ABSTRACT

Too often, value engineering (VE) is used as a buzzword in the water and wastewater infrastructure market, rather than an actual philosophy or process implemented for the betterment of the project. Unfortunately, this means that value engineering practices and principles are not applied until it becomes apparent that the project is not meeting its goals or is approached in a superficial manner. By the time a problem becomes evident, the project is usually in the late design stages, permitting phase, or worse, after bids are received.

Performing such postponed value engineering is an ineffective and painful process for all involved. Resistance to alternative design suggestions is higher during these stages of the project, and acceptance of those ideas is low. True value engineering must be deliberately initiated early in the project and practiced continuously with open-minded and honest evaluation.

McKim & Creed was recently presented with a unique opportunity to demonstrate the benefits of practicing value engineering in its most ideal way through involvement with the Onslow Water and Sewer Authority’s (ONWASA) Northwest Regional Water Reclamation Facility (NRWRF). ONWASA’s NRWRF is the largest USDA-funded project in North Carolina to date, with a construction budget of approximately $25 million.

McKim & Creed became involved in this project after construction bids were received on a previous design. The project was significantly over the allowed construction budget. Afforded the luxury of 20/20 hindsight, engineers were able to implement a rigorous value engineering program that resulted in an almost completely re-designed and re-bid project that met the construction budget and accelerated timeframe. This allowed ONWASA to maintain the permits previously acquired with a minimum number of modifications, as well as retain the USDA and ARRA funding.

In this presentation, we will discuss how McKim & Creed and ONWASA used a back-to-square-one approach and implemented value engineering practices throughout the project, from concept to final design. We will discuss our methods of evaluation and how categorizing project elements into essential components, valuable items, and aspirations, in combination with realistic cost estimations, resulted in an increased value to the project. We will also discuss how the entire project, including the value engineering effort, was a team effort that actively engaged both technical and management level personnel in the ONWASA organization, and incorporated a significant effort to maintain positive engagement of external regulatory and financial stakeholders.

KEYWORDS

Value engineering, water reclamation, membrane
INTRODUCTION

The Richlands WWTP is a 0.25-MGD facility located in the northwest part of Onslow County. Due to excessive flows, Richlands was placed under a moratorium by NC Division of Water Quality (DWQ) and, subsequently, a Special Order of Consent (SOC). To comply with the SOC, ONWASA began the process of meeting deadlines and submitting quarterly reports to the DWQ. Failure to submit reports would result in a $1000 fine that doubled with each subsequent assessment for late reports, and $1000/day for failure to meet scheduled milestones.

ONWASA saw a need for a regional facility in this area because the current plant had several limitations. The plant is located in a flood plain and during heavy rainfall the road to the plant floods and boat access is necessary. The land around the plant is being developed, leaving little room for expansion.

With an SOC in place, the need for this facility was inescapable.

A USDA Grant and Loan package gave ONWASA a budget of approximately 24.955 million with just over 9 million in grants. Funding for this project was in the form of an American Recovery and Reinvestment Act (ARRA). At that time, the project base bid was for a new 1000 gallon per minute (GPM) offsite raw sewage pump station, a new 1 MGD NWRWRF, and a new high rate infiltration basin system with total dispersal capacity of 1 MGD. An add alternate for an additional 1 MGD (for a total of 2 MGD) plant capacity was included in the bid.

The low bidder had a base bid amount of approximately $29.3M and a bid alternate of $7.6M to increase plant capacity to 2 MGD (Total base bid plus 1 MGD expansion = $36.9M). ONWASA attempted to negotiate the scope and cost of the work, such that the project could be constructed within available funds, with the low bidder. To this end, the low bidder submitted a post bid value engineering proposal. The value engineering proposal included modifications to nearly every facility and aspect of the project.

