UBC Social Ecological Economic Development Studies (SEEDS) Student Report

An Investigation into New SUB Rooftop Garden Irrigations Systems

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ABSTRACT

The objective of this report is to assess a variety of irrigation systems and make an informed recommendation to the committee responsible for implementing the new Student Union Building rooftop garden at UBC. While reviewing this paper, the reader should take note that the water source and its availability were not included within the scope of research. It was assumed that access to a reliable supply of potable water would not be an issue.

The following three systems (1) Drip Tape, (2) Sub-irrigation and (3) Conventional sprinklers were analyzed extensively using a triple-bottom line assessment. This evaluation process consisted of examining the ramifications of all possible economic, environmental and social issues. The result is that water consumption, recyclability and durability or life expectancy emerged as critical features to compare. While each system had their own strengths and weaknesses, it was determined that a **conventional sprinkler system** would both meet the crop watering demands and, if installed correctly, serve as a worthy demonstration piece on sustainability.

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GLOSSARY

Coefficient of Determination (R^2)	Statistical measurement of the variance between two data sets. High R^2 values indicate similar data sets, were low R^2 values indicated dissimilar data sets.
Down Cycling	A process in which products are recycled by turning them into products of lower value than from which they were originally derived
Emitters	Plastic devices attached to irrigation piping that provide a controlled local release of water
Polyethylene	A thermoplastic polymer that is widely used for plastic items. While some types are recyclable, it is generally considered non-biodegradable.
Embodied Energy	Embodied energy is the total primary energy consumed during the life time of a product.
Embodied Carbon Dioxide Emissions	This is carbon dioxide emitted at all stages of a good's manufacturing process, from the mining of raw materials through the distribution process, to the final product provided to the consumer.
Cradle-to-Gate	Includes analysis of all energy (in primary form) until the product leaves the factory gate.

LIST OF ABBREVIATIONS

UBC	University of British Columbia
SUB	Student Union Building

1.0 INTRODUCTION

Plans are currently being developed for a new Student Union Building (*SUB)* at the Vancouver campus of the University of British Columbia (*UBC*). Since 2007, various consultations and referendums have been conducted to determine what features and characteristics the UBC student body would like to see implemented in the new SUB. The consensus taken was that, in keeping with the environmental theme of today's world, the building should strive to be fully sustainable with as little impact on its surrounding area as possible. The task presented to the development team, which consists of the Alma Mater Society (AMS), UBC Properties Trust and HBBH+BH Architects, was to determine how best to represent this through the new SUB building. One of the many "green" solutions they created was to incorporate an intensive rooftop garden for urban agricultural purposes. The aim of this paper is to clearly identify the existing watering options available and make a suitable recommendation based on the social, economic and environmental impacts involved.

1.1 EXISTING ROOFTOP GARDEN EXAMPLES

Throughout the world, many city centers have begun integrating organic plant material into buildings in an effort to create a more natural environment and mitigate many of the pollutants found in densely populated urban areas. This comes in the form of green roofs, living walls, parks and other vegetative areas. A prime local example of this movement is the landscape roof atop the recently completed Vancouver Convention Centre. This six-acre ecosystem is irrigated by a conventional impact sprinkler system that uses the building's "blackwater" treatment plant, which results in less clean water consumption.

Another suitable local example is the 650 ft^2 rooftop garden at the YMCA in Vancouver, which provides fresh, nutritious produce for women at a family resource center in the Downtown Eastside. Established in 2007, the garden is now capable of harvesting more than 450 kilograms in organic fruits and vegetables. The garden is a both a container and raised bed layout, as pictured in Figure 1.

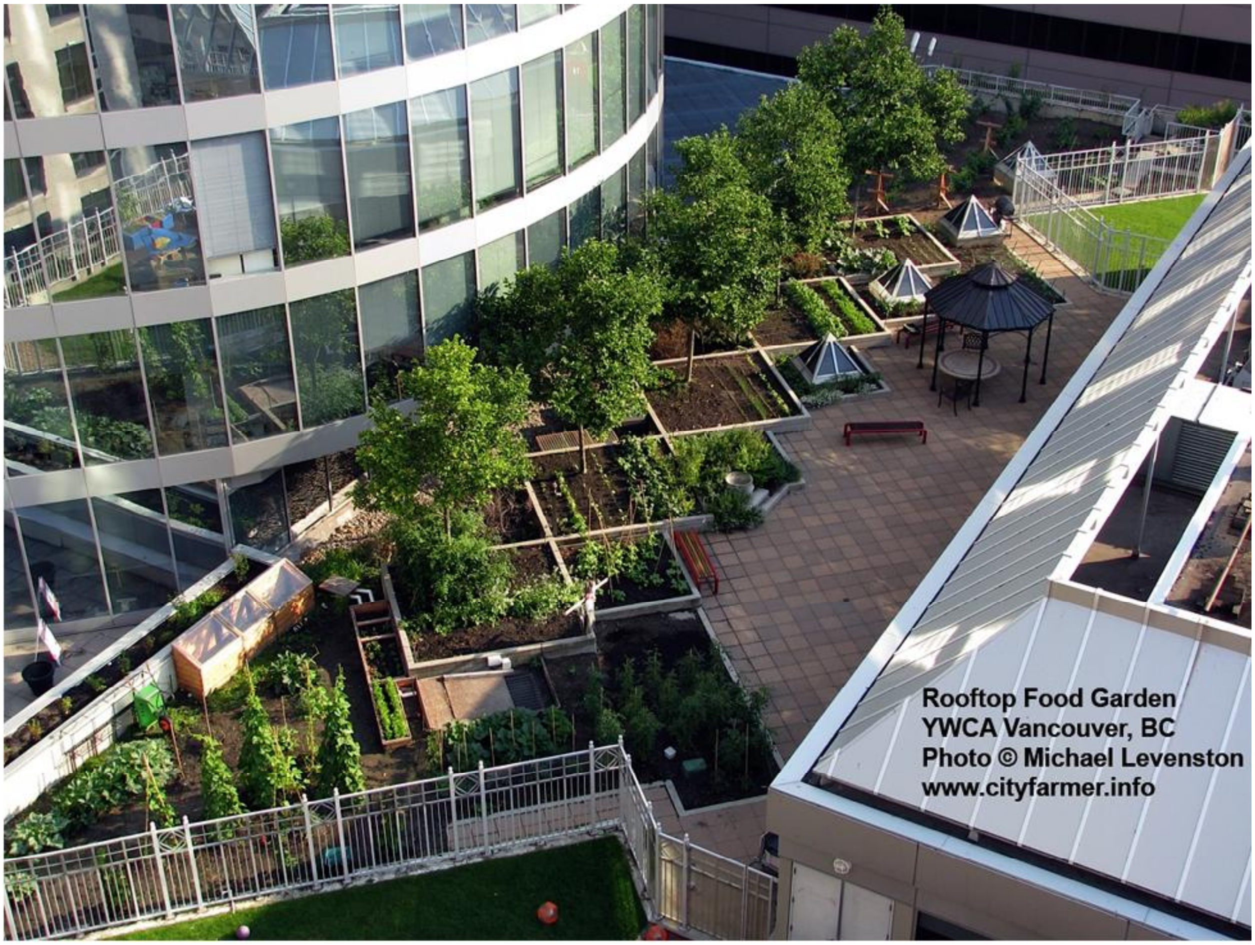

Figure 1 : YMCA Rooftop Food Garden
Source: Michael Levenston, www.cityfarmer.info

However, as will be discussed later in the financial analysis of each system, the YMCA garden is serviced and maintained by a group of volunteers. This obviously reduces costs and allows more hand watering to be used; as opposed to installing a costly automated irrigation system. Still, this is one of the many environmental innovations the new SUB development team is hoping to emulate with the proposed rooftop garden.

