TECHNICAL MEMORANDUM

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TO: Kathleen Harder, Central Valley Regional Water Board

FROM: PG Environmental, LLC

DATE: August 18, 2010

SUBJECT: Technical Review of Estimated Costs for Proposed Changes to the Sacramento Regional Wastewater Treatment Plant

I. Introduction / Purpose / Approach

The Central Valley Regional Water Board (Regional Water Board) is in the process of reissuing the National Pollutant Discharge Elimination System (NPDES) permit for discharges from the Sacramento Regional Wastewater Treatment Plant (SRWTP) to the Sacramento River. In anticipation of more restrictive NPDES permit requirements, the Sacramento Regional County Sanitation District (SRCSD) procured an analysis that evaluated the costs for potential upgrades to the SRWTP to meet the new NPDES permit requirements. This memorandum evaluates each of the advanced treatment alternatives that were considered for the SRWTP and their related costs. The appropriateness of each of these treatment alternatives is addressed relative to the expected NPDES permit requirements. The evaluation specifically looks at five proposed treatment trains for the SRWTP, as set forth in a March 2009 memorandum titled, "Technical Memorandum Advanced Treatment Alternatives for the Sacramento Regional Wastewater Treatment Plant", prepared by Carollo Engineers (hereinafter Carollo 2009 Report).

The purpose of this evaluation is to provide answer to the following questions:

- Is it reasonable to expect that the proposed treatment trains will meet the primary goal of ammonia and nitrate reduction?
- Will the proposed treatment trains also meet the recommendations of the State of California's Department of Public Health (DPH) for pathogen removal for human health protection, as stated in their June 15, 2010 letter to the Regional Water Board?
- Do any of the proposed treatment trains go beyond the expected NPDES permit requirements?
- Are the estimated costs for the proposed treatment trains reasonable?
- Are there potentially less costly options that could be considered by SRCSD that will achieve the same performance?

Each treatment train is evaluated for the ability to meet expected effluent quality requirements of the future NPDES permit, including recent recommendations by DPH for protection of human health protection beneficial uses. If considered feasible, this evaluation recommends consideration of other processes that could meet the effluent quality goals at potentially lower capital and operating costs. The focus was on investigation of alternatives for those treatment processes having significant impacts on the estimated cost for a treatment train option that would achieve the same relative treatment level.

This memorandum also provides recommendations to better define the expected treatment quality of various processes and narrow the constituency spreads in estimating process cost.

II. Background Information

Some brief background information is provided below related to the cost estimates provided by SRCSD, as well as the expected performance of potential treatment options.

A. ***Basis and Accuracy of Estimated Costs***

Section 3.0 of the Carollo 2009 Report acknowledges that capital costs for the various treatment trains are based on Class 5 and Class 4 as defined in Practice 18R-97 of the Association for the Advancement of Cost Estimating (AACE International). Class 5 estimates can have a contingency factor as much as -50 percent on the low side and +100 percent on the high side; Class 4 estimates can have a contingency factor as much as -30 percent on the low side and +50 percent on the high side. It is uncertain, which treatment train cost estimates are based on Class 5 versus Class 4.

B. ***Flow Basis for Cost Estimates***

From page 10 of the Carollo 2009 Report and the corresponding notes in Table 4, page 15, the capital project costs are based on the average daily maximum month flow (ADMMF) of 311 mgd and **not** the average dry weather flow (ADWF) of 218 mgd that is listed in the Tables. Also, operation and maintenance (O&M) costs are based on the average day annual flow (ADAF) of 237 mgd. The use of 311 mgd for purposes of estimating capital costs is consistent with typical peaking factors used for design of wastewater treatment plants. The use of ADAF for estimating O&M costs is also consistent with those typically used for costs estimating.

It should also be noted that the Carollo 2009 Report was developed to anticipate the costs for expansion of the existing SRWTP from 181 mgd ADWF to 218 mgd ADWF. Costs provided in the Carollo 2009 Report were based on expanded SRWTP capacity. Subsequent to the Carollo 2009 Report, SRCSD has withdrawn their request for an increase in flow capacity, due in part, for example, to effective water conservation practices.

