A HYDROLOGICAL AND VEGETATIVE STUDY OF THE BLADEN BRANCH MONKEY RIVER WATERSHED

Arin Simonian

ACADEMIC SEMESTER ABROAD

SCHOOL FOR INTERNATIONAL TRAINING

with advisement from

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Praise and Thanks

To my enthusiastic advisor Jacob Marlin who kept me laughing and inspired the whole way.

To Kelly Marlin, whose passion for the natural world gave me insight.

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To Mom and Dad, who I ultimately owe everything that I've expereince in life to.

And to water and all the ways in which it nurtures the earth.

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INTRODUCTION

Tropical rainforests are among the most diverse and biologically rich ecosystems on earth. These vibrant forest contain half of all the known plants and animals on earth. Healthy tropical forest play a major role in the regulation of the oxygen/carbon dioxide cycle, in the recycling of nutrients that nourish life, in stabilizing ozone depletion, and in controlling the greenhouse effect. Clearly, these ecological havens are vital to all lifeforms considering their contributions to our earths livelihood. Currently, only half of these forests remain intact. It is a frightening realization that by the year 2000, less than 1/4 of tropical forests will remain with current trends of environmental destruction. (Marlin, 95)

I was drawn to study in Belize because of its tropical forest that remain relatively intact in comparison to many developing nations in the tropics. In particular, I was drawn to BFREE (Belize Foundation for Research and Environmental Education) (see map 1). This 1153 acre parcel of land was secured by Jacob and Kelly Marlin in January 1995. Perched along the Bladen River, BFREE is bordered by The Bladen Nature Reserve (BNR), Cockscomb Wildlife Sanctuary, Maya Mountain Forest

Reserve, and Deep River Forest Reserve. The beauty of this piece of land is that it is six miles from the nearest road, and far from any signs of human disturbances. The forests of BFREE not only serve as a vital corridor for the wildlife in the adjacent protected areas, but also provide facilities for researchers and students to gain a better understanding of these ecosystems.

The BNR is one of the last pristine tropical wilderness areas of Belize. This area has escaped resource extraction, development, and agricultural cultivation, due to its inexcessible location within the Maya Mountains. However, this area was inhabited by the ancient Maya, and evidence suggests that agriculture and resource extraction took place during the classic Maya period. The Maya Mountain Massive support breeding populations of the Jaguar (Panthera onca), the Puma (Felix concolor), Barid's tapiris (Tapirs bairdii) and two species of peccary (Tayassu pecari) and (Tayassu tajacu), all which freely roam the Bladen Nature Reserve and are indicative of its pristine nature (Manomet, 1987).

The Bladen River, the heart and blood of this unspoiled environment, starts at the main divide of the Maya Mountains and pours out of a deep limestone gorge into lowland forest, filtering through networks of mangroves and finally entering the sea. The Bladen is part of the Monkey River Watershed (See Map 3) which controls erosion, reduces local floods, regulates the fixing and cycling of nutrients, carries out soil formation, and provides circulation and cleansing of air and water. The health of the nature reserve is intricately woven into the health of the river and its watershed (Marlin, 95).

The Bladen River's undisturbed natural state drew me in and led me to my four week study of the river and its riparian habitat. I spent most of my time observing and mapping a 2100m stretch of the river that runs through BNR, BFREE, and Deep River Forest Reserve. I focused on the size and shapes of the sand and gravel bars and the vegetation which inhabits them. Base line data of this unstudied river is becoming increasingly necessary and will be extremely valuable in the future. In documenting the present pattern of flow, this information can be compared with future research to understand changing patterns of flow over time and to understand the dynamics of this riparian ecosystem.

Another factor that has fueled my interest in studying the Bladen River is a major longterm sand and gravel mining project that will most likely take place in the Deep River Forest Reserve directly below the border of the BNR (see map 4). This presents a major threat to the health of the river upstream and downstream from the extraction site, which may cripple the BNR, BFREE, and the Monkey River Watershed as a whole.

The government of Belize seems to have good intentions on paper, designating part of the Bladen River and its surrounding forests as a nature reserve and providing this area with buffer zones composed of protected areas (See Map 1). Cockscomb Basin is designated as a wildlife sanctuary, allowing recreational activities such as tourism, and the removal of forest resources. Deep River, Colombia River, Maya Mountain north and Maya Mountain south are all designated as forest reserves. The definition of a forest reserve is an area that is set aside for resource extraction, particularly the removal of trees. The Chiquibul has national park status. The Bladen and Chiquibul are the largest government owned protected areas which are truly set aside for conservation. New River Enterprises, a logging company from Orange Walk, has just received a contract to begin a ten year logging project in the Maya Mountain Forest Reserve north and south. Also, Columbia River Forest Reserve is under a forty year logging concession by a Malaysian logging company. These forest reserves look good on paper, but no protection is enforced in reality.

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A longterm sand extraction project has been easily established without an environmental impact assessment. The health of Bladen will decline and may eventually deteriorate if the government continues to treat the reserve as an isolated island demarcated by arbitrary boundaries. All of these areas being disrupted are a part of the Monkey River Watershed.

It is necessary to gain an understanding of the complexities of the Bladen Rivers ecology. Until we understand the components and the interconnected relationships between these components in nature, we will not be successful at preserving anything.

BACKGROUND:

.Watershed Continuum Theory

Historically, rivers and streams studies by ecologists have been perceived to be separate units. During the 1970's, stream habitats were defined by stream flow and substrate. This limited definition of rivers and streams failed to acknowledge the influences of upstream or downstream. The intimate relationship rivers have with the surrounding soils and forests was not understood. As researchers started to focus on the contributions of detritus materials used by aquatic organisms, they began to acknowledge an important connection between land based resources and streams (Nelson, 96).

