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Reply to: 4000

Date: April 8, 1991

Dr. Lawrence S. Hamilton  
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1777 East-West Road  
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Dear Larry,

Enclosed is the report that Walt Megahan and I prepared following our trip to Federated States of Micronesia. As we discussed earlier, we felt that it was redundant to produce a set of guidelines for road construction since the FAO Conservation Guide 13/5 that was issued in 1989 (ISBN 92-5-102789-X) covers the subject extensively. We felt that we could best tailor this report to specific recommendations related to what we observed on our trip and to reference those sections in the FAO Guide that are applicable, and to identify those instances where the FAO Guide is not applicable to conditions in FSM.

I hope this approach and report meets with your approval. If you find that our report is deficient in any way, please let me know and I will make every effort to correct the deficiency. I apologize for the delay in providing this report, but I did not anticipate Walt's back surgery and subsequent retirement.

Sincerely,

ROBERT R. ZIEMER  
Project Leader

cc: M. Falanruw  
K. Dahl  
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EROSION AND SEDIMENTATION CONTROL ON ROADS AND CONSTRUCTION SITES  
IN THE FEDERATED STATES OF MICRONESIA

Robert R. Ziemer & Walter F. Megahan

INTRODUCTION

The East-West Center, Environment and Policy Institute and the South Pacific Region Environment Program developed a cooperative program to reduce sedimentation damage from roads in the Federated States of Micronesia (FSM). As a part of the program, a series of workshops to reduce road erosion and sedimentation were conducted in Yap, Chuuk, Pohnpei, and Kosrae during the period from 10/28/1990 to 11/8/1990. Leading the workshops were Robert R. Ziemer and Walter F. Megahan of the USDA, Forest Service, Pacific Southwest and Intermountain Research Stations, respectively.

We feel the workshops were successful. There was a good turnout at all locations. Participants seemed interested and involved in both the classroom and field portions of the workshops. We thank the local FSM authorities for their support and the local people for their interest and hospitality. Special thanks go to Marjorie Falanruw, Kit Dahl, Bill Raynor, Arthur Ansin, Erick Waguk, and Meriwether Wilson-Molina for their help with local arrangements and logistics, to Jim Maragos for his background work leading up to our trip, and to Larry Hamilton for assistance and support at the East-West Center.

The purpose of the workshops was to: 1) Introduce basic principles of erosion and sedimentation processes and control; 2) Review local on-site problems; 3) Adapt general principles of erosion control to local conditions through office and field discussion; 4) Present supporting information such as handouts, suggestions, and reference materials to serve as references and expand the local knowledge base. At each location, we had an opportunity to conduct one or more field tours in order to obtain an overview of existing and potential problems and to locate specific sites that could be used to illustrate typical erosion and sedimentation problems during the workshop. Problems identified were associated with road and/or building construction (Appendix 1).

Two levels of road construction standards were found on the islands. Main arterial roads, consisting of the cross island road on Yap and the circumferential roads on Pohnpei, Chuuk, and Kosrae, were two-lane roads that were well-designed with respect to vehicle use and trafficability. However, we did find a number of localized problem areas where excessive erosion either has or will occur within or below the road. Secondary roads constructed to provide single lane access to individual homes and gardens were, almost without exception, poorly designed (or commonly not designed at all) and exhibited numerous erosion and sedimentation problems as a result of excessive grades, poor drainage, and inadequate surfacing.

We spent considerable time discussing possible problems from erosion and the resulting downstream sedimentation. Local people were primarily concerned about road erosion with respect to road serviceability and minimizing

maintenance costs, although concern was not always translated into the road design, especially on secondary roads. Some additional concern was also expressed about downslope sedimentation because of damage to gardens (especially taro patches) and to mangroves, sea grass beds, and reefs.

#### RECOMMENDATIONS TO MINIMIZE EROSION AND SEDIMENTATION PROBLEMS

Recently, FAO published the Watershed Management Field Manual as seven separate volumes as FAO Conservation Guide No. 13. One of those volumes (13/5), "Road Design and Construction in Sensitive Watersheds" (FAO, 1989), is recommended as a general guide for road construction to minimize erosion and sedimentation damage from roads in the FSM. During our field tours in FSM, we observed a number of specific road design and erosion problems. It is not our intent to repeat the information contained in the excellent FAO reference. We have, however, identified these problems (below and Appendix 1) along with the appropriate pages in the FAO publication to use for remedial measures. In a few instances, we felt that material in the FAO reference was not appropriate for use in the FSM and have indicated such. Also, some problems found in the FSM are not addressed by the FAO paper and we have provided additional information as needed.

#### GENERAL PRINCIPLES (FAO chapter 1, p. 1-12)

Erosion hazards in the FSM are very high because of the extremely high rainfall rates. The erosion index (R) is used in the Universal Soil Loss Equation (USLE) to predict surface erosion from rainfall (Wischmeier and Smith, 1978). Cooley et al. (1991) show that R values in the FSM are over two times greater than R values in the upper mid-western United States, where the USLE was developed, and are similar to low elevation sites in Hawaii. Chapter 1 of the FAO reference (p. 1-12) is recommended for an overview of some general principles about the interaction of roads and erosion and sedimentation processes.

#### PLANNING AND ROAD LOCATION

A basic tenet for minimizing erosion and sedimentation damage from roads is to avoid problems by using good initial design, rather than relying upon fixing problems after construction. This requires building as few roads as possible in the best possible location (FAO chapter 2, p. 13-47). Much of the FAO reference deals with road location to avoid landslide hazards. The inherent strength of slopes in the FSM is relatively low because of the high weathering of the bedrock that has occurred. However, landslides associated with roads in the FSM are rare because most construction has avoided steep terrain to date. We did see a few areas where small slope failures (landslides) had occurred on large cut slopes on the arterial roads in Yap and in Kosrae. Landslides could be a major problem on the islands if road construction expands to the steeper terrain. In that event, detailed guidelines such as those in the FAO reference will have to be adapted to the FSM.

There was clearly a need for effective state-level direction for road planning and location, especially for secondary roads. Location appeared to be good on arterial roads, although better planning would have eliminated some

problems. For example, better design of dump areas for excess fill materials on Yap could have avoided some excessive erosion problems. In areas of lagoon encroachment on all states, considerable direct supply of sediments to the lagoon could be avoided by the proper installation of filter curtains to contain sediments. By far the most serious and pervasive erosion problems exist on the secondary roads. Such roads are developed by individuals. Lack of knowledge about proper road construction practices,, the desire to minimize costs, and problems with land ownership often lead to serious erosion problems. We saw numerous examples where road grades were too steep for the type of road construction used. Landholders were constructing roads straight up the slope to minimize construction costs or to avoid problems with land ownership. Invariably, road design was inadequate for the steep grades involved. Local guidelines and direction need to be developed to avoid such problems. This requires a state-level land use planning effort that recognizes the benefit of an integrated road system designed to optimize the benefits for all residents while minimizing environmental impacts.

#### SUBGRADES AND SURFACING

In all FSM states, the tropical climate causes rapid rock weathering that results in subgrade materials that are very high in clays. Such materials alone are low in bearing strength and are inadequate for even light-use traffic. Therefore, ballast and/or surfacing is required to prevent rutting and to maintain trafficability. This is especially true on Yap where the bedrock consists of weathered sedimentary rocks. The other states are volcanic in origin and provide a greater opportunity to obtain competent ballast and surfacing materials from local sources. The quality of rock materials improves along a gradient from west to east (from oldest to youngest rocks).

In general, subgrade and surfacing procedures on the arterial roads appear to be appropriate for the intended road uses in the FSM states. On Yap, a chemical treatment called Condor SS is being used to stabilize the subgrade. This is overlain with crushed rock aggregate which is covered with a rubberized asphalt surface. In the other FSM states, pit run or crushed rock ballast is used on arterial roads and is covered with a crushed coral, chip seal, or asphalt surface.

Trafficability is a universal problem on secondary roads because of weak subgrades and inadequate surfacing. Problems were magnified because excessive road grades, sometimes in excess of 20 percent, were the rule rather than the exception. The steep grades tend to rut easily, causing concentration of runoff water that adds to the rutting and causes accelerated erosion at downslope locations. Sometimes, a thin layer of crushed coral is applied in order to improve traction. However, without adequate subgrade preparation, subsequent traffic use (especially during wet weather) rapidly ruts the road, necessitating the application of additional coral surfacing to make the roads drivable. In many areas, post-construction erosion is allowed to proceed until all erodible material is removed, exposing large rocks that then serve as the driving surface.

We recommend that local guidelines be developed for all states to assure adequate surfacing on secondary roads (FAO, 1989 -- p. 84-92). This will undoubtedly require a cooperative effort between individuals and the state

government to develop localized land use plans and environmental impact evaluations along with procedures for cost sharing.

A major part of the problem on secondary roads is the direct result of the lack of subgrade stability. Use of normal practices to construct stable subgrades is not practical on these roads because of high costs. However, the chemical stabilization techniques presently being used on the arterial road in Yap may be effective on secondary roads. We suggest that controlled tests of the Condor SS material be attempted on secondary roads on Yap. Trials of this material may also be appropriate in the other FSM states. However, such trials should be done in cooperation with the manufacturer because of possible problems caused by the volcanic parent materials. Escobar (1984) provides background information on the use, costs, and application of Condor SS. Condor SS is a mixture of ion exchange resins and sulfuric and sulfonic acids that is designed to remove the water of hydration from subgrade clays. This allows the subgrade to be compacted to a dense, highly stable state. The mixture is applied by ripping and sprinkling or by injection into the subgrade, followed by compaction with a vibrating roller (Escobar, 1984). The material is extremely acidic (pH 1.25) so care should be used to avoid spills and to prevent overland flow runoff from treated areas immediately after application. The injection procedure minimizes the opportunity for offsite pollution and is recommended for that reason.

#### ROAD DRAINAGE

Based on a brief review of the streamflow and precipitation data for the FSM compared to the drainage design for the roads visited, we felt that most of the road drainage control structures were underdesigned. This includes channel crossings, ditch relief culverts, ditch capacities, and ditch armoring. The FAO reference (p. 133-145) is appropriate for developing the design of ditch relief culverts, ditch capacities, and ditch armoring. However, the FAO reference is not adequate for design of channel crossings because of the extremely high rainfall intensities and volumes occurring in the FSM.

As a general rule, we recommend bridges at all channel crossings on arterial roads rather than culverts in order to minimize the possibility of clogging by debris. Channel crossings should be designed to carry at least the 25-year flow event for a given design life and chance of failure (FAO, 1989 -- p. 99).

We were able to obtain some information about design standards for the arterial road on Kosrae. There, channel crossings were to be designed for the 25-year return interval storm. An example of the design flow procedure for a 504-acre watershed was provided for our information (Appendix 2). We conducted flow frequency analyses for available streamflow data from 11 streamgage sites on Yap, Chuuk, Pohnpei, and Guam to evaluate the probability of instantaneous peak flows as a function of watershed area (Appendix 3). Our analysis showed a peak flow of about 1700 cubic feet per second (cfs) for a 20-year return interval flow for the 504-acre watershed on Kosrae. The design flow procedure for Kosrae estimated a peak flow of about 940 cfs for a 25-year return interval storm on the same 504-acre watershed. For the Malem River, Kosrae, a peak flow of 940 cfs could be expected to be exceeded about once every 5 years, based upon the stream gage record.

Results from this analysis suggest that the peak flow estimating procedure used for road design on Kosrae tends to underestimate peak flow rates. One factor that may lead to this is the fact that the peak flow estimating procedure used for the Kosrae project uses intensity-duration-depth curves developed for Washington D. C. in the United States. We suggest that the procedure be revised to better reflect conditions in the FSM. Cooley et al. (1991) have developed computer data files for all suitable rainfall intensity data available from the FSM states. These data should be analyzed to update the storm data used for the procedure on Kosrae. Additional data that could be used to improve and/or validate the Kosrae's peak flow estimating procedure include storm probability data from Hawaii and the peak flow analysis procedure developed for this report (Appendix 3). The updated flow prediction procedure should be applicable for all FSM states.

Hydrologic and climatologic data are limited in FSM and will apparently become even more limited in the future. Over the past; decade, the network of stream gaging stations has been drastically reduced. And, within the past year, most of the remaining gaging stations have either been abandoned or are scheduled for abandonment. Many of the questions related to road drainage design need to be verified by local observational data. The usual procedure for estimating design runoff is to use empirical formulae (FAO, 1989 - p. 99). However, serious errors can result if such calculations are used without local verification. Local stream gage data are an invaluable source of such verification. In addition, many of the calculations require information that is difficult to obtain. For example, one commonly used method for watersheds less than 80 hectares (200 acres), the "rational" method, requires a runoff coefficient that is the ratio of runoff rate to rainfall, and a value for rainfall intensity for the time of concentration for the watershed of interest. For small drainage areas, such as ditch relief culverts, the appropriate time of concentration would require the 5-minute rainfall intensity. The NOAA Weather Stations collect this information within FSM (usually at the airport), but we found the data to be unavailable. Also, rainfall intensities at the NOAA station can be quite different than at inland locations in the mountains. There is a trend to reduce the collection of such basic hydrologic information, while at the same time environmental issues requiring such data are increasing.

