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Robert W. Goldsworthy Desalter Foulant Investigation and Performance Assessment

Performance Assessment and Pretreatment Recommendations

November 25, 2020

Water Replenishment District of Southern California

TOR E-20-001

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Project Manager:	Larry Schimmoller, Jacobs Engineering Group Inc. (Jacobs)
Author:	Renee Groskreutz, Jacobs
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Jacobs
1000 Wilshire Boulevard, Suite 2100
Los Angeles, California 90017-2457
United States
www.jacobs.com

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Acronyms and Abbreviations

°C	degree(s) Celsius
µg/L	microgram(s) per liter
µm	micrometer(s)
µS/cm	microsiemen(s) per centimeter
AWC	American Water Chemicals, Inc.
bgs	below ground surface
BWS	backwash supply
BWW	backwash waste
CF	cartridge filter
CIP	clean-in-place
CYW	City Yard Well
DOC	dissolved organic carbon
DDW	Division of Drinking Water
DPW	Delthorne Park Well
EBCT	empty bed contact time
GAC	granulated activated carbon
gfd	gallon(s) per square foot per day
gfd/psi	gallon(s) per square foot per day per pounds per square inch
gpd	gallon(s) per day
gpm	gallon(s) per minute
I&C	instrumentation and controls
Jacobs	Jacobs Engineering Group Inc.
LC-OCD	liquid chromatography with online carbon detection
MG	million(s) of gallons
mg/L	milligram(s) per liter
MTBE	methyl tert-butyl ether
MW	molecular weight
O&M	operations and maintenance
psi	pound(s) per square inch
RO	reverse osmosis
ROC	reverse osmosis concentrate
ROF	reverse osmosis feed
ROP	reverse osmosis permeate
RSSCT	rapid small-scale column testing
RWGD	Robert W. Goldsworthy Desalter
SDC	services during construction
SDI	silt density index

TOC	total organic carbon
UF	ultrafiltration
WQ	water quality
WRD	Water Replenishment District of Southern California

1. Introduction

The Water Replenishment District of Southern California (WRD) owns the Robert W. Goldsworthy Desalter (RWGD), which is maintained and operated by the City of Torrance. In 2017, the RWGD was expanded through the addition of two new wells, Delthorne Park Well (DPW) and City Yard Well (CYW); and a second train of reverse osmosis (RO) membranes. Since the expansion, RWGD has struggled to achieve design production due to RO membrane fouling. The design criteria and current operational conditions for the wells and the RO system is summarized in Table 1.

Table 1. RWGD Design Production versus Average Operations During Sampling Event

Parameter	Design[a]	Current (As of September17, 2020)
DPW Flow (gpm)	1,950	1,667
CYW Flow (gpm)	1,950	1,978
Flow Split, CYW/DPW (percent)[b]	50/50	54/46
RO Feed Flow (gpm)	3,900	3,645
RO Permeate Flow (gpm)	3,120	2,734
Recovery (%)	80	75
Membrane Array (Stage 1: Stage 2)	42:24	42:20
Train 2 Flux, Stage 1/Stage 2 (gfd)	12:12	11:7
Frequency of CIP (days)	N/A	28

[a] Design Parameters as stated on Design Dwg 00-G006, (Carollo 2017).

[b] Flow split adjusted on September 30, 2020, to 50/50.

Notes: % = percent; CIP = clean-in-place; gpm = gallon(s) per minute; gfd = gallon(s) per square foot per day; N/A = not applicable

WRD retained Jacobs Engineering Group Inc. (Jacobs) to evaluate the RWGD's performance and determine both short- and long-term strategies to mitigate RO fouling, in an effort to achieve cost-effective design production. This performance assessment and pretreatment recommendation report summarizes the results of that evaluation and offers recommendations to meet WRD's goals for the plant. Key considerations and anticipated unintended consequences are summarized for each option, and cost estimates are provided for the three proposed long-term solutions.

The recommendations in this report are based on an overall system investigation that included completing an RO membrane autopsy, flow profiling the DPW and the CYW, conducting depth-specific water quality (WQ) sampling at each well and WQ sampling at the RWGD, and completing a historical data review and analysis. The specific results of the sampling effort are summarized under separate cover in the *Water Quality Investigation Summary* (Jacobs 2020). It confirmed and elaborated on previous investigations by WRD. Briefly, the main conclusions from the sampling effort were:

- Significant concentrations of hydrophobic and hydrophilic dissolved organic carbon (DOC) are present in both CYW and DPW and appear to be the main cause of RO fouling.
- Water from the DPW is likely more problematic for RO system operations (consistent with specific flux decline when only treating DPW water). The DPW has greater concentration of organics and has elevated color in the upper screen area.

- Inorganic and organic bridging is occurring both with intra-well mixing of upper-screen high-DOC and low-inorganic waters, with lower-screen low-DOC and high-inorganic waters, as well as inter-well mixing of DPW and CYW of higher humic substances and high inorganics (for example, calcium and sodium).
- Eliminating or reducing the use of DPW, or treating DPW water to remove the problematic organics, may sufficiently mitigate RO fouling (based on short-term stable permeability when treating CYW water); however, the limited specific capacity of, and water production from, the CYW have been issues since its rehabilitation.
- Methyl tert-butyl ether (MTBE) is only present in upper portion of CYW.
- Most flow is from the upper screens in both wells (78 percent for the DPW; 79 percent for the CYW), which is consistent with the well design. The target production and chloride levels are defined in the Well Installation report as follows:

  > "*In general, the new Desalter supply well design recommendations were intended to screen the upper portion of the aquifer containing low-chloride (fresh water) and the lower portion of the aquifer containing high-chloride (brackish water) to achieve the target production and chloride level of 2,200 gpm and 1,400 mg/L, respectively. A blank section of well casing was installed in the transition zone between the fresh water and brackish water to allow for potential future use of a packer in the well to focus flow from the brackish water interval should wellhead chloride concentrations decline.*" (CH2M 2016)

- Significant organic fouling (based on the dark brown discoloration) was observed on the 10-micron (µm) nominal cartridge filters (CFs) when replaced on September 16, 2020. Hydrophobic DOC is being preferentially retained on these filters.

2. Plant Performance Review

This section reviews plant operations and performance in the context of RO membrane fouling. This includes RO permeability, the impact of well flow splits, RO flux, RO system flushing, and CF operations.

2.1 Reverse Osmosis Performance and Cleaning Frequency

To restore the performance of the RO trains, chemical CIP is conducted on the RO membranes. To better quantify the fouling at the RWGD, a series of performance plots were graphed, along with the frequency of the CIP and the water flow split between the CYW and DPW (Appendix A). There are three main drivers for conducting a CIP, as measured for each stage of the RO train:

1. Decrease in permeability (also indicated by increase in train feed pressure)
2. Increase in normalized differential pressure
3. Decrease in normalized salt rejection (or increase in normalized salt passage)

At RWGD, the decrease in permeability (or increase in feed pressure as a trigger for the operations staff) dictates the frequency of the CIPs. On Figure 1, the decline in permeability in Train 2 is evident after every CIP. To balance production and restore permeability, mini-caustic CIPs (shorter duration versions of CIPs) are performed between full CIPs. As Figure 1 shows, there is not a significant difference between the two types of CIPs related to restored permeability immediately following the CIP and the subsequent permeability decline.

Assuming a total allowable permeability reduction of 0.15 gallon per square foot per day per pounds per square inch (gfd/psi) (the difference between the Stage 2 permeability after a CIP [approximately 0.23 gfd/psi]) and the permeability when a CIP is performed (approximately 0.08 gfd/psi [Figure 1]), and a minimum CIP interval of 30 days (as an interim measure), the maximum allowable permeability decline rate is calculated as 0.005 gfd/psi (0.15/30 = 0.005). This maximum allowable permeability decline impacts the selection of the well flow split (discussed further in the following section). The CIP interval of 30 days is not ideal and is considered an interim metric prior to capital improvements. If mitigation measures are implemented, the target CIP interval would be significantly longer than 30 days.

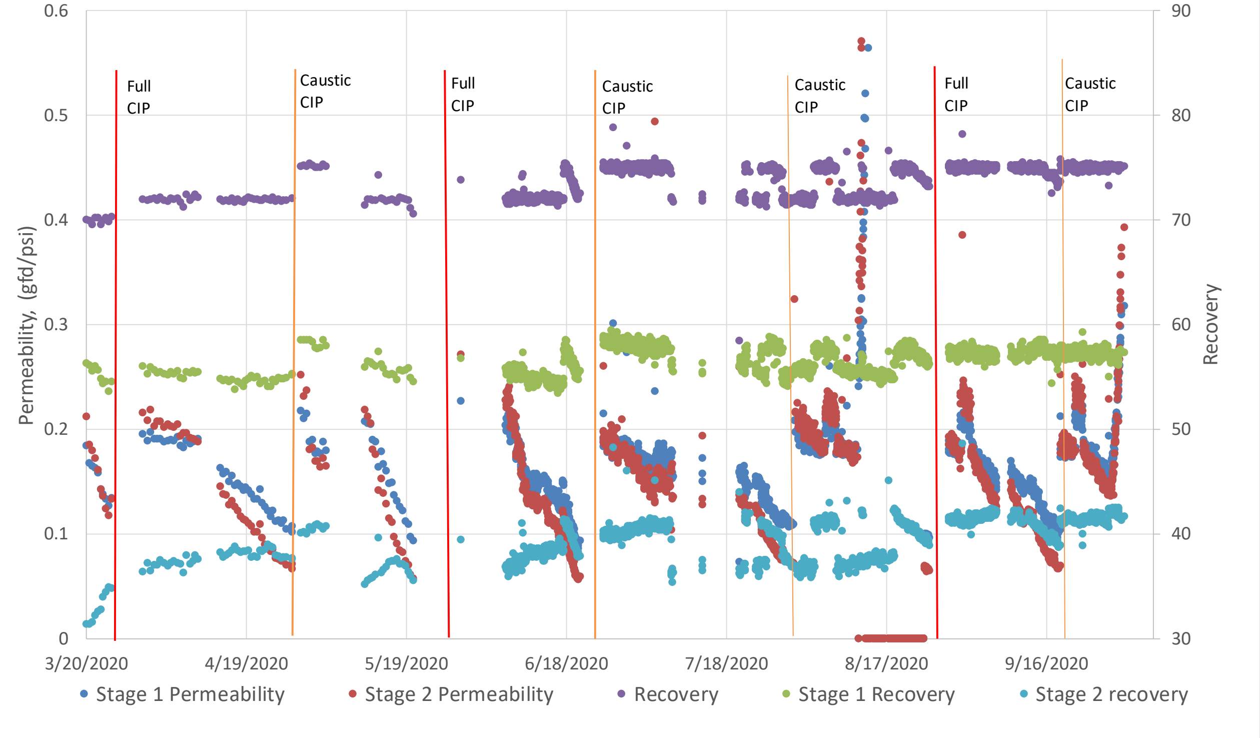


Figure 1. Train 2, Permeability and Recovery per Stage

2.2 Well Flow Splits

RO performance data and DPW and CYW well flow split data were analyzed from February 2018 through September 2020 (Bautista, pers. comm. 2020b; Knoell, pers. comm. 2020b). The results of these analyses indicate RO fouling of both Stage 1 and Stage 2 increases, with increased DPW flow contribution, as shown on Figure 2, which compares the RO permeability decline into four separate flow split categories based on RO ‘runs’ operated near these setpoints (for example, RO runs operated at 34 and 37 percent DPW flow were grouped together in the 35 percent DPW flow category).

Stage 2’s permeability decline is higher than Stage 1, but both are significant when the DPW flow contribution is increased. Based on this rate of decline, the overall DPW flow contribution should be less than 35 percent to maintain a minimum 30-day cleaning frequency unless fouling mitigation measures are implemented (Figure 2).

The permeability decline rate with no DPW flow contribution is low and more typical of RO plants treating brackish groundwater (less than 0.005 gfd/psi per day); this would result in a significantly longer operating period between CIPs. Appendix A provides the full set of data and specific runs. Runs were designated by periods with the same flow split and between cleanings, so it would be possible to measure consistent permeability declines.

It is clear from Figure 2 that the RO membranes’ permeability is impacted when DPW water represents a greater fraction of flow to the RWGD. Reducing the DPW percentage of flow should improve the RO membranes’ performance and reduce the cleaning frequency. If DPW flow is reduced, the benefits of improved RO performance and reduced cleaning frequencies must be weighed against the reduced influent flow to the plant, reduced operational reliability, and resulting reduced water production (refer to Section 3 for more details).

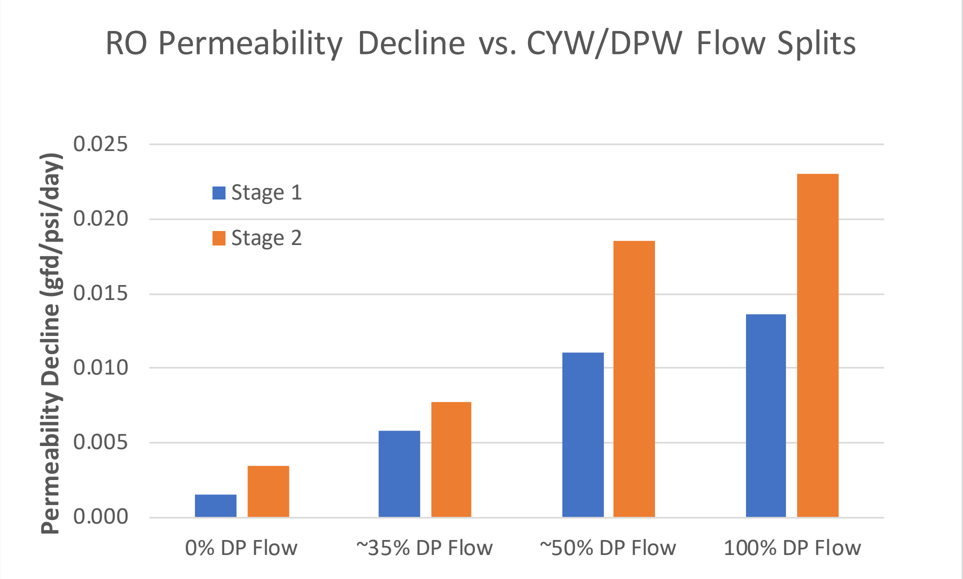


Figure 2. Well Flow Split Impact to Reverse Osmosis Permeability

2.3 Reverse Osmosis Flux

One of the operational parameters WRD adjusted after startup of the DPW and CYW is the flux of stages 1 and 2. As expected, the permeability decline in Stage 2 is greater than Stage 1, since Stage 2 treats a more concentrated stream of organics. By increasing Stage 1 flux, and reducing Stage 2 flux, it is possible to maintain overall RO system flux while reducing the delivery rate of fouling organics (and co-depositing inorganics) to the surface of the Stage 2 membranes, which should reduce the rate of Stage 2 permeability decline. At commissioning of the expanded RWGD, the fluxes for both Stage 1 and Stage 2 were set at 12 gfd. This flux was adjusted to 10 to 13 gfd in Stage 1, and 6 to 9 gfd in Stage 2.

As Figure 3 shows, RO flux does not appear to have a consistent impact on RO permeability. In some cases, greater flux leads to greater permeability decline (for example, note the slightly greater permeability decline at a greater flux for the 0 percent DPW flow case, when both periods were operating at 75 percent recovery). In other cases, though, less flux and less recovery resulted in greater permeability decline (compare 37 percent DPW at 75 percent recovery permeability declines to 34 percent DPW at 72 percent recovery permeability declines). Overall, RO permeability appears to be much more affected by DPW flow contribution than RO flux.

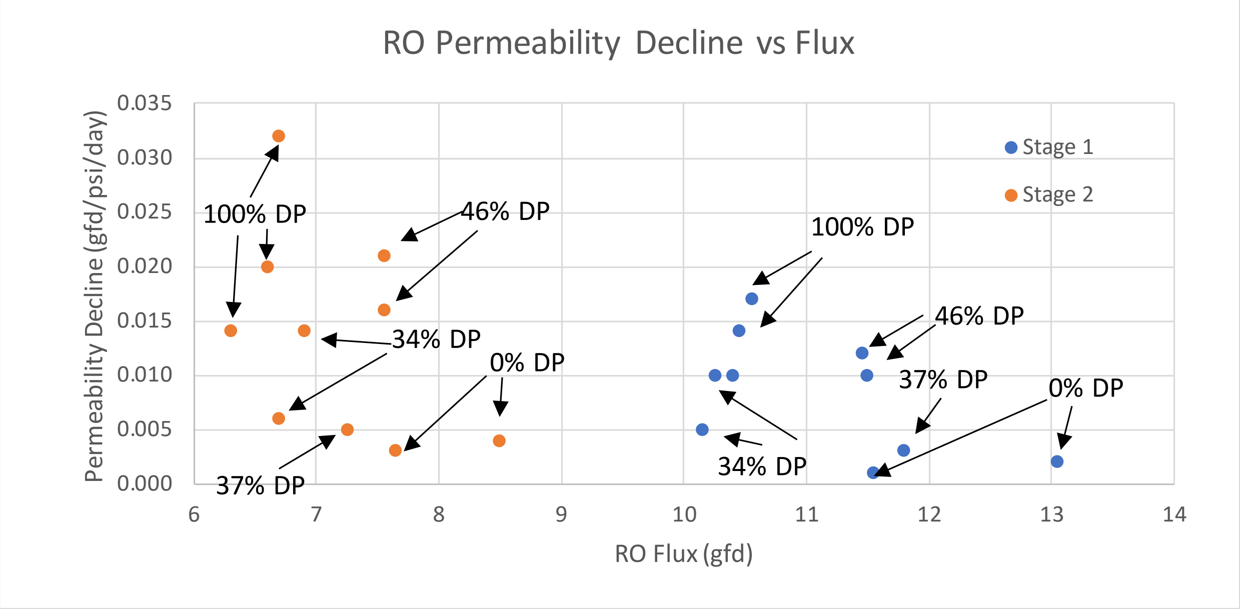


Figure 3. Reverse Osmosis Permeability Decline versus Flux

2.4 Reverse Osmosis System Flushing

City of Torrance operators indicated the RO flushing procedure consists of 3 or 6 minutes of flushing using reverse osmosis feed (ROF) (groundwater). The operator selects a duration based on whether the shutdown will be for a short or long duration (Bautista, pers. comm. 2020a).

