PERFORMANCE EFFICIENCY EVALUATION OF THE HUGHEY AVENUE ALUM STORMWATER TREATMENT SYSTEM

Final Report – August 2017

Prepared for:

City of Orlando, Florida -- City Hall
400 S. Orange Avenue
Orlando, FL 32802-4990

Prepared by:

Environmental Research & Design, Inc.
Harvey H. Harper, Ph.D., P.E.
3419 Trentwood Blvd., Suite 102
Belle Isle, FL 32812-4864
Phone: 407-855-9465

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SECTION 1

INTRODUCTION

This document provides a summary of work efforts conducted by Environmental Research & Design, Inc. (ERD) for GTC Engineering Corporation (GTC) and the City of Orlando (City) to conduct a performance efficiency evaluation of the recently constructed alum stormwater treatment system which provides treatment for significant runoff inflows from the City of Orlando into Lake Concord. This system was constructed to provide alum treatment for runoff discharging through the Hughey Avenue stormsewer system into the south side of Lake Concord on the west side of I-4. A general location map for Lake Concord is provided on Figure 1-1.

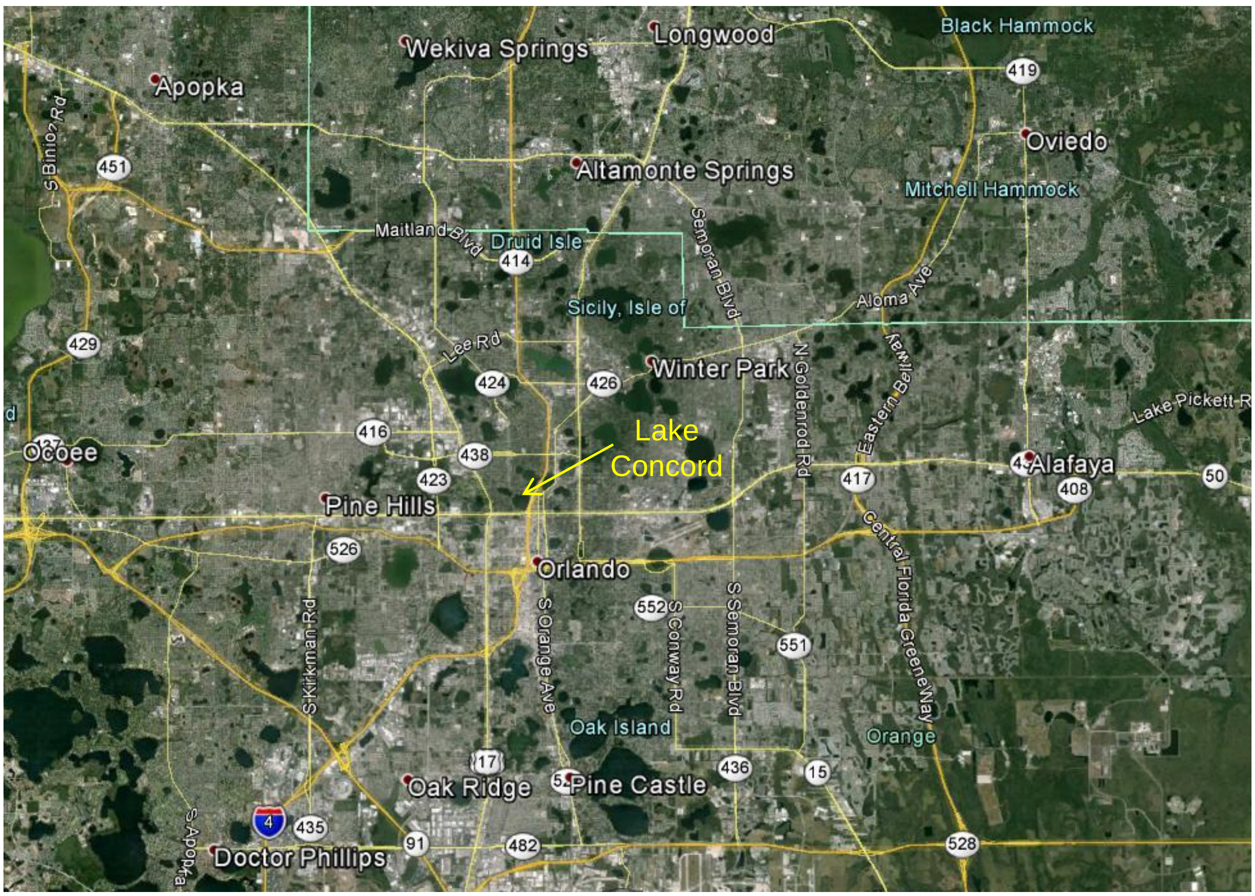


Figure 1-1. Location Map for Lake Concord.

A local vicinity map for Lake Concord is given on Figure 1-2. Lake Concord is a 65-acre waterbody located in the northwest quadrant of the intersection of I-4 and E. Colonial Drive (Highway 50). Lake Dot, a small 5-acre lake, is hydrologically connected to Lake Concord and the two lakes form the headwaters of the Howell Branch Chain-of-Lakes. Lake Concord is a listed TMDL-impaired waterbody in the middle St. Johns River Basin within WBID 2997R, with excess nutrients listed as the cause for impairment. Discharges from Lake Concord flow through a series of downstream lakes, ultimately reaching Lake Jesup on the St. Johns River which has been identified as one of Florida's most degraded lakes. Lake Jesup is also a listed TMDL-impaired waterbody in the middle St. Johns River Basin in WBID 2981 which is impaired for ammonia and nutrients.

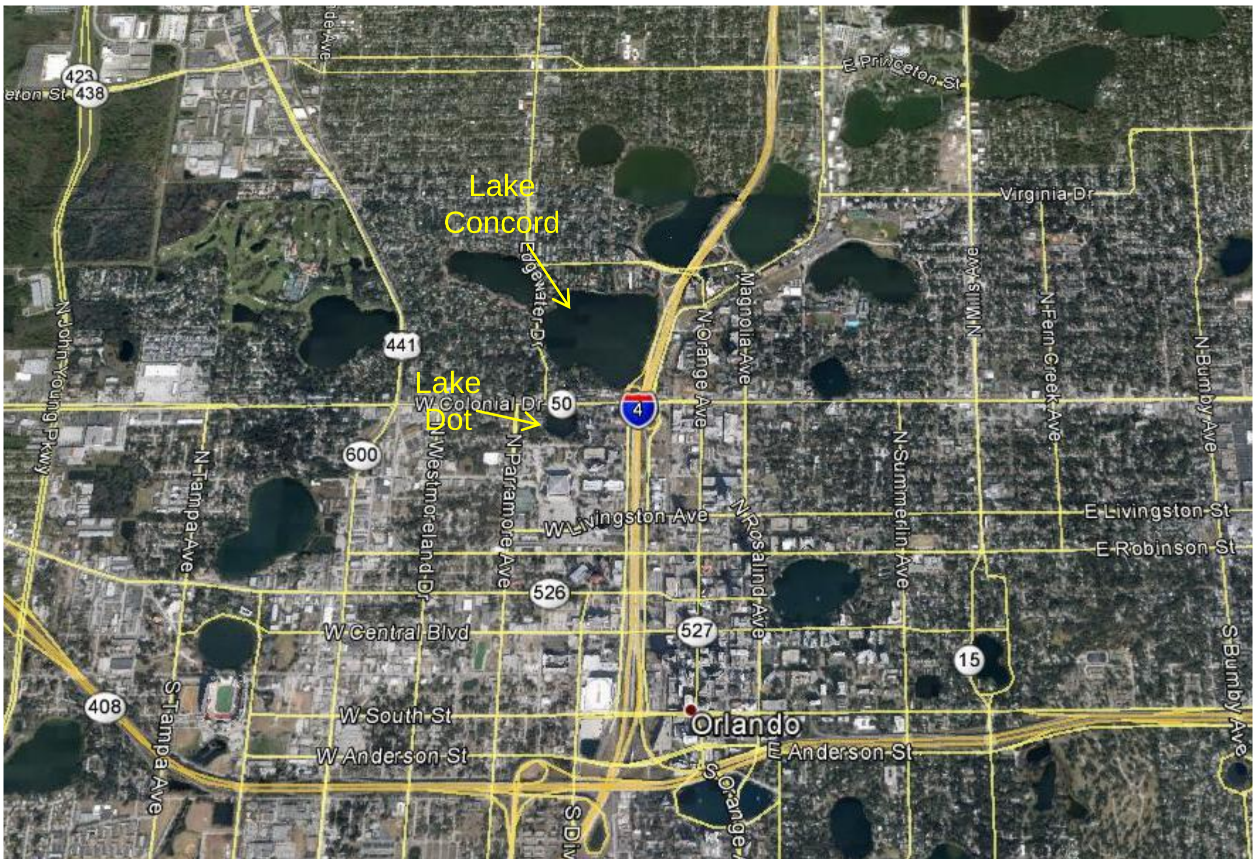


Figure 1-2. Local Vicinity Map for Lake Concord.

1.1 <u>Project Background</u>

During the late-1980s, the City of Orlando constructed a 15,000-seat arena (referred to as the Orlando Centroplex Arena) for sports and entertainment events along with associated parking lots, roadways, and landscaping. The City originally proposed to provide stormwater treatment for the arena facility using an extensive series of underground infiltration chambers. In lieu of the expensive series of chambers, the St. Johns River Water Management District (SJRWMD) issued a permit to the City of Orlando to provide alum stormwater treatment for the runoff discharging from the arena site, with Lake Dot used to collect the generated alum floc.

The arena parcel discharges directly into an existing 108-inch RCP stormsewer which passes beneath the parcel site and provides drainage for approximately 310 acres of commercial, residential, and industrial land uses on the west side of I-4. Runoff generated within these areas flows in a northerly direction, combines with runoff generated from the arena site, and discharges into the south side of Lake Dot. The alum treatment system authorized by SJRWMD is designed to provide alum treatment upstream of the point of discharge into Lake Dot for all runoff generated within the 310-acre watershed, which includes the arena site.

An overview of the Lake Dot alum stormwater treatment system is given on Figure 1-3. All components for the Lake Dot alum stormwater treatment system, including controls and chemical storage tanks, are located in an underground vault in a grassed park area between Lake Dot and W. Concord Street. The runoff flow rate is monitored inside the 108-inch stormsewer, and liquid alum is injected on a flow-proportional basis to maintain the target alum dose regardless of changes in runoff inflow rates. The alum and stormwater mix inside the stormsewer, and the floc generated during treatment of the runoff settles and accumulates in deeper portions of Lake Dot. Lake Dot is a circular sinkhole lake with a maximum water depth of approximately 25-30 ft. Discharges from Lake Dot occur on the south side of the lake through a 77-inch x 121-inch ERCP that runs east along W. Concord Street and intersects with the 5-ft x 6-ft CBC along Hughey Avenue. The Hughey Avenue stormsewer conveys discharges from Lake Dot as well as untreated runoff from downtown Orlando into the southeast lobe of Lake Concord.

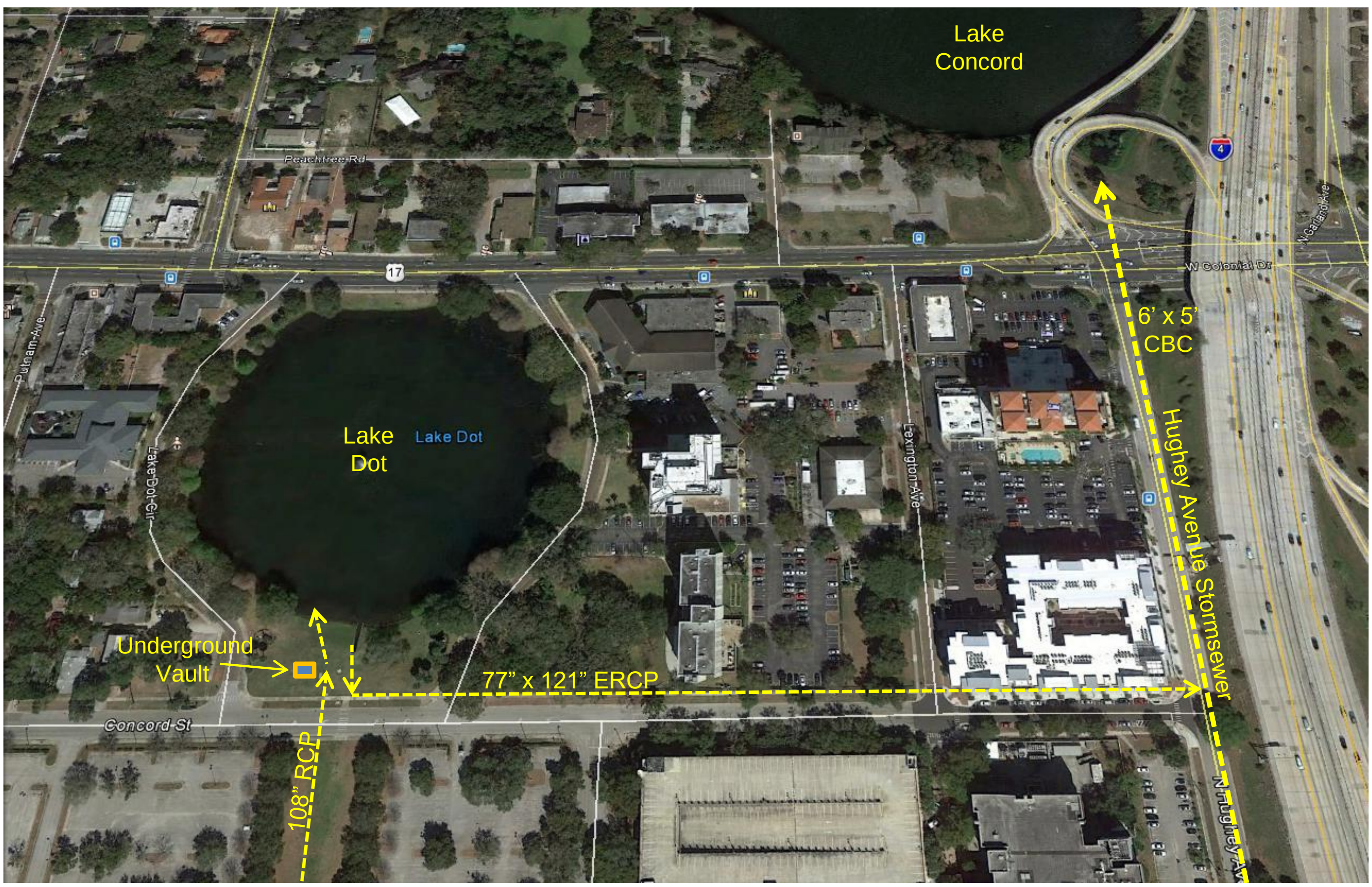


Figure 1-3. Current Lake Dot Alum Treatment System.

1.2 Project Description

A feasibility evaluation for the proposed alum stormwater addition system was conducted by GTC for the City of Orlando with a final report issued in June 2012 titled "Drainage Design Documentation and Calculations – Lake Dot Retrofit". This report provides a discussion of the overall drainage system and proposed modifications to extend a point of flow measurement and alum addition from the existing Lake Dot alum treatment facility to the 5-ft x 6-ft CBC located along Hughey Avenue to provide alum stormwater treatment for a portion of the downtown Orlando area. Underground piping for alum and conduits for flow monitoring and signal cables would be extended from the existing underground Lake Dot alum treatment system eastward along W. Concord Street, south down Revere Avenue, and east along E. Amelia Street to a point of intersection with the Hughey Avenue stormsewer system. The system monitors discharge through the Hughey Avenue stormsewer system and injects liquid alum into the stormsewer on a flow-weighted basis during storm events to provide treatment for untreated runoff generated in portions of downtown Orlando. Construction of the system was completed during 2016.

An annual pollutant loading analysis was included in the June 2012 GTC report which indicates that Sub-basins 200-315, treated by the new alum system expansion, contribute approximately 221 ac-ft/yr of runoff volume, 51 kg/yr of total phosphorus and 427 kg/yr of total nitrogen to Lake Concord. The loading analysis assumed an annual removal efficiency of 85-95% for total phosphorus and 65-75% for total nitrogen using alum treatment and estimated that the alum addition system would remove approximately 43-48 kg/yr of total phosphorus and 278-320 kg/yr of total nitrogen from Lake Concord.

1.3 Project Cost and Funding

This project received partial funding from a Section 319 Grant issued by FDEP. This grant requires performance monitoring to document the effectiveness of the project which is described in this document. A summary of funding activities and sources is given in Table 1-1. The overall project cost to extend the Hughey Avenue alum addition system from the existing Lake Dot facility was $163,778, of which 60% was contributed by a Section 319(h) Grant and 40% contributed by the City of Orlando Stormwater Utility.

TABLE 1-1

FUNDING ACTIVITIES AND SOURCES FOR THE HUGHEY AVENUE ALUM STORMWATER TREATMENT SYSTEM

PROJECT FUNDING ACTIVITY	319(h) AMOUNT	MATCHING CONTRIBUTION	MATCH SOURCE
Construction/BMP Implementation	$ 98,267	$ 68,511	Orlando Stormwater Utility
Total:	**$ 98,267**	**$ 81,889**	Orlando Stormwater Utility
Total Project Cost:	**$ 163,778**	**--**	
Percentage Match	**60%**	**40%**	Orlando Stormwater Utility

1.4 Work Efforts Conducted by ERD

Performance efficiency monitoring was initiated by ERD during May 2015. Automatic stormwater samplers with integral flow meters were installed at locations upstream and downstream of the point of alum addition to document changes in runoff characteristics as a result of the alum treatment process. Field monitoring was initiated during July 2015 and continued until January 2017 to collect flow-weighted samples of treated and untreated runoff discharges through the Hughey Avenue stormsewer. The collected pre- and post-treatment samples were analyzed for general parameters, nutrients, and metals. The results of the field monitoring efforts conducted by ERD are discussed in this report.

This report has been divided into five separate sections. Section 1 contains an introduction to the report and a summary of work efforts performed by ERD. A general description of alum stormwater treatment and details of the Hughey Avenue alum stormwater treatment system is given in Section 2. Section 3 provides a detailed discussion of the methodology used for field and laboratory evaluations. Section 4 includes a discussion of the water quality results, and a summary is provided in Section 5.

SECTION 2

DESCRIPTION OF THE ALUM TREATMENT PROCESS AND SYSTEM

2.1 Alum Stormwater Treatment

2.1.1 Introduction

Since at least Roman times, salts of aluminum have been added to drinking water and surface water to reduce turbidity and improve appearance. Alum has been used extensively as a flocculating agent in the treatment of wastewater for over 100 years. In 1970, Jernelov was apparently the first to use alum to remove phosphorus from the water column of a lake as part of a lake restoration project on Lake Langsjon in Sweden. The first U.S. lake to be treated was Horseshoe Lake which received a surface application of 2.6 mg Al/liter in May 1970. Twelve years later, phosphorus concentrations were still below the pre-treatment level (Garrison and Knauer, 1984).

The addition of alum to water results in the production of chemical precipitates which remove pollutants by two primary mechanisms. Removal of suspended solids, algae, phosphorus, heavy metals and bacteria occurs primarily by enmeshment and adsorption onto aluminum hydroxide precipitate according to the following net reaction:

$$Al^{+3} + 6H_2O \rightarrow Al(OH)_{3(s)} + 3H_3O^+$$

Removal of additional dissolved phosphorus occurs as a result of direct formation of $AlPO_4$ by:

$$Al^{+3} + HnPO_4^{n-3} \leftrightarrow AlPO_{4(s)} + nH^+$$

The aluminum hydroxide precipitate, $AlOH_3$, is a gelatinous floc which attracts and adsorbs colloidal particles onto the growing floc, thus clarifying the water. Phosphorus removal or entrapment can occur by several mechanisms, depending on the solution pH. Inorganic phosphorus is also effectively removed by adsorption to the $AlOH_3$ floc. Removal of particulate phosphorus is most effective in the pH range of 6-8 where maximum floc occurs (Cooke and Kennedy, 1981). At higher pH values, OH^- begins to compete with phosphate ions for aluminum ions, and aluminum hydroxide-phosphate complexes begin to form. At lower pH values and higher inorganic phosphorus concentrations, the formation of aluminum phosphate ($AlPO_4$) is favored.

2.1.2 History of Alum Stormwater Treatment

In 1985, a lake restoration project was initiated at Lake Ella, a shallow, 13.3 acre hypereutrophic lake in Tallahassee, Florida, which receives untreated stormwater runoff from approximately 163 acres of highly impervious urban watershed areas. Initially, conventional stormwater treatment technologies, such as retention basins, exfiltration trenches and filter systems, were considered for reducing available stormwater loadings to Lake Ella in an effort to improve water quality within the lake. Since there was no available land surrounding Lake Ella that could be used for construction of traditional stormwater management facilities, and the cost of purchasing homes and businesses to acquire land for construction of these facilities was prohibitive, alternate stormwater treatment methods were considered.