We saw a number of examples where ditch relief culverts on the arterial road on Yap discharged onto undisturbed slopes below the road. In all cases, the discharge points are probable locations for excessive downslope erosion. A careful evaluation should be made of each of these sites to prevent damage. We suggest that the USDA Soil Conservation Service office in Guam be contacted to conduct the necessary field studies.

In many locations, turnpike (all fill) road construction was placed across areas of standing water, either salt or fresh. Standard channel crossing culvert design is not applicable in such areas because the standing water attenuates the runoff hydrograph and results in much lower peak flows than expected. A factor that is a concern in such areas is the potential ecological impacts of impeded flows on water salinity and other water quality parameters. In these situations, the best approach to adequate drainage is to install as many culverts as possible evenly spaced along the road across the

entire width of the wet area. Culvert sizes should not be less than 18 inches in diameter.

Surface cross drains and intercepting ditches are often recommended to protect the road surface from erosion (FAO, 1989 -- p. 126). We have some reservations about using such structures in the FSM because of the extreme rainfall intensities in the area and the nature of the subgrade materials. We suggest tests of the utility of such structures be made before adopting them for general use.

The inflow and outflow points of many culverts and bridges were not adequately protected. Appropriate rip rap or log cribbing material should be placed at the sides of all culverts and bridges and at the bottom of culverts (FAO, 1989 -- p. 140-143).

#### CONSTRUCTION PRACTICES

All fill construction that we saw was done with a bulldozer by sidecasting (FAO, 1989 -- p. 178) on road fills, in road fill waste areas, and at construction sites. Because of the lack of compaction, sidecast construction of fill material maximizes erosion and this was very apparent from the severe soil losses at many of the sites resulting from sheet, rill, and gully erosion. The severity of erosion was directly proportional to the size of the fills, reaching a maximum at an estimated 30,000 cubic yard fill waste area on the arterial road on Yap. Here, total soil losses amounting to an estimated 1,500 cubic yards had occurred within a few months after construction. Most of this eroded material appeared to have been delivered to a drainage leading directly to the bay about one-quarter of a mile downstream. Much of this type of damage can be avoided by: 1) compacting the fills during construction (FAO, 1989 -- p. 183-184), 2) shaping the fill areas to control surface drainage, 3) protecting the bare surfaces with mulches and rapidly growing vegetation or other slope protective measures (FAO, 1989 -- p. 148-166), and 4) reducing the downslope delivery of eroded materials with the use of filter windrows (FAO, 1989 -- p. 187-188; Note: filter windrows should be placed below the toe of the fill slope -- not on the toe of the fill as shown in the FAO paper) or the use of silt fences (in the case of fill construction on slopes) or silt curtains (in the case of fill placement in water).

We noticed a tendency to use stage construction at some locations. This consists of completion of one stage of the construction for a relatively long distance along the road before completion of the remaining stages of the construction. Such an approach is used because it often reduces costs. As an example, a long distance of road subgrade might be constructed using temporary culverts in order to minimize costs for excavation activities. Usually, such temporary culverts are totally inadequate to handle even small amounts of storm runoff so that storm events of any magnitude can cause road surface and fill erosion and may result in the loss of entire embankments. Stage construction of this type was being used on the new arterial road construction on Kosrae and had resulted in an overtopped road surface at one site. Luckily, the total fill was not yet lost, but some fill slope erosion did occur. Wherever possible, stage construction should be minimized, especially in areas where pronounced dry seasons do not occur.

## SURFACE AND SLOPE PROTECTION MEASURES

We saw a number of sites where slope protection measures were needed to help reduce both surface, and sometimes, mass erosion hazards. A variety of practices are available to accomplish this (FAO chapter 5, p. 148-166). Natural revegetation occurs rapidly in the FSM and is very effective for erosion control, but short-term measures are often needed to protect disturbed soils before natural revegetation occurs. This is especially true in areas where the potential for downslope delivery of water and sediments is high. Transplanting woody vegetation and use of various types of mulches are effective for accomplishing this. We recommend that studies be conducted to evaluate the effectiveness of establishing various local plant materials for soil stabilization. In addition to direct protection, off-site sediment traps such as filter windrows, silt fences, and silt curtains are also effective for reducing sedimentation.

## ROAD MAINTENANCE

Once constructed, a road is only as good as its maintenance. A well-designed maintenance program provides many benefits including: preservation of the original planned access, reduction of off-site damage, and continued public safety. FAO chapter 7 (p. 190-196) provides an excellent overview of necessary road maintenance practices. Included are discussions of practices for maintaining drainage structures and the driving surface and a description of a procedure for developing an emergency storm response plan. The latter is very beneficial in the FSM where extreme rainfall events are common. One last item covered in FAO chapter 7 is the need for proper road abandonment and reclamation. Although not common in the FSM, it is very likely that some secondary roads will (or at least should) be closed in the future. Careful attention to road closure practices is needed to avoid long-term environmental damage in such instances.

## LONG-TERM ISSUES

Many environmental issues concern long-term hydrologic and ecologic consequences of land-use practices. Such concerns have become identified as "cumulative watershed effects." The exact nature of cumulative effects has been discussed for some time, but the definition in the Council of Environmental Quality (CEQ) Guidelines for implementing the National Environmental Quality Act of 1969 suffices to identify the principal issues:

"Cumulative impact" is the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time. (CEQ Guidelines, 40 CFR 1508.7, issued 23 April 1971)

To address issues such as the cumulative effects of road construction on stream or lagoon sedimentation can require projecting erosion and sediment transport over many decades or even centuries. Ziemer et al. (1991) described an approach that might be modified for use in the FSM. Unfortunately, there



is much work that needs to be undertaken to define the basic relationships between climate, erosion, and ecosystem response under tropical conditions.

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APPENDIX 1.

Observations during trip to FSM October 28 to November 8, 1990

OBSERVATIONS DURING TRIP TO FSM  
October 28 to November 8, 1990

Robert R. Ziemer & Walter F. Megahan

YAP

We drove the length of the cross-island road that was being constructed by You One Construction Company from Korea. The new road runs from Colonia through Tomil to the northeastern coast of Maap. Construction began in Maap and is proceeding to Colonia. Construction is nearing completion in Maap and Tomil, but paving had not yet begun. Right-of-way clearing is just beginning near Colonia. The road seems to be well-designed. The subgrade is being stabilized using injected Condor SS. This is designed to chemically extract water from the clay lattice, allowing the lattice to collapse and the clay to be compacted. There was local concern about the environmental safety of Condor SS. There was an unverified report that about 500 gallons of the material had recently been spilled, but we did not see the location.

The road surface is crowned, directing drainage to poured-in-place concrete V-shaped drainage ditches on both sides of the road. We were unable to obtain information on the design flow of the ditches, but they appear in some cases to be too small to carry intense storm runoff. In several cases, the ditches are so constructed that runoff will probably jump the turn at the downhill end and continue down the road rather than be diverted from the road as expected.

The road near Colonia is intended to encroach into the mangrove and lagoon margin. We recommend that during construction, a silt fence be installed to limit migration of sediment into the lagoon. And, upon completion of the subgrade, the road fill be protected by a sea wall or rip-rap.

At the bridge site between Tomil and Maap, the channel has been filled and an extensive soil disposal site has been constructed on the Tomil side of the channel. All flow within the channel has been blocked by the fill and the mangrove appears to be stressed and the leaves seem to be yellowing. A burlap silt fence has been constructed near the disposal site, but it seems to be ineffective. The plan is to construct a bridge and to eventually remove the fill. Construction costs are probably lowered by this method, but the amount of sediment introduced to the channel is very large. The environmental consequences of this additional sediment is unknown.

About 1 mile from the bridge site on Maap, there is a large fill and disposal site containing about 30,000 cubic yards of soil. This material appears to be uncompacted and poor surface drainage has caused severe gullyng on the fill face. Eroded material is being transported to and down a small drainage basin to be discharged into the lagoon about 1/4 mile away. Surface drainage here should be controlled and routed to a hardened and safe location. The fill should be quickly revegetated with woody plants to provide some strength to the weak fill. Revegetation will assist in stabilizing the fill, but since the entire fill was not compacted there is little internal strength and vegetation can not be expected to solve the problem. Unless surface water is directed away from the fill face, a serious gullyng problem can be expected at this location for years. In addition, a silt fence or barrier should be installed at the base of the fill to catch eroded material.

Although the road itself seems to have been well-designed, the provision for dealing with water once it leaves the road is poorly planned. Apparently, concern for off-road environmental damage was not part of the road design. For example, it is not uncommon for roadside ditches to carry water for up to 1600 feet before discharging into a stream or scale. At such discharge points, inadequate provision has been made to protect the slope or stream channel from the volume or force of the water that will be discharged. For a 40-foot wide roadway, the ditch discharge for a 1600-foot run during a 1-inch storm would be  $20 \times 1600 \times (1/12) = 2667$  cubic feet of water. In this climate, it is perhaps not unusual to have a 1-inch rainfall in 10 minutes. It is important to calculate expected 5- and 10-minute intensities for different return intervals, and further to calculate anticipated peak discharges from the road surface and surrounding right-of-way that contributes to ditch flow. The NOAA Weather Service collects such intensity data, but discussions with the local NOAA offices in Yap, Chuuk, Pohnpei, Kosrae, Guam, and Honolulu did not yield the records.

Where energy dissipation and channel lining is provided, it is too small an effort to be very effective during storm flows. Across the road from the Maap fill disposal site is an example of poorly designed discharge of road drainage. The road drainage ditch runs for about 1100 feet to a drop inlet where a box culvert discharges into a small grass and fern vegetated swale. Although water has been directed onto this scale for only about a month, there is evidence that a deep gully will form within a short time. The shallow grass-fern root system has already been penetrated by the incipient gully and there is little soil resistance to prevent accelerated gullying. It is important to control the force of water leaving the culvert and as it travels down this steep swale. We suggested that this would be an ideal place to demonstrate erosion control techniques. It is important to get some woody vegetation established to provide a fibrous root system and strengthen the soil. Marjorie Falanruw suggested that hibiscus can be established by simply pushing cuttings into the ground. It would be useful to test several types of vegetation for effective erosion control. The vegetation should be quick to establish and produce a deep and dense network of fibrous roots. In addition, the vegetation must be capable of withstanding the force of high velocity running water. The force of water could be reduced by placing and staking logs across the slope, creating a series of check dams as the water is routed down the slope. Had the water been routed about another 50 feet down the road, it could have been discharged onto a small ridge, rather than into the swale, and the runoff would have tended to disperse rather than concentrate.

The question of the effectiveness of Vetiver grass was raised. There is concern in Yap that if introduced, Vetiver may escape and become a pest. In general, it is preferable that native rather than introduced species be used for three reasons: the ready availability of native materials, the cost of exotics, and the hazard of exotics becoming a pest.

Not only has off-road erosion control not had high priority in the road design, there are no funds budgeted for continued road maintenance, let alone off-site erosion control.

Unfortunately, without some local responsibility and technical direction, it is doubtful that any preventative action will be taken and large scale gullies will become common at the outfalls of many road ditches. Once the gullies form, repair or control will be extremely expensive and probably beyond the financial and technical capabilities of Yap State. To the direct costs of erosion control must be added the additional environmental damage to hillslopes, streams, taro patches, and lagoon ecology.

Although we spent much of our time observing the major cross-island road, there are numerous secondary and agricultural roads that are constructed with little or no planning or erosion maintenance. In total, these roads produce a large and dispersed source of continuing sedimentation to agriculture, streams, and lagoon. Some of these secondary roads are constructed by the Seabees, sometimes as a favor to the local chief or landowner. It is common for Yap EPA to be excluded from review or notification. There should be some central clearing house agency or procedure for requesting and reviewing road construction plans.

We visited the NOAA Weather Station on Yap, Chuuk, Pohnpei, and Kosrae. The story was the same at each location: the local station does not retain weather data, but sends it all to the National Climate Data Center in Ashville, NC. Each station records the time of each tip of the tipping-bucket raingage (0.01-inch). Rainfall intensities of 24-hour and 1-hour have been published for the past 30+ years, but the 1-hour intensities are on the data-tapes for only the past 3 or so years. NOAA states that previous years have not been "digitized". For estimating erosion hazard from small drainages, it is important to develop intensity curves for time periods as short as 5 minutes. The time of concentration for peak discharge from the road ditches will be 5 to 10 minutes.

