GUIDELINES FOR

THE DESIGN AND CONSTRUCTION OF

SMALL EMBANKMENT DAMS

Report R88

DEPARTMENT OF LAND AND NATURAL RESOURCES
Division of Water and Land Development

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DEPARTMENT OF LAND AND NATURAL RESOURCES
Division of Water and Land Development

Honolulu, Hawaii
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JOHN WAIHEE
Governor

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FOREWORD

These guidelines, in addition to the design and construction of dams, provides the legal and engineering requirements that must be met to construct and own a small dam in Hawaii. Guide specifications are also given for requirements of a typical spillway and outlet works and for various technical items of work. And on a mitigative note, a chapter is devoted to an emergency action plan. The requirements apply specifically to small embankment dams in those rural areas where downstream hazards are minimal and apply to a hypothetical, specific dam at a specific site. Actual site conditions and materials vary widely from site to site and it should be recognized that these specifications and drawings serve to provide technical information, data, design procedures and criteria to guide qualified personnel in the design and construction of small embankment dams.

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INTRODUCTION

These guidelines present instructions, standards, and procedures for use in the Standard Design for Dams and Reservoirs in the State of Hawaii. It is intended to serve primarily as a guide to safe practices for engineers qualified and experienced in the field of design and construction of dams and reservoirs in the State of Hawaii.

The guideline will serve this purpose in three ways: 1) It will provide engineers with information and data necessary for the proper design of small embankment dams; 2) it will provide specialized and highly technical knowledge concerning the design of small embankment dams in a form that can be understood by engineers who do not specialize in this field; and 3) it will simplify design procedures and criteria for small embankment dams.

HISTORY OF HAWAII DAM SAFETY

The Federal Dam Inspection Act, Public Law 92-367, August 1972, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a program of Safety Inspection of Dams throughout the United States.

Public Law 92-367 provided the impetus for the Department of Land and Natural Resources' (DLNR) long, arduous and eventually successful campaign, spanning several years, advocating passage of a dam safety law before the Hawaii State Legislature. The Corps of Engineers assisted during this protracted DLNR effort by providing encouragement and supporting testimony. Public Law 92-367 also provided the authority and funding for the Corps of Engineers, in cooperation with DLNR, to complete an inventory of dams in the State of Hawaii and perform Phase I inspections of 53 non-federal dams in the State of Hawaii between December 1977 and September 1981.

The Federal Water Resources Development Act of 1986, Public Law 99-662 (H.R. 6), November 17, 1986 established the Dam Safety Act of 1986 entitled Title XII - DAM SAFETY appropriating funds to the Secretary of the Army to be distributed to the States establishing a dam safety program. The Secretary shall determine that such program includes the following:

1. A procedure, whereby, prior to any construction, the plans for any dam will be reviewed to provide reasonable assurance of the safety and integrity of such dam over its intended life;

2. A procedure to determine, during and following construction and prior to operation of each dam built in the State, that such dam has been constructed and will be operated in a safe and reasonable manner;

3. A procedure to inspect every dam within such State at least once every five years except that such inspections shall be required at least every three years for any dam the failure of which is likely to result in the loss of human life;

4. A procedure for more detailed and frequent safety inspections, when warranted;

5. The State has or can be expected to have authority to require those changes or modifications in a dam, or its operation, necessary to assure the dam's safety;

6. The State has or can be expected to develop a system of emergency procedures that would be utilized in the event a dam fails or in the event a dam's failure is imminent together with an identification of those dams where failure could be reasonably expected to endanger human life, and of the maximum area that could be inundated in the event of the failure of such dam, as well as identification of those necessary public facilities that would be affected by such inundation;

7. The State has or can be expected to have the authority to assure that any repairs or other changes needed to maintain the integrity of any dam will be undertaken by the dam's owner, or other responsible party; and

8. The State has or can be expected to have authority and necessary emergency funds to assure immediate repairs or other changes to, or removal of, a dam in order to protect human life and property, and if the owner does not take action, to take appropriate action as expeditiously as possible.

Pursuant to Act 179D, Session Laws of Hawaii 1987, The Department of Land and Natural Resources adopted Hawaii Administrative Rules, Title 13, Department of Land and Natural Resources, Sub-Title 7-Water and Land Development, Chapter 190 "DAMS AND RESERVOIRS". It was signed by Governor John Waihee on April 9, 1990 and became effective on April 19, 1990.

Chapter 190 - "DAMS AND RESERVOIRS" placed the supervision for safety of all dams and reservoirs larger than a specified minimum size under the jurisdiction of the Department of Land and Natural Resources. Federal dams are exempt from the Rules. These Hawaii Administrative Rules are administered by the Department through the Division of Water and Land Development. The Division independently analyzes and evaluates plans and specifications for constructing new dams and for enlarging, repaving, altering, or removing existing dams and must grant approval in writing before the owner may proceed with construction. The Division inspects and evaluates each dam and reservoir during construction to verify compliance with the approved plans and specifications and to assure that changes or unforeseen foundation conditions are recognized and the design is modified as necessary. The Division inspects, monitors, and evaluates dams currently in service on a five year cycle, or more frequently as necessary to assure safety.

Guidelines for Design and Construction of Small Embankment Dams in the State of Hawaii is a result of the Dam Safety Act. This guideline is not intended in any way to encourage assumption of undue responsibility on the part of unqualified personnel, but rather to point out the importance of specialized training and to stimulate wider use of technically trained and experienced consultants.

This manual should be of service to all concerned with the planning of safe water storage projects, but in no way does it relieve any agency or person using it of the responsibility for safe and adequate design. The stated limitations of the design procedure should be heeded.

USE OF GUIDELINES

These guidelines are intended to illustrate the general minimum requirements of the Department of Land and Natural Resources (DLNR), Division of Water and Land Development (DOWALD), for the design and construction of a small embankment dam. They are further intended to assist an owner and his engineer in arriving at an acceptable design and adequate plans and specifications, with a minimum of effort. These guidelines obviously are not intended to constitute a text for the design and construction of small embankment dams. Instead, they merely present a sample for an assumed embankment dam on dense soil or rock foundation of typical provisions which will be required in an actual design. Ultimate determinations by the Board of the Department of Land and Natural Resources of the acceptability of design and adequacy of plans and specifications must, by necessity, be made on a case by case basis. Therefore, the Board of the Department of Land and Natural Resources cannot warrant that compliance with these guidelines will result in a totally satisfactory design.

In general, the guidelines are intended only for small embankment dams located in rural type settings, with heights ranging up to 50 feet, with no unique foundations or embankment problems, and with minimal potential for downstream damage.

No explanation is given as to the reasons for some of the requirements, since most will be self-explanatory to a knowledgeable civil engineer. The drawings and specifications, which are part of these Guidelines, depict an assumed small embankment dam. They are only intended to indicate recommended format and minimum design requirements.

As stated above, the Guidelines are suggestive only, and the owner or his engineer is not precluded from developing new ideas of procedures that may differ from them. The Department of Land and Natural Resources' objective is to obtain safe dams. This can be accomplished generally in the manner indicated in these Guidelines, together with reasonable modifications appropriate to the individual problems at each damsite.

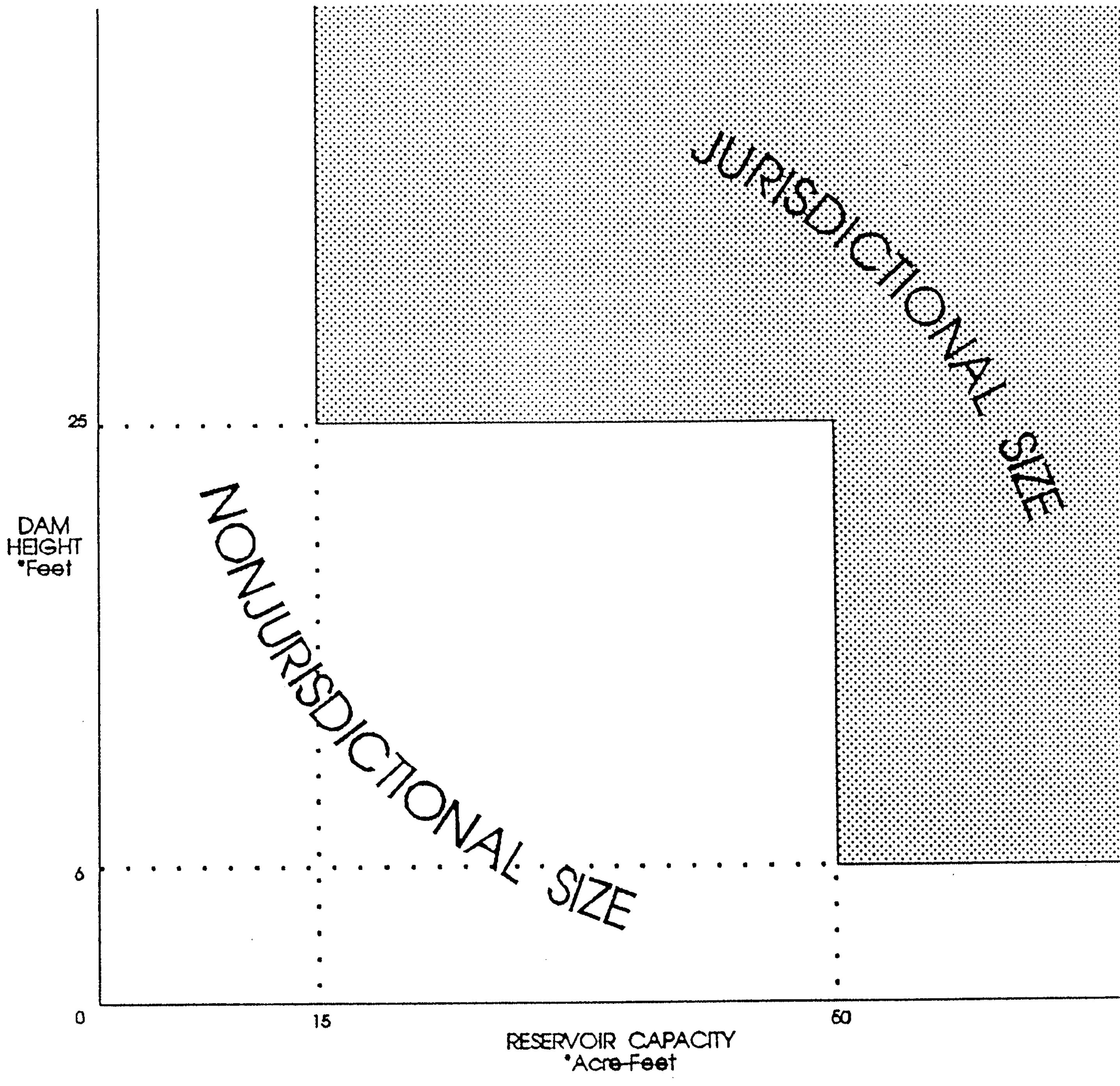
Inasmuch as the approval of an application to construct a dam does not grant the right to appropriate water, the applicant must apply for a water use permit through the Department of Land and Natural Resources prior to filing an application to construct a dam. For private owners of dams, this will initiate action for conformance with the requirements of the Administrative Rules of the State Water Code Chapter 174C, Hawaii Revised Statutes (HRS) effective May 27, 1988. These requirements are explained in detail under Chapter 13-171, Designation and Regulation of Water Management Areas.

APPLICATION

An application for approval of plans and specifications must be filed in duplicate by the owner or his duly appointed representative for dams which will be 25 feet or more in height from the natural bed of the stream or watercourse measured at the downstream toe of the barrier, or from the lowest elevation of the outside limit of the barrier if it is not across a stream channel or watercourse, to the top of spillway crest elevation, or which will have an impounding capacity of 50 acre-feet or more. Barriers which will be 6 feet or less in height or which will have a storage capacity not in excess of 15 acre-feet are not considered to be dams and no application is required.

An "Application for Approval of the Plans and Specifications for the Construction, Enlargement, Repair, Alteration, or Removal of Dams in the State of Hawaii", along with a copy of the Hawaii Administrative Rules, Chapter 13-190, DAMS AND RESERVOIRS, can be obtained from the Department of Land and Natural Resources, Division of Water and Land Development, 1151 Punchbowl Street, Room 227, Honolulu, Hawaii, 96813.

PROVISIONS OF HAWAII DAM SAFETY ACT
AFFECTING JURISDICTION OVER DAMS AND RESERVOIRS



*Metric units not specified in the Water Code are:

1.83 metres = 6 feet	18.50 cubic dekametres = 15 acre-feet
7.62 metres = 25 feet	61.68 cubic dekametres = 60 acre-feet

ADMINISTRATIVE PROCEDURES

Construction of a dam shall not begin until the owner has applied for and obtained from the Board of the Department of Land and Natural Resources, written approval of his application, which includes plans and specifications.

The owner or engineer should first check whether an "Application for Water Use Permit" or an "Application for a Stream Channel Alteration Permit" needs to be completed. Both applications are available from the Department of Land and Natural Resources, Division of Water and Land Development. An application for "Approval of Plans and Specifications for Construction, Enlargement, Repair, Alteration, or Removal of Dam" should then be filed with the Department of Land and Natural Resources, Division of Water and Land Development.

The application for construction of a dam should include duplicate copies of plans and specifications prepared by a registered civil engineer; a filing fee, and any other information which will provide the Division of Water and Land Development a basis for reviewing the design of the dam and appurtenances. Depending on the complexity of the project, dam siting conditions, and other inherent characteristics, the Division of Water and Land Development will usually require some additional information in the form of geological investigation, physical testing to determine properties and behavior of the foundation and embankment materials, hydrologic data, dam operating rules, and structural and hydraulic design notes.

After review of the plans and specifications, etc., and inspection of the site, the application will be either approved, rejected, or changes in the plans and specifications will be required.

The construction work shall be under the responsible charge of a registered civil engineer. During construction the Division of Water and Land Development may make periodic inspections for the purpose of securing conformity with the approved plans and specifications, and may require the owner to perform such work or tests as necessary to disclose information sufficient to enable the Division of Water and Land Development to determine that such conformity is being obtained. Usually, such testing will be limited to verification of embankment compaction, concrete strengths, and other similar requirements. Modifications to the plans and specifications may be required if unforeseen conditions develop during construction.

Immediately after completion of construction, the owner must file a notice of completion with the Department of Land and Natural Resources, and as soon as possible after that he must file with the Department of Land and Natural Resources supplementary as-built drawings showing the dam and reservoir as it was actually constructed.

As soon as practicable after construction, the dam and reservoir will be inspected by the Division of Water and Land Development.

The Division of Water and Land Development will inspect each dam and reservoir during a five year cycle, or 3 years for any dam, the failure of which is likely to result in the loss of human life. Each dam and reservoir will be inspected for signs of embankment erosion, rodent damage, seepage, spillway blockage, and other signs of general deterioration or distress. The owner at his expense will be required to correct any deficiencies.

CHAPTER II

HYDROLOGIC AND HYDRAULIC CONSIDERATIONS

Information in this chapter is intended for use by hydrologic engineers in the preparation of flood hydrology studies necessary for the design of dams and their appurtenant features. This chapter provides general guidance for estimating both the magnitude and frequency of floods. Directions are also provided for the preparation of flood hydrology reports, which document the bases for and the results of flood hydrology studies.

TYPES OF HYDROGRAPH

Probable Maximum Flood (PMF) hydrograph represents the maximum runoff condition resulting from the most severe combination of hydraulic and meteorologic conditions considered reasonably possible for the drainage basin under study. The 100% PMF is used as a basis for design where the failure of the dam from overtopping would cause loss of life or widespread property damage downstream.

Specific frequency flood hydrograph represent an assigned or specific, frequency of occurrence. "Frequency of occurrence" is defined as the probability of a flood of a given magnitude being equaled or exceeded within a specified period, usually one year. Specific frequency flood hydrographs are used in the design of facilities to provide for the care and diversion of flows during the construction of water-controlled structures, such as dams. Where the hazard potential below the proposed damsite is small, a flood of a specific frequency or one that is a percentage of the PMF may be used for determining the reservoir capacity, the spillway size and surcharge storage requirement. Specific frequency flood hydrographs or their peak discharges are also used in the design of flood control facilities.

Every flood-hydrology study should include the compilation and analysis of hydrologic and meteorologic data accumulated before, during and after severe flood events. Hydrologic data include records of runoff accumulated at continuous recording streamflow gauges and at crest-stage streamflow gauges, indirect peak-discharge measurements, and reservoir operation records from which inflow hydrographs may be determined. Meteorologic data include precipitation, temperature, and wind records collected at official National Weather Service first order (staffed by N.W.S. personnel) and second order (supervised by N.W.S. personnel) climatological stations, data from supplemental precipitation surveys conducted immediately after severe storm events to supplement data collected at official National Weather Service stations, and snow surveys conducted by Federal, State, and local agencies in areas susceptible to significant snowmelt runoff.

RECORDED STREAMFLOW DATA

These are compiled and published by the USGS in a series of "Water Supply Papers". They represent the streamflow in terms of the average daily flow for each day and the annual maximum peak discharge for the period the stream gauge has been in operation. However, the value is limited for flood hydrograph analyses. Average daily flow values are developed from recorder charts that provide a continuous record of river stage versus time, at each gauging site. Copies of these charts can be obtained from the USGS together with the rating curve for each gauging station. The rating curve presents the relationships between the discharge, in cubic feet per second, and the river stage above the arbitrary datum, in feet. A hydrograph representing the discharge in cubic feet per second can then be developed for a particular location by reading the river stage values at selected time intervals from the recorder chart and converting these values to discharge, using the rating curve for that station. The USGS has records of fixed hour discharge (cfs) versus time at some gauging stations for some heavy floods.

PEAK DISCHARGE DATA

To supplement the recording stream-gauge network, networks of crest-stage gauges have been established. Evaluations of the relative magnitude and the credibility of flood peak discharge estimates can be obtained by comparison with known historical peak discharges in other watersheds. Also, such information about maximum floods of record in similar hydrologic regions can provide a basis for estimating flood potential at a given site.

FIELD RECONNAISSANCE OF DRAINAGE BASINS FOR FLOOD HYDROLOGY STUDIES

A field reconnaissance is recommended for the subject drainage basin. This is to identify and to document in a trip report the pertinent physical features of the basin, including existing water control facilities, that will affect the magnitude and timing of flood runoff. Four primary characteristics of the drainage basin to be observed are:

a) Drainage network. Observe and document the hydraulic roughness characteristics of the hydraulic systems of the basin. This is done by visually inspecting representative reaches of the network and assigning average Manning's n value to these reaches. The n values assigned are to reflect extreme flood conditions, specifically considering overbank flow, meander cutoff, scour, and the time of year the flood is likely to occur. The values and the reaches should be delineated on the maps used in the field reconnaissance. Values will be averaged and form the basis for selecting an appropriate coefficient for the unit hydrograph lag equation.

   Channels should be described in the report. The description should include a discussion of the type of channel (swale, well-cised), the character of the overbank areas (heavily wooded, grass covered), and the materials (boulders, cobbles, native soil) that form the channel bed and overbank areas.

Photographs should be included as supplementary information in each reconnaissance report and should be appropriately referenced in the narrative portion of the report.

The density of the well-defined channels that make up the drainage network should be observed and described in the report. The descriptions will enhance information shown on topographic maps.

b) Soil and Geologic Conditions. Soil conditions, the types of soils in the drainage basin and the locations of each type of soil, should be observed and documented on a suitable map. The general geologic setting should also be described in the reconnaissance report.

c) Vegetation Cover. To estimate the infiltration-loss characteristics and unit hydrograph parameter, the vegetation cover of the drainage basin needs to be known. Observe and document the types, area, and location of vegetation in the basin. If possible aerial photographs is the best way to accomplish this task.

d) Land Use. Most drainage basins above proposed dams are natural or undeveloped basins. Portions of the drainage basin could be used for agriculture, forestry, or urban development. The extent and intensity of agricultural and forestry land uses should be determined during the field inspection and properly documented in the reconnaissance report. When inspecting an area near an expanding urban center, the local government should be contacted and a projected land-use map secured. Rainfall-runoff response of an urbanized drainage basin is different from the response the same basin would experience in a nonurbanized condition.

FLOOD RUNOFF FROM RAINFALL

When rainfall exceeds the infiltration rate at the surface, excess water begins to accumulate as surface storage in small depressions governed by surface topography. Eventually, overland flow may occur in portions of a watershed, and the flow quickly concentrates into small channels, which then flow into larger streams. Subsurface streamflow and base flow can also contribute to the overall discharge hydrograph from a rainfall event.

Hydrologists are concerned with the amount of runoff generated in a watershed for a given rainfall duration and pattern. Attempts have been made to statistically analyze historical rainfall, evaporation, and streamflow data to develop predictive relationships. Factors such as antecedent rainfall, soil moisture, variable infiltration and variable runoff response with season make the development of such relationships difficult.

INFILTRATION AND OTHER LOSSES

Rainfall separates into several components when it reaches the ground. There are four types of losses:

1. Interception by vegetation and subsequent evaporation or retardation from reaching the ground surface.
2. Evaporation from the ground surface during prolonged rainfall events.

3. Depression storage in surface depressions, which act as miniature reservoirs and do not release their waters until their storage capacity is exceeded.

4. Infiltration into the receiving soil, rock, or combination. Any of the constituents of the earth's mantle can absorb water--whether it be a concrete parking lot or the sandiest soils.

Overland runoff occurs when the rate of rainfall has satisfied the first three losses and exceeds the capacity of the soil to absorb the water. The first three losses are usually minor compared with infiltration losses when rainfall intensities are sufficient to produce severe flood events.

The selection of loss rates is a major consideration in deriving hypothetical floods because a major portion of the rainfall is lost to interception or localized ponding and infiltration. The degree of conservatism in the estimate of the peak design flow is subject to the degree of conservatism by which the loss rates are assumed applied. The loss rate is often not as significant in determining the PMF as it is in determining the 100-year flood. Seasonal variation in minimum loss rates, which should be considered as representative of the most extreme conditions for the season for the hypothetical flood, should be applied.

BASE FLOW AND INTERFLOW

The base flow and interflow are two components of a flood hydrograph. The base-flow component consists of the water that reaches the watercourses after flowing a considerable distance underground as ground water. The hydrograph is depicted as a recession curve, indicating a gradually decreasing rate of surface flow. This flow continues to decrease until the water surface in the stream is in equilibrium with the surface of the adjacent water table, and the flow is maintained by inflow from the groundwater reservoir. When the water table is at a level below the channel bed, there is no surface flow in the stream, but there may be subsurface flow in the river gravel.

The interflow component or subsurface storm flow is generated by precipitation that enters the ground by infiltration and emerges as a direct contribution to the surface runoff within a relatively short time. This occurs during every severe flood event in varying degrees, depending on the characteristics of the drainage basin.

The magnitude of the base flow of a storm is dependent on antecedent storm conditions: the magnitude of that storm and the time between its occurrence and the onset of the subject storm. If sufficient data are available, a complete recession curve representing the base-flow component for a given drainage basin can be determined. The recession, or base flow, used in the development of PMF's should represent conditions that are consistent with antecedent storm conditions provided for in the storm study report.

When preparing a flood study for an ungauged watershed, results of observed flood reconstructions on hydrologically similar drainage basins, relative to the base-flow component, are used to estimate this component for the ungauged basin. This may be accomplished by converting the observed component to cubic feet per second per square mile of basin area. The result is then applied to the area of the subject ungauged basin to determine its appropriate rate of base flow. The flow rate may be assumed uniform for the entire duration of the PMF hydrograph.

When an ungauged watershed is studied, interflow information from observed flood hydrograph reconstructions for nearby, hydrologically similar watersheds may be used to estimate the magnitude and rate of change of discharge over time. In regard to the base-flow component, the conversion from the observed hydrograph to that for the ungauged basin is based on a direct ratio of the respective drainage basin areas. The resulting interflow hydrograph should incorporate a slowly rising limb, a rather broad peak, and a long recession limb.

DESIGN FLOOD HYDROGRAPHS

The PMF (Probable Maximum Flood) hydrographs represent the maximum runoff condition resulting from the most severe combination of hydrologic and meteorologic conditions considered possible for a drainage basin. Because the unit hydrograph is used to develop the PMF hydrograph or other frequency design flood hydrograph, the following considerations should be used in computing the flood hydrograph:

1. The PMF is based on a probable maximum storm. The other frequency hydrographs are based on the desired frequency (design) storm. The duration of rainfall should be 24 hours. The temporal distribution of the storm rainfall should be arranged so that the maximum peak discharge and the maximum concentration of discharge around the peak is achieved. Standard SCS 24-hour, Type I distribution may be used for Hawaii.
2. Infiltration rates subtracted from the storm rainfall to obtain the excess amounts available for surface runoff should be consistent with the soil types and the underlying geologic conditions of the subject basin.
3. The unit hydrograph used to compute the hydrograph should represent extreme discharge conditions. When studies are prepared for gauged basins for which the results of the observed flood hydrographs analyses are available, the unit hydrograph

parameters should adequately reflect the streamflow conditions likely in a rare storm event.

4. The base-flow hydrograph component should reflect the maximum rates of discharge consistent with the magnitude and timing of the antecedent flood event.
5. The interflow component should reflect conditions expected from a rare storm event.

ESTIMATES AND FREQUENCY OF OCCURRENCE OF FLOODS

Estimates of the magnitude of floods are helpful in estimating the requirements for stream diversion prior to the construction of a dam and its appurtenant features. These floods are termed the "5, 10 and 25 year floods." The magnitude of a rare event, such as 50, or 100 year flood, or standard project flood are required to establish the capacity of emergency spillways, to design the storage capacity of dams, and for other purposes. Floods occur randomly; they may be bunched or spread out evenly with respect to time.

If streamflow data for a period of 20 years or more are available for the subject watershed, frequency-curve computations yield acceptable results for estimates up to the 25 year flood. The frequency curve data may be extrapolated to indicate the 100 year flood with a fair chance of obtaining acceptable values. However, in no case should the frequency curve be extrapolated beyond twice the length of record or 100 years, whichever is greater.

For watersheds where runoff originates from rainfall and for which streamflow data are short or not available, an indication of flood frequencies can be obtained by estimating probable design runoff from precipitation data of the desired frequency and desired storm duration. Probable rainfall intensities for fixed time short durations (such as 15, 30, 60 minutes, 1, 3, 6, 12, 24 hours) can be obtained from National Weather Service publications.

FLOOD HYDROLOGY REPORTS

A report clearly documenting all the assumptions, rationale, methodology, and results of hydrologic analyses must be prepared for each flood hydrology study. These reports should include sufficient detail to enable the reader to independently reproduce all flood values in the report. Each report should include the following:

1. Authority - Cite the appropriate legislation, regulations and include the general purpose of the project.
2. Summary of study results - Include design peak, volume and hydrograph information for the PMF or for floods of specific frequencies. Include a summary statement of the reservoir routing recommendations.
3. General - Include a discussion of all formal and informal agreements reached by the various organizational levels on the technical aspects of the flood study. Present a brief discussion of each previous flood study with a summary of its result.
4. Basin description - Cite the geographic location of the basin and its area, and describe the terrain features, including the elevation range, basin development, drainage network, geological setting, soils, and vegetative cover. Include a discussion and the pertinent data for existing water control facilities in the basin. The discussion of basin development should include a statement on anticipated future development based on projections made by the most authoritative source available.

5. Storm study - Reference pertinent summary data (including design rainfall frequency, rainfall duration and rainfall distribution) from the storm study. This reference should include a discussion of the basin and regional climatology.

6. Unit Hydrograph - Cite the basis and rationale for selecting the dimensionless unit hydrograph and the lag curve. If a selection is based on a reconstruction of an observed event, the reconstruction study should be thoroughly described.

