Designing a Village Water Supply System In Papua New Guinea: A Case Study in Third World Development

Barak Bruerd

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Designing a Village Water Supply System in Papua New Guinea: A case study in third world development

Barak Bruerd
Designing A Village Water Supply System
In Papua New Guinea:
A case study in third world development
By Barak Bruerd

Master of Water Resources
Hydroscience

A Professional Project Report Submitted in Partial Fulfillment of the Requirements for the Degree of:
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Tara, my wife, who gave me up for two months so I could go home... Had Solomon known you in his court, the woman of Proverbs would have had a standard beyond reach.

And to Yahweh, the source of eternal water.
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Abstract

Papua New Guinea (PNG) is the second largest island in the world and one of the most biologically and culturally diverse nations on the planet. One of the last true stone age people, they are struggling with the delicate balance of entering the 21st century without losing their unique cultural heritage or devastating the fragile ecosystem they have lived in harmony with for thousands of years. Slow, careful steps are needed in order to ensure sustainable development; however the hardships of living close to nature – disease, drought, malnutrition, and lack of access to healthcare services, are causing Papua New Guineans to take detrimental steps in development, favoring short-term needs over long-term sustainability. Community development can help ease the growth pains of entering the modern world, bringing education and simple advances in agriculture and healthcare without the marring effects westernization often brings to struggling cultures. Foremost among the things needed by tribal communities is clean water.

The Bare (bah-reh) people of Papua New Guinea live in a 300 square kilometer region in the northeast corner of the Easter Highlands province. Of the 22,000 tribal members distributed among approximately 70 villages, only a quarter have access to clean water, and of these, only Kanimpa (kah-neem-pah) has received a clean water supply system.

The Olsons, a couple specialized in linguistics through the Summer Institute of Linguistics (SIL) are working with the Bare people in a variety of linguistic and development capacities. However, when the village of Punano expressed a desire for a clean water supply system, the Olsons had to seek technical assistance to aid in the design of the system. Having spent time with SIL in Papua New Guinea, I contacted their development office in PNG to see if my skills and education could be utilized for a short-term project and was soon after introduced to the Olsons.

During the 4 weeks of June 2002 I worked with the Olsons in the village of Punano in a variety of social and technical roles with the goal of designing the water system and producing a set of plans for its construction. Because of my knowledge of the culture and fluency in the trade language, I was well suited to deal with the intricacies of development, working to instill in the village people both ownership and responsibility for the water project. The village had decided upon a gravity flow system, and with the help of the Olsons, I surveyed the jungle water system using a handheld GPS unit and a sturdy pair of hiking boots.

The water system design is composed of three main sections: (1) the source, a small perennial stream located 85 meters above and 1.254 kilometers northeast of the village; (2) the pipeline, composed mainly of 40 millimeter polyethylene pipe; and (3) the delivery tank, a 4500 liter Tuffa Tank located in the northeast section of the village. At the source, a small concrete reservoir will be constructed, damming the 3.61/s flow rate before it is piped to the 350 inhabitants of Punano. A steep descent into a u-profile 148m below the source will necessitate the construction of a break-pressure tank 73 meters below the source, and a washout at the minimum elevation in the u-profile to remove sediment buildup in the pipeline. While treatment of the water would be ideal, it is not within the tribe’s ability to maintain treatment over the long-term. However the source is located far from anthropogenic influence and carries little disease providing a significant improvement over the muddy irrigation ditch that serves as their current source of water.
Introduction

Project Purpose

Although unique in many respects, Papua New Guinea (PNG) faces problems common in developing countries: poverty, lack of access to healthcare services, a growing population, increasing food scarcity, and of course a lack of potable water. With a population that has jumped in size from 2 million to 5.1 million since 1930 with no signs of slowing down, Papua New Guinea’s sources of clean water are rapidly diminishing. In addition, the vast majority of PNG’s population still exists within tribal communities in remote areas of the jungle where the people have little or no education concerning basic health and hygiene practices. This serves to exacerbate the problems of potable water where clean sources are polluted out of ignorance. Because the majority of people exist in these remote locations, government and non-governmental organizations (NGO) have no broad influence in education and/or regulation of health and water. To reach these people, small teams must target individual villages for education and community development. In order to be effective, these teams (generally made up of 2 - 4 people) must be committed to long-term service, learning the language, building relationships, and patiently educating the people. The teams’ continuing presence make it possible for community development experts in various fields to come and complete projects within the tribe; projects that are both needed and desired by the local people.

In the Eastern Highlands Province of Papua New Guinea, the Olsons, a linguistics team from the Summer Institute of Linguistics (SIL) are currently working with the Bare (bah-reh) language group. As part of their objective, this husband-wife team is educating the village people in basic healthcare, village technology, literacy, and other avenues of community development. Within the 70 villages that make up the Bare people, progress is varied; some villages resist change, either from a sense of tradition or lack of motivation, while others are eager to learn new things and implement positive changes to their traditional way of life. Punano (poo-nah-no) is one village eager for change, however the desires of the people have outpaced the Olsons’ limited knowledge in
community development. When the village asked for a system to provide clean water to replace the muddy source nearly a quarter mile away, the Olsons had to find someone with technical knowledge in village water systems. In a country with rugged terrain, harsh climate, language and cultural barriers, primitive conditions, and a volatile tribal system, technical expertise is hard to find.

Cross cultural barriers are typically the most challenging of any international project, and the ability to overcome these barriers one of the major qualifications organizations consider when examining potential candidates. Having grown up in Papua New Guinea from the age of 11, I was both familiar with the culture and fluent in the trade language spoken throughout most of PNG, making me an ideal candidate for assisting with community development projects within the country. I had attended high school at the SIL boarding school in PNG and had various contacts within their organization. In November 2001 I wrote SIL community development director Bill Thompson in regards to my interest in community development. A month later, Bill introduced me to Ron and Michele Olson. We began corresponding about the water supply system they wished to build in Punano and making plans for the following summer. Although village had already decided on a gravity flow system and had targeted a small stream in the mountains above their village as the source, nothing beyond that had been accomplished. Plans were made for me to arrive in June, at the beginning of the 6-month dry season, where I would work for 4 weeks in a variety of social and technical roles, living a few kilometers away from Punano in the Olsons’ village, Kanampa (Kah-neem-pah). The social design of the project included encouraging and motivating the people for the system construction, unifying the village elders and landowners, collecting money, and organizing labor. The technical design involved surveying for the water system from the source to the village, designing a gravity flow system with a comprehensive parts list, and marking the physical locations of the system from source to delivery site. The customary slow pace of third world countries precluded any possibilities of beginning actual construction during my stay. However, once the Olsons possessed the design for the water system, my assistance in the construction of the system would be unnecessary.
Papua New Guinea