We visited the USGS gaging stations at Burong Stream and Eyeb Stream. We found the concrete weirs, but the gage housing had been removed. When we arrived in Guam, we telephoned Greg Ikehara, USGS Guam (339-5293). He stated that in August the Yap State Legislature did not vote funds to continue data collection. Ikehara has been working primarily with Charles Chieng, Director of Yap Public Works. Adrian Gimed has been the streamgager on Yap for many years. He has not been employed since funding was terminated. Funding for gaging stations is shared equally between each FSM State and the USGS. Earlier in the year, Ikehara and Bill Meyer of the USGS Honolulu office (808-541-2654) visited Yap to explain to the Governor, Legislature, and Public Works Director Chiang the importance of the hydrologic record. Ikehara thought that their arguments were well-received and that funding would be restored, but as of November there has been no further communication with Yap. Ikehara also mentioned that streamgages were discontinued and removed from Chuuk State "several years ago" after a couple years of continued non-payment of the Chuuk State funding share. Ikehara stated that funding was continuing in Pohnpei and Kosrae and the stream gages were still operating there. However, when we arrived in Kosrae we were told by Bruce Howell that the Kosrae legislature had recently voted to terminate funding for the Kosrae gaging station network. Howell stated that the Kosrae share of the cost was \$5000 per year.

#### CHUUK

The major erosion problem on Moen appears to be related to unplanned and uncontrolled population growth with associated roads, traffic, and building site clearing. Grading of building sites seems to be haphazard with inadequate provision for runoff. Whereas on Yap there seemed to be local concern for rural road maintenance (women planting vegetables on road fills and any recently disturbed soil), on Moen it seems that the residents expect the government to be responsible for the roads, even rural roads. There seems to be an enormous amount of erosion coming from the ever-expanding road system and housing sites.

We met with Lt. Governor Marcellino Umwech and discussed the importance of road design and maintenance and the need for environmental legislation to regulate construction of roads and land clearing. We discussed the importance of long-term streamflow and rainfall records and that the USGS streamgages had been discontinued. In 1970, there were 11 gaging stations (5 on Moen; 3 on Tol; 3 on Dublon Island). In 1988, the last station (Wichen River) was removed. The Lt. Governor stated that environmental legislation will be discussed by the legislature on November 5. He stated that an important impediment to progress on environmental issues is education at all levels. There is virtually no understanding for the need for streamflow records anywhere that we visited in FSM. The Lt. Governor stated that there is widespread antipathy to erosion and environmental consequences of sedimentation.

One physical advantage that Chuuk has over Yap is the ready availability of competent rock for subgrade construction and surfacing (Yap must import all hard rock). However, this rock is seldom used for roads because of its cost. Crushed rock costs about \$25/cubic yard, whereas coral dredging is \$12.50/yard. The crushed rock is used for concrete aggregate.

We observed a short road to a new house, an older abandoned house site, and a future house site that typifies many of the problems here. The road leaves the main road and passes an older existing house. This lower segment of the road has some erosion, but it is at a low gradient, has been in place for many years, and has become stable through multiple repairs. The road surface is firm with a rocky subsurface. In contrast, beyond this segment, the road rises sharply (perhaps a 20% grade) for about 300 feet and has become rutted with tire tracks and gullying. The eroded soil has accumulated at the bottom of the hill at a water bar that is deep with slippery clay. Four-wheel drive is now needed to pass this lower 20-foot stretch. Near the top, the road gradient becomes level, then drops to an existing, but new, house. Here, the road has been recently widened using a backhoe. The cutslopes are vertical and there is an inboard ditch of adequate size. However, as the vertical cutslope dries, the soil cracks and falls into the ditch causing it to rapidly fill with soil. Water flows about 200 feet along this ditch to a small concrete box culvert that crosses the road at about 20 degrees. The culvert crossing appears to be a good design, but it is now nearly choked with weeds at the intake. Soil has filled the intake and there is only about a 6-inch diameter hole remaining that was itself nearly blocked with debris. There was a rock cutoff wall constructed at the end of the inboard ditch at the culvert intake and the culvert outfall had rocks placed for energy dissipation. The culvert was well-designed and constructed, but without continued and frequent maintenance will soon become buried and ineffective. Overflow water from this partially clogged culvert is running down and rutting the road surface.

Immediately above this road was a building site that was cleared and apparently abandoned about two years ago. It appears that about 18 inches of soil has been eroded from this bare site. The degraded site has a sparse grass cover and rounded gullies spaced about 5 feet apart and 2 feet deep from bottom to crest. The remainder of the hillside has a dense, grass cover about 4 feet tall.

The new building site is outsloped toward a new sidecast fill. Runoff from this site accumulates, causing small rills and then several deep gullies as the water passes down the new uncompacted fill. Such problems could be minimized if the site was initially back-sloped and the water directed away from the fill and to both sides into the undisturbed vegetation where the cut meets the

natural hillslope. Further, mulch should be placed on the fillslope and a filter windrow of brush placed at the toe of the fill.

#### FEFAN ISLAND

A new circumferential road has been constructed within about the past year by widening the old walking road that was constructed during Japanese or German times. Because of the flat gradient of the road along the old road alignment at the mangrove margin, the new road has a relatively low impact with several exceptions associated with stream crossings. The old walking road crossed small streams using about 4-foot wide by 3-foot high concrete box culverts (bridges). These old box culverts appear to have been constructed with 2- to 3-inch thick concrete slabs placed over similar slabs for the walls, floor, and roadway. This was adequate for foot traffic, but could not support vehicles, and the slabs have broken. Also, the new road was widened and the culverts needed to be extended. These box culverts have now been replaced with round culverts, but in virtually every case, the cross-sectional area of the new culverts are a small fraction of the previous ones and are inadequate to handle the flow during even moderate storms. A 3-foot high by 4-foot wide box culvert is equivalent in area to a 4-foot diameter round culvert. However, the top of the roadway is often 3 feet or less above sea level and a large diameter culvert means that the road over the culvert would be higher than the roadway on either side. During large runoff, the road on either side of the culvert would be flooded before the culvert capacity was reached.

We observed an area where about 5 to 10 acres of mangrove was above the road. Only one 18-inch culvert allowed water to pass into and out of this mangrove. We expect that this does not provide for adequate water circulation. Another 3 or 4 culverts should be installed along the approximately 400-foot length of road. In addition, this size of culvert is probably inadequate to pass the storm discharge from this area--particularly during high tide when the culvert is virtually submerged anyway.

We observed a new access road to a potential building site that was so steep that it is doubtful that a wheeled-vehicle will ever be able to use it unless the roadway is paved. This new road is already a source of sediment. It is not unusual to find numerous examples where access roads are constructed at extremely steep gradients. There seems to be a common desire is to gain access to places without giving adequate consideration to the problems associated with eventually driving a vehicle up the road or maintaining the road surface.

#### POHNPEI

The circumferential road has been constructed and the plan is to pave the entire road over the next several years or perhaps decades. The road is presently paved from Kolonia to just past the Capitol. Paving is presently being extended to just past the Governor's house in U. The next stage will be to extend the paving in Sokehs and proceed along the western side toward Kitti. There are several stretches of road that are quite steep and easily eroded and where the roadside ditches are being deepened by accelerated erosion. A great deal of sediment is continually produced by the heavy traffic on the coral dredging road surface, during even light rain showers. While we were driving from Kitti to U in a light shower, sediment from the road surface had already turned the streams muddy and sediment plumes were visible in the lagoon, even though the rainfall was probably less than 0.1-inch. During heavy

rain, the road surface must produce large amounts of sediment to the streams. Paving the road with properly designed and maintained ditches would substantially reduce sediment loads from this road.

In Kitti, the old Japanese cobble road is still in place. This section of road is quite stable and little sediment would be produced during rains.

It appeared that most of the culverts were undersized to handle large storm runoff. We were unable to find anyone who could tell us the design standards or the size of the design storm for culverts and bridges.

As the road around the island is improved, more branch roads are being constructed toward the interior. The circumferential road is generally flat with much of it being located near the coast or on upland terraces, such as near the capitol (although there are stretches of steep gradient and serious erosion problems). The secondary and tertiary roads to homesites and agricultural areas are nearly all undesigned and, in most cases, have virtually no surfacing materials. Even when surfaced, the thin coating of uncompacted coral dredgings is highly erosive. Compacted roads are rare. Also, the gradient of these roads is extreme--usually going directly upslope along the fall-line. Similar roads are common throughout Yap and Chuuk.

Mass erosion is much more frequent on Pohnpei than on Chuuk, which is, in turn, higher than Yap. Natural landslides are common in the interior steeplands. There is a common belief that farming in the mountains increases landslide frequency. This belief seems reasonable, but we were unable to visit such sites to evaluate the causative factors. Nevertheless, clearly, land clearing for building sites, and particularly leveling land for houses or roads will dramatically increase landslide hazard in these mountains. Expanding roads from the coastal fringe further into the mountains will not only increase erosion rates because of increased road mileage on the island, but the road will become steeper and more unstable in the mountainous interior. In addition, roads always encourage more people to move into previously undeveloped areas, which, in turn, increases the demand for more roads and gives access to heavy equipment. It is important that this cycle of roads, development, expansion, more roads, more expansion, etc, with its attendant environmental consequences, be clearly conceptualized by agencies and the FSM society at large. To date, much of the development has been limited to the coastal fringe, but roads are being pushed inland at an increasing rate. Since these new roads will not have the budget of the circumferential road, their environmental effects will be greater because of lack of design, construction expertise, culverts, subgrade, or surfacing. And, these roads will be accessing steeper and more unstable terrain. Each of these conditions conspire to increase erosion rate and the requirement for frequent and continued maintenance.

We met with U.S. Ambassador Aurelia Erskine Brazeal for about an hour and discussed our impressions of environmental issues, particularly those related to roads and sedimentation. She had been in FSM for about 6 weeks.

#### KOSRAE

There is a common and pervasive problem in Kosrae and all of the States in FSM: no one seems to have an overview of what is going on at a State or National level--at least, either we never found people with a comprehensive view, or the people that we contacted did not volunteer such a view. There appears to be little coordination between agencies and information is poorly dispersed. It seems that in some cases the concept that "knowledge is power"



limits cooperation. On the surface, it seems that in a State such as Kosrae with a 1990 estimated population of 7560, or Yap with 8846 (13,800 including outer islands), that technical information would be widely shared among the few technically educated persons. However, this seems not to be the case.

In comparison to the three other FSM States, Kosrae has several differences that affect the environmental consequences of roads and erosion:

- (1) The fringing reef is close to shore and wave action, though attenuated, can reach shore. Shoreline road fills are subject to wave erosion and must be protected with a strong sea wall or rip rap.
- (2) Sediment entering this narrow lagoon can be redeposited within the lagoon damaging sea grass beds or coral, or, through wave action, eventually may become part of the sandy beach or barrier island. Or, land-derived sediment might be transported through the fringing reef and into the open ocean. In a large lagoon, such as Chuuk, sediment entering the lagoon is likely to stay deposited in the lagoon with little likelihood that it will be driven to shore or out of the lagoon by currents or wave action.
- (3) In some portions of Kosrae there are sandy beaches, while in other portions there are extensive mangroves. There is also a well-developed freshwater swamp above the mangrove in some locations. The trees in the mangrove and swamp are large, but the road is providing new access and the trees are rapidly being cut for fuel wood as the road proceeds. There is presently no sawmill, but Erich Waguk said that someone is planning to bring a portable sawmill to cut the trees.
- (4) Of all of the islands visited, Kosrae has the best rock for roads. Yap must import all of their competent rock and it is used exclusively for concrete aggregate. Chuuk has rock quarries, but the rock must be crushed. On Moen, crushed rock costs \$25/yd and coral was \$12.50/yd. On Pohnpei, crushed rock costs \$15/yd and coral was \$5/yd. On Kosrae, pit run rock costs \$2.50/yd. The lease on the Kosrae rock pit expires this year and the price of rock must be renegotiated. The rock being used on the road is simply tailings left from construction of the runway and airport site. The quarry hillside was last blasted about 1980.

The circumferential road is constructed by pioneering with a bulldozer and sidecasting the fill. No attempt is made to compact the sidecast "because of the rainy weather". Cutslopes are scraped to a 100% slope by excavator. Temporary culverts are installed and later replaced with locally poured concrete box culverts. Box culverts are used instead of bridges or round culverts. The road is being constructed by Kosrae Construction and Engineering Division. They have developed a local expertise in constructing and installing box culverts, but have had difficulty constructing round culverts and bridges. By mid-November, the road is expected to have advanced to Kosrae's largest River. The plan is to install two parallel box culverts rather than a bridge.

