UBC Social, Ecological Economic Development Studies (SEEDS) Student Reports

UBC Farm Water Monitoring Project – Term 1

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UBC FARM WATER MONITORING PROJECT

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

Figures

Tables

1.0 INTRODUCTION

1.1 Report Overview

The purpose of this report is to provide a detailed overview of the Water Monitoring Project we are conducting at the UBC Farm. It introduces the community at UBC farm and details meetings that were held with UBC farm clientele, team mentors, and CSL group members. Also provided is a detailed schedule for how the project tasks will commence. This report contains information about chemical constituents that could be found during the water sampling process. In addition, it outlines how sampling will be conducted, and recommends a schedule on how the farm can continue the water sampling process.

1.2 UBC Farm Background

Located east of the Strait of Georgia, the UBC farm is a student driven farming initiative on the south side of campus. It is a 24 hectare research and learning farm. With the help of students, faculty, and community members, the UBC farm strives to learn, create, and practice sustainability in agriculture, forestry and food systems.

The farm produces many varieties of produce which are sold during the summer months. It is also a research farm, and is used by the faculties of Botany, Forest Sciences, and Land and Food Systems. In addition, it contains a medicinal garden designed to grow native medical plants which are used for research and education. The farm is currently in the process of improving its water management system, and the water sampling project is one of the first steps in achieving this goal.

1.3 Project Background

The UBC farm is concerned about the quality and cleanliness of water which flows around and through the farmlands. The primary concerns of the UBC Farm are environmental friendliness and responsible water usage. Consequently, this project is focused on determining the type of contaminants present in the groundwater flowing beneath the farm, and the sources of these contaminants.

1.4. Project Overview

Our hope is to monitor the water quality of the UBC Farm. We strive to effectively and efficiently test for the most common contaminants, and provide the farm opportunities to continue sampling under budget, time, and material constraints. These objectives are ultimately aimed toward recommending practical and feasible options for the enhancement of groundwater quality, and thus contributing to responsible water use and safe environmental practices at the UBC farm.

1.5 Objectives

Our objective is to measure water quality and cleanliness by sampling ground water from various locations on the farm. To do this, we will create a sampling protocol and discuss sampling methods. Based on this discussion we will recommend the most feasible sampling technique. After initial tests, we will postulate contaminant sources. Following this we will outline treatment options and recommend the most practical one.

Project Goals for the Team:

1. Figuring out the exact location of water bodies that need to be tested.
    - Different locations will have different results, and through which we will determine the source of contamination.
2. Proposing a protocol for extracting groundwater sample in the region of interest.
    - Acquiring water samples from the groundwater flow
3. Acquiring materials or mechanisms that take water samples.
    - Buying the correct mechanism which acquires water in the local geological region.
4. Getting the water sample tested within a limited budget.
    - Sending out the samples to labs for testing.
    - Using relatively common and inexpensive methods to test for certain contaminants.
5. Analyzing the result.
    - Determining whether the amount of contaminants found is detrimental to the environment.
    - Propose treatment options if the analytical results indicate over-polluted groundwater.
6. Proposing future protocols.
    - Creating protocols that can be easily accessed and carried out by the farm.
    - Lay groundwork for future groups which can continue further studies on the water system.

2.0 PLANNING AND SCHEDULE

2.1 Activity Definition

This section will cover each activity that has happened or will happen, over the course of both term 1 and term 2, in order for this project to be completed.

First Term

- Meet With UBC Farms Organization
    ⇒ We were introduced to Andrew (UBC Farms representative) and Geoff (technical contact) during our first meeting
    ⇒ The main goals we established were: measure water quality and cleanliness at various locations around the farm, predict contaminants of interest and postulate sources of these contaminants, discuss and recommend a sampling technique, establish a sampling protocol, determine and recommend groundwater treatment options if the groundwater is found contaminated.

- Research Possible Contaminants
    ⇒ Using suggestions from Geoff and our own research, we found many possible contaminants that could be found in the ground water and wet lands at the UBC Farm
    ⇒ Due to time and money restraints, our list of contaminants was shortened to 5 main categories: pH, Nitrogen, Calcium (water hardness), Chlorine, and heavy metals (K, P, Mg, Hg)

- Establish a Protocol for Groundwater Sampling
    ⇒ Initially there were three methods which were discussed: surface sampling, pore-water sampling, and permanent well sampling
    ⇒ After discussion, though more expensive than the other options, pore-water sampling appears to be the most practical, and because it is not permanently stuck in the ground, there is no risk of leaching from the materials used

Second Term

- Conduct Initial Tests
    ⇒ We plan to use the pore-water sampling protocol outlined later in the report
    ⇒ These samples will be taken at various locations throughout the farm to help us approximate the source of certain contaminants.

- Measure Water Quality and Cleanliness
    ⇒ We plan to buy testing kits for testing pH, Nitrogen, Phosphorus, and Calcium, and, if within our budget, we will find a lab to test for Chlorine, Potassium and Mercury

- Determine Possible Treatment Options
  ⇒ Once results from the tests are gathered we can determine what sort of treatment, if any, is needed

- Recommend the Most Feasible Option
  ⇒ Once a decision is made, we will present our recommendation to the UBC Farm

2.2 Activity Schedule

First Term

- October 20th – First meeting, introductions and client/mentor contacts established
- October 28th – Met with Dr. Nesbit, discussed what needed to be done before first client meeting
- November 5th – Finalized meeting agenda, gathered client contact information
- November 12th – Reviewed client meeting goals
- November 13th – Walked around the farm and drainage ditch to get to know the area before meeting
- November 19th – Discussed client meeting and new objectives, brainstormed goals and final deliverables
- November 26th – Discussed project goals with Dr. Nesbit and distributed roles for final report
- November 28th – Met with Andrew to discuss our ideas and final goals for the project
- November 30th – Met with Alaya to review what had been learned through the course of the project, and its relation to the course
- December 2nd – Combined each individual part of the report and edited
- December 3rd – Final revision of report

Second Term (January – February [inclusive])

- Acquire Sampling Instruments
- Acquire Testing Supplies
- Conduct Initial Tests
- In Needed, Send Samples to Lab for Testing
- Examine Results, Investigate Possible Treatments if Needed
- Recommend the most Feasible Option
- Present our Findings to UBC Farms