2.0 GARDEN DETAILS

As of the writing of this paper, the new SUB building schematics were approximately 75% complete with the exterior color currently being decided. However, the preliminary details of the location and layout of the rooftop garden have been all but established, as seen in Figure 2.

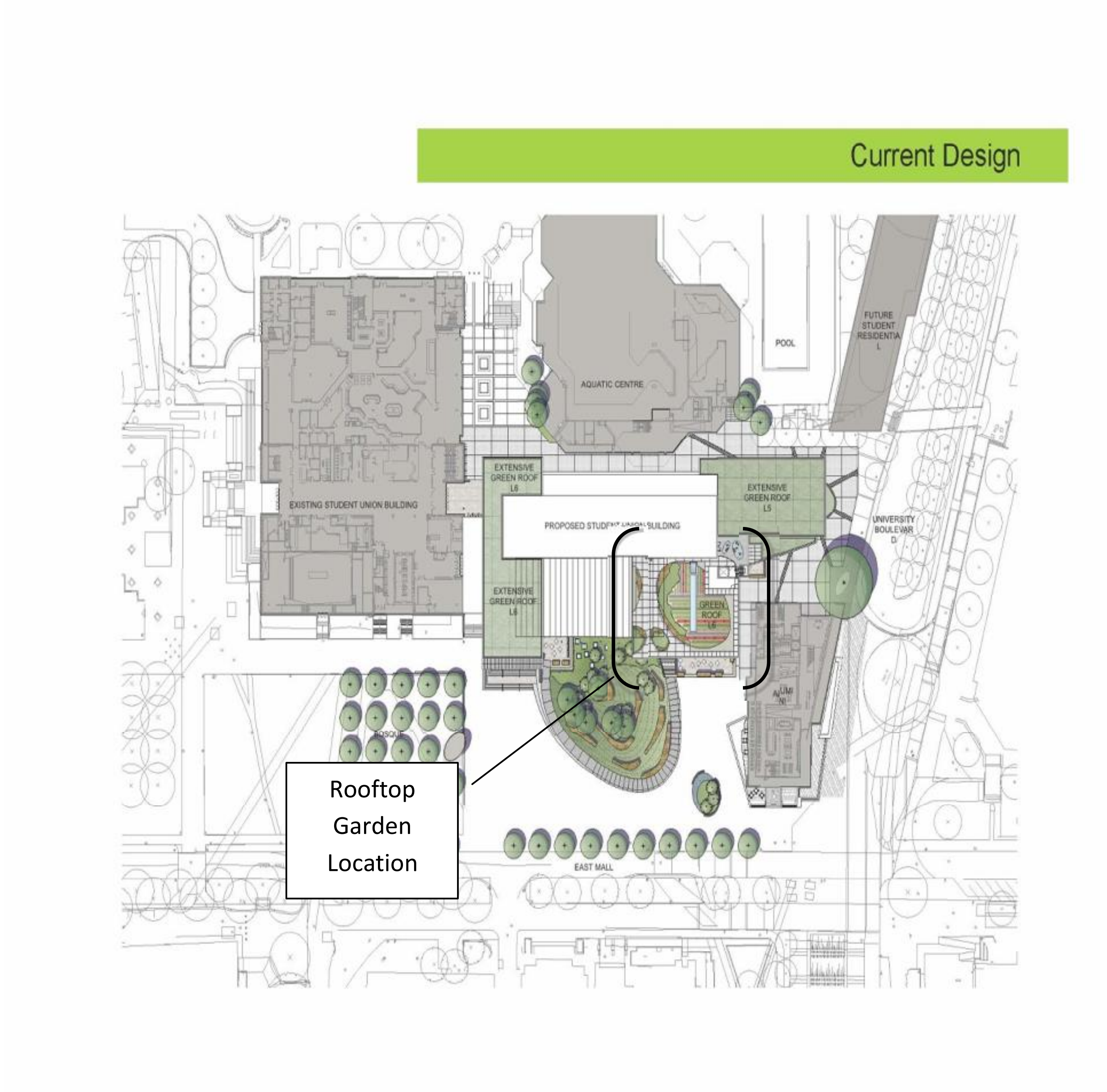

Figure 2 : Overall Layout of new SUB
Source: www.mynewsub.com

The new SUB will be built between the existing SUB, Aquatic Center and the soon to be developed Alumni building. From the rooftop garden, students will be able to look west out onto the remaining grassy knoll and East Mall road.

2.1 SPECIFICATIONS

For the irrigation systems considered in the assessment, each was evaluated based on watering the same garden layout for consistent comparisons. A more detailed planned view is portrayed in Figure 3.

