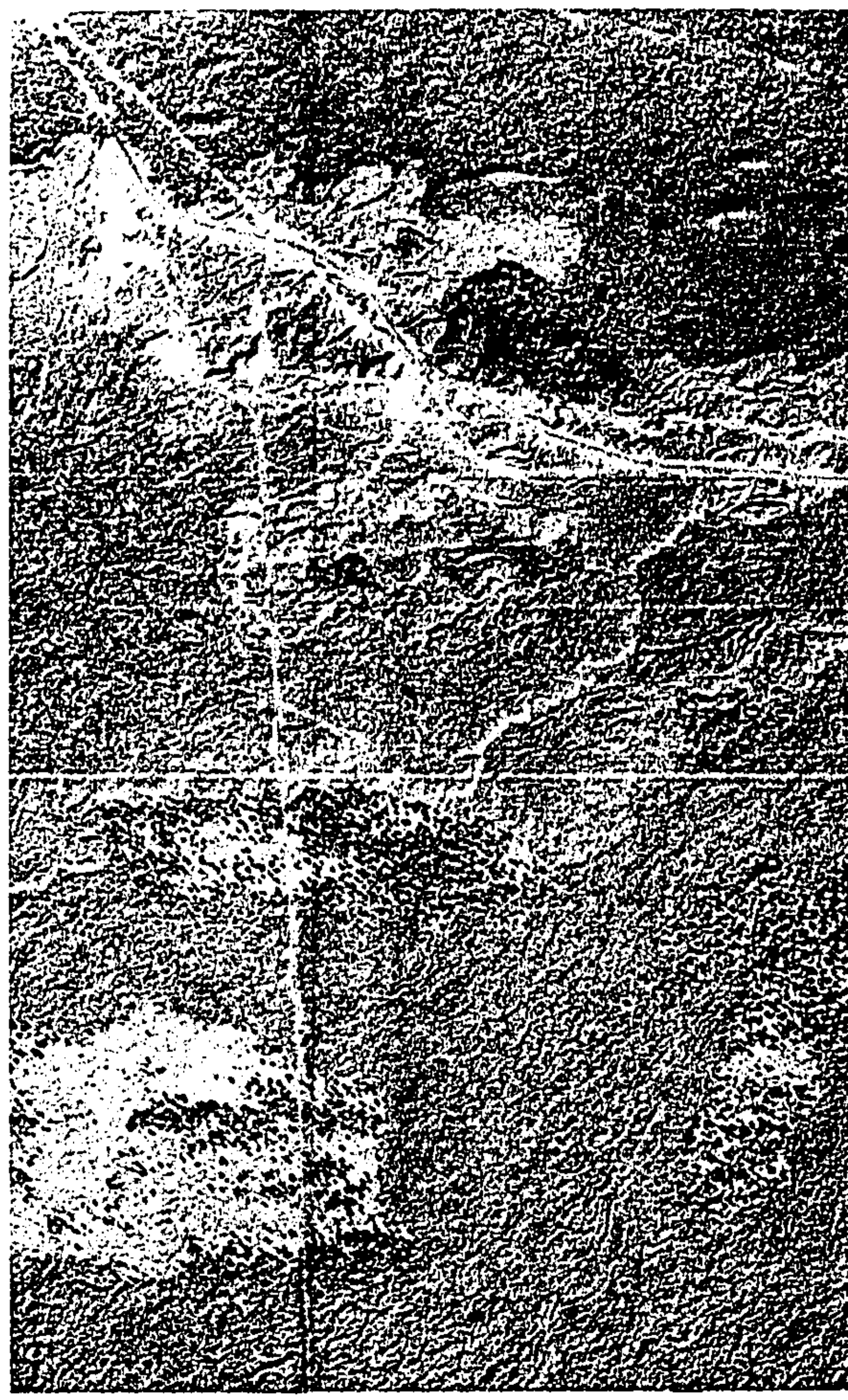

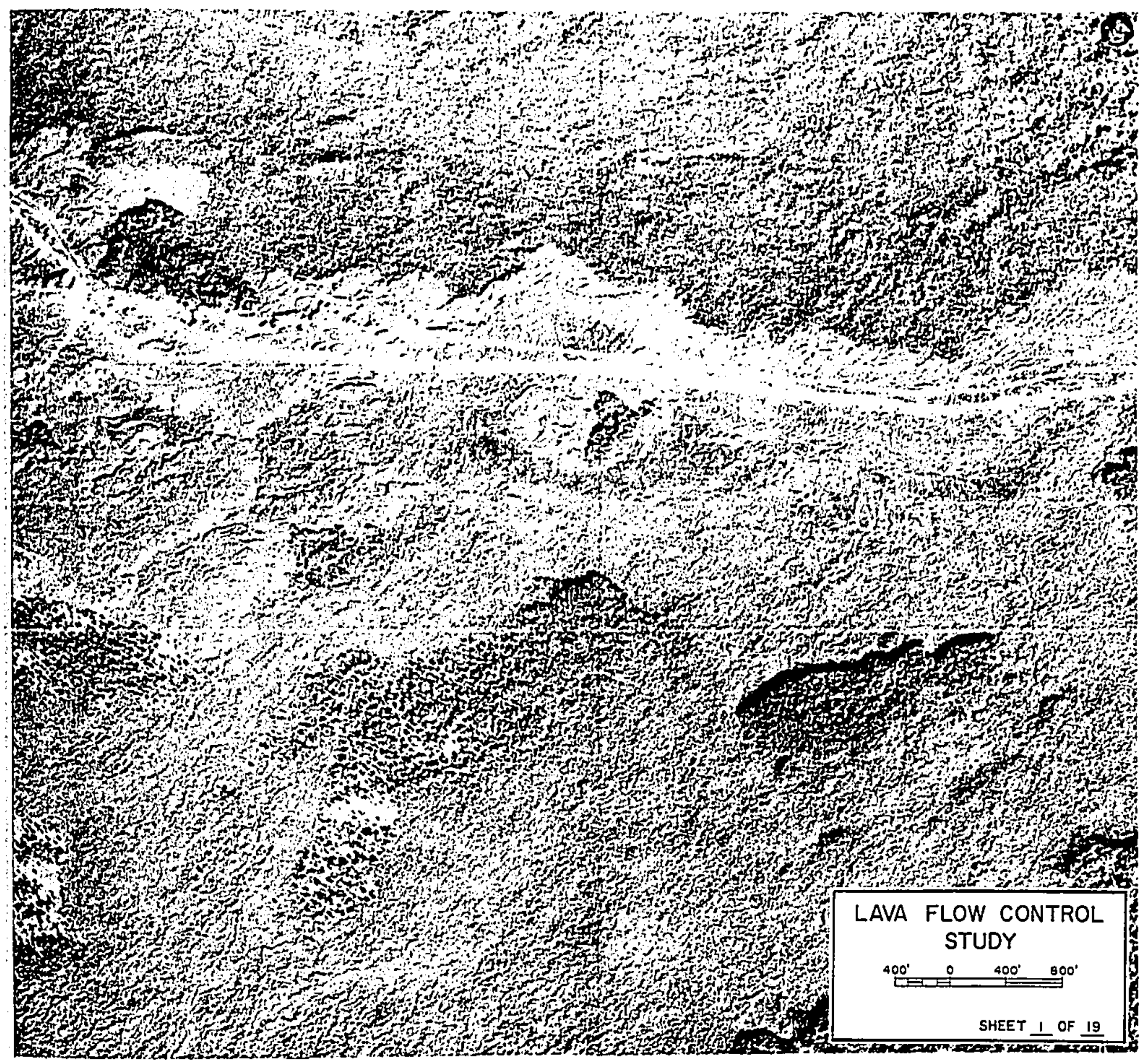
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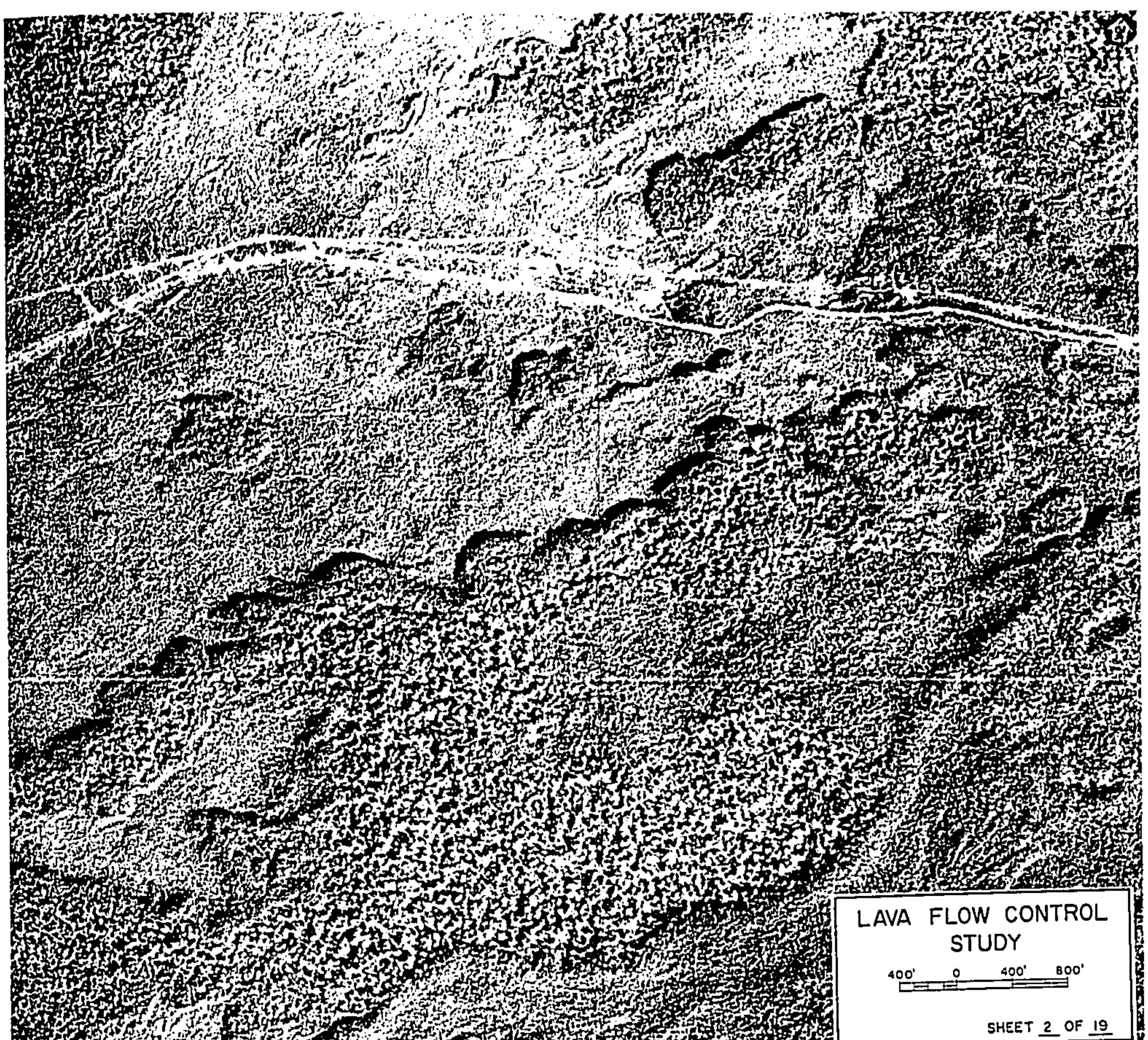
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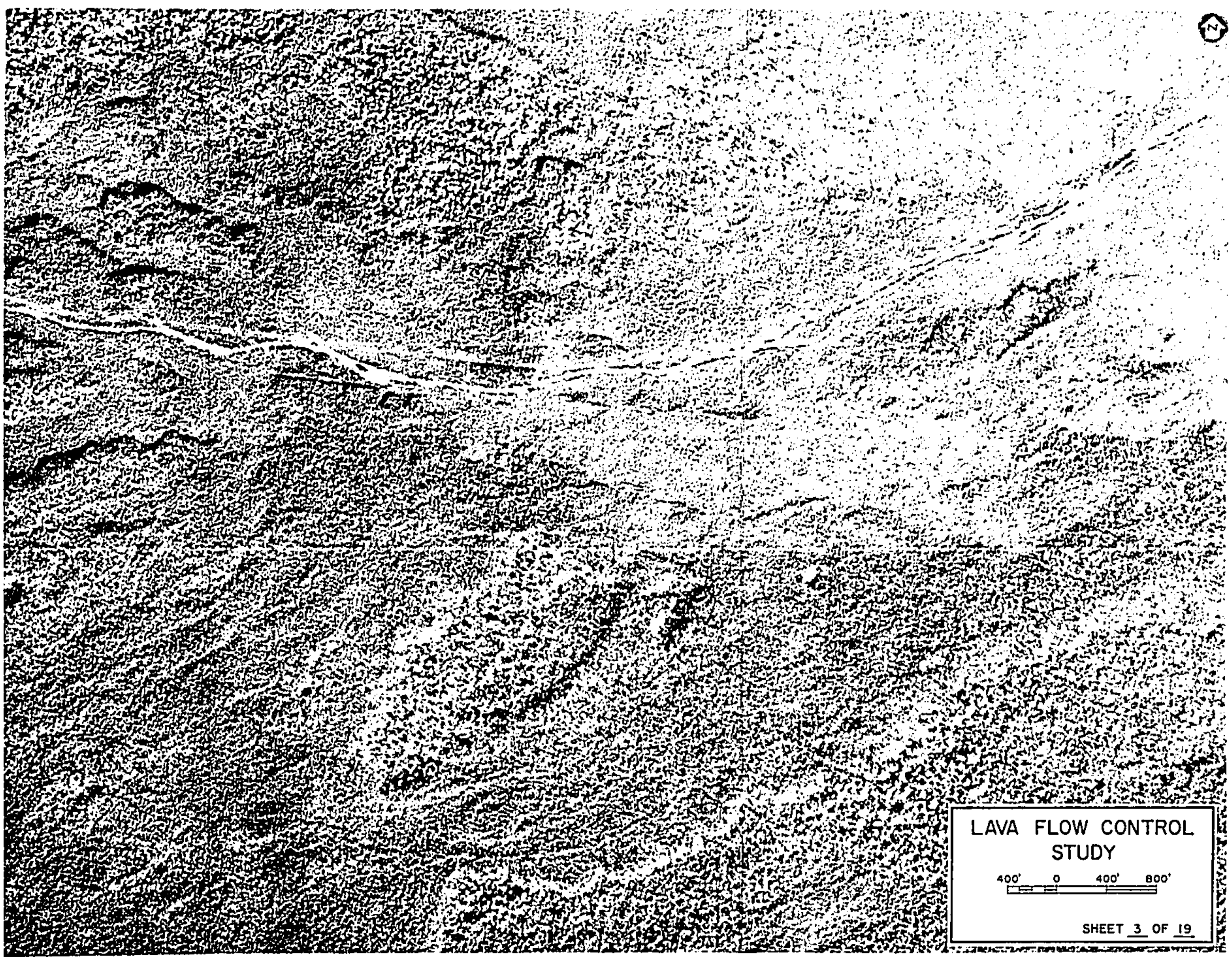
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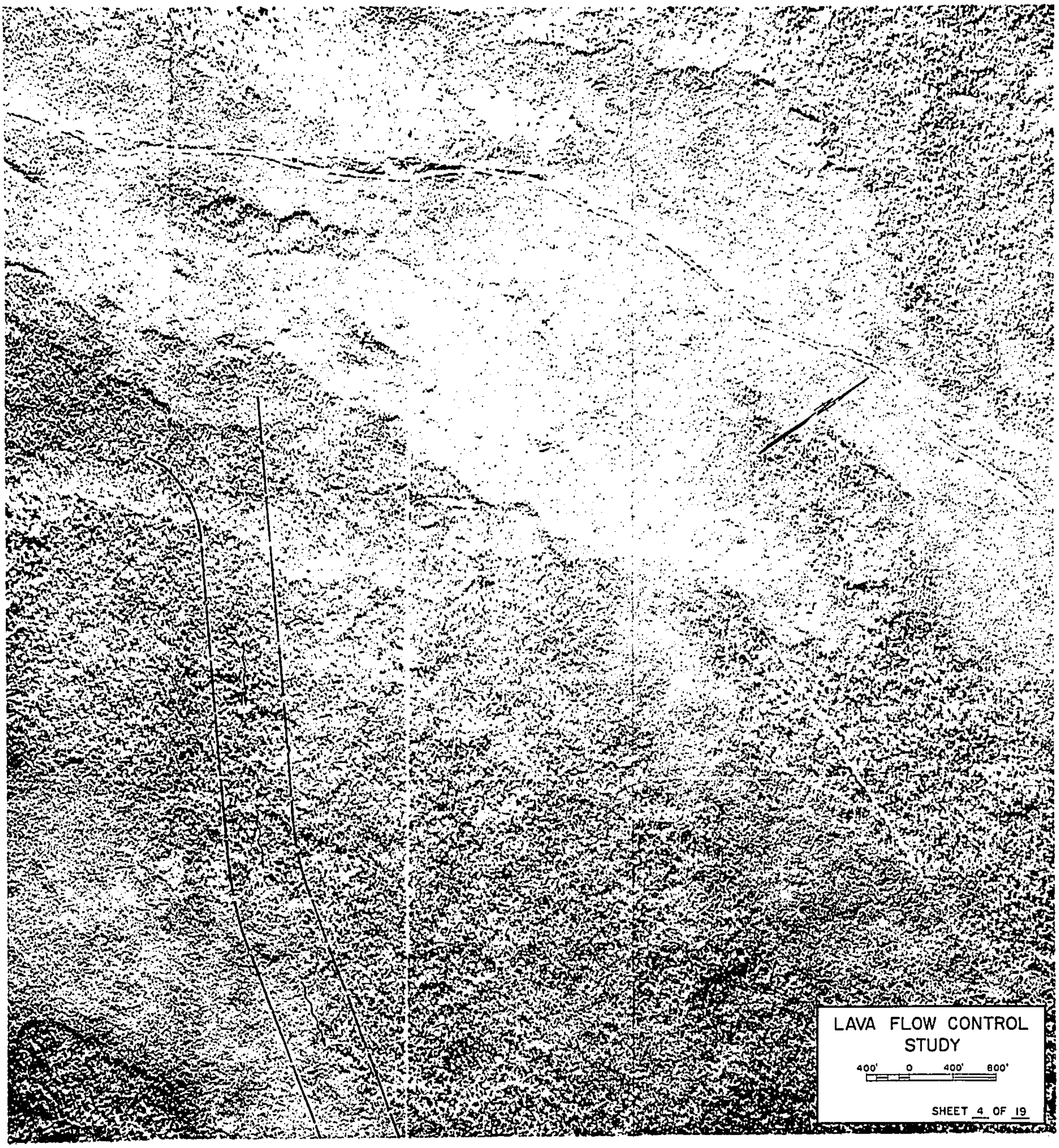
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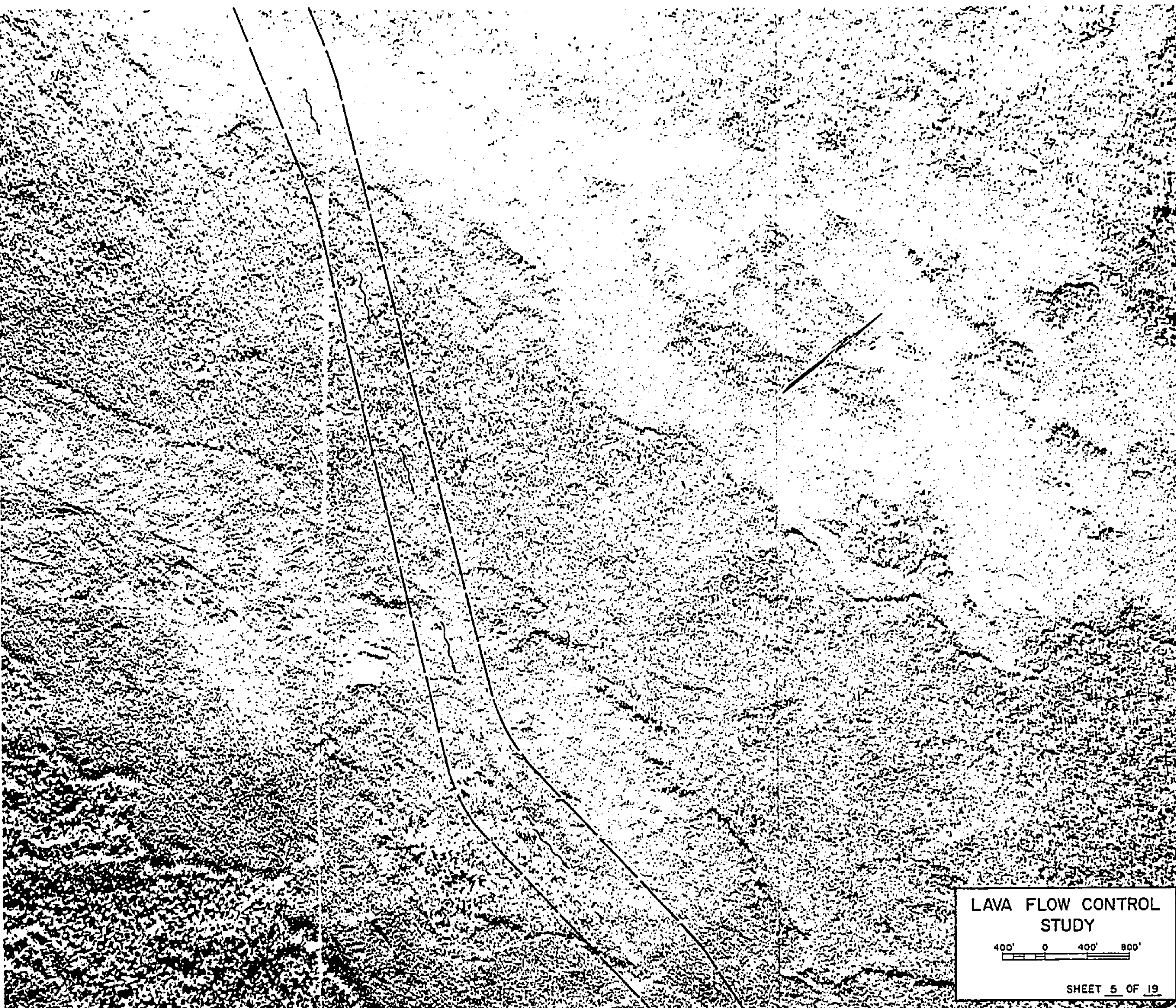