History

In order to understand the cultural and physical complexities of community development in Papua New Guinea and in this project specifically, an understanding of the country's history, culture, and environment is important. New Guinea is the world's second largest island, located just north of Australia along the equator. The island is divided in half with the western portion belonging to Indonesia, and the eastern portion the independent nation of Papua New Guinea. However, these political dividing lines are merely the invention of western rule. The people and land that make up these two nations share a history that reaches back, far beyond even the birth of modern civilization. Some forty thousand years before the great pyramids were build in Egypt, a nomadic Melanesian people group made its way across hundreds of miles of open sea, migrating from island to island across what is now Indonesia, and finally coming to rest on a large volcanic land mass in the south pacific: New Guinea\(^1\). These people remained virtually unchanged for over the next thirty thousand years, a people living in the late Paleolithic era until the modern world discovered them in the early 20\(^{th}\) Century. Settling down from hunting and gathering into a primitive agricultural society, they were a people with only stone tools and fire; a people who never invented the wheel. Over this vast expanse of time their society evolved, splitting and diversifying into nearly 900 unique language groups with well over a thousand tribes, each with its own distinctive culture. Remote and uninvolved in the affairs of the rest of the world, the discovery of the island in 1527 by the Portuguese sparked little interest in the outside world, who believed it to

\(^1\)http://www.geographia.com/papua-newguinea/
be mostly uninhabited. It wasn’t until 1930, four hundred years later, that the very first explorers entered the heart of the island and discovered over one million people.²

Like so many other newly discovered regions of the world, New Guinea quickly became another exotic land to exploit, feeding the whims and fads of western society. During the 1930’s and 40’s, a gold and copper rush began as westerners leaped at the possibility of a modern “Sutter’s Mill” while ladies of fashion competed over the latest gaudy look in hats adorned with Bird of Paradise feathers. Missionaries and anthropologists abounded, looking for converts and museum pieces. But in the midst of it, the tribal people were caught up in the wonder of cornflakes, airplanes, and metal axes, and struggling as their worldview was being dashed to pieces by white ‘gods’ from across the mountains. Tribal economy was thrown into confusion as shells and beads so hard to find in the highlands were now being brought in by the gunny sack full to be exchanged for labor and land rights. Tribal wars increased, some fighting against the invasion of the white takeover, others fighting to profit from it.

British-ruled New Guinea had been given to Australia as a Trust Territory in 1909, and as the destructiveness of western behavior in the country became evident, Australia began to regulate activities, such as outlawing the export of feathers and orchids. Nevertheless, New Guinea was on a downward slope of ecological and cultural devastation, a devastation that was staved off by only two factors. The first was New Guinea’s rugged and harsh environment: steep mountains, dense jungle, and heavy rainfall that seemed to keep out all but the native people. The second was World War II. New Guinea was a strategic focal point in the war and it was the war that allowed New Guinea to ease into

² http://www.geographia.com/papua-newguinea/
the 20th century without many of the scars of exploitation or colonialism suffered by so many other third world nations. The war diverted attention from exotic fads and delusions of riches to the more pressing needs of world order, giving New Guinea time to adapt and the rest of the world time to mature. By the time World War II was over and western society recovered, it had achieved a somewhat more mature attitude towards developing nations. And though New Guinea still offered cultural and biological richness unsurpassed anywhere else in the world, only a small portion of western society now had any interest.

The island was divided, the western portion called Irian Jia, was given to Indonesia, and the eastern portion, Papua was added to Australia’s Territorial Trustee of New Guinea. In 1975, what had become known as Papua New Guinea, was given its independence, and it formed a parliamentary government, recognizing the Queen of England as head of state. However, tribal allegiances and an ill-formed political system caused a great deal of instability and corruption, a condition that has been increasing in recent years.

**Ecological heritage**

An obscure country in the affairs of the world, Papua New Guinea is a country little known to the average westerner. In the last several decades however, PNG has been an increasing target for mining and logging industries, both domestic and international. As a counterbalance to its growing reputation as a nation rich in resources, the global community of conservationists is realizing PNG’s importance and uniqueness in the world, both culturally and environmentally, and making efforts towards its preservation. As a result, there are a growing number of governmental and nongovernmental organizations operating within the country in a wide variety of cultural, developmental, and conservation programs.

New Guinea is the second largest island in the world, with the Papuan side equaling 178,260 sq miles, an area roughly the size of California. The worth of Papua New Guinea’s biological heritage is enormous. PNG contains the third largest remaining continuous rainforest in the world. The main island has a wide range of tropical biomes
including five types of lowland rainforest, thirteen types of montane rainforest, five varieties of palm and swamp forest, three different mangrove forests, a variety of grasslands, swamps, estuaries, alluvial plains, desert and semi-desert, and various marine environments\(^3\). The rainforest itself hosts an estimated 5-7 percent of the world’s biodiversity, with over 11,000 plant species (two thirds of the world’s orchids and 9,000 flowering plants), 214 species of mammals of which 57 are endemic, 170-200 species of frogs, 450 species of butterfly (including the largest and smallest butterfly species in the world, both of which are endemic), and several hundred bird species including 37 of the 43 species of Bird of Paradise\(^4\).

While comparatively pristine, the environment is under constant threat from development, consumption, urbanization, infrastructure development, and population growth. In addition to this, non-sustainable patterns in mining, logging, petroleum exploitation, shifting agriculture, and the use of artificial inputs have had serious negative environmental impacts\(^5\). These impacts include increased soil erosion, deforestation, silting of rivers, pollution, and loss of biodiversity. Regulation by the government is almost pointless

\(^3\) [www.wtgonline.com/data/png/png.asp](http://www.wtgonline.com/data/png/png.asp)

\(^4\) [www.wtgonline.com/data/png/png.asp](http://www.wtgonline.com/data/png/png.asp)

\(^5\) [www.undp.org.pg](http://www.undp.org.pg)
as its ability to monitor and enforce such regulation is extremely limited. But as necessary as preserving this environment may be, development is inevitable; and even as it is inevitable, it is also necessary.

