



Environmental Impact Statement Inarajan River Dam Project

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WERI

**WATER AND ENVIRONMENTAL RESEARCH INSTITUTE
OF THE WESTERN PACIFIC
UNIVERSITY OF GUAM**

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ABSTRACT

At the request of the Guam Waterworks Authority (GWA) formally known as (PUAG) the Barrett Consulting Group (1994) completed surface water development study for the southern Guam. The purpose of this study was to determine the feasibility of developing surface water resources in Southern Guam. According to this study a number of potential dam sites were evaluated. One of the projects suggested is the construction of a dam and a storage reservoir site on Inarajan River, immediately downstream from its confluence with Laolao River. This Environmental Impact Statement report was prepared by Mr. Danko Taborosi and Dr. Khosrowpanah as a class project for the Environmental Impact Assessment EV 513. The format that has been used is in accordance with the Council on Environmental Quality (CEQ) regulation that set forth the National Environmental Policy Act. (NEPA) procedures.

The proposed action is the construction of a dam on Inarajan River, immediately downstream from its confluence with Laolao River. For the purpose of this study, only a No Action alternative was evaluated in addition to the Proposed Action.

Environmental impacts from this project are anticipated in the following areas: habitat modification and loss (including impacts on terrestrial and aquatic flora and fauna); primary construction impacts, effects on cultural, recreational and scenic resources; economic impacts; impacts on existing infrastructure, impacts on loss of agricultural land and impacts on water quality. The most dramatic impacts are expected to be on aquatic organisms and surface water quality.

**Environmental Impact Statement
Inarajan River Dam Project**

Proposed Agency Actions:	Approval of a dam and reservoir construction on the Inarajan River, village of Inarajan, southern Guam.
Type of Statement:	EIS (Environmental Impact Statement)
Lead Agency:	WERI - Water and Environmental Research Institute of the Western Pacific, University of Guam
Cooperating Agencies:	none
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SUMMARY

1.0 Purpose of and Need for Action

Guam is undergoing unprecedented demands on its limited water resources as island population and tourist industry grows. Because of this rapid development, the potential of southern rivers as sources of drinking water is being examined more closely.

2.0 Alternatives Including the Proposed Action

The proposed action is the construction of a dam on Inarajan River, immediately downstream from its confluence with Laolao River. For the purpose of this study, only a No Action alternative was evaluated in addition to the Proposed Action.

3.0 Affected Environment

The area of proposed action is on the Inarajan River, in southern part of the island of Guam. Significant geologic properties of the area, relevant to the construction of the dam, are extensive erosion and slope instability, as well as the presence of numerous faults and lineaments. High concentration of metals found in volcanic rocks may be bleached by groundwater and delivered into the reservoir. Rivers involved in the project are beautiful wild places with high aesthetic and visual values. No archaeological sites were discovered in the area. Rivers upstream of Inarajan are fast, vertically-eroding streams, flowing on bare basaltic rock. Inarajan River, however, downstream from the proposed dam site, widens to form an extensive alluvial floodplain. Shallow aquifer within the Inarajan floodplain exists but contains very limited quantities of water. In surface waters, concentrations of manganese and iron have been reported as some of the highest in Guam. Air quality in the vicinity of the proposed dam site is excellent. Most of the hilly areas around the proposed dam site are currently unused badlands. Access to the site is via Route 4, and then a series of unpaved roads and 4WD tracks. Plant communities typical to the study area include forests (surrounding the rivers), wetlands, savanna and disturbed ground. No endangered plant species have been recorded. In addition to invertebrates, terrestrial fauna is restricted to a small number of mostly introduced vertebrate species. Aquatic fauna, however, is rich and contains some species endemic to Guam. All aquatic species recorded are amphidromous and many are rheophylllic, and would, therefore, be highly impacted by the construction of a dam. Recreation resources in the proposed area include potential for hunting, hiking, fishing, mountain biking, swimming, and picnicking.

4.0 Environmental Impacts

Environmental impacts from this project are anticipated in the following areas: habitat modification and loss (including impacts on terrestrial and aquatic flora and fauna); primary construction impacts, effects on cultural, recreational and scenic resources; economic impacts; impacts on existing infrastructure, impacts on loss of agricultural land and impacts on water quality. The most dramatic impacts are expected to be on aquatic organisms and surface water quality.

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- Appendix B Vegetation Types in the Proposed Area
- Appendix C Road Erosion and Instability

1.0 Purpose of and Need for Action

Guam is undergoing unprecedented demands on its limited water resources as island population and tourist industry grows. Annual tourist attendance on Guam has grown from a few tens of thousands in the early 1980's to one-and-a-half million in 1997. Guam extracts over 151,000 m³ per day (40 mgd) of the current estimated sustainable yield of 215,000 m³ per day (57 mgd) from the limestone aquifer occupying the northern half of the island. This Northern Guam Lens Aquifer (NGLA) is the source of 80% of Guam's water supply. The remaining water comes from the surface waters of southern Guam. In 1996, approximately 59% of the NGLA's sustainable yield have been pumped, and this number is bound to increase in future. In light of these facts, it is obvious that Guam will need alternative source of potable water, to sustain its rapid development. Because of this growing pressure on Guam's water resources, the potential of southern rivers as sources of drinking water is being examined more closely. Barrett Consulting Group (1994), in its "Surface Water Development Study" has evaluated a number of potential dam sites on southern rivers. One of the projects suggested is the construction of a dam and a storage reservoir site on Inarajan River, immediately downstream from its confluence with Laolao River.

The purpose of this Environmental Impact Study is to provide baseline environmental data for the area of the proposed project and to predict, evaluate and suggest ameliorative practices for potential environmental consequences.

2.0 Alternatives Including the Proposed Action

2.1 Proposed Action

The proposed action is the construction of a dam on Inarajan River, immediately downstream from its confluence with Laolao River. According to Barret Consulting Group (1994) report, the dam would be constructed of clay core and outer rock shell. The top of the dam would be at 34 meters of elevation, with the spillway being at 29 meters. Such dam would create a storage reservoir of approximately 5 million m³ of storage, when 22 meters deep at the dam. Such a reservoir could provide a daily draw of about 23,300 m³. Assuming a sedimentation rate of 4.2 tons/year/hectare, an additional 627,000 m³ of storage would be required for sediment collection. Considering this added volume, the water surface elevation of the reservoir would be at an elevation of approximately 26.4 meters. The reservoir level is not expected to drop in an average year. If completed, the reservoir will drown the Inarajan Valley beyond the confluence of Yledigao and Pasamano Rivers. The lake level would drown the Yledigao River up to 150 meters of Inarajan Waterfalls. It is expected that a deltaic wetland would become established in the upper shallow areas of the reservoir. The lake would contain one prominent island, rising to 15.2 meters above the water surface. The Laolao River would be drowned up to few meters of the Laolao waterfalls.

2.1.1 Infrastructure Requirements

The site of proposed action is located in the vicinity of the village of Inarajan, in southern Guam. The project site is remote and is accessed via Route 4 and then by series of unpaved roads and tracks. One of the first necessary infrastructure improvements needed would be widening and paving of the roads to facilitate construction and operation of the project. Water and power utilities at the project site are not available and will have to be extended from the nearest populated area. Pressure or gravity sewer line will also need to be constructed to the nearest interceptor in the Inarajan Village.

2.1.2 Permit Requirements

Government of Guam Agencies and Local Permits

Several Government of Guam agencies have authority or requirement to review the proposed project plans and issue their opinions. These agencies are as follows:

- Bureau of Land Management
- Bureau of Planning
- Department of Agriculture
- Department of Parks and Recreation
- Department of Public Works
- Guam Environmental Protection Agency
- Guam Housing and Urban Renewal Authority
- Guam Power Authority
- Guam Waterworks Authority

Another local government body, not incorporated as an agency, will need to be consulted as well. This is the Guam Land Use Commission's Development Review Committee, and it has the mandate to review and approve or reject development projects on the island. The permits that may be required for the implementation of the proposed project include:

- Construction and Sanitary Permit
- Environmental Protection Plan
- Erosion Control Permit
- Grading and Clearing Permit
- Guam Coastal Management Program Consistency Review
- Land Use Permit
- Zoning Changes Permit

Federal Government and Federal Permits

The federally regulated issues that will have to be addressed include the wetlands and endangered species. After the Government of Guam wetland permit is obtained, a federal permit may be requested. For federal permits regarding the endangered species, the US Fish and Wildlife Service should be consulted. Since this project involves a estuary type river mouth into the ocean, marine endangered species also need to be considered, and permits regarding those should be requested from the National Marine Fisheries Service, which is part of National Oceanographic and Atmospheric Administration. Additionally, a permit is required from the US Army Corps of Engineers.

Finally, to comply with Government of Guam regulations, federal regulations, and the National Environmental Policy Act (NEPA), an Environmental Impact Statement should be prepared for the project. This document is created to fulfill these requirements.

2.2 No Action Alternative

Alternatives to the Proposed Action are numerous and involve construction of dams and reservoirs on other southern rivers, as reported by Barret Consulting Group (1994). For the purpose of this study, however, only a No Action alternative will be evaluated in addition to the Proposed Action described here.

3.0 Affected Environment

This chapter presents relevant resource components of the existing environment in the area of proposed action. The environmental factors described in this chapter should be considered to be baseline information. This section presents all pertinent physical, biological and social factors of the pre-action environment. Anticipated effects of the proposed action on the environment are analyzed in Chapter 4.

3.1 Physical Factors

This chapter examines in detail the baseline physical environment, such as location, geology, climate, visual and cultural resources, water resources, air quality, fire hazards, land use and current infrastructure.

3.1.1 Location

The area of proposed action is on the Inarajan River, in southern portion of the island of Guam. An aerial photograph of the area involved is enclosed as Fig.1. An inset map shows the island of Guam, with the project location. The Inarajan River watershed (map of which is enclosed as Appendix A) encompasses a large area and includes several rivers originating along the line dividing this basin from the Ugum River basin. Dante River, starting at the northeast face of Mt. Sasalaguan is the farthest reach of this drainage basin. This river descends rapidly, through a narrow valley, and then joins with Pasamano River. Topony and Nelansa rivers join to form Yledigao River, which, just like Dante River, flows through a valley bound by steep walls. These two rivers join to form the Inarajan River.

Inarajan River has steep valley walls and the valley floor is covered by wetlands and dense jungle. This can be readily seen from the enclosed aerial photograph (Fig 1). Before flowing into the ocean at Inarajan Bay, Inarajan River is joined by Laolao River. This is a small, fast river, characterized by rapids and waterfalls, as it flows over bare basaltic bedrock. In the past, water from Laolao river, and the Fintasa River which feeds it, used to be drawn as a potable water source.

Surrounding area is generally made up of grassy hills, and two such hills constrict Inarajan River's passage downstream from its confluence with Laolao. That is the location of the proposed project. Downstream from this point, the valley widens into a partially wetland area, partially agricultural land. The exact locations of wetlands and agricultural areas can be easily identified from the aerial photograph in Fig. 1.

