

# Guelph Water Services – SCADA Update

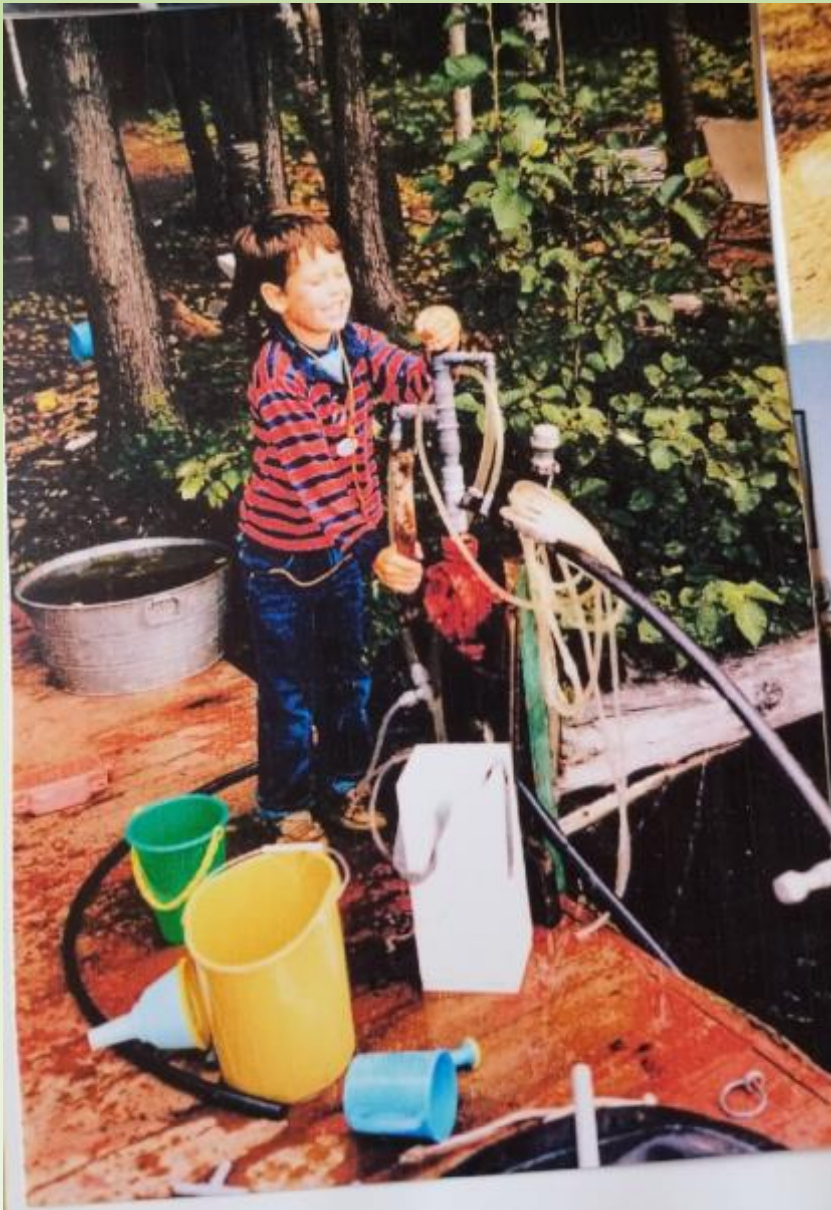
## Power Usage Dashboards

## DMA District Flowmeter Dashboards



**Speaker: Graham Nasby, Water SCADA & Security Specialist**

July 3, 2019 – Guelph, Ontario, Canada



**I wanna be a  
Water Guy  
when I grow up!**

# The Challenge

We are a water utility = a lot of what we do involves pumping water

- How much electricity do we use to pump water?
- How much is this electricity costing us?
- How can we get good/timely data about how we use electricity?
- **Waiting until we get power bills at the end of each month is not that helpful**
- The gold standard is to create an automated reporting tool to give us:
  - kWh per m3 produced
  - \$ of electricity per m3 produced
  - Ability to compare one facility to another
  - Ability to compare one operating strategy vs. another
  - Timely information for the operations team
  - Long term reporting to measure performance over time
  - Something that looks nice

# Prior Work

## Smart Water Initiative (2013)

- Grant money was used to install building digital power meters at all water facilities
- Custom daily power reports created by a system integrator
- Reports stopped working in mid-2015 due to programming/data-feed issues

## Hydro Bill Analysis Company, online services (available since 2015)

- Service the city uses to analyze power bills
- Web-based tool for downloading and analyzing power bills
- Data is only available at the end of each month, **monthly power totals only**

## Online Power Reports 2.0 (2016-2017)

- SCADA Group was asked to work with system integrator to fix online power reports
- After a year of work by the integrator, the power reports were working again
- Reports only provide daily totals (cost, kWh, m3 pumped), **data available “next day”**

**But could we do better?**

**Better granularity, more timely data, better reports, ability to self-edit....**

# Skunkworks



A **Skunkworks project** is a project developed by a small and loosely structured group of people who research and develop a project primarily for the sake of radical innovation.

The term originated with Lockheed's World War II *Skunk Works* project.

**Let's see if we can use Open Source software to build something better!**



# Skunkworks SCADA Team

**Goal:** Make a better power reporting tool

**Kick-off:** Met at May 2017 OWWA conference

Graham Nasby

- Water SCADA & Security Specialist

Jason Little

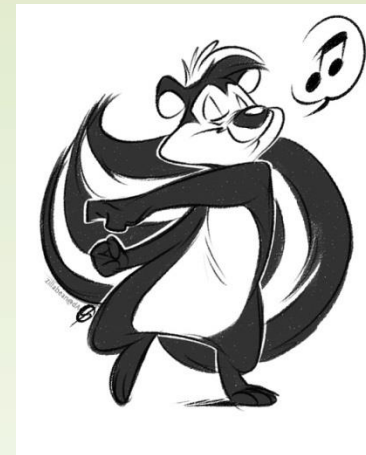
- Open Source Software Developer
- Day job is a SCADA specialist at a nearby utility

Noah Clark

- SCADA co-op student (Jan-Apr 2018)
- Had a previous co-op at an energy management firm

Travis Murray

- SCADA Specialist (Nov`18-Jun`19)



# This is what we built



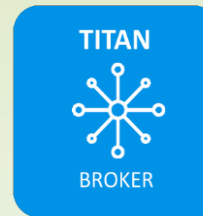
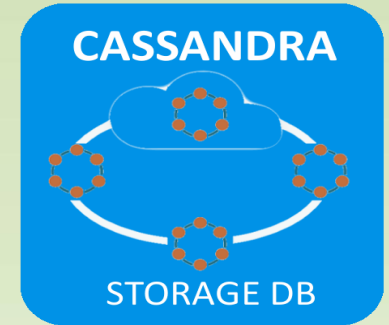
# How it works



Web-based  
Dashboard  
& Reporting  
Tool



Distributed  
Open  
Source  
Database  
(no licensing fees)



Pushes to  
Historizer  
Server



Pushes to  
Time Series  
Database



Digital Power Monitors

Polls Data Every  
Second



Pump Motor Starters



RaspberryPi



Single Board Computer < \$35  
(Neptune Cluster software)

Logs data every 5min  
Logs changes on 1 sec intervals



# Power Calculations

- **Measuring Electricity Usage is EASY...**
- **Calculating Power Costs is HARD!**
- **Ontario has one of the most complicated electricity pricing schemes in the world**
- **Connection Charges**
- **Transmission Charges**
- **Distribution Charges**
- **Energy Usage**
- **Peak Charges**
- **Ontario Hourly Energy Prices**
- **Time of Day Adjustments**
- **Global Adjustment**
- **Global Adjustment Estimates**
- **End of the Month Balancing**
- **Etc.**

# Power Calculations

Hydro One – General Service -Energy

Hydro Cost	
Energy Cost Today	
Accumulating kWh	
>>First Rate (<750kWh)	
>>Remaining Rate (>750kWh)	
>>Debt Retirement Charge	
>>Service Charge	
>>Distribution Volumetric Rate	
>>Transmission Network Charge	
>>Transmission Connection Charge	
>>Loss Factor	
>>Wholesale Market Rate	
>>Rural Rate Assistance	
>>SS Admin Charge	

Hydro One – General Service -Demand

Hydro Cost	
Energy Cost Today	
Accumulating kWh	
>>Debt Retirement Charge	
>>Wholesale Market Rate	
>>Rural Rate Assistance	
>>Service Charge	
>>SS Admin Charge	
>>Loss Factor	
Instantaneous Power	
>>Distribution Volumetric Rate	
>>Transmission Connection Charge	
>>Transmission Connection Charge	
>>Transformer Allowance	

Guelph Hydro – Time of Use

Hydro Cost	
Energy Cost Today	
Accumulating kWh	
>>On Peak Rate	
>>Off Peak Rate	
>>Mid Peak Rate	
>>Distribution Volumetric Rate	
>>Transmission Network Charge	
>>Transmission Connection Charge	
>>Debt Retirement Charge	
>>Loss Factor	
>>Wholesale Market Rate	
>>Rural Rate Assistance	
>>Monthly Service Charge	
>>SS Admin Charge	
>>OEP Charge	
>>Loss Factor Rate	

Guelph Hydro – General Service

Hydro Cost	
Energy Cost Today	
Accumulating kWh	
>>Debt Retirement Charge	
>>Wholesale Market Rate	
>>GA Rate Rider	
>>Service Charge	
>>SS Admin Charge	
>>Loss Factor	
Power Cost Today	
Instantaneous Power	
>>Distribution Volumetric Rate	
>>Transmission Connection Charge	
>>Transmission Connection Charge	
>>Transformer Allowance	

Hydro One	
<50kW	>50kW
General Service – Energy (aka Two Tiered)	General Service – Demand
Arkell 08	Arkell 06
Arkell 14	Arkell 07
Arkell 15	
Guelph Hydro	
<50kW	>50kW
Time of Use	General Service
Calico	Burke Well
Carter	Clythe Creek
Clair Booster	Downey
Dean	Emma
Helmar	Membro
Queensdale	Paisley
Robertson	Park
	Univeristy
	Water Street
	Woods