In 1984, the River Continuum Concept (Nelson, 96) was published which compiled studies of many different sections of streams and rivers. The ultimate conclusion was that the headwaters, midreaches, the lower reaches, river mouth estuary, reef, and open ocean were distinguished by different structures and functions, but that they were all interconnected and dependent on each other. Detrital and photosynthetic energetics, nutrient processing, community structures, watershed mechanics, sediment transport, and integrated longitudinal succession were no longer studied as isolated elements of the river. A good analogy used to visualize this newly developed concept is the leaf. The edges of the leaf are the mountain ridges and hillslopes, the tertiary veins represent the runoff waters running through the soils and bedrock, the secondary veins represent the tributaries collecting runoff waters and pouring into the main vein, or the main river which flows through the valley and out to the sea.

Water is endlessly flowing from ocean to sky to earth to ocean to sky to earth... The suns heat returns rainfall back to the sky from topsoil, lakes, oceans and by transpiration from plants. From the sky, precipitation in the form of rain, snow, or hail replenishes the earth with water. Along the way, the hillslopes and rivers are two kinds of pipes the water passes through. It is interesting to think of your own body as a temporary storage container for the passing water driven by higher forces. Plants, ponds, and lakes are also temporary storage containers. The form of a river is controlled by the amount of rainfall and runoff waters from hillslopes, by the burden of sediments the river is responsible for moving, and the geology of the land that the riverbed carves. To maintain its form, a river would prefer a steady flow, avoiding floods and droughts (Warshall, 1976).

In Peter Warshall's "Streaming Wisdom; Watershed Consciousness in the Twentieth Century", he explains his unfolding perceptions of water. On a walk through the Eel River, the fastest eroding river in North America, Warhsall expresses "I began to understand that watersheds not only had personalities, but they were bodies, sentient beings of sorts, that tried to use their parts to keep the whole (hillslope /river) in balance. The streams were like a nervous system giving early warning of a hillslope falling apart. The head waters were like the mind: a subtle place high on the hillslope where the water tasted clear and pure almost like rainfall; where the hillslope suddenly opened up to start the river; where peace was needed because any change at the headwaters would be felt all the way downstream; and where the bare rock tributaries provided minerals to be used and stored downstream. The whole attitude of land seemed to be: Delay the water from passing through. slow it down by making it run underground or snaking the river shape. Create lakes and bogs and marshes in the flood plain. Slow it down and hold so the hillslope can keep its shape. Water just does what it does and pays no mind."

Ultimately, the mountaintops, the hillslopes, the riparian forests, and the flood-formed bottomlands are all interconnected parts of one watershed. In the past, sciences segmented perceptions has not considered the abiotic portions of the watershed to be intricately tied to the biotic portions of the watershed. If we remove a forest along a river side, the water that would have been taken up and transpired by the leaves is now going to flow into the river and carry in a new sediment load. This will increase the energy feeding into the river, and the hillslopes and stream channels will rapidly change form to adjust.

The Monkey River Watershed

We need to apply the watershed continuum theory to our own lives and the watersheds that support us. The Monkey River watershed, is comprised of three main rivers, Bladen River, Trio River, and the Swazey River which feed into the sea at Monkey River Village. (see map 3). The watershed starts at the main divide of the Maya Mountain Massive where rain waters flow over granitic hillslopes feeding into the tributaries and into the three branches. These branches flow over karst limestone bedrock, joining to form the Monkey River which funnels water over the reef and into the open ocean.

The Geology of the Bladen Nature Reserve

The geological history defines the structure of the watershed. The landscape currently known as Belize first emerged from under sea level along a volcanic fissure which extends from Richardsons peak southwest to Little Quarts Ridge (see map 3). Sedimentary rocks of the Paleozoic Age (400-230 million years ago) are combined with volcanic rock that makes up the BNR. This is a result of the molten lava that exploded out of the volcanic fissure, mingling with accumulated layers of sand and silt that had settled to the floor of the Paleozoic ocean. This mixture of sedimentary rock and volcanic rock comprises most of the BNR highland. Most of the Bladen River runs over a limestone base (Wright, unpub.)

In early Triassic period (230 million years ago), As the supercontinent of Pangea was breaking up, and the continental plates were drifting towards their current state, the paleozoic ocean rose and fell a number of times. The earths continual life and death processes buried the older rocks with new marine sediment. These new sediments were calcium carbonates from the shells and bones of marine life, whereas the earlier sediments were rich in silica and poor in calcium magnesium. This completely changed the chemical composition of the bedrock which created soils rich in plant nutrients. This change fostered new, diverse vegetation, which in turn changed the patterns of the wildlife.

The Maya Mountains were under sea level in the Cretaceous period where limestone rock was deposited over the Paleozoic rock. A property of limestone is that it decays relatively rapidly in solution. Only 2-10% of limestone is insoluble mineral impurities. The persistence of rain penetrates the fissures and cracks of the rock creating tunnels, potholes, and underground stream channels among small peaks. This is called

"Karst" or "karstic" landscape. The Bladen River and other affluent streams take underground routes through the karstic landscapes. Magnificent sink holes have formed with almost vertical walls, some over 400 ft deep. In these mysterious micro-habitats you can find rare plants and animals that have survived intervals of environmental change (Wright, unpub.).

The soils that have resulted from the geological structure of the BNR are slightly alkaline and rich in plant nutrients. With the natural healthy forest cover, the soils have adequate aeration which allows steady water drainage into the tributaries. The earths geological metamorphosis has affected the topography of the BNR which affects and is affected by the flow of the Bladen River and the entire watershed (Wright, unpub.).