Chemical treatment of stormwater runoff was evaluated using various chemical coagulants, including aluminum sulfate, ferric salts and polymers. Aluminum sulfate (alum) consistently provided the highest removal efficiencies and produced the most stable end product. In view of successful jar test results on runoff samples collected from the Lake Ella watershed, the design of a prototype alum injection stormwater system was completed. Construction of the Lake Ella alum stormwater treatment system was completed in January 1987, resulting in a significant improvement in water quality within the lake.

The alum precipitate formed during coagulation of stormwater can be allowed to settle in receiving waterbodies, collected in dedicated settling basins, or discharged to the sanitary sewer system. Alum precipitates are exceptionally stable in sediments and will not redissolve due to changes in redox potential or pH under conditions normally found in surface waterbodies. Over time, the freshly precipitated floc ages into even more stable complexes, eventually forming gibbsite.

The solubility of dissolved aluminum in the treated water is regulated entirely by pH-based chemical equilibrium. As long as the pH of the treated water is maintained within the range of 5.5-7.5, dissolved aluminum concentrations will be minimal. In most instances, the concentration of dissolved aluminum in the treated water will be less than the concentration in the raw untreated water due to adjustment of pH into the range of minimum solubility.

Alum treatment of stormwater runoff has now been used as a viable stormwater treatment alternative in urban areas for over 30 years. Over that time, a large amount of information has been collected related to optimum system configuration, water chemistry, sediment accumulation and stability, benthic impacts, construction and operation costs, comparisons with other stormwater management techniques, and floc collection and disposal. A summary of current knowledge in these areas is given in the following sections.

2.1.3 System Design and Configuration

Once alum has been identified as an option in a stormwater retrofit project, extensive laboratory testing must be performed to verify the feasibility of alum treatment and to establish process design parameters. The feasibility of alum treatment for a particular stormwater stream is evaluated in a series of laboratory jar tests conducted on representative runoff samples collected from the project watershed area. This extensive laboratory testing is an essential part of the evaluation process necessary to determine design, maintenance and operational parameters such as the optimum coagulant dose required to achieve the desired water quality goals, chemical pumping rates and pump sizes, the need for additional chemicals to buffer receiving water pH, post-treatment water quality characteristics, floc formation and settling characteristics, required detention time for treated water to provide maximum settling, floc accumulation, annual chemical costs and storage requirements, and maintenance procedures. In addition to determining the optimum coagulant dose, jar tests can also be used to determine floc strength and stability, required mixing intensity and duration, and determine design criteria for settling basins.

In a typical alum stormwater treatment system, alum is injected into the stormwater flow on a flow-proportioned basis so that the same dose of alum is added to the stormwater flow regardless of the discharge rate. A variable speed chemical metering pump is typically used as the injection pump. The operation of the injection pump is regulated by a flow meter device attached to each incoming stormwater line to be treated. Measured flow from each stormwater flow meter is transformed into a 4-20 mA electronic signal which instructs the metering pump to inject alum according to the measured flow of runoff discharging through each individual stormsewer line. Mixing of the alum and stormwater occurs as a result of natural turbulence in the stormsewer line or artificial turbulence generated using aeration or addition of a high-pressure water stream.

Mechanical components for the alum stormwater treatment system, including chemical metering pumps, stormsewer flow meters and electronic controls, are typically housed in a central facility which can be constructed as an above-ground or below-ground structure. A 5,000-8,000 gallon alum storage tank is typically used for bulk alum storage. Alum feed lines and electrical conduits are run from the central facility to each point of alum addition and flow measurement. Alum injection points can be located as far as 2,000-3,000 ft or more from the central pumping facility.

2.1.4 Water Chemistry

Construction and operation of alum stormwater treatment systems has resulted in significant improvements in water quality for treated waterbodies. The degree of observed improvement in water quality is directly related to the percentage of annual hydraulic inputs treated by the alum stormwater treatment system. A comparison of pre- and post-modification water quality characteristics for typical alum stormwater treatment systems, including Lake Ella, Lake Dot (which provide treatment for approximately 95-96% of the annual runoff inputs entering these lake systems), and Lake Osceola (which provides treatment for only 9% of the annual runoff inputs entering this lake system) is given in Table 2-1.

TABLE 2-1

COMPARISON OF PRE- AND POST-MODIFICATION WATER QUALITY CHARACTERISTICS FOR TYPICAL ALUM STORMWATER TREATMENT SYSTEMS

PARAMETER	UNITS	LAKE ELLA		LAKE DOT		LAKE OSCEOLA	
		Before (1974-85)	**After (1/88-5/90)**	**Before (1986-88)**	**After (3/89-8/91)**	**Before (6/91-6/92)**	**After (2/93-12/96)**
# of Samples	--	15	11	5	15	12	46
pH	s.u.	7.41	6.43	7.27	7.17	8.22	7.63
Diss. O_2 (1 m)	mg/l	3.5	7.4	6.6	8.8	8.8	8.8
Total N	µg/l	1876	417	1545	696	892	856
Total P	µg/l	232	26	351	24	37	26
BOD	mg/l	41	3.0	16.8	2.7	4.4	3.4
Chlorophyll-a	mg/m^3	180	5.1	55.8	6.3	24.8	21.7
Secchi Disk Depth	m	0.5	> 2.2	< 0.8	2.5	1.1	1.2
Diss. Al	µg/l	--	44	--	65	18	51
Florida TSI Value	--	98 (Hypereutrophic)	47 (Oligotrophic)	86 (Hypereutrophic)	42 (Oligotrophic)	61 (Eutrophic)	56 (Mesotrophic)
Lake Area	--	5.38 ha (13.3 ac)		2.4 ha (5.9 ac)		22.4 ha (55.4 ac)	
Watershed Area	--	63.7 ha (57 ac)		123 ha (305 ac)		61.5 ha (153 ac)	
Percent of Annual Hydraulic Inputs Treated	%	95		96		9	

Significant improvements in dissolved oxygen were observed in both Lake Ella and Lake Dot. Alum treatment of stormwater runoff resulted in a 78% reduction in total nitrogen concentrations in Lake Ella, with a 55% reduction in Lake Dot and a 4% reduction in Lake Osceola where only a small portion of the annual runoff inputs are treated. Total nitrogen removal is primarily a result of reducing concentrations of dissolved organic nitrogen and particulate nitrogen since alum is generally ineffective in reducing concentrations of inorganic nitrogen species, such as ammonia or NO_x. Alum stormwater treatment results in a substantial reduction in measured concentrations of orthophosphorus and total phosphorus in each of the three lake systems, with total removals of 89%, 93% and 30% for Lake Ella, Lake Dot and Lake Osceola, respectively. Alum stormwater treatment also reduced in-lake concentrations of BOD in each of the three lake systems, with a reduction of 93% in Lake Ella and 84% in Lake Dot.

Alum stormwater treatment appears to be extremely effective in reducing concentrations of chlorophyll-a in receiving waterbodies, with a reduction of 97% in Lake Ella, 89% in Lake Dot and 13% in Lake Osceola. Reductions in measured concentrations of chlorophyll-a occur as a result of enmeshment and precipitation of algal particles within the water column of the lake by alum floc as well as phosphorus limitation created by low levels of available phosphorus in the water column. Substantial increases in Secchi disk depth were observed in Lake Ella and Lake Dot, and to a lesser extent in Lake Osceola, with improvements of 340% in Lake Ella, 212% in Lake Dot and 9% in Lake Osceola. Based upon the Florida TSI Index (Brezonik, 1984), Lake Ella and Lake Dot have been converted from hypereutrophic to oligotrophic status, with a conversion from eutrophic to mesotrophic in Lake Osceola.

A graphical history of total phosphorus concentrations in Lake Lucerne, which was retrofitted with an alum stormwater treatment system in June 1993 that provides treatment for approximately 82% of the annual runoff inputs into the lake, is given in Figure 2-1. Prior to construction of the alum stormwater treatment system, total phosphorus concentrations in Lake Lucerne fluctuated widely, with a mean concentration of approximately 100 μg/l. Following start-up of the alum treatment system, total phosphorus concentrations began to decline steadily, reaching equilibrium concentrations of approximately 20-40 μg/l. A slight increase in total phosphorus concentrations is observed during the last half of 1995 when the system was off-line due to lightning damage. When system operation resumed in June 1996, total phosphorus concentrations returned to equilibrium values of approximately 20 μg/l.

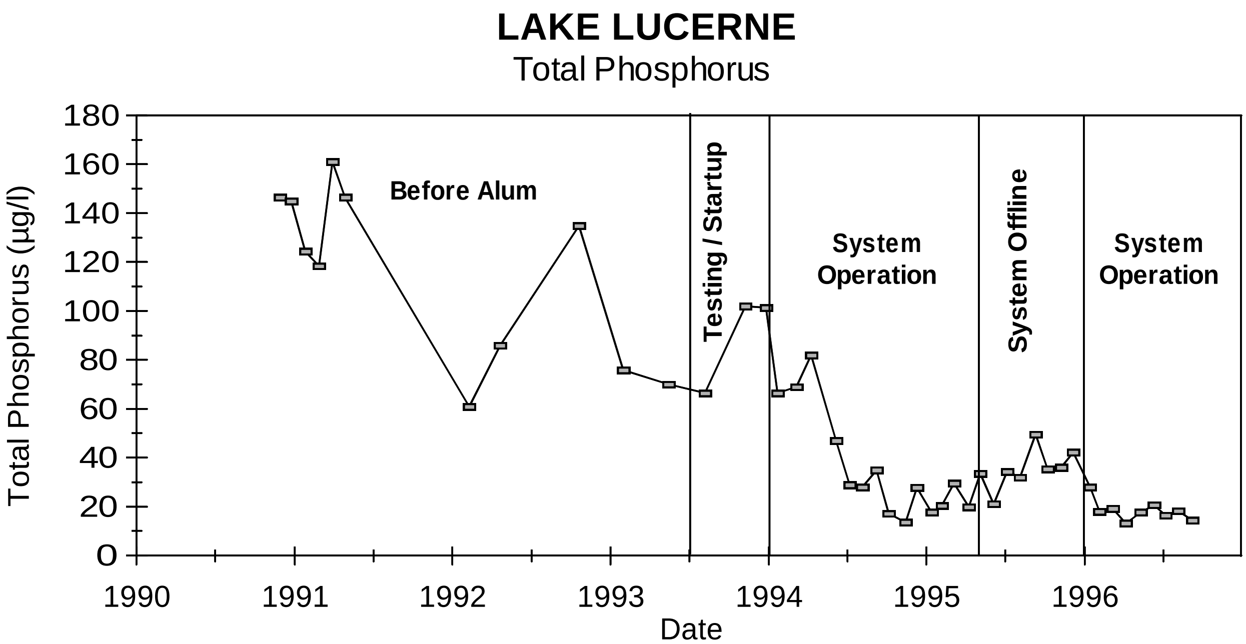


Figure 2-1. Trends in Total Phosphorus Concentrations in Lake Lucerne Before and After Alum Treatment of Stormwater Runoff.

In general, measured concentrations of heavy metals have been extremely low in value in all waterbodies retrofitted with alum stormwater treatment systems, with no violations of heavy metal standards observed in any of these lake systems. In addition, measured levels of dissolved aluminum have also remained low in each lake system. Mean dissolved aluminum concentrations for Lake Ella, Lake Dot and Lake Osceola have averaged 44 μg/l, 65 μg/l and 51 μg/l, respectively. Although there is no standard for dissolved aluminum in the State of Florida, the U.S. EPA has recommended a long-term average of 87 μg/l for protection of all species present in the U.S. The solubility of dissolved aluminum is regulated almost exclusively by pH. As long as the pH of the treated water can be maintained in the range of 6.0-7.5 during the treatment process, dissolved aluminum concentrations will remain at minimal levels.

2.1.5 Floc Accumulation

Laboratory investigations have been conducted on stormwater runoff collected from a wide range of land uses typical of urban areas to quantify the amount of alum floc generated as a result of alum treatment of stormwater runoff at various treatment doses. After initial formation, alum floc appears to consolidate rapidly for a period of approximately 6-8 days, consolidating to approximately 20% of the initial floc volume. Additional consolidation appears to occur over a settling period of approximately 30 days, after which collected sludge volumes appear to approach maximum consolidation (Harper, 1990).

Estimates of maximum anticipated sludge production, based upon literally hundreds of laboratory tests involving coagulation of stormwater runoff with alum at various doses, and based upon a consolidation period of approximately 30 days, is given in Table 2-2. At alum doses typically used for treatment of stormwater runoff, ranging from 5-10 mg/l as Al, sludge production is equivalent to approximately 0.16-0.28% of the treated runoff flow. Sludge production values listed in Table 2-2 reflect the combined mass generated by alum floc as well as solids settling from the stormwater sample.

TABLE 2-2

ANTICIPATED PRODUCTION OF ALUM SLUDGE FROM ALUM TREATMENT OF STORMWATER AT VARIOUS DOSES

ALUM DOSE (mg/l as Al)	SLUDGE PRODUCTION[1]		
	As Percent of Treated Flow	per 1000 m^3 Treated	Per 10^6 Gallons Treated
5	0.16	1.6 m^3	214 ft^3
7.5	0.20	2.0 m^3	268 ft^3
10	0.28	2.8 m^3	374 ft^3

1. Based on a minimum settling time of 30 days

Field investigations have also been performed in lake systems receiving alum treated stormwater runoff to document the accumulation rate of alum floc within the sediments of the lake. This documentation has been conducted primarily by collection and visual inspection of sediment core samples collected in clear acrylic tubes or split-spoon core collectors at selected monitoring sites in each lake. A comparison of observed and predicted floc accumulation rates in lake systems receiving stormwater treatment is given in Table 2-3. Each of the listed lakes has been receiving alum treatment for many years. The primary predicted settling area for floc accumulation was determined by evaluating lake bottom topography and stormsewer inflow characteristics. Predicted floc accumulation rates are based upon the anticipated floc production rates summarized in Table 2-2.

TABLE 2-3

COMPARISON OF OBSERVED AND PREDICTED FLOC ACCUMULATION RATES IN LAKE SYSTEMS WITH ALUM STORMWATER TREATMENT

LAKE	PREDICTED SETTLING AREA	PREDICTED ACCUMULATION RATE (cm/yr)	OBSERVED ACCUMULATION RATE
Lake Ella	50% of lake bottom	1 cm/yr	0.33 cm/yr
Lake Lucerne	areas 10 ft or deeper	3.3 cm/yr	None
Lake Osceola	50% of lake bottom	0.5 cm/yr	None

Annual floc production in Lake Ella was predicted to be approximately 1 cm/yr over 50% of the lake bottom. However, floc accumulation evaluations performed in 1990 indicate an observed accumulation rate of approximately 0.33 cm/yr, approximately one-third of the predicted accumulation rate. The reduced observed accumulation rate is thought to be a result of additional floc consolidation over time and incorporation of the alum floc into the existing sediments. The observed post-treatment floc accumulation rate in Lake Ella is similar to the pre-treatment sediment accumulation rate in the lake resulting from the extremely high algal production prior to the lake restoration efforts in 1985.

Sediment accumulation in Lake Lucerne was anticipated to occur in areas 10 ft or deeper, with a predicted accumulation of 3.3 cm/yr. However, no sediment accumulation was observed at any of the 10 fixed monitoring locations within the lake during an initial 2-year monitoring program. A similar conclusion has been reached in Lake Osceola which had no visible floc accumulation after approximately five years of alum stormwater treatment. Both Lake Lucerne and Lake Osceola appear to be incorporating alum floc into the existing sediments with no visible surface floc layer.

2.1.6 Sediment Stability

A large amount of research has been conducted to evaluate the stability of phosphorus and heavy metals in sediments receiving alum floc. These evaluations have been performed using a variety of methodologies, including sediment phosphorus speciation, incubation experiments, and analysis of sediment pore water characteristics.

Fractionation of inorganic sediment phosphorus has been performed on both pre- and post-alum treatment sediment samples for numerous lakes which have received whole-lake alum treatments for sediment inactivation. A modified Chang and Jackson procedure was developed by ERD and used for each speciation procedure which divides phosphorus associations into saloid, defined as soluble plus easily exchangeable phosphorus, iron phosphate and aluminum phosphate. Phosphorus associations with saloid and iron phosphate are generally considered to be potentially available within the sediments for recycle back into the water column, particularly under a reduced environment. Sediment associations with aluminum are typically considered to be inert and stable under a wide range of pH and redox conditions.

In all lake systems where phosphorus fractionation has been evaluated, the introduction of alum floc into the sediments has resulted in a substantial reduction in both saloid and iron-bound associations and an increase in aluminum-bound associations, indicating that phosphorus sediment associations have become more stable following introduction of alum floc. As an example, a comparison of pre- and post-treatment phosphorus fractions in Lake Ella is presented graphically in Figure 2-2. This figure presents post-treatment phosphorus associations as a fraction of pre-treatment concentrations for soluble, iron and aluminum associations. Values presented in this figure represent the results of sediment cores collected in Lake Ella after approximately 2.5 years of treatment system operation.

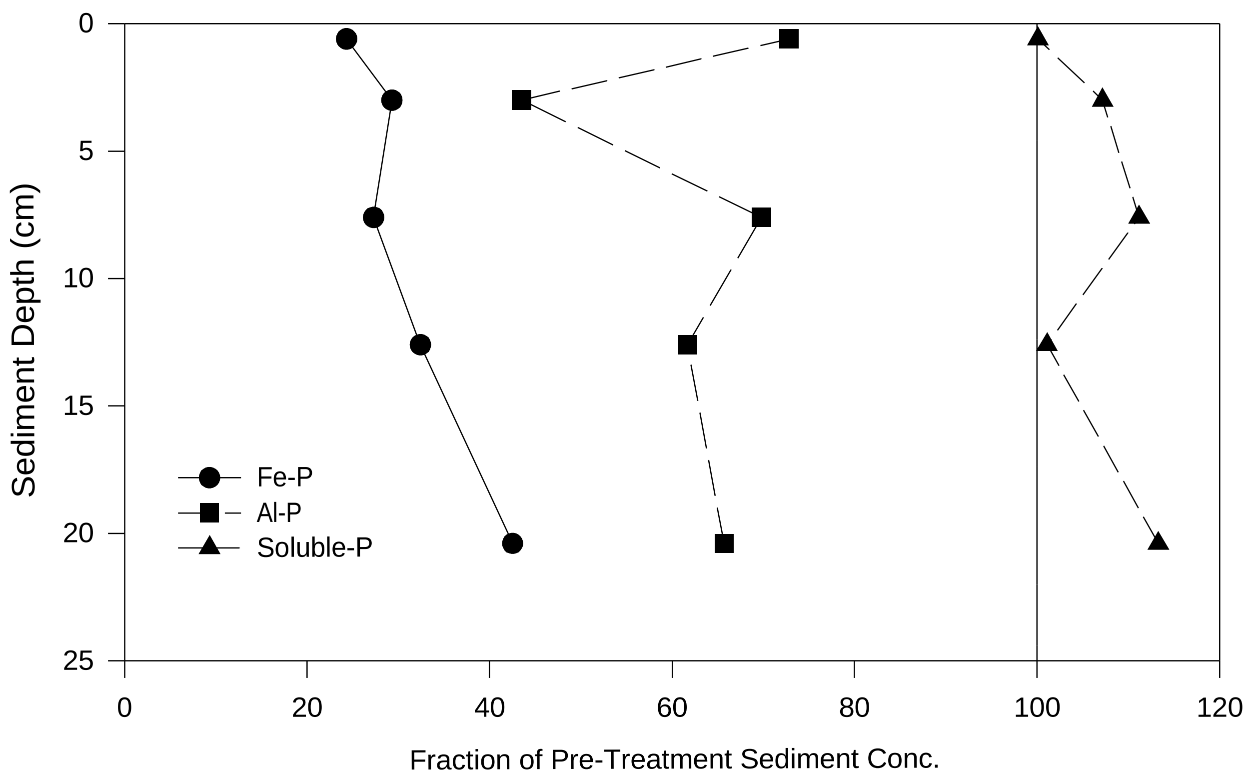


Figure 2-2. Comparison of Pre- and Post-Alum Treatment Phosphorus Fractionation in Lake Ella.

Overall, sediment soluble phosphorus concentrations have been reduced to only 60% of the values found in the pre-treatment sediments. Phosphorus associations with iron in post-treatment sediments have been reduced to approximately 30% of the values found prior to alum treatment. The sediment profile for iron-bound phosphorus presented in Figure 2-2 suggests that the effects of aluminum floc within the sediments has altered sediment phosphorus associations as deep as 15-25 cm within the sediment, although changes in sediment fractions are most apparent in the top 10 cm of the sediments.