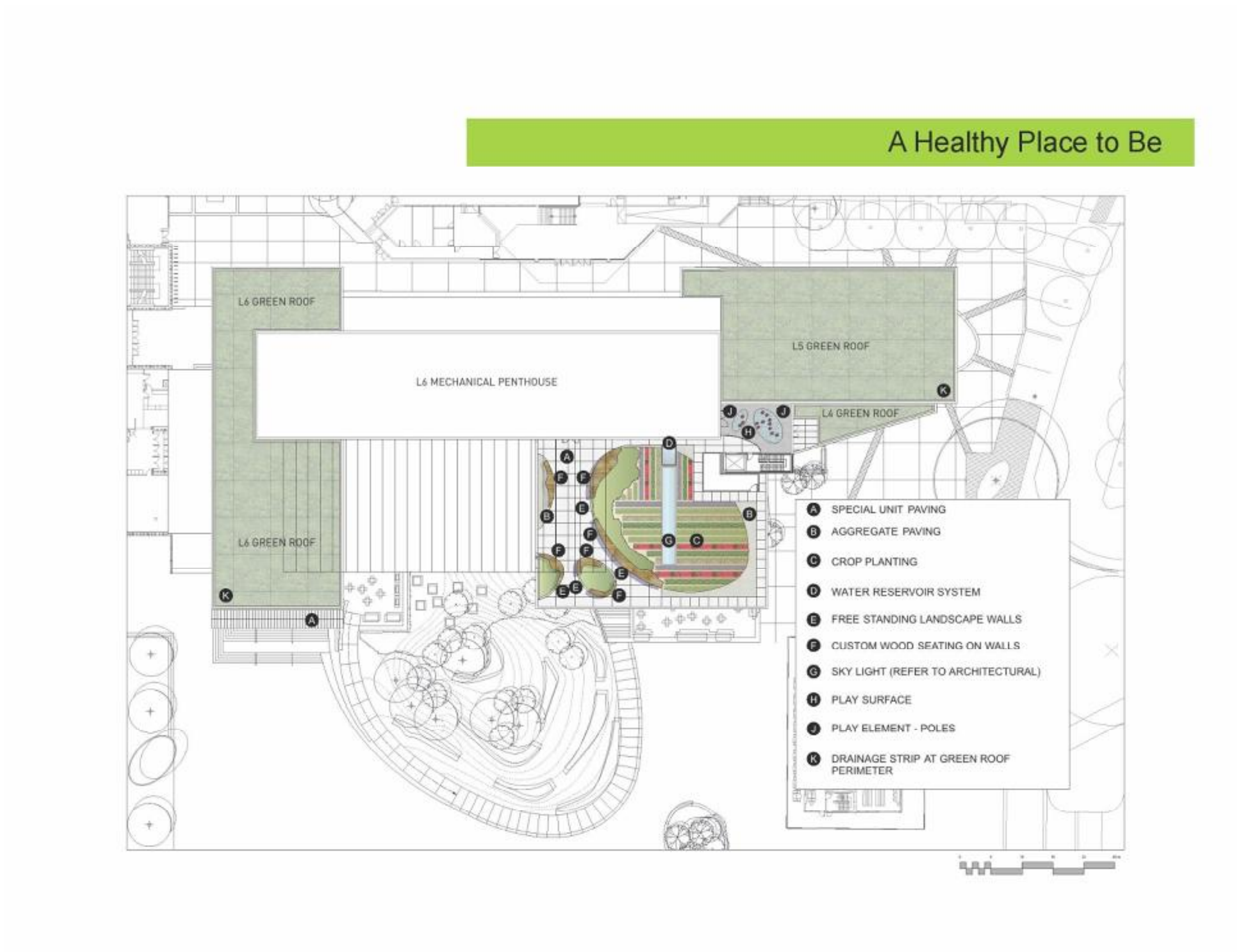

Figure 3 : Closer look at rooftop garden
Source: www.mynewsub.com

The garden will consist of approximately 4600-6500 ft^2 of actual crop production and will be situated on the 5th floor. It will most likely be a raised bed design with an accompanying greenhouse, artificial beehives, water storage wells/reservoirs and a storage shed for landscape tools and supplies. All access will be limited to either the stairs or elevators which must be taken into account, since this limits the size and weight of any machinery or tools that may be required for installation/ maintenance of the irrigation system.

The systems being analyzed are to provide water for a variety of crops that will provide fresh produce for the restaurants operating in the new SUB. The potential crops for production will consist of mainly herbs, basic vegetables and certain perennial fruits.

2.2 WATER REQUIREMENTS

Another aspect to consider with this feasibility study was to include some additional information on water monitoring systems. To aid in water conservation, the new SUB development desired a device that would be capable of determining not only when to water but also how much water to distribute.

However, the authors of this report found that to speculate on which crops would be planted and attempt to make a pertinent recommendation based on that assumption would be foolhardy. Instead, the decision was made to focus on the relevant systems and emphasize how different water control techniques could be implemented with each irrigation set-up.

It should also be noted that throughout this study, the source of the water was not considered or discussed. Ideally, this water source would be suitable for growing, clean enough for produce consumption and come from a renewable resource. However, as discussed with Ms. Andreanne Doyon, the new SUB Project Coordinator, the scope of this paper is not the water source but rather, the preferred method of distribution.

3.0 DRIP IRRIGATION

Drip irrigation is one of the most efficient and common irrigation techniques used for commercial and home gardens. It also seems to be the most popular technique for green roofs on commercial buildings. It can be implemented at a very large scale for commercial farming or at a small scale for home landscaping. Like most irrigation systems, drip irrigation is not complicated. An average drip tape setup is meant to be put together by anyone with a proper drawing of the system layout.

On a small scale, in this case roughly 6000 ft^2, a drip tape system consists of less than a dozen components. Since our rooftop garden is located on the 5th floor of the new SUB building, we will presumably be using water pumped from the building's central supply. For this configuration, a simple drip irrigation system consists of the following components:

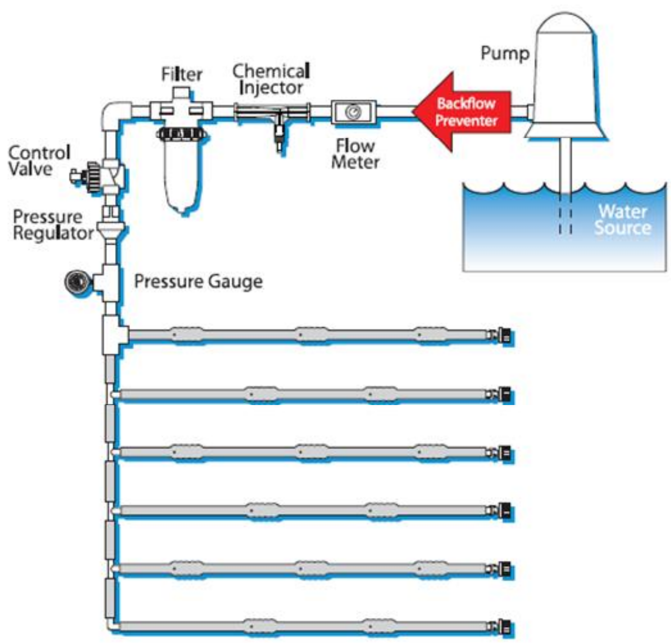

Figure 4 : Typical layout of a drip irrigation system
Source: http://www.dripirrigation.org/images/ALT142_What%20Is%20Drip%20article_WEB.pdf

COMPONENTS	DESCRIPTION
Pump	Not needed since we are, presumably, using the building's water source
Backflow Preventer	To stop water backflow
Flow Meter	To measure water consumption
Chemical Injector	For accurate and efficient distribution of fertilizers and other chemicals
Filter	Filters out the particles in the water to prevent pipes from clogging. (This might not be needed since the water will be filtered by a central system.)
Control Valve	To start and stop the system
Pressure Regulator	For regulating the water pressure to prevent bursting of the tapes or connectors.
Pressure Gauge	For measuring the water pressure
Mainline/Sub-main	Pipes for delivering the water to the drip lines
Drip Tape	Polyethylene drip tape with pressure compensating emitters on them to distribute water to the plants.

Table 1: Typical Drip irrigation system components

3.1 ECONOMIC ASSESSMENT

Advantages

Drip irrigation has many economical benefits; some are evident and can be quantified, while others are more difficult to distinguish because they are imbedded in the day to day running of the garden. Versatility is a major advantage of drip irrigation as it can be tailored to fit the soil and plant type to provide maximum efficiency [28].

One significant saving from using drip irrigation is water. Other irrigation systems like sprinklers tend to waste a large amount of water because it moistens not only the plants, but also the empty row spacing and the leaf of the plants. The resulting evaporation and run off makes sprinkler irrigation system not very water efficient. By using a drip system, we can minimize or even eliminate water runoff, leaching and wetting of non-targeted areas. The resulting savings is up to 70% in water cost [6][30].