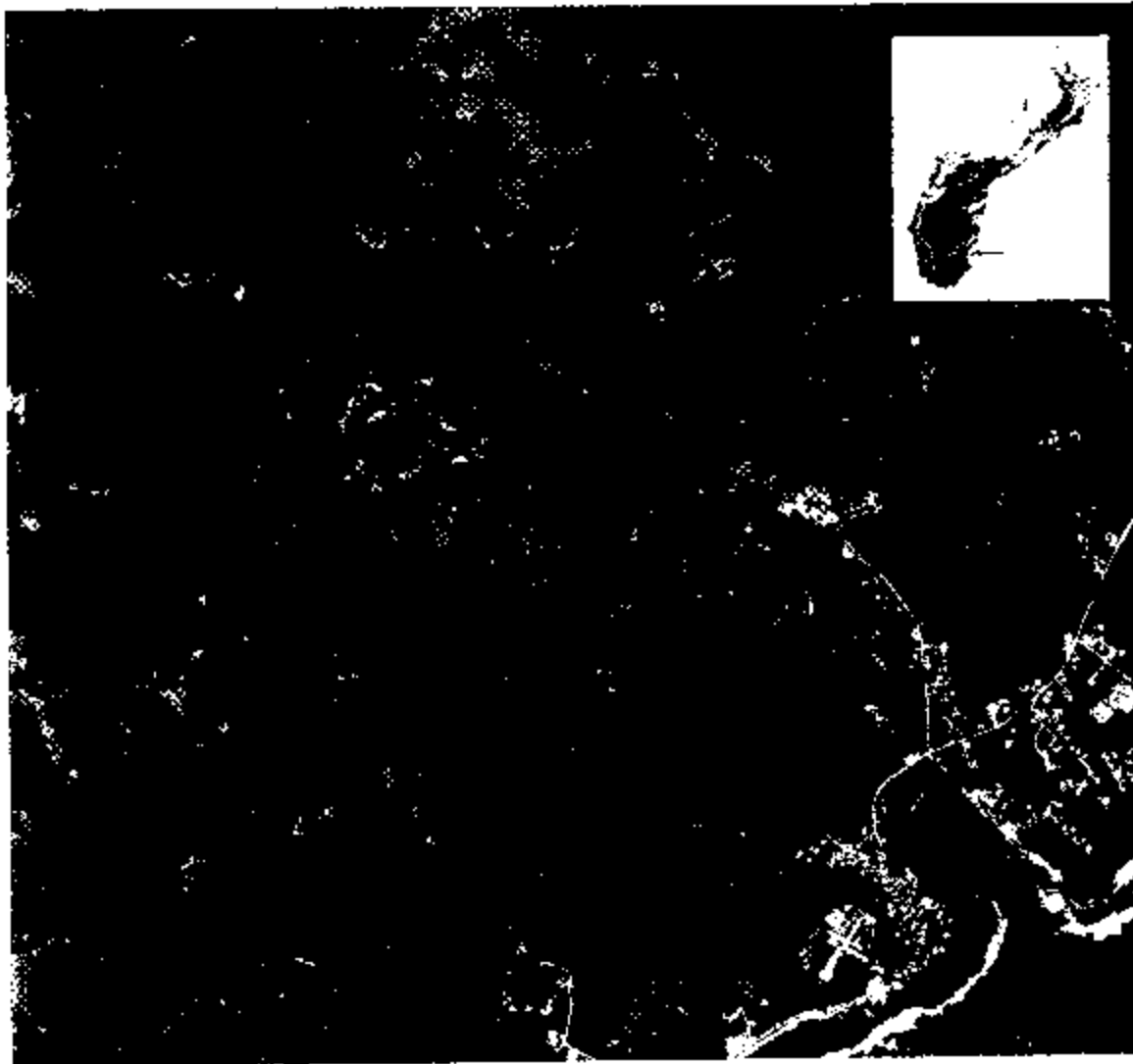


Fig. 1: Aerial view of the project area, with inset map of Guam indicating location

3.1.2 Geology and Geomorphology of the Area

Geomorphology of River Valleys Involved

Inarajan River drainage basin covers an approximate area of 11.39 square kilometers, with the Inarajan River flowing predominantly from west to east. This is shown by the map enclosed as Appendix A. The majority of the area of this drainage basin falls within the USGS 7.5-minute Inarajan Quadrangle topographic maps, with extreme portions laying within Merizo, Agat and Talofofo Quadrangles. Overall relief of the drainage basin area is about 100 meters.

Inarajan River is made at the confluence of Yledigao and Pasamano rivers which merge about 800 meters upstream from the proposed dam site. Average gradient of the river in this area is about 10-15 meters per kilometer, and the slopes of the valley walls range from 2:1 to 3:1 ratio. The valley walls are frequently disrupted

by slope failures. These valley walls withdraw from the river downstream of the proposed dam site. Narrow river valley widens to form an extensive alluvial floodplain, reaching a width of 750 meters at its widest point. This alluvial valley fuses into a river delta at Inarajan River's mouth into the Pacific Ocean. Inarajan River meanders throughout the floodplain, with the exception of the first 400 meters downstream from the dam site, where a 1-2 meters deep canal has been incised by the river.

Laolao River is a short permanent stream formed by joining of Fintasa and Fensol Rivers. Its watershed drains about 3.5 million square meters of grassy hills and badlands, generally north and west of the main Inarajan River Valley. Laolao River flows mostly through a narrow steep valley, which drops about 35 meters (over a distance of 650 meters, giving it a gradient of 54 meters/kilometer. This river has no floodplain and flows on bare basaltic bedrock throughout its length.

Topographic map of the project area, with a blue outline showing the surface of the proposed reservoir is shown on Fig. 2.

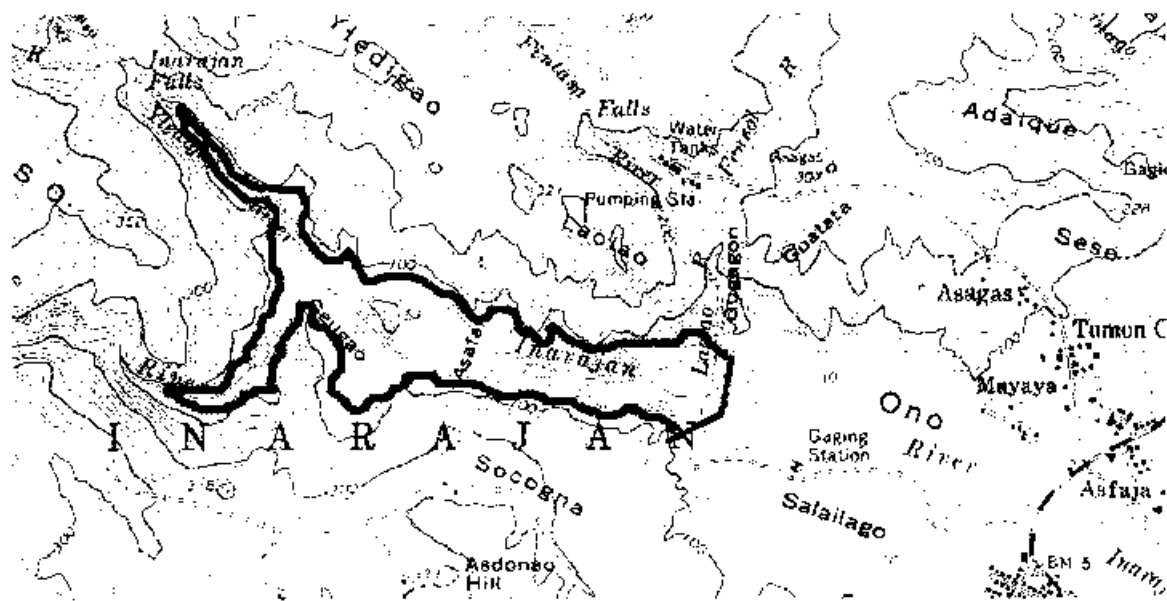


Fig. 2: Topographic map of the project area, outlining the inundation area by the proposed reservoir lake

Geologic Formations

A portion of the geologic map of Guam developed by Tracey et al. (1964) is enclosed as Fig. 3. From this figure, it is evident that the bedrock in the entire area is comprised of Bolanos Member of the Umatac Formation. This is a volcanic rock formation, created as a series of shallow submarine and subaerial eruptions. Several smaller units can be recognized within this formation and these are associated with particular environments at the time of eruption. Most of the rocks are well-bedded tuffaceous mudstone and sandstones, flow breccias, and agglomerates, although larger clasts are present as well. Clasts are usually

basalt fragments, although limestone xenoliths may also be found. These are the only rocks found in the immediate vicinity of the study site. Underlying Alutom Formation and overlying Maemong Limestone are not exposed near the proposed dam site. However, scattered boulders of the Dandan Flow Member of the Umatac Formation may be seen in the badlands in certain parts of the Inarajan River watershed.

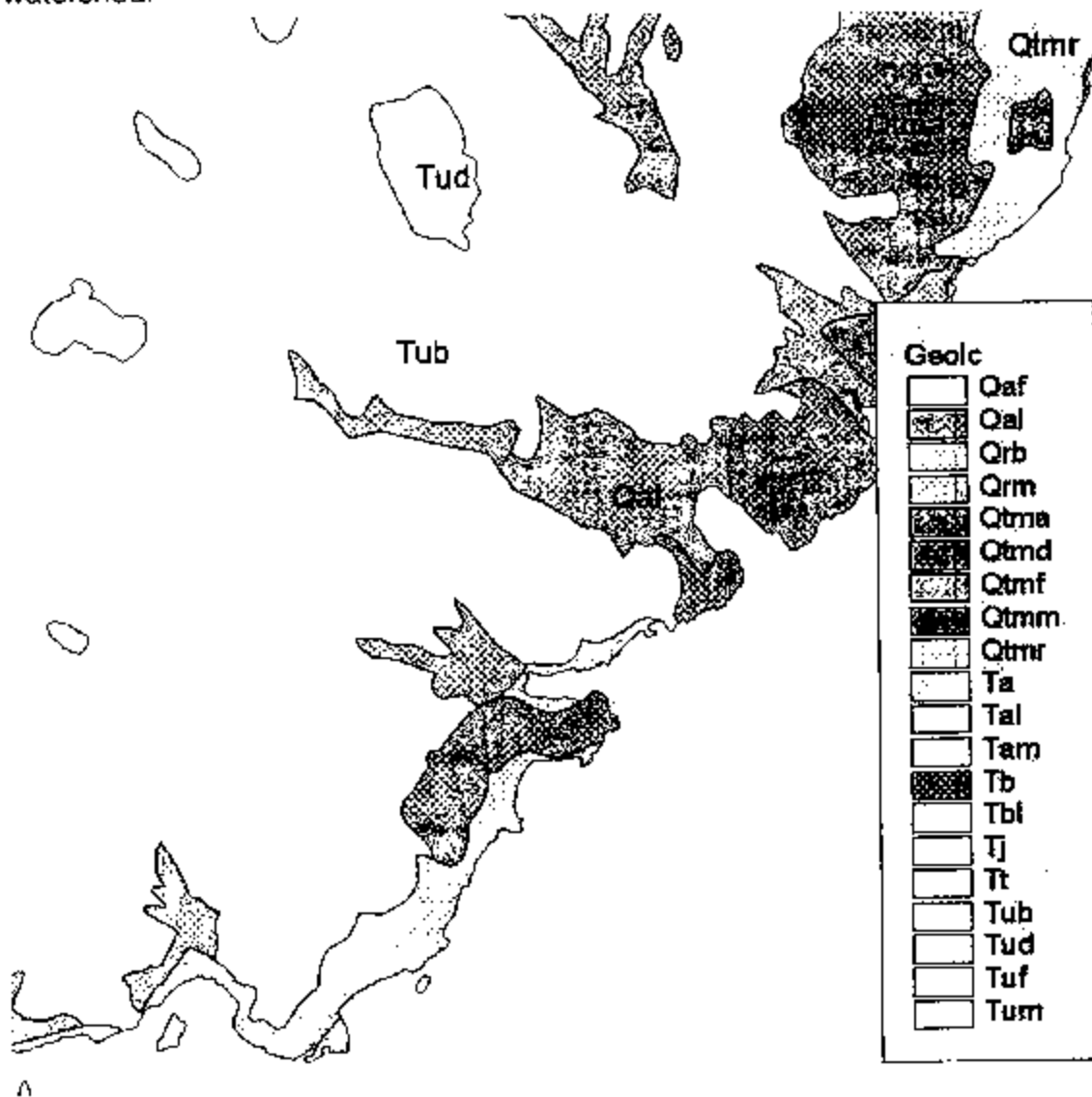


Fig. 3: Geologic map of the project area (Tub=Boanos pyroclastic member (Umatac Fm.), Tud=Dandan flow member (Umatac Fm.), Qtmr=reef facies (Mariana Limestone), Qtma=Agana argillaceous member (Mariana Limestone), Qal=alluvium)

Structural Geology and Geologic Hazards

There are several potential geologic hazards that must be carefully evaluated when planning a project such as a dam and a reservoir lake. The fact that Guam is located in a seismically active area makes a structure such as a dam very vulnerable. Furthermore, in Southern Guam, weak bedrock, combined with steep

slopes and extensive patches of land with little or no vegetative cover make this area very prone to slope failure and erosion. This section addresses mainly concerns regarding geologic faults and lineaments, while the baseline information regarding erosion and slope failure are discussed in the "Soils and Slope Instability" section.