In contrast, phosphorus associations with aluminum increased in alum-treated sediments by 7% in the 1-5 cm layer, 12% in the 5-10 cm layer, 4% in the 10-15 cm layer, and 14% in the 15-25 cm layer. The observed reductions in both saloid and iron-bound associations, combined with the increase in aluminum phosphorus associations, suggests that phosphorus in post-treatment sediments is substantially more stable than phosphorus in pre-treatment sediments. Since aluminum phosphorus associations are virtually immune to changes in redox potential and pH, which can cause iron phosphorus associations to break apart with a subsequent release of phosphorus in soluble forms, the conversion to aluminum phosphate forms indicates that the probability of phosphorus being released from post-treatment sediments is substantially reduced compared with pre-treatment sediments.

Laboratory experiments have also been conducted on sediment samples collected from multiple lakes to evaluate the influence of pH and redox potential on the stability of heavy metals in alum treated sediments. An incubation apparatus was constructed which allows a circulating sediment slurry to be maintained under precise controlled conditions of pH and redox potential. Samples can then be collected from the sediment slurry to evaluate the solubility of heavy metals within the sediments under various pH and redox conditions. Experiments were conducted at selected pH values typical of values within the sediments of each lake, as well as redox potentials from highly reduced to highly oxidized.

The results of incubation experiments conducted on pre- and post-sediment samples collected from Lake Ella for chromium, copper, lead and zinc are given in Figure 2-3. Sediment release is substantially less in alum treated samples than observed in pre-treatment samples collected from the lake under a wide range of pH conditions and under redox potentials ranging from highly oxidized to highly reduced. Alum floc is capable of tightly binding heavy metals within the sediments, substantially reducing the potential toxicity of in-place sediments. Similar results were obtained for copper, nickel and lead. As alum floc ages, the freshly precipitated $AlOH_3$ forms into a series of ringed structures which are extremely stable and which tightly bind phosphorus and heavy metals in a crystalline lattice network. These phosphorus and metal associations, once combined with alum, are apparently inert to changes in pH and redox potential normally observed in a natural lake system.

The impact of alum floc on lake sediments has also been evaluated by comparison of pre- and post-treatment sediment pore water concentrations in Lake Ella, Lake Lucerne and Lake Cannon, as well as Lake Davis and Lake Conine which have received whole-lake alum applications. A comparison of sediment pore water concentrations in Lake Lucerne before and after stormwater treatment is given in Table 2-4. Post-treatment samples reflect approximately four years of operation of the alum stormwater treatment system. Introduction of alum floc into the lake sediments has significantly reduced measured concentrations of total nitrogen, total phosphorus and each of the listed heavy metals. Pore water concentrations of total aluminum have also been reduced as a result of replacing pre-treatment aluminum associations with stable $AlOH_3$ associations. The reduced pore water concentrations indicated in Table 2-4 provide an enhanced environment for sediment-dwelling organisms.

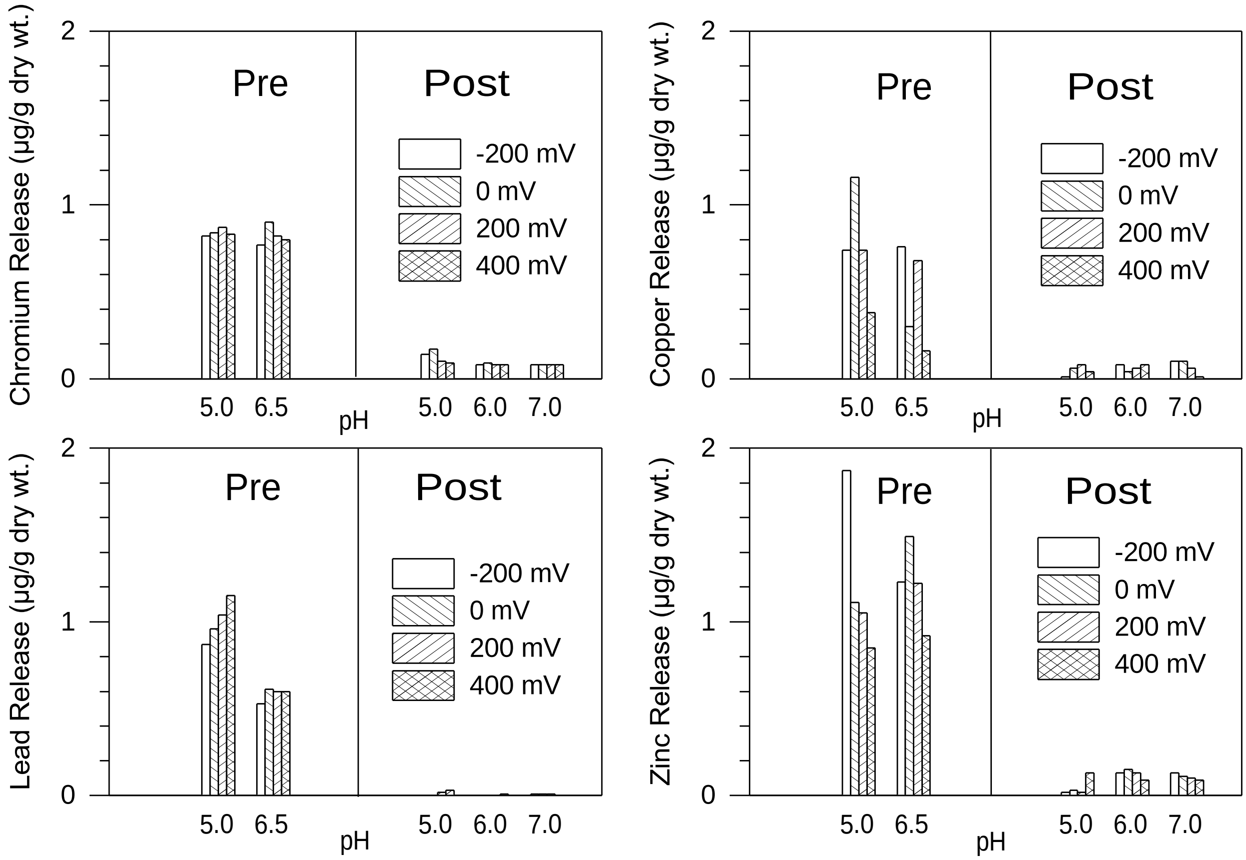


Figure 2-3. Comparison of Sediment-Metal Phase in Pre- and Post-Treatment Sediments in Lake Ella.

TABLE 2-4

COMPARISON OF SEDIMENT PORE WATER CONCENTRATIONS IN LAKE LUCERNE BEFORE AND AFTER ALUM STORMWATER TREATMENT

PARAMETER	UNITS	PRE-TREATMENT SAMPLES (12/92)	POST-TREATMENT SAMPLES (5/97)	PERCENT CHANGE
Total N	µg/l	9978	5846	-41
Total P	µg/l	531	189	-64
Total Al	µg/l	417	123	-70
Total Cu	µg/l	21	6	-71
Total Fe	µg/l	1389	50	-96
Total Ni	µg/l	17	8	-53
Total Mn	µg/l	314	36	-89
Total Zn	µg/l	80	12	-85

2.1.7 Benthic Impacts

Monitoring of benthic macroinvertebrates has been conducted on an annual basis in many of the lake systems currently receiving alum stormwater treatment. Based upon this available data, long-term trends in benthic macroinvertebrate populations are now becoming apparent. Lake Mizell has received periodic addition of alum floc from multiple alum stormwater treatment systems since the mid-1990s. In addition, during 1998, Lake Mizell received a whole-lake alum treatment for sediment inactivation. A comparison of pre-treatment and post-treatment macroinvertebrate assemblages at monitoring Site 1 in Lake Mizell is given on Table 2-5. Site 1 is located in the northern portion of Lake Mizell which receives substantial alum inputs from an on-going alum stormwater treatment process in addition to the whole-lake alum treatment.

TABLE 2-5

COMPARISON OF DOMINANT PRE-TREATMENT AND POST-TREATMENT MACROINVERTEBRATE ASSEMBLAGE AT SITE 1 IN LAKE MIZELL

TAXA	1/28/97		1/29/98		1/27/99		1/31/00	
	Mean (#/m^2)	%	Mean (#/m^2)	%	Mean (#/m^2)	%	Mean (#/m^2)	%
Chaborus punctipennis	4664	77.9	253	41.7	30	2.0	4502	66.3
Chironomus sp.	647	10.8	74	12.2	1095	73.2	119	1.7
Limnodrilus hoffmeisteri	396	6.6	--	--	74	4.9	592	8.7
Procladius bellus	15	0.2	148	24.4	--	--	252	3.7
Tanytarsus sp.	30	0.5	58	9.6	--	--	--	--
Ablabesmyia rhamphe group	--	--	44	7.2	--	--	--	--
Cladopelma sp.	--	--	15	2.2	--	--	30	0.4
Hyalella azteca	57	0.9	15	2.2	--	--	296	4.4
Dero Nivea	--	--	--	--	237	15.8	74	1.1
Dero Trifida	--	--	--	--	15	1.0	30	0.4
Unid. *Ceratopogonidae*	--	--	--	--	30	2.0	15	0.2
Thienemanniella sp.	--	--	--	--	15	1.0	--	--
Clyptotendipes paripes	--	--	--	--	--	--	726	10.7
Pristina sp.	--	--	--	--	--	--	59	0.9
Cryptochironomus sp.	--	--	--	--	--	--	59	0.2
Ablabesmyia peleensis	--	--	--	--	--	--	15	0.2
Chaetogastor diaphanus	--	--	--	--	--	--	15	0.2

Prior to the use of alum for stormwater treatment and sediment inactivation, the macroinvertebrate assemblage in Lake Mizell was dominated primarily by *Chaoborus punctipennis* and *Chironomus* sp., both of which are indicators of polluted systems. However, after completion of the whole-lake alum treatment, additional macroinvertebrate communities began to become re-established in Lake Mizell, although the overall organism density was reduced compared with the pre-treatment assemblage. Beginning approximately two years following the alum treatment, population densities began to increase along with introduction of more clean water indicator-type organisms. Approximately three years after the whole-lake alum treatment, the number of benthic species in Lake Mizell had more than doubled and organism densities were substantially greater than existed prior to the use of alum within the lake.

A graphical comparison of pre- and post-treatment macroinvertebrate assemblages in Lake Mizell is given on Figure 2-4. Macroinvertebrate density, mean taxa, species diversity, and evenness increased after approximately three years in the north lobe which receives alum floc from both stormwater treatment as well as a whole-lake sediment inactivation process. Introduction of the alum floc into the sediments appears to improve conditions for the microorganisms, resulting in enhancements in the macroinvertebrate assemblages.

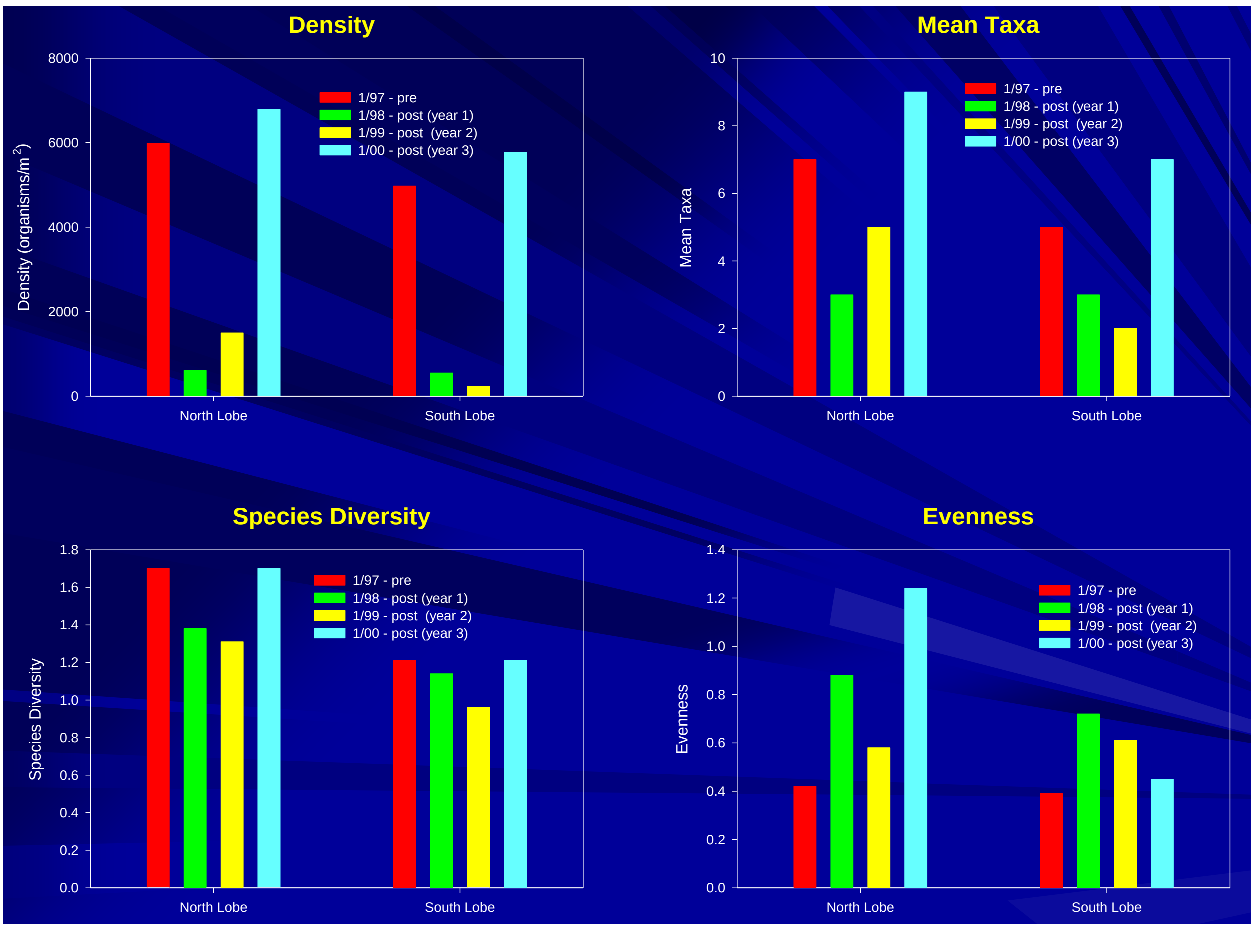


Figure 2-4. Comparison of Pre- and Post-Treatment Macroinvertebrate Assemblages in Lake Mizell.

2.1.8 Comparison with Other Stormwater Treatment Alternatives

In general, removal efficiencies obtained with alum stormwater treatment exceed removal efficiencies obtained using dry retention or wet detention stormwater management systems for many parameters. A comparison of treatment efficiencies for common stormwater management systems is given in Table 2-6 (Harper, 1995). Estimated removal efficiencies for alum treatment exceed removal efficiencies achieved in dry retention for total phosphorus and TSS, but removal efficiencies for total nitrogen appear to be slightly lower than those achieved in dry retention. In general, dry retention is considered to be the most effective common stormwater management technique in use today. Removal efficiencies achieved with alum treatment appear to exceed removal efficiencies which can be obtained using wet detention or dry detention.

TABLE 2-6

COMPARISON OF TREATMENT EFFICIENCIES FOR COMMON STORMWATER MANAGEMENT SYSTEMS

TYPE OF SYSTEM	ESTIMATED REMOVAL EFFICIENCIES (%)			
	Total N	Total P	TSS	BOD
Dry Retention (0.50-inch)	65	65	65	65
Wet Detention	20-30	60-70	85	50-60
Dry Detention	10-20	20-40	60-80	30-50
Alum Treatment	30-50	> 90	> 95	50-60

2.1.9 Floc Collection and Disposal

Many alum stormwater treatment systems allow for floc settling directly in receiving waterbodies, and only beneficial aspects of alum floc accumulation have been observed to date. However, some alum treatment system designs emphasize collection and disposal of floc rather than allowing floc accumulation within surface water systems. Several innovative designs have been developed for collection and disposal of alum floc. Where possible, sump areas have been constructed to provide a basin for accumulation and collection of alum floc. The accumulated floc can then be pumped out of the sump area, using either manual or automatic techniques, on a periodic basis. Several current treatment systems provide for automatic floc disposal into the sanitary sewer system at a slow controlled rate. Since alum floc is virtually inert and has a consistency similar to that of water, acceptance of alum floc on a periodic basis poses no operational problem for wastewater treatment facilities.

2.2 Hughey Avenue System Design

The Hughey Avenue stormsewer system receives runoff from approximately 160 acres of downtown Orlando consisting primarily of commercial and highway land uses. Much of the drainage basin area was constructed prior to implementation of regulations requiring treatment of stormwater in Florida, and introduces largely untreated runoff into the southeast lobe of Lake Concord.

An overview of sub-basin areas discharging to Lake Dot and the Hughey Avenue stormsewer system is given on Figure 2-5 (GTC, 2010). Sub-basins 100-175 are all located in the Lake Dot drainage basin, most of which discharge to the lake through the existing 108-inch RCP that currently receives alum stormwater treatment. Sub-basins discharging directly to the Hughey Avenue stormsewer system are identified as 200s, 300s, and 400s on Figure 2-5, most of which have no existing on-site stormwater treatment systems.

An overview of the alum treatment system extension from Lake Dot to Hughey Avenue is given on Figure 2-6, and locations for flow measurement and alum addition are shown on Figure 2-7. Manhole structures were installed on top of the 5-ft x 6-ft CBC and 2-ft x 3-ft openings were cut into the top of the CBC to allow access for a point of flow measurement and point of alum addition as well as provide a platform for installation of sampling equipment to conduct post-treatment monitoring. All controls, pumps, and instrumentation necessary for injection of alum into the Hughey Avenue stormsewer system are located in the existing underground Lake Dot alum system vault. Construction drawings for the alum treatment system extension are provided in Appendix A.

The alum stormwater treatment system expansion provides treatment for all discharges into the Hughey Avenue stormsewer system, originating from Sub-basins 200-315 (indicated on Figure 2-5), with an overall area of approximately 86.8 acres of residential, commercial, and industrial land use. Hughey Avenue sub-basins 400-430 discharge into the Hughey Avenue system downstream of the point of alum addition and are not treated by the alum injection system. An overview of basin areas treated by the Hughey Avenue system is given on Figure 2-8.

Photographs inside the Hughey Avenue stormsewer system are given on Figure 2-9. The point of intersection of the 5-ft x 6-ft CBC and the 54-inch RCP, upstream of the point of alum addition, is illustrated on Figure 2-9a. Portions of the 5-ft x 6-ft CBC downstream from the point of alum addition are shown on Figure 2-9b.

Photographs of selected treatment system components for the Hughey Avenue alum treatment system are given on Figure 2-10. The SonTek flow meter device is illustrated on Figure 2-10a. This device provides highly accurate measurements of discharge using the area-velocity method. The SonTek probe conducts simultaneous measurements of water velocity and water depth. The depth measurement is used, along with the geometry of the channel, to calculate the cross-sectional area of flow, and the velocity is used to calculate the discharge using the Continuity Equation:

$$Q = V \bullet A$$

where: Q = discharge (cfs)

A = cross-sectional area of flow (ft^2)

V = velocity (fps)

Figure 2-5. Sub-basin Areas Discharging to Lake Dot and the Hughey Avenue Stormsewer Site.

Figure 2-6. Overview of Hughey Avenue Alum Treatment System.

