Well System Monitor
6 month review

Version 1.0; date: 1/9/2022

Summary

The well system monitor has performed a valuable function for the well system owner. It has detected several problems with the system and aided the system owner in having a better understanding of the operation of his system. At times human monitoring of the data let us alert the owner quickly enough for a problem to be corrected before harm could be done.

In the future we may enhance the system to remove the alerts on every event and instead raise alerts when an anomalous condition is detected. From experience we know we can detect at least the following situations:

A. Well pump runs so long that it may be overflowing the holding tank.
B. Pressure pump runs so long that there may be a leak in the household system.
C. A failure in the holding tank refill sensor that causes the tank to empty.
D. A failure in the plumbing system.

Background

After a long delay the well system was finally installed by the user in June 2021. The well system has several components.

1. A **well pump (WP)** that pumps about 6.7 gallons per minute into a holding tank
2. A **holding tank** of about 1,300 gallons
3. A **floating level sensor** in the holding tank that turns the well pump on and off at set low and high water levels
4. A **pressure pump (PP)** that draws from the holding tank and feeds water into a pressure tank
5. A **pressure tank** that holds about 30 gallons. The household system is fed from this tank.
6. A **pressure sensor** that turns the pressure pump on and off at set low and high pressure levels

As the household uses water it is fed from the pressure tank. As water leaves the tank the pressure drops. Eventually the pressure pump comes on to refill and pressurize the tank. The pressure pump draws water from the holding tank. Eventually enough water has been drawn from the holding tank that the well pump comes on to refill the holding tank.

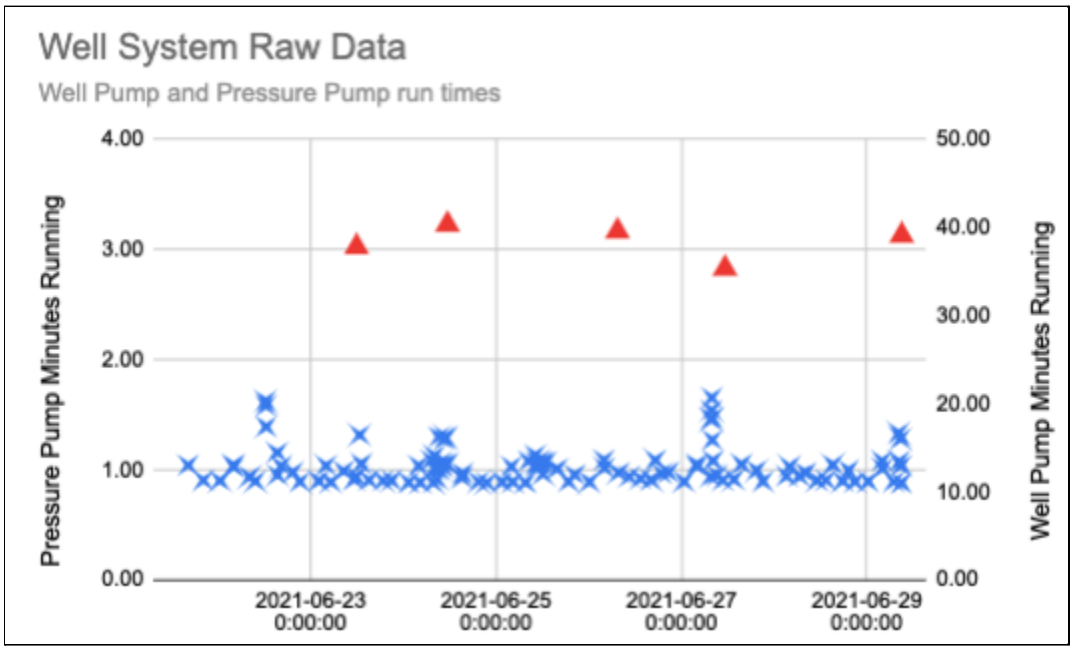
Our device monitors the relays that control power to the well pump and pressure pump. The device reports when these pumps go on and off. The data is saved in a cloud database. These alerts are also sent as SMS messages to the system owner. The SMS are also sent to our cell phones so we can monitor the operation of our device. These SMS messages led us to detect several system problems.

