



Addressing Threats to Water Quality in Suan Phung Nature Education Park: Ratchaburi, Thailand

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Abstract

The water sources of Thailand's Suan Phung Nature Park may pose a health risk to locals. The goal of this project was to address threats to the water quality in the Huay Naam Sai watershed and provide recommendations for sustainable management. This was accomplished by testing fourteen locations for the types and levels of contaminants present and then assessing the water contamination and consumption habits of locals. Acceptable water quality was found for the parameters tested but variations in data corresponding to human impact indicate threats to the future quality of water.

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Executive Summary

This project focused on the threats to water quality in the Suan Phung area of Thailand. Located on the remote western border, this area is characteristic of rural Thailand. However, setting this region apart is its ecological diversity, which has been recognized by the Office of Her Royal Highness Princess Maha Chakri Sirindhorn's Projects. While primarily concerned with improving the lives of underprivileged Thai citizens, HRH also understands the need to protect Thailand's ecological resources. In an effort to convey the importance of preserving the environment, HRH created Suan Phung Nature Education Park in 1995, applying a new strategy of ecotourism that balances development and conservation. By giving communities a stake in the economics of local tourism, HRH hoped they would be financially motivated to police themselves in protecting the environment.

In spite of this move towards ecotourism, development throughout the area fails to follow conservative practices. Local villages have no treatment system in place for their wastewater, and resorts provide an additional strain on the water system by supporting their many tourists. Above and beyond daily activity, the water resources are also being threatened by activities such as farming and mining. Officials are now concerned about the quality of the park's water, due to the threat of contamination and also because this water is the main source of drinking water for this remote area. Our project focused on this threat to water quality at one specific watershed in Suan Phung. We chose to focus on the Huay Naam Sai watershed because it is the largest and most developed of the four watersheds in the park, posing the biggest threats to the environment.

The goal of our project was to provide recommendations for a water management plan at the Huay Naam Sai watershed in order to preserve the quality of its water. We approached this goal by performing three major objectives: analyzing water quality indicators, assessing threats to water resources, and evaluating the threats to human health based on consumption habits. By collecting data on current water conditions we were able to generate a picture of the overall water quality and determine the effects of sources of contamination. Observation of human activities confirmed potential threats to the quality of the water as well as threats to human health. This analysis led to management recommendations for behavioral modification as a way of reducing the human impact on the watershed. Our plan, aside from being used as a tool for water quality improvement in Huay Naam Sai, can also serve as an example for conservation strategies in similar communities throughout Thailand.

Analyzing several water quality indicators made it possible to determine the general condition of the water sources in the area. For this analysis, we devised a sampling plan, which included the determination of sampling locations, sampling techniques, and testing methods. We chose each of the fourteen sampling sites based on their proximity to villages, resorts, orange orchards and tin mines. Samples were taken both up and downstream from this potential contamination and human exposure, to discover any alterations in the water quality. We measured flow rate and temperature, and tested for acidity, biological oxygen demand, phosphates, hardness, heavy metals, and pesticides, as well as analyzed larvae and aquatic life.

This analytical testing concluded that there were no serious levels of hazards present in the water throughout Huay Naam Sai during the time we tested. No heavy metals or pesticides were detected, and all levels for water hardness, biochemical oxygen demand, dissolved oxygen, and phosphates registered within acceptable limits for drinking water. To support this data, all of our collected larvae indicated average to excellent water quality. However, once we compared the analytical results of each sampled point in relation to the others, we were able to distinguish certain patterns. An example of such trends can be seen in Figures i & ii where hardness, BOD, phosphate, and pH levels increased as the water passed through Baan Huay Naam Sai. Further investigation was necessary to determine the cause of such alterations.

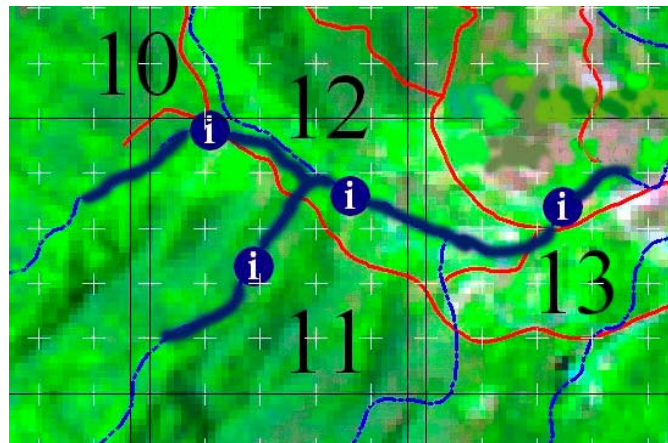


Figure i: Map of Sampling Sites in Baan Huay Naam Sai

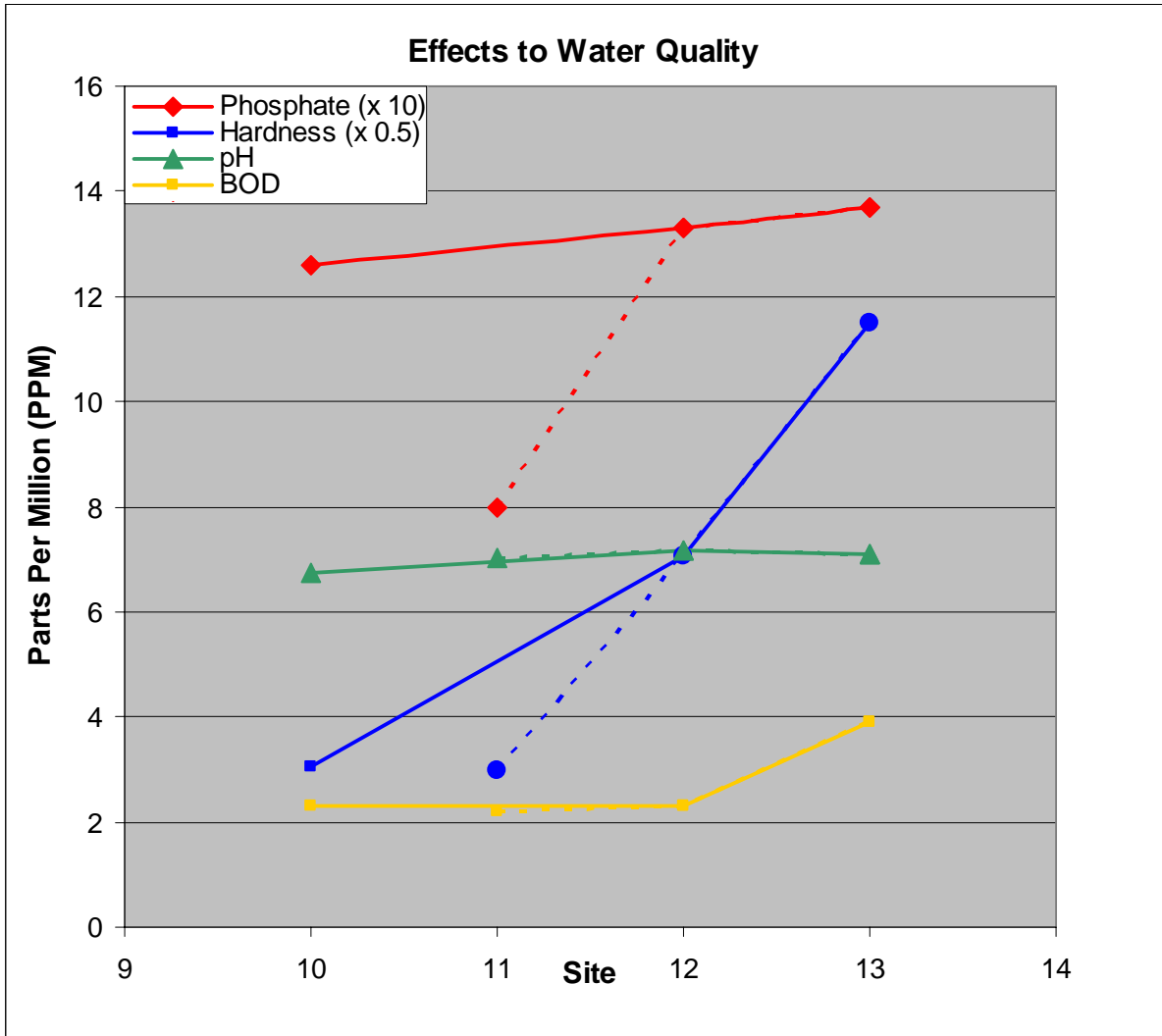


Figure ii: Graph with Variations in Data as Water Flows through Baan Huay Naam Sai

We examined local activities throughout the Huay Naam Sai watershed in search of evidence which could confirm water contamination. Among the possible sources of pollution, we observed improper wastewater disposal from the adjacent villages, uncontrolled expansion of resorts, and heavy use of pesticides and fertilizers on the orange plantations. We discovered that the use of agrochemicals at the Baan Pha Pok orchard was responsible for the increased hardness and phosphate concentrations across the sampling sites. In Baan Huay Naam Sai, improperly disposed wastewater caused an increase in levels for BOD and phosphates. Resort development also threatens both areas, increasing the water hardness and pH due to the introduction of lime (CaO) from the masonry used for their construction. These trends, while occurring at levels safe for human consumption, foreshadow problems for the Huay Naam Sai watershed if development continues and resource management is not implemented.

Taking into consideration the potential hazards present in the water, we proceeded to investigate human exposure by studying the consumption habits of the locals. This evaluation included observations and research on water retrieval, storage, purification, and disposal techniques. We collected this information in order to analyze the current management strategies enforced at the Huay Naam Sai watershed and assess its efficiency to prevent further contamination of their drinking water. This consumption assessment led to management recommendations on the household basis, to avoid human exposure while a long term plan is fully implemented.

However, we did encounter several limitations that may have affected our analysis of the water samples and the assessment of local activities. As far as sampling, we were only able to test during the dry season, preventing us from determining a long-term trend of changes. This is particularly important since Thailand receives four times more water during the raining season, and there is greater probability of detecting pesticides and heavy metals picked up from the runoff (NEA, 2002). We visited two resorts during the low tourist season, making it impossible to evaluate their strain on the water resources. Another limitation came from the fact that we could only perform informal interviews to authorities and locals since the language barrier prevented us from asking specific questions or receiving detailed answers.

Despite these limitations we created management recommendations for the improvement of the Suan Phung Park water quality, as well as ways to obtain more data to compare with the baseline that this project established. Our management recommendations addressed issues concerning the proper treatment of wastewater, reduction of pesticide use, control policies on the tourism industry expansion, and behavioral modifications for household use. These recommendations were presented as cost-effective alternatives to local authorities to be implemented around the community and serve as educational media to the villagers.

We also provided several recommendations on how to enrich this study in order to be able to track changes and modify the management strategies accordingly. First, sampling should be performed many times throughout the year during both the dry and wet seasons. It is also necessary to increase the number of sampled points at each sampling site to determine where exactly alterations are introduced. For heavy metals, it will be better to first test the soil to confirm any leaking, since most heavy metals precipitate and collect on the stream bed. As far as testing methods, a bacteria analysis must be included since it is the biggest concern for drinking water sources as the cause of waterborne diseases. Another important

test is for nitrates, which pose a toxic threat to humans created by a lack of wastewater treatment.

Our methodology was designed to provide us with as many water quality indicators and social observations as possible. A careful assessment revealed serious threats to the Huay Naam Sai watershed. To accomplish our overall goal, we analyzed and organized these findings and developed proper water management recommendations. By implementing our management solutions, officials and authorities at Suan Phung Park will be able to rehabilitate and maintain the quality of their water resources. These recommendations also promote the participation of the villagers and resort owners, as they will be the first affected by degradation of the water quality.

1. Introduction

Ninety-percent of Thailand's poor live in rural areas, and without the proper resources this population places its environment under a significant amount of stress (Ahmad, 2003). These communities are forced to live off the land and survive by whatever means necessary. Their current behavior, combined with the lack of management and law enforcement, allows unregulated degradation of the surrounding environment. Specifically, the lack of wastewater treatment poses a number of problems to water supplies in these areas. Human waste water, containing both feces and detergents, is often piped directly into bodies of fresh water, introducing harmful bacteria and other chemicals to the environment. Economic activities, such as plantations, mines, and resorts, also cause a strain on the water system by consuming marginal amounts of the fresh water supply. This water can then return to the environment untreated, containing agrochemicals, heavy metals, and other chemical substances (TDRI, 1998). Because there are currently no enforced laws preventing these actions, exposure to these contaminants is a potential problem for the very same villagers who are polluting the water. Proper management is required in these areas before pollution accelerates out of control and serious health epidemics occur.

Our project focused on this threat to water quality and, more specifically, how it applies to the Suan Phung area of Thailand. Located on the remote western border, this area is characteristic of rural Thailand. Setting this region apart is its ecological diversity, which has been recognized by the Office of Her Royal Highness Princess Maha Chakri Sirindhorn's Projects. This office, while primarily concerned with improving the lives of underprivileged Thai citizens, also understands the need to protect Thailand's ecological resources. In an effort to convey the importance of preserving the environment, Her Royal Highness created Suan Phung Nature Education Park in 1995, applying a new strategy of ecotourism that balances development and conservation. By giving communities a stake in the economics of local tourism, people are financially motivated to police themselves in protecting the environment. This cooperation is important because poor water quality can affect the livelihood of everyone exposed to it. Environmental education is required as the water quality transgresses the boundaries of villages, plantations, and tin mines and begins to negatively affect their future.

The livelihood of Suan Phung is deeply ingrained in the area's natural resources. During the mining boom, many people crossed the Thai-Burmese border for employment. This immigration led to today's mixed population, which includes Thai, Burmese, Karen, and

Mon. Since the mines were abandoned twenty years ago, due to the falling value of tin, people began investing in other forms of economic activities. Agriculture and tourism became the two main forms of income based off the land. Large orange orchards can be found throughout the area as well as many resorts, which use natural hot springs and waterfalls to attract tourists into the area. These establishments use a lot of water for irrigation and the demands of their visitors. Despite the current burden to the watershed, people are now looking to develop this area even further, with the hope of eventually opening trade across the border. This future development threatens as well as depends on conservation of the area.

Despite the initial plan for ecotourism, concerns had been raised by park officials regarding the negative externalities of these economic developments, as well as the history of tin mining. They speculated contamination from the heavy use of pesticides and fertilizers on the orange orchards, as well as the lack of wastewater treatment in the surrounding villages. The officials employed the assistance of Bangkok's Chulalongkorn University, and last December a group of scientists began an initial analysis of heavy metals dissolved in the water throughout Suan Phung Nature Education Park.

While the results from all six test sites came back clear of any significant hazards, several test methods were needed to get a better sense of the overall water quality. The mere six samples from previous testing gave a representation that was far too broad. Therefore, a greater number of samples needed to be obtained in order to get an accurate representation of one specific area. Biological, chemical, and physical testing was also needed to determine any and all of the contaminants present in the water. Correlations could then be identified between potential sources of contamination and test results to determine the effects they have on the water quality.

The goal of this project was to provide water quality management recommendations for the largest and most developed area of Suan Phung, the Huay Naam Sai watershed. We approached this goal by identifying hazards, sources of contamination, and risks of consumption. By collecting data on current water conditions we were able to generate a picture of the overall water quality. Observation of human activities then supported our hypothesis for existing threats to the quality of the watershed. These steps allowed us to form management recommendations as a way of reducing human impact on the watershed. Our plan, aside from being used as a tool for water quality improvement in Huay Naam Sai, can also serve as an example for conservation strategies in similar communities throughout Thailand.

2. Background

Suan Phung Nature Education Park was created by Her Royal Highness Princess Sirindhorn as an opportunity for tourists to enjoy natural attractions while supporting the local economy. Its attractions include trails, hot springs, waterfalls, and a nature study camp for children. The park was designed to implement ecotourism methods in order to help people learn about and appreciate nature while also conserving natural resources.

However, Suan Phung's beauty and water resources are of concern for park officials since local activities posed potential contamination threats on future conservation. Most of the population and economic activities are concentrated around Huay Naam Sai watershed. Therefore, by correlating the water flow and human interactions with the water resources, we were able to understand water usage and determine potential threats to water quality. In local villages no standard treatment system is in place for wastewater, which potentially ends up in the nearby streams. The continued development of resorts also provides an ever-growing strain on the water system because of the high influx of tourists and the construction activities. Beyond daily activity of individuals, the watershed is also being threatened by practices such as farming and mining. These introduce toxic substances in the water supply such as pesticides and heavy metals. Consequently, a water quality analysis was needed to determine which of these threats, if any, were negatively affecting the water quality at Suan Phung.