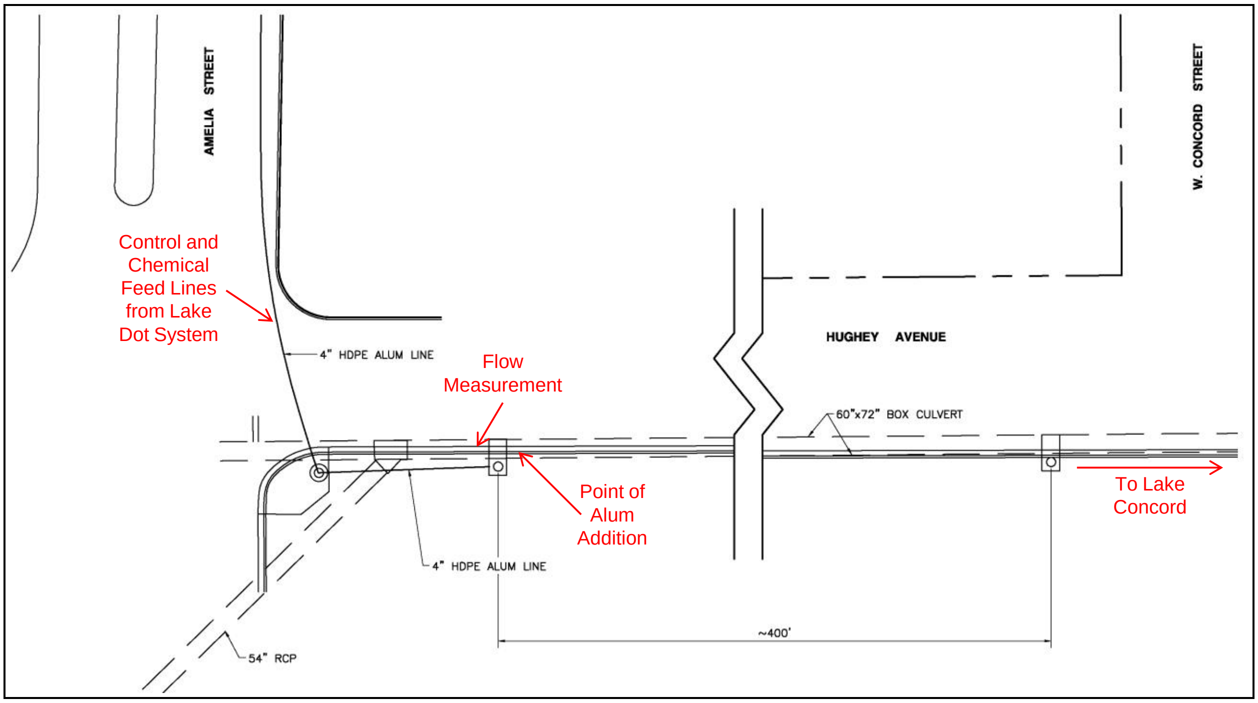


Figure 2-7. Overview of Locations for Flow Measurement and Alum Addition.

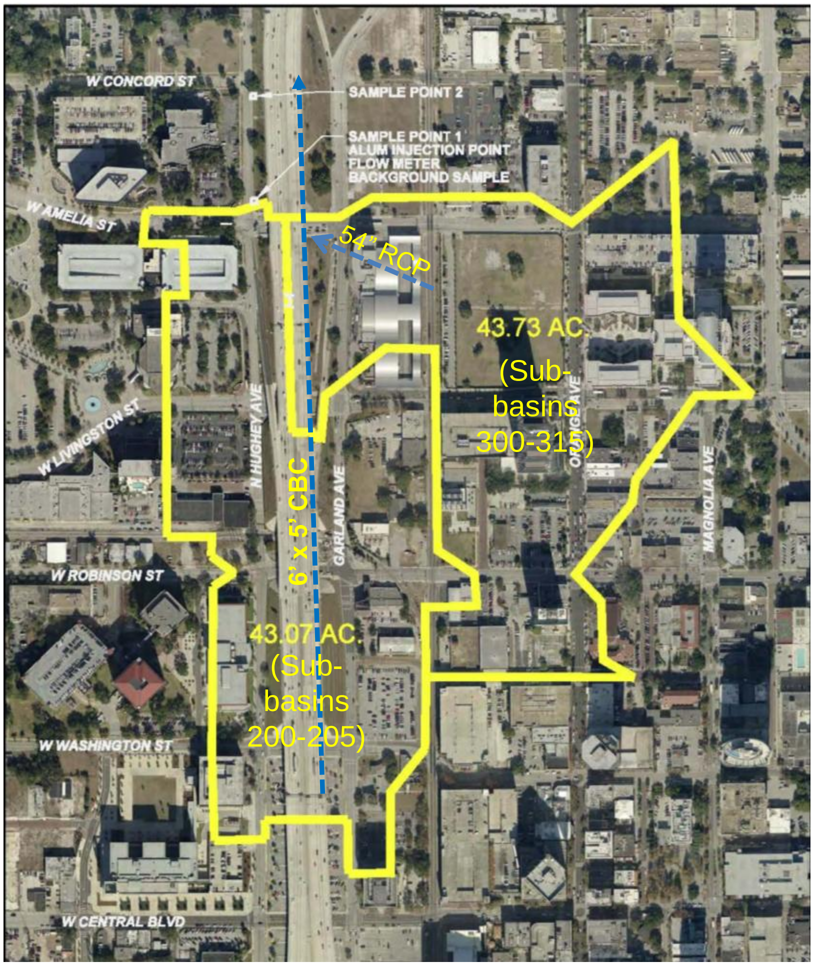


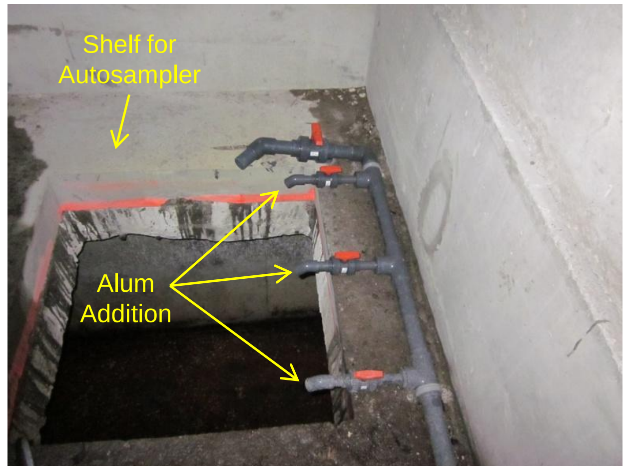
Figure 2-8.

Basin Areas Treated by the Hughey Avenue Alum Stormwater Treatment System.

a. Merging of 54-inch RCP and Hughey Avenue CBC

b. Hughey Avenue CBC downstream of alum addition

Figure 2-9. Photographs of the Hughey Avenue Stormsewer System.



a. SonTek Acoustic Doppler Flow Meter

b. Point of alum addition

Figure 2-10. Photographs of Treatment System Components.

The SonTek probe is mounted approximately 1 inch off the bottom so that sediment accumulation does not impact velocity measurements. Visual observations during the monitoring program indicate that the channel is self-cleaning during significant storm events so sediment accumulation tends to be temporary.

A photograph of the point of alum addition is given in Figure 2-10b. Alum is pumped from the Lake Dot facility to the point of alum addition. According to Technical Solutions, which installed the alum addition components, the alum treatment system will inject alum at a dose of 7.5 mg Al/liter up to a maximum stormsewer flow rate of 86 cfs. At flow rates in excess of 86 cfs, alum will still be added at the maximum pump capacity of 4.9 gpm, although the applied dose will be less than the target dose of 7.5 mg Al/liter. The alum drips into the stormsewer flow during storm events and mixing occurs from turbulence in the stormsewer. The 2-ft x 3-ft hole was cut into the top of the CBC to allow access for alum addition and efficiency monitoring.

The design for the Hughey Avenue alum stormwater treatment system also includes a floc settling basin at the point of inflow to Lake Concord to collect a portion of the generated alum floc. An overview of the floc settling area is given on Figure 2-11. The floc retention basin was constructed on the southeast lobe of Lake Concord near the exit ramp for I-4 and E. Colonial Drive and has a capacity of approximately 0.20 ac-ft. GTC estimated that the annual floc production generated by treatment of runoff from Sub-basins 200-315 would be approximately 0.2% of the treated flow equal to 0.38 ac-ft/yr, suggesting that the floc collection area would need to be dredged on a semi-annual basis.

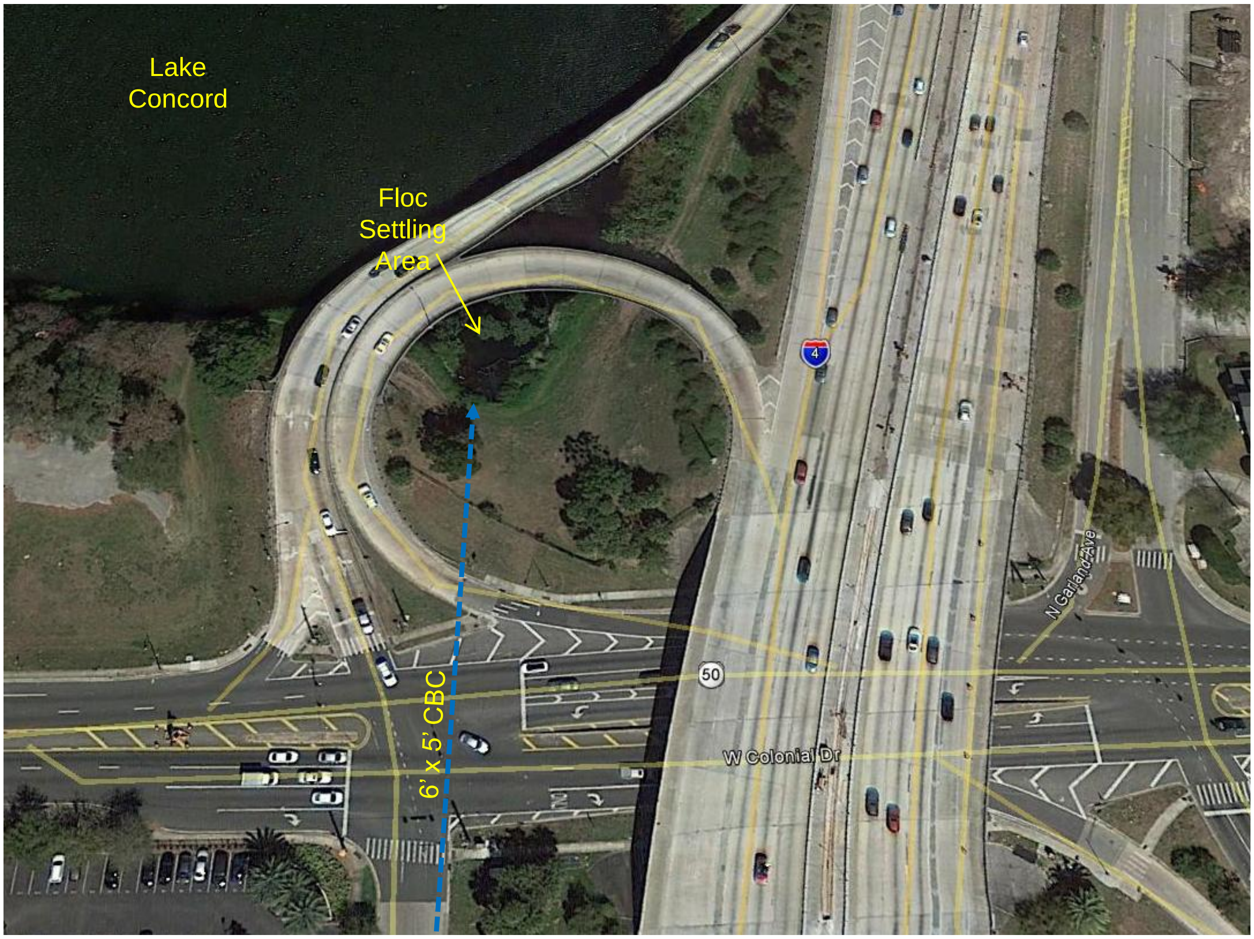


Figure 2-11. Overview of Floc Settling Area.

Design for the proposed Hughey Avenue alum stormwater treatment system was prepared by GTC and completed in January 2013. In addition to the expansion of the existing alum stormwater treatment process, the GTC plans also included a baffle box for a densely wooded portion of the Lake Dot drainage basin, although the baffle box portion of the project is not part of the Hughey Avenue watershed and was not evaluated as part of this analysis. Construction for the expansion of the alum treatment system to Hughey Avenue was initiated during January 2014 and completed during March 2015.

SECTION 3

FIELD AND LABORATORY ACTIVITIES

Field and laboratory investigations were conducted by ERD over an 18-month period from July 2015-December 2016 to evaluate the effectiveness of the Hughey Avenue alum stormwater treatment system. Field monitoring was conducted within the Hughey Avenue stormwater system at locations upstream and downstream of the point of alum addition, with 10 sets of pre- and post-treatment samples collected during the monitoring program. Laboratory analyses were conducted on collected treated and untreated samples for general parameters, nutrients, and metals to assist in quantifying concentration-based removal efficiencies. Specific details of monitoring efforts conducted for the Hughey Avenue alum system evaluation are given in the following sections.

3.1 Field Instrumentation and Monitoring

Monitoring locations used to evaluate the performance efficiency of the Lake Concord alum stormwater treatment system are illustrated on Figure 3-1. Automated stormwater monitoring was conducted at two locations, with Site 1 located upstream of the point of alum addition to reflect the characteristics of the raw stormwater, and Site 2 located approximately 400 ft downstream in the 5-ft x 6-ft CBC to reflect the characteristics of the alum treated runoff after mixing of the alum and the runoff during discharge through the stormsewer system. A schematic of the pre- and post-treatment monitoring sites is given on Figure 3-2. Each of the two monitoring sites were located inside a manhole structure constructed on top of the 5-ft x 6-ft CBC, with a 2-ft x 3-ft hole in the top of the CBC to allow access into the stormsewer system for alum addition, measurement of stormwater discharge, and pre- and post-treatment monitoring. A photograph of the access hole in the top of the CBC is given on Figure 2-10b.

3.1.1 Site 1 – Untreated Runoff

Monitoring conducted at Site 1 was designed to characterize the raw stormwater prior to alum addition. An ISCO Model 6712 automatic sequential stormwater sampler with integral flow meter was installed inside the manhole structure located on top of the 5-ft x 6-ft CBC. Flow sensor cables and sample tubing were extended approximately 20 ft upstream inside the stormsewer system to collect samples upstream from the point of alum addition. A photograph of the upstream intake strainer for the untreated runoff site is given on Figure 3-3. Flow monitoring was conducted using an ISCO Model 750 area-velocity probe which performs simultaneous measurements of water depth and velocity, with discharge calculated internally using the Continuity Equation. The flow meter probe was attached to a steel plate fastened to the bottom of the CBC.

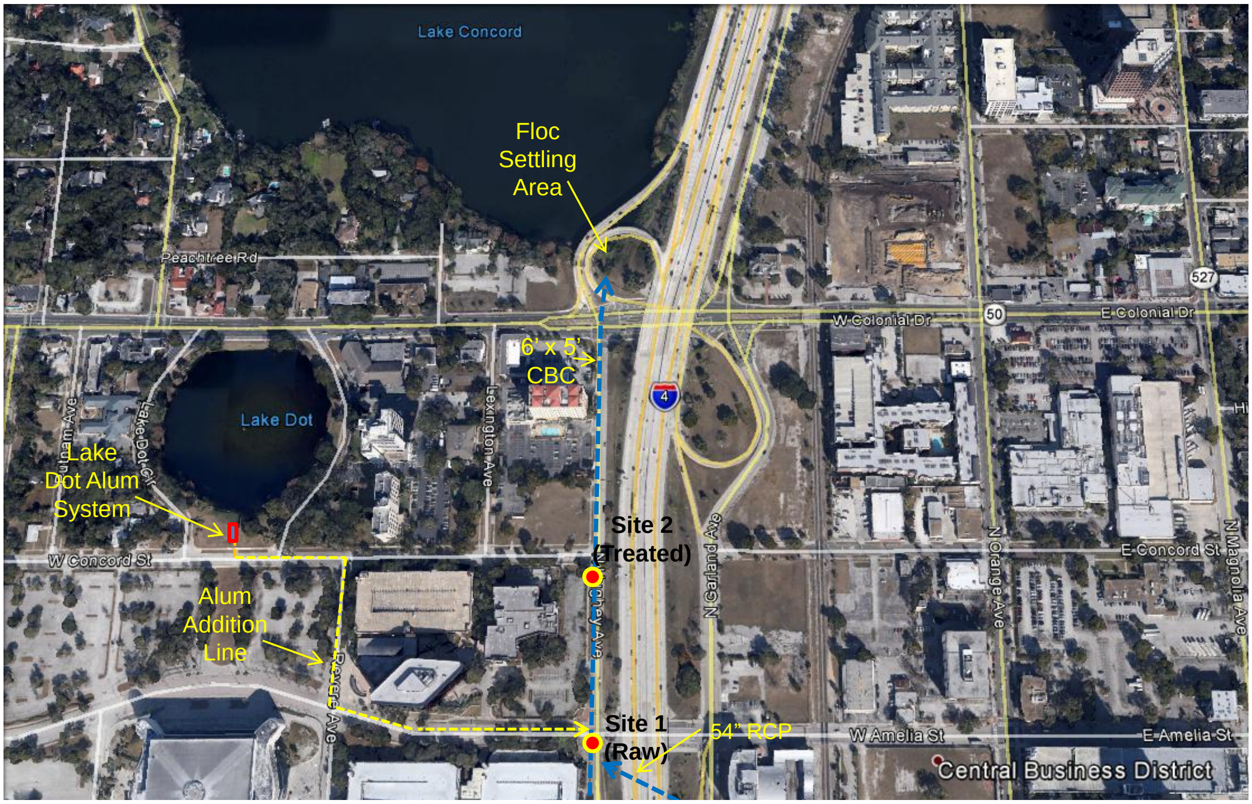


Figure 3-1. Overview of Pre- and Post-Treatment Stormwater Monitoring Sites.

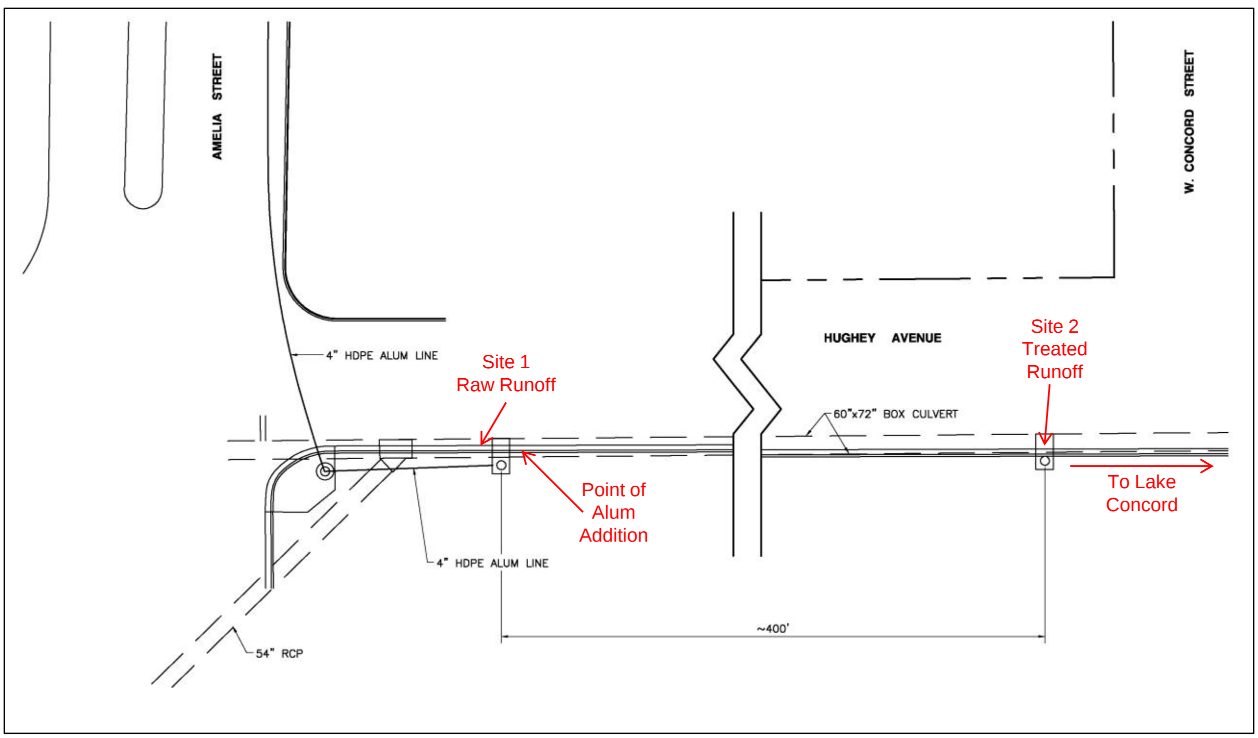


Figure 3-2. Schematic of Pre- and Post-Treatment Monitoring Sites.

Figure 3-3. Upstream Intake Strainer for the Untreated Runoff Site.

The flow meter was programmed to provide a continuous record of discharges through the Hughey Avenue stormsewer system, with measurements stored into internal memory at 10-minute intervals. The automatic sampler contained a single 20-liter polyethylene bottle and was programmed to collect samples in a flow-weighted mode, with 500-ml aliquots pumped into the collection bottle with every programmed increment of flow. Since 120-VAC power was not available at the site, the automatic sampler was operated on 12 VDC batteries which were replaced during each weekly site visit or following significant rain events.

3.1.2 Site 2 – Alum Treated Runoff

Monitoring Site 2 was located approximately 400 ft downstream from the point of alum addition within the 5-ft x 6-ft CBC. This site was located sufficiently downstream from the point of alum addition to ensure that the alum and stormwater had an opportunity to completely mix within the stormsewer system prior to reaching the downstream monitoring site. Access into the box culvert was obtained through a 2-ft x 3-ft opening inside a manhole structure constructed on top of the box culvert which was added during the project to assist in providing access for post-treatment monitoring.

