"How much flow can the plant handle?"
An approach to evaluating maximum wet-weather capacities

Authors: Micah Blate[1]*, Samantha Burke[2], Mohammad Ibrahim[2], Matt Jackson[2], Mary Ellen Senss[2], Ya-Chi Tsao[2], Paul Pitt[1], Don Tian[1], Alonso Griborio[1], Ron Latimer[1]

[1] Hazen and Sawyer
*Email: mblate@hazenandsawyer.com
[2] Philadelphia Water Department

Abstract:

As utilities with combined sewer systems are faced with mandates to reduce combined sewer overflows (CSOs), many common strategies involve increasing conveyance and treatment capacity, adding storage capacity, building Green Stormwater Infrastructure, and optimizing existing infrastructure. In many cases, reducing CSOs involves increasing the capacity of the collection system and thus, sending more wet-weather flow to wastewater treatment facilities. But, how much more flow is too much?

This presentation will provide a defined approach to assessing the impacts of increased wet-weather flow on wastewater treatment plants, using scientific modeling that is specific to the facilities. The use of both hydraulic and treatment process models allows utilities a comprehensive picture of the impacts of high-flow events on their wastewater facilities. Within the presentation, details on the development of hydraulic and process models will be discussed, which involve extensive field sampling at wastewater facilities to properly characterize them.

Utilizing this model-based approached, the Philadelphia Water Department (PWD), in conjunction with Hazen and Sawyer, developed calibrated hydraulic, process, and CFD models for the Southwest Water Pollution Control Plant (SWWPCP). The models were utilized to evaluate the peak wet-weather capacity with existing infrastructure, as well as identify the required infrastructure to meet a 2,267 ML/day (600 MGD) event. Additionally, through the development of the calibrated models, a hydraulic constraint was identified and removed.

Keywords: wet-weather, treatment, modeling, CFD

Introduction:

As utilities with combined sewer systems are faced with mandates to reduce combined sewer overflows (CSOs), many common strategies involve increasing conveyance and treatment capacity, adding storage capacity, building Green Stormwater Infrastructure, and optimizing existing infrastructure. In many cases, reducing CSOs involves increasing the capacity of the collection system and thus, sending more wet-weather flow to wastewater treatment facilities. But, how much more flow is too much?

Approach:

Evaluating the maximum capacity of a WPCP requires a comprehensive understanding of unit process performances during typical and stressed (wet-weather) conditions. Increased peak flows pose additional challenges to the unit treatment process, and retention of the solids is a key factor in ensuring adequate treatment after the storm event has passed. Site-specific issues, such as uneven flow distribution, present additional challenges and can upset the implementation of wet weather strategies. Whole-plant simulators, such as BioWin™, are powerful tools for plant evaluations, but they are limited in their ability to represent plant hydraulics and in the physical representation of clarifiers, both critical during simulation of wet weather events. Considering the complex nature of WPCPs, symbiotic use of hydraulic, process, and clarifier models is required to accurately represent plant process performance and should be considered as the future for whole plant evaluation.

The complex relationship between plant hydraulics and biological processes can be systemically modeled: The hydraulic model identifies flow splits to and through process units. The primary clarifier model outputs are input into the process model, which is utilized to identify mixed liquor suspended solids, which are input into the final clarifier models.

Development of Models:

For development and verification of fully calibrated models, data collection and field testing activities are required, which include extensive sampling programs. The hydraulic, process, and clarifier modeling software used in this approach are InfoWorks™, BioWin™, and 2Dc Clarifier Computational Fluid Dynamics (CFD).

To develop and verify a hydraulic model in InfoWorks™, water surface data (over a 3-to-6-month period) should be collected throughout the plant. The data can then be used in the model; the model can be calibrated against a dry-weather day and wet-weather event and verified against a wet-weather event experienced at the plant during the metering period.

The development and verification of a BioWin™ model requires proper characterization and fractionation of a plant's influent sources, which provides insight into the biodegradability and solids production of each source.