Aside of studying the effects of these specific threats, water quality could also be analyzed by the assessing different indicators such as dissolved oxygen (DO), Biochemical Oxygen Demand (BOD) and larvae. In order to study the condition of Huay Naam Sai watershed, the first step of risk assessment, hazard identification, was considered. This step involved the design of a sampling and testing plan to obtain the most accurate picture of the water quality this water quality. The most important part of this is to choose meaningful sampling locations and the appropriate tests to reveal any degradation of the quality. Finally, the last part of this study includes understanding the effects of contamination on human health, and how the Thai government is already working to create standards of acceptable limits. Compiling this knowledge makes it possible to move forward in our assessment of water quality and helps introduce new approaches to managing this resource.

A. Watershed Geography and Threats

Our research focused on Huay Naam Sai, Suan Phung's largest and most developed watershed. The water distribution of the area has defined local water retrieval methods, as

well as shape local behaviors towards the water supply. “Huay Naam Sai” means "Canal of Clear Water", but it may not be living up to its name since its geography causes water to flow through several potential sources of contamination. Villages, resorts, plantations, and tin mines pose the greatest threats.

Water distribution throughout the watershed can be explained in terms of the geography of the area. Referring to the map in Figure 1, fresh water flow starts in the mountains both at the northern border of the park and the Thai-Burmese border to the west, proceeds south-east and exits the watershed at a single outlet point. Waterfalls in the north of Huay Naam Sai lead to a dam and reservoir, which service many local people. From this reservoir people pump water to their homes and use it to fish for food. Other villages throughout the watershed draw their water through pipes from nearby streams, while large reservoirs were built to supply the irrigation systems at two local orange orchards. Fresh springs near the western border are used at resorts, where the water’s therapeutic effects are advertised, and by villagers, many of whom illegally crossed the border into Thailand for the tin mining that was popular in this area. The same activities for which water is retrieved are also impacting the quality of the water that flows downstream by them.

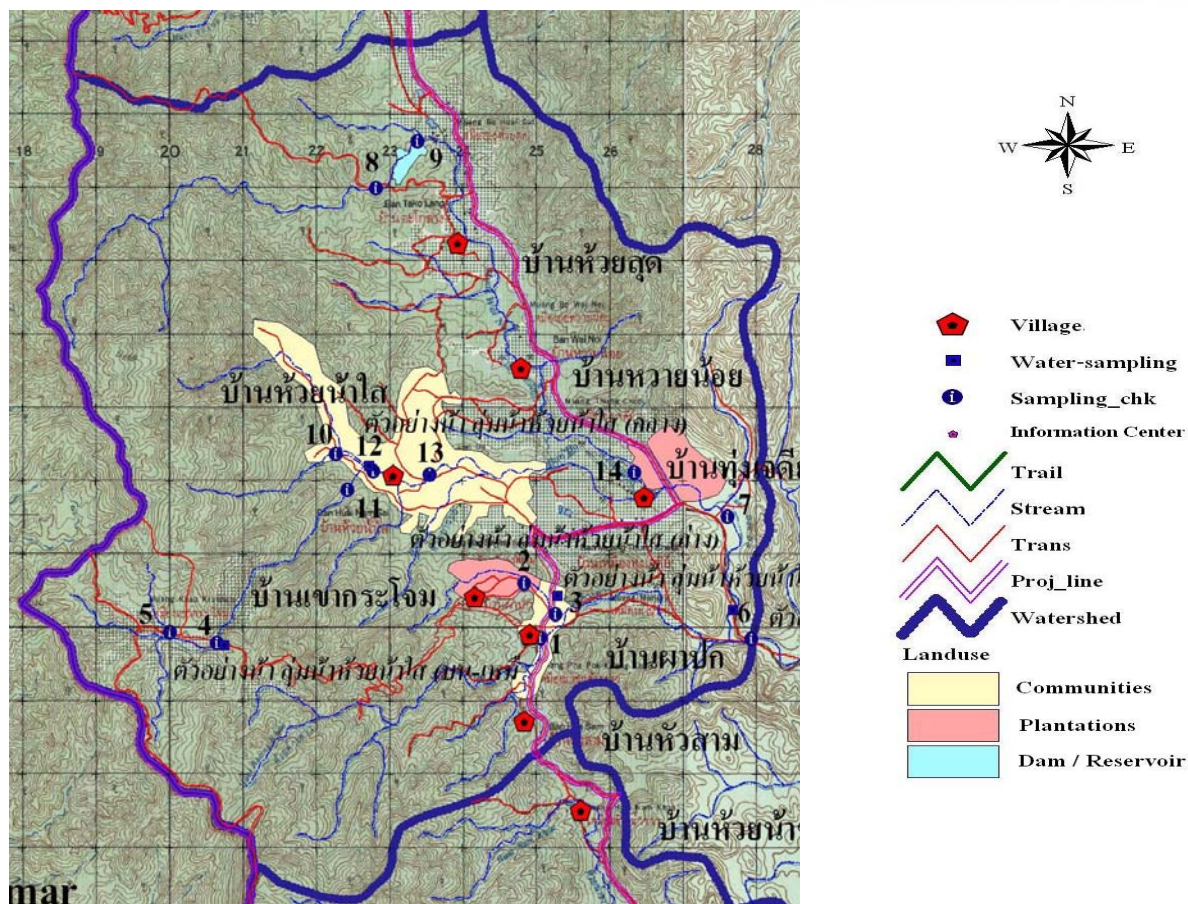


Figure 1: Map of Huay Naam Sai Watershed

The possible negative impact of villages and their economic activities such as agriculture and mining on the water quality was characterized by researching their effects. In order to establish to better he decentralization of its population makes wastewater treatment cost prohibitive. This is significant considering the speculation of local wastewater being sent directly to nearby streams. With villager and weekend tourist populations numbering in the hundreds, several tons of wastewater can be produced throughout the year from some of the larger communities. Another concern is the orange orchards, which treat their crops with pesticides and fertilizers. These chemicals could be leaking into the groundwater or otherwise contaminating the water system via spills, improper disposal, and storm run-off (Hester, R.E., 1996). The orange orchards use fresh water for irrigation and if they return significant amounts of contaminated water back to the areas supply it could endanger the ecological balance of the watershed. The tin mines, although abandoned, are unsealed and pose the threat of long-term contamination at Huay Naam Sai. When water is polluted by mining it is commonly reddish-brown from iron minerals and acidic from the dissolution of iron pyrites (Hester, 1994). The acids present can then release other metals which may be found in the mine. The resulting water is thus highly acidic and contains harmful metals such

as cadmium, copper, and zinc, plus suspended materials (Hester, 1994). Runoff from rain can then carry this contaminated water to nearby streams.

It is clear that in Suan Phung Park there are potential sources of contamination that might be decreasing the quality of the water supply, on which many villagers, park staff and visitors depend. By potentially overlooking the issue of water quality in Huay Naam Sai, people are putting themselves at risk.

B. Threats to Water Quality

Considering the several threats to water quality throughout the watershed, further investigation into the possible effects of these threats must be considered. Each threat can create a number of problems for the water and in turn poses a threat to the humans consuming this water. Water could be contaminated in many ways that can be categorized by source. For example, runoff from plantations in the area can contaminate groundwater with pesticides. Therefore, this section will specifically address negative externalities from villages, plantations, and tin mines, as well as overview indicators of general water quality.

i. Wastewater from Villages & Resorts

Villages and resorts in the Huay Naam Sai watershed can contaminate their water sources by casing strain and mishandling of wastewater disposal. Ongoing construction in these communities can introduce contaminants found in building materials and increase the hardness of the water. Also, the human wastewater produced at these sites contains harmful bacteria, pathogens, and phosphates, which combine to affect human health and deteriorate overall water quality.

Construction of new resorts in the area can introduce lime and other chemicals to surrounding water sources. Lime (calcium oxide, CaO) can be found in almost every type of cement or mortar. Runoff from storms, as well as the direct cleaning of masonry tools in nearby streams, can release this chemical into the environment. The result is raised alkalinity and "hardening" of the water. Water is said to be "hard" if it has high concentrations of dissolved minerals, specifically calcium and magnesium, which are acquired through contact with rocks and sediment in the environment. This is related to the concentration of multivalent cations dissolved in the water (Maunder, P., 2001.) Depending on the pH and alkalinity, water with hardness above 200 mg/L can cause scale deposits in water distribution systems. However, soft water, with a hardness of less than 100 mg/L, can have a low buffering capacity and therefore can be corrosive to certain types of piping. In terms of

human effects, water can become intolerable to some consumers if its hardness is in excess of 500 mg/L. (EPA)

Although hard water is not a serious health hazard, it does pose many problems for household use. Hard water interferes with almost every cleaning task from laundering and dishwashing to bathing and personal grooming. Dishes and glasses may come out spotted along with shower doors and bathtubs. Hair washed in hard water may become sticky and look dull. Deposits can also build up in pipes severely reducing the water flow and dealing with these problems in the home can become a long and annoying process (Oram, B. 2005). The amount of these minerals in the water also increases the amount of soap and detergents necessary for cleaning. Soap combines with the minerals to form a sticky soap curd, sometimes known as "scum". Many synthetic detergents are weakened by hard water because their active ingredients are partially deactivated, even though it stays dissolved. Since bathing with hard water leaves a sticky soap film on the skin, soil and bacteria may not be removed. This film also stops the skin from returning to its normal, slightly acidic condition, and can cause severe irritation. The life of clothing is also shortened by cleansing with hard water making it even less practical to use considering the costs involved (Oram, B. 2005).

Appliances which use water are also negatively affected by hard water. When this water becomes heated, it leaves a scale of calcium and magnesium minerals that can cause inefficient operation or total failure. Pipes can become clogged from build up and eventually have to be replaced. Some people spend years saving money for hot water appliances. If they have hard water they will be tormented by many costly repairs that they simply cannot afford (Oram, B. 2005.)

Aside from construction, human waste water from these areas also poses a threat. This water contains pathogens which are the most dangerous microbiological organisms found in human waste. These organisms, which include viruses, bacteria, protozoa, and parasitic worms, are disease-producing agents found in the feces of the people infected by them. They are mainly spread through contaminated water and are commonly found in areas with poor sanitary conditions. They can travel through water sources and are also passed directly through handling food and water. Hepatitis, cholera, dysentery, and typhoid are the more common diseases that affect large populations in the tropical regions.

Along with harmful pathogens and bacteria, phosphates can also be introduced by villages and resorts in many different ways, including laundry detergents, pesticide and fertilizer run-off, and animal and human wastes (Campbell). Since phosphate is a vital

nutrient to all living things, it serves as a growth-limiting factor for aquatic life. (Standard Methods 4-139) The immediate result of increasing these nutrients in a stream is an increased growth of aquatic plants. While this may seem beneficial, it is actually quite harmful to the ecosystem, as it leads to an imbalance in the cycle of life and death. The overabundance of plants leads to an overabundance of dead plant material on the streambed at the end of the growing season. Microorganisms on the streambed must then use larger amounts of oxygen in order to decompose the increased amount of organic material. This leads to depletion in the amount of dissolved oxygen in the stream water. This oxygen-deprivation in water is defined as eutrophication, and is a threat to fish and other animals in the water system. Although phosphates are not directly hazardous to humans, eutrophication negatively affects us by clogging water-intake pipes with algae and causing an odor that makes the water undesirable for consumption (Murphy).

ii. Pesticide Use on Plantations

High levels of phosphates in the environment are contributed by pesticide use on plantations. Since the plantation owners depend on their crops for financial income, they are forced to do whatever is necessary to ensure healthy growth of these crops. In many cases they rely on harmful pesticides, rather than the more expensive, environmentally friendly alternatives.

Pesticides make up a large group of chemical products that are used to destroy or otherwise control pests. The chemicals used to control these pests can be found in the air, soil and water near pesticide application. Some adverse reactions to pesticide exposure that are listed by the EPA include: skin rash, complications with mucous membranes of the eyes, nose and mouth, lung injury, stomach and intestinal problems, and nervous system disorder (Murphy). Very often there is a balance between stability and toxicity, with the most stable chemical being least toxic. However, this balance is often disrupted in the environment. Chloride based pesticides are of great environmental concern because they do not break down in water. Organophosphates, on the other hand, are less stable, but are more threatening to people because their solubility leads to greater bioaccumulation in organic tissue (Chau 2-4). Organophosphates and carbonates present in pesticides also affect and damage the nervous system and may cause cancer when safe carcinogen levels are exceeded.

iii. Heavy Metals from Mining

Several abandoned tin mines throughout the watershed threaten the quality of water with heavy metal content. The term “heavy metals” is used to describe any metallic chemical that has a relatively high density and is toxic or poisonous at low concentrations. This toxicity is caused by mineral replacement in tissue and bioaccumulation. Mercury, cadmium, arsenic, chromium, thallium, and lead are a few examples of heavy metals that can cause these threats. These compounds can enter a water supply by means of industrial waste and also by run off through mines and soil into streams and groundwater. (Lenntech, 2005) Although these metals can be found in humans in small doses, they are becoming more widely present in our environment, leading to serious human health concerns. (Haas, E. 2005)

Consumption of high levels of these metals, through drinking water or the food chain, can cause harmful health effects in a number of ways. Heavy metals can displace or replace related minerals that are essential for bodily functions. For example, cadmium can replace zinc, and lead displaces calcium. The cadmium or lead is then stored in the bones or other tissues and is very hard to remove. This hinders the important functions of the minerals that are replaced leading to various diseases. (Lenntech, 2005)

Heavy metals are also dangerous because they can bioaccumulate. Over time, the biological concentrations of these contaminants increases, compared to their concentration in the environment. This is a direct cause of heavy metal poisoning (Lenntech, 2005). Considering these health effects and the suspected heavy metal contamination in Huay Naam Sai watershed, proper management strategies must be researched.

As well as masonry, heavy metal contamination is also associated with water hardness.

iv. General Water Quality Indicators

In addition to studying the threats of the previously mentioned sources, several other indicators can be helpful in determining the overall quality of any body of water. The dissolved oxygen (DO), biological oxygen demand (BOD), and invertebrate larvae present in water can give basic hints to the contamination present.

A low level of DO indicates the presence of unhealthy organic material (e.g. bacteria, fungi, algae, sewage, and dead plant and animal matter) or fertilizers, including phosphate-based detergents. This is because oxygen and nonliving organic pollution is consumed by bacteria and fungi. Meanwhile, fertilizers increase growth levels of water plants such as algae and other phytoplankton. When excess algae prevent sunlight from penetrating far into the water, photosynthesis is reduced and less oxygen is released near the stream bed.

Measuring the biochemical oxygen demand (BOD) is a common way of determining the total amount of organics present in a water sample. The test measures how much oxygen is removed from solution by reaction with the organics after a certain time period.

Larvae are defined as the juvenile form of animals which undergo metamorphosis (e.g. a caterpillar is the larval stage of a butterfly). Certain species require high levels of dissolved oxygen to survive and are subsequently sensitive to poor water quality. Other species thrive in lower quality water due to their ability to store air from the surface. For example, mayfly and caddisfly larvae cannot tolerate water pollution while black fly and horse fly larvae can live in any kind of water (Boquet River Assoc. 2005). In addition to particular species being desired, the more varied the population, the better the water quality. By collecting and identifying larvae from a particular water source, one can get a good sense of the quality of the water there.

Studying bio-indicators, such as larvae, is also generally easier than physicochemical testing because the procedure is more direct and less time consuming. Also, while physicochemical tests only give information about current conditions, bio-indicators inherently provide information about water quality over time. It should be noted however that freshwater invertebrates are only reliable indicators in flowing water. The ecological factors governing their presence in stagnant water are too varied to get conclusive results (Kanjavanit, O. & Moonchinda, N., 2002).

Based on the threats to the environment throughout the watershed and the potential effects of these threats, there is a possibility that humans could be harmed by consuming water from their nearby sources. Proper sampling and testing of the previously mentioned indicators must be performed to discover the hazards affecting the current quality of the water. Only then can proper management solutions be recommended and implemented.