7. Loss Rates - Provide the basis and rationale for selecting the infiltration rates used to develop the flood hydrograph.

8. Design flood hydrograph - Provide a brief discussion of abstraction of losses from rainfall and unit hydrograph applications of excess rainfall to arrive at the design hydrograph. Include information on the base-flow assumptions, and summarize peak and volume data.

9. Frequency Analysis - Provide a peak discharge-frequency curve to determine diversion requirements and for possible use in risk-based analyses. The narrative should provide information on the source of the streamflow data, length of records available, and use of a regionalized approach. If specific-frequency floods developed by the rainfall-runoff model approach are used to define the discharge-frequency curve, information cited in paragraphs 5 to 7 above should be presented.

10. Antecedent flood - Provide the basis and rationale for the antecedent flood selected, particularly in regard to its magnitude and timing. Together the antecedent flood and the design hydrograph make up the design hydrograph series and should be presented as such in the report.

11. Reservoir routing criteria - Provide recommendations on the pool level assumed at the onset of the design hydrograph series. Include flood control regulations, if

appropriate. Discuss the assumptions relative to the use of hydraulic release features during the design hydrograph and antecedent floods.

12. Curves - Show all points used to position the curve. Label each point with either the station name or a number referring to an accompanying table that lists the name and location of each station.

13. Design Spillway Q:
    1. Less than existing Q down.
    2. Less than these Q downstream can carry on.

14. References - Show literatures referred.

CHAPTER III

FOUNDATIONS AND CONSTRUCTION MATERIALS

GENERAL

Information concerning geology, seismicity, foundation conditions, and construction materials is essential even for the design and construction of a small earth dam. Preconstruction investigation and testing are required to determine whether a safe dam can be constructed at the proposed site, and the data obtained will assist in the planning, design, and construction of the dam, spillway, and outlet facilities.

The Division of Water and Land Development should be notified when an exploration investigation is being done so that the field work can be observed. This could preclude a possibility of having to do additional exploration for the benefit of the Division of Water and Land Development.

After the investigation and testing are completed, all the information should be included in a geology, foundation, and construction materials report. This report must be submitted to the Department of Land and Natural Resources as support data for the design and construction of the dam and appurtenant facilities.

GEOLOGY

The regional and site geologic setting are critical in evaluating the adequacy of the site for a proposed dam. Additionally, the seismic environment of the site will affect the design of the foundation and embankment of the dam. Landslides and potential landslides at the damsite or in the reservoir area must be considered in the design. Foundation conditions for the dam, spillway, and outlet works need to be determined in advance of final design. These can generally be resolved through review of geologic literature, geologic reconnaissance, and explorations.

EXPLORATION AND TESTING FOR FOUNDATIONS

If the site has numerous rock outcrops, and it is apparent by visual examination that the foundation will be bedrock with very little soil cover, a subsurface investigation may not be required.

However, if the site has a thick soil cover, a subsurface investigation will be required. Either exploratory test pits using a backhoe or exploratory borings drilled with a drill rig may be used for the investigation. Several test pits or borings are excavated or drilled along the alignment of the dam, spillway, and outlet works to determine the depth to adequate foundation for the proposed structure. The test pits or borings should be examined and logged, located on a site map, and samples taken for laboratory classification testing.

FOUNDATION FOR EMBANKMENT

Classification testing for embankment foundations comprised of soils would include mechanical analysis, and liquid and plastic limits (ASTM D-2487-85). If the strength of the soil overlying the bedrock is questionable, density tests and compaction tests (ASTM D-1557-78) should be performed at several depths so that the relative compaction can be determined to establish the adequacy of the foundation and the depth of excavation required.

FOUNDATION FOR OUTLET WORKS

The foundation for the outlet conduit should be investigated by at least two test pits or borings to determine location and character of adequate base materials. If the foundation is bedrock, often no testing is required. If the foundation is weathered bedrock or soil, the same testing as required for an embankment foundation is necessary.

FOUNDATION FOR SPILLWAY

The investigation for a spillway in weathered or firm bedrock is primarily to determine if the foundation at design grade is erodible. Usually, a test pit or boring at the crest and one or two along the channel would be sufficient. If the foundation is not erodible, laboratory testing would not be required. However, if a concrete lining is required for erosion control, classification testing should be done. If the strength of the foundation is questionable, tests should be made so that an index of its competence can be determined.

EMBANKMENT MATERIALS

Several test pits or borings should be located in proposed borrow areas for each type of material to be used in the dam. The purposes of the investigation are to determine the quantity and engineering properties of each material. Classification tests and compaction tests are required.

WATER

Wherever practicable, embankment materials should be moisture conditioned in the borrow areas. Additionally, haul roads should be watered. Air drying of soil is often required on the fill to provide optimum moisture requirements due to high insitu moisture contents in Hawaiian soils. Watering may be needed to prevent drying of the surface materials during construction. Ideal construction time is usually in early summer.

CHAPTER IV

RIPRAP FOR BANK PROTECTION

Embankments and streambanks are sometimes protected by walls or continuous revetments such as slope paving or articulated concrete blocks. Of the various bank protection materials, riprap has been most used and the most economical and successful material. Riprap is a layer, facing or protective mound of stones randomly place to prevent erosion, scour, or sloughing of a structure or embankment.

DESIGN FEATURES OF VARIOUS RIPRAP TYPES

Dumped Riprap

Dumped riprap is graded stone dumped on a prepared slope in such a manner that segregation will not take place. Dumped stone riprap is the most flexible of the types considered and will adjust itself to uneven bank settlement. In most areas dumped stone is the least costly type.

Stone used for dumped riprap should be hard, durable, angular in shape; resistant to weathering; free from overburden, spoil, shale, and organic material; and should meet the gradation requirements for the class specified. Neither breadth nor thickness of a single stone should be less than one third its length. Rounded stones or boulders are not acceptable. The minimum weight of the stone should be 155 pounds per cubic foot as computed by multiplying the specific gravity (bulk saturated surface dry basis, AASHO Test T 85) times 62.3 pound per cubic foot.

The sources from which the stone is to be obtained should be selected well in advance of the time when the material will be required in the work. The acceptability of the stone is determined by service records and/or by suitable test. If testing is required, suitable samples of stone should be taken in the presence of the engineer in sufficient time for testing before the placing of riprap is expected to begin.

In the absence of service records, resistance to disintegration from environmental exposure is determined by the sulfate soundness test or by the abrasion test in the Los Angeles machine. The freezing and thawing test furnishes a useful guide in judging the soundness of stone subject to weathering action. In locations not subject to freezing or where the stone is exposed to salt water, the sulfate soundness test (AASHO Test T 104 for ledge rock using sodium sulphate) should be used. Stones should have a loss not exceeding 10 percent with the sulfate test after five cycles. When the abrasion test in the Los Angeles machine (AASHO Test T 96) is used, the stone should have a percentage loss of not more than 40 after 500 revolutions. The limits given here for the tests should be checked by testing local rock that has given good service when used as riprap under similar environmental conditions.

Large stones should be uniform in size. Failure to require well graded stone may result in a blanket with large voids that will allow the embankment or the filter material to be withdrawn through the riprap by the action of the water.

Each load of riprap should be reasonably well graded from the smallest to the maximum size specified. Stones smaller than the specified 10 percent size and spalls should not be permitted in an amount exceeding 10 percent by weight of each load.

Gradation of the riprap being placed is controlled by visual inspection. To aid the inspector's judgement, two or more samples of riprap of the specified gradation should be prepared by sorting, weighing and remixing in proper proportions. Each sample should weigh about 5 tons. One sample should be placed at the quarry and one sample at the construction site. The sample at the construction site could be a part of the finished riprap blanket. These samples should be used as a frequent reference for judging the gradation of the riprap supplied.

The resistance of dumped stone to displacement by moving water depends upon:

1. Weight, size, shape, and composition of the individual stones.
2. The gradation of the stone.
3. The depth of water over the stone blanket.
4. The steepness and stability of the protected slope.
5. The stability and effectiveness of the filter blanket on which the stone is placed.
6. The velocity of the flowing water against the stone.
7. The protection of toe and terminals of the stone blanket.

The size of stone needed to protect a streambank from erosion by a current moving parallel to the embankment is determined by the use of Figures 1 and 2. Size (k) is the diameter, in feet, of a spherical stone that would have the same weight as the 50 percent size of stone. The size of stone is found by a trial-and-error procedure which consists of first estimating a stone size.

The size of stone required to resist displacement from direct impingement of the current as might occur with a sharp change in stream alignment is greater than the value obtained from Figure 2.

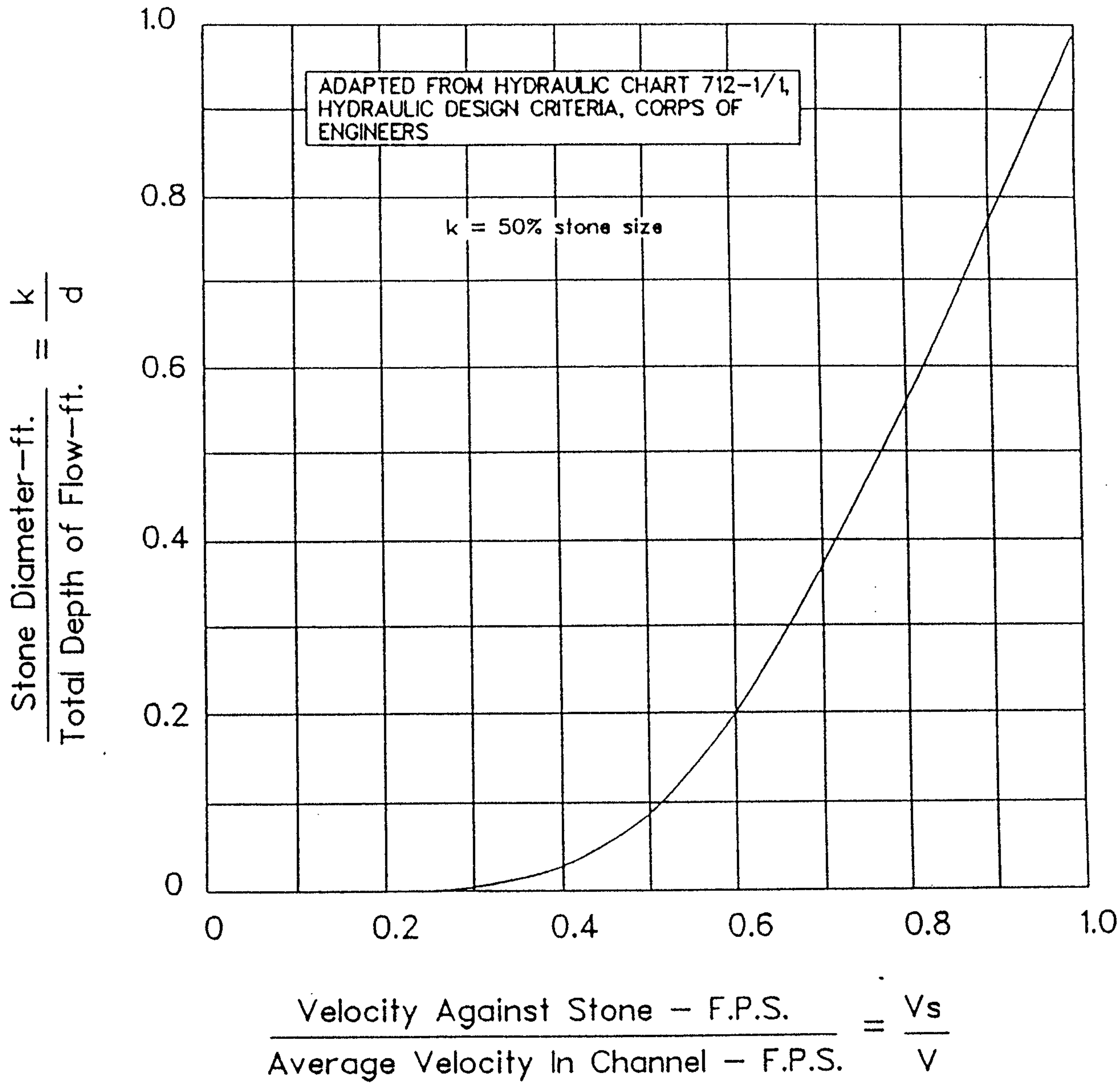


FIGURE 1 – VELOCITY AGAINST STONE ON CHANNEL BOTTOM

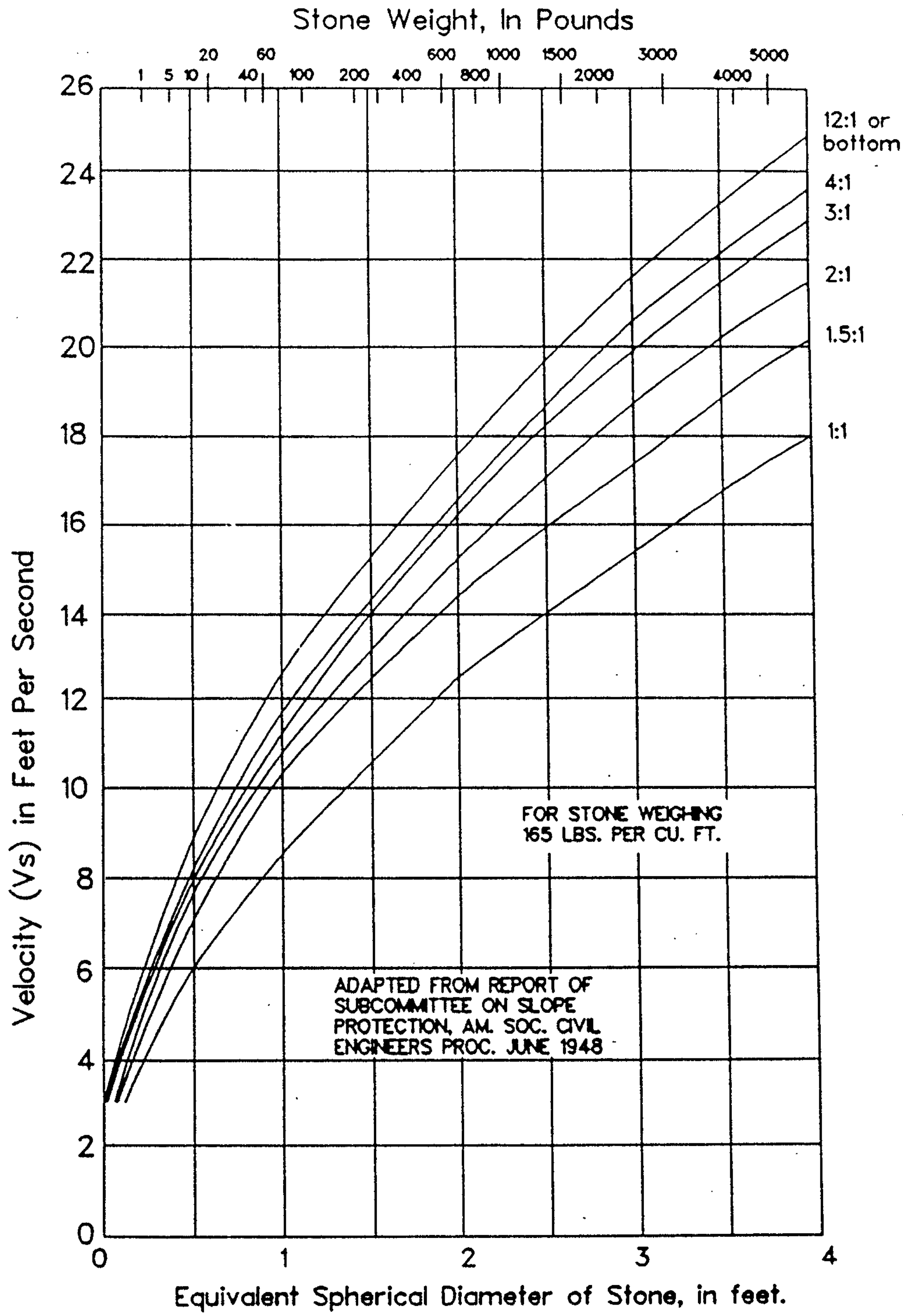


Figure 2 — SIZE OF STONE THAT WILL RESIST DISPLACEMENT FOR VARIOUS VELOCITIES AND SIDE SLOPES

The upper vertical limit of the protective cover should extend above design high water. The allowance of freeboard depends upon the velocities near the riprap cover and, at some locations, upon the height of waves that might be generated on the water surface. Established sod above the stone protection will provide considerable protection from floods which overtop the riprap cover.

Where the stream channel is composed of sand or silt, bank protection should extend a minimum vertical distance of 5 feet below the streambed on a continuous slope with the embankment. On the outside of curves or sharp bends, scour is particularly severe, and the toe of the bank protection should be placed deeper than in straight reaches. Where a toe trench cannot be dug, the riprap blanket should terminate in a stone toe at the level of the streambed. The toe provides material which will fall into a scour hole and thus extend the blanket.

On large rivers or tidal estuaries having a considerable depth of flow at low water stages, the Corps of Engineers carries the stone protection 5 feet vertically below mean low water and omits the toe. The stone blanket should be keyed into a berm when a toe or toe trench is not provided. The purpose of the toe protection is to prevent undermining, not to support the blanket. Unless the protection has sufficient stability to support itself on the embankment slope, the protection cannot be considered adequate.

The bank protection should extend both upstream and downstream from the points of reverse curvature on the outside of a curved channel. Bank protection is usually not required on the inside of the curve unless return of overbank flow creates a scour problem. On a straight channel, bank protection should begin and end at a stable feature in the bank if practicable. Such features might be outcroppings of erosion resistant materials, trees, vegetation, or other evidence of stability. When a stable feature does not exist, cutoffs should be provided. If the protective cover is long, intermediate cutoffs might be required to reduce the hazard of complete failure of the stone blanket.

Hand Placed Riprap

Hand placed riprap is stone laid carefully by hand or by derrick following a more or less definite pattern with the voids between the larger stones filled with smaller stones and the surface kept relatively even. The resulting protection approaches good dry rubble in quality and appearance, but this type of riprap is rigid and lacks the strength necessary to bridge even minor movement of the surface which it protects.

Stone used for hand placed riprap should be of better quality than specified for dumped riprap. Stone should be roughly square or rectangular to facilitate laying them up. The gradation curves for dumped riprap are not applicable. Only enough rock fragments to fill the openings between the larger stone should be permitted.

Hand placed riprap requires a much firmer support from the bank being protected than does dumped riprap because it does not have the strength to resist nor the capability to adjust to movement of the supporting material. Hand place riprap is particularly susceptible to damage from ice floating in the stream.

Except for method of placing and greater emphasis on firm support and protection of blanket edges, the discussion under dumped riprap applies to hand placed riprap.

Wire Enclosed Riprap (Gabions)

Wire enclosed riprap (gabions) consists of stone placed in wire baskets or in wire covered mats. It is generally used because rock of suitable size is not available. This riprap is effective only until the wire enclosure fails. In addition to being more resistant to vandalism, wire enclosed riprap provides a dependable erosion resistant bank or bottom and permits the use of smaller sized rocks because the wire basket tends to make the entire basket act monolithically. Gabions are also very useful in urban drainage work as drops with either vertical or stepped faces.

Stone used for wire enclosed riprap should meet the requirements for dumped stone riprap except for size and gradation of stone. The stone should be well graded within the sizes available and 70 percent of the stone, by weight, should exceed in least dimension the wire mesh opening. The maximum size of stone should not exceed the thickness of the riprap.

Baskets for the riprap are generally formed of galvanized woven wire fencing of No. 9 or No. 12 gage wire. Ties, hog rings, and lacing wire should be No. 9 galvanized wire.

The use of wire enclosed riprap is restricted to locations where the only rock economically available is too small for dumped riprap. The design of wire enclosed riprap is somewhat arbitrary, being dependent upon the size of rock used for riprap. The mesh size of the wire is also dependent upon the size of rock used for riprap. Wire enclosed riprap had been used in some instances as toe protection for other typed of riprap. This type of protection is flexible to an extent, but the protection is limited to the life of the wire for enclosing the stone.

The wire baskets are first formed and then filled with stone. The baskets are tied together to form a mattress and anchored to the slope. For light exposure, a continuous blanket of small stones retained between top and bottom spreads of wire fencing might suffice. On all designs the blanket should be divided into compartments so that one compartment can fail without losing all of the blanket.

Blankets 4 or 5 feet square are a convenient size, although larger sizes might be used. The dimensions of commercial fencing available might govern the dimensions of the baskets in order to minimize cutting of the wire in fabricating the baskets. Mattresses may be placed with the long dimensions either traverse to the slope or parallel to the slope.

Grouted Riprap

Grouted riprap is riprap with the interstices filled with portland cement mortar. The uses of grouted riprap is seldom justifiable when stone of suitable size is available. Grouted riprap is useful in that it ties the individual rock pieces together, providing a somewhat monolithic mass, and it also permits the use of smaller rock. Care should be taken with grouting of riprap in urban areas however, to insure a reasonably acceptable appearance. The grout may be a weak mixture with a 28 day strength of at least 2,000 psi.

It is important that the grout penetrate into the riprap mass, and not simply create a veneer with the top few inches of the riprap. It is more effective hydraulically and from the appearance standpoint to have a rough surface with portions of the rock particles projecting out from the grout surfaces. After completing the placement of the grout, it is desirable to clean off the projecting rocks with a wet broom. Cracking of the grouted riprap will occur with settlement.

Grout for grouted riprap consists of one part portland cement and three parts of sand, thoroughly mixed with water to produce grout having a thick creamy consistency. The minimum amount of water should be used to prevent excess shrinkage of the grout after placement. The cement, sand, and mixing shall conform to the specifications for concrete masonry.

The stones for grouted riprap should meet the requirements for dumped riprap except for size and gradation should be determined for each particular project, depending on the availability of stone. Stone should be clean and free of fines which prevent penetration of grout; care should be taken in placing the stone to keep earth or sand from filling the spaces between the stones.

Grouted riprap is used where stone of suitable size for other types of riprap are not available. Wire can be embedded in the riprap to increase the tensile strength of the protective cover. The finished protection is rigid and has little strength. The embankment protected must provide adequate support and the edges of the riprap cover must be protected from undermining at the toe and at the terminals. The grouted riprap may be left with a rough surface by brushing the grout until from one fourth to one half the depth of the stone is exposed.

Weep holes should be provided in the blanket to provide rapid relief of any hydrostatic pressure behind the blanket. Filter blankets are generally necessary as in the case of other types of riprap.

Concrete Riprap

Concrete riprap in bags (sacked concrete) consists of approximately 2/3 cubic foot of class C concrete (3-1/2 bags cement per yard) in cement sacks or suitable burlap bags that are hand placed in contact with adjacent bags.

This type of riprap provides a heavy protection regardless of the requirements of the site. The riprap has little flexibility, low tensile strength, and is susceptible to damage from floating debris. It requires firm support from the protected bank and requires a filter blanket underneath the riprap. Adequate

protection of the terminals and toe is essential. The toe trench must end in firm support and extend below the depth of anticipated scour.

The bags make close contact with each other and some bond is secured between the bags by the cement mortar leaking through the porous bags. Flat slopes reduce the area of contact between the sacks, thus reducing the bond. Slopes of the protected embankment are generally 1-1/2:1. If the slopes are as flat a 2:1, all sacks after the bottom row should be laid as headers rather than as stretchers.

Concrete riprap in bags is sometimes placed as a dry mix. The riprap is thoroughly wetted as the work progresses. Some bond between sacks is probably lost by this method, but it allows the sacks to be filled at a convenient location and brought to the construction site. A well graded filter blanket is essential to drain the water that is added during construction.

Concrete Slab Riprap

Concrete slab riprap consists of plain or reinforced concrete slabs poured or placed on the surface to be protected. The slab is generally 4 inches thick of class B concrete (4-1/2 bags cement per yard) except when the slab is exposed to salt water in which case class A concrete is used. The slabs are not connected.

Concrete slabs 6-1/2 feet by 5 feet and 8 inches thick were used on the Belle Fourche Dam in South Dakota. The slabs were much deteriorated after 40 years of service in spite of considerable maintenance. Continuous reinforced concrete pavement used on earth dam faces has a much better service record than concrete slab riprap.

CONSTRUCTION OF RIPRAP

Brush, trees, stumps, and other objectionable material should be removed from slopes and other area to be protected by riprap, and the areas should be dressed to a smooth surface. All soft or spongy material should be removed to the depth determined by the soils engineer and replaced with suitable material. Filled areas should be compacted as for embankments. Sand slopes protected by riprap should be no steeper than 2:1. The toe trench, when specified, should be dug and maintained until the riprap is placed. The filter blanket should be placed on the prepared slope or on the area to be provided with foundation protection. Protection for structure foundation should be provided as early as the foundation construction permits.

When required, a filter blanket should be placed on the prepared slope or area to the full specified thickness of each layer in one operation, using methods which will not cause segregation of particle sizes within the bedding. Compaction of filter is not required, but the surface of the finished layer should be reasonably even and free from mounds or windrows. Additional layers of filter material, when required, should be placed in the same manner, using methods which will not cause mixing of the materials in the different layers.

Inspection by the engineer during all phases of construction is essential to ensure proper placement of the protective cover.

CHAPTER V

EMBANKMENT DESIGN

GENERAL

An earthfill dam of any size must be designed to be safe and stable during its entire life, including construction. The following design considerations indicate many of the requirements which must be met if safety is to be assured:

1. The slopes must be stable and resistant to deformation under all operating conditions, including rapid reservoir drawdown.
2. Seepage through the embankment and its abutments and foundation must be controlled so that piping and sloughing do not occur.
3. The embankment must be safe from overtopping by both flood inflow and wave action.
4. The embankment must be safe from catastrophic failure during reasonably expectable earthquakes at the site.
5. The slopes must be safe from excessive damage from wave action or rain.

A small earthfill dam designed to meet the above criteria should prove to be safe, provided proper construction methods and control are achieved.

The embankment for this type of dam is normally constructed of native materials from the immediate vicinity of the dam. The materials are first moisture conditioned and then hauled to the dam by scraper or truck. A bulldozer is usually used to spread the material in loose lifts about 8 inches thick, and each lift is thoroughly compacted by a tractor-drawn sheepsfoot roller or a power-operated tamping roller.

These guidelines are considered applicable to foundations that can be determined to be suitable by visual inspection or by density and gradation tests. Such foundations may consist either of fairly dense soils, or of fresh or weathered bedrock. The foundation can be impervious soil or bedrock, or pervious soils with a cutoff trench.

DESIGN FEATURES

Embankment materials vary widely from site to site, particularly with respect to gradation and permeability. If the difference in permeability between the core and the downstream shell is great, no internal drainage is required. If the variation of the permeability between the core and shell is not sufficient, the dam will become nearly completely saturated after prolonged storage, and the downstream slope will show seepage to a height of approximately one-third the depth of the reservoir. Such saturation reduces the stability of the dam and creates maintenance problems. Major maintenance problems are (1) growth of undesired vegetation, and (2) minor sloughing from human and animal traffic.

All embankment dams are subject to some seepage passing through, under, and around them. If uncontrolled, seepage may be detrimental to the stability of the structure as a result of excessive internal pore water pressures or by piping. Seepage should be effectively controlled to preclude structural damage or interference with normal operations.

In the evaluation of seepage reduction or seepage control measures as they pertain to dam safety, one should review and evaluate the following:

1. Protective control measures such as relief wells, weighted graded filters, horizontal drains, or chimney drains which prevent seepage forces from endangering the stability of the downstream slope.