To estimate clarifier performance, CFD models are created for both primary and final clarifiers. Stress testing is performed on the clarifiers to systemically increase the surface overflow rate while collecting key data parameters, including effluent water quality, blanket levels, and sludge characteristics (settling, SVI, compression, etc.).

Combined Use of Models:

After the models are developed and verified, they are then used together to identify the maximum capacity of the plant. Specifically, InfoWorks™ is used to predict flow distribution to the aeration tanks and to the clarifiers, BioWin™ is used to predict biological performance and associated MLSS, then, based on the predicted flow distribution to the clarifiers and the MLSS (BioWin™), the 2Dc Model is used to assess the capacity and performance of the clarifiers. The performance of the final clarifiers, typically the final step before disinfection and discharge to a receiving water, can indicate the effluent water quality and estimate a plant's ability to meet NPDES permit requirements during peak flow events.

Case Study:

PWD owns and operates the SWWPCP, a high purity oxygen facility with a rated design average flow of 757 megaliter per day (ML/day) (200 million gallons per day (MGD)). As part of PWD's CSO management program, strategies are evaluated to most cost-effectively manage CSOs; one potential strategy is to increase the conveyance capacity of the collection system, thus increasing flow delivery to the SWWPCP. As part of this strategy, PWD sought to evaluate the existing maximum capacity of the SWWPCP. PWD teamed with Hazen and Sawyer (Hazen) to identify the existing wet-weather capacity of the SWWPCP using fully-calibrated hydraulic, process, and clarifier models.

The SWWPCP includes screening, grit removal, primary treatment, secondary treatment and disinfection, as illustrated on **Figure 1**. There are three influent sources, which complicates the characterization of the plant influent. A centralized biosolids processing facility handles all solids generated from PWD's three WPCPs. The centrate and condensate from the biosolids facility is conveyed to the SWWPCP's low-level sewer, resulting in a significant solids and nutrient loading from the low-level source. The flows from the other two influent sources were evaluated and found to be within typical domestic wastewater constituent concentrations; however, the influents have proportionally increased loadings during wet-weather events, meaning the plant does not experience a dilute wastewater during wet-weather events, even after the first flush. Rather, the loads continue to increase as the flow increases.