Several large faults and fracture zones were mapped by Tracey et al. (1964). Additional lineaments were mapped by Siegrist and Lewis (1997). Figure 4 was made based on information from WERI Tech Report 78 (Dumaliang et al., 1997). These lineaments are not necessarily faults but are defined well enough at the surface to be a reason of concern when proposing a construction of a large structure such as a dam. The lineaments and their relationship to the proposed dam site are illustrated by Fig. 4.

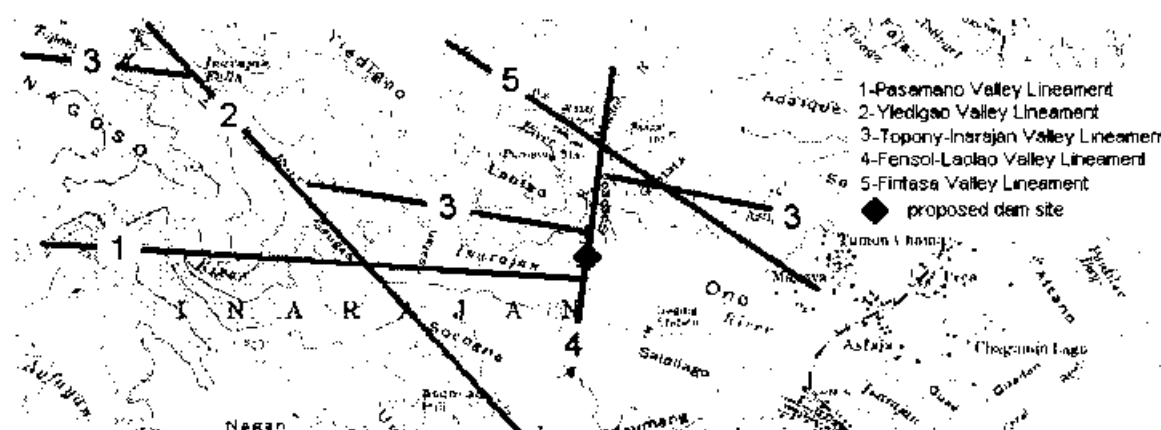


Fig. 4: Geologic lineaments in the project area. (Information from Dumaliang et al. 1997)

Several of the lineaments, however, are likely to be faults: Fintasa Valley, Fensol-Laolao Valley, and the Yledigao Valley. According to Siegrist and Lewis (1997), bedrock outcrops show a high joint density, thrust faulted beds, brecciated zones, mineralized zones, slickensides - all features indicative of faulting, and generally discordant to the bedding. Exact fault planes and characteristics could not be resolved from the surface. Fintasa Valley Fault is probably a vertically or southwest dipping normal fault, with the upthrown side to the northeast. The Fensol-Laolao Valley seems to be eastward dipping high angle normal fault. The nature of the lineaments in the area is summarized in the following table, Table 1.

Trend	Name of Lineament	Description
N55°W	Fintasa Valley	Follows Fintasa River, extending northwestward to the sharp double bend in the Uguim River, and Southeastward to Guafan Point on the north coast of Inarajan Bay. Coincides with normal fault trace Mapped by Tracey et al (1964)
N80°W	Topony-Inarajan Valley	Follows along Topony River, southeast to Inarajan Falls; offset by Yledigao Valley Lineament, follows Northern valley wall of Inarajan River, offset to the north by Fensol-Laolao Lineament
N44°W	Yledigao Valley	Follows the Yledigao River southeast to Asdonao Hill and to the coast at Agfayan Bay
N85°W N5°E	Pasamano Valley Fensol-Laolao Valley	Follows Pasamano River extending to dam site Follows the almost north-south trend of the Fensol and Laolao Rivers through the dam site

Table 1: Summary of geologic lineaments in the area. (Dumaliang et al. 1997)

Mineralogy and Metals

According to Dumaliang et al. (1997), some of the small faults and joints (about 15%) in the area are partially mineralized with manganese and/or iron oxides. Some 3-5% are mineralized with chalcedony (SiO₂). Precipitation of these minerals in spaces within fractures is a common occurrence in Guam's volcanic geologic province. These mineralized zones may be an indicator of concentrated groundwater flow. According to Stark and Tracey (1963), volcanic rocks and soils in Southern Guam may contain a series of heavy metals, such as Ni, Cr, Mn, etc. These metals are potentially toxic.

Soils and Slope Instability

Many exposed hills in the vicinity of the proposed project site are unvegetated, revealing a colorful, red, orange, purple, yellow and gray pigmentation. These are not developed soils, but saprolites, rich in iron oxides and hydroxides. Saprolites reach the thickness of about 10 meters, and rest on the andesitic pyroclastic basalt. Extensive badland development in the study area indicates frequent slope failures and intensive erosion. Rock falls, slumps, debris flows.

Inarajan River floodplain is composed of sediment deposited during flooding episodes. In the peripheral parts of the floodplain, sediment is added by alluvial fans from smaller streams coming from the hills. In a study evaluating potential aquifers in Southern Guam, Ayres and Clayshulte (1983) state that the alluvium is about 4 meters thick and overlays marine sediments. No data is available on the sediment yield from the Inarajan River. Estimates for Inarajan River, based on Uguim River data, are approximately 4.236×10^5 kg/yr/km² (Barrett Consulting Group, 1994). Soils of the project area are illustrated by Fig. 5.



Fig. 5: Soil map of the project area

3.1.3 Climate

Guam's climate is characterized by uniform temperature and humidity but highly variable rainfall and wind conditions. The mean annual temperature is 81°F, and relative humidity averages 73%. There are two primary seasons, with transitional periods between them. The dry season extends from January through April, while the rainy season lasts from July to November. A summary of mean monthly and annual climatic data as well as climatic extremes is provided in the following tables.

YEAR	86	75	80	91	1992	87	1973
JAN	85	75	80	91	1992	87	1973
FEB	85	75	80	93	1946	85	1973
MAR	86	75	81	93	1964	84	1965
APR	87	76	82	96	1971	86	1965
MAY	87	77	82	94	1971	70	1961
JUN	87	77	80	96	1969	70	1966
JUL	87	76	80	95	1969	70	1969
AUG	87	76	80	95	1966	70	1966
SEP	87	76	82	95	1907	70	1972
OCT	87	76	82	93	1964	67	1966
NOV	87	77	80	92	1970	66	1967
DEC	87	76	81	91	1968	68	1962

Table 2: Temperature climatic data

YEAR	E	10	21	31	1/1
JAN	ENE	14	<1	1/15	1/15
FEB	FNE	15	<1	1/46	1/46
MAR	ENE	14	<1	1/46	1/46
APR	ENE	13	<1	1/23	1/12
MAY	E	10	<1	1/23	1/9
JUN	E	9	1	1/9	1/46
JUL	ESE	6	4	1/4	1/21
AUG	ESE	5	5	1/3	1/21
SEP	SE	2	5	1/2	1/8
OCT	LSE	4	3	1/2	1/8
NOV	E	11	1	1/2	1/7
DEC	CNE	14	1	1/2	1/8

Table 3: Wind climatic data

YEAR	86	71	86.3	130.5	1976	59	1973	27	1976
JAN	84	69	4.3	18.1	1976	0.9	1983	7.4	1990
FEB	84	67	3.1	13.6	1980	0.3	1980	8.6	1980
MAR	84	65	2.6	9.3	1974	0.4	1978	2.2	1976
APR	83	66	3.3	15.3	1969	0.5	1966	5.8	1963
MAY	85	68	5.5	24.1	1976	0.4	1987	27	1976
JUN	85	70	5.6	13.3	1986	0.8	1983	3.9	1982
JUL	88	74	9.8	17.7	1962	4.5	1954	6.8	1906
AUG	89	75	13	24.4	1986	3.9	1965	5.7	1962
SEP	89	76	13.2	24.3	1982	3.9	1951	9.3	1950
OCT	88	75	12.5	26.5	1953	4.3	1976	15.5	1953
NOV	87	73	8.3	16.1	1978	2.6	1945	4	1967
DEC	85	71	5	9	1986	1.9	1968	4	1990

Table 4: Humidity and precipitation climatic data

3.1.4 Visual Resources

This area includes several rivers originating along the line dividing this basin from the Ugum River basin. Small, fast, vertically-eroding rivers include Dante River, Pasamano River, and Topony and Nelansa which join to form Yledigao River. Dante and Yledigao join to form the Inarajan River. Inarajan River is then joined by Laolao River. These rivers are small and fast, characterized by rapids and waterfalls, as they flow over bare basaltic bedrock. These are beautiful wild places with high aesthetic value to people who visit them. Several areas along the banks of the rivers are used by locals for picnics and relaxation. Three major waterfalls are located within the area: Inarajan, Fintasa, and Laolao falls, all of which are beautiful scenic spots, often visited by people.

The badlands in the area are aesthetically pleasing to nature-loving people. Beautiful shades of red, orange, yellow and purple dominate these unvegetated hills. The area is excellent for hiking and mountain biking.

3.1.5 Cultural and Archeological Resources

During this study no cultural artifacts were discovered in the area. Ancient Chamorro pottery, however, may be found in many places around Guam and is probably present at this site as well. No known villages or cultural sites from Guam's past are known to occur in this area.

No World War II artifacts were discovered. Artifacts of Japanese origin and war paraphernalia is often found in Guam, and some may be present in the area. Following the war, many Japanese soldiers went into hiding, and some have spent many years straggling in Guam's interior. There are no limestone areas and no caves in the vicinity of project site, so no artifacts left by stragglers are expected in the area.

3.1.6 Water Resources

Drainage Patterns and Streamflow Regimes

The drainage pattern in Southern Guam is generally a dendritic or somewhat a rectangular one. This indicates random drainage, with elements of fracture control. Inarajan River basin seems to have a predominantly fracture-controlled, rectangular drainage. Most dominant channel orientations are approximately N75°W and N50°W. Direct north-south orientation is also common.