To analyze how well the RO flushing process works, Figure 4 graphs the conductivity in the reverse osmosis concentrate (ROC) over the course of a flushing procedure and then compares that to typical ROF conductivity. If the flushing procedure effectively removes the concentrated salts from the RO membranes, the ROC conductivity should approach that of the ROF. If the process is too short, the ROC conductivity will remain elevated.

For the period shown on Figure 4, conductivity in the ROC was reduced from 15,250 microsiemens per centimeter (µS/cm) to 8,250 µS/cm but did not approach the ROF conductivity of 4,500 µS/cm. This degree of conductivity reduction may be adequate to reduce the concentration of sparingly soluble salts to less than saturation (thus, prevent mineral precipitation while the train is offline). However, it may not be sufficient to displace the organics concentrating in Stage 2 and those observed to be more concentrated on the bottom portion of the RO element fiberglass wrap. If the organics are not more thoroughly displaced, then they could increase the risk of inorganic and organic bridging on the surface of the membranes, as discussed later in this report.

Based on the concentrate flowrate of 525 gpm during most of the 3-minute flush sequence (Figure 4) through the 20 vessels in Stage 2, the per-vessel flow was only approximately 26 gpm. This flow is significantly less than typically used during a CIP (40 gpm) and roughly one-third of the maximum allowable flow for the elements used in the RWGD trains (75 gpm). Therefore, it is recommended to increase the flushing RO concentrate flow to at least 800 gpm to increase flow velocity; the objective of this would be to more effectively displace organics from the elements during flushing.

As a modification to the standard flushing process, WRD may wish to consider using ROP in place of ROF, based on the benefits to permeability observed when American Water Chemicals, Inc. (AWC) soaked fouled membrane coupons with de-ionized water during its element autopsies (AWC 2020). Depending on how long the RO train is offline following the flush, contact between the membrane foulant and the ROP may result in a similar increase in permeability once the train is brought back into service.

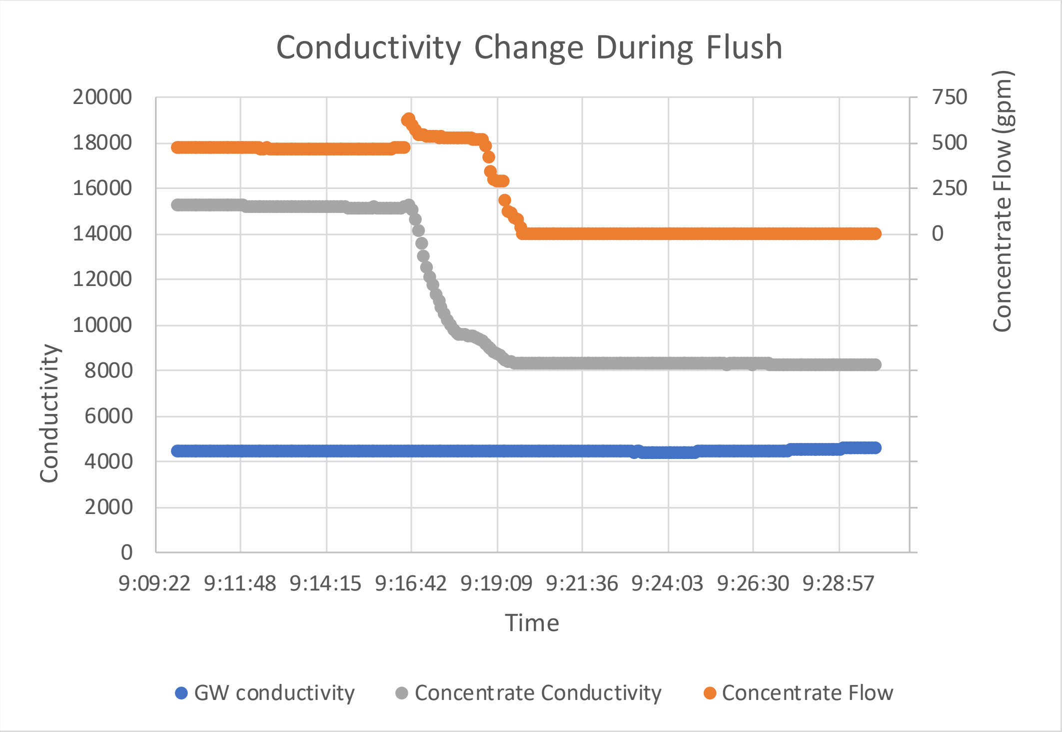


Figure 4. Reverse Osmosis Concentrate Conductivity Change during Reverse Osmosis Train Flush

2.5 Cartridge Filters

CYW and DPW water passes through the CFs (before the threshold inhibitor addition) to remove larger particulates that can accumulate within the RO element feed-brine spacer. The current filters have a nominal pore size of 10 µm. Two filters are in operation with one in standby. Each vessel comprises 118 filters that require replacement. The design hydraulic loading of the 40-inch filters was 4 gpm per 10-inch equivalent with two duty and one standby; the current operation is 3.86 gpm per 10-inch equivalent, which is within the acceptable range.

During Jacobs' September 2020 sampling, the CFs from each vessel were replaced, and a dark brown to black residue was observed throughout the depth of each filter (Figure 5) (Jacobs 2020), similar in color to the foulant observed on the membrane surface of the autopsied RO elements. Although the filter foulant was not characterized, the similarity in color suggests the CFs are retaining some of the organics from the well water. However, the adenosine triphosphate sample results before and after the CFs were replaced were essentially the same, suggesting that no biological growth is occurring on the filters.

On Figure 6, the 2020 CF differential pressure data (normalized to total flow) is trended (Knoell, pers. comm. 2020a). The figure also shows total flow through the CFs and the CYW and DPW flow splits. Sudden drops in the normalized differential pressure were caused by a reduction in total flow or replacement of CFs. CF replacement uses the standby vessel to allow for continued flow to the RO trains. However, on several occasions, filters in all three vessels were replaced in conjunction with a plant shutdown.

Figure 5. Fouled Cartridge Filters prior to Replacement on September 16, 2020

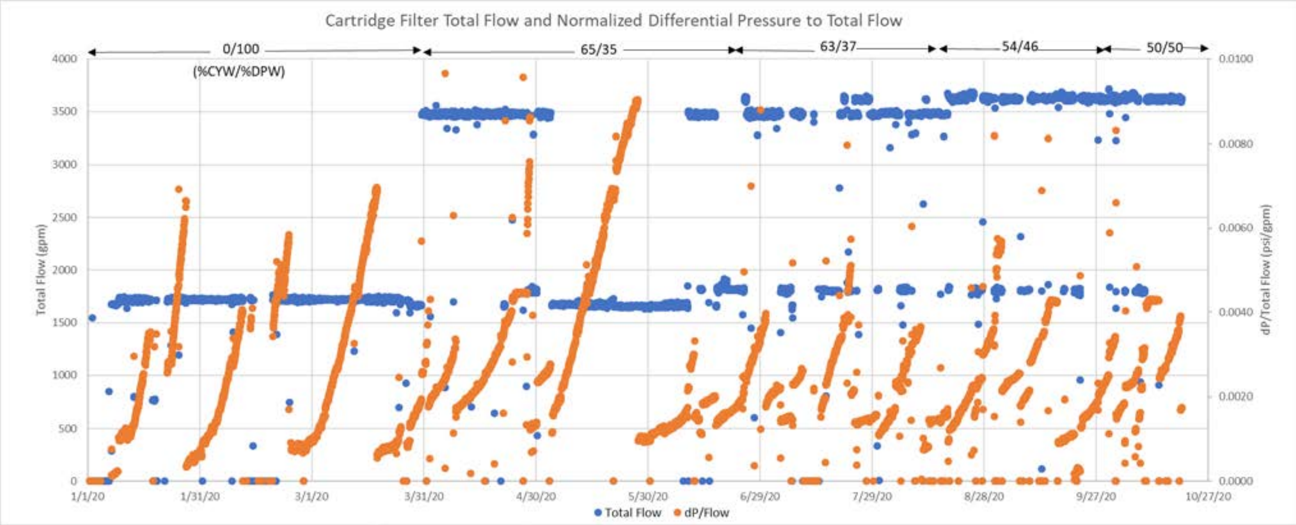


Figure 6. 2020 Cartridge Filter Total Flow and Normalized Differential Pressure

The parameters associated with CF operation include total flow, well flow split, and run time between replacements, each of which will impact the differential pressure trends. The operators manage CF operations and differential pressure increases by bringing the standby vessel online to replace filters and balance the flows (Goldsworthy Operations, pers. comm. 2020; Bautista, pers. comm. 2020c). The variation in plant flow, the replacement schedule for the filters, and the limited data on when the filters are returned to service make it difficult to determine to what extent different flow splits result in different rates of filter fouling (rate of differential pressure increase).

However, by grouping operating durations (months) of similar well contributions on Figure 7, along with the total volume of water for a given number of replacement events during a specific period, the data suggest that larger DPW contribution yields a lower volume of water that can be processed before filter replacement. As further detailed in Table 2, during the first 3 months of 2020, the filters were processing primarily DPW water, with a total of 166 million gallons (MG) treated. During this period, four filter replacements occurred, resulting in an average of 41.5 MG treated per replacement. During September and October, flow to the filters comprised a nearly 50/50 flow split between CYW and DPW, with 264 MG treated and six filter replacements, for an average of 44.0 MG treated per replacement. In July and August, the flow split was approximately 65/35, for a total of 228 MG treated and five filter replacements, resulting in an average of 45.6 MG treated per replacement. Although the differences are not large, the CF replacement frequency does increase by approximately 10 percent when only DPW water is treated and is consistent with the WQ investigation, which indicated organic matter retention by the filters.

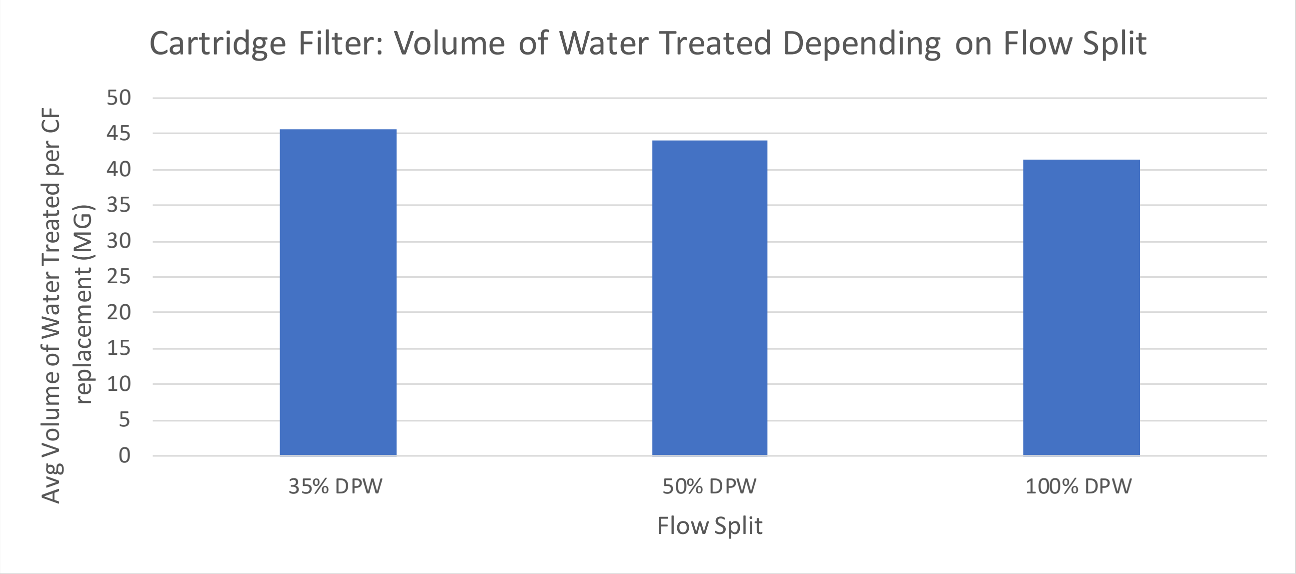


Figure 7. Average Volume of Water Treated by Cartridge Filters between Replacements

Table 2. 2020 Cartridge Filter Replacement Dates and Totalizer Data

Month, 2020	Vessel 1	Vessel 2	Vessel 3[a]	No. of Filter Changes	DPW Totalizer (MG)	CYW Totalizer (MG)	Monthly Total to CF (MG)	MG per No. of Filter Changes
1	1/10	--	--	1	45.6	0.0	45.6	--
2	--	--	2/5	1	47.8	0.0	47.8	--
3	3/18	3/5	--	2	57.6	15.0	72.6	--
Jan – Mar (when CYW was being rehabilitated)				**4**	**~0/100 split Totals**		**166**	**41.5**
4	--	4/28	4/3	2	42.8	89.1	132.0	--
5	5/18	--	--	1	70.2	9.7	79.8	--
6	--	6/11 6/30	6/11	3	60.6	38.0	98.6	--
7	7/23		7/24	2	31.0	67.8	98.8	--
8	8/11	8/11	8/11	3	47.3	82.0	129.3	--
Jul – Aug had consistent flow split				**5**	**~65/35 split Totals**		**228**	**45.6**
9	9/16	9/16	9/16	3	56.3	78.3	134.6	--
10	10/20	10/14	10/13	3	59.3	69.7	129.1	--
Sep – Oct had consistent flow split				**6**	**~50/50 split Totals**		**264**	**44.0**
Totals (Jan – Oct)				**20**	**Totals**		**968**	**48.4**

[a] On April 3, 2020, the Vessel 3 CF inlet valve would not properly seal; therefore, Vessel 3 CF was replaced as needed during plant shutdowns and immediately returned to service (Goldsworthy Operations, pers. comm. 2020). Normally, two duty CFs are replaced immediately following each other, the first returned to operation and the second left as the future standby. This replacement procedure is appropriate and should be continued with proper documentation of when the standby CF is placed in service so that the performance of the CF may be better trended.

Notes:

flow split= CYW/DPW in percentage

No. = number

In September 2020, a liquid chromatography with online carbon detection (LC-OCD) analysis was conducted on samples of the CF influent (well water blend) and effluent (ROF). The results of the analysis showed that the filters were removing a portion of the hydrophobic organics (Jacobs 2020). Given that the LC-OCD analysis of foulant removed from the membrane surface contained a significant fraction of hydrophobic organics, removing more of this hydrophobic fraction from the well water may reduce the degree of RO fouling and permeability decline. If the organics retained by the CFs were being removed by sieving (filtration), a smaller pore size filter (for example, 1 or 5 µm) could improve organics removal but would likely increase the frequency of filter replacement, which is undesirable.

However, given the retention rating of the current filters (10 µm), compared to the size of the retained organics (0.01 µm or less), the more probable mechanism for organics retention is through adsorption. In this case, a larger pore size filter (20 µm) may achieve the same organics removal but result in a lower replacement frequency, depending on whether the filter is also retaining particulate matter from the well water.

Melt blown CF may provide an advantage over string wound CF if adsorption of dissolved organics is occurring. WRD may want to test multiple melt blow filter sizes in the pilot system to balance the replacement frequency with the removal of organics. WRD may consider evaluating the impact on both CF replacement frequency, combined with RO permeability changes, of a range of pore size filters at pilot scale (discussed further in Section 3).

3. Short-term Operational Recommendations

Operational modifications to various system components may reduce RO fouling, leading to improved plant performance and greater water production at the RWGD facility. The operational strategies are short-term options that can be implemented with existing infrastructure but may result in some additional operating costs. The following short-term operational recommendations were developed by analyzing the groundwater well flow profiling, WQ sampling, and membrane autopsy results, and by evaluating the RWGD's performance metrics.

3.1 Reverse Osmosis Flushing

Jacobs recommends modifying the RO flushing process in a series of steps:

1) Increase the flushing flow from approximately 525 to 800 gpm.
2) Extend the flushing time from 3 to 6 minutes for a short-term shutdown.
3) Use ROP instead of ROF, and observe whether permeability improves when the RO train is returned to service.

The objective of increasing the flushing flow is to more effectively displace the organics from the elements during flushing. WRD should evaluate the conductivity and DOC of the concentrate immediately after flushing and compare to the existing flushing procedure. If conductivity in the concentrate does not further decrease with increased velocity, or DOC levels stay the same, then proceed to the next step of extending the flushing time. Evaluate the efficacy of this approach by comparing conductivity and DOC of the concentrate and permeability decline of the RO. If there is not an observable difference from the existing flushing procedure, then consider using ROP instead of ROF to flush. If greater DOC is measured at the higher flushing rate, this would suggest a better displacement of organics.

