ENVIRONMENTAL ASSESSMENT FOR NON-POINT SOURCES OF POLLUTION FOR UGUM WATERSHED

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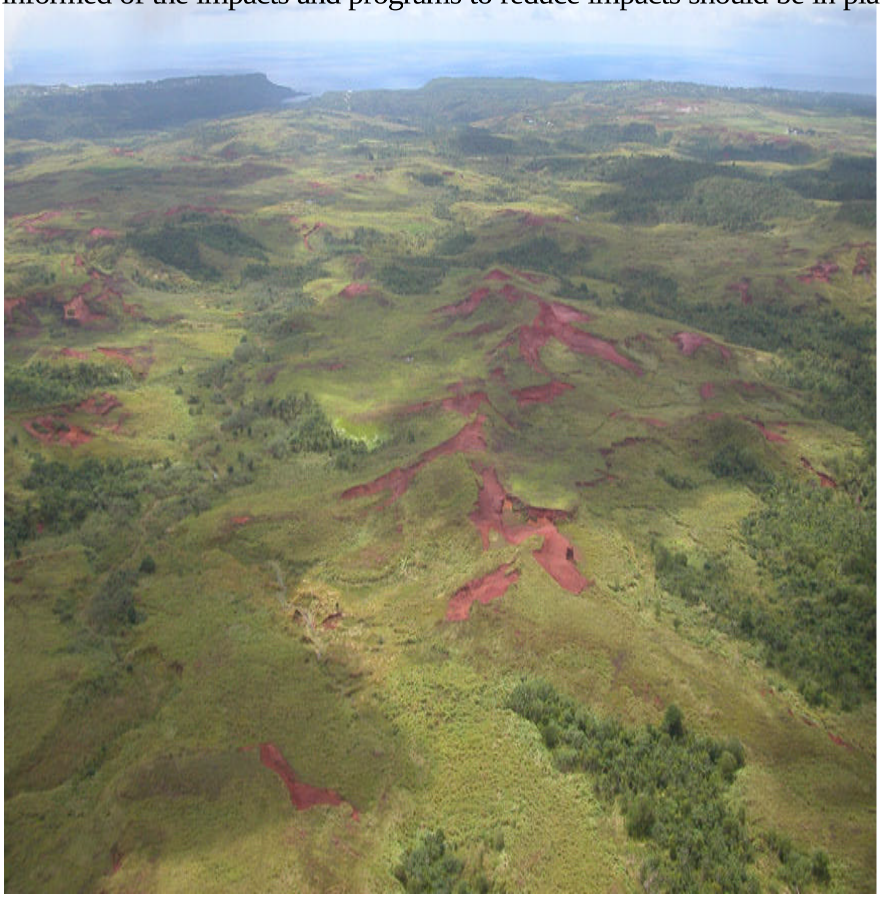
ABSTRACT

The existing physical and environmental components of the 4,672.6-acre Ugum Watershed in Southern Guam were studied and their potential impact on the streams were discussed. The overall goal was to review natural resources for better understanding the potential for protecting and improving water quality of the streams within the Ugum Watershed. For this study we used Geographic Information System (GIS) and Arc Hydro programs to organize and register all available information about the Ugum Watershed. The projection that was used for this study was WGS 84 (Latitude/Longitude World Grid System 84). To locate areas of interest such as farms, badland, and riverbank erosion sites etc we took a set of low elevation geo-referenced non-corrected aerial photos from a helicopter from altitudes ranging from 1500 to 2500 feet.

The sites that have potential to be considered as non-point sources of pollution (contributing sediment particles into the streams) were identified in the aerial photos that were taken above the Ugum and Bubulao rivers. Sites were selected based on the steepness of the river section, changes in river direction, bank erosion and land slumping (observed from aerial photos). The impacts of the badlands, off-road vehicle excursions, and sheet and rill erosion were discussed. Badlands could contribute a large amount of the sediment into the waterways. They need to be monitored and an effective re-vegetation method should be applied. The off-road vehicle excursions and sheet and rill erosion (mostly due to intended fire) are mostly due to human activities. The public should be informed of the impacts and programs to reduce impacts should be in place.



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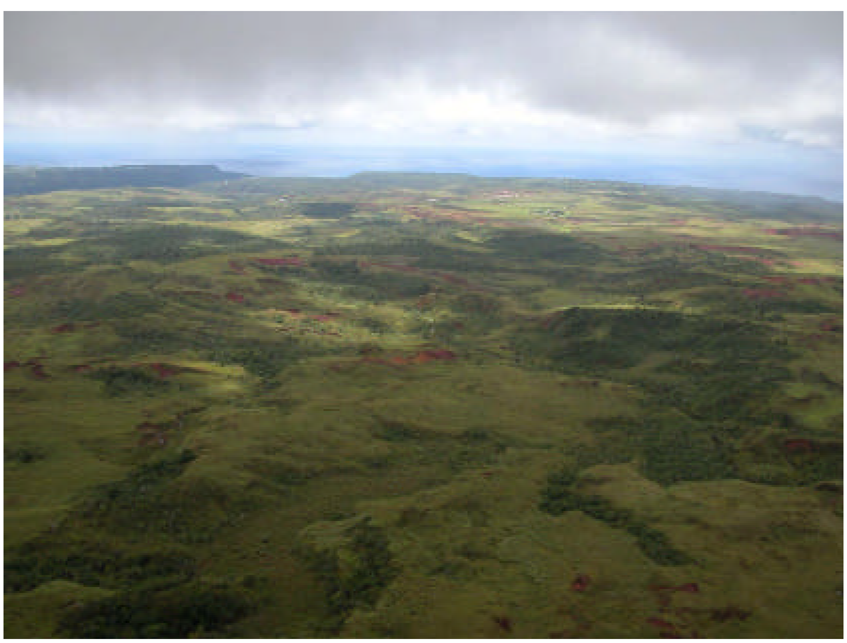
1. INTRODUCTION

The programmatic implementation of the Guam Coastal Nonpoint Pollution Control Program (GCNPCP) in accordance with the requirements of Section 6217 of the Coastal Zone Act Reauthorization Amendment (CZARA) of 1990 requires the development of a multi-year watershed restoration strategy. According to the guidance of Section 6217, the Watershed Restoration Action Strategies should include watershed assessment and identification of opportunities to reduce nonpoint sources pollution.

According to the Guam Comprehensive Watershed Planning Process Report Guam has nineteen (19) watersheds, including the northern Guam aquifer as one watershed. For this year, the Ugum Watershed was selected for developing watershed assessment. The selection was based on the Guam's Water Planning Committee recommendation.

This report presents the resource assessment for the 4,672.6-acre Ugum Watershed in Southern Guam. The purpose of this study was to assess natural resources for better understanding the potential for protecting and improving water quality of the streams within the Ugum Watershed. The watershed assessment included reviewing the existing environment, documenting land activities, and identifying areas that could be considered as non-point sources of pollution. During the course of this study we used Geographic Information System (GIS) and Arc Hydro programs to organize and register all available information about the Ugum Watershed. The projection that was used for this study was WGS 84 (Latitude/Longitude World Grid System 84). To identify areas of interest such as farms, badland, riverbank erosion sites we took a set of low elevation geo-referenced non-corrected aerial photos from a helicopter from altitudes ranging from 1500 to 2500 feet.



a. Watershed Location

Figure 1 shows Guam, the largest and southernmost of the Mariana Islands, located at N Latitude 13° 28' and E Longitude 144° 45'. It is 30 miles long, 4 to 11.5 miles wide, and 212 square miles in area. The Mariana Trench lies 60 to 100 miles east of Guam. It lies about 1,200 nautical miles east of Philippine Islands, 1,500 miles south southeast of Japan, and 1000 miles north of New Guinea.

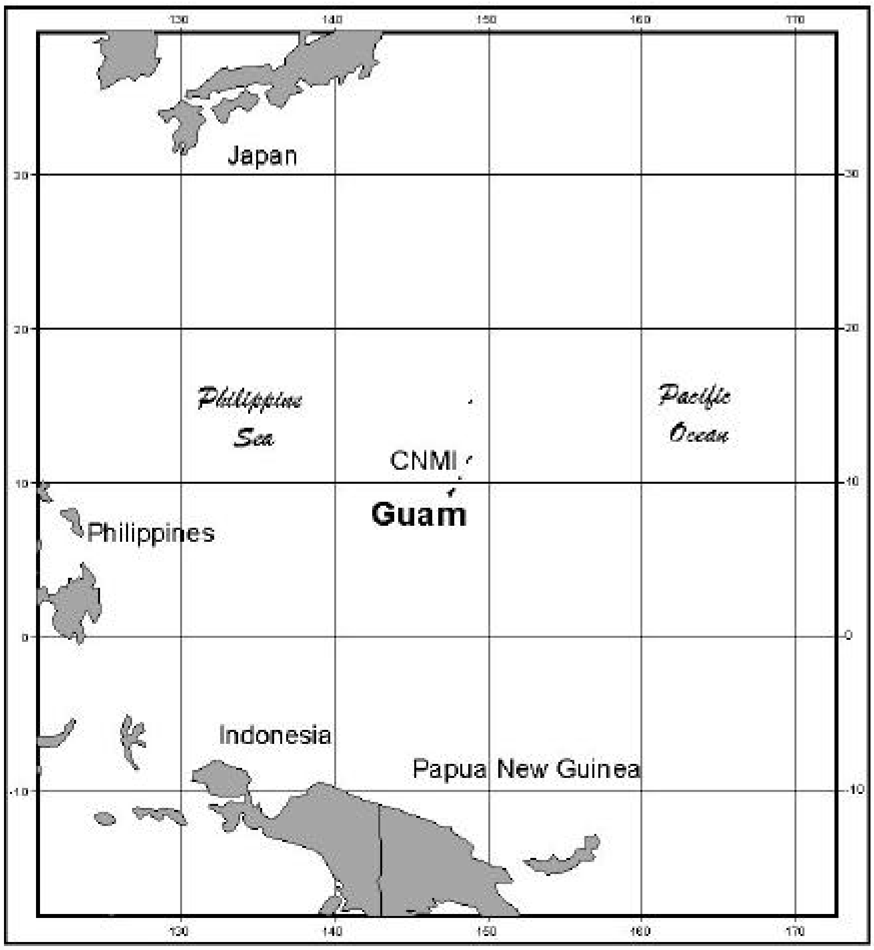


Figure 1. Guam's location.

The Ugum Watershed, which serves as a major source of the domestic water supply for Guam is located in Southern Guam. As shown in Figures 2 and 3 it stretches from Mount Bolanos, which rises to 1,241 feet and forms the western limits of the Watershed, to Talofofo River in the east. Mount Bolanos includes the headwaters of the Atate and Bubulao river systems, which flow into the Ugum River. The watershed has an area of 4,672.6 acres (7.3 square miles) of rolling hills with areas of very steep slopes. The 23 miles of rivers and streams in the Ugum Watershed spread from the mountains to sea level where the Ugum River drains into the Talafofo River and then into the Talafofo Bay.

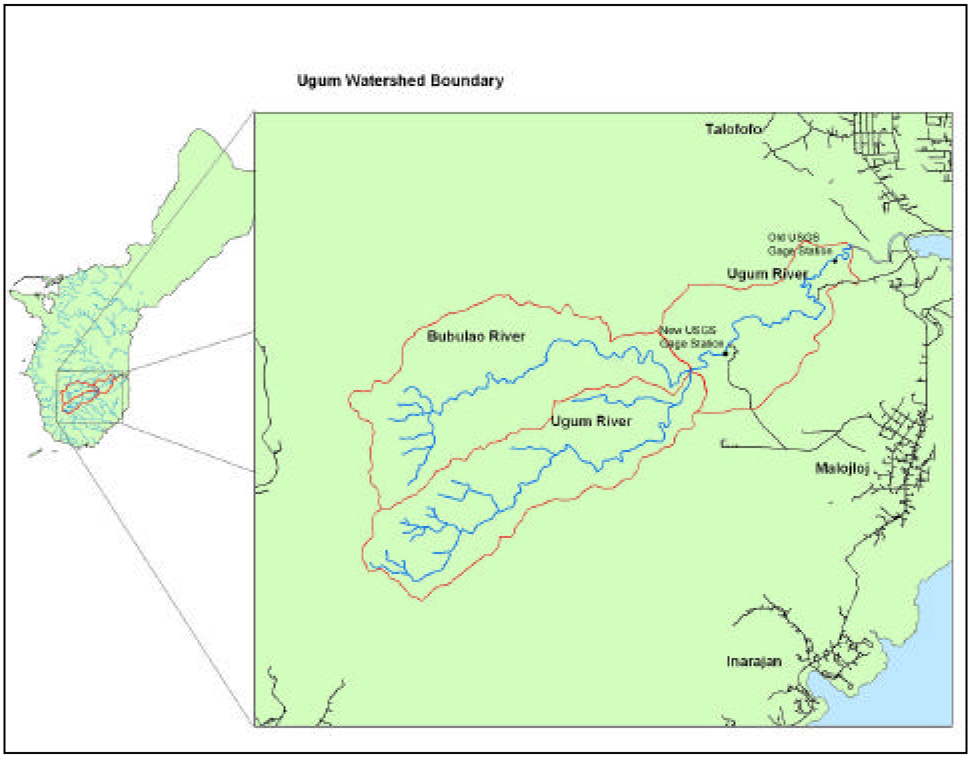


Figure 2. Location and boundary of the Ugum Watershed. The watershed's boundary is shown in red lines and streams are in blue.