An ISCO Model 6712 automatic sequential stormwater sampler with integral flow meter was installed inside the manhole structure. Flow sensor cables and sample tubing were extended approximately 15 ft downstream in the box culvert to provide continuous measurements of discharge rates and collect samples on a flow-weighted basis. Discharge monitoring was conducted using an ISCO Model 750 area-velocity probe which conducts simultaneous measurements of water depth and velocity, and calculates discharge using the Continuity Equation and the physical characteristics of the box culvert. The integral flow meter was programmed to provide a continuous record of discharges through the box culvert, with measurements stored into internal memory at 10-minute intervals. The automatic sampler contained a single 20-liter polyethylene bottle and was programmed to collect samples in a flow-weighted mode, with 500-ml aliquots pumped into the collection bottle with every programmed interval of flow. The autosampler was operated on 12 VDC batteries which were replaced on a weekly basis or following significant storm events.

Discharge measurements at both the treated and untreated monitoring sites were conducted using the area-velocity method. The flow probe utilized at these sites provides simultaneous measurements of water depth and flow velocity. The depth measurements are converted into a cross-sectional area based upon the geometry of the stormsewer, and the velocity of flow is measured directly by the probe. Discharge is then calculated internally within the flow meter using the Continuity Equation with discharge provided in ft^3 (cfs).

In addition to the two autosamplers, a continuous rainfall recorder was also installed on a 4-inch x 4-inch wooden post adjacent to the floc settling area illustrated on Figure 3-1. The rainfall recorder (ISCO Model 670) produced a continuous record of all rainfall which occurred at the site, with a resolution of 0.01 inch. Rainfall data were stored inside a digital storage device (Hobo Event Rainfall Logger) which was attached to the wooden post inside a waterproof enclosure. The rainfall record is used to provide information on rainfall characteristics for each of the monitored storm events.

ERD field personnel visited the monitoring sites at least once each week, or following significant rain events, to retrieve raw and treated samples and to download stored hydrologic data from each of the automatic samplers. This information was used to evaluate the characteristics of the monitored storm events at the two sites and to ensure that the collected samples reflect a single monitoring event.

Upon return to the ERD Laboratory, the collected alum treated samples were allowed to settle overnight to allow settling of the alum floc which would normally occur in the floc basin. The supernatant was siphoned off and submitted for lab analysis. The raw runoff samples were analyzed as collected.

3.2 Laboratory Analyses

A summary of laboratory methods and MDLs for analyses conducted on water samples collected during this project is given in Table 3-1. All laboratory analyses were conducted in the ERD Laboratory which is NELAC-certified (No. 1031026). Details on field operations, laboratory procedures, and quality assurance methodologies are provided in the FDEP-approved Comprehensive Quality Assurance Plan for Environmental Research & Design, Inc.

TABLE 3-1

ANALYTICAL METHODS AND DETECTION LIMITS FOR LABORATORY ANALYSES

PARAMETER	METHOD OF ANALYSIS	METHOD DETECTION LIMITS (MDLs)[1]
Ph	SM-21, Sec. 4500-H^+ B[2]	N/A
Conductivity	SM-21, Sec. 2510 B	0.3 μmho/cm
Alkalinity	SM-21, Sec. 2320 B	0.5 mg/l
Ammonia	SM-21, Sec. 4500-NH_3 G	0.005 mg/l
NO_x	SM-21, Sec. 4500-NO_3 F	0.005 mg/l
Total Nitrogen	SM-21, Sec. 4500-N C	0.01 mg/l
Ortho-P	SM-21, Sec. 4500-P F	0.001 mg/l
Total Phosphorus	SM-21, Sec. 4500-P B.5 F	0.002 mg/l
Turbidity	SM-21, Sec. 2130 B	0.1 NTU
Color	SM-21, Sec. 2120 C	1 Pt-Co Unit
TSS	SM-21, Sec. 2540 D	1.1 mg/l
Aluminum	SM-21, Sec. 3111 D	11 μg/l
Cadmium	SM-21, Sec. 3111 B	0.8 μg/l
Chromium	SM-21, Sec. 3111 B	1.5 μg/l
Copper	SM-21, Sec. 3111 B	1.1 μg/l
Iron	SM-21, Sec. 3111 B	18 μg/l
Manganese	SM-21, Sec. 3111 B	0.6 μg/l
Nickel	SM-21, Sec. 3111 B	1.8 μg/l
Lead	SM-21, Sec. 3111 B	1 μg/l
Zinc	SM-21, Sec. 3111 B	2 μg/l

1. MDLs are calculated based on the EPA method of determining detection limits
2. Standard Methods for the Examination of Water and Wastewater, 21st ed., 2005.

SECTION 4

RESULTS

Field monitoring, sample collection, and laboratory analyses were conducted by ERD over an 18-month period from July 2015-December 2016 to evaluate the pollutant removal efficiencies of the Hughey Avenue alum stormwater treatment system. A discussion of the results of these efforts is given in the following sections.

4.1 <u>Raw Stormwater Characteristics</u>

A complete listing of laboratory analyses conducted on untreated runoff samples collected from the Hughey Avenue stormsewer system during the field monitoring program is given in Appendix B. Flow-weighted composite runoff samples were collected during a total of 10 storm events, with monitored event rainfall ranging from 0.21-1.42 inches and an overall geometric mean of 0.85 inches per event.

A tabular distribution of monitored rain events at the Hughey Avenue stormsewer sites is given on Table 4-1. One of the monitored events had a rainfall of less than 0.5 inches, with four events in the range of 0.50-0.99 inches, and five events with rainfall depths ranging from 1.00-1.49 inches. Information on rainfall depths during monitored storm events was obtained from the recording rainfall gauge installed adjacent to the floc settling pond on Lake Concord.

TABLE 4-1

DISTRIBUTION OF MONITORED RAIN EVENTS AT THE HUGHEY AVENUE STORMSEWER SITES

RAIN EVENT (inches)	NUMBER OF MONITORING EVENTS
< 0.50	1
0.50-0.99	4
1.00-1.49	5

A tabular summary of the characteristics of raw runoff samples collected from the Hughey Avenue stormsewer system is given on Table 4-2. Information is provided for the minimum value, maximum value, and overall geometric mean value for each of the laboratory measured parameters. In general, collected runoff samples ranged from slightly acidic to slightly alkaline, with an overall mean pH value of 7.21. Measured alkalinity values in the raw runoff sample ranged from poorly buffered to well buffered, with an overall geometric mean alkalinity of 57.0 mg/l. Measured conductivity values in the raw runoff samples ranged from 80-291 μmho/cm, with an overall geometric mean of 129 μmho/cm, reflecting relatively low values.

TABLE 4-2

CHARACTERISTICS OF RAW RUNOFF SAMPLES COLLECTED FROM THE HUGHEY AVENUE STORMSEWER SYSTEM

PARAMETER	UNITS	MINIMUM VALUE	MAXIMUM VALUE	GEOMETRIC MEAN
Event Rainfall	inches	0.21	1.42	0.85
pH	s.u.	6.81	7.73	7.21
Alkalinity	mg/l	32.8	127	57.0
Conductivity	μmho/cm	80	291	129
Ammonia N	μg/l	3	328	49
NOx-N	μg/l	40	606	200
Diss. Organic N	μg/l	54	1,006	285
Particulate N	μg/l	88	2,012	351
Total N	μg/l	404	3,061	1,132
SRP	μg/l	28	111	59
Diss. Organic P	μg/l	25	115	42
Particulate P	μg/l	49	593	164
Total P	μg/l	115	805	282
Turbidity	NTU	6.6	214	25.1
Color	Pt-Co	10	93	25
TSS	mg/l	36.4	295	69.0
Total Al	μg/l	489	7,482	1,507
Total Cd	μg/l	0.01	1.00	0.08
Total Cr	μg/l	3	29	9
Total Cu	μg/l	11	111	28
Total Fe	μg/l	345	3,524	885
Total Mn	μg/l	6	56	18
Total Ni	μg/l	1	4	2
Total Pb	μg/l	1	33	6
Total Zn	μg/l	22	189	70

Measured concentrations of total nitrogen in the raw runoff samples ranged from low to elevated in value, with an overall geometric mean of 1,132 μg/l. The largest proportion of the total nitrogen was contributed by particulate nitrogen which comprised 41% of the measured total nitrogen. Overall, approximately 30% of the total nitrogen was contributed by dissolved organic nitrogen, with 24% by NO_x and 5% by ammonia, although the proportions of the individual nitrogen species varied somewhat between individual storm events.

Measured concentrations of total phosphorus in the raw runoff samples ranged from moderate to substantially elevated in value, with an overall geometric mean of 282 μg/l. The dominant phosphorus species was particulate phosphorus which comprised 57% of the overall observed total phosphorus. Approximately 28% of the total phosphorus in the raw runoff was contributed by soluble reactive phosphorus (SRP), with 15% contributed by dissolved organic phosphorus, although the proportions of phosphorus species varied somewhat between individual storm events. The overall geometric total phosphorus concentration of 282 μg/l is typical of total phosphorus concentrations observed in high-intensity urbanized areas.

Measured concentrations of both turbidity and TSS were highly variable in the collected raw runoff samples, with measured values for both parameters ranging from relatively low to substantially elevated. However, the overall geometric mean value of 25.1 NTU for turbidity and 69.0 mg/l for TSS are typical of values for these parameters observed in urban runoff. Measured color concentrations in the runoff samples ranged from low to moderately elevated, with an overall geometric mean of 25 Pt-Co units.

Highly variable concentrations were observed for each of the measured metals, with many parameters exhibiting one order of magnitude or more between minimum and maximum values for individual metal species. Measured concentrations of total aluminum in the raw runoff samples were moderate to highly elevated in value, with a measured concentration of 7,482 μg/l measured in one of the runoff samples and five of the runoff samples exceeding 1,000 μg/l for aluminum. Measured concentrations of cadmium were also highly variable, with an overall geometric mean of 0.08 μg/l. In contrast, measured values for chromium were generally low, ranging from 3-29 μg/l with an overall geometric mean of 9 μg/l.

Elevated values for copper were observed in each of the collected raw runoff samples, with individual measurements ranging from 11-111 μg/l and an overall geometric mean of 28 μg/l. Moderate to substantially elevated values were observed for iron, with measurements ranging from 345-3,524 μg/l and an overall geometric mean of 885 μg/l. In contrast, measured values for both manganese and nickel were low in value in each of the composite samples. Highly variable concentrations were observed in the collected runoff samples for both lead and zinc, with approximately one order of magnitude difference between minimum and maximum values for these metals.

A tabular summary of exceedances of the Class III surface water quality standards for metals observed in the raw runoff samples is given in Figure 4-2. This information is provided for comparative purposes only since the water quality standards do not apply until the runoff reaches the receiving waterbody. During the field monitoring program, the Class III water quality criterion for cadmium was exceeded in 4 of the 10 raw runoff samples, with exceedances for the copper criterion in each of the 10 raw runoff samples. Exceedances of the Class III surface water quality standards were observed for iron in 5 of the raw composite samples, for lead in 7 of the composite samples, and for zinc in 6 of the raw runoff samples.

TABLE 4-3

EXCEEDANCES OF CLASS III SURFACE WATER QUALITY STANDARDS IN RAW RUNOFF SAMPLES

PARAMETER	CLASS III CRITERION[1] (μg/l)	NUMBER OF EXCEEDANCES
Cadmium	0.16	4
Chromium	49	0
Copper	5	10
Iron	1,000	5
Nickel	26	0
Lead	1.3	7
Zinc	67	6

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4.2 Characteristics of Alum Treated Runoff Samples

A complete listing of laboratory analyses conducted on alum treated runoff samples collected from the Hughey Avenue stormsewer system during the field monitoring program is given in Appendix C. A tabular summary of the chemical characteristics of alum treated runoff samples collected from the Hughey Avenue stormsewer system during the field monitoring program is given on Table 4-4. As discussed in Section 3, the alum treated runoff samples were collected approximately 400 ft downstream from the point of alum addition to allow sufficient opportunity for mixing of the alum and stormwater flow.

The alum treated runoff samples exhibited pH values ranging from slightly acidic to slightly alkaline, with an overall geometric mean of 6.89. The treated runoff was poorly buffered to moderately well buffered, with measured alkalinity values ranging from 27.7-72.8 mg/l and an overall geometric mean of 43.5 mg/l. Measured conductivity values were low to moderate in value.

In general, measured concentrations of total nitrogen in the alum treated runoff samples were substantially lower than values measured in the raw runoff samples, with treated total nitrogen concentrations ranging from 291-1,219 μg/l and an overall geometric mean of 595 μg/l. In contrast to the raw runoff samples, where particulate nitrogen comprised the dominant nitrogen species, particulate nitrogen contributed the smallest portion of total nitrogen in the alum treated samples, comprising only 15% of the overall total nitrogen measured. The dominant nitrogen species present in the alum treated samples was dissolved organic nitrogen, although the overall geometric mean value of 171 μg/l measured in the alum treated samples is substantially lower than the geometric mean value of 285 μg/l measured in the raw samples. Approximately 30% of the total nitrogen was contributed by NO_x, with an overall geometric mean of 145 μg/l in the alum treated samples compared with 200 μg/l in the raw samples. The remaining measured nitrogen was contributed by ammonia which exhibited an overall geometric mean of 83 μg/l in the alum treated samples compared with 49 μg/l in the raw samples. Slight increases in ammonia are commonly observed following alum treatment due to trace amounts of ammonia in the alum product.

TABLE 4-4

CHARACTERISTICS OF ALUM TREATED RUNOFF SAMPLES COLLECTED FROM THE HUGHEY AVENUE STORMSEWER SYSTEM

PARAMETER	UNITS	MINIMUM VALUE	MAXIMUM VALUE	GEOMETRIC MEAN
pH	s.u.	6.38	7.65	6.89
Alkalinity	mg/l	27.7	72.8	43.5
Conductivity	μmho/cm	67	247	109
Ammonia N	μg/l	3	295	83
NOx-N	μg/l	36	412	145
Diss. Organic N	μg/l	34	656	171
Particulate N	μg/l	23	524	69
Total N	μg/l	291	1,219	595
SRP	μg/l	3	14	5
Diss. Organic P	μg/l	16	67	31
Particulate P	μg/l	9	32	19
Total P	μg/l	36	99	58
Turbidity	NTU	1.6	12.9	3.2
Color	Pt-Co	7	57	18
TSS	mg/l	2.2	32.0	6.3
Total Al	μg/l	69	454	143
Total Cd	μg/l	0.01	0.50	0.04
Total Cr	μg/l	1	15	3
Total Cu	μg/l	4	15	8
Total Fe	μg/l	59	328	146
Total Mn	μg/l	3	24	6
Total Ni	μg/l	1	1	1
Total Pb	μg/l	1	5	2
Total Zn	μg/l	4	68	27

Measured concentrations of phosphorus species were generally low in value in the alum treated samples, particularly in comparison with characteristics measured in the raw runoff. The alum treatment resulted in substantial reductions in particulate phosphorus, with an overall treated geometric mean of 19 μg/l compared with 164 μg/l for particulate phosphorus measured in the raw runoff samples. A reduction was also observed for dissolved organic phosphorus which decreased from 42 μg/l in the raw samples to 31 μg/l in the alum treated samples. The most significant reduction in phosphorus species was observed for SRP which decreased from a geometric mean of 59 μg/l in the raw samples to only 5 μg/l in the alum treated samples.

In general, measured concentrations for turbidity and TSS were generally low in value in the alum treated samples, particularly in comparison with measured values in the raw samples. On an overall mean basis, turbidity was reduced from 25.1 NTU in the raw samples to 3.2 NTU in the treated samples, with TSS decreasing from 69 mg/l in the raw samples to 6.3 mg/l in the treated samples. A reduction in color was also observed, decreasing from 25 Pt-Co units in the raw samples to 18 Pt-Co units in the treated samples.

Measured concentrations for each of the metal species were substantially lower in value in the alum treated samples than observed in the raw stormwater for virtually every measured metal. Total aluminum concentrations decreased from 1,507 μg/l in the raw samples to 141 μg/l in the alum treated samples. Similar reductions were observed for cadmium, chromium, copper, and iron, all of which were substantially lower in the alum treated samples than observed in the raw runoff. Alum treatment also reduced measured concentrations for manganese, nickel, lead, and zinc by approximately 50-75% compared with values measured in the raw runoff samples.

A tabular summary of observed exceedances of Class III surface water criteria standards in the alum treated runoff samples is given in Table 4-5. Alum treatment of the runoff samples resulted in a reduction in the number of observed exceedances of the Class III metal standards for each of the measured metals. Overall, a total of 32 separate exceedances of surface water quality standards were observed in the raw runoff samples compared with 16 exceedances of Class III surface water criteria for metal standards in the alum treated runoff samples, although many of the metal concentrations in the alum treated runoff samples were only slightly greater than the applicable Class III standard.

TABLE 4-5

EXCEEDANCES OF CLASS III SURFACE WATER QUALITY STANDARDS IN THE ALUM TREATED RUNOFF SAMPLES

PARAMETER	CLASS III CRITERION[1] (μg/l)	NUMBER OF EXCEEDANCES
Cadmium	0.16	3
Chromium	49	0
Copper	5	9
Iron	1,000	0
Nickel	26	0
Lead	1.3	4
Zinc	67	0

1. Chapter 62-302

4.3 Comparison of Raw and Alum Treated Runoff Samples

Graphical comparisons of the chemical characteristics of raw and alum treated runoff samples collected from the Hughey Avenue stormsewer system were developed for general parameters, nitrogen species, phosphorus species, and metals in the form of Tukey Box Plots, also often called "box and whisker plots". The bottom of the box portion of each plot represents the lower quartile, with 25% of the data points falling below this value. The upper line of the box represents the 75% upper quartile, with 25% of the data falling above this value. The **blue horizontal line** within the box represents the median value, with 50% of the data falling both above and below this value. The vertical lines, also known as "whiskers", represent the 10 and 90 percentiles for the data sets. Individual values which fall outside of the 10-90 percentile range are indicated as **red dots**.

A statistical comparison of measured values for pH, alkalinity, conductivity, and turbidity in raw and alum treated samples collected from the Hughey Avenue stormsewer system is given on Figure 4-1. In general, alum treatment resulted in a slight decrease in pH in the treated samples, with an overall median decrease of approximately 0.3 pH unit. Alum treatment also resulted in a slight reduction in measured alkalinity in the treated water which is commonly observed during alum treatment since alum is an acid salt that consumes alkalinity from the treated water. However, none of the alum treated samples had an alkalinity value less than the Class III minimum criterion of 20 mg/l for alkalinity.

Alum addition also resulted in a slight decrease in conductivity although the difference in median values between the raw and treated samples is low. Alum addition generally results in a slight increase in conductivity following alum treatment, and the observed slight decrease in conductivity observed at the Hughey Avenue site is unusual. Alum treatment resulted in virtual elimination of turbidity from the raw stormwater samples, decreasing turbidity to a very narrow range of low values.

A statistical comparison of measured values for nitrogen species in raw and alum treated runoff samples collected from the Hughey Avenue stormsewer system is given on Figure 4-2. Alum treatment has little impact on concentrations of ammonia, although a slight increase in ammonia is sometimes observed due to trace contamination of ammonia in the alum solution. Alum addition resulted in a slight decrease in concentrations of NO_x, with a smaller degree of variability in NO_x concentrations observed in treated runoff compared with the untreated samples. Alum addition also resulted in a small decrease in concentrations of dissolved organic nitrogen and a substantial reduction in concentrations of particulate nitrogen. Concentrations of particulate nitrogen in the treated samples were substantially lower in value and exhibited relatively consistent concentrations compared with higher values and a higher degree of variability observed for the untreated samples. Overall, alum treatment resulted in a relatively significant decrease in concentrations of total nitrogen in the treated samples and also resulted in a lower degree of variability in measured total nitrogen concentrations in the treated samples compared with untreated runoff.