The value engineering proposal reduced the base bid cost to $24.8M (for a new 1000 GPM offsite raw sewage pump station, a new 1 MGD NWRWRF, and a new high rate infiltration basin system with total dispersal capacity of 1 MGD). However, ONWASA did not move forward with the value engineering proposal due to the potential for protests by other bidders. In fact, ONWASA received a letter from the second lowest bidder inquiring about the preconstruction steps taken toward awarding the project and indicating they were second lowest bidder by only $25,000. Considering the potential for legal action by the other bidders if ONWASA were to award the project to the low bidder based on a post bidding value engineering proposal, ONWASA ended negotiations with the low bidder.

ONWASA was now under the gun from both the SOC and the fact that the ARRA fund availability is conditioned that all recovery act funds must be expended and the project closed out, including final audits, by September 30, 2015 or they will be cancelled and shall not be available for expenditure for any purposes. The ONWASA Board of Directors adopted a resolution rejecting all bids because the available funds were insufficient to fund the construction. The Board also dismissed the original design firm and authorized staff to negotiate a task order with a qualified engineering firm within ONWASA’s “pool” of engineering firms.

METHODOLOGY

No one likes to be told they have an ugly baby – let alone make that assessment of their own! We love them too much to see it, and frankly it’s too late to do anything about it anyway.
Of course I am being facetious to make a point – much of what is not accomplished in Value Engineering is the result of blindness caused by pride of ownership, in combination with performing the exercise at the wrong point in the process – or at least at a sub-optimal time.

Q: When IS the best time to perform VE?

A: As soon as possible, and repetitively.

Clearly, the biggest gains to be realized are by re-examining larger scale options and alternatives early in the process, no later than the 30% completion stage.

Too many times, VE is not performed until the project design is virtually complete (or even later), and it becomes an exercise in counting paper clips. That said, there can be an accumulation of small tweaks and changes, or paper clips, that can make the design significantly better, but these options do not reveal themselves until later in the process.

If one definition of insanity is doing the same things over and over and expecting different results, and Einstein observed that we will not solve problems with the same level of thinking that created them, then often our VE processes are a bit looney if not committable. Often, it is precisely the same internal project team exclusively responsible for the VE evaluation.

The reasons for this are manifold: misplaced ownership in design, unwillingness to examine alternatives, too late and too much invested, too late and no time for major changes, have staked themselves out with external stakeholders.

And when an external third-party is introduced to the process, often the benefit of an added perspective is counter-balanced by engendering feelings of mistrust or defensiveness in the core team.

As John Kotter observed, one of the key early ingredients in instituting change is to create a shared vision and sense of urgency.

For good or ill, the ONWASA situation did not lack for urgency. With the massive overrun in the budget, and the ticking timebomb with respect to the SOC and funding obligations, clearly something major needed to be accomplished in an extremely short timeframe. The project itself hung in the balance.

We also had the luxury of a virtually completely new cast of characters involved in the re-examination of the project, and the ability to start from square one.

So, armed with a blessing and a curse, where did we go?

RESULTS / DISCUSSION

ONWASA was familiar with McKim & Creed’s batch treatment process designs through their work together on other regional wastewater treatment systems, so McKim & Creed and ONWASA were able to work together to quickly reprogram the entire project. Less than a month after the ONWASA Board of Directors rejected all construction bids, dismissed the original design firm, and authorized staff to negotiate redesign with McKim & Creed as one of the qualified engineering firm within ONWASA’s "pool" of engineering firms, McKim & Creed and ONWASA had modified the NWRWRF project basis for design to include a Sequential Batch Reactor (SBR) based treatment process to reduce project construction costs versus the previously bid 5-stage biological nutrient removal (BNR) membrane bioreactor (MBR)
system. Design modifications to the off-site pump station and infiltration basins were also proposed as a means to further reduce construction costs.