**Reasons for development**

Compared to so many other third world countries, the people of Papua New Guinea are fortunate. Frequent rain, good soil, and a year-round growing season has provided them with adequate food, and malnutrition is rare. In addition, isolation from other countries has safeguarded them against many of the horrific diseases that plague the majority of third world countries along the equator. Consequently, while they may be poor in terms of material goods, they have not lacked the necessities of life. Yet the hardships of living life so close to Mother Nature have had their effects. Papua New Guineans have an average life expectancy of just 56 years. While this may seem incredibly low, it is actually a 16-year increase from two decades ago when life expectancy was only 40 years—a life span that a large percentage of tribal people still face. Papua New Guinea is also estimated to have the fifth highest mortality rate in the world. Some areas have been found to have a mortality rate of over 90% in children under the age of six. It is no surprise that only a small percentage of the population has access to healthcare, and little or no education in the basics of standard hygiene. The terrors of Ebola and Scarlet Fever do not exist in PNG, but in the absence of healthcare, even diarrhea can be deadly. Only an estimated 15% of the population has access to safe water and sanitation services, making the leading causes of death, diarrhea, typhoid, and cholera, (as well non-water related diseases such as malaria, meningitis, pneumonia, and tuberculosis).

While the people have never lacked for the bare necessities, that is slowly changing. Curiosity of westerners and the possibility of employment and education that would lead to money and prestige within their tribe is drawing a growing number of people from their tribal lands to towns created by foreigners. As people migrate to urban areas, unplanned urban settlements spring up and government services are taken away from

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6 [www.undp.org.pg](http://www.undp.org.pg)
rural efforts and focused on urban development. Unfortunately the government’s resources are not adequate to deal with a population that is no longer self-sustaining and urban poverty is further aggravated even as crime rates increase. This in turn discourages foreign investment and tourism, which further exacerbates the economic roots of poverty.8

Unfortunately, development is often seen in a negative light. Pictures of large regions of deforested land replaced by forests of concrete smoke stacks, congested highways, and cookie-cutter suburbs often fill the mind. But the abuses of modern man on the environment can blind us to the truth that it is possible to live in harmony with nature and still provide opportunities for education, healthcare, and the general betterment of life. But the road that enables both development and conservation to exist simultaneously is long and difficult and requires a level of maturity and self-sacrifice that too often we are unwilling to exercise. The short-term needs for cash and the desire for instant development too often outweighs the long-term need for conserving for future generations. This tendency is increased in third world countries where aspirations of money and prestige is often a blindfold that keeps the nation from making wise decisions, even as ignorance ties the knot. This creates a burden of responsibility on first world parent nations to act maturely towards third world countries, rather than exploiting weakness or ignorance for profit and power. Ironically, while Hollywood invents concepts like Star Trek’s “Prime Directive,” depicting a slow, careful approach to developing people groups, those with the power to affect positive development in the real world continue to exploit the resources of developing countries as well as introducing such things as drugs and alcohol and harmful technologies like

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8 Edoni, W; SII. Public Relations Director. 2002
pesticides without providing a foundation for responsible use. In recent years, these attitudes have begun to change, and many groups are working hard to assist third world nations provide stability for their people and develop a responsible attitude towards their wealth of natural resources.

**Development Approach**

When addressing the needs of a third world community, the historical western attitude has been one of superiority and control. Unfortunately, while westerners do possess potentially helpful knowledge and technology, integrating them into a developing culture requires time and trust. In order to achieve this, relationships must be built over time, the desires of the village must be given priority, education provided to enable them in making wise decisions, and a sense of ownership and responsibility instilled so that projects are maintained by the local people in the long-term. These philosophies have been incorporated by the Olsons in their work with the Bare people and it has been through their relationships in various villages that positive changes have been affected. Among these villages, Punano has displayed a strong desire, not only for development, but also a willingness to invest themselves both financially and physically in community development projects. For this reason, a large portion of the Olsons’ efforts has been focused on the village of Punano, and where the second water system in the Bare language group will be installed.
The Project

**Punano Overview**

![Map of Punano with labels](image)

Figure 6. The village of Punano is located in the northeast corner of the Eastern Highlands Province, and in the southern region of the Bare language group. The watershed for the source is roughly 1.5 square kilometers and ranges from an elevation of 1900 meters at its head, to 1550 meters where it joins a larger stream. The vegetation cover for the watershed varies widely, however, in general, vegetation up to 1650 meters is characterized by gardens, coffee, one-meter kunai grass, and scattered forest. Above 1650 (in green) is dense rainforest. During the four weeks of the project, I was based at the Olsons', village of Kanimpia, several miles away.
The village of Punano is located in the northeast corner of the Eastern Highlands, along the southern boundaries of the Bare language group. A small road offers access to the Highlands Highway, the major road through the heart of the island. From there the village has access to trading posts and a small health clinic, and can sell locally grown coffee to coffee producers who drive by and pick up the bags of beans dried on tarps in the village center. The village itself is spread out over half a kilometer, though the majority of the village's 350 inhabitants live within the hectare that makes up the village center. Gardens are grown in the valley and on the mountainsides, and water is collected from a muddy stream half a kilometer away which serves as a laundry site, an irrigation ditch and in many places, the only path through the three-meter pitpit cane. Water for drinking and cooking purposes is carried in cooking pots to houses by hand. Most families have only one pot for cooking, leaving nothing else in which to keep a constant supply of boiled drinking water.

Typhoid and amoebic dysentery are the primary water-borne diseases, though hepatitis, cholera, and giardia are frequent, and cold and flu infections spread quickly due to infrequent bathing. Pigs, the only livestock indigenous to Papua New Guinea, carry many diseases contractible by humans. In addition, pigs often eat human waste, serving as an intermediate host for pathogens, which are then cycled back into the human population. Pit toilets are only beginning to appear, but improper use quickly creates an infestation of flying insects and they are typically avoided.
Social Design

Although my primary function was designing the system I also worked with the Olsons in coordinating the village in various efforts related to the project. Together, we spent the first two weeks making trips to the village and holding council with the people and also with individual leaders discussing expectations and collecting village data. Although the local people initiated the water system, expectations concerning their role in the construction and maintenance of the water system had to be clarified. Their role in the water system involved providing 100% of the general labor, contributing 2 Kina per person, and providing and individual who would be responsible for maintaining the system after its completion. Our involvement then consisted of the remaining responsibilities: providing the bulk of the funding, technical expertise, and training for maintenance of the system. Once these expectations had been agreed upon, collection of the village's portion of the funding commenced as a sign of their commitment to the project.