A complete description of the well system monitor project (including complete plans on how to build your own) can be found at https://github.com/TeamPracticalProjects/WellSystemMonitor

Initial observations

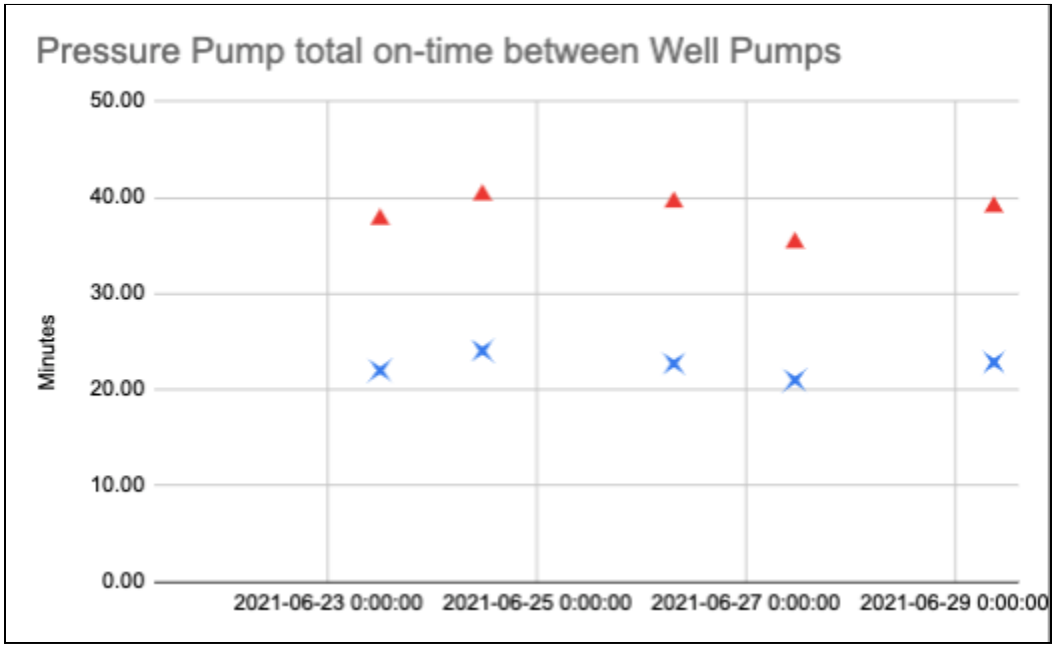
Neither we nor the well system owner knew what to expect. The system owner had a good gut feel of how the system worked, but little hard data.

This graph shows a typical week when we started monitoring. The pressure pump would run 7 or 8 times a day for about one minute at a time. Sometimes it would run longer and more often; these were times when someone was using a lot of water, such as watering the vegetable garden. The well pump would run about 40 minutes at a time to refill the holding tank. We did not know what to expect, and this data seemed reasonable to all of us.