C. Hazard Identification

The first step in determining water quality is hazard identification. In this step, the assessor reviews information about the assessment site, such as location, land use, and plans for future development, in order to define the nature and extent of the problem. Then a list is made of chemicals and pathogenic agents that are of concern. These pollutants are chosen based on the likeliest highest concentrations, longest persistence in the environment, highest toxicity, greatest mobility, and highest public concern. (Friedman, 1994 and Burmaster & Appling, 1995)

Once the sampling locations are determined by assessing land use and general human behavior, in order to study and analyze the presence of these chemical and pathogenic agents in the water supply, a sampling plan, which includes determination of sampling location, sampling techniques and testing, must be devised.

According to Tchobanoglous & Schroeder (1987), a reliable and accurate sampling methodology should be based on three questions: Where are the samples going to be taken from? How can a descriptive sample be obtained? What testing methods should be used in order to obtain significant data? This information is important because proper sampling is crucial to a successful water quality management plan. Furthermore, detailed knowledge of the water-body to be tested is helpful in selecting the best sampling spots within it (Hunt & Wilson, 1986).

Addressing the first question, locating reliable sampling sites, the length, width and depth of each body of water should be taken into consideration as well as tracing contaminants further downstream from the source. Hunt & Wilson (1986) point out that the sampling locations along rivers or streams should be at cross-sections, where vertical and lateral mixing of any effluents are complete. Moreover, non-representative samples due to surface films or entrainment of bottom deposits must be avoided. Prioritizing these locations is essential in order to perform a practical sampling plan within the available time frame.

However, as the second Tchobanoglous & Schroeder's question implies, sampling involves more than just obtaining them from areas of concern, since changes in concentration levels occur as time passes. Therefore, it is sometimes necessary to obtain several samples per day over a long period of time, including the dry and wet seasons in order to gather comprehensive information.

To address the third question, several tests should be performed. A bacteriological analysis, which is related to fecal contamination, will identify the threat from villages and resorts. A physicochemical analysis for phosphates, pH, dissolved oxygen, along with an aesthetic analysis, determining turbidity, color, taste and odor, are also important, given our likely contaminants. Other relevant analyses are those for heavy metals, nitrates and pesticides (World Health Organization, Ch. 4).

In general, there are several types of methods for analyzing water, such as gravimetric, electrochemical and optical. However, most of the time, physical separations or chemical procedures are needed before measurements are done (Gordon, 1997). Moreover, analysis is likely to be of very small concentrations of material, on the order of parts per million or finer, so sensitive equipment is needed for accurate results (Gordon, 1997).

When analyzing the samples, issues dealing with precision and consistency could arise. Some measurements, such as temperature, pH, dissolved-oxygen concentration and flow rate, can be done on-site but testing for many pollutants requires the samples be taken to a lab. The time between collection and lab analysis could cause the break down, evaporation, oxidation, or reaction of contaminants. Therefore, proper sample storage methods must be determined in order to counteract these time effects. (Tchobanoglous & Schroeder, 1987)

Once the proper sampling and testing is complete, an accurate account of the water quality in the Huay Naam Sai watershed will be established. These results will lead to recommendations for management strategies that best address the problems in the area. These strategies can help suppress the threats of contamination and help preserve the water sources throughout the park.

D. Water Policies and Management

Several existing water quality management policies can be adapted for use at Suan Phung. Thailand currently has a number of such plans intended to preserve its water resources. However, it should be noted that “the Thai regulatory system is centralized and fragmented”; while some institutions develop plans, it is on the will of others to implement them. The enforcement of these laws is also weak due to the lack coordination among agencies, a low capability to prove violation, and limited access to information. Based on the current quality standards and the lack of water regulation, we researched rudimentary methods for safe water consumption that could be implemented at the household level. (Illangovan et. al, 2001)

i. Current Water Management Policies in Thailand

Thailand has several different environmental acts intended to protect and improve its water resources. The five-year National Economic and Social Development plan aims for sustainable development, rehabilitation of the water quality, and greater participation of the local communities (Illangovan et. al, 2001.) The 20 year Policy and Perspective Plan for Enhancement and Conservation of National Environmental Quality highlights an accelerated improvement of the water quality, reduction and control of water pollution, application of the polluter pays principle, and promotion of private investment in solving water pollution problems (Illangovan et. al, 2001.) Among the major legislations, water quality is a priority for the Environmental Quality Act and the Decentralization Act of 1999 that allows local government authorities to manage and control natural resources, as well as, operate solid waste and wastewater treatment plants. Other legislation acts are summarized in Figure 2.

Water Pollution Legislation

Legislation	Regulated Activities	Remarks
Enhancement and Conservation of National Environment Quality Act (NEQA) of 1992	Regulates specified point sources for wastewater discharges into public water resources, or the environment, based on effluent standards	Amendment to NEQA is being drafted; key environmental legislation to fill gaps; no criminal or civil liability for violation of standards
Factories Act of 1992	Limits level of effluent discharged and restricts concentration levels of chemical and/or metal pollutants	MoInd also promotes industrial development activities which creates conflicts of interest. An amendment to the Act is being drafted to require polluters to pay for clean-up costs.
Navigation in Thai Waterways Act (Volume 14) as amended in 1992	Prohibits dumping of any refuse including oil and chemicals into rivers, canals, swamps, reservoirs, lakes or waterways that may pollute the environment or disrupt navigation in Thai waterways	Many cases have been successfully brought against polluters
Public Health Act of 1992	Regulates nuisance activities related to water pollution such as odor, chemical fumes, wastewater discharge system of buildings, factories or animal feedlots that cause harmful health effects	Decentralized implementation to LGAs
Cleanliness and Tidiness of the Country Act of 1992	Prohibits dumping of refuse in waterways	Decentralized implementation to LGAs
Canal Maintenance Act of 1983	Prohibits dumping or discharging of wastewater in canals	Little used
Building Control Act of 1979	Regulates discharges of water pollution from buildings	Decentralized implementation to LGAs
Penal Code of 1956	Prohibits adding harmful substances in water resources reserved for consumption	Little used
Fisheries Act of 1947	Prohibits dumping or discharging of hazardous chemicals into water resources reserved for fishing	Difficult to prove intention for criminal liability
Royal Irrigation Act of 1942	Prohibits dumping of garbage or discharging polluted water or chemicals into irrigation canals	Limited jurisdiction

Figure 2: Water Pollution Legislation (Illangovan, et al, 2001)

All these different policies and laws are written, administered and implemented by different institutions, including six ministries and thirty agencies (Illangovan et. al, 2001). The Office of Environmental Policy and Planning (OEPP), Department of Pollution Control (PCD), and Department of Environmental Quality Promotion (DEQP) include divisions dedicated to water resources. These departments establish development guidelines to protect the environment and provide information to communities on preservation and treatment. Specifically, the PCD has published different water standards tables for drinking water, effluents, coastal water quality, surface water, groundwater, and also water quality for fresh water animals. The detailed drinking and surface water quality standards can be seen in Appendix A.

These existing programs and standards lead to management suggestions and plans. The management programs start at the national level and continue on to reach small and rural communities where, most of the time, the needs are more basic but still important. Our plans

are suggested to supplement existing programs, which are weakened by an absence of law enforcement capabilities. Although the government is working on this issue by implementing market based instruments, such as public disclosure tools and citizen participation, situations similar to Suan Phung clearly depict a problem with the enforcement of environmental regulations (Illangovan et. al, 2001). While long-term water quality management issues are dealt with, basic water treatment methods can first be implemented.

ii. Water Consumption Strategies

Our project explored different management possibilities considering factors such as costs, effectiveness, and time. Among these, it is important to explain basic household water treatments including chemical disinfection, solar disinfection, filtration, combined flocculation/chlorination systems, boiling and safe storage that could help in the short term while community plans are implemented. All of the following methods were extracted from the "Household Water Treatment and Safe Storage Following Emergencies and Disasters" document, created by the WHO. Detailed instructions and information about each method can be found in Appendix B.

Water can be disinfected using chlorine and iodine. In case tablets are not available, the water can be disinfected using other types of chlorine compounds. At doses of a few mg/liter and contact times of about 30 minutes, free chlorine generally inactivates >99.99% of enteric bacteria and viruses, provided water is clear. Community members can use a 1% chlorine stock solution of liquid bleach, calcium hypochlorite or powdered chlorine. The amount of chlorine needed depends mainly on the concentration of organic matter in the water and should ideally be determined for each situation. This solution should be added to water to leave a free residual chlorine concentration of 0.4 to 0.5 mg/l after 30 minutes, which can be determined using a special test kit. If this is not available, the slight smell of chlorine is a crude indicator.

Solar disinfection is an effective water treatment method that is applicable when no chemical disinfectants are available. Ultra-violet rays from the sun are used to deactivate pathogens present in water. This technique involves exposing water in clear plastic bottles to sunlight for a day, possibly on the roof of a house. The bottles need to be cleaned, filled to three quarters full and shaken thoroughly 20 times, before being filled completely. The bottles are then exposed to sunlight for approximately six hours. For drinking, this water should only be consumed directly from the bottle or transferred to a clean glass.

If filters are available, then water filtration is another option to purify water. Ceramic filters with small pores, often coated with silver for bacteriostasis, have been shown to be effective at removing microbes and other suspended solids. Monthly maintenance consists of scrubbing the ceramic filter element to unclog pores and washing the receptacle tank and spigot to prevent bacterial growth. If properly maintained, they can be used for several years.

Commercially available sachets can also dramatically improve the microbial quality of drinking water. These are formulated to coagulate and flocculate sediments in water followed by a timed release of chlorine. These can typically treat about ten liters of water. The water is normally stirred for few minutes and then strained, and then allowed to stand for another half hour.

Regardless of whether household water contains acceptable levels of microbiological organisms, it can become contaminated with pathogens of fecal origin during retrieval and storage, due to unhygienic handling practices. The use of containers with narrow openings for filling, and dispensing devices such as spouts, taps, or spigots, protect the collected water during storage and household use. These containers protect stored household water from the introduction of microbial contaminants via contact with hands, dippers, and other contaminated items. Aside from the safe storage, the community should also consider checking the pipelines for cracks, indicated by leaks, which could be another pathway to water contamination.

All of these procedures are very basic and only a small portion of the management possibilities that can help the communities of the Huay Naam Sai watershed to access safer water, while capturing their attention towards the necessity of preserving their resources.

E. Summary

As stated, there is an issue of water contamination throughout the Huay Naam Sai watershed. The humans living here are potentially contributing several contaminants to the area through the use of its water sources. The main causes of pollution are speculated to be runoff from leaking tin mines and pesticides from local plantations, as well as the mishandling of wastewater. Due to their potential health effects to locals, it is necessary to assess the risks of exposure to these contaminants and devise a practical management program to limit future contamination.

Analyzing the watershed itself is important in order to obtain information on its geography and the locations of potentially contaminated water sources. As data is collected on these potential sites, one can begin to prioritize sampling locations and designate areas of

greater concern. These areas will likely be the villages downstream from sources of contamination, where the greatest number of people could be exposed.

Along with general park information, knowledge of the possible encountered contaminants helps to choose the appropriate tests and analytical methods. The park community is threatened by pathogenic agents that could be present in the water due to the lack of a waste regulation system. Consuming such water is dangerous as it can lead to acute disease, including gastrointestinal infections. Another concern is the use of agrochemicals on plantations in the park. These chemicals run off freely into the surrounding water and have the potential to be harmful if consumed in high doses. It is also known that the 20 year-old tin mines in the area may contribute doses of heavy metals to the surrounding water; the resulting water can be highly acidic and contain many harmful chemicals, which can also affect the hardness of the water.

The devised sampling plan must provide a reliable and accurate representation of the water condition. The general geography of each body of water needs to be considered. Samples should also be taken many times during the day. This will prevent from deeming one site as hazardous bases solely on one sample which could be tainted. Some testing can be done on site, but other tests need to be done in a lab. The samples must be kept in a safe place and not exposed to open air, as any evaporation will distort concentration measurements. Once the chemicals in the water are found, a plan of action can begin to be formed.

In formulating recommendations for keeping the water quality above par, consideration will be given to the work done by others in similar situations and to water quality standards currently in place in Thailand. Basic water treatment methods can also be implemented at the household level while large scale management operations are devised. This knowledge can be then applied to our project to create the best system possible.

3. Methodology

Our goal was to assess the water quality at Huay Naam Sai watershed in order to provide officials at Suan Phung Park with water management recommendations. This assessment was completed by sampling and testing for the presence of pollutants and observing human behavior that may be linked to deteriorating water quality. By performing our first objective, analyzing different water quality indicators, we made water quality data available for Huay Naam Sai. Once this analysis was completed, we assessed potential sources of contamination by observing use of water reserves, and evaluating impact on the watershed. Since threats to the water potentially impact the villagers who consume this resource, we also considered the risks of human exposure. To achieve this third objective, we analyzed current water usage and determined if their household water management practices are also compromising the quality of their drinking water. Together these objectives enabled us to reach our ultimate goal, which was to present to the park staff a water quality management plan which was supported by our chemical analysis. Our data and observations were designed in such a way that their results could support suitable recommendations for the rehabilitation of the watershed, as well as the prevention of human exposure to contamination. Inserted in Figure 3 is a graphical view of our methodology.

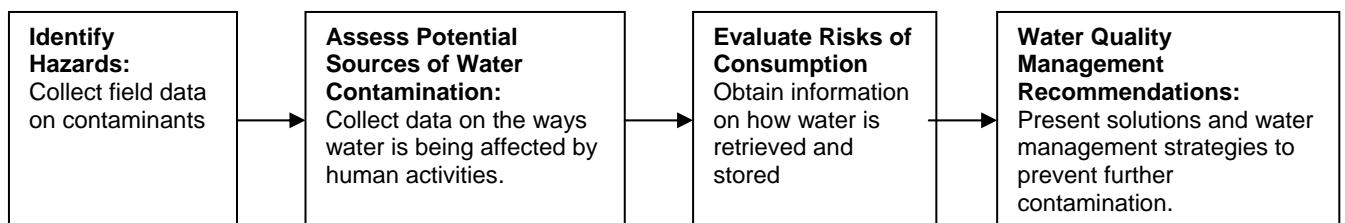


Figure 3: Graphic of Methodology

A. Identify Hazards

Our first objective was to determine the types of contamination threatening Suan Phung Nature Education Park and delineate the scope of these threats. We first reviewed general information about the area, such as population, geography, land use, and plans for future development in the region to define the nature and extent of potential pollutants and devise the most suitable sampling and testing strategy. In creating our sampling plan, we narrowed the scope of our analysis to focus on only one of the four watersheds in Suan Phung Park. Huay Naam Sai watershed was chosen because it comprised all the different threats to the water resources that worried park officials, such as human population, tin mining, agriculture and tourism. A preliminary sampling of six points scattered across the entire park had been

done by our liaisons at Chulalongkorn University, but this widespread approach led to inconclusive results that needed further testing. By focusing on one area, we were able to get a more comprehensive view of each individual threat as it applied to water quality.

Around the watershed, samples were taken in close proximity to water retrieval sources, water disposal sites, pesticides runoff, or tin ore extraction. Our procedure called for separate samples for chemical analysis, biochemical oxygen demand, and heavy metal determination. This sampling plan was complemented by larvae collection at each site, with the identification of these macro invertebrates serving as another general water quality indicator. Measurements of physical properties such as temperature, pH and flow rate were determined on-site, and the samples were then transported to Chulalongkorn University for further laboratory testing. Figure 4 relates each sampling location with possible threats and applicable tests. See also Figure 1 in the background chapter for the positioning of sampling points with respect to local activities. Criteria for sampling site selection will be explained in the following sub-section.


Sampling Points 	Description	Possible Contamination	Special Tests Performed*
1	Upstream from Baan Pha Pok		
2	Stream in the middle of an orange orchard	Pesticide runoff	Pesticide determination by GC/MS
3	Downstream from site 2	Pesticide runoff	Pesticide determination by GC/MS
4	Huay Naam Sai river, mountain site. Flooding in road.		
5	Huay Naam Sai river, Mountain site. Pond		
6	Watershed outlet, near orange orchards	Tin mines, phosphates, bacterial contamination	Biochemical oxygen demand determination
7	Downstream from an orange orchard	Pesticide runoff	Pesticide determination by GC/MS, Biochemical oxygen demand determination
8	Upstream from waterfall		
9	Reservoir downstream from waterfall		
10	Mountain stream 1, upstream water source for Huay Naam Sai Village		Biochemical oxygen demand determination
11	Mountain stream 2, upstream water source for Huay Naam Sai village.		Biochemical oxygen demand determination
12	Merge of streams 1&2 at Huay Naam Sai village.	Phosphates, bacterial contamination	Biochemical oxygen demand determination
13	Huay Naam Sai village outlet	Phosphates, bacterial contamination	Biochemical oxygen demand determination
14	Downstream from reservoir and upstream from orange orchards		Pesticide determination by GC/MS, Biochemical oxygen demand determination
*Standard Tests performed on all the samples include larvae analysis, hardness, heavy metals determination, and titration for phosphates concentration			

Figure 4: Relationship between Sampling Plan and Testing Procedures

i. Sampling Locations

After reviewing the results from preliminary water testing in Suan Phung, we decided to focus our efforts on one, representative area of the park: Huay Naam Sai watershed. Our liaisons had sampled six different points for heavy metals and pesticides throughout the park's four different watersheds in December, 2004. Their results didn't reveal any sign of contamination, but the analysis was only preliminary since those few sampling points did not necessarily represent a true picture of the park's overall water quality. We decided to narrow our scope and focus on one watershed that enclosed, in a smaller scale, all the different threats around Suan Phung.