A statistical comparison of measured values of phosphorus species in raw and alum treated runoff samples collected from the Hughey Avenue stormsewer system is given on Figure 4-3. Alum treatment resulted in substantial reductions in measured concentrations of SRP, with low

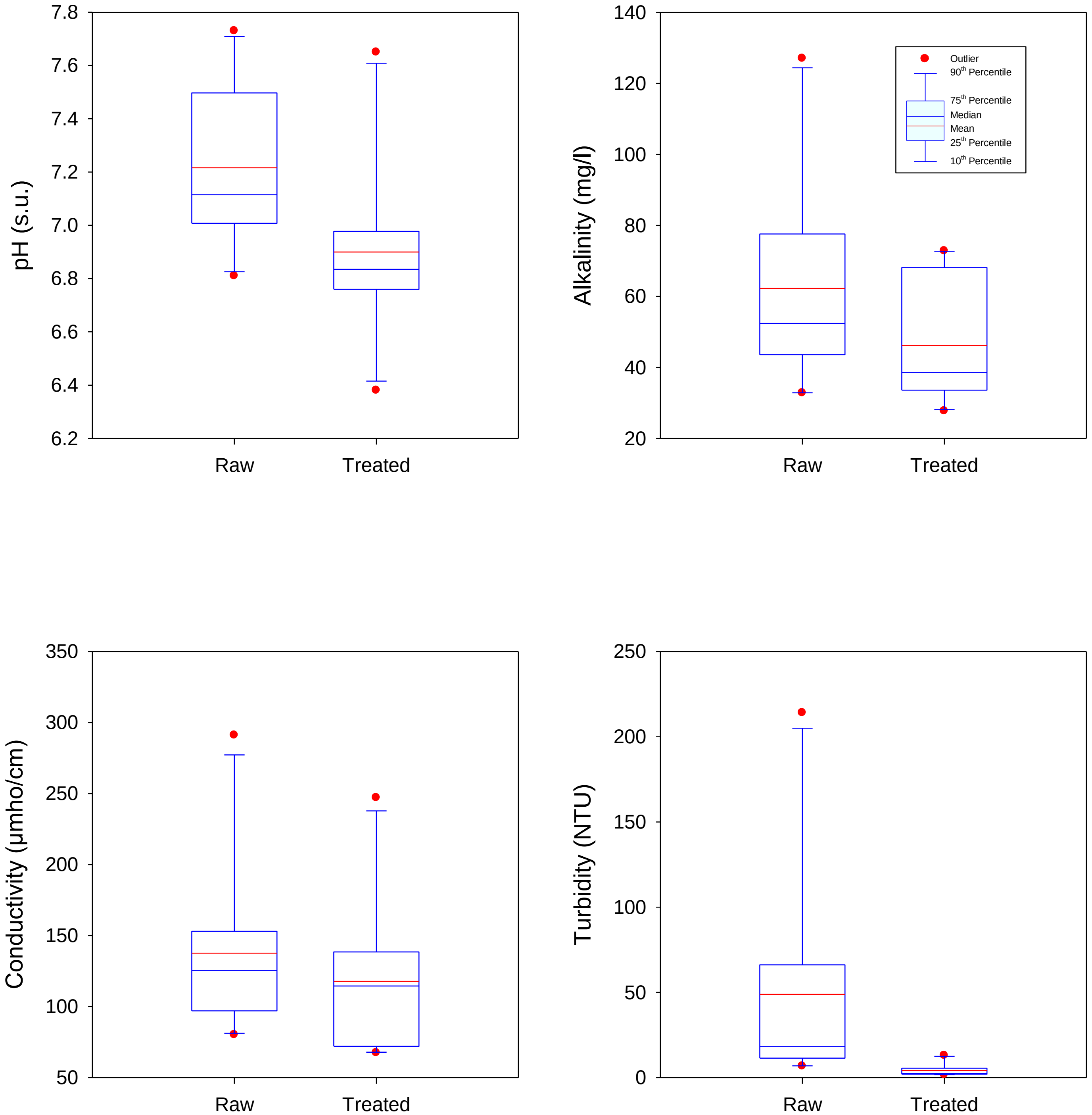


Figure 4-1. Statistical Comparison of Measured Values for pH, Alkalinity, Conductivity, and Turbidity in Raw and Alum Treated Runoff Samples Collected from the Hughey Avenue Stormsewer System.

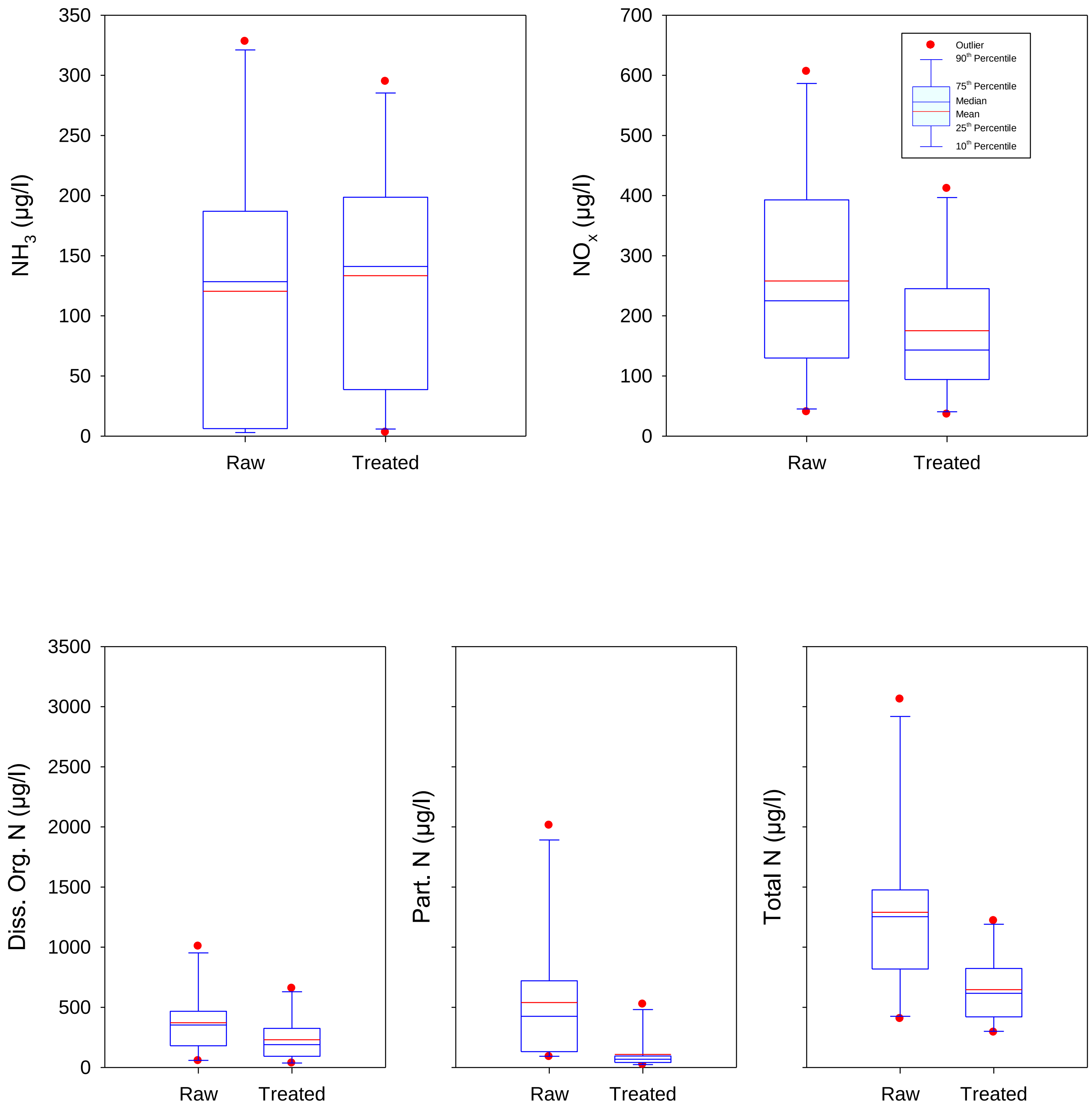


Figure 4-2. Statistical Comparison of Measured Values for Nitrogen Species in Raw and Alum Treated Runoff Samples Collected from the Hughey Avenue Stormsewer System.

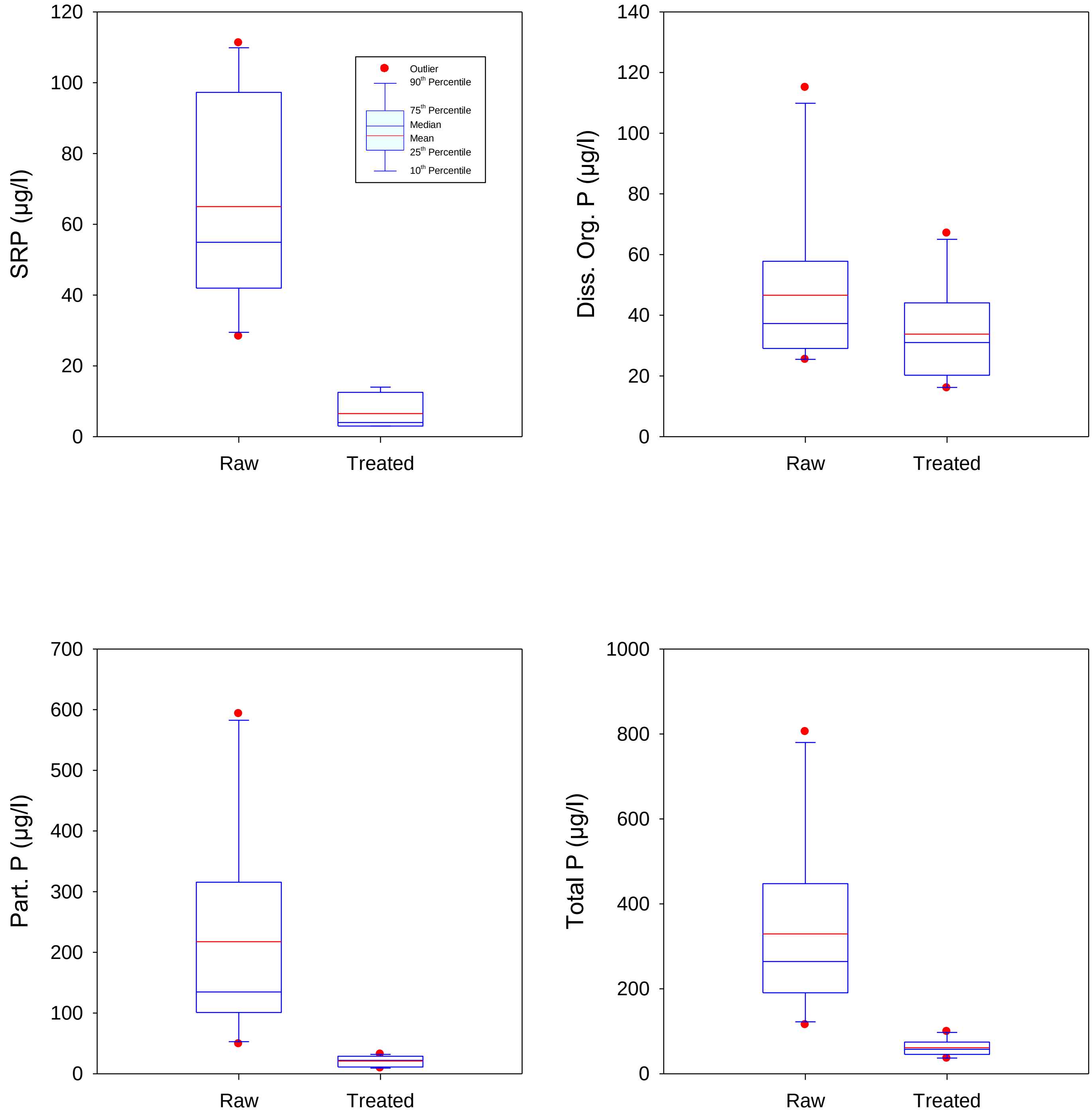


Figure 4-3. Statistical Comparison of Measured Values for Phosphorus Species in Raw and Alum Treated Runoff Samples Collected from the Hughey Avenue Stormsewer System.

concentrations and a low degree of variability in the treated samples compared with substantially higher concentrations and variability in the untreated runoff. Alum treatment resulted in a slight decrease in concentrations of dissolved organic phosphorus, although the median values for the treated and untreated samples are relatively similar. Substantial reductions were observed for concentrations of particulate phosphorus which was virtually eliminated from the runoff as a result of alum treatment. Particulate phosphorus concentrations in alum treated runoff were extremely low in value and exhibited a relatively low degree of variability in measured values compared with untreated runoff. Overall, alum treatment substantially reduced measured concentrations of total phosphorus with relatively consistent low total phosphorus concentrations in the treated samples throughout the field monitoring program in spite of the large degree of variability observed in the raw total phosphorus concentrations.

A statistical comparison of measured values for color and TSS in raw and alum treated runoff samples collected from the Hughey Avenue stormsewer system is given on Figure 4-4. Alum treatment resulted in a slight decrease in color values compared with the raw stormwater values and exhibited a lower degree of variability compared with raw runoff characteristics. Alum treatment substantially reduced measured concentrations for TSS which exhibited both low concentrations and a low degree of variability in alum treated samples compared with highly elevated and variable concentrations of TSS in the raw runoff.

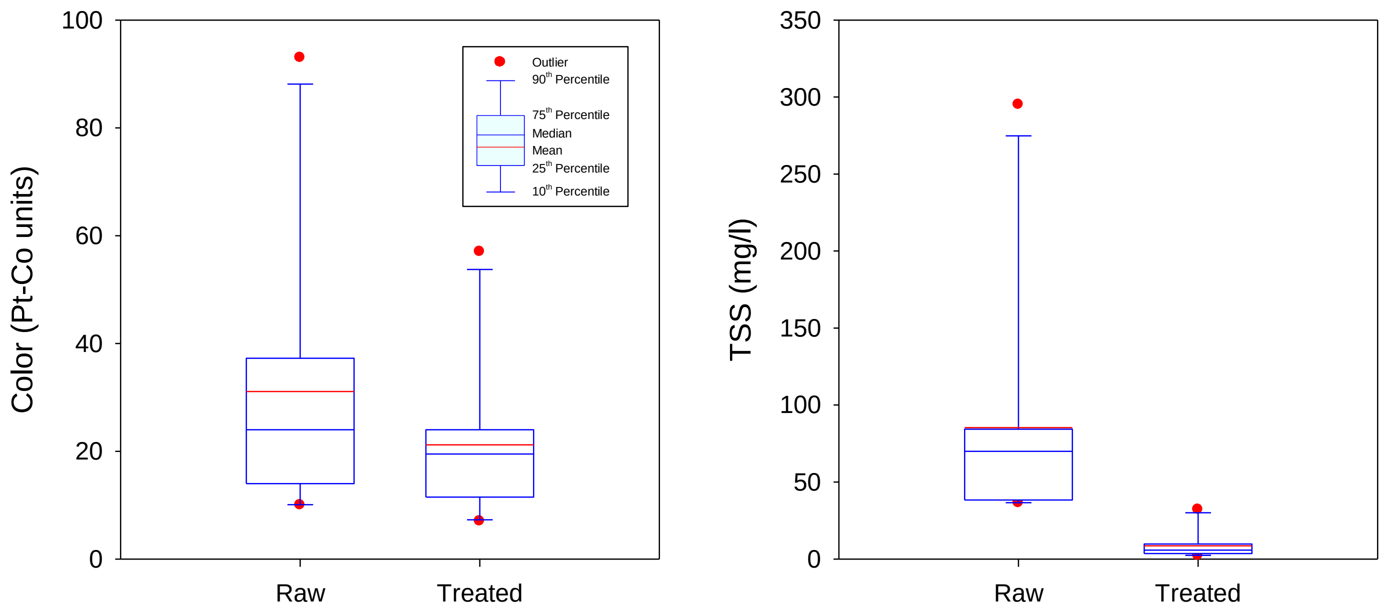


Figure 4-4. Statistical Comparison of Measured Values for Color and TSS in Raw and Alum Treated Runoff Samples Collected from the Hughey Avenue Stormsewer System.

A statistical comparison of measured values for aluminum, copper, iron, and zinc in raw and alum treated runoff samples collected from the Hughey Avenue stormsewer system is given on Figure 4-5. Alum treatment substantially reduced concentrations of aluminum in the raw runoff to values ranging from 69-454 μg/l and an overall geometric mean of 143 μg/l. The aluminum concentrations in the alum treated samples were substantially lower than the highly elevated and variable aluminum concentrations measured in the raw runoff. Alum treatment also substantially reduced the concentrations and variability for copper in the runoff samples. A similar pattern was observed for iron which was reduced to extremely low levels as a result of the alum treatment, with no exceedances of the Class III criterion of 1,000 μg/l for iron following alum treatment. Alum treatment also reduced concentrations and variability for zinc in the treated samples compared with higher concentrations and a substantially higher degree of variability in the raw samples.

A statistical comparison of measured concentrations for cadmium, manganese, chromium, nickel, and lead in raw and alum treated runoff samples collected from the Hughey Avenue stormsewer system is given on Figure 4-6. Alum treatment reduced both the concentrations and degree of variability of cadmium compared with concentrations measured in the raw runoff samples. A similar pattern was also observed for manganese, with substantially lower concentrations and lower degree of variability in the alum treated samples compared with the untreated runoff. A similar pattern was also observed for chromium. Alum treatment resulted in substantial reductions in both concentrations and degree of variability for nickel compared with concentrations measured in the raw runoff. As commonly observed, alum treatment virtually eliminated lead from the stormwater runoff, with below detectable limits for lead measured in a majority of the alum treated samples compared with more elevated concentrations and a high degree of variability in the raw runoff.

4.4 System Removal Efficiencies

A tabular summary of monitored removal efficiencies for the Hughey Avenue stormwater treatment system is given on Table 4-6. These efficiencies are calculated using the geometric mean characteristics of the raw stormwater runoff (summarized in Table 4-2) and the geometric mean characteristics of the alum treated runoff (summarized in Table 4-4). Overall, alum treatment resulted in a reduction in measured concentrations for each of the evaluated general parameters, nutrients, and heavy metals, with the sole exception of ammonia. Alum treatment of the stormwater resulted in slight decreases in pH, alkalinity, conductivity, and color, while reducing concentrations of turbidity by 87% and TSS by 91%.

Alum treatment resulted in a slight increase in concentrations of ammonia in the treated runoff. However, concentrations of NO_x were reduced by approximately 28%, with a 40% reduction in dissolved organic nitrogen, 80% reduction in particulate nitrogen, and 47% reduction in total nitrogen.

The alum treatment process provided excellent reductions for phosphorus species, with a 91% reduction in SRP, 26% reduction in dissolved organic phosphorus, 88% reduction in particulate phosphorus, and a 79% reduction in total phosphorus. The observed 79% reduction for total phosphorus is on the lower end of the range of total phosphorus removal efficiencies commonly observed with alum treatment systems which typically range from approximately 80-95%. The design alum dose of 7.5 mg Al/liter is in the middle of the range of alum doses used for stormwater treatment, and the total phosphorus removal could likely be enhanced by increasing the dose to 8.0-8.5 mg Al/liter.

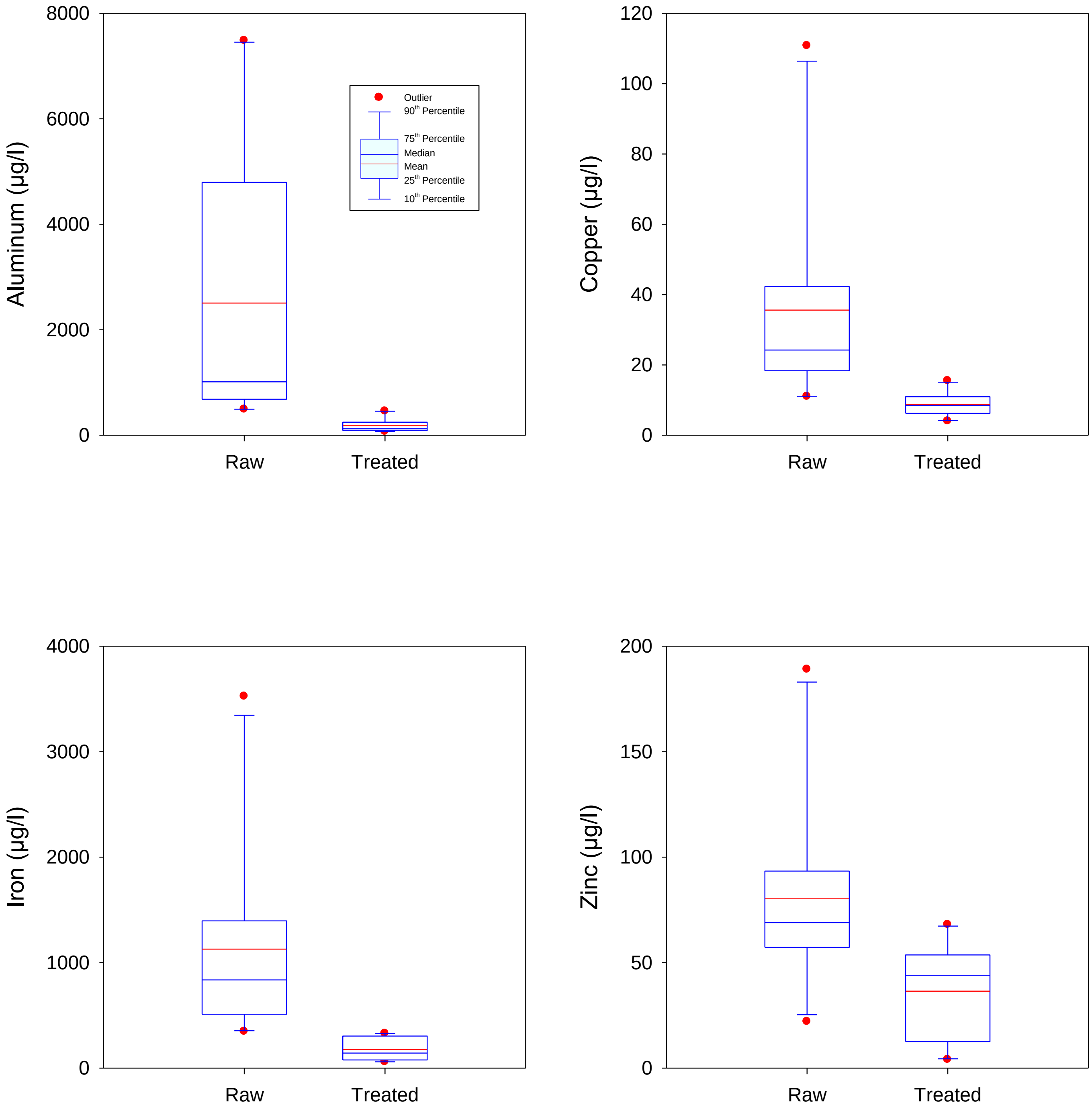


Figure 4-5. Statistical Comparison of Measured Values for Aluminum, Copper, Iron, and Zinc in Raw and Alum Treated Runoff Samples Collected from the Hughey Avenue Stormsewer System.