# Power Calcs



Live Feed of Hourly Global Adjustment Hourly Energy Prices



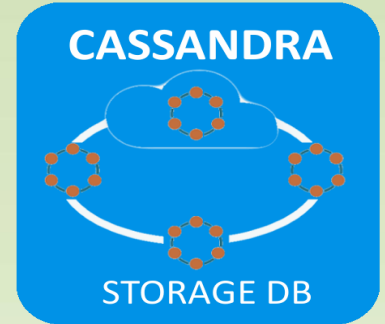
Web-based Dashboard & Reporting Tool



Plant PLC's (Flow Data)



Distributed Open Source Database



Digital Power Monitors

Polls Data Every Second



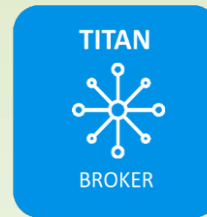
RaspberryPi

Calculates Live Energy Costs every 5 mins



Single Board Computer < \$35 (Neptune Cluster software)

Logs data every 5min  
Logs changes on 1 sec intervals



Pushes to Historizer Server

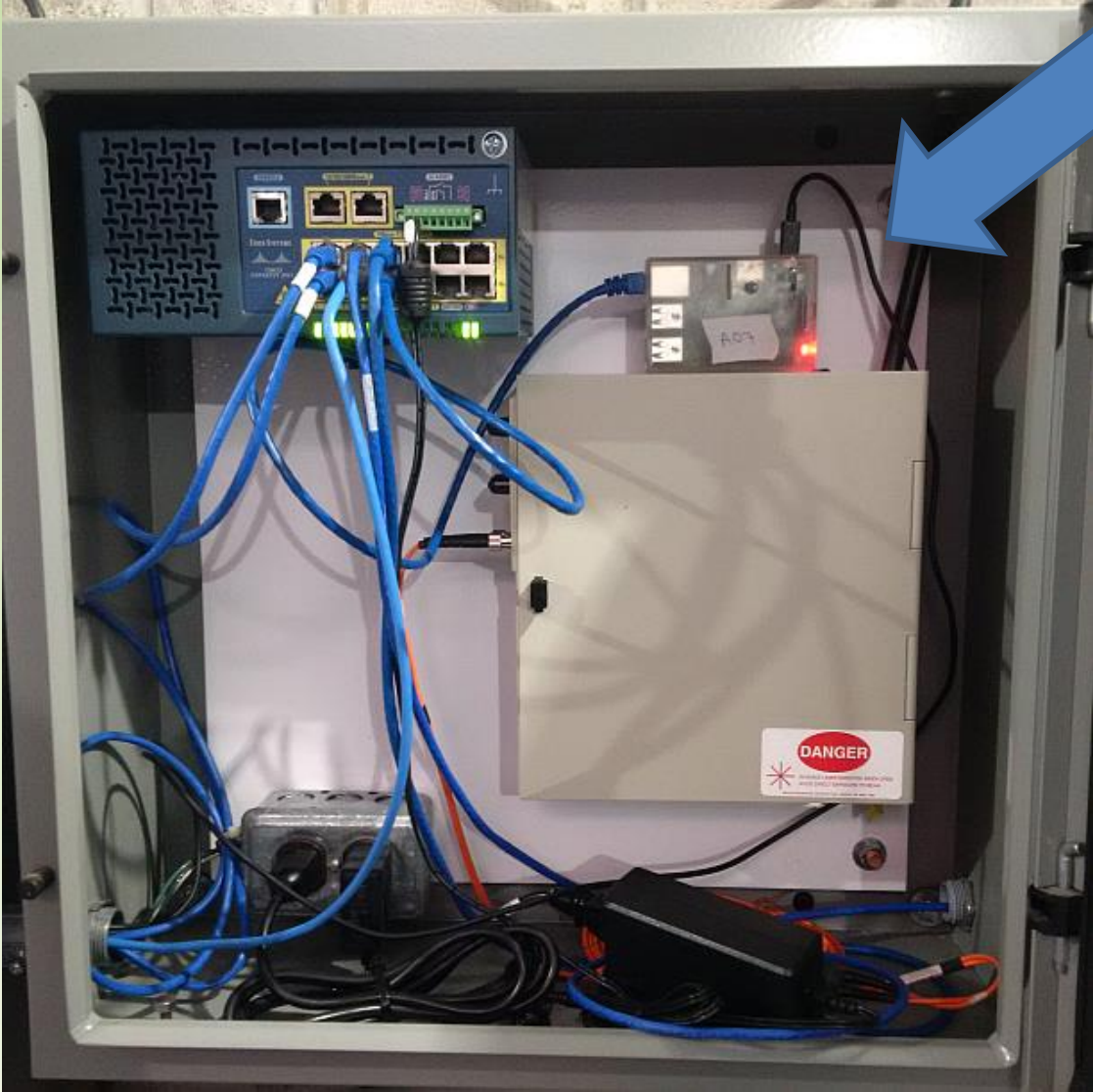


Pushes to Time Series Database



Pump Motor Starters

# Raspberry Pi Installed



# Collecting the Data

Grafana - DMA Overview | Grafana - Report - Monthly Power | 172.16.1.122:8080 | Node-RED Dashboard | Trident Historizer : 172.16.1.120

Not secure | 172.16.1.122:1880/ui/#/0

## Neptune Cluster Dashboard

### Triton Edge Messengers

Site	State	Buffer	Poll	RBE	CPU	IP	Uptime
A06	ONLINE	0	52	3	0.63	172.16.65.29	507.89
A07	ONLINE	0	56	8	0.79	172.16.65.39	503.22
A08	ONLINE	0	55	13	0.89	172.16.65.49	385.23
A14	ONLINE	0	53	10	0.66	172.16.65.19	41.38
A15	ONLINE	0	55	2	0.62	172.16.65.9	507.87
ADV	ONLINE	0	7	1	0.20	172.16.65.59	507.88
BKS	ONLINE	0	40	3	0.88	172.16.72.49	148.31
CAB	ONLINE	0	49	12	0.63	172.16.28.49	510.82
CBS	ONLINE	0	58	7	0.74	172.16.73.49	349.00
CCB	ONLINE	0	51	6	0.72	172.16.51.49	116.16
CLT	ONLINE	0	5	0	0.22	172.16.73.46	30.63
CWS	ONLINE	0	52	6	0.57	172.16.53.49	99.34
DEB	ONLINE	0	50	2	0.61	172.16.22.49	70.16
DOB	ONLINE	0	56	13	0.72	172.16.71.49	210.07
EWS	ONLINE	0	52	1	0.64	172.16.43.49	56.23
HEB	ONLINE	0	60	5	0.87	172.16.45.49	350.18
MEB	ONLINE	0	53	13	0.69	172.16.23.49	507.74
PAB	ONLINE	0	54	7	0.61	172.16.44.49	127.15
PRB	ONLINE	0	51	2	0.53	172.16.26.49	15.17
QUB	ONLINE	0	49	4	0.53	172.16.25.49	510.79
ROB	ONLINE	0	52	11	0.65	172.16.41.49	36.30
SCS	ONLINE	0	2	0	0.09	172.16.52.49	507.91
SPT	ONLINE	0	5	0	0.24	172.16.27.49	41.27
UNB	ONLINE	0	57	3	0.72	172.16.24.49	13.18
VET	ONLINE	0	4	0	0.14	172.16.42.49	52.86
WDB	ONLINE	0	13	1	0.33	172.16.1.79	166.96
WWS	ONLINE	0	52	2	0.63	172.16.21.49	237.14

### Titan Brokers

Broker 1: **ONLINE**  
response **0.382 ms**

### Trident Historizers

Historizer 1: **ONLINE**  
Tag Count: **6617**

Tag Rate

131 tags/sec

Tag Rate History

Insert Rate

15 inserts/sec

Insert Rate History

### Clustered Storage Nodes

Node 1: **ONLINE**  
response **1.03 ms**



# Pulling Data from Digital Power Monitors

The screenshot displays a Node-RED dashboard for Triton Edge Messenger. The main workspace shows a flow starting with a 'timestamp' node, followed by a function node that calls '/home/pi/lab\_pm3000.py' with a 'pid:18628' parameter. This is followed by a 'delay 10s' node. The flow then branches into 28 parallel paths, each leading to an 'Analytics' node. The nodes are labeled with various power monitor parameters such as 'F15\_L1Current', 'F15\_L2Current', 'F15\_L3Current', 'F15\_AvgCurrent', 'F15\_L1-NVoltage', 'F15\_L2-NVoltage', 'F15\_L3-NVoltage', 'F15\_AvgL-NVoltage', 'F15\_L1-L2Voltage', 'F15\_L2-L3Voltage', 'F15\_L3-L1Voltage', 'F15\_AvgL-LVoltage', 'F15\_Frequency', 'F16\_L4Current', 'F16\_PositiveSequenceCurrent', 'F16\_NegativeSequenceCurrent', 'F16\_%CurrentUnbalance', 'F16\_PositiveSequenceVoltage', 'F16\_NegativeSequenceVoltage', 'F16\_%VoltageUnbalance', 'F16\_PhaseRotation', 'F16\_AverageFrequency', 'F17\_L1RealPower', and 'F17\_L2RealPower'. The left sidebar contains a 'filter nodes' search bar and a list of input and output nodes. The right sidebar shows the 'info' tab for the selected flow, displaying details like 'Flow: \*40d8bdad.c63914\*', 'Name: PM3000', and 'Status: Enabled'. At the bottom right of the info panel, there are instructions: 'Show the Info tab with ctrl-g i' and 'the Debug tab with ctrl-g d'.