METHODOLOGY:

It seemed like an impossible task to try and understand and grasp the nature of this powerful river. I started by observing. I spent about four days establishing a friendship with the river, starting at the northwest boundary of BFREE going downstream. I proceeded to explore the curves and dips listening to the hollow gurgling sounds of the rapids. During this time I explored the crevices, pools, and the many paths that the water took around to take place sometime in May along the Bladen River, I conducted two informal interviews. Charles Wright, expert soil biologist and environmental consultant based in Punta Gorda, was my first interviewee. He has been a key figure in the making of the southern highway because his knowledge of the soils and ecology of southern Belize has been vital to developers and resource extractors.

Mr. Penell, owner of a hardware store in Punta Gorda, has a concession for extraction of sand mining from the Bladen river for the making of the southern highway. He was my next interviewee.

Body:

I. Map Interpretation

The map that I produced (see back folder) documents the form of the Bladen River. The mapping started at the rope, which marks the northwest border of BFREE, and continued just past the boundary of the BNR and into Deep River Forest Reserve. The form of the sand and gravel bars and the types of vegetation they support are represented. The two main types of vegetation which colonizes the bars are Baccarus sp. and Gynerium sp. The

Baccarus was usually found on the edges of the gravel bars closer to the water. The Gynerium sp. was often found behind the Baccarus, further from the water. It seems that the Gynerium reproduces vegetatively, producing groups of clones that are genetically and physically connected by a common root system (Brewer, per.com.) This seems to render Gynerium sensitive to unstable areas, hence its position on the gravel bars. Since the areas closer to water are probably more frequently disturbed, they are less stable. Baccarus seems to cope well with this and takes every opportunity it has to grow on newly formed bars. Very small islands in the river that seem to be newly born, are consistently colonized by Baccarus. From these observations I suspect that Baccarus germinates and grows quickly in disturbed areas.

Several species of vines and herbs were found colonizing the edges of the bars along with the Baccarus. Some of the more common types were Cyprus sp., Solanum sp., Hamelia sp., Stachytarpheta sp., and Aristochales sp. The Aristocales vine blooms a dazzling flower thought to be the largest in the Americas (Brewer, per.com.) In comparison with the Baccarus, these herbs and vines were less common.

Some shrubs that inhabited areas farther away from the water among Gynerium and Baccarus were Cassia reticulata and Inga sp., which are both in the Leguminoseae family, and Cayoense sp.

Trees were mostly found in the center of very large islands, or around the edges of gravel bars that connected with the bank and riparian forests. The two most prominent trees found in these areas were Ficus sp., and Cecropia sp., a pioneer species.

The vegetation of the river is represented by three symbols, one for Baccarus, one for Gynerium, and one for the herbs, vines, shrubs, and trees mentioned above. These were encountered infrequently in comparison to the dominant Baccarus and Gynerium.

The numbered points on the map represent observations of the vegetation and other pertaining information listed below.

-Point 1 marks where the high waters reach in the rainy season. This is evident due to the increase in slope of the bank.

- From point 11 to point 12, dense cane is found (approximately 4m high) starting at the water.

-From point 14 to point 16 there is gap where a diversity of vegetation is found, including Ficus sp, Cassia reticulata, Cecropia sp., Solanum sp., Baccarus sp., and other vines and herbs.

-At point 17, a majestic Aristoloces was found in bloom.

-At points 21 and 22, a small gravel bar is colonized by Baccarus approximately 2m in height.

- From point 35 to 36 is a 5m space after which Baccarus begins to grow.

-From point 37 to 40, Baccarus, approximately 2m in height, grows at the edge of the gravel bar.

-From point 40 to 42, mostly Gynerium is found, along with Cassia reticulata, Cyprus sp., Ficus sp., and composite herbs.

-At point 42, Baccarus grows 2-4 m in height.

-At point 43, the high water mark starts a meter in from the waters edge.

-At point 46, the high water mark and the vegetation starts 3m from the waters edge.

-From point 42 to 50, Baccarus grows along with the less frequent Ficus sp. The middle of the first major island is densely colonized by Cecropia sp., Gynerium sp., Ficus sp., and Baccarus sp.

-Point 55 is where the river once forked off. This route is now dried out and is being taken over by plants and trees.

-At point 54 mostly Baccarus is found.

-Above point 62 is a swampy area. There may be an underground flow which surfaces in this area.

-At point 64, the high water mark is 1 m from the waters edge. Baccarus starts growing at the high water mark.

-From pt. 65 to 66, Bach grows 1 to 2 m from the waters edge. The Baccarus is 1 to 2 m in height. Behind this is Baccarus 2 to 4 m in height. Behind this is Gynerium and some Ficus.

-At pt 69, Baccarus (approx. 1m in height) grows 4 m from the waters edge. Baccarus (approx. 2m in height) grows 14.2 m from the waters edge. Behind this is Gynerium (approx. 4-5m in height).

-From pt. 72 to 73, sparse Baccarus is found (approx. 1m in height) 4.8 m from the waters edge.

-Past pt 73, Baccarus and Gynerium is found (2-4m in height). Behind this grows Gynerium (approx. 5m in height), and behind this grows Cecropia and Ficus.

-At pt 74, Baccarus and other herbs start 3m from waters edge. Baccarus, 2-3m in height, starts 8m from waters edge. Behind this grows taller Gynerium.

-At pt 76, Baccarus (1/2m in height) grows 2.5m from waters edge. This is also where the high water mark is. Gynerium (4m in height) is found 5m from waters edge.

-At pt 79, Gynerium is found 4m in height.

-From pt 79 to 80, Gynerium, Cecropia, Ficus, and Baccarus are found.

-At pt 83, Baccarus (1m in height) is found 2.4 m from the waters edge. Baccarus 3 to 4 m high grows behind this.

-Between 85 and 86, Inga sp. is found along with Baccarus, Gynerium, and Ficus.

-At pt 89 Baccarus grows 2m in height.

-At pt. 91, Baccarus Ficus and Cecropia are found.

- At pt. 95, Baccarus starts 3m from waters edge. Behind this is Gynerium that grows 2 to 3 m in height.