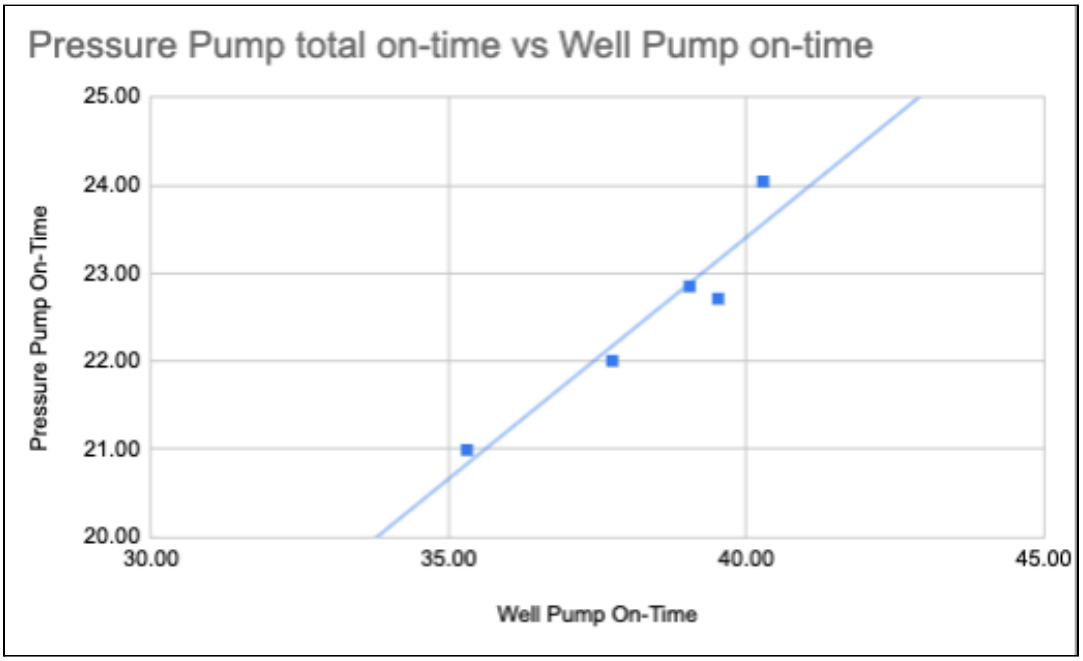


Graph: A typical early week. (PP in blue, left axis).

We looked at the total time the pressure pump would run between cycles of the well pump. We found there was a good correlation between these. And a scatter gram verified this.



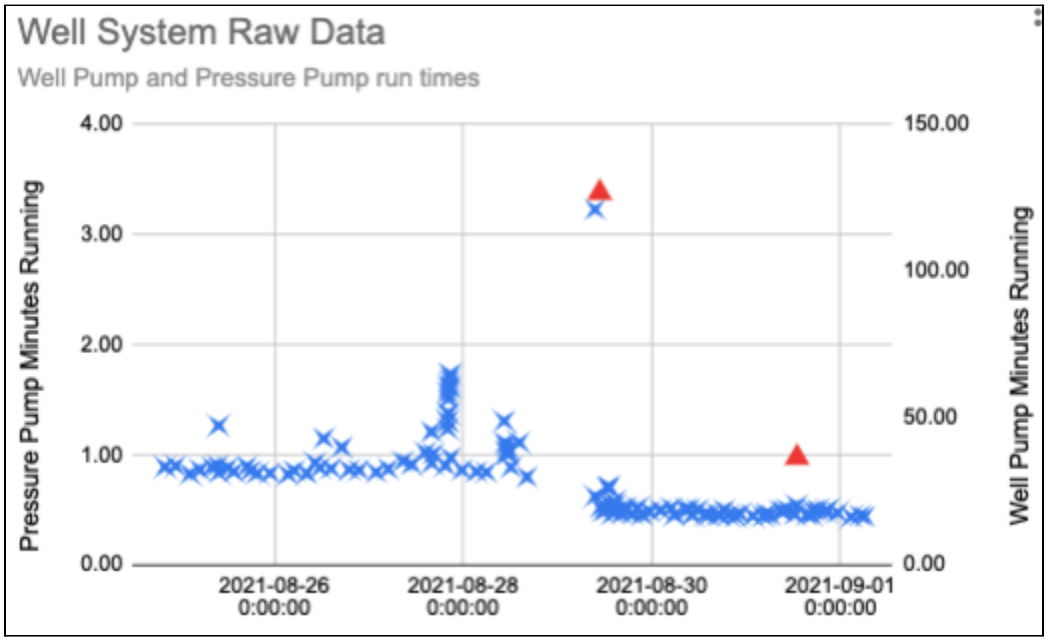
Graph: Total pressure pump time between well pump time. (PP in blue.)



