Solar Irrigation for Leo Creek Preserve

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July 2017

Introduction

The Leo Creek Preserve is a not-for-profit, outdoor learning laboratory and permaculture garden located on the Leelanau Trail (part of the TART trail from Traverse City), a quarter mile south of the Fourth Street trail access in Suttons Bay, Michigan. Founded in 2016 by Kate Thornhill, the nine-acre preserve is in its first growing season with roughly 1.25 acres planted with fruits, vegetables, herbs and flowers. See www.leocreekpreserve.com for more details. Kate Thornhill, a Northport Energy member, ask Steve Smiley and Tom Gallery of Leelanau Solar if they could provide a solar water irrigation system for the gardens. Steve and Tom donated materials and Steve and his partner Susan Kopka (with help from others) donated many hours to design and construct the irrigation system describe in the article below.

Tours and educational presentations are available. E-mail: smiley27@earthlink.net

SOLAR IRRIGATION FOR LEO CREEK PRESERVE

Tired of hauling heavy buckets of water from the creek, Kate dreamed of entering the modern age with solar energy to irrigate her two acres of flowers, fruits, herbs and vegetables. Independent solar energy was the obvious choice given limited access to the Preserve. Teaming up with Steve Smiley, Susan Kopka and Bob Otwell, a plan was made to draw water from the high ground water table. Holes dug for the outhouse storage tank nearby indicated the ground water level was just three to four feet below. Steve calculated a flow of two gallons a minute would serve the irrigation requirements. Bob surmised that a hand driven wellpoint to penetrate the water bearing formation below would be adequate. The wellpoint is shown below:

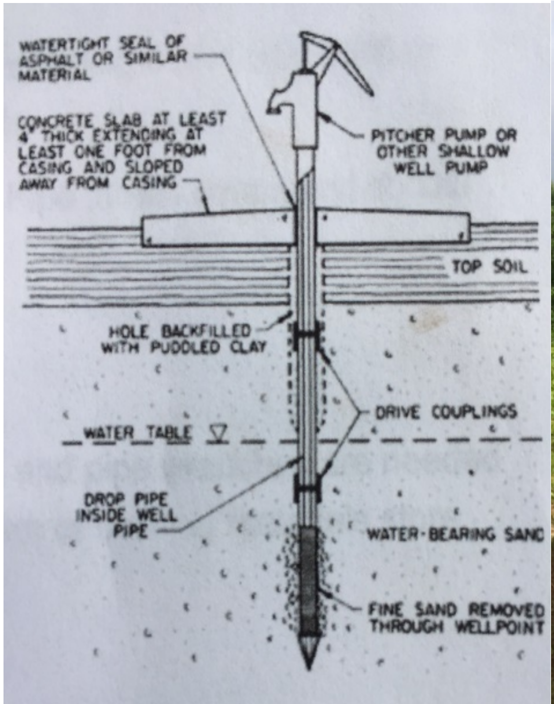


Figure 1. Installed wellpoint.

Kate estimated that as much as 1000 gallons a day might be required if an extensive drip or sprinkling system was installed. Irrigation requirements to date indicated that well under 500 gallons per day is adequate during dry periods, as much of the 1.25 acres growing area is not planted. The blueberries apparently draw water directly from the existing high-water table and have survived for over 50 years without irrigation.

After selecting a site in the north “utility area” which had the best solar access in the Preserve,
we began digging a small hole with a post hole digger to reach the water table. At that point, the two-inch diameter wellpoint was inserted and we drove it down with a pipe extension using a sledge hammer. We immediately hit a very hard, dense sand formation. Each hit of the sledge hammer moved the wellpoint barely 1/16th of inch. After an exhausting couple of hours, Bob and Steve quit after reaching roughly five feet below ground. The pipe extension and joint were smashed and cracked, as well. It was time to stop hand drilling. Bob tested the water supply, getting roughly a half gallon per minute, but we surmised we could increase the flow over time.