2.3 Resource Planning, Roles, and Responsibilities

First Term

- Attending meetings – All
- Taking notes during meetings – All
- Mentor contact – Matthew
- Client contact – Brandon
- Report
  ⇒ Introduction, Research – Navratna
  ⇒ Background on UBC Farm, Objectives – Joseph
  ⇒ Sampling Techniques, Sampling Protocol, Recommendations, Treatment Options – Matthew
  ⇒ Cost, Guidelines for Water Quality, Possible Sources of Contamination – Brandon
  ⇒ Activities, Schedule – Kevin
  ⇒ Background on Contaminants & Associated Risks – Time
  ⇒ Formatting and Editing the Report - All

Second Term

- Locate Outflow Pipe in Drainage Ditch – Tim, Kevin
- Sampling Groundwater – Brandon, Joseph, Matthew, Navratna
- Measure Water Quality & Cleanliness –All (Roles divided amongst different contaminants)
- Determine Possible Treatments – All
- Final Recommendations & Report – All

3.0 CONTAMINANTS OF INTEREST

We have chosen to test for the following parameters: Hg, pH, Cl, K, Mg, P, N, Ca. Below, we have given a background on these parameters and explained how they affect the environment, why they are harmful, why they maybe present on the farmland, and their possible sources.

3.1 Environmental Effects of Suspected Contaminants

Contaminant / Indicator	Environmental Effects / Implications
Mercury (Hg)	High doses of mercury in water cause sensory and neurological damage to aquatic wildlife. Also, it causes developmental damage, especially to the eggs of mature fish. Furthermore, as the element is soluble in lipids, it may accumulate in fish, presenting a hazard to humans when eaten. A similar danger arises when plants absorb excess mercury from the soil, and are consumed by humans.
Acidity (pH)	Typically, forms of plant and soil life prefer fairly neutral soil pH levels; growing and flourishing at levels around 6.0 to 7.0. Examples are broccoli, cabbage, cauliflower, cucumbers, egg plants, peas, pumpkins, squash, turnips, strawberries, asparagus, beets, celery, lettuce, melons, onions, and spinach. If soil is too acidic or basic, the environment may be toxic for the plant life listed above (an exception is potatoes and blueberries, which while fairly common in the above range, actually prefer a pH of 4.5 – 5.5). The main reason for this is because certain mineral and nutrient are only absorbed by plants at specific acidity levels. For example, nitrogen is typically available to a plant at a pH of 5.5 or greater. However, at higher levels, availability is lost as nitrogen is used in reaction to produce ammonia. Another example is phosphorus, which is available from pH level 6.0 to 7.0. Without nutrients readily available, plants may also be vulnerable to disease. Aquatic wildlife exists roughly between pH levels 5.0 and 9.0. Water outside of this range is toxic to fish, damaging their skin, gills, and eyes. Eventually, it may be difficult for aquatic organisms to maintain proper blood pH, and death will result.

Chlorine (Cl)	The official Material Safety Data Sheet (MSDS) for sodium hypochlorite (bleach) classifies the product as harmless to the environment.
	However, research from the Pesticide Action Network claims otherwise. They tested the effects of sodium hypochlorite (chlorine) on aquatic wildlife, and found it to be toxic to fish, insects, crustaceans, molluscs, and various other organisms. It appears that the MSDS rating is due to the fact that aquatic wildlife will avoid sodium hypochlorite, and thus are rarely affected by it. Also, the compound decomposes in water systems and soils, eventually rendering it harmless.
	Overall, it takes a large amount of sodium hypochlorite to cause ecological harm. Nevertheless, we should test the drainage ditch for it.
Potassium (K)	Potassium is considered a macronutrient as it is vital to plant growth; other macronutrients include nitrogen, phosphorus, calcium, magnesium, and sulphur. Potassium's functions include aiding protein synthesis and controlling stomata (thus aiding in gas exchange).
	As with any nutrient deficiency, a lack of potassium would be detrimental to the plant's growth. The plant would be susceptible to disease and environmental conditions (temperature, etc).
	An excess of potassium absorption would interfere with the absorption of other nutrients, especially magnesium and calcium. This effect is called antagonism, also resulting in hindered plant growth and increased vulnerability.
Magnesium (Mg)	As mentioned above, magnesium is a plant macronutrient. It's fundamental in the formation of chlorophyll, which is vital for photosynthesis.
	A shortage of chlorophyll is called chlorosis, and is the result of magnesium deficiency. An afflicted plant would wither and die.
	A plant can tolerate some excess of magnesium. However, after a certain point, antagonism will exist, resulting in other nutrient deficiencies.

Phosphorus (P)	As mentioned above, phosphorus is a plant macronutrient. It's a fundamental component of nucleic acid, and therefore has great effect on all plant functions. Thus, a deficiency of phosphorus would greatly hamper a plant's growth, even more so than a magnesium or potassium deficiency. Excess phosphorus would cause antagonism, resulting in iron and zinc deficiencies specifically. Overall, there is an ideal nutrient ratio for plant growth, with some discrepancies between species. As long as the ratios are fairly within those bounds, the farm will yield successfully.
Nitrogen (N)	As mentioned above, nitrogen is a plant macronutrient. It's a fundamental component of amino acids, thus aiding in plant growth, structure, and other functions. A deficiency of nitrogen would greatly hamper a plant's growth, especially fruit development. Excess nitrogen would leave the plant and fruit susceptible to rot and disease. Nitrogen has various other effects on the environment, especially in water bodies. Ammonia, a by-product formed when bacteria decomposes the nitrogen, is highly toxic to aquatic wildlife. Nitrate, another by-product, is known to boost algae growth. Excessive algae growth is toxic to any ocean ecosystem.
Calcium (Water Hardness)	As mentioned above, calcium carbonate increases pH, which has its own environmental implications; these implications will be discussed later.