3.2 Revised Clean-in-Place Protocol

Based on the review of the data, the short-term mini-caustic CIPs are as effective in restoring permeability loss as the full CIPs. Although the time to complete each CIP is approximately the same, the cost of the chemicals and the overall time to return to service can be reduced by shifting to more mini-CIPs.

Jacobs recommends WRD work with City of Torrance to determine the optimal CIP protocol. This can be accomplished by maintaining Train 1 on the current CIP protocol, which rotates mini-caustic CIPs and full CIP; and comparing that to Train 2, which increases the number of mini-caustic CIPs before a full CIP. Reviewing the performance data over a longer period of time will provide insights into the impact of this protocol on the performance of the RO membranes, while reducing downtime and chemical costs.

3.3 Well Flow Split

As Section 2 discussed, the flow split between the CYW and DPW is a critical factor for the CFs and RO performance. Reducing the DPW contribution will improve overall fouling rates on both the membranes and the CFs. However, this benefit must be balanced with the specific capacity of each well and, ultimately, the water production from the RWGD. From the perspective of reducing membrane fouling, the target split is 70 percent CYW and 30 percent DPW, or higher (such as 80/20) if a third well is brought online, as discussed in the following section.

3.4 Madrona 2 Well Modifications

Rehabilitation of the existing Madrona 2 well as a supply should be considered to reduce flow from DPW while maintaining design flow conditions to RWGD, but the well's WQ will need to be evaluated to determine whether it is suitable for treatment. The well should be inspected to determine the improvements needed to make the well functional. At a minimum, it will require piping and pump motor modifications and Division of Drinking Water

(DDW) approval. WQ testing should include similar parameters tested for CYW and DPW as during the WQ investigation (Jacobs 2020). There may be limitations on the use of Madrona 2 as bypass water or blended product water stream, depending on the WQ results, specifically the MTBE levels.

3.5 Cartridge Filter Pilot Recommendations

Pilot testing melt blown CFs and various pore size string wound filters on the RO pilot skid at RWGD is recommended before testing at full scale, which would require that 118 filters be replaced in 1 vessel. After establishing a baseline with the current string wound filter pore size of 10 µm, WRD should document the fouling rate, replacement frequency, differential pressures, and corresponding RO permeability changes. These data will be used to compare to the other type and pore sizes and evaluate whether shifting to a melt blown CF or changing the pore size will benefit or impact RO performance and replacement frequency.

If the organics are retained on the CF by sieving (filtration), a smaller pore size filter (for example, 1 or 5 µm) could improve organics removal but would likely increase the frequency of filter replacement. If the organics are retained on the CF by adsorption, a larger pore size filter (20 µm) may achieve the same organics removal but result in a lower replacement frequency, depending on whether the filter is also retaining particulate matter from the well water.

Piloting a melt blown CF compared to the baseline string wound CF would provide data and insights on differences of downstream operation. Piloting the 1-, 5-, 20-µm string wound filter CF would be a cost-effective method of evaluating the impact of changing CF size to RO permeability and resulting CF replacement frequency. It is not the intent of this recommendation to increase the frequency of filter replacements.

4. Long-term Recommendations

4.1 Well Modifications

The well modification options focus on balancing the intent of the groundwater wells to treat the saline plume, while limiting sources of fouling organics generated in certain portions of the screen intervals.

4.1.1 Delthorne Park Well Modifications

One suspected source of organics that may be significantly contributing to RO fouling is the upper zone of the upper screen, where very high color was observed. True color was estimated at 142 color units in the interval from 300 feet below ground surface (bgs) to 310 feet bgs (Jacobs 2020). To decrease this contribution of colored water from entering the well, an inflatable packer could be installed on the tailpipe of the existing well pumping equipment. The packer would be installed at approximately 320 feet bgs, which corresponds to the shallowest welding collar adjoining sections of well screen. Inflating the packer at this depth will provide a better seal than doing so in the well screen.

To install the packer, the pumping equipment would have to be removed. It would then be reinstalled with the addition of approximately 50 feet of pipe from the bottom of the pump to position the packer at the desired depth and stainless-steel tubing from the packer to ground surface to inflate the packer. Installing an additional 65 feet of drop tube below the packer would position the intake in the blank section between the upper and lower screens. This reduces the likelihood of organics from the upper zone of the upper screen migrating to the intake.

Both the inflatable packer and drop tube can be installed when the well pump is removed. The estimated cost for this modification is $163,000 (Appendix B). Potential risks or disadvantages associated with this approach include:

- Packer may eliminate future use of camera tube.
- Well production may be reduced (the flow contribution from 300 feet bgs to 320 feet bgs was estimated at approximately 10 percent of total well production during well profiling), but the chloride concentration in this zone is very low so it will have little impact on WRD's goal of desalinating the aquifer. Based on subsequent pumping of DPW, removing the contribution of the upper well will not impact DPW flow contribution to RWGD and may increase the chloride concentration.
- Other organics in the water column also likely contribute to RO fouling, so eliminating this source may not adequately address the RO fouling issue.
- Colored water might still migrate through the aquifer and enter the well at a different elevation.

Note, the installation of a permanent well liner from 300 feet to 320 feet bgs was also considered but was dismissed because of higher cost and the inability to economically remove the liner if it proves unsuccessful in reducing RO fouling.

4.1.2 Installation of a Third Well

The addition of a third well to supply water to the RWGD facility could reduce RO fouling by locating a water source that has sufficient salinity for mitigation of the saline plume but also has a low concentration of fouling organics, which are suspected to be hydrophobic organics and colored hydrophilic organics. Once a consistent feed water flow to RWGD is achieved, installation of an additional well (that is, a fourth well) would allow rotation of the wells and a period of rest, which may increase well stability and sustainability.

These new water supplies would combine with CYW and DPW water to feed the RWGD facility. The contribution ratio from the wells would be controlled so flow from the DPW was maintained at less than 35 percent to avoid excessive fouling of the RO membranes.

4.2 Pretreatment Alternatives for Organics Removal

4.2.1 Screening Analysis

Organics in the water provided by the DPW and CYW are suspected to have a significant impact on RO fouling at the RWGD. Table 3 identifies four potential pretreatment options to mitigate the organics in the feed water, including granular activated carbon (GAC), coagulation-filtration, ultrafiltration (UF), and ozone-biofiltration. These options can be applied to the DPW water only, which would address the organics suspected to more directly impact RO fouling; or to the combined flow from DPW and CYW.

The additional process complexity, larger footprint, and higher relative capital costs of coagulation-filtration, UF, and ozone-biofiltration eliminated these options from further consideration. The potential benefits and risks outlined in Table 3 indicate GAC treatment maximizes the potential benefits, while minimizing the potential risks and cost. Therefore, two GAC pretreatment options will be carried forward for conceptual consideration and costing: (1) GAC pretreatment of DPW flow only, and (2) GAC pretreatment of combined flow from DPW and CYW.

Table 3. Screening Analysis of Potential Long-term Treatment Options

Treatment Options	Potential Benefits	Potential Risks	Relative Cost[a]
GAC	▪ Pressurized vessels can be used – no need to break head ▪ Bulk TOC not excessively high; reasonable bed life expected, although RSSCT and pilot testing required to confirm	▪ Elevated sulfate may impact bed life ▪ Hydrophilic compounds (humic substances) may break through before hydrophobic compounds; impact to RO fouling is unknown – pilot testing needed to confirm ▪ Excessive GAC media replacement required to maintain low RO fouling ▪ Fouling of GAC media from well silt and sand	$$
Coagulation-Filtration	▪ Coagulation-filtration typically used to remove natural organic matter ▪ Can handle multiple fouling concerns ▪ Can process large flows, consistently	▪ Coagulation of fouling fraction of organics unknown ▪ Breaking head may be required for proper floc formation, requiring another pump station ▪ Potential for oxidation of manganese, which could cause additional increased RO fouling ▪ Complex operation required to maintain proper water chemistry and particle charge for good organics removal and effective filtration ▪ Chemical addition necessary ▪ Space limitations – siting concerns	$$$
UF	▪ UF may remove hydrophobic organics (similar to the CFs), but to a greater extent; pilot testing required	▪ Complex and costly pretreatment ▪ Additional waste stream (5-10%) ▪ Space limitations – siting concerns for UF and for additional CIP	$$$$
Ozone-biofiltration	▪ Ozone would break down high MW compounds followed by low MW removal in biofiltration; pilot testing required to confirm effectiveness (to reduce RO fouling) ▪ Pressure system possible – no need to break head	▪ Multiple processes needed; complex and costly pretreatment ▪ Potential for oxidation of manganese caused by presence of strong oxidant ▪ Biology present in biofilters can create unexpected WQ issues (e.g., iron and manganese release, biopolymer accumulation and release)	$$$$

[a]More $ means higher relative cost.

Notes:

MW = molecular weight

RSSCT = rapid small-scale column testing

4.2.2 Granulated Activated Carbon Pretreatment: Conceptual Design and Cost Estimate

Two GAC treatment approaches were considered for the RWGD facility: (1) treatment of only DPW water, and (2) treatment of the combined flow from DPW and CYW. Figures 8 and 9 provide simplified process flow diagrams identifying major infrastructure components for these two approaches. Backwash supply (BWS) and backwash waste (BWW) systems are included to backwash GAC media, as necessary, and a bypass around the GAC is shown to allow system optimization through partial well water treatment. GAC adsorption for the combined flow from DPW and CYW is shown downstream of the existing CFs because of the CYW's tendency to pump silt and sand. It is assumed that cartridge filtration is not necessary for treatment of DPW only, but this should be confirmed during pilot testing.

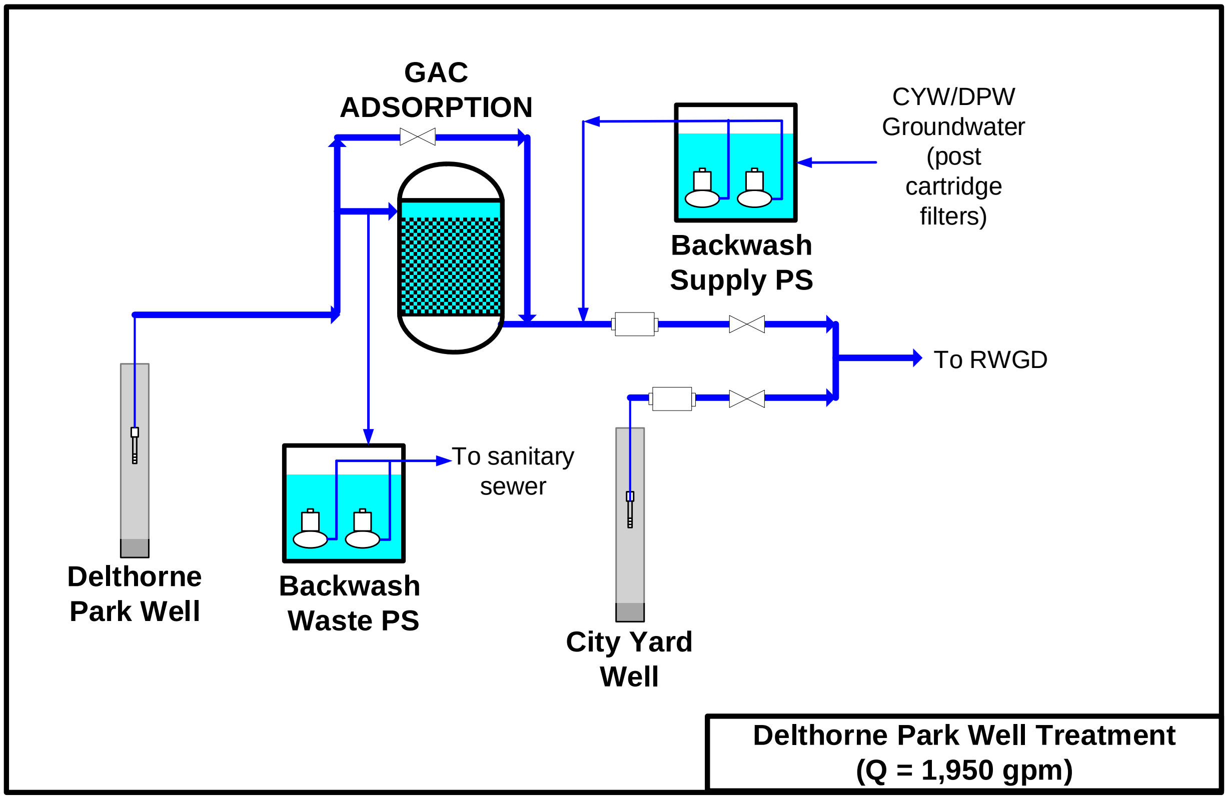


Figure 8. Process Flow Diagram for Delthorne Park Well Treatment

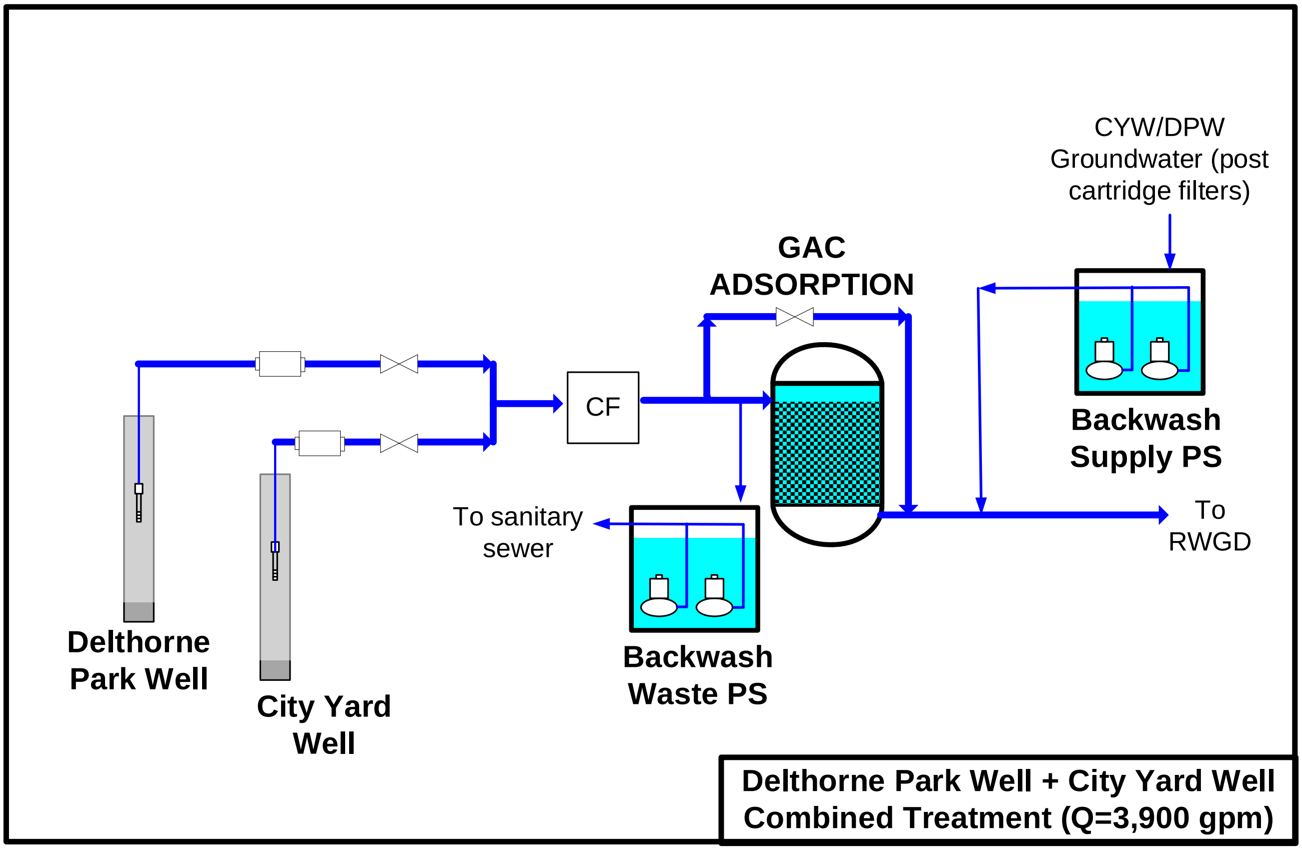


Figure 9. Process Flow Diagram for Delthorne Park Well and City Yard Well Combined Treatment

The following major factors affect the practicality and cost of implementing GAC treatment at the existing RWGD site:

- **Flow:** Although the combined maximum flow currently pumped by CYW and DPW is limited to 3,600 gpm due to RO fouling limitations, the intent is to return treatment capacity to the original design capacity (3,900 gpm; 1,950 gpm from each well). The design flow has a large impact on footprint requirements for GAC treatment.
- **Empty Bed Contact Time (EBCT):** The EBCT provided in a GAC vessel has a large impact on organics removal and bed life (that is, GAC replacement frequency). Longer EBCTs provide more organics removal and a longer duration between the replacement of GAC media, but result in higher capital costs. EBCTs for natural organic matter removal in drinking water applications typically range from 10 to 20 minutes, although site-specific bench- and pilot-scale testing are often conducted to establish an appropriate design EBCT.
- **Facility Configuration and Footprint:** GAC contactors can be implemented in either gravity or pressure configurations. A pressure configuration is preferred at the RWGD facility because it avoids breaking head, which can lead to undesirable consequences when treating anoxic well water (for example, oxidation of reduced metals). Pressure vessels with a maximum diameter of 12 feet are typically used to avoid vehicle transportation restrictions associated with shipping pressure vessels of larger diameter. The straight shell height of the pressure vessel, which directly impacts the EBCT provided, can be customized, although standard sizes are often used to reduce cost.