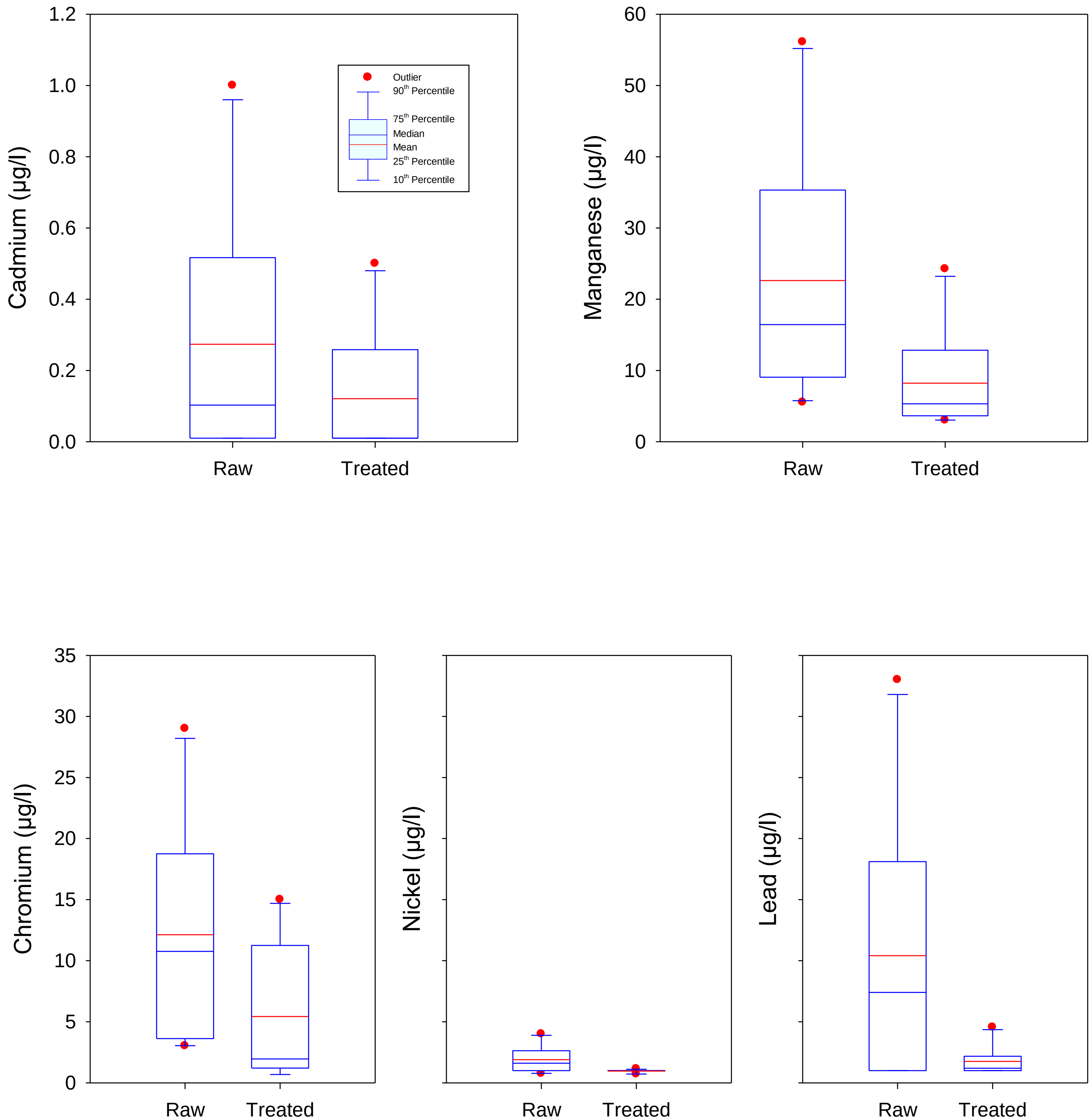


Figure 4-6. Statistical Comparison of Measured Values for Cadmium, Manganese, Chromium, Nickel, and Lead in Raw and Alum Treated Runoff Samples Collected from the Hughey Avenue Stormsewer System.

TABLE 4-6

MONITORED REMOVAL EFFICIENCIES FOR THE HUGHEY AVENUE STORMWATER TREATMENT SYSTEM

PARAMETER	UNITS	MEAN RAW CONCENTRATION	MEAN TREATED CONCENTRATION	PERCENT CHANGE (%)
pH	s.u.	7.21	6.89	-4
Alkalinity	mg/l	57.0	43.5	-24
Conductivity	µmho/cm	129	109	-16
Ammonia N	µg/l	49	83	70
NOx-N	µg/l	200	145	-28
Diss. Organic N	µg/l	285	171	-40
Particulate N	µg/l	351	69	-80
Total N	µg/l	1,132	595	-47
SRP	µg/l	59	5	-91
Diss. Organic P	µg/l	42	31	-26
Particulate P	µg/l	164	19	-88
Total P	µg/l	282	58	-79
Turbidity	NTU	25.1	3.2	-87
Color	Pt-Co	25	18	-27
TSS	mg/l	69.0	6.3	-91
Total Al	µg/l	1,507	143	-91
Total Cd	µg/l	0.08	0.04	-55
Total Cr	µg/l	9	3	-67
Total Cu	µg/l	28	8	-70
Total Fe	µg/l	885	146	-83
Total Mn	µg/l	18	6	-64
Total Ni	µg/l	2	1	-42
Total Pb	µg/l	6	2	-73
Total Zn	µg/l	70	27	-62

The alum treatment process resulted in excellent removals for each of the evaluated metals species, reducing total aluminum by 91%, cadmium by 55%, chromium by 67%, copper by 70%, iron by 83%, manganese by 64%, nickel by 42%, lead by 73%, and zinc by 62%.

Overall, the alum treatment process appears to have substantially improved the characteristics of runoff discharging to Lake Concord through the Hughey Avenue stormwater system. The observed reductions for total nitrogen, total phosphorus, and the measured metals should result in measurable improvements in water quality characteristics for these parameters in Lake Concord.

4.5 Annual Load Reductions

A summary of estimated annual load reductions for the Hughey Avenue stormwater system is given on Table 4-7. As discussed in Section 2, the feasibility evaluation for the proposed alum stormwater addition system, conducted by GTC, estimated that Sub-basins 200-315 which are treated by the new alum system expansion contribute approximately 427 kg/yr of nitrogen and 51 kg/yr of total phosphorus to Lake Concord. Based upon the removal efficiencies summarized in Table 4-6, total nitrogen removal with the alum treatment system is expected to be approximately 47%, with a 79% removal for total phosphorus. Based upon the removal efficiencies measured in the field monitoring program, the Hughey Avenue stormwater treatment system is expected to remove approximately 201 kg/yr of total nitrogen and 40 kg/yr of total phosphorus from Lake Concord. These values are slightly lower than the initial load reductions of 278-320 kg/yr for total nitrogen and 43-48 kg/yr for total phosphorus estimated by GTC, but the efficiency of the system could be enhanced by a small increase in the applied alum dose.

TABLE 4-7

ESTIMATED ANNUAL LOAD REDUCTIONS FOR THE HUGHEY AVENUE ALUM STORMWATER TREATMENT SYSTEM

PARAMETER	ESTIMATED CURRENT LOADING (kg/yr)	REMOVAL BY ALUM SYSTEM (%)	ESTIMATED ANNUAL LOAD REDUCTION (kg/yr)
Total Nitrogen	427	47	201
Total Phosphorus	51	79	40

4.6 Annual O&M Costs

A summary of estimated O&M costs for the Hughey Avenue stormwater treatment system is given in Table 4-8. As mentioned previously, sub-basins receiving alum treatment generate approximately 221 ac-ft of runoff volume each year which will be treated with alum at a dose of approximately 7.5 mg Al/liter. The estimated annual alum consumption for treatment of 221 ac-ft/yr at the assumed alum dose is 9,202 gallons. At a contract unit cost of approximately $0.45/gallon, the annual alum cost is estimated to be approximately $4,141 per year.

Additional O&M costs will be incurred for routine maintenance of the Hughey Avenue treatment system outside of the normal existing maintenance activities for the Lake Dot alum treatment system. The annual O&M costs for components associated with the Hughey Avenue system are estimated to be approximately $5,000. The overall annual O&M cost, consisting of alum cost plus labor costs, is $9,141 per year.

TABLE 4-8

ESTIMATED ANNUAL O&M COSTS FOR THE HUGHEY AVENUE ALUM TREATMENT SYSTEM

PARAMETER	UNITS	VALUE
Annual Runoff Volume	ac-ft/yr	221
Assumed Alum Dose	mg Al/liter	5.0
Annual Alum Use	gallons	9,202
Alum Unit Cost	$/gallon	0.45
Annual Alum Cost	$	4,141
Additional O&M Cost	$/year	5,000
Total Annual O&M Costs:	**$/year**	**9,141**

4.7 Mass Removal Costs

A calculated summary of present worth (PW) costs for the Hughey Avenue alum treatment system is given in Table 4-9. The initial capital cost for the components associated with the Hughey Avenue alum treatment system is approximately $163,778, with an annual O&M cost of $9,141 per year. The corresponding present worth cost for the system, based upon an analysis cycle of 20 years and an interest rate (i) of 2.5%, is $306,277.

TABLE 4-9

CALCULATED PRESENT WORTH (PW) COST FOR THE HUGHEY AVENUE ALUM TREATMENT SYSTEM

PARAMETER	UNITS	VALUE
Capital Cost	$	163,778
Annual O&M Costs	$	9,141
Present Worth Cost[1]	$	306,277

1. n = 20 years; i = 2.5%

A summary of 20-year mass removal costs for the Hughey Avenue alum stormwater treatment system is given in Table 4-10. Based upon the field monitoring conducted by ERD, the Hughey Avenue alum treatment system is expected to remove approximately 201 kg/yr of total nitrogen and 40 kg/yr of total phosphorus. Over the 20-year life cycle analysis, the system will remove a total of 4,020 kg (201 kg/yr x 20 years) of total nitrogen and 800 kg (40 kg/yr x 20 years) of total phosphorus. The mass removal costs for total nitrogen and total phosphorus are calculated by dividing the 20-year present worth cost by the overall load reductions for total nitrogen and total phosphorus over the 20-year period. The resulting mass removal costs for the Hughey Avenue alum treatment system are $76/kg for total nitrogen and $383/kg for total phosphorus.

TABLE 4-10

CALCULATED 20-YEAR MASS REMOVAL COSTS FOR THE HUGHEY AVENUE ALUM TREATMENT SYSTEM

PARAMETER	UNITS	VALUE
Present Worth Cost	$	306,277
Total Nitrogen Load Reduction	kg/yr kg[1]	201 4,020
Total Phosphorus Load Reduction	kg/yr kg[1]	40 800
Total Nitrogen Mass Removal Cost	$/kg	76
Total Phosphorus Mass Removal Cost	$/kg	383

1. Total mass removal over 20-year cycle

SECTION 5

SUMMARY

During 2015-2016, the City of Orlando constructed an expansion of the existing Lake Dot alum stormwater treatment system to include addition of alum into a 5-ft x 6-ft CBC stormsewer line along Hughey Avenue which discharges into the south side of Lake Concord. The new system extends a point of flow measurement and alum addition from the Lake Dot system to the Hughey Avenue system through a series of underground conduits. The new system provides alum stormwater treatment for an additional 86.8 acres of residential, commercial, and industrial land use in downtown Orlando. Floc generated as a result of alum addition and flocculation is collected in a dedicated settling basin upstream of the point of discharge into Lake Concord. The alum system expansion was constructed at a cost of approximately $163,778, with 60% of the cost provided by FDEP through a 319(h) Grant and the remaining 40% portion provided by the Orlando Stormwater Utility Department. Design of the system was constructed by GTC Engineering which estimated that the system will treat approximately 221 ac-ft/yr of runoff and remove 43-48 kg/yr of total phosphorus and 278-320 kg/yr of total nitrogen from Lake Concord.

Field monitoring was conducted by ERD over an 18-month period from July 2015-December 2016 to evaluate the effectiveness of the Hughey Avenue alum stormwater treatment system. Field monitoring was conducted within the Hughey Avenue stormsewer system at locations upstream and downstream of the point of alum addition, with 10 sets of pre- and post-treatment samples collected during the monitoring program. Laboratory analyses were conducted on collected treated and untreated samples for general parameters, nutrients, and metals to assist in quantifying concentration-based removal efficiencies.

The alum treatment system provided substantial reductions in runoff concentrations for each of the evaluated parameters with the exception of ammonia. The system provided an overall concentration reduction of 47% for total nitrogen and 79% for total phosphorus, with removal efficiencies ranging from 42-91% for the evaluated metals. Based upon the removal efficiencies obtained during the field monitoring program, the alum treatment system is expected to reduce loadings to Lake Concord by approximately 201 kg/yr of total nitrogen and 40 kg/yr of total phosphorus, slightly lower than the range of values estimated by GTC.

The Hughey Avenue alum treatment system will provide treatment for approximately 221 ac-ft of runoff per year. At an alum dose of 7.5 mg Al/liter, treatment of this volume will require approximately 9,202 gallons of alum, and at a contract unit price of $0.45/gallon, the estimated annual alum cost is $4,141 per year. Annual O&M costs for the system are expected to be approximately $5,000 per year, for a total annual fee of $9,141 per year.

A present worth analysis was conducted for the treatment system which resulted in a 20-year present worth cost (i = 2.5%) of $306,277. Based upon the anticipated load reductions for total nitrogen and total phosphorus, the present worth mass removal costs for the system are $76/kg for total nitrogen and $383/kg for total phosphorus.

APPENDICES

APPENDIX A

CONSTRUCTION DRAWINGS OF THE ALUM TREATMENT SYSTEM EXTENSION FOR THE HUGHEY AVENUE STORMSEWER SYSTEM

CITY OF ORLANDO
DEPARTMENT OF PUBLIC WORKS

LAKE CONCORD ALUM TREATMENT & BAFFLE BOX
DISTRICTS NO. 3 & 5

PROJECT NO: 1461

CITY COUNCIL OF ORLANDO

MAYOR BUDDY DYER

COMMISSIONER JIM GRAY
DISTRICT 1

COMMISSIONER TONY ORTIZ
DISTRICT 2

COMMISSIONER ROBERT F. STUART
DISTRICT 3

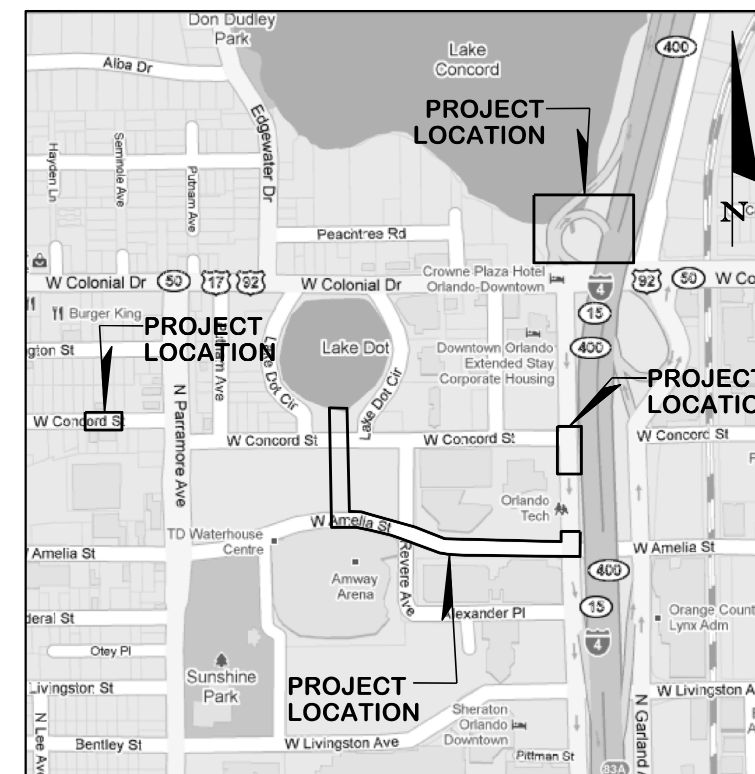
COMMISSIONER PATTY SHEEHAN
DISTRICT 4

COMMISSIONER DAISY W. LYNUM
DISTRICT 5

COMMISSIONER SAMUEL B. INGS
DISTRICT 6

CITY OF ORLANDO, FLORIDA "THE CITY BEAUTIFUL"

INDEX OF DRAWINGS



LOCATION MAP

PREPARED BY :

GTC ENGINEERING CORPORATION

DEPUTY DIRECTOR / CITY ENGINEER, JAMES D. HUNT, P.E.
MANAGER OF CAPITAL IMPROVEMENT AND INFRASTRUCTURE DIVISION, TOM CONNERY, P.E.
STORMWATER DIVISION MANAGER, LISA HENRY
FINAL SUBMITTAL JANUARY, 2013

LAKE CONCORD ALUM TREATMENT & BAFFLE BOX   PROJECT NO. 2859   FINAL SUBMITTAL JANUARY, 2013

PRINT DATE & TIME: 1/25/2013 9:55:27 AM
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GENERAL NOTES:

1. THE CONTRACTOR IS ADVISED TO BRING ANY DESIGN DISCREPANCIES TO THE IMMEDIATE ATTENTION OF THE ENGINEER PRIOR TO CONSTRUCTION.

2. BEFORE A CONNECTION IS TO BE MADE IN THE FIELD TO AN EXISTING PIPE OR MANHOLE, THE CONTRACTOR WILL EXCAVATE THE AREA TO VERIFY THE TYPE OF PIPE, THE PIPE SIZE AND GRADE, AND CONDITION OF THE MANHOLE PRIOR TO INSTALLING MATERIALS. THE CONTRACTOR SHALL ADJUST EXISTING SEWER STUB-OUTS TO THE NEW PLAN SLOPES WHERE NECESSARY.

3. UNDER NO CIRCUMSTANCE SHALL THE ACTIVITIES OF THE CONTRACTOR OR HIS SUBCONTRACTORS CAUSE ANY INTERRUPTIONS TO THE SERVICE OR OPERATION OF EXISTING UTILITIES WITHOUT WRITTEN AUTHORIZATION FROM AN AUTHORIZED REPRESENTATIVE OF THE UTILITY COMPANY OR CITY. ANY PIPING OR OTHER UTILITIES WHICH CAN BE REMOVED DURING CONSTRUCTION WITHOUT UNDUE INTERRUPTION OF SERVICE MAY BE REMOVED AND REPLACED BY THE CONTRACTOR WITH THE PERMISSION OF THE CITY.