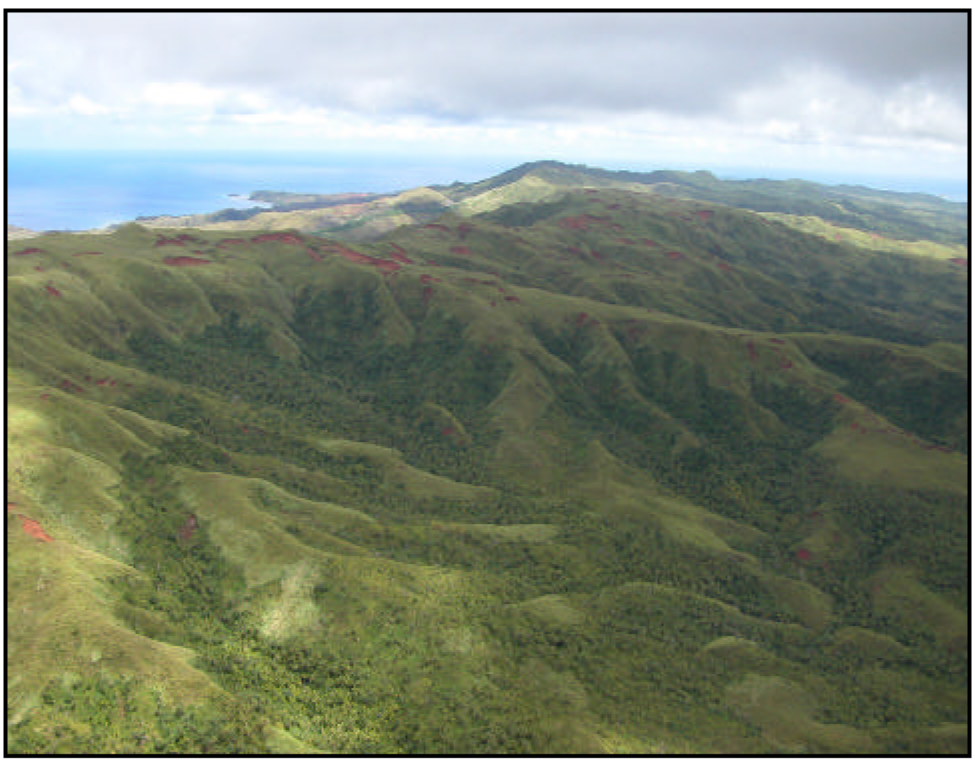


Figure 3. Headlands of the Ugum Watershed.

The Guam Waterworks Authority (GWA) is presently permitted to pump 4 million gallons per day (mgd) from the Ugum River to the treatment facility, which was built in 1992. The facility includes an intake structure in the river, a pumping station next to the riverbank at the intake structure, transmission lines and a water treatment plant. In recent years GWA has faced an increasingly difficult task of keeping the plant operating at full capacity when the river is running with high turbidity rates. This highly turbid water has increased operational costs and, along with poor operation and maintenance practices, has led to premature failure of many components of the treatment plant system. Water that passes the Ugum treatment plant intake eventually makes its way to the outlet of the river and into the estuary and reef environment. The negative impact of sediment loading on the aquatic environment of Guam has been recorded by several researchers (Rogers, 1990; Richmond, 1993). These researchers observed that coral reef decline, due to sediment deposition, is directly linked with reduction in the quantity and quality of solar radiation in part due to the sediment load from stream runoff. The degradation of coral reefs has raised several concerns, including negative impacts on fish populations and tourism. Figure 4 shows Talofofo Bay after heavy rainfall.

Figure 4. Talofofo Bay after heavy rainfall event. The bay is choked by sediment washed down from the Talofofo and Ugum River systems.

b. Project Goals

The overall objective of this project was to assess the existing natural resources and identify the areas that have potential to contribute pollution into the streams and eventually into the coastal areas within the Ugum Watershed. The specific objectives were:

1. Gather physical and environmental data of the Ugum Watershed. This includes: a digital elevation model (DEM) and Geographic Information System (GIS) layers of soil coverage, wetlands, badlands, roads, and vegetation. Data also includes: rainfall information, sediment concentration in streams, and compilations of available stream flow records.

2. Develop a GIS watershed management database for Ugum Watershed that identifies the spatial distribution and extent of such items as: soil types, land slopes, location and extent of forest, grassland, wetland and badland areas, extent of unpaved roads, land use areas including conservation and preserve areas, low density housing areas, areas impacted by agricultural operations, lengths and locations of streambank erosion, and areas impacted by off-road activities. Data will also include NPDES permits, 303(d) impaired waters listings and Total Maximum Daily Loads (MDL). The Watershed database also includes GIS layers of satellite imagery and available aerial photography. Data will not only be useful in this study but also will serve as a reference to measure how various changes in the basin affect sediment production and thus water quality in the stream.

3. Using tools available in ESRI's Arc Map GIS and Arc Hydro products to identify areas that have the highest potential to contribute pollution to the streams.

c. Data Collection & Methodology

One of the earliest steps toward developing a Watershed Restoration Action Strategy is to characterize the watershed by using immediately available information. This characterization in general will reveal several benefits such as: brief summaries of the most important or relevant information and issues, provide preliminary findings, identify sources for more information or analysis, and suggest additional characterization and restoration work. Also, it should be noted that the watershed characterization and watershed restoration action strategy should be maintained as living documents. These documents be updated periodically as new information becomes available.

To characterize the Ugum Watershed we used Geographic Information System (GIS) and Arc Hydro programs to organize and register all available information about the Ugum Watershed. The projection that was used during the course of this study was WGS 84 (Latitude/Longitude World Grid System 84).

The project was divided into two phases. Phase I was data collection. During this phase the following information was collected and entered into the Ugum Watershed database:

Digital elevation model (DEM) data, digital ortho photography, soil type and plant coverage data, rainfall data, stream flow, and surface water quality data were collected from various sources and compiled into a single database for the Ugum watershed. A set of low elevation geo-referenced non-corrected aerial photos of the Ugum and Bubulao rivers was taken for the purpose of locating farming areas, areas of high erosion and slope failure. These aerial photos were taken from a helicopter at altitudes ranging from 1500 to 2500 ft. Most of the photos are not plan view hence distortion is encountered during geo-referencing. Although these photos may not be suitable for survey grade coordinate location, their main purpose was to help identify areas of interest such as farms, badland, and riverbank erosion sites.

Phase II was development of GIS models of the Ugum Watershed that identify the areas that have potential to be non point sources of pollution. The methodology and procedure that was used for this project will be a model for similar study for any other watershed in Southern Guam.

d. Previous Studies

There have been a few studies pertaining to the resource assessment for the Ugum Watershed. The Natural Resources Conservation Service (NRSC) (Resources Assessment, 1995) evaluated the resources within the Ugum Watershed for determining the methods of protection for the Ugum River from non point source of pollution. They estimated the amount of the potential erosion from the upland and road erosion inside the Watershed. Researchers from WERI completed a study “Wetlands resources in the Ugum Watershed” (Siegrist et al., 1996). The project goals were to identify and describe wetlands resources, functions, and values within a time frame for field observations and measurements. They concluded that, for the most part Ugum watershed is a clean, relatively undisturbed environment showing local geomorphic and geologic characteristics, the indigenous biota, seasonal change, and anaerobic processes occurring in the wetland soils. Their study also indicated that the wetlands in the Ugum-Bubulao River study sites are absolutely critical in controlling water quality by regulating and recycling nutrients and trace metals within the ecosystem. Guam Forestry completed a report on Ugum Watershed Restoration Strategy in 1999. This report evaluates the parameters that are causing erosion within the Ugum Watershed. The entire evaluation was based on the findings of the NRCS’s study in 1995.

2. GEOGRAPHIC INFORMATION SYSTEM (GIS)

Over the last several years the utilization of Geographic Information Systems (GIS) as a management tool for natural resources has grown considerably. GIS has evolved over the years from a system for simple map-making and storing and organizing spatial data to being able to conduct various tasks such as spatial and hydrologic modeling, statistical analysis, networking, routing and other environmental applications.

The geographic information system (GIS) layers for the Ugum watershed were attained from several local and federal government agencies and modified from various sources explained below. Many of the layers were derived from existing GIS layers for the entire island. The GIS software used for this project was ESRI®'s ArcGis ArcEditor™ Version 9.0. Also, two ESRI GIS extensions were use in this project, 3D Analyst and Spatial Analyst. Most of the final GIS layers for the watershed were projected into the geographic coordinate system Latitude/Longitude WSG84. This provides a layer that is easily re-projected into other projections that end-users may need. The WS84 projection is also the default setting on most Global Position System (GPS) units making it easier for users to overlay GPS data with the layers. Listed below are the GIS layers created or derived from existing layers for this project including descriptions for each layer.

***5mClipTopo_wgs84.shp*:** 5-meter contours line generated from the USGS DEM layer for Guam. The projection is lat/long WGS 84.

***Jeep trails_Projectwgs84.shp*:** Jeep and off-road trails digitized from Guam 1994 orthophotos and Ikonos® satellite images. Projection is WGS 84 lat/long.

Ugum_riversystem_wgs84.shp: Ugum river system, subset of original Guam rivers layer. Projection is lat/long WGS 84.

***Ugum_wgs84*:** Clipped from the Guam "orthophotos" of the watershed projected into lat/long WGS 84. The original files are from the 1994 Guam orthophoto set.

***Ugum_wildlife_refuges.shp* :** Property on the ugum watershed that is designated as wildlife refuge. Original layer is National Wildlife refuge layer.

***Ugumbadlandsfinal_Project.shp*:** Badlands shapefile derived from Guam vegetation layer and Guam orthophotos.

***Ugumpolywatershed.shp*:** Polygon shapefile of ugum watershed, projected to WSG 84 lat/long. Watershed boundary was digitized from the 1:24000 scale USGS topographic maps.

Ugumrelief: Relief map for the Ugum basin based on the USGS Digital Elevation Model (DEM). Geographic Coordinate system is WGS 84 Lat/Long.

Ugumgeology.shp**:** Polygon shape file of the geologic formations of the area based on the USGS geologic map of Guam produced by Tracey et al. 1964 and digitized by the Natural Resource Conservation Service (NRCS).

Ugumwetlands.shp: Polygon shapefile of ugum wetlands taken from the National Wetlands Inventory Layer.

Ugumsoilsclip.shp: Polygon shapefile of the soil types of the area based on the NRCS soil survey map of Guam and digitized by the Natural Resource Conservation Service (NRCS).

Ugumveg: Raster data set of the vegetation type for the Ugum river basin derived from the Guam Vegetation Layer produced by the USDA Forestry Division.

Organization of Data Layers CD

The GIS and Aerial photos of the Ugum watershed are stored on CD accompanying the report. The files are contained in the folders labeled *GIS Layers*, *Finished Maps*, and *Aerial Images*. The *GIS Layers* folder contains all the GIS shape files, raster data, and geo-referenced images. The *Finished Map* folder contains jpeg Images of full size maps produced for quick reference and the *Aerial Images* folder is the collection of non-referenced images taken from the various helicopter trips over the Ugum watershed.

3. RESOURCE ASSESSMENTS

a. Geology & Soils

Guam is a raised volcanic island and the largest and southernmost of the Mariana Islands. The island is divided into two major geologic and hydrogeologic regimes: the older, volcanic highlands in the south and the uplifted limestone plateau in the north and southeast. Northern and southern Guam are separated by the Pago-Adelup Fault, which runs northwest to southeast in central Guam (Tracey et al., 1964).

The topography of the northern half of Guam is a relatively smooth gently sloping limestone plateau with three prominent hills that rise above the plateau. Mount Santa Rosa (858 ft) and Mataguac Hill (630 ft) are inliers of volcanic rock, and Barrigada Hill (665 ft) is made of limestone. The limestone plateau overlies volcanic basement rock, a structure that allows for a modified Ghyben-Herzberg freshwater aquifer. The topography of Northern Guam is often referred to as karst topography, replete with sinkholes, limestone caverns, no permanent above ground streams, and many natural artesian springs of fresh water at the shore (Tracey et al., 1964).

The southern half of the Guam is primarily comprised of dissected volcanic formations, which are relatively impermeable and home to many streams and surface water reservoirs. It is formed mostly of the Umatac formation (a thick sequence of volcanic rocks with minor inter bedded limestone and calcareous shale). A ridge of high ground runs north south close to the western coast. The slope of the terrain is very steep from ridgeline to the western coast; from the ridgeline towards the eastern coast the slope is more gradual. The highest point on the ridge, which is known as Mount Lam Lam in the indigenous island language, rises to 1,334 feet and is capped by limestone. Reefs surround the south half of the island, and are cut by numerous bays at the mouths of the large permanent streams that drain the volcanic upland.

Soil conditions, including soil type, materials in which they formed, soil permeability, and soil moisture greatly affect how the land may be used, the potential for vegetation and habitat, and also overland runoff that causes land erosion and land slides. According to Soil Survey of Territory of Guam (USDA-SCS, 1985), the Ugum Watershed has nine major soil series (soil series characterizes the soils and the materials in which they formed) with 26 mapping units. The mapping units explain the properties and slope of the areas that contained the specific units. The soils in the Ugum Watershed area are: Agfayan, Akina, Atate, Inarajan, Pulantat, Sasalguan, Togcha, and Ylig group (Tracey et al., 1964). Figure 5 shows the soil coverage in Ugum Watershed. Description and properties of each soil in Ugum Watershed, with their acreages, are listed in Table 1.