Drip irrigation also reduces fertilizer and pesticide costs because the chemicals are delivered much more accurately and efficiently using the chemical injector than simply using a manual sprayer. It is also simpler to control the amount of chemical for each plant. Since the water is targeted and distributed evenly among plants, there are less weed and grass growth, and therefore less labour is needed to remove them. This could save up to 1-2 man hours every day during the growing season. Since drip tape only waters the root of the plant, most farmers using drip irrigation system notice an increase in crop yield and quality, which in the long term can translate into more revenue per square foot of land [6].

Disadvantages

Drip irrigation requires much more planning than conventional systems. They need to be laid out at the start of the season and collected for storage at the end of the season. The initial setup at the start of each season takes more than three times the time to setup a sprinkler system [30]. The water filters needs to be checked regularly to ensure no water impurities are building up and clogging the emitters.

One factor that stops some farmers from using a drip is its high initial cost. Depending on the wall thickness of the drip tape, they need to be replaced every one to three years [29][30][33]. They are drip tapes designed to last longer, but they need to be stored carefully on a big spool to prevent the tapes from bending and breaking. Since no heavy machinery can be transported up the service elevator, this might not be an option [11].

3.3 ENVIRONMENTAL ASSESSMENT

Advantages

Water is becoming one of the most previous resources on earth, and farming is a huge consumer of water. For people living in Vancouver, water shortage is typically never a concern, but for places like California or South Africa, water shortage is a common occurrence. Drip irrigation is especially popular in these areas since it conserves water.

Disadvantages

Drip tape is made of *polyethylene* plastic. Since polyethylene cannot be consumed by micro organisms, they only break down into smaller and possibly more toxic polymers; which has the ability to attract industrial contaminants and pollute our soil and waterways [31]. Although there are some bio-degradable drip tapes coming into the market, currently they are not readily available in Canada yet. Therefore, the major environmental concern with drip irrigation is recycling. Although recycling facilities are extremely limited, they do exist. Westcoast Plastic Recycling Inc.[32], located in Richmond BC, is a company that recycles drip tape. They collect and process rigid plastics by either a hydraulic baler or by an industrial grinding machine. The resulting bulk material is shipped to North American plastic manufactures for producing various plastic products. Although a fee isn't charged for recycling drip tapes, the company does require the user to clean and package the drip tapes into designated containers and deliver it to their facility.

3.4 SOCIAL ASSESSMENT

Advantages

Since our roof top garden is surrounding a sky light, the drip irrigation system will ensure that no irrigation water splashes over the sky light constantly and disturbs the people resting below, see Figure 5.

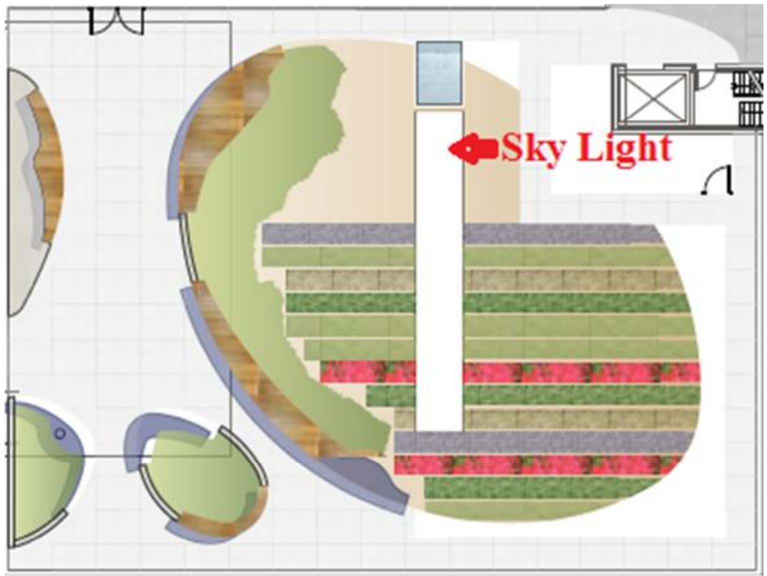

Figure 5 : Overview of the Rooftop Garden Layout
Source: www.mynewsub.com

Another benefit is that since drip tapes operate silently and have no moving parts, it is more calming than most conventional irrigation methods. Since this is mainly meant to be a demonstration project, the ability to emulate natural surroundings is important.

Disadvantages

After the initial setup at the start of the season, a drip irrigation system requires very little maintenance. Everything can be controlled by one switch, and fertilizers can be added directly to chemical injector. Because the garden requires less system maintenance and weed removing, a few possible work study positions or volunteer positions for students will be eliminated. The system also makes it possible to implement a computer controlled monitoring system which can reduce the labour requirement further more [7].

4.0 SUB-IRRIGATION

Sub irrigation is a method by which the water table is raised by putting water into the soil from below the surface. Sub surface irrigation has been in existence since ancient times in arid region were clay pipes were buried between rows of crops and feed water. Today sub irrigation is either used in green houses, or in Farmers' fields using polyethylene drip tape. For this project we will only consider the polyethylene drip tape since it is much more readily available and commonly used for similar environments.

Two subsurface polyethylene systems are available on the market. The first uses traditional drip tape, which may or may not include built in *emitters*. The other method uses a special copper coated drip line which prevents root intrusion.

Figure 6 : Cut away diagram of sub irrigation drip tape
Source: http://www.dwc-water.com

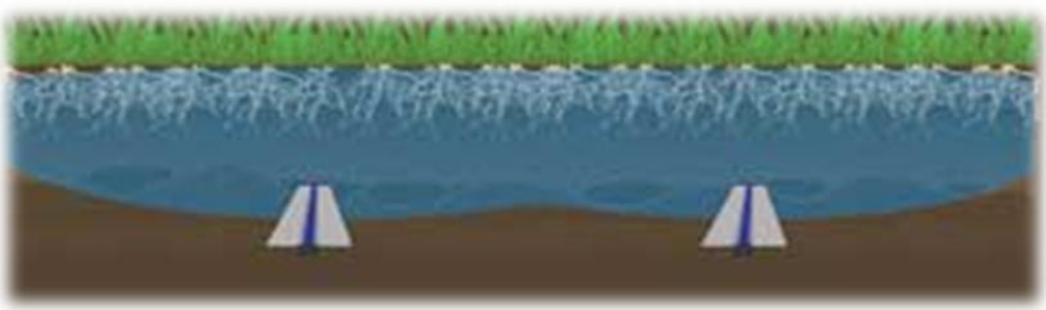

Figure 7 : Wetting pattern of soil above sub irrigation drip tape
Source: http://www.fao.org

4.1 ECONOMIC ASSESSMENT

Advantages

Sub irrigation is the most water and nutrient efficient system of the 3 options presented in this report. One can obtain evaporation rates as low as 4 mm per day with sub irrigation. Sub irrigation is also very predictable with one study citing a *coefficient of determination* value of R^2=0.98 between predicted and measured soil moisture content. With both precision and efficiency one can effectively optimize the growing condition for a crop. An additional benefit is that with few weeds one saves on labour costs, and with few crops lost to disease or leaf burn one can sell more food.