3.2 Possible Sources of Contaminants

Contaminant / Indicator	Sources
Mercury (Hg)	Fertilizers that are made from recycled waste products usually contain some toxic elements, including mercury. The problem is that fertilizers are rarely monitored or labelled with the toxic substances they contain. It's unlikely that the sul-po-mag contains any mercury, due to its basic chemical structure consisting of sulphur, potassium, and magnesium. Further, it's a naturally occurring mineral (or so the producer claims). On the other hand, the fish fertilizer can't be ruled out due to its less organic and more complicated nature. Basically, fish are heated and pressed, and then the resulting oils are processed, boiled, and stirred. During this lengthy process, there is always the potential for other recyclables and wastes to be added, thus the possible presence of mercury.
Acidity (pH)	Soil pH decreases (acidifies) by the addition of hydrogen, which is present in organic material. This means that decomposing plant matter, including that in the compost, as well as conifer needles and leaves present on the ground, contribute to the acidification of soil. Also, acid rain can contribute to low pH levels. Soil pH increases (de-acidifies) by the addition of calcium. This includes calcium carbonate (lime), which is used at the UBC Farm. Furthermore, fertilizers containing nitrate will increase soil pH levels. Whether or not nitrate is contained in the fish fertilizer is yet to be known. Lastly, soap is utilized at the harvest hut for washing and rinsing vegetables. Soap typically has a pH value of 9 to 10, which could affect the soil pH. Ultimately, we hope for a pH level of around 7.0 when we extract samples.

Chlorine (Cl)	Sodium hypochlorite, or chlorine, is used for in bleach for cleaning, disinfecting and sterilizing vegetables at the basin beside the harvest hut. The drain leads to a pipe, which leads under the fields to the drainage ditch, which flows into the ocean.
Potassium (K)	Potassium is present in the sul-po-mag fertilizer used by the farm.
	Also, potassium is present in manure, which is occasionally used by the farm.
Magnesium (Mg)	Magnesium is present in the sul-po-mag fertilizer used by the farm.
Phosphorus (P)	Phosphorus is common in fertilizers, and therefore expected in the soil from the fish fertilizer and sul-po-mag.
Nitrogen (N)	Nitrogen is common in fertilizers, and therefore expected in the soil from the fish fertilizer and sul-po-mag.
	The compost is another source of nitrogen, as nitrogen makes up 40-50% of dead plant material.
Hardness (Calcium)	Calcium carbonate (liming) is utilized at the UBC Farm.

4.0 SAMPLING METHODOLOGY

4.1 Sampling Rationale

Analysis of groundwater samples from various locations around the farm will be made in recognition of the potential for groundwater contamination. Such contamination is a consequence of local farm and human activities: the washing of farm goods at the UBC Farm Harvest Hut, the regular additions of mulches, composts, and fertilizers to the farmland, and the neighbouring construction of university residences. The groundwater monitoring efforts proposed in this report will permit the UBC Farm staff to monitor groundwater conditions, including fluctuations in chemical contaminants, throughout the year. Such monitoring efforts will be essential in determining the most appropriate methods for groundwater rehabilitation. The following section of the report will discuss possible methods of sampling, and will outline sampling and analysis protocols for the contaminants of interest; methods of analysis will be outlined in more detail later in the report. Time and expense of sampling methods place restraints on the sampling methods employed, and these restraints have been considered in our recommendation of a sampling technique. Lastly, for a greater understanding of groundwater conditions, hydrologic, chemical, and soil investigations should be conducted. But, because these investigations are beyond the scope of our report we will only make recommendations for future research. If such research is conducted, the success of sampling is certain to increase as a broader, more accurate representation of the farms groundwater will be obtained.

4.2 Sampling Techniques

For effective sampling and representative results, the method of sampling employed must be simple in design, provide sampling reliability and sample reproducibility at different locations, and be both cleanable and repairable. Further, a sampling method should cause little disturbance of the samples, possess operational simplicity, and minimize the exposure of the sample to foreign material. The three sampling methods proposed in this report exhibit all of these characteristics; however, some methods exhibit the characteristics better than others.

Surface sampling is the sampling of surface water: water that lies on the ground surface. This method of sampling is extremely simple, merely consisting of collecting water from a saturated area of low elevation, or a flowing stream, on the farmland. A sample person simply dips the open end of a pre-cleaned sample tube into the desired body of water and collects an appreciable sample. The sample person must be sure, however, not to contaminate the sample with suspended organic or inorganic matter. For example, when a sample is taken in a flowing body of water (such as the drainage ditch on the farm's property line) the sample person must stand downstream as not to

disturb bottom sediments and then collect them in the sample. Once the sample is taken, field determinations can be conducted and then the sample can be transported to a laboratory for further analysis. Surface sampling can be employed under the assumption that surface water bodies are common points of discharge for groundwater; thus, a low-lying wetland or stream near the farm would be representative of the groundwater under the farmland. Even so, a better understanding of groundwater contamination can be achieved by sampling groundwater before it is discharged into a surface water body. After all, a surface water body may be clean but the groundwater beneath it may be contaminated, and vice-versa.

Pore-water sampling is the sampling of water beneath bodies of surface water; usually, such samples are taken at points of groundwater discharge. A pore-water sampler – or Push Point – is a mechanism that is composed of a strengthening rod, a semi-perforated sheath, and a syringe; the strengthening rod provides support to the perforated zone while temporarily blocking water from entering the hollow sheath; the perforated zone allows water to infiltrate the sheath; the syringe allows for manual extraction of the infiltrating water (see Figures 1, 2, 3, and 4). After choosing a location to sample, the sample person inserts the pore-water sampler into the sediment to some desired depth – 18 in. is usually adequate as such a depth prevents surface water invasion. Once the ground surface has been penetrated, the stainless steel rod is removed; this initiates the infiltration of water into the stainless steel sheath. Tubing, which is attached to a syringe, is then clamped to the top of the pore water sampler – clamped to the top of the sampling mechanism that remains above ground. The syringe can now be utilized as a pump to manually extract water from the saturated sediment below. This same syringe (see Figures 1 and 4) can be used as the sample container, or, alternatively, the groundwater can be transferred to a more appropriate container for transport to a laboratory for analysis.