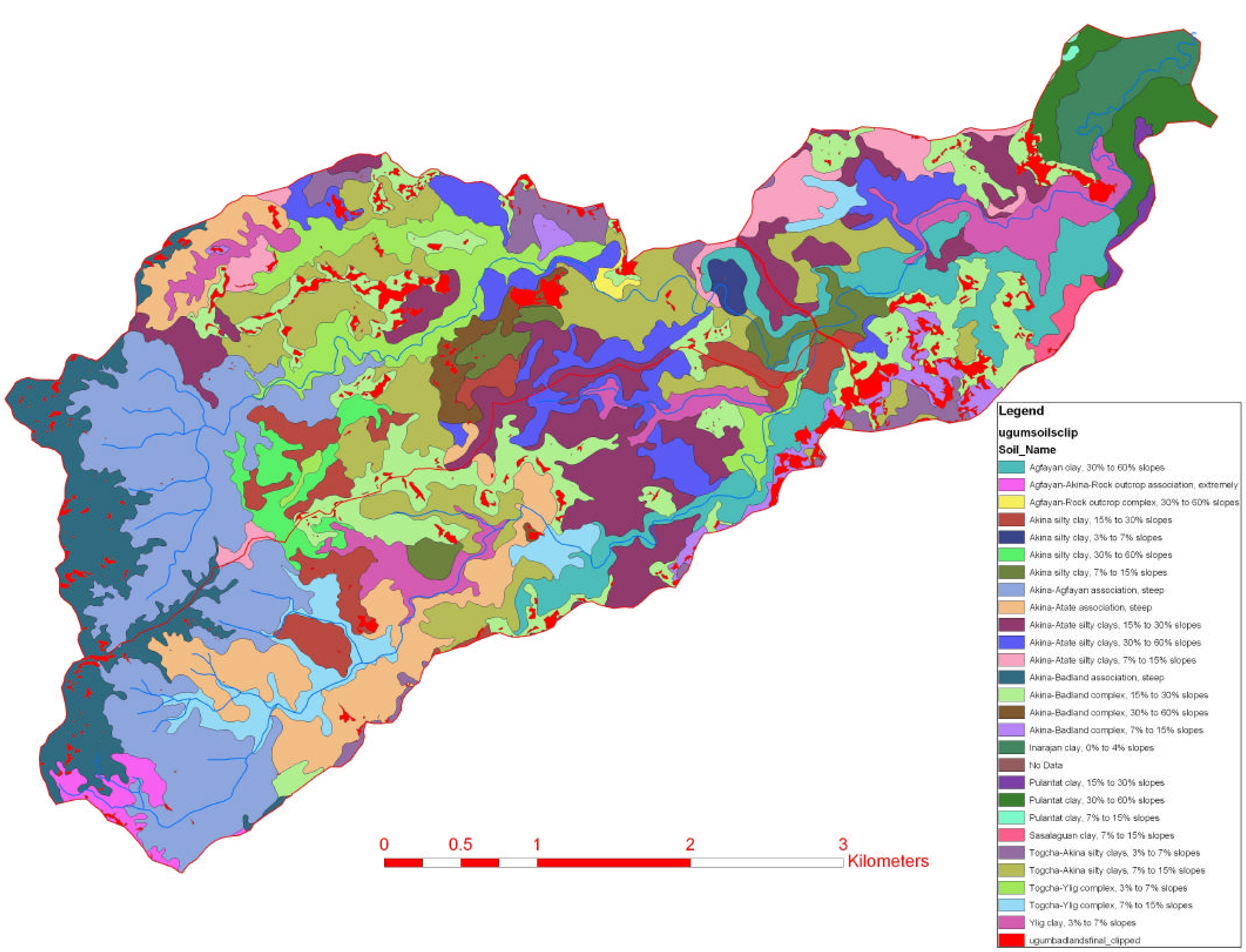


Figure 5. Soil Types within the Ugum Watershed.

TABLE 1. Soils Type within the Ugum Watershed

UNIT	DESCRIPTION	PROPERTIES	ACRES
2	Agfayan clay, 30 to 60 percent slopes	Permeability of this *Agfayan* soil is moderately slow. Available water capacity is very low. Effective rooting depth is 10 to 38 cm. Roots may penetrate the soft bedrock along fractures. Runoff is rapid, & hazard of water erosion is severe.	268.6
4	Agfayan-Rock outcrop complex, 15 to 30 percent slopes	Permeability of this *Agfayan* soil is moderately slow. Available water capacity is very low. Effective rooting depth is 10 to 38 cm. Roots may penetrate the soft bedrock along fractures. Runoff is rapid, & hazard of water erosion is severe. Water penetrates the areas of *Rock* outcrop only along cracks & seams. Runoff is very rapid, which may result in erosion in downslope areas. The Rock outcrop is moderately resistant to erosion.	13.9
6	Agfayan-Akina association, extremely steep	Permeability of this *Agfayan* soil is moderately slow. Available water capacity is very low. Effective rooting depth is 10 to 38 cm. Roots may penetrate the soft bedrock along fractures. Runoff is rapid, & hazard of water erosion is severe. Permeability of this *Akina* soil is moderately slow. Available water capacity is very moderate. Effective rooting depth is 150 cm or more. Runoff is rapid, & hazard of water erosion is severe.	6.2
7	Agfayan-Akina-Rock outcrop association, extremely steep	Permeability of this *Agfayan* soil is moderately slow. Available water capacity is very low. Effective rooting depth is 10 to 38 cm. Roots may penetrate the soft bedrock along fractures. Runoff is rapid, & hazard of water erosion is severe. Permeability of this *Akina* soil is moderately slow. Available water capacity is moderate. Effective rooting depth is 150 cm or more. Runoff is medium, & hazard of water erosion is moderate. Water penetrates the areas of *Rock* outcrop only along cracks & seams. Runoff is very rapid, which may result in erosion in downslope areas. The Rock outcrop is moderately resistant to erosion.	37.5
8	Akina silty clay, 3 to 7 percent slopes	Permeability of this *Akina* soil is moderately slow. Available water capacity is moderate. Effective rooting depth is 150 cm or more. Runoff is medium, & hazard of water erosion is moderate.	16.8

TABLE 1. Soils Type within the Ugum Watershed (continued)

10	Akina silty clay, 15 to 30 percent slopes	Permeability of this *Akina* soil is moderately slow. Available water capacity is moderate. Effective rooting depth is 150 cm or more. Runoff is rapid, & hazard of water erosion is severe.	181.5
11	Akina silty clay, 30 to 60 percent slopes	Permeability of this *Akina* soil is moderately slow. Available water capacity is moderate. Effective rooting depth is 150 cm or more. Runoff is rapid, & hazard of water erosion is severe.	58.1
12	Akina-Agfayan association, steep	Permeability of this *Akina* soil is moderately slow. Available water capacity is very low. Effective rooting depth is 150 cm or more. Runoff is rapid, & hazard of water erosion is severe. Permeability of this *Agfayan* soil is moderately slow. Available water capacity is very low. Effective rooting depth is 10 to 38 cm. Roots may penetrate the soft bedrock along fractures. Runoff is rapid, and the hazard of erosion is severe.	698.8
14	Akina-Atate silty clays, 7 to 15 percent slopes	Permeability of this *Akina* soil is moderately slow. Available water capacity is moderate. Effective rooting depth is 150 cm or more. Runoff is medium, & hazard of water erosion is moderate. Permeability of this *Atate* soil is moderate. Available water capacity is moderate. Effective rooting depth is 150 cm or more. Runoff is medium , and the hazard of water erosion is moderate.	140.5
15	Akina-Atate silty clays, 15 to 30 percent slopes	Permeability of this *Akina* soil is moderately slow. Available water capacity is moderate. Effective rooting depth is 150 cm or more. Runoff is rapid, & hazard of water erosion is severe. Permeability of this *Atate* soil is moderately slow. Available water capacity is moderate. Effective rooting depth is 150 cm or more. Runoff is rapid, & hazard of water erosion is severe.	413.4
16	Akina-Atate silty clays, 30 to 60 percent slopes	Permeability of this *Akina* soil is moderately slow. Available water capacity is moderate. Effective rooting depth is 150 cm or more. Runoff is rapid, & hazard of water erosion is severe. Permeability of this *Atate* soil is moderately slow. Available water capacity is moderate. Effective rooting depth is 150 cm or more. Runoff is rapid, & hazard of water erosion is severe.	218.4

TABLE 1. Soils Type within the Ugum Watershed (continued)

17	Akina-Atate association,steep	Permeability of this *Akina* soil is moderately slow. Available water capacity is moderate. Effective rooting depth is 150 cm or more. Runoff is rapid, & hazard of water erosion is severe. Permeability of this *Atate* soil is moderately slow. Available water capacity is moderate. Effective rooting depth is 150 cm or more. Runoff is rapid, & hazard of water erosion is severe.	293.3
18	Akina-Badland complex, 7 to 15 percent slopes	Permeability of this *Akina* soil is moderately slow. Available water capacity is moderate. Effective rooting depth is 150 cm or more. Runoff is medium, and the hazard of water erosion is moderate. Permeability of the *Badland* is moderately slow. Runoff is rapid, and the hazard of water erosion is severe.	27.8
19	Akina-Badland complex, 15 to 30 percent slopes	Permeability of this *Akina* soil is moderately slow. Available water capacity is moderate. Effective rooting depth is 150 cm or more. Runoff is rapid, and the hazard of water erosion is severe. Permeability of the *Badland* is moderately slow. Runoff is rapid, and the hazard of water erosion is severe.	539.3
20	Akina-Badland complex, 30 to 60 percent slopes	Permeability of this *Akina* soil is moderately slow. Available water capacity is moderate. Effective rooting depth is 150 cm or more. Runoff is rapid, and the hazard of water erosion is severe. Permeability of the *Badland* is moderately slow. Runoff is rapid, and the hazard of water erosion is severe.	44.5
21	Akina-Badland association, steep	Permeability of this *Akina* soil is moderately slow. Available water capacity is moderate. Effective rooting depth is 150 cm or more. Runoff is rapid, and the hazard of water erosion is severe. Permeability of the *Badland* is moderately slow. Runoff is rapid, and the hazard of water erosion is severe.	416.1
48	Togcha-Akina clays. 3 to 7 percent	Permeability of this *Togcha* soil is moderate. Available water capacity is moderate. Effective rooting depth 150 cm or more. Runoff is medium, and the hazard of water erosion is moderate. Some lower lying areas are saturated with water from brief periods during the rainy season. Permeability of this *Akina* soil is moderately slow. Available water capacity is moderate. Effective rooting depth is 51 to 102 cm. Runoff is medium, and the hazard of water erosion is moderate.	70.9

TABLE 1. Soils Type within the Ugum Watershed (continued)

49	Togcha-Akina clays. 7 to 15 percent slopes	Permeability of this *Togcha* soil is moderate. Available water capacity is moderate. Effective rooting depth 150 cm or more. Runoff is medium, and the hazard of water erosion is moderate. Some lower lying areas are saturated with water from brief periods during the rainy season. Permeability of this *Akina* soil is moderately slow. Available water capacity is moderate. Effective rooting depth is 51 to 102 cm. Runoff is medium, and the hazard of water erosion is moderate.	479.8
50	Togcha-Ylig complex, 3 to 7 percent slopes	Permeability of this *Togcha* soil is moderate. Available water capacity is moderate. Effective rooting depth 150 cm. Runoff is medium, and the hazard of water erosion is moderate. Some lower lying areas are saturated with water from brief periods during the rainy season. Permeability of this *Ylig* soil is moderately slow. Available water capacity is very high. Effective rooting depth is more than 150 cm. Runoff is medium, and the hazard of water erosion is moderate. A seasonal high water table fluctuates between depths of 25 and 102 cm during the rainy season, and it recedes during dry season. Soil is subject to brief periods of flooding during rainy season. The surface may crack during the dry season.	191.5
51	Togcha-Ylig complex, 7 to 15 percent slopes	Permeability of this *Togcha* soil is moderate. Available water capacity is moderate. Effective rooting depth 150 cm. Runoff is medium, and the hazard of water erosion is moderate. Some lower lying areas are saturated with water from brief periods during the rainy season. Permeability of this *Ylig* soil is moderately slow. Available water capacity is very high. Effective rooting depth is more than 150 cm. Runoff is medium, and the hazard of water erosion is moderate. A seasonal high water table fluctuates between depths of 25 and 102 cm during the rainy season, and it recedes during dry season. Soil is subject to brief periods of flooding during rainy season. The surface may crack during the dry season.	124.9
55	Ylig clay, 3 to 7 percent slopes	Permeability of this *Ylig* soil is moderately slow. Available water capacity is very high. Effective rooting depth is more than 150 cm. Runoff is medium, and the hazard of water erosion is moderate. A seasonal high water table fluctuates between depths of 25 and 102 cm during the rainy season, and it recedes during dry season. Soil is subject to brief periods of flooding during rainy season. The surface may crack during the dry season.	165.2

TABLE 1. Soils Type within the Ugum Watershed (continued)

30	Inarajan clay, 0 to 4 percent slopes	Permeability of this Inarajan soil is slow. Available water capacity is high. Runoff is very slow to ponded, and the hazard of water erosion is slight. A seasonal high water table fluctuates between depth of 51 and 102 cm during the rainy season. This soil is subject to brief periods of flooding during the rainy season. Surface cracks extend to a depth of about 51 cm during the dry season.	78.1
46	Sasalaguan clay, 7 to 15 percent slopes	Permeability of this Sasalaguan soil is slow. Available water capacity is moderate. Effective rooting depth is 100 to 150 cm. Runoff is medium, and the cracks extend into the underlying saprolite during the dry season.	11.3
		TOTAL ACERAGE	**4585.4**

b. Vegetation

Plant communities and vegetation resources of the Ugum Watershed have been studied by Fosberg (1960), Raulerson, et al. (1978), and Government of Guam (1988), and a reconnaissance botanical survey of the Ugum Riverine Forest (1995). According to these studies savanna grasslands and ravine forests are the predominate plant communities within the Ugum Watershed. According to Fosberg (1960) human intervention has resulted in changes to both species composition and structure. Examples are conversion of the ravine forests into savanna grasslands and plantation of Coconut (Cocos nucifera), mango (Mangifera indica), bamboo (Bambusa vulgaris), betel nut (Areca catechu), and Papaya (Carica papaya) in Southern Guam. These changes probably were due to use for food or cultural values.

Figure 6 shows the vegetation coverage of the Ugum Watershed. Table 2 shows the vegetation distribution within the Ugum Watershed.