2. Filters and transition zones designed to prevent movement of soil particles that could clog drains or result in piping.

3. Drainage blankets, chimney drains, and toe drains designed to ensure that they control and safely discharge seepage for all conditions. The design of these features must also provide sufficient flow capacity to safely control seepage through potential cracks in the embankment impervious zone.

4. Contacts of seepage control features with the foundation, abutments, embedded structures, etc., designed to prevent the occurrence of piping an/or hydrofracturing of embankment and/or foundation materials. If conduits or pipes exist through the embankment, they should be inspected to ensure that they are functional or have been properly sealed.

5. Grouting, cut-off trenches, and impervious blankets.

6. Measures such as compaction requirements, placement of special materials, or other similar features to prevent internal erosion from seepage at the interface with concrete structures.

To eliminate such problems in dams where the downstream shell is relatively impervious, the Department of Land and Natural Resources requires the construction of internal drains on all but the smallest dams. In this type of design, small amounts of strategically placed pervious materials control the seepage and saturation.

To obtain some of the advantages of a zoned dam, the coarser more pervious embankment materials, when available, should be placed in zones at the outer slopes (shells) and the finer more impervious embankment materials placed in the central portion of the dam (core).

If enough native pervious materials, such as sand and sand-gravel mixtures are available to construct a substantial downstream pervious zone, internal drainage is not required. Usually, if not more than 5 percent of the material is finer than the No. 200 sieve, the material can be considered pervious. The embankment impervious core must have a width at its base equal to at least one-half the height of the dam, or a minimum of 14 feet.

The slopes for most embankments on strong foundations can be 3:1 upstream and 2:1 downstream. However, flatter slopes should be considered for dams constructed on inorganic clay or high plasticity and very fine inorganic silt. Organic soils are not usable as embankment materials. Regardless of embankment material, all side slopes should be verified by slope stability analyses.

The embankment soil must be compacted, based on ASTM D-1557-78, to an average relative compaction of 97 percent in low seismic areas and 100 percent in high seismic areas. This degree of compaction can generally be achieved with soils having moisture contents near optimum, utilizing 6-inch compacted lifts, and requiring the number of roller passes as follows:

Weight of Tamping Roller #/Lin. Ft.	Low Seismic Area	High Seismic Area
2,500	12	14
3,000	10	12
3,500	9	11
4,000	8	10

Where drain material is required, in most cases it will have to be a processed material purchased from an aggregate supplier. Pit run borrow is usually too dirty. The following graduation has given satisfactory results:

Sieve Size	Percentage Passing
1-1/2	90-100
3/4	45-75
4	30-45
50	4-10
100	1-3
200	0-2

However, the suitability of the drain material must meet the following criteria:

1. $\frac{D_{15} \text{ of the drain}}{D_{15} \text{ of the adjacent material}} = 5 \text{ to } 40$

2. $\frac{D_{15} \text{ of the drain}}{D_{85} \text{ of the adjacent material}} = 5 \text{ or less}$

3. $\frac{D_{85} \text{ of the drain}}{\text{Diameter of hole in perforated pipe}} = 2 \text{ or more}$

Toe drains incorporating a drain pipe are often installed along the downstream toe of dams in conjunction with a drainage blanket, for the purpose of collecting seepage waters from the foundation and embankment. Drain pipes are also used at other locations for controlling seepage, such as under spillway linings. Because of corrosion and strength considerations, the following are the only types of drainpipes allowed: concrete, clay, and plastic (PVC).

The minimum embankment crest width shall be 12 feet. The minimum freeboard (vertical distance from the maximum design flood level in the reservoir to the crest of the dam) shall be 4 feet.

Surface drainage of the crest must be provided by sloping the crest 3 percent toward the reservoir. A camber of about 1 foot should normally be provided at the maximum section of the dam.

The need for riprap or other types of upstream slope protection must usually be determined on a case-by-case evaluation, although many small dams with small reservoirs and constructed of cohesive soils have performed well with no slope protection.

EMBANKMENT DESIGN ON SOIL FOUNDATIONS

Soil foundations should have strength properties equal to or greater than that of the embankment. To provide an objective basis for judgment, several in-place density tests and accompanying compaction test curves would have to be made, as discussed in Chapter III. The average relative compaction of foundation soils should be 97 percent of ASTM D-1557-78 in low seismic areas, and 100 percent of this standard in high seismic areas. The entire area to be occupied by the dam should be stripped to a sufficient depth to remove all unsuitable materials, including surface boulders, loose rock, debris, topsoil, and vegetation, that might interfere with the proper bonding of the embankment with the foundation.

Under the central portion of the dam section, a cutoff trench must be provided. The cutoff should have side slopes no steeper than 1(H):1(V) for depths up to about 12 feet, and no steeper than 1-1/2(H):1(V) for greater depths. The bottom width of the trench should be equal to one-half of the height of the dam, or a minimum of 14 feet. The depth of the cutoff would generally extend to bedrock, or to an impervious strata of soil that can be determined to be of sufficient extent as to prevent excessive seepage beneath the dam. Prior to placing embankment material, the cutoff trench should be unwatered and should be cleaned of all loose, soft, and disintegrated materials.

The cutoff trench should also extend and key into the sides of each abutment to minimize future problems. The cutoff trench should be keyed a minimum of 10 feet laterally into both abutments.

Design of dams on pervious soil foundations, where a cutoff to bedrock or to an impervious soil strata cannot be achieved, are beyond the scope of these guidelines. Also, those foundations with densities less than indicated above represent special conditions outside the scope of these guidelines.

CHAPTER VI

SPILLWAY

LOCATION

The spillway should be located sufficiently apart from the dam to prevent erosion of the dam embankment. The best location is in a saddle or cut completely isolated from the dam. Most dams have the spillway located adjacent to the dam, with a bedrock barrier between the dam and spillway. A spillway over the dam embankment is not acceptable.

SPILLWAY DESIGN FLOOD

For a small dam and reservoir where the downstream hazard from dam failure is minor, the minimum spillway design flood should have a return period of at least 100 years.

Spillway design peak flow rate criteria should be:

1. Less than existing conditions when an upstream watershed will be developed (no runoff increase).
2. Less than the downstream reach can handle.

FREEBOARD

It is common practice to provide an extra height of dam over the computed maximum reservoir level for the design hydrograph. This added height, termed freeboard, is the allowance for waves, wave runup, and wind surge or pileup of water that could be caused by strong winds over the full reservoir surface or the uncertainty for the hydraulic calculations used. The type of dam, its geographical location and directional orientation, and the synoptic situation producing the PMP or design storm are all factors to be considered in the determination of freeboard allowance.

A major consideration, the synoptic situation, should deal with the timing of the maximum winds, their orientation and duration that accompany the study storm. For example, some types of storm systems, such as hurricanes, usually have the heavy rain-producing mechanism in the forefront, followed by the maximum winds. This scenario on certain watersheds could result in the maximum winds occurring after the PMF has filled the reservoir.

For assessing freeboard requirements, estimates are needed for the velocities, directions, and durations of winds that reasonably could occur with the reservoir at or near full pool. The "fetch," or maximum over-water distance adjacent to the dam in the direction of the wind, and depths of the reservoir also are needed in estimating wind effects. A number of approaches to computing these wind effects are available in U.S. Army Corps of Engineers' Reports (1968b, 1976). The results of such computations will give the wave height and setup and runup elevations for the selected conditions. Common practice for major dams is to add from 3 to 5 feet to the maximum computed (designed) water surface level, including wind effects, to establish top of dam.

Minimum freeboard (vertical distance from the maximum design flood level in the reservoir to the crest of the dam) shall be 4 feet. Minimum residual freeboard (distance from maximum reservoir stage for spillway design flood and dam crest) is 3 feet.

HYDRAULICS

For the spillway design flood, the spillway walls in the vicinity of the dam must maintain the same residual freeboard as required for the dam. The downstream chute of the spillway must not be overtopped for this flood. The rating curve for the spillway and the reservoir area-capacity curve should be shown on the drawings. Traditional flood routing cannot be used when the reservoir is shallow in depth and wide in water area, or when large amounts of overgrown vegetation exist in the reservoir.

DESIGN CONSIDERATIONS

In rock, where the erosion due to spillway flows will be minor to nil, the spillway can be natural or an excavated channel.

In rock, where erosion may be minor to moderate, the spillway can be an excavated channel with a concrete control sill at the entrance to the spillway. As erosion occurs, concrete and/or rock protection will be required.

When the spillway is to be located on soil or deeply weathered rock, the entire length of the spillway should be concrete or gunite lined. The average relative compaction of the foundation should be at least 97 percent of ASTM D-1557-78. A stilling basin, flipbucket, or other type protection may be required to prevent erosion at the terminal end of the spillway.

Spillway crest gates are frequently used to provide required storage capacity and to control the release of spillway discharges. The gates are designed to operate under controlled conditions during the occurrence of major floods. Proper operation of spillway gates for flood control can prevent downstream flooding that might otherwise occur with a fixed crest spillway. Also, the gates must be operated properly to prevent the release of reservoir discharges larger than those of the natural flood. The gates should be maintained and tested on a regular basis to assure that they will be fully operational during the flood season.

For some projects it may be unsafe to assume that regulating gates would be attended during the occurrence of the Standard Design Flood (SDF). The lag time between intense rainfall and the occurrence of the peak reservoir level could be too short for the gate operator to operate the gates properly, especially if the storm occurs at night. In this case gates should be assumed to be in the open position if they are normally open during the flood season, or closed if they are normally closed. No credit should be taken for any gate operation in the SDF routing unless it can be assured that the gates would be operated properly.

STRUCTURAL

Concrete design should be in accordance with the latest edition of the Building Code Requirements for Reinforced Concrete (ACI 318). Working stresses and ultimate strength designs should be based on a 28-day concrete strength of at least 3,000 psi. However, since spillways and outlet works are usually subjected to high flow velocities, durability of the concrete is a more crucial property than compressive strength. To ensure that durable concrete is provided, a maximum water-cement ratio of 0.45 is recommended for these structures. Use of this maximum water-cement ratio will automatically provide compressive strengths in excess of 4,000 psi at 28 days.

Reinforced masonry design should be based on the latest edition of the Uniform Building Code. Reinforcing steel should conform to ASTM 615. Structural steel design should be based on the latest edition of the AISC specifications.

The minimum thickness of all formed walls utilizing a single layer of reinforcing steel should be 6 inches. In addition, consideration should be given to the height of wall and the placement of concrete, therein, in setting the minimum wall thickness.

Cutoff walls and concrete control sills should have a minimum thickness of 12 inches. Concrete control sills should have a minimum depth of 3 feet in soils or weathered rock.

All concrete walls and slabs 10 inches or more in thickness should have two layers of reinforcing steel.

For concrete walls, including cutoff walls and concrete control sills, the minimum area of horizontal steel should be not less than .0025 and that of vertical steel not less than .0015 times the cross-sectional area of the wall.

The minimum steel area for floors, slabs, and footings should be .0020 times the cross-sectional area of the section.

All structures must be designed for the most severe load combinations anticipated. Seismic loadings need not be considered to act concurrently with storm water discharges. Buoyancy should be checked for U-shaped inlet structures. Earth loadings should be assumed on the basis of equivalent fluid pressures, based on cohesionless soil, as given by Rankine. No vertical walls (vertical walls being defined as any wall steeper than the angle of repose of the backfill material) should be designed for an equivalent fluid pressure of less than 30 pounds per square foot. Due to the possibility of the earth backfill being pulled away from the wall during dry periods, all vertical walls should be designed for internal hydrostatic loadings, as well as external loadings.

Wall footings should be safeguarded against vertical movement, and wall panels should be articulated to provide for adjustments in the event of foundation yielding or unequal settlement.

Spillway channel linings, where required, can consist of several types, with concrete and air-blown mortar being the most common. The absolute minimum thickness of a concrete lining should be 4 inches. Both lining types should be reinforced with 0.2 percent reinforcing bars or wire mesh in each direction. Depending on the foundation materials, underdrains may be required to prevent uplift pressures. Contraction joints should be installed at intervals of 10 to 50 feet, depending on the lining thickness, reinforcing steel, and the subgrade materials.

Asphaltic concrete is not allowed for spillway channel linings.

CHAPTER VII

OUTLETS

GENERAL

A low level outlet is required for emptying or lowering the reservoir: for inspection and maintenance of the dam, reservoir, and appurtenances; in routine work and in case of emergency; and for releasing waters to meet downstream water rights, project water use and/or flood control requirement.

LOCATION

The outlet conduit should be located near the base of one of the abutments on native competent material, preferably bedrock. The average relative compaction, if the foundation material is weathered bedrock or soil, should be at least 97 percent of ASTM D-1557-78. The entire length of the conduit should be bedded on foundation materials of uniform density and consistency. If this is not possible, then the conduit should have the capability of deforming without cracking under differential settlement. This can be accomplished by using short lengths of conduit sections with articulated joints.

The final alignment of the outlet conduit may be determined in the field after site stripping operations, and after the embankment cutoff trench is excavated. Curved alignments and changes in grade may be desirable or necessary to locate the conduit on the most competent materials.

The outlet conduit should be positioned such that the full reservoir capacity, except for a small silt storage volume, can be discharged by gravity. In all cases, it should be able to drain at least two-thirds the volume of the reservoir.

CAPACITY

Outlet conduits should be sized such that, as a minimum, one-half the reservoir capacity can be discharged by gravity in a period of two days. The absolute minimum diameter of the conduit is 12 inches.

CONTROLS

Outlet conduits must have an upstream control device (gate or valve) capable of controlling the discharge through all ranges of flow. A trashrack in front of this control is required. The trashrack bars and supports should be designed for a minimum of 25 percent of the reservoir head to which they would be subjected if completely clogged. An air vent pipe is required just downstream of the control gate. An outlet conduit which is connected directly to a distribution system should have a blow-off valve at or near the downstream toe of the dam.

CONDUIT

Types of outlet conduits may include precast reinforced concrete, cast-in-place reinforced concrete, or metal pipe encased in concrete. Asphalt dipped or other metal pipe is not acceptable.

The precast pipe should have a reinforced concrete bedding and should be backfilled with concrete up to the pipe springline.

All types of conduits should be installed or constructed in a trench. The bottom of the conduit trench should be at or lower than the bottom of the dam embankment cutoff trench at the point where the two cross. Constructing a conduit that bridges the cutoff trench is not allowed.

Cast-in-place conduits should be reinforced with at least 0.2 percent reinforcing steel, both longitudinally and transversely as hoops.

The minimum thickness of concrete should be 8 inches.

Expansion joints in the outlet conduit, spaced at a maximum of 32 feet, are required for compressible foundations. Water stops should be provided at all expansion joints.

DESIGN

All outlet conduits should be designed for internal pressure equal to the full reservoir head and for superimposed embankment loads, acting separately. Embankment loads should be computed in accordance with Marston's Theory. Internal liners of cast-in-place conduits should not be considered as adding structural strength unless concrete liners are used.

CHAPTER VIII

GUIDE SPECIFICATIONS

GENERAL

These guide specifications describe the various technical items of work pertaining to a fairly typical small embankment dam founded on acceptably strong soil and with a cutoff trench to weathered bedrock. Requirements for a typical spillway and outlet works are also given. Omitted are the general and special provisions usually included in a set of specifications and other work the owner may want included in the contract.

The guide specifications are written without any pay items of work. The assumption has been made for this size of project that the work would best be accomplished on a lump-sum basis. This does not preclude the owner from establishing pay items as he believes appropriate.

It should be understood that these guide specifications are strictly applicable only to the particular dam assumed for this example, and that the specifications for any other specific dam would, of necessity, require modifications, varying from minor to major, to suit the unique requirements met at each separate damsite.

GUIDE SPECIFICATIONS

1. Control and Diversion of Water

2. Clearing

3. Grubbing

4. Stripping

5. Excavation

6. Cutoff Trench Foundation Preparation

7. Embankment

8. Underdrains

9. Riprap

10. Concrete Structures

11. Outlet Pipe

12. Gates and Appurtenances

1. Control and Diversion of Water

(a) General

The contractor shall furnish or procure all materials and labor required for constructing and maintaining all necessary cofferdams, channels, flumes, drains, sumps, and/or other temporary diversion and protective works and shall furnish, install, maintain, and operate all necessary pumping and other equipment for removal of water from the various parts of the work and for maintaining the foundations and other parts of the work free from water.

(b) Plan

Prior to beginning any work on the diversion and care of the stream and the removal of water from foundations, the contractor shall submit for the engineer's approval a water control plan showing his proposed method for the diversion and care of the stream during construction and removal of water from foundations and other parts of the work. Construction of the embankment and spillway must be completed by the first of November (beginning of winter season in Hawaii) to prevent failure during construction due to overtopping of the embankment from flood.

2. Clearing

Areas to be cleared consist of the reservoir area, site of dam embankment, a 25-foot strip adjoining the downstream toe of the dam embankment, spillway area, and borrow and stockpile areas. Clearing shall consist of removal and disposal of all trees, brush, down timber, rubbish, and any existing fences.

3. Grubbing

The entire foundation area for the dam embankment and other structures and all portions of the borrow areas shall be grubbed. Grubbing of foundation areas shall consist of the removal of all stumps and roots 1-1/2 inches or more in diameter to a depth of 3 feet below natural ground surface. The borrow areas shall be grubbed to the extent necessary to obtain material free of stumps and roots.

4. Stripping

The entire area and a minimum of 5 feet beyond the footprint of the dam, spillway, and outlet works shall be stripped to a minimum depth of 12 inches.

5. Excavation

(a) General

All construction operations shall be so conducted as to avoid stream sedimentation in accordance with the requirements of the Department of Land and Natural Resources.

All excavation shall be carried to lines, grades, and dimensions shown on the drawings or established by the engineer. During the progress of the work, it may be found necessary or desirable to vary the slopes or the dimensions of the excavation from those specified herein.

(b) Dam Embankment Foundation and Cutoff Trench

The entire area to be occupied by the foundation of the dam shall be stripped to material having strength parameters equal to or greater than those required of the embankment material.

The cutoff shall be excavated to impervious, moderately weathered rock.

(c) Spillway

Excavation for spillway includes all excavation required for the approach channel, spillway crest, and spillway discharge channel.

(d) Concrete Structure Foundations

The foundations for all concrete structures shall be excavated to firm weathered bedrock. Overexcavation shall be replaced with concrete backfill as specified in Section 10(e) (2).

(e) Outlet Conduit Trench

The trench in which the conduit is to be laid or constructed shall be carefully excavated to the established lines and grades shown on the drawings, or as revised and approved by the engineer, to provide a firm, uniform, and unyielding foundation for the entire length of the conduit. The alignment and grade of the outlet conduit shall be selected so as to cross the embankment cutoff trench at or below the trench bottom. If the characteristics of the foundation at any point are such that they might cause unequal settlement or provide unequal bearing or are otherwise unsuitable for a foundation, then the unsatisfactory materials shall be removed to such depth as may be directed by the engineer. The unsuitable materials shall be replaced with backfill concrete as specified in Section 10(e) (2).

(f) <u>Utilization of Excavated Materials</u>

It is the intent of these specifications that all required excavation suitable for embankment shall be utilized in the permanent construction. Suitable materials shall be excavated separately from the materials to be wasted. The suitable materials shall be segregated by loads during the excavation operations and shall be placed in the designated final locations directly from excavation. Excavated materials, if any, which are unsuitable for, or in excess of, dam embankment or other construction requirements, shall be disposed of within the vicinity as directed. Waste areas shall be left reasonably smooth and shall be sloped to drain.

(g) <u>Borrow Excavation</u>

Except for utilization of material obtained from required excavation as herein specified and shown on drawings, all material necessary for construction of required embankments shall be obtained from the borrow area shown on the drawings within the reservoir site. The method of excavation in the borrow area shall be subject to the approval of the engineer.

Borrow areas shall be stripped of all topsoil containing humus, roots, rubbish, and other materials not suitable for placing in the compacted fill. The sequence of stripping operations shall be coordinated with the excavation and fill so as to effect required moisture control with minimum addition of moisture to the excavated material.

Unsuitable material encountered in the borrow areas shall be wasted as directed by the engineer. The surface of all waste areas shall be left in a reasonably smooth condition and shall be sloped to drain.

6. Cutoff Trench Foundation Preparation

(a) General

The cutoff trench shall have a bottom width of not less than 14 feet, and shall be excavated to the approximate depth and at the location shown on the drawings. The exact depth will be determined by the nature of the materials encountered. The foundation of the cutoff trench shall consist of firm, impermeable, in-place, weathered rock.

(b) Cleanup

All loose rock fragments, dirt, gravel, standing or running water, and other objectionable materials shall be removed from the surface of the entire area of the cutoff trench foundations, by hand if necessary, to the extent directed by the engineer. Open cracks or joints shall be filled with backfill concrete or grout after removing soft or erodible crack-filling materials to a depth directed by the engineer. No fill shall be placed in the trench until the area to be covered has been inspected and approved by the engineer and by duly designated representatives of the Department of Land and Natural Resources, Division of Water and Land Development.

7. Embankment

(a) Requirements

Embankments shall be constructed to the lines and grades and cross sections indicated on the drawings, unless otherwise directed by the engineer. The contractor shall maintain and protect the embankment in a satisfactory condition at all times until final completion and acceptance of all work.

Any material placed in the embankment which fails to meet the requirements of the specifications, or which may have been placed or compacted at times or in a manner not acceptable to the engineer, shall be removed and disposed of or replaced properly at no cost to the owner.

(b) Materials

Embankments are to be constructed of suitable earth or rock materials obtained from borrow areas, cutoff trench, spillway and other required excavations. It is the intention of these specifications to use the most suitable materials obtainable from these sources without special processing. Materials containing brush, root, sod, or other perishable materials will not be considered suitable. The suitability of materials shall be subject to approval, and the disposition of materials in the embankment will be as directed by the engineer. The contractor shall excavate at the locations directed by the engineer whenever such control is necessary to obtain the type of material required for the embankment. Blending of materials by the excavation process in the borrow area may be required.

(c) Foundation Preparation

After clearing and stripping has been completed as specified, earth foundations shall be prepared as follows:

The sides of stump holes, test pits, and other similar cavities or depressions shall be broken down, where so directed, so as to flatten out the slopes; and the sides of the cut or hole shall be scarified to provide bond between the foundation material and the fill where directed. Unless otherwise directed, each depression shall be filled with properly moisture-conditioned impervious materials. The fill shall be placed in layers and compacted in accordance with the applicable provisions of this section. Materials which cannot be compacted by roller equipment because of inadequate clearances shall be spread in 4-in-thick layers and each layer shall be compacted with power tampers to the required density of the contiguous compacted materials. After filling of depressions, and immediately prior to placement of compacted fill in the embankment, the embankment foundation, excluding the cutoff trench foundation and bedrock foundations, shall be scarified to a depth of 3 inches.

After removal of roots or other debris turned up in the process of scarification, the entire surface of the embankment foundation material shall be moisture conditioned and compacted in accordance with the applicable provisions of Sections 6(e) and (f).

(d) Placement

No fill shall be placed on any part of the embankment foundation until the area to be covered has been inspected and approved. The distribution of materials shall be such that the embankment will be free from lenses, pockets, streaks, and layers of material differing substantially in texture or gradation from the surrounding material. Materials shall be spread in layers of uniform thickness. Unless otherwise directed, the thickness of layers before compaction shall be not more than 8 inches. Compaction of each layer shall be conducted in a systematic and continuous manner so as to ensure the specified coverage. Rolling shall be done parallel to the axis of the dam wherever possible. The embankment shall be brought up in layers such that the surface is essentially level at all times, except for a slight slope for drainage. In general, the more fine impervious materials shall be placed toward the center of the embankment, and the coarse more pervious materials toward the outer portion of the embankment. Materials placed in the cutoff trench and in the central portion of the dam shall have at least 15 percent of the material by weight passing the No. 200 sieve. No material larger than 6-inch maximum dimension will be permitted in an 8-inch layer, and each large piece shall be surrounded by fine material. Several large pieces in contact with each other will not be acceptable. Embankment construction shall be suspended when the ambient temperature drops below 32 degrees F.

(e) Moisture Control

The fill material shall have a moisture content throughout each layer at time of compaction of from "optimum minus one percent" to "optimum plus two percent," as determined by ASTM D-1557-78, Method A, unless otherwise directed. The contractor will be required to add water and manipulate the fill materials by harrowing or other approved methods so as to provide a uniform distribution of moisture in the material within the limits specified above. The application of water to the fill material shall be done at the site of excavation or stockpile, and shall be supplemented, if necessary, by sprinkling on the embankment.

If, in the opinion of the engineer, the top or contact surfaces of a fill section become too dry or smooth to permit suitable bond between these surfaces and the additional fill to be placed thereon, it shall be moistened and/or worked with a harrow, scarifier, or other suitable equipment in an approved manner to a sufficient depth to provide satisfactory bonding before the next succeeding layer of earth fill material is placed.

(f) Compaction

When the moisture content and conditions of the embankment material are satisfactory, fill material shall be placed as previously specified and compacted by a minimum of eight passes of the specified sheepsfoot tamper roller or approved equivalent. Roller drums shall be no less than 60 inches in diameter and not less than 60 inches in length. The weight of the roller shall not be less than 4,000 pounds per linear foot of drum length. If, with the required water content, it is found necessary to roll each 8-inch layer more than 8 times to obtain the required compaction, the number of passes shall be changed accordingly as directed by the engineer. However, the embankment fill shall be compacted to an average density of at least 97 percent, with no test less than 95 percent, as determined by ASTM D-1557-78, Method A. Compaction by flooding or jetting will not be permitted.

(g) Finishing Embankments

After completion of the embankment, the slopes shall be dressed and graded so as to provide a uniform surface and slope. The crest shall be dressed and sloped for drainage as shown on the drawings.

(h) Structure Backfill

Backfill within 2 feet of structures shall be placed in layers not more than 4 inches in uncompacted thickness and no material larger than 3-inch maximum dimension will be permitted. Compaction shall be performed with the use of hand-held power tampers as approved by the engineer.

8. Underdrains

(a) General

The contractor shall furnish all materials and labor required for installing the drainage blanket, toe drain, drains, perforated underdrain pipes, and terminal pipe as shown on the drawings.

(b) Pipe

The kind of perforated pipe underdrain to be installed shall be at the option of the contractor, but shall consist of one of the following types (or other non-metallic types) as approved by the engineer:

Perforated clay pipe shall conform to ASTM C-700, extra strength.

Perforated concrete pipe shall conform to ASTM C-444, Type I, and to ASTM C-14, Class I.

Perforated PVC and ABS pipe.

In no case should asbestos-cement pipe be used.

(c) Terminal Pipe

The terminal pipe shall be of the same material as the underdrain pipe, except that it shall not be perforated.

(d) Permeable Material

Permeable material for use in backfilling trenches; under, around, and over underdrains; and permeable material for drain blankets, riprap bedding, or other subdrainage purposes shall consist of hard, durable, clean sand, gravel, or crushed stone and shall be free from organic material, clay balls, or other deleterious substances.

The percentage composition by weight of permeable material in-place shall conform to the following gradings when determined by ASTM D-422-63:

Sieve Size	Percentage Passing
1-1/2 inch	90-100
3/4 inch	45-75
No. 4	30-45
No. 50	4-10
No. 100	1-3
No. 200	0-2

(e) Installing Underdrains

Trenches for underdrains shall be excavated, the pipe installed, and the trench backfilled with permeable material according to the dimensions and details shown on the drawings. Permeable drain material shall be placed and compacted thoroughly wet.

Perforated pipes shall be laid with the perforations down.