Figure 1: Groundwater Extraction via Pore Water Sampler and Syringe
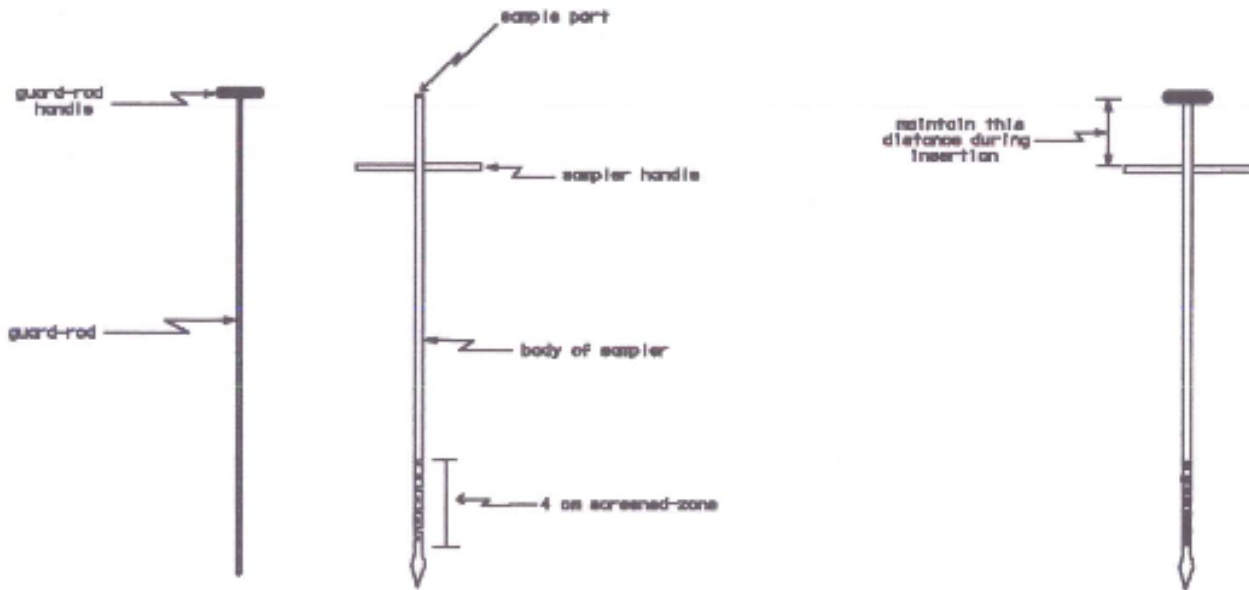Source: www.mheproducts.com

Figure 2: Pore-Water Sampling Apparatus
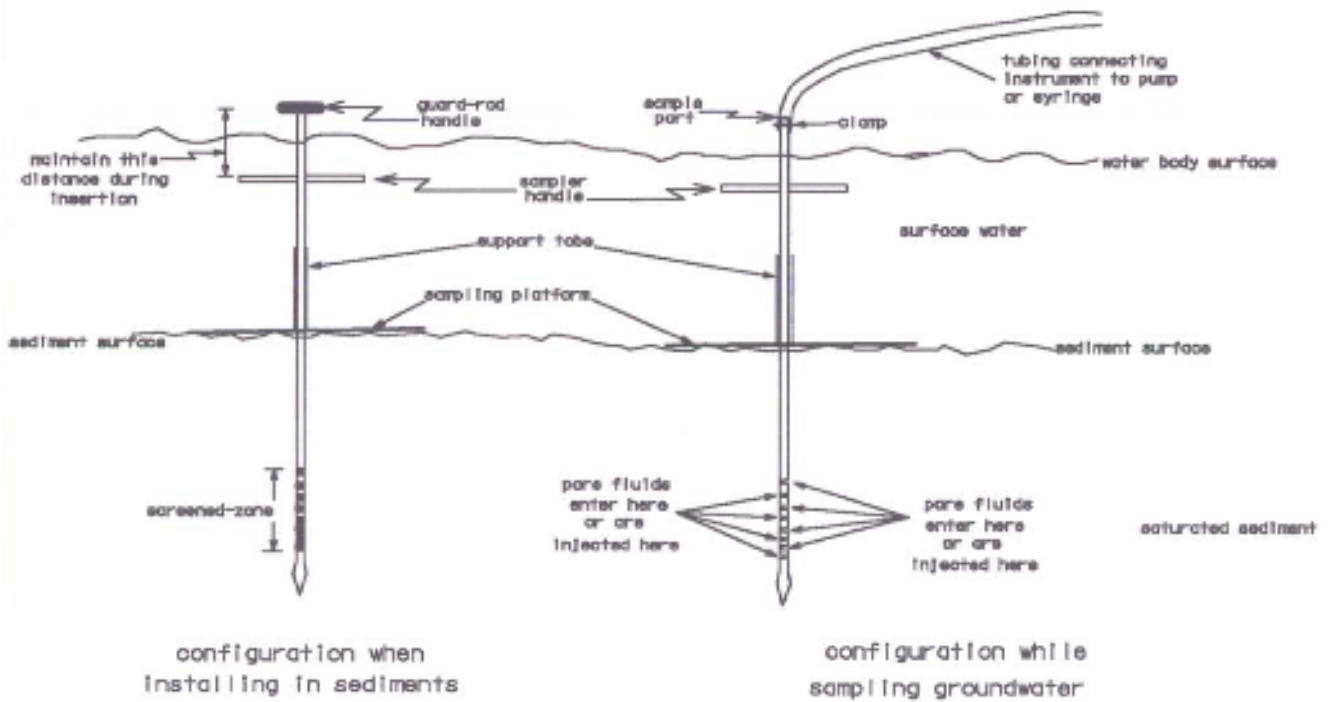Source: www.mheproducts.com