Table 4 summarizes the proposed major design criteria for the addition of GAC treatment. Standard 12-foot-diameter GAC pressure vessels have been assumed, each housing approximately 40,000 pounds of GAC media, resulting in a total vessel height of about 26.5 feet. Treating only the DPW would require two pressure vessels, for a nominal EBCT of 10 minutes, and four vessels, for a nominal EBCT of 20 minutes. Treating the combined flow from the DPW and CYW would require four pressure vessels, for a nominal EBCT of 10 minutes, and eight vessels, for a nominal EBCT of 20-minutes. Appendix C provides representative pressure vessel configuration drawings. Pressure loss through the vendors' GAC system is estimated at 5 pounds per square inch (psi) for the 20-minute EBCT configurations and 18 psi for the 10-minute EBCT configurations. A preliminary review of the well pump performance curves suggests this increased pressure could be accommodated by the existing pumps while maintaining the design flow of 1,950 gpm (Appendix D). However, a detailed hydraulic evaluation should be conducted after the design EBCT has been established though bench- and pilot-scale testing and a specific GAC contactor configuration and location has been established.

Figures 10, 11, and 12 show potential siting locations for the two- vessel, four-vessel, and eight-vessel configurations. Space allocation for BWS and BWW equalization and pumping is also shown.

Table 4. Granulated Activated Carbon Design Criteria

Item	DPW Only		DPW+CYW		Notes
	EBCT=10 min	EBCT=20 min	EBCT=10 min	EBCT=20 min	
Flow	1,950 gpm		3,900 gpm		Matches original design flow for wells
Media volume	1,469 CF per vessel		1,469 CF per vessel		
No. of pressure vessels	2	4	4	8	Calgon 12-40 system includes two pressure vessels
Calculated EBCT	11.3 min	22.6 min	11.3 min	22.6 min	
EBCT with one vessel out of service	5.6 min	16.9 min	8.5 in	19.7 min	One vessel out of service during backwash or GAC replacement
Total GAC media	80,000 lb	160,000 lb	160,000 lb	320,000 lb	Assumes 40,000 lb per vessel
Flow per vessel	975 gpm	488 gpm	975 gpm	488 gpm	
GAC system headloss	18 psi	5 psi	18 psi	5 psi	GAC system only; does not include piping and fittings to and from vessels

Notes:

lb = pound(s)

min = minute(s)

Figure 10. Site Plan for Two-vessel Granulated Activated Carbon Contactor Facility with Backwash Supply and Backwash Waste Tank and Pumping

Figure 11. Site Plan for Four-vessel Granulated Activated Carbon Contactor Facility with Backwash Supply and Backwash Waste Tank and Pumping

Figure 12. Site Plan for Eight-vessel Granulated Activated Carbon Contactor Facility with Backwash Supply and Backwash Waste Tank and Pumping

4.2.3 Cost Estimates for Granulated Activated Carbon Treatment Alternatives

Capital cost estimates were prepared to treat only the DPW, and to treat the combined flow for the DPW and CYW at two EBCTs (Table 5). The capital cost estimates are AACE International Class 5 estimates for process industries, which represent a design that is 0 to 2 percent complete and has a stated accuracy of +100 percent and -50 percent. Capital cost estimates include a 22 percent markup for contractor overhead, profit, mobilization, bonding, and insurance; 30 percent for contingency; and 18 percent for engineering, services during construction, permitting, and commissioning. The estimates assume the GAC facility would be uncovered (that is, no building) and all treatment processes would be contained in the City of Torrance City Yard fenced area. Contingencies for site civil, site piping, site electrical, site utilities, and instrumentation and control have been included in the cost estimates. These costs should be refined when the final site has been selected and it is possible to further define these items. Detailed cost estimates for the GAC facility, BWS tank and pump station, and BWW tank and pump station are provided in Appendix B.

The GAC replacement represents the largest component of nonlabor operations and maintenance (O&M) costs (Table 6). The maximum GAC replacement frequency has been estimated based on a TOC effluent goal of 1 milligram per liter (mg/L) and characteristic TOC breakthrough curves from other utilities, which results in a maximum expected replacement frequency for DPW treatment of 3 and 6 months for the 10- and 20-minute EBCTs, respectively. The effectiveness of reducing the RO fouling at a TOC concentration of 1 mg/L is unknown and must be verified through pilot testing, but has been assumed at this stage of the analysis to provide a rough estimate on potential annual GAC replacement costs.

In addition, TOC breakthrough curves can vary significantly between waters and should be verified through RSSCT or pilot testing, or both. Breakthrough curves for some waters have shown to provide indefinite removal of some TOC; in which case, the GAC replacement frequency may be extended for years. In the scenario that all source water is treated through GAC, it may extend the breakthrough time due to the reduced organics loading; however, this approach would result in higher capital costs because of the higher flow, and the actual breakthrough curves must be determined through pilot testing prior to capital investment. Table 6 includes O&M costs for this potential extended GAC life condition, as represented by the minimum GAC replacement frequency.

Table 7 summarizes the capital cost, annual O&M cost, and net present value for each option. The annual O&M costs only include GAC replacement; labor and other nonlabor costs and property leasing costs between alternatives have been assumed equivalent so were excluded. However, these should be revisited after bench- and pilot-scale testing is complete and GAC contactor alternatives are re-evaluated. Net present value calculations are based on a 25-year life, an interest rate of 4.5 percent, and an inflation rate of 2.5 percent.

Table 5. Capital Cost Estimates for Granulated Activated Carbon Pretreatment Alternatives

Description	DPW; EBCT=10 min ($)	DPW; EBCT= 20 min ($)	DPW+CYW; EBCT=10 min ($)	DPW+CYW; EBCT=20 min ($)
Process Facilities				
GAC Facility	1,139,000	2,271,000	2,271,000	4,520,000
BWS tank and pump station	174,000	174,000	174,000	174,000
BWW tank and pump station	174,000	174,000	174,000	174,000
Subtotal	***1,487,000***	***2,619,000***	***2,619,000***	***4,868,000***
Allowances				
Sitework Allowance	30,000	53,000	53,000	98,000
I&C Allowance	30,000	53,000	53,000	98,000
Mechanical Allowance	119,000	210,000	210,000	390,000
Electrical Allowance	30,000	53,000	53,000	98,000
Subtotal	***1,696,000***	***2,988,000***	***2,988,000***	***5,552,000***
Overhead, Profit, Mobilization, Bonds, and Insurance (22%)	374,000	658,000	658,000	1,222,000
Subtotal	***2,070,000***	***3,646,000***	***3,646,000***	***6,774,000***
Contingency (30%)	621,000	1,093,800	1,093,800	2,032,200
Total Construction Cost	**2,691,000**	**4,739,800**	**4,739,800**	**8,806,200**
Permitting Allowance (1%)	27,000	48,000	48,000	89,000
Engineering (8%)	216,000	380,000	380,000	705,000
SDC (8%)	216,000	380,000	380,000	705,000
Commissioning and Startup (1%)	27,000	48,000	48,000	89,000
Total Cost	**3,177,000**	**5,595,800**	**5,595,800**	**10,394,200**

Notes:

I&C = instrumentation and controls

SDC = services during construction

Table 6. Estimated Annual Operations and Maintenance Cost Estimates

Item	DPW; EBCT=10 min	DPW; EBCT=20 min	DPW+CYW; EBCT=10 min	DPW+CYW; EBCT=20 min
Total GAC Mass (lb)	85,819	171,637	171,637	343,275
Unit Cost for GAC Replacement ($)	1.66	1.66	1.66	1.66
Maximum Expected Replacement Frequency (months)	3	6	6	12
Minimum Expected Replacement Frequency (months)	12	24	24	48
Maximum Expected Annual Replacement Cost ($)	570,000	570,000	570,000	570,000
Minimum Expected Annual Replacement Cost ($)	143,000	143,000	143,000	143,000

Table 7. Cost Summary

Item	DPW; EBCT=10 min ($ millions)	DPW; EBCT= 20 min ($ millions)	DPW+CYW; EBCT=10 min ($ millions)	DPW+CYW; EBCT=20 min ($ millions)
Capital Cost	3.2	5.6	5.6	10.4
Annual O&M Cost	0.14-0.57	0.14-0.57	0.14-0.57	0.14-0.57
Net Present Value	6.0-14.4	8.4-16.8	8.4-16.8	13.2-21.6

5. Implementation Strategy

Table 8 summarizes the proposed implementation strategy to address the RO fouling issue at the RWGD facility. The expected time frame to implement each option is shown (short-, mid-, and long term). This table also includes next steps for WRD to investigate and address, as well as related considerations. Each short-term option can be conducted in parallel, but the full implementation of the mid- and long-term options depends on the relative success of the others. For example, if WRD elects to proceed with installation of an inflatable packer and drop tube in the DPW, the GAC implementation should be delayed until the impact to RO fouling from the new water supply has been established. However, to streamline the overall process, portions of the GAC pretreatment option could be implemented in parallel, such as conducting RSSCT bench-scale testing.

Table 8. Implementation Strategy

Option	Time Frame	Further Investigation Required by WRD Before Implementation	Considerations
RO Flushing	Short term	1. Evaluate the capacity of existing flushing system for increased flow (from current 525 gpm to 800 gpm) and the use of ROP for flushing. 2. Test the revised flushing approach: (a) Increase flushing to 800 gpm; (b) Extend time of flushing from 3 to 6 min; (c) Use ROP instead of ROF. Compare conductivity and TOC in flush water under the current flushing procedure with each of the revised flushing procedure.	
CIP Protocol Changes	Short term	1. Increase the number of mini-caustic CIPs between full CIPs on one train while maintaining the same protocol of alternating mini-caustic CIPs with full CIP on the other train. Monitor the change in differential pressure over time.	Although the time for the CIPs are similar, downtime is reduced if shifting to more caustic CIPs.
Well Flow Split Adjustments	Short term	2. Determine the maximum practical CYW pumping rate and minimum practical DPW pumping rate to establish a possible range of CYW and DPW flow splits. Determine if RWGD water production will be adequate at the recommended flow split. 3. Investigate control programming, system hydraulics and pump performance to better understand CYW fluctuations and limitations.	To limit RO fouling, the recommended CYW and DPW flow split is 70/30.
CF Modifications	Short term	1. Test a range of CF filter sizes (5, 10, 20) and a melt blown filter in the existing pilot. Evaluate CF differential pressure rise, RO permeability decline, SDI, and hydrophobic organics removal across the CF. 2. Evaluate the performance and test the selected CFs at the full-scale plant, if appropriate.	
Madrona 2 Well Modifications	Short term	1. Evaluate the feasibility of using the existing Madrona 2 well (i.e., WQ, functionality, hydraulics). 2. Determine piping and pump motor modifications, specific WQ testing, and DDW approval.	Target DPW total contribution to no greater than 30%.
DPW Modifications (inflatable packer and drop tube)	Mid term	1. Install an inflatable packer and drop tube in the DPW. 2. Compare the quality (e.g., DOC, color) of that new water supply from DPW to that of the previous water supply. 3. Operate the RWGD at various CYW and DPW blend ratios and evaluate performance.	Pump removal required for installation of inflatable packer and drop tube. Packer may eliminate future use of camera tube.
Third Well Installations	Mid term	1. Evaluate the feasibility of siting and installing other wells.	Increase reliability and sustainability of RWGD feed water, and allow time for wells to rest.
GAC Pretreatment	Long term	1. Conduct RSSCT bench-scale testing for two alternatives (DPW only and blended feed) to evaluate the effectiveness of GAC for TOC removal at EBCTs of 10 and 20 minutes. Measure true color removal, and use LC-OCD to better quantify the specific organic removal. Estimate the GAC's media life, and revise the net present value cost estimates. 2. Conduct GAC and RO pilot testing on DPW water and blended CYW and DPW water to evaluate effectiveness of GAC pretreatment in controlling RO fouling. 3. Revise the conceptual design and cost evaluation based on RSSCT and pilot testing results.	Consider conducting RSSCT testing in the short term and then proceeding with pilot testing only if RSSCT yields positive results and DPW modifications are not successful (if implemented).

Notes:

SDI = silt density index

6. References

American Water Chemicals, Inc. (AWC). 2020. *Membrane Autopsy Report*. AWC LSA#: 0220147. October 7.

Bautista, Mario, Water Replenishment District of Southern California. 2020a. Personal communication (email with Flushing Procedure) with Renee Groskreutz, Jacobs. October 13.

Bautista, Mario, Water Replenishment District of Southern California. 2020b. Personal communication (email with Updated RO Performance Data) with Renee Groskreutz, Jacobs. October 14.

Bautista, Mario, Water Replenishment District of Southern California. 2020c. Personal communication (email with Cartridge Filter Operation Data) with Renee Groskreutz, Jacobs. November 3.

Carollo. 2017. *Robert W. Goldsworthy Desalter Expansion and Completion of New Source Water Wells and Conveyance Pipelines Project*. As-Built Drawings prepared for Water Replenishment District of Southern California. August.

CH2M HILL Engineers, Inc. (CH2M). 2016. *Robert W. Goldsworthy Desalter Expansion, New Source Water Wells Installation Report*. Prepared for Water Replenishment District of Southern California. May.

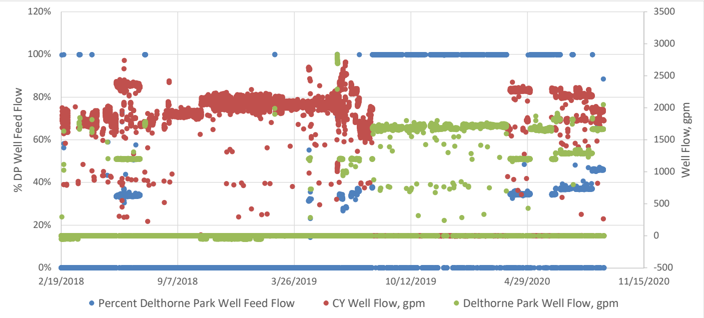
Goldsworthy Operations, City of Torrance. 2020. Personal communication (email with Cleaning Frequency) with Renee Groskreutz, Jacobs. October 1.

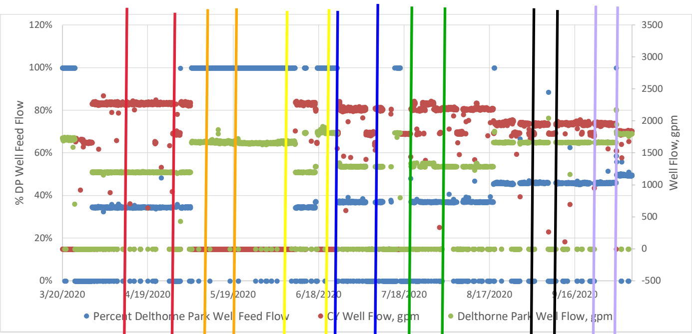
Jacobs Engineering Group Inc. (Jacobs). 2020. *Water Quality Investigation Summary*. Prepared for Water Replenishment District of Southern California. Final. October 30.

Knoell, Tom, Water Replenishment District of Southern California. 2020a. Personal communication (email with Cartridge Filter Data) with Renee Groskreutz, Jacobs. October 21.

Knoell, Tom, Water Replenishment District of Southern California. 2020b. Personal communication (email with Flow Split Data) with Renee Groskreutz, Jacobs. October 26.

