






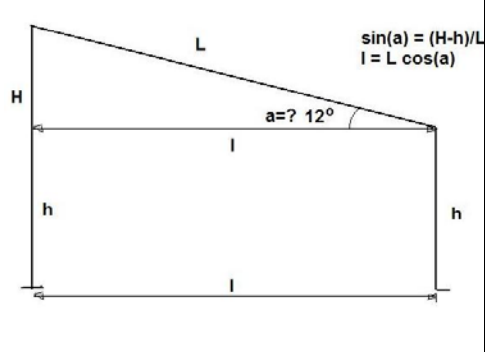


The manual tracking array was chosen by Asofenix and made locally to allow future growth in system performance and water output. Asofenix' plan is to keep the array fixed for the first year, and only use tracking when the population needs have grown beyond initial system delivery. *See tech specs at the end.*

Step by step installation	&	comments
	<p>Day 1: Before leaving Managua, we review the project to check whether we have all the parts to complete the project. We also check wiring tables to verify that the cable sizes and lengths we have will result in acceptable voltage drops.</p> <p>We compare the vendor shipping list with the contents of the boxes that arrived, draw electric and hydraulic connection diagrams to check that we have all cables, fittings, T's and elbows, tools and glue and voltmeter, etc. Everything missing has to be purchased before leaving town, and loaded on the truck.</p> <p>Jaime rented a small 4WD truck, to carry PV panels and all hardware over rough dirt road, and a pickup for us and more equipment.</p>	
		<p>We arrive to the site only shortly before sunset. Just enough time to unload.</p> <p>The local house next to the array site will act as safe storage until completion. The old couple living there doesn't seem to mind having their space invaded.</p>
		<p>Day2: Work crews have been organized in advance between Asofenix and the local committee, so there are workers from the community available X hours every day. Men dig holes and trenches. Kids and women scrub, paint, carry loads.</p>
		<p>Impromptu task: fill in a small ditch with flat rocks so that the pick up can carry loads closer to the work site. First digging is for the anchoring of the main rack posts. Holes need to be big enough (1.2x1.2x1.5m) for solid foundations.</p>



The main parts of the structure are semi-assembled on the ground to check fit and dimensions and double check at what distance the holes and posts need to be.
The structure is designed to provide a tilt angle of 12 deg, i.e. the latitude.



To avoid measurement errors, we use Jaime's calculator to compute the exact distance needed between the bases of the posts, based on the parts dimensions.
The two main holes are dug first. The terrain will be leveled and cleaned later.



The manual tracking mechanism will use a motorcycle chain and gears. Since the axle of the rack is designed to be tilted by 12 deg (the local latitude), the main gear axle is also supposed to be on a 12deg slope.. Actual implementation is not ideal, with misaligned ball bearings housings.



Check, and double-check!
The holes must be deep enough for the anchors + concrete, and the anchors, tied together, must fit the holes in the metal base of the post.



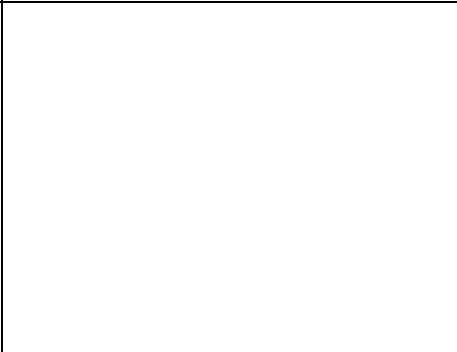
All parts of the frame are scrubbed with a wire brush, then painted for corrosion protection



The structure will have a N-S axle, mounted on two posts. The bases of both posts need to be at the same horizontal level, and on a N-S line. Flat stones are placed at the bottom of the foundation holes to support and position the anchor bars. A line is strung over the holes as horizontal N-S reference.



Since the holes in the post base do not allow any “wobble room”, the assembly of the anchor bars needs to fit exactly, and is re-tested several times. A cardboard pattern is used to replicate the base and help position the assembly.