Unknown to the local people, the real purpose of their financial input was not to contribute to the expense of the water system. Given that their contribution amounted to less than 10% of the total cost, the real purpose for collecting money was to instill a sense of ownership in the project and thus an incentive to maintain it independently. Although meager in terms of total cost, to the local people, the investment was significant. The meagerness of their contribution was rooted in two sources. First, all are subsistence farmers; aside from occasional garden surplus, their only cash crop is coffee. Most internal 'purchases' are done with goods not cash, which is used for purchasing external goods such as axes and coffee drying tarps. The second reason is due to the severe devaluation of the Kina. In 1988 the Kina was worth $1.45. Today the Kina is worth about 25 cents, though the prices on domestic goods have responded slowly to the devaluation, making the cost of living cheap for
expatriates who have an external source of income. In the village, devaluation and inflation are concepts difficult to translate and local prices have not changed at all. To the village people, a Kina is still a Kina and to produce 500 Kina now is as hard as it was 14 years ago.

Beyond money collection, it was essential to gain permission from the landowners to build the water system on the land between the source and the village. This can be highly difficult as multiple landowners can exist in a small area, and some of them may not be from the village receiving the water system. In this instance, however, the land between Punano and the source belonged to Punano men who would benefit from the clean water and were quite willing to allow development of the source and pipeline.

Finally, the labor required to survey and begin initial construction of the water system had to be organized. Manpower is a rich commodity in Papua New Guinea, and small as the people are, their ability in physical labor is nothing short of miraculous. During the course of the project, galvanized pipe, fittings, sand, and concrete will all have to be carried through the steep mountains to the source in addition to clearing a path through the dense jungle and hand digging the trench for the 1520 meters of pipe. While working with the village people, simple observation over time quickly divulged whom the natural leaders in the group were through their willingness to take charge, make wise decisions, and ability to motivate the rest of the work team. It was to them that we gave charge of marking key locations, organizing and delegating group efforts, and looking after supplies. Later this year, during construction of the project, it will be these leaders that the Olsons look to for training in maintenance and repair of the system.

**Choosing a supply system**

In Papua New Guinea there are four major types of water systems used: wells, roof-rain collection, hydraulic ram, and gravity flow. The choice of a gravity flow system was based on several factors. First, because of the sprawling nature of the village and the anticipation of clean, accessible water, the people wanted multiple taps interspersed throughout the village. This ruled out wells, which in general are not common due to a
scarcity in drilling rigs (which are expensive, must be brought in from the coast, and require the presence of a road to drill sites), and because of a rock layer several feet down covering most of the highlands, making drilling difficult. No clean source was available below the village for hydraulic ram pumping; and roof-rain collection systems would have involved tin roofs and storage tanks for every member of the village, or at least construction of a large single roof and several storage tanks with capacity great enough to supply the entire village's drinking water requirements. Due to the high level of yearly rainfall, roof-rain collection systems are used extensively throughout PNG; but in the village they are usually implemented only when a school building or central meetinghouse is present from which enough water can be collected to serve the village's drinking and cooking needs. Several possible sources for a gravity flow system existed. Once one of them had been settled on, data had to be gathered to assess the feasibility of the system. The proposed system possessed three main sections: a concrete reservoir to collect water from a small stream in the mountains above the village, a pipeline to the village, and a storage tank in the village.

**Village Data**

The methods for gathering village data consisted mostly of piecing together information through long talks with the local people, as well as using data previously collected by the Olsons and historical government surveys. The Olsons' had previously estimated the village population to be 350 individuals, roughly divided between 60 families. Although water use per person was difficult to assess, 40 liters per person per day was estimated. Compared to American standards, or even those of other third world communities, this is significantly low; but among Papua New Guineans, this is a generous estimate. Generally, water use is closer to 20 liters per day per person, as water is used mainly for drinking and cooking, and laundry and bathing occurs only 1 to 3 times a month.
Table 1. *Average per person per day water use including projected increases in bathing and laundry frequencies.*

<table>
<thead>
<tr>
<th>Water Use (person/day)</th>
<th>Water (l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drinking</td>
<td>4</td>
</tr>
<tr>
<td>Cooking</td>
<td>4</td>
</tr>
<tr>
<td>Bathing</td>
<td>20</td>
</tr>
<tr>
<td>Laundry</td>
<td>12</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>40</strong></td>
</tr>
</tbody>
</table>

The World Health Organization determined the standard per capita daily demand for third world communities as 45 liters. This figure includes allowances for personal washing, drinking, cooking, and a portion of domestic animal needs. When calculating village demands however, I chose to use 190 liters per person per day (50 gallons) to incorporate the typical water use increase normally accompanied by the presence of accessible clean water, to account for technological advances in the future which would also increase water use (such as basic indoor plumbing, flushable outdoor toilets etc), and to provide a wide margin of safety in my calculations. In the Olsons’ village, where the first water system was installed, families are now bathing nearly every morning, laundry is done weekly, and cooking pots and dishes are washed after every meal. This increased water use has been accompanied by decreased disease. While no technical survey has been conducted, the Olsons have observed a marked decrease in cold and flu sicknesses, parasites, and skin diseases. Washing coffee during coffee season may also appropriate a portion of the water for several months of the year and must be taken into consideration.

**Surveying the Gravity Flow System**

**The source**

Surveying was accomplished with a handheld Garmin GPS unit equipped with a barometer for accurate elevation readings. In general, reception was excellent; however, at points closer to the source reception was poor due to obstruction by steep mountains and ravines, and dense canopy coverage (leaf area index for tropical rainforest can exceed

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300%). To insure accuracy, several readings were taken over the course of two weeks, and the data averaged to give estimated distance (±15m) and elevation (±10m). The source was located at 1715m, 85m above the village; located at 1630m. As the crow flies, the distance between the source and the delivery tank in the village was 1.254km.

In the limited amount of time I was in Punano it was impossible to survey the stream’s entire watershed above the source. However, people, gardens, and domestic animals were all located below the point we had selected for the source, which insured that the water would be as free as possible from pollution and disease. The stream was also chosen for its dependability and clarity. According to local information, the stream flows year around, and maintained flow during a severe six-month drought in 1997 indicating that it might be spring fed. Rainfall in this region of Papua New Guinea averages 1.5 to 2 meters of rain a year\textsuperscript{10}, and as rain falls weekly even in the dry season, the stream should provide a steady source of water in years to come.