Appendix A
Detailed Reverse Osmosis Performance Data





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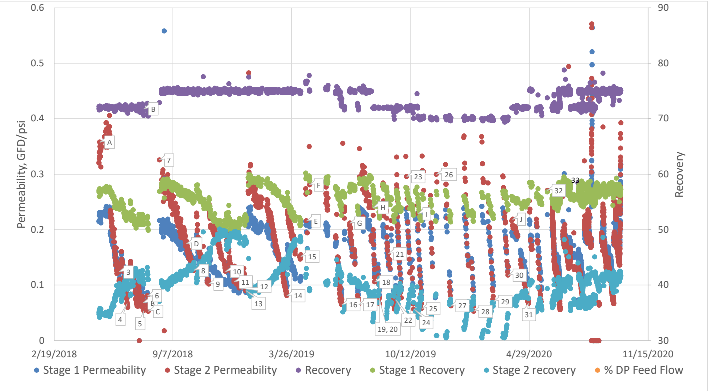
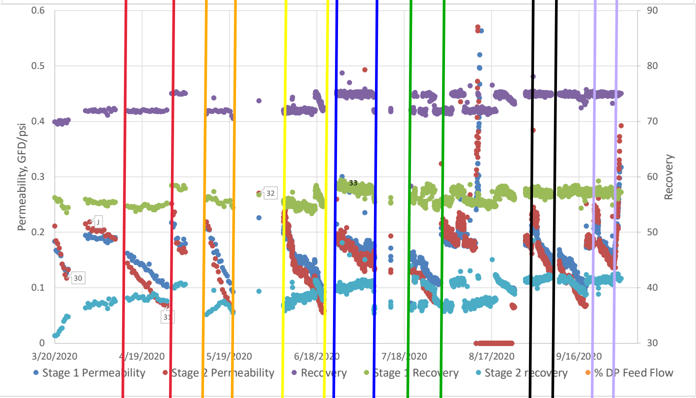
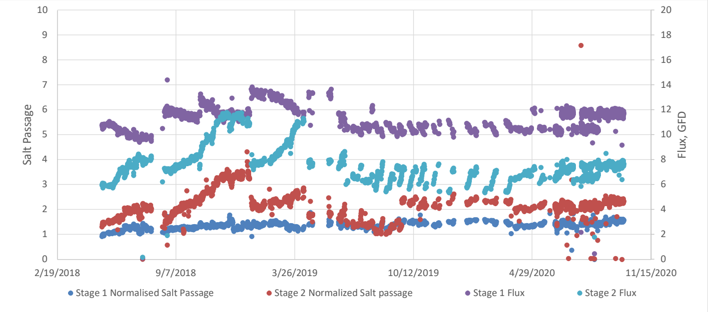
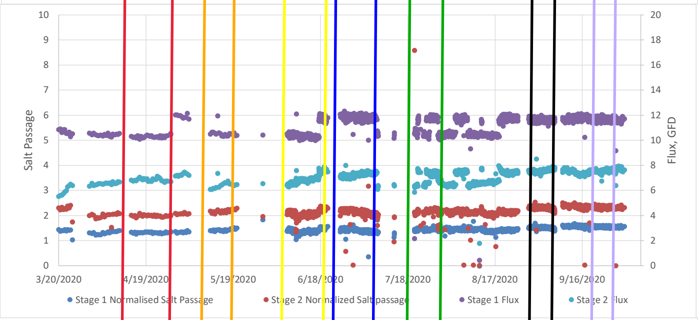
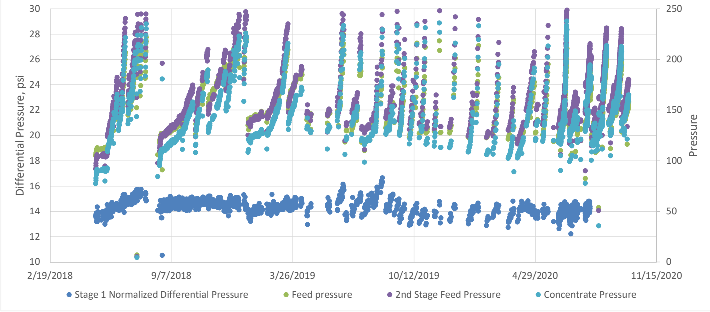
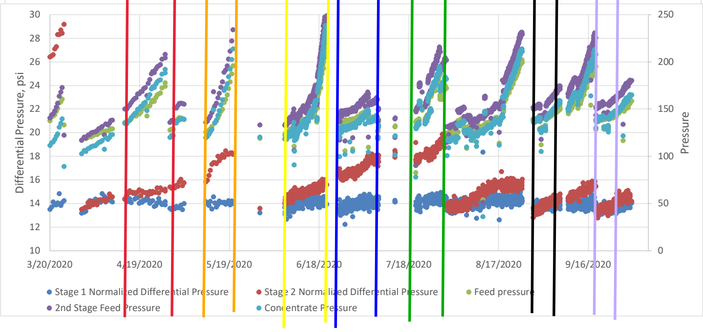












			Flux, GFD		Perm. Drop,GFD/psi/day		Norm DP Increase, psi/day	
"Run"		Blend	Stage 1	Stage 2	Stage 1	Stage 2	Stage 1	Stage 2
8/21/2018	10/12/2018	0%	11.9-11.2	7.1-8.2	0.001	0.003	-0.010	0.023
1/15/2019	3/17/2019	0%	13.6-12.5	7.6-9.4	0.002	0.004	0.015	0.020

			Flux, GFD		Perm. Drop,GFD/psi/day		Norm DP Increase, psi/day	
"Run"		Blend	Stage 1	Stage 2	Stage 1	Stage 2	Stage 1	Stage 2
4/14/2020	4/27/2020	34%	10.1-10.2	6.7	0.005	0.006	-0.046	0.052
5/11/2020	5/20/2020	100%	10.5-10.4	6.1-6.5	0.014	0.017	0	0.256
6/7/2020	6/20/2020	34%	10.3-10.2	6.3-7.5	0.010	0.014	0.062	0.138
6/25/2020	7/7/2020	37%	11.9-11.7	7.1-7.4	0.003	0.005	0.042	0.100
7/20/2020	7/30/2020	37%	(10-12)	(6.2-7.2)	0.005	0.006	0	0.150
8/31/2020	9/6/2020	46%	11.4-11.5	7.5-7.6	0.012	0.021	0.050	0.167
9/21/2020	9/28/2020	46%	11.5	7.5-7.6	0.010	0.016	0.057	0.157

Appendix B
Detailed Cost Estimate

Goldsworthy Pump Modifications
K.Bral
10/30/2020

Budget Cost Construction Install Packer at 320 feet

Description	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**
Pump Removal				
Remove & Reinstall Existing Pump	1	each	$30,000	$30,000
Additional 10" Column Pipe (304SST)	115	feet	$400	$46,000
Contractor Markup: Overhead, profit, mob/bonds/insurance	22	%		$10,120
Continency	30	%		$25,836
SUBTOTAL				$111,956
Packer				
10" by 20" Inflatable Packer	1	each	$25,000	$25,000
SST Inflation Tubing	340	feet	$5	$1,700
Installation	1	each	$1,000	$1,000
Miscellaneous Smal Parts	15	%		$4,155
Contractor Markup: Overhead, profit, mob/bonds/insurance	22	%		$6,788
Contingency	30	%		$11,593
SUBTOTAL with Markups				$50,236
Construction Total				**$163,000**

COST ESTIMATE

Description	Quantity (English)	Unit (English)	Quantity (Metric)	Unit (Metric)	$/Unit	Total Cost	User Over-Write
SITEWORK:							
Filter Building							
Excavation	100.74	CY	77.02	m3	$6.72	$677	
Imported Structural Backfill	93.33	CY	71.36	m3	$50.94	$4,755	
Native Backfill	8.28	CY	6.33	m3	$8.27	$68	
Haul Excess	92.46	CY	70.69	m3	$8.27	$764	
Blower Room							
Excavation	0.00	CY	0.00	m3	$6.72	$0	
Imported Structural Backfill	0.00	CY	0.00	m3	$50.94	$0	
Native Backfill	0.00	CY	0.00	m3	$8.27	$0	
Haul Excess	0.00	CY	0.00	m3	$8.27	$0	
Electrical Room							
Excavation	10.21	CY	7.80	m3	$6.72	$69	
Imported Structural Backfill	7.60	CY	5.81	m3	$50.94	$387	
Native Backfill	2.46	CY	1.88	m3	$8.27	$20	
Haul Excess	7.75	CY	5.92	m3	$8.27	$64	
Allowance for Misc Items	5%				$6,804.85	$340	
Subtotal						$7,145	
CONCRETE:							
Slab on Grade	28.22	CY	21.58	m3	$490.62	$13,846	
Allowance for Misc Items	5%				$13,846	$692	
Subtotal						$14,539	
MASONRY:	Low						
Filter Building	0.00	SF	0.00	m2	$132.24	$0	
Blower Room	0.00	SF	0.00	m2	$132.24	$0	
Electrical Room	32.00	SF	2.97	m2	$132.24	$4,232	
Subtotal	32.00					$4,232	
THERMAL & MOISTURE PROTECTION:							
Pressure Vessel Liner	0.00	SF	0.00	m2	$16.00	$0	
Allowance for Misc Items	10%				$0.00	$0	
Subtotal						$0	
EQUIPMENT:							Budgetary Quote: (CPES will automatically add Installation Factor)
Vertical Pressure Filter Systems	2	EA			$435,160.25	$696,000	$580,000.00
(Includes Tanks, Underdrain, System Piping, Actuated Valves, Instrumentation, and Automatic PLC Control Panel)							
Filter Media (Granular Activated Carbon (GAC))	2940.53	CF	83.27	m3	$65.85	$193,628	
Blowers	0	EA			$0.00	$0	
Allowance for Misc Items	5%				$889,627.56	$44,481	
Subtotal						$934,109	
I&C:							
Instruments							
Filter Effluent Header Magmeter (FEH, 14 inch)	0	EA			$18,522.88	$0	
Filter Effluent Lateral Magmeter (FEL, 10 inch)	2	EA			$14,682.15	$12,761	$12,761.00
Backwash Air Supply Header Magmeter (ASH, 0 inch)	0	EA			$5,080.31	$0	
Isolation Valve Actuators (Electric)	4	EA			$6,362.11	$6,362	$6,362.00
Turbidimeters	2	EA			$4,919.32	$0	$0.00
Particle Counters	0	EA			$10,621.25	$0	
Differential Pressure Transmitters	2	EA			$11,180.26	$22,361	
Air Scour Differential Pressure Transmitter	0	EA			$11,180.26	$0	
Air Scour Discharge Pressure Indicator Transmitter	0	EA			$11,180.26	$0	
Air Scour Blowoff Valve	0	EA			$13,805.32	$0	
Number of Analog I/O Counts	12	EA			$262.30	$3,148	
Number of Digital I/O Counts	24	EA			$62.12	$1,491	
Number of Local Panels	2	EA			$12,977.00	$0	$0.00
Number of PLC's	1	EA			$13,805.32	$0	$0.00
I&C Conduit Wire	390.00	LF	118.87	m	$11.97	$4,668	
Allowance for Misc Items	5%				$50,790.11	$2,540	
Subtotal						$53,330	
MECHANICAL:							
Pipe:							
Filter Influent Header (FIH, 14 inch, Steel)	34.00	LF	10.36	m	$290.82	$9,888	
Filter Influent Lateral (FIL, 10 inch, HDPE)	80.54	LF	24.55	m	$26.24	$2,113	
Filter Effluent Header (FEH, 14 inch, HDPE)	34.00	LF	10.36	m	$36.73	$1,249	
Filter Effluent Lateral (FEL, 10 inch, HDPE)	25.00	LF	7.62	m	$26.24	$656	
Backwash Supply Header (BSH, 12 inch, HDPE)	36.00	LF	10.97	m	$31.48	$1,133	
Backwash Waste Header (BWH, 12 inch, HDPE)	36.00	LF	10.97	m	$31.48	$1,133	
Raw Water Bypass Header (BPH, 0 inch, Steel)	34.00	LF	10.36	m	$0.00	$0	
Backwash Air Supply Header (ASH, 0 inch, SST)	0.00	LF	0.00	m	$0.00	$0	
Elbows:							
Filter Influent Header (FIH, 14 inch, Steel)	0	EA			$1,934.29	$0	
Filter Influent Lateral (FIL, 10 inch, HDPE)	6	EA			$821.76	$4,931	
Filter Effluent Header (FEH, 14 inch, HDPE)	0	EA			$1,150.46	$0	
Filter Effluent Lateral (FEL, 10 inch, HDPE)	2	EA			$821.76	$1,644	
Backwash Supply Header (BSH, 12 inch, HDPE)	0	EA			$986.11	$0	
Backwash Waste Header (BWH, 12 inch, HDPE)	0	EA			$986.11	$0	
Raw Water Bypass Header (BPH, 0 inch, Steel)	2	EA			$0.00	$0	
Backwash Air Supply Header (ASH, 0 inch, SST)	0	EA			$0.00	$0	
Tee:							
Filter Influent Header (FIH, 14 inch, Steel)	2	EA			$4,407.04	$8,814	
Filter Influent Lateral (FIL, 10 inch, HDPE)	0	EA			$987.72	$0	
Filter Effluent Header (FEH, 14 inch, HDPE)	2	EA			$1,382.80	$2,766	
Filter Effluent Lateral (FEL, 10 inch, HDPE)	0	EA			$987.72	$0	
Backwash Supply Header (BSH, 12 inch, HDPE)	2	EA			$1,185.26	$2,371	
Backwash Waste Header (BWH, 12 inch, HDPE)	2	EA			$1,185.26	$2,371	
Raw Water Bypass Header (BPH, 0 inch, Steel)	0	EA			$0.00	$0	
Backwash Air Supply Header (ASH, 0 inch, SST)	0	EA			$0.00	$0	
Valves:							
Filter Influent Header (FIH, 14 inch, Steel)	0	EA			$14,146.92	$0	
Filter Influent Lateral (FIL, 10 inch, HDPE)	2	EA			$8,794.68	$0	$0.00
Filter Effluent Header (FEH, 14 inch, HDPE)	0	EA			$12,312.55	$0	

Filter Effluent Lateral (FEL, 10 inch, HDPE)	2	EA			*$8,794.68*	$0	**$0.00**
Backwash Supply Header (BSH, 12 inch, HDPE)	2	EA			*$10,553.61*	$0	**$0.00**
Backwash Waste Header (BWH, 12 inch, HDPE)	2	EA			*$10,553.61*	$0	**$0.00**
Raw Water Bypass Header (BPH, 0 inch, Steel)	2	EA			*$0.00*	$0	
Backwash Air Supply Header (ASH, 0 inch, SST)	0	EA			*$0.00*	$0	
Allowance for Misc Items	2%				$39,067.22	$781	
Subtotal						$39,849	
ELECTRICAL:							
# MCC Sections	4	EA			$10,353.99	$10,353	**$10,353.00**
Switchgear	0	EA			$47,628.34	$0	
Adjustable Frequency Drives							
Air Scour Blower (Active) (0 hp each)	0	EA			***$8,799.56***	$0	
Air Scour Blower (Standby) (0 hp each)	0	EA			***$8,799.56***	$0	
Electrical Conduit & Wire	0.00	LF	0.00	m	*$11.97*	$0	
Allowance for Misc Items	5%				$10,353.00	$518	
Subtotal						$10,871	
Subtotal						$1,064,073	
ALLOWANCES:		**User Override**					
Finishes Allowance	2.00%		$1,138,046	$22,761			
I&C Allowance	1.00%		$1,138,046	$11,380			
Mechanical Allowance	1.00%		$1,138,046	$11,380			
Electrical Allowance	2.50%		$1,138,046	$28,451			
					Facilty Cost Name		
Facility Cost	**2,808,018**	**GPD**	**$0.41**	**$1,138,046**	FLVFC01		