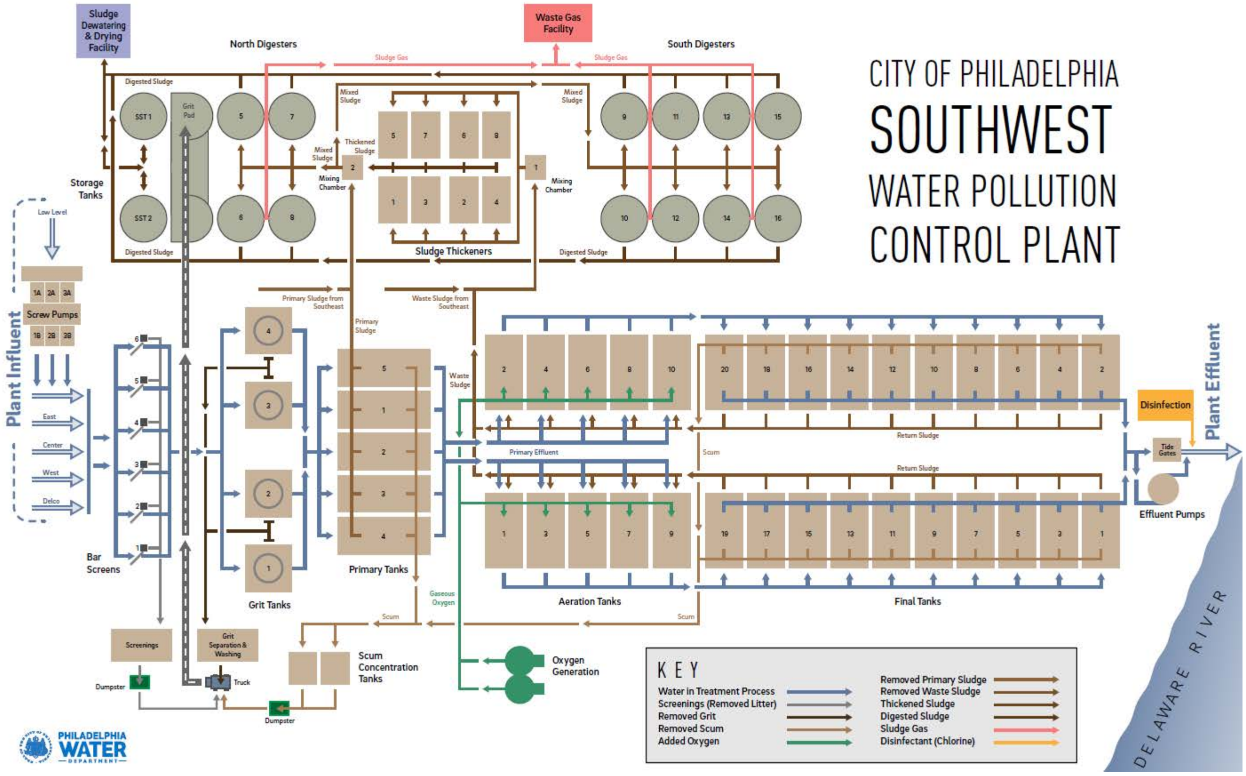

Figure 1: SWWPCP Process Flow Diagram

The collaborative analysis involved intensive monitoring of water surface levels and sampling of wastewater in each process unit to determine the maximum capacity of the SWWPCP. The development of the hydraulic model required data to be collected from 55 key locations within the plant over 4 months. An example calibration plot is provided in **Figure 2**, which illustrates metered WSE versus modeled WSE at a key location in the plant. The BioWin™ model required over 1,500 samples to be collected and analyzed; **Figure 3** illustrates the model and **Table 1** shows the fractionated influent sources. The clarifier models over 1,000 samples to be collected and analyzed during typical and stressed conditions; **Figure 4** illustrates a cross-section of the calibrated final clarifier CFD model.