Graph: Total Pressure Pump run time vs Water Pump run time

First failure detected

Our first anomaly in the data came on August 29. At that point there was a long time without pressure pump data then the pressure pump ran for over 3 minutes, the well pump ran for almost 2 hours. After that event the pressure pump cycle time dropped to 30 seconds.



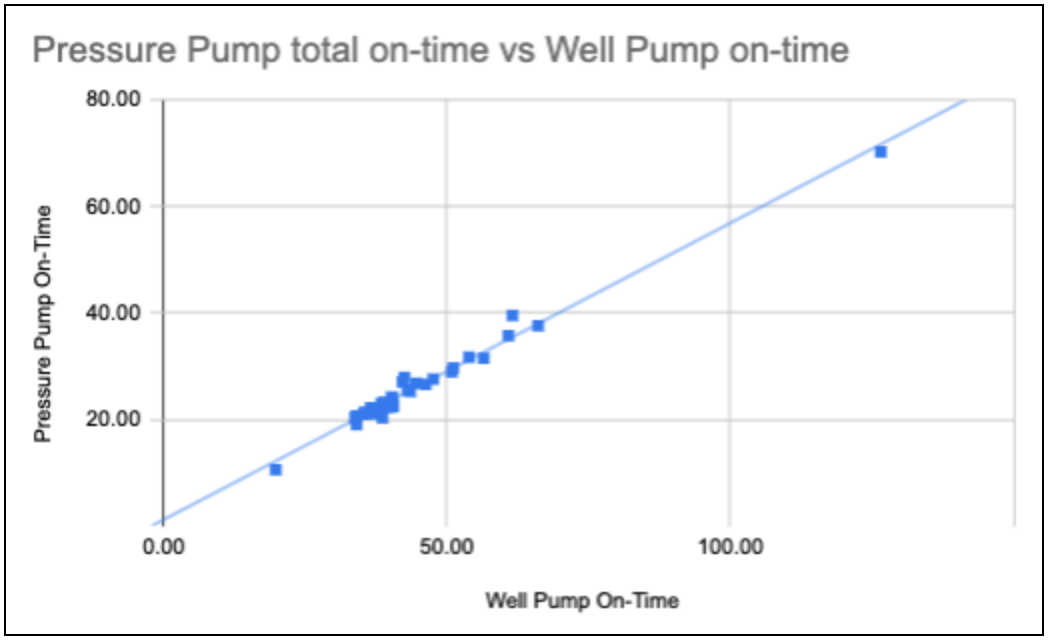
Graph: Pressure pump cycle time drops (PP blue, left axis)

Investigation found that the holding tank level sensor had failed and allowed the holding tank to reach its lowest level. There is another sensor at the bottom of the tank that shuts off power to the pressure pump so that it will not pump the holding tank dry. The household was without water.

The system owner reset the holding tank level sensor, and the pressure pump ran a long time because the pressure pump was emptied; the well pump ran a long time to refill the holding tank. After the reset the system functioned normally again. We see the well pump run on 8/31 for its normal 40 minute cycle.

However, the pressure pump continued to cycle for 30 seconds at a time instead of its normal one minute. Clearly the event had affected the pressure pump system. But we did not know why.

Interestingly, the pressure pump vs well pump time remained a linear relationship.