COST ESTIMATE

Description	Quantity (English)	Unit (English)	Quantity (Metric)	Unit (Metric)	$/Unit	Total Cost	User Over-Write
SITEWORK:							
Filter Building							
Excavation	161.83	CY	123.73	m3	$6.72	$1,088	
Imported Structural Backfill	153.33	CY	117.23	m3	$50.94	$7,811	
Native Backfill	10.32	CY	7.89	m3	$8.27	$85	
Haul Excess	151.51	CY	115.83	m3	$8.27	$1,252	
Blower Room							
Excavation	0.00	CY	0.00	m3	$6.72	$0	
Imported Structural Backfill	0.00	CY	0.00	m3	$50.94	$0	
Native Backfill	0.00	CY	0.00	m3	$8.27	$0	
Haul Excess	0.00	CY	0.00	m3	$8.27	$0	
Electrical Room							
Excavation	10.21	CY	7.80	m3	$6.72	$69	
Imported Structural Backfill	7.60	CY	5.81	m3	$50.94	$387	
Native Backfill	2.46	CY	1.88	m3	$8.27	$20	
Haul Excess	7.75	CY	5.92	m3	$8.27	$64	
Allowance for Misc Items	5%				$10,776.94	$539	
Subtotal						$11,316	
CONCRETE:							
Slab on Grade	48.72	CY	37.25	m3	$490.62	$23,904	
Allowance for Misc Items	5%				$23,904	$1,195	
Subtotal						$25,099	
MASONRY:	Low						
Filter Building	0.00	SF	0.00	m2	$132.24	$0	
Blower Room	0.00	SF	0.00	m2	$132.24	$0	
Electrical Room	32.00	SF	2.97	m2	$132.24	$4,232	
Subtotal	32.00					$4,232	
THERMAL & MOISTURE PROTECTION:							
Pressure Vessel Liner	0.00	SF	0.00	m2	$16.00	$0	
Allowance for Misc Items	10%				$0.00	$0	
Subtotal						$0	
EQUIPMENT:							Budgetary Quote: (CPES will automatically add Installation Factor)
Vertical Pressure Filter Systems	4	EA			$435,160.25	$1,392,000	$1,160,000.00
(Includes Tanks, Underdrain, System Piping, Actuated Valves, Instrumentation, and Automatic PLC Control Panel)							
Filter Media (Granular Activated Carbon (GAC))	5881.06	CF	166.53	m3	$65.85	$387,255	
Blowers	0	EA			$0.00	$0	
Allowance for Misc Items	5%				$1,779,255.11	$88,963	
Subtotal						$1,868,218	
I&C:							
Instruments							
Filter Effluent Header Magmeter (FEH, 14 inch)	0	EA			$18,522.88	$0	
Filter Effluent Lateral Magmeter (FEL, 8 inch)	4	EA			$12,761.78	$25,522	$25,522.00
Backwash Air Supply Header Magmeter (ASH, 0 inch)	0	EA			$5,080.31	$0	
Isolation Valve Actuators (Electric)	8	EA			$6,362.11	$12,724	$12,724.00
Turbidimeters	4	EA			$4,919.32	$0	$0.00
Particle Counters	0	EA			$10,621.25	$0	
Differential Pressure Transmitters	4	EA			$11,180.26	$44,721	
Air Scour Differential Pressure Transmitter	0	EA			$11,180.26	$0	
Air Scour Discharge Pressure Indicator Transmitter	0	EA			$11,180.26	$0	
Air Scour Blowoff Valve	0	EA			$13,805.32	$0	
Number of Analog I/O Counts	20	EA			$262.30	$5,246	
Number of Digital I/O Counts	48	EA			$62.12	$2,982	
Number of Local Panels	4	EA			$12,977.00	$0	$0.00
Number of PLC's	1	EA			$13,805.32	$0	$0.00
I&C Conduit Wire	780.00	LF	237.74	m	$11.97	$9,336	
Allowance for Misc Items	5%				$100,531.01	$5,027	
Subtotal						$105,558	
MECHANICAL:							
Pipe:							
Filter Influent Header (FIH, 14 inch, Steel)	34.00	LF	10.36	m	$290.82	$9,888	
Filter Influent Lateral (FIL, 8 inch, HDPE)	197.09	LF	60.07	m	$20.99	$4,137	
Filter Effluent Header (FEH, 14 inch, HDPE)	34.00	LF	10.36	m	$36.73	$1,249	
Filter Effluent Lateral (FEL, 8 inch, HDPE)	86.00	LF	26.21	m	$20.99	$1,805	
Backwash Supply Header (BSH, 12 inch, HDPE)	38.00	LF	11.58	m	$31.48	$1,196	
Backwash Waste Header (BWH, 12 inch, HDPE)	38.00	LF	11.58	m	$31.48	$1,196	
Raw Water Bypass Header (BPH, 0 inch, Steel)	34.00	LF	10.36	m	$0.00	$0	
Backwash Air Supply Header (ASH, 0 inch, SST)	0.00	LF	0.00	m	$0.00	$0	
Elbows:							
Filter Influent Header (FIH, 14 inch, Steel)	0	EA			$1,934.29	$0	
Filter Influent Lateral (FIL, 8 inch, HDPE)	12	EA			$657.40	$7,889	
Filter Effluent Header (FEH, 14 inch, HDPE)	0	EA			$1,150.46	$0	
Filter Effluent Lateral (FEL, 8 inch, HDPE)	6	EA			$657.40	$3,944	
Backwash Supply Header (BSH, 12 inch, HDPE)	0	EA			$986.11	$0	
Backwash Waste Header (BWH, 12 inch, HDPE)	0	EA			$986.11	$0	
Raw Water Bypass Header (BPH, 0 inch, Steel)	2	EA			$0.00	$0	
Backwash Air Supply Header (ASH, 0 inch, SST)	0	EA			$0.00	$0	
Tee:							
Filter Influent Header (FIH, 14 inch, Steel)	4	EA			$4,407.04	$17,628	
Filter Influent Lateral (FIL, 8 inch, HDPE)	0	EA			$790.17	$0	
Filter Effluent Header (FEH, 14 inch, HDPE)	4	EA			$1,382.80	$5,531	
Filter Effluent Lateral (FEL, 8 inch, HDPE)	0	EA			$790.17	$0	
Backwash Supply Header (BSH, 12 inch, HDPE)	4	EA			$1,185.26	$4,741	
Backwash Waste Header (BWH, 12 inch, HDPE)	4	EA			$1,185.26	$4,741	
Raw Water Bypass Header (BPH, 0 inch, Steel)	0	EA			$0.00	$0	
Backwash Air Supply Header (ASH, 0 inch, SST)	0	EA			$0.00	$0	
Valves:							
Filter Influent Header (FIH, 14 inch, Steel)	0	EA			$14,146.92	$0	
Filter Influent Lateral (FIL, 8 inch, HDPE)	4	EA			$7,035.74	$0	$0.00
Filter Effluent Header (FEH, 14 inch, HDPE)	0	EA			$12,312.55	$0	

Filter Effluent Lateral (FEL, 8 inch, HDPE)	4	EA			***$7,035.74***	$0	**$0.00**
Backwash Supply Header (BSH, 12 inch, HDPE)	4	EA			***$10,553.61***	$0	**$0.00**
Backwash Waste Header (BWH, 12 inch, HDPE)	4	EA			***$10,553.61***	$0	**$0.00**
Raw Water Bypass Header (BPH, 0 inch, Steel)	2	EA			***$0.00***	$0	
Backwash Air Supply Header (ASH, 0 inch, SST)	0	EA			***$0.00***	$0	
Allowance for Misc Items	2%				$63,945.68	$1,279	
Subtotal						$65,225	
ELECTRICAL:							
# MCC Sections	4	EA			$10,353.99	$41,416	
Switchgear	0	EA			$47,628.34	$0	
Adjustable Frequency Drives							
Air Scour Blower (Active) (0 hp each)	0	EA			***$8,799.56***	$0	
Air Scour Blower (Standby) (0 hp each)	0	EA			***$8,799.56***	$0	
Electrical Conduit & Wire	0.00	LF	0.00	m	***$11.97***	$0	
Allowance for Misc Items	5%				$41,415.95	$2,071	
Subtotal						$43,487	
Subtotal						$2,123,133	
ALLOWANCES:		**User Override**					
Finishes Allowance	2.00%		$2,270,731	$45,415			
I&C Allowance	1.00%		$2,270,731	$22,707			
Mechanical Allowance	1.00%		$2,270,731	$22,707			
Electrical Allowance	2.50%		$2,270,731	$56,768			
					Facilty Cost Name		
Facility Cost	**2,808,018**	**GPD**	**$0.81**	**$2,270,731**	FLVFC01		

COST ESTIMATE

Description	Quantity (English)	Unit (English)	Quantity (Metric)	Unit (Metric)	$/Unit	Total Cost	User Over-Write
SITEWORK:							
Filter Building							
Excavation	279.68	CY	213.83	m3	$6.72	$1,880	
Imported Structural Backfill	269.19	CY	205.81	m3	$50.94	$13,713	
Native Backfill	14.18	CY	10.84	m3	$8.27	$117	
Haul Excess	265.50	CY	202.99	m3	$8.27	$2,194	
Blower Room							
Excavation	0.00	CY	0.00	m3	$6.72	$0	
Imported Structural Backfill	0.00	CY	0.00	m3	$50.94	$0	
Native Backfill	0.00	CY	0.00	m3	$8.27	$0	
Haul Excess	0.00	CY	0.00	m3	$8.27	$0	
Electrical Room							
Excavation	10.21	CY	7.80	m3	$6.72	$69	
Imported Structural Backfill	7.60	CY	5.81	m3	$50.94	$387	
Native Backfill	2.46	CY	1.88	m3	$8.27	$20	
Haul Excess	7.75	CY	5.92	m3	$8.27	$64	
Allowance for Misc Items	5%				$18,445.06	$922	
Subtotal						$19,367	
CONCRETE:							
Slab on Grade	88.39	CY	67.58	m3	$490.62	$43,365	
Allowance for Misc Items	5%				$43,365	$2,168	
Subtotal						$45,533	
MASONRY:	Low						
Filter Building	0.00	SF	0.00	m2	$132.24	$0	
Blower Room	0.00	SF	0.00	m2	$132.24	$0	
Electrical Room	32.00	SF	2.97	m2	$132.24	$4,232	
Subtotal	32.00					$4,232	
THERMAL & MOISTURE PROTECTION:							
Pressure Vessel Liner	0.00	SF	0.00	m2	$16.00	$0	
Allowance for Misc Items	10%				$0.00	$0	
Subtotal						$0	
EQUIPMENT:							**Budgetary Quote: (CPES will automatically add Installation Factor)**
Vertical Pressure Filter Systems	8	EA			$435,160.25	$2,784,000	$2,320,000.00
(Includes Tanks, Underdrain, System Piping, Actuated Valves, Instrumentation, and Automatic PLC Control Panel)							
Filter Media (Granular Activated Carbon (GAC))	11762.12	CF	333.07	m3	$65.85	$774,510	
Blowers	0	EA			$0.00	$0	
Allowance for Misc Items	5%				$3,558,510.22	$177,926	
Subtotal						$3,736,436	
I&C:							
Instruments							
Filter Effluent Header Magmeter (FEH, 18 inch)	0	EA			$22,363.62	$0	
Filter Effluent Lateral Magmeter (FEL, 8 inch)	8	EA			$12,761.78	$51,044	$51,044.00
Backwash Air Supply Header Magmeter (ASH, 0 inch)	0	EA			$5,080.31	$0	
Isolation Valve Actuators (Electric)	16	EA			$6,362.11	$25,448	$25,448.00
Turbidimeters	8	EA			$4,919.32	$0	$0.00
Particle Counters	0	EA			$10,621.25	$0	
Differential Pressure Transmitters	8	EA			$11,180.26	$89,442	
Air Scour Differential Pressure Transmitter	0	EA			$11,180.26	$0	
Air Scour Discharge Pressure Indicator Transmitter	0	EA			$11,180.26	$0	
Air Scour Blowoff Valve	0	EA			$13,805.32	$0	
Number of Analog I/O Counts	34	EA			$262.30	$8,918	
Number of Digital I/O Counts	96	EA			$62.12	$5,964	
Number of Local Panels	8	EA			$12,977.00	$0	$0.00
Number of PLC's	2	EA			$13,805.32	$0	$0.00
I&C Conduit Wire	2920.00	LF	890.02	m	$11.97	$34,950	
Allowance for Misc Items	5%				$215,766.34	$10,788	
Subtotal						$226,555	
MECHANICAL:							
Pipe:							
Filter Influent Header (FIH, 18 inch, Steel)	68.00	LF	20.73	m	$373.91	$25,426	
Filter Influent Lateral (FIL, 8 inch, HDPE)	394.18	LF	120.14	m	$20.99	$8,273	
Filter Effluent Header (FEH, 18 inch, HDPE)	68.00	LF	20.73	m	$47.22	$3,211	
Filter Effluent Lateral (FEL, 8 inch, HDPE)	172.00	LF	52.43	m	$20.99	$3,610	
Backwash Supply Header (BSH, 12 inch, HDPE)	76.00	LF	23.16	m	$31.48	$2,393	
Backwash Waste Header (BWH, 12 inch, HDPE)	76.00	LF	23.16	m	$31.48	$2,393	
Raw Water Bypass Header (BPH, 0 inch, Steel)	68.00	LF	20.73	m	$0.00	$0	
Backwash Air Supply Header (ASH, 0 inch, SST)	0.00	LF	0.00	m	$0.00	$0	
Elbows:							
Filter Influent Header (FIH, 18 inch, Steel)	0	EA			$2,486.95	$0	
Filter Influent Lateral (FIL, 8 inch, HDPE)	24	EA			$657.40	$15,778	
Filter Effluent Header (FEH, 18 inch, HDPE)	0	EA			$1,479.16	$0	
Filter Effluent Lateral (FEL, 8 inch, HDPE)	12	EA			$657.40	$7,889	
Backwash Supply Header (BSH, 12 inch, HDPE)	0	EA			$986.11	$0	
Backwash Waste Header (BWH, 12 inch, HDPE)	0	EA			$986.11	$0	
Raw Water Bypass Header (BPH, 0 inch, Steel)	2	EA			$0.00	$0	
Backwash Air Supply Header (ASH, 0 inch, SST)	0	EA			$0.00	$0	
Tee:							
Filter Influent Header (FIH, 18 inch, Steel)	8	EA			$5,666.20	$45,330	
Filter Influent Lateral (FIL, 8 inch, HDPE)	0	EA			$790.17	$0	
Filter Effluent Header (FEH, 18 inch, HDPE)	8	EA			$1,777.89	$14,223	
Filter Effluent Lateral (FEL, 8 inch, HDPE)	0	EA			$790.17	$0	
Backwash Supply Header (BSH, 12 inch, HDPE)	8	EA			$1,185.26	$9,482	
Backwash Waste Header (BWH, 12 inch, HDPE)	8	EA			$1,185.26	$9,482	
Raw Water Bypass Header (BPH, 0 inch, Steel)	0	EA			$0.00	$0	
Backwash Air Supply Header (ASH, 0 inch, SST)	0	EA			$0.00	$0	
Valves:							
Filter Influent Header (FIH, 18 inch, Steel)	0	EA			$18,188.89	$0	
Filter Influent Lateral (FIL, 8 inch, HDPE)	8	EA			$7,035.74	$0	$0.00
Filter Effluent Header (FEH, 18 inch, HDPE)	0	EA			$15,830.42	$0	

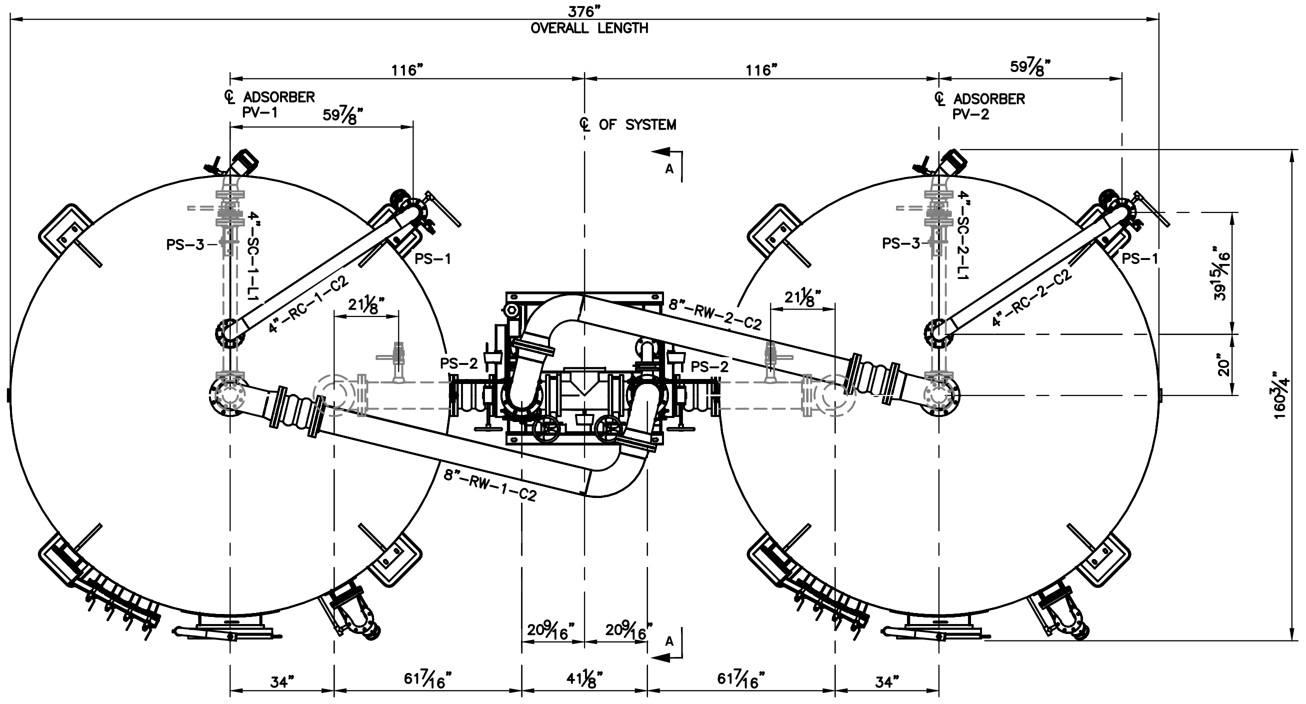
Filter Effluent Lateral (FEL, 8 inch, HDPE)	8	EA			*$7,035.74*	$0	**$0.00**
Backwash Supply Header (BSH, 12 inch, HDPE)	8	EA			*$10,553.61*	$0	**$0.00**
Backwash Waste Header (BWH, 12 inch, HDPE)	8	EA			*$10,553.61*	$0	**$0.00**
Raw Water Bypass Header (BPH, 0 inch, Steel)	2	EA			*$0.00*	$0	
Backwash Air Supply Header (ASH, 0 inch, SST)	0	EA			*$0.00*	$0	
Allowance for Misc Items	2%				$147,489.12	$2,950	
Subtotal						$150,439	
ELECTRICAL:							
# MCC Sections	4	EA			$10,353.99	$41,416	
Switchgear	0	EA			$47,628.34	$0	
Adjustable Frequency Drives							
Air Scour Blower (Active) (0 hp each)	0	EA			***$8,799.56***	$0	
Air Scour Blower (Standby) (0 hp each)	0	EA			***$8,799.56***	$0	
Electrical Conduit & Wire	0.00	LF	0.00	m	*$11.97*	$0	
Allowance for Misc Items	5%				$41,415.95	$2,071	
Subtotal						$43,487	
Subtotal						$4,226,048	
ALLOWANCES:		**User Override**					
Finishes Allowance	2.00%		$4,519,838	$90,397			
I&C Allowance	1.00%		$4,519,838	$45,198			
Mechanical Allowance	1.00%		$4,519,838	$45,198			
Electrical Allowance	2.50%		$4,519,838	$112,996			
					Facilty Cost Name		
Facility Cost	**5,616,036**	**GPD**	**$0.80**	**$4,519,838**	FLVFC01		