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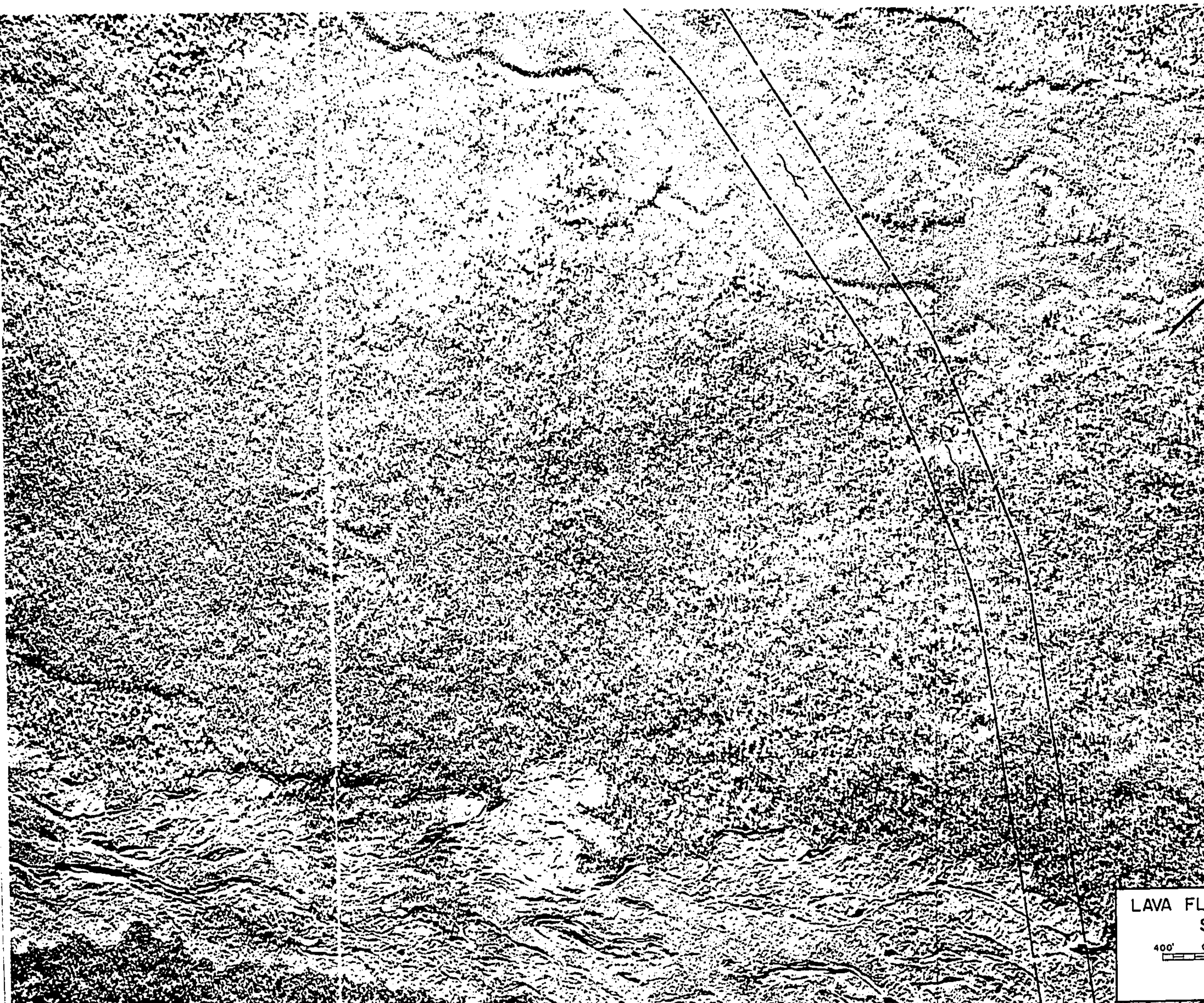
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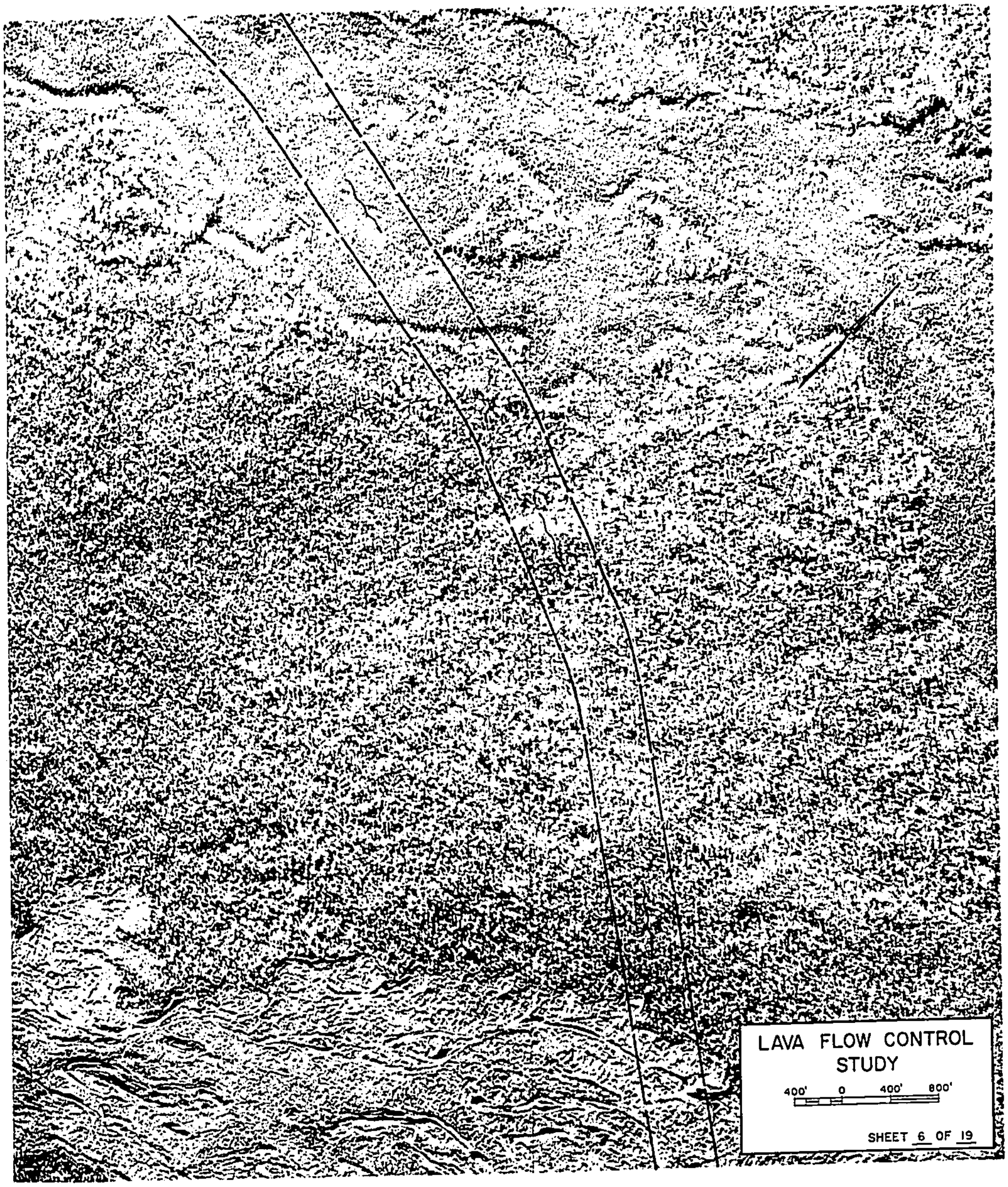
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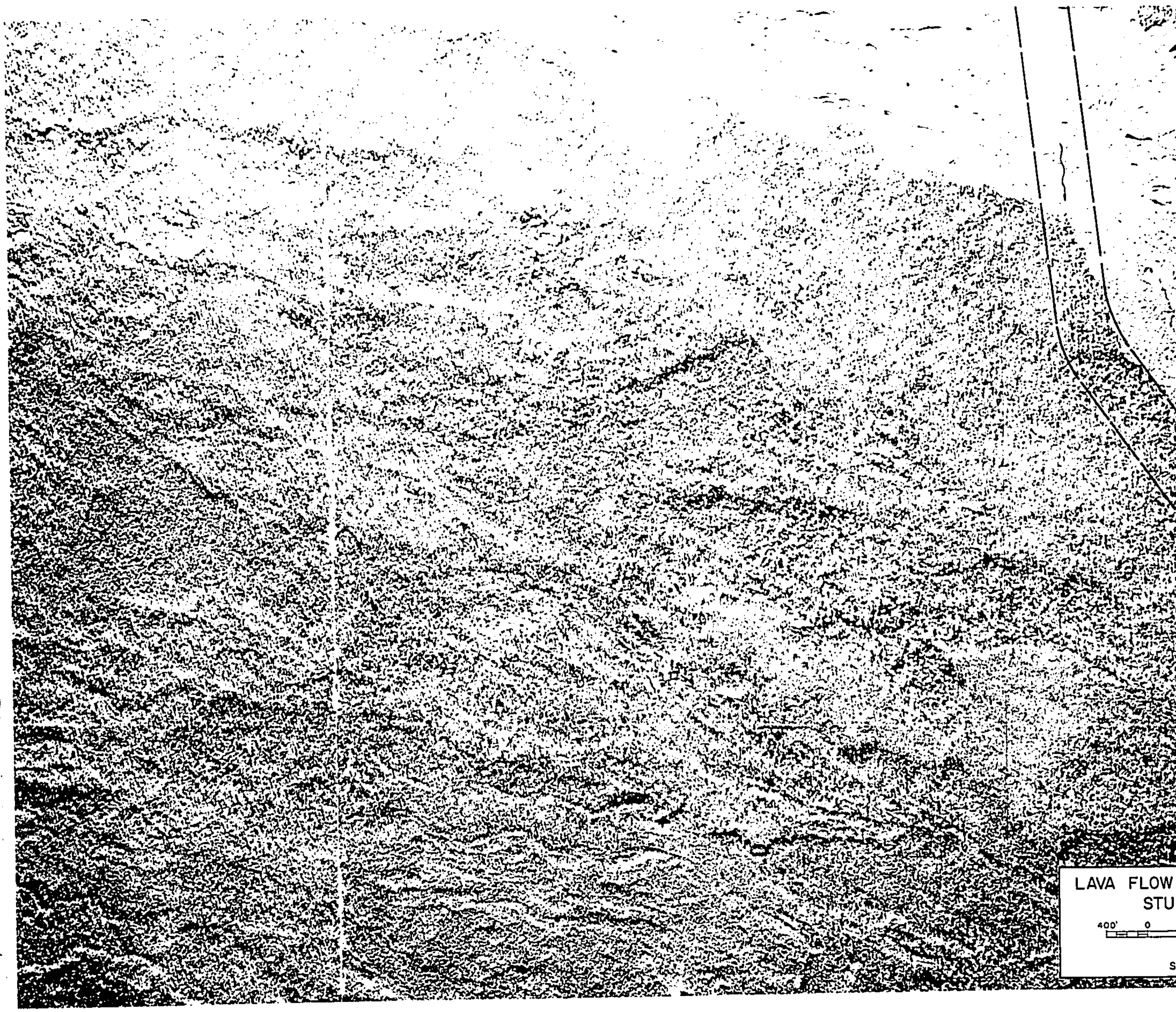
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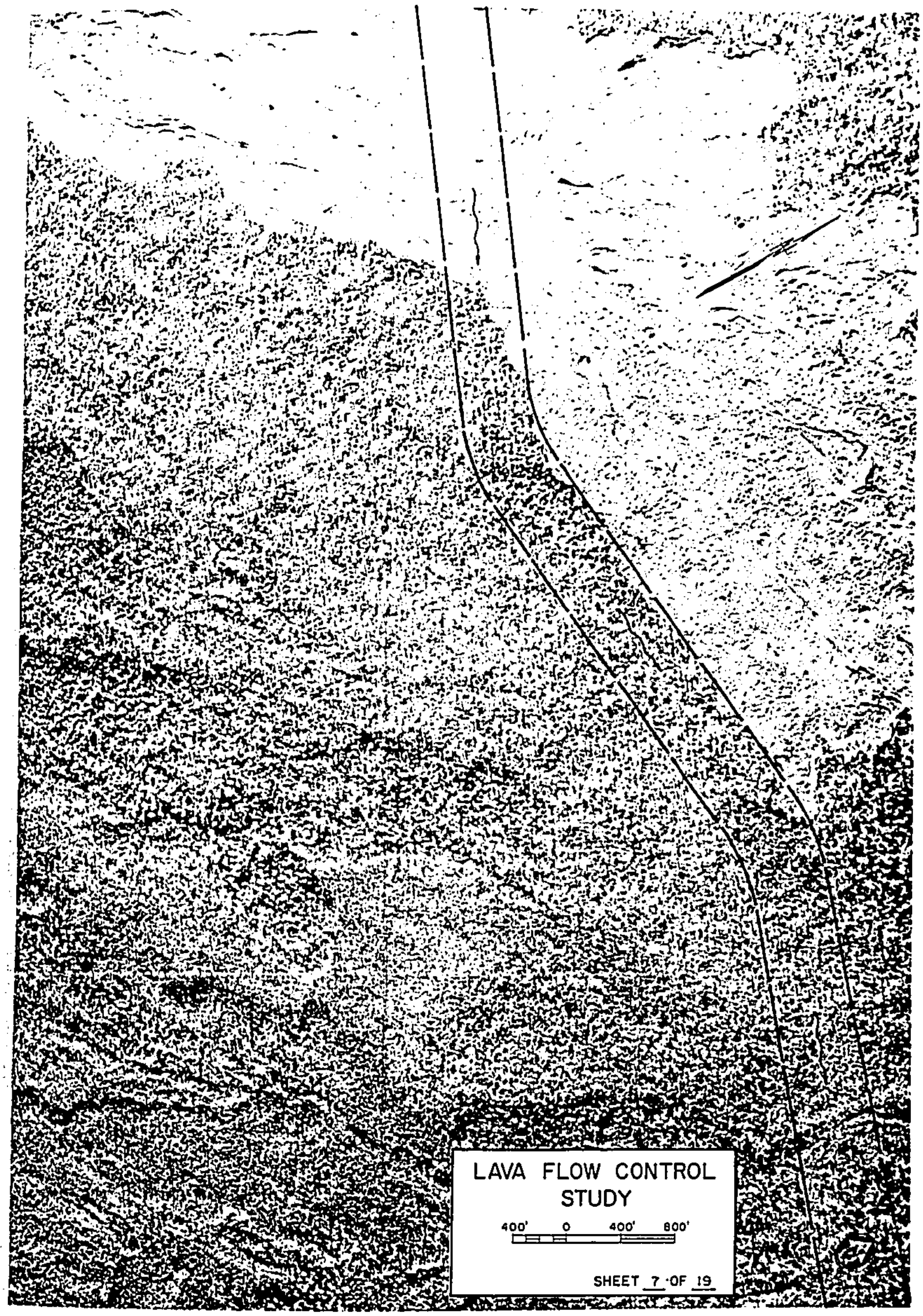
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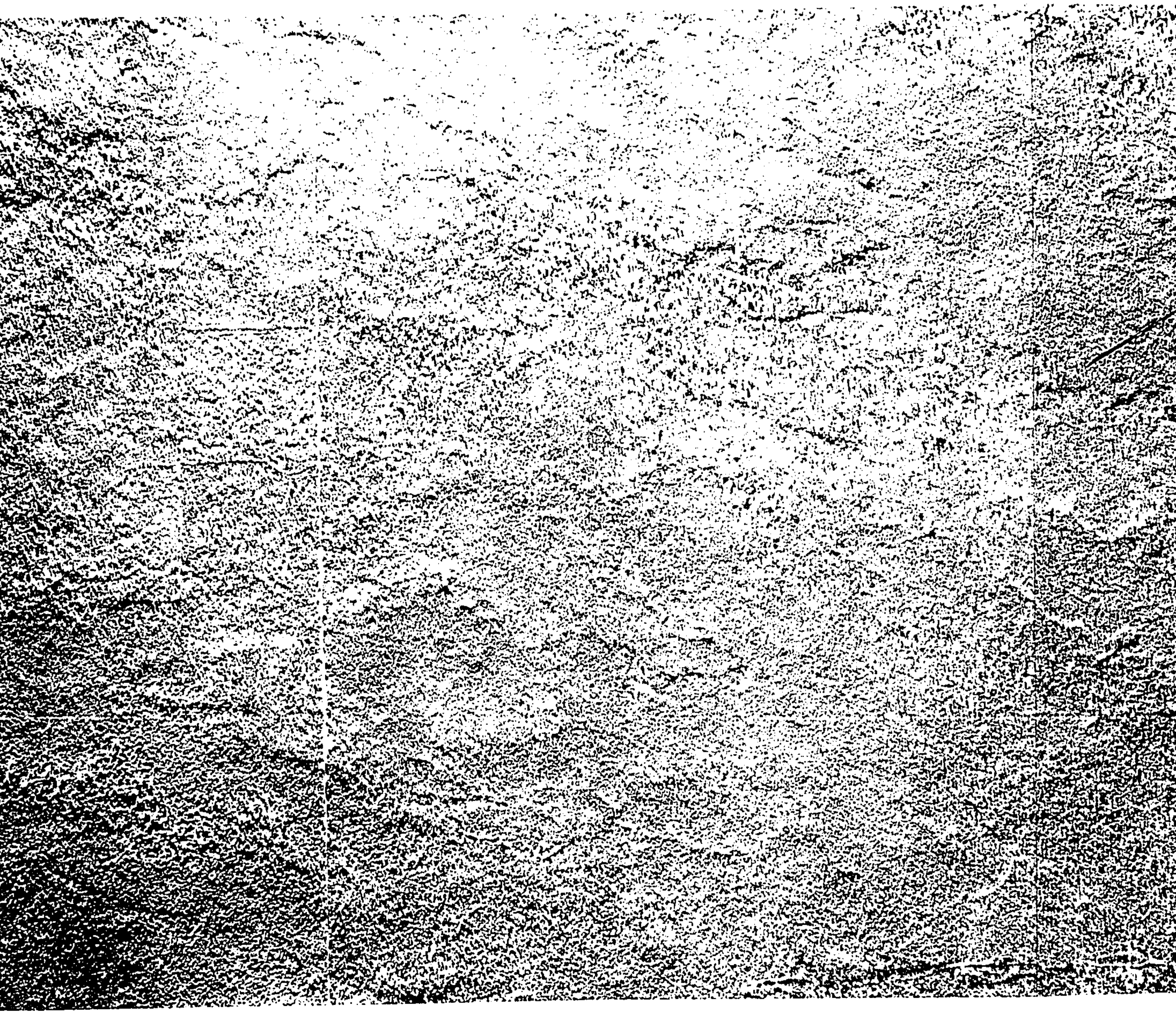


