

Managing Wet-weather Flows Through Phased Improvements to the Sims South WWTP

Keith O'Connor, P.E.
Weston Solutions, Inc.
5599 San Felipe, Suite 700
Houston, TX 77056

ABSTRACT

Expansion of a major wastewater treatment plant (WWTP) required considerations to cost, constructability, and maintaining plant operation. The Sims South WWTP located in southeast Houston, TX is a major City of Houston plant that required expansion to handle increased flows. The service area for the plant had experienced numerous sanitary surges during and shortly after major rainfall events over the past several years largely due to excessive infiltration and inflow into the sewer system. The Sims South Wastewater Treatment Plant, which is currently permitted for an average daily flow of 36 million gallons per day (MGD), required expansion from 125.6 MGD to 190 MGD permitted peak two-hour flow to prevent surcharge in the collection system trunk sewers. By listening to the clients' needs and budgetary constraints, Weston Solutions (WESTON), the consulting engineer for the project, developed a three phase construction approach that maximized the efficiency of operation, construction, and design activities.

KEYWORDS

Wastewater expansion, construction, phased improvements

INTRODUCTION

The Sims South WWTP is a nearly 20-year old advanced secondary treatment plant. Prior to construction of the plant improvements, raw wastewater was pumped via four screw pumps, two dry-weather submersible pumps, and two wet-weather submersible pumps to the preliminary treatment headworks that contains four bar screens (two manual and two mechanical) and two aerated grit chambers. From the grit chambers, wastewater flows through the activated sludge train consisting of four aeration basins and six clarifiers. Upon discharge from the clarifiers, the clarified effluent flows through three scum flotation basins (no longer in operation) and is chlorinated in two disinfection contact basins. Flow is subsequently dechlorinated prior to discharge to the Sims Bayou. Wasted solids are sent to the Sims North WWTP where they are thickened and dewatered through belt presses prior to offsite disposal. Figure 1 shows the plan view of the Sims South WWTP prior to improvements.

Several sanitary surges during and after major rainfall events required the City of Houston (COH) to address plant expansion to increase wet-weather treatment capacity. The plant was originally permitted at an average daily flow of 36 MGD average daily flow and a two-hour peak flow of 125.6 MGD. Hydraulic modeling of the service area determined the need to expand the two-hour peak flow capacity to 190 MGD.

WESTON, the consulting engineer for the project, was tasked with making recommendations for design and construction of expansion improvements to the facility as well as other miscellaneous operational enhancements. A hydraulic analysis of the plant was required to identify restrictions in plant capacity rather than simply expanding the quantity of unit processes. Based on extensive research, WESTON recommended a three phase approach to plant expansion. Each phase involved the following:

Phase 1: New 175 MGD Influent Lift Station (LS)

Phase 2: Plant Process Expansion to 165 MGD (Permitted Two-Hour Peak Flow)

Phase 3: Plant Process Expansion to 190 MGD (Permitted Two-Hour Peak Flow)

PHASE 1 IMPROVEMENTS

Design Considerations

The first phase of expansion involved construction of a new 175 MGD dual-caisson submersible pump influent LS. WESTON was tasked with design of a new submersible LS that accomplished two goals: to replace the old screw pump LS, and to allow a free hydraulic discharge from the influent trunk sewer. This was intended to alleviate chronic sanitary sewer surcharges and overflows in the Sims Bayou Service Area. The new submersible LS would provide 175 MGD (firm capacity) two-hour peak treatment capacity and would supplement a 15 MGD onsite wet-weather LS.

Between January and April 2000, all four of the existing screw pumps failed and repair was considered impractical. They were temporarily replaced with four submersible pumps. The floor elevation of the existing LS was only 1.3 ft below the invert of the influent sewer, and the top of the volutes of the temporary submersible pumps were about 3.8 ft above the LS floor. Consequently, the minimum water surface elevation in the LS was approximately 2.5 ft above the plant influent. This resulted in the pumps-off level being 2.5 ft above the influent sewer invert elevation and necessitated the need of a new submersible lift station.

The design challenges of this project included finding available space to construct a new LS while maintaining the old LS in service. A critical component of the project was having the capability of splitting flows between the new LS, Sims North WWTP, and sending flow directly to the Sims South WWTP's headworks. The design of the diversion structure was very complex as it received flows from four locations: the 84" and 60" truck sewers, and two off-site force mains, and routed flows to three locations: the new Influent LS, directly to Sims North WWTP, or to an on-site wet-weather LS.