After the roadbed is pioneered and constructed using native weathered material, about 18 inches of pit-run rock is imported about 5 miles and laid over the local silt-clay base. Then about 6 inches of coral dredging is placed over the rock base. The road is then left in this condition for "4 to 6 years", then the plan is to later surface the road with chip-seal. Chip-seal surfacing is presently being tested on a stretch of road near Leleu and this surfacing is now being extended to the airport.

In general, this road looks very good. There are a few areas of cutbank slumps, but this is to be expected with a 1:1 cutslope on this deeply weathered basalt. The slumps are easily removed with equipment on site.

The fill slopes are left unprotected during construction and there is evidence of gullying. However, for the road section that we observed, the

downhill side of the road terminated at the upper edge of the freshwater swamp and the eroded material deposits within a short distance. As the road reaches the river and streamflow becomes available to transport the sediment long distances, it will be increasingly important to control the movement of soil from the road.

The potential for damage to the fresh water swamp vegetation by such sedimentation is not known. However, this area is just now being opened to easy access and agriculture is expanding as the road advances. This is a different situation compared to other areas where the road passes through and damages existing agriculture. Perhaps more damaging to the natural vegetation than sediment is the access provided by the road to firewood cutters. In several locations, the mangrove has been clearcut to a distance of several hundred feet on both sides of the road -- well beyond the distance of road sedimentation had the forest remained intact.

One fortunate aspect in Kosrae is that public (government) land extends from the high tide line through the reef. At least there is theoretically a possibility that environmental regulations could provide some protection to the mangrove and lagoon from over-exploitation. The evidence to date is not very encouraging, however. Great dredge holes have been dug in the lagoon to obtain materials for constructing the airport. Environmental protection does not appear to be high on the agenda, but neither does planned exploitative destruction. Education and awareness of the costs, risks, and benefits over varying time frames is critical to informed use or protection of these resources. Unfortunately, the data and infrastructure for such a program seem lacking. On Kosrae, there is a reasonable probability that if the community and central church organizational structure could be tapped, a better informed and stronger ecological ethic could emerge.

**APPENDIX 2.**

**Hydraulic analysis, Circumferential Road Project, Kosrae State.**

# **DESIGN STANDARDS**

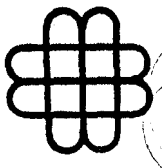
**FOR**

**KOSRAE CIRCUMFERENTIAL ROAD  
EXTENSION PROJECT**

**PREPARED FOR**

**STATE OF KOSRAE**

**OCTOBER 9, 1987**



**BARRETT CONSULTING GROUP INC.**

**12 SOUTH KING STREET, SUITE 200**

**HONOLULU, HAWAII 96813**

## CHAPTER IV

### DRAINAGE STRUCTURES

#### CALCULATION OF FLOW RATE

##### RATIONAL METHOD

For small drainage areas of 100 acres or less, the rational method shall be used to compute the flow rates.

The Formula  $Q = CIA$  shall be used to determine quantities of flow rate, in which:

$Q$  = Flow rate in cubic feet per second;

$C$  = Runoff coefficient;

$I$  = Rainfall intensity in inches per hour for a duration equal to the time of concentration; and

$A$  = Drainage areas in acres.

##### A. Runoff Coefficient (C)

The runoff coefficient shall be determined from Table 1 (Standard Detail No. 32) for agricultural and open areas and from Table 2 (Standard Detail No. 33) for built-up areas. Land usage shall be based on the ultimate use of the drainage area. For distinctive composite drainage areas, a weighted value of runoff coefficient shall be used.

##### B. Time of Concentration (Tc)

The time of concentration for runoff, from the beginning or highest point in the drainage basin to the point of discharge (i.e., inlet of design culvert), is utilized to convert one-hour rainfall to rainfall intensity of various durations (see Table 5, Standard Detail No. 34). Methods for determining Tc are listed below.

1. Determine overland flow time from Table 4 (Standard Detail No. 34) generally. for paved, bare soil and grassed areas.

2. Determine flow time over small agricultural areas with well defined divides and drainage channels from Table 6 (Standard Detail No. 35).
3. In case of uncertainty, check the time of concentration by dividing the estimated longest route of runoff by the appropriate runoff velocity from Table 3 (Standard Detail No. 33).

**C. Rainfall Intensity (I)**

1. Since there is insufficient local climatological data for Kosrae, assume a one-hour rainfall intensity value of 3.5 inches for recurrence interval ( $T_m$ ) of 10 years. This assumption is based on a comparison to the islands in the state of Hawaii which have similar topography, terrain and average rainfall to that of Kosrae.
2. Enter Table 5 (Standard Detail No. 34) with the rainfall intensity duration equal to the required time of concentration. Select the corresponding correction factor, and multiply the one-hour rainfall value of 3.5 inches by the factor to obtain the design rainfall intensity.

**D. Drainage Area (A)**

The drainage area shall be determined from United States Geological Survey (USGS) topographic maps or other topographic maps suitable for delineating the hydrologic boundaries of the drainage basin.

**E. Example**

A two-acre drainage basin near Utwe is covered with an average grassed surface. Runoff drains into a moderately steep ditch at an approximate grade of 10 percent and a length of 300 feet. Compute the runoff flow rate from the ditch at its discharge point into the Pacific Ocean.

1. The runoff coefficient ( $C$ ) as determined from Table I is 0.40.
2. The time of concentration ( $T_c$ ) as determined from Table 4 is 14 minutes.
3. The rainfall correction factor ( $CF$ ) as determined from Table 5 is 2.0.

4. The design rainfall intensity (I) is computed by multiplying the one-hour rainfall (i) of 3.5 inches by the correction factor, where:

$$I = (i)(CF) = (3.5)(2.0) = 7.0 \text{ inches per hour}$$

5. Compute the flow rate (Q), where:

$$Q = CIA = (0.40)(7.0)(2) = 5.6 \text{ cubic feet per second}$$

#### **SOIL CONSERVATION SERVICE (SCS) METHOD**

For drainage areas larger than 100 acres, the Soil Conservation Service (SCS) method or flow analysis based upon measured streamflow rates should be utilized.

The SCS method estimates peak runoff from a drainage basin based on rainfall amounts, soil types, land use, ground cover conditions and average drainage basin slope. Rainfall is the principal source of water that may run off the surface of small drainage basins. The kind of soil and type of vegetation growing in it have a major effect on the amount of water that runs off. Mechanical treatment on a watershed, along with its topography and shape, affect the rate at which water runs off. The combined effects of soil, vegetative cover and conservation practices on the amount of rainfall that runs off the drainage basin are represented by "runoff-curve numbers" (CNs). The relationships between CNs and other drainage basin parameters will be described subsequently in this section.

##### **A. Hydrologic Soil Groups**

The hydrologic soil classification (i.e., A, B, C or D) is an indicator of the minimum rate of infiltration obtained for a bare soil after prolonged wetting. By using the hydrologic classification and the associated land use, runoff curve numbers can be determined as discussed hereafter.

The hydrologic soil classifications, as defined by SCS soil scientists, are as follows:

- A. (Low runoff potential) Soils having high (rapid) infiltration rates when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands or gravels, but include some soils with strong micro-aggregation. These soils have a high rate of water transmission;
- B. (Moderately low runoff potential) Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures and moderately slow to moderately rapid permeability. These soils have a moderate rate of water transmission;
- C. (Moderately high runoff potential) Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, soils with moderately fine to fine texture, or soils with moderate water table. These soils may be somewhat poorly drained; or they may be well and moderately well drained soils with slowly and very slowly permeable layers (hardpans, hard bedrock and the like) at moderate depth (20 to 40 inches). These soils have a slow rate of water transmission; and
- D. (High runoff potential) Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

Hydrologic soil classifications for each soil series found on Kosrae are provided in Table 7 (Standard Detail No. 52). The location of soil series can be found on the maps provided in the report entitled, "Soil Survey of, Island of Kosrae, Federated States of Micronesia, March 1983," by the U.S. Department of Agriculture, Soil Conservation Service.

#### B. Runoff Curve Numbers

Once land use and hydrologic soil classification are known for a particular drainage basin, the aforementioned runoff curve numbers (CNs) can then be determined from Table 8 (Standard Detail No. 53).



Depth of runoff for particular CNs and amount of rainfall can be determined from Table 9 (Standard Detail No. 54).

**C. Peak Rate of Discharge**

After determining the curve number and drainage area (in acres), the peak discharge of a basin (in cubic feet per second, CFS, per inch of runoff) can be determined for flat, moderate or steep sloped basins from Standard Detail Nos. 55, 56, and 57, respectively. Subsequently, the peak discharge (in CFS) can then be determined by multiplying the peak rate of discharge by the runoff depth.

The peak rates of discharge in Standard Detail Nos. 55, 56 and 57 are based upon a 24-hour duration storm with a flat, one percent slope; moderate, four percent slope; or steep, 16 percent slope. Adjustments to the peak rate of discharge for slopes different from the one, four or 16 percent slopes may be accomplished by using Table 10 (Standard Detail No. 58).

**D. EXAMPLE 1**

Compute the peak discharge for a 1,000-acre drainage basin with an average slope of seven percent and a CN of 80 for four inches of rainfall.

1. Determine the peak discharge for a watershed with a moderate slope (four percent). From Standard Detail No. 56, read a peak discharge of 192 CFS per inch of runoff for 1,000 acres and a CN of 80. From Table 9, find 2.04 inches of runoff for four inches of rainfall and a CN of 80. The peak discharge is then  $192 \times 2.04$  or 392 CFS.
2. Determine the interpolation factor. From Table 10, find seven percent slope under MODERATE heading and read an interpolation factor of 1.23 for a drainage area of 1,000 acres. (The peak from a 1,000-acre drainage basin with a slope of seven percent is 1.23 times greater than for an average basin slope of four percent.)
3. Determine the peak discharge for seven percent slope.

$$q = (392)(1.23) = 482 \text{ CFS}$$

## **E. EXAMPLE 2**

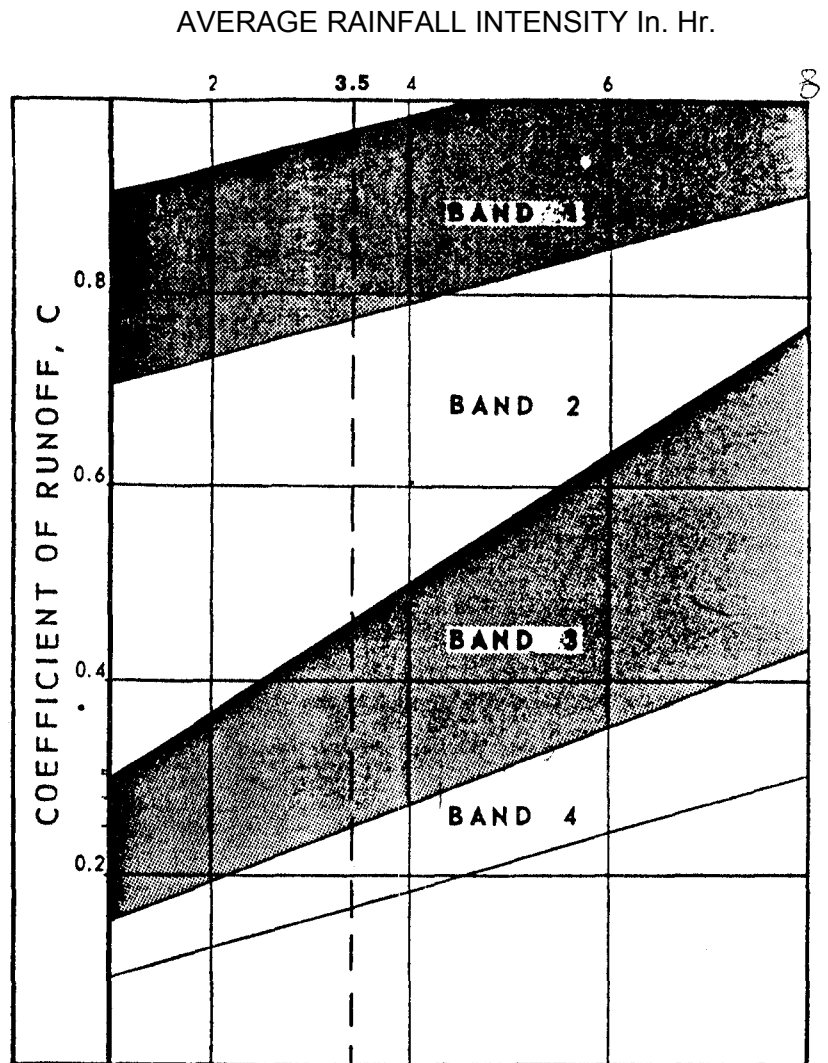
**Compute the peak discharge for a 15-acre drainage basin with an average slope of 0.5 percent and a runoff curve number of 80 for four inches of rainfall.**