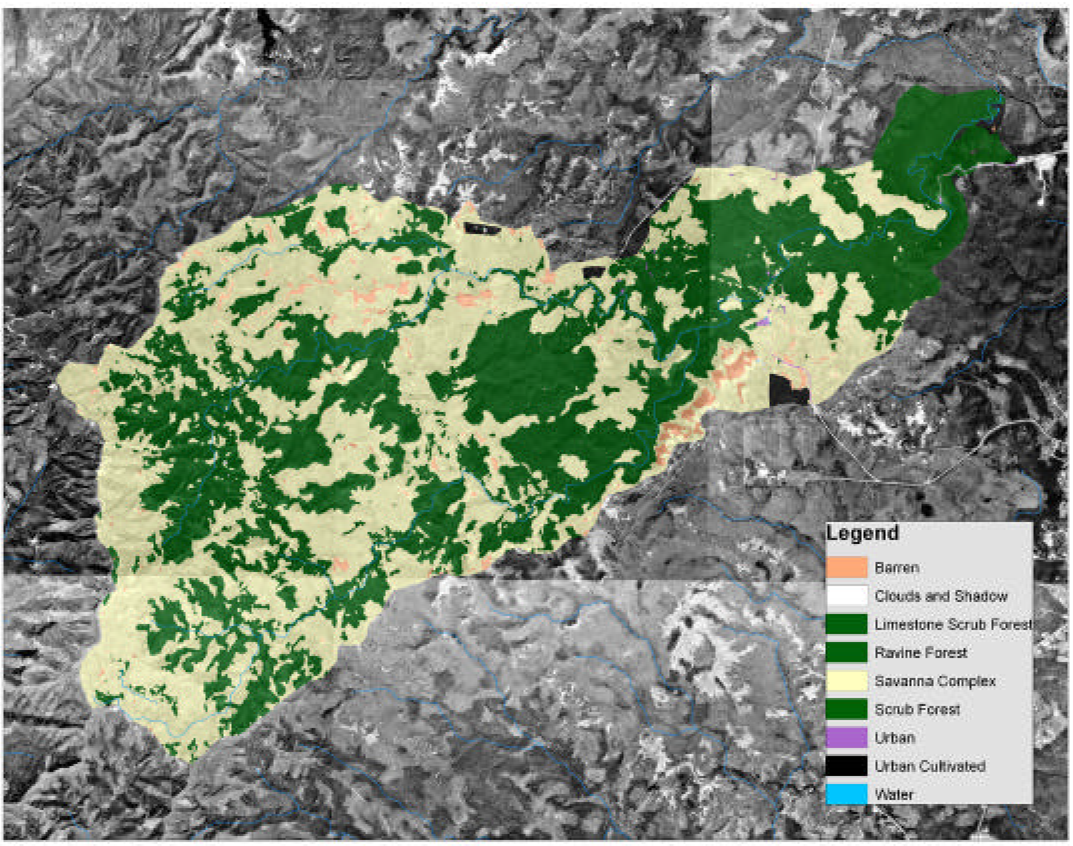


Figure 6. Vegetative Coverage of the Ugum Watershed.

Table 2. Vegetation Distribution.

VEGETATION TYPE	COVERAGE AREA (acre)	% OF THE TOTAL WATERSHED AREA
Ravine Forest	1859	43
Savanna Grassland	2336	54
Agriculture	33	0.76
Wetland	6	0.14
Badland	96	2

SAVANNAH

The savannah or grassland community covers a rather large portion of the island's surface and is continuous from about the middle to the south end of the island (Plants of Guam 1974). In the Ugum Watershed the Savanna grassland covers 2336 acres or 54% of the watershed. The dominant grasses are swordgrass (*Miscanthus floridulus*) Gramineae and foxtail (*Pennisetum polystachyon*) Gramineae.

Miscanthus grasslands

Swordgrass is a tall perennial bunch grass. Mature swordgrass can reach a height of 3 m and cover large areas. Tall, dense swordgrass swards monopolize light and moisture such that these swards prevent the establishment of most other plants. Swordgrass is suspected of having allopathic properties, which retards the germination, establishment and growth of other plants. The soil chemistry (pH) in *Miscanthus* grasslands is often more acid. Other measures of soil quality, such as soil organic matter, water-holding capacity, and mineral nutrients are lower than those found in an intact forest plant community.

Pennisetum grasslands

Foxtail is tufted annual bunch grass that can grow up to 2 m tall. Foxtail is common in disturbed areas in the savanna plant communities where swordgrass is not dominant. Other grasses, including a perennial tall grass, wildcane, (*Sacrum spontaneous*) Gramineae and the annual broadleaf weed (introduced), misigsig (*Chromolaena odorata*) are common in frequently disturbed areas or along transitional zones between grasslands and forested scrub or roadways. In disturbed sites, misigsig is an early colonizer and can form pure and dense stands preventing the establishment of other vegetation.

RAVINE FOREST

The floristic composition of the ravine forest communities is diverse and usually includes a combination of native, naturalized, and alien species. Transitional zones between intact ravine forest habitat and degraded forest sites or grassland sites show a varying mixture of introduced and native species depending upon browsing and fire pressure. The function of Ravine forest is to store essential nutrients and cycle these nutrients. The soils beneath the Ravine Forest contain larger amounts of organic matter, which increases the amount of water that the soil profile can store. When ravine forest communities do burn, the fires do not destroy all of the plants. Ground plants and organic matter may be destroyed, however the plant community remains largely intact. Ravine forest could protect the soil surface from the direct impact of intensive tropical rainstorms, and minimizes sediment runoff. Because these forests are typically located next to watershed streams, they serve as catchments to filter eroding sediments from savanna grasslands and badlands, which occupy ridge tops and road ridges of the area. Clearing of the ravine forest is usually done for road construction, agriculture, or construction of ranch homes.

c. Rainfall

Climate on Guam is warm and humid throughout the year despite two distinct seasons, one wet (July-December) and one dry (January-June). The mean annual temperature is 81°F (27°C). Daily maximums and minimums vary no more than 10°F (6°C). Relative humidity on Guam ranges from values of 65-80% during daylight hours to 85-100% at night. A subtropical high-pressure area lying north of the island throughout much of the year results in a dominant airflow pattern characterized by trade winds prevailing from the northeast. Frequent storms, common in the summer and fall, disrupt this pattern and occasionally intensify to typhoon status (Lander, 1994).

The mean annual rainfall in the northern limestone plateau, central and coastal lowlands, varies between 80 in (220 cm) to 110 in (279 cm) over the uplands of southern Guam. Although severe droughts in the dry season are common, the wet season is highly reliable with an average of 63 in (160 cm) rainfall. A long-term study on Guam indicated a positive correlation between increasing elevation and precipitation on the island. However, Lander noted the presence of an extreme rainfall gradient across both the northern and southern halves of the island. He went on further to stress that one raingage within the boundaries of a watershed on Guam might not yield an adequate representation of rainfall in that area. Rainfall accumulation over the course of a typhoon however would remain uniform.

A temporal variability of rainfall also exists on Guam. For example, at the NASA Satellite Tracking Station that is 1,640 feet from the Ugum Watershed boundary, the annual average rainfall from 1973-1994 was 91 inches. In contrast, between 1973 and 1994 the mean annual rainfall at the same raingage varied between 54 inches (1983) and 130 inches (1976). The wettest monthly total in May 1976 was 20.91 inches and the driest monthly total was 0.51 inches recorded in May of 1987. The raingage at Inarajan Agriculture Station, which is about 14,436 feet from the Ugum Watershed boundary, averaged 93.6 inches of rainfall from 1978-2000; the maximum average rainfall was 152 inches 1980 and the lowest average annual rainfall was 50 inches in 1998. Rainfall data for these two stations are listed in Tables 3 and 4.

Table 3. Rainfall data, Inarajan Ag. Station 1979-2000, numbers in red are estimated rainfall.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1979	6.40	3.09	3.82	2.35	3.81	5.13	11.96	15.71	10.13	27.06	10.54	9.18	109.18
1980	2.95	12.40	6.39	6.07	10.75	9.16	13.50	10.00	32.00	25.93	11.76	11.05	151.96
1981	4.76	2.14	3.33	5.77	4.79	9.72	15.21	27.00	7.40	12.17	11.62	13.08	116.99
1982	2.50	9.50	3.50	3.04	5.74	12.02	11.29	5.32	18.41	9.00	13.12	5.50	98.94
1983	0.54	1.58	3.00	1.50	3.81	1.25	11.35	9.22	7.12	8.21	10.76	5.00	63.34
1984	2.25	4.02	4.74	1.19	4.93	8.87	10.45	14.00	14.76	12.78	13.25	10.38	101.62
1985	6.43	4.73	5.85	4.60	7.08	12.48	6.85	16.15	13.00	10.00	4.50	8.00	99.67
1986	2.00	6.00	8.31	4.81	10.85	9.44	10.95	26.58	9.00	10.94	5.50	10.60	114.98
1987	1.49	1.74	4.78	2.00	0.70	1.93	10.85	8.65	8.15	7.46	10.00	6.76	64.51
1988	9.84	2.04	1.32	2.26	2.16	14.33	11.19	6.30	9.06	14.00	5.25	1.75	79.50
1989	5.01	8.42	1.06	13.31	3.24	9.40	11.50	16.00	12.00	13.00	8.54	3.61	105.09
1990	9.15	1.18	1.12	2.50	2.20	7.43	11.00	17.00	15.00	8.79	12.56	18.00	105.93
1991	2.94	2.87	1.00	4.30	5.23	4.98	9.29	21.75	11.21	13.23	12.67	4.74	94.21
1992	5.50	0.58	0.50	0.99	1.24	3.85	9.29	28.32	8.62	12.40	14.38	1.62	87.29
1993	2.60	1.95	1.62	0.23	0.44	1.62	6.50	11.09	14.50	9.00	7.58	4.64	61.77
1994	3.21	1.08	4.58	1.70	5.00	3.50	17.00	4.99	18.00	8.80	3.37	4.76	75.99
1995	2.00	1.00	1.50	2.01	4.19	3.68	7.72	20.64	16.50	18.44	7.50	7.31	92.49
1996	9.34	4.88	6.75	2.28	3.23	1.90	15.02	11.00	18.75	8.50	16.00	10.34	107.99
1997	6.66	2.13	2.83	9.00	1.63	8.00	10.22	24.52	9.63	10.05	11.62	11.77	108.06
1998	2.25	0.27	1.30	2.05	0.67	3.00	4.48	5.47	15.00	6.80	5.34	3.30	49.93
1999	3.10	9.00	2.92	2.02	5.32	10.67	14.00	9.00	13.25	9.15	9.78	5.30	93.51
2000	3.01	7.82	5.47	2.48	10.78	4.58	6.51	13.27	13.74	20.92	5.28	5.91	99.77
Mon Ave	4.27	4.02	3.44	3.48	4.45	6.68	10.73	14.64	13.42	12.57	9.59	7.39	94.67

Table 4. Rainfall data, NASA Sat. System 1973-1994, numbers in red are estimated rainfall.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1973	1.52	3.08	1.07	1.73	1.71	2.91	8.05	11.27	9.12	19.18	4.76	6.30	**70.7**
1974	7.10	3.09	10.62	12.28	11.66	10.81	10.38	21.20	6.51	9.49	10.42	5.38	**118.94**
1975	5.53	1.27	1.44	3.19	2.22	1.99	10.92	14.16	9.44	12.09	17.10	3.09	**82.44**
1976	13.86	9.97	7.61	3.04	20.91	7.52	16.20	18.40	12.94	5.37	7.61	7.54	**130.97**
1977	3.72	2.73	5.03	3.21	4.32	3.78	5.62	6.67	18.20	13.20	10.81	4.94	**82.23**
1978	2.41	3.81	0.43	2.02	3.34	5.83	9.16	18.09	10.84	9.87	17.58	5.06	**88.44**
1979	5.37	2.50	2.92	2.95	3.46	2.53	12.00	13.47	13.63	23.41	7.02	8.04	**97.3**
1980	2.06	13.37	3.59	3.63	9.32	11.28	10.04	7.64	36.33	13.35	5.93	6.61	**123.15**
1981	4.53	2.04	3.08	6.66	4.22	7.34	10.58	25.85	6.75	8.20	12.34	7.27	**98.86**
1982	1.35	8.18	2.13	2.40	5.31	10.31	11.72	8.41	19.18	12.69	11.50	5.00	**98.18**
1983	0.46	0.83	2.68	1.63	1.62	0.95	7.00	9.63	9.53	5.83	9.69	4.28	**54.13**
1984	2.02	2.58	1.60	3.00	2.88	9.17	9.91	14.79	13.98	10.95	10.32	5.15	**86.35**
1985	3.11	0.99	2.29	4.00	10.15	10.82	7.85	11.37	14.54	8.06	3.25	4.62	**81.05**
1986	1.50	5.33	6.58	2.11	8.08	6.85	17.18	22.10	8.25	13.79	5.05	9.44	**106.26**
1987	2.13	1.97	2.92	1.58	0.51	1.75	11.17	7.83	9.44	8.78	9.84	5.58	**63.5**
1988	8.39	1.12	1.51	2.20	1.30	12.62	12.68	8.30	9.25	13.79	4.81	1.81	**77.78**
1989	5.77	11.15	1.45	13.04	3.78	8.28	11.33	17.42	11.45	17.06	8.72	4.08	**113.53**
1990	9.00	1.50	1.73	2.05	3.36	6.54	10.74	17.41	14.93	7.10	18.48	15.00	**107.84**
1991	2.66	3.25	1.35	5.03	5.62	5.50	6.78	19.04	12.41	17.40	13.00	4.25	**96.29**
1992													**0**
1993	1.20	2.90	1.10	0.25	1.03	1.90	6.80	13.80	14.40	8.70	8.80	5.00	**65.88**
1994	4.80	3.40	5.20	2.00	5.50	3.20	17.70	4.10	17.00	8.00	3.00	4.50	**78.4**
Mon Ave	**4.21**	**4.05**	**3.16**	**3.71**	**5.25**	**6.28**	**10.66**	**13.85**	**13.24**	**11.73**	**9.53**	**5.85**	**87.37**

d. Wetlands

Wetlands are areas that are saturated or inundated at certain times of the year with hydric soils, plants typically adapted to hydrologic conditions, and generally include swamps and bogs. In the Ugum Watershed most of the wetlands are lying between deepwater (open streams) and terrestrial (upland) ecosystem, and some are depressional (Siegrist et al., 1996). Wetland vegetation includes sedges and grasses or woody plants. Definitions and delineation criteria of wetlands, adjacent deepwater aquatic habitats, and non-wetlands are well described by the U.S. Army, Corp of Engineers (1987). According to the 1996 wetland study (Siegrist et al., 1996), wetlands influence Ugum River stream flows and sedimentation in the dry season when sudden rains follow weeks of dry weather. Flow stages and stream and sediment discharges are modulated by the baffling effect of marsh grasses and tree hummocks and the absorbency of water in thick porous mats of decaying biomass. Wet season brings the wetlands biomass and soils to a more water-saturated condition and hydrodynamic and sedimentologic functions are not as well demonstrated during these months. They also concluded that the wetlands are absolutely critical in controlling water quality by regulating and recycling nutrients and trace metals within the ecosystem.

The total wetland areas within Ugum Watershed were estimated to be 245 acres or 5.2% of the total area. This estimation was based on using the GIS digitized National Wetlands Inventory map Figure 7.