Figure 8 : Crops which are sub irrigated can produce higher yield than crops which are irrigated using other systems.
Source: http://modpod.modfarm.org

Disadvantages

While fewer workers are not needed while the system is in operation, many workers are needed when the system in being installed or maintained. When the system in installed the first time, it will hopefully be done before the top soil is added. However, when the system is due for maintenance it must be dug up. To remove the soil from the drip tape and recover the new drip tape will cost an estimated $20,000 (see Appendix C). Sub irrigation systems also will require professional installation since staff will be unfamiliar with the system and how to set it up. This is a significant additional cost every time maintenance is required on the system. Additional maintenance may be provided by UBC staff, however instructing them on how to maintain the system will cost an indeterminate amount of money.

4.2 ENVIRONMENTAL ASSESSMENT

Advantages

Polyethylene is a very common plastic which is used in numerous consumer products like pop bottles and plastic bags. Sub irrigation drip tape last for longer before needing replacement since it isn't exposed to UV radiation. Retailers claim that sub irrigation drip tape should last at least 5 years before needing replacement. When the drip tape reaches the end of its service life it can be recycled at West Coast Plastic Recycling. One can obtain bio-derived polyethylene in from the Braskem and Toyota Tsusho Corporations in Brazil.

Figure 9 : In the future, the park bench you sit on may be made from recycled drip tape from the SUB's roof top farm. This is an example of down cycling.

Source: http://www.travelphoto.net

Disadvantages

One cannot ignore the environmental cost of producing the drip tape. For every kilogram of polyethylene produced, 80.5MJ of energy is needed and 2.73 kilograms of carbon is emitted. This equates to needing 2083.5MJ to make the drip tape and emit 70.66 kg of CO_2 . 2083.5MJ is equivalent to 77.74L of gasoline, which could fuel the UBC Supermileage Car (69.5km/L) from UBC to Quebec City!

Once the drip tape has reached the end of its useable life it must be recycled. The plastic will have to be transported to West Coast Plastic Recycling via truck. The process of recycling plastics itself requires energy and produces additional carbon. Despite being recycled, the drip tape might be *down cycled* and tuned into products like synthetic wood or planter pots. It would be more environmentally friendly to use drip tape that was made from recycled drip tape.

4.3 SOCIAL ASSESSMENT

Advantages

When in operation, a sub irrigation system is very discrete; making a garden or farm visually appealing. The system is equally pleasing for the operator since watering is controlled either automatically by a computer or by the push of a button. Those who have worked on the UBC Farm will be familiar with drip tape irrigation and be familiar with how to operate the system. Farm employees will also be pleased with a sub surface irrigation system since it would reduce weeds, reduced plant disease, and fewer plants with leaf burn.

Disadvantages

While the system is discrete in operation, the installation and routine maintenance of the system involves digging up the tape. Since they drip tape may be damaged by machinery, the digging must be done by hand. This is a laborious process and might detract from a passerby's' impression of sustainable urban agriculture. When the system is not being maintained, it must be monitored closely since any problems such as clogs or breaks will not be apparent. One must also ensure that if sensors are being used to monitor the soil, that the measurements are reasonable.

Since sub irrigation in not suitable for germinating seeds, the UBC Farm will have to start its crops in a green house and then transplant the seedlings to the SUB roof top garden. Restaurants in the SUB might also be frustrated that the growing season stops at the first frost since the sub irrigation system provides no protection against frost. Restaurants may also be disappointed that permanent crops such as apples and berries cannot be grown with sub irrigation.

Figure 10 : Frost can destroy crops and marks the end of the crowing season for a farm. Sub irrigation will not protect the new SUB's rooftop farm's crops from frost.
Source: http://tinyfarmblog.com

5.0 SPRINKLER IRRIGATION

This irrigation method consists of water being piped to a sprinkler or gun where it is sprayed from above onto crops. The most common types of sprinkler irrigation are central pivot, lateral move and general impact sprinkler (see figures below).

Figure 11: Central Pivot Irrigation
Source: en.wikipedia.org

Figure 12: Lateral Move Irrigation
Source: www.centerirrigation.com

Figure 13: Impact Sprinkler Irrigation
Source: www.irritec.ie

Central pivot irrigation consists of a metal arm with sprinklers rotating around a central point via wheels. In the lateral move irrigation the sprinkler arm moves laterally across the field instead of pivoting.

The simplest method of sprinkler irrigation is the impact sprinkler. Here the water drives a spring loaded arm that periodically impacts the water stream, resulting in a uniform waterfall closer to the sprinkler. [ref 17]

Impact sprinkler irrigation was selected for TBL assessment over central pivot and lateral move because it's more adaptable to small scale operations and less mechanized (decreased cost). A summary of pros and cons of this method is shown in Table 2.

PROS	CONS
Simple and, therefore, cost effective	Susceptible to wind drift
Promotes cooling of crops in hot days through direct watering and a lower surrounding ambient temperature	Prone to evaporation
Robust and longer lasting (than plastic)	Water consumption higher than other irrigation systems (ie. Drip)
Suitable for all types of soils, crops	More maintenance then some irrigation systems (occasional unclogging)
Usable for uneven terrain	Prone to tree/plant blockage
Available in variety of discharge capacities	High operating pressures

Table 2: Pros/Cons of Impact Sprinkler Irrigation [ref 18, 30]

5.1 ECONOMIC ASSESSMENT

Advantages

Low purchase cost is a major benefit of impact sprinkler irrigation as this system comprises common garden hoses and sprinklers [ref 19, 20, 21].

Other advantages:

- Large availability of replacements parts reduces maintenance cost.
- Longer life means reduced replacement costs [ref 30].

Disadvantages

There are significant costs associated with the large water consumption inherent in this system. Using a quarterly estimate in Metro Vancouver [ref 25], the annual water cost is $443.99 per sprinkler (see Appendix A). Since sprinklers are two to three times more water consuming then alternatives such as drip tape, we could save up to $295.99 annually by irrigating the same area using a drip system.

Other disadvantages:

- Necessity to weed means extra labour costs. Could be $2500 per acre for hand weeding (study by California Polytechnic State University). [ref 26]

5.2 ENVIRONMENTAL ASSESSMENT

Advantages

A significant environmental benefit of impact sprinkler irrigation is that the major constituent, brass, is locally recyclable at Allied Salvage Metals. This leads to less CO_2 emission when transporting the sprinkler for recycling [ref 27].

Additional advantages:

- CO2 emissions reduced by attaining sprinklers locally (eg. Watertec in Langley).
- Rubber can be reused at end of life to reduce waste.

Disadvantages

A major challenge with impact sprinklers is that they consume approximately two to three times more water than drip tape [ref 30].

Additional disadvantages:

- Water efficiency is affected by wind strength and water evaporation (especially on hot days).
- Plant scorching due to salts left behind from evaporated water droplets [ref 18].

Figure 14 : Scorching of Leaves
Source: www.extension.umn.edu

5.3 SOCIAL ASSESSMENT

Advantages

The major social benefit of impact sprinklers is that it's a very familiar technology and no special training is required to install this system as it involves common garden hoses and sprinklers.