To allow for a comparison to the costs provided in the Carollo 2009 Report, estimated capital costs for alternative treatment options were also based on 311 mgd. Associated O&M costs were not specifically provided, however, some indication as to the relative impact on O&M costs is provided.

C. ***Anticipated NPDES Permit Requirements***

The Regional Water Board provided a range of anticipated effluent limitations for the NPDES permit renewal for the SRWTP. The range of potential effluent limitations are based on several mixing zone/dilution credit scenarios, ranging from no dilution credit to granting mixing zones for all those requested by SRCSD. For example, effluent limitations for nitrate could be as stringent as

10 mg/L (as N) or as high as 300 mg/L (as N); potential effluent limitations for ammonia range from a low of 1.8 mg/L (as N) to 41 mg/L (as N).

Therefore, and for purposes of this evaluation, the lower end of the potential range of effluent limitations was considered to be the treatment system target for compliance. Adoption of NPDES effluent limitations at the higher end of the range (e.g., assuming all mixing zones are granted), would generally negate the need for the more aggressive treatment trains being proposed by SRCSD.

III. Overall Conclusions

Exhibit 1 provides a summary of the evaluation of the five treatment trains considered by SRCSD as described in the Carollo 2009 Report. For consistency with the Carollo 2009 Report, Exhibit 1 provides comparisons based on a design flow of 311 mgd, as well as based on a design flow of 258 mgd, which reflects the equivalent design flow for SRWTP based on the existing ADWF flow.

Of the five treatment trains evaluated in the Carollo 2009 Report, Treatment Train C and E offer the best potential to reduce ammonia and nitrate nutrients and provide effluent that will likely meet DPH recommendations. Some modifications to Treatment Train C could potentially reduce the cost by as much as $859 million and achieve the same effluent quality goals. Treatment Train E is the most costly and is not considered to be a cost-effective approach when considering the likely NPDES permit requirements. If future permits should require removal of emerging “chemicals of concern” (e.g., endocrine blockers) and priority pollutants, there are additional treatment trains that could be considered that are compatible with Treatment Train C. These additional treatment trains are presented later in this memorandum.

From an overall perspective, however, it appears that modifications to Treatment Train C, identified as Proposed Train M-C later in this memorandum, would ultimately yield the lowest construction and operating costs in meeting ammonia/nitrate removal goals, DPH microbial removal goals, and be compatible with potential future “chemicals of concern” removal goals . Proposed Train M-C includes:

1. Existing head works, followed by;
2. Existing pure oxygen system, followed by;
3. New nitrifying trickling filter (NTF) process followed by;
4. New fluidized bed reactors (FBR) for denitrification;
5. New chemical conditioning with flocculation followed by;
6. New sand or mixed media filtration, followed by;
7. New Ozone/Peroxide Oxidation;
8. Existing chlorine disinfection system would be abandoned.

Exhibit 1. Summary Evaluation of the Five Treatment Trains Considered by SRCSD

Treatment Train	Carollo Proposal	Carollo Capital Cost Estimate		Alternative	Alternative Capital Cost Estimate		Percent Capital Cost Reduction
		At 311 mgd ($ millions)	At 258 mgd[1] ($ millions)		At 311 mgd ($ millions)	At 258 mgd[1] ($ millions)	
A	MF → UV	$1,543	$1,281	--	--	--	--
B	NTF → FBR → Cl_2	$939	$780	--	--	--	--
C	NTF → FBR → MF → UV	$2,482	$2,061	NTF → FBR → Co/Floc → MMF → O_3/H_2O_2	$1,623	$1,346	35%
D	MF → RO → O_3/H_2O_2 → Cl_2	$665	$552	--	--	--	--
E	MF → RO → O_3/H_2O_2	$3,088	$2,564	NTF → FBR → MF → O_3/H_2O_2	$2,364	$1,961	23%

NTF = Nitrifying Trickling Filter
FBR = Fluidized Bed Reactor
Co/Floc = Coagulation & Flocculation
MF = Microfiltration
RO = Reverse Osmosis
Cl2 = Chlorine Disinfection
O3/H2O2 = Ozone or Peroxide Disinfection
MMF = Sand or Mixed-Media Filter

1. 258 mgd was computed on the basis of the permitted daily flow (181 mgd) and the apparent peaking factor (1.43) used in the Carollo 2009 Report.
2. Capital costs assumed to approximate a linear relationship with permitted capacity.