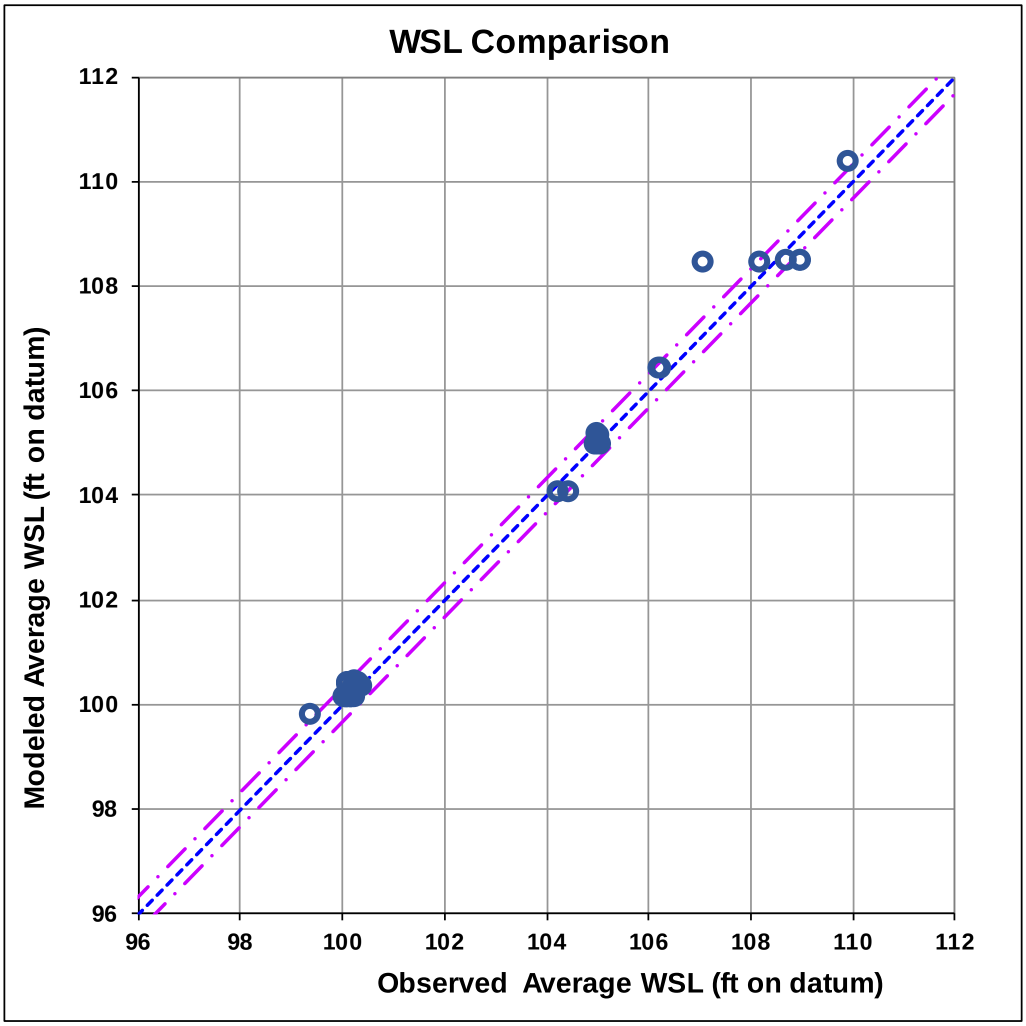

Figure 2: Calibration Plot Example

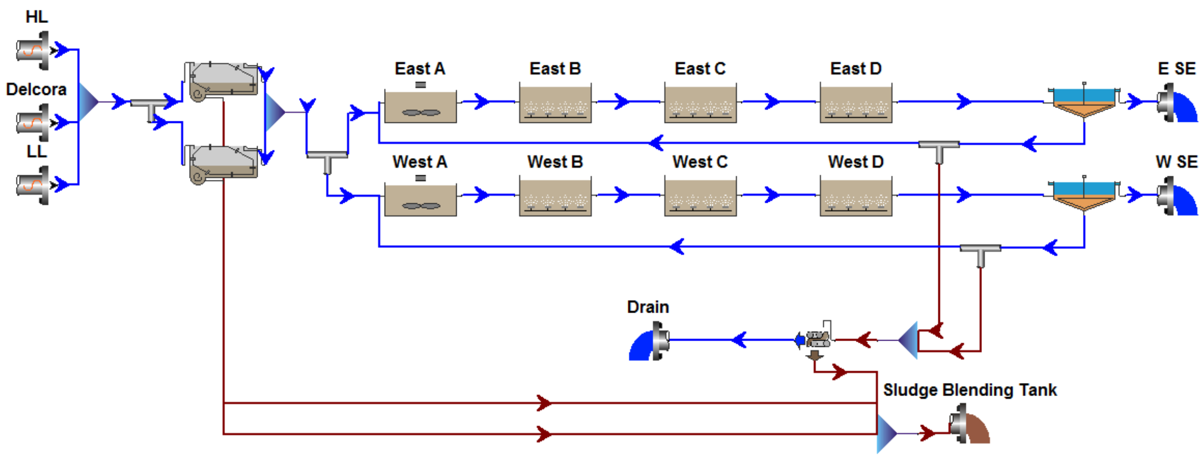

Figure 3: BioWin Process Model

Table 1: Wastewater Characterization Results

Description	BioWin Default Raw	HL	Delcora	LL	Typical Observed Range
Readily biodegradable (including Acetate) [gCOD/g of total COD]	0.16	0.06	0.04	0.02	0.09 – 0.26
Acetate [gCOD/g of readily biodegradable COD]	0.15	0.15	0.15	0.015	0.1-0.4
Non-colloidal slowly biodegradable [gCOD/g of slowly degradable COD]	0.75	0.78	0.61	0.80	0.50 – 0.90
Unbiodegradable soluble [gCOD/g of total COD]	0.05	0.07	0.04	0.03	0.02 – 0.11
Unbiodegradable particulate [gCOD/g of total COD]	0.13	0.13	0.16	0.210	0.15 -0.28
Ammonia [gNH_3-N/gTKN]	0.66	0.76	0.79	0.77	0.30 – 0.78
Particulate organic nitrogen [gN/g Organic N]	0.50	0.50	0.50	0.50	0.50 -0.90
Soluble unbiodegradable TKN [gN/gTKN]	0.02	0.02	0.02	0.02	0.00 – 0.06
N:COD ratio for unbiodegradable part. COD [gN/gCOD]	0.035	0.035	0.035	0.035	-
Phosphate [gPO_4-P/gTP]	0.50	0.15	0.23	0.01	0.20 – 0.80