Initially I took soil samples of the streambed, which showed 97% sand, 2.5% clay, and .5% organics. Given the low clay content, the stream should run clearer during peak-flow periods as opposed to lower in the valley where clay contents are higher. This is favorable since it will require a shorter settling time for suspended particles, and thus a smaller reservoir. The site chosen for the source was one of the few flat spots along the stream, an area with the fewest boulders and no large trees directly along the stream bank. Nevertheless, a fair amount of work will be required to clear the dense foliage and boulders from the area and level the ground before pouring the concrete for the reservoir

\footnotesize\textsuperscript{10} Land Management Group, PNGRIS
To measure stream flow, I obtained an old piece of roofing iron and cut a 60-degree angle in it to create a v-notched weir. Carrying it up to the source we inserted it into the stream bank to form a dam. Once the stream had stabilized, the height of the water flowing through the ‘V’ was measured. Using the graph in Appendix A, the stream’s flow volume was calculated to be 3.6 liters per second.

By arriving in late June, the second month of the dry season, my measurements were an estimate of base flow. While not a truly accurate picture of average yearly base flow, it will provide a point of reference for future comparisons. These future measurements will be accomplished via a v-notched weir located at the inflow point of the reservoir making accurate readings easy for the local people to record. The final piece of data missing was maximum flow, as would occur during rainy season. Because the stream at its current base flow will support the village’s present population, the maximum flow is not important. However, 10 liters/sec would be a reasonable guess, knowing that streams in the highlands often double and triple in size during the rainy season. Accurate information will be important when the village population size increases such that it requires storage during the rainy months of November to May in order to provide adequate water during the drier portion of the year.

Having collected the stream source data, I combined it with the village data to determine the stream’s adequacy for the village demand, the size of storage tank required, and the stream’s ability to support future demand. Using a spreadsheet, I created a series of formulas that would allow easy input of data to calculate changes in the system and their resulting effects (table 2).
Table 2. Stream source and village data providing calculations.

**Input Data - Metric**

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Village Population</td>
<td>350.00</td>
</tr>
<tr>
<td>Per Person Per Day Use (liter/day)</td>
<td>190.00</td>
</tr>
<tr>
<td>Source Baseflow (dry season) (liter/sec)</td>
<td>3.60</td>
</tr>
<tr>
<td>Estimated Max Spring Outflow (rainy season) (liters/sec)</td>
<td>10.00</td>
</tr>
<tr>
<td>Source Height above village (m)</td>
<td>85.00</td>
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<tr>
<td>Particulate settling time (days)</td>
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</tbody>
</table>

**Output Data - Metric**

<table>
<thead>
<tr>
<th>Metric</th>
<th>liters/sec</th>
<th>liters/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Baseflow (dry season)</td>
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<td>311,040.00</td>
</tr>
<tr>
<td>Max Supply Outflow (rainy season)</td>
<td>10.00</td>
<td>864,000.00</td>
</tr>
<tr>
<td>Village water needs</td>
<td>0.77</td>
<td>66,500.00</td>
</tr>
<tr>
<td>Reservoir Volume (for Residence T) (m³)</td>
<td>34.56</td>
<td></td>
</tr>
<tr>
<td>Time Village drains entire reservoir (days)</td>
<td>0.52</td>
<td></td>
</tr>
<tr>
<td>Max Population the Spring will support</td>
<td>1,637.05</td>
<td></td>
</tr>
</tbody>
</table>

Table 2 shows that the source will provide more than enough water, even at base flow, to supply the village needs. In addition, it could theoretically supply a population as high as 1,637 people, though at the current per capita water use of 40 liters, the number is actually triple that amount.

The concrete reservoir will act as both a sedimentation tank and a secondary storage tank, though its storage function is more of a by-product. A concrete, rather than an earthen reservoir is being constructed for several reasons. Most important is stability. Peak flow during rainy season can cause heavy erosion, eroding an earthen reservoir and stirring up sediments lying at the bottom. Sediment buildup is easier to remove from a concrete reservoir, and in a climate where plants require only a minimum of soil to grow, a cement pool will help keep the reservoir from becoming a small terrarium. Schematics of the proposed reservoir are provided in Appendix B.
Figure 11. This is a photo taken below the source overlooking the two ridges between the source and the village. The arrow indicates the location of the village and the delivery tank. Rather than crossing the ridges, the pipeline will descend into the valley to the left, skirting the base of the two ridges, before climbing up to the delivery tank (indicated by the line).

The pipeline

The pipeline design was intimidating given the terrain and conditions between the source and the village. Along the direct line of sight lay two ridges and a deep ravine in the jungle just below the source for which a crossing will have to be built. In addition, a u-profile dipping down 53 meters below the village will have to be traversed with enough residual head to allow flow into the tank without bursting the pipes at the bottom of the profile (fig. 11). In order to avoid the two ridges and maintain a continuous downward slope, a more circuitous route is required. This increases the total distance along the pipeline to 1.52km. This distance, from source to tank involves 240 meters of dense jungle with slopes exceeding 70 degrees, 310 meters of waist-

Figure 12. The blue line indicates the vertical profile of the pipeline as described in the photo above with its respective land cover. The red line is an overlay of the vertical profile across the direct "line of sight" were the pipeline to cross the ridges instead of going around them. While somewhat longer, the chosen route is much simpler to design and construct.
high kunai grass descending along two ridges that drop sharply into 760 meters of coffee and gardens, followed by a steep climb of 53 meters over the remaining 210 meters to the delivery tank.

Forty millimeter polyethylene pipe (poly pipe) was chosen for the entire length of the pipeline due to its cost effectiveness. It provides a high volume flow rate with a pressure rating of 100m, while still being reasonably affordable. Because the elevation of the source exceeds 100m, a break-pressure tank (Appendix C) will be needed at a point along the pipeline while still allowing enough head for flow through the u-profile. A site for the break-pressure tank was marked at an elevation of 1650m, 20m above the delivery tank, 86m above the minimum elevation in the u-profile, and 65m below the source keeping the pressures within the 100m rating for the pipe (fig. 12). Using friction factor tables for 40mm poly pipe I created a second spreadsheet to calculate the head over the various reaches of the pipeline. Only two main reaches exist: source to the break-

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**Figure 13.** Vertical profile of the pipeline showing the hydraulic gradient with static and steady flow, and the location of the crossings, break-pressure tank, and the washout. This figure can be seen in better detail in appendix d.
pressure tank, and the break-pressure tank to the delivery tank. For the first reach, friction will hold the water at 2.2 l/s, maintaining a head of 17m above the break-pressure tank. The head across the u-profile will be maintained at a level of 3m above the tank, providing a 1.2 l/s flow volume. Currently, this will provide sufficient flow to supply the village. However, at 1.2l/s the water system will only support a maximum population of 545 people if 190 liters per capita is assumed. If the national population growth rate of 2.5%\textsuperscript{11} is applied, the village’s needs will exceed this supply rate in just under 20 years. A new source of water will then be required, or additional tanks added to the system to store surplus water during the rainy season supplying the village during the drier months of the year.