# Pulling Data from Water Supply Site PLCs

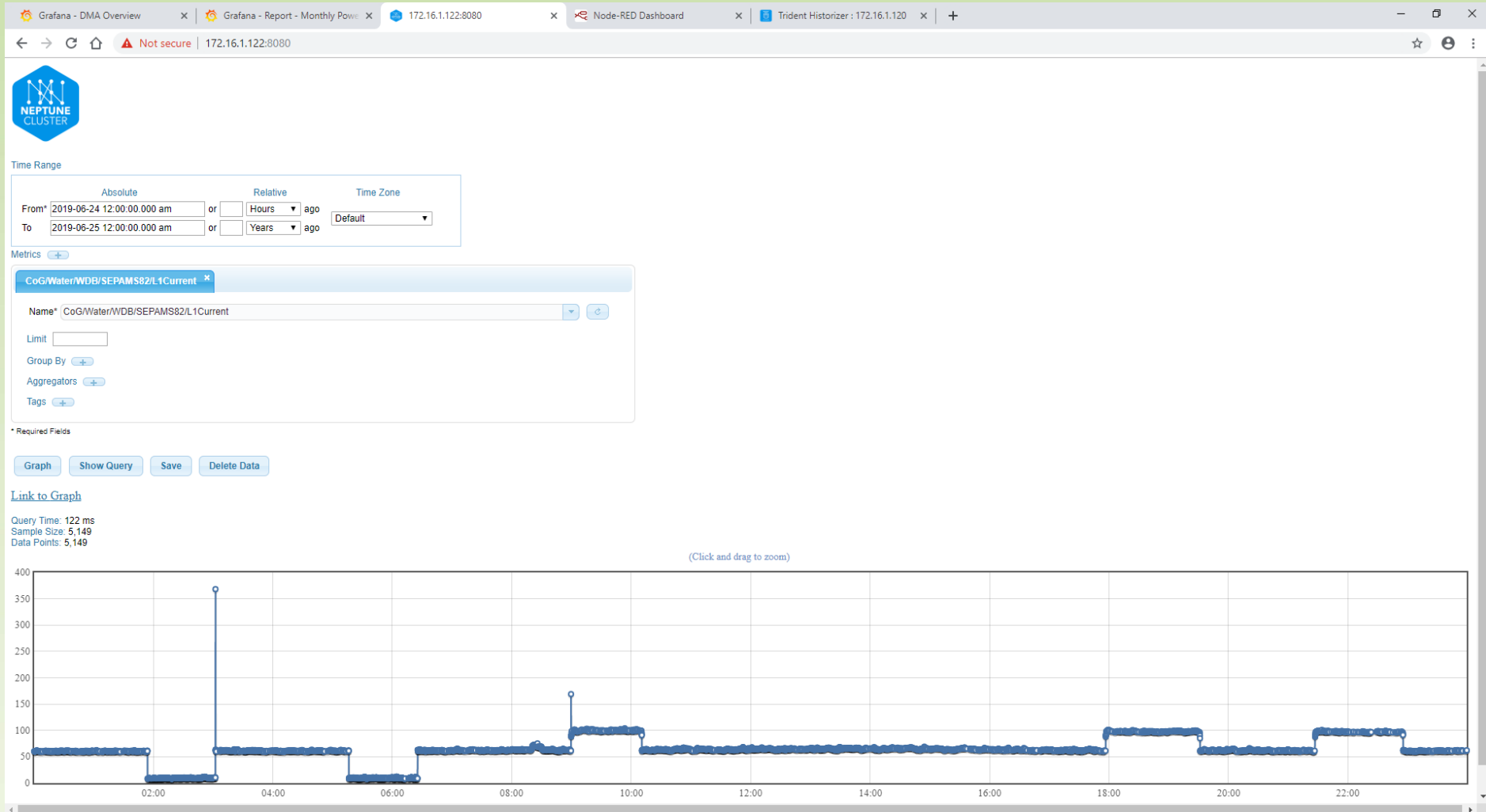
The screenshot displays the Triton Edge Messenger interface with a Node-RED flow. The flow starts with a 'timestamp' node, followed by a script node '/home/pi/ab\_slc.py' (SID: 467). The output of the script node is connected to a 'json' node, which then feeds into a 'split' node. The 'split' node has five outputs, each connected to a specific PLC data node: 'PLC1/Well1\_FlowRate', 'PLC1/POE\_FlowRate', 'PLC1/POE\_Pressure', 'PLC1/POE\_ChlorineResidual', and 'PLC1/Reservoir1\_Level'. Each of these PLC data nodes is connected to an 'Analytics' node. A 'delay 10s' node is also present in the flow, connected to the script node. The interface includes a left sidebar with various input and output nodes, a top navigation bar with tabs for 'PM3000', 'SLC Read', 'Logix Read', and 'Out', and a right sidebar with 'info', 'debug', and 'dashboard' tabs. The 'info' tab is active, showing details for the flow: 'Flow: \*6a20adf9.255594\*', 'Name: SLC Read', and 'Status: Enabled'. A footer note indicates that the Info tab can be shown with 'ctrl-g i' and the Debug tab with 'ctrl-g d'.

# Buffering Data in the Raspberry Pi's

The screenshot shows a web browser window with several tabs. The active tab is a Grafana dashboard titled "Current Tag Values". The dashboard has a blue header with the title. Below the header, there is a "Tag Filter" section with a "REFRESH" button. A toggle for "auto refresh" is turned off, and the "Tag Filter Results Count" is 67. Below this is a table with three columns: "Tag", "Value", and "Age (s)". The table lists 67 tags with their corresponding values and ages.

Tag	Value	Age (s)
PLC1/Booster1_Running	1.00	3
PLC1/POE_ChlorineResidual	0.82	3
PLC1/POE_FlowDayTotal	1,083.04	3
PLC1/POE_FlowRate	16.64	3
PLC1/POE_FlowYesterdayTotal	1,418.97	3
PLC1/POE_Pressure	505.83	3
PLC1/Reservoir1_Level	1.77	3
PLC1/Well1_FlowDayTotal	1,092.94	3
PLC1/Well1_FlowRate	19.06	3
PLC1/Well1_FlowYesterdayTotal	1,395.55	3
PLC1/Well1_Running	1.00	3
PM3000/F15_AvgCurrent	38.78	1
PM3000/F15_AvgL-LVoltage	584.20	1
PM3000/F15_AvgL-NVoltage	0.00	1
PM3000/F15_Frequency	59.96	1
PM3000/F15_L1-L2Voltage	585.42	1
PM3000/F15_L1-NVoltage	0.00	1
PM3000/F15_L1Current	33.84	1
PM3000/F15_L2-L3Voltage	584.32	1
PM3000/F15_L2-NVoltage	0.00	1
PM3000/F15_L2Current	40.06	1
PM3000/F15_L3-L1Voltage	582.87	1
PM3000/F15_L3-NVoltage	0.00	1

# Direct Query Tool for Cassandra Database



# Direct Query Tool for Cassandra Database

The screenshot displays the Neptune Cluster Direct Query Tool interface. The browser tabs include Grafana - DMA Overview, Grafana - Report - Monthly Power, 172.16.1.122:8080, Node-RED Dashboard, and Trident Historizer - 172.16.1.120. The address bar shows the URL 172.16.1.122:8080.

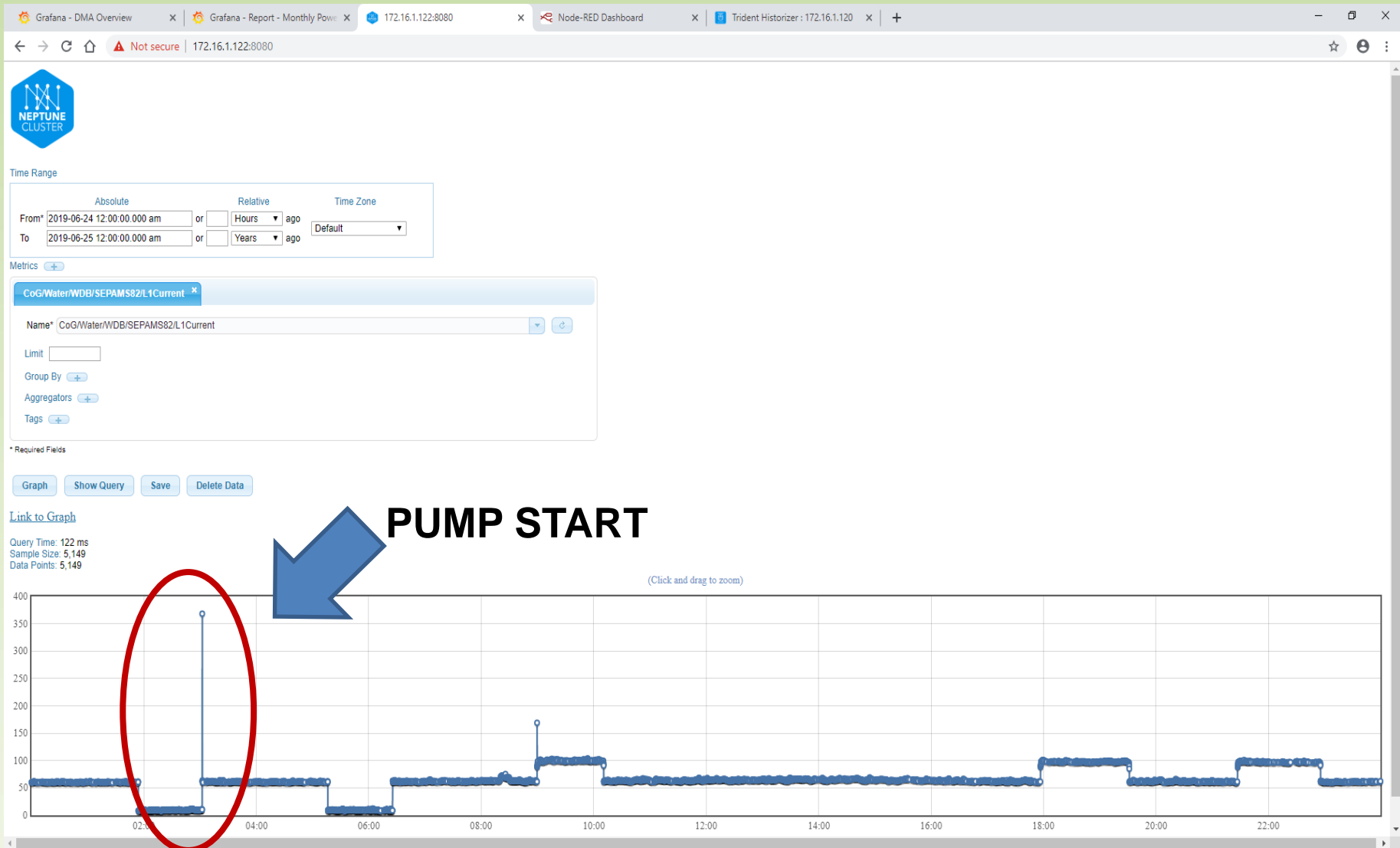
The interface features a sidebar on the left with the Neptune Cluster logo and a 'Time Range' section. The main content area is divided into two panels. The top panel, titled 'Time Range', shows the 'Absolute' tab selected. The 'From' field is set to '2019-06-24 12:00:00.000 am' and the 'To' field is set to '2019-06-25 12:00:00.000 am'. The 'Relative' tab is also visible, with 'Hours' and 'Years' options. The 'Time Zone' is set to 'Default'.