Permeable drain material shall be compacted in layers not exceeding eight inches by at least three passes of a heavy-duty, vibrating baseplate compactor weighing no less than 200 pounds, and having a vibration frequency of no less than 1,600 cycles per minute. Extreme care shall be exercised in compacting the permeable drain material so that the underdrain pipe is not damaged or dislocated. The compactor shall be subject to the approval of the engineer.

9. Riprap

(a) General

The contractor shall furnish all materials and labor required for placing riprap and bedding to the lines and dimensions as shown on the drawings.

(b) Quality

Individual rocks shall be dense, sound, and resistant to abrasion and shall be free from cracks, seams, and other defects that would tend to increase unduly their alternation by water and frost actions. The rocks may be either angular, as obtained from quarry operations, or round, except that round rocks shall not be placed on any surfaces having slopes steeper than 2:1. The minimum weight of the stone should be 155 pounds per cubic foot as computed by multiplying the specific gravity (bulk saturated surface dry basis, AASHO Test T 85) times 62.3 pound per cubic foot.

(c) Gradation

Riprap shall be reasonably well graded from the smallest to the maximum size. Stones smaller than the specified 10 percent size and spalls shall not be permitted in an amount exceeding 10 percent by weight of each load.

(d) Bedding

Bedding material shall conform to Section 8(d), "Permeable Material". Bedding material shall be compacted in layers not exceeding 10 inches in loose thickness by at least three coverages of the tread of a D8 tractor weighing at least 34,500 pounds. Bedding material within 5 feet of structures shall be compacted in layers not exceeding 6 inches in loose thickness by hand-held power tampers. Bedding material shall be placed and compacted thoroughly wet. The compaction and/or alternate methods of compaction shall be subject to the approval of the engineer.

(e) Installing Riprap

The riprap need not be compacted, but shall be placed to grade in a manner to insure that the larger rock fragments are uniformly distributed, and the smaller rock fragments serve to fill the spaces between the larger rock fragments so as to result in well-keyed, densely placed, uniform layers of riprap of the specified thickness. Hand placing will be required only to the extent necessary to secure the results specified above.

10. Concrete Structures

(a) General

The contractor shall furnish or procure all materials and labor required for constructing all the concrete structures, including the spillway sill and intake structure, to the lines and grades shown on the drawings. Excavation shall be as specified in Section 5(c), (d), and (e).

(b) Composition

Concrete shall meet the requirements of ASTM C-94 specifications.

(c) Cement

The cement used for all concrete structures shall be ASTM C-150, Portland Cement. Cement conforming to ASTM C150, Type I, is normally satisfactory for concrete subjected to ordinary exposure conditions. ASTM C150, Type II cement is only required where concrete is exposed to seawater, sewage, or other unusual conditions.

(d) Aggregates

All concrete aggregate shall be from proven sources of materials not reactive to alkali or sulfates, with maximum size particles passing 1-1/2-inch-square opening. Aggregates conforming to ASTM C-33, Size 67 (3/4-inch maximum nominal size) should be used for concrete members that are 6 inches, or less, in minimum dimension.

(e) Strength and Consistency

(1) Structural Concrete -- See paragraph 10(c) Cement. Maximum slump may range from 2 to 4-inch for normal concrete and maximum 8-inch slump for concrete with an approved superplasticizer.

(2) Backfill Concrete -- shall contain not less than four 94-pound sacks of Type I Portland Cement per cubic yard of concrete and shall have only sufficient water to provide the necessary consistency for placing. Type II cement shall be used as required (see paragraph 10(c) above).

(f) Steel Reinforcement

Steel reinforcement shall consist of intermediate grade deformed bars, conforming to ASTM A-615, Grade 40. Reinforcing steel shall be clean and free from heavy rust, scale, or coating of any kind and shall be held in place and tied at slices, corners, and intersections with 16-gauge annealed wire.

The spacing of bars, measured center to center, shall be as shown on the drawings or as directed by the engineer.

All splices in steel reinforcement shall provide an overlap of 24-bar-diameters or as shown on the drawings.

(g) Waterstop

Rubber or polyvinyl chloride waterstop shall be furnished and installed in the joints at the locations shown on the drawings. The contractor shall take suitable precautions to support and protect the waterstop during the progress of the work, and shall repair or replace any damaged waterstop. All waterstop shall be stored in as cool a place as practicable, preferably at 70 degrees F. or less. Waterstop shall not be stored in the open, or where it will be exposed to the direct rays of the sun. All waterstop shall be subject to the approval of the engineer.

(h) Forms

Forms shall be true to line and grade, mortar tight, and sufficiently rigid to prevent bulging and deformation under load.

No forms shall be removed within four days of placing concrete, or without approval by the engineer, and all removal shall be accomplished in a manner which will prevent injury to the concrete.

(i) Transportation and Placing

Concrete shall be transported from the mixer to the forms as rapidly as possible by methods that will prevent segregation and loss of ingredients. Any concrete which, during transportation, has become too stiff for effective placement or consolidation shall be wasted. In no case shall concrete be used which has been retained in truck mixers for more than 90 minutes after the introduction of mixing water to the batch.

Concrete retained in truck mixers for more than 45 minutes shall be continuously agitated.

Before placing concrete, the forms and steel reinforcement shall be approved for position, stability, and cleanliness. Concrete placement shall not commence until the engineer's approval has been obtained. All concrete shall be placed in the presence of the engineer. The concrete shall be deposited as nearly as possible in its final position. Drop chutes and elephant trunks shall be used on drops greater than 5 feet. Concrete shall be placed at such a rate that all concrete in the same lift will be deposited on plastic concrete. The concrete comprising each unit of work shall be placed in a continuous lift.

Concrete shall be transported from the mixer and placed within the forms within limits of time and by methods that will prevent segregation and loss of ingredients, so as to provide a dense and homogeneous mass, free from voids or rock pockets, and conforming to the lines and grades shown on the drawings.

All concrete shall be thoroughly compacted into place by use of approved immersion-type vibrators, supplemented by hand spading, rodding, and tamping, as necessary. The duration of vibration shall be limited to the minimum required to produce satisfactory consolidation without causing segregation. Vibrators shall not be used to promote horizontal movement of concrete within the forms.

(j) Finishing

Immediately after removal of forms, all unsightly ridges or lips shall be removed from permanently exposed surfaces. Defective concrete and concrete containing voids or rock pockets shall be removed and repaired as directed by the engineer. All permanently exposed concrete (other than formed faces) shall have wood flat finish.

(k) Embedded Items

Before placing concrete, care shall be taken to determine that all embedded items are firmly and securely fastened in place in true alignment, as indicated on the drawings or as required. Embedded items shall be free of oil and other foreign matter, such as loose coatings of rust, paint, and scale.

(l) Curing and Protection

All concrete shall be moist cured by maintaining all surfaces continuously wet for a period of not less than 14 days after being placed by sprinkling or spraying or by other methods approved by the engineer. At the option of the contractor, and if approved, concrete may be cured with pigmented curing compound of the surface membrane type instead of water. Curing compound, if used, shall be applied and maintained in strict compliance with the manufacturer's recommendations. All fresh concrete shall be adequately protected from damage by construction equipment.

11. Outlet Conduit

(a) General

The contractor shall furnish all materials and labor required for installing or placing the outlet conduit to the lines and grades shown on the drawings. The outlet conduit shall be either precast reinforced concrete pipe, cast-in-place reinforced concrete pipe, or of metal pipe encased in concrete, at the contractor's option. However, only one type will be allowed throughout the work. Conduit trench excavation shall be as specified in Section 5(e), "Outlet Conduit Trench". Outlet conduit bedding and/or encasement concrete shall be placed in the trench without forming.

(b) Alignment

The conduit alignment shown on the drawings is only approximate. The final alignment is to be determined in the field after the embankment foundation has been stripped and after the cutoff trench has been excavated. The conduit shall be located on native, undisturbed, competent material, as determined by the engineer.

(c) Precast Reinforced Concrete Pipe

Precast reinforced concrete pipe shall be of the class shown on the drawings and shall conform to ASTM C-76. Cement shall conform to ASTM C-150, Type I or Type II as stated in paragraph 10(c) above. The pipe shall have a reinforced concrete bedding placed concurrently with or after the pipe is in position. The concrete shall be structural concrete and shall conform to Section 10, "Concrete Structures." The concrete shall extend up the sides of the pipe to the centerline of the pipe. The pipe shall be laid upgrade, unless otherwise permitted by the engineer.

Pipe joints shall have rubber gaskets conforming to ASTM C-443, and shall be flexible and able to withstand expansion, contraction, and settlement. Rubber gaskets shall be stored in as cool a place as practicable, preferably at 70 degrees F. or less, and in no case shall the rubber gaskets be exposed to the direct rays of the sun for more than 72 hours.

(d) Cast-In-Place Pipe

Concrete for cast-in-place pipe shall be structural concrete and shall conform to the requirements of Section 10, "Concrete Structures."

The liner, at the option of the contractor, shall be of one of the following types:

1. Corrugated metal pipe shall conform to the requirements of AASHO M-36. Pipe sections shall be connected with standard field couplers 12 inches wide and of the same gauge as the pipe.
2. Welded steel pipe shall conform to the requirements of AWWA C-201. Steel shall be ASTM A-36.

Other types of pipes may be substituted, subject to the approval of the engineer. Only one type of pipe will be allowed in the work.

(e) Expansion Joints

Expansion joints shall be installed at the locations shown on the drawings and shall conform to ASTM D-994. Water stops shall be provided at all expansion joints.

12. Gates and Appurtenances

(a) Gates

Gates are to be installed at the locations shown on the drawings.

Gates, lifts, and accessories shall be of the size, type, and construction shown on the drawings, and as specified herein. They shall be the product of one manufacturer regularly engaged in the manufacture of gates and accessories, such as Armco, Waterman Industries, or Rodney Hunt, etc.

The gates, lifts, and accessories shall operate properly for the use intended, with a practical degree of water-tightness and have seating heads equal to, or in excess of, the heads shown on the drawings. The seating head shall be the vertical distance from the centerline of the gate opening to the maximum water surface.

The gates shall have a flatback design, and bronze seats, rising stem, galvanized assembly bolts, galvanized anchor bolts, and galvanized frame.

(b) Gate Stem

The gate stems shall be naval bronze and cold rolled steel, as shown on the drawings, with cold drawn steel stem splices, as recommended by the manufacturer.

(c) Gate Lift

The gate lift shall be manually operated, and shall be sized to operate the gate with a pull of not more than 40 pounds, when raising or lowering the gate under maximum operating head. The lift nuts shall be bronze, and the anchor bolts shall be galvanized.

(d) Oil Seal

The oil seals shall be as recommended by the manufacturer.

(e) Trashrack

Trashracks shall consist of galvanized structural steel members, fabricated and installed in accordance with the details shown on the drawings. All structural steel shall conform to ASTM A-36. Bolts, washers, and nuts shall conform to ASTM A-307.

CHAPTER IX

EMERGENCY ACTION PLAN

GENERAL

Emergency Action Plans (EAP's) should be developed for all projects where downstream lives and property are at risk from the failure or misoperation of all or a part of the facility. A plan should identify situations which could pose a threat to downstream areas and list the actions to be taken by the owner or dam tender to mitigate the problem. A principal section of the EAP should contain a list of appropriate authorities responsible for providing warning and evacuation notice to downstream inhabitants.

It is strongly recommended that the dam owner and consultant (s) coordinate the development of the EAP with appropriate local government agencies.

EMERGENCY ACTION PLAN GUIDELINES

Although most dam owners have a high level of confidence in the structures they own and are certain their dams will not fail, history has shown that on occasion dams do fail and that often these failures cause loss of life, injuries and extensive property damage. A dam owner should prepare for this possibility by developing an emergency action plan which provides a systematic means to:

1) Identify emergency conditions threatening a dam.
2) Expedite effective response actions to prevent failure.
3) Reduce loss of life and property damage should failure occur.

A dam owner is responsible for preparing a plan covering these measures and listing actions that the owner and operating personnel should take. He should be familiar with the local government officials and agencies responsible for warning and evacuating the public.

It is important that dam owners make full use of others who are concerned with dam safety; emergency plans, will be more effective if they integrate the actions of others who can expedite response. People and organizations with whom the dam owner should consult in preparing an emergency action plan include numerous local participants, state and federal agencies.

An essential part of the emergency action plan is a list of agencies/persons to be notified in the event of a potential failure. Possible inclusions for this list should be obtained from and coordinated with local law enforcement agencies and local disaster emergency services. These are key people or agencies who can activate public warning and evacuation procedures or who might be able to assist the dam owner in delaying or preventing failure.

Certain key elements must be included in every notification plan. Information about potential inundation (flooding) areas and travel times for the breach (flood) wave is essential. Inundation maps are especially useful in local warning and evacuation planning. Detailed information about identification of inundation areas or the development of maps can be found by contacting the Department of Land and Natural Resources (DLNR).

PLAN MAINTENANCE

This plan will be reviewed annually or whenever new data is received which would require the modification of the down channel inundation zones or the evacuation strategy. During the review, special attention will be given to:

1) The accuracy and completeness of formatted public address, public service and Emergency Broadcast System scripts currently on file in OCDA.

2) The status of current and projected education and awareness programs dealing with the warning and evacuation of threatened populations below dams and reservoirs located within the City.

EMERGENCY CONDITIONS

The following constitute emergency conditions on any dam or reservoir.

1) Failure of the dam; or
2) The occurrence of a critical condition such that the integrity of the dam or any of its appurtenances is immediately threatened, including for example:
   a) Excessive and unusual seepage on the outer slope or downstream from the toe of the dam or near or around a conduit through the dam as indicated by unusual damp areas, boils, cones, and deltas;
   b) bulging of the downstream slope of the dam;
   c) subsidence or cracking of the crest on either slope of the dam and slopes in the reservoir area;

d) substantial or threatening surface erosion, gullying, or wave erosion on the upstream or downstream slope of the dam, including berms and the area beyond the downstream toe of the dam and below or around conduits exiting the dam or spillways; and

e) an inflow that equals or exceed the maximum inflow design flood.

UNSAFE DAM CONDITIONS

1) Slowly Developing - Days or weeks are available for response.

2) Rapidly Developing - Days or hours are available for response.

3) Instantaneous - Only minutes to hours are available for response.

Note 1: If a local earthquake occurs (usually identifiable when individuals have difficulty standing or maintaining their balance), residents in the downstream areas of the dams listed in this plan should accomplish a precautionary evacuation as soon as the shaking stops.

Note 2: City response forces will automatically implement the warning and evacuation provisions of this plan under local earthquake conditions.

EVACUATION

Note: It is not essential that evacuees utilize public shelters/shelter areas for their survival. If evacuees deem movement to a shelter/shelter area to be impractical or impossible, they should relocate to any area outside the downstream inundation zone even though cover from the elements or other necessities are not available. Such a personal evacuation strategy is highly recommended.

CONCEPT OF OPERATIONS

1) Slowly Developing Condition Which May Result in Failure

Upon notification of an unsafe dam condition, OCDA will alert selected response agencies and coordinate with the owner/operator of the affected dam/reservoir in the development and issuance of emergency public information. Activation of the City Emergency Operating Center (EOC) will be considered and preparations made for the possibility that dam deterioration may accelerate. (See Response Checklist A, page A-13)

2) Rapidly Developing Condition

The City EOC will be activated for a rapidly developing unsafe condition. Roadblock, warning, evacuation and sheltering personnel will be placed on alert. In coordination with the owner/operator of the affected dam/reservoir, emergency guidance and instructions will be provided to the public. Depending on dam failure estimates received from the owner/operator or other consulting engineering organizations, decisions will be made to either prepare residents for evacuation or to begin a precautionary evacuation of threatened zones in anticipation of a probable dam failure. (See Response Checklist B, page A-15)

3) Instantaneous Failure

A. If the City EOC has been activated and staffed and an instantaneous failure occurs, OCDA will direct the activation of roadblocks, and the implementation of warning, evacuation, and sheltering operations.

B. If dam failure occurs when the City EOC is not activated and staffed, HPD, in coordination with HFD, will immediately implement roadblock, warning and evacuation operations and notify OCDA of actions taken. OCDA will subsequently activate the City EOC and coordinate further emergency management actions and support as required and requested.

C. Refer to Checklist B, page A-15, for response procedures.

MODEL EMERGENCY ACTION PLAN

____
(Name of Dam)

(OWNER'S NAME)
(OWNER'S ADDRESS)

DATE

If (Dam name) is failing or failure seems imminent, call:

DLNR . . . .

Disaster and Emergency Services . . . .

Dam Owner . . . .

CONTENTS

I. INTRODUCTION

PURPOSE

The purpose of this emergency action plan (EAP) is primarily to safeguard the lives of and secondarily to reduce property damage to the citizens of __________ County living along _______ River in the event of flooding caused by a failure of (Dam Name).

DESCRIPTION OF DAM

(Dam Name) is located________________________________. It is owned by __(Owner's Name and Address)________________, and is used for_________________________. Technical data pertaining to (Dam Name) are listed in Appendix A, and its structures are shown in Appendix B.

ACCESS TO DAM

(Dam Name) is located off (road) . See the inundation maps in Appendix C.

HAZARD AREA

The evacuation area extends along ____ as shown in Appendix C. Hazards include _______________________________. Inundation and evacuation maps are in Appendix C.

RESPONSIBILITY AND AUTHORITY

Roles and Responsibilities

1) Owners and operators of Oahu dams/reservoirs will:

   A. Promptly notify the Oahu Civil Defense Agency and the Honolulu Police Department of any unsafe condition affecting their facilities.

   B. Assist the City in evaluating dam/reservoir condition, and when necessary, in preparing emergency public information and accomplishing the warning and evacuation of threatened populations.

2) Oahu Civil Defense Agency (OCDA)

   Upon notification that an unsafe condition exists at any Oahu dam/reservoir:

   A. Determine the time available for response.

   B. Alert all necessary response agencies.

   C. Accomplish the actions outlined in Concept of Operations paragraph and in Response Checklists A and B.

3) Oahu Civil Defense District Volunteer Organizations

   A. Assist HPD in traffic control, warning and evacuation.

   B. Coordinate volunteer use with their respective District Police Station Commanders or their on-duty representatives.

   NOTE: District I will coordinate volunteer assignment through the Communications Division Watch Commander or Supervisor if the City EOC is not activated or with the Police representative in the City EOC when the EOC is activated.

4) Oahu Civil Defense RACES Volunteers

   Within capabilities and as assigned, provide radio communications to the City EOC from activated shelters/shelter areas, hospitals, command and control facilities, etc.

5) American Red Cross

When requested by OCDA or HPD, and in coordination with the State Department of Education and the Department of Parks and Recreation:

A. Activate, staff and operate identified shelters and/or shelter areas for evacuees.

B. Operate fixed or mobile feeding stations, emergency first aid stations, or other similar facilities, as necessary.

C. Operate emergency registration, welfare and casualty inquiry services as the situation permits.

D. Arrange and provide for medical and nursing care for evacuees in shelters/shelter areas.

6) Board of Water Supply

When requested, advise and assist OCDA and HPD in evaluating unsafe dam conditions.

7) Health Department

Ambulance crews located within or in proximity to the inundation zones, will assist HPD in warning and evacuation if not otherwise committed.

8) Honolulu Fire Department (HFD)

Within capabilities, assist HPD in warning and evacuation operations.

9) Honolulu Police Department (HPD)

Upon notification by OCDA or the owner/operator of a dam/reservoir that an unsafe condition exists:

A. Determine the time available for response.

B. Accomplish necessary notifications.

C. When directed by OCDA, or under instantaneous dam failure conditions, or in the event of a local earthquake:

1. Immediately establish roadblocks on the perimeter of the inundation areas.
2. Conduct warning and evacuation of down channel zones.
3. Contact the Fire Alarm Bureau and Ambulance Dispatch and coordinate the use of available units in warning and evacuation.
4. Maintain security for areas that have been evacuated.

10) <u>Human Resources</u>

A. Coordinate with the American Red Cross and other City Departments/private sector agencies in providing for the special needs of the elderly and disabled.

B. Time permitting, staff a telephone answering service for emergency calls from elderly and disabled requiring assistance.

11) <u>Information and Complaint (OID)</u>

Assist OCDA in providing the public, the media, the hearing impaired, and the City's non-English speaking population with warning and evacuation advisories and instructions. Staff rumor control.

12) <u>Land Utilization (DLU)</u>

Provide personnel to maintain City EOC evacuation map and activity displays.

13) <u>Parks and Recreation (DPR)</u>

A. Act as the City's primary point of contact for coordinating American Red Cross sheltering functions and requirements.

B. Coordinate the use of City facilities to be used as shelters/shelter areas, and trained employees for use on Red Cross or City mass care management teams.

C. DPR personnel, operating in City/managed recreation and/or beach areas which could be affected by inundation, assist HPD in warning and evacuation.

14) Public Works

A. Within capabilities, assist HPD in warning and evacuating down channel inundation areas.

B. Provide roadblock or other traffic or crowd control barricade materials as requested.

C. Prepare to alert and deploy the Initial Damage Assessment Teams.

D. Provide engineering and sanitation services which may be required at evacuation shelters or shelter areas.

15) Transportation Services

A. Coordinate all transportation requirements in support of warning and evacuation operations to include those of the elderly and disabled.

B. Provide MTL busses, as the situation and time permits, to transport evacuees to and from shelters/shelter areas.

16) Supporting State Departments

A. Provide assistance to the City in accordance with departmental authority, functions, resources, and capabilities.

B. State Civil Defense and the State Department of Education - Be responsive to Red Cross requests for the use of facilities/grounds as shelters/shelter areas.

17) Cooperating Agencies

Community, neighborhood, charitable, and church groups will provide volunteer relief programs for evacuees and victims in accordance with pre-planned arrangements and mutual agreements with the American Red Cross. These groups include but are not limited to:

A. Salvation Army

B. Hawaii Conference of Seventh Day Adventists

C. Hawaii Baptist Convention

D. Volunteer Organizations Active In Disasters (VOAID)

E. Hawaii Council of Churches

PERIODIC REVIEW/UPDATE

The owner will review/update this EAP annually. Review/update by a qualified professional engineer will be accomplished as required by the dam's operating permit, but no less than every five years.

II. NOTIFICATION PROCEDURES

IMMINENT OR ACTUAL FAILURE

It is important that you accurately judge whether the dam is about to fail. If you are not sure whether the dam is threatened, seek advice from a qualified engineer or call the Dam Safety Section (Ph. 587-0248) of the Department of Land and Natural Resources (DLNR). If (Dam Name) is failing, two things must be done immediately: 1) the hazard area downstream from the dam must be evacuated, and 2) any steps that might save the dam or reduce damage to the dam or hazard area downstream should be taken. (Refer to the map in Appendix C to determine the areas that are likely to be inundated if the dam fails). The evacuation will be handled according to the county warning plan, and should be initiated as shown in Figure 1.

As dam owner, it is your responsibility to:

1. Call the Oahu Civil Defense Agency (ph. #) and the Department of Land and Natural Resources (DLNR). Be sure to say, "This is an emergency." They will notify DLNR, and call other authorities and the media and begin evacuation.
2. Do whatever is necessary to bring anyone in immediate danger to safety. This includes someone on the dam, directly below the dam, or boating on the reservoir, or evacuees if so directed by the DLNR.
3. Keep in frequent touch with DLNR staff. They will tell you how to handle the emergency.
4. If all means of communication are lost:
    a. Try to find out why
    b. Try to get to another radio or telephone that works
    c. Get someone else to try to reestablish communications.

POTENTIALLY HAZARDOUS SITUATION

A potentially hazardous situation is an event or condition not normally encountered in the routine operation of the dam and reservoir. Among the unusual occurrences that may affect the dam are dam embankment problems, failure of the spillway or outlet works, heavy precipitation, landslides, earthquakes, erosion, theft, vandalism, acts of sabotage, and serious accidents. These occurrences may endanger the dam, the public, or the downstream valley and may necessitate a temporary or permanent revision of the dam's operating procedures. Help in these situations can be obtained by notifying those people shown in Figure 2.

If the dam owner discovers an unusual condition of the dam embankment that could threaten the structure:

1. Have a qualified engineer inspect the dam as soon as possible to determine whether emergency action is necessary.
2. Notify the DLNR (Ph. 587-0227) of the potential problem.
3. Contact the Dam Safety Section (Ph 587-0248) of the DLNR.

Among the conditions the dam owner should watch for are:

1. Overtopping of the dam by flood waters.
2. Loss of material from the dam crest due to storm wave erosion.
3. Slides on either the upstream or downstream slope of the embankment as evidenced by
    a. Sloughing
    b. Cracking
    c. Bulging
    d. Scarping

4. Erosional flows through, beneath, or around the embankment as evidenced by
   a. Excessive seepage
   b. Discoloration of the seepage
   c. Boils on the downstream side
   d. Sinkholes
   e. Changes in piezometer levels
   f. Changes in the flow from drains
5. Failure of outlets or spillways due to clogging or erosion.
6. Movement of the dam on its foundation as evidenced by:
   a. Misalignment
   b. Settlement
   c. Cracking
7. Loss of abutment support as evidenced by cracking in the concrete dams

When the dam owner calls either an engineer or the DLNR to report a problem, use the form in Appendix A to ensure you can provide sufficient information for the engineer to analyze the problems. In addition, prepare a sketch and photograph showing the extent of the problem. Revise the sketch periodically if the problem develops further. Section III includes further guidelines for courses of action to take to mitigate the effect of many problems.

<u>POSTING OF THE NOTIFICATION FLOWCHART AND DISTRIBUTION OF THE EAP</u>

The notification Flowchart is posted at the dam, and a copy of the EAP is in the gatehouse. The DLNR has copies of the plan.

III. MITIGATION ACTIONS

Besides normal monitoring of the dam's condition, which is done at least monthly, the owner will provide continuous monitoring and inspection during and after extreme events such as storms and earthquakes. Information on the magnitude of an earthquake or storm can be obtained from the DLNR Dam Safety Section (Ph. 587-0248). Actions are suggested below to mitigate problems that may develop, but those actions should never be continued at the risk of injury or at the expense of lessening efforts related to evacuation. Monitoring should identify any of the following potential problems.

POTENTIAL PROBLEMS AND IMMEDIATE RESPONSE ACTIONS

1. <u>Overtopping by flood waters</u>

   a. Open outlet to its maximum safe capacity to lower the water level.

   b. Place sandbags along the crest to increase freeboard and force more water through the spillway and outlet.

   c. Provide erosion-resistent protection to the downstream slope by placing plastic sheets or other materials over eroding areas.

   d. Divert flood waters around the reservoir basin, if possible.

   e. Create additional spillway capacity by making a controlled breach in a low embankment or dike section where the foundation materials are erosion-resistent.

2. <u>Loss of freeboard or dam cross section due to storm wave erosion</u>

   a. Place additional riprap or sandbags in damaged areas to prevent further embankment erosion.

   b. Lower the water level to an elevation below the damaged area.

3. <u>Slides in the upstream or downstream slope of the embankment</u>

   a. Lower the water level at a rate and to an elevation considered safe, given the slope condition. If the outlet is damaged or blocked, pumping, siphoning, or a controlled breach may be required.

   b. Stabilize slides on the downstream slope by

      1. weighting the toe area with additional soil, rock, or gravel, and then

      2. restoring lost freeboard by placing sandbags at the crest.

4. <u>Erosional flows through the embankment, foundation, or abutments</u>

   a. Plug the flow with whatever material is available (hay bales, bentonite, or plastic sheeting if the entrance to the leak is in the reservoir basin).

   b. Lower the water level until the flow decreases to a non-erosive velocity or stops.

   c. Place a protective sand-and-gravel filter or boil ring over the exit area to hold materials in place.