There used to be a USGS stream gage on Inarajan River, approximately 0.5 kilometers downstream from proposed dam site. Data acquired from this gauging station are continuous stage and flow values for the period of 1953 to 1988. Hydrologic studies on Inarajan River included development of a flow-duration

curve. From the calibration graph for Inarajan River (Barrett Consulting Group, 1994) it can be seen that, during low flows, groundwater represents a significant portion of the flow. Minimum flow of Inarajan River, which must be maintained for the preservation of aquatic habitat, if set to 90% exceedance value, is approximately 5,670 m³/day (1.5 mgd). Current drainage and related water resources are illustrated by figure 6:

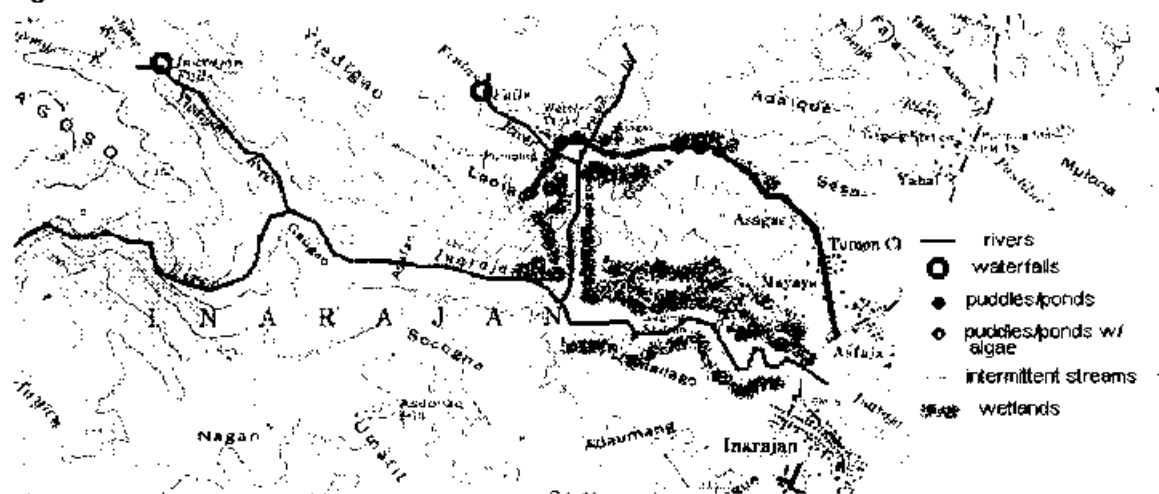


Fig. 6: Permanent and temporary drainage pathways and areas of water accumulation

Floodplains and Wetlands

Fintasa and Laolao Rivers are fast, vertically-eroding streams, flowing on bare basaltic rock. Their valleys have steep valley walls, and no floodplain exists. Some sediment is deposited in pockets along the course of the rivers, but this is just river-load, not alluvium. Inarajan River, as well, starts as a fast river, with steep valley slopes. However, downstream from the proposed dam site, the narrow valley widens to form an extensive alluvial floodplain. At the widest point, the floodplain reaches a width of 750 meters, and gradually fuses into a delta. Only the first 400 meters downstream from the proposed dam have a 1-2 meters deep incised canal, whereas the river meanders randomly throughout the rest of the floodplain. Wetlands occur throughout the project area. Areas of water accumulation adjacent to the roads and rivers have well developed wetland vegetation, which will be further discussed in the biological resources section. Additionally, the entire Inarajan River floodplain is classified as a wetland but it is currently used for agricultural purposes, mainly pasture.

Groundwater

On Guam, groundwater resources are usually equated with the northern limestone rocks. However, southern volcanic rocks are aquifers as well. No development of these aquifers has occurred so far, because these rock layers would probably yield uneconomic low water quantities. Potentially significant water quantities could perhaps be drawn from fracture areas, where high permeability zones conduct groundwater. Shallow aquifer within the Inarajan

floodplain could contain water quantities that are potentially exploitable. Alluvial sands and gravel of the floodplain could provide a yield of about 12 m³ of water per day, suitable for irrigation purposes (Ayers and Clayshulte, 1983).

Surface Water Quality

Guam Environmental Protection Agency periodically analyzes water quality of some southern rivers, but Inarajan River is not one of them. Water samples from Laolao River and Fintasa River were analyzed by WERI in 1993. This data is presented in Table 5, which summarized the results of WERI's research. Manganese and iron levels reported are some of the highest in Guam.

WERI #	River	Date	General Location	Channel Samples	Fe (mg/liter) (filtered)	Mn (mg/liter) (filtered)
L3/L4	Laolao	10-Nov	5 m south of Laolao waterfall		40/570	180/210
F5/F6	Fintasa	23-Nov	15 m upstream from abandoned weir		150/760	280/260
F7/F8	Fintasa	23-Nov	70 m upstream from abandoned weir		60/1100	1210/1200
F9/F10	Fintasa	23-Nov	100 m upstream from abandoned weir		260/800	230/270
F13/F14	Fintasa	23-Nov	150 m upstream from abandoned weir		140/440	130/140
F15/F16	Fintasa	23-Nov	200 m upstream from abandoned weir		220/820	260/270
F17/F18	Fintasa	23-Nov	250 m upstream from abandoned weir		310/880	170/150
F19/F20	Fintasa	23-Nov	285 m upstream from abandoned weir		210/900	150/170
F21/F22	Fintasa	23-Nov	325 m upstream from abandoned weir		280/880	150/160
F23/F24	Fintasa	23-Nov	400 m upstream from abandoned weir		880/1320	170/180
F29/F30	Fintasa	17-Nov	300 m downstream from Nelansa confl.		60/140	50/50
F31/F32	Fintasa	17-Nov	250 m downstream from Nelansa confl.		320/480	70/70
F33/F34	Fintasa	17-Nov	Seep, 215 m downstr. from Nelansa		10210/11180	390/400
F35/F36	Fintasa	17-Nov	100 m downstream from Nelansa confl.		2550/3600	190/30
F37/F38	Fintasa	17-Nov	50 m downstream from Nelansa confl.		3340/3720	170/170
F39/F40	Nelansa	17-Nov	5 m above Fintasa River confluence		20/80	<10/<10
F43/F44	Fintasa	17-Nov	50 m above Nelansa River confl.		1220/1600	40/40
F45/F46	Fintasa	17-Nov	150 m above Nelansa River confl.		1160/1220	130/130

Table 5: Summary of WERI's 1993 study on Fe and Mn in surface waters in the Inarajan watershed

Groundwater Quality

Data on groundwater quality in the area comes from a single shallow observation well, made in the alluvium to a depth of 2 to 4 meters. Analysis of the water samples, carried out by Barrett Consulting Group (1994), reports that most metals and nutrients fall below the Federal and Territorial upper limits. The only exceptions were manganese, iron and nitrate-nitrogen, which are present in high quantities due to agricultural waste (N) and mobilization of metal precipitates in volcanic rocks by groundwater (Mn, Fe). Information on pesticides, other organic and microbial is not available.

3.1.7 Air Quality and Noise

Air quality in the vicinity of the proposed dam site is excellent. There are no industrial complexes, factories, power plants or any other emission-producing activities nearby. A minimal impact to air quality is made by exhaust fumes from vehicular traffic along Route 4.

Noise levels in the area are extremely low. Sufficient distance and vegetation cover successfully minimize noise from the traffic along Route 4. Human activities and rare vehicular traffic along the dirt roads in the immediate vicinity of the site are the only potential sources of noise.

3.1.8 Fire

Fire in southern Guam represents a common and widespread problem during the dry season. No direct impacts of fire have been observed in the area during this study, but it is expected that wildfires or human-started fires do occur. Such fires are not a real threat to savanna vegetation which is well adapted to them, but definitely have a negative effect on the wooded areas. Fires are capable of wiping out wooded areas which are then replaced by savanna-type vegetation. This process advances erosion and slope processes. Fires should not be considered a real threat to humans because no permanent structures exist in this area. A fire barrier would be beneficial if this project was to proceed.

3.1.9 Agriculture and Current Land Use

Most of the hilly areas around the proposed dam site are currently unused badlands. These areas lack true soil and are thus unsuitable to agriculture. However, significant tracts of land around the site are designated for development by the Government of Guam, as part of its "Land for the Landless" program. Land in the Inarajan River floodplain, however, is well suited for agriculture. Currently, it is used primarily as a pasture.

3.1.10 Current Infrastructure

Access to the site is via Route 4, from the village of Inarajan. A road branches off from Route 4, and passes by the Inarajan middle school, and reaches a neighborhood of several homes. The road then continues as an unpaved road, passes a water reservoir on the left, and reaches Laolao River. From this point on, a network of dirt road and tracks criss-crosses the area. Most of these are in a bad condition and can only be used during the dry season or by 4 wheel drive vehicles.

Power and telephone service can be derived from power poles located along Route 4, or from the mentioned neighborhood. There are no existing sewer lines in the vicinity of the proposed project area. The nearest solid waste collection

area is the mentioned neighborhood, located several kilometers away from the proposed dam site. The nearest solid waste disposal site is located in Malojloj, but this site is selective and temporary.

3.2 Biological Factors

3.2.1 Terrestrial Flora

Plant communities typical to the study area include forests (surrounding the rivers), wetlands, savanna and disturbed ground. Identification of individual species was done according to Raulerson and Rinehart (1991). A photograph of Inarajan River valley as seen from the hills to the east of it is shown on Fig. 7. This figure visually illustrates the main plant communities in the project area. A map showing approximate distribution of main plant communities is shown in Fig. 8.

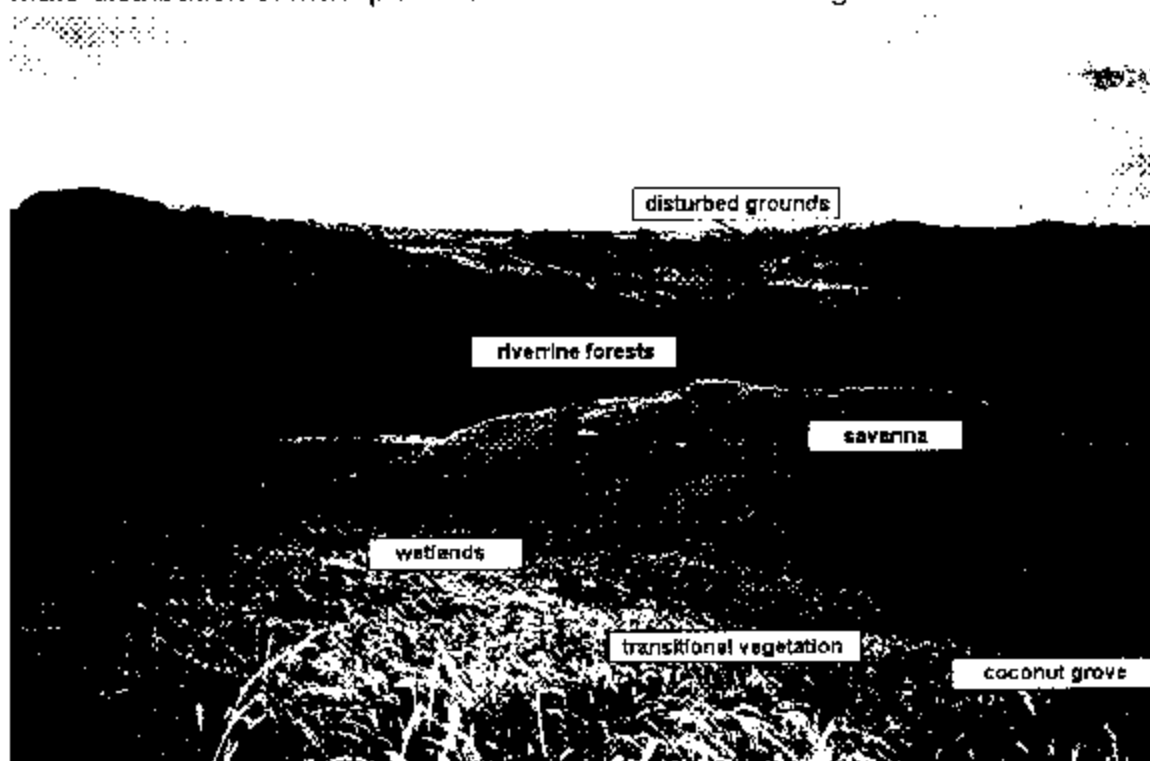


Fig. 7: Plant communities in the vicinity of Inarajan River valley

Forests

Forests in the area generally occur in the immediate vicinity of the rivers (see Appendix B, photo 6). These plant communities are not extensive in area, but are quite densely vegetated and support a range of species. The canopy exists in limited areas and its level is only 2-4 meters above the ground. It has irregular upper surface, and is predominantly made by bushy plants. Taller trees do rise above the canopy, but these occur in smaller numbers and do not form canopy of

its own. Forests in the vicinity of the site are extremely difficult to walk through, even when following animal paths.