The bottom panel, titled 'Metrics', shows the 'CoG/Water/ROB/PM3000/F17\_L1RealPower' metric selected. The 'Name' field is set to 'CoG/Water/ROB/PM3000/F17\_L1RealPower'. The 'Limit' field is empty. The 'Group By', 'Aggregators', and 'Tags' fields are also empty.

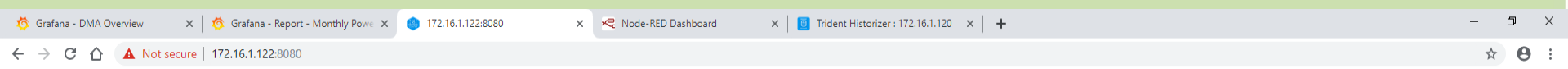
At the bottom of the interface, there are buttons for 'Graph', 'Show Query', 'Save', and 'Delete Data'. A 'Link to Graph' section is visible on the left sidebar, showing 'Query Time: 122 ms', 'Sample Size: 5,149', and 'Data Points: 5,149'. A line graph is partially visible at the bottom left, showing data points over time.



# Direct Query Tool: Woods Pump Starts



# Direct Query Tool: Woods Pump Starts



Time Range

Absolute      Relative      Time Zone

From\* 2019-06-24 12:00:00.000 am      or      Hours      ago      Default

To 2019-06-25 12:00:00.000 am      or      Years      ago

Metrics +

CoG/Water/WDB/SEPAMS82/L1Current

Name\* CoG/Water/WDB/SEPAMS82/L1Current

Limit

Group By +

Aggregators +

Tags +

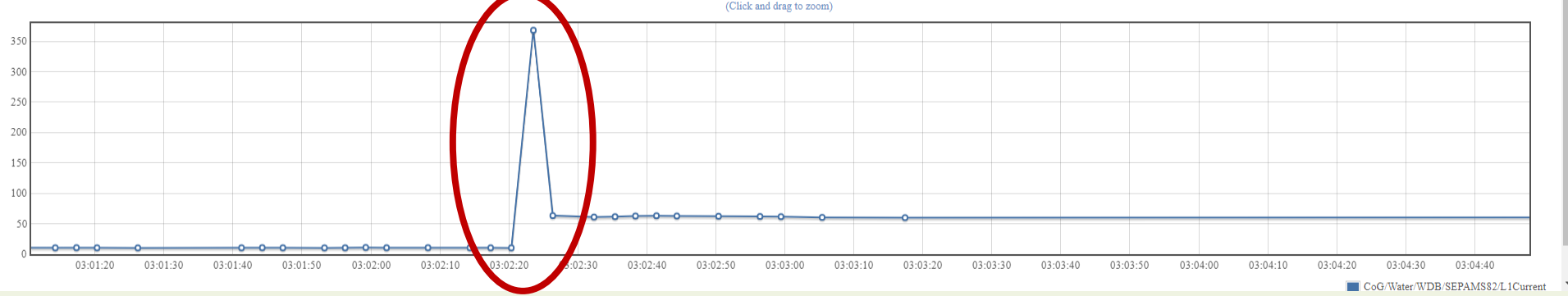
\* Required Fields

Graph    Show Query    Save    Delete Data

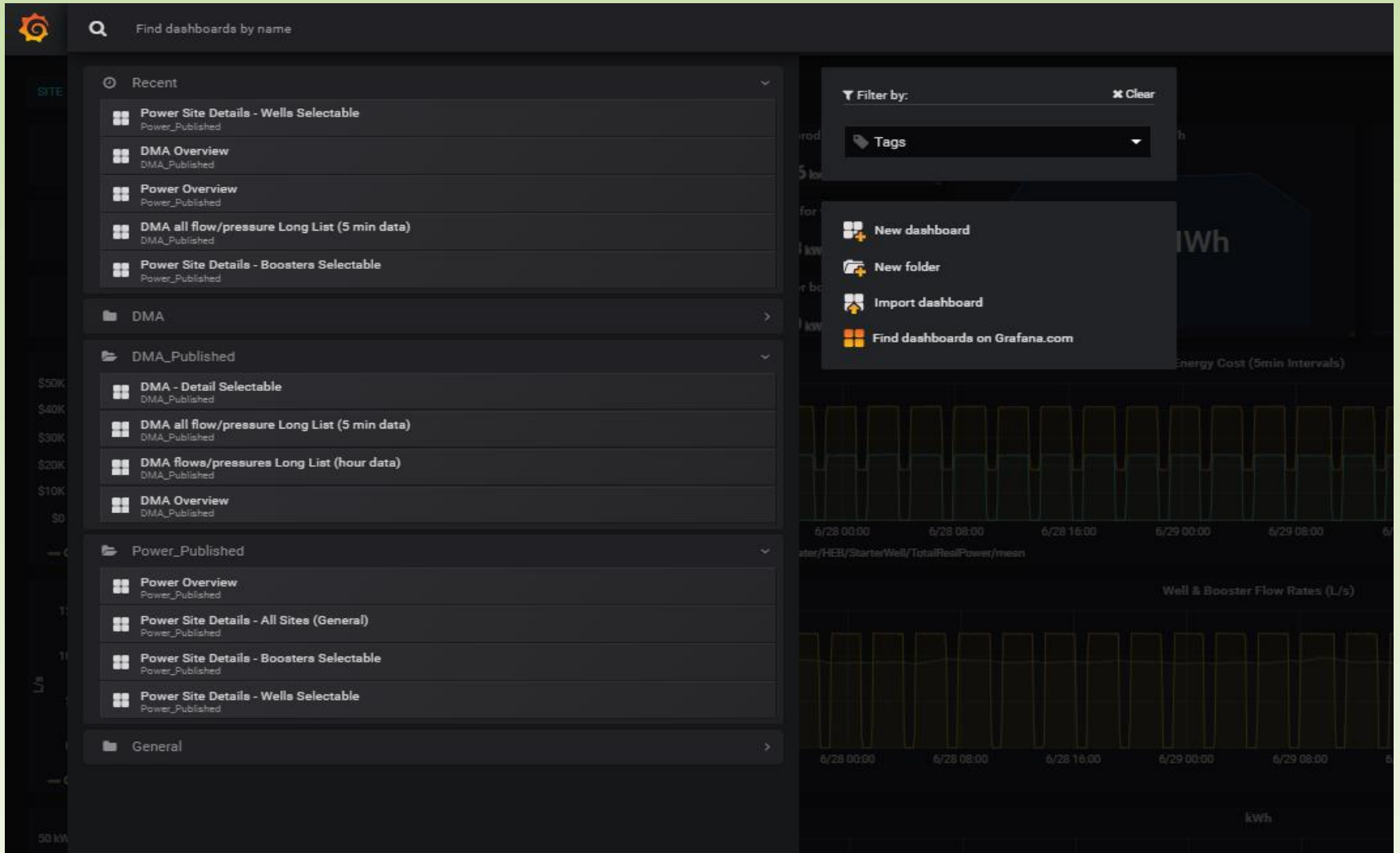
[Link to Graph](#)