Figure 3: Pore-Water Sampler – Sampling Synopsis
Source: www.mheproducts.com

Lastly, permanent well sampling could be employed to obtain the samples needed for the farm's water monitoring objectives. Such a sampling technique requires a build-component: PVC pipe is assembled in the formation shown in Figure 4, with a permeable cap at either end of the inverted T-branch and a removable, impermeable cap at the top of the PVC tube which protrudes above the ground surface. This PVC apparatus requires the laborious excavation of a desired sampling location, followed by the placement and partial burial of the apparatus. After installation, natural conditions will be restored, and groundwater will re-saturate the surrounding sediment. When this occurs, groundwater will enter the apparatus through the pair of permeable caps, and the groundwater will remain there until sampling occurs. Samples are obtained by removing the impermeable cap and inserting a plastic tube to the bottom the shaft. This tube is clamped to a syringe, and a groundwater sample is extracted manually. As with the pore-water sampler, extracted groundwater can be transferred to a sample container for transport to a laboratory. A disadvantage of this sampling method is the potential for materials (PVC) to leach toxic chemicals into the soil and thus into the groundwater which will be sampled.
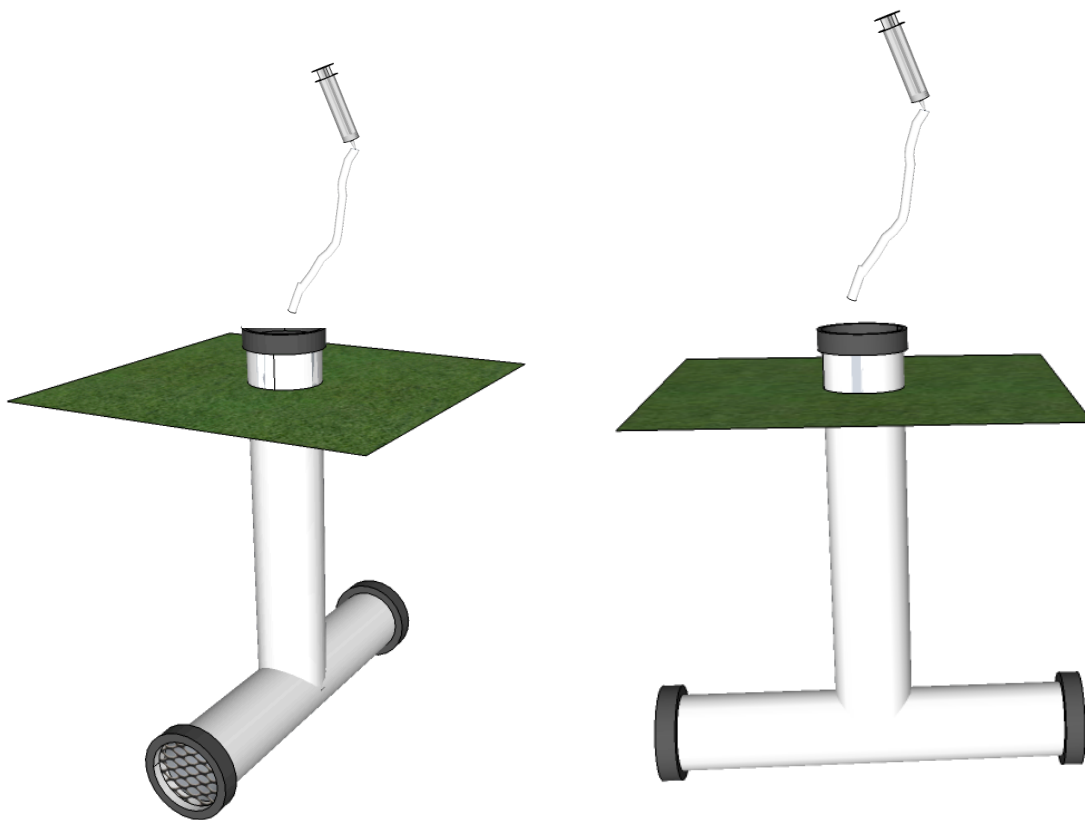

Figure 4: Permanent Well Sampling Apparatus with Syringe Assembly
Source: Google Sketch Up