The Huay Naam Sai watershed was chosen as our new target for a number of reasons. This watershed is the most populated part of Suan Phung Park, due to the large influx of immigrants from Burma, as well as other different ethnic groups such as Karen and Mon. We also found increased demand on the water supply from local resorts, especially during high seasons. There are also a number of old mines and plantations in the area that contribute to the greatest number of potentially contaminated sites in the park. The combination of a heavy population and the most potential contamination made Huay Naam Sai the best choice for assessment.

Choosing appropriate sampling locations within Huay Naam Sai allowed us to create the most informative picture of water quality for the watershed. Geographical Information System (GIS) layers of topography and waterways were provided by Royal Project employees familiar with the area, and allowed us to assess water flow of Huay Naam Sai. Fourteen sites were selected to best represent water extraction and disposal from villages and resorts, in addition to runoff from orange orchards and tin mines. Samples were taken upstream and downstream from human exposure and contamination. This approach allowed us to determine if people had clean water available to them, and also whether or not they had a negative effect on water quality further downstream. The sampling sites were numbered in chronological order of visitation, and their GPS position and altitude were noted. This information was compiled into a map that shows the locations of our testing sites and potential sources of contamination in relation to each other. This map can be seen in Figure 5.

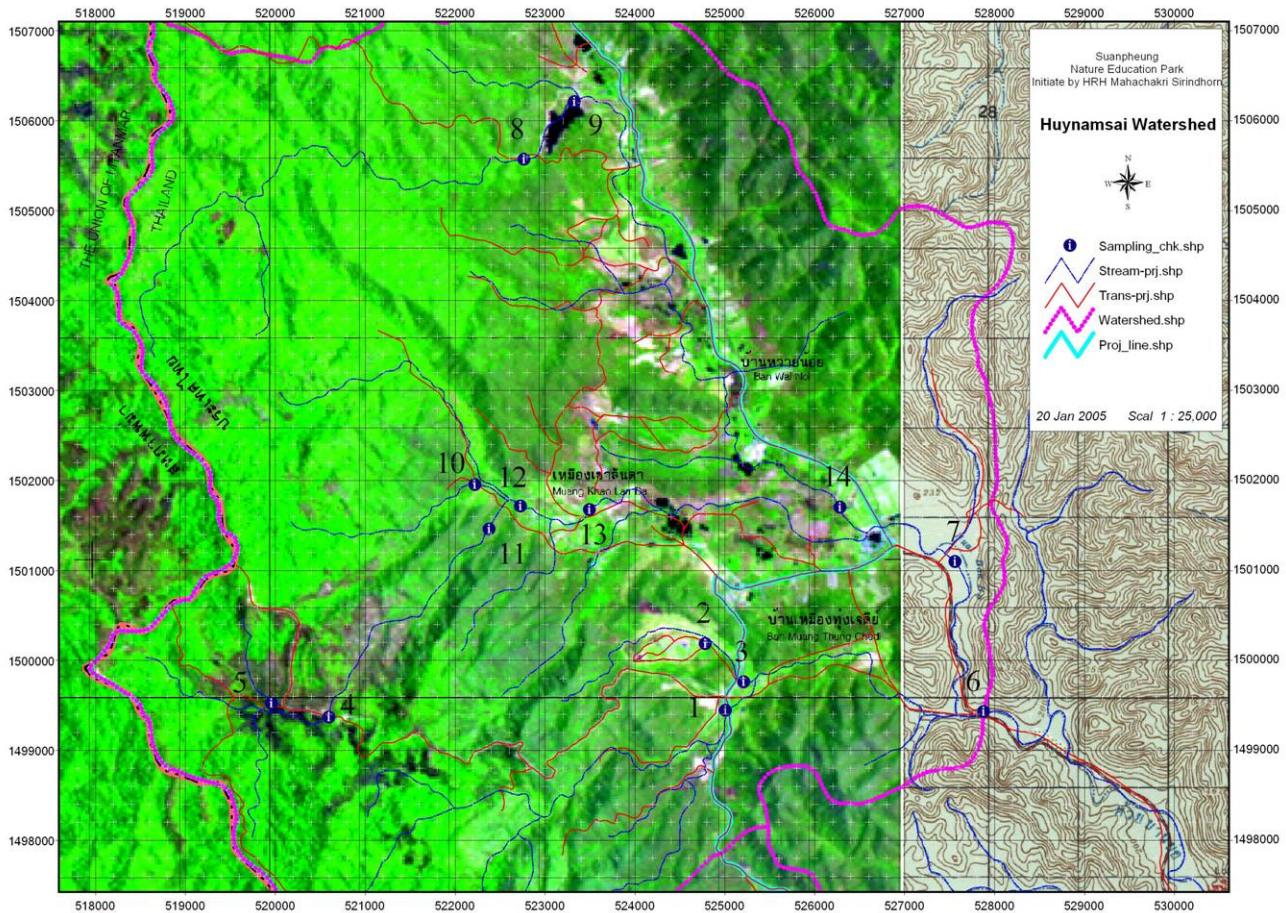


Figure 5: Sampling Points throughout Huay Naam Sai Watershed

ii. On-Site Sampling Procedure

Once we arrived at each designated site, several things were done while sampling the water. We recorded the date and time of sampling because it was important to complete our tests before certain characteristics of water changed over time. All sampled water sources were photographed for reference and further visual analysis. We obtained our general chemical analysis sample as well as any different samples necessary for special testing in the lab. We performed any and all tests that could be done on-site, as well as collected several larvae samples, before moving on to the next site.

One-liter samples of the water were placed in plastic bottles to be brought back to the laboratory for further analysis. These “grab” samples were obtained by dipping the bottle underwater, taking care not to disturb sediment in the streambed. This sediment could alter the contaminants natural to the water by itself, so when picking the retrieval sites we chose areas deep enough to pull samples without skimming any other contaminants. This practice was also observed in avoiding surface contaminants, except when floating oil was present, in

which case a sample including the oil was taken for analysis. In larger bodies of water, “composite” samples were taken in various locations, so that one bottle contained water from many different sites around the pool. This ensured the collection of a more representative overall sample.

Special sampling procedures were needed for heavy metal and biochemical oxygen demand analysis. Some water from each site was set aside in a separate bottle, filtered of sediment and preserved with nitric acid for heavy metal analysis. By making the solution acidic, it prevented metals from being absorbed by the plastic container. For cases of likely and notable biological activity, an air-free sample was also taken in a glass bottle to run a crude, five-day biochemical oxygen demand (BOD) test. To ensure that no air entered the sample, the bottle was opened after being fully submerged, and then recapped underwater once all bubbles were evacuated. These specially prepared bottles were then brought back to the lab for their specific testing purposes.

Indicators such as acidity, dissolved oxygen and larvae analysis combined to reveal general water quality information for the Huay Naam Sai watershed. Some chemicals produce acidic water, which cannot support much aquatic life, making acidity an indicator of poor water quality. Low levels of dissolved oxygen inhibit animal life, and these values also indicate the presence of unhealthy organic matter in the water. Finally, the presence of different kind of larvae, fish and other aquatic life was noted as an indicator of water quality since the dissolved oxygen levels affect them over time.

Measurements like water temperature, acidity, and dissolved oxygen (DO) content were made on-site. The temperature of water was taken near the surface using a mercury thermometer, which is much more accurate than one that uses alcohol. We measured acidity by dipping litmus paper in the water and comparing the dried sample to a color scale that denoted a pH from 1-14. The pH of the collected samples was later confirmed with a digital pH meter in the lab. This helped eliminate potential error from reading litmus paper too soon, when the base color of the paper coincides with the indicator for 6.0.

Dissolved oxygen was measured next by dangling the probe of a portable D.O. meter into flowing water. If flow rate was below one foot per second, the probe was swung from its cord to keep water flowing around the probe receptor. After the reading was taken from the digital display, the results were calibrated for altitude differences by rescaling the value by - 1.1% per 100 meters above sea level.

Larvae samples were also collected by net or scraped from a rock and bottled separately according to sampling site and location of retrieval within the streambed. These samples

were placed in glass jars filled with 70% ethanol solution and brought back to the lab for identification.

iii. Laboratory Analysis

Upon completion of our work at the park, we brought our samples back to the laboratory at Chulalongkorn University for further testing. We performed five tests to determine the following: biochemical oxygen demand (BOD), hardness, phosphate concentration, and pesticide and heavy metal content. The biochemical oxygen demand helps to determine the organic content of the water based on the dissolved oxygen in water. Hardness is a measure of the concentration of calcium and magnesium cations in water. Presence of phosphates in the water resources increases the growth of algae and is caused by pesticide runoff and wastewater disposal. Pesticides and heavy metals can accumulate in the body and impair enzyme functions. Our tests were selected to cover each specific threat to the watershed as well as general water quality. The technical data and procedures for these tests can be found in Appendix C.

Biochemical Oxygen Demand

Our BOD test was performed with samples specially bottled on-site for this particular analysis. We used a portable dissolved oxygen meter to measure the DO present initially on-site, and measured the dissolved oxygen again after a five day incubation period. The BOD was calculated as the difference between these two measurements. This method was chosen due to the lack of these nutrients and microorganisms necessary for a more accurate method. That method requires that the sample water be diluted with well-oxygenated, nutrient-containing water before microorganisms are added. The sample is then stored in the dark at a temperature of 20 degrees Celsius (APHA, 1998)

Hardness

The second test we performed tested the hardness of our water samples. We used the ethylenediaminetetraacetic (EDTA) titrimetric method that allowed us to calculate the amount of calcium in relation to a known standard.

We began the procedure by diluting our sample with distilled water and adding a buffer solution to raise the pH to approximately 10 +/- 0.1. An indicator turned the solution to the color of red wine. Standard EDTA titrate was then added slowly, with continuous stirring, until the last reddish tinge disappeared. The last few drops were added slowly at five-second intervals to obtain a blue liquid that marked the end of titration.

More accurate results can be obtained much more quickly by using a water testing kit not found in our laboratory. These kits, which are expensive, can detect the presence of iron, aluminum, manganese, strontium, zinc, magnesium, calcium, and hydrogen ions in water.

Phosphate Concentration

To test for the amount of phosphate ions present in our samples, we chose the Vanadomolybdophosphoric Acid Colorimetric Method based on the materials and equipment available to us. This method used a spectrophotometer to measure the intensity of the yellow color contained in our samples after the addition of certain reagents.

All water coloration was initially removed by stirring our sample with activated carbon for five minutes. The mixture was then filtered to remove the carbon particles, which would throw off the color scale. Vanadate-molybdate reagent was added to the filtrate, and the entire solution was then diluted with deionized water. After waiting ten minutes for the reaction, we measured the absorbance of the sample against a blank solution of deionized water and reagent. The spectrometer was set at a wavelength of 450 nm for this procedure.

This method was used as an alternative to Ion Chromatography, which is a more direct and efficient method that was not available to us.

Pesticide Determination by Gas Chromatography Mass Spectrometer

We also tested for pesticides at a few locations near orange orchards with heavy pesticide use. To prepare our samples, we chose a liquid-liquid extraction method that only required a few hours of lab work using equipment that was readily available at our laboratory at Chulalongkorn University.

First, organic compounds were removed from samples taken at sites numbered 2, 3, 7, and 14 (See Table 2). The organic phase was separated using dichloromethane and a settling cone. We then analyzed the sample for the presence of pesticides using gas chromatography mass spectrometry (GC/MS).

Heavy Metals

An analysis of the concentrations of any metals present in water allowed us to estimate the risk of heavy metal poisoning to humans. We used the Inductive Coupled Plasma spectrometer, which is one of the most accurate techniques used to determine heavy metal content. It is also sensitive to very small concentration and has the advantages of using a small amount of sample and processing the information quickly.

B. Assess Potential Sources of Contamination

Once we obtained all the analytical data from our first objective, we proceeded to determine potential sources of contamination by investigating how humans might be degrading the quality of Huay Naam Sai watershed. In order to study how people negatively affect the water supply, we analyzed the local economic activities by performing personal observations and informal interviews. Finally, we correlated our testing results with the social data obtained by tracking small variations in the parameters values along the streams and associating them with the nearby human activities. These associations allowed us to determine if the local activities were altering the water quality and the severity of their future impact. Determining the threats to Huay Naam Sai watershed led us to accomplish our overall goal of providing effective management recommendations for the Suan Phung Park community.

Once local activities were characterized, we linked their locations and possible impacts with the actual analytical data in order to track alterations in the quality along the water path. Since most of our analytical tests were just indicators of water quality, we could not quantify the hazards. Instead, we were able to confirm or deny the presence of hazards and assess their impact by carefully studying variations in water quality along the streams. Since we tested the water at its source, before any human activity took place, we were able to compare these values with results from further downstream to observe the effects from activity to water quality. Therefore, we determined the sources of pollution by linking this information with our observation on local activities. Assessing the land use at Huay Naam Sai watershed and knowing its effects on the water quality was just one part of understanding the problem. Once this information was correlated with analytical data, we were able to address threats to water quality and provide suitable management solutions.

Our investigation focused on examining day-to-day human activities in Huay Naam Sai watershed to comprehend their negative impact on the water resources. Interviews with local villagers, resort owners, park staff and authorities allowed us to better frame our observations by considering descriptions of their own behavior. In order to obtain plenty of information, we prepared a field form to record data such as population, water sources used, waste disposal methods, and filtration practices. This form can be found in Appendix D. This guide for questions and observations was applied to two villages within the watershed: Baan Huay Naam Sai and Baan Pha Pok. In these two settlements, we found relatively large populations and economic activities such as orange plantations, tourist resorts, and tin ore

extraction. By observing local water habits and using them as a guide to understand pollution sources, we could better analyze sources of water threats in Huay Naam Sai.

Economic activities and daily household behaviors can be used as classifiers for different types of water contamination. We witnessed household activities among villagers, such as washing, cleaning, bathing and disposing of wastewater, which could introduce phosphates, organic matter and bacteria into the water. By interviewing resort owners, we surveyed how the tourism industry could negatively impact the water supply. We focused on learning about their water use and disposal since any of the possible threats mentioned under household activities could be introduced in larger amounts, especially during high tourist season. In the farming areas, we focused our analysis on establishing positional relationships with respect to the water resources and identifying chemicals used. Locating the orange orchards in terms of the water supply allowed us to determine points of possible runoff. Moreover, by learning the types of fertilizers and pesticides used on the farms and orange plantations, it was possible to scrutinize effects these areas have on water quality. In the case of tin mines, we decided to observe if any people still work to extract tin, even though the mines were officially closed 20 years ago. All these details allowed us to characterize each human activity in terms of threats they posed on watershed. We then proceeded to verify effects of human activity along the streams pathway.

Finally, we considered how concentrations of contaminants would be affected by the change of rainfall during monsoon seasons. It was not possible for us to test and sample during the wet season, so we needed to formulate a hypothesis. By researching how much water Thailand receives during the rainy months and comparing this information with our observations of the area, it was possible to picture Huay Naam Sai watershed during this season. We then hypothesized the extent of threats from contaminants during the rainy season in order to include another sampling plan as part of our recommendations. Understanding changes of water quality during rainy season allowed us to support the importance of additional sampling as part of our proposed management plan.

The overall assessment of the water quality at Huay Naam provided us with enough resources to establish reasonable and effective recommendations. Interviews and observations within the Huay Naam Sai watershed helped us to determine which human activities may be affecting the water quality. Categorizing this information by sources of contamination relative to the streams, we were able to estimate the scope of environmental impact. We finally linked our social data with our analytical results, and tracked variations along the water path in order to support our conclusions about potential sources of pollution.