The design of the system operation was very unique for the new LS. Two separate sets of operating conditions were set for operation under dry-weather conditions and wet-weather conditions. During dry-weather conditions, the flow needs to build inside the wet-well to provide a better split in flow between the Sims South WWTP and Sims North WWTP. During wet-weather conditions, the operating sequence is trying to empty the wet-well as fast as possible to prevent surcharge in the

collection system. This results in the elevation for “All Pumps On” during wet-weather being below the “Lead Pump On” during dry-weather. This required unique programming requirements to facilitate the transition between dry-weather and wet-weather. This allows the LS to ensure that all pumps are rotated and used equally while addressing both operating conditions. The pump curve appears in Figure 2.

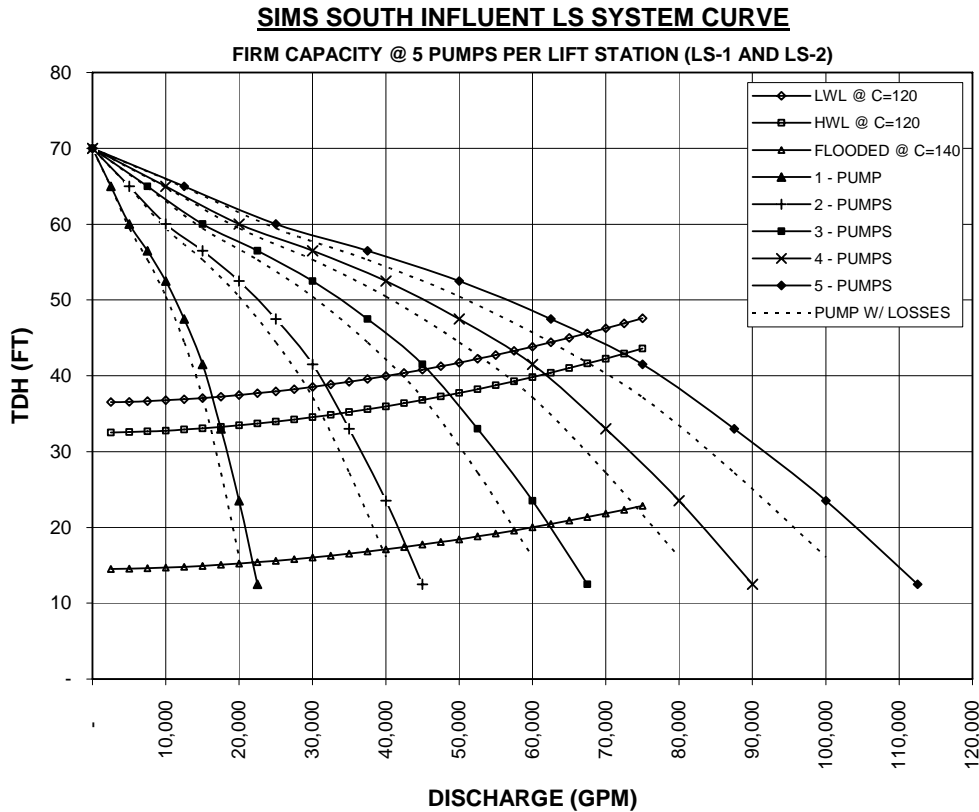


Figure 2: New Influent Lift Stations’ Pump Curves

Construction & Plant Operation Considerations

WESTON had to ensure the continued operation of the plant during construction in its design documents. Only small duration plant shutdowns (such as 24-hour timeframe) were possible to avoid costly bypass pumping. Consideration had to be given the challenge of connecting the proposed LS to the headworks while maintaining the plant operations. In addition, physical constraints required that the new force main piping be routed over the existing LS.

These constraints led to the recommendation that dual-caisson LSs be constructed. Both submersible LSs were equal in size and pumping capacity. Dimensions of each LS were 40-ft in diameter by 36-ft deep. Both LSs contained six pumps each rated at 17.5 MGD. Figure 3 shows photos of construction of the new caisson LSs.



Figure 3: New Caisson Influent Lift Stations Construction

The Contractor was required to maintain at least 120 MGD pumping capacity at all times during construction. By constructing two independently operating submersible LSs, part of the existing LS could be isolated allowing it to continue to operate while construction of force main piping was carried out for one of the proposed caisson submersible LS. Upon completion of the first new LS, flow was partially transitioned from the existing LS to the new station. The old LS was then decommissioned and force main piping for the second caisson submersible LS was constructed.

Two parallel 48-inch ductile iron force mains delivered flow from each new LS to the headworks. Figure 4 shows photos of the force main construction.