During the reprogramming effort, McKim & Creed completed a detailed treatment process alternatives analysis to help ONWASA find a solution that balanced long term benefits against initial capital cost as well as a solution that could be implemented quickly to allow ONWASA to comply with financing deadlines and maintain their ARRA funding. This alternatives analysis evaluated several biological nutrient removal treatment processes that were capable of treating the projected NWRWRF design year raw influent flow and pollutant loading to reliably and consistently produce an effluent complying with North Carolina “Reclaimed Water” standards as defined in 15A NCAC 02T.0906 and meeting the previously permitted NWRWRF effluent standards but at a lower initial capital cost and lower long term annual O&M cost as compared to the original design. McKim & Creed’s alternatives analysis found cost saving advantages to utilizing SBR technology rather than the originally designed 5-stage BNR MBR process and recommended that the 2 MGD biological nutrient removal treatment process be redesigned.

The originally designed 2 MGD 5-stage BNR MBR process consisted of an influent equalization tank, anaerobic (ANA) stage, two anoxic (ANX) stages, and one aerobic (AER) stage, followed by a membrane operating system (MOS) which consisted of an open tank with multiple ultrafiltration (UF) modules suspended directly into the mixed liquor, diffused aeration system with blowers, a recycle pumping station, and a clean in place (CIP) system. Mixed liquor suspended solids (MLSS) rich in O2 and NO3-N is continuously recycled from the MOS to the ANA zone resulting in the need to expend more energy in recycle pumping as well as required the ANA zone to be designed with three cells, the aerated MLSS recycle being discharged to the first cell (to provide time for deoxygenation) while the raw wastewater enters the second cell, to maintain the effectiveness of the ANA selector for production of phosphorus accumulating organisms. The 5-stage BNR MBR process provided not only nutrient removal (phosphorous and nitrogen), but carbon removal as well by dividing the bioreactor of the BNR system into three biological reaction zones in five different stages based on different biochemical environments created in separate, fixed volume process tanks.

The redesigned dual train 2 MGD SBR system is an activated sludge system designed to simultaneously achieve biological denitrification, carbonaceous BOD removal, and nitrification of ammonia to nitrate. Further, the SBR system is able to provide mixing, aeration cycles, and settling in the same tank but at different points in time via a phased process sequence including anoxic mixed fill, aerated fill, aerated reaction, settling, decanting, and waste biosolids pumping. The SBR system is followed by a single post equalization tank, dual train tertiary disk filtration, and a quadraplex UF membrane system. Since the peak hour flow is equalized through the SBR and post equalization tank, the disk filters and the UF system are designed for a peak flow of 4 MGD.

Redesigning to an SBR system reduced the amount of process tanks since separate influent equalization volume was incorporated in the reactor design above the normal operating level and the biological treatment was achieved within a single tank rather than in several separate tanks as with the previously designed 5-stage BNR MBR system. Similar to the 5-stage BNR MBR system, the SBR system does not require separate secondary clarifiers since solid/liquid separation is achieved in the main biological reactor tank via a settling time cycle. Further, the SBR system does not require a recycle pumping system since the biosolids are kept in the reactor tank with periodic wasting. Fewer process tanks and process equipment associated with the redesigned SBR system minimized both initial capital costs and annual O&M costs as compared to previously designed 5-stage BNR MBR system.

Despite the NWRWRF design capacity of 2 MGD, initial flows are expected to be < 10% of design flow. A significant advantage of the redesigned SBR process is the ability to vary processing times to optimize
treatment performance as flows and loadings change over time. The SBR system was designed with temporarily modifications to initially operate utilizing either reactor tank as a dedicated pre-equalization basin and the other as the active SBR reactor by providing a set of duplex transfer pumps to pump to the active SBR reactor during the fill cycle.

Operation of either the previously designed 5-stage BNR MBR or the redesigned SBR system at low initial flows and loadings required the design of supplemental chemical addition systems (carbon source and alum) to meet the stringent effluent nutrient limits. However, the previously designed 5-stage BNR MBR system required substantially more carbon addition compared to the batch process when flows are less than 0.5 MGD. This is because the continuous flow process has fixed reactor sizes which are necessarily designed for the design year condition in contrast to batch processes which can easily adjust reactor volumes to accommodate actual flows by dropping the normal operating level in the reactors. Lower chemical feed requirements during initial operation years where the plant is under loaded leads to the redesigned SBR system having a lower annual O&M cost compared to the previously designed 5-stage BNR MBR system.