Finally, we extrapolated the results of the tested parameters to the conditions during rainy season in order to provide a better picture of the hazard trends at Huay Naam Sai watershed. By analyzing this information, we were able to put together the most complete picture of Huay Naam Sai watershed and establish an appropriate management plan according to the problems that the area faces.

C. Evaluate Risks of Consumption

After studying how people's behavior could negatively affect water resources, we researched daily consumption habits and observed whether or not sources of contamination have pathways to reach people. Although this study was not part of the water quality scope of our project, we decided to include it since the results helped us to provide better management recommendations. Our assessment focused on the water retrieval, storage, and purification techniques available in Huay Naam Sai, and once we had studied how these methods were performed we were able to formulate suggestions for their optimal use or replacement. It was then possible to form short-term recommendations to be implemented while management plans are formulated.

Our first focus was to observe how the population obtained water for their daily needs. Some people do not have direct access to water at home, so they might use storage methods and materials whose condition can potentially reduce water quality. We analyzed reservoirs, pumps and pipelines, in order to characterize them as factors of diminishing water quality. We observed reservoirs built by local government, orchard owners, and households, and compared their design and functionality based on their designated use. These water sources can vary from large dams to small collecting pools. The smaller, more stagnant basins introduce higher risk to contamination because bacteria are allowed to reproduce exponentially. The presence of pumps can indicate the use of standing groundwater as opposed to fresher water flowing downhill in pipes. Even the condition of the pipes could be significant; for example, publicly owned pipes may not be maintained well without supporting resources. Without knowledge of government involvement with water delivery, it is difficult to know if the water system is being managed properly, or if this could be another area for improvement. Water retrieval technology and an understanding of its ownership and upkeep provide the first fundamental understanding needed in our overall technology assessment before analyzing further water management in the household.

Water storage introduces significant threats to contamination if handled improperly. Open-container environments breed mosquitoes and other host organisms that can carry

water-borne or parasitic diseases. We looked for tight-fitting lids on all water storage tanks as well as a narrow mouth or spigot to counteract potential contamination from storage and retrieval. Proper water storage can significantly reduce contamination and ensure that nothing is infecting water immediately before consumption.

Our next step was to find out more information about water purification techniques practiced around the community. We spoke with villagers to discover if methods such as filtration, boiling, or chemical disinfection were commonly practiced. These discussions allowed us to better estimate health risks and understand the community's views of their own water quality. For the people who did not have clean water available to them, we were interested in how they treated their water or whether they had to drink bottled water. This third step in our analysis of individual behavior concluded our study of water-related technology at Huay Naam Sai.

This consumption assessment began at a higher level, involving local government, and scaled down to household behavior and habits. Observations of the community's daily consumption and its related technologies provided us with the information needed to make suggestions that can help communities prevent contamination from poor water quality.

D. Summary

Our methodology accomplished our goal of providing officials at Suan Phung Park with management recommendations for rehabilitating the park's water resources and preventing human exposure to existing hazards. In order to provide effective solutions, we performed a water quality assessment at two levels to gather analytical and social data. Our first objective corresponded to identifying pollutants present in the water supply through a sampling and testing plan. Our methodology was applied in only one watershed at Suan Phung in order to obtain a more reliable picture of the water quality. Samples were taken in proximity to water retrieval sources, water disposal sites, pesticides runoff and tin ore extraction. This water sampling was complemented with larvae collection because of their sensitivity to water changes, making them reliable water quality indicators. This plan addressed park officials' concerns and the limitations in their preliminary sampling.

For our second objective, related to social data collection, we confirmed potential sources of contamination by assessing the ways in which humans degrade the quality of water at the Huay Naam Sai watershed. Through personal observations and informal interviews, we characterized each human activity and estimated its possible impact on the water quality. These observations and interviews were based on a filed form, found in Appendix D, and

were applied on the two biggest villages around Huay Naam Sai watershed, Baan Huay Naam Sai and Baan Pha Pok. Among these local activities, we observed wastewater disposal at villages, resorts, and plantations. We then correlated our test results with the land use analysis by tracking variations along the water path. These variations supported our conclusions about the existence of hazards and their origins.

Since the existence of hazards indicates possible health risks, we included, as our third objective, an assessment of the human exposure pathways. For these pathways, we based our study on assessing consumption habits such as water retrieval, storage, purification, and disposal. Our overall assessment of the water quality at Huay Naam Sai shaped our recommendations to prepare the most suitable solutions for Suan Phung Park.

Overall, in order to provide appropriate water management strategies, we gathered analytical and social data. Each set of data alone was not able to support our goal. By establishing relationships among them and tracking variations along the water path, we were able to better understand and assess the water quality of Huay Naam Sai Watershed. This improved description of the water problem and the future threats posed on the watershed enabled us to create suitable and effective water management alternatives for officials at Suan Phung.

4. Findings and Discussion

Our testing methodology provided us with chemical data from Huay Naam Sai that we analyzed in order to provide a baseline of water quality conditions during our visit to the park. Our data was compared with standards from Thailand's Pollution Control Department (PCD) and the United States Environmental Protection Agency (EPA). All values were found within limits deemed acceptable by these agencies, but there were some inconsistencies that called for further attention. Spikes in our data were found in certain locations, and a return trip to the park revealed that these sites were downstream from threatening human activity. Correlations were drawn between human behavior and deteriorating water quality, and are outlined in this chapter.

A. Water Quality

The chemical parameters we tested at Huay Naam Sai indicated values within allowable limits for ground water quality standards for drinking purposes as set by Thailand's Pollution Control Department (PCD 2004). Our test parameters focused on the potential negative externalities around the park, including those from orange orchards (shown below, in pink) and more populated villages (shown in yellow). The specific results for each test site are shown in Figure 7.

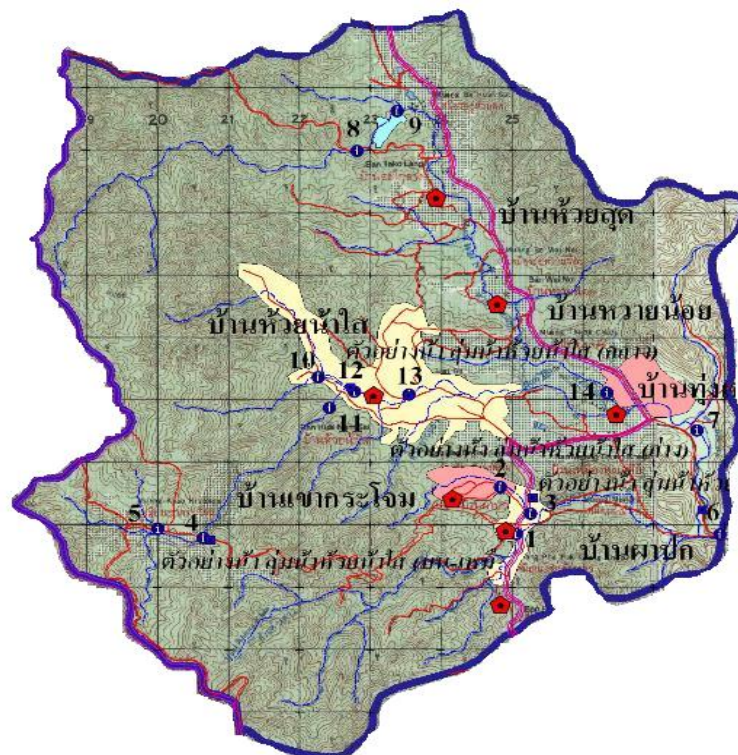


Figure 6: Huay Naam Sai Watershed

Site	Location	BOD*	DO*	pH	Larvae Analysis	Phosphate*	Hardness*	Heavy Metals	Pesticides
1	Village Source	NT	6.7	6.6	Good	0.94	19.22	Normal	NT
2	Orchard	2	9.9	7.5	Average - Good	1.6	47.54	Normal	None Found
3	Orchard Outlet	NT	8.4	7.36	Good	2.6	72.06	Normal	None Found
4	Mountain	NT	2.7	5.95	Inconclusive**	0.4	5.66	Normal	NT
5	Mountain	NT	5.4	6.15	Inconclusive**	0.69	5.25	Normal	NT
6	Village Outlet	1.7	8.3	7.51	Good	0.46	77.57	Normal	NT
7	Orchard	1	7.7	7.7	Average	0.4	91.58	Normal	None Found
8	Waterfall	NT	9.8	7.15	Good	0.74	9.61	Normal	NT
9	Dam Reservoir	NT	10.9	7.97	Average	0.97	16.8	Normal	NT
10	Village Source	2.3	9.2	6.73	Inconclusive**	1.26	6.11	Normal	NT
11	Village Source	2.2	9.4	7.02	Good	0.8	5.96	Normal	NT
12	Village	2.3	9.3	7.15	Good	1.37	14.11	Normal	NT
13	Village Outlet	3.9	10.5	7.11	Good - Excellent	1.37	22.97	Normal	NT
14	Orchard Outlet	2.3	7.2	7.12	Excellent	0.57	78.07	Normal	None Found
* Measured in ppm (parts per million)									
** Due to testing in stagnant water									
NT = Not Tested									

Figure 7: Water Quality – Huay Naam Sai Watershed

The acidity was found to be within the standard range of pH 5-9 as recommended by the Pollution Control Department. Also, biochemical oxygen demand was also acceptable at all sites where tested (refer to Figure 7), with values above the recommended 1.5 ppm (PCD 2004). Dissolved oxygen satisfied the PCD requirement of 6.0 ppm at all sites except for two still-water sites found high in the mountains. Due to unique physical parameters of the water from these sites as compared to the rest of our sampling, our tests are inconclusive at these two sites. The absence of water flow decreased water turbulence, and therefore decreased opportunity for oxygen to dissolve in the water. This unavailability of dissolved oxygen in the water also affected the life of macro invertebrate larvae. (EPA 2003)

At all sites tested, with the exception of the two mountain pools, larvae species present indicated water quality ranging from average to excellent. For example, the invertebrates present at site 8 (flattened mayfly, long-headed caddisfly, and the balloon-tailed damselfly) all breathe through gills and thin skin, and need good quality water with lots of oxygen to survive. Besides their physical characteristics, the wide variety of species present is another good indicator of water quality. (Kanjanvanit 2002) Graphs depicting our results in comparison to their relative thresholds for acceptable water quality can be seen in Figures 8 and 9.

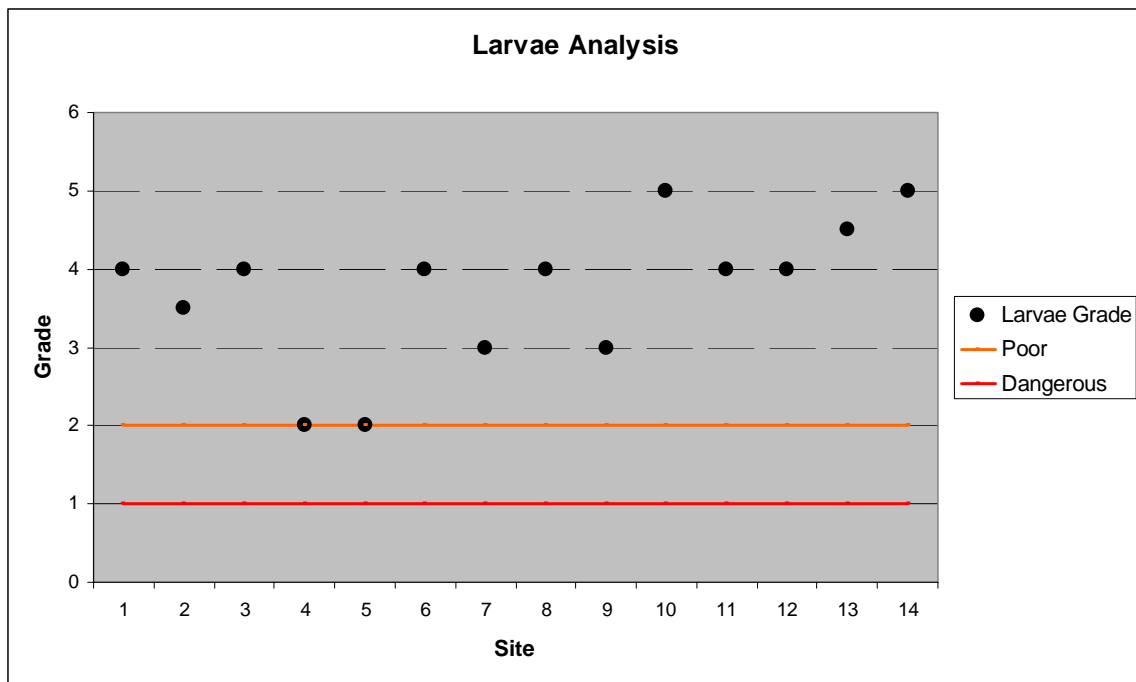


Figure 8: Larvae Analysis in Hay Naam Sai Watershed

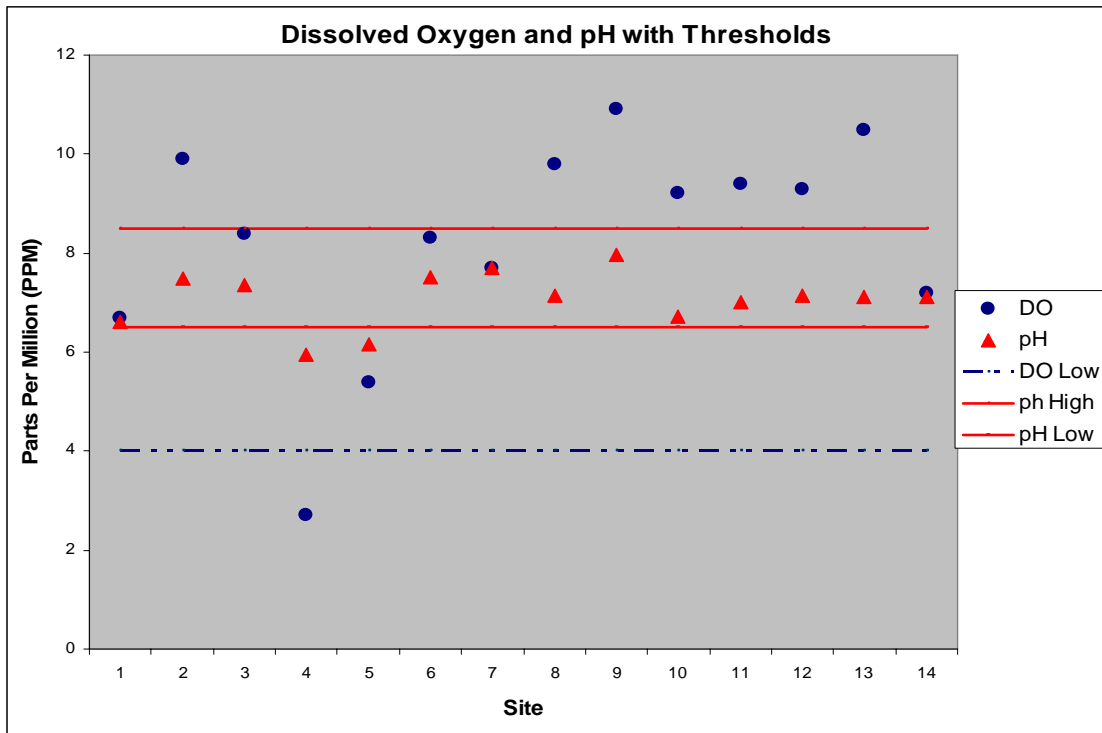


Figure 9: Dissolved Oxygen and pH in Huay Naam Sai Watershed

Hard water can be eliminated from the list of concerns for the Huay Naam Sai watershed, too. Ten of the fourteen sites had very soft water, with CaCO_3 levels ranging from 0 - 25 ppm, while the remaining four sites had moderately hard water with levels between 70 and 100 ppm as seen in Figure 10. All of these sites are acceptable under the Pollution Control Department guideline of 300 ppm (PCD 2004). (Hardness thresholds set by the U.S. Geological Survey.)