IV. Proposed Treatment Trains - Performance and Cost

The Carollo 2009 Report proposed five treatment trains for the SRWTP. Each of these is described briefly below, followed by comments on the performance and cost for each proposed treatment train.

A. Treatment Train A

The goal of Treatment Train A as proposed is to reduce contaminants that can be removed by filtration, allowing more effective removal or inactivation of coliform bacteria and protozoan pathogens (*Cryptosporidium* and *Giardia*). The Carollo 2009 Report states that this will be achieved by adding Microfiltration (MF) and ultraviolent (UV) Disinfection advanced treatment processes.

Comments

A major limitation in the performance of Treatment Train A is that it does not address the removal of inorganic nitrogen. Most ammonia will be converted to nitrate and be discharged as a nitrate loading. However it does treat the effluent to inactivate coliform bacteria and protozoan pathogens.

B. Treatment Train B

The goal is to provide significant reduction of the nutrients ammonia and nitrate. The Carollo 2009 Report states that this will be achieved by adding the advanced treatment processes of Nitrifying Trickling Filters (NTF), Fluidized Bed Reactors (FBR), and Chlorine Disinfection.

Comments

Treatment Train B utilizes NTF for the conversion of ammonia to nitrate. This is followed by denitrification using biofilters in which nitrate is converted to nitrogen gas. The final process in Treatment Train B is disinfection with chlorine. The application of combined nitrification and denitrification processes will significantly reduce nutrient loadings to the Sacramento River, meeting the requirements of the NPDES permit.

However, Treatment Train B does not address the issues associated with protozoan pathogens, although some removal of these microorganisms can occur in the biological nitrification and denitrification processes. Biofilters develop biological-growth that produces polymers. These slim growths act as adsorbents, capturing and retaining colloidal and soluble contaminants, but the efficiency of removal for microorganisms is low and variable. Treatment Train B also has limitations on the ability to achieve significant reduction of coliform bacteria, since there is no filtration to improve suspended solids removal. It does not appear that Treatment Train B will be able to consistently meet DPH recommendations.

C. Treatment Train C

The goals of Treatment Train C are to provide (1) significant reduction of the nutrients ammonia and nitrate; (2) reduction of contaminants that can be removed by filtration; and (3) inactivation or removal of coliform bacteria and protozoan pathogens (*Cryptosporidium* and *Giardia*). These goals will be achieved by adding the advanced treatment processes of NTF, FBR, MF and UV Disinfection to existing SRWTP processes.

Comments

Use of NTF and FBR processes in Treatment Train C will reduce ammonia and nitrate and provide effluent that will meet the NPDES effluent limitations. Treatment Train C also utilizes MF and UV disinfection. The UV disinfection coupled with MF will achieve removal of pathogenic microorganisms such as *Cryptosporidium* and *Giardia* that would meet DPH recommendations.

A savings of approximately $260,000 in capital costs can be realized by replacing the UV Disinfection with Ozone/Peroxide Oxidation treatment (a chemical oxidation process). The Ozone/Peroxide Oxidation capital and O&M costs are roughly half of the costs for UV Disinfection. Ozone/Peroxide Oxidation is effective for destroying the protozoan pathogens as well as various organic chemicals. Priority pollutants and other "chemicals of concern" (e.g., endocrine blockers) can be destroyed by oxidation given the proper ozone-peroxide dose and contact time. The ability to inactivate these compounds is only a function of chemical oxidant concentration and contact time. This process could be easily modified to address destruction of these compounds if future permits requirements are propagated for their removal.