The pipe will be buried half a meter to meter deep along the entire length, except when crossing ravines or garden irrigation ditches. In these exposed stretches, the pipe will be protected by a bamboo sheath. Three crossings exist, one 30m crossing in the jungle near the source and two 10m crossings in the garden and coffee area. If sheathed in a few stout sections of bamboo, the 10m crossings will require no other support system. However the 30m crossing is too long and located in unstable soil and will require a suspended crossing with posts set in concrete on either side. Diagrams and calculations for the 30m crossing are given in Appendix E.

The final important addition to the pipeline is a washout just before entering the upward climb to the delivery tank. In large u-profiles where flow velocities are relatively slow, sediments in the water can settle out in the lowest section of the pipe. Over time these sediments can become significant enough to block flow to the tank. To solve this problem, a washout valve must be installed to allow sediments to be flushed when needed.

**The delivery site**

The delivery site is located in the village at an elevation of 1630m along the edge of a ridge facing the source. There, a 4500 liter tank will store water for village needs. Flow

\textsuperscript{11} World Bank
into the tank will be continuous with an overflow pipe providing for excess runoff. While concrete or corrugated iron tanks are cheaper, a Tuffa Tank will be used instead. Made of 4mm Polyethylene, Tuffa Tanks utilize a unique combination of dyes in the plastic to inhibit algae growth and tank degradation due to UV radiation\textsuperscript{12}. Lightweight and easy to transport, Tuffa Tanks outlast most other forms of storage.

The tank will feed multiple taps throughout the village. Initially, 5 taps will be installed, though more may be added later. Like the pipeline, lines leading to the tap stands will also be buried while the tap stands themselves will stand aboveground, supported by a post.

At this point, no form of water treatment is being implemented, though occasional chlorination may be required to remove algal growth. Treatment of the water would be ideal; however the responsibilities and costs involved in continual chlorination or boiling of the water would be beyond the current abilities of the tribe. The source, located far from anthropogenic influences, carries little disease, and while sparse pathogens may exist, the water will prove a significant improvement upon their current source of drinking water. Boiling individual quantities of water for their families will be an option for those progressive enough to make the effort.

**Cultural design considerations**

When designing the system, two important considerations governed the design: simplicity and durability. Simplicity is important for fewer breakdowns and easier repairs, qualities highly valued in the third world. Materials such as concrete and poly pipe, while cost-effective, also possess other favorable qualities: with very little

\textsuperscript{12} http://www.global.net.pg/tprojects/tuf_tecinfo.htm
instruction, the average person can learn to construct and repair either of these two materials. Poly pipe requires no threading or glues, it can be easily cut flush with a machete, and replacement joints can be fitted by hand or with a few common tools. This makes it possible to train local people, giving them total responsibility for maintenance of the system. The second cultural design consideration is durability. Durability is usually assumed important for fewer breakdowns. While this is true, system failures are not always due to accidents. Cutting off the nose to spite the face is a frequent form of disfigurement in Papua New Guinea, and more than one community development project has failed due to a disgruntled villager. Burying the pipe helps forestall such behavior as well as protects the pipe from the elements, brush fires, and stray shovels and digging sticks searching for sweet potato. To discourage tampering, important valves, such as the washout valve and the gate valve at the reservoir will have the handles removed and will be kept safe by a responsible member of the village.

Cost

With the instability of the Kina in recent years, costs are often difficult to project for projects requiring more than a year to complete. However at current prices, the cost breakdown of the Punano water system is listed in Table 3 and provides a reasonable estimate of the total cost of the system. Labor costs will be minimized as the village will provide all the labor except for technical labor which will be volunteered by SIL personnel such as the Olsons or individuals like myself.
Table 3. A cost breakdown of Punano’s water system. While not a complete part list, it nevertheless provides a working estimate for the total cost of the system.

### Estimate for a 1500m Water Supply System

<table>
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<th>Quantity</th>
<th>Unit Price (PGK)</th>
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<td>Galvanized pipe</td>
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<td>117.58</td>
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<tr>
<td>Cement bags</td>
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<tr>
<td>Gate valve</td>
<td>1</td>
<td>32.64</td>
<td>32.64</td>
</tr>
<tr>
<td>Female adaptor</td>
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<td>15.12</td>
<td>15.12</td>
</tr>
<tr>
<td>Meters of Poly pipe 40mm</td>
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<td>Coupling</td>
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<td>22.58</td>
</tr>
<tr>
<td>Tee</td>
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<td>29.76</td>
<td>59.52</td>
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<tr>
<td>Male adaptor</td>
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<td>4.48</td>
<td>13.44</td>
</tr>
<tr>
<td>Coupling #2</td>
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<tr>
<td>Meters of Poly pipe 25mm</td>
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<td>910.00</td>
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<td>300.00</td>
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<tr>
<td>Thread Tapes</td>
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<tr>
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<td>50.00</td>
<td>2500.00</td>
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<tr>
<td>Tuffa Tank</td>
<td>1</td>
<td>1775.48</td>
<td>1775.48</td>
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<td>Total Kina</td>
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<td></td>
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<tr>
<td>Conversion</td>
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<tr>
<td>Total US$</td>
<td></td>
<td></td>
<td>3034.14</td>
</tr>
</tbody>
</table>

### Future design considerations

Currently, the Punano water system has been designed to ensure sufficient water for the village and a 2.5% growth rate over 19 years. Beyond that time period, changes to the system will have to be made. In addition, a second village adjacent to Punano has requested a water system. The water system can be adapted to include their village of 400 people with the following modifications. First, the pipe will have to be split before entering the delivery tank to allow half the water to flow to the second village. It will be essential that each village receives 50% of the water, and that no tampering can occur to cut the supply to one or the other. A second tank will have to be installed in the second village, and should supply not meet demand, larger tanks may be required.
Learning From This Experience

*A Brief Look at Community Development*

Community development is a concept that has been evolving in recent decades, and philosophies and approaches are much debated. One theme that is consistent throughout however is ownership. Without ownership, no project will ever be sustained by the people in the long term. Ownership is that quality that motivates people to take pride in what has been accomplished because their hands have had a part in it. It is the sense of value derived from because something of value was put in. It is ownership that takes a completely foreign and outside idea, and in the process of making that idea reality, changes it into one that becomes ingrained in the fabric of the village culture. How is ownership instilled? Instilling ownership is a quality of a true team leader. A team leader is someone who can lead a group of people and make them feel as if the destination was their idea all along. It requires strong relationships, trust, and commitment. Ownership is instilled by giving the power to the local people to make wise decisions through education and awareness. And it is by taking deep-rooted values inherent in the culture and using those as a foundation to inspire the people.