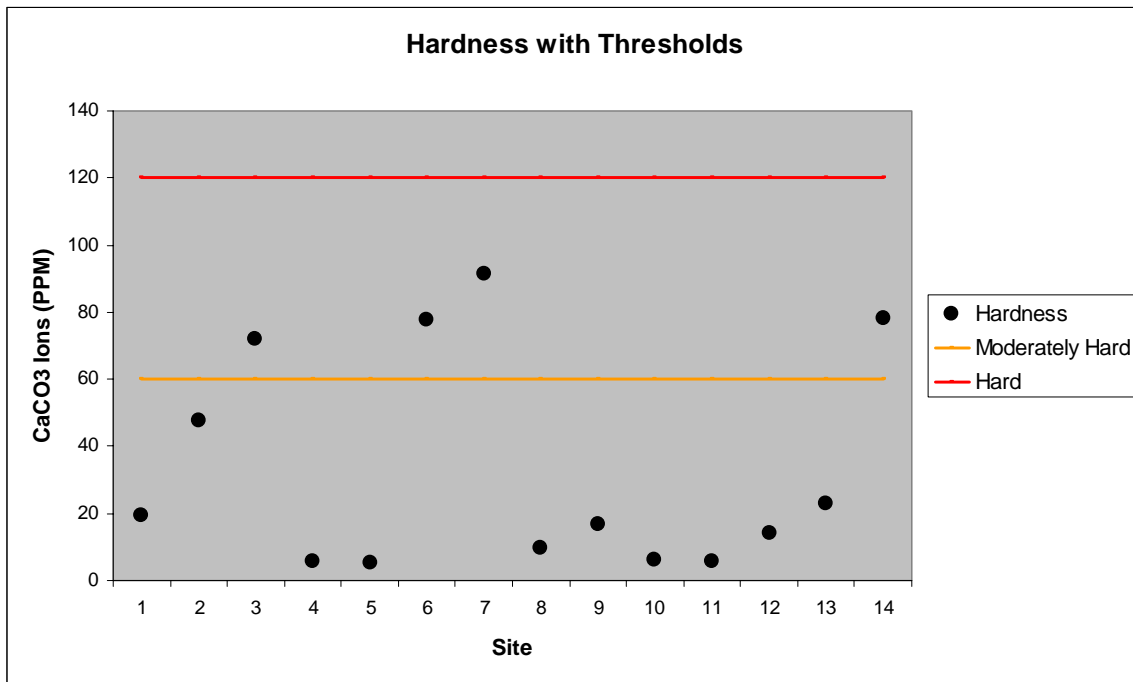


Figure 10: Hardness in Huay Naam Sai Watershed

Phosphate levels at every site were within acceptable limits. Fresh water is expected to contain less than 4.0 ppm of phosphates, whereas our values ranged from 0.4 to 2.6 ppm as seen in Figure 11. These results cannot be expressed as absolute values, because our analysis was based on a scale relative to standard concentrations of phosphate ions synthesized in the lab. Considering this limitation, we had to look at these values as they relate to each other. We found that phosphate concentrations were not consistent throughout the watershed; in fact, one of our sites was considerably higher in phosphate concentration. This value became a concern, and led to a secondary data analysis that will be addressed in the next section of this chapter.

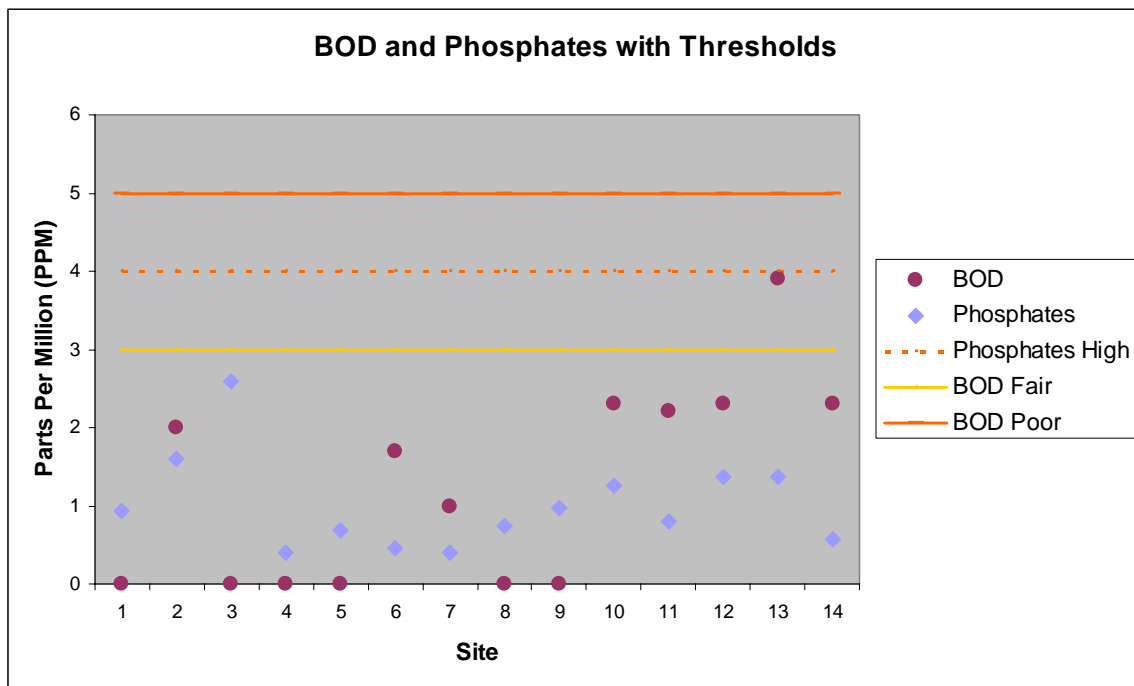


Figure 11: Phosphates and BOD in Huay Naam Sai Watershed

Our tests found all concentrations of pesticides and heavy metals to be within allowable limits. We tested for pesticides at four of the sampling sites that were in or around orange orchards and no traces were detected, in compliance PCD regulations for industrial effluents (PCD 2004). Similarly, the results from testing for heavy metals came back with readings for every site being below the limits set for industrial effluents (PCD 2004).

We can speculate that the concentration of heavy metals and pesticides would be higher if tested in the wet season. The wet season, during the months of May through October, receives over six times the amount of rain as the rest of the year (NEA, 2002). The large amount of precipitation can capture pesticides and metals from the soil before running off into water sources. This allows a greater opportunity for agrochemicals and heavy metals to be present in freshwater streams and rivers.

As for sites 4 & 5, they were mountain locations with high altitudes compared to the other sites. They both had very low dissolved oxygen, the lowest of any sites, and low pH. There are several possible explanations of this. One is that there is more carbon dioxide dissolved in the water at that altitude, making the water more acidic and displacing the oxygen dissolved. However, more data is needed before any conclusions can be made.

Despite the speculation of several sources of contamination throughout Huay Naam Sai, current water quality conditions were found to be acceptable to Thai environment and health regulations. No toxic materials from pesticides or heavy metals were detected, and general

water quality indicators such as BOD, DO, and hardness were all within acceptable limits. Since this primary analysis comparing our results to water quality standards revealed nothing of concern, we decided to compare the results from sites that flow along the same water streams in order to track any changes. We noticed similar trends in data for a number of water quality indicators.

B. Threats to Water Quality

Variations in water quality became apparent when we looked at our data from a different angle. These trends were evaluated and then correlated with human activity in two areas of the watershed. This second-order analysis led to further investigation of each location to find the cause of the variations in the data. We discovered that the use of agrochemicals at the Baan Pha Pok orchard was the most feasible cause for the increased phosphate concentrations across the sampling sites. In Baan Huay Naam Sai, improperly disposed wastewater could cause increases in levels for BOD and phosphates. Resort development also threatens this area, potentially increasing the water hardness and pH due to the introduction of lime (CaO) from masonry used in construction. These trends, while occurring at levels still safe for human consumption, foreshadow problems for the Huay Naam Sai watershed if development continues and resource management is not implemented.

i. Baan Pha Pok

Our test results from Pha Pok village show a drastic increase in phosphate levels as the water flows through the plantation. A map of the area, showing our first three sampling locations, can be seen in Figure 12. Water flows from Sites 1 & 2 and combines at Site 3 after flowing through the community. At the orange orchard upstream from the village, there is only 0.94 ppm of phosphate, whereas further downstream at Site 3 there is a level of 2.6 ppm. A graph showing this difference in phosphate levels can be seen in Figure 13. This difference is the greatest jump in our data for phosphate content and such a steep increase was most likely not caused by nature alone.



Figure 12: Pha Pok Village with Sampling Locations

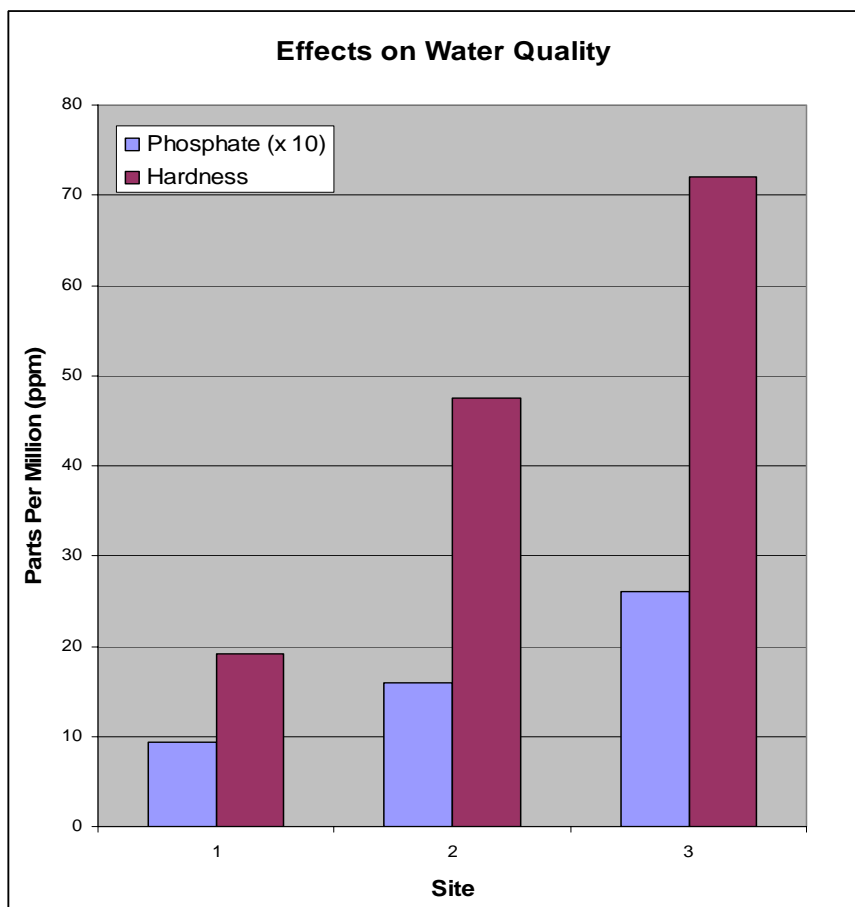


Figure 13: Variations in Pha Pok Village

When we visited this area for further investigation we saw first hand how the water runs off the land after irrigation and collects in pools at the bottom of the hill, as seen in Figure 14. This water was highly discolored with a bluish tint and contained a noticeable amount of algae. Increased plant growth in water, or eutrophication, is a common result of high concentrations of phosphates (EPA, 2002). After speaking with the plantation owners we

verified our speculation by learning that they do in fact use organophosphate based fertilizers. This was clearly the cause of the rising phosphate values as water flowed through the community.



Figure 14: Bluish Water with Algae from Plantation Runoff

ii. Baan Huay Naam Sai

At Baan Huay Naam Sai, values for BOD, phosphates, pH, and hardness increased as the stream flowed through town. The location of four of our sampling locations, this village is shown in Figure 15, where sites 10 and 11 are the sources of water to the community and site 13 is the outlet. At sources 10 and 11, the water contains 6.11 and 5.96 ppm of CaCO_3 , respectively. In contrast, the outlet contains 22.97 ppm of CaCO_3 . This is only one of the four trends which occur over a distance of only two kilometers. The rises in pH, BOD, and phosphates, as well as hardness, can be seen in Figure 16 which clearly shows that the village is affecting the quality of water.

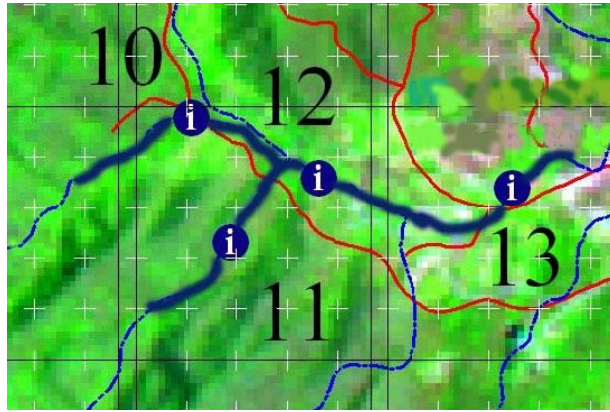


Figure 15: Map of Huay Naam Sai Village with Sampling Sites

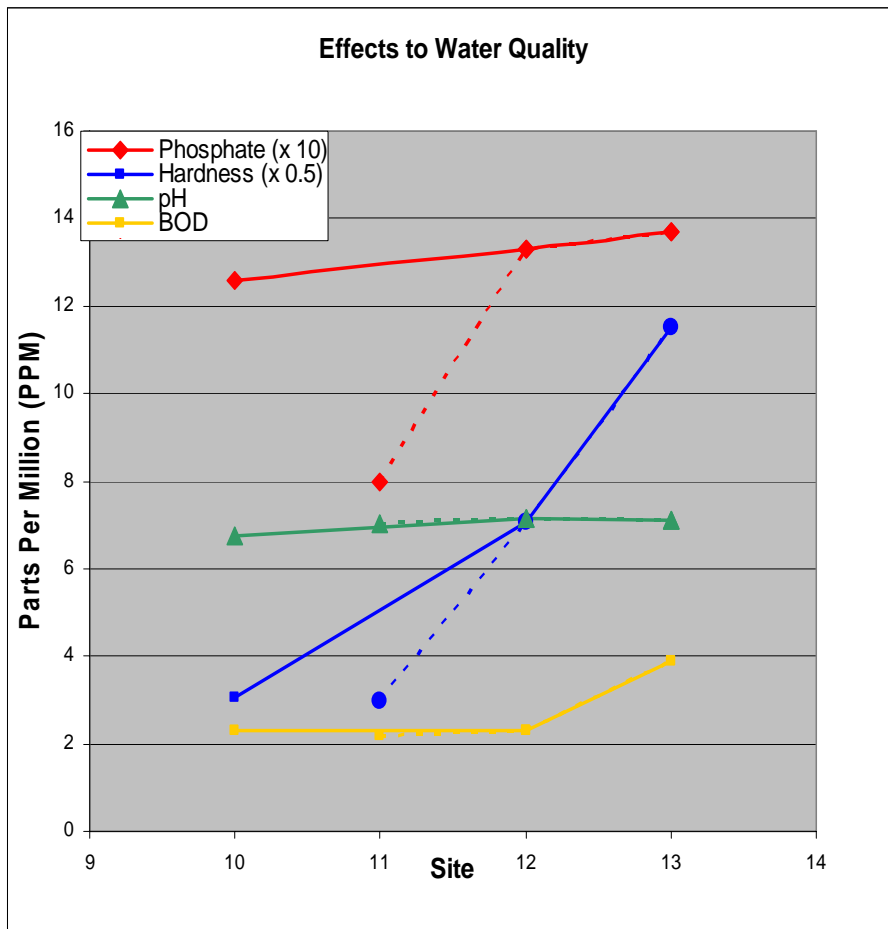


Figure 16: Variations in Data from Huay Naam Sai Village

After visiting the area we found several sources of contamination that could explain the variations in data. With a population of about 400 people, almost all of the households lacked any form of waste water treatment. In most cases, the waste water was piped directly to nearby streams as seen in Figure 17. This photo also shows that the streambed is overgrown with plant life, which can be a sign of high concentration of phosphates coming from the waste water (EPA, 2002).

We also explored several construction sites where new resorts were being built. These resorts used a lot of masonry to shape the area and increase its attractiveness. However, as illustrated in Figure 18, the nearby water had become gray, suggesting runoff from cement mixing or cleaning processes. Cement and mortar contain high levels of lime (calcium oxide, CaO) or calcium carbonate (CaCO_3). Calcium ions can buffer slightly acidic water, so when the water picks up the calcium ions from lime it not only becomes less acidic (raising the pH), but it also increase the hardness of the water by collecting these ions (USGS n.d.).