-From pt 96 to 97, Baccarus starts 1m from waters edge.

-At pt 98, the high water mark is 10m from waters edge.

-At pt 99, Gynerium (2 to 4m in height) is found.

-At pt 105, Baccarus 1m in height is found.

-At pt 106, Baccarus, Gynerium, Ficus, and Cecropia is found. - Pt. 106 to 107 is the high water mark.

-At pt 107, tall Ficus, Baccarus, and Cecropia grow.

-At pt 118, Baccarus 1m in height is found.

-At pt 120 and 121, Gynerium, Baccarus, and Cecropia are found.

-At pt. 126, dense Gynerium is found.

-At pt 129, Baccarus grows 2m in height. This point also represents the high water mark.

-At pt 136, Baccarus grows 1/2m from the waters edge. 3m from the waters edge grows Baccarus 3m in height.

-Between 139 and 140, Baccarus and Gynerium grow 2 to 4 m in height.

-At pt 143, dense Gynerium, Cecropia, Legumes, and Ficus is found.

-Between 142 and 143, Acacia sp., Cayoense sp., Inga sp., and Cecropia sp. is found.

-At pt 146, Baccarus grows 2 to 4m tall. Gynerium is found behind this.

-At pt 157, Baccarus starts to grow at the edge of the gravel bar.

-At 158, Baccarus starts at the edge of the gravel bar. Gynerium, Ficus, and Cecropia are found behind the Baccarus.

The different heights of the plants are important in understanding their ages and the different pattern of growth. It is important to take note of the high water marks so that variations between wet and dry season are taken into account.

II. The Nature of the Sand and Gravel Bars

In the wet season, heavy rains transform the peaceful babbling rivers into ragging waters of threatening power. The increase in potential energy increases the erosion and accretion (opposite of erosion) rates of the sand and gravel bars. Year after year water is transporting gravel, sand and silt downstream, while replacing the losses with upstream sediments. There are a few different scenarios to the rivers equilibrium. 1.There could be a net increase in sand and gravel bars; sand and gravel could be accumulating faster than the water carries it away. 2. There could be no net gain or loss; the force of the water could erode approximately the same amount that it accretes. 3.The third possibility is that there is a net loss; the force of the water is washing away more material than is being accumulated. Each scenario creates different patterns of flow which creates a new balance within the watershed.

Much more than just the shape of the gravel bars is being affected. The gravel bars which are a buffer to the erosion of the banks are continually being sculpted. The water and its river bed have an intimate account with eachother. They modify and stabilize the flow of the river.

The silt that mingles with the sand and gravel helps bind all of the material together solidifying the rivers margins. The vegetation which grows on these microhabitats, especially the Gynerium, helps the islands and bars to withstand serious floods.

III. Wildlife of the Bladen River

The Baccarus and Gynerium provide a home for many nesting birds. Although the tangle of green often prevented me from identifying the spectrum of songbirds, their songs and flashes of color kept me company as I mapped.

Some of the more common birds I saw included the Lineated Woodpecker (Dryocopus lineatus), Spotted Sandpiper (Actitis macularia) which pecks at insects and invertebrates at the waters edge, Olive throated Parakeet (Aratinga nana), and Amazon Kingfisher (Chloroceryle amazona). Three species of kingfishers thrive on the abundance of fish in the river. The larger birds were easier to spot and identify. The Great Swallow-tailed Kite (Elanoides forficatus) was seen nearly everyday sailing through the air in pairs, gracefully swooping up their next meal from the water. The beautiful Great Egret (Casmerodius albus) was occasionally seen peacefully perched on a naked branch. The Little Blue Heron (Egretta caerulea) and the Bare Throated Tiger Heron (Tigrisoma mexicana) were frequently observed sitting in one spot for a long period of time. Cattle Egrets (Bubulcus ibis) were occasionally seen in flocks of 10 to 12. Two species of toucans were seen infrequently, the Keel Billed Toucan

(Ramphastos sulfuratus) and the Collared Aracari (Pteroglossus torquatus). The Yellowheaded Parrot (Amazona oratrix) was often seen flying noisily in pairs. The noisy and abundant Montezuma oropendola (Psarocolius montezuma) would rise in the early hours of dawn to feed their nestlings. The ten orupendula nests hanging off a dead tree along the river, (see pt. B of Bladen River Map), was a good place to observe the mothers' instinctual nurturing (Howell and Webb, 1995).

Another critter which benefits from the health of the aquatic life is the River Otter (Lutra longicaudis). I saw three of these cute, furry mammals during my field work. The first one gracefully swam away at the sight of a human (See pt C). The other two noticed my presence before I noticed theirs and dove underwater so that the only clue to their presence was a splash far to loud to be made by a fish. As I swam into the deep pool where the noise had come from, two little brown faces popped up from the water, sheltered by the roots of a fallen tree. Only a couple of meters away, the couple barked at me in defense for about ten seconds, then plunged into the water never to be found again. (See Pt E). Fellow student and mammologist, John Kenneth Horton, observed another couple of River Otters, which could have been the same pair previously observed, playfully frolicking in the water and clumsily walking onto to the bank (See Pt. D).

These mammals are dependant on a healthy river, feeding mostly on fish and crustaceans. These otters favor clear rivers or streams and are rarely found in sluggish, silt-laden rivers (Emmons 1990).

Although I never saw the Water Opposum (Chironectes minimus), they are known to inhabit the Bladen river. These Oppossoms are uniquely marbled with broad black bands across their back. They feed on the rivers fish, crustaceans and invertebrates. The female's pouch has a watertight seal to keep her young dry when she swims. They also are commonly found in clear flowing streams and absent from sluggish silt-laden waters (Emmons, 1990).

The Green-tree snake (Leptophis ahaetulla) was found at pt. A, spraweled along the edge of the gravel bar, perfectly resembling the green hose-like runners of the Gynerium. A turtle was sighted at point F (Kinosternon sp.) .