COST ESTIMATE

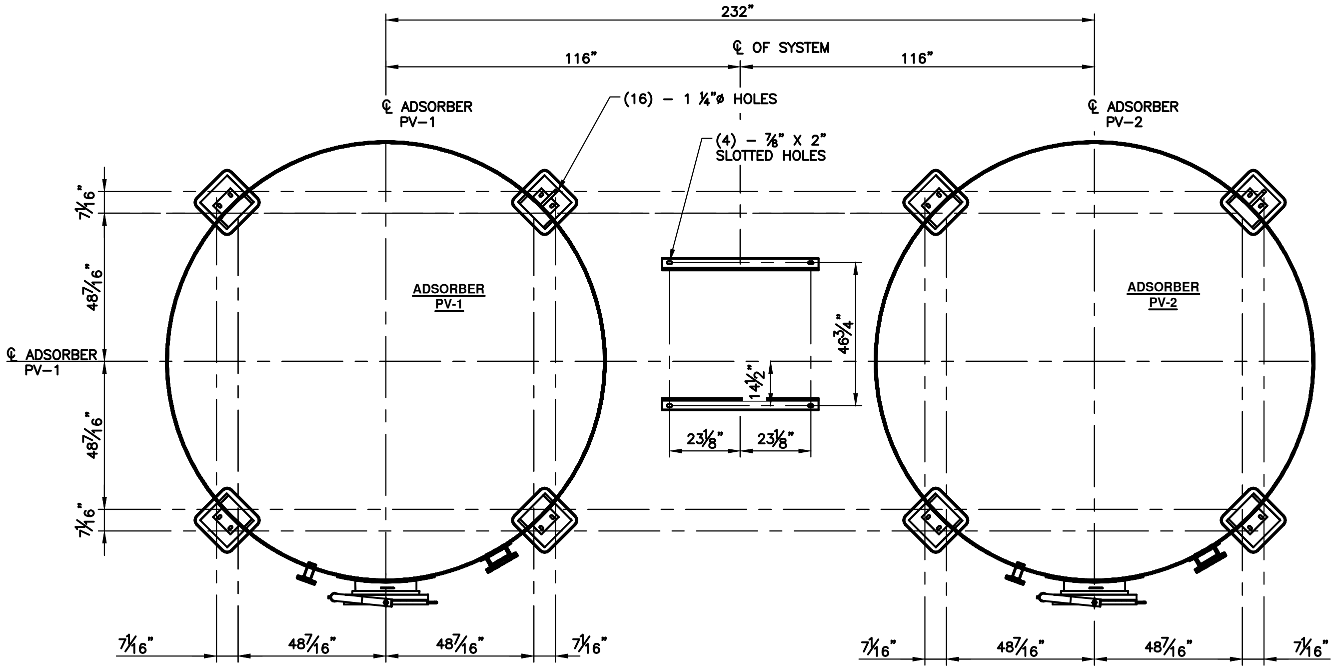
Description	Quantity (English)	Unit (English)	Quantity (Metric)	Unit (Metric)	$/Unit	Total Cost	User Over-Write
SITEWORK:							
Operating Room:							
Excavation	16.12	CY	12.33	m3	***$6.72***	$0	**$0.00**
Imported Structural Backfill	24.72	CY	18.90	m3	***$50.94***	$0	**$0.00**
Native Backfill	2.04	CY	1.56	m3	***$8.27***	$0	**$0.00**
Haul Excess	14.09	CY	10.77	m3	***$8.27***	$0	**$0.00**
Wet Well:							
Excavation	868.21	CY	663.79	m3	***$6.72***	$5,837	
Imported Structural Backfill	50.07	CY	38.28	m3	***$50.94***	$2,551	
Native Backfill	424.67	CY	324.68	m3	***$8.27***	$3,510	
Haul Excess	443.54	CY	339.11	m3	***$8.27***	$3,666	
Surge Protection:							
Excavation	16.86	CY	12.89	m3	***$6.72***	$0	**$0.00**
Imported Structural Backfill	9.91	CY	7.58	m3	***$50.94***	$0	**$0.00**
Native Backfill	5.14	CY	3.93	m3	***$8.27***	$0	**$0.00**
Haul Excess	11.72	CY	8.96	m3	***$8.27***	$0	**$0.00**
Hatch Access Room:							
Excavation	7.66	CY	5.85	m3	***$6.72***	$51	
Imported Structural Backfill	4.30	CY	3.28	m3	***$50.94***	$219	
Native Backfill	2.54	CY	1.94	m3	***$8.27***	$21	
Haul Excess	5.12	CY	3.91	m3	***$8.27***	$42	
Electrical Room:							
Excavation	23.18	CY	17.73	m3	***$6.72***	$156	
Imported Structural Backfill	14.49	CY	11.08	m3	***$50.94***	$738	
Native Backfill	6.22	CY	4.75	m3	***$8.27***	$51	
Haul Excess	16.97	CY	12.97	m3	***$8.27***	$140	
Allowance for Misc Items	5%				$16,982.88	$849	
Subtotal						$17,832	
CONCRETE:							
Operating Room							
Foundation	11.15	CY	8.52	m3	***$541.11***	$0	**$0.00**
Pipe Supports	0.12	CY	0.09	m3	***$490.62***	$0	**$0.00**
Electrical Room							
Foundation	3.54	CY	2.71	m3	***$541.11***	$1,915	
Surge Protection							
Foundation	1.88	CY	1.44	m3	***$541.11***	$0	**$0.00**
Pump Station Wet Well							
Floor Slab	17.93	CY	13.71	m3	***$490.62***	$8,795	
Wet Well Walls	37.33	CY	28.54	m3	***$880.79***	$32,883	
Ceiling Slab	17.93	CY	13.71	m3	***$1,333.77***	$23,909	
Pump Baffling	9.57	CY	7.31	m3	***$880.79***	$0	**$0.00**
Inlet Slope	0.14	CY	0.11	m3	***$490.62***	$70	
Pipe Support Fitting	5.50	CY	4.21	m3	***$490.62***	$0	**$0.00**
Hatch Access Room							
Foundation	1.96	CY	1.50	m3	***$198.37***	$389	
Allowance for Misc Items	5%				$67,960.74	$3,398	
Subtotal						$71,359	
MASONRY:	**Moderate**						
Operating Room	322.01	SF	29.92	m2	***$165.31***	$0	**$0.00**
Hatch Access Room	0.00	SF	0.00	m2	***$165.31***	$0	
Surge Building	0.00	SF	0.00	m2	***$165.31***	$0	
Electrical Room	95.56	SF	8.88	m2	***$165.31***	$0	**$0.00**
Subtotal	417.57					$0	
METALS:							
Pump Removal Hatches	23.72	SF	2.20	m2	***$159.05***	$3,772	
Stairs	10.00	Risers			***$495.92***	$0	**$0.00**
Access Hatch Ladder	12.00	VLF	3.66	VLM	***$139.97***	$0	**$0.00**
Allowance for Misc Items	10%				$3,772.12	$377	
Subtotal						$4,149	
THERMAL & MOISTURE PROTECTION:							
Wet Well Liner	0.00	SF	0.00	m2	**$16.00**	$0	
Allowance for Misc Items	10%				$0.00	$0	
Subtotal						$0	
EQUIPMENT:							**Budgetary Quote: (CPES will automatically add Installation Factor)**
Pumps							
Active Pump # 1	1.00	EA			***$13,677.83***	$13,678	
Active Pump # 2	0.00	EA			***$0.00***	$0	
Active Pump # 3	0.00	EA			***$0.00***	$0	
Active Pump # 4	0.00	EA			***$0.00***	$0	
Active Pump # 5	0.00	EA			***$0.00***	$0	
Active Pump # 6	0.00	EA			***$0.00***	$0	
Active Pump # 7	0.00	EA			***$0.00***	$0	
Standby Pump	1.00	EA			***$13,677.83***	$13,678	
Allowance for Misc Items	10%				$27,355.67	$2,736	
Subtotal						$30,091	
INSTRUMENTATION & CONTROLS:							
Instruments							
Isolation Valve Actuators	3.00	EA			***$6,362.11***	$0	**$0.00**
Control Valve Actuators	2.00	EA			***$6,362.11***	$0	**$0.00**
Level Indicator Transmitters	2.00	EA			***$10,621.25***	$0	**$0.00**
Level Swithces	0.00	EA			***$11,180.26***	$0	
Pressure Indicator Transmitters	1.00	EA			***$11,180.26***	$0	**$0.00**
Pressure Switches	2.00	EA			***$11,180.26***	$0	**$0.00**
Number of Analog I/O Counts	14.40	EA			***$262.30***	$3,777	

Number of Digital I/O Counts	32.40	EA			*$62.12*	$2,013	
Number of PLC's	1.00	EA			*$12,977.00*	$0	**$0.00**
I&C Conduit & Wire	158.70	LF	48.37	m	*$11.97*	$1,900	
Allowance for Misc Items	10%				$7,690	$769	
Subtotal						$8,458	
MECHANICAL:							
Pipe:							
Discharge Lateral Pipe (4-inch,DIS, Exposed, Steel, Cement Mortar, Paint)	28.00	LF	8.53	m	*$108.88*	$3,049	
Discharge Header Pipe (4-inch,DIS, Exposed/Buried, Steel, Cement Mortar, Paint)	7.20	LF	2.20	m	*$108.88*	$784	
Elbows:							
Pump Discharge (6-inch)	2.00	EA			*$456.68*	$913	
Discharge Lateral Pipe (4-inch)	2.00	EA			*$198.30*	$397	
Discharge Header Pipe (4-inch)	2.00	EA			*$198.30*	$397	
Tees:							
Discharge Header Pipe (4-inch)	2.00	EA			*$310.05*	$620	
Valves:							
Discharge Lateral Isolation Valve (4-inch - Butterfly Valve)	2.00	EA			*($86.44)*	($173)	
Pump Control Valve (4-inch, Check Valve)	2.00	EA			*$1,441.57*	$0	**$0.00**
Discharge Header Isolation Valve (4-inch, BFV)	1.00	EA			*($86.44)*	$0	**$0.00**
Air Release Vacuum Valves	1.00	EA			*$1,908.63*	$1,909	
Increasers:							
Pump Discharge to Discharge Lateral (6-inch to 4-inch)	2.00	EA			*$198.30*	$397	
Discharge Lateral to Discharge Header (4-inch to 4-inch)	2.00	EA			*$198.30*	$397	
Allowance for Misc Items	10%				$8,688.75	$869	
Subtotal						$9,558	
ELECTRICAL:							
MCC's							
Sections	5.00	EA			***$10,650.39***	$10,650	**$10,650.00**
AFD's							
Active Pump # 1	0.00	hp	0.00	kW	***$0.00***	$0	
Active Pump # 2	0.00	hp	0.00	kW	***$0.00***	$0	
Active Pump # 3	0.00	hp	0.00	kW	***$0.00***	$0	
Active Pump # 4	0.00	hp	0.00	kW	***$0.00***	$0	
Active Pump # 5	0.00	hp	0.00	kW	***$0.00***	$0	
Active Pump # 6	0.00	hp	0.00	kW	***$0.00***	$0	
Active Pump # 7	0.00	hp	0.00	kW	***$0.00***	$0	
Standby Pump	0.00	hp	0.00	kW	***$0.00***	$0	
Switchgear							
Units	0.00	EA			***$48,991.79***	$0	
Electrical Conduit & Wire	31.74	LF	9.67	m	*$11.97*	$380	
Allowance for Misc Items	5%				$11,030	$551	
Subtotal						$11,581	
Subtotal						$153,029	
ALLOWANCES:		**User Override**					
Finishes Allowance	5.00%	0.00%	$173,896	$0			
I&C Allowance	2.00%		$173,896	$3,478			
Surge Allowance	5.00%	0.00%	$173,896	$0			
Mechanical Allowance	5.00%		$173,896	$8,695			
Electrical Allowance	5.00%		$173,896	$8,695			
Facility Cost	**10**	**Total Pump HP**	**$17,389.64**	**$173,896**			

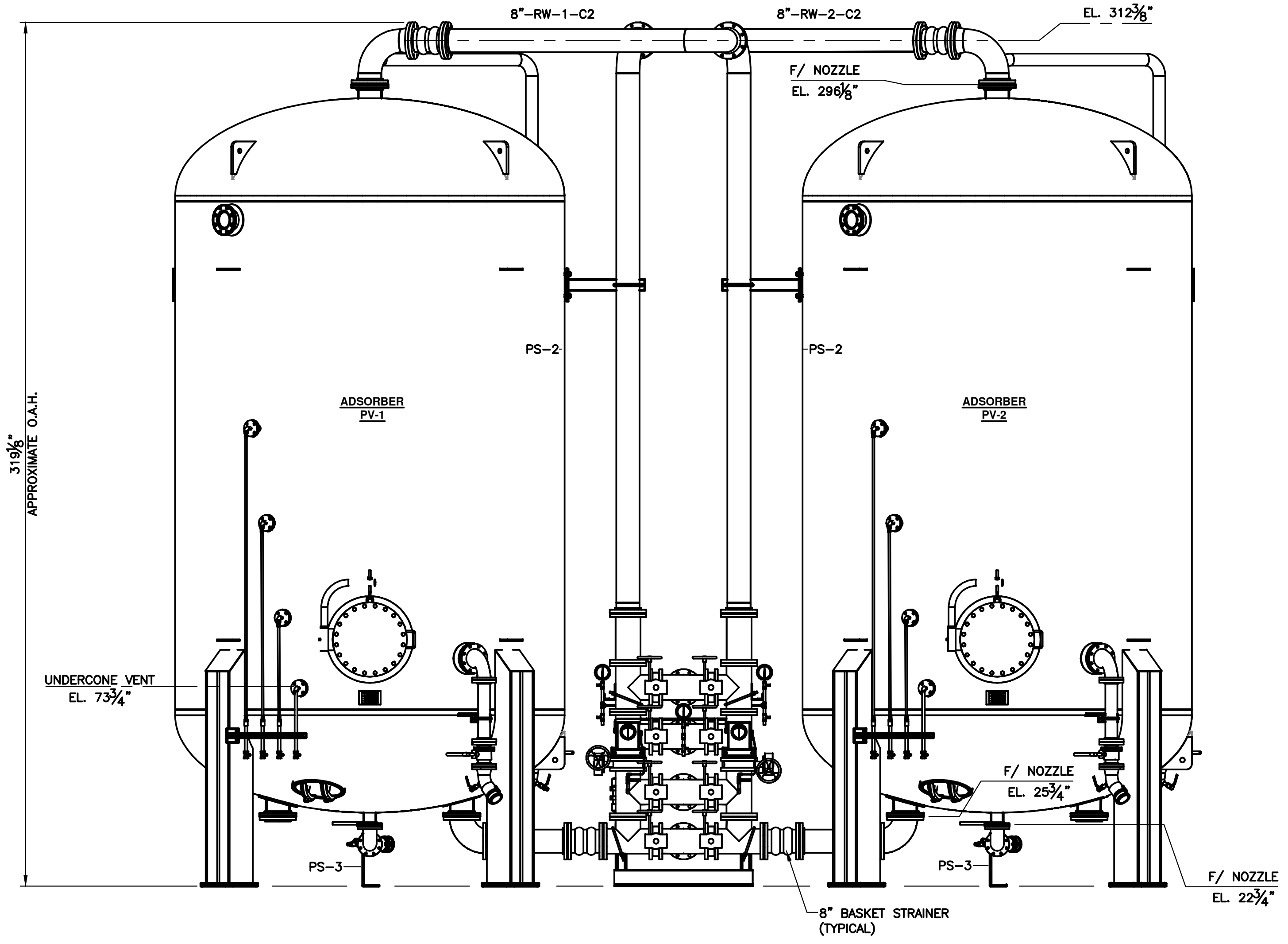
Appendix C
Granulated Activated Carbon Pressure Vessel Configuration Drawings