5. <u>Failure of appurtenant structures such as outlets or spillways</u>

   a. Implement temporary measures to protect the damaged structure, such as closing an outlet or protecting a damaged spillway with riprap.

   b. Lower the water level to a safe elevation. If the outlet is inoperable, pumping, siphoning, or a controlled breach may be required.

6. <u>Mass movement of the dam on its foundation (spreading or mass sliding failure)</u>

   a. Immediately lower the water level until excessive movement stops.

7. <u>Excessive seepage and high level saturation of the embankment</u>

   a. Lower the water to a safe level.

   b. Continue frequent monitoring for signs of slides, cracking or concentrated seepage.

8. Spillway backcutting, threatening reservoir evacuation

   a. Reduce the flow over the spillway by fully opening the main outlet.

   b. Provide temporary protection at the point of erosion by placing sandbags, riprap materials, or plastic sheets weighted with sandbags.

   c. When the inflow subsides, lower the water to a safe level.

9. Excessive settlement of the embankment

   a. Lower the water level by releasing it through the outlet, pumping, siphoning, or a controlled breach.

   b. If necessary, restore freeboard, preferably by placing sandbags.

10. Loss of abutment support or extensive cracking in concrete dams

   a. Lower the water level by releasing it through the outlet.

   b. Attempt to block water movement through the dam by placing plastic sheets on the upstream face.

EMERGENCY SUPPLIES AND RESOURCES

In the vicinity of (Dam Name) are soils suitable for emergency repairs. ____(Soil types and locations relevant to dam site)____.

LOCAL CONTRACTORS AND ENGINEERS

Name Ph. #

Name Ph. #

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APPENDICES

APPENDIX A

TECHNICAL DATA FOR __(DAM NAME)__

Purpose . . . .

Maximum Reservoir Capacity to the Crest of the Dam . . . .

Normal Reservoir Capacity Measured to the Emergency Spillway Crest . . . .

Normal Water Depth Measured from the Streambed to the Crest of the Emergency Spillway . . . .

Dam Height Measured from the Streambed to the Crest of the Dam . . . .

Dam Crest Elevation . . . .

Spillway Crest Elevation . . . .

Dam Crest Width . . . .

Dam Width at Base . . . .

Length of Dam Crest . . . .

Outlet Capacity (at water surface elevation =) . . . .

Spillway Capacity (at water surface elevation =) . . . .

Date of Construction . . . .

Slope of Upstream Face of Dam (Horizontal to Vertical) . . . .

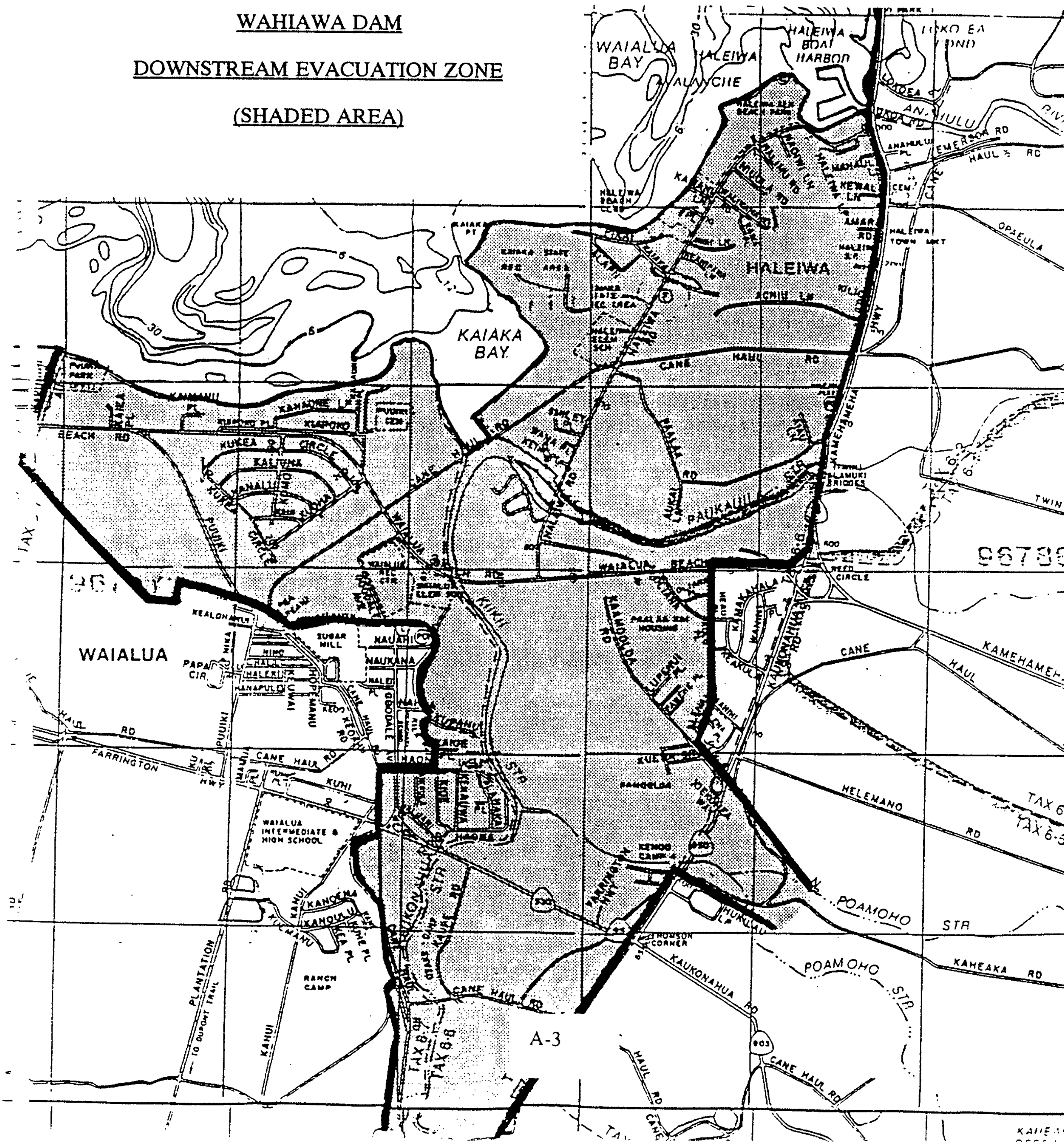
Slope of Downstream Face of Dam (Horizontal to Vertical) . . . .

APPENDIX B

EXAMPLES OF PLANS FOR DAM CONSTRUCTION

APPENDIX C

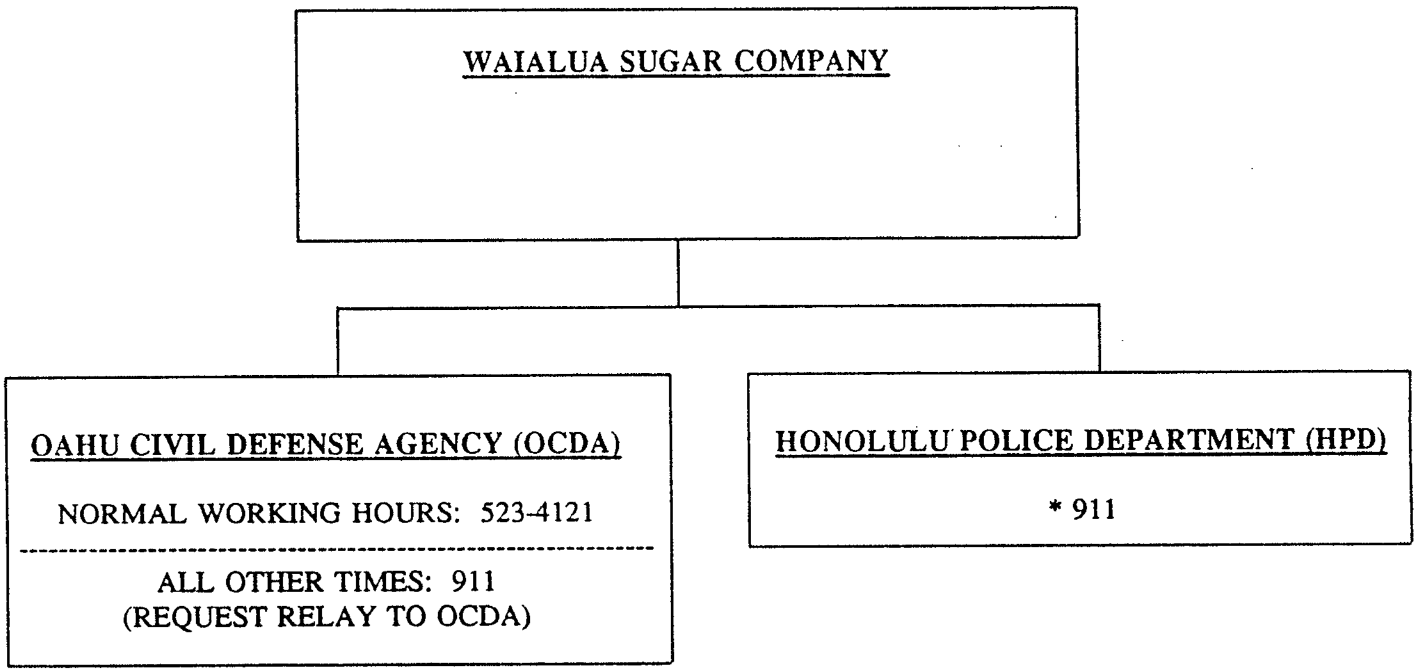
SAMPLE INUNDATION/EVACUATION MAP



APPENDIX D

(SAMPLE TELEPHONE DIRECTORY)

WAHIAWA DAM TELEPHONE NOTIFICATION



* CALL ONLY FOR RAPIDLY DEVELOPING CONDITIONS OR INSTANTANEOUS FAILURES

APPENDIX E

DAM INCIDENT REPORT FORM

DATE:________________________ TIME:__________ A.M. / P.M.

NAME OF DAM: ________________________

STREAM NAME: ________________________

LOCATION: ________________________

COUNTY: ________________________

OBSERVER: ________________________

OBSERVER TELEPHONE: ________________________

NATURE OF PROBLEM: ________________________

____

LOCATION OF PROBLEM AREA (Looking Downstream): ________________________

____

EXTENT OF PROBLEM AREA: ________________________

____

FLOW QUANTITY AND COLOR: ________________________

____

WATER LEVEL IN RESERVOIR: ________________________

IS SITUATION WORSENING? ________________________

EMERGENCY STATUS: ________________________

CURRENT WEATHER CONDITIONS: ________________________

____

ADDITIONAL COMMENTS: ________________________

____

____

____

DATA SHEET

NAME OF DAM ______________________________

NAME OF DAM OWNER ______________________________

* **OWNER'S REPRESENTATIVE RESPONSIBLE FOR EXECUTING THE EMERGENCY PLAN**

	Name	**Position**	**Contact at Phone**
*1.	____________	____________	____________
*2.	____________	____________	____________

PERSON RESPONSIBLE FOR DRAFTING AND UPDATING THIS PLAN ____________

DAM LOCATION:__________Sec.__________Twnship.__________Rng.__________PM ________

RIVER OR STREAM______________COUNTY ______________

FOREST OR OTHER ______________________________

NEAREST TOWN IN FLOOD PLAIN ______________________________

ESTIMATED TIME FOR FLOOD TO REACH NEAREST TOWN__________HR

ESTIMATED TIME FOR FLOOD TO REACH NEAREST HOME__________HR

DIRECTIONS FROM TOWN TO DAM ______________________________

____

DAM HEIGHT__________Ft., CAPACITY__________A.F.

SURFACE AREA__________A.C., HAZARD RATING__________

CREST LENGTH__________Ft., CREST WIDTH__________Ft.

MAX. OUTLET CAPACITY ______________________________

SPILLWAY CAPACITY FOR EACH FOOT OF DEPTH

Depth Spillway	**Surcharge Storage**	**Service Spillway Capacity**	**Emergency Capacity**
1 ft.	______ AF	________ CFS	________ CFS
2 ft.	______ AF	________ CFS	________ CFS
3 ft.	______ AF	________ CFS	________ CFS
4 ft.	______ AF	________ CFS	________ CFS
5 ft.	______ AF	________ CFS	________ CFS
6 ft.	______ AF	________ CFS	________ CFS

WHERE DRAWINGS AND DAMSITE EQUIPMENT ARE KEPT ______________

EMERGENCY PLAN

ESTIMATED TRAVEL TIME TO SITE

1. Arrange for immediate inspection of the site:

Person responsible ____________________

Person familiar with site to make inspection ____________________ ________ hr.

Engineer to make inspection ____________________ ________ hr.

2. Establish communication with participants:

Person responsible ____________________

Alternate ____________________

3. Notify State Engineer's Office:

Water Commissioner ____________________ ________ hr.
To make provision for increased flow downstream

Dam Safety Branch ____________________ ________ hr.
To inspect dam and recommend or concur with remedial action

4. Provide required equipment and materials:

Owner can provide ____________________

____________________ ________ hr.

Contractor "A" can provide ____________________

____________________ ________ hr.

Contractor "B" can provide ____________________

____________________ ________ hr.

Highway Department can provide ____________________

____________________ ________ hr.

D.O.D.E.S. CAN PROVIDE ____________________

____________________ ________ hr.

Contractor "C" can provide ____________________

____________________ ________ hr.

EMERGENCY PLAN (Cont'd)

Estimated Travel
Time to Site

5. Provide required manpower:

Owner can provide____________________ ________ hr.

College "A" can provide____________________ ________ hr.

U.S. Military can provide____________________ ________ hr.

Radio appeal can provide____________________ ________ hr.

6. Implement warning and/or evacuation:

Owner will____________________ ________ hr.

D.O.D.E.S. will____________________ ________ hr.

____

County Sheriff will________________________

____________________ ________ hr.

State Patrol will ________________________

____________________ ________ hr.

Fire Department will ________________________

____________________ ________ hr.

7. Medical or other assistance:

________________will provide__________ ________ hr.

8. Helicopter Service:

________________will provide__________ ________ hr.

9. Engineering firm can provide ____________________

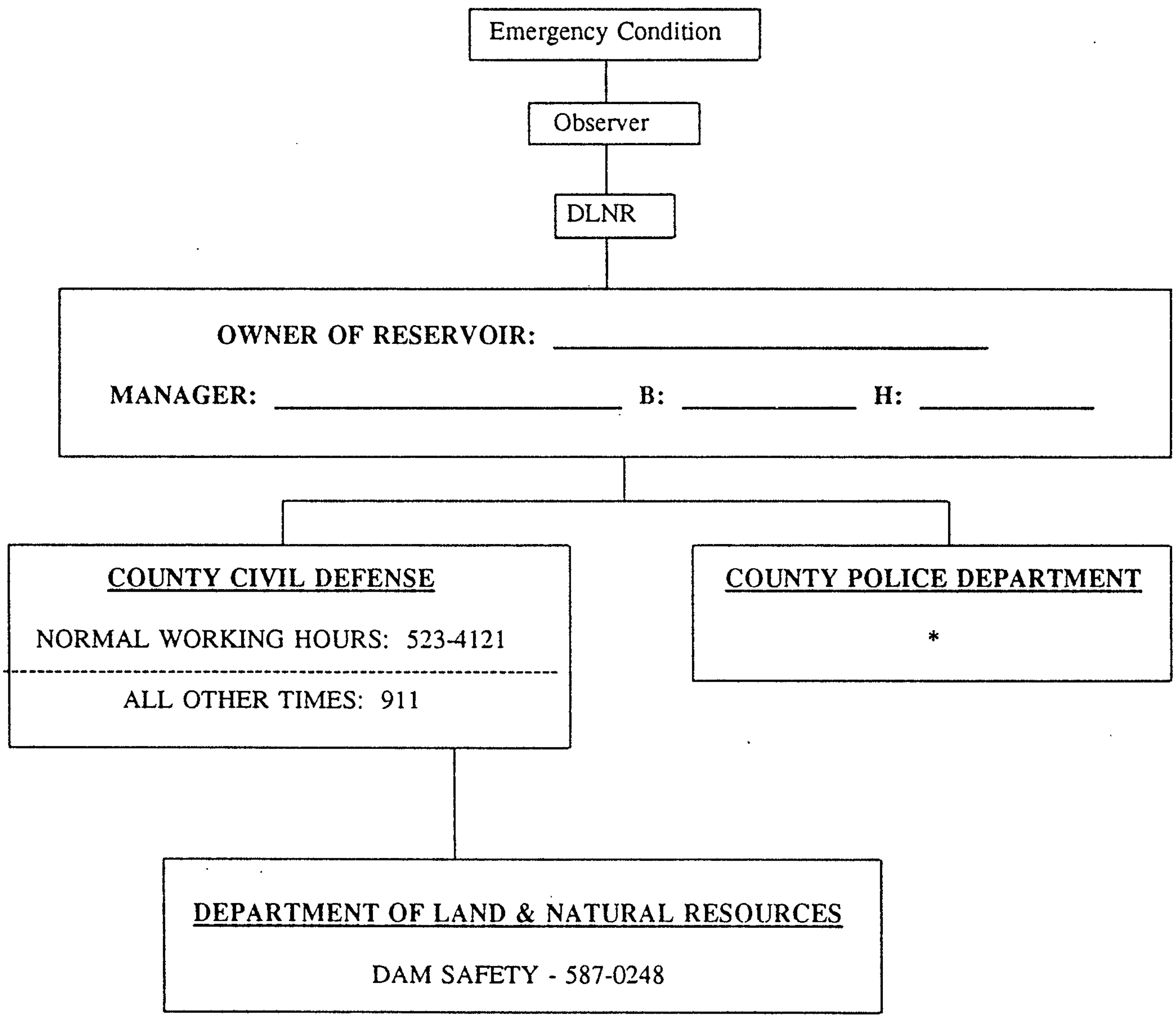
____________________ ________ hr.

10. Report on actions taken:

Person Responsible ________________________

____________________ ________ hr.

FIGURE 1
(DAM NAME)
ACTUAL OR IMMINENT FAILURE
NOTIFICATION FLOWCHART



NOTE: Nearest Phone is located ______

* CALL FIRST ONLY FOR RAPIDLY DEVELOPING CONDITIONS OR INSTANTANEOUS FAILURES

FIGURE 2

DIRECTORY

OWNERS REPRESENTATIVES RESPONSIBLE FOR PLANNED ACTION & CONTACT LOCATION

Name	Position	Address	Phone
1.			
2.			
3.			
4.			
5.			

CITY OF

Name	Position	Address	Phone
1.			
2.			

COUNTY POLICE

Name	Position	Address	Phone
1.			
2.			

OFFICE OF STATE ENGINEER

Name	Position	Address	Phone

D.O.D.E.S.

Name	Position	Address	Phone
1.			
2.			

AMBULANCE SERVICE

Name	Position	Address	Phone
1.			
2.			

HELICOPTER SERVICE

Name	Position	Address	Phone
1.			
2.			

DIVING SERVICE

Name	Position	Address	Phone
1.			
2.			

OTHER

Name	Position	Address	Phone
1.			
2.			

PERSONS DOWNSTREAM FIRST AFFECTED BY FLOOD WATERS

Name	Address	Phone	No. of Residents
1.			
2.			
3.			
4.			
5.			
6.			

DAM SPECIFIC EVACUATION PLAN
(SAMPLE)

WAHIAWA DAM EVACUATION PLAN

MAJOR FACILITIES TO BE EVACUATED

Waialua Fire Station
Western Haleiwa Beach Park
Haleiwa Shopping Plaza
Haleiwa Post Office
Kaiaka State Rec. Area
Waialua Rec. Center
Paalaa Kai Housing
Otake Camp
Puuliki Beach Park
Haleiwa Boat Harbor
Hale Kila Plaza
Haleiwa Alii Beach Park
Haleiwa Elementary School
Waialua Elementary School
Kemoo Camp 4
Waialua Clinic

EVACUATION SHELTERS/AREAS

Waialua High School
Eastern Haleiwa Beach Park
Waialua Community Center

ROADBLOCKS

Kam Hwy. and Lahalewai Pl.
Helemano & Kaukonahua Rds.
Kaheaka & Kaukonahua Rds.
Puuiki & Kealohanui Rds.
Weed Circle
Thompson Corner
Farrington Hwy. & Kahui St.
Waialua Beach Rd. & Apuhihi St.
Cane Haul Road Intersection Southeast of Sugar Mill

CHECK POSTS

Kupahu St. to Kila Way to Haona St.

ADDITIONAL ROADBLOCKS MAY BE ESTABLISHED, OR IDENTIFIED ROADBLOCKS CANCELED BY ON-SCENE OFFICIALS.

CHECKLIST A

UNSAFE DAM/RESERVOIR RESPONSE CHECKLIST

SLOWLY DEVELOPING CONDITION

1. Owner/operator notifies OCDA of unsafe condition.

   Date______________ Time_______________

2. Name of owner/operator:

   ____

3. Location of dam/reservoir:

   ____

4. Description of unsafe condition:

   ____
   ____
   ____
   ____

		Date/Time	Initials
5.	Determine response time available	_____	_____
	- Days______ - Hours______		
	- Consider activating the City EOC	_____	_____
6.	Accomplish initial notifications (OCDA)	_____	_____

DDD___	E&T___	OIC___	COE___
P&O___	HPD___	HD ___	SCD___
LOG___	HFD___	DLU___	D1 ___
COM___	DPW___	ARC___	D2 ___
DPO___	DTS___	DPR___	D4 ___
HAZ___	OHR___		D6 ___

		Date/Time	Initials
7.	Request technical assistance, if required.	_____	_____

BWS___ DPW___ COE___ DLNR___

		Date/Time	Initials
8.	Prepare and issue emergency public information, if required.	______	______
	- Coordinate with owner/operator	______	______
	- Consider closed circuit EBS use		
9.	Review and discuss "Rapidly Developing/Instantaneous Failure" checklist.	______	______

CHECKLIST B

UNSAFE DAM/RESERVOIR RESPONSE CHECKLIST

RAPIDLY DEVELOPING CONDITION/INSTANTANEOUS FAILURE

1. Owner/operator notifies OCDA of unsafe condition.

   Date______________ Time_______________

2. Name of owner/operator:

   ____

3. Location of dam/reservoir:

   ____

4. Description of unsafe condition:

   ____
   ____
   ____
   ____

	Date/Time	Initials
5. Determine response time available	_____	_____
- Hours______ - Minutes______		
6. Under instantaneous failure conditions:		
- OCDA or HPD will immediately:		
- Alert the principal response agencies if not already accomplished	_____	_____

OCDA___	HD ___	D1 ___
HPD ___	ARC___	D2 ___
HFD___	DPR___	D3 ___
DPW___	DOE___	D4 ___
DTS___	SCD___	

	Date/Time	Initials
- Direct the establishment of roadblocks	_____	_____

	Date/Time	Initials
- Coordinate the use of public address system announcements	______	______
- Direct the warning and evacuation of down channel areas. (See dam specific instructions)	______	______
- Relocation of City Resources located within inundation zones.	______	______
- Mobilization of MTL buses for area evacuation.	______	______
- Opening and staffing of shelter/shelter areas.	______	______
- Activation of OHR Elderly/Disabled plan.	______	______
- Closure of affected beaches and beach parks (DPR/DLNR)	______	______
- Provision of security for evacuated areas.	______	______
7. Under rapidly developing conditions and, following instantaneous failures:	______	______
- OCDA will:		
- Accomplish appropriate steps in Paragraph 6 above depending on actions taken by HPD, dam condition, weather, and other factors.		
- Activate EOC's		
- City	______	______
- NAWAS to SWP	______	______
- PERDISREP to SCD	______	______
- Notify HMB parking	______	______
- Request security (HPD)	______	______
- District	______	______
- D1 D2 D4 D6	______	______
- Log activation & volunteer availability.	______	______

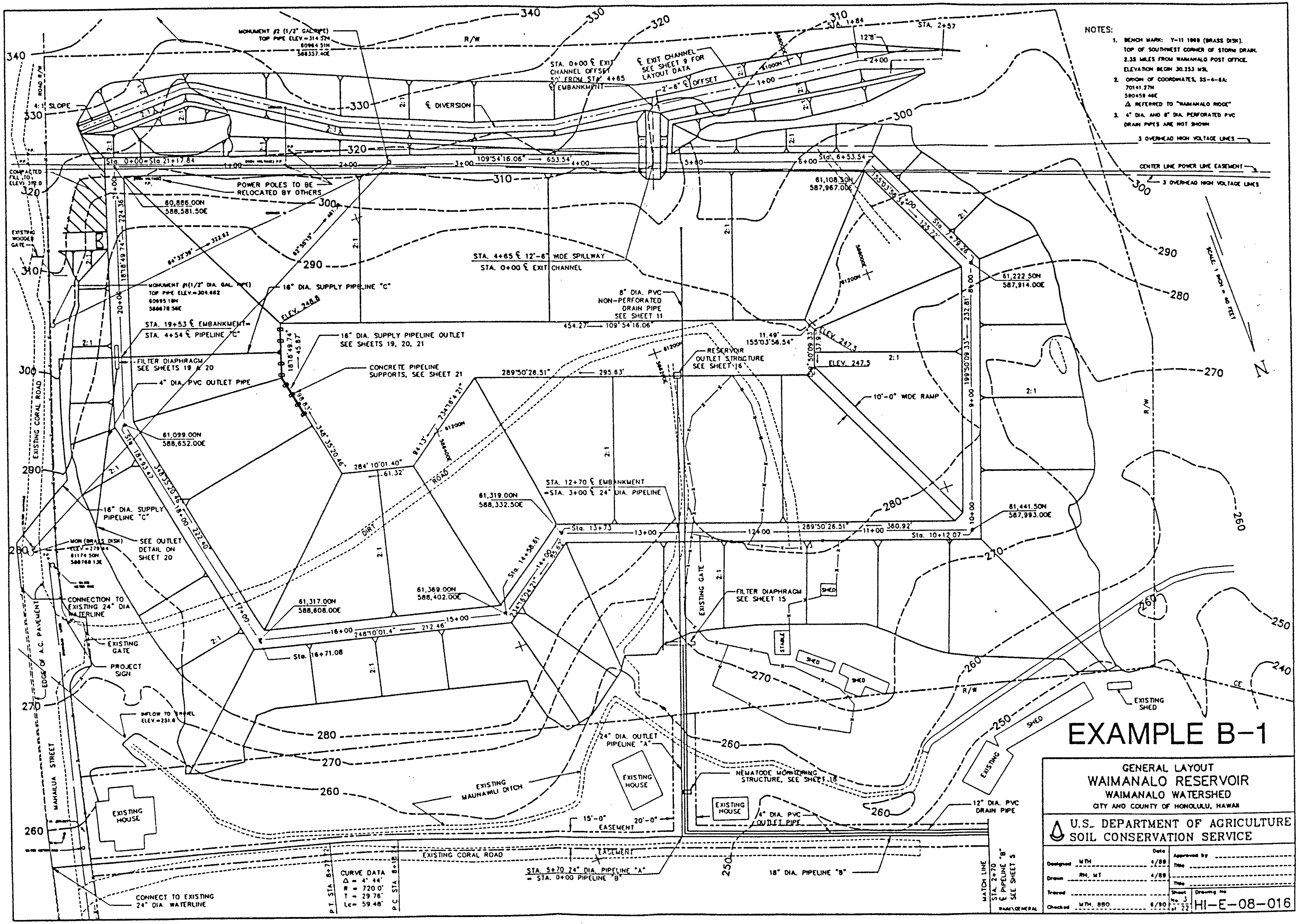
	Date/Time	Initial
- Assure coordination with HPD	______	______
- Recall/Notify, as appropriate		
- All agencies in Paragraph 6 above and the following:	______	______