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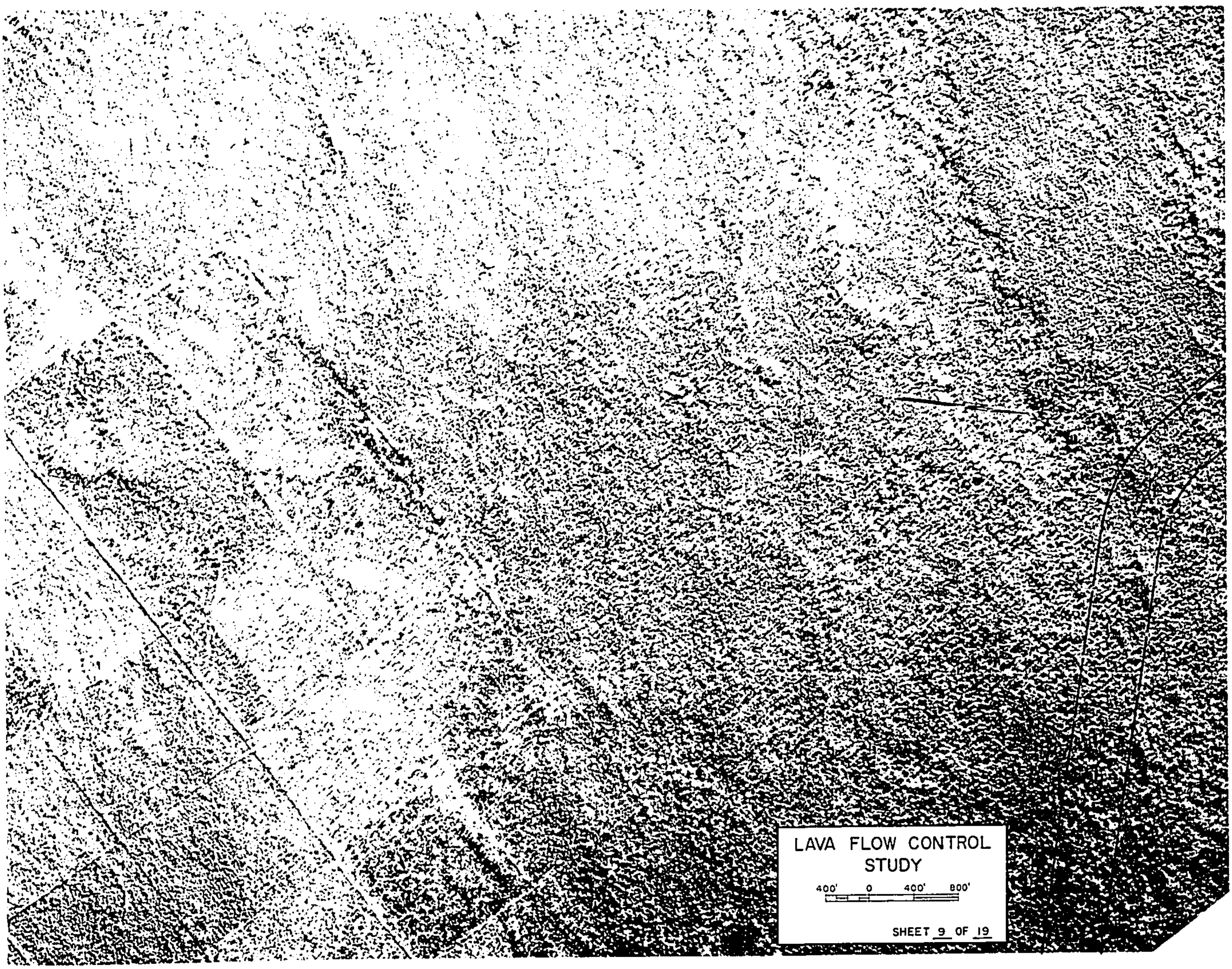
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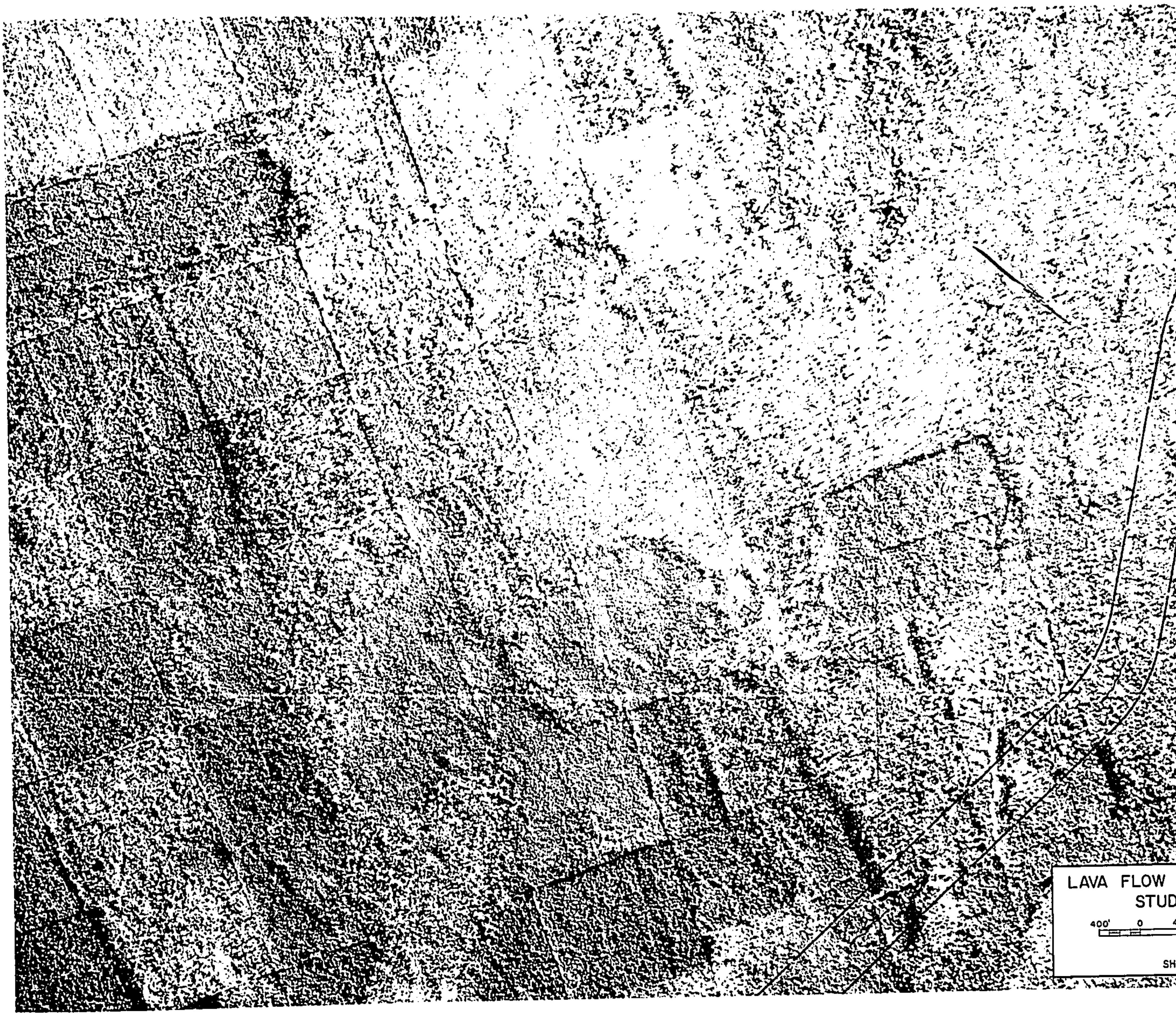
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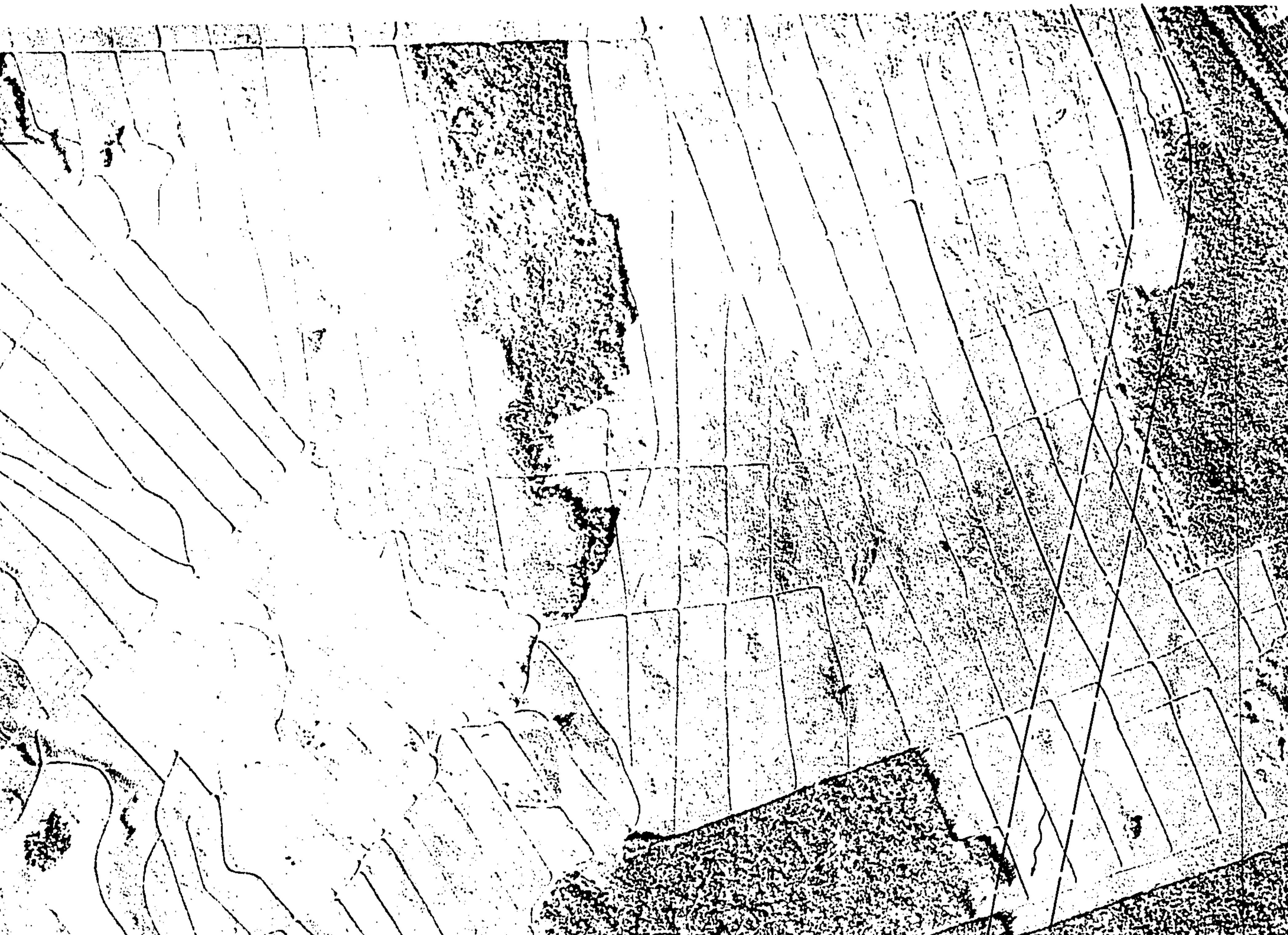