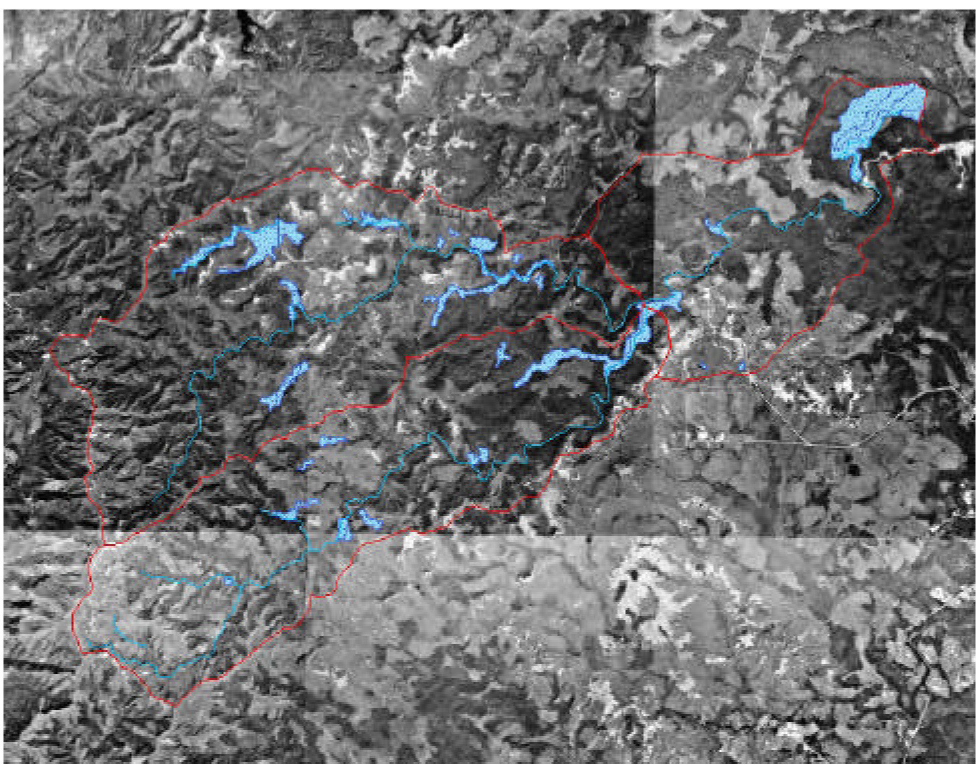


Figure 7. Wetlands within the Ugum Watershed (blue areas).

e. Badlands

The term "badlands" on Guam refers to pitted, sloping sites void of vegetation (NRCS, 1995). Young (1988) described badlands on Guam as actively eroding areas of very deep, well drained saprolite derived from tuff and tuff breccia. Saprolites are weathered rocks, in this case volcanic in origin, whose original textures and structures are preserved despite replacement of the fresh minerals by clay (Carrol and Hathaway, 1963). Since badlands are exposed to the direct impact of overland flow, wind and rain, they are considered the effect of sheet and rill erosion. Sheet erosion occurs when rain falls faster than the soil can absorb it and carries off the soil particles. Rill erosion occurs when surface flow establishes paths. If the soil remains unprotected, some of the small paths give way to larger rills, or small eroding channels, where water flows through and detaches soil from the floor and sides of the channel. Recent study by NRCS indicated that the Guam sheet and rill erosion contributes nearly 93% of the erosion and sedimentation in Fena Watershed (NRCS 2001).

The total badland area within Ugum Watershed was estimated to be 168 acres or 3.6% of the entire watershed. This estimation is based on summing up the badland areas that were identified by WERI researchers using the 1993 aerial photos of the southern Guam. A study that was completed by Khosrowpanah et al, 2002, indicated that badlands across the steepest slopes of the watershed contribute an average of 65.90 tons/acre/year in soil yield. Comparably, badlands from lower lying, less steep areas of the watershed averaged 13.70-tons/acre/ year in sediment yield. Figures 8a and 8b shows the location of the badlands within the Ugum Watershed.

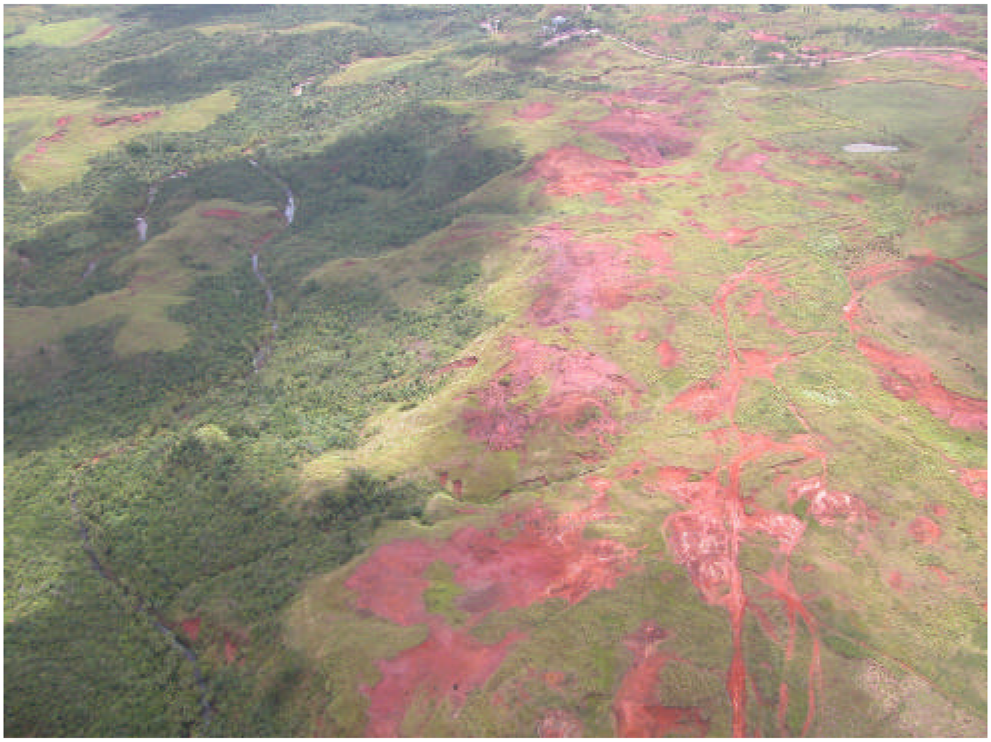


Figure 8a. Badlands within the Ugum Watershed.

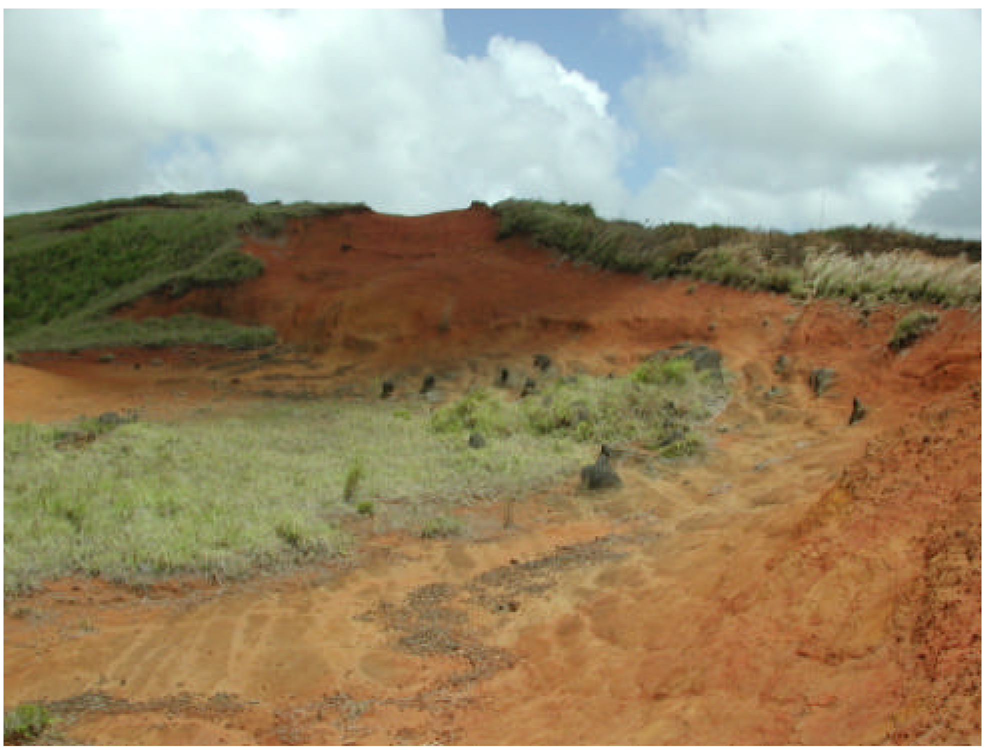


Figure 8b. Badlands within the Ugum Watershed, a close up view.

4. WATER QUANTITY AND QUALITY

a. Surface Water – Quantity

There are two major streams in the Ugum watershed, Ugum River and Bubulao River with their tributaries. The Ugum River originates in the rugged interior in the vicinity of Mount Bolanos. A ridge of high, grass-covered peaks forms a distinctive divide on the west end of the watershed. The Ieygo, Atate, and Ugum Rivers start in a forested bowl just below the divide and combine after a rapid drop in elevation. The Bubulao River receives water from a series of branches along the divide to the north of the bowl. Both the Ugum and Bubulao Rivers travel for several miles of densely forested valley through rugged terrain. The rivers continue to lose elevation quickly in the upper reaches and gradually flatten before joining just above Talafofo Falls. Below the falls, the Ugum River has relatively little slope and the valley continues to become wider while the side slope remains steep. This condition continues until the river joins with the Talafofo River.

The USGS installed two stream gage stations on the Ugum River. The first gage station 16854500 is located 300 feet upstream from Talafofo Falls with stream flow records from 1977 to present with drainage areas of 3,686 acres (5.76 square miles). The other gage 1685500 had discharge flow data from 1953 to 1977 with drainage areas of 4,416 acres (6.96 square miles). This gage station has been discontinued since 1977, because of the tidal influence. Table 5 and 6 shows the stream gage data and the location of the USGS's stream gages are marked in Figure 2.

The average daily discharge of the Ugum River is 24.32 cubic feet per second (cfs). The minimum flow recorded is 2.50 cfs and the maximum discharge on the Ugum River is 1000 cfs. The flow duration curve that shows the anticipated flows as a function of historic data is shown in Figure 9. The horizontal axis indicates the percentage of all flow measurements, taken from 1977 to 2000, which a particular flow measurement on the vertical axis would exceed. For example, 60 % of the time the flow at the Ugum River's USGS Gage Station will be at 10 cfs or bigger.

Table 5. UGUM RIVER, Station 168550, 1953 – 1977.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Decr	Year
# Days	620	565	645	630	651	644	651	651	630	620	600	620	7527
Avg Day	15.74	15.65	10.37	9.02	9.09	10.26	19.51	43.17	50.57	45.29	39.72	24.11	24.32
Max Day	301	1000	122	194	258	143	504	556	950	448	556	350	1000
Min Day	4.2	6	4.7	3.5	2.7	2.7	2.5	3.5	4.4	9.9	10	8.9	2.5
# Months	20	20	20	21	21	21	21	21	21	20	20	20	19
SDev Month	6.96	10.58	4.61	5.72	6.05	7.35	13.17	31.67	25.3	17.52	17.88	7.9	7.72
Skew Month	1.41	2.96	2.13	2.49	1.6	1.35	1.23	1.27	1.77	0.378	0.777	0.62	0.625
Min Month	7.61	8.47	6.51	4.24	3.52	3.09	5.59	6.92	20.77	15.77	14.2	11.99	13.97
Max Month	32.45	54.55	23.32	28.4	24.65	30.3	56.26	119.9	131.9	84.61	75.47	41.13	40.9
Exceedences													
1%	80.8	78.55	37.2	56.2	56.92	74.8	148.8	305.8	329.6	269.8	307	153.4	196.2
5%	31	25	20	14	20	29.4	54.45	152.8	151.5	130	101	47	74
10%	22	17	14	12	14	19	39.9	102	99	85	66	36	47
20%	17	14	12	10	11	13	26.8	53	64	55	45	28	30
50%	12	10	9.1	7	6.3	6.2	11	23	32	31	26	18	13
80%	10	8.8	7	5.3	4.7	4.38	5.4	12	18	20	19	14	7
90%	9	8	6.3	4.7	4	3.9	4.4	8	14	16	16	13	5.2
95%	8.5	7.8	5.7	4.05	3.5	3.5	3.8	5.5	11	13	15	11	4.4
99%	5.32	7	5.14	3.7	2.9	2.84	2.85	4.3	5.09	11	11	9.4	3.4

Table 6. UGUM RIVER, Station 16854500, 1977 – 2000.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Year
# Days	620	565	645	630	651	644	651	651	630	620	600	620	7527
Avg Day	15.74	15.65	10.37	9.02	9.09	10.26	19.51	43.17	50.57	45.29	39.72	24.11	24.32
Max Day	301	1000	122	194	258	143	504	556	950	448	556	350	1000
Min Day	4.2	6	4.7	3.5	2.7	2.7	2.5	3.5	4.4	9.9	10	8.9	2.5
# Months	20	20	20	21	21	21	21	21	21	20	20	20	19
SDev Month	6.96	10.58	4.61	5.72	6.05	7.35	13.17	31.67	25.3	17.52	17.88	7.9	7.72
Skew Month	1.41	2.96	2.13	2.49	1.6	1.35	1.23	1.27	1.77	0.378	0.777	0.62	0.625
Min Month	7.61	8.47	6.51	4.24	3.52	3.09	5.59	6.92	20.77	15.77	14.2	11.99	13.97
Max Month	32.45	54.55	23.32	28.4	24.65	30.3	56.26	119.9	131.9	84.61	75.47	41.13	40.9
Exceedences													
1%	80.8	78.55	37.2	56.2	56.92	74.8	148.8	305.8	329.6	269.8	307	153.4	196.2
5%	31	25	20	14	20	29.4	54.45	152.8	151.5	130	101	47	74
10%	22	17	14	12	14	19	39.9	102	99	85	66	36	47
20%	17	14	12	10	11	13	26.8	53	64	55	45	28	30
50%	12	10	9.1	7	6.3	6.2	11	23	32	31	26	18	13
80%	10	8.8	7	5.3	4.7	4.38	5.4	12	18	20	19	14	7
90%	9	8	6.3	4.7	4	3.9	4.4	8	14	16	16	13	5.2
95%	8.5	7.8	5.7	4.05	3.5	3.5	3.8	5.5	11	13	15	11	4.4
99%	5.32	7	5.14	3.7	2.9	2.84	2.85	4.3	5.09	11	11	9.4	3.4