Query Time: 122 ms  
Sample Size: 5,149  
Data Points: 5,149

**In-Rush Current of Pump Starting**



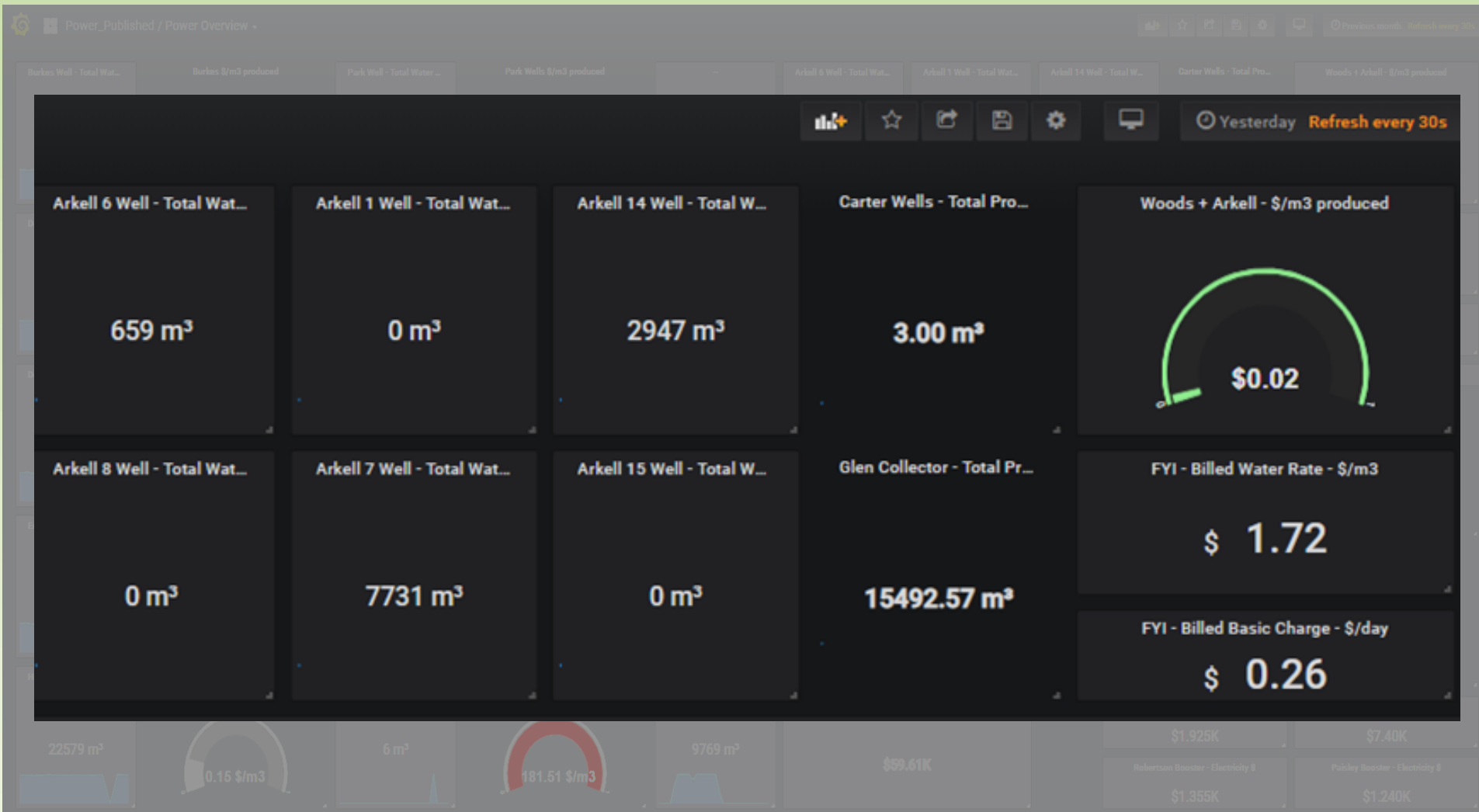
# Grafana web-based Dashboarding Tool



# Power Overview Dashboard

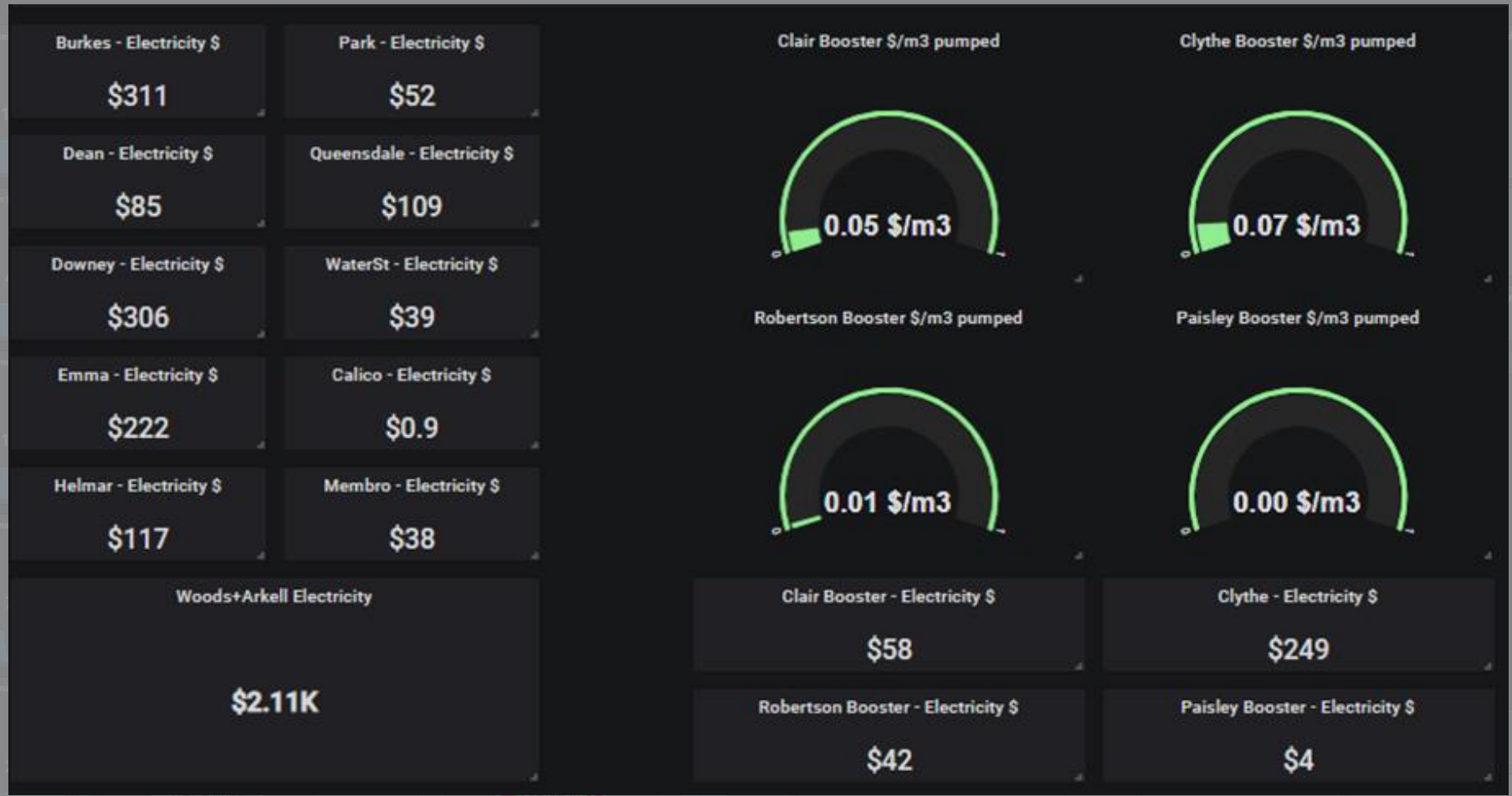


# Power Overview Dashboard





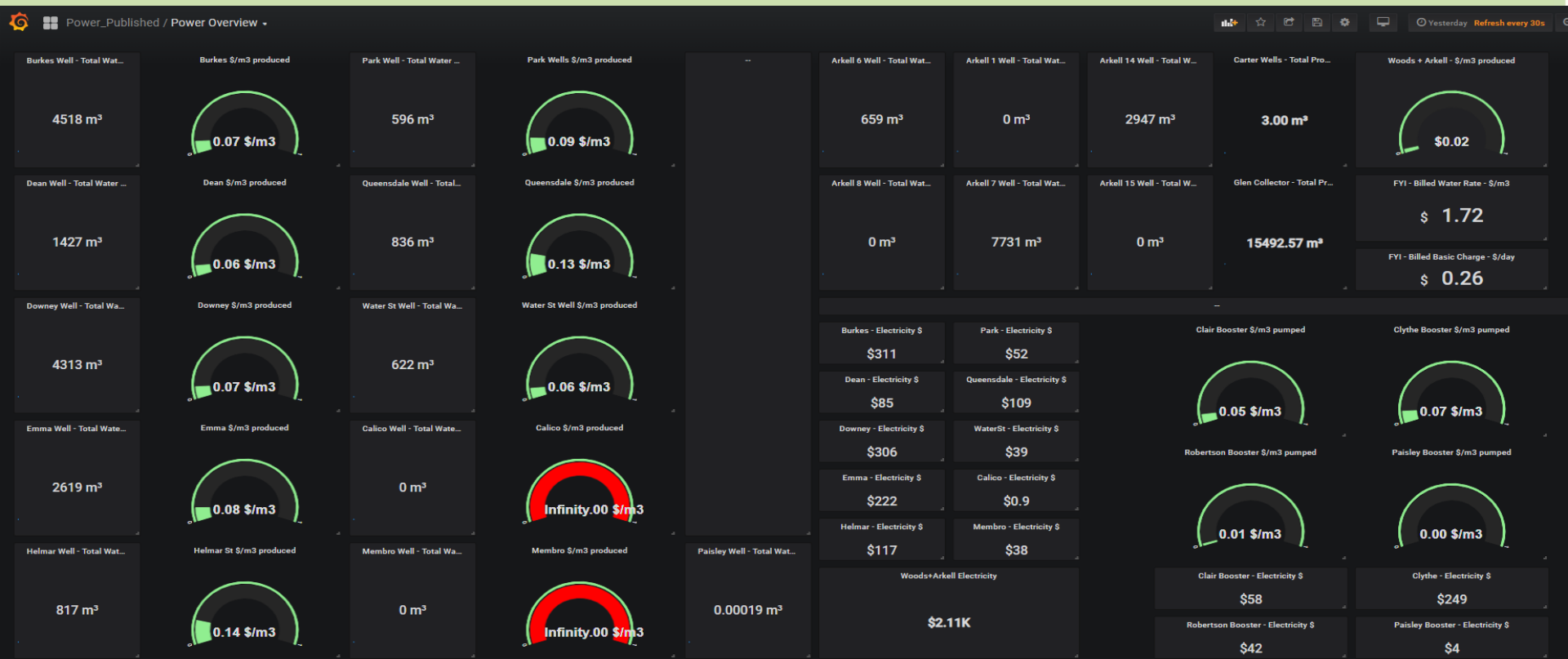
# Power Overview Dashboard



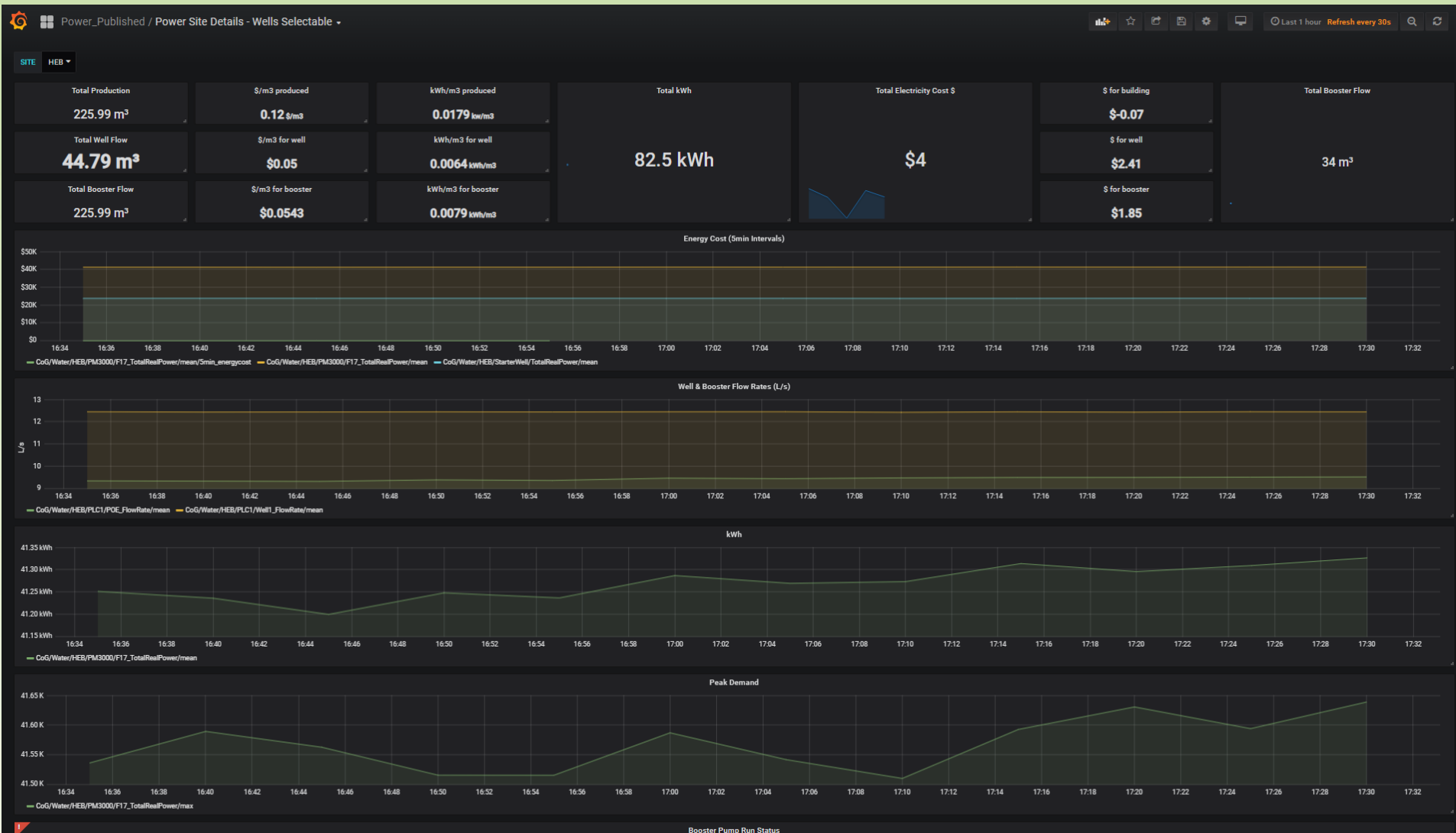
# Power Overview Dashboard



# Power Overview Dashboard



# Site Detail - Helmar Well (1hour)



# Site Detail– Robertson Booster (2 days)

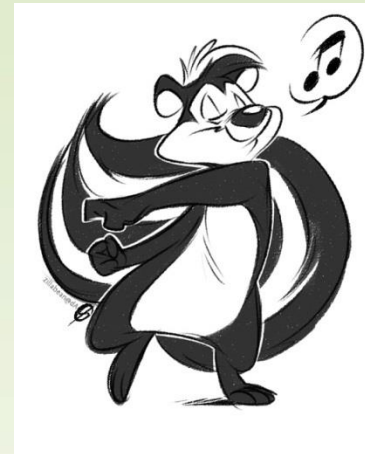