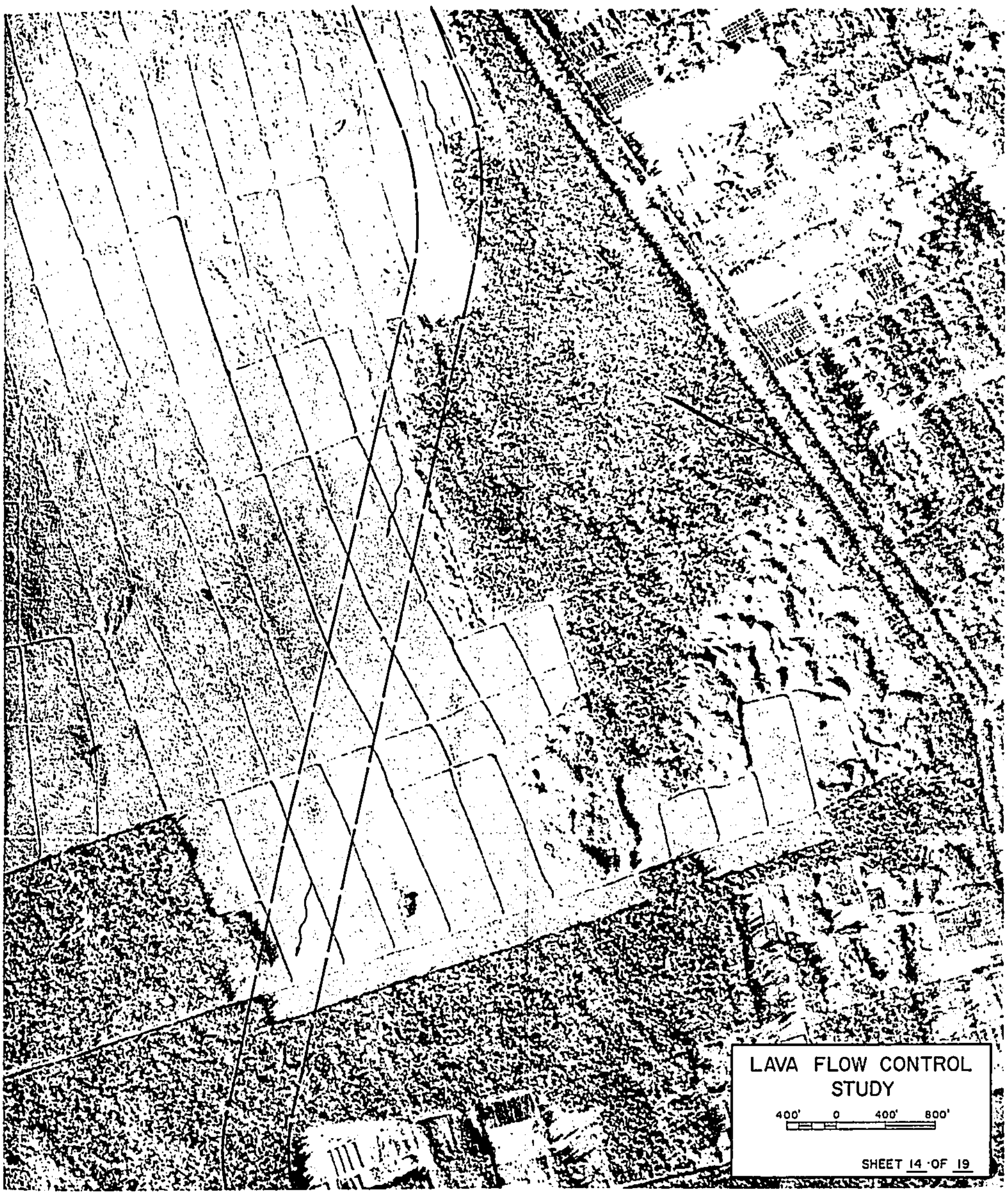
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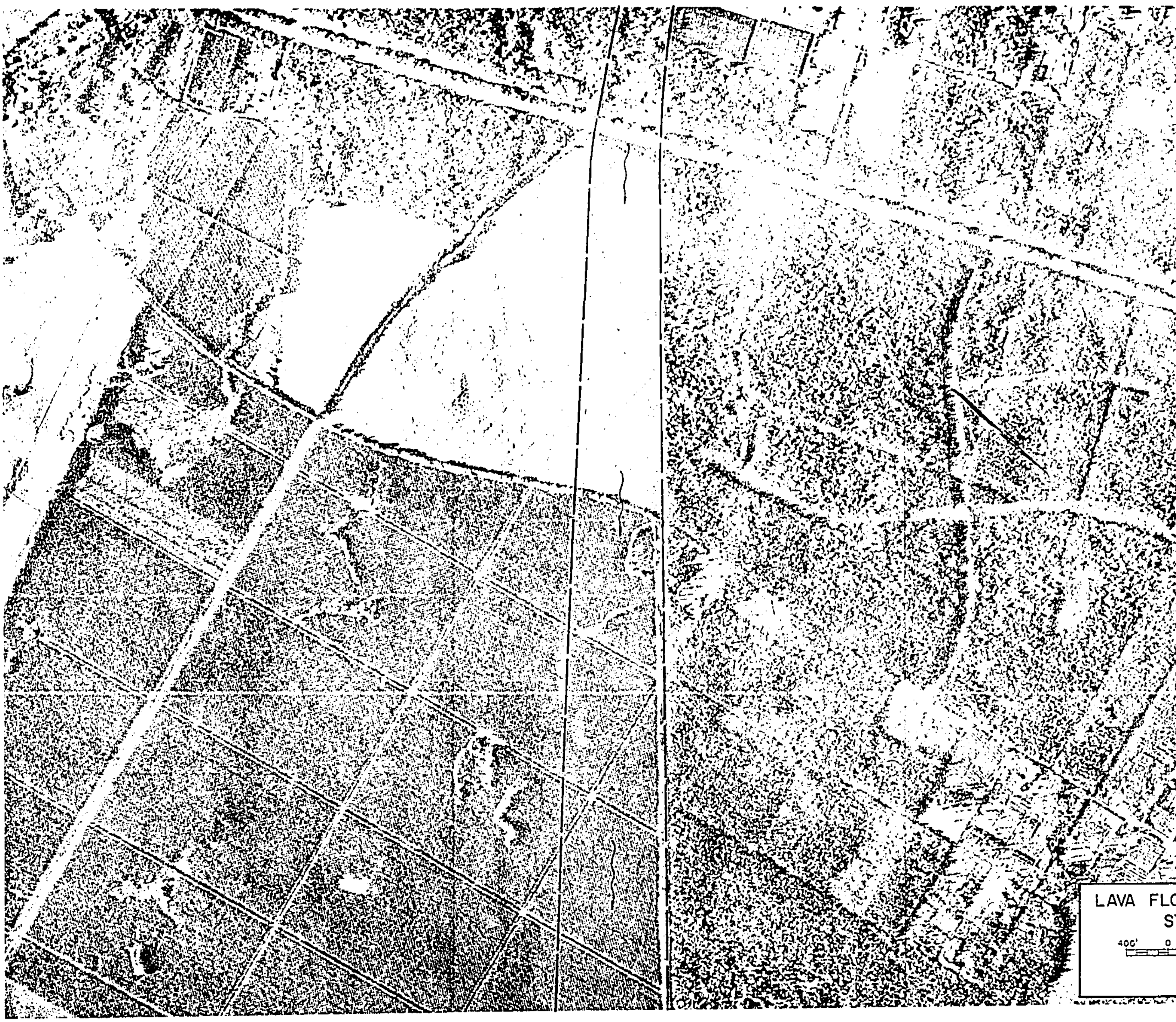
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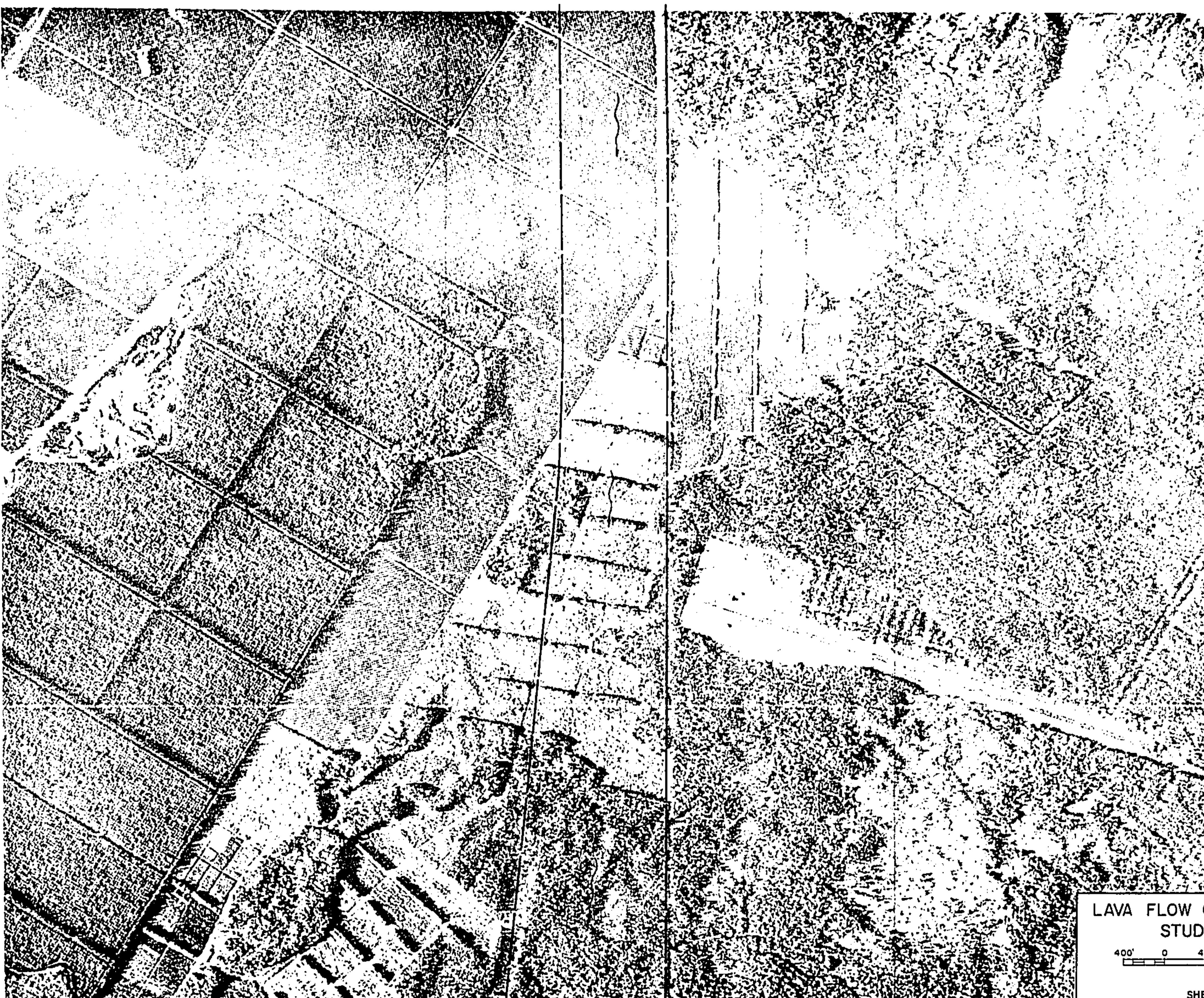
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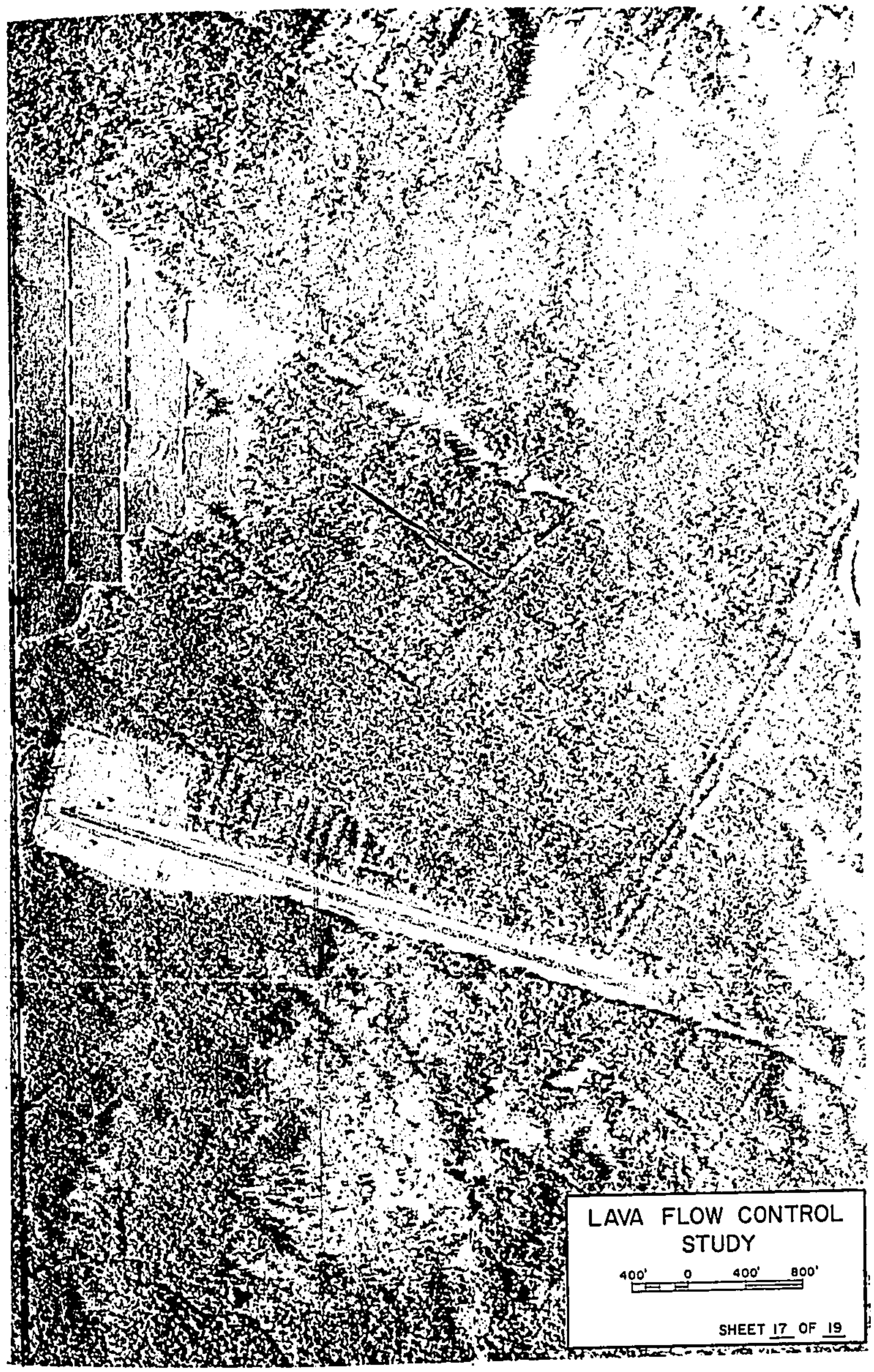
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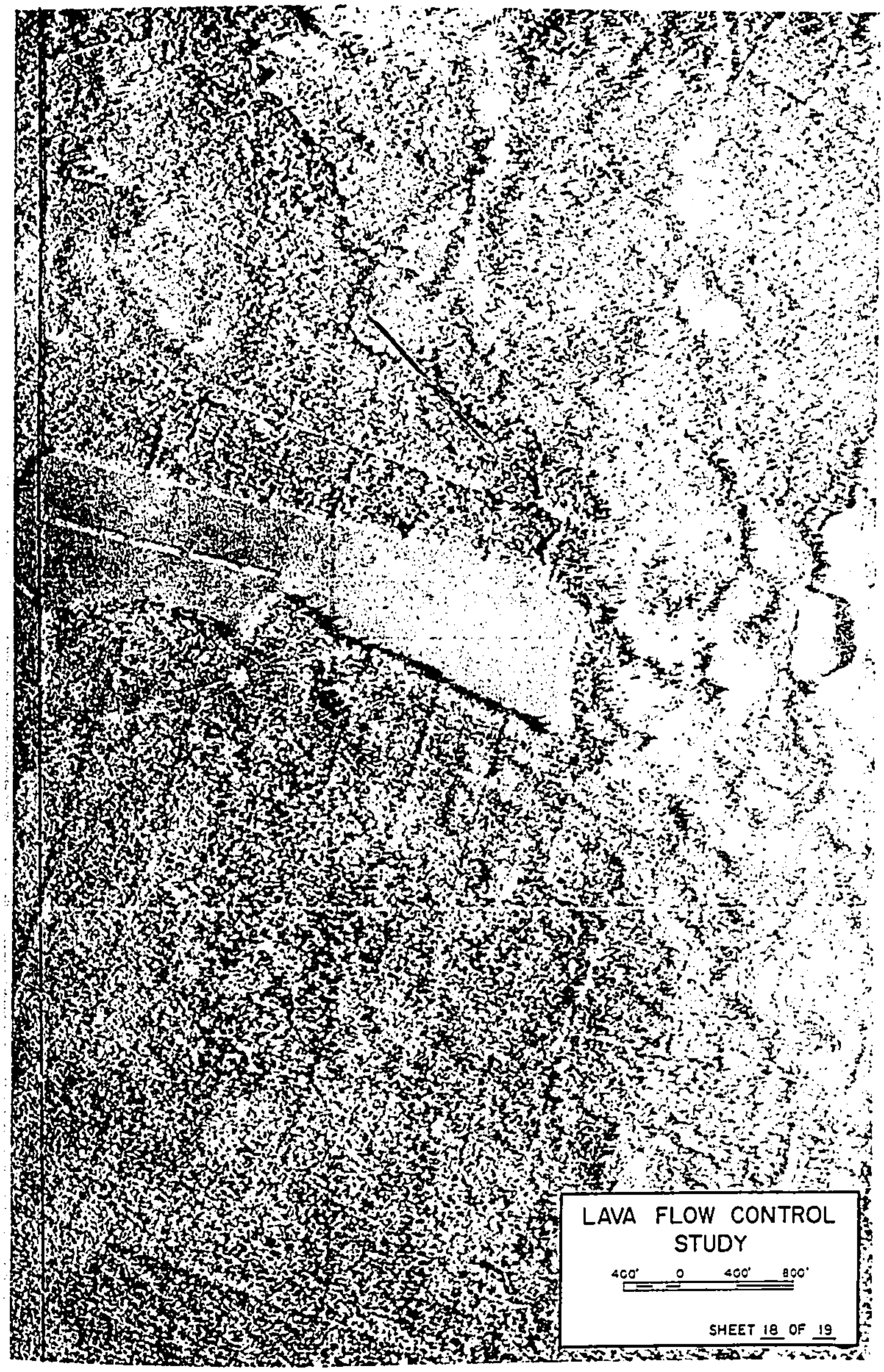
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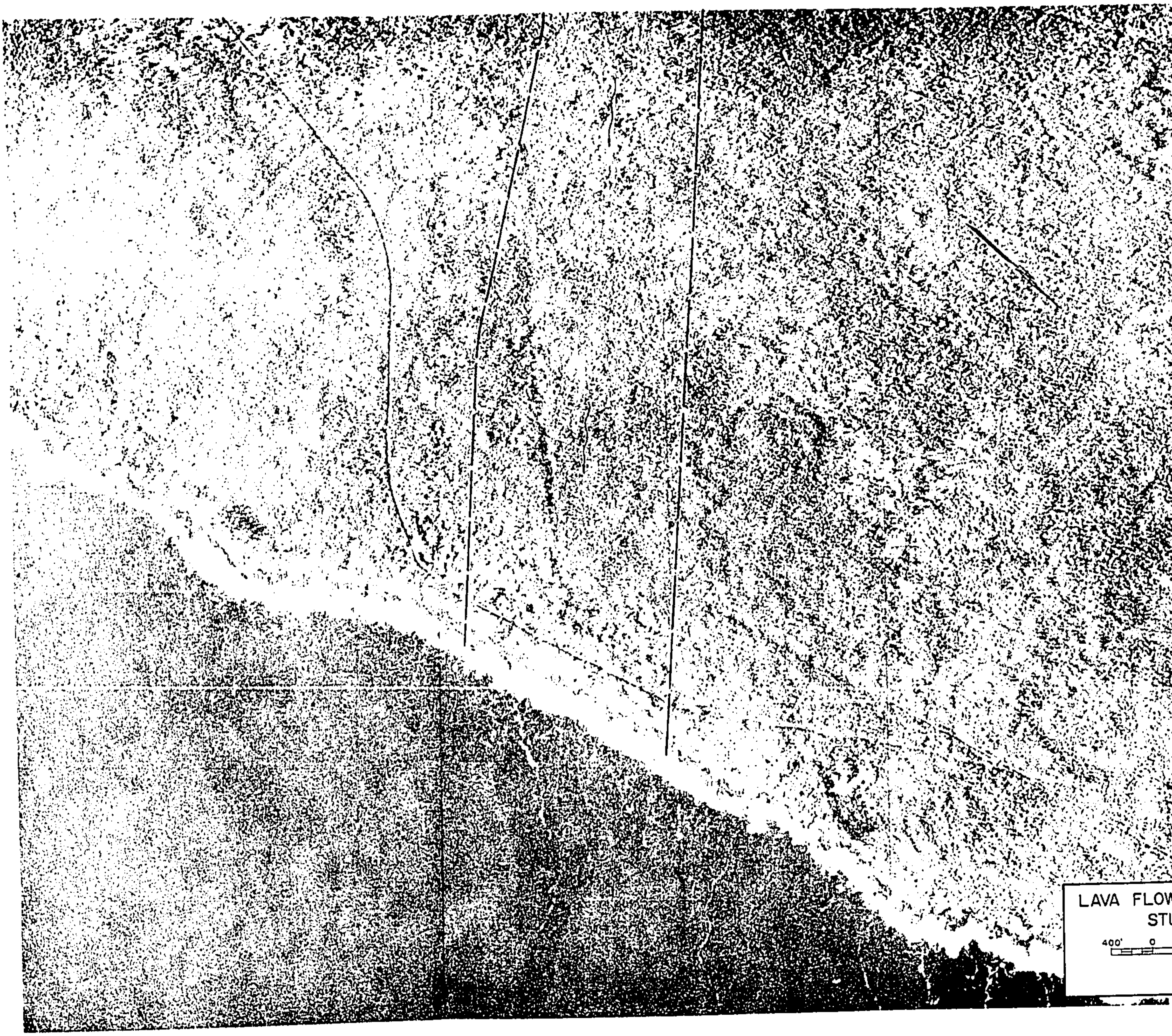
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LAVA FLOW CONTROL STUDY
ISLAND OF HAWAII