The concrete mix is made on the ground, with sand and gravel “harvested” from the surrounding area and brought in buckets by the community. The cement bags were brought from Managua in the truck.



Layers of concrete and stones are poured in the foundation holes. Position and alignment of both anchors are checked and adjusted several times for position on the N-S line, angle vs. N-S, and horizontal alignment before and during pouring. It takes so long that the last bucket of concrete is poured at dusk.





Day 3:

The concrete is deemed dry enough to position and attach the posts, but soft enough to “give” when there are small adjustments.

After struggling to align the 4 base plate holes exactly over the anchor threaded bars, eventually both posts are in.



Visual check: the two posts are almost perfectly parallel, and the alignment of the two plates which will support the axle bearings is pretty good..



No special equipment to raise the axle and attach the bearing support to the first top plate. A rope is used as safety belt, and cut branches guide and hold the axle.



At each end of the axle, there is a ball bearing in a casing. Two holes need to be aligned on the top plate of the post in order to insert nuts and bolts.



With some effort, the chain is put in place on the gears, and then all bolts can be tightened. We will use the crank now to facilitate assembly of the array.

Long term, the intent is to only track the sun to increase water output when the population & needs grow, within 1 or 2 years. The array position would be changed 3 times a day.



Before assembling the flat frames on top of the axle, we check that the solar panels will mount correctly.

There are 3 6-panel frames and 1 4-panel frame. Mounting holes on their sides have been “custom-made”, and there is a specific order to mounting the 4 frames. They were numbered in advanced.

Ooops! The numbers have been painted over, so we need to try every combination of relative position of those 4 frames to reach the right order before raising and assembling them.

Eventually, it all works.



The frames are screwed to each other with nuts & bolts, and to the square axle with u-shape rigid iron straps. In addition, stiffeners are added at each frame edge.





To reinforce the structure against sagging, a third post is added to the structure, not quite in the middle. The anchoring is simpler (two threaded rods vs. 4 for the end posts).



The link to the axle includes a spherical ball bearing to allow some rotation of the axle.



Finally, towards the end of the day, the PV panels are mounted on the structure. We try to mount them all before dark.



At the last minute, some burrs and asperities have to be filed away to allow smooth positioning of the panels.



Standardized, polarized cabling came with the PV panels. We spend a while discussing where each cable needs to be connected, then realized that both cables interconnections and connection terminals are clearly marked + and -



Connecting and tightening all wires (screws + strain relieves) on a ladder is not very comfortable. We finally realize it's much better to connect the wires in the box while the panel is on the ground, before raising it on the rack!



Day4: We couldn't install all the PV panels before sunset yesterday, so there are still a couple to install. Wires are left dangling so that no electricity flows between panels.



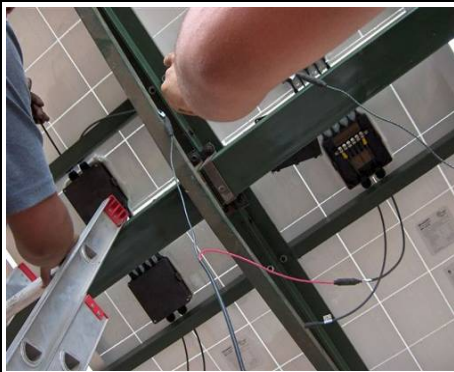
The trench crew makes progress. The trench will receive the cable from the Array + Controller to the pump down the hill.

Meanwhile, water still needs to be carried in a bucket.



There is no work safety inspection here, so workers climb on whatever they can.