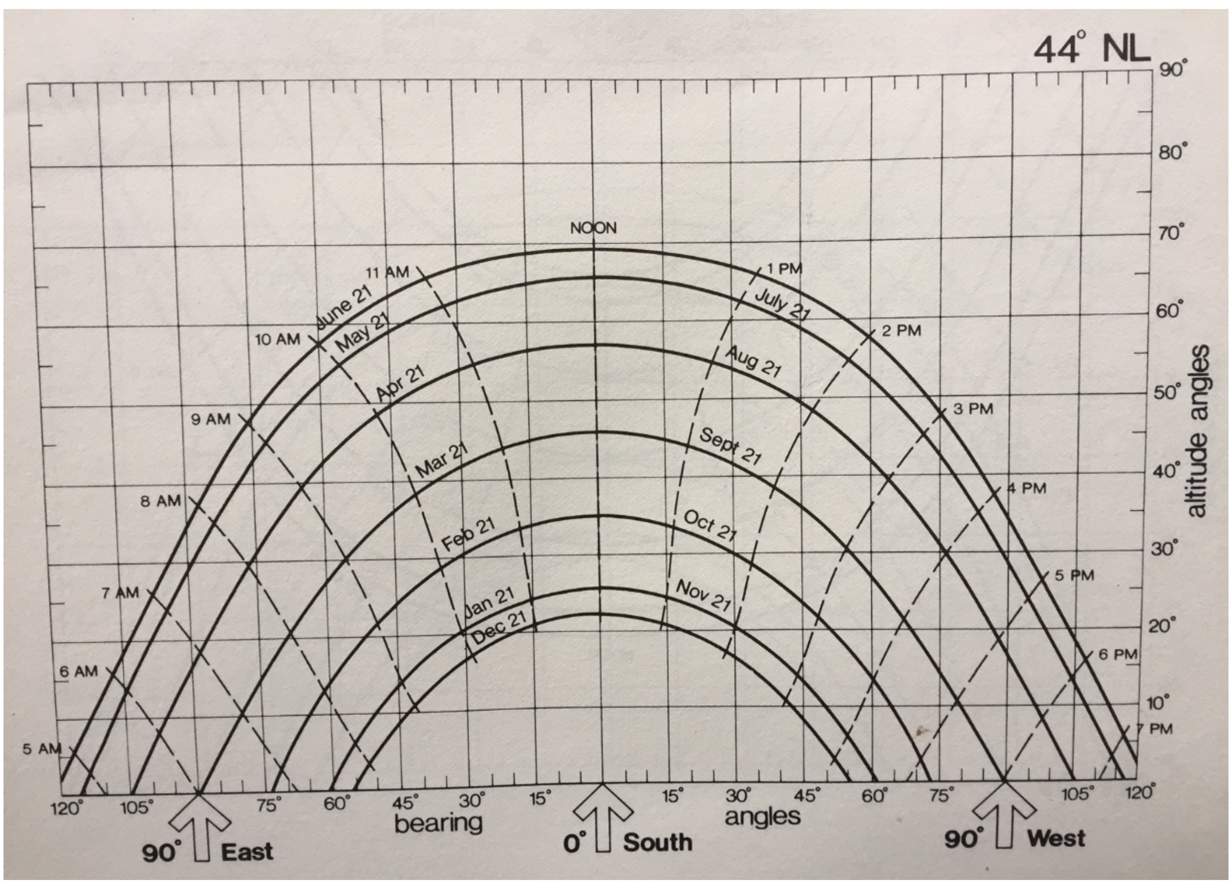
Water testing by Kate Thornhill and Bob Otwell

Other options were considered to get a higher flow rate: driving another wellpoint, hiring a well drilling rig (cost estimate $10,000), or modifying the existing well. After days of discussion, Steve set to digging a three-and a half foot diameter hole, four feet deep surrounding the well point, below the water table. It became nearly impossible to dig further into the dense sand formation. We then filled the hole with a couple feet of drain gravel and covered the hole and well area with soil to the surface. The water, now flowing at nearly one gallon a minute on average was a brown tannin color but with little sediment-- good enough for irrigation. Steve then installed a solar/battery powered pump which can deliver two gallons a minute to the storage tank. At this rate, filling the 550-gallon storage tank takes a pump run time of 4.5 hours, an acceptable rate.

The 550-gallon water storage tank was donated by Steve and Susan, repurposed from their home garden. Roughly eighty percent of the solar irrigation system is from recycled or repurposed materials supplied by Steve and Susan; including the 15-year-old solar electric panels (that still work great!), the metal siding (to porcupine proof the plywood solar box), hundreds of feet of PVC distribution pipe, electric and solar frame materials (some supplied from Leelanau Solar/Tom Gallery).

The three main components of the solar irrigation system are: the solar electric (PV's or photovoltaic) panels, the battery storage system and the water storage and distribution system. Like your automobile gas tank or a pile of dirty coal, we need storage for the electric energy and water so we can drive the system anytime of the day. Solar resources are abundant in Leelanau County. The solar energy falling on Leelanau County amounts to over ten times the electric consumption of the State of Michigan. Capturing a tiny portion was all we needed.