FISH AND WILDLIFE SERVICE PLANNING AID REPORT

APPENDIX E

LAVA FLOW CONTROL STUDY

Island of Hawaii, Hawaii

(Hilo)

Planning Aid Report

Prepared By

U.S. Fish and Wildlife Service
Ecological Services
Honolulu, Hawaii

September 1979

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1.0 Introduction

This is the planning aid report of the U.S. Fish and Wildlife Service on the U.S. Army Corps of Engineers proposed Hilo Lava Diversion project, City of Hilo, Island of Hawaii.

This report has been prepared under the authority of and in accordance with the provisions of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.) and other authorities mandating Department of Interior concern for environmental values. It is also consistent with the intent of the National Environmental Policy Act.

This report provides a preliminary biological analysis of the probable impacts associated with emergency action concepts proposed by the U.S. Army Corps of Engineers relayed to this office 15 November 1978, and the July 1979 draft interim report and environmental impact statement (27).

This report does not fulfill the Service's responsibility under Section 2(b) of the Fish and Wildlife Coordination Act. Should plans to construct a Wailuku River diversion be pursued, the Service must review them and provide a detailed report fulfilling this mandate. Additional transfer funding will be required.

The initial Hilo Lava Diversion project was undertaken under the authority of two Congressional Committee Resolutions and Section 208 of the Flood Control Act of 1960. Findings published by the U.S. Army Corps of Engineers in 1966 concluded that the preparation of a pre-emergency planning program and the implementation of this program during the first hours of eruption should reduce damages effectively. Therefore no Federal project was recommended for authorization at that time.

A more recent study, initiated in 1977, was authorized by the U.S. Senate Public Works Committee Resolution adopted on 14 November 1975. Its scope included 1) an evaluation of potential lava flow damage to the City of Hilo and 2) development of a feasible plan which would prevent lava flow inundation and related problems.

Although this project was initiated as a pre-emergency program, we understand that current planning efforts are evaluating potential sites for barrier construction should an eruption occur on Mauna Loa, endangering the City of Hilo. Legal authorities for this post-emergency program have not been established.

The Service provided a draft report on this project dated 18 December 1978.

2.0 Study Area

The study area is located on the eastern portion of the Island of Hawaii. It consists essentially of an elongated lava flow zone extending from about the 7,000 foot elevation on the northeastern slope of Mauna Loa to the City of Hilo (Fig. 1) (1, 27). This zone is about 6 miles wide and 23 miles long (138 square miles).

Mauna Loa is the largest and most active volcano in the world, and is the origin of lava flows potentially affecting the City of Hilo. Four additional volcanoes are found on the Island of Hawaii; two, geologically older Mauna Kea and Kohala, have been dormant in the historic period extending from about 1790 to present day. Kilauea and Hualalai remain active (Fig. 2) (2).

The study area is located in an area of geologically recent lava flows whose age is estimated to be 1000 years. Lava flows potentially affecting Hilo originate from a rift line extending north and south through the Mokuaweoweo crater. As such these flows usually travel in a northeast or southwest direction (Fig. 2). Although 37 eruptions have occurred during historic times, only 6 have resulted in extensive lava flows exuding from the northeast rift and moving toward Hilo (2). The 1881 lava flow came within 7 miles of the city (1,2).

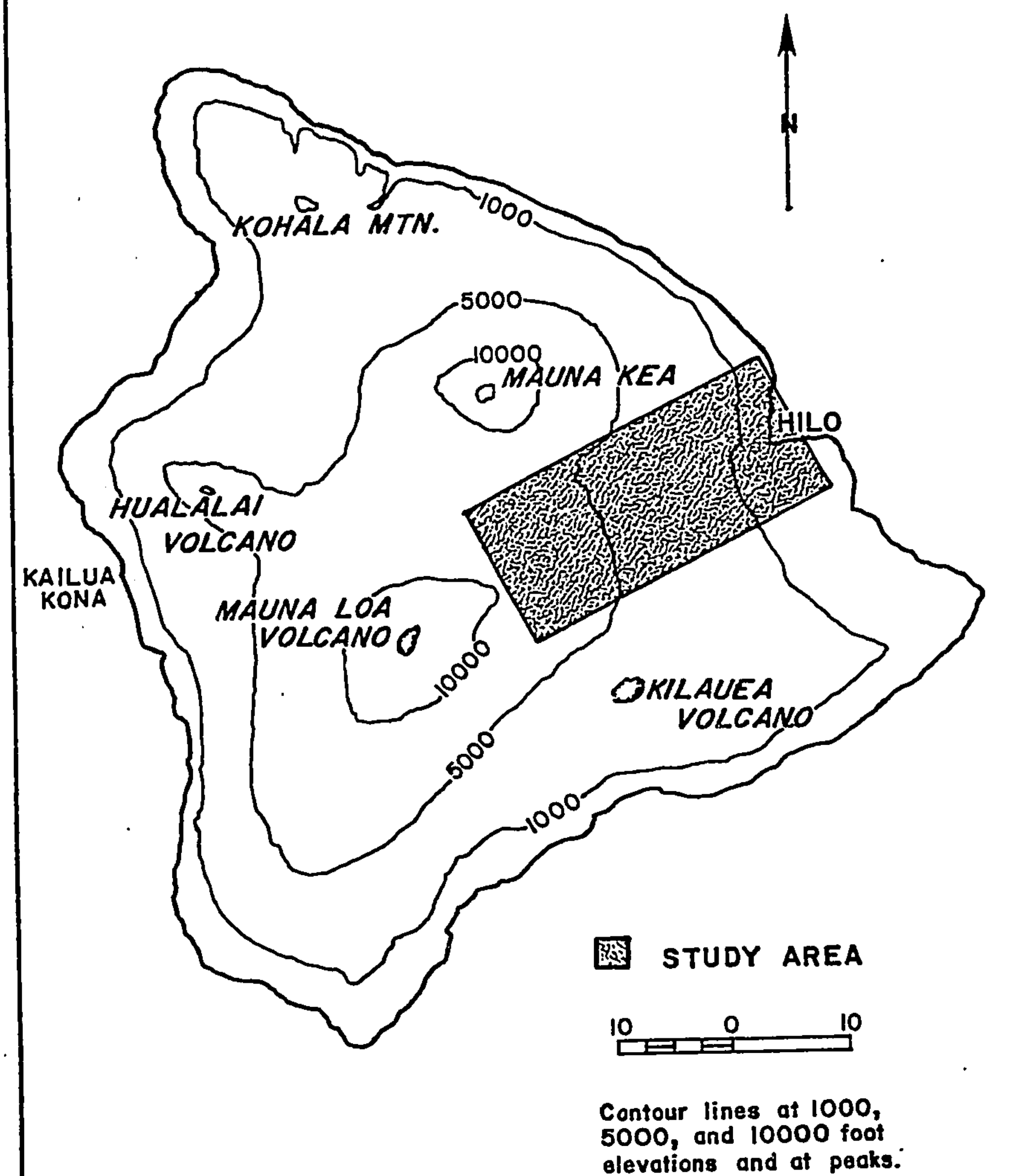

Figure 1. Location of the Hilo Lava Diversion study area, Island of Hawaii [1].