In Papua New Guinea, the most successful projects are those that have taken the longest. And many of the best community development case studies have not been community development projects at all, but simply the influence and presence of one person whose original purpose was not focused on community development. In 1968, Marilyn Laszlo began linguistic work in the village of Hauna in the East Sepik region\(^1\). Though her work was not development based, the people gained awareness of things they could do to improve their quality of life. With her help, they implemented a host of community projects including building a school, a health clinic, putting in clean water supply systems, and purchasing mosquito nets. Because the village chose to implement change and because it occurred over a long period of time (15 plus years) giving their local

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\(^1\) [http://www.hauna.com/](http://www.hauna.com/)
culture time to adapt, they have developed the skills and desires to maintain these projects over the long-term.

Judging the success of community development is not always easy. Although originally designed as environmental sustainability indicators, the following six indicators can be used to mark the success and sustainability of conservation and development efforts within a third world community:

1. Sustained Increases in Productivity
2. Decreases in Resource Degradation
3. Increases in Local Resilience & Decreases in Vulnerability
4. Increases in Self-Sufficiency of Local Communities
5. Replication to Non-Project Sites
6. Change in Operational Procedures of Support Institution and Attitudes of Professionals

These provide both a guideline for evaluating the state of a project or community, as well as a set of goals on which projects can focus in order to attain sustainability. Number five, “Replication to non-project sites” should be an important goal of every community development project. Word of mouth is by far the most powerful tool, and can make or break future efforts in community development. A failed project in one village will often create skepticism in neighboring tribes who will then reject outside attempts at development. It is far better to take the extra time needed to insure the success of a project, knowing that a single success will have a strong influence on future projects, both within the village and in surrounding communities.

**Community Development in Papua New Guinea**

The water supply system at Punano is an example of a typical community development project in Papua New Guinea. Long periods of initial groundwork are required in evaluating various villages, talking with people, and considering alternatives. This is followed by a period of planning the project with the people and coordinating efforts,

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14 Thomson, J. 1996
though usually overlooked, children are extremely important in community development. While the current decisions in development will be made by their parents, the future of the tribe will ultimately depend on who these children grow up to be. Papua New Guinean adults are deeply entrenched in the values and beliefs of their ancestral way of life, often rejecting or simply unable to comprehend conservation and development ideas. By involving village children in projects and teaching them the value of their land, they will become a powerful force in their village in later years, able to make wise decisions towards their future while still retaining their unique tribal identity.

providing them with the burden of responsibility for moving the project along. Finally, materials are purchased and construction begins — whether completion occurs quickly or not is entirely dependent upon chance — two to six months is typical depending on whether or not supplies are readily available or must be ordered. In general, these are the steps seen in community development projects around the world. Papua New Guinea has its own unique qualities, and these strengths and weaknesses must be taken into account when approaching any community. In general, Papua New Guineans are easy to inspire, quick to help, possess incredible abilities in physical labor, and more often than not have a good attitude about most everything. There are however, two major challenges to Papua New Guinean culture that make them exceedingly difficult to work with.

First is a cultural belief that permeates throughout most tribal cultures known as the cargo cult. Though it has a hazy beginning, the cargo cult dates back as early as 1917, combining Christianity and ancestral beliefs with the concept that a ship laden with
wealth would arrive, manned by the ancestors. Though most people do not consciously practice cargo cult as a religion, it combines the human tendency towards laziness with the mentality that westerners in general represent the bearers of wealth and goods, which we have come to bestow on them freely.

The second challenge to westerners working in Papua New Guinean culture is Papua New Guineans' inability to project into the future. In a country where a stick stuck in the ground produces food, where the climate maintains a nearly steady state year around, and large predators, except for an occasional head hunter, do not exist, there is little to plan for in life. Consequently, it is difficult to instill forethought in Papua New Guineans, and deductions we would consider a simple leap in logic, they will not understand. This poses a formidable barrier in community development where tribes will often forego a water system rather than pay the up-front cost, not understanding that, in the long run, it will cost them more to pay for medicine and transport to a health clinic once a month. Similarly, the concept of budgeting money over the long term is a difficult, and projects frequently go unrepaired due to a lack of funds. Environmental conservation is another concept foreign to Papuan New Guineans who do not recognize the impact pollution and industry can have on the natural environment. Thus making conservation and community development awareness extremely frustrating for westerners who cannot understand a train of logic that extends only as far as tomorrow's dinner.

**Evaluating the Punano Water System**

The choice of a gravity flow system for Punano was excellent in terms of location, supply and demand, and feasibility. However, gravity flow systems involve continual maintenance and are more complex than a roof rain collection system or a well. For this reason they are often rejected by community development workers, due to poor history of sustainability. Two wells drilled with a portable well drilling device and located at either end of the village would have perhaps been a wiser choice, though less desirable by the village.

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15 [http://philtar.ucsm.ac.uk/encyclopedia/westoc/genesis.html](http://philtar.ucsm.ac.uk/encyclopedia/westoc/genesis.html)
The system itself is adequate for the needs of the people, however, there are various
designs and approaches that could have been implemented to improve it. During the
initial stages of discussion with the village concerning the possibility of building a water
system, a greater sense of village responsibility should have been emphasized. Although
the villagers could not be expected to provide a significant amount of funding, the
amount collected should have been higher. Unfortunately a target figure was not
communicated, but rather an off-hand per person amount. Since the population of the
village is only estimated, no evidence could be supplied as to whether or not everyone
had truly contributed. Despite their poverty, Papua New Guineans can produce a
surprising amount of money for ceremonies and other purposes important to the tribe,
precluding any excuses that they might express concerning their inability to provide a
more generous contribution. By holding them to a high expectation from the beginning, a
precedent is established that emphasizes their position as owners of the project, rather
than beneficiaries.