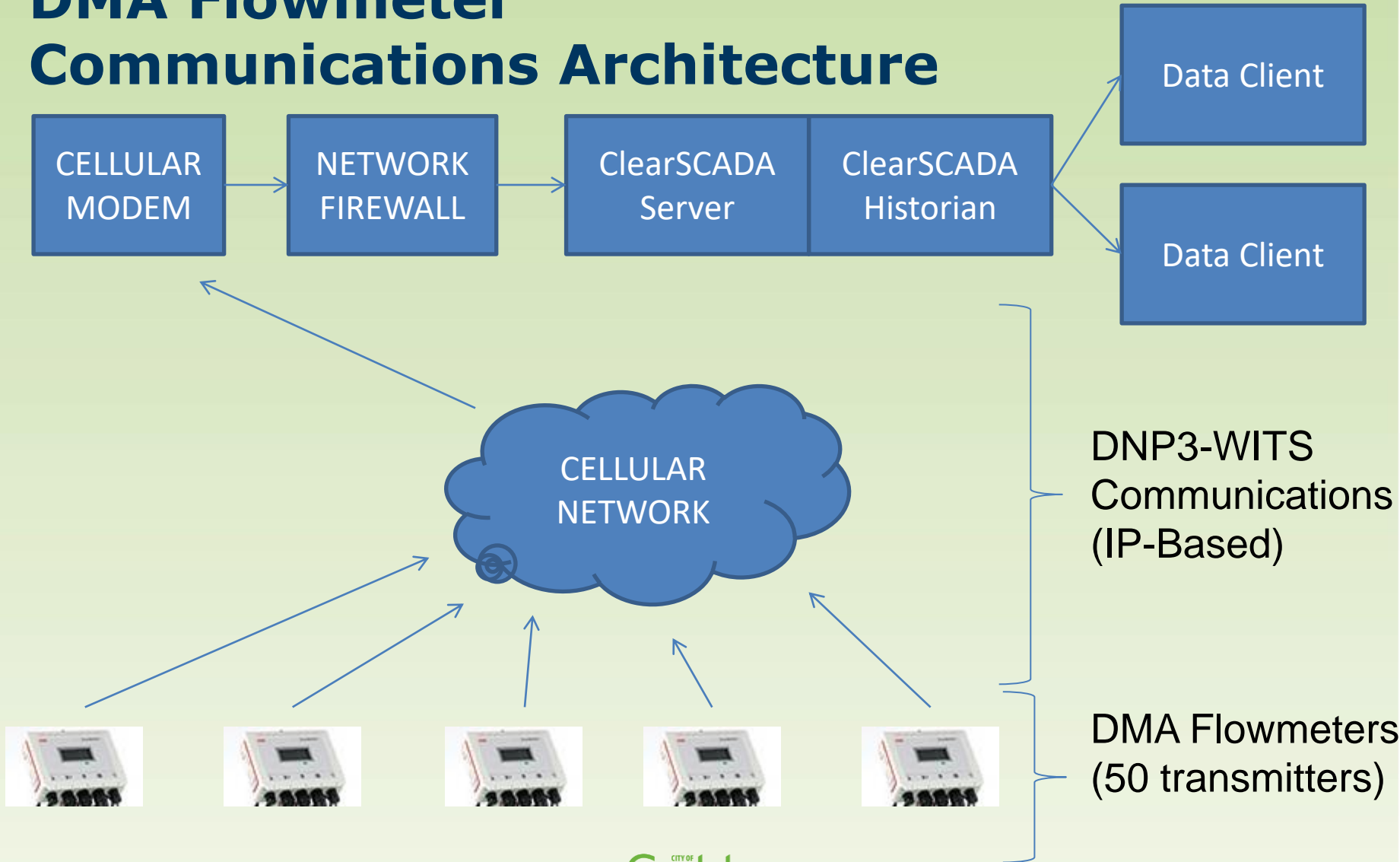
# Site Detail– Robertson Booster (30 days)



# Let's use Neptune to manage our DMA Flowmeter Data...

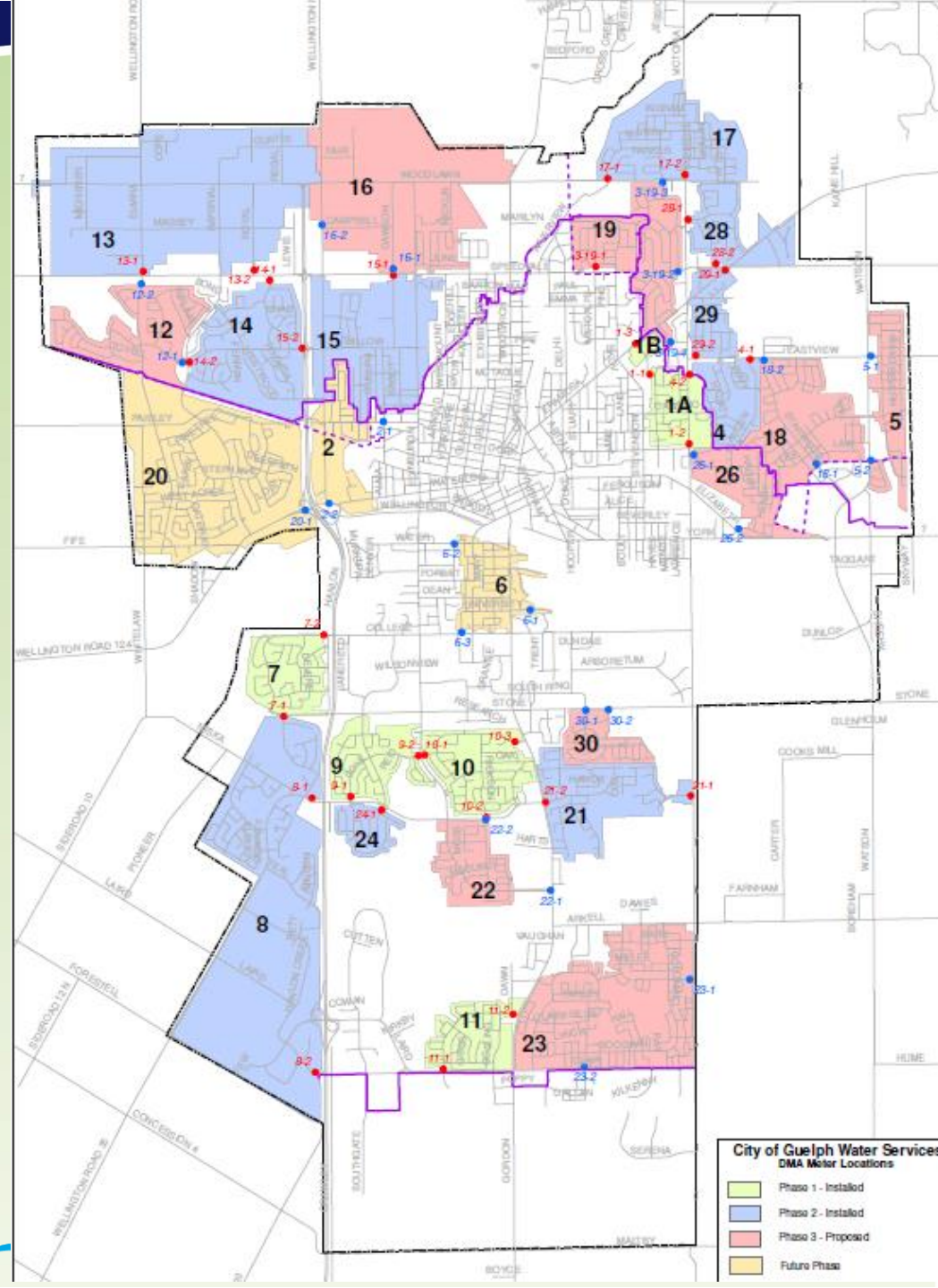


# DMA Flowmeter Communications Architecture



# District Metered Areas

- Segments Water Distribution into DMA Areas with 1-3 connections on borders
- Put flowmeters on the DMA's border connections
- What this give us:
  - Water in/out of DMAs
  - Compare to Customer Meters
  - Compare to Wells & Pumping Station meters
  - Calibrate Water Models