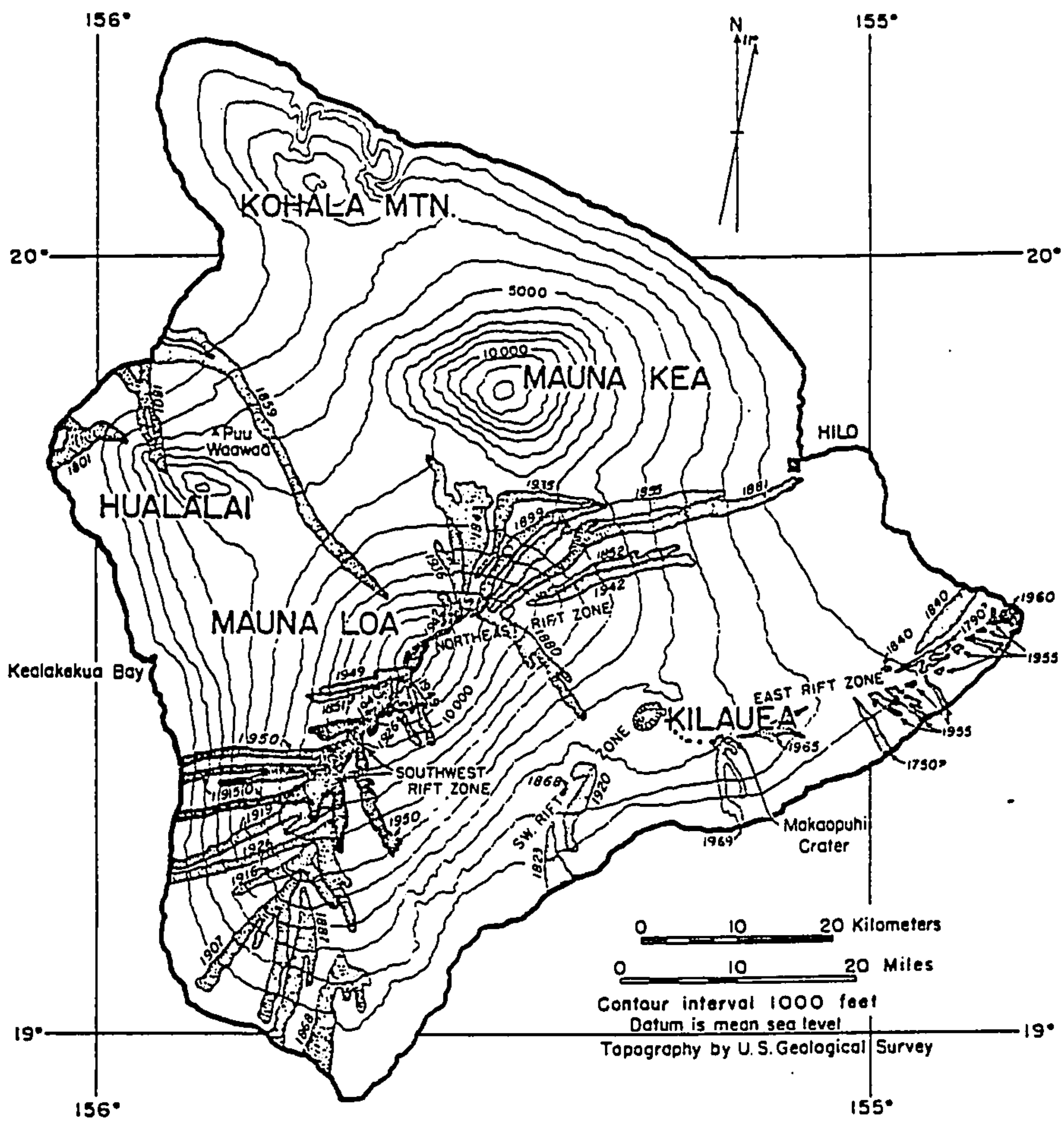

FIGURE 2: Map of the Island of Hawaii, showing the five major volcanoes that make up the island, and the historic lava flows [23].

From: Volcanoes in the Sea, Gordon A. Macdonald and Agatin T. Abbott, University of Hawaii Press, p. 52.

The maximum height of these flows was estimated to be approximately 15 feet (3). They covered an area of about 88 square miles (2). The fluidity of Hawaiian lava may permit flows in the main channel to reach speeds of 35 miles per hour (1). However, common speeds range from a few tens of feet to 1000 feet per hour. Based on this data it would take approximately one week for lava from Mauna Loa to reach Hilo Bay should it flow consistently at the higher rate.

The city of Hilo is located at the confluence of the Wailuku River and Hilo Bay. Hilo Bay is the only major port located along the relatively precipitous eastern coastline of the Big Island.

In 1976 the population of Hilo was estimated to be 39,000 approximately 51 percent of the Island's population. Based on proportional Island-wide projections for the year 2000, this number could increase to about 62,900 (1, 27). In the event lava flows endanger Hilo, present plans call for the evacuation of the area.

3.0 Project Descriptions

3.1 Pre-emergency Alternatives

Five project alternatives were proposed as pre-emergency concepts (27). Two of these proposals including a no development alternative, are essentially non-structural and two are structural. Approximate project locations developed thus far are shown in Figure 3.

Structural Alternatives

Alternatives A and B: A lava diversion dike with a design height of approximately 30 feet would be constructed on the northeastern slope of Mauna Loa between elevations 5700 and 200 feet, msl. This dike structure and associated diversion channel would be aligned to prevent lava flows from reaching the City of Hilo. The dike alignment probably would be as shown on Figure 3. These alignments are about 22 and 19 miles long, respectively.

Construction materials for the dike probably will come from the southwestern slope of the alignment. The diversion channel and dike would be constructed concurrently. The channel would be approximately 400 feet wide.

Alternative D: This alternative incorporates the dike alignment being proposed in Alternative B. In

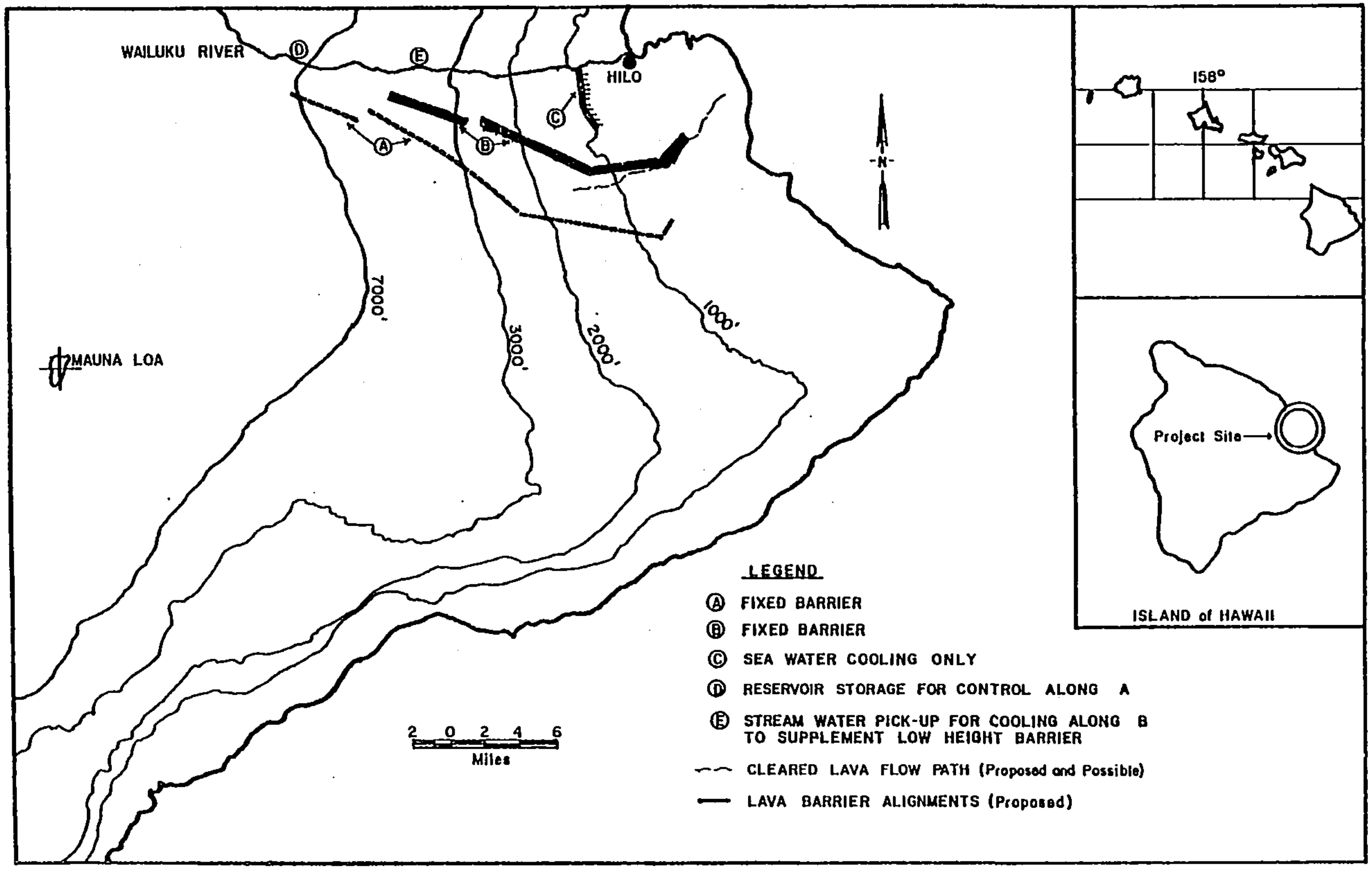

Figure 3. Location of the structural and non-structural alternatives under consideration. Hilo Lava Diversion Study, Island of Hawaii (1)

addition, cooling waters piped from the Wailuku River would be sprayed on the lava flow. Because of this supplementary feature, the proposed dike probably would have a lower crest height than the one proposed for Alternative B and therefore, require less borrow material. To aid in cooling lava, a stream diversion structure would be constructed to carry water from the Wailuku River drainage at or above elevation 3400 ft, msl to the barrier site.

Non-Structural Alternatives

Alternative C: A saltwater spraying system would be activated along an alignment located immediately southwest of the City of Hilo (Fig. 3). Pipes would be stored in Hilo and laid when needed. Water from Hilo Bay would be pumped inland and sprayed on the advancing lava front.

3.2 Alternative E (Emergency Operation)

This alternative has been proposed for investigation as a reactive measure to reduce or prevent lava flow damage in the City of Hilo. Areas would be surveyed to determine the value and feasibility of constructing selected barriers on an emergency basis. Construction would not begin until it was determined that lava flows would enter Hilo. Alignments could correspond to those considered in the pre-emergency alternatives but would be reduced in size. No specific alignments have been proposed.

4.0 Environmental Setting Without the Project

4.1 Terrestrial Habitat

The proposed project area incorporates subalpine habitat, rainforest barren lava flows, coastal wetlands, agricultural lands and urban areas. Perhaps the most important habitat for native plants and animals is located between elevations 3000 and 7000 ft., msl. Below this zone agricultural development has resulted in the destruction of native ecosystems. Here introduced birds, mammals and insects as well as plants comprise most of the biota. Above this zone, low temperatures and lack of cover limit habitation by native animals as well as introduced species. However, within the rainforest zone are found the island's remaining populations of increasingly rare native forest birds, the Hawaiian goose or nene, and its only native mammal the endangered hoary bat (Appendix A) (4,5). Forest birds federally listed as endangered species and found within the study area are the 'akiapola'au, Hawaii 'akepa, Hawaiian creeper and 'o'u.

These species generally are associated with the 'ohi'a lehua forest ecosystem. A recent forest bird census conducted by the U.S. Fish and Wildlife Service in cooperation with other state and federal natural resource agencies has provided more detailed information on the distribution of these birds (Fig. 4). However, relatively little is known about their life history or population dynamics (5).

Numbers of individual birds recorded during this study varied considerably when different species are compared. For example only 31 'o'u were observed at a total of 4 significantly separated areas while more than 394 Hawaiian creeper were observed evenly distributed throughout the upper limits of the rainforest (5). The number of birds required to maintain a viable population is unknown but probably species specific. Therefore, even though there appeared to be a greater number of Hawaiian creeper than 'o'u, their chances for survival may be the same. Perhaps more important is the apparent limited amount of habitat which can be used by the 'o'u. Approximately 20% of this habitat is located within the study area (5).

In addition to the honey creepers, the Hawaiian hawk and nene also are found in the study area. The nene is generally found between

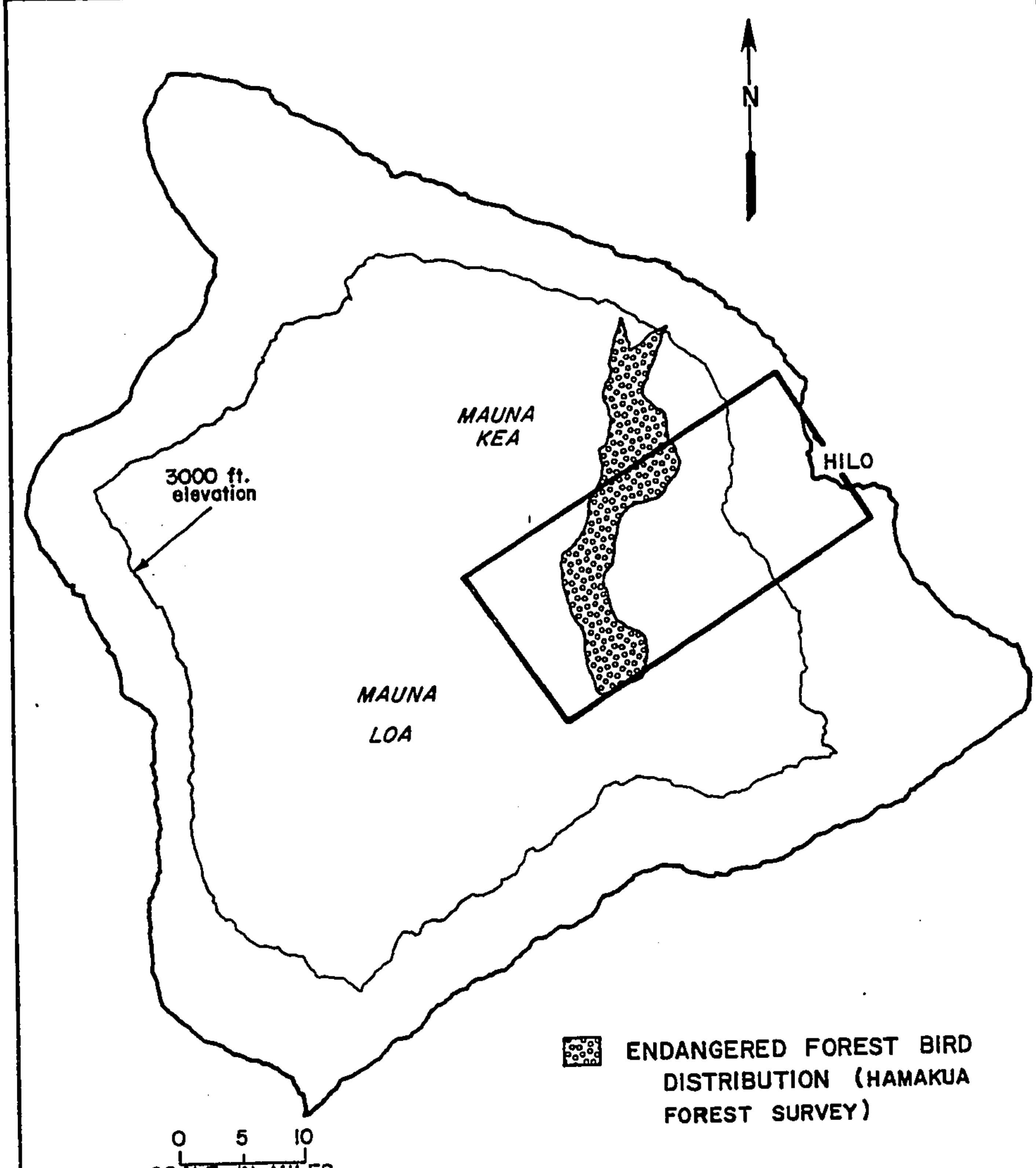

Figure 4. Distribution of endangered forest birds within the study area[5].

elevations 3000 and 7000 ft., msl, while the Hawaiian hawk's range extends from sea level to the upper limits of the rainforest (Fig. 5) (5). While the hawk does utilize the agricultural portions of the study area for feeding, its principle nesting habitat is located in the rainforest (4).

The threatened Newell's Shearwater also has been observed nesting along the banks of the Wailuku River at approximately elevation 2600 ft., msl (6).

Degradation of rainforest habitat has been attributed to both natural and man-related factors. Natural factors include volcanic activity and lava flows which alternately create and destroy the Island's terrestrial habitat. In addition to covering existing habitat, forest fires started by the molten lava have extended the destructive powers of these volcanic eruptions. Lava flows also have acted as isolating mechanisms assisting in the evolution of unique plant and animal life (7). As flows descended from Mauna Loa, they surrounded areas of slightly higher elevation, forming kipuka. These kipuka acted as refugia for surviving animals and vegetation. Isolated from the rest of the gene pool, the less mobile forms evolved into new species.