As previously mentioned, surface sampling is the most simplistic sampling technique. Nonetheless, because it may not provide an accurate representation of the contaminants present in the groundwater – which is the ultimate objective of the farm and the motivation for implementing a water monitoring system – we do not recommend its use. In comparison to surface sampling, pore-water sampling is more effective in generating accurate, representative results. Further, this sampling technique is operationally simplistic, portable, and reliable. Disadvantageous is the costs associated with this technique. Costs of this sampling technique, as well as the costs of materials for other sampling techniques, are provided in Table 3. Another disadvantage of the pore-water sampler is its inability to extract water samples from subsurface regions of large-grained material (large gravels and rocky soils), as well as from unsaturated soils; nonetheless, we have assumed that the farmland soils that we are extracting samples from is mainly small, well-sorted fluvial deposits that would allow easy penetration of the pore-water sampler. Further, sampling locations will be determined by the migration of farmland groundwater (see Figure 5); therefore, sampling will always occur in saturated soils. Alternatively, a shallow, permanent well could be installed, but given the time and labour required for construction and installation of this sampling mechanism, and the inconvenience of only being able to sample the location at which these wells are installed, we are not advising that the farm build such a sampling device. Thus, given the associated costs, operational simplicity, accuracy, reliability, and the time and labour requirements for the use of certain sampling mechanisms, we recommend that the farm purchase a pore-water sampling device at the cost specified in Table 3. Purchasing such a device will also allow for fast, practical sampling at various locations around the farm; more specifically, sampling will not be limited to a single surface water body in a low elevation area of the farm, nor will it be limited to a specific location along the drainage ditch. Instead, groundwater samples can be taken at any location – at the Harvest Hut, on the farmland where composts, fertilizers, and mulches are laid, at numerous locations along the drainage ditches and around the low-elevation areas where surface water-bodies are prominent. The only constraint is that soils at these locations must be saturated.
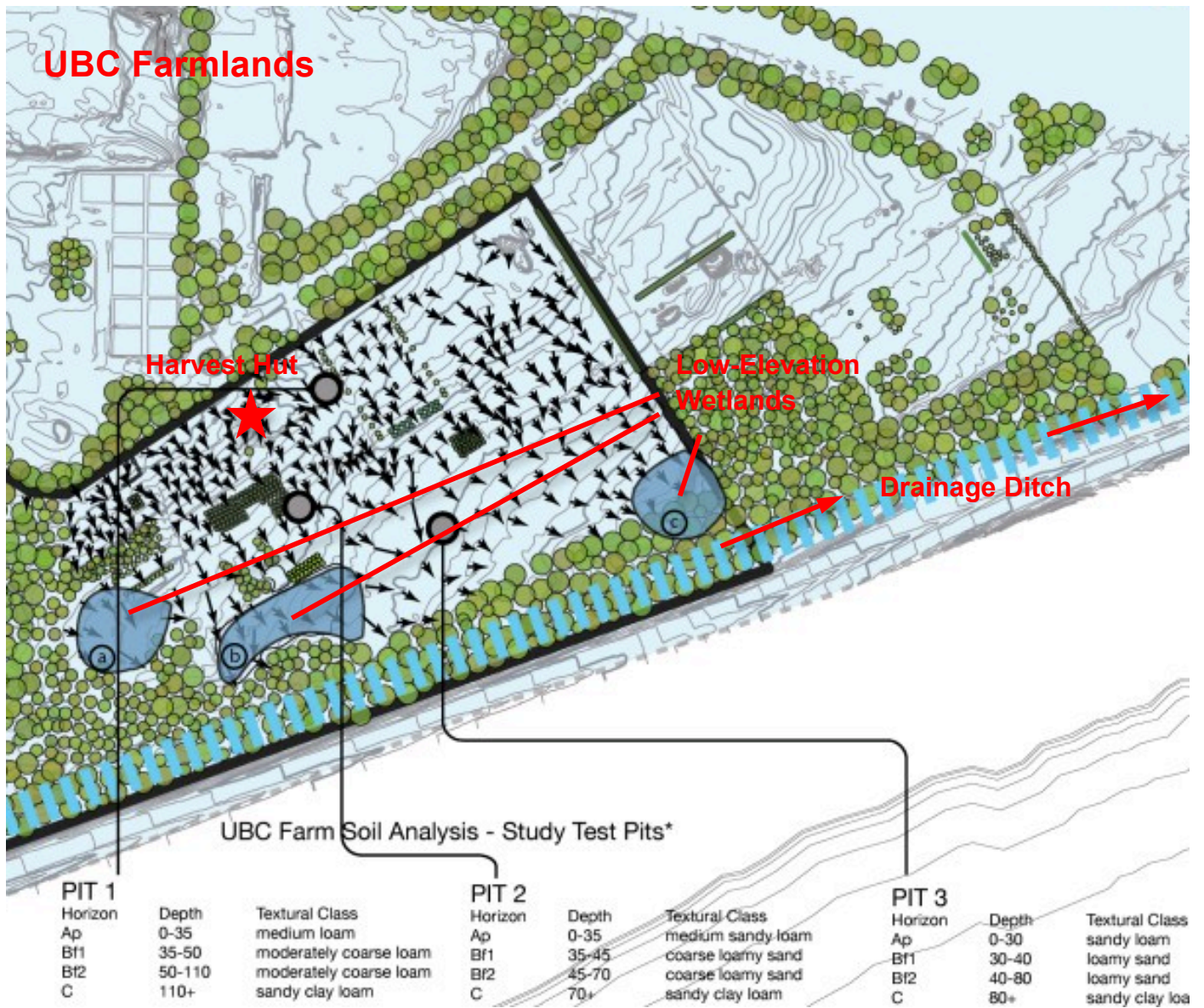
Figure 5: UBC Farm Groundwater Flow Pattern
Source: UBC Farm Archives

4.3 Sampling Protocol

Regardless of the technique chosen for the extraction of groundwater samples, there are common sampling protocols that should be employed to ensure accurate analytical results. After all, laboratories and persons conducting field tests can only report data based on the quality of the samples: sampling errors are carried over into laboratory analysis. The following sampling protocol will minimize such errors.

4.3.1 Preparation

Before samples are collected, some preliminary measures must be taken. Firstly, sampling equipment must be cleaned and decontaminated: sample bottles must be emptied, rinsed, and dried, and the pore-water sampler must be rinsed and decontaminated. This is especially important when testing for contaminants of interest that exist in low concentrations. Secondly, sampling labels and forms should be completed to the furthest extent possible before sampling occurs. Lastly, a sample person should anticipate the contaminants present in the region they are going to sample in an attempt to establish quality objectives; for example, when testing for trace metals, it may be advisable to use new sample bottles as any residual water or soaps from rinsing out old bottles may compromise the sample. Further, gloves should be worn while sampling and should not come in contact with the media being sampled.

4.3.2 Assessment

Also before sampling, a sample person should observe and document the weather and the depth of the surface water (as changes in water levels may correspond to changes in groundwater quality changes). All other observational data concerning groundwater should also be recorded (see Figure 6): odour, visible contamination, color, and turbidity. Documenting such observations can aid in the explanation of results.

4.3.3 Location

The geologic setting, the site hydrology, water level information, and direction of surface water flow should influence the locations of sampling points. With regard to the UBC Farm, the Harvest Hut washbasin and the fertilizers, mulches, and composts added to the farmland are the most likely sources of contaminants. It is known that the wash water from the Harvest Hut drains into the drainage ditch and that the chemical constituents from the farmlands migrate toward the lower elevation regions of the property. Thus, logical locations for sampling include the saturated, low-elevation areas, and various points along the drainage ditch (see Figure 5). Locations of sampling should be marked on a map for future reference. Documentation protocols are outlined below.

4.3.4 Frequency

Sampling frequency is largely dependent on the site and the monitoring objectives. For example, during the summer months when the crops are plentiful and the Harvest Hut is in regular use, sampling frequency may increase; this sampling increase is resultant of increased chemicals being washed down the Harvest Hut drain, and the increase in composts, fertilizers, and mulches – in addition to increased irrigation – added to the fields. Time and money also place constraints on the frequency of sampling at the UBC farm. Under the initial budget, and after the purchasing of the sampling equipment, only initial tests will be conducted; however, after these initial tests are conducted, and after the samples have been analyzed, we will have a better understanding of the sampling frequency needed to meet quality objectives. Until then, we propose that sampling should occur quarterly, or, if the budget allows, monthly.

4.3.5 Documentation

As previously mentioned, all labels and forms should be partially completed before sampling. During sampling, the remainder of these forms should be filled out. A typical sample log is included in the figure below (see Figure 6). This sample log, which records dates, times, and locations of collection, as well as time of storage, should accompany the documents that outline the analytical results from both the field and the laboratory. Such documents are essential to mapping contaminant concentrations and locations over time. Also, locations of sampling should be recorded on a map of the UBC Farm (see Figure 5).