Dominant forest plants include otot (*Discocalyx megacarpa*), coconut palms (*Cocos nucifera*) (which grow in clusters and form coconut groves-- see Appendix B, photo 4), lagundi (*Vites parviflora*), betel nut palms (*Areca catechu*), ilang-ilang (*Cananga odorata*), gafus (*Medinilla medilliana*), rattan (*Flagellaria indica*), and pandanus (*Freycinnetia reineckeii*).

Wetlands

Even though entire Inarajan River floodplain is classified as wetlands, it is used predominantly for agriculture. Wetlands do occur in the area but are not extensive. More extensive are areas of temporary water accumulation, but due to periodic drying out, they do not support aquatic vegetation and do not develop into wetlands. Certain areas, however, do qualify as wetlands. These are located adjacent to the rivers (see Appendix B, photo 2). Wetlands are made by one of two mechanisms: 1) shallow groundwater table which is near the surface or above the surface, and supports the growth of aquatic plants, or 2) shallow basins that are fed by runoff on a permanent basis. In the vicinity of the study site, both types have been observed. The first type occurs solely within the Inarajan River floodplain where shallow groundwater table exists within the alluvium, and the second type exists adjacent to the rivers in upper areas of the drainage basin.

Typical wetlands vegetation includes tall tropical reed (*Phragmites karka*), wetland fern (*Acrostichum aureum*), *Scripus littoralis*, galak (*Lygodium microphyllum*), *Mikania scandens*, agasi (*Cassytha filiformis*), *Nephrolepis hirsutula*, *Nephrolepis biserrata*, *Fimbristylis dichotoma*, *Centosteca lappacea*, *Panicum muticum*. Adjacent to the rivers, *Hibiscus* (*Hibiscus tiliaceus*) and *Pandanus* (*Pandanus tectorius*) trees are common.

Savanna

As we move away from the rivers, forests gradually phase (see Appendix B, photo 1: transitional vegetation) into savanna-type vegetation. Forests initially give space to a *Phragmites* community, which then phases into swordgrass (*Miscanthus floridulus*) areas. Other common plants within the savanna grasslands include Guam grass (*Dimeria chloridiformis*), lada (*Morinda citrifolia*), chosga (*Glochidion marianum*), and scattered *Pandanus tectorius* trees. A typical savanna environment is illustrated by Appendix B, photo 3.

Disturbed Grounds

Throughout the savanna areas in the Inarajan River basin, erosion scars, unvegetated slopes and extensive areas of bare saprolith are common (see

Appendix B, photo 5). Vegetation in these areas is typically of a pioneering type, made up of fast and resilient colonizers, and species with horizontal rhizome propagation.

Erosion scars are most commonly vegetated by savanna fern (*Gleichenia linearis*), gapit (*Wikstroemia elliptica*) and *Melastoma marianum*. Disturbed areas typically exhibit a variety of weed species, including false verbena (*Stachytarpetta jamaicensis*), papago (*Elephantopus mollis*), buttonweed (*Hyptis capitata*), *Chloris inflata*, mission grass (*Pennisetum polystachyon*), sleeping grass (*Mimosa pudica*), kamachile (*Pithecellobium dulce*), taki biha (*Cassia alata*), *Crotalaria retusa*, rattlebox (*Crotalaria pallida*), *Passiflora foetida*, passion flower (*Passiflora suberosa*), and tangantangan (*Leucaena leucocephala*). Some of these species occasionally extend into the savanna.

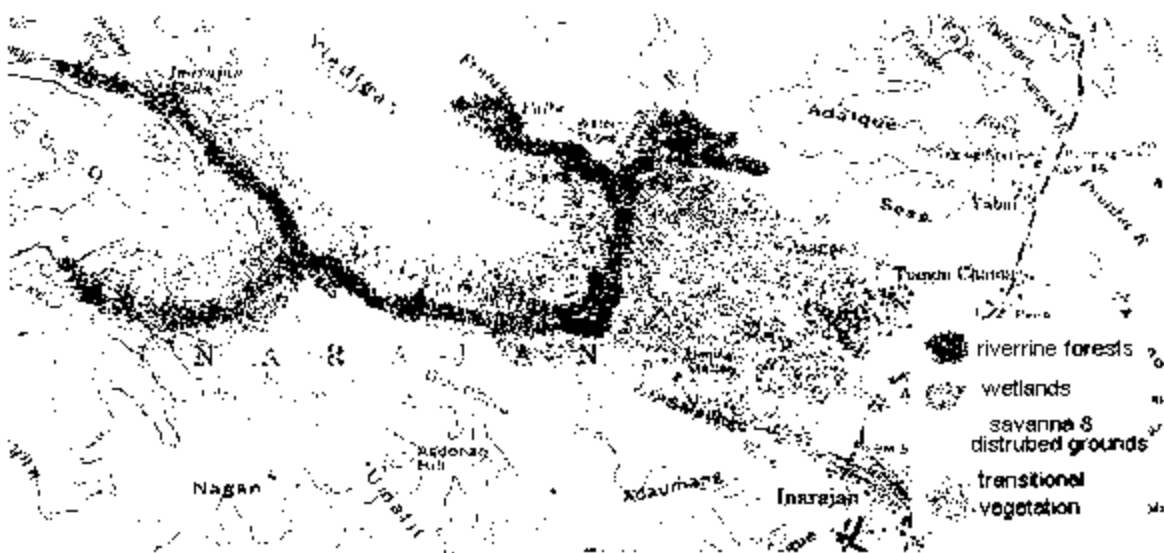


Fig. 8: Approximate distribution of major plant communities in the project area

3.2.2 Terrestrial Fauna

Terrestrial fauna of Guam has been very disturbed by introduction of alien species, and extinction of many native species, due to predation and/or competition by aliens, and human disturbance. Identification of species was based on unpublished "Checklist of Terrestrial Vertebrates and Selected Terrestrial Invertebrates of Guam" prepared by the Guam Department of Agriculture, Division of Aquatic and Wildlife Resources (1993) and unpublished report by Fritts et al.

Invertebrates

Dominant terrestrial invertebrates in the vicinity of the project site include arthropod and mollusk species. Insects are numerous, but no unusual species

were noticed. Several large black ant nests occur in the canopy. Other arthropods include land crabs and coconut crabs. Terrestrial snails, which are extremely endangered on Guam, may be present in the area, and further evaluation by an expert is recommended.

Amphibians

There are only two amphibian species living on Guam: cane toad (*Bufo marinus*) and tree frog (*Litoria falax*). Only toads were actually observed on site, but tree frogs are also expected to occur. Both of these species were introduced to Guam.

Reptiles

Reptile fauna of Guam is limited to a few native species and a variety of introduced aliens. Two species of gecko were observed in the area: stump-toed gecko (*Gehyra mutilata*), and mourning gecko (*Lepidodactylus lugubris*). A third species, *Hemidactylus frenatus*, is ubiquitous on Guam and is expected to occur within this area as well. Two skink species were recorded as well. The most common skinks species are four-toed skink (*Carlia fusca*), and the blue-tailed skink (*Emoia caeruleocauda*). Even though other skink species occur on Guam, none are expected in this area. One adult monitor lizard (*Varanus indicus*) was seen near Inarajan Falls. An introduced iguanid species known as the "American chameleon" (*Anolis carolinensis*) is becoming increasingly common in Guam and may be found in the study area. Both species of snakes living in Guam were recorded in the forest adjacent to Laolao River: blind-snake (*Ramphotyphlops braminus*) and brown tree snake (*Boiga irregularis*).

Birds

Only three species of birds were observed in the area. Black frankolin (*Francolinus francolinus*) was commonly seen and heard in the forest adjacent to the rivers. No population estimates were made. Introduced Philippine turtle doves (*Streptopelia bitorquata*) were else seen on several occasions. One quail (*Coturnix sinensis*) was seen in the savanna near Inarajan Falls. Species of birds that were not observed but may be present in the area include yellow bittern (*Ixobrychus sinensis*), black drongo (*Dicrurus macrocercus*), sparrow (*Passer montanus*), and golden plover (*Pluvialis dominica*).

Mammals

No mammals were directly observed in the area. Expected to occur our mouse (*Mus musculus*), rats (*Rattus rattus* and *Rattus exulans*), musk shrew (*Suncus murinus*), deer (*Cervus unicolor mariannus*), feral pig (*Sus scrofa*), feral dog (*Cannis familiaris*), feral cat (*Felis domesticus*), and carabao (*Bubalus bubalis*).

There are probably no wild carabao in the area, but domestic individuals are often brought here by the locals to graze.

Vertebrate terrestrial species are summarized in the following table:

AMPHIBIANS & REPTILES			BIRDS			MAMMALS		
1	<i>Littoria falax</i>		1	<i>Francolinus francolinus</i>		1	<i>Mus musculus</i>	
2	<i>Bufo marinus</i>		2	<i>Streptopelia bitorquata</i>		2	<i>Rattus rattus</i>	
3	<i>Gehyra mutilata</i>		3	<i>Coturnix sinensis</i>		3	<i>Rattus exulans</i>	
4	<i>Lepidodactylus lugubris</i>		4	<i>Ixobrychus sinensis</i>		4	<i>Suncus murinus</i>	
5	<i>Hemidactylus frenatus</i>		5	<i>Dicrurus macrocercus</i>		5	<i>Cervus unicolor mariannus</i>	
6	<i>Carlia fusca</i>		6	<i>Passer montanus</i>		6	<i>Sus scrofa</i>	
7	<i>Emola caeruleocauda</i>		7	<i>Pluvialis dominica</i>		7	<i>Canis familiaris</i>	
8	<i>Varanus indicus</i>		8	<i>Felis domesticus</i>				
9	<i>Anolis carolinensis</i>		9	<i>Bubalus bubalis</i>				
10	<i>Ramphotyphlops braminus</i>							
11	<i>Boiga irregularis</i>							

Table 6: Terrestrial vertebrates seen (number bold) or expected to occur (number not bold) in the area

Endangered species

No endangered vertebrate species were observed in the study area. Further analysis of invertebrate fauna is recommended, due to potential presence of endangered land snail species in the area.

3.2.3 Algae and Aquatic Fauna

Several green algae can be seen in the streams. Most occur in deeper pools or sections of rivers with slower flow velocities. The most conspicuous is filamentous *Spyrogyra*. Red algae are also represented, by species of *Oedogonium* genus.