Figure 4: New Influent LS Force Main Construction

As briefly mentioned above, the conversion of a junction structure that received flow from four locations and routed flow to three location into a diversion structure was one of the more challenging aspects of this project. The new diversion structure had automated gates that would open/close based upon initiation of a wet-weather event/return to dry-weather status that occurred at a predetermined wet-well level. When a wet-weather event was initiated, an isolation gate to Sims North WWTP would close routing all flow that collects in the diversion structure to the Sims South WWTP. Another isolation gate would open that allows flow to the onsite wet-weather LS.

The design of the diversion structure had to take into account constructability and maintaining the plant in operation. During work in the active portions of this structure, dry-weather bypass pumping was required to route flows. Allowances were made for “flood-out” events in case of peak rain events that exceeded the dry-weather pumping capacity. The Contractor was required to pull out temporary

sewer plugs and open sluice gates during these rain events. A very extensive work sequence description for the conversion assisted the Contractor in completing the work without incident.

PHASE 2 IMPROVEMENTS

Design Requirements

The second phase involved expansions to process and hydraulic capacity. An extensive hydraulic analysis (from downstream to upstream) was performed to determine where the hydraulic limitations occurred. Additionally, process calculations for the unit operations were verified to determine the need for expansion.

Based on all calculations, the primary limiting factor to expanding plant capacity was hydraulic considerations. The greatest restriction to expanding hydraulic capacity appeared in the piping between the aeration basins and clarifiers and the piping between the clarifiers and scum flotation basins. WESTON was required to increase the carrying capacity of the process lines to accommodate more flow during peak weather events. The need for three additional clarifiers was also identified.

Budgetary limitations required that the plant be expanded in two phases (Phase 2 and Phase 3). Phase 2 construction would increase the permitted two-hour peak capacity to 165 MGD. The Phase 2 construction package involved the addition of two 138-ft suction-draw clarifiers, construction of 36-inch aeration basin effluent relief piping to splitter boxes, and construction of clarifier effluent relief lines (36-inch through 60-inch) to bring plant capacity up to 165 MGD.

The need for relief piping was necessary to reduce the hydraulic grade line within the aeration basins and clarifiers. During rain events prior to construction, the weirs would flood at flows above 125 MGD. The greatest restriction to the clarifier was the 36-inch influent pipe; however, this pipe ran under the structure and it was deemed not feasible to replace. Instead, it was determined by adding relief lines between structures, significant headloss reduction was achieved.

Construction & Plant Operation Considerations

WESTON's recommendation to expand process piping capacity was a difficult construction task. All existing piping was underground and varied in size between 36-inch to 90-inch in size. From a constructability and continued plant operation perspective, it would have been very costly to remove and replace piping with larger diameter pipes. Also, the existing piping was shallow in some locations (3-ft to 5-ft deep) and would have required expensive concrete tie-downs to address buoyancy concerns.

WESTON developed an approach that was not only cost effective but also minimized plant shutdowns. In lieu of removing and replacing piping, WESTON designed relief piping through the plant that would provide the additional carrying capacity needed to treat the 165 MGD permitted two-hour peak capacity. New 36-inch through 60-inch relief pipe was designed to supplement existing process piping. The design also minimized the number of shutdowns required as new piping could be installed without taking any process units offline. Shutdowns were only required to make tie-ins to existing piping/structures. Figure 5 shows the plan view of the proposed relief piping improvements.