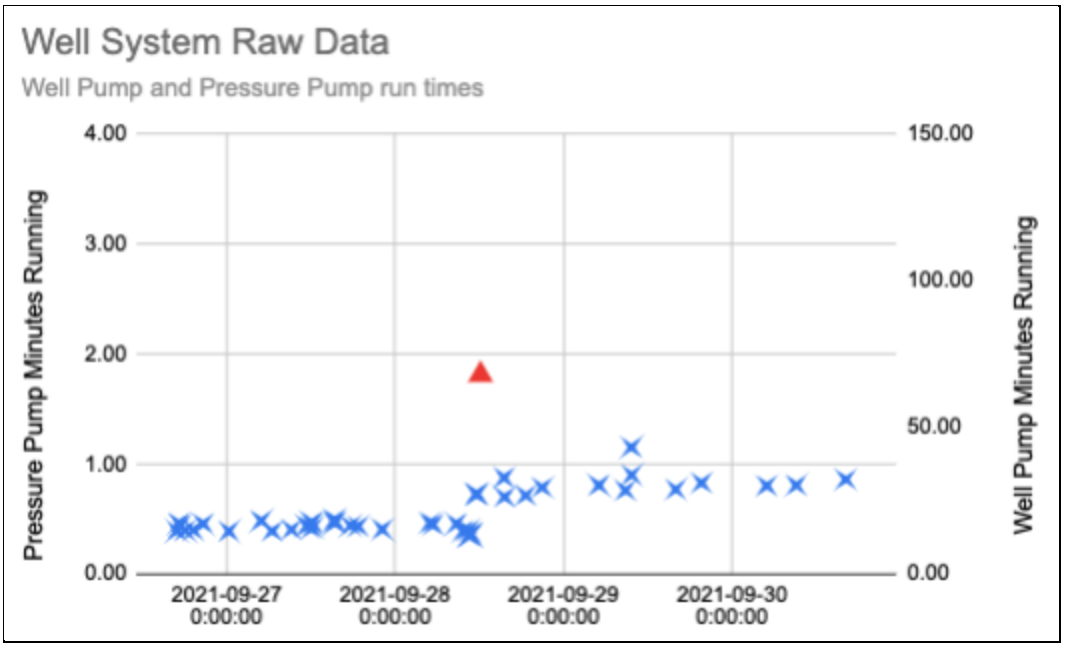
The long well pump time still correlates to total pressure pump time.

Pressure pump restored

The system owner had a gut feeling that the pressure pump should run more than 30 seconds at a time. In fact, our first weeks of monitoring showed that it ran almost a minute for each cycle. The pressure tank contains a bladder that expands when water is added. His theory was that the pressure tank bladder had developed a leak and the pressure tank was now flooded.

On September 28 the owner emptied the pressure tank completely and then used an external pump to repressurize the tank that contains the bladder.

As seen in the graph below, this repressurization immediately restored the pressure pump to a longer cycle time.



Graph: Pressure pump is recharged on 9/28 (PP blue, left axis)

Failure of the holding tank sensor

The pressure pump continued to have a 45 second on-time until a second holding tank low point event occurred. In this instance it was found that the holding tank float sensor again did not trigger correctly when the tank was draining. The sensor is a simple floating switch. The owner banged his hand on the side of the tank and the well pump immediately came on. The system was restored.

This event again caused the pressure pump routine cycle time to drop to 30 seconds. We theorize that as the holding tank approached its low point the pressure pump may have taken some air into the pressure tank; the owner says this is not possible. Another theory is that the pressure tank bladder has some very small leak in it that is only exposed when the household draws water from the tank when the pressure pump is shut off due to a low holding tank condition. The pressure tank might drain below its usual low pressure point and thus expose the bladder leak. At this time the cause that couples low holding tank level to the pressure pump cycle time remains a mystery.

Operator error detected

At one point we noticed a situation where the well pump alert for ON was received, but no OFF alert came. We feared that the pump was running wild and flooding his pump house. We alerted the system owner.