Invertebrate fauna is represented by decapods and mollusks. The dominant decapod species is *Macrobrachium* lar (large shrimp) and smaller *Atyoida serrata* shrimps. Dominant mollusk is the snail *Neritina puligera*.

Fish species seen in the rivers include species of the following genera: *Anguilla*, *Kuhlia*, *Stenogobius*, *Awaous*, *Eleotris*, *Stiphodon*, *Sicyopus* and *Sicyopterus*. Not all of these species were recorded in this survey, but all are known from Inarajan River watershed or neighboring rivers and should be occurring in this area.

Marine and brackish water fauna found in the estuarine areas at the mouth of Inarajan Rivers was not examined during the course of this study.

When considering aquatic fauna, it is important to understand that these are amphidromous organisms, which means that their life history includes both marine and freshwater life stages. They must have access to the marine

environment in order to mature. With the exception of eels (*Anguilla* and *Kuhlia*) which migrate to the ocean to spawn, these animals breed in freshwater and their larvae are carried to the ocean. In the ocean, they go through one or more developmental stages, before returning to fresh water to mature.

Additionally, the preferred habitat of many gobiid species and some atyid shrimp is a high flow habitat. These organisms, known as rheophyllic, do not inhabit slow moving or stagnant waters. Rheophyllic species are marked by an asterisk* in the following table which lists aquatic invertebrates and vertebrates recorded from or expected to occur in the Inarajan River basin.

MOLLUSKS	DECAPODS	FISH
1 <i>Clithon corona</i>	1 <i>Atyoida pilipes</i> *	1 <i>Anguilla marmorata</i>
2 <i>Clithon oualaniensis</i>	2 <i>Atyoida serrata</i>	2 <i>Anguilla bicolor</i>
3 <i>Neritina auriculata</i>	3 <i>Atyopsis spinipes</i>	3 <i>Kuhlia rupestris</i>
4 <i>Neritina petiti</i>	4 <i>Caradina nilotica</i>	4 <i>Stenogobius</i> sp.
5 <i>Neritina pulligera</i>	5 <i>Caradina serratirostris</i>	5 <i>Awaeus guamensis</i>
6 <i>Neritina squampicta</i>	6 <i>Caradina typus</i>	6 <i>Eleotris fusca</i>
7 <i>Neritina turrita</i>	7 <i>Macrobrachium</i> lar	7 <i>Stiphodon elegans</i> *
8 <i>Neritina variegata</i>	8 <i>Macrobrachium latidactylus</i>	8 <i>Stiphodon</i> sp.*
9 <i>Septaria lineata</i>	9 <i>Veruna littorana</i>	9 <i>Sicyopus leprurus</i> *
10 <i>Septaria porcellana</i>		10 <i>Sicyopterus macrostetholepis</i>
11 <i>Melanoides tuberculata</i>		
12 <i>Melanoides riqueti</i>		
13 <i>Thiara granifera</i>		
14 <i>Thiara scabra</i>		

Table 7: Aquatic invertebrates and vertebrates recorded or expected to occur in the area (*=rheophyllic)

3.3 Social Factors

The nature of this project is such that no major social impacts are expected. Because of this, baseline information included in this section is limited.

3.3.1 Population

The village closest to the project site is Inarajan. Outside of the main village, several clustered neighborhoods exist, one of which is a few kilometers away from the proposed dam site. Majority of the population in the area is of Chamorro ethnicity.

3.3.2 Ways of Life

It should be noted that this project is proposed in Southern Guam, where many traditional customs and lifestyles (not dominant in the north) persist on a large scale.

3.3.3 Land Use

Current land use is limited to agriculture and recreation. The floodplain of Inarajan River is used as a pasture for domestic animals. Most land area in the domain of this project is currently unused. However, it has been identified by the Government of Guam as a part of the "Land for the Landless" program and further development is expected.

3.3.4 Recreation Resources

Inarajan Waterfalls is a popular recreation spot on Yledigao River, about 1 kilometer upstream from its confluence with Pasamano River. This waterfall is about 7 meters tall. Downstream from this spot, at least 15 low falls and rapids occur before reaching the proposed dam site. On Laolao River, a 10 meter high waterfall (Laolao Waterfalls) exists halfway between the confluence of Fintasa and Fensol Rivers and the proposed dam site. On Fintasa River itself, another 10 meter waterfall (Fintasa Waterfalls) may be found. Just like Inarajan Falls, these waterfalls are also made by resistant well-cemented flow breccia.

The waterfalls and areas along the banks of the rivers are used by locals for picnics and relaxation. Certain areas, where the water is deep enough, can be used for swimming. Fishing for eels, used for food, is another activity linked to the rivers.

Certain localities within the forests and grasslands in the area can be used for hiking and boonie stomping, trapping pig, hunting and collecting coconut crabs. The badlands and unvegetated areas are aesthetically pleasing. These areas represent a great resource for hiking and mountain biking.

4.0 Environmental Consequences

No Action Alternative

If no action was taken in the area, no environmental impacts and no change is anticipated. Baseline environment, as described in Chapter 3, is expected to remain unaltered.

Proposed Action Alternative

Environmental impacts from this project are anticipated in the following areas: habitat modification and loss (including impacts on terrestrial and aquatic flora and fauna); primary construction impacts, effects on cultural, recreational and scenic resources; economic impacts; impacts on existing infrastructure and impacts on loss of agricultural land. This chapter is organized in sections separately dealing with each of these impacts as they relate to the project site. If the dam is constructed, the area in question will look as shown on the map, in figure 9.

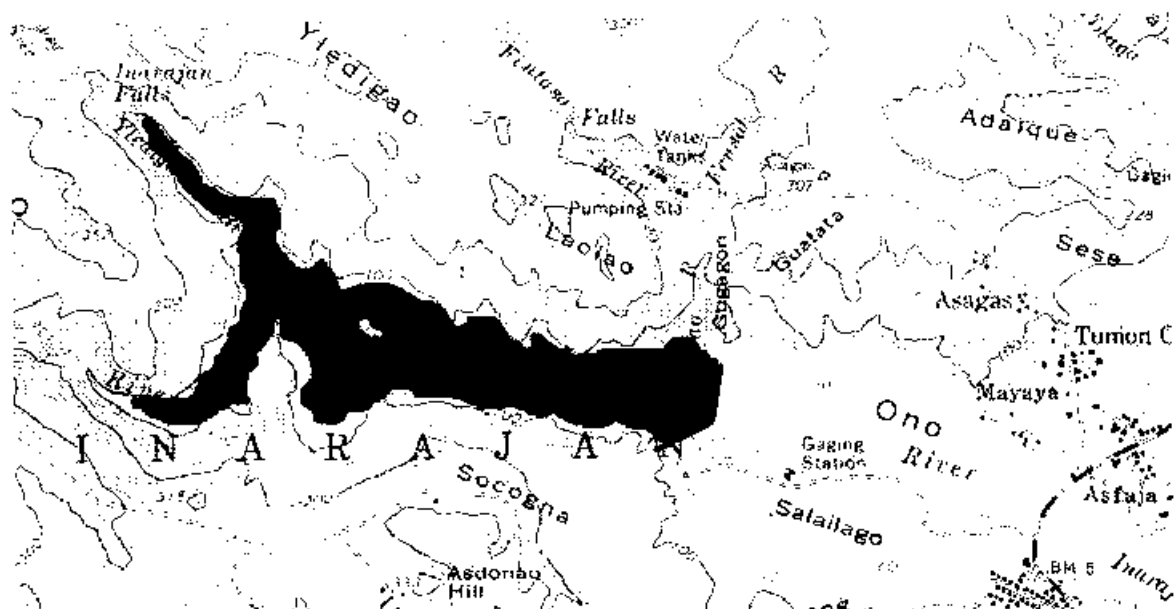


Fig. 9: Map of the project area, as it would look if the dam is constructed

4.1 Habitat modification and loss

The development of this project will require destruction of a series of habitats by inundation. Extensive riverine forests and savanna areas will be submerged, and fast flowing river habitats will be partially destroyed. Existing wetlands will be destroyed. The loss of terrestrial habitats will subsequently result in a loss of habitat for wildlife. Although no endangered species were recorded in the area, habitat that could potentially support certain endangered species (such as the fruit bat, the swiftlet, the tree fern and the giant fern) will be lost.

4.1.1 Loss of vegetation

Extensive tracts of forest and savanna will be flooded and lost. However, forest habitats are expected to get established along the shores of the lake, in much the same way they now line the river banks. However, these new habitats may take extended periods of time to become healthy and valuable habitats.

4.1.2 Displacement of fauna

The impact on the wildlife will not be dramatic. Birds found in the area are expected to utilize adjacent suitable habitats, and new forest habitats are expected to eventually get established along the lake's shore. Mammals, such as pigs, deer and rodents will move to adjacent suitable habitat, provided that those areas have not reached their maximum carrying capacity. In that case, a drop in population size is expected. Invertebrates, amphibians and reptiles are expected to survive in adjacent habitats. Some populations or parts of populations are expected to be killed by accumulating water. Because invertebrates and smaller animals are not as mobile as mammal and birds, for example, an expert

evaluation of invertebrate species in the area is recommended. Endangered species of land snails could be inhabiting this area.

4.1.3 Effects on aquatic fauna

All native Guam freshwater species must have access to seawater in order to complete their life cycle. Typically, young larvae migrate to the ocean environment where they spend part of their life. After they reach a certain age, they move back to the freshwater environment where they reproduce. If a dam was built without providing access to the ocean to the freshwater fauna, all native fish and aquatic invertebrates in the Inarajan River basin are expected to go extinct.

The most common method for allowing fish to pass by the dam is the fish ladder. The fish ladder usually consists of a number of steps, or weirs, which allow the fish to swim upstream on a gradual incline. The specific design requirements and types may be obtained from the U.S. Forest Service, the U.S. Army Corps of Engineers, or the U.S. Fish and Wildlife Service.

Additional problem involved in preserving the aquatic fauna in the event the dam was built is caused by the fact that a number of species inhabiting Inarajan River basin are rheophilic. This means that they inhabit fast running waters and cannot survive in stagnant waters such as a lake. It is therefore imperative that the fish ladder design applied to Inarajan River dam is such that it completely by-passes lake's waters. Larvae must not be made to enter the stagnant lake waters because they pose an effective barrier to their movement.

It is suggested that similar projects carried out in Hawaii, having a native aquatic fauna with identical lifestyles as in Guam, be examined in detail and their solutions, if effective, be applied in Guam.

The rheophilic species found in Inarajan River basin are: *Atyoida pilipes* (shrimp), and fish: *Stiphodon elegans*, *Stiphodon* sp., *Sicyopus leprurus*, and *Sicyopterus macrostetholepis*.

4.1.4 Effects on wetlands

Since the current wetlands will be destroyed, those species are not likely to persist in the area. Deep water habitats found in the lake will not be able to support majority of wetland species. To counteract this negative impact, it would be beneficial to create shallow water habitats in the marginal areas of the lake where wetland vegetation may get established. This would potentially attract wetland fauna to re-colonize the area. At least the same area of wetlands lost should be recreated in the peripheral parts of the lake. This project provides a rare opportunity to create extensive new wetlands, and this should become one of the environmental priorities of the project.

4.1.5 Effects on the bay and estuarine environment

Effects on the brackish and marine water environments in the estuarine mouth of Inarajan River and the Inarajan Bay are difficult to predict. Potential adverse effects are most likely to occur during the construction phase. Sediment control is one of the major steps that must be undertaken in order to prevent damages to the marine environment. Ecology of the bay and estuary is extremely complex and effects and interactions with a nearby reservoir lake are difficult to predict. Information should be acquired from the results of similar projects and/or by a professional ecological investigation.