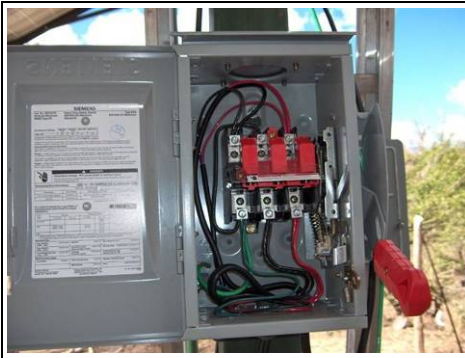
A deep 8-ft hole is dug for the ground rod. For good conductivity, the hole is filled with a mixture of charcoal and salt blended with the local soil. The pump cable in its conduit are laid in the trench.



30m of PVC pipe are assembled and positioned to be connected to the pump as the drop pipe. Meanwhile, the last standardized cable is prepared, to connect the PV panels to the electrical switches, circuit breakers, and controller. The 22 panels are grouped in 2 x 11. 11 panels in series for 180Voc. The 2 subgroups are connected in parallel.

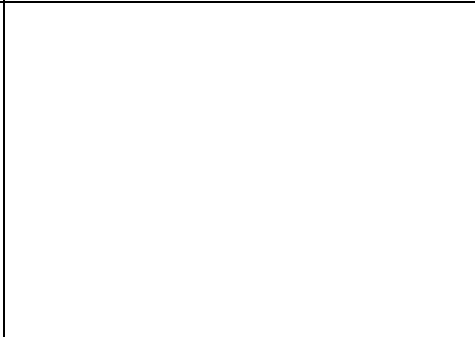


A 12V deep discharge battery + AC inverter allows to operate standard AC tools, e.g. a drill. Until all cabling is finished, the battery can be recharged by connecting it directly to one of the PV panels. Each half array is connected to a blade switch with a lightning arrester.



From blade switches to Main circuit breaker, then to pump controller.

All switch boxes are grounded, like the rest of the circuit. The common ground is connected to the ground rod under the array.



After double-checking everything, the PV panels are interconnected and connected to the switches.



Now to the pump: the old manual rope pump has been removed. The new centrifugal pump will go in the 4" pipe installed by the water utility a few years ago. The pump cable, safety rope, and drop pipe, need to go through corresponding holes in the well seal.



The wires from the pump need to be connected to the underground cable using an underwater splice kit. First, wires are crimped. Since the crimp we have is too big, a nail helps get the correct tight pressure.



The PVC drop pipe gets glued to the proper fitting at the pump output. When the glue is dry, tube, cable, and safety cable are tied at regular intervals with cable ties before lowering into the well. We keep a loop in the electrical cable as strain relief



The drop pipe is held up in an arch to avoid damaging it when lowering the pump.



First, the pump is lowered only to the static water level, to test the controller's "low water cut-off" circuit.

The pump is turned on and draws water, and when a change in noise tells us it's running dry, we count how many seconds until the pump is shut down automatically by the controller.



When the pump is lowered to planned depth, the well seal is installed and tightened, an elbow is glued to the end of the drop pipe, and a temporary pipe is installed for the villagers to fill their buckets. The safety cable is secured to hold the pump.

If the drop pipe was metallic, it would be strong enough to hold the whole weight. With PVC, Asofenix thinks it is safer to use the safety cable to hold everything.



It works!

Now we measure the flow rate with a bucket and a stopwatch.

We'll repeat the measurement at different time of day, and with half of the array. If we had a manometer and a valve, we could simulate the full future dynamic head and check the flow rate under those conditions.



Concerned that the PVC elbow looked like it was bearing the weight of the pump, we tighten the safety cable to hold everything a bit higher and release that strain. During that time, a temporary fence is installed to keep the cattle away. A sturdier permanent enclosure will be installed later.



We temporarily connect and test the float switch, which will switch off the pump when the main tank is full, and turn it on again when the level drops. All cables are securely tied to the structure, and the grounding cable is connected to all panels and the structure. And the whole structure is anchored in a fixed position with cables to resist wind forces.



The main switch is labeled in Spanish, and the phone number to call in case of problem is provided. The moment they were waiting for: two villagers are instructed on how to turn the pump on and off!