The pressurized effluent UF process proposed in the redesigned SBR is considerably different than the previously designed submerged UF MBR process. In the redesigned system, the membrane flux (or throughput) can be significantly increased (up to 40 gpd/sf of membrane area) as compared to the 8 – 10 gpd/sf common with the submerged UF MBR processes. This is because the upstream disk filters remove 95% of the solids loading from the effluent BEFORE the filtrate is pumped to the UF process. The cleaner feed water translates into increased flux rates, less membrane area, and lower initial capital cost as compared to the previously designed submerged UF MBR.

It is clear that the previously referenced treatment process alternatives analysis' recommendation to redesign the NWRWRF to utilize SBR treatment technology followed by tertiary disk filtration and UF membrane presented significant cost savings. However, to reduce the projected construction cost to within existing budgetary constraints, additional value engineering was required. It is important to note that high level cost estimating effort was done during the alternatives analysis and subsequent project reprogramming without the benefit of detailed designs for the proposed SBR system. The unique hindsight that was granted to McKim & Creed during this project lead to detailed construction cost estimating efforts being performed at regular intervals throughout the design. These regular construction cost estimating and value engineering efforts performed constantly throughout the design process helped identify and execute several additional cost saving items discussed below.

McKim & Creed identified an opportunity to raise the hydraulic profile of the previously designed system during the redesign. Raising the hydraulic profile in combination with the redesign to a SBR system allowed for incorporation of above grade pre-stressed concrete tanks into the design rather than the previously designed below grade cast in place concrete tanks. This presented significant construction cost savings in both the material costs as well as excavation costs.

McKim & Creed redesigned the offsite pump station utilizing a precast concrete wetwell with submersible pumps in lieu of the originally designed cast-in-place wetwell-drywell design. Similarly, the valve vault design was also revised from cast in place to precast concrete. McKim & Creed also made other minor modifications to the pump station design in order to enhance general constructability and reduce cost of the pump station.

The previously designed administration and maintenance buildings were also identified as having room for significant value engineering. McKim & Creed and ONWASA worked together to value engineer both
buildings. The administration building was significantly downsized as compared to the original design and the maintenance building was redesigned to be a pre-engineered steel shell with minimal facilities.

During redesign efforts, McKim & Creed and ONWASA worked with sub consultants to complete pilot testing on two of the infiltration basin sites. Pilot testing indicated that fracture and removal of a layer of limestone as originally designed and permitted was not necessary to achieve dispersal of 1 MGD of treated effluent. To that end, the originally permitted infiltration basin design was modified to include excavation only to the limestone layer and eliminated the requirement for blasting or ripping of the rock. The same is true for the basin under drain system which was redesigned to be 100 feet from the high water level (as opposed to the original 50 foot design) and at an elevation of 18 feet above mean sea level only at sites where this was above rock. Additionally, the pilot testing confirmed that the loading rate could be increased from the previously designed and permitted rate of 2.55 GPD per square foot to 3.285 GPD per square foot. This increased loading rate reduced the overall number of basins required from ten to four as well as reduced the area of the basins to approximately 300,000 square feet to further reduce project cost.

McKim & Creed and ONWASA worked together to further categorize the elements of the redesigned project into essential components, valuable items, and aspirations. ONWASA was then able to quickly and definitively make important decisions regarding the project elements to stay in the base bid and those to put into add alternate bids. Add alternate bids were used extensively on this project to ensure that the construction bid would fit within the previously established budget constraints and allow flexibility to an increased value to the project should the bids come back favorable.

The vertical screen in the offsite pump station wetwell was identified as an item that was not integral to the performance of the system and meeting the permitted effluent limits and as such was included in the design as an add alternate bid item. Similarly, the second automated screen at the plant headworks was not required to meet peak flows and was included as an alternate bid item.