Another phenomena termed 'ohi'a decline also has resulted in the degradation of rainforest habitat. Previously 'ohi'a decline or

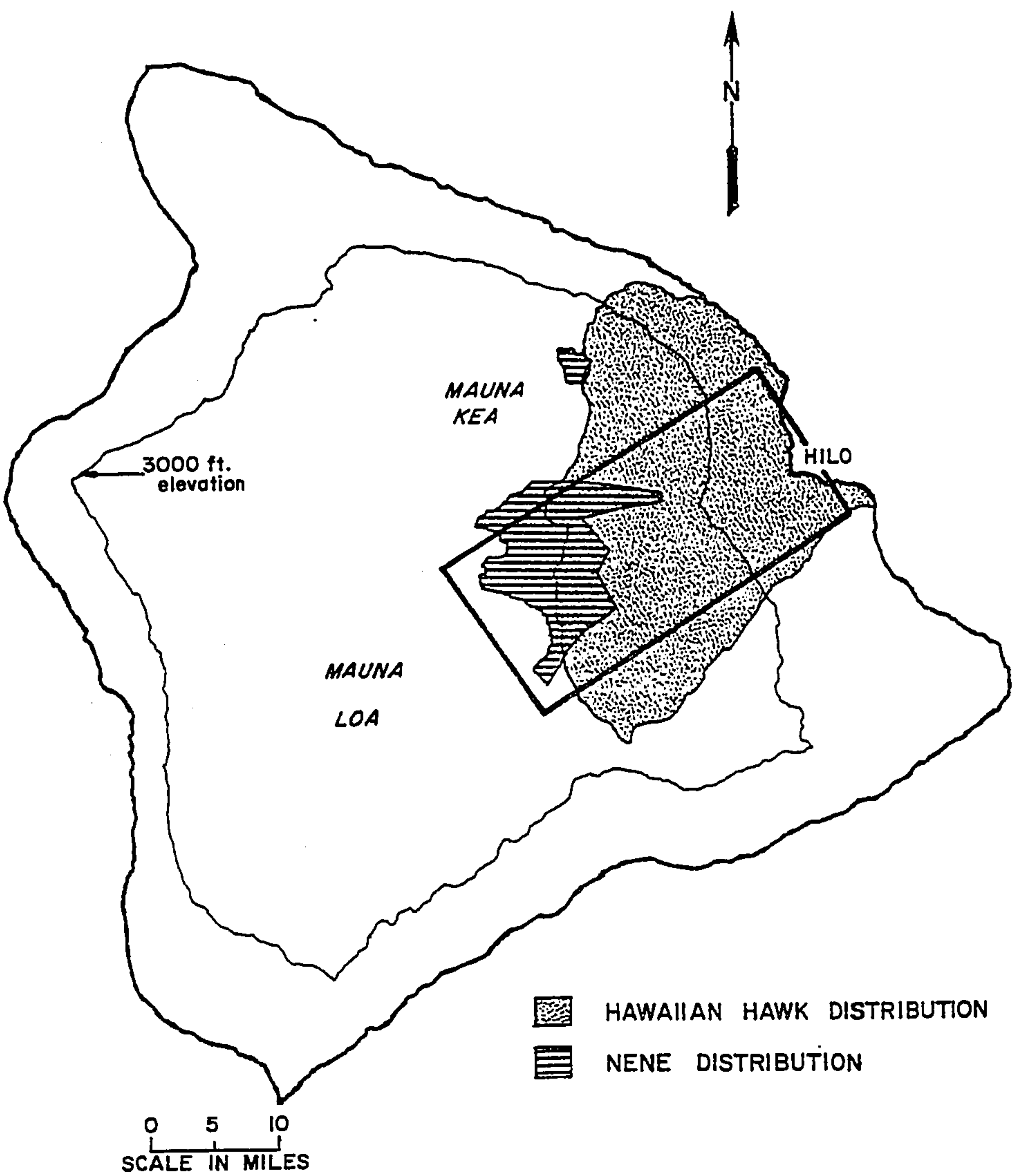

Figure 5. Distribution of endangered forest birds within the study area [5].

dieback was thought to be strictly disease related. However, recent studies indicate that it is associated with climatological factors and geological changes in soil drainage characteristics (8). While the result is the same, the actual mechanisms differ markedly. For example, the orographic rainfall pattern results in low rainfall along the porous upper limit of the rainforest. O'hia may receive insufficient water during dry years which, in turn, results in dieback. Substrate breakdown and compaction in high rainfall areas results in poor drainage. The root system of the O'hia is inundated in "ponding areas" and dieback occurs.

As silviculture and agriculture developed in Hawaii, a significant portion of its native forests were harvested and replaced with introduced vegetation. The resulting loss of habitat coupled with predation by introduced wildlife including rats and the mongoose, competition with exotic birds, and avian disease brought in and transmitted by introduced vectors, have contributed to the decline of native birds (4). The survival of the Island's native forest birds depends directly upon the preservation and enhancement of the remaining native forest ecosystems. Earlier efforts by the State to conserve native biota included the establishment of the 640 acre Waiakea 1942 Lava Flow Natural Area Reserve and the designation of state forest reserves (9). Portions of three of these, the Upper Waiakea, Waiakea and Hilo Forest Reserve are located in the study area. An additional area, the 10,000 acre Piihonua Natural Area Reserve, was being considered for reserve system status, however action on this proposal has been deferred. Establishment of the Kipuka Ainahou Nene Sanctuary set aside about 38,400 acres for the perpetuation of the nene in an area bordering the upper limit of the Upper Waiakea Forest Reserve (10).

The U.S. Fish and Wildlife Service is now in the process of completing the vegetation mapping for the Hamakua forest bird survey. When the resultant data has been analyzed and the remaining forest habitat on the Island of Hawaii surveyed, critical habitat designations for the Island's endangered forest birds will be established.

Data being gathered during the vegetation mapping segment of this study include the identification and location of federally proposed endangered plants. Proposed endangered plants found in the rainforest during the initial bird survey and those tentatively identified in the 'ohi'a decline study are listed in Table 1.

While endangered forest birds are limited to above the 3000 foot elevation, proposed endangered plants have been found as low as 5 ft., msl, within the study area (11). However, in general, the majority of endangered plants are found above 2000 ft., msl, in

Table 1. Proposed endangered plants recently identified in the Hilo Study Area. Since Mueller - Dombois (1977) did not identify taxa found in the area, the number of varieties being considered for endangered status are listed as undifferentiated taxa. (*) indicates plants not included in St. John's (1973) distribution[18].

Family/Species	Undifferentiated Taxa	Source
Araliaceae		
Tetraplasandra meiandra (*)	(proposed endangered species: 5 varieties)	Mueller - Dombois 1977
Tetraplasandra kavaiensis var. *dipyrena*		Scott *et al* 1977
Arecaeae		
Pritchardia spp. (*)	(proposed endangered species: 10 varieties)	Mueller - Dombois 1977
Campanulaceae		
Clermonitia hawaiiensis (Hbd.) Rock var. *hawaiiensis*		Scott *et al* 1977
Clermontia lindseyana Rock		"
Clermontia peleana Rock		"
Clermontia pyularia Hbd.		"
Cyranea tritomantha Gray var. *titromantha*		"
Flagellariaceae		
Joinvillea ascendens Brongn. & Gris. ssp. *ascendens*		Scott *et al* 1977
Gesneriaceae		
Cytrandra lysiosepala	(proposed endangered species: 1 variety)	Mueller - Dombois 1977
Lamiaceae		
Phyllostegia floribunda	(proposed endangered species: 1 variety)	Mueller - Dombois 1977

areas undisturbed by urban and agricultural development. Figure 6 illustrates the areas of high native biological value within the study area.

Although endangered species recognition was initially given to Hawaii's endemic birds and its few native mammals, recent concern over the islands less conspicuous residents has increased. Endemic invertebrates gradually are being accepted as part of Hawaii's biological legacy. Many of these species occupy such unique habitat as lava tubes and kipuka, vegetated areas isolated by lava flows (12). Others including land snails are extremely limited in their geographic range and may be found only in a single gulch (13). At this time little is known about endemic invertebrate composition or distribution within the study area.

In additon to the native plants and animals, the study area is inhabited by a number of introduced species. Some wildlife introductions were made purposely to provide game resources, livestock or biological controls for other introduced pest species. However, the majority of introductions including numerous insects, rodents, and non-game birds, were accidental. Appendix B lists introduced birds and mammals found in the study area.

Game animals found within the study area include the feral pig, a limited number of the ring-necked pheasant and laced-neck and

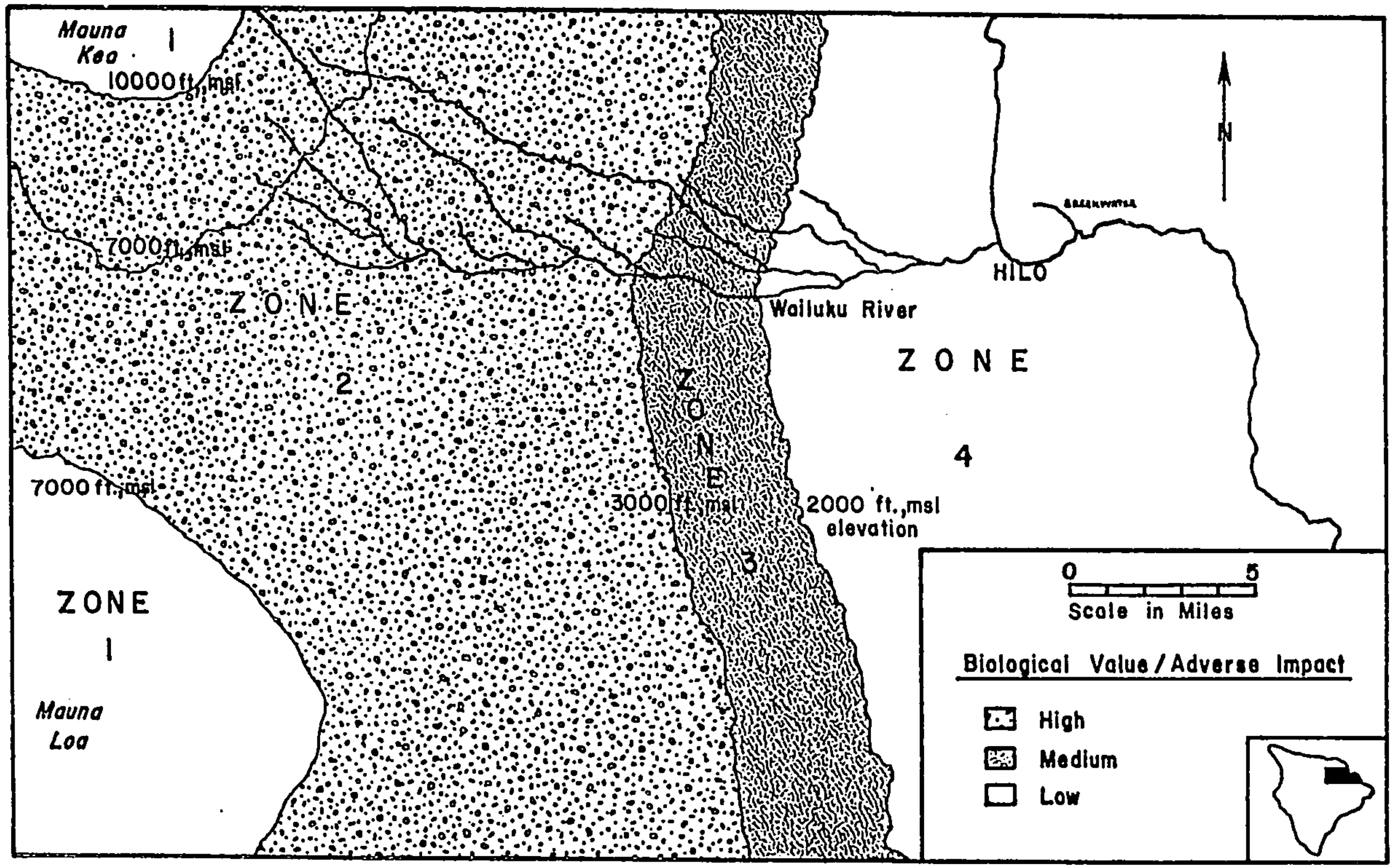

Figure 6. Biologically sensitive zones within the Hilo Lava Diversion study area, Island of Hawaii.

barred dove (14). Feral pig populations in the more remote rainforest portion of the study area can reach 1 pig/2 acres (15). This significantly exceeds suggested habitat maintenance densities of 1 pig/12 acres (15). Human access to these areas is virtually impossible and pig rooting behavior has created significant erosion problems (5,8). Pig rooting also reduces successful 'ohi'a regeneration in dieback areas (8). Habitat disturbance whether by man or animal generally favors establishment of introduced plants (16).

Gamebird populations are relatively low in rainforest areas. Here high humidity limits successful hatching and rearing of their young (17).

4.2 Aquatic Resources

Approximately 60 percent of the Wailuku River drainage is included within the study area. From its channel origin at 10,830 ft., msl to its confluence with the sea, this river is approximately 25.6 miles in length, the longest stream in Hawaii (18). Following the rugged topography of this geologically young island, it descends over many steep falls.

Hawaii's native freshwater fish and shrimp are diadromous. Their young require ready access to the marine environment where they spend the larval stage. When they return to ascend streams, barriers such as Rainbow Falls limit their migration. This is reflected in the limited distribution of diadromous stream macrofauna within the Wailuku River system. Table 2 lists stream macrofauna observed or reported as found in this river system and, Table 3 illustrates their distribution.

In the upper reaches of the Wailuku River, at about elevation 3500 ft., msl, stream macrofauna were low in volume, number and diversity. Here native and exotic insects are the dominant stream macrofauna with the introduced caddisfly (Cheumatopsyche analis) being the most abundant (18). Of the diadromous species only the river shrimp, opae kala'ole, was found in the Wailuku River at about elevation 3400 ft., msl.

Both native and exotic fish have been sighted above Rainbow Falls (18,19). However, during a recent survey, no native fish were observed above this natural barrier (19).

The lower Wailuku transports heavy sediment loads during periods of high flow. The major portion of this load appears to originate from agricultural lands located in the lower part of the basin. 'O'opu have exhibited an avoidance response to high silt loads (21). Therefore, this phenomena may contribute to the lack of native fish in this stream.

Table 2. Checklist of aquatic macrofauna in the Wailuku River, Island of Hawaii, Hawaii, 1967-1978. [18]

SCIENTIFIC NAME	COMMON NAME	ORIGIN	LISTING[1]
Insects			
Coleoptera			
Dytiscidae	water beetles	endemic	none
Diptera			
Chironomidae	midges	endemic	none
Odonata			
Megalagrion blackburni	damselfly	endemic	none
Trichoptera			
Cheumatopsyche analis	caddisfly	introduced	none
Crustaceans			
Atya bisulcata	'opae kala'ole	indigneous	none
Macrobrachium grandimanus	'opae oeha'a	endemic	none
Macrobrachium lar	Tahitian prawn	introduced	none
Procambarus clarkii	crayfish	introduced	none
Mollusks			
Neritina granosa	hihiwai	endemic	depleted[2]
Fish			
Awaous stamineus	'o'opu nakea	endemic	depleted[3]
Kuhlia sandwicensis	aholehole	endemic	
Misgurnus angiollicaudatus	dojo	introduced	none
Poecilia reticulata	mosquito fish	introduced	none
Sicydium stimpsoni	'o'opu nopili	endemic	rare[2]
Tilapia mossambica	Tilapia	introduced	none
Xiphorus helleri	swordtail	introduced	none

Table 2. Cont'd

SCIENTIFIC NAME	COMMON NAME	ORIGIN	LISTING[1]
Amphibians			
Rana catesbeiana	bullfrog	introduced	none

Footnote

1. Considered as rare, endangered threatened or depleted in official register or scientific publications.
2. Maciolek, in press [24]
3. Miller 1972 [25]

Table 3 . Distribution of Stream Macrofauna in the Wailuku River, Island of Hawaii. [8]

Number Elevation (ft/msl)	1 3490	2 3360	3 1440	4 1380	5 360	6 300-100
Stream Fauna						
Insects						
Native						
Diptera						
Chironomidae	X	X	X	X	X	
Coleoptera						
Dysticidae		X		X		
Odonata						
Megalagrion blackburni	X	X	X	X		
Exotic						
Trichoptera						
Cheumatopsyche analis	X	X	X	X	X	
Odonate - unidentified			X			
Crustaceans						
Native						
Atya bisulcata		X[1]	X	X		X
Macrobrachium grandimanus						X
Macrobrachium lar						X
Procambarus clarkii					X	
Mollusks						
Native						
Neritina granosa						X
Fishes						
Native						
Awaous stamineus						X
Sicydium stimpsoni						X
Kuhlia sandwicensis						X
Exotic						
Xiphorous helleri			X	X	X	
Poecilia reticulata					X	
Misgurnus anguillicaudatus					X	
Tilapia mossambica						X
Exotic Amphibians						
Rana catesbieana	X	X	X	X	X	

1) Molt only

River shrimp were found in pool and riffle areas above Rainbow Falls. Those seen at elevation 1500 ft., msl, exhibited shell disease. Chan (in press) hypothesized that this disease was caused by silt abrasion creating surfaces of attack for shell-eating bacteria (20). The watershed's highest sediment loads were recorded well below this site. However, erosion resulting from pig damage within the upper forest area and loss of cover in 'ohi'a decline areas probably contribute to adverse water quality conditions in the river's middle reach.

Fisherman interviewed by Service biologists also revealed that native freshwater mollusk (hihiwai) and native and introduced freshwater fish and crustacea were taken below Rainbow Falls.

Hilo Harbor, into which the Wailuku River drains, also has been adversely affected by siltation from agricultural lands, poor circulation, commercial harbor use and sugar mill effluent. In general water quality is considered poor with total phosphorous and nitrogen exceeding State Water Quality Standards for Class B as well as Class A waters (22).

The most biologically productive areas within the harbor are located in the vicinity of Blonde reef and around Kaulainaiwi and Coconut Island as well as seaward from Reeds Bay. However, coral formations in the nearshore areas appear to have died recently (22). This may indicate a continuing decrease in marine habitat quality within the harbor area.

5.0 Environmental Setting With the Project

Alternatives presented in this report are concepts rather than plans cast in concrete. Therefore potential impacts must be presented in general rather than specific terms.