Having a mostly unshaded location is critical. Since the sun moves across the southern sky here in the northern hemisphere, where we are above the Tropic of Cancer, we faced the solar array south-ward. It can face thirty degrees azimuth from south without much impact on performance; it does not need to be too accurate. Modern advances in solar panel glass coverings provide better energy capture from diffused solar energy and lower sun angles. At this site, minimizing shading from the location of the east and west trees is the most important factor. A solar "pathfinder" tool can be used to accurately measure potential shading effects, if needed. Here, at near the 45th parallel north, at solar noon the sun is 45 degrees above the horizon on the spring and fall equinox (March and September), when the sun is rising and setting directly over the equator. Between March and September, the growing season at Leo Creek, the noon sun is always above 45 degrees, rising to above 68 degrees on the summer solstice, June 21. The solar path is shown below, for 44 degrees north latitude. For this application, with a fixed array, a shallow angle of, roughly 30 degrees (off horizonal) for the solar panels, is best. Also, since this system is not needed in the winter, we don't have to worry about snow shedding—or the water freezing for that matter.



Path of the sun at Leo Creek Preserve

“Utility” area at the Preserve

We need the right amount of solar PV panel area and wattage. Steve and Susan had 300 watts of solar panels consisting of six, fifty watt modules. This was more than adequate. Steve calculated that 200 watts would be enough, but the extra wattage can supply energy for future expansions. We decided on a 12-volt direct current (vdc) system because the pumps and equipment for this voltage are very common and low in cost. They are commonly used in RV’s and other travel vehicles. Technically speaking, twelve volts is a “nominal” number because the system is rarely operating at 12 volts. Typically, it will range from 11 volts to over 14 volts. This is just like your house electric grid supply, which is rarely running at the rated 120 volts AC. Plug in an electric meter to see for yourself.

The solar panels are set to charge a 12 vdc system, such as in your car. Each fifty (50) watt panel runs at 2.7 amperes. We wired the six, fifty watt solar panels in series, to keep the voltage the same while increasing the current to 16 amps. We could have wired the system for a nominal 24 vdc or even 36 vdc with our six panels, if we had cost effective equipment to utilize that higher voltage. If one wires in parallel (+ to + and – to --) the voltage increases proportionally and the amperes stay the same.   As the amps (“current”) increase we need bigger wires for the higher resistance, so higher voltage means smaller wires for the same energy. A simple basic electrical formula everyone should know, is Watts = Volts X Amps. For our example, with the 50-watt solar panel roughly 50 watts = 18 volts x 2.7 amps. The panels push higher voltage to charge the 12-volt system. Our 12 vdc pumps are rated at 7 amps, so 12 volts X 7 amps = 84 watts. Roughly speaking one can see our 300 watts of solar can power up to four of these pumps, when the sun is shining. This amount of energy and pumping would far exceed the needs of the Leo Creek irrigation system by a factor of five or more. We will get to more calculations below.

Sophisticated solar energy calculation programs are freely available, such as "PVWATTS" from the National Renewable Energy Laboratory (NREL). A simple way to think of solar energy is that there are 1,000 watts of solar irradiation falling on one square meter when the sun is shining. Our solar array has 2.4 m^2 (26 sq. ft.), so it sees 2,400 watts of incoming solar radiation, which is converted to 300 watts of electric energy by the PV's. This is a conversion efficiency of 12.5% (300/2,400), typical for a 15-year-old solar panel. Recent solar PV technologies are running in the 17% to 20% efficiency range. From our 300 watts, we can take the average hours of sun we see in Suttons Bay during the irrigation season to determine the total solar energy production. This information is available on the NREL web site, and can calculate solar energy accounting for any array type, angle, shading, etc. But for simplicity, if we assumed six hours of sun (during watering times), our 300-watt array would produce 1,800 watt hours (1.8 kW-hours). Our two pumps, totaling 168 watts, could run over 10 hours (not deducting for efficiency losses); a total of 1,200 gallons (at 2 gallons / minute). This is much more irrigation water than we expect. Since our batteries hold 5,400 watt hours, at an 80% draw down, we have two and half days of battery capacity without sun.

It is interesting to note, that with rapid developments in solar panel technology, our 300 watts of solar panels (15 years old), could now be replaced with a single panel that would weigh half as much, be 30% more efficient and would cost 80% less! This is why solar electric generation is now the cheapest new generation (next to commercial wind power). The vast majority of new power generation in the USA is solar and wind power. The solar age is upon us.