The original NWRWRF design included a 10 million gallon lined 5-day upset basin. McKim & Creed’s redesigned system utilized two separate bid alternatives to allow greater flexibility for cost savings on bid day. The first (i.e. Base Bid) included the initial construction of only the first half (i.e. 5 MG) of the 5-day upset basin. The second (i.e. Add Alternate Bid) provided ONWASA with the option to construct the full 10.0 million gallon 5-day upset basin. Although the treatment process itself was designed with a full 2 MGD average daily flow capacity (thus the need for 10 MG of lined upset storage), the effluent infiltration dispersal system only included 1 MGD average daily flow capacity. As such, ONWASA had the flexibility to start operations with a “permitted” system capacity of only 1.0 MGD but then, as flows increase in the future, ONWASA would merely need to construct the second half of the 5-day basin (along with the additional 1.0 MGD of effluent reuse/dispersal capacity) to allow the system to be re-permitted for 2.0 MGD.

The incorporation of effluent UF treatment following the tertiary disk filters significantly improves the final effluent by removing particles down to 0.1 micron particle size. Unlike sand or disk filtration, UF physically removes microorganisms and viruses and, when combined with UV irradiation, acts as a dual-barrier to microbial contamination. While this level of treatment is not currently required by ONWASA’s draft non-discharge permit limits for the NWRWRF, ONWASA’s plan to disperse the final effluent via high rate infiltration basins which over time allow for dispersal through infiltration of final effluent certainly warrants the advanced treatment and double barrier approach that is gained with the addition of UF membranes. Further, inclusion of the UF membrane system greatly improves the flexibility ONWASA will have for beneficially reusing the reclaimed wastewater for a variety of purposes as water scarcity becomes a more severe problem in the future with increasing population. As such, the pre-engineered
steel filter / membrane building as well as the UF membrane units themselves were included in separate add alternate bids. Provisions were made in the base bid design to allow the process equipment to be incorporated in future expansions if adequate funding was not available on bid day.

CONCLUSIONS

After the first bids were received and subsequently rejected, ONWASA and McKim & Creed began to work tirelessly on the redesign of the Northwest plant. In order to shore up all the design, permits, and financing many local, state, and federal agencies were involved in this project. The normal process of permitting and designing of a treatment facility was not an option. McKim & Creed established an aggressive schedule and value engineering program that allowed the project team to meet the previously established project deadlines within the required total construction budget so that the project could move forward. The authorization to construct was signed in March of 2013 and the redesigned plant is currently in construction.

The philosophies that were integral to the success of McKim & Creed’s value engineering approach on the Northwest Regional Water Reclamation Facility project include:

1. Start early – no, earlier than that! The further down the path one gets, the more options either go by the boards, or are much harder to implement and with more resistance.
2. Don’t take it personally, focus on the objective and outcome. That’s really all anyone cares about (except you).
3. Learn to see with new eyes. “The real voyage of discovery consists not in seeking new landscapes, but in having new eyes” - Marcel Proust. We all have our paradigms and filters. Learn to step outside yours.
4. Listen attentively and constructively – don’t defend. A wise trial lawyer once told me, as an expert witness “If you are arguing, you are losing”. The same thing applies here. Rather than mentally mounting your defense, look for a kernel of truth or something useful in the criticism or alternate viewpoint being expressed.
5. Ask questions, of others AND of yourself. Actively seek other viewpoints and perspectives. Hey, at least you will ‘seem’ collaborative, and some say the best start to being something is acting that way.
6. Anything not impossible is by definition possible, however improbable – suspend disbelief!

The success of this project would not be possible without the work effort of McKim & Creed and ONWASA staff being able to come together on a common goal. The project team would like to recognize all other agencies that were called upon to keep this project on time and on budget. Those agencies are listed in the acknowledgements section of this paper.

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