DDD___	RACES___	DOH ___	GAS ___
P&O___	OIC ___	COE ___	GCA ___
LOG___	BWS ___	CC ___	HTA ___
COM___	HCD ___	CS ___	HAH ___
DPO___	DDS ___	SA ___	KPISC___
E&T___	DLU ___	SDA ___	
HAZ___	ME ___	HECO___	
EBS___	DOT ___	HTEL___	

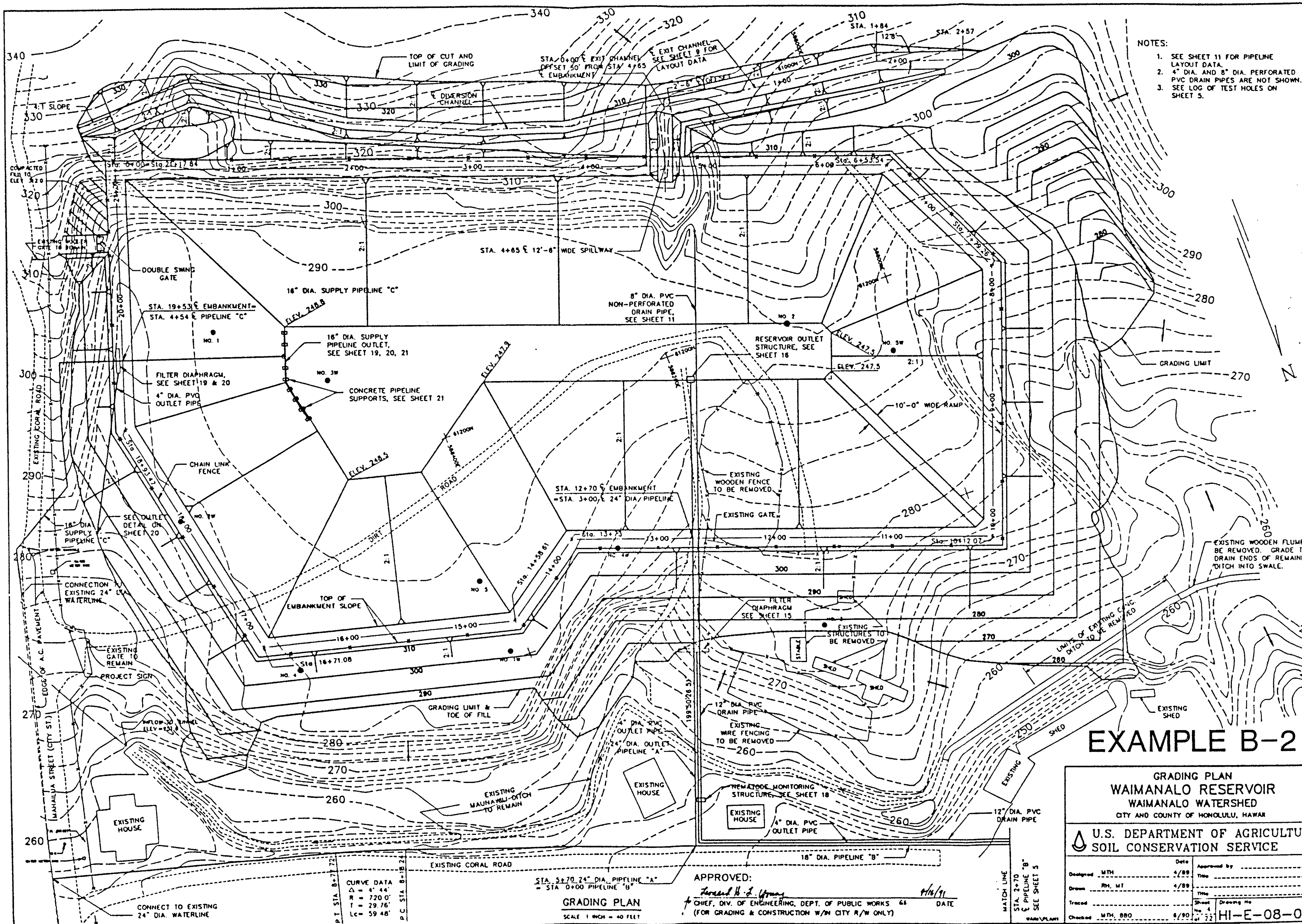
NOTE: Utilize Notifier/Speedcall as appropriate

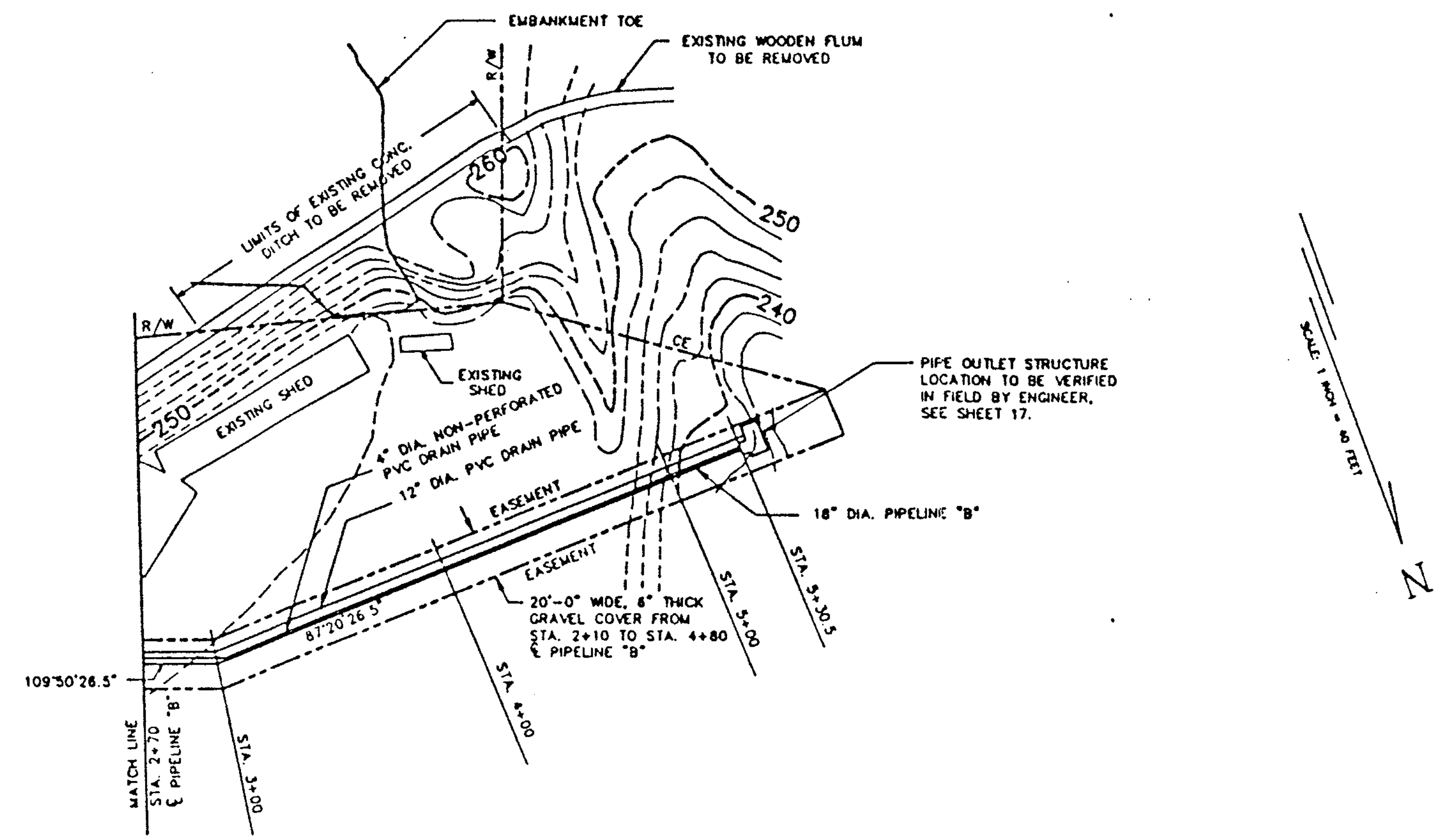
	Date/Time	Initial
- Advise Mayor/MD/CBO - Prepare Declaration of Emergency	______	______
- Prepare and issue EPI	______	______
- Consider use of EBS	______	______
- TV crawls for hearing impaired	______	______
- Foreign language outreach (KPISC)	______	______
- Activate Rumor Control (OIC)	______	______
- Establish an EIC, if required	______	______
- Determine:		
- HPD/HFD helicopter availability	______	______
- Need for HARNG resources	______	______
- Coordinate RACES assignments	______	______
8. Alert/dispatch Damage Assessment Team(s)	______	______
9. Respond to requests for assistance	______	______
10. Make PERDISREP/SPOT REPORTS to SCD	______	______

	Date/Time	Initial
11. Implement initial recovery procedures	______	______
- Establish EOC shift schedules	______	______
- Dispatch HD/DOH to determine health/people needs	______	______
- Determine utility status (HECO/HAWTEL/GASCO/BWS)	______	______
- Determine waste water status (DPW)	______	______
- Coordinate care for evacuees/victims with ARC/SA/SDA	______	______
- Open ARC/City Assistance Centers	______	______
- Activate Volunteer Program Procedures (CS)	______	______
- Provide comprehensive damage reports to Mayor/staff and SCD (DDS)	______	______
- Prepare Mayor's request for State/Federal assistance, if required	______	______
- Dispatch OIC to pictorially document damage	______	______
- Respond to requests for assistance	______	______



EXAMPLE B-1
GENERAL LAYOUT
WAIMANALO RESERVOIR
WAIMANALO WATERSHED
CITY AND COUNTY OF HONOLULU, HAWAII
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
HI-E-08-016
NOTES:
1. BENCH MARK: Y-11 1969 (BRASS DISK). TOP OF SOUTHWEST CORNER OF STORM DRAIN. 2.35 MILES FROM WAIMANALO POST OFFICE. ELEVATION BEGIN 30.253 MSL
2. ORIGIN OF COORDINATES, SS-4-6A: 70141.27N 590459.46E
△ REFERRED TO "WAIMANALO RIDGE"
3. 4" DIA. AND 8" DIA. PERFORATED PVC DRAIN PIPES ARE NOT SHOWN
3 OVERHEAD HIGH VOLTAGE LINES
CENTER LINE POWER LINE EASEMENT
R/W
℄ DIVERSION
STA. 4+65 ℄ 12'-6" WIDE SPILLWAY
STA. 0+00 ℄ EXIT CHANNEL
POWER POLES TO BE RELOCATED BY OTHERS
16" DIA. SUPPLY PIPELINE "C"
16" DIA. SUPPLY PIPELINE OUTLET SEE SHEETS 19, 20, 21
CONCRETE PIPELINE SUPPORTS, SEE SHEET 21
FILTER DIAPHRAGM SEE SHEETS 19 & 20
4" DIA. PVC OUTLET PIPE
8" DIA. PVC NON-PERFORATED DRAIN PIPE SEE SHEET 11
RESERVOIR OUTLET STRUCTURE SEE SHEET 16
10'-0" WIDE RAMP
STA. 12+70 ℄ EMBANKMENT =STA. 3+00 ℄ 24" DIA. PIPELINE
FILTER DIAPHRAGM SEE SHEET 15
EXISTING GATE
EXISTING SHED
EXISTING HOUSE
EXISTING MAUNAWILI DITCH
24" DIA. OUTLET PIPELINE "A"
NEMATODE MONITORING STRUCTURE, SEE SHEET 18
4" DIA. PVC OUTLET PIPE
12" DIA. PVC DRAIN PIPE
EXISTING CORAL ROAD
EXISTING CORAL ROAD
MAHAILUA STREET
EDGE OF A.C. PAVEMENT
CONNECTION TO EXISTING 24" DIA WATERLINE
PROJECT SIGN
INFLOW TO SHOVEL ELEV.=251.6
CONNECT TO EXISTING 24" DIA. WATERLINE
STA. 5+70 24" DIA. PIPELINE "A" = STA. 0+00 PIPELINE "B"
18" DIA. PIPELINE "B"
CURVE DATA
Δ = 4° 44'
R = 720.0'
T = 29.76'
Lc = 59.48'
MATCH LINE STA. 2+70 ℄ PIPELINE "B" SEE SHEET 5
SCALE 1 INCH = 40 FEET

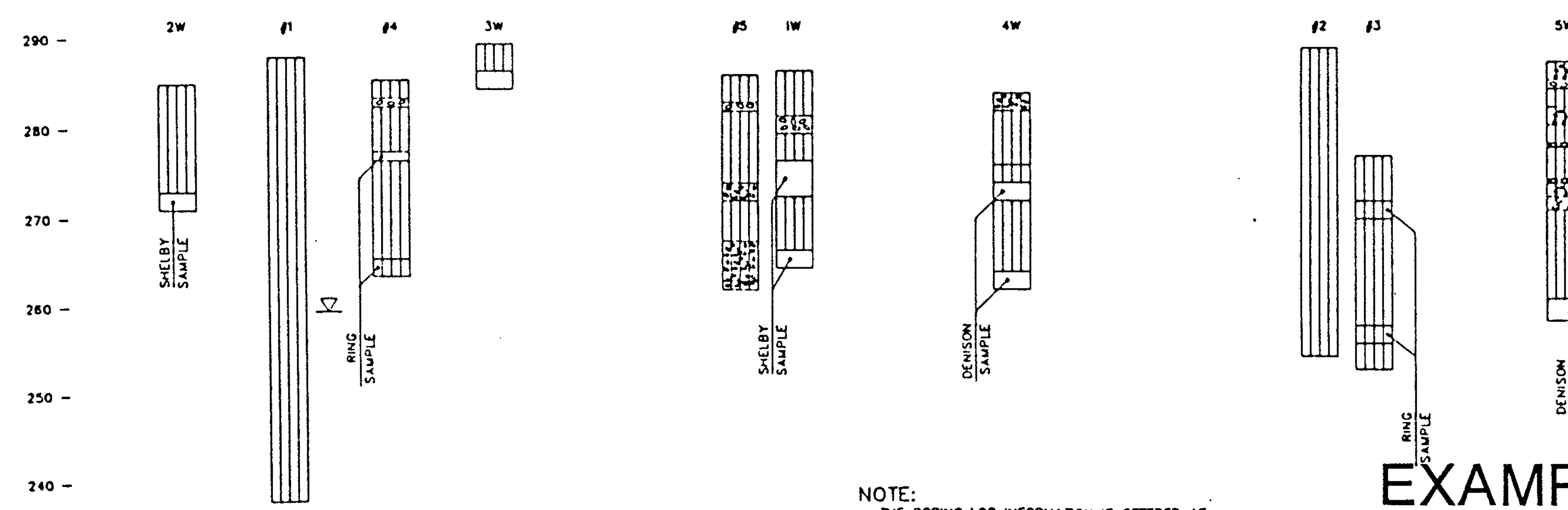

NOTES:
1. SEE SHEET 11 FOR PIPELINE LAYOUT DATA.
2. 4" DIA. AND 8" DIA. PERFORATED PVC DRAIN PIPES ARE NOT SHOWN.
3. SEE LOG OF TEST HOLES ON SHEET 5.
TOP OF CUT AND LIMIT OF GRADING
STA. 0+00 ℄ EXIT CHANNEL OFFSET 50' FROM STA. 4+65 ℄ EMBANKMENT
℄ EXIT CHANNEL SEE SHEET 9 FOR LAYOUT DATA
℄ DIVERSION CHANNEL
STA. 4+65 ℄ 12'-6" WIDE SPILLWAY
DOUBLE SWING GATE
16" DIA. SUPPLY PIPELINE "C"
STA. 19+53 ℄ EMBANKMENT = STA. 4+54 ℄ PIPELINE "C"
16" DIA. SUPPLY PIPELINE OUTLET, SEE SHEET 19, 20, 21
FILTER DIAPHRAGM, SEE SHEET 19 & 20
4" DIA. PVC OUTLET PIPE
CONCRETE PIPELINE SUPPORTS, SEE SHEET 21
8" DIA. PVC NON-PERFORATED DRAIN PIPE, SEE SHEET 11
RESERVOIR OUTLET STRUCTURE, SEE SHEET 16
ELEV. 247.5
10'-0" WIDE RAMP
GRADING LIMIT
CHAIN LINK FENCE
EXISTING WOODEN FENCE TO BE REMOVED
STA. 12+70 ℄ EMBANKMENT = STA. 3+00 ℄ 24" DIA. PIPELINE
EXISTING GATE
SEE OUTLET DETAIL ON SHEET 20
16" DIA. SUPPLY PIPELINE "C"
CONNECTION EXISTING 24" DIA. WATERLINE
TOP OF EMBANKMENT SLOPE
EXISTING WOODEN FLUME TO BE REMOVED. GRADE TO DRAIN ENDS OF REMAINING DITCH INTO SWALE.
FILTER DIAPHRAGM SEE SHEET 15
EXISTING STRUCTURES TO BE REMOVED
LIMITS OF EXISTING CONC. DITCH TO BE REMOVED
EXISTING GATE TO REMAIN
PROJECT SIGN
GRADING LIMIT & TOE OF FILL
12" DIA. PVC DRAIN PIPE
EXISTING WIRE FENCING TO BE REMOVED
4" DIA. PVC OUTLET PIPE
24" DIA. OUTLET PIPELINE "A"
EXISTING SHED
EXAMPLE B-2
EXISTING MAUNAWILI DITCH TO REMAIN
EXISTING HOUSE
NEMATODE MONITORING STRUCTURE, SEE SHEET 18
12" DIA. PVC DRAIN PIPE
WAIMANALO STREET (CITY ST.)
EDGE OF A.C. PAVEMENT
EXISTING CORAL ROAD
18" DIA. PIPELINE "B"
CONNECT TO EXISTING 24" DIA. WATERLINE
CURVE DATA
Δ = 4° 44'
R = 720.0'
T = 29.76'
Lc = 59.48'
STA. 5+70 24" DIA. PIPELINE "A" = STA. 0+00 PIPELINE "B"
GRADING PLAN
SCALE 1 INCH = 40 FEET
APPROVED:
CHIEF, DIV. OF ENGINEERING, DEPT. OF PUBLIC WORKS
(FOR GRADING & CONSTRUCTION W/IN CITY R/W ONLY)
DATE
MATCH LINE STA. 2+70 ℄ PIPELINE "B" SEE SHEET 5
GRADING PLAN
WAIMANALO RESERVOIR
WAIMANALO WATERSHED
CITY AND COUNTY OF HONOLULU, HAWAII
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
HI-E-08-016



PLAN

LEGEND

- SILT (MH, ML)
- BOULDER
- GRAVEL, SILT (GM)
- WATER LEVEL @ 9/10/80
- SAMPLE TESTED HOLE LOCATION



NOTE:
THE BORING LOG INFORMATION IS OFFERED AS SUPPLEMENTARY INFORMATION ONLY.

LOG OF TEST HOLES

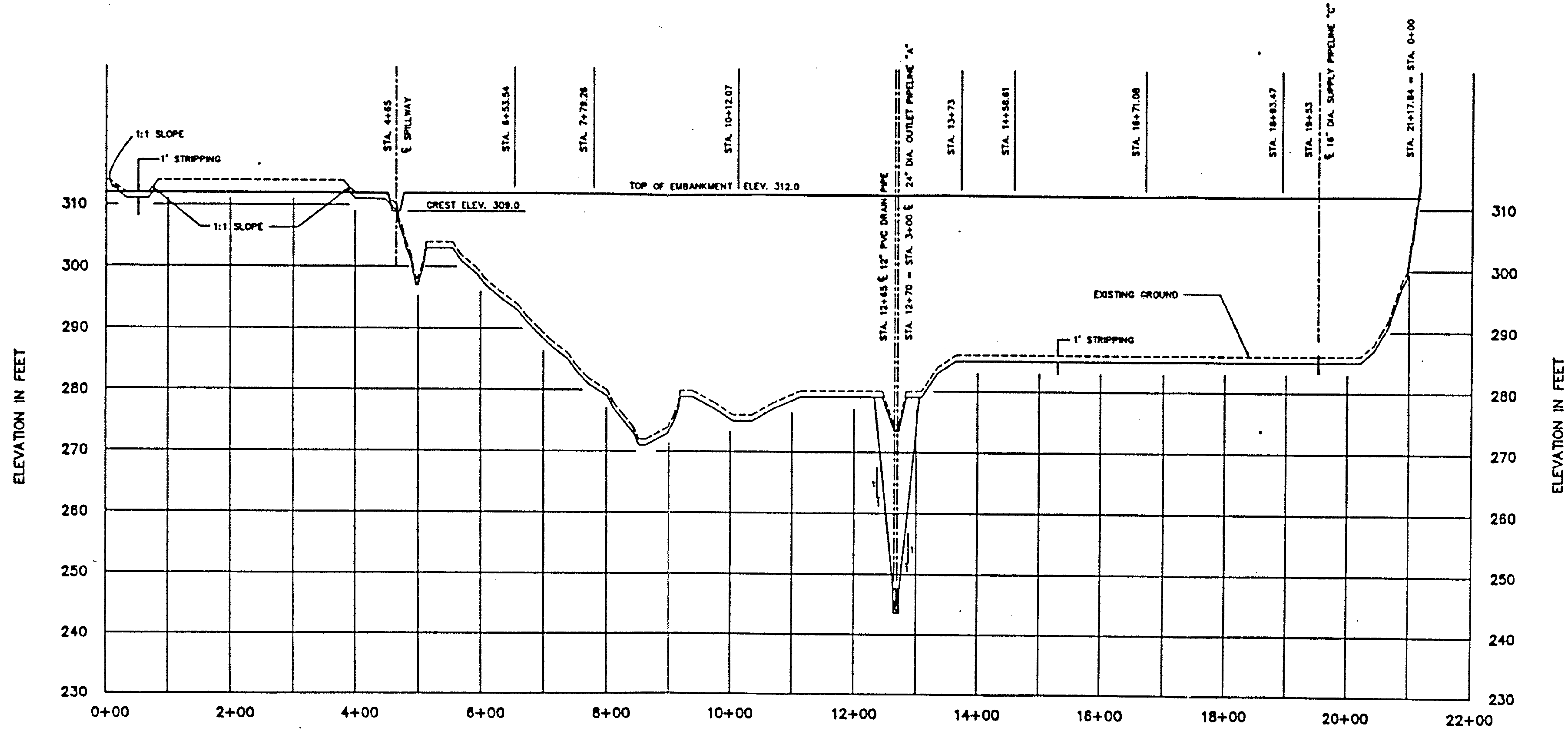
EXAMPLE B-3

LOG OF TEST HOLES
WAIMANALO RESERVOIR
WAIMANALO WATERSHED
CITY AND COUNTY OF HONOLULU, HAWAII

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

		Date	
Designed	MTH	4/89	Approved by
Drawn	RH, MT, SK	4/89	Title
Traced			Title
Checked	MTH, BBO	6/90	Sheet No. 5 of 22 — Drawing No. HI-E-08-016

WAIM\SOILOG



EMBANKMENT ℄ PROFILE

NOTE:
SEE SHEET 2 FOR
EXCAVATION SAFETY NOTES.

APPROVED:

CHIEF, DIV. OF ENGINEERING, DEPARTMENT OF PUBLIC WORKS — DATE
(FOR GRADING ONLY)

EXAMPLE B-4

EMBANKMENT ℄ PROFILE
WAIMANALO RESERVOIR
WAIMANALO WATERSHED
CITY & COUNTY OF HONOLULU, HAWAII

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed MTH	Date 3/90	Approved by
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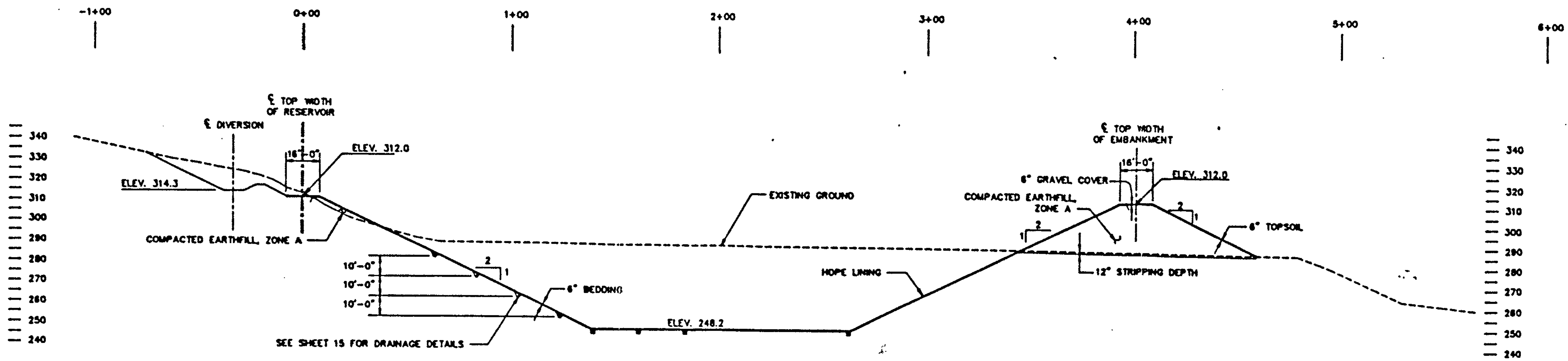
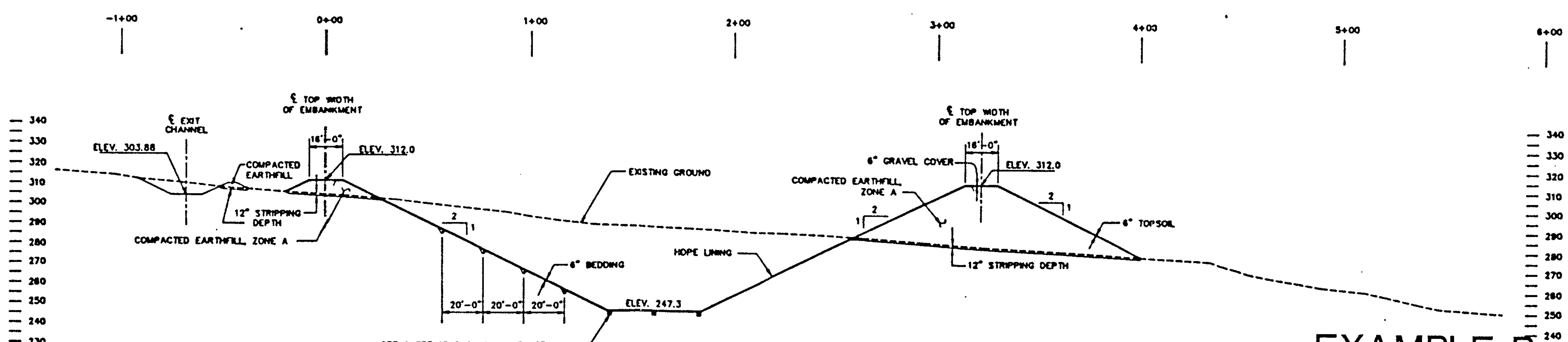
Traced		Title
Checked MTH, BBO	6/90	Sheet No. 6 of 22 — Drawing No. HI-E-08-016



