On-site Water Capture for the GCUOF

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Abstract. The Guelph Centre for Urban Organic Farming (GCUOF) is a developing organic demonstration farm that will teach more sustainable agricultural practices. The two acre farm is located in the Arboretum of the University of Guelph campus, Guelph, Ontario. An irrigation water supply system has been designed for the GCUOF. The system is based on on-site capture and storage of precipitation runoff. The design consists of two 'swales' (or waterways) to capture local snowmelt and spring rain runoff. The swales direct runoff to an on-site pond for storage. The pond has been sized to hold 212 m^3 of water, which is sufficient for crop sustenance during drought periods. From the pond, a treadle pump will be used to pump water to an above ground cistern located at the highest elevation of the site, ready for use. The total cost of the system has been estimated at $11,000.

Key words: organic farm, pond, swale, treadle pump, water capture.

1 Introduction

A growing global emphasis has been placed on increasing the use of sustainable practices in agriculture. The Guelph Centre for Urban Organic Farming (GCUOF) is developing an organic farm within the Arboretum of the University of Guelph campus, in Guelph, Ontario. The farm is intended to be a learning centre and model for sustainable practices. This design for the irrigation-water supply system needed to meet these objectives. Constraints on the water supply design include the non-existence of a municipal water source or well, and the use of renewable energy resources. The criteria for the design include minimizing costs and maximizing water capture, storing runoff, and using recycled materials. The client has requested that the design implement a pond and a manually-powered pump with a tank located at the highest elevation of the site. A method for rain-water harvesting was investigated and an optimal solution was designed.

Rain-water harvesting is defined as the "capturing, diverting and storing of rainwater for later use" Here 'swales' (or grassed waterways) channel runoff water to a pond. This approach was selected after analysis determined that precipitation amounts are greater than evaporation at the site. The annual precipitation is greater than the water needs of the crops. However, a period of water deficit occurs during the summer months. This led to the principle of redistributing on-site rainfall. This method relies on the assumption that prior to spring, the ground is either frozen or saturated, producing high levels of runoff. Capturing and storing this runoof will ensure a sufficient volume of water is available for periods of irrigation.

2 Design Overview

The layout of the design is shown in Figure 1. The collection system comprises of two swales on either side of a storage pond; the field swale and roadside swale. Both collect into a circular pond. A source pipe feeds into a treadle pump near the pond which directs water to a cistern located at the high point of the site.

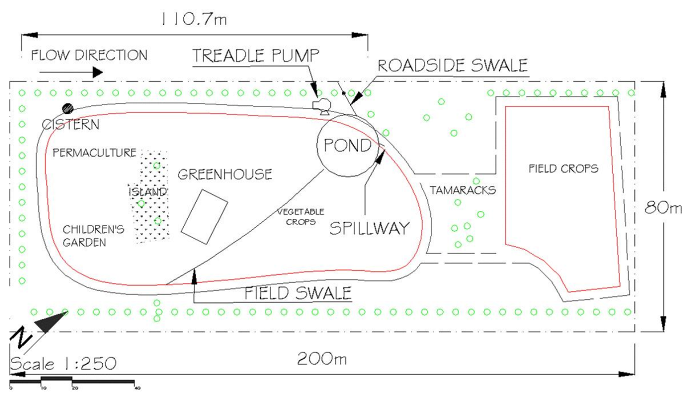

Fig. 1. Final Design Layout

3 Detailed Design

3.1 Water Needs

The farm will be comprised of permaculture, field crops and vegetable crops; only the 2/3 acres covered by the vegetable crops will require irrigation. The next step was to define the most critical period, i.e. time of drought. Two methods were used to estimate this period, the first was to determine the lowest precipitation values on a 5 year return period for every month (from 1985 - 2005). From this analysis, a value of 260 m^3 of water was found. Secondly, a local farmer was contacted. It was noted that his water needs were 253 m^3 for an equivalent GCUOF irrigation area. However, since this farmer did not use any conservation techniques such as mulching or drip irrigation, the needs of the farm in this design were assumed to be significantly lower.

3.2 Swale Design

The field and roadside swale are designed to channel snowmelt and spring rain runoff, respectively, to the pond. The water available for capture by this method was based on historic rainfall equivalent depths for the 5-yr low flows for the months between January and April. The catchment area was determined using topographic maps. The volume of available water could be determined by multiplying the rainfall equivalent depth, the catchment area, and the runoff coefficient. Runoff coefficients of 89 and 86 were determined for the field and roadside swale, respectively, to indicate the percent of water that would runoff.

The swales were designed with a triangular cross-sectional geometry and the capacity to handle the peak discharge estimated for the 5-yr low flows. The peak discharges for each swale were determined using the Rational Method [1].

The Manning's velocity equation was employed. It is a standard empirical formula applied to determine capacity of natural and artifical channels [1]. Ultimately, the maximum discharge, Q, that could be handled by the swales was determined to be 0.51 and 0.59 m^3/s for the field and roadside swales, respectively. Using the same cross-sectional area for each swale as $0.4m^2$. These swales would sufficiently handle the peak discharges previously calculated.

3.3 Pond Design

A circular, conical frustrum pond is used. A side slope of 2.5 was used to prevent slumpage. A depth of 3.5m was used to reduce the ratio between the amount of volume excavated to the volume available for irrigation. The top diameter is 20m and the bottom diameter is 2.5m. The total volume excavated is $418m^3$, the total water volume capacity is $212m^3$, and the final amount available for irrigation after evaporation losses and dead water is $160m^3$.

If water overflows, it will follow the natural drainage of the site, away from the growing field. Regardless, an outlet was still designed with its invert 0.2m lower than the invert of the inlets to the pond. This ensures the water will flow out the outlet before flooding in the swales. A recycled swimming pool liner is used to prevent seepage with 0.15cm of soil to protect the liner from punctures.

3.4 Treadle Pump

A treadle pump was chosen to pump the water from the pond to a cistern located 2.5 m uphill at the highpoint of the site. This cistern will be used to store 2 m^3 of water that can be later used for crop irrigation.

The treadle pump is powered by the natural motion of the human body, where the operator pushes up and down on each treadle in a reciprocal motion. This movement produces a steady ouput that can be sustained for an extended period of time. Within the treadle pump, there are two cylinders and pistons that are used to create a suction lift to draw water from the source. Water uptake occurs due to a vacuuum pressure that is created when the piston is lifted upwards. On the downstroke, water is expelled from the pump into the outlet pipe and is pressurized to be conveyed to the cistern.

Given a human power input of 75 Watts, the flowrate of the pump was determined was calculated to be 0.30 L/s. Recognizing 177 m^3 is necessary to satisfy drought scenarios, it was calculated that $2m^3$/day would be required to satisfy water demand. The time required to fill the cistern with this volume using the treadle pump was calculated to be approximately 2 hours.

4 Discussion

This design uses small-scale low technology. Pond excavation is the major expense, totalling $6,270 from the total cost of $11,000. This will require the use of heavy machinery, which partially undermines the implementing post oil agriculture practices. However, it is minimized. It became apparent during the design process, that the hydrology of any site is very difficult to model. The benefits of the system describes is its flexibility. If there is not enough snowmelt, the roadside swale can collect spring rain. If the pond does not provide enough water, it can be expanded. Southern Ontario is very fortunate to have a surplus of precipitation, and this design benefits from capturing this excess without disturbing the hydrologic cycle. The pond allows the farmer to observe and remain conscious of the amount of water being used rather then extracting unlimited amounts from wells or municipal sources. Many of these techniques are being introduced in developing countries, it is about time to have Canada implement simpler technology on home soil.

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References

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