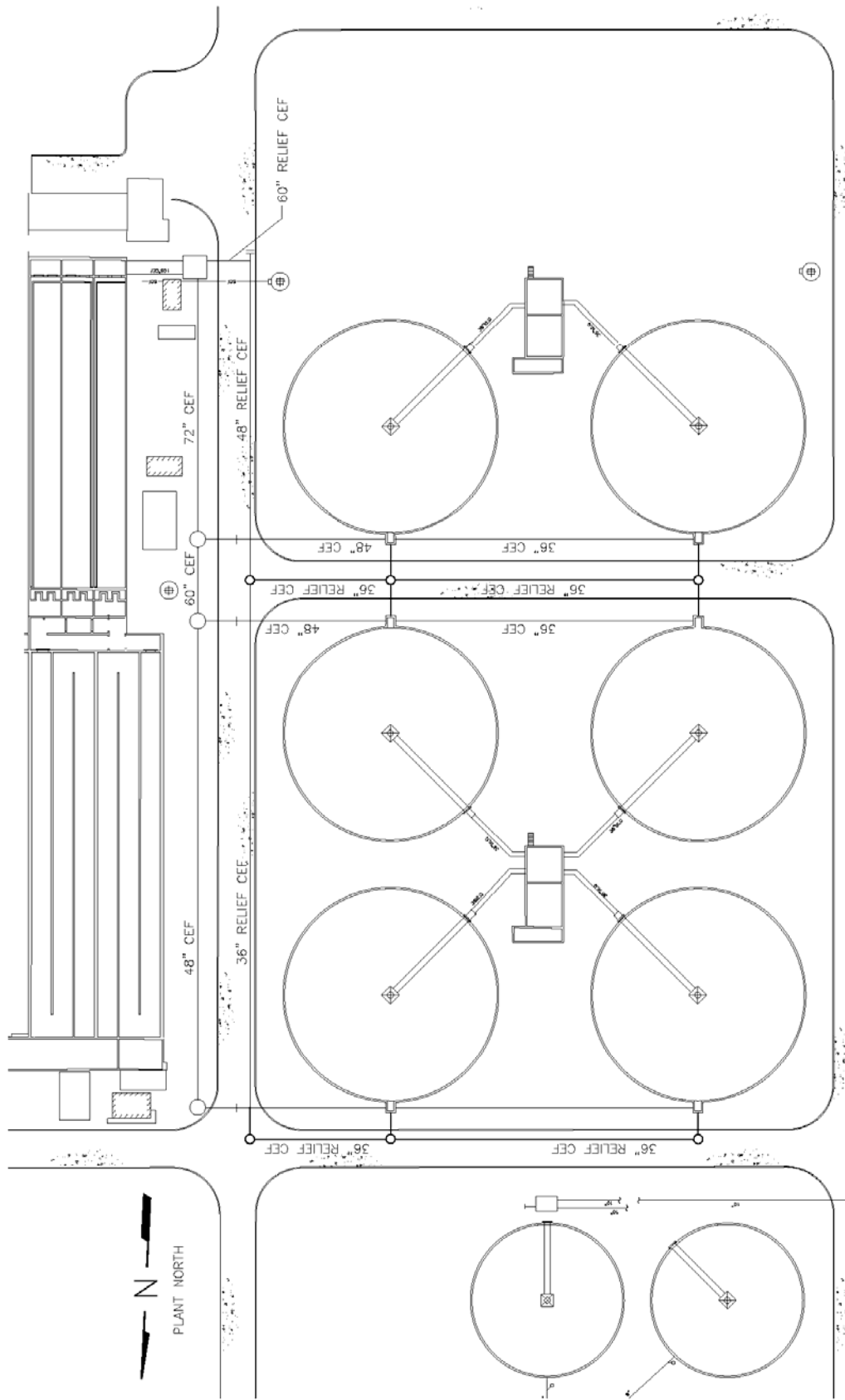


Figure 5: Proposed Relief Piping Improvements

Due to the significant amount of underground work, a detailed yard piping analysis (including site visits, record drawing research, and exploratory digging by the Contractor) was conducted to delineate underground plant piping and electrical duct banks. The plan and profile of all of these utilities were established in the area of proposed construction. The most convenient and least costly pipe routing with the least amount of conflicts was determined based on this analysis.

As a result of WESTON's work, several process lines and duct banks required rerouting. The upfront time and effort to locate existing process lines was made to reduce the potential for change orders during construction. Extra unit cost items were used in the bid form to address lines that may require relocation.

As a result of the extensive upfront work during design and consideration for plant operation, the WWTP is able to continue to operate with existing facilities and only require short duration tie-ins. The construction costs were also significantly reduced.

PHASE 3 IMPROVEMENTS

Design Considerations

The final phase of expansion, which will soon start construction, will increase the two-hour peak flow capacity of the plant to 190 MGD. The final package involves both construction of new facilities as well as renovations of existing facilities. The scope of work for this package includes conversion of one manual bar screen to a new mechanical screen, construction of one new clarifier, renovations and improvements to the chlorination facilities, and rehabilitation of aeration system in three aeration basins.

The complications of this design package arose from the variable flow conditions experienced at the plant. Expanding a plant to treat 190 MGD isn't itself a difficult task; however, this plant is unique in that dry weather flows routinely average less than 20 MGD. This added a degree of difficulty to operation as several unit processes (such as clarifiers) would remain empty a majority of the time while other unit processes (such as the chlorination facilities) would be less than a quarter of their capacity. These difficulties led to some unique design opportunities to incorporate design improvements that streamlined operation of the plant.