We need an adequate amount of battery electrical storage to start and run two pumps when the sun is not shining--early in the morning or late at night. Sizing the battery capacity is of critical importance; having enough capacity to start and run the highest electrical loads for as long as needed, while not discharging the batteries to low levels (below 20% of rated capacity). To cover potential needs, and some future growth, we installed more than adequate battery capacity--a total of 450 amp-hours (rated capacity). We installed four, 6-volt, 225 amp-hour, Trojan T-105, flooded deep cycle batteries. These are the most cost-effective batteries for this application. They cost 20% of the modern light weight lithium-ion batteries used in electric vehicles.

Wiring these, two in series (for 12 vdc) and then the two sets of 12 vdc in parallel, we end up with 12 vdc at 2 X 225 amp-hours or 450 amp-hours. From our formula above, if we multiplied 12 vdc times 450 amp-hours we see we have 5,400 watt hours (5.4 kW-hours) of battery capacity. The weight and size of these batteries fit well in our solar system compartment, shown below. Using the simple formula above, one can see that the two 7 amp pumps (14 amps) could run the batteries down to a 50% state of charge without solar charging, for 16 hours (450 amps/14 X .5). With our pump, at 2 gallons per minute, this would amount to nearly 2,000 gallons of water. Efficiency losses must be considered too, but this is a minor adjustment. These batteries, under these operating conditions, will last well over ten years, and then can be recycled for new batteries.

Battery charging must be controlled, to not over charge the batteries and to shut down the system when battery voltage drops too low. A solar charge controller (repurposed from Steve) was installed to control the various stages of battery charging from the solar panels. Once the batteries are nearly fully charged, the charge controller tapers the charge in the “float” stage. This protects the batteries from being overcharged. The batteries are sitting fully charged most of the time, with a voltage of roughly 13.7 vdc.

Four 6 Vdc batteries wired in series and parallel for 450 amp-hours at 12 vdc. Shurflo pump in foreground, charge controller (L), 1,500 watt inverter (R), in a ventilated cabinet.

For an added feature, Kate wanted 120 volt alternating current (vac) to charge her cell phone, run some 120 vac tools, and perhaps power an evening music event with some lighting and amplifiers. To accomplish this we installed a small, low cost, 1500 watt vac inverter. Inverter technologies have become very inexpensive. This one costs only $120. This is the maximum size our batteries can handle, using the “C-5” calculation. The C-5 calculation simply means we don’t want the amperage draw (“load”) to exceed one-fifth of the battery capacity, to protect the batteries and maintain their longevity. Using our simple formula, we see that one-fifth of 450 amp-hours is 90 amps. 12 volts x 90 amps = 1080 watts, so the 1500-watt inverter, if fully loaded, pushes the limits of the batteries. Kate, however, does not expect to use big electrical equipment. This system will easily run hand tools, like drills and saws.

The water storage and distribution system was our next challenge. Bob Otwell figured that elevating the 550- gallon storage tank could provide adequate pressure and flow. Jesse Fox built a platform that supports the 4,600 pounds of water. We tested the flow and pressure and, while it was adequate, the three hose faucets placed around the grounds did not have enough pressure to spray water more than a few feet. After much consideration, we decided a second pump, drawing water directly out of the tank, was needed to obtain the pressure and flow desired. Steve calculated there was adequate solar and battery capacity and plumbed and wired the second pump. These pumps, a Shurflo, 2 gallons per minute, a 30-pound pressure pump does the job. These pumps are also commonly found in RV’s and are inexpensive and reliable. When switched on, the pump runs with a pressure control switch which turns it on and off as water is used.

Good pressure! Kate, Susan and Steve (l-r)

Since the well pump will draw water at two gallons per minute for only 25 to 50 minutes (50 to 100 gallons per run) before dropping down to 1 gallon per minute, the well pump must be turned on and off periodically. Therefore, the well pump is turned on whenever someone is on site to keep the water tank full. The only other option would be to drill a new deeper well, at considerable expense.

With much trial and error, while a good reliable irrigation system is up and running, this system is a work in progress. In the future, different types of sprinklers may be considered to reduce the time it takes to water by hand. If over time, the ground water supply increases to two gallons, more controls can be added to automate the system.

The entire solar irrigation system equipment cost was approximately $2,500, $1,500 in out-of-pocket money, mostly for the batteries, pumps, well and plumbing parts, and another roughly $1,000 in donated equipment costs. Labor was donated as well.

Our hope is that the lessons learned from this small Leo Creek Preserve solar irrigation system can be used by students, teachers and all other visitors.