STATION 2+50

30 0 30
SCALE IN FEET
HORIZONTAL & VERTICAL



STATION 5+50

30 0 30
SCALE IN FEET
HORIZONTAL & VERTICAL

EXAMPLE B-5

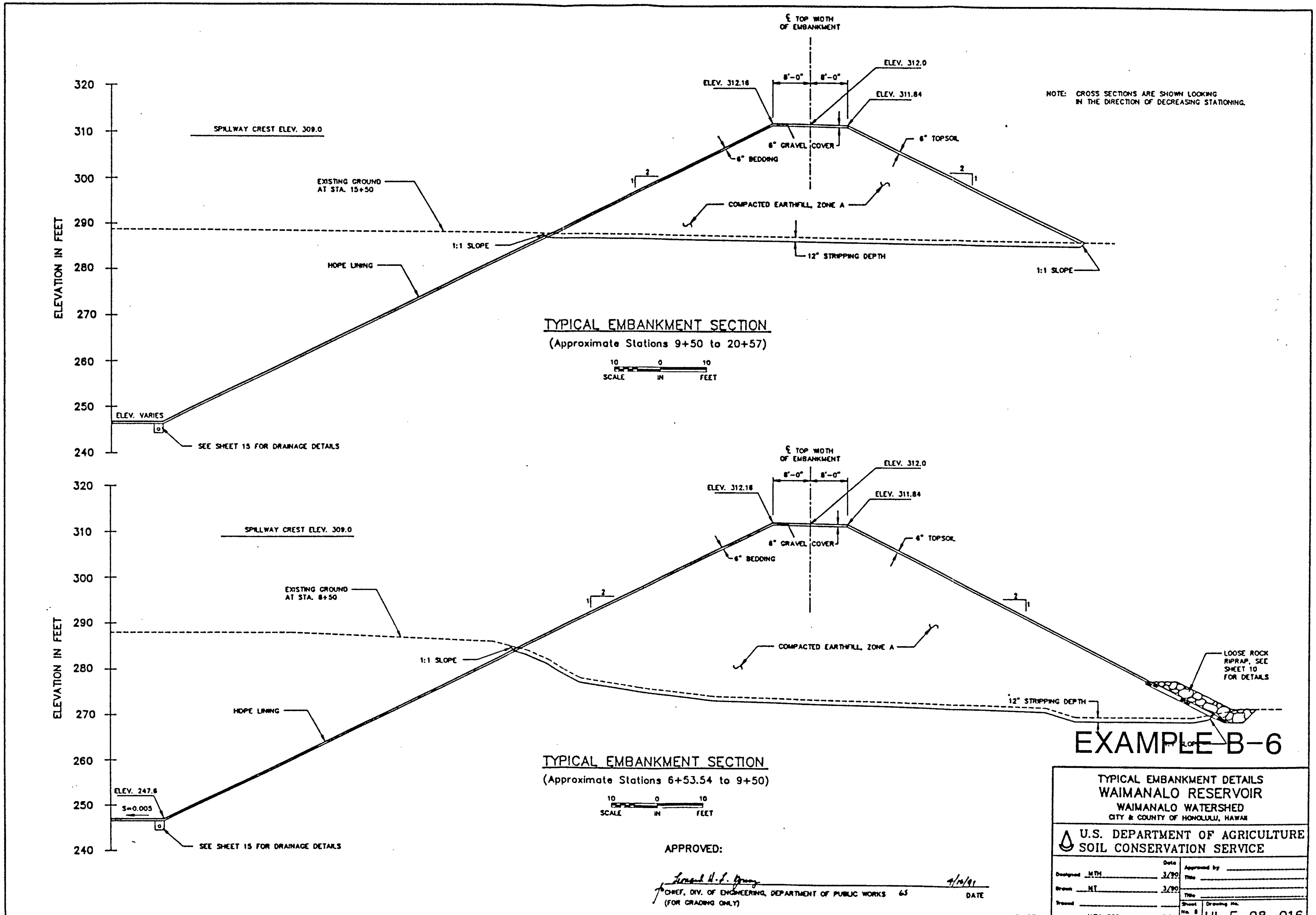
APPROVED:

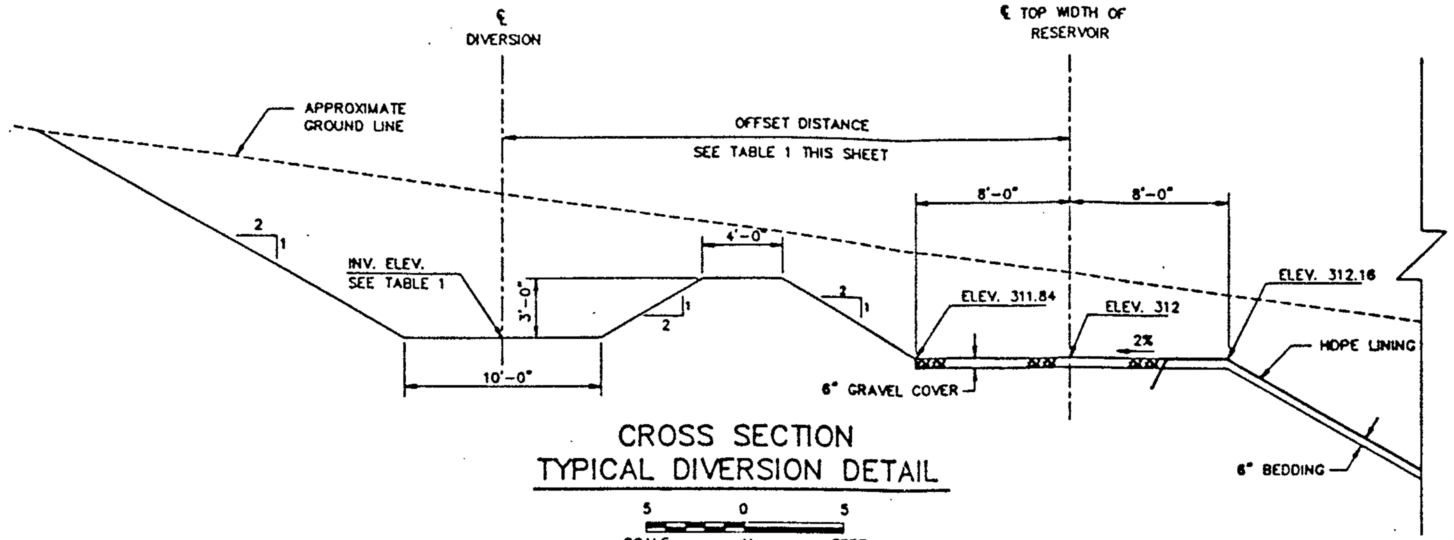
CHIEF, DIV. OF ENGINEERING, DEPARTMENT OF PUBLIC WORKS 4/2/91 DATE
(FOR GRADING ONLY)

CROSS SECTIONS
WAIMANALO RESERVOIR
WAIMANALO WATERSHED
CITY & COUNTY OF HONOLULU, HAWAII

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

		Date	
Designed	MTH	3/90	Approved by
Drawn	MT	3/90	Title
Traced			Title
Checked	MTH, BBO	6/90	Sheet No. 7 of 22 — Drawing No. HI-E-08-016

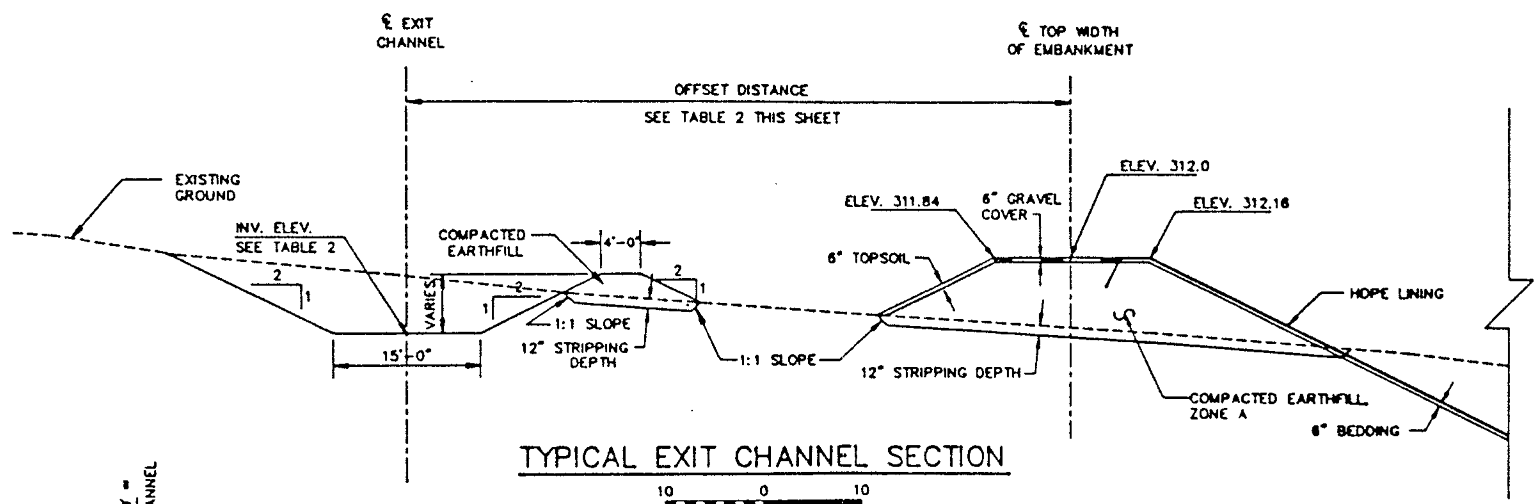

EXAMPLE B-6
NOTE: CROSS SECTIONS ARE SHOWN LOOKING IN THE DIRECTION OF DECREASING STATIONING.
℄ TOP WIDTH OF EMBANKMENT
8'-0"
8'-0"
ELEV. 312.0
ELEV. 312.16
ELEV. 311.84
6" GRAVEL COVER
6" TOPSOIL
6" BEDDING
SPILLWAY CREST ELEV. 309.0
EXISTING GROUND AT STA. 15+50
COMPACTED EARTHFILL, ZONE A
1:1 SLOPE
12" STRIPPING DEPTH
HDPE LINING
ELEV. VARIES
SEE SHEET 15 FOR DRAINAGE DETAILS
ELEVATION IN FEET
TYPICAL EMBANKMENT SECTION
(Approximate Stations 9+50 to 20+57)
SCALE IN FEET
EXISTING GROUND AT STA. 8+50
LOOSE ROCK RIPRAP, SEE SHEET 10 FOR DETAILS
ELEV. 247.6
S=0.005
TYPICAL EMBANKMENT SECTION
(Approximate Stations 6+53.54 to 9+50)
APPROVED:
CHIEF, DIV. OF ENGINEERING, DEPARTMENT OF PUBLIC WORKS
(FOR GRADING ONLY)
DATE
TYPICAL EMBANKMENT DETAILS
WAIMANALO RESERVOIR
WAIMANALO WATERSHED
CITY & COUNTY OF HONOLULU, HAWAII
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Designed MTH 3/90
Drawn MT 3/90
Checked MTH, BBO 6/90
Sheet No. 8 of 22
HI-E-08-016



CROSS SECTION
TYPICAL DIVERSION DETAIL

TABLE 1

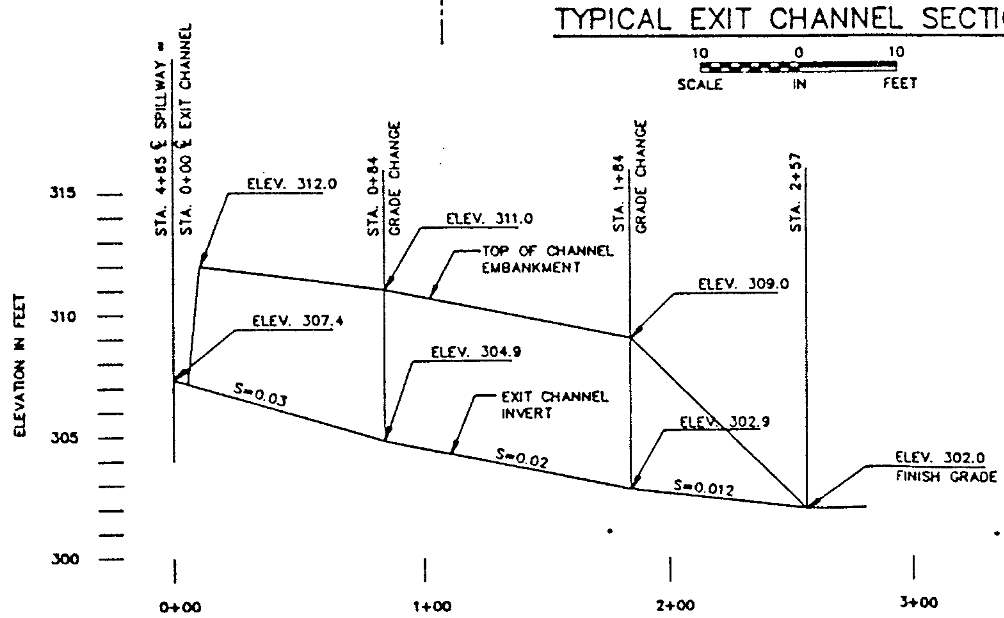
RESERVOIR ℄ STATION	RESERVOIR ℄ TO DIVERSION ℄ OFFSET, FT.	DIVERSION INV. ELEV.
0+00	45	320.5
0+61	68	318.1
1+42	45	316.9
1+95	38	316.1
2+55	34	314.3
3+08.5	31	312.7
3+77	34	310.6
4+50	49	308.3



TYPICAL EXIT CHANNEL SECTION

TABLE 2

EXIT CHANNEL ℄ STATION	EMBANKMENT ℄ STATION	EMBANKMENT ℄ TO EXIT CHANNEL ℄ OFFSET, FT.	EXIT CHANNEL INV. ELEV.
0+00	4+65	50	307.4
0+84	5+49	68	304.9
1+84	6+47	89	302.9



EXIT CHANNEL PROFILE

APPROVED:

Leonard H. L. Young 4/16/91

CHIEF, DIV. OF ENGINEERING, DEPARTMENT OF PUBLIC WORKS — DATE
(FOR GRADING ONLY)

EXAMPLE B-7

CONSTRUCTION DETAILS
WAIMANALO RESERVOIR
WAIMANALO WATERSHED
CITY & COUNTY OF HONOLULU, HAWAII

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

		Date	
Designed	MTH	3/90	Approved by
Drawn	MT	3/90	Title
Traced			Title
Checked	MTH, 880	6/90	Sheet No. 9 of 22 — Drawing No. HI-E-08-016

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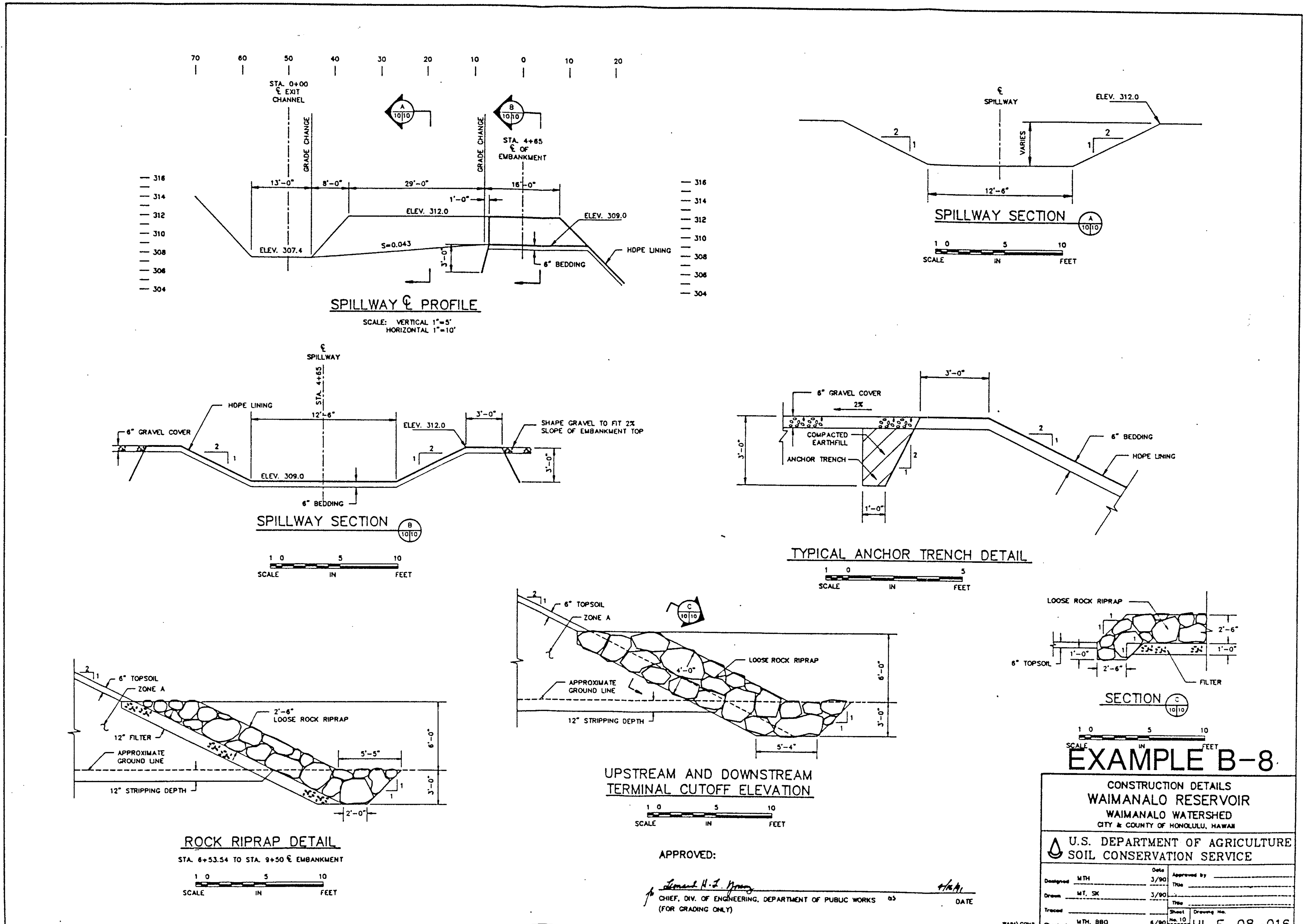
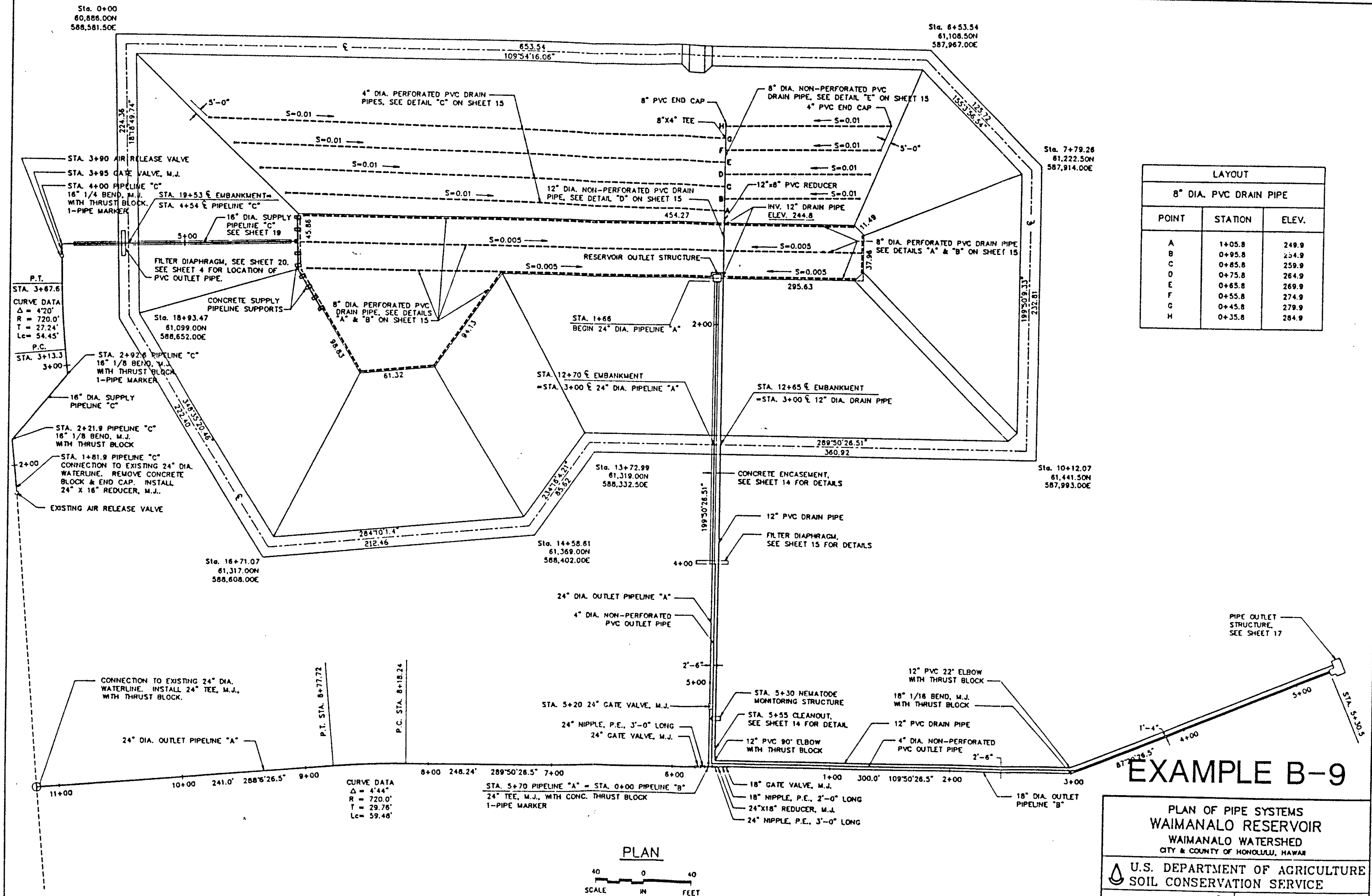

SPILLWAY ℄ PROFILE
SCALE: VERTICAL 1"=5' HORIZONTAL 1"=10'
STA. 0+00 ℄ EXIT CHANNEL
GRADE CHANGE
STA. 4+65 ℄ OF EMBANKMENT
13'-0"
8'-0"
29'-0"
18'-0"
1'-0"
ELEV. 312.0
ELEV. 309.0
ELEV. 307.4
S=0.043
3'-0"
6" BEDDING
HDPE LINING
SPILLWAY SECTION
VARIES
ELEV. 312.0
12'-6"
SPILLWAY SECTION
HDPE LINING
6" GRAVEL COVER
ELEV. 312.0
ELEV. 309.0
6" BEDDING
SHAPE GRAVEL TO FIT 2% SLOPE OF EMBANKMENT TOP
TYPICAL ANCHOR TRENCH DETAIL
6" GRAVEL COVER
COMPACTED EARTHFILL
ANCHOR TRENCH
6" BEDDING
HDPE LINING
ROCK RIPRAP DETAIL
STA. 6+53.54 TO STA. 9+50 ℄ EMBANKMENT
6" TOPSOIL
ZONE A
2'-6" LOOSE ROCK RIPRAP
12" FILTER
APPROXIMATE GROUND LINE
12" STRIPPING DEPTH
5'-5"
2'-0"
UPSTREAM AND DOWNSTREAM TERMINAL CUTOFF ELEVATION
6" TOPSOIL
ZONE A
LOOSE ROCK RIPRAP
4'-0"
APPROXIMATE GROUND LINE
12" STRIPPING DEPTH
5'-4"
SECTION
LOOSE ROCK RIPRAP
6" TOPSOIL
FILTER
2'-6"
1'-0"
SCALE IN FEET
EXAMPLE B-8
CONSTRUCTION DETAILS
WAIMANALO RESERVOIR
WAIMANALO WATERSHED
CITY & COUNTY OF HONOLULU, HAWAII
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
APPROVED:
CHIEF, DIV. OF ENGINEERING, DEPARTMENT OF PUBLIC WORKS
(FOR GRADING ONLY)
DATE
Designed MTH 3/90
Drawn MT. SK 3/90
Checked MTH. BBO 6/90
Sheet No. 10 of 22
Drawing No. HI-E-08-016
WAIM\CON2



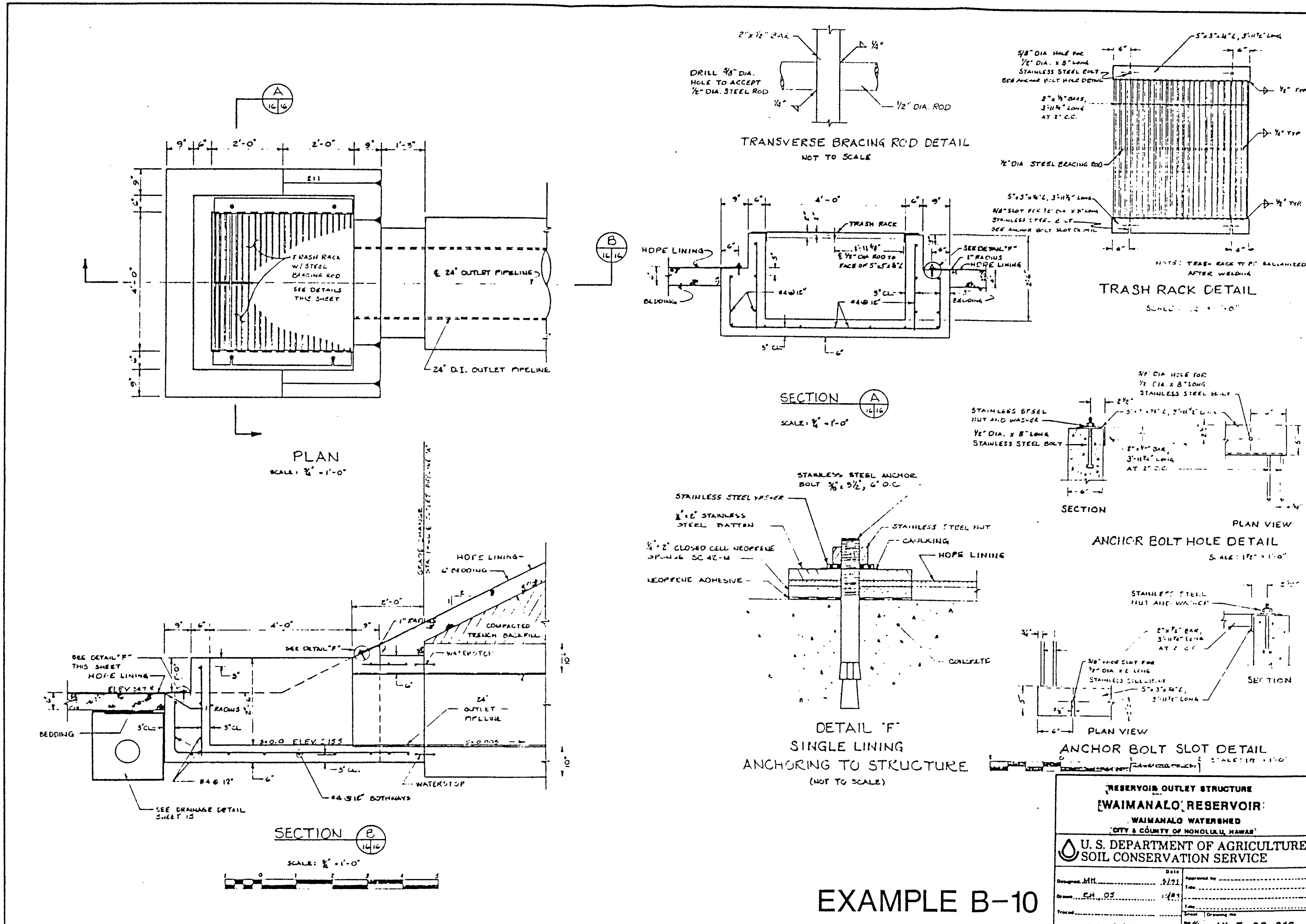
LAYOUT		
8" DIA. PVC DRAIN PIPE		
POINT	STATION	ELEV.
A	1+05.8	249.9
B	0+95.8	254.9
C	0+85.8	259.9
D	0+75.8	264.9
E	0+65.8	269.9
F	0+55.8	274.9
G	0+45.8	279.9
H	0+35.8	284.9