MONITORING WELL SAMPLING DATA   **WELL NO:**_____

Project:_____

Location descript.:_____ Township:_____ Range:_____ Section:_____.

Sample no.(s):_____ GPS Lat.:_____ GPS Long.:_____

Sampling date:_____ Sampled by: _____

Sampling method:_____ Weather:_____

Sampling time:_____ Amb. Temp. (°F):_____

Observations/Field Information: _____

_____
_____

Figure 6: Sample Log
Source: Source: Practical Guide for Groundwater Sampling, 1985

4.3.6 Quality Control

The basis of our water-monitoring project is groundwater quality in relation to the total dissolved solids content: Ca, N, K, P, Mg, Hg, Cl. To ensure quality of the samples, and thus accurate analytical results, we advise that turbidity be minimized. Turbidity (the amount of suspended solid particles) can drastically affect the results by absorbing the dissolved solids listed above and therefore inhibiting their detection in analysis. Further, stagnant water should be avoided when sampling as these water bodies can promote bacterial growth and changes in chemical composition of contaminants – events that are uncharacteristic of groundwater flows. Lastly, when sampling groundwater in an attempt to determine a certain locations pH, be sure to collect samples a generous distance away from outflow sources. For example, when testing for pH, a groundwater sample should be extracted from a field or low-elevation wet area. A sample should not be extracted by a flowing body of water (such as the drainage ditch) as water flows will continually saturate the surrounding area and increase the alkalinity of the groundwater; this occurs due to the de-concentration of acids present in the groundwater.

4.3.7 Extraction and Collection

Extraction and collection methods are outlined in the Sampling Techniques section above. It should be noted, however, that modification of the extraction and collection methods will likely be necessary once initial samples are obtained.

4.3.8 Storage and Transport

Proper storage and transportation of the samples collected guarantees that the water quality of the sample is not compromised between the time of collection and the time of analysis. In most sampling procedures, chemical reactions must be limited, as does exposure to heat and light, but for our sampling objectives and contaminants of interest, this precaution will not be necessary. Nonetheless, analysis should be conducted soon after sampling, and therefore groundwater sampling should be correlated with laboratory hours of operation. If possible, field analysis should be conducted using test kits; such analysis will be explained later in our report.

5.0 METHODS OF ANALYSIS AND INTERPRETATION OF RESULTS

pH

pH will be determined using pH test strips. The strips are dipped into the sample water and then removed, at which point the strip will change colour depending the pH level. The strip will then be compared to a colour chart to find the matching colour which will then allow for the determination the corresponding pH value. It can then be determined if the reading is safe by consulting the table for maximum and minimum pH values (see Tables 1 and 2).

Water Hardness

The water hardness will be measured using testing strips. The strips are dipped into the sample water and then removed, at which point the strip will change colour depending the water hardness. The strip can then be compared to a colour chart to determine the corresponding water hardness in ppm (parts per million). These values will be recorded and monitored to determine if there are any trends relating the pH and water hardness.

Nitrogen

Nitrogen concentrations can be determined using test strips. The strips are dipped into the sample water and then removed, at which point the strip will change colour depending on the nitrogen level. The strip will then be compared to a colour chart to determine the corresponding nitrogen level in ppm. This value must then be converted to mg/L using the approximation of 1 ppm = 1 mg/L for aqueous solutions (Conversion from ppm to mg/L, 2009). Once the nitrogen level has been determined in mg/L, it can be compared to the maximum allowable level found in Table 1.

Note: Maximum allowable level for nitrogen is dependent on temperature and pH so these parameters must be determined prior to conducting a nitrogen test.

Mercury

Mercury levels cannot easily be determined in the field; therefore, samples will need to be sent to a laboratory for more comprehensive water analysis. Once the results are received from the lab they can be compared to the maximum allowable levels to determine if the mercury is within a safe range.

Chlorine

We had originally planned to test chlorine using a simple titration method, but, unfortunately, the test was not sensitive enough to detect the low levels that we expect. The field test that must be used to detect small levels is very expensive and well outside our budget, so we will attempt to find a laboratory that can test for small levels within our budget. Once we determine the chlorine level we can compare it to the maximum allowable level to determine if the amount in the drainage ditch is safe or not.

Potassium

Potassium cannot be tested cheaply in the field so we will be sending a water sample to a laboratory for more comprehensive tests. The results from the laboratory will indicate the amount of potassium present.

Phosphorus

Phosphorus can easily be tested in the field using a common test kit used for aquariums. Unfortunately, this is only effective for a small range, and we will therefore only use this test kit to determine the amount of phosphates present. But, if it proves to be inadequate for our needs we will send a sample to a laboratory for more comprehensive tests.

6.0 WATER QUALITY GUIDELINES

Once the results of the groundwater analysis are received, we will interpret them to determine if the water in the drainage ditch is safe enough to support aquatic life. We will compare the results to fresh water standards establish by the BC Government. The following table provides the maximum safe levels for various contaminates and nutrients.

Table 1. Contaminant Regulations

pH	6.5-9.0 As long as Carbon Dioxide levels stay within 10 µmol/L and 1360 µmol/L
Water Hardness*	Varied. Rivers and streams tend to range from 1ppm to 100ppm
Nitrogen	Dependent on pH and temperature. (See Table 1)
Mercury	0.1 µg/L
Chlorine	100µg/L
Magnesium	Included in Water Hardness
Phosphorus	Non Proposed. Lakes with aquatic life are recommended to be below 15 µg/L
Potassium	No recommended levels.

Source: www.env.gov.bc.ca/wat/wg/BCguidelines

* There is no maximum or minimum range for water hardness since levels tend to vary significantly depending on region. Water Hardness does however tend to significantly affect other aspects of a streams chemistry such as pH, therefore it will be monitored to determine if any changes in pH correspond to changes in Hardness.