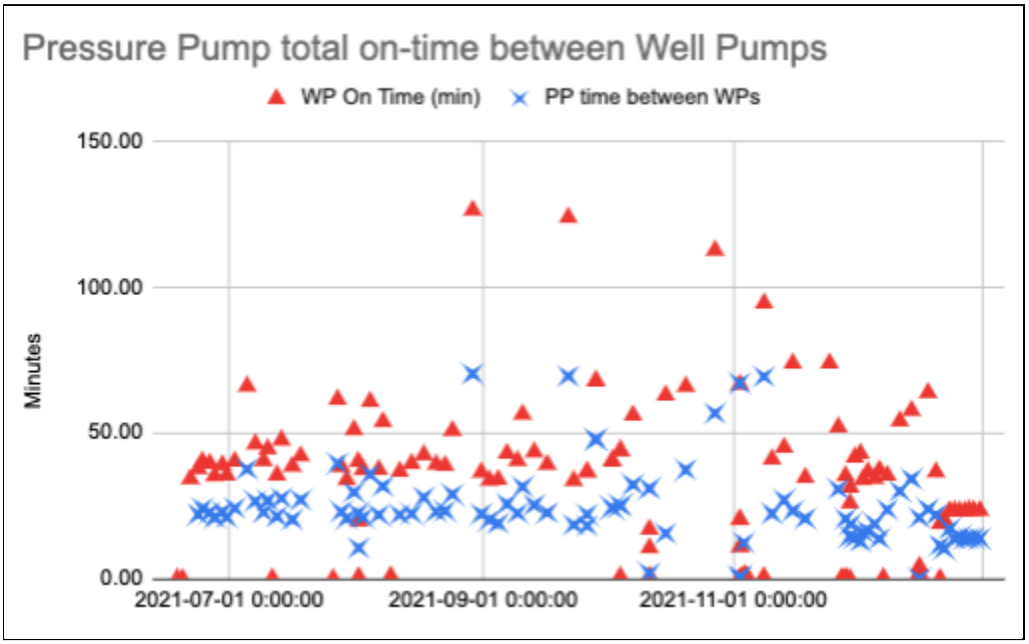
His investigation found that the well pump power had been switched off. He had been working on the system and restored power to the sensors, but not to the master well pump power. This

left the sensors able to call for the well pump, and our device to report it, but since the water pump did not run, the holding tank continued to drain. The system owner was able to intervene before the holding tank ran out of water.

Power was restored to the well pump and the system returned to normal. Because of our human based alert, the holding tank did not get to the point of affecting the pressure pump cycle time.