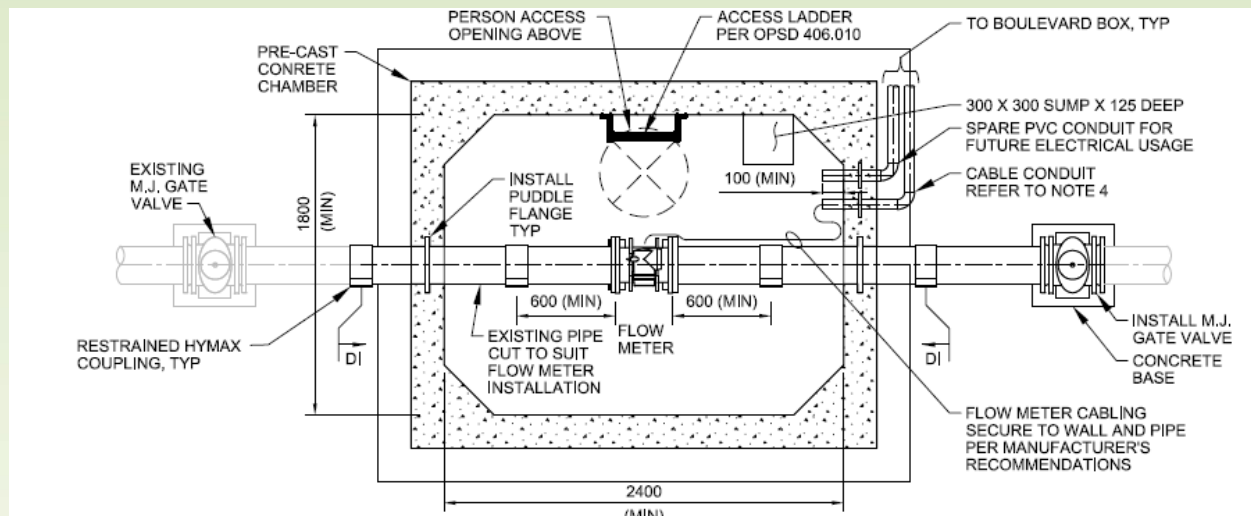
# District Flow Meters

- Magnetic Flowmeter
- Integrated Remote Transmitter
  - Transmitter
  - Data Logger
  - Cellular Modem & Antenna
  - Built-in DNP3-WITS Protocol
  - IP 68 Submersion Rated
  - Long Life Battery
- Flow Tube
  - IP68 Submersion Rated



# Flowmeter Chambers

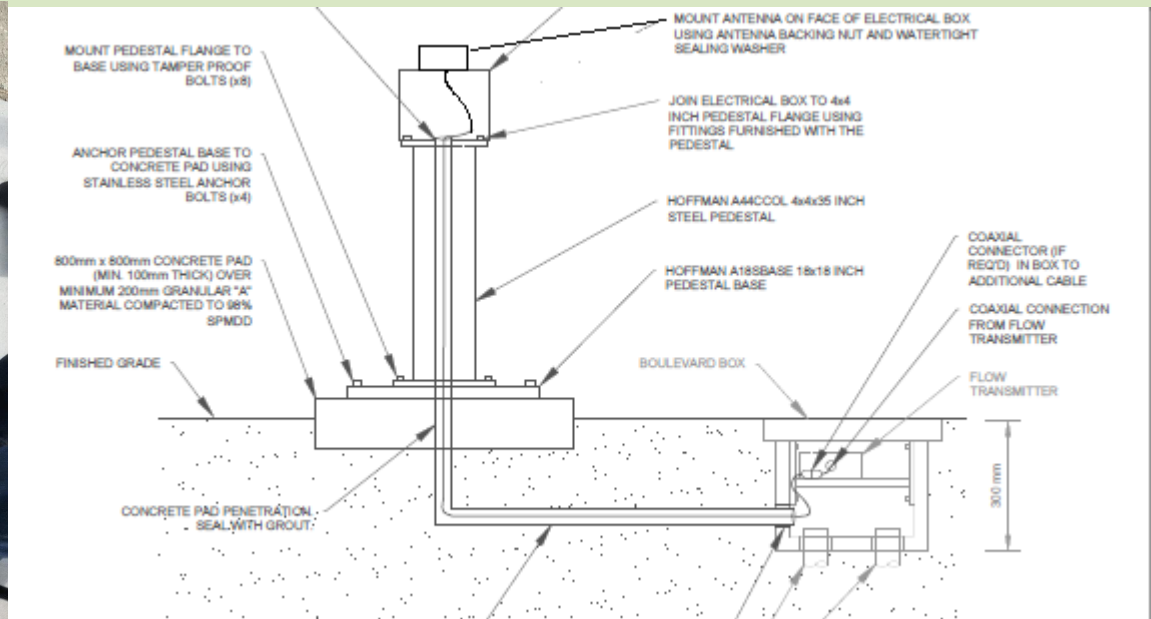
- Each DMA is enabled by closing valves, so only 2-3 entry points
- Put Flowmeter chamber on each of DMA's entry points
  - Chamber contains the Flowmeter “flow tube”
  - Pressure sensor (also monitored by flowmeter electronics)
  - Upstream and downstream isolation valves





# Flowmeter Transmitters

- Flowmeters installed into boulevard boxes
- Antenna pedestals to mount cellular antennas on

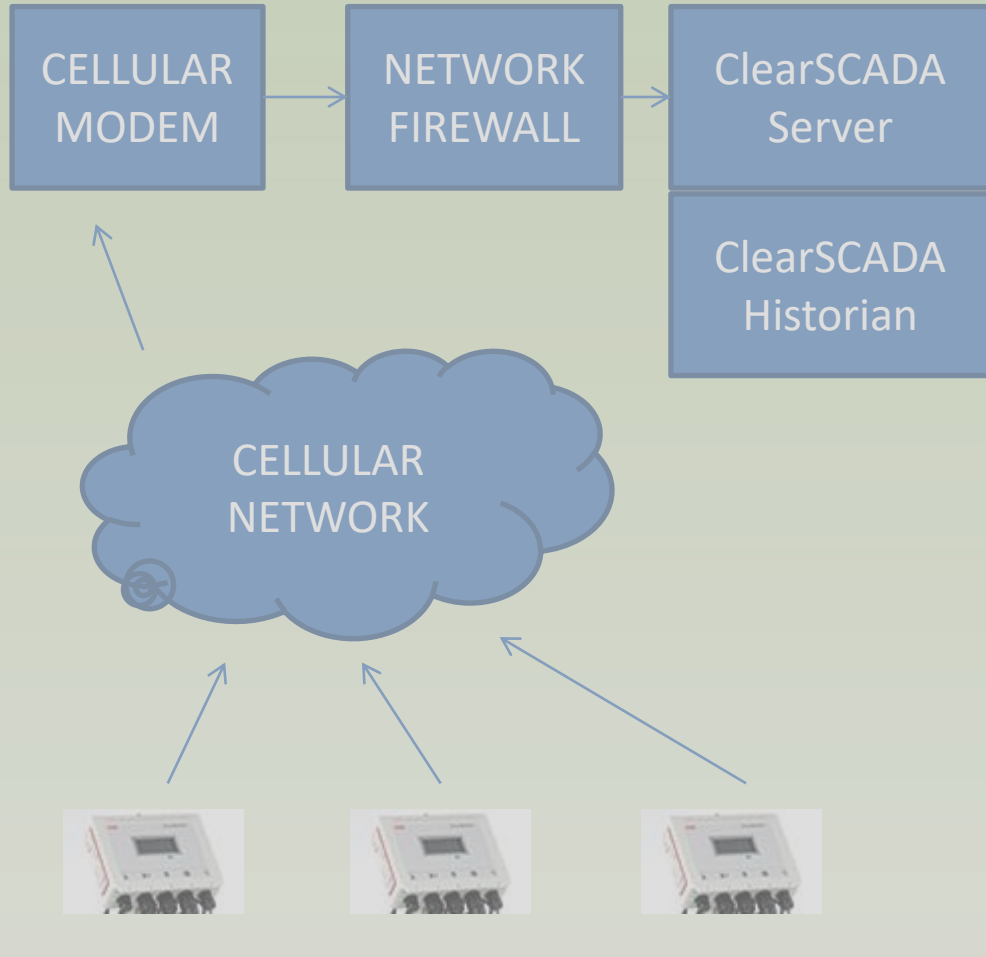




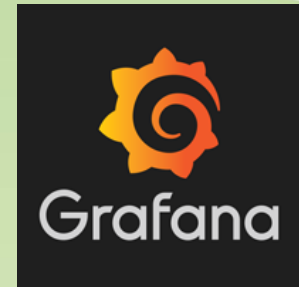


# Applying Neptune to DMAs

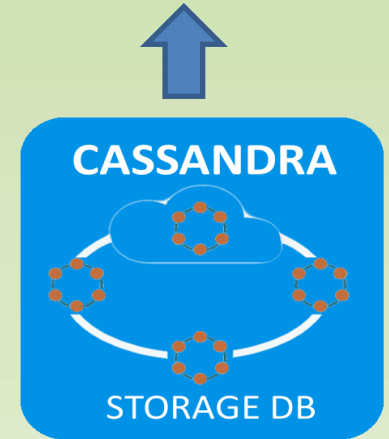
## Existing SCADA Infrastructure



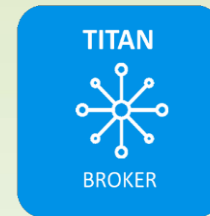
Web-based  
Dashboard  
& Reporting  
Tool



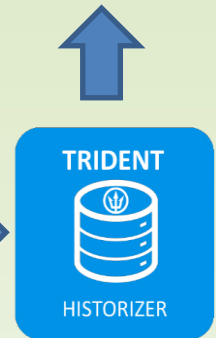
Distributed  
Open  
Source  
Database  
(no licensing fees)



Hourly  
Data Sync  
Script



Pushes to  
Historizer  
Server



Pushes to  
Time Series  
Database

# Neptune Hourly Data Sync Scripting

The screenshot displays a Node-RED flow titled "ClearSCADA ETL" within a browser window. The flow starts with an "inject" node, followed by a "change: 2 rules" node. It then branches into two paths: one leading to an "http request" node, and another leading to a "timestamp" node. The "http request" path continues through a "json" node, a "change: 4 rules" node, and a "query historical data for specific tag and time range (returns max 40000 records)" node. The "timestamp" path goes through a "get all the tags to pull data for" node and a "change: 3 rules" node. Both paths merge at a function node "f". From here, the flow splits into two branches: one through a "set msg.payload" node and a "change: 2 rules" node, and another through a "catch (1)" node. The main path then goes through a "delay 500ms" node, a "parse data" node, and another "change: 2 rules" node. The flow concludes with an "msg" node. A "Midnight backfill" node is also present at the bottom of the flow.