The wet sand along the water served as a wildlife guestbook, keeping track of all of the feet that had passed through the area. Tapir tracks were commonly found along the river. The Gynerium is one of their main food sources, which leads them to the gravel bars. Paca (Agouti paca) tracks and Central American

Agouti (Dasyprocta punctata) tracks were often seen. These animals frequent the river for drinks. There was only one incident of a cat track, probably Jaguar (Panthers once), observed on a sandy shore.

The abundance and diversity of wildlife with the BNR and BFREE depend on the riparian environment for habitat, food and water.

IV. Resource extraction from the Bladen River

At the time that I decided to study the ways of the Bladen, Jake and Kelly Marlin had just been informed that a major threat to the Bladen River was soon to come in the form of sand extraction. This gave my study more meaning and fueled my interest in river ecology.

An interview with Mr. Penell gave me basic information that was useful in understanding the magnitude of the sand mining. I approached him with apprehension, but he proved to be a very friendly and informative man. He told me that a large quantity of sand is needed to mix with cement for the construction of the Southern Highway. He told me that Kuwait was a major funder of the Southern Highway and had a contract with a Costa Rican company, Mako Santa Fe, to extract sand for the construction. So Penell was hired by Mako Santa Fe to be in charge of the project. Penell and about nine other workers will make a road to the river on Deep River Forest Reserve grounds, directly below the southeast border of the BNR (see Map 4). They are restricted from the east side of the river which is BFREE property. If the project proceeds as planned, a camp for ten men will be set up and sand dredging will begin during the month of May. Two machines will be brought to the sight, a truck to scoop the sand, and a crusher. The crusher is the size of a house, sifting and crushing the material until only the desired sand is left. The machine uses electricity which is provided by a generator on site. This generator requires diesel fuel.

The sand is needed for a 30 km stretch of the highway. Every 100 m of highway requires 6 to 7 truck loads (11 cubic meters) full of sand. He estimated that the sand mining will take 5-6 years and will span 3 to 5 miles of the sand bars. The depth of dredging is approximately 5 to 10 ft deep.

The inconvenience of the rainy season usually cripples any kind of development or construction work, but Penell said that this would not stop them. They will do as much as they can before the rains start; 10 trucks per day is average. Their work will continue during the dry stretches of the rainy season. When I asked him where they would go if they ran out of sand, he told me that they would never run out of sand to extract due to the rivers infinite resources.

What about the legality of this major project? Mining and dredging is regulated on paper. Before you begin gravel mining in Belize you need a liscence from the Geology and Petroleum Department. In order to get this license, one must submit an Environmental Impact Assessment, according to the Government of Belize's Mines and Minerals Safety, Health and Environmental Regulations (1994). Information that is required for the EIA includes the "ecology of the area, an account of all surface and ground water systems, vegetation, wildlife, potential visual impacts and an environmental assessment of the potential impacts on sensitive and biologically diverse ares. In addition this proposal must include methods for waste disposal, drainage control and an environmental monitoring program including a system for analyzing water quality. Finally, the proposed manager must submit a report prepared by a qualified hydrogeological engineer on the impacts on surface and ground water, including potential river diversions and increased flooding" (Nelson 96). All of these ecological factors must be studied, the impacts of this major project must be understood before any roads start being built and monstrous, noisy machines violate the integrity of the River.

"Under section 20 (1) in Part V of the Environmental Protection Act, any person intending to undertake any project, program or activity that may significantly affect the environment shall cause an EIA to be carried out by a suitably qualified person and shall submit the same to the Department of the Environment (DoE) for evaluation and recommendation. The current practice of the Department of the Environment is to request preparers of EIAs to submit copies of their curriculum vitae along with the EIA" (McCalla 96) Belize has good intentions on paper, but these intentions become very questionable when they are not enforced or regulated.

When I asked Penell if an EIA was carried out, he gave me a vague answer. Supposedly, the Geology and Petroleum Department did an EIA before they granted him a license. But the Geology and Petroleum Department makes money from resource extraction and has no part in EIA proposals. A brief inspection of the area was probably the extent of the environmental assessment in this case. EIA's are known to be inefficient to non-existent in many cases of sand and gravel mining (Nelson, 96).

When I asked Penell about his thoughts on the dredging and how it would affect the natural environment, he said he didn't really think it would harm the river. He believes, just like many people, that the material will be easily replaced. If the water is strong enough to wash down all of the sand and gravel that is present, it will have no problem replacing it. This sounds reasonable and logical to most people, but that's because we don't have any idea about the value and complexity of our watersheds.

V. Effects of Sand and Gravel Mining

Most waterways on earth are threatened by the clearing of trees and vegetation along riverbanks, large scale agriculture, pesticide and herbicide use, and mining and gravel extraction. The Sibun River is suffering from these destructive practices. The river begins high in the mountain pine ridge. As the draining water gathers energy, the streams join and pass through the Sibun Gorge, then through the limestone hills, and finally traversing savanna and pouring out to the sea. Dredging for gravel has been one of the major disruption to the health of the Sibun River. Dredging has been going on for years here and its once clear, clean waters now run thick and muddy during times of actual mining. The water is unsuitable for drinking and no longer serves as a recreational spot for locals or tourists.

Many households and nearby residents rely 100 % on the rivers water in the dry season. Also, many villages are dependant on the river downstream, which will inevitably be affected by the years of mining. Not only does this slowly deteriorate the quality of the water, but it effects the health of the whole watershed, the health and happiness of many lives, and eventually the health of the delicate reef.

The damage done to the Sibun river is rather obvious, and much of the future affects on the water quality and damage to the reef is just speculation. We cannot stop these dangerous pursuits with speculation.