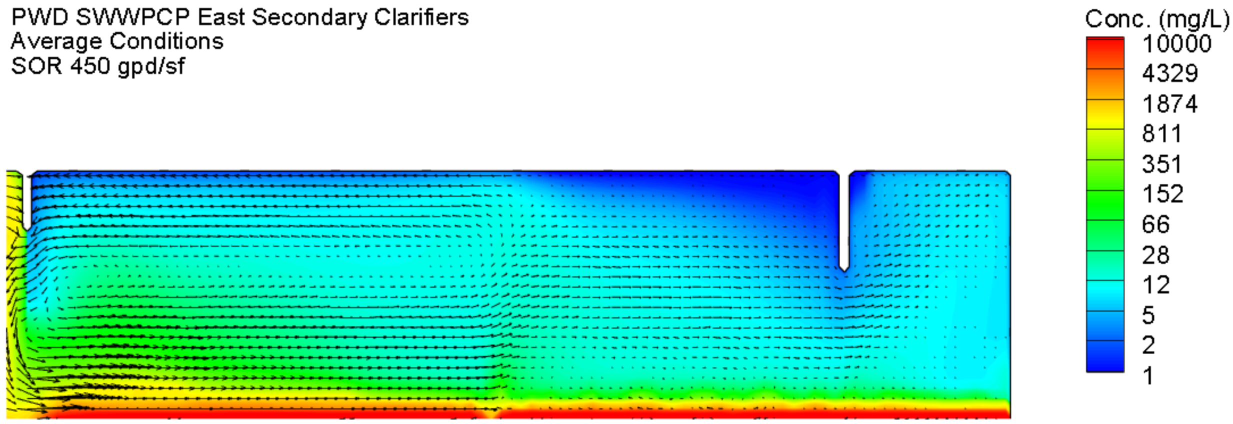

Figure 4: Example Final Clarifier CFD Model Cross-Section

Through the combined use of these models, the *maximum* capacity of the SWWPCP was identified as 2,040 ML/d (540 MGD). An example plot of the dynamic analysis is shown on **Figure 5**, which shows effluent water quality under various SVIs in the east effluent. The graphic shows that with an SVI of 75, at 2,040 ML/d (540 MGD), the SWWPCP the east channel hits a peak effluent TSS (ESS) concentration around 65 mg/L. **Figure 6** illustrates the ESS of both effluent channels with an SVI of 75, at a flow rate of 2,040 ML/d (540 MGD).