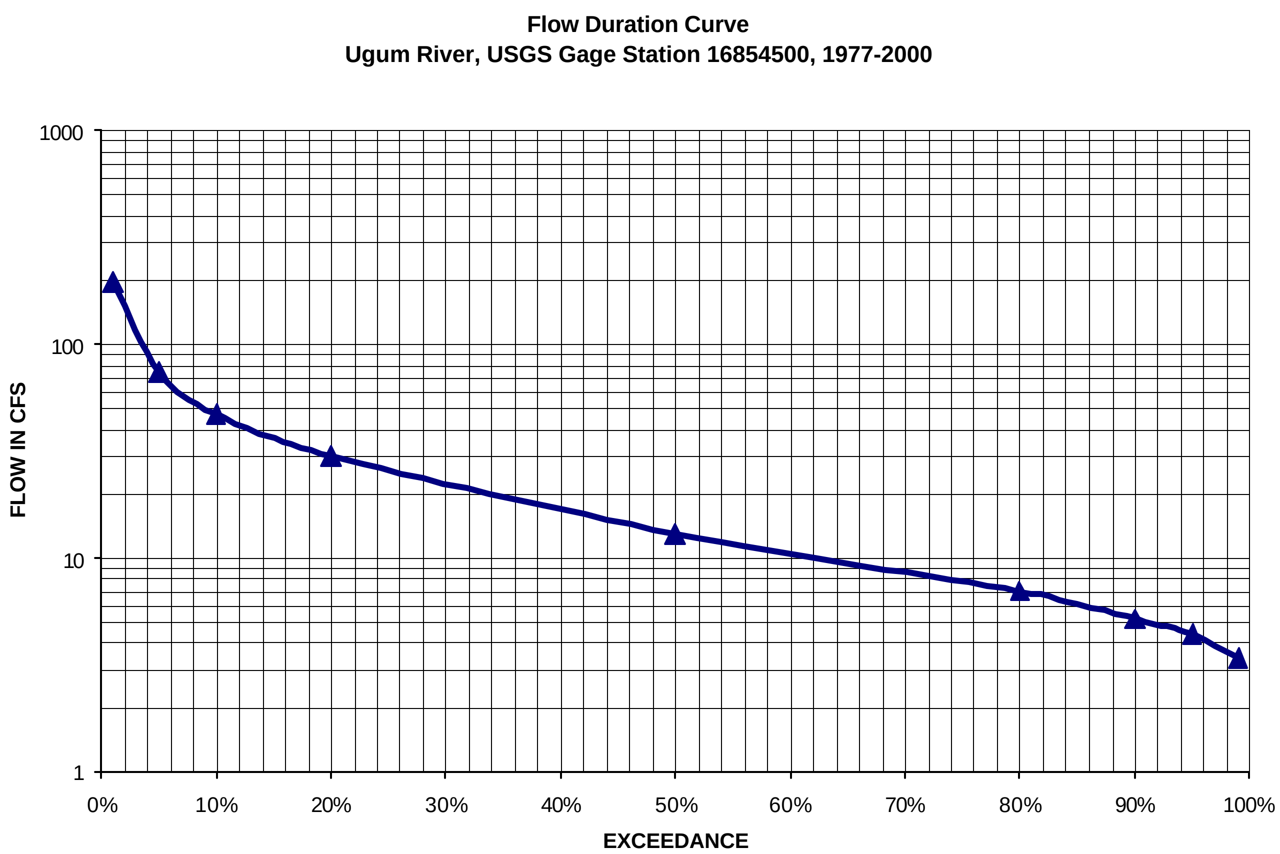


Figure 9. Flow Duration Curves, Ugum River at USGS Gage Station 168545.

b. Surface Water-Quality

Reducing or eliminating areas of poor water quality in the Ugum Watershed is one of the motivations behind generating a Watershed Restoration Action Strategy. A regulatory definition for poor water quality is waters that fail to meet the water quality criteria specific to the designated uses. More generally, poor water quality may be considered waters that are unhealthful or objectionable for human use or for supporting desirable aquatic species. For the Ugum Watershed the parameter of concern is turbidity. According to the Section 303(d) of the Federal Clean Water Act, the Ugum River did not support their designated use in a prioritized list of "Water Quality Basin Segments," sometimes called the 303(d) list (GEPA). Table 7 shows the Guam's Section 303(d) listing of impaired waters. According to this table, in 1996, 84% of the time the turbidity level exceeded the Guam Water Quality Standards.

As part of 1996 wetlands study (Siegrist et al 1996) researchers did a complete water quality analysis for Ugum and Bubulao Rivers and the results are shown in Table 8. For detailed information on the significance and the standard levels of the each parameter in Table 8 Please refer to WERI technical Report No. 76. Guam Waterworks Authority completed water quality analysis for raw water at Ugum River in January 2000 and these data reported in Table 9.

According to Guam EPA, a federally mandated quantitative pollutant-loading plan, a Total Maximum Daily Load (TMDL), is being developed for the Ugum Watershed (anticipated completion date is 2006). The draft TMDL identifies the reduction in turbidity levels in the river that are necessary to achieve the drinking water objective, the sources of turbidity in the watershed and their estimated contributions, and the anticipated reductions in turbidity when the restoration plan is implemented. This strategy is consistent with the draft TMDL targets.

Table 7. Data for Guam's Section 303(d) listing of Impaired Waters.

Summarized Data for Guam's Section 303(d) Listing of Impaired Waters

Tumon Bay (M-2 waters) Data from 2001 except where noted

Parameter	*GWQS*	*# of Violations*	*# of Samples*	*Mean*	*Geometric Mean*	*Median*	*Max*	*Min*	*Mode*
Nitrates (mg/L)	> 0.20	6	129	0.070		0.025	0.990	0.001	0.007
Dissolved Oxygen (mg/L)	< 4.6	6	98	6.41		6.33	11.80	2.46	5.90
Enterococci 2003* (CFU/100mL)	geometric mean of =35	4	260	15	14	13	47	9	9
	instantaneous of =104	6	260	35	14	9	3877	9	9
Enterococci 2002* (CFU/100mL)	geometric mean of =35	38	247	24	20	17	198	9	11
	instantaneous of =104	24	247	116	19	10	17329	9	9
Tetrachloroethene (PCE) µg/L 2000-2002	5.0µg/L	3	32	0.6406		0	5.4	0	0
Trichloroethene (TCE) µg/L 2000-2002	5.0µg/L	1	32	0.1625		0	5.2	0	0
Antimony 2000-2002	-----	1	32						
Arsenic 2000-2002	0.05mg/L	3	24						
Dieldrin 2000-2002	0.1µg/L	14	32	**Got hits for these analytes, need data review**					
Alpha-Chlordane 2000-2002	0.1µg/L	2	32						
Gamma-Chlordane 2000-2002	0.1µg/L	1	32						

Ugum River (S-1 waters) Data from 1996

Parameter	*GWQS*	*# of Violations*	*# of Samples*	*Mean*	*Geometric Mean*	*Median*	*Max*	*Min*	*Mode*
Turbidity (NTU)	>9.1 (Ambient Value)	126	150	33.2		21.5	154.1	5.6	11.8

Table 7. Data for Guam's Section 303(d) listing of Impaired Waters (continued).

Pago River (S-2 waters) Data from 1997 and 1998

Parameter	GWQS	# of Violations	# of Samples	Mean	Geometric Mean	Median	Max	Min	Mode
Enterococci (ECU/100mL)	Instantaneous of =61	38	47	435		240	4200	1	1
E. coli (cfu/100mL)	instantaneous of =126	6	38	106		40	780	1	1
NO3-N (mg/L)	> 0.20	20	57	0.417		0.022	5.484	0	0
Dissolved Oxygen (mg/L)	<4.6	14	77	5.8825		6.31	9.08	0.4	7.6
Turbidity (NTU)	>1.0	46	77	2.2136		1.3	15	0.1	1.6

Pago Bay (M-2 waters) Data from 1997 and 1998 except where noted

Parameter	GWQS	# of Violations	# of Samples	Mean	Geometric Mean	Median	Max	Min	Mode
Dissolved Oxygen (mg/L)	<4.6	17	80	6.27		6.45	10.90	2.70	7.70
Enterococci 2003* (CFU/100mL)	geometric mean of =35	16	52	35	29	27	124	9	14
	instantaneous of =104	11	52	101	28	15	1376	9	9
Enterococci 2002* (CFU/100mL)	geometric mean of =35	19	48	53	35	26	335	12	21
	instantaneous of =104	9	48	763	38	15	14140	9	9
Enterococci (ECU/100mL)	>104	9	80	38		9	308	1	1
NO3-N (mg/L)	>0.2	8	67	0.072		0.025	0.754	0	0.005
Turbidity (NTU)	>1	22	72	1.14		0.50	17.00	0.10	0.20

Agana River (S-2 waters) Data from 1997, 1998, and 1999

Parameter	GWQS	# of Violations	# of Samples	Mean	Geometric Mean	Median	Max	Min	Mode
Dissolved Oxygen (mg/L)	<4.6	31	42	3.23		2.79	7.21	1.30	1.30
Enterococci (ECU/100mL)	>104	21	24	682		270	2300	60	2001
NO3-N (mg/L)	>0.2	3	35	0.084		0.037	0.844	0	0.075
Turbidity (NTU)	>1	41	42	15.91		5.05	118.00	0.50	#N/A

Table 7. Data for Guam's Section 303(d) listing of Impaired Waters (continued).

Agana Bay (M-2 waters) Data from 2002 and 2003

Parameter	*GWQS*	*# of Violations*	*# of Samples*	*Mean*	*Geometric Mean*	*Median*	*Max*	*Min*	*Mode*
Enterococci 2003* (CFU/100mL)	geometric mean of =35	90	208	41	33	28	289	9	9
	instantaneous of =104	44	208	1001	36	20	130000	9	9
Enterococci 2002* (CFU/100mL)	geometric mean of =35	112	196	73	47	43	499	9	9
	instantaneous of =104	53	196	359	47	30	24190	9	9

Categories of Guam Waters

Category	**Quality**	**Description**
M-2	Good	Marine Waters (recreation, mariculture)
S-2	Medium	Freshwaters (recreation, drinking if treated, aquatic life, aesthetics)
S-1	High	Freshwaters (drinking water, wilderness areas, aquatic life, aesthetics)

Table 8. Elemental Analysis of Surface Waters from the Bubulao & Ugum Rivers (18 May 1995), Siegrist et al, 1996.

Elements	Ugum	Bubulao	EPA Standard 1994
Aluminum (soluble)	**	**	**
Arsenic	<1.2 µg/L	<1.2 µg/L	50 µg/L
Barium			2000 µg/L
Cadmium	<0.1 µg/L	<0.1 µg/L	5 µg/L
Chromium	**	**	100 µg/L
Copper	1.3 µg/L	1.7 µg/L	1000 µg/L
Iron	258 µg/L	314 µg/L	300 µg/L
Lead	<0.5 µg/L	<0.5 µg/L	50 µg/L
Mercury	<0.4 µg/L	<0.4 µg/L	2 µg/L
Manganese	38.2 µg/L	35.5 µg/L	0 µg/L
Nickel	**	**	100 µg/L
Silver	<0.2 µg/L	<0.2 µg/L	100 µg/L
Calcium	7.0 mg/L	6.6 mg/L	**
Magnesium	5.3 mg/L	5.2 mg/L	50 mg/L
Sodium	**	**	**
Potassium	**	**	**
Sulfate	**	**	250 mg/L
Percent Sodium	**	**	**
Chloride	**	**	250 mg/L
SAR	**	**	**
pH	7.3	7.2	6.5-8.5
Conductivity micromhos	170 µS	159 µS	**
Total Dissolved solides	**	**	500 mg/L
Hardness	**	**	**

Table 9. Ugum River water quality analysis, Guam Waterworks Authority, January 2000.

SOURCE	3-Jan-00	13-Jan-00	26-Jan-00	EPA Standards 2001
PH	7.29	6.52	7.07	6.5 – 8.5
TURBIDITY	4.80	5.16	3.56	<9.1
CONDUCTIVITY	129	139	163	
CALCIUM HARDNESS	11.4	16	16	**
TOTAL HARDNESS	22.8	27.4	27.4	**
CHLORIDES	15.0	15.0	15.0	<250 mg/l
TOTAL COLIFORM	+	+	+	
[1]FECAL COLIFORM	+	+	+	<126CFU/100ml
CHLORINE RESIDUAL	0.0	0.0	0.0	**
ALKALINITY	62	52	60	**
FLUROIDE (mg/l)	N/S	N/S	N/S	**

[1]Fecal Coliform is an older standard and is not currently used. It has been replaced by E. Coli. According to EPA standards 2001, concentration of E. Coli shall be no greater that 126 CFU/100 ml based upon the geometric of five sequential samples taken over a 30 days period. No instantaneous reading shall exceed 235 CFU/100ml.

5. POINT & NON-POINT SOURCES POLLUTION

a. Point Sources

Discharges from discrete conveyances like pipes are called "point sources". Point sources may contribute pollution to surface water or groundwater. Examples of point sources are: discharges from waste treatment facilities, storm water discharges, industrial point sources, broken sewer pipes, and piggeries. Fortunately, there are no records of point sources of pollution within the Ugum Watershed.

b. Nonpoint Sources

Pollution from Nonpoint sources (diffuse sources) can be related to weathering of minerals (soil erosion), or artificial or semi artificial sources. This includes pollution due to fertilizer application, agricultural chemicals, erosion of soil materials due to farming and animal feedlots, construction sites, and any other activities causing pollution. Eroded sediment can carry nutrients, particularly phosphates, to waterways, and contribute to eutrophication of streams (Elliot and Ward, 1995). Soil erosion is the main contributor to nonpoint pollution within the Ugum Watershed. According to the Section 303(d) of the Federal Clean Water Act, the Ugum River did not support their designated use in a prioritized list of "Water Quality Basin Segments" sometimes called the 303(d) list (GEPA). Turbidity level at the Ugum River exceeds 84%, than the Guam Water Quality Standards (GWCS).