Since my field work alone cannot provide insight into the nature of the Monkey River Watershed, I will continue to speculate the future effects of years of dredging in this vulnerable area of the Bladen River. The immediate effects are the most obvious ones. The construction of the road through this relatively untouched portion of the forest reserve is a noisy, destructive process. The camp that will be set up for the ten workers will involve clearing a portion of the forest. The workers will undoubtedly pollute the area with trash. Unbiodegradable soap will contaminate the river. Hunting and fishing might occur, further interfering with the wildlife.

Often times the trucks leak oil into the river due to careless mining.

During my conversation with Penell, he informed that the rules concerning environmental factors are always followed because the Geology and Petroleum dept. check up on them every six months. Apparently, a fine is issued if environmental guidelines are not followed. Since the environmental guidelines are not even defined in this case, and the enforcement happens only twice a year, it is hard to believe that the sand will be extracted with respect towards the river.

The longterm effects are very inconspicuous and therefore are the most dangerous. When massive amounts of sand are removed that once modified the energy and direction of the river, water from upstream will quickly replace this empty space. As a result, the more sand that is removed, the faster the water will flow upstream and downstream. The unnatural change in flow rate will change the path of the river. Other components of the watershed such as hillslopes and tributaries will have to compensate for this change throwing off the delicate balance of the whole watershed. A major increase in flow will undoubtedly increase erosion along the banks downstream and upstream. The Gynerium will probably suffer, decreasing the tapirs food source and further destabilizing the sand and gravel. The riparian vegetation will be damaged by increased erosion and flooding, degrading vital habitat for wildlife.

Siltation will undoubtedly be a major side-effect of the dredging along the Bladen River. Instream suspended sediments are known to drastically decrease the abundance of life in many streams and rivers. Siltation in primary receiving streams severely damages epiphytic communities (organism living on sediment surface) and reduces the productivity of these communities. In a 1917-1918 study of English lakes, Pearsals studies showed that Isoetes was easily choked by siltation because it could not adjust its root structure to accommodate the disturbance. Potamogeton perfoliatus replaced Isoetes in many instances, altering the biotic structure of the stream. In 1976, Fremlin showed that "increases in sedimentation rates accompanied alternations in flow patterns from dredging in the Mississippi River. This combination destroyed plant and animal communities of the marsh, leaving a barren windswept body of shallow, unproductive water"(Cooper, 93).

In the streams of northern Mississippi, the increases in discharge of water from major storms causes an increase in movement of sediments. This kills the benthic invertebrates and periphyton communities and hardly any growth of aquatic plant communities can form because of excessive siltation. This scour-aggredation cycle buries and destroys reproductive habitat for fish, causing reproductive failure (Cooper, 93).

The health of river and stream systems are often measured by biotic indicators such as fish and benthos. In 1955, Tebo showed that "high rates of sedimentation reduced benthos, both by mortality and drift." In 1970, Gammon studied the changes in fish and invertebrate population in a stream that was effected by a crushed limestone quarry. "When sediment load increased so that sediments accumulated, benthic population decreased by 60%. Densities varied from 10,750 organisms/m2 above the quarry to 86 organisms/m2 below the quarry." In 1977, Reed documented decrease in the number of fish and invertebrate species by 23% and the number of organisms by 40% due to siltation from highway construction. Cooper did a set of studies evaluating the effects of siltation on nonmobile invertebrates. An 83 km long stream located within an agriculturally cultivated watershed showed "that bryozoans, especially the environmentally sensitive Pectinatella magnifica, progressively disappeared in downstream areas with degraded habitat and increased total solids." Cooper also showed that the benthos suffered when sedimentation eliminated the sediment-sensitive organisms, especially the most sensitive larval stages (Cooper, 93).

"In lakes and reservoirs... the growth of most limnetic algae are dampened by light reduction from suspended sediments. Depth of light penetration into the water column is also reduced by suspended sediments, shrinking the photic zone." (Tilzer et al,. 1976). During a long-term study of Lake Chicot, Ar, which is within an agriculturally cultivated watershed, Cooper showed that "phytoplankton production was limited seasonally in the main basin by suspended sediments." These studies, among many other, have been able to document the specific species in streams, rivers, and lakes that are harmed because of the altered habitats resulting from siltation (Cooper 93).

Another important aspect of the Bladen River, and all rivers, is the microhabitat provided by the boundary layer. This is the space where a layer of water just over the river bed slows down due to friction. This layer of still or slow moving water is where algae, bacteria, and fungi are able to feed on and breakdown detritus. Invertebrates and insects are able to latch on to the rocks in this slow moving layer, feeding on the algae and detritus. The fish and crustaceans in turn feed on the insects and invertebrates. Detritus, which is at the base of that were once inexcessable and untouched. This will require natural resources. The demand for sand and gravel for the growing number of houses, buildings, and roads will just increase overtime. The need for economic development and advancement will continually and increasingly stress the Bladen River and the Monkey River Watershed.

Research on the Bladen River and other pristine riparian ecosystems must be pursued before they are no longer pristine and functioning in their natural state. The more we observe and study the nature of these ecosystems, the better we will understand how human interferences affect them. With this knowledge, we are equipped to interact with nature in a less destructive manner.

The mapping of this 2100m stretch of the Bladen River and the information that accompanies it will provide baseline data that can be referred to in future studies and mappings of the river. This slice of information should be just the beginning of our efforts to comprehend the ways of water and all it passes through. Their is a need for more detailed, longterm studies concerning water quality and patterns of waterflow of the Bladen River and its watershed.

Watershed consciousness needs to be fostered and implemented in our communities. Due to concerns of the health of the Sibun, a watershed organization made of citizens is gathering help from several other organizations. Lighthawk, an environmental organization, has volunteered to fly over the Sibun and collect data to make a detailed map of the watershed and the land use of the area. The watershed association will use this information along with the community member's observations to develop goals and objectives. This information will help determine if the water quality needs to be improved or just maintained. This project has heightened the awareness of the diversity of issues concerning the Sibun and has promoted community involvement (Nelson, 96).