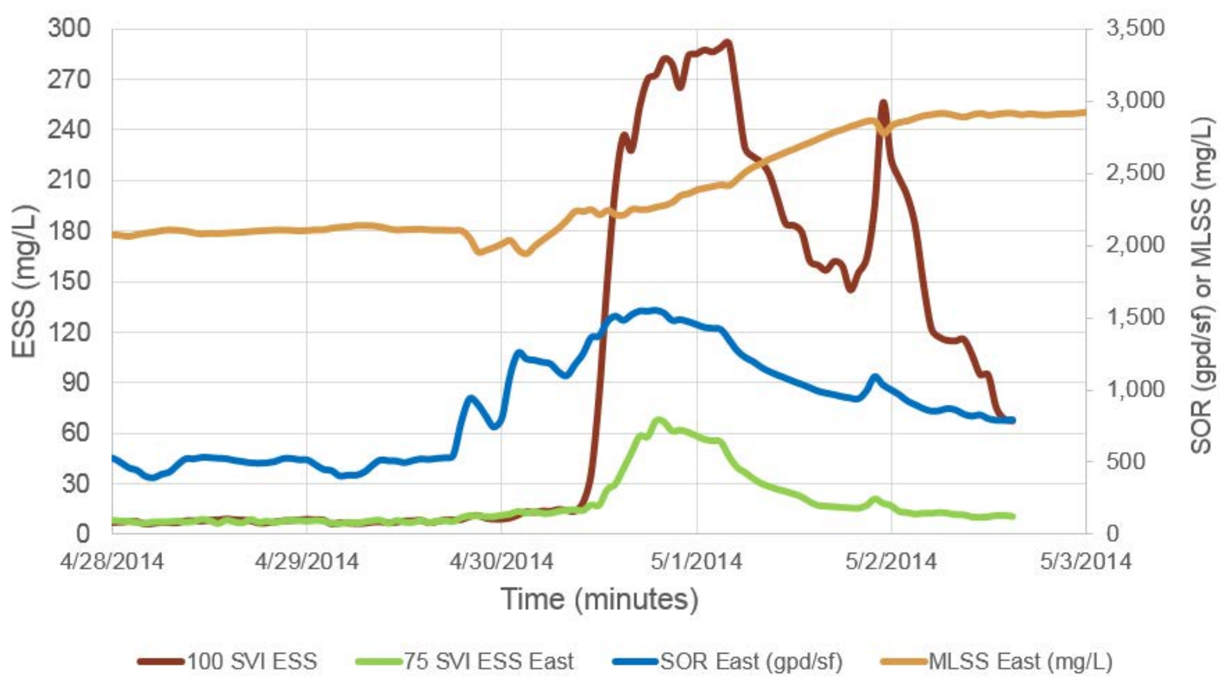

Figure 5: Combined Use of Models Output Graphic (East Side)

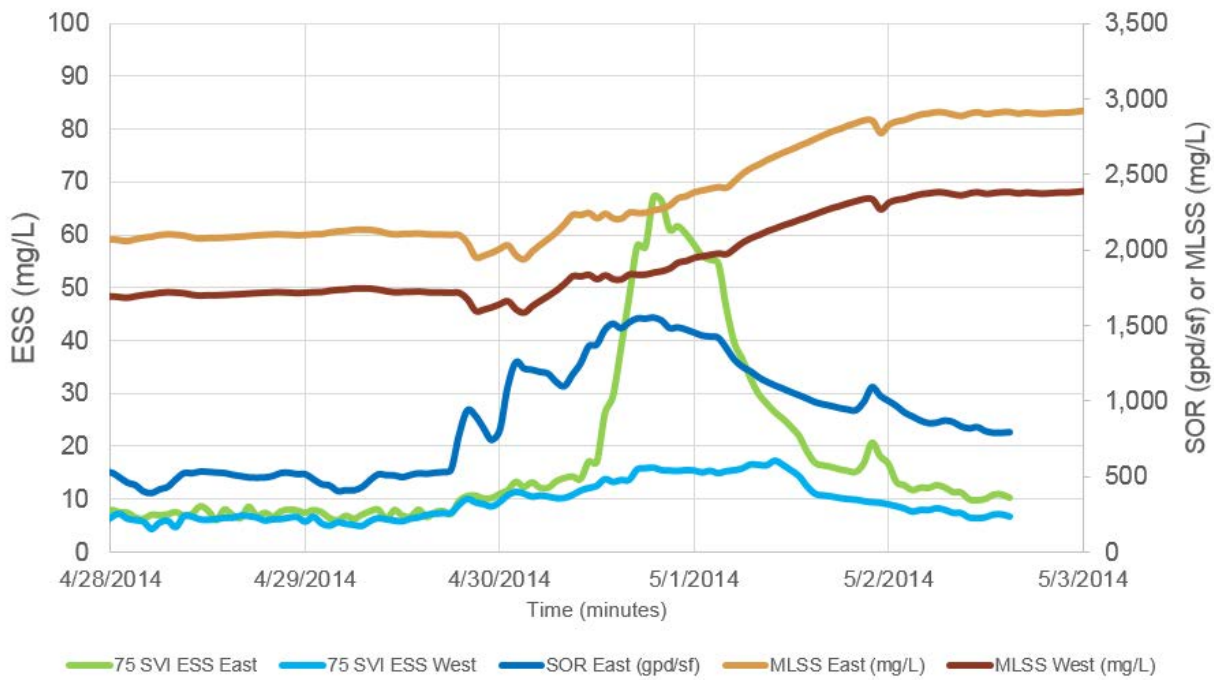

Figure 6: Combined Use of Models Output Graphic (East and West Channels)