EXAMPLE B-9

PLAN OF PIPE SYSTEMS
WAIMANALO RESERVOIR
WAIMANALO WATERSHED
CITY & COUNTY OF HONOLULU, HAWAII

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed MTH 3/90 Approved by
Drawn MT 3/90
Traced
Checked MTH, 890 8/90 Sheet No. 11 of 72 Drawing No. HI-E-08-016

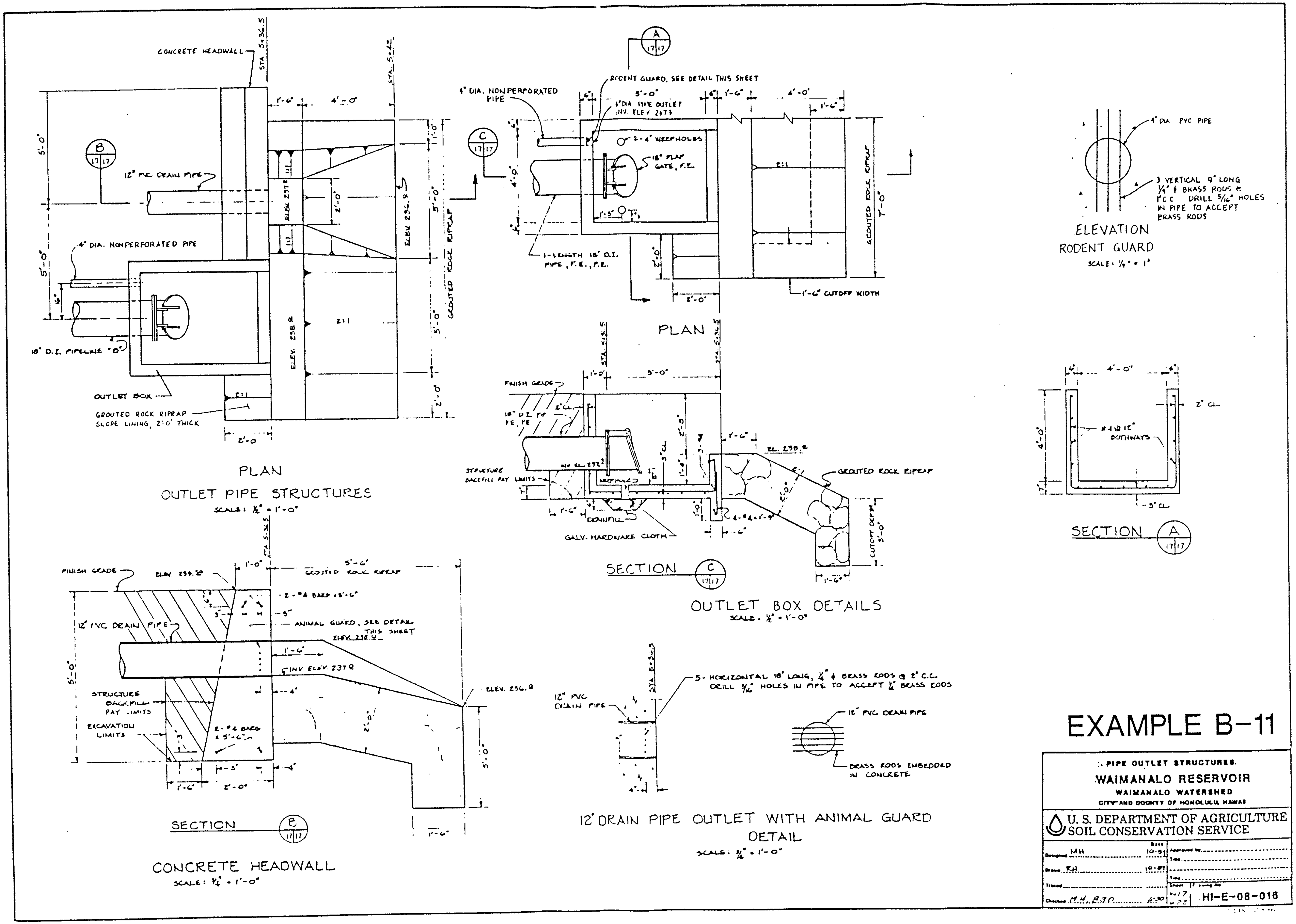


RESERVOIR OUTLET STRUCTURE
WAIMANALO RESERVOIR
WAIMANALO WATERSHED
CITY & COUNTY OF HONOLULU, HAWAII

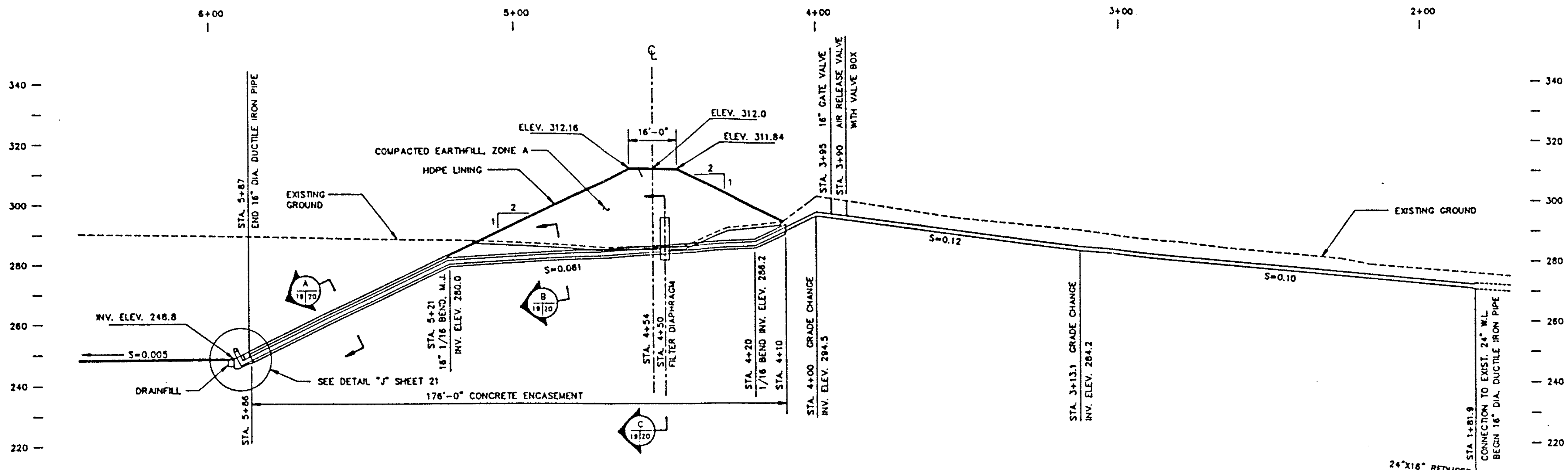
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

HI-E-08-016

EXAMPLE B-10

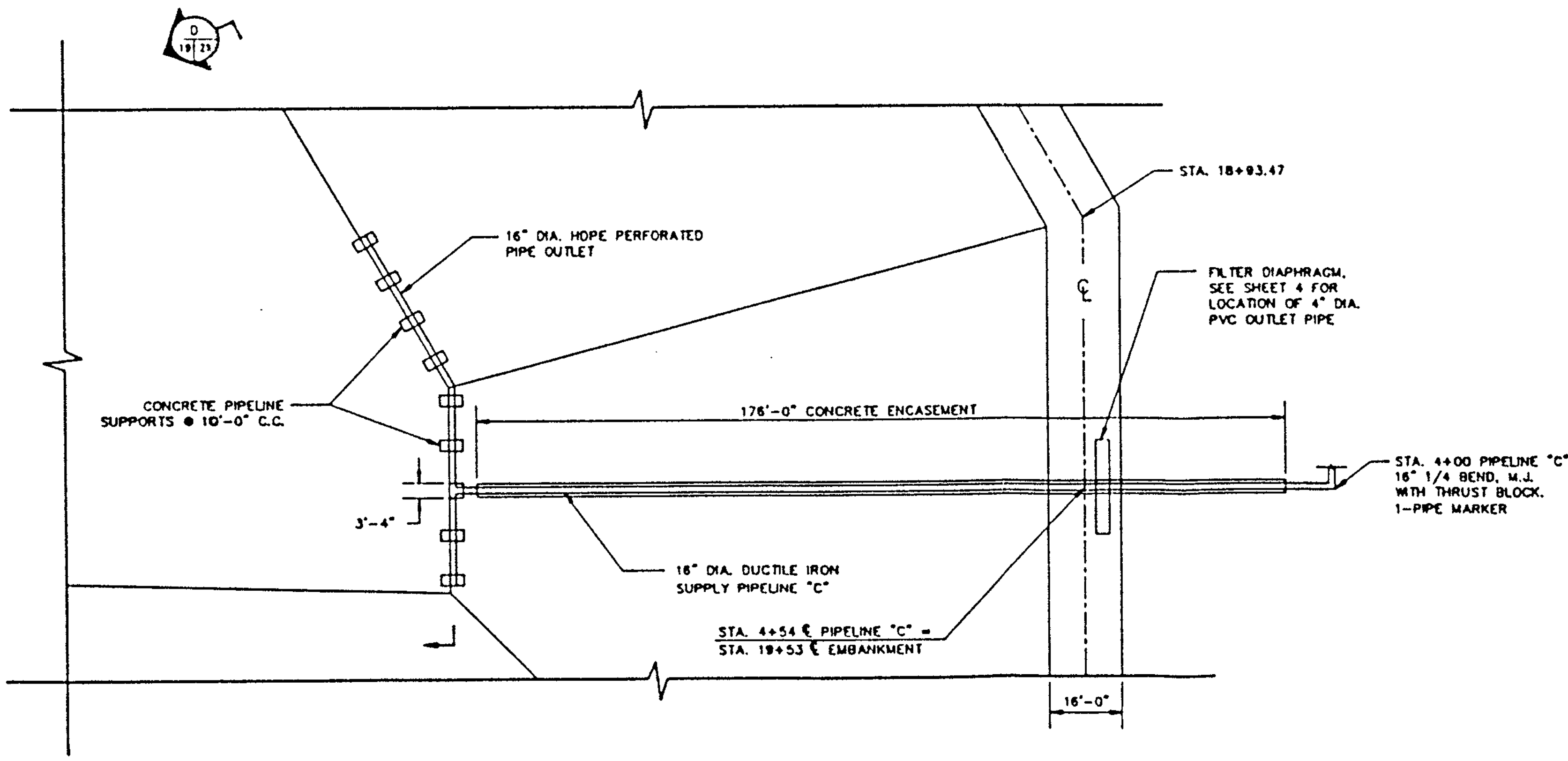


CONCRETE HEADWALL
12" PVC DRAIN PIPE
4" DIA. NONPERFORATED PIPE
18" D.I. PIPELINE "D"
OUTLET BOX
GROUTED ROCK RIPRAP SLOPE LINING, 2'-0" THICK
GROUTED ROCK RIPRAP
ELEV. 237.8
ELEV. 236.8
ELEV. 238.8
PLAN
OUTLET PIPE STRUCTURES
SCALE: ¼" = 1'-0"
RODENT GUARD, SEE DETAIL THIS SHEET
4" DIA. NONPERFORATED PIPE
2-4" WEEPHOLES
18" FLAP GATE, F.E.
1-LENGTH 18" D.I. PIPE, F.E., P.E.
1'-6" CUTOFF WIDTH
PLAN
FINISH GRADE
STRUCTURE BACKFILL PAY LIMITS
GALV. HARDWARE CLOTH
GROUTED ROCK RIPRAP
SECTION C
OUTLET BOX DETAILS
SCALE: ¼" = 1'-0"
4" DIA PVC PIPE
3 VERTICAL 9" LONG ¼" ϕ BRASS RODS @ 1" C.C. DRILL 5/16" HOLES IN PIPE TO ACCEPT BRASS RODS
ELEVATION
RODENT GUARD
SCALE: ¼" = 1"
#4 @ 12" BOTHWAYS
SECTION A
FINISH GRADE
12" PVC DRAIN PIPE
2-#4 BARS x 5'-6"
ANIMAL GUARD, SEE DETAIL THIS SHEET
INV. ELEV. 237.8
STRUCTURE BACKFILL PAY LIMITS
EXCAVATION LIMITS
ELEV. 236.8
SECTION B
CONCRETE HEADWALL
SCALE: ¼" = 1'-0"
5-HORIZONTAL 18" LONG, ¼" ϕ BRASS RODS @ 2" C.C. DRILL 5/16" HOLES IN PIPE TO ACCEPT ¼" BRASS RODS
12" PVC DRAIN PIPE
BRASS RODS EMBEDDED IN CONCRETE
12" DRAIN PIPE OUTLET WITH ANIMAL GUARD DETAIL
SCALE: ¾" = 1'-0"
EXAMPLE B-11
PIPE OUTLET STRUCTURES
WAIMANALO RESERVOIR
WAIMANALO WATERSHED
CITY AND COUNTY OF HONOLULU, HAWAII
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
HI-E-08-016



PROFILE OF 16" SUPPLY PIPELINE "C"

20 0 20 40
SCALE IN FEET



PARTIAL PLAN OF 16" SUPPLY PIPELINE "C"

20 0 20 40
SCALE IN FEET

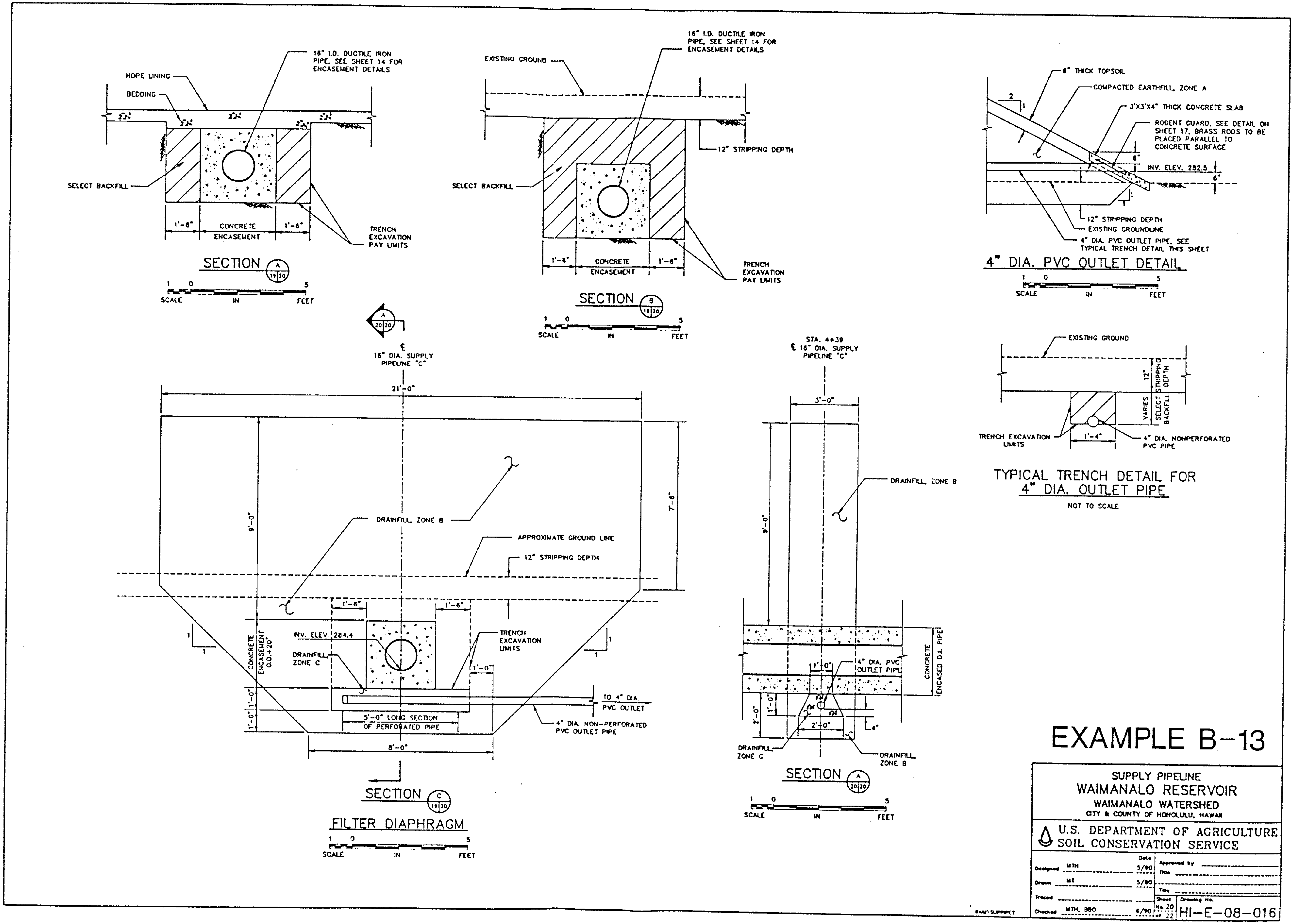
EXAMPLE B-12

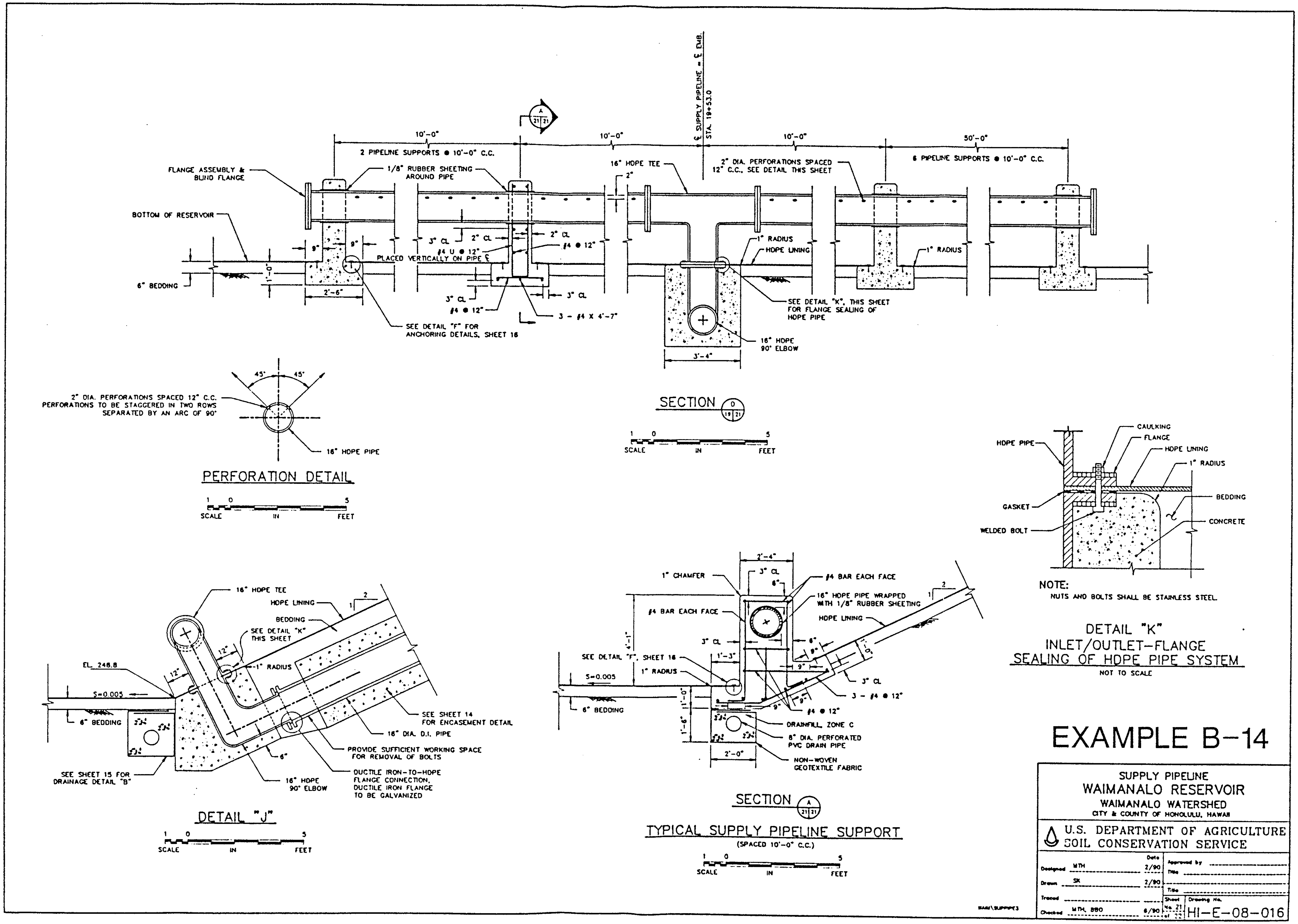
SUPPLY PIPELINE
WAIMANALO RESERVOIR
WAIMANALO WATERSHED
CITY & COUNTY OF HONOLULU, HAWAII

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

		Date	
Designed	MTH	2/90	Approved by
Drawn	SK	2/90	Title
Traced			Title
Checked	MTH, SBO	3/90	Sheet No. 19 of 22 — Drawing No. HI-E-08-016

WAIM\SUPPIPC


16" I.D. DUCTILE IRON PIPE, SEE SHEET 14 FOR ENCASEMENT DETAILS
HDPE LINING
BEDDING
SELECT BACKFILL
1'-6"
CONCRETE ENCASEMENT
TRENCH EXCAVATION PAY LIMITS
SECTION A 19|20
SCALE IN FEET
EXISTING GROUND
12" STRIPPING DEPTH
SECTION B 19|20
6" THICK TOPSOIL
COMPACTED EARTHFILL, ZONE A
3'X3'X4" THICK CONCRETE SLAB
RODENT GUARD, SEE DETAIL ON SHEET 17, BRASS RODS TO BE PLACED PARALLEL TO CONCRETE SURFACE
INV. ELEV. 282.5
EXISTING GROUNDLINE
4" DIA. PVC OUTLET PIPE, SEE TYPICAL TRENCH DETAIL THIS SHEET
4" DIA. PVC OUTLET DETAIL
℄ 16" DIA. SUPPLY PIPELINE "C"
21'-0"
9'-0"
7'-6"
DRAINFILL, ZONE B
APPROXIMATE GROUND LINE
INV. ELEV. 284.4
DRAINFILL ZONE C
CONCRETE ENCASEMENT O.D.+20"
TRENCH EXCAVATION LIMITS
TO 4" DIA. PVC OUTLET
5'-0" LONG SECTION OF PERFORATED PIPE
4" DIA. NON-PERFORATED PVC OUTLET PIPE
8'-0"
SECTION C 19|20
FILTER DIAPHRAGM
STA. 4+39 ℄ 16" DIA. SUPPLY PIPELINE "C"
3'-0"
CONCRETE ENCASED D.I. PIPE
4" DIA. PVC OUTLET PIPE
DRAINFILL ZONE C
DRAINFILL, ZONE B
SECTION A 20|20
TRENCH EXCAVATION LIMITS
SELECT BACKFILL
STRIPPING DEPTH
VARIES
4" DIA. NONPERFORATED PVC PIPE
TYPICAL TRENCH DETAIL FOR 4" DIA. OUTLET PIPE
NOT TO SCALE
EXAMPLE B-13
SUPPLY PIPELINE
WAIMANALO RESERVOIR
WAIMANALO WATERSHED
CITY & COUNTY OF HONOLULU, HAWAII
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Designed MTH 5/90
Drawn MT 5/90
Traced
Checked MTH, BBO 6/90
Sheet No. 20 of 22
Drawing No. HI-E-08-016



℄ SUPPLY PIPELINE = ℄ EMB.
STA. 19+53.0
10'-0"
2 PIPELINE SUPPORTS @ 10'-0" C.C.
10'-0"
10'-0"
50'-0"
6 PIPELINE SUPPORTS @ 10'-0" C.C.
FLANGE ASSEMBLY & BLIND FLANGE
1/8" RUBBER SHEETING AROUND PIPE
16" HDPE TEE
2" DIA. PERFORATIONS SPACED 12" C.C., SEE DETAIL THIS SHEET
BOTTOM OF RESERVOIR
2"
9"
9"
3" CL
2" CL
2" CL
#4 U @ 12" PLACED VERTICALLY ON PIPE ℄
#4 @ 12"
1" RADIUS
HDPE LINING
1" RADIUS
1'-0"
6" BEDDING
2'-6"
3" CL
#4 @ 12"
3" CL
3 - #4 X 4'-7"
SEE DETAIL "F" FOR ANCHORING DETAILS, SHEET 16
SEE DETAIL "K", THIS SHEET FOR FLANGE SEALING OF HDPE PIPE
16" HDPE 90° ELBOW
3'-4"
SECTION D 19 21
SCALE 1 0 5 IN FEET
45°
45°
2" DIA. PERFORATIONS SPACED 12" C.C. PERFORATIONS TO BE STAGGERED IN TWO ROWS SEPARATED BY AN ARC OF 90°
16" HDPE PIPE
PERFORATION DETAIL
SCALE 1 0 5 IN FEET
HDPE PIPE
CAULKING
FLANGE
HDPE LINING
1" RADIUS
GASKET
BEDDING
WELDED BOLT
CONCRETE
NOTE:
NUTS AND BOLTS SHALL BE STAINLESS STEEL.
DETAIL "K"
INLET/OUTLET-FLANGE
SEALING OF HDPE PIPE SYSTEM
NOT TO SCALE
16" HDPE TEE
HDPE LINING
BEDDING
SEE DETAIL "K" THIS SHEET
12"
1" RADIUS
12"
EL. 246.8
S=0.005
6" BEDDING
SEE SHEET 14 FOR ENCASEMENT DETAIL
16" DIA. D.I. PIPE
PROVIDE SUFFICIENT WORKING SPACE FOR REMOVAL OF BOLTS
6"
DUCTILE IRON-TO-HDPE FLANGE CONNECTION, DUCTILE IRON FLANGE TO BE GALVANIZED
16" HDPE 90° ELBOW
SEE SHEET 15 FOR DRAINAGE DETAIL "B"
DETAIL "J"
SCALE 1 0 5 IN FEET
2'-4"
3" CL
6"
1" CHAMFER
#4 BAR EACH FACE
16" HDPE PIPE WRAPPED WITH 1/8" RUBBER SHEETING
#4 BAR EACH FACE
HDPE LINING
4'-1"
3" CL
6"
SEE DETAIL "F", SHEET 16
1'-3"
9"
1" RADIUS
9"
S=0.005
3" CL
3 - #4 @ 12"
#4 @ 12"
6" BEDDING
1'-0"
1'-6"
DRAINFILL, ZONE C
6" DIA. PERFORATED PVC DRAIN PIPE
2'-0"
NON-WOVEN GEOTEXTILE FABRIC
SECTION A 21 21
TYPICAL SUPPLY PIPELINE SUPPORT
(SPACED 10'-0" C.C.)
SCALE 1 0 5 IN FEET
EXAMPLE B-14
SUPPLY PIPELINE
WAIMANALO RESERVOIR
WAIMANALO WATERSHED
CITY & COUNTY OF HONOLULU, HAWAII
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Designed MTH 2/90
Drawn SK 2/90
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Title
Sheet No. 21 of 22
Drawing No. HI-E-08-016