Developing watershed organizations run by community members will open communication channels between watershed residents and the government. This will give a voice to the watershed and help lessen the degradation of our waterways.

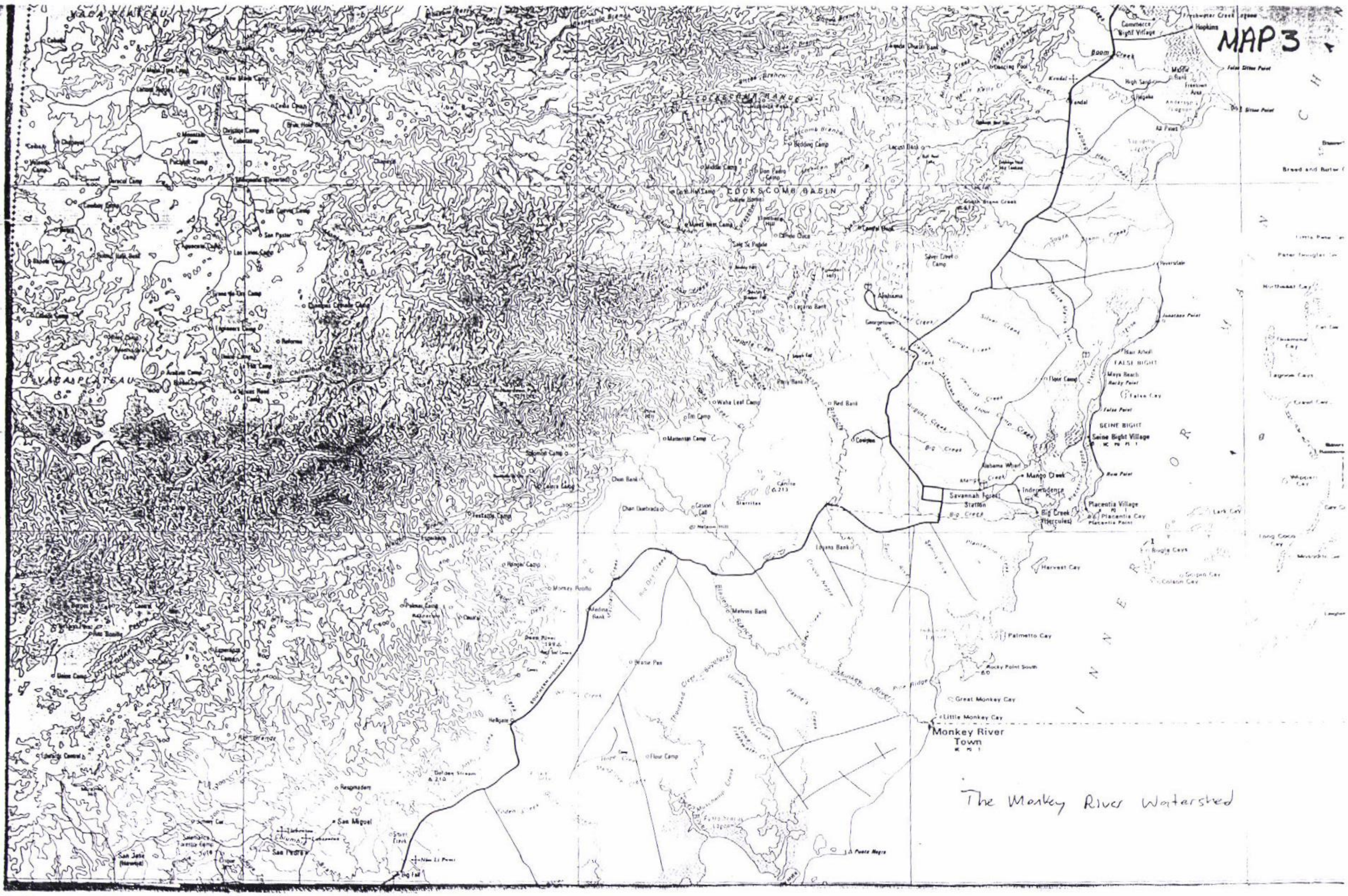
Not only will a better understanding of watersheds help stop their ignorant destruction, but a fostering of watershed consciousness will heal our fragmented perceptions of the earth.

Appendix 1: Temperature and Rainfall Data - April 3 to April 27

Date	Temp-Min/Max (c)	Rainfall (mm)
3	21/31	0
4	22/31	0
5	24/32	0
6	23/34	0
7	22/34	0
8	22/34	T
9	22/32	0
10	22/32	T
11	22/32	0
12	----	----
13	22/34	0
14	23/34	0
15	24/34	20
16	23/33	0
17	23/31	0
18	22/32	6
19	22/31	T
20	23/31	0
21	25/32	2
22	25/33	0
23	25/34	12
24	24/37	0
25	25/34	0
26	24/34	0
27	23/36	0