Soil erosion is the detachment and movement of soil material by raindrop splash (impact of raindrop), runoff (overland flow), gravitational movement (sliding), and flowing water (streams). Types of water erosion include sheet and rill, gully, and stream channel erosion. Sheet erosion is uniform displacement of soil particles by flowing water without the development of water channel. Rill erosion is the soil displacement by a concentrated flow of water. Gully erosion produces channels larger than rill. These channels carry water during and immediately after rain. The rate of gully erosion depends primarily on the runoff –producing characteristics of the watershed, the drainage areas, soil characteristics, size, shape, and the slope in the channel (Bradford et al., 1973). Stream channel erosion consists of soil removal from stream banks or soil movements in the channel. Stream banks erode either by runoff flowing over the side of the stream bank, or by scouring and undercutting below the water surface.

In streams, sediment either moves in suspension or is shifted on the bottom. The suspended portion is called washload, while bedload is the portion that moves at or near the bottom in an erratic movement along the stream bed (Novotny and Chester, 1981). The concentration of the suspended sediment in streams is highly variable and is influenced by several factors that causes overland erosion. These include rainfall duration and intensity, soil condition, topography, geology, vegetation cover, and disturbing activities taking place in the watershed.

The negative impacts due to sediment within the Ugum Watershed are: deleterious effects on benthic biota and fish and impairment of the water for human consumption. Suspended sediment alters aquatic environment primarily by inhibiting light, changing heat radiation, blanketing the stream bottom, and retaining organic materials and other substances that create unfavorable conditions for benthic organisms.

As mentioned earlier the Guam Water Authority has continueing problems with the operation of pumps and treatment plant. As the flow moves through the pump's impeller, the suspended sediments act as sand paper and erode the impeller blades. High turbid flow also creates problems with the rapid filtration process at the treatment plant. The sediment particles will reduce the flocculation process at the plant.

c. Bank Erosion

Bank erosion, which erodes the channel laterally, is due to the two processes; fluvial entrainment and weakening and weathering (Throne 1982). Fluvial entrainment increases the bank erosion by the shear stress generated in the river flow and cohesiveness of the bank materials. As the flow velocity increases the shear stress on the bank will increase (Ritter, 1986) and the rate of bank erosion increases. The weakening and weathering tend to reduce the strength of bank materials and thereby promote instability and failure. The mechanics of failure depend on many variables such as geometry and structure of the bank and also soil properties along the bank. Bank erosion along the Ugum River is shown in Figure 10.

Figure 10. Bank Erosion, Ugum River.

d. Land Slide (Slumping)

A landslide is down slope movement of soil and or rock under the influence of gravity. The failure of the slope happens when gravity exceeds the strength of the earth materials. Some of the fundamental causes of slope failure that lead to land loss are: 1) slope over-steeping 2) slope overloading, 3) shocks and vibrations due to earthquake, 4) water saturation, and 5) removal of natural vegetation. Earthquakes, typically those of 4.0 magnitude and above, can create stresses that weaken slopes. Earthquakes tend to produce the largest and most destructive landslides (USGS, 1998).

According to the digital elevation map and the aerial photography that was taken along the streams inside the Ugum Watershed, most of the slumping areas are due to the steep slope, surface runoff during heavy rainfall, and probably earth movement due to earthquakes. Figures 11a and 11b shows two land sliding sites within the Ugum Watershed.

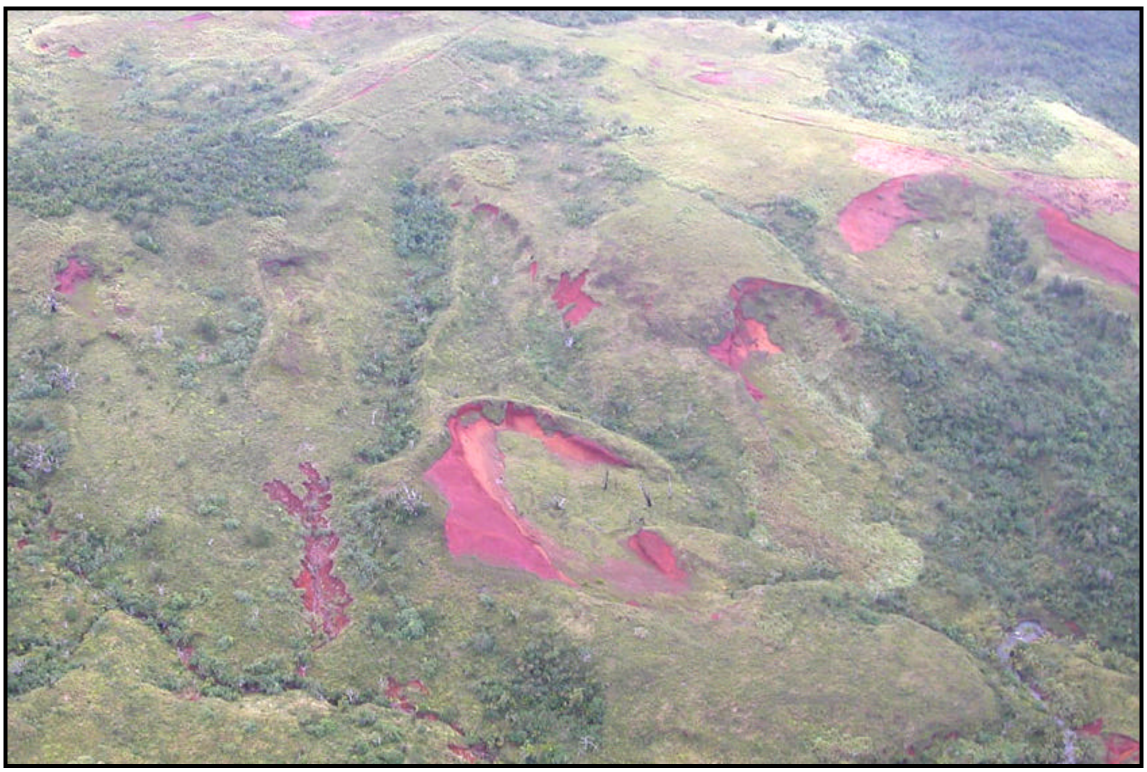


Figure 11a. Land sliding within the Ugum Watershed.

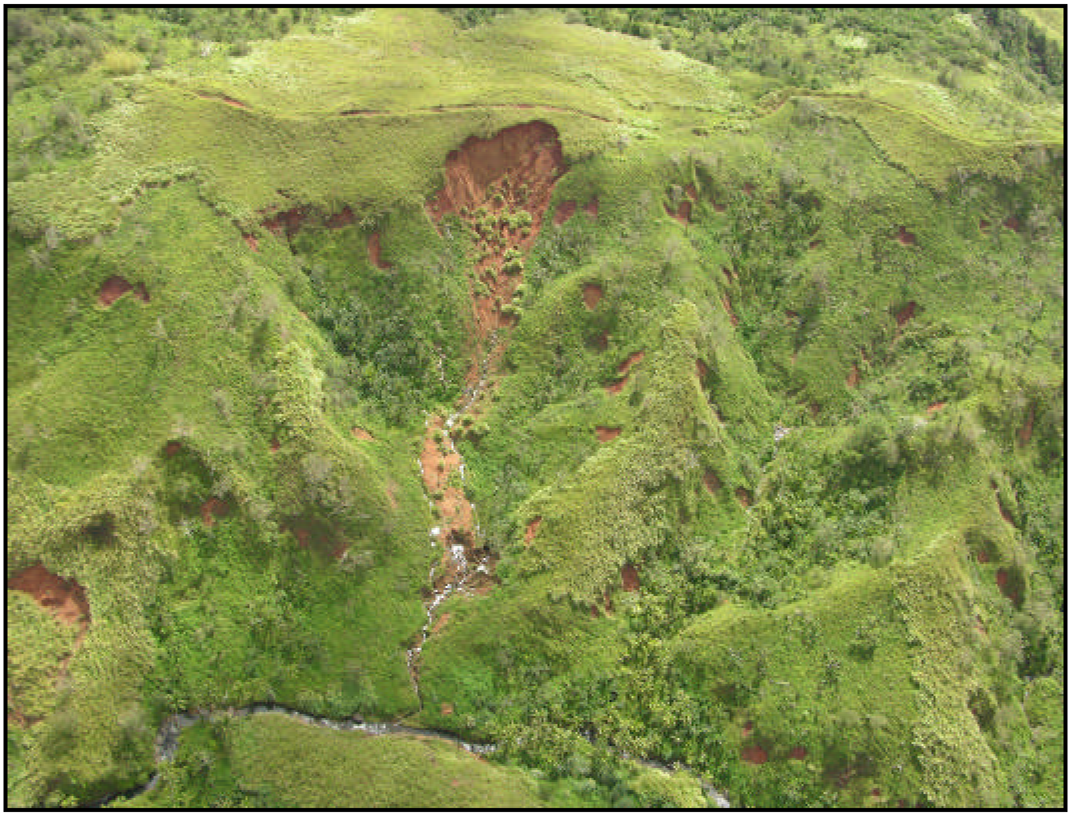


Figure 11b. Mass wasting within the Ugum Watershed.

6. LAND USE

a. Land Ownership

The Ugum Watershed has an area of approximately 4,672.6 acres (7.3 square miles) and is presently 70% (3,283 acres) privately owned and 30% (1,407 acres) public owned. The Government of Guam and the U.S. Naval Reservation own the public lands in the Ugum Watershed. Fifteen (15) private landowners own the private lands of the Ugum Watershed.

As shown in Figure 12, the headwater areas of the Ugum Watershed that are held by the Government of Guam and the Navy have been designated by the Division of Aquatic and Wildlife Resources as conservation areas. This guards it against any development, helping to maintain the health of the watershed and water quality. The public land areas are very steep and the majority of the vegetation is savanna grassland.

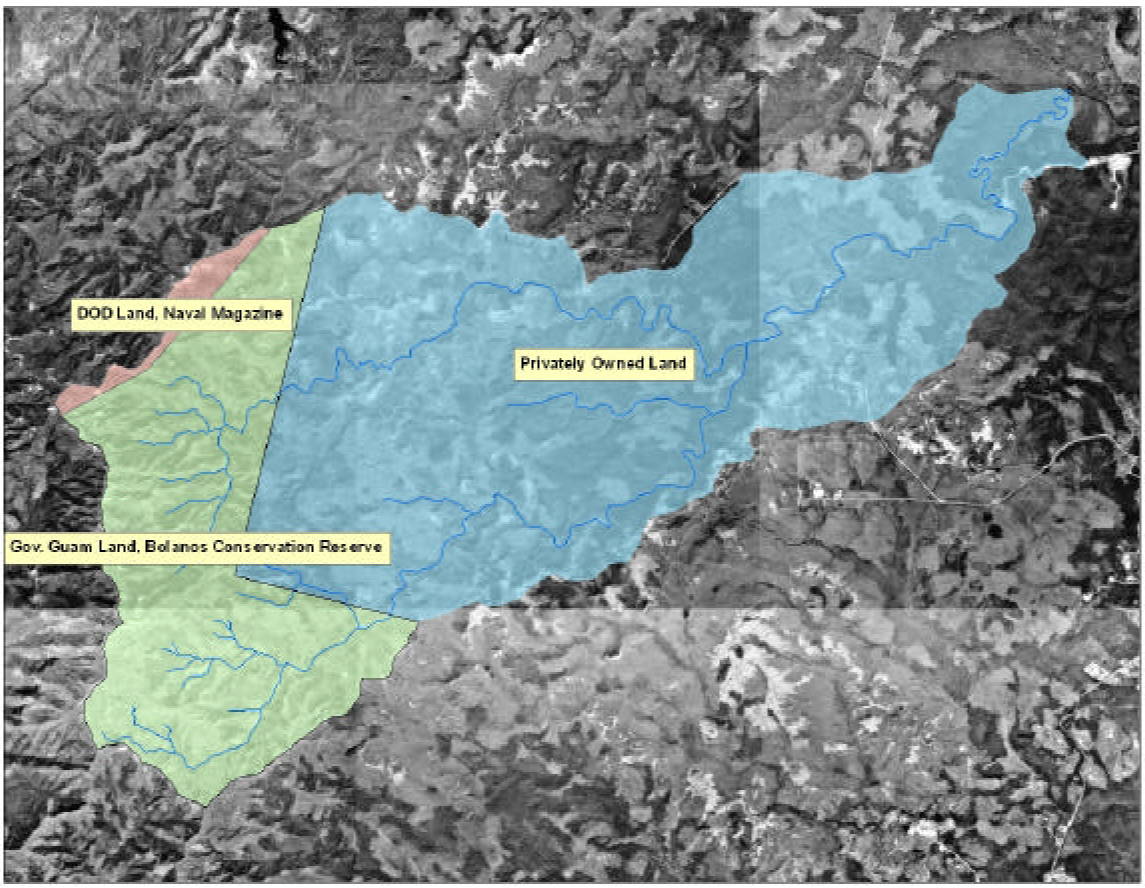


Figure 12. Land Ownership, Ugum Watershed.

All of the privately owned lands within the Ugum Watershed are zoned “Agriculture”. The 1986 Guidebook to development requirements on Guam (Guam Coastal management Program Publication 1986) defines the following land use for agricultural or rural zone:

1. One-family dwellings and duplexes.
2. Farming and fisheries, including all types of activities and pursuits customarily carried on in the field of agriculture and fisheries, including the raising of crops and fruits, poultry and livestock, grazing and dairying, and tree and other vegetative production, whether for commercial or personal uses.
3. Use customarily accessory to any of the above uses, including home occupations and private automobile parking areas as well as accessory buildings and structures such as private garages, warehouses, barns, or other similar structures.

b. Land Activities

There are three types of land use activities that occur in the Ugum Watershed: 1) agricultural activities, 2) tourism activities, and 3) recreational activities such as hiking and off road vehicle use in the area.

c. Agricultural Activities

Seventy percent or 1,407 acres of the land belongs to the 15 private individual. According to our recent aerial photography and conversation with the Government of Guam, Department of Agriculture, at the present time 17.5 acres or only 1.2% of the private land are being used for agricultural activities. The agricultural activities are seasonal, typically in the early dry season (January – May). Typical crops are watermelon, beans and cucumber. The aerial photography that has been taken by WERI shows the location of the farms Figure 13.