Figure 17: Waste Water Piped into Stream at Huay Naam Sai Village



Figure 18: Masonry in Huay Naam Sai Village

Even though we were unable to determine any dangerous levels of pollution in the water, we found many behavioral factors that threaten the quality of water at Huay Naam Sai watershed. The variations in water quality found upstream and downstream from sources of contamination such as orchards, villages, and resorts were confirmed after investigating these areas. These variations indicate a need for future resource management to protect this water resource and the people who depend on it for survival. Furthermore, we also took note of the current water retrieval and disposal techniques because they will eventually cause exposure to contamination if the water reaches hazardous levels.

C. Threats to Human Health

After revealing the threat of human activity on the water quality at Baan Huay Naam Sai and Baan Pha Pok, the observed consumption habits of the villagers and the lack of proper water management are seen to be exposing the community to different health risks and further compromising the quality of their drinking water. We assessed their methods of water sourcing, distribution, and storage. All revealed the necessity of a new management plan to prevent human exposure. Locals use crude techniques to determine which water bodies are safe as fresh water sources. During the dry season, the water table does not provide enough drinking water for villagers and any water that is obtained is delivered via pipes, which lack centralized maintenance. When the water is made available at home, improper storage is increasing the risk of the spread of disease. Water collection, delivery, and storage all show room for improvements guarding against contamination and overall inefficiency.

Without a reliable water supply, the villagers installed their own piping systems, retrieving their own water without knowledge of its quality. Based solely on appearance, taste and odor, villagers distinguish which of the five main streams are safe to drink and which to use for other activities, such as washing, cleaning and agriculture. Most of the locals pipe their fresh water from Huay Khao Jome, a large stream up in the mountains, and use nearby streams such as Huay Dam Toom and Huay Naam Sai for the rest of their needs. The local government also owns the water reservoirs found above orange plantations. However, their condition is not suitable for human consumption and has been strictly reserved for agricultural use. The safety of these resources is not monitored, creating potential danger in a lack of knowledge regarding water quality.

Without resource conservation, the water supply cannot sustain the current population. Resorts have installed large pipelines stretching all the way to freshwater sources, using such large amounts of water that there isn't enough left for their neighbors' households. The

diameter of the pipelines makes it easy to distinguish ownership by the resorts versus by the villagers. The wider blue pipes supply resorts all year around with enough water for their different uses such as household necessities, gardens, irrigation, and fish hatcheries. Even during the dry season, resorts' water supplies continue to support them without any problems, to the point that villagers depend on them for water. This shortage was confirmed by the local leader, who told us that they deliver drinking water by truck to alleviate the problem during peak summer months. Unfortunately this is only a short-term solution for these people, and does not guard against future problems with this resource.

Water quality is compromised at the household level by unsanitary handling. We observed drinking water stored in uncovered plastic containers and accessed by ladling. These storage procedure used at Baan Huay Naam Sai and Baan Pha Pok could still be improved by basic recommendations of hygiene proposed by World Health Organization (WHO) or the Department of Pollution Control (PCD) in Thailand. Sanitary guidelines proposed by these agencies include the use of storage containers with narrow openings for filling and dispensers such as spouts or taps. Storage that lacks this potentially exposes drinking water to dangerous pathogens and other contaminants. Although they recognize the importance of pre-treating their drinking water, methods such as boiling or filtering through fabric are not sufficient in dealing with the possible health risks present.

Our consumption assessment demonstrated how the community is vulnerable to the same threats that they are posing on their water resources. Their sourcing, distribution, and storage methods are not appropriate ways to deal with the contaminants potentially present in their drinking water. Therefore, it is necessary to devise recommendations to prevent further contamination, to start alleviating threats to the water supply and to reduce human exposure.

D. Summary

When compared to standards of potable water quality, our testing results revealed acceptable water quality in the Huay Naam Sai watershed of Suan Phung Nature Park. The expected contaminants of heavy metals and pesticides were not found. Overall, we've determined an accurate picture of the water quality at the time of year we tested and better identified the human threats to it. This can act as a benchmark for future testing.

However, it should be noted these findings are limited in several regards. Notably, we tested only in the dry season so our conclusions are not necessary applicable year round. Also, our analysis was based on limited test parameters- with some identified threats

deserving other tests (notably bacterial analysis as it corresponds directly to wastewater and its human health effects).

Despite our primary conclusion that the water of Huay Naam Sai is acceptable overall, trends of decreasing water quality were uncovered and found to correspond to human activities. An increase in phosphate concentration, ostensibly from the use of agrochemicals, was found in the Pha Pok village. And an increase in multiple parameters through the village of Huay Naam Sai is accountable to construction and improper wastewater disposal. If current future development causes these contaminating activities to increase, these trends could amplify and lead to unhealthy water. From this concern, the importance of limiting contamination via improvements in water collection, delivery, and storage was mentioned. This leads directly to several water quality management recommendations.

5. Recommendations

Although our analytical results indicated good water quality at Huay Naam Sai, our social observations indicated several threats to the water quality. However, once we established relationships and traced the variations from water sources to outlets, we were able to reveal alterations caused by local activities on the water resources and predict future impact. Among all the different human activities occurring at the watershed, we determined that the biggest potential cause of water quality degradation was the improper handling of wastewater at villages and plantations. On the other hand, we were also concerned about the current water consumption habits since our assessment pointed to poor water treatment and storage techniques that could also compromise the quality of drinking water for villagers. Based on this knowledge, we researched the best water management strategies and put together a series of viable and effective recommendations for rehabilitating the water supply and preventing human exposure. These short and long-term recommendations target the responsibility of authorities and the consciences of villagers, in an effort towards preserving the water resources.

One of the most troubling issues at Huay Naam Sai watershed is the absence of wastewater management. This problem must be addressed at both the household and community levels, in order to prevent further contamination. First, the authorities and villagers should understand the risks involved with improper wastewater disposal since bacterial contamination causes the development of waterborne diseases. Basic solutions directed toward villagers and resorts owners should be implemented immediately to start reducing the impact of wastewater on the streams. Among the most simple and effective techniques, we propose the use of septic tanks and composting latrines. Septic systems have the advantage of little maintenance, isolation of excreta, few problems with odor and flies, and the possibility of a future connection to community sewerage systems. The composting latrines are cheaper, and the excreta that are disposed into them can be later used as soil conditioner. However, they require a relatively high level of training to ensure their proper use. (WHO Sanitation Factsheet) In order to implement these suggestions, authorities might distribute written information from WHO to communities on how they should be installed. However, since the level of education of some villagers is relatively low, demonstrations can be a better option over written instructions. Therefore, the local authorities can build a model at the community center and villagers can participate during the construction process. Extra material and assistance should be also available at the community center. For a long-term

solution, we recommend the implementation of a sewerage system. As the population continues to grow, the wastewater problem will get worse. Even though this is the most expensive solution, it treats larger amounts of wastewater making it a more practical disposal strategy. Park staff and local authorities should get together to seek the help and guidance of the Pollution Control Department of Thailand (PCD) in order to plan the most suitable sewerage system at the lowest possible cost. This organization is also able to provide more suggestions on how to manage the water resources in order to prevent further contamination. Moreover, it is the responsibility of local authorities to establish wastewater guidelines and enforce them. For example, the expansion of resorts in the area should be regulated based on the capacity of the natural resources, and special requirements such as sewage treatment should be addressed at the time of construction.

While establishing guidelines and enforcing them, authorities should also focus their attention on the agricultural activities in Huay Naam Sai watershed. However, before enforcing guidelines, it is necessary to educate the farmers about the use of efficient and less toxic methods, and make the materials available to them. For instance, the use of effective, biodegradable pesticides is a good start to eliminate the runoff of dangerous chemicals in the water resources. This information is readily available at the U.S. Environmental Protection Agency (EPA), the Department of Agriculture in Thailand or institutions of higher education such as Chulalongkorn University. Once farmers are informed and have access to the right tools, authorities can ask them to implement these less harmful alternatives.

Managing wastewater and controlling local activities, such as the orange plantations, begins with the knowledge of a water quality baseline from which future impact can be moderated. A monitoring plan can track changes on parameters such BOD, DO, phosphates and nitrates in order to indicate improvement or degradation of the water quality. This monitoring plan is best when practiced several times during the year, testing numerous sampling points around the potential threats to better determine developing trends. Once again, involvement of the PCD would be of assistance; this qualified institution is already in charge of monitoring other basins in Thailand. Finally, local authorities and park staff must work together to convince the communities about accepting these new methods in order to prevent further contamination and ensure a safe future. This can be done by using different types of media, such as the video produced by WPI's Educational Outreach team (Blow, et al 2005) or conservation camps like the ones found at Rabbit in the Moon (rabbitinthemoon.org).

While this water management plan is implemented to control pollution, it is also necessary to address poor consumption habits currently practiced throughout the Huay Naam Sai watershed. These consumption habits include water retrieval, storage and purification, and must be modified at the household and community levels. We recommend first educating villagers about safe and basic water handling techniques. These handling methods should enable them to make their drinking water as safe for consumption as possible. Since it is difficult to find completely reliable sources of water, they should receive advice from authorities while selecting which streams to drink from. By implementing the previously mentioned monitoring plan, authorities and park staff will be able to inform villagers about the conditions of the different streams and indicate which are safe for consumption.

Another source for drinking water can be obtained during the wet season through the use of rainwater collectors; however proper storage design is essential to prevent bacteriological contamination of the water. Basic standards, such as narrow filling openings, a cover, and a spout must be used to ensure the sanitation of the storage container. We recommend that park officials make these containers available around the park since they are inexpensive models that comply with all the basic requirements proposed by PCD and WHO. Furthermore, emphasizing the importance of purification techniques and providing the necessary information will allow villagers to treat their own water at home. Organizations such as the WHO provide useful fact sheets on simple water treatments such as boiling, solar disinfection, chemical disinfection, coagulation, stone filtration, to name a few. Details on how each one should be performed can be found in Appendix B. Long-term solutions include the installation of filters connected to the pipeline, community purification centers, and a treatment plant that supplies pre-treated water to the community pipelines. Filters would only be accomplished by the efforts from individual households, and can be costly. Community purification centers are easier and cheaper; moreover, they are already used in several parts of Thailand. These centers consist of filtration units with technologies such as reverse osmosis to produce drinking water. An appropriate fee should be charged in order to repay for the unit and any maintenance service. The last suggestion, a treatment plant, is more difficult to implement because of the costs; however, as Thailand's economy continues to develop, the national government might be able to reach more communities and improve living standards. All of these strategies will prevent human exposure to contaminated water.

Our management recommendations intend to tackle all of the different threats that we disclosed in our findings and discussion, in order to begin alleviating the contamination of the Huay Naam Sai watershed. These management strategies can be enforced by the local

authorities and focus on the community as a whole, as well as the individuals themselves. The different alternatives that we are proposing can only be implemented if the villagers gain the knowledge to understand the importance of conservation as well as the fundamentals of these practices. Policies and guidelines can be followed only if the appropriate tools are available; therefore, authorities and park staff must work together to ensure that villagers receive the materials and information for their use. The effort to prevent human exposure is also important in Huay Naam Sai watershed considering the potential hazards present in the water supply. The villagers must be informed about the health risks and be prepared to take actions on their own. Modifying human behavior in terms of the ways local activities are performed and how the water resources are used will help to contribute towards the overall goal of HRH Princess Sirindhorn, to guarantee the successful future of Suan Phung Nature Education Park.

6. Summary

The goal of our project was to inform Suan Phung park officials of the water quality in the Huay Naam Sai watershed and provide recommendations for improved management of its water resources. Basic chemical tests, supplemented with a larvae analysis, revealed that the water quality was acceptable for consumption. We were also able to observe some threats to water quality which were supported by a behavioral analysis. Based on these threats we developed recommendations for the Royal Projects Office to conduct more conclusive sampling in the future. The results from a more complete water quality analysis will help to form a management plan that will protect the local people and their water resources from future contamination.

Our chemical analysis of the water quality in Huay Naam Sai did not reveal any toxic hazards present in the water, but the accuracy of our results was limited by the scope of our sampling. We recommend that more sampling points are tested along each stream to reduce error from anecdotal data. Monitoring during different times of the year, specifically the wet and dry seasons, is strongly suggested in order to assess the effects of varying amounts of rainfall and groundwater flow. This is significant in the Huay Naam Sai watershed since it sees up to four times the amount of rainfall during the wet season as it does during the dry (NEA 2002). The increased number of samples collected over a longer period of time will provide more data for examination and therefore more credibility to the study as a whole.

Although no heavy metals or pesticides were detected during the dry season, we cannot be certain that we obtained a representative sample. The increased rainfall and subsequent groundwater flow during the wet season may flush any toxic materials from the soil and carry them to nearby water sources. For heavy metals, we suggest soil sampling in addition to water testing in the wet and dry seasons. Different liquid-liquid extraction procedures used in preparation for Gas Chromatography/Mass Spectrometer (GC/MS) analysis are recommended to ensure that any pesticides present in water are extracted from the sample. One method to ensure accuracy in the lab would be to synthesize pesticides or heavy metal samples at known concentrations and run them through the same series of tests with Inductively Coupled Plasma (ICP, for analysis of heavy metals by elements) and GC/MS. If these laboratory capabilities are not available, we recommend surveying orchard owners for the amounts of pesticides used throughout the year.

Even though pesticides or heavy metals were not found in the water, their effects may be indirectly observed in other water quality indicators. Biochemical Oxygen Demand (BOD),

Dissolved Oxygen (DO) and phosphate levels all increased as water flowed downstream through the orchards. This finding supports speculation that pesticides are affecting the water quality. Further support is needed before this link can be confirmed, and we suggest that further phosphate testing be done via Ion Chromatography (IC) in place of our titration procedure. Our results were obtained with a vanadomolybdophosphoric acid method, which can produce up to twice the amount of error as shown by Ion Chromatography (21.6%, vs. a 10% bias) (APHA 1998). Future data on these three water quality indicators can be used to monitor the negative externalities from agrochemical use.

Besides agriculture and mining, the daily activities of local residents pose additional threats to the quality of Huay Naam Sai's water. Recommended future tests include those for nitrates and bacteria. Testing for nitrates (via Ion Chromatography) is recommended because these ions are related to wastewater contamination and can quickly escalate to toxic levels in water if untreated. Similarly, a bacterial analysis would complement our chemical study by assessing the hazard of fecal contamination. We speculate that this test provides a worst-case scenario during the dry season when there is less ground water available to dilute bacterial waste. The addition of these tests is suggested based on observations made in villages without wastewater treatment. Considering our observations and the future development in the area, this threat must be assessed so that proper management strategies can be implemented at the Huay Naam Sai area.

With the addition of this new testing we understand that time may be a limiting factor, as it was in our own sampling. If this becomes the case, titrating for hardness and testing at mountain sites may be eliminated. The EDTA titration procedure for hardness required a significant commitment of both time and labor. On average, our analysis showed very soft water throughout the watershed, and although hardness seemed to increase at outlets this was consistent with our expectations. As acidic rainwater flows through rocks and sediment, it picks up calcium and magnesium cations which act as a buffer for the solution. Water hardness is not affected by human activity unless the use of water softener is released with wastewater, which would have caused a shift opposite from what we observed. Testing at remote mountain locations is also of lower priority. Our results at the two mountainous sites near Muang Khao Krathong showed less desirable water quality, but there was no human interaction that would suffer from those conditions, nor serve as a cause for the conditions we found. We recommend allocating the time and resources to more pertinent sampling procedures in order to obtain the most effective results.

Sufficient water quality analysis was needed in Huay Naam Sai to create a better resource management plan. Our results confirmed the absence of toxic chemicals in the area. The recommendations to further investigate these preliminary findings will help create a better picture of the problems facing the watershed. By combining our results with this future analysis, the Royal Projects will have a more comprehensive assessment available to them. They will be able to develop a water management plan that can reduce future contamination. The Royal Project's Office can then use this water quality preservation program to help Huay Naam Sai serve as a model for resource conservation and human health, and spread successful management ideas to similar areas throughout rural Thailand.