There are two distinctive designs to this construction phase. The first is rehabilitation of the conventional fine bubble aeration system in the aeration basins with new hinged-grid diffuser grids. The second involves improvements to the chlorination facilities. Both improvements were designed to improve maintenance and operation of the aeration and chlorination unit processes.

Construction & Plant Operation Considerations

Heavy emphasis on improving operator efficiency was placed on this phase of construction. Renovations to the bar screens, aeration basins, and chlorine contact basins were all performed to reduce daily operator attention. Constructability was an equally important aspect of the design of this package. The desire to minimize downtime of unit processes and capability to treat wet-weather flows had to be incorporated into the scope of work.

Working from upstream to downstream, the first major scope item of this project was replacement of one manual bar screen with a new mechanical screen. Prior to design, the plant had two mechanical bar screens and two manual bypass screens placed at higher elevations. The manual screens, however, would clog at relatively moderate flows through the plant (i.e. non-heavy rain events). To reduce operator maintenance, a new mechanical screen will be installed to prevent excessive head buildup due to clogged screens. It will also reduce the hydraulic grade line upstream of the bar screens which will then reduce the clogging of the manual screen to remain.

Replacement of the fine bubble ceramic diffusers in three of four aeration basins is one of the more important aspects of this design package. The aeration system in Aeration Basin No. 1 had previously been replaced several years prior to this project. The aeration piping in Basins No. 2, 3, and 4 were originally installed as a conventional system (i.e. covering the entire floor of the basin). The ceramic disk diffusers were installed, however, as a tapered system, allowing more air at the front end of the basin and less air at the downstream end. Inactive disk holders were left in-place in case it was desired to convert the aeration system to a conventional system. Because process requirements are being met with the tapered system, there has been no need to use the conventional system. The conventional system would result in higher costs over time as more air would be needed to run the system.

One of the primary concerns with the conventional aeration piping in the basins was that it made the yearly cleaning of the basins to remove organic and inorganic material buildup within the basins very difficult. The piping was very brittle (i.e. schedule 20 equivalent) and left very little room for an operator to move around the basin to collect settled material. It took an operator with a shovel (the only cleaning utensil that could fit in the basin) several weeks to clean a single basin.

WESTON designed a more efficient system that would allow cleaning of the basins to occur much easier. The first aspect of the new aeration system would include a sturdier (schedule 40 equivalent) tapered aeration piping system that would reduce the diffuser coverage of the basin floor and exclude the use of inactive disk holders. The second aspect of the new aeration system included a hinged grid at the manifold that would allow rotation of each distribution header containing the disks. By unbolting the support at the cantilevered end of each distribution header, the piping can be swung out of the way of the basin floor. This significantly reduced the cleaning operations of the basins by allowing nearly full access of the basin floor and even the capability to put construction equipment such as a small front-end loader onto the basin floor to more rapidly clean.

In order to provide the most cost-effective solution, the project was bid with alternates. The base bid included removing and disposing of old diffusers and the alternate base bid included cleaning of existing diffusers. The City had already invested a large amount into the initial purchase of the diffusers and had a large supply of used diffusers on-site. The required quantity of 7-inch diffusers in a single basin is 7,608. To ensure cleaning of existing diffusers was a proper technical approach, several disks were sent to a third-party for testing. The diffusers' dynamic wetted pressures were tested before and after acid-soaking. The results of the testing determined that an acid-soak would return the diffusers to near-new condition. Figure 6 shows a section view of the rotation capability of the diffuser arms.