The two outstanding technicians can finally sit down!



Day 5: Community meeting in the school. After Jaime reviews the project and instructions for use to the villagers, the ENACAL “social promoter” reviews the collective commitment to better hygiene which was promised in exchange for water distribution: usage of latrines &

hand-washing stations, keeping animals out of the house, etc. Then, the water committee president (a woman) and treasurer (a man) post and review the list of who has paid or not their connection fee, and who has still not signed up for the service. 70 families out of 100 are represented.

Quantitative impact data

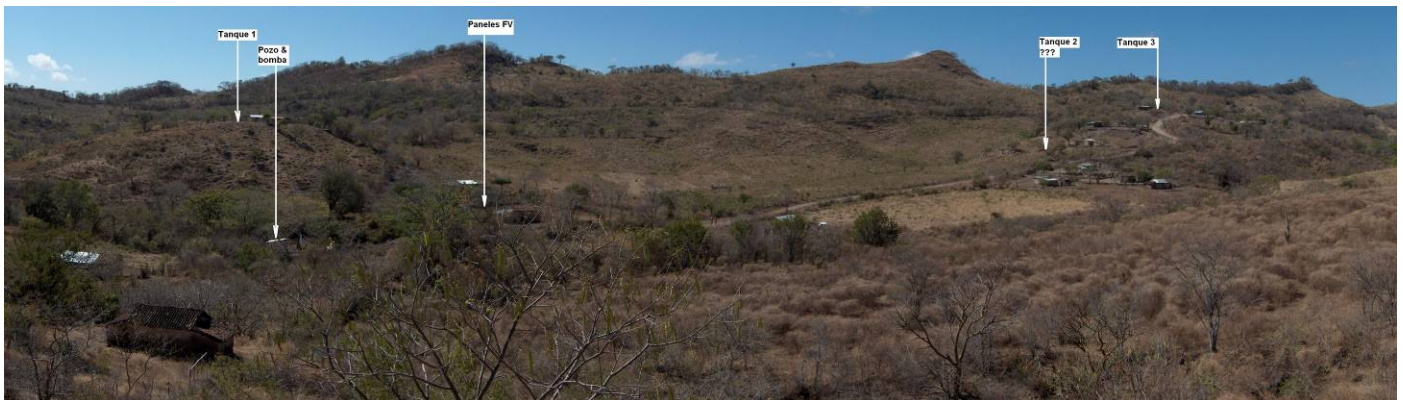
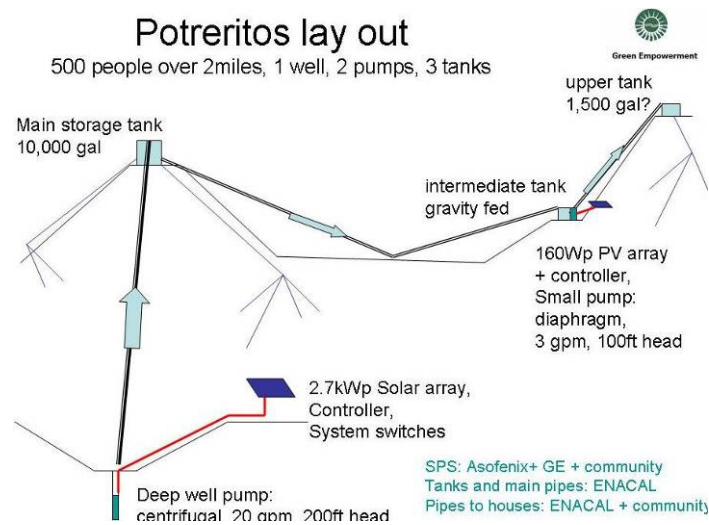
The complete water pumping and distribution system will serve a total of 500 people along one valley – serviced by one dirt road, spread over approx. 3km /2 miles

Tech specs

Design goal: provide 12 gal/day (46l) per person, i.e. 6000 gal/day (23m³) of clean water, under the worse monthly average solar conditions of 4.9 kWh/m² (which happen in May & June, the start of the rainy season). Lift the water from the well to the main tank, located on a hill above (total static elevation from water level to the tank: 58 m (180 ft)). From the main tank, and in order to service a small part of the community located still higher, feed a secondary tank by gravity, then use a second, smaller pump to lift the water to a final small tank a total of xxx m/ft above ground level at the pump location.