Other advantages:

- Simple maintenance requiring occasional unclogging and spring or washer replacement (see figure 15) [ref 23].
- Reduced user interaction through wireless automation [ref 22].

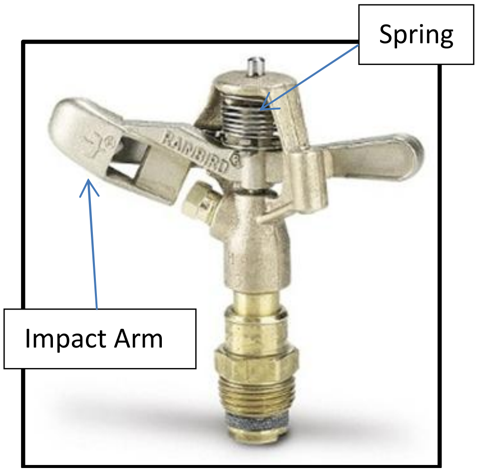

Figure 15 : Impact Sprinkler
Source: www.rainbird.com

Disadvantages

Impact sprinklers are less aesthetically pleasing as compared to other irrigation (eg. Drip tape). Both the sprinkler head and rubber hoses visibly protrude above the ground where as drip tape sits either below the ground or is hard to spot on surface applications.

Other disadvantages:

- Spray stream visibility and noise of impacting action.
- Noise from water impacting sides of SUB walls.
- More user maintenance from weed growth (no weeds with drip tape).

6.0 TBL COMPARISON OF IRRIGATION SYSTEMS

This section compares the environmental, economic and social aspects of the alternative irrigation methods so as to help select the most viable alternative.

6.1 ECONOMIC COMPARISON

Cost analysis was performed on the systems based on five categories and the results are shown in table 3 (see Appendix C.3):

	(0.25") dripline 50' length	0.5" brass nozzle sprinkler + hose	Sub-irrigation XPS-tape per 100ft
Unit Price	16.95	16.95	29.99
Initial Purchase Cost	542.40	227.80	779.74
Maintenance Cost for 30years (parts cost only)	2712.00	271.20	3898.70
Maintenance for 30years (labour costs only)	2400.00	960.00	100000.00
Recycling Cost (Travel only)	1.50	1.57	N/A
Total Cost:	**5655.90**	**1460.57**	**104678.44**

Table 3: Economic Analysis of Systems

From the table, Impact Sprinklers are the most promising alternative economically. However, segmented replacement of drip tape and impact spring replacement weren't included in the analysis. If this were done, the total cost of Drip Line Irrigation might become more comparable to the Impact Sprinkler system.

6.2 SOCIAL COMPARISON

Based on the analysis of previous sections, the most important social aspects of an irrigation design were used to compare the viability of the three systems. The scoring was based on a range of 1 to 3. One was given to the lowest performer and three to the highest (Table 4). The highest score indicates the best overall performer.

	Drip Tape	Sprinkler Irrigation	Sub-Irrigation
Aesthetics	2	1	3
Training Required	2	3	1
Ease of Use	2	3	2
Employment Opportunities	2	1	3
Noise Emission	3	1	3
Opportunity for Visitor Involvement	3	3	1
Total	**14**	**12**	**13**

Table 4: Social Comparison

This crude analysis indicates that Drip Tape Irrigation would be the best alternative socially. Keep in mind this analysis is very speculative. This is likely why there was very little difference in scores.

6.3 ENVIRONMENTAL COMPARISON

Embodied energy calculations were performed for each system and the results are shown in Table 5 (see Appendix C for detailed explanation of calculations).

Material	Embodied Energy MJ/kg	Impact Sprinkler+hoses: Embodied Energy (MJ)	Drip Line Surface: Total Embodied Energy (MJ)	Sub-Irrigation: Total Embodied Energy (MJ)
Rubber General	91	388.00	N/A	N/A
General Brass	44	47.87	N/A	N/A
Recycled B	20	21.76	N/A	N/A
General Polyethylene	80.5	N/A	1666.59	2083.50
	Totals:	**435.87**	**1666.59**	**2083.50**

Table 5: Embodied Energy Calculation Results

As seen, the total energy consumed (in primary form) in the life of the product (Cradle-to-Gate) is much less for the components of the impact sprinkler system. This two-thirds difference compared to Drip Line Irrigation, and three quarters as compared to Sub-Irrigation, makes Impact Sprinklers the more environmentally friendly alternative.

Table 6 summarizes the calculations of embodied CO2 emissions associated with each irrigation system. (see Appendix C for detailed explanation of calculations).

Material	Embodied carbon (kg CO2/kg)	Impact Sprinkler + Hoses: Total CO2 Em (kg)	Drip Line Surface: Total CO2 Em (kg)	Sub-Irrigation: Total CO2 Em (kg)
Rubber General	2.66	11.34	N/A	N/A
General Brass	2.46	2.68	N/A	N/A
Recycled B	1.12	1.22	N/A	N/A
General Polyethylene	2.73	N/A	56.52	70.66
	Total CO2 Em (kg):	**14.02**	**56.52**	**70.66**

Table 6: Embodied CO2 Calculation Results

Again, the Sprinkler Irrigation system appears more environmentally friendly as there are less CO2 emissions associated with the manufacturing processes of sprinkler and hose materials.

Note that this analysis didn't include any energy calculations based on water consumption, which could help make the drip and sub-irrigation alternatives more favourable.

7.0 CONCLUSION & RECOMMENDATION

After reviewing all three systems presented and comparing them to each other, it was agreed that the preferred system to implement is a **conventional sprinkler system**. Not only does it provide a reliable, simple system with easy to install components, it will operate for decades to come with minimal maintenance or required maintenance, as found with the drip tape system.

Although it does consume more water, multiple reports are currently being conducted to examine the possibility of installing rain catching and recycling systems. This would, therefore, alleviate the additional water demands from the irrigation system.

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APPENDIX A

Calculation of Water Consumption for and Impact Sprinkler system

The total cost can be calculated using the Metro Vancouver meter charge rate of $2.251 per 623 gallons, which is charged quarterly. In addition, a sprinkler flow rate of 180 GPH can be used, along with the assumption that the sprinkler is on 5hours/day, for 4 days a week, for 4 months a year.

180GPH was based on sprinkler from Rain Bird [ref Rain Bird A]

We calculate water costs of $832.47 for four impact sprinklers using the following formula:

Cost =
($2.251/623Gal)*(180Gal/hr)*(5hrs/day)*(4days/week)*(4weeks/month)*(4months)*4sprinklers

APPENDIX B

Economical Cost of Drip Tape

Since the crops used on the roof top garden is similar to the current crops in the UBC farm, we are going to make the assumption that the drip tape lay out is going to be similar in both areas.