According to Department of Agriculture the impacts of the Agricultural activities on the streams are considered minor. The reason is that only small percent of the land is being used for growing plants, the activities happens only during the dry season, and the residue that is typically left on the surface at the end of dry season will protect the soil surface from erosion.

Figure 13. Farmland in the northern watershed boundary next to the Bubulao River.

d. Tourism Activities

Tourism activities within the Ugum Watershed include visits to the Talafofo Falls and the Ugum River daily boat tour.

The Talafofo Falls is a 30-foot drop of the Ugum River cascading into a deep pool framed by steep bluffs and level rock ledges. Every year approximately 4,500 visitors visit the fall. The recreation area includes a paved parking lot for cars and busses, monorail to the fall and one restaurant and shop next to the fall.

The Ugum River trip has two daily boat tours up the Ugum River from Talafofo bay to share a taste of traditional Chamorro life. There used to be a Safari Tour that took tourists on jeep trails into the upper Bubulao area to view the native ravine forests and wildlife of Guam. This tour is not in operation any more. Location of the Talafofo fall is shown in Figure 14.

Figure 14. Talafofo falls Water Park, Ugum Watershed.

e. Recreational Activities

The recreational activities within the Ugum watershed include hunting, hiking and off-road vehicle excursions.

Hunting methods can be classified into two types, legal and illegal hunting, the later could have a huge impact of creating soil erosion within the Ugum Watershed. According to (Raulerson 1978) most of the wild fires in the Ugum Watershed are due to illegal hunting. Illegal hunters set fire to the savanna grasslands causing new grass to rejuvenate as well as spread by burning the edge of the ravine forest. The new shoots attract the deer and the hunters wait at the edge of the burned areas at night with spotlights.

Following wildfires, soils are exposed to the impact of raindrops and sheet flow. Repeated burning of grassland results in an increase in soil erosion and a decrease in soil quality, which could create badlands. According to Ugum Watershed Restoration Strategy, 1999, fires are a serious problem in the Ugum Watershed. Virtually all are human caused, whether from hunting and food-gathering access or from carelessness or recreation, and most are intentionally started. Table 10 shows the fire statistics in Ugum Watershed 1985-1997.

Table 10. Fire Statistics 1985-1997, Ugum Watershed.

Ugum Watershed Guam Fire Statistics (1985-1997)		
Year	**Number of Fires**	**Acres Burned**
1987	921	8,800
1988	436	10,263
1990	110	800
1991	318	1,338
1992	558	5,686
1993	693	2,341
1994	152	221
1995	427	4,862
1996	174	500
1997	344	844
1998	1,200	13,000

Another recreational activity within Ugum Watershed is off-road vehicle excursions. Figures 15a and 15b shows unimproved roads within the watershed. The uncontrolled roads or "jeep trails" will damage the vegetation and eventually create gullies that carry the sediment particles into the streams. The extent of jeep trails appears to vary depending on the season. During the wet season many of the trails go unused due to higher risk of getting bogged down in deep mud. Thus, allowing vegetation to grow back to the point where the trail is no longer passable. Dry season however allows a wider range of area for off road vehicles. The dry conditions allow for vegetation die back and promote conditions favorable off road vehicles to make new trails. The resources assessment of the Ugum Watershed in 1995 indicated that there were 43 miles of unimproved roads within the Ugum Watershed. The GIS analysis that was done for this study showed total road miles have decreased to 30.8 miles. The jeep trails were compared using the Guam ortho-photos taken in 1993 and Ikonos satellite images taker between 2002-2004. Low attitude aerial photos taken from a helicopter aided in the locating and mapping of jeep trails.

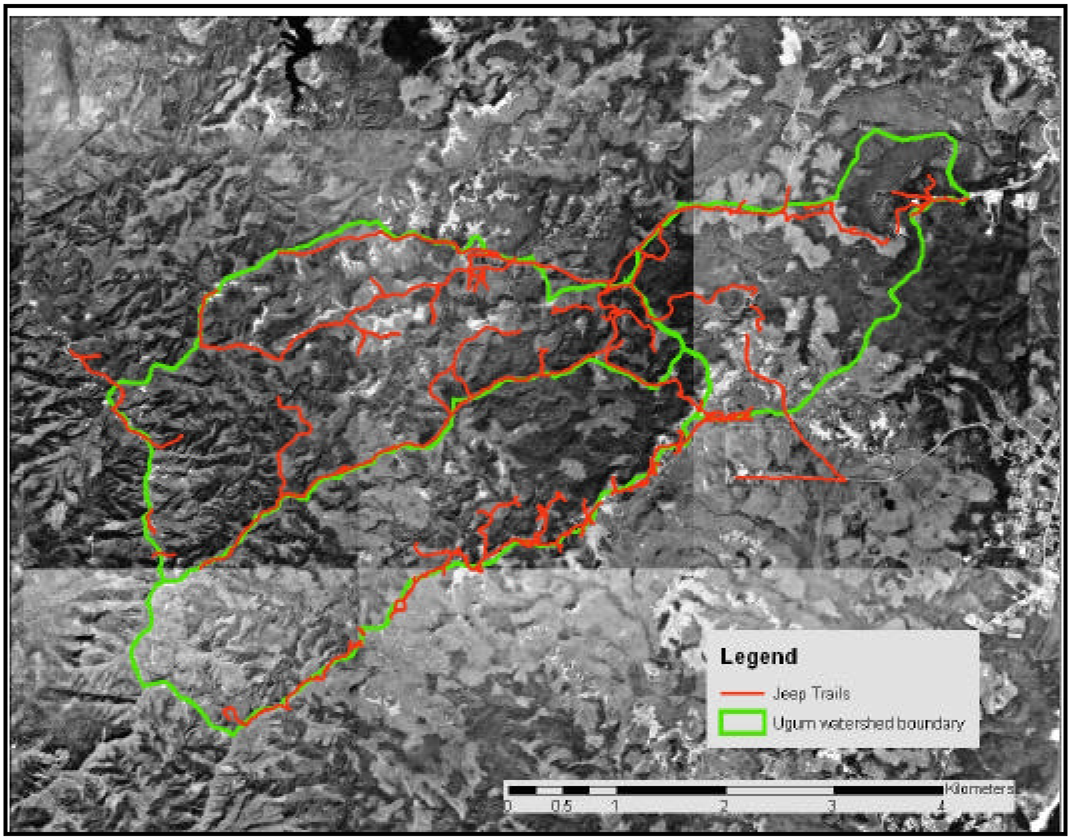


Figure 15a. Jeep Trails within the Ugum Watershed, red line shows the trails.

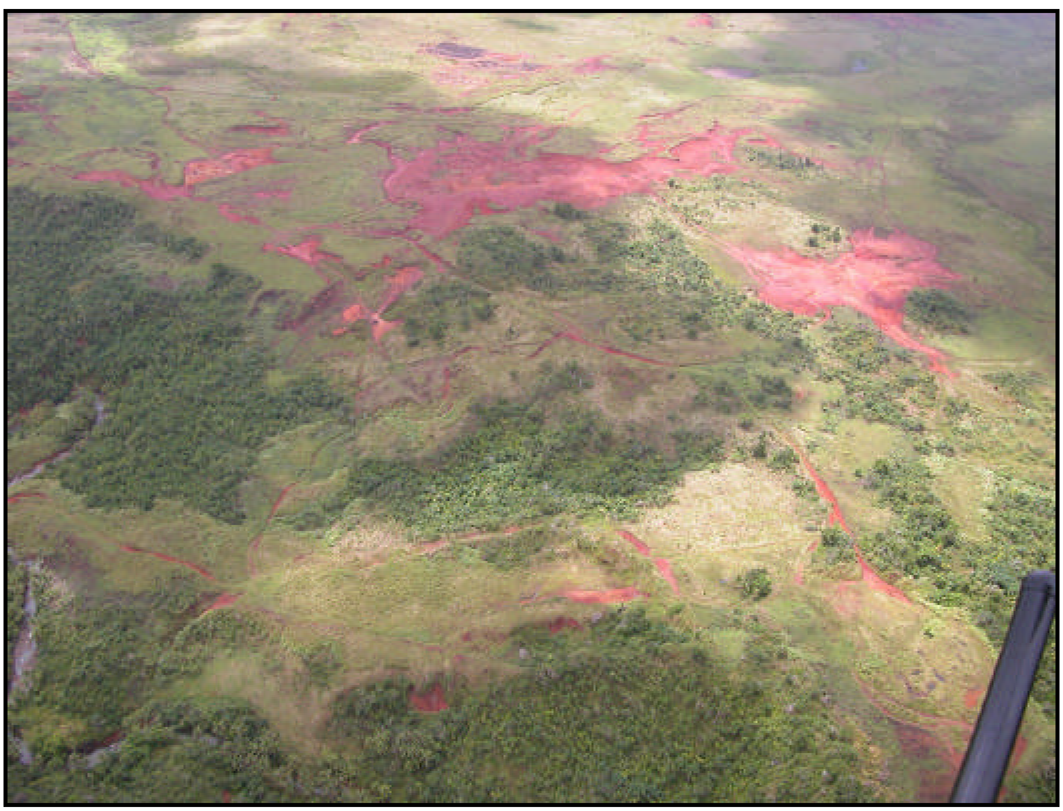


Figure 15b. Jeep Trails within the Ugum Watershed, red line shows the trails.

7. RESULTS AND DISCUSSION

Reducing or eliminating areas of poor water quality in the Ugum Watershed was one of the motivations behind generating a Watershed Restoration Action Strategy. For the Ugum Watershed the parameter of concern is turbidity. According to the Section 303(d) of the Federal Clean Water Act, the Ugum River did not support their designated use in a prioritized list of "Water Quality Basin Segments". In 1996, 84% of the time the turbidity level exceeded Guam Water Quality Standards. The high turbidity is causing the recent failure of the Ugum treatment facility to deliver safe drinking water to southern Guam's residents. It also negatively impacts aquatic life (e.g.; fish, aquatic invertebrates, reefs) in the watershed's streams and downstream coastal areas.

The stream's turbidity however, is due to the sediment particles that are carried by the stream as suspended sediment. Suspended sediments are those sediment particles that have been introduced to the stream by upland soil erosion, bank erosion, and land sliding. As the stream's velocity increases (stream's kinetic energy) the capacity for carrying more sediment particle increases. High velocity flow occurs when the stream passes through steep terrain and or the cross section of the streams becomes narrow. Ugum watershed has very steep terrain. Approximately 75% of the slopes are greater than 30 percent slope. The steep slope increases the kinetic energy of the surface run off to carry the eroded particles into the streams.

The sites that have potential to be considered as non-point sources pollution (contributing sediment particles into the streams) have been identified (marked) in the aerial photos of the Ugum and Bubulao rivers. These aerial photos, taken from helicopter runs from altitudes ranging from 1500 to 2500 feet are in the attached diskette and shown in Figure 16 and a close up is shown in Figure 17. The site selections were based on the steepness of the river section, changes in river direction, bank erosion and land slumping (observed from aerial photos). As mentioned earlier there are other sites that contribute sediment into the streams such as: badlands, off-road vehicle excursions, and sheet and rill erosion. Badlands could contribute a large amount of the sediment into the waterways. They need to be monitored and an effective re-vegetation method should be applied. The off-road vehicle excursions, and sheet and rill erosion (mostly due to intended fire) are mostly due to human activities. The public should be informed of the impacts and necessary fines should be in place.

Presently there is an ongoing project for Ugum Watershed to develop a GIS based erosion model for estimating the sediment delivery to the streams and defining a correlation between rainfall, stream flow, and sediment delivery within the watershed. The results of this project will be helpful to identify the sediment contribution of each source and how the sediment changes over time.

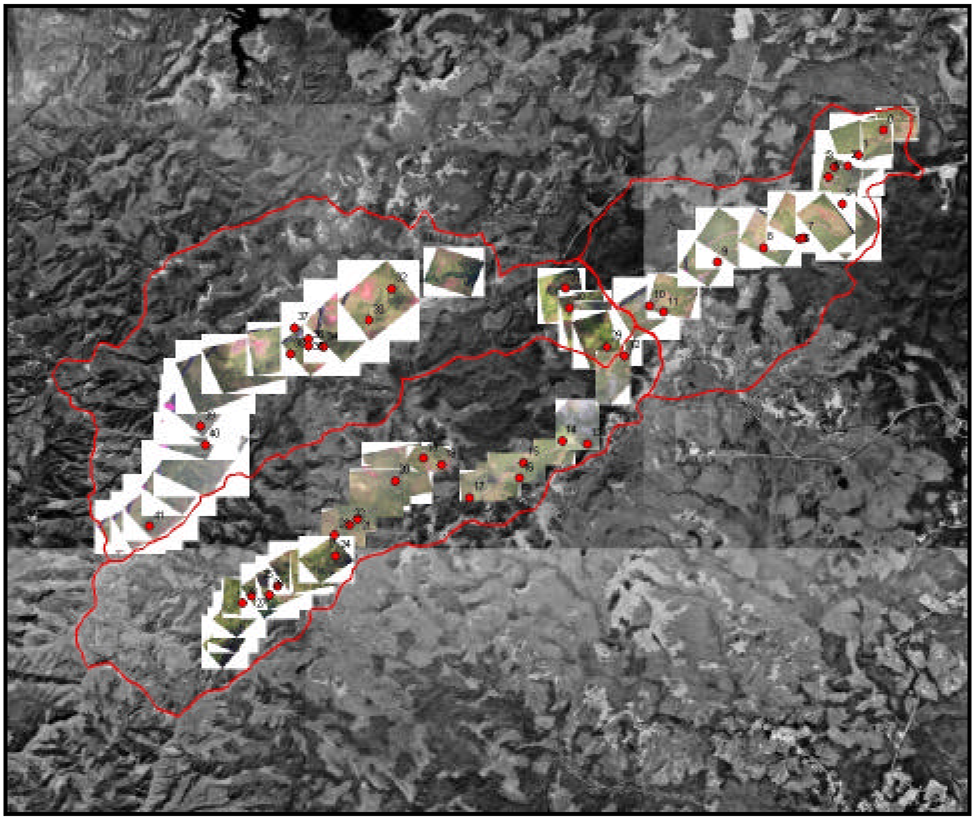


Figure 16. Aerial Photo of the Ugum and Bubulao Rivers. Red dots are sites with potential erosion.

Figure 17. A close up of the sites with bank erosion.

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