In addition to identification of plant capacity, the effort identified a hydraulic constraint in one of the primary effluent conduits, which feeds the aeration tank splitter box. The hydraulic constraint was causing more flow (up to 20% more) to be sent through the east secondary treatment system, hindering the capacity of the plant. Through field reconnaissance, PWD identified stop logs existing in the mouth of the conduit. PWD was able to remove the stop logs (**Figure 7**), which provided the ability to balance the flow through the secondary system (**Figure 8**). The well-defined approach and associated modeling results provided PWD with information to be used in capital planning and decision-making for the future.

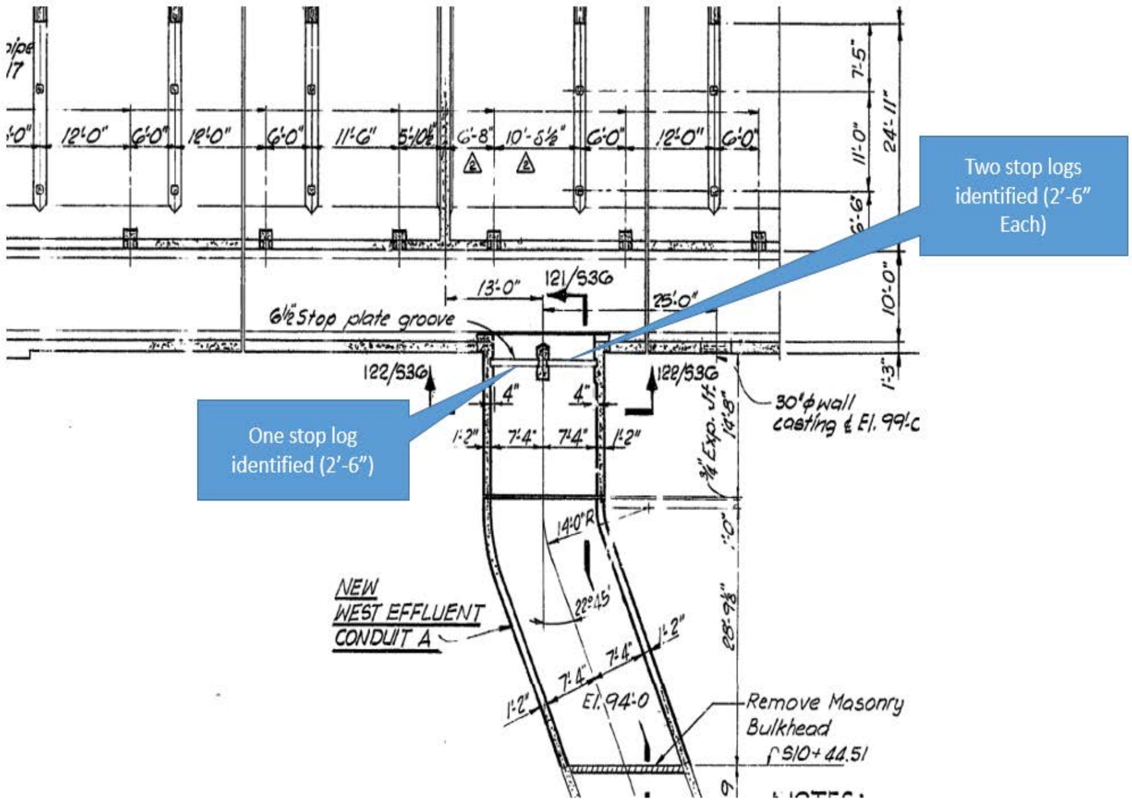

Figure 7: Stop Logs in West Effluent Conduit

Figure 8: Stop Log Removal