MF removes solids that hinder the efficiency of disinfection. The MF process represents a very significant portion of the advanced treatment costs. The MF process is 55.1 percent of the total cost ($161 million of $292 million; from Table 4, page 14 of Carollo 2009 Report). The Carollo 2009 Report, appendix page APP-1, notes that SRCSD has performed pilot testing of MF and it was proven to be an effective advanced treatment for SRWTP's secondary effluent.[1]

There are four alternatives to Treatment Train C that, through implementation of one or some combination of these alternatives, the SRWTP may achieve the same effluent goals at a reduced cost.

1. Evaluate other filtration processes such as sand filters and mixed media filters to replace MF, with the goal of reducing total cost.

   Many secondary effluents from activated sludge units have been treated with advanced treatment systems that use mixed media filters followed by disinfection. These systems have achieved very low coliform levels and virus inactivation (Cookson 1975). With the selection of the proper disinfection process, this alternate would also achieve effective inactivation of *Cryptosporidium, Giardia* and viruses.

[1] Note that the pilot testing data could have been used by SRCSD to provide a more refined cost estimate than a Class 5 estimate.

Mixed media filters have been found to be effective in removing *Cryptosporidium oocysts*, by a magnitude greater than 3 logs when the influent to the filters have been preconditioned with chemical coagulant and oxidants; for example ferric chloride and polymers in combination with pre-oxidation (Yates 1997). SRCSD has the ability to evaluate this approach at the existing SRWTP (see Section VI. Other Observations and Considerations).

2. The UV Disinfection can be replaced with Ozone/Peroxide Oxidation. The Ozone/Peroxide Oxidation capital and O&M costs are expected to be approximately half of the costs of UV Disinfection. Another important aspect is that simple modifications to the operation, such as increasing ozone-peroxide concentrations, could result in improved removal of "chemicals of concern" in the effluent.

3. Evaluate low-cost modifications that can be made to the inlet and outlet structures of the secondary settling tanks to improve removal of suspended solids, colloidal material, and soluble organic compounds. Such options could include physical modifications to provide more appropriate hydrodynamics for good floc growth prior to the secondary sedimentation process.

4. Operational changes could be evaluated for improving the existing performance of secondary settling. These could enhance the removal of suspended particles and *Cryptosporidium oocysts*. This would include testing of various chemical coagulants, polymers, chemical oxidants, and pH levels to improve removal of suspended solids and *Cryptosporidium oocysts.*

D. Treatment Train D

The goal of Treatment Train D is to have no net increase in pollutant loadings as compared to the current discharge by providing advanced wastewater treatment to only a portion of the SRWTP flow (i.e., only the increase in flow above the current design flow of the SRWTP). The portion of flow receiving advanced treatment would utilize the processes of MF, Reverse Osmosis (RO) and Ozone/Peroxide Oxidation.

Comments

These advanced treatment processes will reduce coliform and pathogenic protozoan. However, the effluent from the advanced treatment would be blended with the remaining secondary effluent. The blended final effluent would not be expected to meet the DPH recommendations. As a result, this treatment train does not achieve any of the objectives of significant nutrient removal or requirements for coliform and pathogenic protozoan. Further, treating only a portion of the total SRWTP flow may constitute bypassing, and SRCSD has withdrawn its request for an increase in flow capacity. Therefore, this alternative was eliminated from further consideration.

E. ***Treatment Train E***

The primary goal of Treatment Train E is to provide for maximum reduction of trace organic and inorganic compounds for the full SRWTP flow. Train E uses advanced treatment processes of MF, RO, and Ozone/Peroxide Oxidation. These treatment processes will also achieve DPH recommendations for coliform and pathogen protozoan, as well as ammonia and nitrate removal.

Comments

The MF and RO processes are not nearly as cost effective for ammonia and nitrate removal as the biological processes proposed in Treatment Trains B and C. However, RO will produce a quality of effluent that goes beyond the requirements of the anticipated NPDES permit. In fact, there are existing drinking water purification facilities that produce water for human consumption that would be lower in quality than that produced by the proposed RO treatment.