5.1 Pre-Emergency Program

Structural Alternatives A and B and D:

Construction of Alternative A and B could result in the destruction of as much as 2000 acres of wildlife habitat. Implementation of Alternative D probably would result in slightly less habitat alteration because of the reduced need for borrow material. This figure does not include the area required for construction of access roads.

The magnitude of project impact will be dependent upon the precise location of the barrier, the amount of endangered species habitat destroyed and the number of kipuka altered or eliminated through project construction and lava diversion. Barrier construction below 2000 ft., msl, is not expected to produce significant impacts on unique habitat. However, a biological survey of the construction area and lava diversion pathway should be done prior to alternative selection.

Construction activity along the upper portion of the alignment above 3000 ft., msl, will affect endangered species habitat. The area in which the 'o'u has been sighted may not be affected directly by clearing and construction. However, noise levels and habitat disturbance in the surrounding area may produce significant adverse impacts on this, one of the four remaining areas, utilized by these birds.

Road and barrier construction could provide one benefit: improved hunter access to the surplus of feral pigs inhabiting the more remote sections of the study area. This could assist in reducing the amount of pig damage to endangered species habitat in areas adjacent to the access roads.

Probably most of the proposed endangered plants found in the study area are located between approximately 2000 and 7000 ft., msl. Construction of the barriers proposed in Alternative A-B, and D would eliminate such plants located in this area and their habitat. In addition to the mechanical destruction, clearing for roads and barrier site preparation generally favors the introduction and spread of exotic plants which in turn replace native species.

Construction of Alternative D also would entail the diversion and possibly impoundment of the upper portion of the Wailuku River. Flows here constitute less than 7% of the total recorded at the U. S. Geological Survey Hilo gaging station for the period of March to September 1978(26). Temporary or even permanent loss of flow downstream from this depauperate reach is not expected to produce a severe impact on stream fauna in, above and immediately below this reach. However, an impoundment at location D or E in Figure 3 would inundate areas where nene, Hawaiian hawks, Hawaiian creepers, akiapola'au, 'o'u and, Newell's shearwater are found. Construction of the impoundment would involve clearing and possibly grubbing operations. This would result in increased sediment loads downstream of the project site as well as the destruction of terrestrial habitat within the reservoir.

Spraying freshwater at the barrier is not anticipated to cause significant adverse impacts. Lava coverage and the extreme heat generating from these flows would cause the principal damage in these areas.

Alternative C

The area impacted by the saltwater spraying system may contain endangered plants. This vegetation would be stunted severely or destroyed by saltwater spraying. However, if lava flows did reach the spraying alignment, this habitat probably would be lost in any case. Saltwater removal from Hilo Bay is not expected to affect its marine habitat or fishery resources to a significant extent.

5.2 Alternative E (Emergency Operations)

This plan program as presently conceived, consists of a reduced version of the diversion barrier proposals proposed in Alternatives A-B and D. The impacts discussed in conjunction with these earlier barrier proposals also would occur should an emergency program be implemented. If road construction and site preparation are required this impact would result prior to the actual emergency.

The area altered probably would be slightly less since the length of barrier would be shorter than those developed on a long-range pre-emergency basis. If barrier construction islimited to below the 3000 foot elevation the potential impact on proposed endangered and endangered plants and animals and their habitat would be significantly reduced (Fig. 6).

6.0 Discussion

Implementation of the pre-emergency alternatives or the emergency operation incorporating similar barrier configurations, could result in the unavoidable destruction of endangered species habitat. In the case of Alternative D, the upper Wailuku River would be diverted and, potentially impounded. This would result in the additional destruction of native forest bird habitat as well as the degradation of the stream within and below this area. This latter impact is not anticipated to be severe in the upper depauperate reach of this river. However, it could contribute to increased sediment loads in the Wailuku River's middle and lower reaches.

Non-structural Alternative C would require seawater spraying in areas of limited wildlife value. It is unlikely that sea water uptake from Hilo Bay would affect marine habitat or organisms to any significant degree. Although the construction of barriers would prove detrimental to as much as 2000 acres of rainforest, one benefit, improved hunter access, would be derived from their implementation. Not only would recreational (and economic) benefits be derived; habitat destruction resulting from pig damage would be reduced in areas adjacent to these roads. However, even with this potential benefit, the overall impact of barrier construction is expected to be adverse.

Justification of the early action alternatives is based on two probabilities: (1) lava will flow into and destroy a signigicant portion of the City of Hilo and (2) the proposed structural devices will deter this impact. Lava flows moving from the northeast rift on Mauna Loa toward Hilo would destroy rainforest habitat whether or not the barrier existed. However, the one certainty evident with the implementation of any of the proposed structural alternatives is the potential destruction of more than 2000 acres of endangered forest bird habitat.

Implementation of the emergency action alternative also could result in the unavoidable destruction of endangered species habitat. In this case, barrier construction would take place at a site located in the path of the lava flow. However, lava flow diversion, the construction of access roads and potential pre-emergency site preparation could all contribute to the further destruction of refugia and endangered species habitat. The potential adverse impacts of lava barrier construction would be significantly reduced if it is limited to below 2000 ft., msl.

7.0 Recommendations

The following recommendations are made under and with respect to two public laws. In accordance with provisions established in the

Endangered Species Act of 1973, as amended, it is the construction agency's responsibility to review their mandates under this law. Should a water resource development alternative, i.e., impoundment and/or diversion of the Wailuku River be pursued, fish and wildlife in addition to endangered species must receive consideration and suitable mitigation measures instituted. Toward this latter aim, the Service makes the following preliminary recommendation:

1. Construction of any dam/diversion structure be accomplished during low flow periods.

2. Every effort should be made to prevent barrier construction resulting in diversion of lava flows into the Piihonoa and Waiakea Natural Area Reserves providing this recommendation does not conflict with any Service biological opinion concerning endangered species in the area.

Maurice H. Taylor

Oct. 3, 1979 Date

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Appendix A. Checklist of Native Birds and Mammals Found in the Hilo Lava Diversion Study Area, Hilo, Hawaii.

SCIENTIFIC NAME	COMMON NAME	HAWAIIAN NAME
Native Birds		
Family ANATIDAE		
∘*Branta sandvicensis*	Hawaiian Goose	Nene
Family DREPANIDIDAE		
Subfamily PSITTIROSTRINAE		
∘*Hemignathus wilsoni*	Hawaii Nukupuu	'Akiapola'au
•*Loxops c. coccinea*	Hawaii Akepa	'Akepa
•*Loxops maculata mana*	Hawaii Creeper	
Loxops v. virens	Hawaii Amakihi	'Amakihi
•*Psittirostra psittacea*	Ou	'O'u
Subfamily DREPANIDINAE		
Himatione sanguinea sanguinea	Apapane	'Apapane
Vestiaria coccinea	I'iwi	'I'iwi
Family MUSCICAPIDAE		
Chasiempis s. sandwichensis	Hawaii Elepaio	'Elepaio
Family STRIGIDAE		
Asio flammeus sandwichensis	Hawaiian short-eared Owl	Pueo
Family TURIDAE		
Phaeornis o. obscurus	Hawaii Thrush	'Oma'o
Migratory Birds		
Family CHARADRIIDAE		
Pluvialis dominica fulva	American Golden Plover	Kolea
Sea Birds		
Family FREGATIDAE		
Fregata minor palmerstoni	Great Frigatebird	Iwa

Appendix A. Cont'd

SCIENTIFIC NAME	COMMON NAME	HAWAIIAN NAME
Family PHAETHONTIDAE		
Phaethon lepturus dorotheae	White-tailed Tropicbird	Koae
Family PROCELLARIIDAE		
•_Puffinus puffinus newelli_	Newell's Shearwater	Ao
Native Mammals		
•_Lasiurus cinereus semotus_	Hoary Bat	Opea

•Federal endangered/threatened species

Appendix B. Checklist of Introduced Birds and Mammals Found in the Hilo Lava Diversion Study Area.

SCIENTIFIC NAME	COMMON NAME	HAWAIIAN NAME
Introduced Birds		
Song Birds		
Family ALAUDIDAE		
Alauda arvensis pekinensis	Skylark	
Family FRINGILLIDAE		
Richmondena cardinalis	Eastern Cardinal	
Carpodacus mexicana frontalis	House Finch	
Lonchura punctulata	Spotted Munia	
Passer domesticus	House Sparrow	
Family MIMIDAE		
Mimus polyglottos	Mockingbird	
Family STURNIDAE		
Acridotheres tristis	Common Mynah	
Family TIMALIIDAE		
Leiothrix lutea	Red-billed Leiothrix	
Garrulax canorus	Melodious Laughing Thrush	
Family ZOSTEROPIDAE		
Zosterops japonica	Japanese White Eye (Mejiro)	
Game Birds		
Family COLUMBIDAE		
Geopelia s. striata	Barred Dove	
Streptopelia c. chinensis	Spotted Dove	
Family MELEAGRIDIDAE		
Meleagris gallopavo intermidia	Rio Grand Turkey	
Family PHASIANIDAE		
Alectoris graeca chukar	Chukar	
Coturnix coturnix japonica	Japanese Quail	
Francolinus erckelii	Erckel's Francolin	
Lophortyx californicus	California Valley Quail	Manukapalulu

Appendix B. Cont'd

SCIENTIFIC NAME	COMMON NAME	HAWAIIAN NAME
Lophura leucomelana	Nepal Kalij	
Phasiasus colchicus torquatus	Ring-Necked Pheasant	Kolohala
Phasianus versicolor	Blue Pheasant	
Predators		
Family TYTONIDAE		
Tyto alba pratinicola	Barn Owl	
Introduced Game		
Family BOVIIDAE		
Capra h. hircus	Feral Goat	
Family SUIDAE		
Sus s. scrofa	Pig	
Other		
Family MURIDAE (Rodents)		
Rattus rattus	Roof (Black) Rat	
Rattus norvegious	Brown Rat	
Rattus exulans hawaiiensis	Polynesian Rat	
Mas musoulus	House Mouse	
Family CANIDAE		
Canis familiaris	Feral Dog	
Family Felidae		
Felis domestious	Feral Cat	
Family Viverridae		
Herpestes auropunctatus	Mongoose	

LAVA FLOW CONTROL STUDY
ISLAND OF HAWAII

FORMAL BIOLOGICAL OPINION
ENDANGERED SPECIES OFFICE
FISH AND WILDLIFE SERVICE

APPENDIX F

United States Department of the Interior

FISH AND WILDLIFE SERVICE
LLOYD 500 BUILDING, SUITE 1692
500 N.E. MULTNOMAH STREET
PORTLAND, OREGON 97232

November 15, 1979

In reply refer to
AFA-SE, #1-2-79-F-107

Mr. Kisuk Cheung
Chief, Engineering Division
Pacific Ocean Division
Corps of Engineers
Building 230
Fort Shafter, Hawaii 96858

Dear Mr. Cheung:

This responds to your letter of August 20, 1979, requesting formal consultation pursuant to Section 7 of the Endangered Species Act of 1973 and Amendments of 1978 (PL 95-632). It concerns the Hilo Lava Flow Control Study which attempts to develop a long-range plan for protecting the city of Hilo from lava flows. These listed species which may be affected by this project are: the endangered Hawaii creeper (Loxops maculata mana); Hawaii 'akepa (Loxops c. coccinea); 'akaipola'au (Hemignathus wilsoni); 'o'u (Psittirostra psittacea); 'io (Buteo solitarius); nene (Branta sandvicensis); Hawaiian hoary bat (Lasiurus cinereus semotus); and the threatened 'a'o (Puffinus puffinus newelli).

Project Description

The Corps draft interim report and environmental impact statement identifies a fully prepared emergency barrier plan as being the most desirable long term plan of protection. This plan is the tentatively selected Alternative E. The impacts of this plan, Alternative E, on endangered species will be addressed in this opinion.

This alternative is basically an emergency reaction plan. Barriers would be built (using available material) only during a volcanic eruption and in response to the flow of lava that occurs. These unknown and uncontrollable natural phenomena will determine the location and extent of lava diversion barriers, as described in Alternative E. There may be direct impacts on endangered species through destruction of habitat when the lava diversion barriers are constructed and/or indirect impacts may result from diversion of lava flows onto habitats important to these species, destroying these forest habitats.

Species Account

All of the listed species in question were once abundant or common, either throughout or at specified locales on the Island of Hawaii (Perkins, 1903, Baldwin, 1945, Peale, 1848). A number of causative factors have played a role in the decline of one or more of the species. Among the factors are: 1) avian disease, particularly introduced pathogens; 2) competition with exotic birds and other animals; 3) indiscriminate collecting; 4) elimination or degradation of habitat by cultivation, lumbering, livestock grazing, and exotic plant and animal introductions; and 5) predation. Island species are particularly vulnerable to any such factors because of their frequently low numbers, restricted geographical distribution, and the susceptibility of their ecosystems to drastic changes from introduced plants and animals.

Present population baseline data for these species are generally lacking, though continued forest bird surveys and studies are providing new information. Current data has shown the Hawaii creeper to be restricted to native forests above the 4,000-foot elevation where they are considered rare. Known populations occur in the Kilauea Forest Reserve and Keauhou Ranch on the eastern slope of Mauna Loa.

The Hawaii 'akepa is comparatively rare, reported from the eastern slopes of Mauna Loa and southwestern slopes of Hualalai. They are mostly concentrated in the Waiakea Forest Reserve and Keauhou Ranch.

The 'akiapola'au is locally common on the eastern slopes and high elevation of Mauna Loa and rare on Mauna Kea (Scott, et al. 1978). Present data show this species restricted mainly to the Waiakea Forest Reserve.

The 'o'u has only recently been reported from the Olaa Tract and adjacent forest lands of the Puna District of Hawaii. During the Hamakua Forest Bird Survey, the 'o'u was observed in the upper Waiakea and Hilo Forest Reserves. It also occurs in small numbers within the Alakai Swamp on the Island of Kauai.

The 'io is widely distributed over the island, but is not considered common in any district.

The nene occupies a remnant of its former range. They occur primarily from 5,000 to 8,000 feet in elevation on the Island of Hawaii. Investigation of known nesting areas and observations of pen-reared nene released in the wild indicate a population of approximately 750 individuals, which is stable or slightly increasing.

The 'a'o was recently reported from the Hawaii Volcanoes National Park. Others were observed in the Hamakua Forest and may be nesting undetected on the forested slopes of Mauna Loa in the study area. However, the species mainly breeds on the Island of Kauai.

The Hawaiian hoary bat is considered rare and presently has a scattered population on Kauai, Oahu, Maui, and Hawaii due to their nonsocial behavior (Tomich, 1969).

Conclusion

Because of the inability to predict barrier placement and lava flows, it is also difficult to predict potential impacts to these endangered species. However, we do know that a particular placement of a barrier, or directing a lava flow through a specific area, can have severe detrimental effects on those species that have restricted distribution on the eastern side of Mauna Loa.

The 'akepa, 'o'u, and 'akiapola'au have such population characteristics. These species are comparatively rare and significant numbers have been censused in portions of the forested areas of the Upper Waiakea Forest Reserve between approximately 3,500 to 5,800 feet.

It is, therefore, our opinion that Alternative E of the Hilo Lava Flow Control Study, as discussed above, is likely to jeopardize the continued existence of the 'akepa, 'o'u, and 'akiapola'au, due to the restricted distribution and the potential for catastrophic results should the Corps place a barrier and/or direct a lava flow through their habitat. Further, we are of the opinion that the subject project is not likely to jeopardize the continued existence of the Hawaii creeper, 'io, nene, 'a'o, and Hawaiian hoary bat due to their more dispersed distribution or because their population concentrations are outside of the project area.

The 1978 amendments to the Endangered Species Act include a mandate that "reasonable and prudent alternatives" be provided when a Biological Opinion indicates jeopardy to a listed species. "Reasonable and prudent" refer to alternative courses of action open to the Federal agency with respect to an activity or program that are technically capable of being implemented and consistent with the intended primary purpose of the activity or program. We believe the following recommendations are consistent with the definition:

1. The possibility of a lava flow inundating the Upper Wiakea Forest Reserve should be considered, and a "corridor" through the less environmentally sensitive areas should be determined. This corridor might consist of recent flows which are barren, or those with vegetation in an early successional state.

2. Lava diversion barriers should be designed for placement to protect the prime forest bird habitat in the study area.

3. The material for constructing the lava diversion barriers should be obtained from unforested portions of this study area whenever feasible.

We would also like to emphasize that the Corps of Engineers has the opportunity to utilize this project authority to promote the conservation of these endangered and threatened species as outlined in Section 7(a) of the Endangered Species Act. To meet this mandate of the Act, the Corps of Engineers, in cooperation with this Service, should identify sensitive areas in the general study area and should initiate studies necessary to ensure maximum conservation of endangered species of flora and fauna.

This concludes our formal consultation on the Hilo Lava Flow Control Study. If a plan other than Alternative E is selected, and if project modification beyond those suggested as alternatives occur, or if new information on listed species becomes available, reinitiation of consultation will be appropriate. We would appreciate notification of your intent in light of this opinion.

Sincerely yours,

Bill Meyer

William H. Meyer
Acting Regional Director