This approach, with 2 pumps, was proposed locally as an alternative to a single high power and high cost pump which would have required a large drilled well than already in place.

The future complete lay out and how it will fit in the landscape.



Equipment used

Nominal specs of the main pump: 20gpm (76l/min) at 200ft (60m) dynamic head; 2HP motor (1750W); centrifugal multistage SunPumps SCS 20-200 2 H.P. submersible pump. Fed through a solid-state SunPumps PCB180BL-M1 pump controller, from a 2700Wp photovoltaic array of 22 Sharp 123 watt solar modules - MC [ND-L3EJEA].

Nominal specs of the secondary pump: 3.7gpm Max (14l/min) at 100ft (30m) dynamic head; 116W Max motor; positive displacement SunPumps SDS Q-128 submersible pump (Quad-diaphragm).

Fed through a solid-state SunPumps PCA-30-M1 pump controller, from a 160Wp photovoltaic array made of 2 Sharp 80 watt modules NE-80E1U.

LESSONS LEARNED

- The local labor needs to be flexible in its availability. Sometimes, the work crew is unused, waiting for some critical step to be completed by the technicians.
- Being able to track the sun during the day is a great concept to get up to 20% more output out of a given solar system, but for a two (/three) posts design, there needs to be plenty of “play” everywhere to make adjustments to the structure during installation in all 3 directions as well as angles.
- Instead of a flat bases + anchor bars in the foundation, single longer posts buried deep in the concrete would be sturdier and easier to install. But then, parallel verticality of the posts is crucial.
- The third support post, if needed, needs an attachment that allows full rotation of the axis, for example a bearing on the axis itself.
- A manual crank is cheap and could be motorized later, but for strength and wind resistance it would be better to attach it farther from the axis of the array
- All similar parts should be designed to be identical and interchangeable, including in regards to hole positions. Looking at every assembly step for the next part that will fit, takes a lot of time.
- Little trick of the trade: to carry and pour concrete, a piece of rag or paper is always put at the bottom of the bucket before filling it, so the concrete doesn't stick to the bucket.
- Even with a laptop nearby, it's a good idea to have a scientific calculator.
- Even though Jaime had no system drawing, structure drawing, project schedule or anything else documented in a way I could see, he had in his head the whole installation process, tasks scheduling, etc. So don't always expect a formal documentation.
- Trust the locals: things do work out in the end.
- Shipment & import time always takes longer than we expect. Be prepared to reschedule installation work.
- When parts get lost in shipment, be creative to find replacements.
- And on a different topic, for foreign visitors: It's a bad idea to try new, uncooked food just when you need to be productive!

PLANNED FUTURE WORK & IMPROVEMENTS

Short term:

- Replace temporary fence with durable metal one.
- Replace temporary array anchors with more durable ones due to wind.
- Cover any holes in the metal structure through which water could penetrate during the rainy season.
- In the well, replace metal safety cable with a sturdy nylon rope to resist long term corrosion.
- Install the second, smaller pump (with small fixed array)

Long term:

- Over time, identify and train local technical responsible for basic maintenance: cleaning panels, checking contacts and structure for corrosion, checking anchors, etc. and then to be able to interpret LED's in the controller.
- When actual sun tracking is desired – within 1-2 years:
 - Replace the current orientation mechanism with something sturdier which would connect to the array further from its axis, for better leverage and solidity against wind.
 - If anchoring is still necessary, change it to allow 3 positions a day.
 - Replace the current attachment to the third post to allow better rotation of the axle.