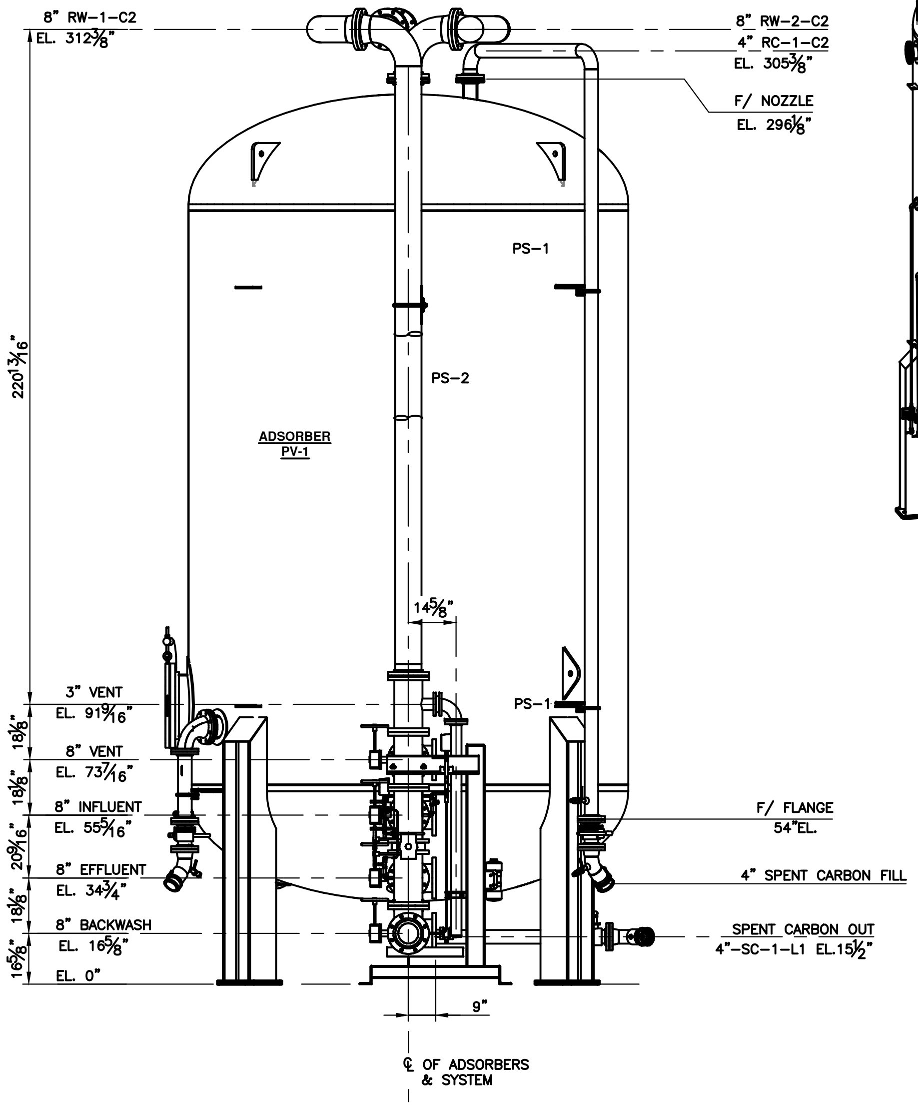
PLAN



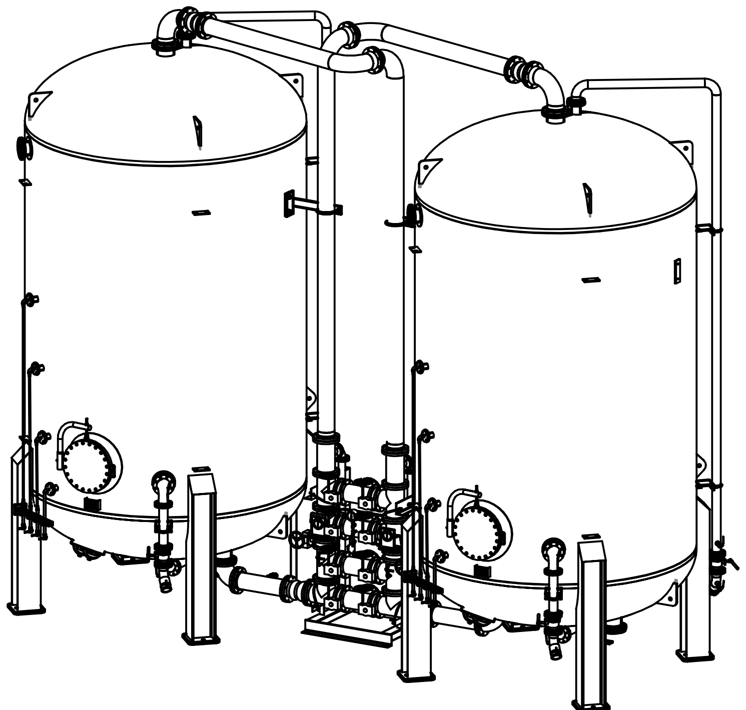
ANCHOR BOLT PLAN



ELEVATION



VIEW A-A



ISOMETRIC

REV	DESCRIPTION	APP	DATE

REVISIONS

TOLERANCES (unless otherwise specified)

ANGULAR	±0°30'	DECIMAL (2 PLACES)	±.010
FRACTIONAL	±1/16"	DECIMAL (3 PLACES)	±.005
DECIMAL (1 PLACE)	±.015	DECIMAL (4 PLACES)	±.0005

CalgonCarbon

	NAME	DATE
DRAFTER	JGP	6/14/2010
DESIGNER		
CHECKER		
APPROVAL		
PROJECT No.	STANDARD	

CLIENT: STANDARD

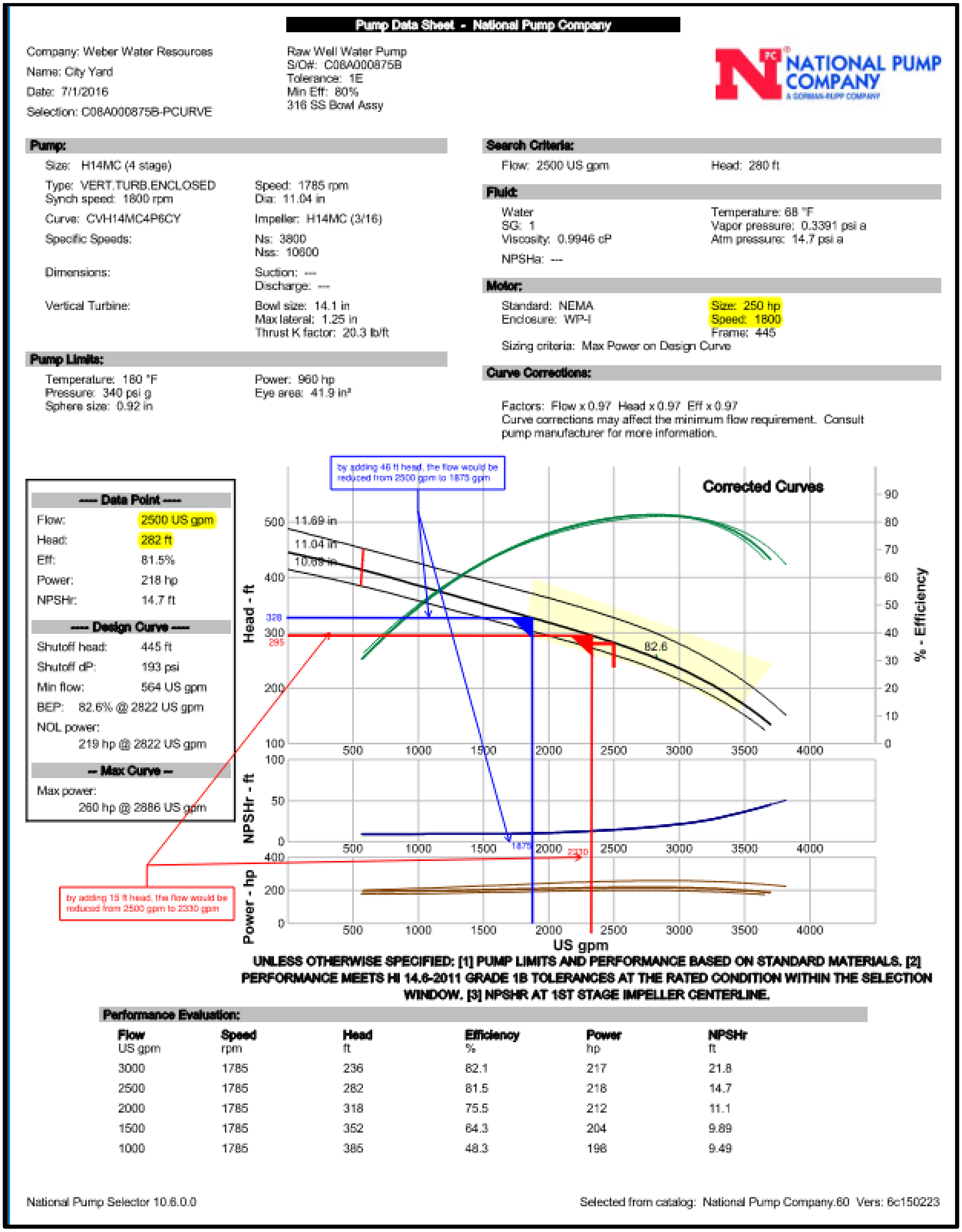
TITLE:
MODULAR ADSORBER SYSTEM
MODEL 12-40, 8" PIPING
GENERAL ARRANGEMENT

DWG. Size	SHEET No.	SCALE
D	1 OF 1	NONE

DWG. No. 90110100 REV. B

V:\Products\Carbon\Model 12-40\General Arrangement\90110100 M12-40 GA.dwg Jan 12, 2017 - 8:41am

Appendix D
Well Pump Performance Curves



Pump Data Sheet - National Pump Company

Company: Weber Water Resources
Name: City Yard
Date: 7/1/2016
Selection: C08A000875B-PCURVE

Raw Well Water Pump
S/O#: C08A000875B
Tolerance: 1E
Min Eff: 80%
316 SS Bowl Assy

Pump:

Size: H14MC (4 stage)
Type: VERT.TURB.ENCLOSED
Synch speed: 1800 rpm
Speed: 1785 rpm
Dia: 11.04 in
Curve: CVH14MC4P6CY
Impeller: H14MC (3/16)
Specific Speeds:
Ns: 3800
Nss: 10600
Dimensions:
Suction: ---
Discharge: ---
Vertical Turbine:
Bowl size: 14.1 in
Max lateral: 1.25 in
Thrust K factor: 20.3 lb/ft

Pump Limits:

Temperature: 180 °F
Pressure: 340 psi g
Sphere size: 0.92 in
Power: 960 hp
Eye area: 41.9 in²

Search Criteria:

Flow: 2500 US gpm
Head: 280 ft

Fluid:

Water
SG: 1
Viscosity: 0.9946 cP
NPSHa: ---
Temperature: 68 °F
Vapor pressure: 0.3391 psi a
Atm pressure: 14.7 psi a

Motor:

Standard: NEMA
Enclosure: WP-I
Size: 250 hp
Speed: 1800
Frame: 445
Sizing criteria: Max Power on Design Curve

Curve Corrections:

Factors: Flow x 0.97 Head x 0.97 Eff x 0.97
Curve corrections may affect the minimum flow requirement. Consult pump manufacturer for more information.

---- Data Point ----

Flow:	2500 US gpm
Head:	282 ft
Eff:	81.5%
Power:	218 hp
NPSHr:	14.7 ft

---- Design Curve ----

Shutoff head:	445 ft
Shutoff dP:	193 psi
Min flow:	564 US gpm
BEP:	82.6% @ 2822 US gpm
NOL power:	219 hp @ 2822 US gpm

-- Max Curve --

Max power:
260 hp @ 2886 US gpm

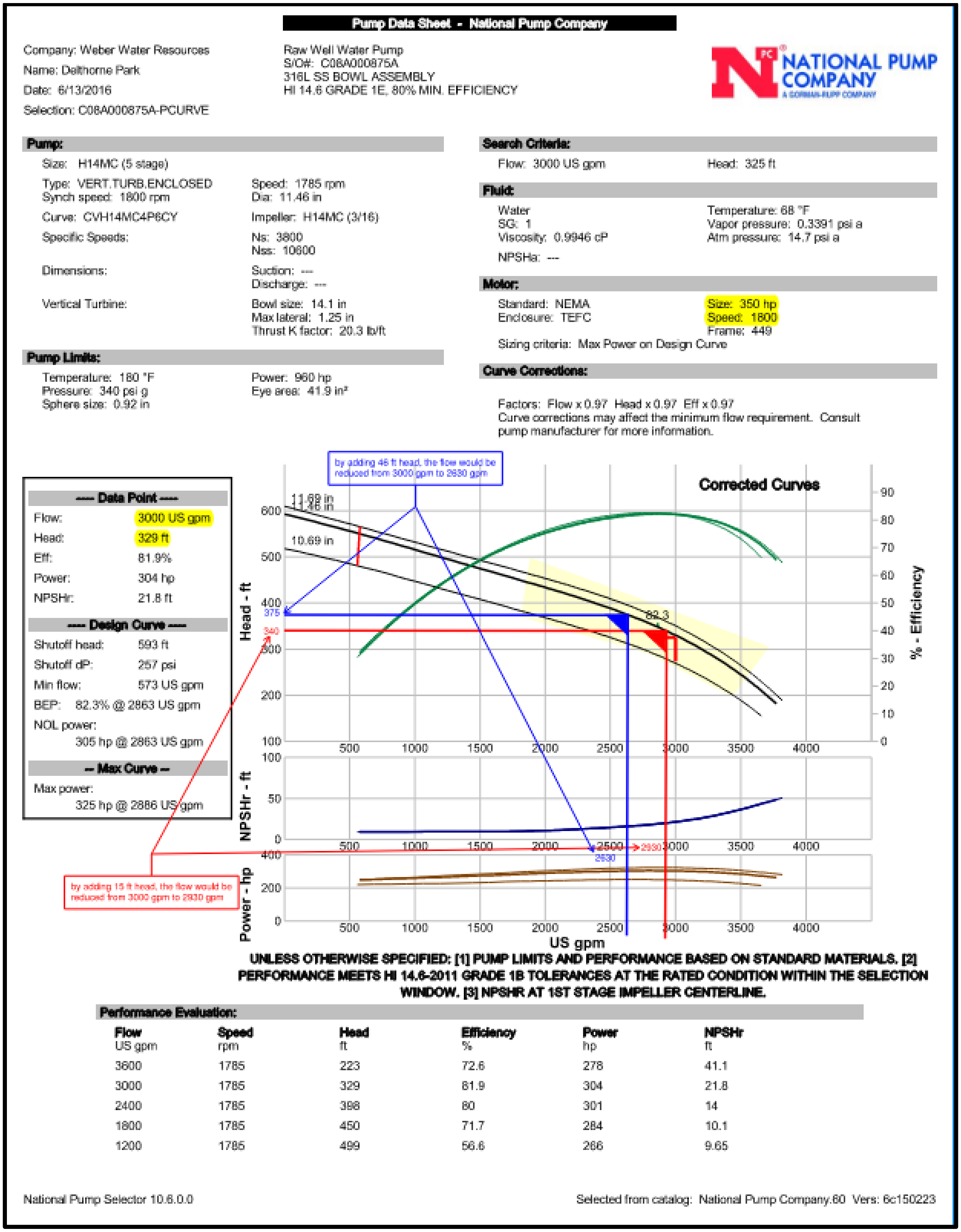
UNLESS OTHERWISE SPECIFIED: [1] PUMP LIMITS AND PERFORMANCE BASED ON STANDARD MATERIALS. [2] PERFORMANCE MEETS HI 14.6-2011 GRADE 1B TOLERANCES AT THE RATED CONDITION WITHIN THE SELECTION WINDOW. [3] NPSHR AT 1ST STAGE IMPELLER CENTERLINE.

Performance Evaluation:

Flow US gpm	**Speed** rpm	**Head** ft	**Efficiency** %	**Power** hp	**NPSHr** ft
3000	1785	236	82.1	217	21.8
2500	1785	282	81.5	218	14.7
2000	1785	318	75.5	212	11.1
1500	1785	352	64.3	204	9.89
1000	1785	385	48.3	198	9.49

National Pump Selector 10.6.0.0

Selected from catalog: National Pump Company.60 Vers: 6c150223



Pump Data Sheet - National Pump Company

Company: Weber Water Resources
Name: Delthorne Park
Date: 6/13/2016
Selection: C08A000875A-PCURVE

Raw Well Water Pump
S/O#: C08A000875A
316L SS BOWL ASSEMBLY
HI 14.6 GRADE 1E, 80% MIN. EFFICIENCY

Pump:

Size: H14MC (5 stage)

Type: VERT.TURB.ENCLOSED Synch speed: 1800 rpm	Speed: 1785 rpm Dia: 11.46 in
Curve: CVH14MC4P6CY	Impeller: H14MC (3/16)
Specific Speeds:	Ns: 3800 Nss: 10600
Dimensions:	Suction: --- Discharge: ---
Vertical Turbine:	Bowl size: 14.1 in Max lateral: 1.25 in Thrust K factor: 20.3 lb/ft

Pump Limits:

Temperature: 180 °F Pressure: 340 psi g Sphere size: 0.92 in	Power: 960 hp Eye area: 41.9 in²

Search Criteria:

Flow: 3000 US gpm	Head: 325 ft

Fluid:

Water SG: 1 Viscosity: 0.9946 cP	Temperature: 68 °F Vapor pressure: 0.3391 psi a Atm pressure: 14.7 psi a
NPSHa: ---	

Motor:

Standard: NEMA Enclosure: TEFC	Size: 350 hp Speed: 1800 Frame: 449

Sizing criteria: Max Power on Design Curve

Curve Corrections:

Factors: Flow x 0.97 Head x 0.97 Eff x 0.97
Curve corrections may affect the minimum flow requirement. Consult pump manufacturer for more information.

---- Data Point ----

Flow:	3000 US gpm
Head:	329 ft
Eff:	81.9%
Power:	304 hp
NPSHr:	21.8 ft

---- Design Curve ----

Shutoff head:	593 ft
Shutoff dP:	257 psi
Min flow:	573 US gpm
BEP:	82.3% @ 2863 US gpm
NOL power:	305 hp @ 2863 US gpm

-- Max Curve --

Max power:
325 hp @ 2886 US gpm

UNLESS OTHERWISE SPECIFIED: [1] PUMP LIMITS AND PERFORMANCE BASED ON STANDARD MATERIALS. [2] PERFORMANCE MEETS HI 14.6-2011 GRADE 1B TOLERANCES AT THE RATED CONDITION WITHIN THE SELECTION WINDOW. [3] NPSHR AT 1ST STAGE IMPELLER CENTERLINE.

Performance Evaluation:

Flow US gpm	**Speed** rpm	**Head** ft	**Efficiency** %	**Power** hp	**NPSHr** ft
3600	1785	223	72.6	278	41.1
3000	1785	329	81.9	304	21.8
2400	1785	398	80	301	14
1800	1785	450	71.7	284	10.1
1200	1785	499	56.6	266	9.65

National Pump Selector 10.6.0.0

Selected from catalog: National Pump Company.60 Vers: 6c150223