Table 2. Maximum Concentration of Total Ammonia Nitrogen for Protection of Aquatic Life in mg/L

Temperature (T) in degrees Celsius

pH	T=0.0	T=1.0	T=2.0	T=3.0	T=4.0	T=5.0	T=6.0
6.5	27.7	28.3	27.9	27.5	27.2	26.8	26.5
6.6	27.9	27.5	27.2	26.8	26.4	26.1	25.8
6.7	26.9	26.5	26.2	25.9	25.5	25.2	24.9
6.8	25.8	25.5	25.1	24.8	24.5	24.2	23.9
6.9	24.6	24.2	23.9	23.6	23.3	23.0	22.7
7.0	23.2	22.8	22.5	22.2	21.9	21.6	21.4
7.1	21.6	21.3	20.9	20.7	20.4	20.2	19.9
7.2	19.9	19.6	19.3	19.0	18.8	18.6	18.3
7.3	18.1	17.8	17.5	17.3	17.1	16.9	16.7
7.4	16.2	16.0	15.7	15.5	15.3	15.2	15.0
7.5	14.4	14.1	14.0	13.8	13.6	13.4	13.3
7.6	12.6	12.4	12.2	12.0	11.9	11.7	11.6
7.7	10.8	10.7	10.5	10.4	10.3	10.1	10.0
7.8	9.26	9.12	8.98	8.88	8.77	8.67	8.57
7.9	7.82	7.71	7.60	7.51	7.42	7.33	7.25
8.0	6.55	6.46	6.37	6.29	6.22	6.14	6.08
8.1	5.21	5.14	5.07	5.01	4.95	4.90	4.84
8.2	4.15	4.09	4.04	3.99	3.95	3.90	3.86
8.3	3.31	3.27	3.22	3.19	3.15	3.12	3.09
8.4	2.64	2.61	2.57	2.54	2.52	2.49	2.47
8.5	2.11	2.08	2.06	2.03	2.01	1.99	1.98
8.6	1.69	1.67	1.65	1.63	1.61	1.60	1.59
8.7	1.35	1.33	1.32	1.31	1.30	1.29	1.28
8.8	1.08	1.07	1.06	1.05	1.04	1.04	1.03
8.9	0.871	0.863	0.856	0.849	0.844	0.839	0.836
9.0	0.703	0.697	0.692	0.688	0.685	0.682	0.681

Source: www.env.gov.bc.ca/wat/wg/BCguidelines

7.0 GROUNDWATER MONITORING EXPENSES

Table 3. Equipment, Material, and Analysis Costs for Groundwater Testing

Test	Test Cost	Where to Buy
Phosphorus	$15 – 75 tests	Local Pet Supply Store
	$36 – 3 tests	ALS Laboratories
Chlorine	$33 – 3 tests	ALS Laboratories
Mercury	$45 – 3 tests	ALS Laboratories
Potassium	$45 – 3 tests	ALS Laboratories
pH	$10 – 50 test strips	-Local Pet Supply Store -Chemistry Supply Store
Nitrogen	$20 – 100 tests strips	Anachemia Science On-line Catalogue (pg 1266)
Water Hardness	$20 – 50 tests	Anachemia Science On-Line Catalogue (pg 1266)

Equipment Required	Equipment Cost	Where to Buy
36" Push Point 1/4" ϕ	$60	mheproducts.com
27" Push Point 1/8" ϕ	$100	mheproducts.com
Syringe Assembley 1/8" ϕ	$5	mheproducts.com
Syringe Assembley 1/8" ϕ	$6	mheproducts.com
Shipping	$15	mheproducts.com
PVC, Permanent Well Apparatus	$0	Materials supplied by/salvaged at the farm
Sampling Containers	$0	Provided by ALS Laboratories (the price of the sampling containers is included within the cost for laboratory analysis – ie. the $45)

Source: ALS Laboratories, Anachemia Science, www.mheproducts.com

8.0 CONCLUSION

8.1 Recommendations

- We recommend that the sampling protocol issued in this report be followed when extracting groundwater. Sampling procedures affect analytical results and contribute to the overall quality of the data set; therefore, following the outlined protocol will minimize analytical error.
- Considering operational simplicity and reliability in sample quality, as well as portability, time and labour requirements, we recommend that the farm purchase a pore-water sampling device for their groundwater sampling needs. This device's equipment costs are provided in Table 3; also, refer to Figures 1-4 for associated graphics, and refer to the Sampling Techniques section for information on utilization of the device.
- Through research of the expected contaminants present in the farmland's groundwater, we have concluded the following:
    - pH alterations in the groundwater can be attributed to various sources. Thus, regular monitoring should be conducted to ensure that groundwater acidity remains within practical bounds – between 6.5 and 9.
    - The presence of calcium in the groundwater is natural, but large variations in calcium concentrations can be attributed to the lime additives distributed on the farmland.
    - Large fluctuations in the nutrients N, K, and P are a result of the compost and mulch additions.
    - Variations in chlorine concentrations are resultant of bleach use at the Harvest Hut.
- We hypothesize that the fertilizers, mulches, and compost additions are regular sources of Nitrogen, Potassium, and Phosphorous. Further, fluctuations in pH are likely resultant of the compost and lime additions, and the chlorine can be traced to the use of bleach at the Harvest Hut.
- We recommend that a soil case study group analyze the soil type and soil distribution throughout the farmland as well as the soil's effect on the velocity of groundwater flow. Such an investigation will allow for the determination of an appropriate sampling frequency.
- We recommend that other students trace the exact sources of the contaminants found during sample analysis; this will require an investigation of the composition of soaps used at the Harvest Hut. The chemical and organic mixtures – the mulches, fertilizers, and composts – should also be studied to determine their composition.

8.2 Treatment Options

A list of treatment options for the contaminants of interest has been compiled below:

- The chemical constituents present in the fertilizer, mulch, and compost will not require additional treatment to that of natural treatment processes: we suggest that the marshlands that occupy the lower elevation regions of the farm be utilized as a medium for filtration. Through this natural filtration process, K,P, N, Ca, and Mg will be reduced to natural levels before being leached into the drainage ditch.
- With respect to the additions of mulch, fertilizer, and compost, we recommend numerous hours of leaching by rainfall before vegetation is planted. This will allow for the initially high, and potentially harmful, salt and nitrate concentrations to subside.
- Regarding the chlorine present in the groundwater, we recommend that new, environmentally friendly soaps be used.

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