MAP 1

MEXICO
YUCATAN
YUCATAN
89°00'
88°30'
88°00'
87°30'
18° 00'
17° 30'
17° 00'
16° 30'
16° 00'
GUATEMALA
CARIBBEAN SEA
BARRIER REEF
INNER CHANNEL
TURNEFFE ISLANDS
LIGHTHOUSE REEF
GLOVERS REEF
AMBERGRIS CAYE
Rio Hondo
New River
Shipstern
Freshwater Creek
Aguas Turbias
Rio Bravo
Hol Chan
Crooked Tree
Bermudian Landing
Belize River
Burdon Canal
Labouring Creek
Sibun River
Terra Nova
Guanacaste National Park
Belize River
Monkey Bay
Manatee
Blue Hole
Five Blue Lakes
Tapir Mountain
Blue Hole
Half Moon Caye
Sibun
Grants Works
North Stann Creek
Vaca
Mountain Pine Ridge
Sittee River
Commerce Bight
Chiquibul
South Stann Creek
Caracol
Cockscomb Basin
Glovers Reef
Maya Mountain
Chiquibul
Mango Creek
← BFREE
Swasey Bladen
Bladen
Laughing Bird Caye National Park
Columbia River
Maya Mountain
Deep River
Paynes Creek
Machaca
Rio Grande
Temash-Sarstoon
Sarstoon River
N
W
E
S
PROTECTED AREAS
Forest reserve
Nature reserve
Wildlife sanctuary
National park
Private reserve
Natural monument
Marine reserve
Archaeological reserve
0
5
10
15 miles
Scale
GUATEMALA 89°00'
88°30'
88°00'
HONDURAS
87°30


MAP 3
The Monkey River Watershed
COCKSCOMB BASIN
Monkey River Town
Little Monkey Cay
Great Monkey Cay
Rocky Point South
Palmetto Cay
Harvest Cay
Placentia Village
Placentia Cay
Big Creek (Hercules)
Independence
Mango Creek
Savannah Forest Station
Seine Bight Village
SEINE BIGHT
FALSE BIGHT
Mays Beach
Hopkins
Boom Creek
Red Bank
Georgetown
Alabama
San Miguel
San Pedro
Medina Bank
Monkey Falls
Bladen Branch
Payne's Creek
Golden Stream
Big Creek
Silver Creek
Lark Cay
Bugle Cays

Mesurments and Angles

Points	distance (m)	angle (°)
1 to 2	6.5	228°
1 to 3	42	228°
1 to 4	54	228°
3 to 5	52	140°
6 to 7	41	62°
5 to 8	39	140°
8 to 9	44	134°
9 to 10	15	72°
9 to 11	26	72°
11 to 12	45	140°
12 to 13	9.5	47°
12 to 14	6	
14 to 15	26	128°
15 to 16	33	142°
16 to 17	23	137°
16 to 18	36	152°
18 to 19	16	56°
18 to 20	15	192°
21 to 22	10 M	
20 to 23	48	162°
23 to 24	8	~~156°~~
24 to 25	20	156°
25 to 26	35	180
25 to 27	14 M	

26 to 28	20 M	64°
28 to 29	30	188°
29 to 30	26	160°
29 to 31	18	202°
29 to 32	26.5	232°
32 to 33	17	350°
33 to 34	35	288°
34 to 37	36	340°
34 to 38	50.5	333°
38 to 39	17.5	236°
38 to 40	35	335°
38 to 41	50.5	325°
41 to 42	22	326°
41 to 43	50.5	322°
43 to 44	13	238
43 to 45	49	318
45 to 46	15	311
45 to 47	18.5	298
46 to 48	50.5	344°
48 to 49	5	255
48 to 50	14	338
50 to 8	27 M	18
30 to 51	19	150
30 to 52	26	62
51 to 53	49	172

76 to 78	16	124
78 to 79	5	48°
79 to 80	31	124°
80 to 82	23	211°
80 to 81	8	161°

53 to 54	50.5	160°
54 to 57	27	76°
54 to 58	14	148°
58 to 59	29	180°
59 to 60	26	203°
60 to 61	27	154
60 to 62	38	228°
62 to 63	33	152°
63 to 64	21.8	63°
64 to 65	27.6	165
65 to 66	35.5	160°
66 to 67	80	147
67 to 68	10 M	186°
68 to 69	13.5	132°
68 to 70	24	152
70 to 71	8	134°
71 to 74	35	124
74 to 75	16	218°
74 to 76	49	~~218°~~ 116°
76 to 77	21.6	210°
76 to 78	16	124
78 to 79	5	48°
79 to 80	31	124°
80 to 82	23	211°
80 to 81	8	161°

81 to 83	11.2 M	124°
83 to 84	16.7	203
83 to 85	24.8	98
85 to 86	13	55
86 to 87	14.4	137
86 to 88	16.5	137
86 to 89	20	137°
88 to 90	6.4	212
88 to 91	15.4	207
88 to 92	21.4	234°
88 to 93	5.5	~~77~~
86 to 94	8 M	77
86 to 95	21.8	88°
86 to 96	22.5	118°
96 to 97	5	118°
95 to 98	10	323°
95 to 99	11	9°
95 to 100	15	45
102 to 101	10.7M	152°
102 to 103	24.5	236
102 to 104	17.5	244
102 to 105	8	274
102 to 106	19.5	274°
102 to 107	17.8	332
102 to 108	14	0°

102-109	5M	44°
102-110	30.5	21°
102-111	24	8
102-112	28.1	359
113-114	13.2	105
114-115	6.2	337
114-116	28.2	13
114-117	26.6	22°
114-118	9	315
114-119	19.8	310
114-120	29.8	310
114-121	26.5	261°
114-122	30M	250
114-123	11.4	187°
114-124	30.5	213
124-125	39.5	231
124-126	17.5	281
117-127	13.3	10°
117-128	11.7	
117-129	24.5	316
127-130	14.6	341
130-130	8.9	310
130-132	10.8	70
131-133	10.3	194
131-134	6	248

131-135	8.6	348
131-136	24.5	320
136-137	40	320
137-138	15	50
137-140	14.8	206°
140-141	14	206
140-142	15	263
140-143	41	265
137-139	6.8	206
137-144	36.5	294
137-145	50.5	281
145-146	5.3	202°
145-147	19.9	0°
145-148	52	280
148-149	88	197
148-150	17.5	7°
148-151	14.5	286°
151-152	16.8	348°
151-153	15	330
151-154	34.5	313
151-155	7.3	176
151-156	10.5	274
156-157	12	246
157-158	81	231
158-110 #	17	286
159-160	14.5	122