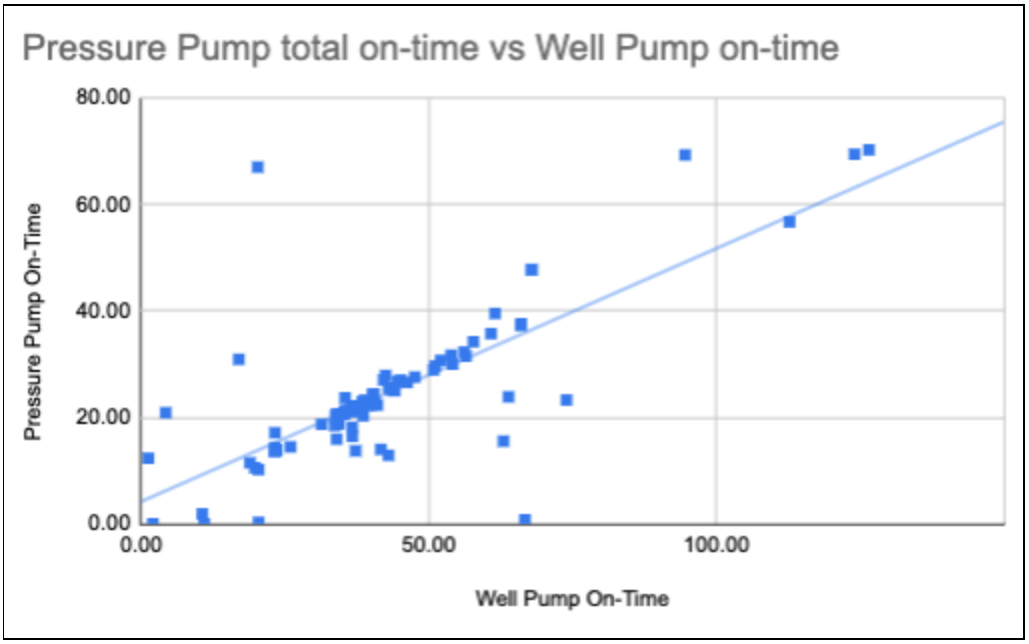
Holding tank sensor replaced

The system owner was unhappy with the wide variation in well pump times. He felt that the floating level sensor should exert much tighter control of the holding tank level. Looking at six months of data we see wide variation in the cycle time of the well pump. (The far right of the graph shows that stability has been obtained, as discussed later.)



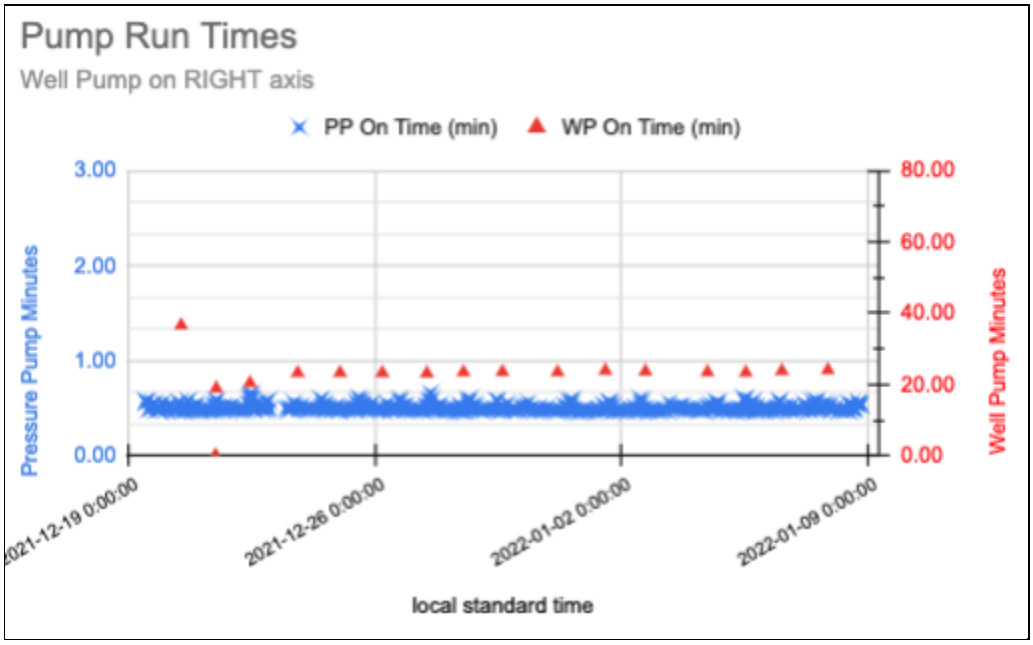
Graph: Well pump cycle times (red) have a wide distribution

In the graph below we see that even with wide variation in the well pump cycle times, the relationship to total pressure pump time remains fairly linear. Outliers at the low times were caused by events when the system owner was working on the system. The system owner was certain that the variation in well pump times were caused by a defective holding tank float sensor.