- 1. Determine the peak discharge for a watershed with a flat slope (one percent). From Standard Detail No. 55 read a peak discharge of 6.3 CFS per inch of runoff for 15 acres and a CN of 80. From Table 9, find 2.04 inches of runoff for four inches of rainfall and a CN of 80. The peak discharge is then  $6.3 \times 2.04$  or 13 CFS.**
- 2. Determine the interpolation factor. From Table 10 find 0.5 percent slope under FLAT heading. Read a slope interpolation factor of 0.81 interpolated between the values for 10 acres and 20 acres.**
- 3. Determine the peak discharge for 0.5 percent slope.**

$$q = (13)(.81) = 10 \text{ CFS}$$

# Table 1

RUNOFF COEFFICIENT  
FOR AGRICULTURAL  
AND OPEN AREAS



- |        |  |
|--------|--|
| BAND 1 | Steep, barren, impervious surfaces   |
| BAND 2 | Rolling barren in upper band values, flat barren in lower part of band, steep forested and steep grass meadows |
| BAND 3 | Timber lands of moderate to steep slopes, mountainous, farming   |
| BAND 4 | Flat pervious surface, flat farmlands, wooded areas and meadows  |

SOURCE: CITY AND COUNTY OF HONOLULU  
DEPARTMENT OF PUBLIC WORKS

**Table 2****MINIMUM RUNOFF COEFFICIENTS FOR BUILT-UP AREAS**

<b>RESIDENTIAL AREAS:</b>	<b>C = 0.55 to 0.70</b>
<b>HOTEL-APARTMENT AREAS:</b>	<b>C = 0.70 to 0.90</b>
<b>BUSINESS AREAS:</b>	<b>C = 0.80 to 0.90</b>
<b>INDUSTRIAL AREAS:</b>	<b>C = 0.80 to 0.90</b>

*The type of soil, the type of open space and ground cover and the slope of the ground shall be considered in arriving at reasonable and acceptable runoff coefficients.*

**Table 3****APPROXIMATE AVERAGE VELOCITIES OF RUNOFF  
FOR CALCULATING TIME OF CONCENTRATION**

<b>TYPE OF FLOW</b>	<b>VELOCITY IN FPS FOR SLOPES (in percent) INDICATED</b>			
	<b>0-3%</b>	<b>4-7%</b>	<b>8-11%</b>	<b>12-15%</b>
<b>OVERLAND FLOW:</b>				
Woodlands	1.0	2.0	3.0	3.5
Pastures	1.5	3.0	4.0	4.5
Cultivated	2.0	4.0	5.0	6.0
Pavements	5.0	12.0	15.0	18.0
<b>OPEN CHANNEL FLOW:</b>				
Improved Channels	Determine Velocity by Manning Formula			
Natural Channel* (not well defined)	1.0	3.0	5.0	8.0

*\*These values vary with the channel size and other conditions so that the ones given are the averages of a wide range. Wherever possible, more accurate determinations should be made for particular conditions by Manning Formula or from Plate 5.*

**SOURCE: CITY AND COUNTY OF HONOLULU  
DEPARTMENT OF PUBLIC WORKS**

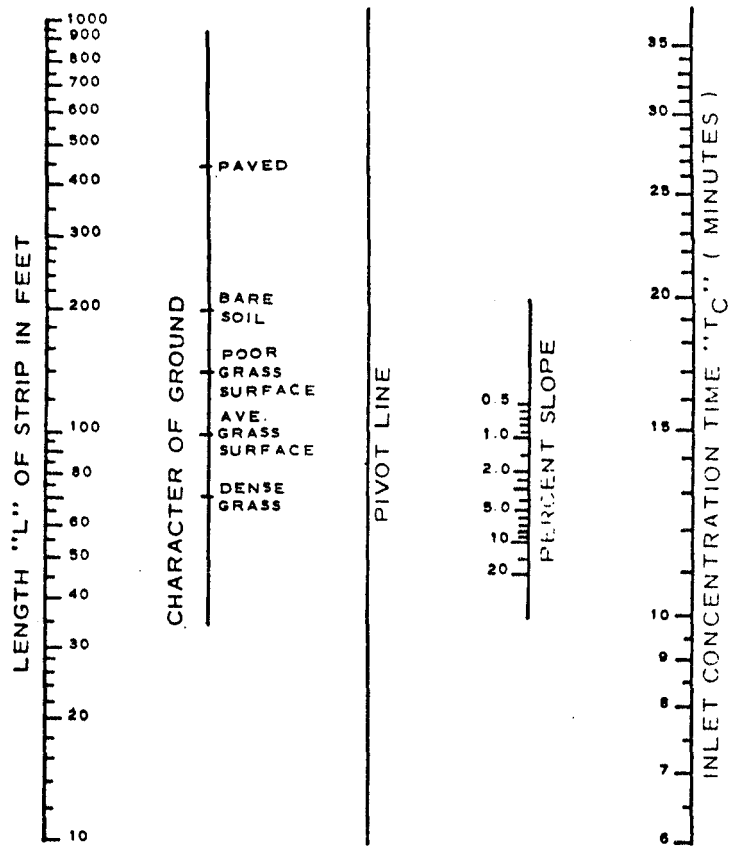
**OFFICE OF CONSTRUCTION & ENGINEERING  
STATE OF KOSRAE**

**DESIGN STANDARDS FOR  
CIRCUMFERENTIAL ROAD  
EXTENSION PROJECT**

**STANDARD  
DETAIL NO.  
  
33**

# TABLE 4

## Overland Flow Chart

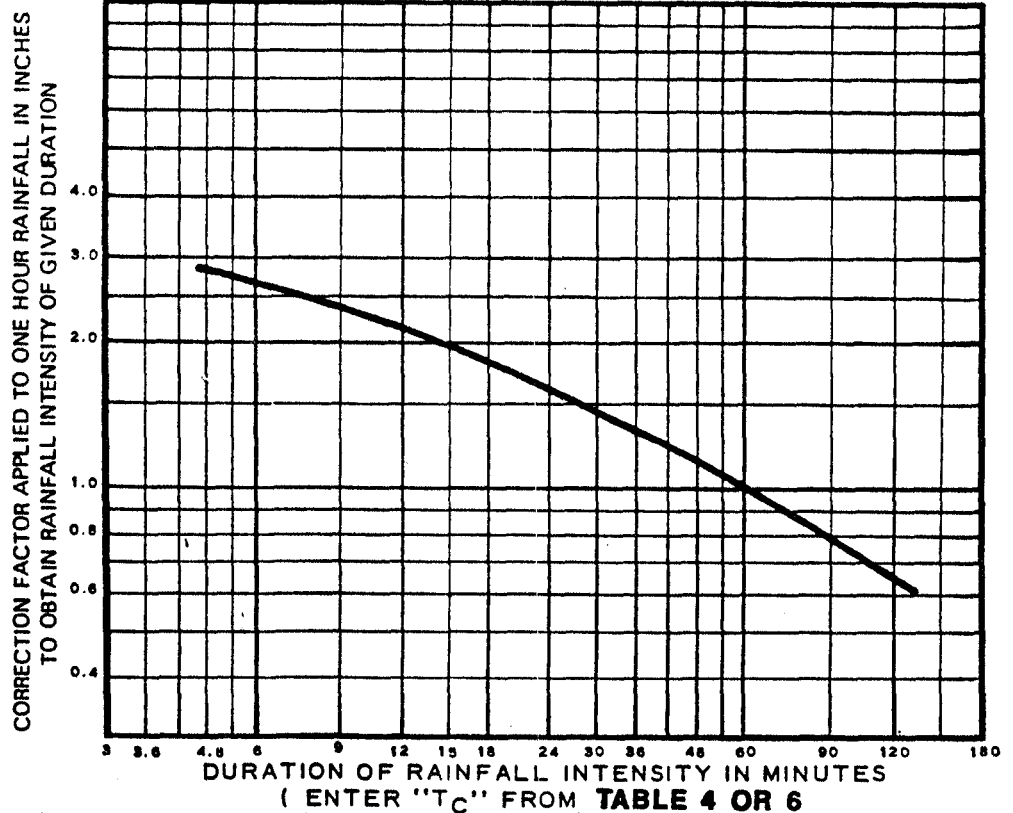


# TABLE 5

## CORRECTION FACTOR

FOR CONVERTING 1 HR RAINFALL  
TO RAINFALL INTENSITY  
OF VARIOUS DURATIONS

TO BE USED FOR AREA  
LESS THAN 100 ACRES



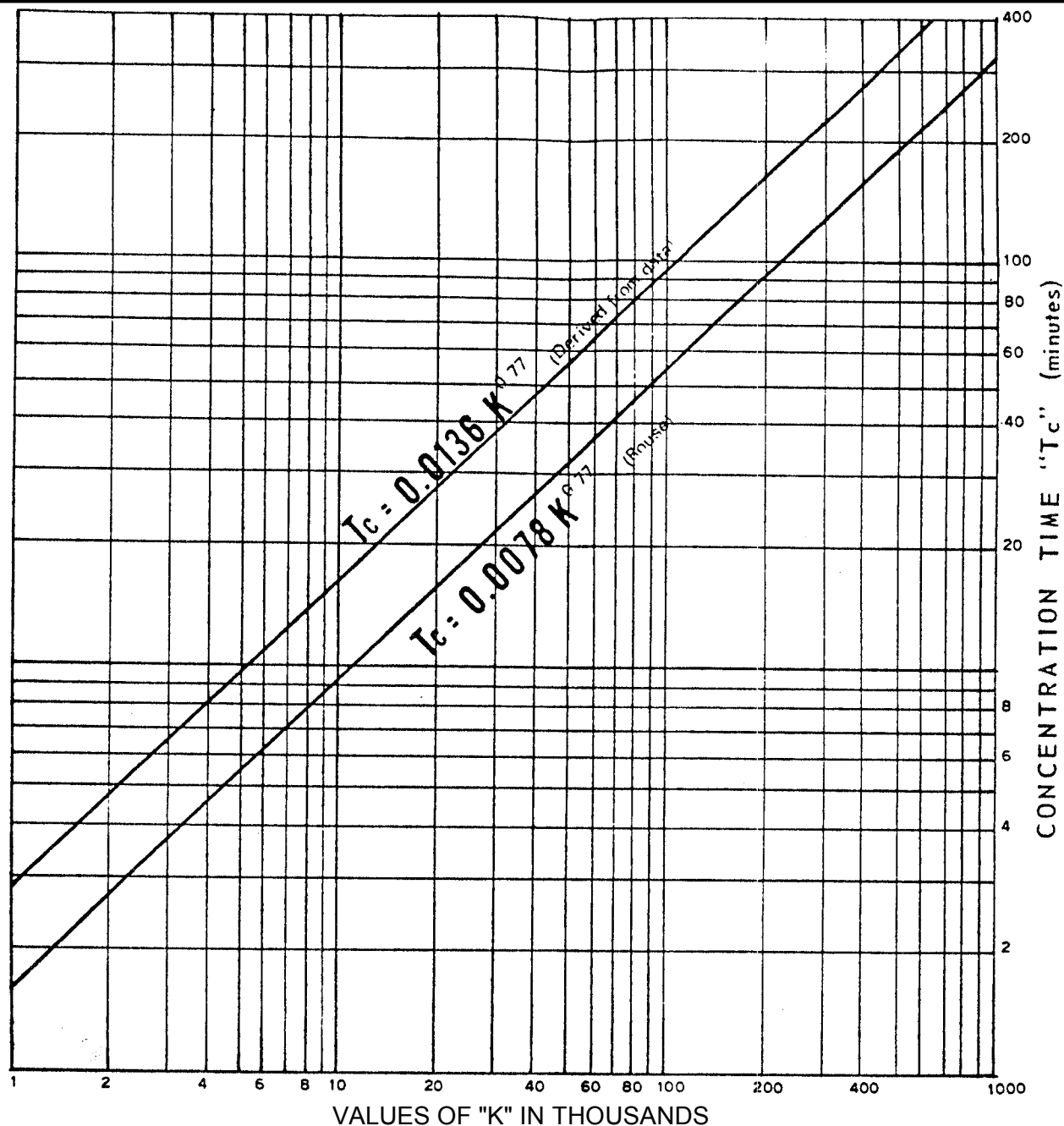
SOURCE: CITY AND COUNTY OF HONOLULU  
DEPARTMENT OF PUBLIC WORKS

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STATE OF KOSRAE

DESIGN STANDARDS FOR  
CIRCUMFERENTIAL ROAD  
EXTENSION PROJECT

STANDARD  
DETAIL NO.