Our course director forwarded an email from Timothy Carter who is from the UBC farm that outlined the drip irrigation layout that they are using. Here we are only considering the drip tape setup, it includes:

- 15 mil T-Tape
- 8'' emitter spacing to grow annual vegetable crops
- Row spacing anywhere between 22'' to 10 feet

Based on that description, we can sketched an approximate lay out for the drip irrigation system. Since most people do not have a good concept of how big 6000 square foot is, we are going to use a NHL hockey rink end zone (from blue line to the end of the rink on one side) to give the readers a better understanding of the space and layout. Basic on the above drip irrigation system description and practical examination of a typical annual vegetable farm in Richmond and the UBC farm, we assume that three rows of crops with spacing of 22'' in between followed by a walkway of 52'' form a basic pattern that is repeated through the width of the field. We can place 8 of these patterns, which is 24 rows of crops. (Please see Figure X)

$$\frac{64 \times 12''}{22'' \times 2 + 52''} = 8\,patterns$$

$$8 \times 3 = 24\,rows\,of\,crops$$

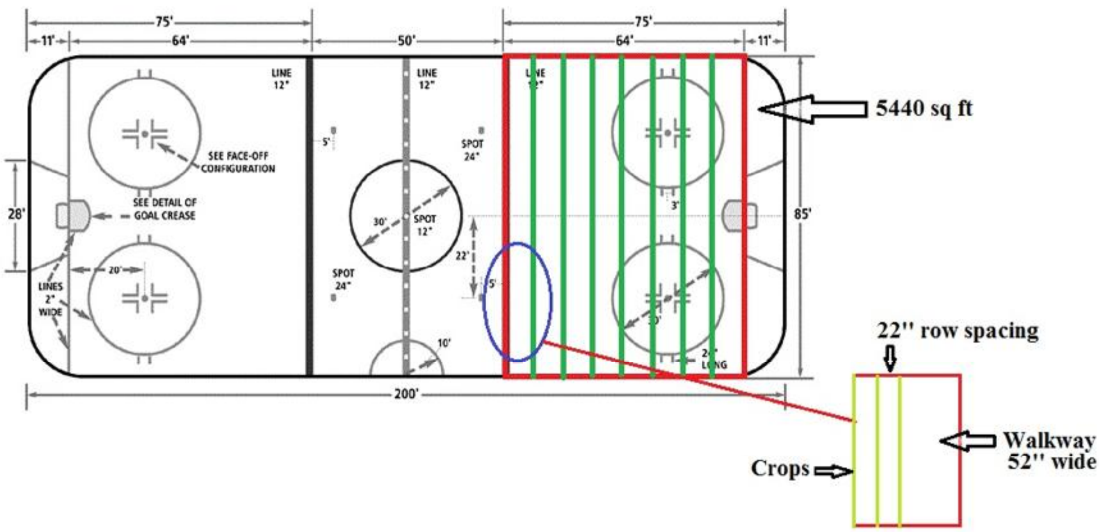

Figure X: Possible setup of the drip irrigation system.

Source: http://cdn.nhl.com/images/upload/2008/06/rink_diagram.gif

Since for the John Deere Water T-Tape the emitters are pre-installed into the tape, we can calculate the cost of the drip lines based on length. For each of the 24 rows of crop, we need from 1 to 2 drip tapes. In total, we are going to need the following length of drip tapes:

2* 24 * 85' long drip tape with a 15mil wall thickness = 4080 ft

At $426.35 per 4100 ft for the 15mil T-Tape, it will cost about $424.27 to purchase them.

If they are replaced them every three years, in 30 years, the drip tapes alone will cost $4242.7.

For the basic components like flow meter, chemical injector, filter, control valve, pressure regulator, pressure gauge, main hose, and various connectors, the price of them varies depends on the grade and material of the product. In total, they range from $500 to $3000+.

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APPENDIX C

Comparison of Systems Calculations

C.1 Environmental

In order to calculate embodied energy (in Mega Jules) and embodied carbon dioxide (CO2) emissions (in kilograms) of each system, the weight of each system had to be first determined. To provide a standardized comparison, each system was selected so as to water an entire area of 6400 sq ft (assume 80ft x 80ft) of farmland. For the Impact Sprinkler irrigation, this would mean using four sprinklers (0.5"nozzle, Brass, 30ft spray radius) to ensure the entire area is covered sufficiently (see fig C1). In addition, four hoses were also added to the calculations as they supply water to the sprinkler heads. For the drip line surface system, a 0.634" (16.1mm) OD, 0.536" (13.6mm) ID and 0.049" (1.6mm) WT drip line was used. It was determined that, using a 5ft row spacing, and assuming a purchase length of 50ft per line , 1280ft of Drip Line was required to cover the 80ft x 80ft farm land [see fig C2]. For the Sub-Irrigation method, a 0.5" (1.12cm) OD and 1cm ID drip tape was used to calculate the weight. This drip tape comes in 100ft rolls, so assuming a row spacing of 2.5ft, the total amount of drip tape needed is 2560ft [see fig C2]. Note that all components were sources from Rain Bird [ref Rain Bird C].

The layouts used to calculate weight for each system are shown in the figures below.