4.1.6 Beneficial habitat modification

A lake may become an attractive habitat for certain species. Once edge vegetation, cover and food species are established, the reservoir lake may become a valuable habitat for local and migratory birds. Mammals are expected to visit the lake and use it as a permanent water source. A year-round lacustrine environment could provide a welcome new habitat for terrestrial fauna. The lake may prove to be beneficial for certain aquatic species as well. Endangered Marianas moorhen (*Gallinula chloropus guami*) may establish a population in the newly created wetlands along the lake's shoreline.

The lake would contain one prominent island, rising to 15.2 meters above the water surface. This island should by all means be cleared of the brown tree snake presence and efforts should be made to establish nesting sites for one or more bird species. Many Guam's bird species are desperately in need of safe nesting sites, due to predation pressures by the snakes, and this island may prove to be a valuable predator-free habitat. Bird experts should be informed and allowed to make decisions and preparation regarding this issue. In addition to the birds, certain native skink lizard species are gradually becoming extinct due to predation by the snakes and competition by introduced skinks. It would be possible to eliminate four-toed skink and the blue-tailed skink from the island and attempt establishing a population of any one (or maybe more) of the following endangered species of skinks and geckos: *Cryptoblepharus poecilopleurus*, *Lipinia noctua*, *Emoia slevini*, *Nactus pelagicus* or *Perochirus ateles*. If this was to be carried out, this project could play a role in preserving the biodiversity of Guam.

4.1.7 Indirect dangers

Caution should be exercised regarding potential introductions of new species. Local population has been known to use stagnant water environments on the island to release unwanted pets. Many of such species, namely turtles and fish, are exotics and potentially very dangerous, not only as direct predators and competitors to the native species, but also as disease and parasite vectors.

Ponds and lakes on Guam, such as the Agana Swamp, Agana Springs, Fena Lake, The Lost Pond, and others, are introduced species hotspots. New turtle species and aquarium fish are routinely reported from these areas. Local population should be informed about this problem.

4.2 Primary construction impacts

Primary construction impacts include all temporary problems associated with any large-scale development. These include land clearing disturbances on the site in order to prepare the land for the main structure (dam), supporting infrastructure, supporting buildings, storage areas, heavy machinery access roads, etc. Heavy equipment would be working in the area for an extended time period. Increased noise levels and degraded air quality, both due to dust particles and gases emissions, are expected to occur during the construction phase. Paving of roads and laying down water pipes and setting power poles are some of the temporary disturbances during the construction phase. Traffic along Route 4 is expected to increase.

Erosion control will be of particular importance during the construction phase. Necessary precautions must be taken to ensure that erodable soils and saprolites do not cause sediment problems. An Erosion Control Plan should be prepared by the developer prior to commencing any site work.

All of these impacts are expected to get ameliorated, as the construction phase is completed.

4.3 Effects on recreational and scenic resources and archaeological resources

This section addresses potential impacts of the proposed project, on the people. People directly using the area may be affected by the changes in availability of recreational uses or change of quality of visual resources. Indirectly, people would be harmed by destruction of archaeological resources, if present in the area.

4.3.1 Effects of Recreational Use

The proposed site is used for recreational purposes such as hiking and boonie stomping, swimming, fishing, hunting, etc. Adjacent areas to the proposed reservoir lake are suitable for such activities as well, so no dramatic loss is expected here. The presence of a lake may actually offer additional recreational activities.

4.3.2 Effects on Scenic Resources

If this project is completed, the lake will be visually prominent from the village of Inarajan and the coastal highway. Significant areas currently forested, would be inundated. The main scenic resources of the area, however, would remain undamaged. Laolao Falls and Inarajan Falls would not be flooded, although the water level in the lake would reach a short distance away from the falls. Fintasa Falls are located further upstream and the area around them would remain largely uninfluenced.

Smaller waterfalls, and many sets of rapids, however, would be drowned. Many of these are very scenic, aesthetically valuable, resources, often visited by people.

Additional adverse effects on the visual values of the area are due to planned extensive use of concrete. It is recommended that architectural treatments, such as concrete darkening, be employed in minimizing adverse visual impact.

On the positive end, the lake itself, once edge vegetation is established, is expected to be visually beneficial resource. The lake would contain one prominent island, rising to 15.2 meters above the water surface, which would further contribute to visual appeal.

4.3.3 Effects on Archaeological Resources

No evaluation of subsurface artifacts and cultural resources has taken place. There is always a possibility that potentially significant yet unidentified features or deposits would be encountered during the project construction process. Should this occur, archaeological consultation should be sought immediately.

4.4 Socio-Economic Impacts

The proposed project would provide the necessary water supply to the people in southern Guam. The water supply from the lake would complement water from the Northern Guam Lens Aquifer and the Fena Lake Reservoir. Primary economic impact of this project would be through sale of potable water, and would mean profit for the Government of Guam. This project will generate a number of jobs for the local community. Secondary and support services will also be created by the project. Grounds maintenance, transportation, and other services will be necessary.

The reservoir lake may also act as flood control, which would reduce potential damages resulting from floods. This will, secondarily, reduce public expenditures regarding flood emergency work and cleanup activities.

Virtually all of the area involved in the project is privately owned. This is an additional constraint to the project considering that extensive land acquisitions will have to take place.

4.5 Impacts on Existing Infrastructure

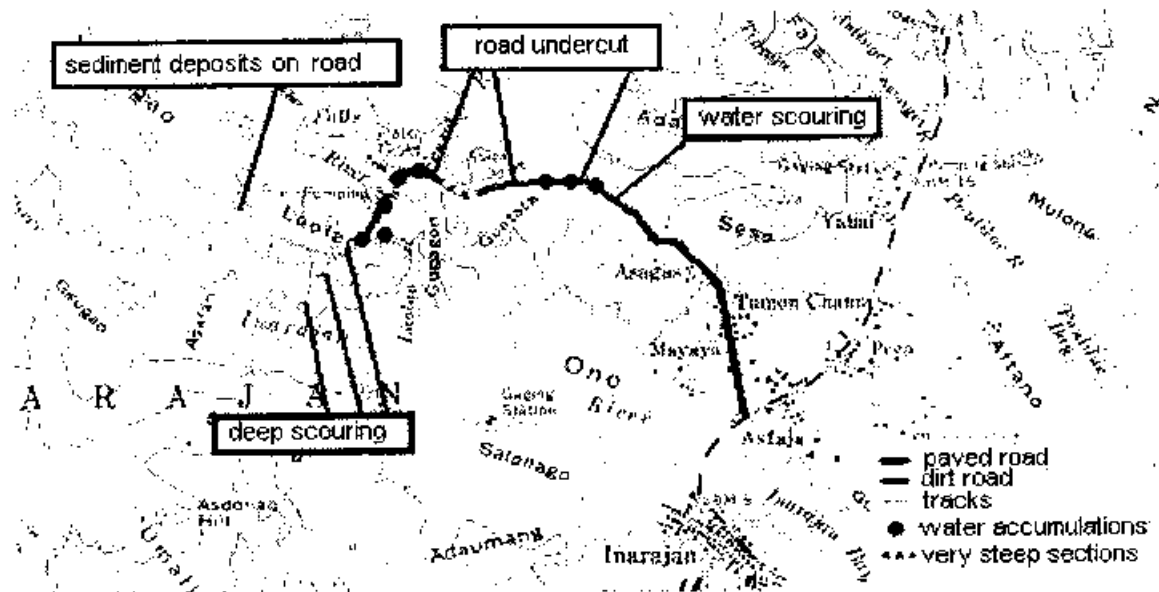
Access to the site is via Route 4, which will see increased traffic during the construction stage. A road branches off from Route 4, and passes by the Inarajan Middle School, and reaches a neighborhood of several homes. The road then continues as an unpaved road, passes a water reservoir on the left, and continues downhill. Extensive water scouring evidence, road undercutting, and puddle accumulation is visible on the road. This road will have to be paved if the project was to be completed, which will cause additional problems. The access road crosses Fensol and Fintasa rivers. A network of dirt roads in the area may have to be paved to facilitate construction and operation of this project.

This area is very active in a geomorphologic sense. Unpaved roads in the area are potentially unstable. Several areas along the roads are actively being eroded. Rocks and soil slumps are being deposited on the road. Road cuts and unstable hills next to the road may be modified or removed to prevent problems, but the instability of the road itself poses a more serious threat. In some areas, erosion by small streams has created deep undercuts on the side of the road, and threatens to cause the road to collapse. If the road here is paved, cracks may be expected to appear in the road soon after paving, and portions of pavement to break off and fall into depressions on the side of the road.

There is a network of dirt roads in the area. Many of these are potential areas of sedimentation. In certain areas, deep sediment layers, practically alluvium, accumulates right on the road (see Appendix C, photo 1). This will only be exacerbated by paving the roads. Several roads are very steep and water running down these sections may have energy high enough to slowly cause the deterioration of lower sections. Deep canals in the rocks along the side of some roads (see Appendix C, photo 5) clearly indicate high-energy water flows. If these areas were paved, the amount of water available would be greatly magnified and it would continue scouring existing canals with far greater intensity. In addition to existing extensive puddles (see Appendix C, photo 3) and water accumulations on the road, even the driest locations show evidence of mudcracks and other indicators of prolonged water accumulations. In certain places, water accumulations on the road are permanent enough to have an algal and aquatic invertebrate community established (see Appendix C, photo 4). Wetland vegetation along the sides of the roads demonstrates that water accumulations are significant in volumes and are long lasting. Wetland areas as well as other hydrologically significant features are mapped and are shown in figure 6.

Several perennial and temporary streams flows underneath and across the roads. Appendix C, photo 2 shows a temporary deeply incised stream canal

Current infrastructure, with notes pointing out potential problems associated with development is illustrated in figure 10:



As far as other infrastructure is concerned, telephone service can be derived from the closest neighborhood. The closest power poles are located in the mentioned neighborhood. The power needs of the project are anticipated not to cause a problem to the existing system. There are no existing sewer lines in the vicinity of the proposed project area. All these will have to be extended and developed to service the project site. A treatment plant will have to be constructed, as a planned part of the project.

Although much of the area affected by the project is suitable for subsistence and commercial farming and grazing, most of the area is not being used for that purpose at present time. Limited areas are used for small scale farming and grazing. Owners of those lands will have to be compensated. In fact, almost all of the land affected by the project is privately owned and will have to be acquired.

This section discusses the potential impacts on the water quality in the proposed lake. These potential negative factors include erosion, water chemistry, geologic fractures, and waste disposal.

4.7.1 Erosion

Due to heavy erosion in the badlands areas upstream, storms are expected to deliver massive amounts of sediment to the lake. Erosion would also make the lake shoreline quite unstable. Sediment laden water, mostly in form of flash floods during the rainy season, will find its way into the reservoir lake and impact its water quality.

4.7.2 Water Chemistry

Groundwater, as well as surface runoff, may mobilize heavy metals from rocks and soils and may deliver these toxic elements to the reservoir. According to a WERI study (1993), manganese and iron levels in Fintasa and Laolao rivers are some of the highest in Guam. If we assume that all of the iron and manganese would arrive to the reservoir, a discharge of 1 MGD, and concentrations of 1500 mg/L of Fe, and 230 mg/L of Mn, the reservoir lake would receive over 2 tons of iron and 350 kilograms of manganese per year. These amounts certainly have the potential for a local buildup to toxic levels, especially in the anoxic bottom waters.