Annotations in the flow include:

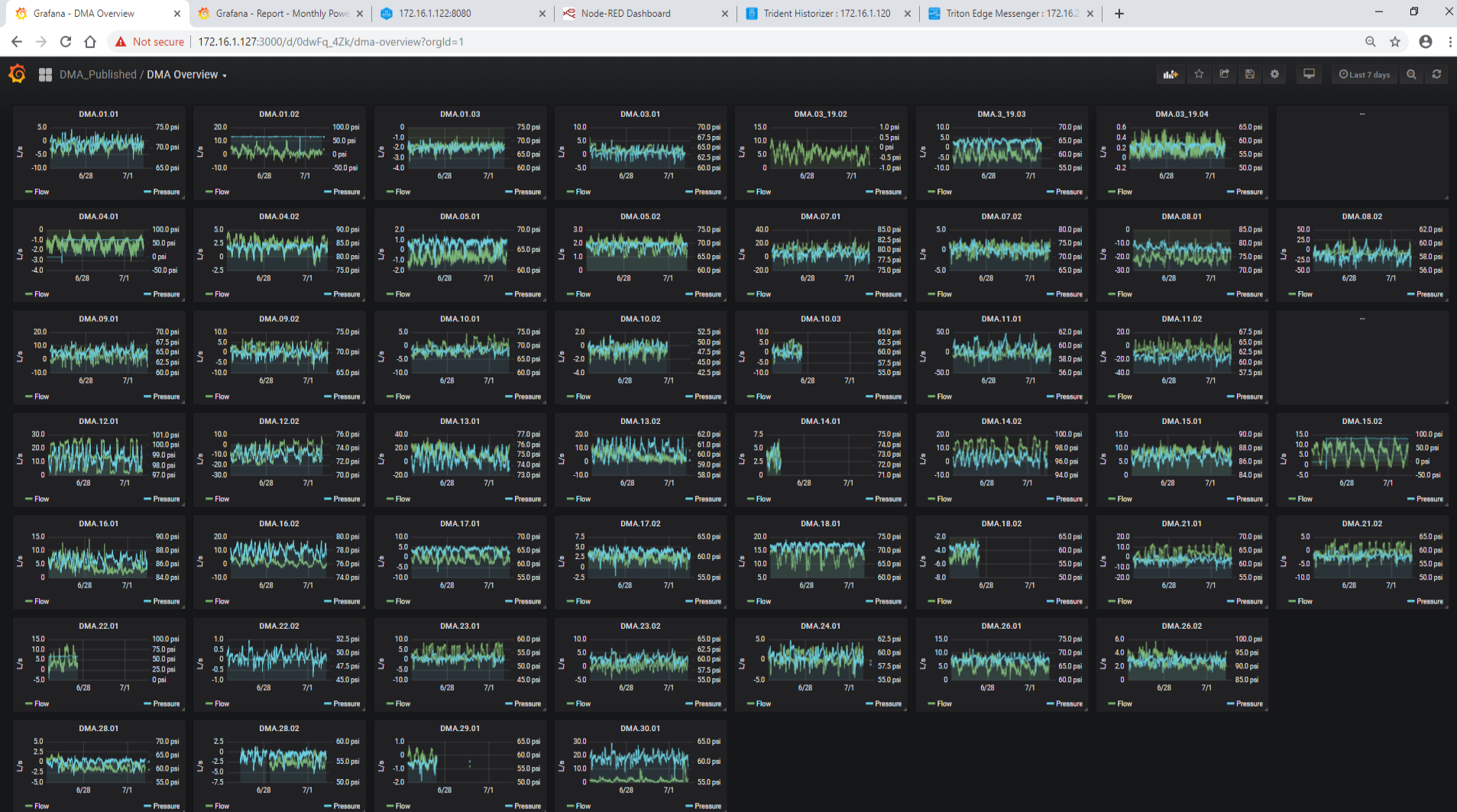
- Runs Every Hour**: Located above the initial inject node.
- auto time entry**: Located above the query historical data node.
- Auto Backfill Data at Midnight for two weeks (Runs @ 12:30am so hourly is done by 12:15am, no collisions)**: Located above the "Midnight backfill" node.

The right-hand panel shows the "info" tab for the flow:

Flow	
Name	ClearSCADA ETL
ID	"3786ddf3.2ca782"
Status	Enabled

Below the info tab, there is a section for "Information" and a note: "Show the Info tab with `ctrl-g i` or the Debug tab with `ctrl-g d`".

# DMA Dashboard





# DMA Dashboard – showing last 7 days



# DMA Dashboard – showing last 30 days



# DMA Dashboard – or last 2 days





# DMA Dashboard – Detail View



# DMA Dashboard – Individual Flowmeter



# DMA Dashboard – Setting up Email Alerts

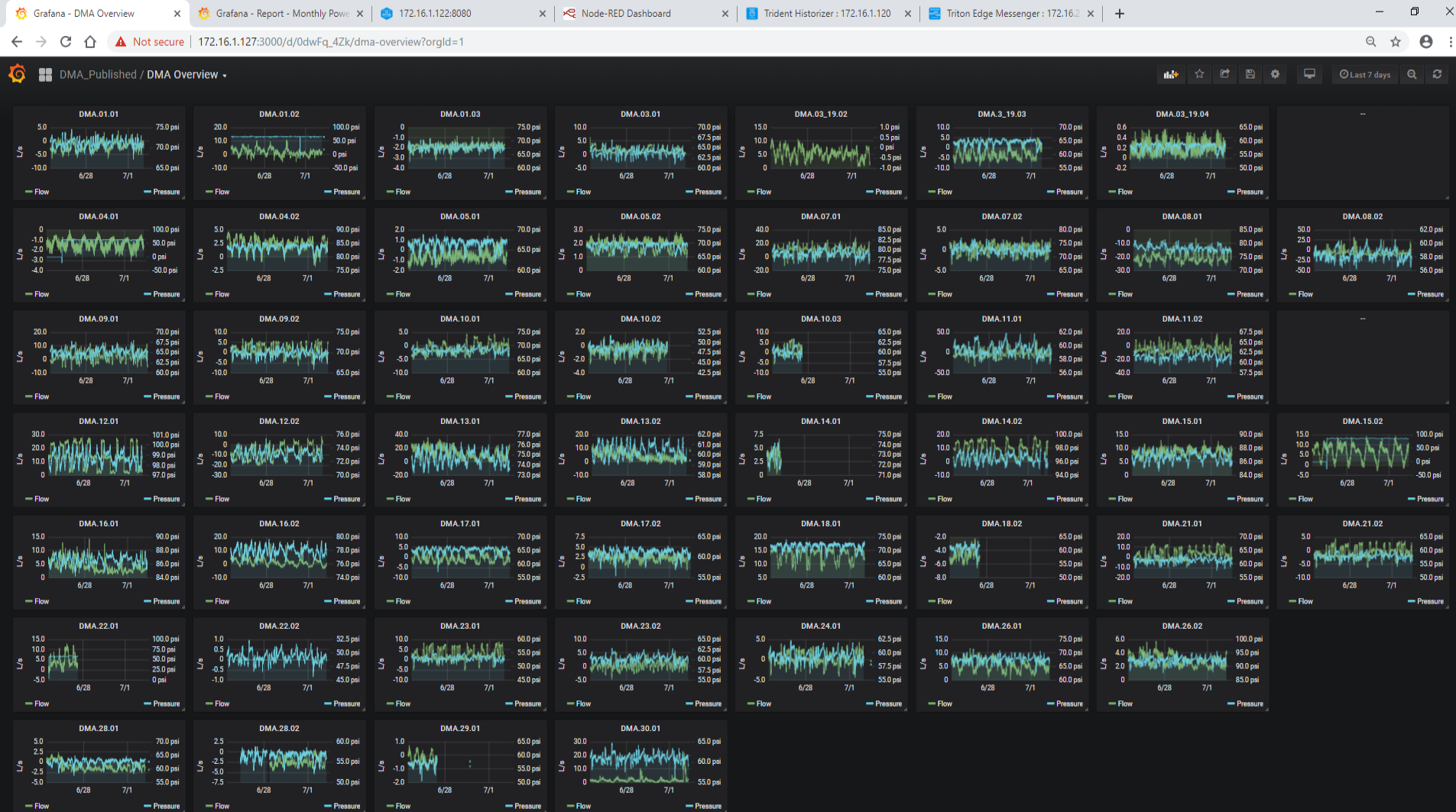
The screenshot displays a Grafana dashboard titled "DMA\_Published / DMA flows/pressures Long List (hour data)". The main panel shows a line graph for "A-series" with a red horizontal threshold line at 45. The x-axis represents time from 13:50:30 to 13:55:00. The y-axis represents flow/pressure values from 0 to 60. The graph shows a sharp increase in the A-series value starting around 13:54:30, crossing the 45 threshold.

An "Alert Config" panel is open, showing the following configuration:

- Name:** High Flow
- Evaluate every:** 1hr
- Conditions:** WHEN avg () OF query (A, 5m, now) IS ABOVE 45
- State history:** (empty)
- Delete:** (button)
- SET STATE TO:** No Data

Surrounding the main graph are several smaller panels, each displaying a different DMA flow/pressure series over time. The series names include "CoG/Water/DMA\_Project.DMA.05.01.FIT.PL.CV" and "CoG/Water/DMA\_Project.DMA.05.02.FIT.PL.CV".

# DMA Dashboard





# Power Overview Dashboard



# Next Steps

## Power Usage Dashboards

- Has been gathering data for past 12 months
- Final testing and adjustments in progress
  - Some tweaking still left to do
  - Automatic PDF email reports feature still under development (initial testing done)
  - Install work for network connections to existing Pump Motor Starters is in progress
- Next Steps
  - Mount display in Woods hallway as a realtime energy dashboard
  - Making Data-query web-interface accessible to Water Services staff (via desktop)
  - Making Grafana web-interface available to make dashboards for Water Serv. staff

## DMA Flow & Pressure Dashboards

- All DMA flowmeter flow/pressure hardware issues resolved as of Jun 28, 2019
- Each flowmeter pushes data to server very approx. 6 hrs, longer if poor weather/signal
- Five meters need site visits every 2 weeks to push data (upgrades in 2020 should fix)
- Final testing and adjustments in progress
  - Some tweaking of dashboards & reporting tool still left to do
  - Selecting criteria to test out email alert feature (e.g. high flow rates) and testing
- Next Steps
  - Mount display in Woods hallway near Distribution Ops as a realtime dashboard
  - Making Data-query and Grafana web-interface available to Water Services staff