From a cost standpoint, Treatment Train E is not the most cost-effective approach for treating municipal wastewater when considering the likely NPDES permit effluent limitations. Treatment Train E also has a very large carbon dioxide footprint, energy consumption. The process requires thermal concentration and the disposal of 122,275 tons/year of concentrated solids.

The cost of the RO process represents 59 percent of the Treatment Train E cost. The application of RO appears to be unnecessary, and is probably being considered because of the growing attention being given to "chemicals of concern" as well as priority pollutants. Based on the anticipated NPDES requirements, more cost-effective alternatives other than RO can be used by SCRSD to comply with potential requirements for "chemicals of concern".

The combined processes of MF, RO, and Ozone/Peroxide Oxidation will remove "chemicals of concern" such as endocrine blockers and many priority pollutants. If the goal is to reduce these "chemicals of concern" in the SRWTP effluent discharge, the cost of utilizing MF and RO should be compared with other alternatives. For example, sand or mixed media filters followed by activated carbon beds would prove effective in removing these chemicals and both of these technologies have been used in a number of tertiary treatment facilities. Also, the application of chemical oxidants with slow release catalysts have been developed for destroying priority pollutants. Chemical oxidation is a very appropriate alternative to consider because of its ability to be modified from a disinfectant to provide more aggressive treatment for oxidizing "chemicals of concern".

One effective approach to removal of "chemicals of concern" is to design the Ozone/Peroxide Oxidation process to provide adequate chemical dosing and contact time to oxidize targeted chemicals to degradation products that result in their detoxification. Another approach is to add activated carbon adsorption beds. The addition of activated carbon beds would be compatible following either MF or mixed media filtration. Mixed media filtration and activated carbon have been used successfully in wastewater tertiary treatment plants. These combinations could be considered as alternative process sequences for Treatment Train E, if the removal of "chemicals of concern" is to be a future permit requirement.

V. Other Possible Treatment Trains

The removal of ammonia and nitrate to meet NPDES permit effluent limitatins, and the inactivation of *Cryptosporidium* and *Giardia* to satisfy requirements of DPH, can be achieved in the following proposed train at a cost less than Treatment Train C. The following proposed treatment train, Treatment Train M-C could be considered.

A. Treatment Train M-C

Proposed Train M-C is a modification of Treatment Train C. Train M-C is estimated to have a capital cost of approximately $859 million less than Treatment Train C, which is $2.76 million less per mgd. Treatment Train M-C has the advantage of utilizing Ozone/Peroxide Oxidation for disinfection, which can be easily modified to bring about destruction of “chemicals of concern” by chemical oxidation. This modification may be as simple as changing chemical dosing.

Treatment Train M-C will achieve the same performance as Train C, but at a reduced cost by replacing MF with mixed media filters that have a preconditioning basin, using chemicals for flocculation and oxidation that will improve suspended particle removal. Cost savings is also realized by replacing the more costly UV Disinfection with Ozone/Peroxide disinfection. The process flow sequence is provided below.

1. Existing head works, followed by;
2. Existing pure oxygen system, followed by;
3. New NTF process, followed by;
4. New FBR for denitrification, followed by;
5. New chemical conditioning-flocculation basin, followed by;
6. New sand or mixed media filtration, followed by;
7. New Ozone/Peroxide Oxidation;
8. The Chlorine disinfection system would be abandoned

B. Proposed Train M-E

Treatment Train M-E is estimated to be $725 million less than Treatment Train E. Treatment Train M-E should be considered for two reasons. First, it utilizes MF rather than mixed media filters. It is recognized that SRWTP has conducted pilot studies with the MF process. The second reason is that mixed media filters require a relatively large footprint because of storage basins to hold wash and backwash waters for the filters. The cost savings for Treatment Train M-E results from removing the RO process and substituting NTF and FBR processes for ammonia and nitrate removal.