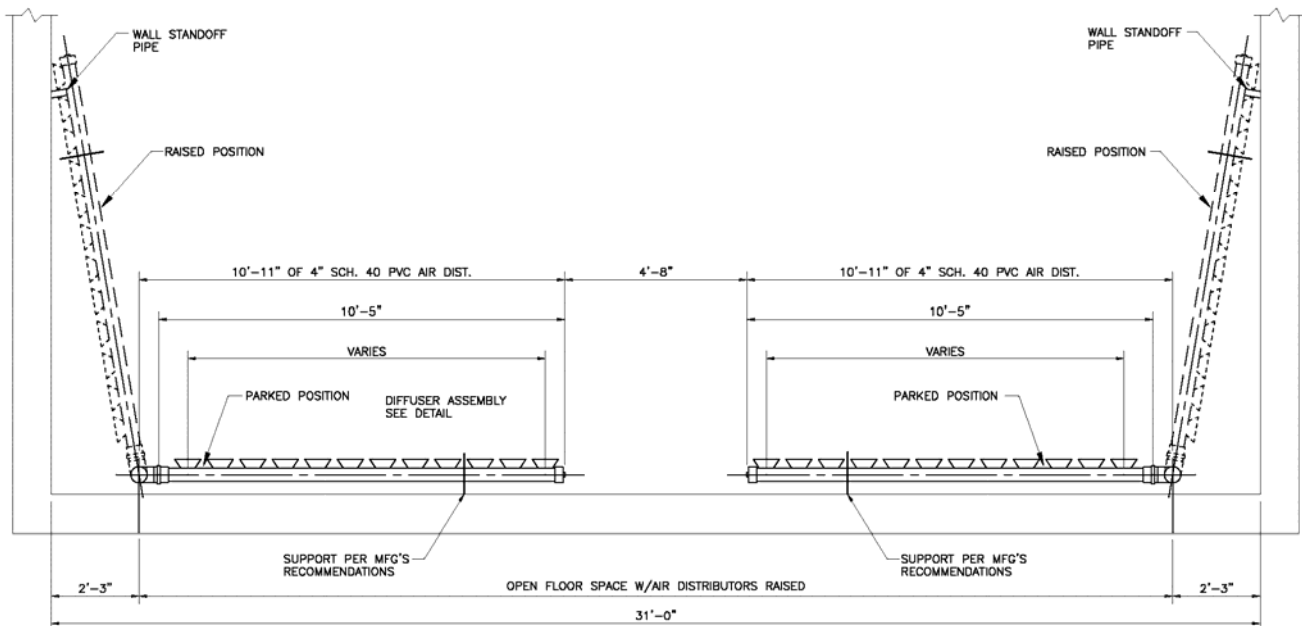


Figure 6: Proposed Diffuser System

Moving downstream, WESTON designed a new 138-ft diameter, suction-draw clarifier (to make a total of nine) that was required for both hydraulic and process reasons to treat the new two-hour peak flow requirement of 190 MGD. A new splitter structure was also designed. The splitter structure collects flow from the aeration basin effluent piping and distributes to a total of four clarifiers (including provisions for three future clarifiers) via isolation weir gates.

The final primary scope of the project involved improvements to the chlorination facilities. This design was heavily influenced by the flow conditions of the plant. During dry-weather which occurred greater than 90% of the time, typical plant flows were around 20 MGD. The chlorination facilities, however, had to be ultimately designed to handle two-hour peak flows up to 190 MGD. During dry-weather flows, flow in the basins was at less than one-quarter of capacity. This condition created much longer detention times than the Texas Commission on Environmental Quality (TCEQ) required 20 minutes which in turn caused excessive usage of sodium hypochlorite and increased plant operating costs. In fact, the City provided the data in the following table regarding excessive usage of chemical compared to the Southwest WWTP chlorination system that had been recently renovated.

Table 1: Sodium Hypochlorite Usage at Sims South WWTP & Southwest WWTP

	Sims Bayou	Southwest WWTP
	Percent Excess Use of Chemical $CL_2 < 1$	Percent Excess Use of Chemical $CL_2 < 1$
Oct-04	37%	6%
Nov-04	56%	3%
Dec-04	36%	3%
Jan-05	62%	4%
Feb-05	39%	4%
Mar-05	43%	8%
Apr-05	44%	11%
May-05	56%	14%
Jun-05	51%	0%
Avg	47%	6%

WESTON had to incorporate two concepts into their design: how to expand facilities to treat 190 MGD of flow while considering how to reduce chemical usage during ordinary, low-flow conditions. The first task was much easier to tackle. There were already two three-pass, 250-ft long by 13-ft wide basins. WESTON added another basin with the same configuration to meet the greater flow.

The issue regarding the low-flow took much more creativity to design a workable solution. Upstream of the chlorination basins, there were three dissolved air flotation (DAF) basins that weren't in use. The DAF basins required a lot of energy and were not needed to meet the plant discharge requirements. WESTON used these basins as a focal point of the new design improvements to reduce chlorine usage. The compliance

WESTON realized that there were three conditions that had to be addressed to improve the system conditions: field conditions (i.e. flow conditions), field devices (i.e. analyzers), and the dosing control system. All of these systems were modified as part of the design. The primary concern was reducing the contact time for dry-weather flow. A wet-weather and dry-weather split flow pattern was created to reduce the time between the chlorination and dechlorination dosing locations. A single-pass, 10-ft low-flow channel would bypass the two existing and one new contact basins. Overflow weirs were used to delineate flow between the two flow patterns. A 6-ft overflow weir would direct flows up to 32 MGD (during dry-weather conditions) to the dry-weather basin. A 150-ft overflow weir set at a higher elevation was then used to pass much larger flows through the larger chlorine contact basins. Figure 7 shows a plan view of the proposed basin improvements.