4.7.3 Fractures in Underlying Rocks

Water chemistry of a reservoir lake could be somewhat influenced by fracture zones which allow high groundwater flow. Groundwater, flowing through fractures, may mobilize heavy metals from surrounding rocks. These toxic elements would be delivered to the reservoir. In addition to obvious hazards related to stability of structures such as dams, fractures underlying the reservoir may actually take in water from the lake.

4.7.4 Future Construction and Waste Disposal Problems

The quality of the water in the reservoir could also be potentially affected by human activities. The badlands up gradient from the lake are designated for development, and ephemeral streams would quickly deliver any construction waste to the lake. The headwaters of the streams are areas of intensive erosion and potential sites for unregulated waste disposal. Any housing development in the area could have its wastes delivered to the lake via underground seepage, as well as surface flow. Even if no development takes place, vast quantities of sediment are likely to severely degrade water quality in the planned lake.

5.0 List of Preparers

This report was prepared by Danko Taborosi, graduate student of the University of Guam Environmental Science graduate program, and Dr. Khosrowpanah at the Water and Environmental Research Institute of the Western Pacific.

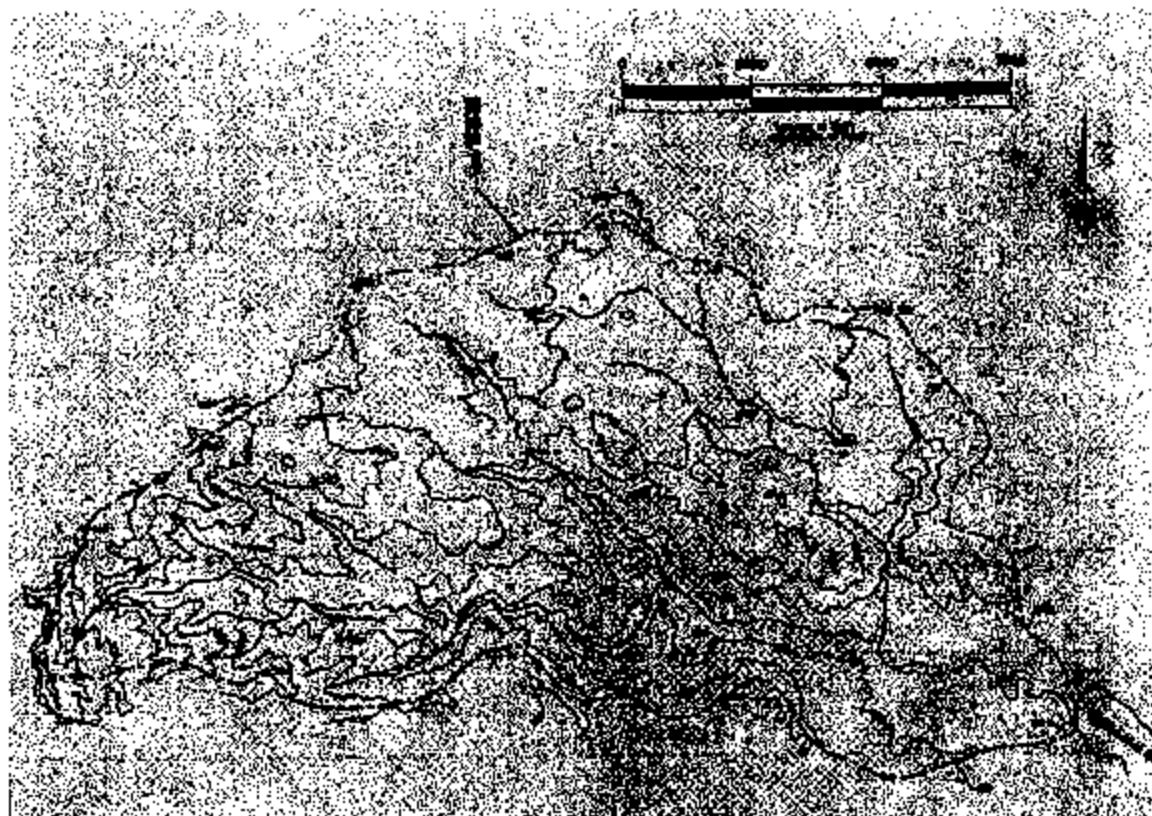
6.0 List of Agencies, Organizations, and Persons to whom copies of the Statement are sent: N/A

Copies of this report are available from the Water and Environmental Research Institute of the Western Pacific, University of Guam.

REFERENCES

- Ayres J. F., and R. N. Clayshulte (1983) Feasibility study of developing valley fill aquifer from village water supplies in southern Guam. UOG, WERI Tech. Rept. 41:105 p.
- Barrett Consulting Group (1994) Surface Water Development Study. Prepared for PUAG, Public Utility Agency of Guam. Vol. 1 and 2.
- Denton, G., and H.G. Siegrist (1993) Manganese in Watershed Environments of Southern Guam. Unpublished report.
- Department of Agriculture, Division of Aquatic and Wildlife Resources, Government of Guam (1993). Checklist of Terrestrial Vertebrates and Selected Terrestrial Invertebrates of Guam.
- Dumaliang et al., (1997) Reconnaissance Geology of a Proposed Dam/Reservoir Site in Southern Guam. WERI Tech. Rept. 78:36p.
- Fritts, T.H., Rodda G.H. and Michael J. McCoid (1993) A checklist and Key to the Amphibian and Reptiles of Marianas. Unpublished report. 23p.
- Raulerson, L. and Agnes Rinehart (1991) Trees and Shrubs of the Northern Mariana Islands. Coastal Resources Management, Saipan, Northern Mariana Islands. 120pp.
- Siegrist, H.G. and K. Lewis (1997) Bedrock fractures and implications to water resources in southern Guam. WERI Tech. Rept. In preparation
- Stark J. T. and J. I. Tracey (1963) Petrology of the volcanic rocks of Guam. U.S. Geol. Surv. Prof. Paper 403-C 32p.
- Tracey, J. I. et al. (1964) General Geology of Guam. U.S. Geol. Surv. Prof. Paper 403-A, 104p.
- United States Geological Survey (1968) Agat Quadrangle, Mariana Islands-Island of Guam, 1:24,000 Series (Topographic)
- United States Geological Survey (1968) Inarajan Quadrangle, Mariana Islands-Island of Guam, 1:24,000 Series (Topographic)
- United States Geological Survey (1968) Merizo Quadrangle, Mariana Islands-Island of Guam, 1:24,000 Series (Topographic)
- United States Geological Survey (1968) Talofofo Quadrangle, Mariana Islands-Island of Guam, 1:24,000 Series (Topographic)

Appendix A: Map of Inarajan River Drainage Basin



APPENDIX B: VEGETATION TYPES IN THE PROJECT AREA



Photo 1: transitional grassland-woodland vegetation



Photo 2: wetland vegetation, savanna in background



Photo 3: savanna (grasslands)



Photo 4: coconut groves

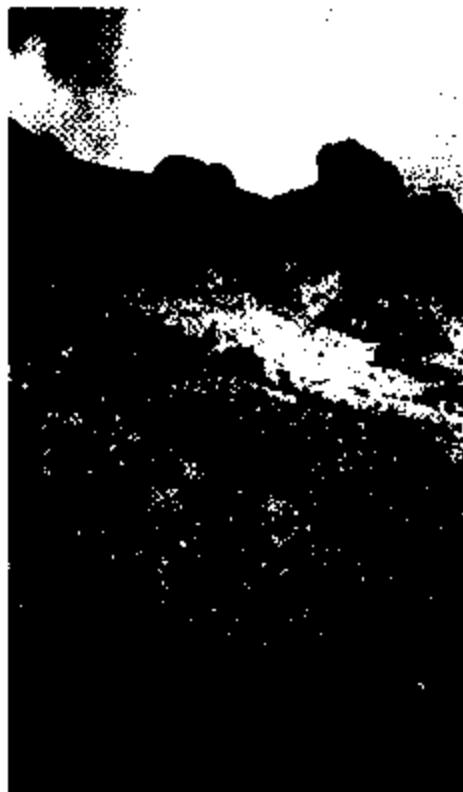


Photo 5: unvegetated, disturbed areas



Photo 6: forest vegetation adjacent to rivers

APPENDIX C: ROAD EROSION AND INSTABILITY



Photo 1: sedimentation on the roads (almost alluvium!)

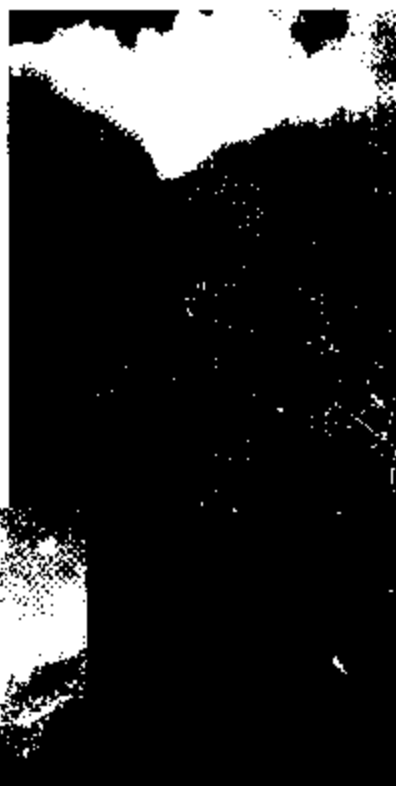


Photo 5: deep scouring

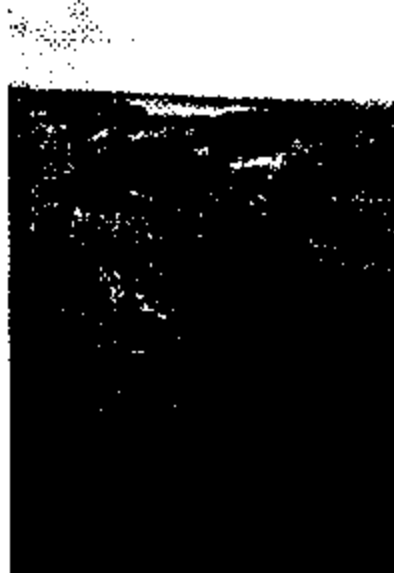


Photo 2: temporary stream canal



Photo 3: water accumulation



Photo 4: puddles on the road - algae and aquatic fauna present!

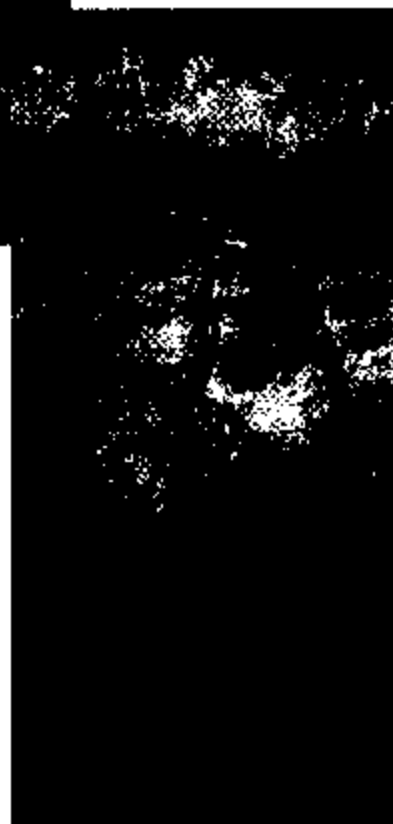


Photo 6: erosion of road-cut slopes