Reflecting on the design of the system itself, I would have increased the complexity of
the pipeline by utilizing multiple pipe diameters to optimize flow volume. While the
source provides 3.6 l/s, much of that will be lost as overflow at the break-pressure tank as
flow through the u-profile will only provide an estimated 1.2 l/s flow rate. Currently, this
is adequate for the village’s needs; however, it cannot be improved upon once the system
is in place should a higher demand for water be required. If the full potential of the
stream were utilized, it could support three times the current population, extending the
life of the water system, or making it easier to include the second village. In addition, I
would choose a 9000 liter storage tank over the 4500 liter tank as it would provide greater
storage for peak-use times of day. Also the cost of two 4500 liter tanks is nearly three times that
of a single 9000 liter tank. Given their longevity, it would prove a more responsible
use of funds, as a second tank will more than likely be required down the road.

Figure 17. A tap stand in Kanimpa. Poly pipe is run under ground and a galvanized pipe with a tap is
staked in place. An old tire on the ground serves as a baffle to reduce erosion.
Finally, the tap stands themselves require a more robust construction. Currently, poly pipe is run to the desired location of a tap stand where a galvanized section of pipe is fitted at a 90-degree angle and staked to hold it upright. A faucet is then attached, and in a few cases, a small concrete receptacle poured underneath to reduce erosion around the tap stand. The durability of these tap stands is rather dubious and, in my opinion, a waste of money since frequent repairs are usually needed or stolen taps replace. In addition, the area surrounding the tap stand generally becomes extremely muddy and eroded and a breeding ground for parasites. An alternative design is provided in Appendix F. While slightly more expensive, the tap stands will never need replacing and require minimal maintenance while providing an adequate foundation to prevent erosion and standing water.

These improvements serve not only to increase the durability of the system and its sustainability for future growth, but they instill a sense of pride and value in something that has been built to a higher standard of excellence. To a people who live each day just getting by, accomplishing something of excellence builds an irreplaceable sense of pride. And it is this pride in one’s work, more than anything, which creates ownership and the desire to maintain a project long after outside influences have left.
Conclusion

"At any given time perhaps one-half of all peoples in the developing world are suffering from one or more of the six main diseases associated with water supply and sanitation (diarrhea, ascaris, dracunculiasis, hookworm, schistosomiasis and trachoma)."

World Health Organization

Clean water, while extremely important to disease-free living, must be coupled with positive hygiene practices, latrines, and healthy eating habits. For these factors to all be present, a holistic approach to community development must be carried out. And in the face of global population increases and decreases in availability of clean water, there is an even greater need for third world development. Papua New Guinea, while not faced with the horrors seen in other third world countries, is on a downward spiral that will not stop unless action is taken against it. Those with the optimistic perspective that “it can only get so bad,” need only look at the poorest nations of Africa to know that change within a country does not occur without widespread changes in the hearts of its people. For Papua New Guinea’s cultural and ecological heritage to be preserved, grassroots conservation and development is essential. While a single project such as a water system in a remote village may appear a drop in the bucket, strong community development may prove the flash flood that affects nations.
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Edoni, W. SIL Public Relations Director, native of Miln Bay, Papua New Guinea.

*AT Projects. Tufa Tanks*

*The Village of Hauna*


*World Bank*


^Animal Info – Papua New Guinea
http://www.animalinfo.org/country/papua_ne.htm Accessed 11/02

^Mining in Papua New Guinea http://www.american.edu/projects/mandala/TED/papua.htm Accessed 11/02

^Forest Conservation Portal http://www.forests.org Accessed 11/02


Appendix A: V-Notched Weir & Flow Graph

\[ \frac{X}{Y} = \frac{1}{1.73} \]
Appendix B: Reservoir

The reservoir dimensions will be roughly 6m by 6m and 1 meter in depth. The stream above the reservoir will be channeled through a v-notched weir as it enters the reservoir so that flow volume can be easily measured by the village people. The baffles allow for a quicker settling time and keep the water in the reservoir from whirl-pooling.

The pipe fittings include a gate valve so that the system can be drained for repairs. The vent serves to allow air to escape from the pipeline without bubbling out through the intake and interfering with flow. It also allows air into the pipeline whenever the pipeline is drained without creating suction in the pipe.

The overflow pipe is located near the top of the reservoir while the washout is located at the bottom allowing for easy cleaning of the reservoir.
Appendix C: Break-Pressure Tank

A concrete encased 55gal drum sedimentation tank in Kanimpa – a similar construction will be used for the BPT at Punano

The function of the break-pressure tank (BPT) is to allow the flow to discharge into the atmosphere, thereby reducing its hydrostatic pressure to zero, and establishing a new static level. The BPT for the Punano water system will be constructed similar to the photo above, while the diagrams provide a visual aid for the internal fittings.
Vertical Profile

Elevation (m)

Distance (m)

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</tr>
</tbody>
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Appendix E: 30m Ravine Crossing

A GI pipe set in concrete will serve as the anchor for the 30m crossing. The following calculations will be used to determine the tension from which appropriate cable size and GI pipe will be selected. Bamboo will be used to sheath the pipe, protecting it from the elements.

1. W_c = weight per length of cable (kg/m)
2. W_p = weight per length of pipe (kg/m)
3. W_w = weight per length of pipe (kg/m)
4. W = total weight per length of crossing (W_c + W_p + W_w)
5. S = length of span between anchors (m)
6. Y = vertical sag of cable (m)
7. L = total length of cable including anchors (m)
8. t = horizontal tension in cable at mid-span (kg)
9. T = total tension in cable at anchors (kg)
10. B = angle between the horizontal & tension vector (degrees)

A. Select vertical sag - 8%-10% of the span (Y)
B. Determine 1, 2. & 3 and calculate 4, adding in wind forces (15% of W).
C. Calculate \( t = \frac{W S^2}{8Y} \) for GI post maximum horizontal tension, t.
D. Calculate \( B = \arctan \frac{4Y}{S} \)
E. Calculate \( T = 4t \cos B \)
F. Compare the total tension, T, with the allowable tension of the selected cable and select a large or smaller cable size if necessary and repeat the calculations.
G. Calculate the required length of cable, \( L = S(1+8Y^2) + \text{extra for anchoring} \)
Appendix F: Tap Stands

Design Variations

Basic tap stand construction