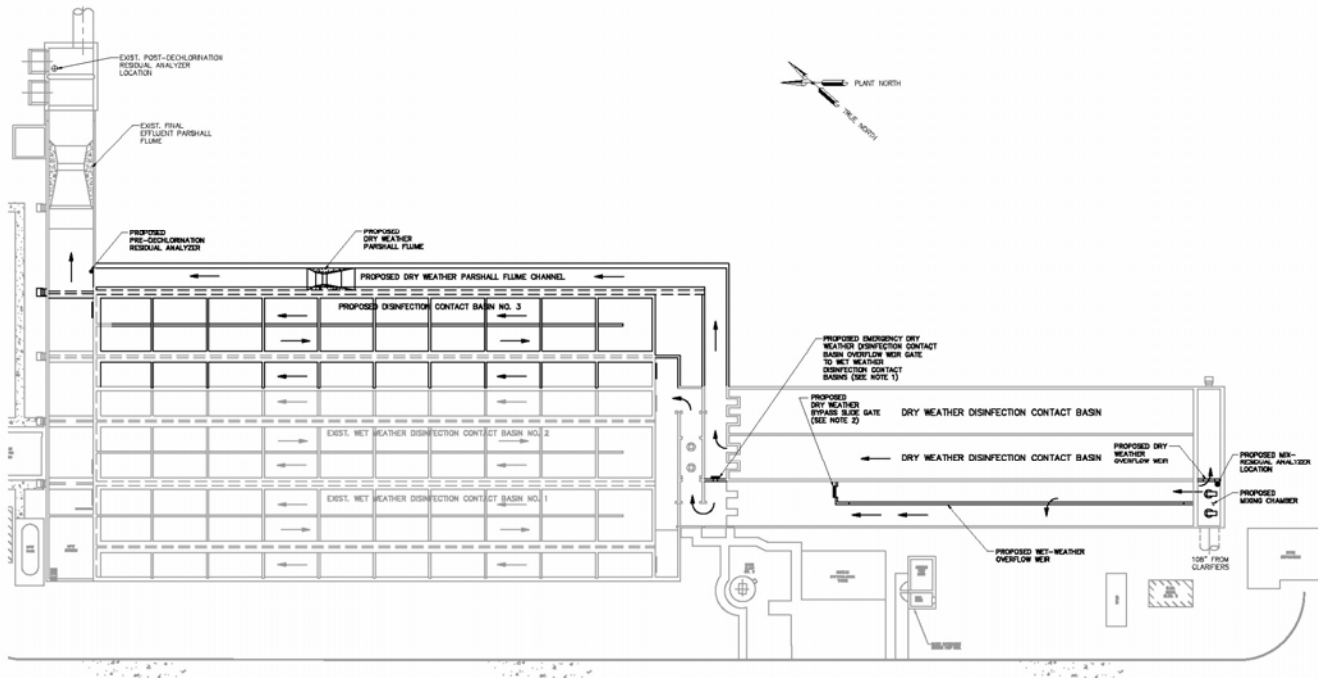


Figure 7: Proposed Disinfection Basin Improvements

To improve the chlorine dosing control, the control system was also modified. The typical COH WWTP chlorination control system consists of a feedback PID control loop. The mix-point analyzer controls the dosage rate based on a pre-determined level setpoint. The pre-determined level is manually inputted based on observed and measured values. The pre-chlorination analyzer is only used to record the concentration and confirm the 1 mg/l dosage at 20-minutes contact time per TCEQ standards and does not provide any feedback to the mix-point analyzer.

The COH had experienced better dosage control by incorporating a controller utilizing internal model control (IMC) into the system. The IMC takes inputs from the pre-chlorination analyzer and the flow meter to determine a sufficient mix-point analyzer reading and modifies the mix-point to this reading based on set conditions programmed into the control system. This system is thought to be superior because it is a feed forward controller that allows it “intelligent” capability. It utilizes past readings to predict what the response to the feed rate will be and adjusts the mix analyzer setpoint. All of these improvements are intended to reduce operating costs of the chlorination facilities.

CONCLUSION

In every rehabilitation project to an existing facility, there are three primary project drivers—cost, constructability, and maintaining plant operation. All three should be considered during preliminary engineering to determine the most cost-effective manner to rehabilitate and expand existing facilities. By incorporating a phased approach into the improvements to the Sims South WWTP, WESTON was able to meet the client’s budgetary constraints and minimized plant shutdowns while carrying out expansions/rehabilitations. Figure 8 shows the final layout of the plant site after construction of all proposed improvements.