34



L = Maximum length of travel in feet  
H = Difference in elevation between most remote point and outlet in feet.  
S = Slope H/L

$$K = \frac{L}{\sqrt{S}} = \sqrt{\frac{L^3}{H}}$$

Use upper curve for well forested areas  
Use lower curve for areas with little or no cover.

NOTE. Use 5 minutes if Tc is 5 minutes or less.

**TABLE 6**

## Time of Concentration

(OF SMALL AGRICULTURAL DRAINAGE BASIN)

SOURCE: CITY AND COUNTY OF HONOLULU  
DEPARTMENT OF PUBLIC WORKS

OFFICE OF CONSTRUCTION & ENGINEERING  
STATE OF KOSRAE

DESIGN STANDARDS FOR  
CIRCUMFERENTIAL ROAD  
EXTENSION PROJECT

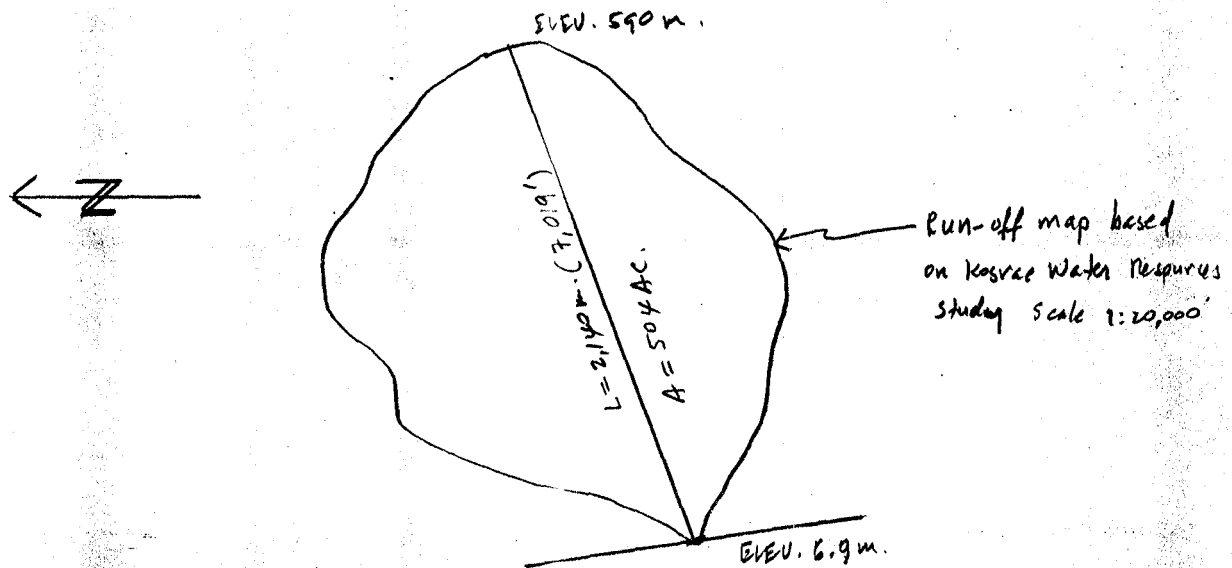
STANDARD  
DETAIL NO.  
35

PROJECT: RS-3 CIRCUMFERENTIAL ROAD PROJECT	DEPARTMENT OF PUBLIC WORKS	SHEET NO. 1
ITEM HYDRAULIC ANALYSIS	KOSRAE STATE, ECI 96944	JOB NO.
		DATE 8-25-87
		ENGINEER: A.M. BAHILLO

STA. 86+00

### HYDRAULIC COMPUTATION

25 YEARS FREQUENCY  
MELO RIVER



#### I- TIME OF CONCENTRATION ( $T_c$ )

$$\text{Highest Point} = 590 \text{ m.} = 1,935.20'$$

$$\text{lowest Point} = 6.90 \text{ m.} = 22.63'$$

$$\text{Diff. in elev. (H)} = 1,912.57'$$

$$\text{Slope (S)} = \frac{H}{L} = \frac{1,912.57}{7,019} = 27.25\%$$

From Fig. 2-1 (Attached)

$$m = \frac{L}{\sqrt{S}} = \frac{7019}{\sqrt{0.2725}} = 13,446.00$$

$$\text{Time of Concentration } (T_c) = 18.50 \text{ Min.}$$

PROJECT: RS-3 CIRCUMFERENTIAL ROAD PROJECT	DEPARTMENT OF PUBLIC WORKS	SHEET NO. 2
ITEM HYDRAULIC ANALYSIS	KOSRAE STATE, ECI 96944	JOB NO.
		DATE 8-25-87
		ENGINEER: A. M. BAHILLO

STA. 86+00

II - RUN-OFF COEFFICIENT = 0.275 (FORESTED AREA)

III - RAINFALL - INTENSITY (see Fig. C)

Ref. Washington D.C. Rainfall Intensity Data Multiplied  
by 1.25 (Multiplier Factor) for Kosrae Rainfall  
Intensity.

$$I = 5.40 \times 1.25 = 6.75 \text{ inches/hr. @ 25 years return period}$$

IV - DISCHARGE : ( $Q_{25}$ )

$$Q = C I A$$

$$Q_{25} = 0.275 \times 6.75 \times 504 = \underline{935.55 \text{ cfs.}}$$

See Chart 1 and Fig. 7 for determining  
the headwater :

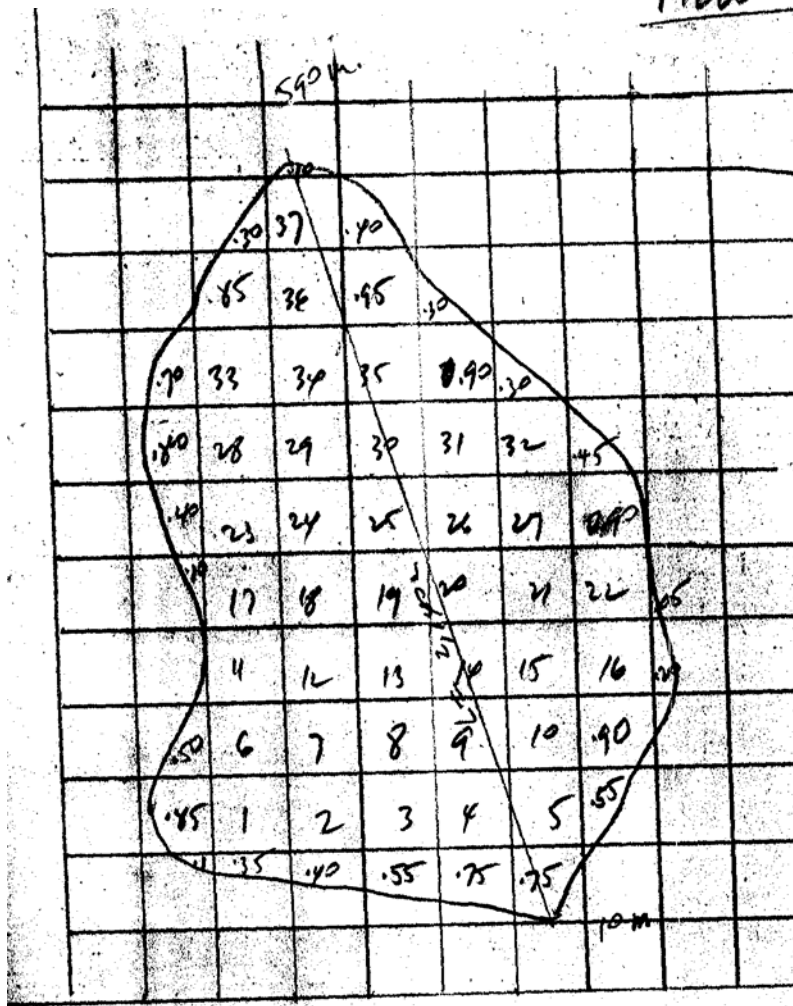
Use R.C. Box Culvert : 12' x 10'



STA. 86+00

MEW

12



Kosice Water Resources Study  
Principal Watersheds

SCALE:

1:20,000

$$50.40 \text{ squares} \times 4 \text{ ha/square} = 201.6 \text{ ha.}$$

$$A = \frac{201.6}{0.4} = \underline{\underline{504 \text{ AC.}}}$$

STA. 86+00

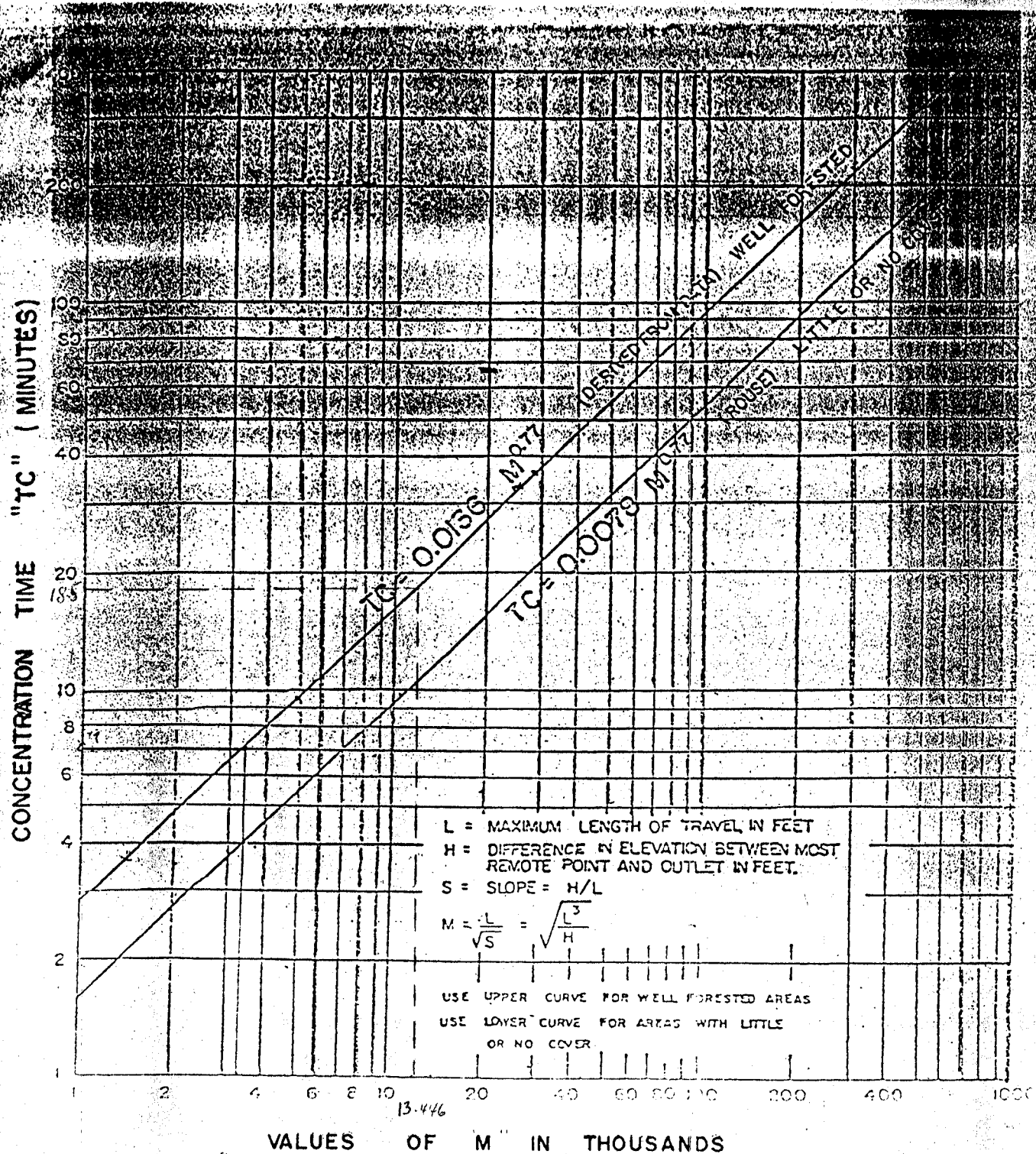


FIGURE 2-1 TIME OF CONCENTRATION OF SMALL AGRICULTURAL DRAINAGE BASINS

STA. 86+00

FIG - C

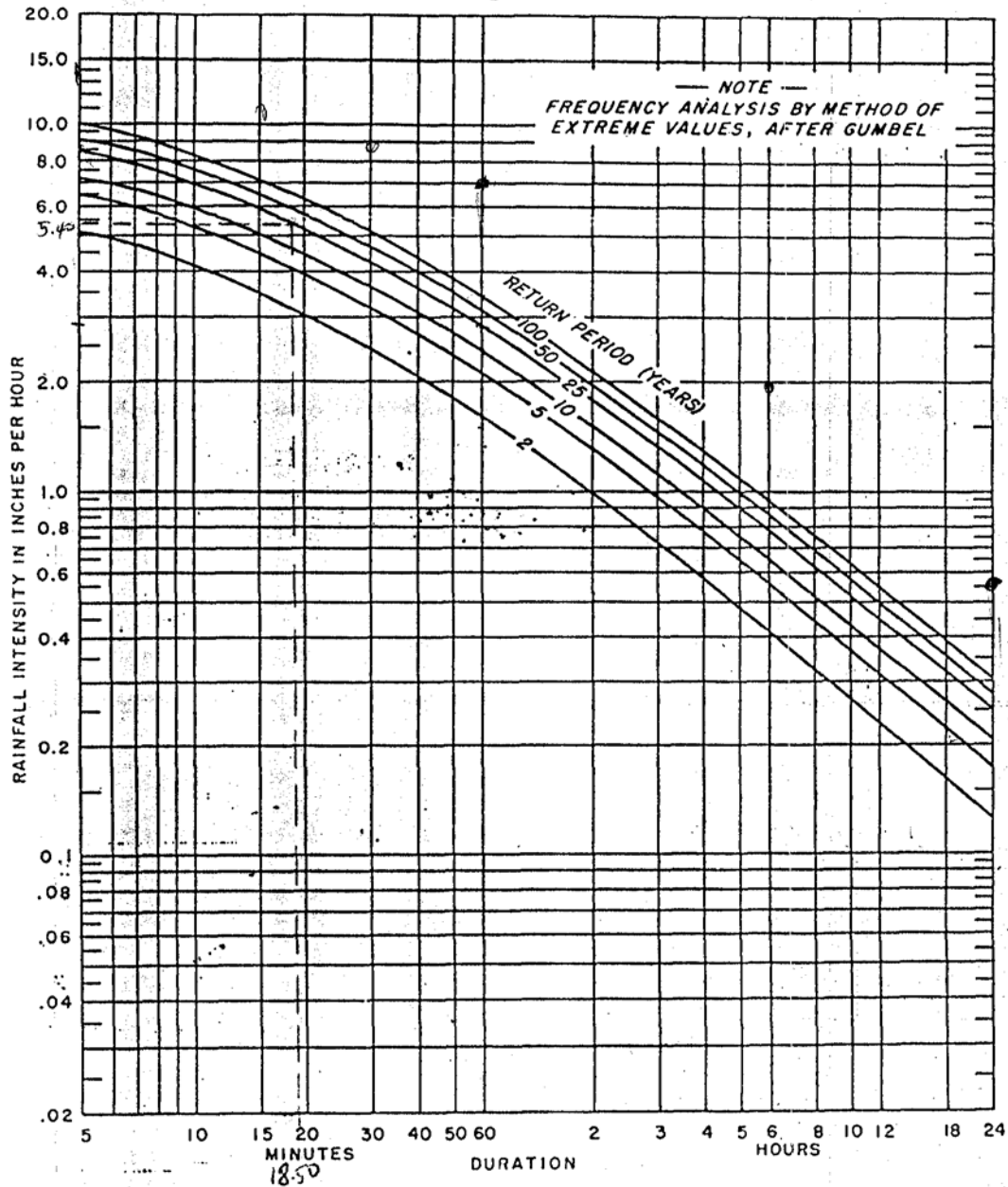
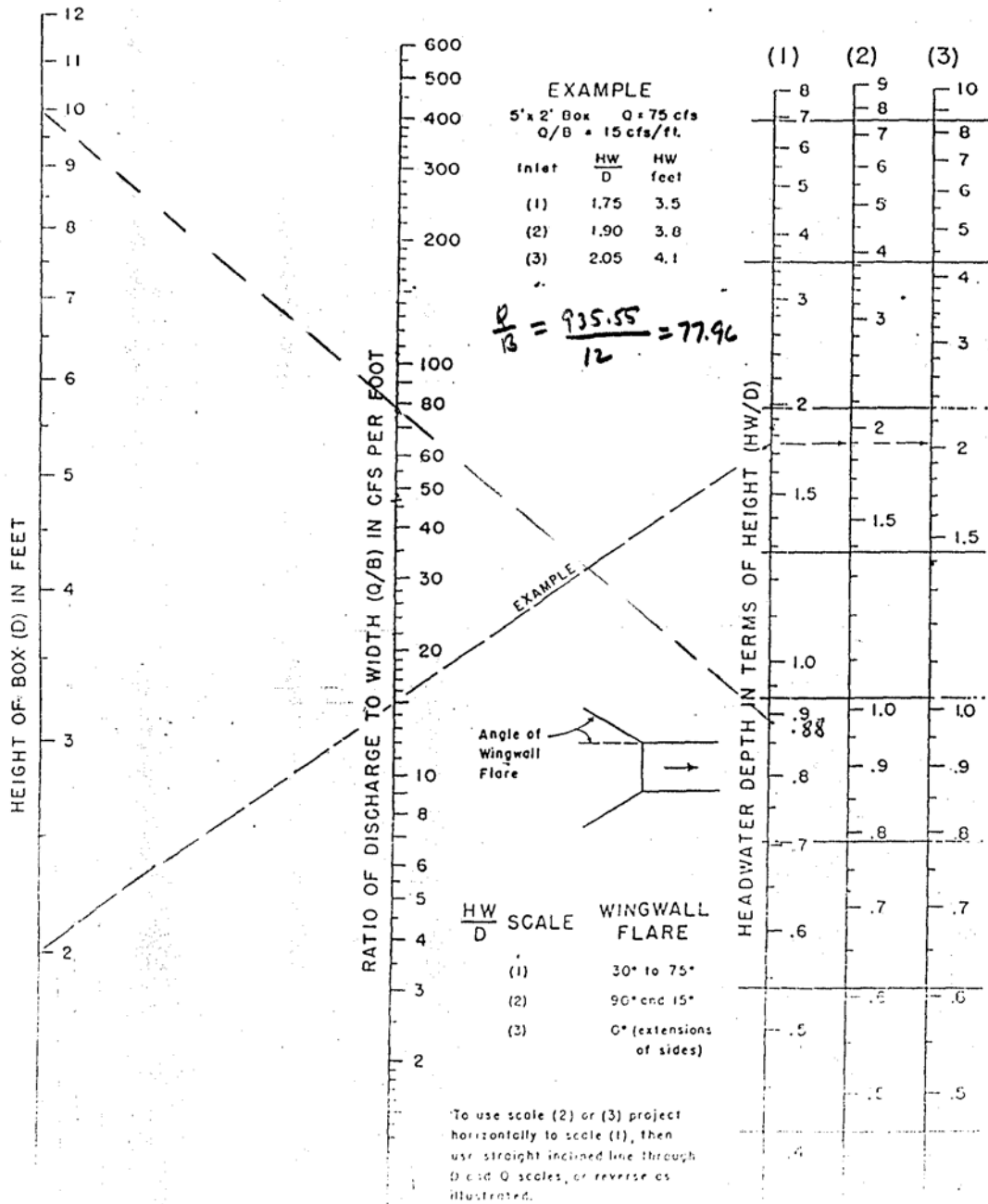


FIG. 6 RAINFALL INTENSITY-DURATION-FREQUENCY CURVE  
FOR WASH., D.C., 1896-97, 1899-1953 (U.S. WEATHER BUREAU)

Figure 6.—Rainfall intensity—duration—frequency curve for Wash. D.C., 1896-97, 1899-1953  
(U.S. Weather Bureau).