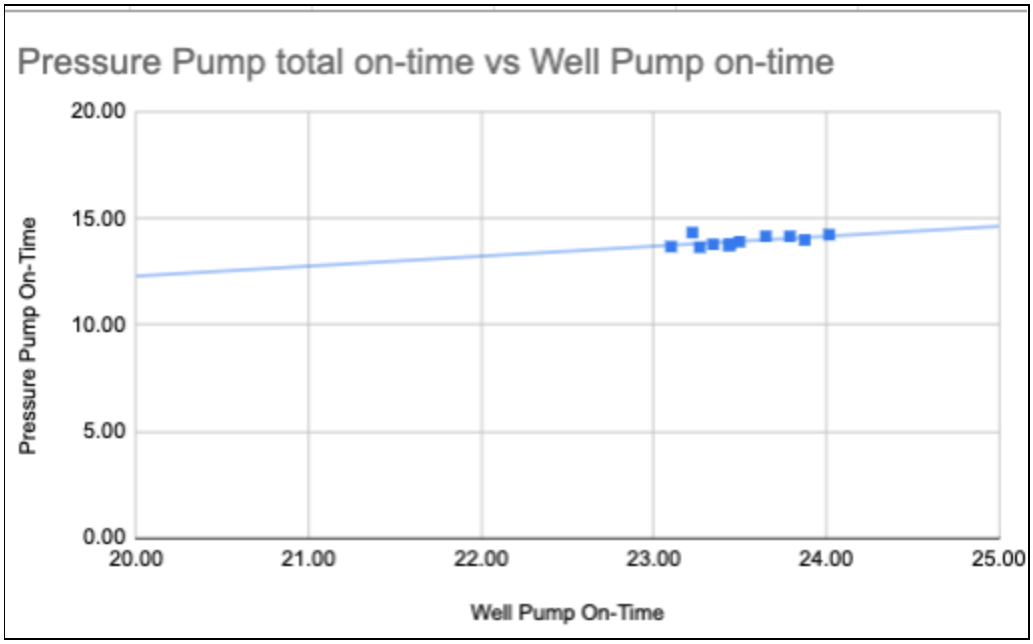
Graph: Well pump times vary from 20 to 150 seconds

On December 22 the system owner replaced the problematic floating level sensor. At that point the well pump cycle time became very regular. The pressure pump continues to cycle at 30 seconds.



Graph: Regular well pump cycle times in red

As seen below, the correlation to pressure pump time is now very tight.



Graph: Well pump times vary less than 1 minute (note x-axis scale)

Future Work

We have thought about enhancements to the system. The current system owner is very happy with the current system, but we envision a system that alerts the owner only when there is a problem. Changes we might consider:

1. Routine Operation - Today we SMS when the well pump turns on and again when it turns off. The owner likes these alerts, but to anyone else they become a burden.
    a. Alert on well pump turning off: Include the date/time in that alert
    b. Alert on well pump turning on: Remove this alert
2. Well Pump Runs Too Long: SMS when the well pump runs more than 30 minutes. Possible failures:
    a. Holding tank float sensor has waited too long to call for the well pump.
    b. Holding tank float sensor and overflow sensor have failed. Water is running out the top of the tank.
    c. Holding tank or plumbing has a leak of more than 6.7 gallons per minute.
    d. Well has run dry
    e. Power to the well pump has been turned off
3. Well Pump Runs Too Often: SMS when the well pump runs a total of more than 60 minutes in a 24 hour period.
    a. Plumbing leak
    b. Well has run dry
    c. Power to the well pump has been turned off
4. Pressure Pump Too Short: SMS when the pressure pump cycle lasts less than 45 seconds.

    a. Pressure tank failure
5. Pressure Pump Too Long: SMS when the pressure pump cycle lasts longer than 5 minutes.
    a. Leak in the plumbing
    b. Power to the pressure pump has been turned off
6. PP to WP Ratio: SMS when the cumulative PP time to well pump time is outside the norm. Establish bands on the PP/WP scatter gram and alert when a data point falls outside the norm.
    a. PP/WP Too Low
        i. Plumbing leak between holding tank and pressure tank.
    b. PP/WP Too High
        i. Pressure pump is failing
7.

Conclusion

Our well system monitor successfully detected a number of serious problems in the system. Our alerts were used to initiate corrective action. With the system running in a stable manner we could now remove the log alerts we have been issuing and replace them with actual trouble alerts.