If land availability is an issue, SRCSD could consider replacing the NTF option for nitrification with biofilters. Biofilters have a significantly smaller footprint than trickling filters, and they are more consistent in performance for nitrogen removal.

Proposed Treatment Train M-E will meet requirements of the anticipated NPDES permit as well as DPH recommendations. The effluent quality would be equivalent to that of Treatment Train C. The process sequence for Treatment Train M-E is:

1. Existing head works, followed by;
2. Existing pure oxygen system, followed by;
3. New NTF process for nitrification, followed by;
4. New FBR for denitrification, followed by;
5. New microfiltration; followed by;
6. New Ozone / Peroxide Oxidation;
7. Chlorine disinfection system would be abandoned.

VI. Other Observations and Considerations

A. Pilot Study

According to SRWTP 2020 Master Plan (Master Plan 2020) a Water Reclamation Facility (WRF) was under construction in 2000 and should be processing 5 mgd of effluent from SRWTP for reuse as landscape irrigation and non potable water replacement for SRWTP. The WRF processes effluent by adding alum and polymers for flocculation followed by filtration. This pretreatment allows sand filters to be more effective at adsorbing soluble chemicals and colloidal particles from the effluent. The WRF has four filters.

The existence of the WRF provides the advantage that pilot studies can be conducted to obtain more precise cost estimates. The pilot study would yield cost information that is more precise than the Class 5 estimates. Class 5 estimates can have a contingency factor as much as -50 percent on the low side and +100percent on the high side. This makes it difficult to draw conclusions between alternate processes.

The Master Plan 2020 also indicates that SRWTP has the necessary chemicals on-site; including ferric chloride, polymers, and activated carbon. These are used in sludge conditioning and other processes at the facility. With some modifications to one of the filters of the WRF, applying chemicals prior to filtration, the operating parameters to meet removals for *Cryptosporidium*, *Giardia* and coliform can be evaluated. In addition, it would be wise to monitor the effluent to establish the ability of the modified filter operation to remove “chemicals of concern” as well as priority pollutants.

An activated carbon bed is very effective in removing “chemicals of concern” as well as viruses and other pathogens. The cost effectiveness of using activated carbon for this purpose can be evaluated. The addition of an activated carbon process could be achieved by placing an activated carbon bed in line with one of the filters.

An ozone peroxide oxidation sequence could easily be evaluated on the effluent. The pilot testing could provide major cost savings by demonstrating that an activated carbon process would not be required to obtain significant destruction of “chemicals of concern”. Application of these recommendations would yield valuable information prior to scaling up to a full size facility.

These options could be evaluated for cost and compared with that of MF and RO. These studies are highly recommended not only for establishing performance, but appears to be very prudent approach before designing a very costly and energy demanding system such as MF and RO.

B. Other Considerations

Utilizing biofilters for nitrification is projected to cost approximately $832 million in capital or $2.68 million per mgd. This compares with $2.13 million per mgd for the NTF process. This is a minor cost increase compared to the total cost and would result in a significantly smaller footprint than the NTF. This would also offset the increased footprint of the suggested mixed media filters over MF. Biofilters for nitrification is a hardware change and not a biological process change. Performance would also be better since biofilters are more consistent in the degree of nitrification, resulting in the ability to achieve greater total nitrogen removal. The cost of biofilters was estimated by taking the projected cost set forth in a report by Trussell Technologies Inc., dated May 31, 2010 and prepared for Sacramento Regional County Sanitation District. Their costs were prepared for a flow of 154 mgd, which were scaled up to a flow of 311 mgd for comparison with the cost of NTF as set forth in the Carollo 2009 Report.

VII. References

Carollo Engineers, 2009. “Technical Memorandum Advanced Treatment Alternatives for the Sacramento Regional Wastewater Treatment Plant Final”, Carollo Engineers, March 2009

Cookson, J.T., Jr., and Robson, C.M., "Disinfection of Wastewater Effluents for Virus Inactivation", Water and Wastewater Disinfection, Ed. J.D. Johnson, Ann Arbor Science Publishers, Inc., pp. 391-417, 1975.

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