# CHART 1



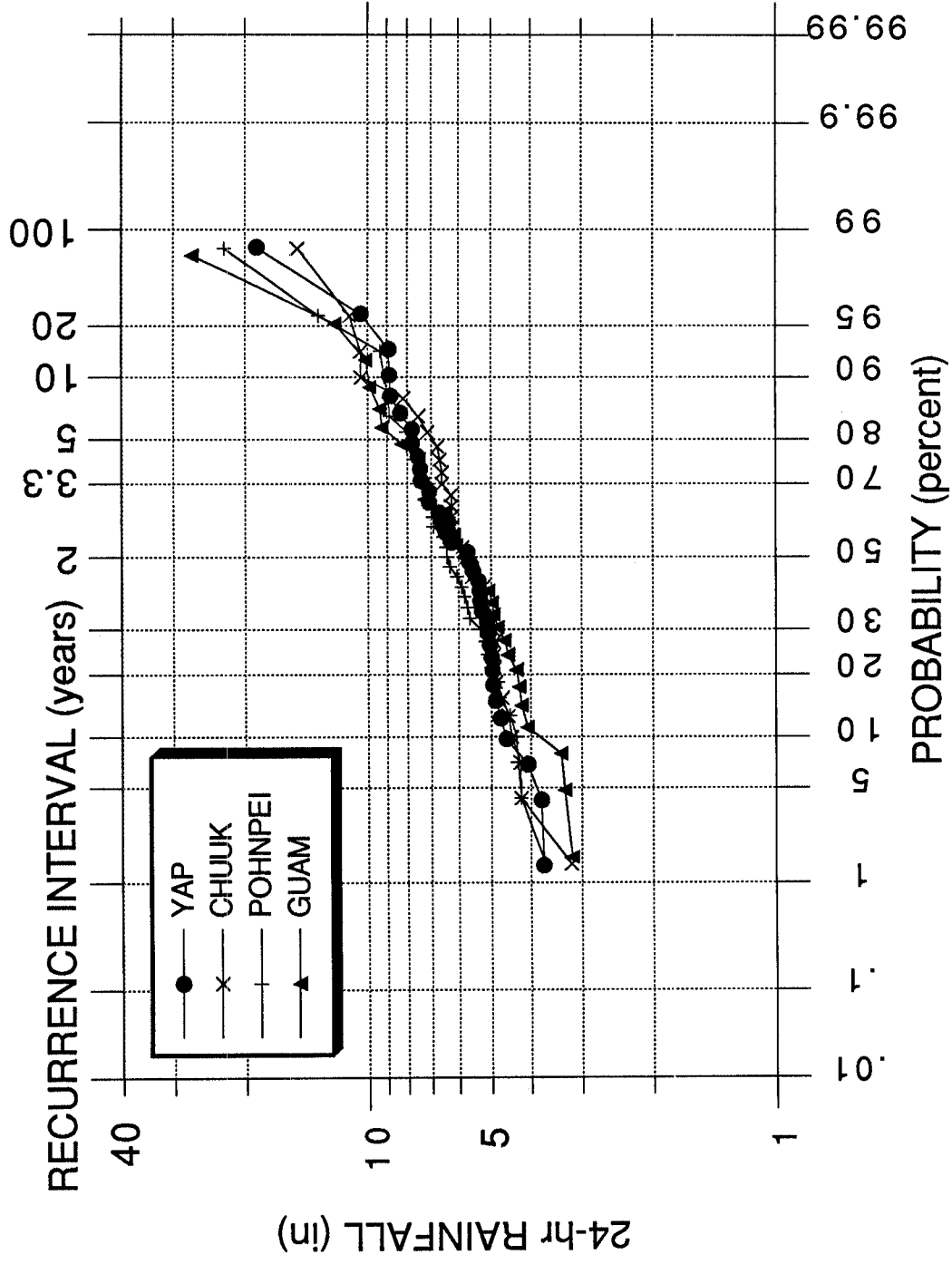
HEADWATER DEPTH

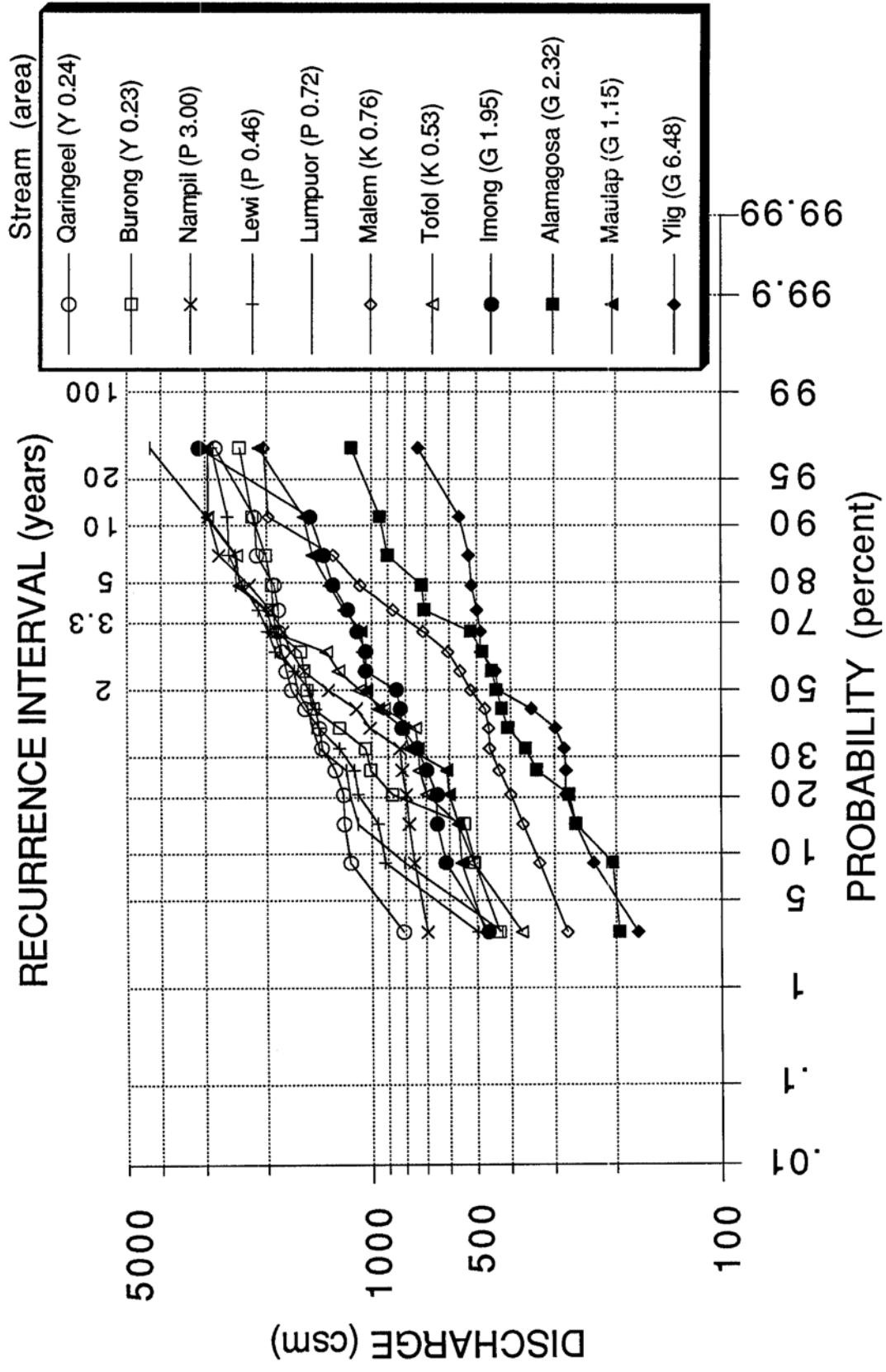
WITH INLET CONTROL

[illegible]

**APPENDIX 3.**

**Rainfall and annual instantaneous peak flows for the FSM.**



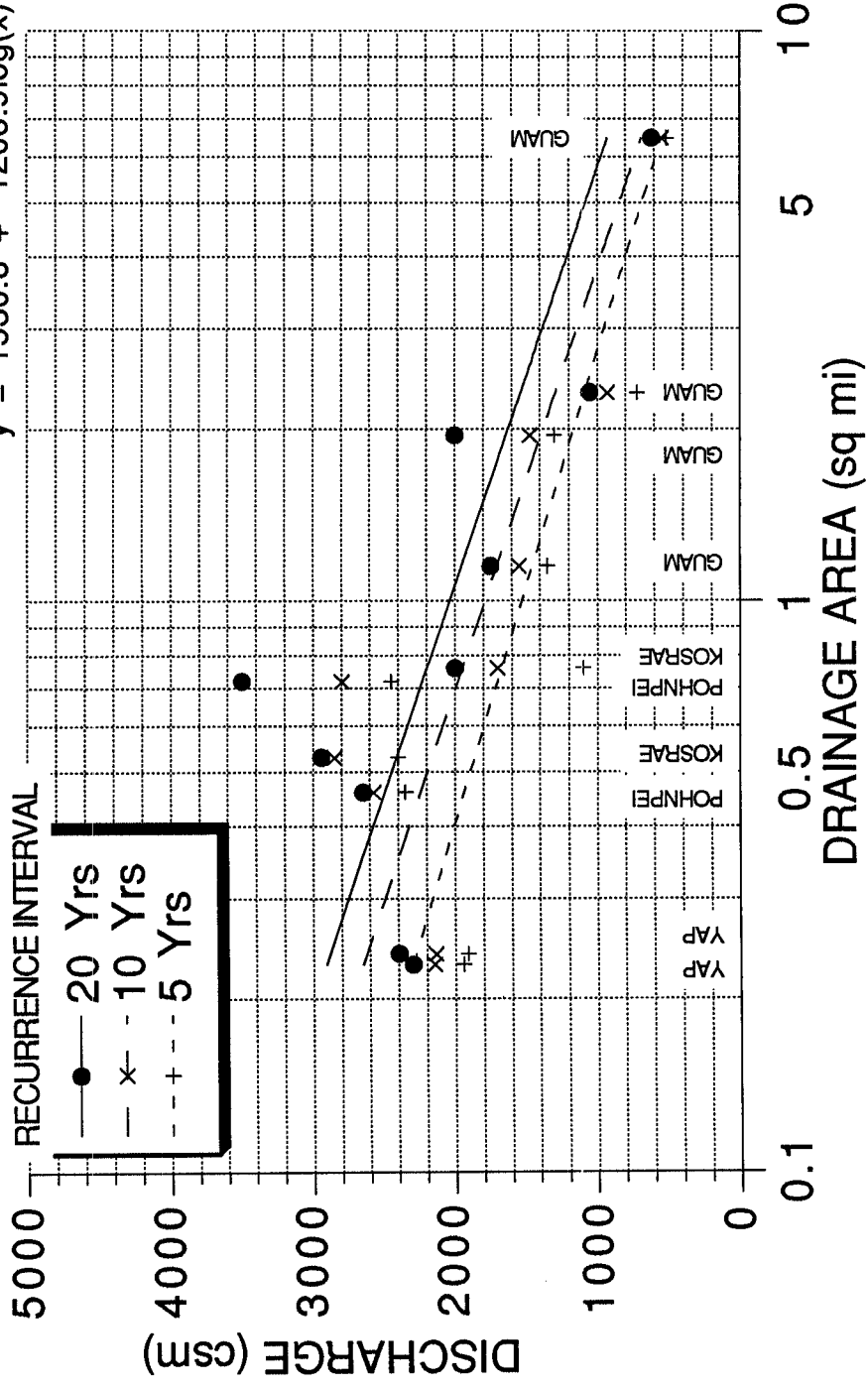




$$\text{---} y = 2038.6 + -1367\log(x) \quad R = 0.72919$$

$$\text{-- --} y = 1790.2 + -1352.2\log(x) \quad R = 0.79439$$

$$\text{---} y = 1530.8 + -1206.9\log(x) \quad R = 0.77715$$



**APPENDIX 4.**

**List of workshop attendees.**

# ATTENDANCE--YAP

George Ken	DAF 350-2183
John Waayun	OPB 350-2166
Godfrey Chochol	OPB 350-2166
Joe Xavier	EPA 350-2113
Sean Baker	EPA 350-2113
Richard Schnabel	CAT 350-2189
Louis Lukan Gan	WTC 350-2300
Ben Nifsag	EPA 350-2113
Francis Faney	EPA 350-2113
Paul Paatwag	MRMD 350-2294
Melinda Pianifen	YINS 350-3115
Martin Faimaw	YINS 350-3115
S. Nallanathan	Com CE Yap 350-2296
Daniel Gafalyer	CES/Com Yap 350-2325
Carmen Chigiy	YINS 350-3304
Pius Liyagel	R&D Forestry Section 350-2183
Like Gilnifrad	ED Dept 350-2200
Jay K.L. Karmacharya	DAF 350-2183

## ATTENDANCE--CHUUK

Maxima T. Baroy	Dept of Agriculture Box 219, Weno 330-2755
Joe Konno	EPA Box 400 330-2395
Kit Dahl	Sea Grant/CCM Box 159, Kolonia, Pohnpei 320-2482
Amanisio L. Joseph	Dept of Agriculture Box 219, Weno 330-2755
Solden Manas	Dept of Commerce & Industry Box 513 330-2552
Tolove Takis	UMDA Box BK 330-2227
Tim S. Apichin	Dept of Agriculture Box 219, Weno 330-2755
Sleeper Sarad	Dept of Agriculture Box 219, Weno 330-2755
Leo M. Shirai	Rural Sanitation Program P.O. Box 400 330-2389
Sixto T. Howard	Private P.O. Box 523 330-2293
Risauo R. Alifios	Environmental Health & Sanitation P.O. Box 400 330-2395
Excuse Sananap	PW P.O. Box 670 330-2244
Hermes Refit	Dept of Agriculture P.O. Box 219 330-2755

Joakim K. Kaminanga      Dept of Public Works  
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Joshua Simon              EPA  
P.O. Box 400  
330-2395

Kowas Santa              EPA  
P.O. Box 400  
330-2395

Innocente Penno          Dept of Agriculture  
Box 219  
330-2755

Julian Sivas              Dept of Agriculture  
Box 219  
330-2755

## ATTENDANCE--POHNPEI

Nora Devoe	USDA Forest Service/IPIF 1151 Punchbowl St., Rm. 323 Honolulu, HI 96813 (808)-541-2628
Felisa Alteros	Pacific Missionary Aviation Kolonia
Iper Irens	Public Works Nett District Government Nett
Valentine Amor	Chief of Public Works U Municipal Government U
Toshiro Ludwig	Chief Division of Marine Resources Department of C & RS Kolonia
Flinn Curren	Advisor Division of Marine Resources Dept. of C & RS Kolonia
Adelino Lorens	Chief Division of Agriculture Dept. of Conservation & Resources Surveillance Kolonia
Augustine Damarlane	Equipment Services Division of Agriculture Department of Conservation & Resource Surveillance Kolonia
Arthur Solomon	Construction Management Division (CMD) Division of Planning, Budget, and Statistics Pohnpei State Government Kolonia
Welsin Hemon	Construction Management Division (CMD) Division of Planning, Budget, and Statistics Pohnpei State Government Kolonia
Bermin Weilbacher	Director Department of Conservation and Resource Surveillance Pohnpei State Government Kolonia
Sungiwo Hadley	Department of Land

	Pohnpei State Government Kolonia
Immensio Eperiam	Chief Historic Preservation Division Department of Land Pohnpei State Government Kolonia
John Weilbacher	Department of Land Pohnpei State Government Kolonia
Andre Adams	Engineer Office of Planning and Statistics FSM National Government Palikir
Daniel Isaac	Office of Planning and Statistics FSM National Government Palikir
Bill Raynor	Researcher College of Micronesia Land Grant Program P.O. Box 1179 Kolonia
Reuben Dayrit	USDA Soil Conservation Service F.S.M. Office P.O. Box 24 Kolonia
Robert Wescom	Agroforester USDA Soil Conservation Service Suite 602, 414 W. Soledad Ave. Agana, GUAM 96910 (617) 477-5940
Anthony Bird	Civic Action Team P.O. Box 507 Kolonia
Kit Dahl	Sea Grant Community College of Micronesia (CCM) Kolonia
Herson Anson	Chief Division of Forestry Dept. of Conservation & Resource Surveillance Kolonia
Salis Peter	Division of Forestry Dept. of Conservation & Resource Surveillance Kolonia

Tadasy William	Division of Forestry Dept. of Conservation & Resource Surveillance Kolonias
Valentine Santiago	Division of Forestry Dept. of Conservation & Resource Surveillance Kolonias
Mike Gawel	Marine Resources Division Dept. of Resource and Development FSM National Government Palikir
Sado Martin	Pohnpei Transportation Authority (PTA) P.O. Box 36 Kolonias



## ATTENDANCE--KOSRAE

Chanry Likiakon	KSL 370-3019
Jim Obrien	KSL 370-3019
Abraham M. Bahillo	DPW 370-3011
Bruce Howell	Office of Planning & Budget Construction & Engineering Div 370-3169 FAX 370-3058
Jack Sigrah	Kosrae Marine Resources Div 370-3031
Kasuo Isisaki	KSL 370-3019
Antonio Su Sison	Office of Planning & Statistics 370-3163
Fanry Albert	Environmental Protection Board 370-3608
Erich Waguk	State Forester 370-3017
Mike Molina	Kosrae Marine Resources Board 370-3031
Likiak P. Wesley	Planning & Statistics 370-3163
Meriwether Wilson-Molina	Island Resources Consultant 370-2233
Katchuo William	Environmental Health Division 370-3199
Ittu Ittu	Land Management 370-3026