The overall duration for construction of these projects has been several years. Construction of the LS began in July 2004. Package 3 is anticipated to be complete by end of 2008. The construction costs for all three projects appear below:

Table 2: Construction Costs of Sims South Packages

	Construction Cost
Package 1	\$7,500,000
Package 2	\$5,000,000
Package 3	\$6,500,000*

*Engineer's Estimated Construction Cost. Project is currently advertising.

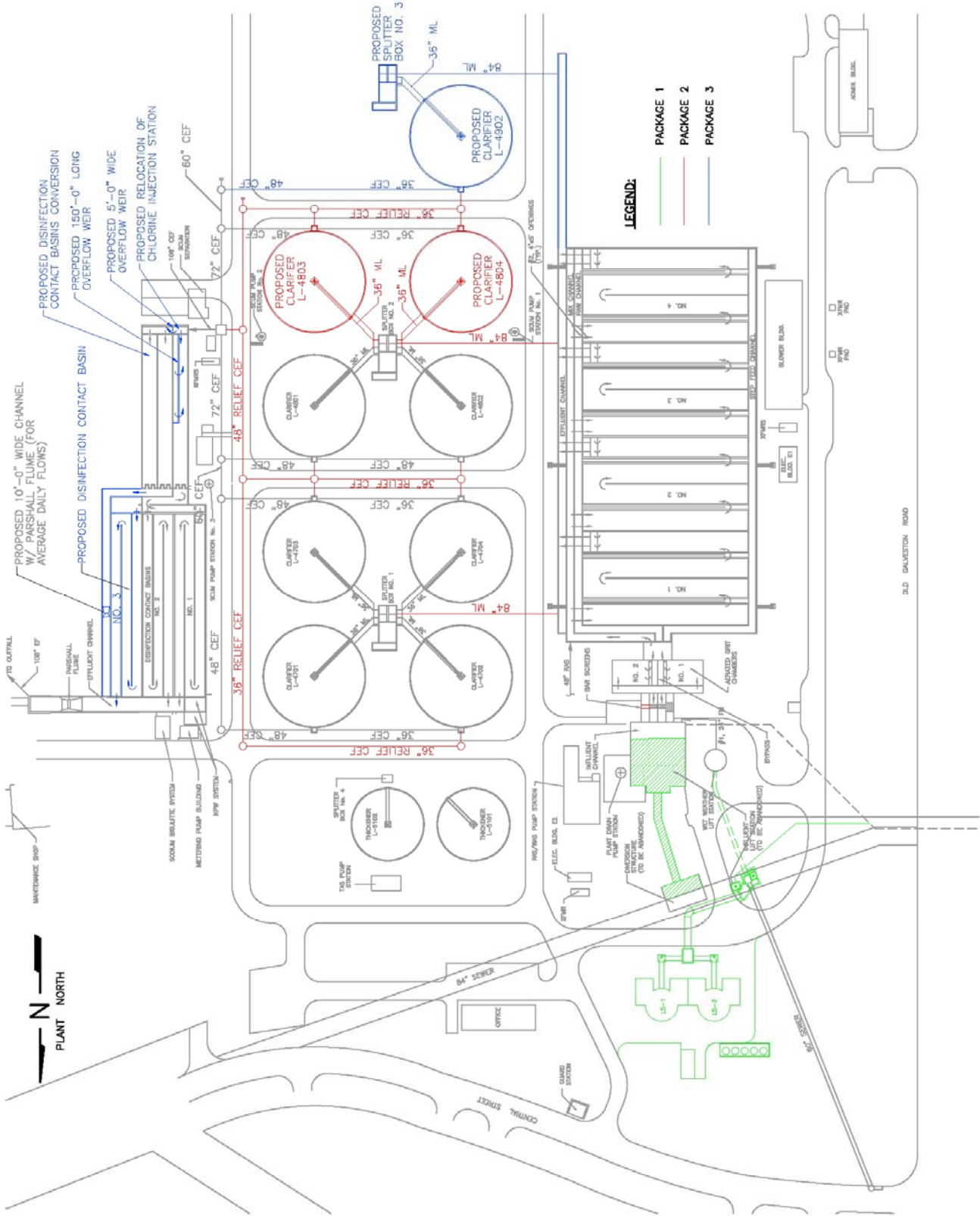


Figure 8: Expansion of Sims South WWT to 190 MGD Two-Hour Peak Capacity