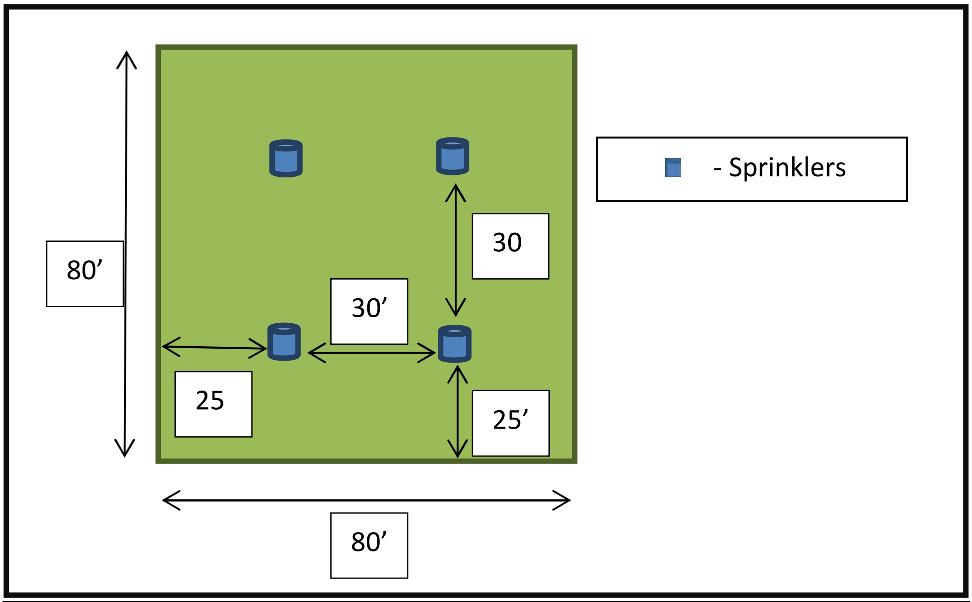

Figure C1 - Sprinkler Irrigation Set-Up for Calculations

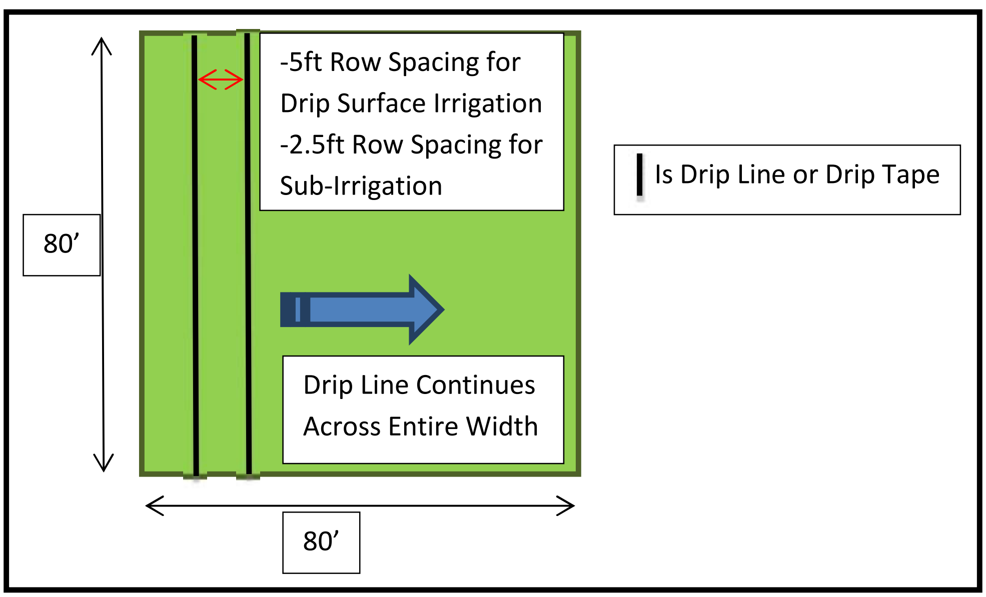

Figure C2 - Set Up for Drip Line Surface Irrigation and Sub-Irrigation

The sample calculations are shown below for each irrigation method:

<u>Sprinkler Irrigation:</u>

Weight = 4sprinklers * Brass Sprinkler Unit Weight

= 4*0.272kg (note: called Watertec in Langley for Weight of these brass sprinklers)

Drip Line Surface Irrigation:

Weight = Polyethylene density*drip line volume*drip line length

= ((0.91g/cm^3)/1000)*((PI()/4)*((1.61^2)-(1.36^2)))*((1280*12*2.54))

Sub Irrigation:

Weight = Polyethylene density*drip tape volume*drip line length

=((0.91g/cm^3)/1000)* ((PI()/4)*((1.21^2)-(1^2)))*(2560*12*2.54)

All calculation results are shown in Table C1 below:

Table C1 – Weight Calculations for Each System

	Impact Sprinkler (General Brass)	Impact Sprinkler (Recycled Brass)	Garden Hose (General Rubber)	Drip Line	Sub-Irrigation Tape
Calculated Weight To Irrigate 6400sq ft of Farm Land (kg)	1.09	1.09	4.26	20.70	25.88

Data for embodied energy for Rubber, Brass , Recycled Brass and General Polyethylene was retrieved from the University of Bath research database [ref H. Geoff]. These numbers are shown in the table below. Using the total masses calculated in Table C1, the total embodied energy for each system was found and is shown in Table C2.

Table C2 - Embodied Energies for All Systems

Material	Embodied Energy MJ/kg	Impact Sprinkler+hoses: Embodied Energy (MJ)	Drip Line Surface: Total Embodied Energy (MJ)	Sub-Irrigation: Total Embodied Energy (MJ)
Rubber General	91	388.00	N/A	N/A
General Brass	44	47.87	N/A	N/A
Recycled B	20	21.76	N/A	N/A
General Polyethylene	80.5	N/A	1666.59	2083.50
	Totals:	**435.87**	**1666.59**	**2083.50**

The embodied CO2 data for each material in the table below was also retrieved from the University of Bath database [ref H. Geoff]. Again, the weight from table one was used to calculate the total embodied CO2 emissions associated with each system.

Table C3 - Embodied CO2 Emission for All Systems

Material	Embodied carbon (kg CO2/kg)	Impact Sprinkler + Hoses: Total CO2 Em (kg)	Drip Line Surface: Total CO2 Em (kg)	Sub-Irrigation: Total CO2 Em (kg)
Rubber General	2.66	11.34	N/A	N/A
General Brass	2.46	2.68	N/A	N/A
Recycled B	1.12	1.22	N/A	N/A
General Polyethylene	2.73	N/A	56.52	70.66
	Total CO2 Em (kg):	**14.02**	**56.52**	**70.66**

C.2 Economics

Using the same system set up as in Appendix C.1 for each irrigation method, along with the unit price, the different costs were calculated as follows:

Initial Purchase Cost:

- Sprinkler Irrigation; 4 sprinklers and 4 hoses

- Drip Line Irrigation; enough 0.25” 50’ drip line to cover 80’x80’ field (1280ft of length)

- Sub-Irrigation; enough XPS-tape to cover entire 80’x80’ field (2560ft of length)

Maintenance Cost for 30 yrs (parts only):

-Sprinkler Irrigation; based on 5-10 year replacement cycle, assuming all sprinklers will be replaced at once, rubber is on lifetime warranty so not include in cost

-Drip Line Irrigation; based on 5year life span, replace all lines 5 times

-Sub-Irrigation; based on 5year life span, replace all tape 5 times

Maintenance Cost for 30yrs (labour only):

-Sprinkler Irrigation; assumed 4 replacements in 30years, 4 sprinklers replaced each time, 2 hours per sprinkler and $60/hr cost to UBC (wage + benefits)

-Drip Line Irrigation; assumed 5 replacements, takes 30 minutes to replace one drip line, have 16 drip lines to cover 80’x80’ field, used rate of $60/hr

-Sub-Irrigation; Digging estimation - assume it a worker can dig 2 cubic meters of soil per hour, assume that the worker must dig down 0.3 meters (the average depth for a sub irrigation system) and costs $60.00 per hour to UBC, it will take at least 156 man hours and a cost of $9360.00 to dip up the drip tape and another 9360.00 to cover it, estimate $20,000 per one replacement, need 5 replacements total

Recycling Costs:

-Sprinkler Irrigation; use toyota corolla combined highway + city mileage 6.6L/100km, use price of fuel as 130.4C/L, cost to travel 18.2km to Allied Salvage Metals in Richmond

- Drip Line Irrigation; use toyota corolla mileage 6.6L/100km,use price of fuel as 130.4C/L, cost to travel 17.4km to West Coast Plastic Recycling in Richmond

- Sub-Irrigation; calculation was not performed as total cost of Sub-Irrigation high already

Note: All parts sourced from Rain Bird [ref Rain Bird C]

Table C4 – Cost Comparison

	(0.25") dripline 50' length	0.5" brass nozzle sprinkler + hose	Sub-irrigation XPS-tape per 100ft
Unit Price	16.95	16.95	29.99
Initial Purchase Cost	542.40	227.80	779.74
Maintenance Cost for 30years (parts cost only)	2712.00	271.20	3898.70
Maintenance for 30years (labour costs only)	2400.00	960.00	100000.00
Recycling Cost (Travel only)	1.50	1.57	N/A
Total Cost:	**5655.90**	**1460.57**	**104678.44**

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