Appendices

A. Water Quality Standards

Properties	Parameters	Units	Standards	
			Maximum Acceptable Concentration	Maximum Allowable Concentration
Physical	1. Colour	Platinum-Cobalt (Pt-Co)	5	15
	2. Taste	-	Non Objectionable	Non Objectionable
	3. Odour	-	Non Objectionable	Non Objectionable
	4. Turbidity	Silica scale unit (SSU)	5	20
	5. pH	-	6.5-8.5	9.2
Chemical	6. Total Solids	mg/dm ³	500	1,500
	7. Iron (Fe)	mg/dm ³	0.5	1.0
	8. Manganese (Mn)	mg/dm ³	0.3	0.5
	9. Iron & Manganese (Fe&Mn)	mg/dm ³	0.5	1.0
	10. Copper (Cu)	mg/dm ³	1.0	1.5
	11. Zinc (Zn)	mg/dm ³	5.0	15.0
	12. Calcium (Ca)	mg/dm ³	75 ^b	200
	13. Magnesium (Mg)	mg/dm ³	50	150
	14. Sulphate (SO ₄)	mg/dm ³	200	250 ^c
	15. Chloride (Cl)	mg/dm ³	250	600
	16. Fluoride (F)	mg/dm ³	0.7	1.0
	17. Nitrate (NO ₃)	mg/dm ³	45	45
	18. Alkylbenzyl Sulfonates (ABS)	mg/dm ³	0.5	1.0
	19. Phenolic substance (as phenol)	mg/dm ³	0.001	0.002
Toxic elements	20. Mercury (Hg)	mg/dm ³	0.001	-
	21. Lead (Pb)	mg/dm ³	0.05	-
	22. Arsenic (As)	mg/dm ³	0.05	-
	23. Selenium (Se)	mg/dm ³	0.01	-

	24.Chromium (Cr hexavalent)	mg/dm ³	0.05	-
	25.Cyanide (CN)	mg/dm ³	0.2	-
	26.Cadmium (Cd)	mg/dm ³	0.01	-
	27.Barium (Ba)	mg/dm ³	1.0	-
Bacterial	28.Standard plate count	Colonies/cm ³	500	-
	29.Total coliform	MPN/100 cm ³	< 2.2	-
	30.E.coli	MPN/100 cm ³	None	-

Remarks : mg/dm³ milligram per cubic decimeter

MPN Most Probable Number

- a These values are allowed for tap water or ground water that is used as temporary drinking water. Such water with a parameter between the maximum acceptable concentration and the maximum allowable concentration can not be certified as standard drinking water for industrial products and stamped with the standard logo.
- b If the calcium concentration is higher than the standard and magnesium concentration is lower than the standard, calcium and magnesium will be identified in terms of total hardness with a standard value of less than 300 mg/dm³ (as CaCO₃)
- c If a sulphate concentration of 250 mg/dm³ is reached, magnesium concentration must not be more than 30 mg/dm³.

Source : Notification of the Ministry of Industry, No. 322, B.E. 2521 (1978), issued under the Industrial Products Standards Act B.E. 2511 (1968), published in the Royal Gazette, Vol. 95, Part 68, dated July 4, B.E. 2521 (1978).

Classification

Objectives/Condition and Beneficial Usage

- Class 1** Extra clean fresh surface water resources used for :
 (1) conservation not necessary pass through water treatment process require only ordinary process for pathogenic destruction
 (2) ecosystem conservation where basic organisms can breed naturally
- Class 2** Very clean fresh surface water resources used for :
 (1) consumption which requires ordinary water treatment process before use
 (2) aquatic organism of conservation
 (3) fisheries
 (4) recreation
- Class 3** Medium clean fresh surface water resources used for :
 (1) consumption, but passing through an ordinary treatment process before using
 (2) agriculture
- Class 4** Fairly clean fresh surface water resources used for :
 (1) consumption, but requires special water treatment process before using
 (2) industry
- Class 5** The sources which are not classification in class 1-4 and used for navigation.

Parameter ¹ /	Units	Statistics	Standard Value for Class ² /					Methods for Examination
			Class1	Class2	Class3	Class4	Class5	
1. Colour, Odour and Taste	-	-	n	n'	n'	n'	-	-
2. Temperature	C°	-	n	n'	n'	n'	-	Thermometer
3. pH	-	-	n	5-9	5-9	5-9	-	Electrometric pH Meter
4. Dissolved Oxygen (DO) ² /	mg/l	P20	n	6.0	4.0	2.0	-	Azide Modification
5. BOD (5 days, 20°C)	mg/l	P80	n	1.5	2.0	4.0	-	Azide Modification at 20°C, 5 days
6. Total Coliform Bacteria	MPN/100 ml	P80	n	5,000	20,000	-	-	Multiple Tube Fermentation Technique
7. Fecal Coliform Bacteria	MPN/100 ml	P80	n	1,000	4,000	-	-	Multiple Tube Fermentation Technique
8. NO ₃ -N	mg/l	-	n	-	5.0	-	-	Cadmium Reduction
9. NH ₃ -N	mg/l	-	n	-	0.5	-	-	Distillation Nesslerization
10. Phenols	mg/l	-	n	-	0.005	-	-	Distillation, 4-Amino antipyrine
11. Copper (Cu)	mg/l	-	n	-	0.1	-	-	Atomic Absorption - Direct Aspiration
12. Nickel (Ni)	mg/l	-	n	-	0.1	-	-	Atomic Absorption - Direct Aspiration
13. Manganese (Mn)	mg/l	-	n	-	1.0	-	-	Atomic Absorption - Direct Aspiration
14. Zinc (Zn)	mg/l	-	n	-	1.0	-	-	Atomic Absorption - Direct Aspiration
15. Cadmium (Cd)	mg/l	-	n	-	0.005* 0.05* *	-	-	Atomic Absorption - Direct Aspiration
16. Chromium Hexavalent	mg/l	-	n	-	0.05	-	-	Atomic Absorption - Direct Aspiration
17. Lead (Pb)	mg/l	-	n	-	0.05	-	-	Atomic Absorption - Direct Aspiration
18. Total Mercury (Total Hg)	mg/l	-	n	-	0.002	-	-	Atomic Absorption-Cold Vapour Technique
19. Arsenic (As)	mg/l	-	n	-	0.01	-	-	Atomic Absorption - Direct Aspiration
20. Cyanide (Cyanide)	mg/l	-	n	-	0.005	-	-	Pyridine-Barbituric Acid
21. Radioactivity - Alpha - Beta	Becquerel/l	-	n	-	0.1 1.0	-	-	Gas-Chromatography
22. Total Organochlorine Pesticides	mg/l	-	n	-	0.05	-	-	Gas-Chromatography
23. DDT	µg/l	-	n	-	1.0	-	-	Gas-Chromatography
24. Alpha-BHC	µg/l	-	n	-	0.02	-	-	Gas-Chromatography
25. Dieldrin	µg/l	-	n	-	0.1	-	-	Gas-Chromatography
26. Aldrin	µg/l	-	n	-	0.1	-	-	Gas-Chromatography
27. Heptachlor & Heptachlorepoxyde	µg/l	-	n	-	0.2	-	-	Gas-Chromatography
28. Endrin	µg/l	-	n	-	None	-	-	Gas-Chromatography

Source : [Notification of the National Environmental Board, No. 8, B.E. 2537 \(1994\), issued under the Enhancement and Conservation of National Environmental Quality Act B.E.2535 \(1992\)](#) , published in the Royal Government Gazette, Vol. 111, Part 16, dated February 24, B.E.2537 (1994).

B. Household Water Treatments

Chlorination

Table 1: Preparation of 1% chlorine stock solution

To prepare the solution, add the quantity of one of the chemical sources shown below to water, mix, and make up to 1 litre in a glass, plastic or wooden container:

Chemical source	Percentage available chlorine	Quantity required	Approximate measures
Bleaching powder	35	30g	2 heaped tablespoons
Stabilized/tropical	25	40g	3 heaped tablespoons
High-test hypochlorite	70	14ml	1 tablespoon solution
Liquid laundry bleach	5	200ml	1 teacup or 6-oz milk tin
Liquid laundry bleach	7	145ml	10 tablespoons
Javelle water	1	Is itself a 1% stock solution	

A 1% solution contains 10 g of chlorine per litre = 10000mg/l or 10000ppm (parts per million).

1 tablespoon = 4 teaspoons

Avoid skin contact with any of the chemical sources or the stock solution, and avoid inhaling chlorine fumes.

This stock solution should be *fresh*, i.e. made every day, and protected from heat and light.

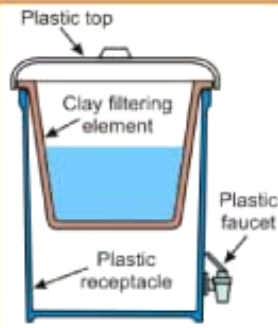
Table 2: Disinfecting water using a 1% stock solution

To produce an initial chlorine concentration sufficient to leave a free residual chlorine concentration of 0.4–0.5 mg/l after 30 minutes:

1. Prepare a 1% chlorine solution
2. Take 4 nonmetallic water containers (e.g. 20-litre plastic buckets) and put 10 litres of the water to be chlorinated in each one.
3. Using a syringe or another measure, add progressively greater doses of 1% chlorine solution to the containers:
 - 1st container: 1ml
 - 2nd container: 1.5 ml
 - 3rd container: 2ml
 - 4th container: 5ml
4. Wait for 30 minutes and then measure the residual free chlorine concentration, using a comparator or test strip.
5. Choose the sample with between 0.4–0.5 mg/l of free residual chlorine.
6. Calculate the amount of 1% chlorine solution needed for the quantity of water to be treated.

Ceramic filtration

HOW TO USE YOUR FILTER



1. Washing the RECEPTACLE

Wash your hands with soap .
 Attach the spigot (faucet) to the plastic receptacle.
 Fill the receptacle one quarter full with water and add two tablespoons of chlorine bleach.
 Leave this for thirty minutes to disinfect the plastic receptacle.
 Use this water to wash the entire inside of the plastic receptacle and the lid with a brush or cloth.
 Drain the water out through the spigot to disinfect.
 If you do not have bleach, wash the receptacle and lid with soap and water as described above.
 You can use either filtered or boiled water to rinse.



2) Place the plastic receptacle in a location that is stable and out of the way of activity.

Using both hands on the edge of the clay filter, place it on the mouth of the receptacle.



3) To get rid of the clay taste of the new filter, fill it with water and drain through the spigot. Repeat until all taste is gone.



4) If your water is turbid, strain it through a clean piece of fine cloth. Tie the cloth in place around the outside of the plastic receptacle.



5) Keep your filter filled and covered at all times.

The filter will flow more rapidly (one to two liters per hour) if it is kept full. Remember: Before serving water wash your hands and cups with soap.

HOW TO CLEAN YOUR FILTER



Cleaning your CLAY FILTER

1) When the flow rate decreases, it is a signal that the pores of the clay filter are clogged.

To wash:

- Do not lift the clay filter when it is full of water. Wait until the clay filter is empty and there is filtered water in the plastic receptacle.
- Wash your hands with soap.
- Remove the clay filter from the plastic receptacle and put it on a plate that has been washed with filtered water.



- Pour a few inches of filtered water back into the filter.
- Scrub the filter with a stiff laundry brush on the inside and outside to remove any debris or particles.
- Do not worry if some of the clay comes off. It means you are scrubbing well.
- Rinse with filtered water until the water is clear.

Attention! Never use chlorinated water or soap to wash the clay filter.



3) Washing the PLASTIC RECEPTACLE

Wash the plastic receptacle each month with chlorinated water or with soap as explained in part 1. Once you have finished washing, return the clay filter to the plastic receptacle to begin use.

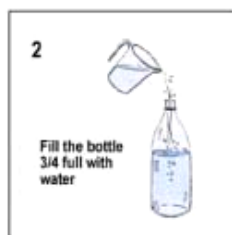
Attention: The Filtron filter generally functions well for a year and a half or more. If you have problems, contact the organization that distributed your filter for advice on what to do.



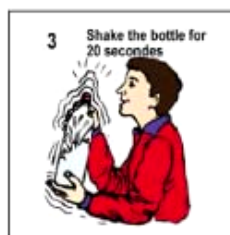
SODIS Application



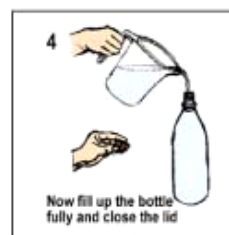
**Clean
PET Bottles**



**Fill Bottles
partly to 3/4**



**Aerate the Water
through Shaking**



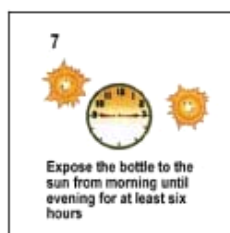
**Fill Bottles
completely**



**Expose Bottles
to Sunlight**



**Exposure on Roofs
are adequate**



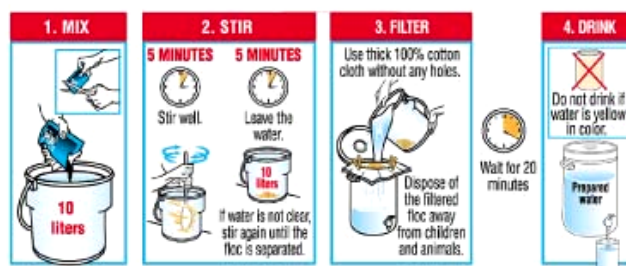
**Expose the Bottles
for 6 Hours**



**Drink the Water
from the Bottles**

Combined flocculation/chlorination systems

Inclusion of the directions for "PUR" in this annex – an example of a combined flocculation/ chlorination technology – does not imply WHO endorsement.



C. Technical Procedures for Testing

i. Pesticide Extraction by GC/MS Method

Materials

1. 4 round bottom flasks, stirrers
2. 100mL of water from sites 2, 3, 7, 14
3. 20mL Dichloromethane

Procedure

1. Add 5mL of Dichloromethane to 100mL of each sample.
2. Stir continuously for 1 hour.
3. Transport these mixtures to separatory funnels and wait for 2 distinct layers to appear.

4. Drain the bottom layer into a glass container.
5. Inject these samples into a Gas Chromatography Mass Spectrometer.

ii. Phosphate Content by Vanadomolybdophosphoric Acid Colorimetric Method

Materials

1. Spectrophotometer, for use at 450 nm.
2. Various Pyrex glassware.

Reagents

1. Phenolphthalein indicator aqueous solution.
2. Activated Carbon
3. Vanadate-molybdate reagent
4. Standard phosphate solutions (0.05, 0.1, 0.2, 0.4, 0.6, 0.8, 1.0, 3.0, 5.0 in ppm)

Procedure

1. *Color removal from sample.* Remove excess color in sample by shaking about 50mL with 200mg activated carbon in an Erlenmeyer flask for 5 minutes and filter to remove carbon.
2. *Color development in sample.* Place 25mL of sample, into a 50mL volumetric flask. Add 10mL vanadate-molybdate reagent and dilute to the mark with distilled water. Prepare a blank in which 25mL distilled water is substituted for the sample. After 10 min or more measure the sample versus a blank at a wavelength of 450 nm.
3. *Preparation of calibration curve.* Prepare a calibration curve by using suitable volumes of standard phosphate solutions.

Methods taken from (Standard Methods, 1998)

iii. Biological Oxygen Demand

Materials

1. B.O.D. bottles containing samples
2. Magnetic stirrer
3. Dissolved Oxygen meter

Procedure

1. Wait 5 days from time of collection.
2. Place BOD bottle on magnetic stirrer platform.
3. Open BOD bottle and place the magnetic stirrer in the bottle.
4. Insert DO probe into bottle and turn on stirring device.
5. Wait 3 minutes for probe to settle and record measurement.

Methods taken from Dr. Apichat

iv. Heavy Metal Content by Inductively Coupled Plasma (ICP) Method

Materials

1. ICP machine
2. 50mL of each sample to be tested
3. Concentrated Nitric Acid
4. Syringe with filter

Procedure

1. Collect 50mL of sample and filter using the syringe.
2. Add 3 drops of concentrate nitric acid to preserve sample.
3. Inject samples into the ICP machine and wait for readouts.

Methods obtained from Dr. Apichat

D. Social Field Forms

Date:		Time:	
Location:	<input type="checkbox"/> Village <input type="checkbox"/> Resort <input type="checkbox"/> Farm <input type="checkbox"/> Nature <input type="checkbox"/> Other:		
Relation to test sites:			
Relation to water sources:			
Relation to water disposal:			
Est. population:			
Occupations:			
Avg. annual income:			
Education level:			
Description of water source:			
Water retrieval method:			
	# pipes:		Ownership:
	Description:		
	% of population connected:		
Drinking water storage:			
Water treatment (if any):			
Wastewater disposal:			
Flow rate:			
	Retrieval site:		
	Disposal site:		
Village:			
	Avg. household population		
	# toilets/# people using them		
Resorts:		High Season	Low Season
	Capacity		
	Avg. # of guests:		
	# of residents		
Farm:			
	Residents		
	Avg. hectares		
	Product		
	Pesticides		
	Fertilizers		
Other Observations:			

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