4. LOCATIONS, ELEVATIONS AND DIMENSIONS OF EXISTING UTILITIES AND STRUCTURES ARE APPROXIMATE. WHILE CONSIDERABLE EFFORT HAS BEEN MADE BY THE CITY, THE SURVEYOR, THE VARIOUS UTILITY COMPANIES AND THE ENGINEER TO ACCURATELY LOCATE EXISTING LINES AND APPURTENANCES, IT IS THE CONTRACTOR'S RESPONSIBILITY TO VERIFY ALL UTILITY LOCATIONS, ELEVATIONS AND DIMENSIONS BY UTILIZING EXPLORATORY EXCAVATIONS WHICH SHALL BE MADE 7 DAYS OR 1,000 FEET IN ADVANCE OF THE WORK, WHICHEVER IS GREATER. IF THERE IS A POTENTIAL CONFLICT, THE CONTRACTOR IS TO NOTIFY THE ENGINEER IMMEDIATELY. ANY DAMAGE TO UTILITIES, STRUCTURES AND/OR SERVICES SHALL BE REPAIRED AT THE CONTRACTOR'S EXPENSE, IN A MANNER APPROVED BY AND COORDINATED WITH THE UTILITY CITY.

5. THE CONTRACTOR SHALL NOTIFY ALL CITY UTILITIES A MINIMUM OF SEVEN (7) WORKING DAYS PRIOR TO COMMENCING OF CONSTRUCTION. RECORDS OF ALL NOTICES SHALL BE SUBMITTED TO THE CITY'S REPRESENTATIVE UPON REQUEST.

6. THE CONTRACTOR SHALL CALL SUNSHINE ONE CALL AT 1-800-432-4770 AT LEAST TWO WORKING DAYSBEFORE DIGGING. IT SHALL BE THE CONTRACTOR'S RESPONSIBILITY TO ARRANGE WITH THE UTILITY CITY FOR THE PROTECTION AND/OR RELOCATION OF FACILITIES AS REQUIRED.

7. THE CONTRACTOR SHALL CHECK PLANS FOR CONFLICTS AND DISCREPANCIES PRIOR TO CONSTRUCTION. THE CONTRACTOR SHALL NOTIFY THE CITY'S REPRESENTATIVE OF ANY CONFLICT BEFORE PERFORMING ANY WORK IN THE AFFECTED AREA.

8. ALL CONSTRUCTION SHALL BE IN ACCORDANCE WITH THE CITY OF ORLANDO STANDARD SPECIFICATION FOR ROAD, BRIDGE AND UTILITY CONSTRUCTION, THE CITY OF ORLANDO ROADWAY AND TRAFFIC DESIGN STANDARDS AND THE CITY OF ORLANDO ENGINEERING STANDARD MANUAL (LATEST EDITIONS). ALL INDEX REFERENCED IN THE PLANS REFER TO THE FDOT ROADWAY AND TRAFFIC DESIGN STANDARDS, LATEST EDITION.

9. THE CONTRACTOR SHALL OBTAIN A CITY RIGHT OF WAY UTILIZATION PERMIT AND A DEWATERING PERMIT FROM SJRWMD IF REQUIRED. THE CONTRACTOR SHALL BECOME FAMILIAR WITH AND ABIDE BY ALL PERMIT CONDITIONS, INSPECTION SCHEDULES, AND OTHER RELEVANT REGULATORY AGENCY RULES AND REGULATIONS.

10. ALL DISTURBED AREAS SHALL BE RESTORED TO ORIGINAL OR BETTER CONDITION. ALL PERVIOUS AREAS SHALL BE SODDED. THE CONTRACTOR SHALL BE RESPONSIBLE FOR ALL DAMAGES CAUSED DURING CONSTRUCTION.

11. THE CONTRACTOR SHALL ENSURE THAT ALL SURVEY CONTROL POINTS SHOWN ON THE PLANS AND ANY PROPERTY CORNERS ALONG THE ROUTE OF THE PROJECT ARE PROTECTED AND SHALL BE REFERENCED AND MAINTAINED PRIOR TO BEING DISTURBED. THIS WORK MUST BE PERFORMED UNDER THE DIRECT SUPERVISION OF A FLORIDA LICENSED SURVEYOR AND MAPPER WHO SHALL PROVIDE SIGNED AND SEALED COPIES OF THE WORK AT THE REQUEST OF THE CITY. ALL REFERENCING WORK IS SUBJECT TO REVIEW AND APPROVAL BY THE OFFICE OF THE CITY SURVEYOR. CONTRACTOR TO OBTAIN ELECTRONIC COPY OF PLANS FOR ASBUILTS AS REQUIRED BY SECTION 01050 OF CONTRACT DOCUMENTS.

12. IF BY-PASS/WELL POINT PUMPING IS NECESSARY TO MAINTAIN UTILITY SERVICE, USE DIESEL ENGINES EQUIPPED TO KEEP NOISE AT OR BELOW THE CITY STANDARDS, ENCLOSED IN SHELTER (OR ELECTRIC) WITH BACKUP EQUIPMENT, AND ATTENDED BY A COMPETENT OPERATOR AT ALL TIMES WHEN IN USE. ALL DISCHARGE ACCESSORIES SHALL BE PVC, HARD RUBBER OR OTHER SUITABLE MATERIAL WITH NO LEAKING JOINTS. SOFT HOSE IS NOT ACCEPTABLE. SUBMITTALS REQUIRED PRIOR TO START OF WORK. THE CONTRACTOR SHALL PROVIDE WOOD OR EARTHEN RAMPS OVER WELL POINTS AND/OR HEADER PIPE AT EACH DRIVEWAY TO PERMIT ACCESS AT ALL TIMES. DEWATERING SYSTEM SHALL BE UTILIZED IN ACCORDANCE WITH GOOD STANDARD PRACTICES AND MUST BE EFFICIENT ENOUGH TO LOWER THE WATER LEVEL IN ADVANCE OF EXCAVATION TO KEEP THE TRENCH BOTTOM AND SIDES FIRM AND DRY. NO POLLUTED WATERS SHALL BE DISCHARGED INTO STORM SYSTEM OR BODIES OF WATER. ANY POLLUTED WATERS DISCHARGED INTO SANITARY SEWERS MUST BE APPROVED BY THE BUREAU OF WASTEWATER BEFORE DISCHARGING.

13. ALL EXCAVATIONS SHALL CONFORM TO THE REQUIREMENTS OF THE TRENCH SAFETY ACT. THE CONTRACTOR SHALL BE RESPONSIBLE FOR PROPER DISPOSAL OF ALL EXCAVATED MATERIAL.

14. CONTRACTOR SHALL EMPLOY A LICENSED PROFESSIONAL ENGINEER TO PREPARE CALCULATIONS AND DESIGN FOR ANY SHEET PILING SYSTEM USED DURING CONSTRUCTION OF THE STORM SEWER TRENCHING AS NECESSARY TO MAINTAIN TRAFFIC. SIGNED AND SEALED PLANS SHALL BE SUBMITTED TO THE CITY FOR REVIEW PRIOR TO START OF CONSTRUCTION.

15. THE CONTRACTOR IS RESPONSIBLE TO FIND AND MAINTAIN HIS OWN SECURE EQUIPMENT AND MATERIAL STORAGE YARD.

16. THE CONTRACTOR SHALL SET THE STORM MANHOLE RIMS AT THE FINISHED GRADE ELEVATIONS. THIS MAY REQUIRE FIELD ADJUSTMENT IF THE FINISHED GRADE IS DIFFERENT THAN THE PROPOSED RIM ELEVATIONS.

17. PROPOSED MANHOLE RING AND STANDARD HINGED COVERS TO BE USED FOR MAN HOLE LIDS AND SHALL CONFORM TO THE CITY OF ORLANDO REQUIREMENTS WITH THE LOGO AND NAME "CITY OF ORLANDO" ON THE COVERS. ANY EXISTING MANHOLE RINGS AND COVERS SHALL BE RETURNED TO THE CITY OF ORLANDO BUREAU OF WASTEWATER YARD AT 5100 L.B. McLEOD ROAD.

18. THE PIPE SHALL BE LAID IN THE DRY TRENCH TO THE ELEVATIONS AND SLOPE SHOWN ON THE CONSTRUCTION DRAWINGS. LASER EQUIPMENT SHALL BE USED TO PROVIDE LINE AND GRADE. THE LASER EQUIPMENT SHALL HAVE A SLOPE INDICATOR TO FACILITATE CHECKING BY BOTH THE PIPELAYING FOREMAN AND THE CITY'S REPRESENTATIVE. A ZERO TOLERANCE FOR ERRORS IN LINE AND GRADE WILL BE ALLOWED.

19. A MINIMUM HORIZONTAL SEPARATION OF TEN FEET SHALL BE MAINTAINED BETWEEN POTABLE WATER LINES AND PARALLEL INSTALLATION OF SANITARY SEWER. A MINIMUM VERTICAL SEPARATION OF 18" AT CROSSINGS MUST BE MAINTAINED. IF THESE MINIMUM SEPARATIONS CAN NOT BE MAINTAINED, THE CONTRACTOR SHALL INSTALL DUCTILE IRON PIPE WITH HIGH PRESSURE JOINTS OR ALTERNATE SOLUTIONS ACCORDING TO"RECOMMENDED STANDARDS FOR WATER WORKS". WATER MAINS MUST NOT PASS THROUGH, OR COME IN CONTACT WITH ANY SANITARY OR STORM SEWER MANHOLE OR STRUCTURE.

20. IF THE CONTRACTOR DURING THE COURSE OF THE INSTALLATION WILL ENCOUNTER AND CROSS UNDER WATER SERVICE LINES, HE SHALL COORDINATE WITH THE UTILITY TO ADJUST THE WATER SERVICE LINES TO PROVIDE 18 INCH MINIMUM VERTICAL CLEARANCE AND 10 FEET HORIZONTAL CLEARANCE BETWEEN THE NEW SEWER LINE AND THE WATER SERVICE LINES.

21. CLEANOUT IN DRIVEWAYS AND OTHER PAVED AREAS SHALL BE CAST IN PLACE RINGS WITH METAL COVERS STAMPED WITH THE WORD "SEWER".

22. THE CONTRACTOR SHALL BACKFILL TRENCHES EACH EVENING. HE SHALL LAY NO MORE THAN 100 L.F. OF SEWER WITHOUT RETURNING TO COMPACT THE SUBGRADE AND CONSTRUCT AND SEAL THE ROAD BASE. UPON COMPLETION OF THE WORK, THE LINES SHALL BE CLEANED, WITH ALL DEBRIS REMOVED AT DOWNSTREAM MANHOLE. EACH SECTION OF PIPE WILL BE TV INSPECTED BY THE CITY TO INDICATE ANY PIPE DEFECTS. BELLIES OR OTHER DEFORMITIES WILL BE RELAID TO PROVIDE THE CORRECT LINE AND GRADE. THE CITY WILL BILL THE CONTRACTOR DIRECTLY FOR TV RE-INSPECTION PROVIDED BY THE CITY (PER LINEAR FOOT), IF THE LINE FAILS THE INITIAL INSPECTION. ALL PIPE SHALL BE BURIED WITH IDENTIFICATION TAPE ABOVE THE TOP OF THE PIPE. THE TAPE SHALL INDICATE THE PRESENCE OF STORM OR SANITARY SEWERS PLAINLY ON THE TAPE FACE. INDICATOR TAPE BURIED WITH RCP AND PVC PIPE SHALL BE ABLE TO BE DETECTED BY STANDARD METAL DETECTOR EQUIPMENT.

A FINAL VISUAL INSPECTION SHALL BE MADE BY THE ENGINEER. ALL MANHOLES AND INLETS SHALL BE EXAMINED FOR PROPER GRADE AND WATER TIGHTNESS. THE CONTRACTOR SHALL ASSIST THE ENGINEER BY PROVIDING ALL LABOR AS REQUIRED. THE CONTRACTOR SHALL MAKE NOTE OF ANY CORRECTIONS REQUIRED AND SHALL PERFORM ALL REMEDIAL ACTIONS PRIOR TO THE FINAL ACCEPTANCE BY THE CITY. THE ASPHALT SURFACE MAY BE PLACED AFTER THE WORK AND TESTING IS COMPLETED AND ACCEPTED BY THE CITY.

23. THE CITY SHALL PROVIDE THE SERVICES OF A TESTING LABORATORY TO DETERMINE WHETHER THE REQUIREMENTS FOR MATERIALS SPECIFICATIONS ARE MET. THE CONTRACTOR SHALL GIVE THE ENGINEER A MINIMUM OF 48 HOURS NOTICE REQUESTING FIELD TESTS.

24. THE CONTRACTOR SHALL BE RESPONSIBLE FOR ANY TEMPORARY CONTROLS AND/OR STRUCTURES REQUIRED TO MAINTAIN SUITABLE AND SAFE WORKING CONDITIONS AT ALL TIMES. SUCH ITEMS SHALL BE REMOVED ONCE THAT PORTION OF WORK HAS BEEN COMPLETED.

25. THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE STABILITY OF EMBANKMENTS AND SHALL REPLACE ANY PORTION WHICH, IN THE OPINION OF THE ENGINEER, HAS BECOME DISPLACED DUE TO EROSION OR DUE TO CARELESSNESS OR NEGLIGENCE ON THE PART OF THE CONTRACTOR.

26. ALL DRAINAGE COURSES THAT ARE CROSSED AND/ OR DISTURBED DURING CONSTRUCTION, SHALL REMAIN FUNCTIONAL AT ALL TIMES OR THE CONTRACTOR SHALL INSTALL FACILITIES TO PASS THE FLOW.

27. INLETS AND CATCH BASINS SHALL BE PROTECTED FROM SEDIMENT UNTIL THE COMPLETION OF ALL CONSTRUCTION OPERATIONS. EROSION CONTROL AT ALL INLET DRAINAGE STRUCTURES DURING CONSTRUCTION SHALL BE DONE IN ACCORDANCE WITH FDOT INDEX No. 102.

28. EXISTING PAVEMENT MARKINGS AND MESSAGES ARE TO BE INVENTORIED AND REPLACED BY THE CONTRACTOR UNLESS OTHERWISE SPECIFIED IN THE PLANS OR LATEST DESIGN STANDARD. ALL PERMANENT PAVEMENT MARKINGS SHALL BE ALKYD THERMOPLASTIC. TEMPORARY MARKINGS MAY BE PAINTED (ON AREAS TO BE RESURFACED) OR TEMPORARY TAPE (ON ALL AREAS NOT BEING RESURFACED). TEMPORARY TAPE SHALL BE 3M BRAND, SCOTCH-LANE REMOVABLE TAPE SERIES 5710, 6350 AND SMF-270, FOR BLACK-OUT TAPE SERIES 145. ALL CONFLICTING EXISTING MARKINGS SHALL BE REMOVED.

29. SUBSURFACE INFORMATION SHOWN ON THESE DRAWINGS WAS OBTAINED FOR USE IN ESTABLISHING DESIGN CRITERIA FOR THE PROJECT. THE ACCURACY OF THIS INFORMATION IS NOT GUARANTEED AND IS NOT TO BE CONSTRUED AS PART OF THE PLANS GOVERNING CONSTRUCTION OF THE PROJECT. IT IS THE RESPONSIBILITY OF THE CONTRACTOR TO INQUIRE OF THE ENGINEER IF ADDITIONAL INFORMATION IS AVAILABLE, TO MAKE ARRANGEMENTS TO REVIEW SAME PRIOR TO BIDDING, AND TO MAKE HIS OWN DETERMINATION AS TO ALL SUBSURFACE CONDITIONS.

30. THE CONTRACTOR SHALL COORDINATE ALL WATER SERVICE CUTS AND REPAIRS WITH KEITH BROWNING, O.U.C.(407-649-4487).

31. CONTRACTOR'S USE OF THE PREMISES SHALL BE CONFINED TO THE LIMITS OF THE EXISTING RIGHT OF WAY AND/OR EASEMENTS. ALL PUBLIC AND PRIVATE PROPERTY AFFECTED BY THE CONSTRUCTION SHALL BE PROTECTED WHERE POSSIBLE. ALL AREAS DISTURBED AS PART OF THIS WORK SHALL BE RESTORED TO ORIGINAL OR BETTER CONDITION. CONTRACTOR SHALL MAKE AN EFFORT TO MINIMIZE DISTURBANCE OF THE AREA BEHIND THE PROPOSED CURB AND STRUCTURES, AND WILL BE RESPONSIBLE FOR ALL DAMAGES CAUSED. ALL EXISTING GRASSED AREAS DISTURBED DURING THE CONSTRUCTION SHALL BE REPLACED WITH THE SAME TYPE OF SOD IN CONFORMANCE WITH THE CITY'S STANDARDS. ANY EXISTING IRRIGATION SYSTEMS DAMAGED DURING CONSTRUCTION WILL BE REPAIRED AS REQUIRED, AT NO COST TO THE CITY OR PROPERTY CITY. PROPER TEMPORARY ADJUSTMENTS SHALL BE DONE AT SUCH TIME TO MAINTAIN IRRIGATION SYSTEMS INTERRUPTED DURING CONSTRUCTION. THE CONTRACTOR WILL BE RESPONSIBLE FOR MAINTENANCE OF ALL NEWLY PLANTED GRASS OR VEGETATION UNTIL THE WORK HAS BEEN ACCEPTED BY THE CITY.

32. THE CONTRACTOR SHALL PROTECT EXISTING TREES IN ACCORDANCE WITH THE CITY'S TREE PROTECTION ORDINANCE, SECTION 60.21 OF LDC, INCLUDING MAINTAINING MINIMUM UNDISTURBED AREAS. WHEN NECESSARY TO CUT ROOTS OVER 1-1/2 " DIA., THE CUT MUST BE CLEAN. TEMPORARILY COVER EXPOSED ROOTS WITH WET BURLAP TO PREVENT DRYING AND COVER WITH EARTH AS SOON AS POSSIBLE. INTERFERING BRANCHES MAY BE REMOVED AT THE DIRECTION OF THE PARKS BUREAU REPRESENTATIVE BY A QUALIFIED TREE SURGEON. REPAIR OR REPLACE TREES DAMAGED DURING CONSTRUCTION AT THE DIRECTION OF THE CITY PARK BUREAU'S URBAN FORESTER, ANDREW KITTSLEY(407-246-2283) AND OBTAIN PRIOR APPROVAL OF TREE REMOVAL, WHERE NECESSARY. EMPLOY A QUALIFIED TREE SURGEON TO REPAIR MAJOR DAMAGE TO TREES PROMPTLY TO PREVENT PROGRESSIVE DETERIORATION CAUSED BY THE DAMAGE. CONTRACTOR SHALL BE RESPONSIBLE FOR THE REPLACEMENT OF TREES DAMAGED BEYOND REPAIR WITH 3 TREES OF SIMILAR QUALITY AND SPECIES SIZED AT THE DIRECTION OF THE PARKS BUREAU REPRESENTATIVE. IF TREES ARE HARMED THROUGH LACK OF PROTECTION OR THROUGH NEGLIGENCE OF ANY PARTY, THE PARTY SHALL BEAR COST OF REPAIR AND REPLACEMENT.

33. THE CONTRACTOR SHALL SUBMIT AND PAY FOR (INCLUDING REQUIRED REVISIONS) MAINTENANCE OF TRAFFIC PLAN (M.O.T.), SIGNED AND SEALED BY A LICENSED TRAFFIC ENGINEER IN THE STATE OF FLORIDA, TO THE CITY'S REPRESENTATIVE FOR REVIEW PRIOR TO THE NOTICE OF AWARD. THE PLAN SHALL BE PREPARED IN ACCORDANCE WITH F.D.O.T. INDEX NO.600, AND MAY INCLUDE JERSEY BARRIERS. THE COST OF SHEET PILING ALONG TRENCHES, IF REQUIRED, SHALL BE INCLUDED IN THE UNIT PRICE FOR STORM AND SANITARY SEWER CONSTRUCTION. ALL WORK SHALL BE IN ACCORDANCE WITH THE F.H.W.A. MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES AND F.D.O.T. SPECIFICATIONS FOR ROAD AND BRIDGE CONSTRUCTION, LATEST EDITION AND REVISION, AND MEET WITH THE APPROVAL OF THE CITY OF ORLANDO TRAFFIC CONTROL MANAGER (PH. NO.407-246-2372). ALL CLOSURES SHALL REQUIRE COORDINATION WITH THE TRAFFIC CONTROL MANAGER, A MINIMUM OF ONE (1) WEEK PRIOR TO THE CLOSURE(EXCLUDING WEEKEND NOTIFICATION). ADDITIONAL SIGNING AND BARRICADING MAY BE REQUIRED AS DIRECTED BY THE TRAFFIC CONTROL MANAGER. PEDESTRIAN CONTROL SHALL BE MAINTAINED IN ACCORDANCE WITH F.D.O.T. INDEX 660.

34. LOCAL RESIDENTIAL AND BUSINESS TRAFFIC ACCESS SHALL BE MAINTAINED AT ALL TIMES. IF UNABLE TO DO SO, THE CONTRACTOR IS RESPONSIBLE FOR NOTIFICATION TO AFFECTED RESIDENTS AND BUSINESSES A MINIMUM OF ONE (1) WEEK IN ADVANCE IN WRITTING TO COORDINATE ALTERNATIVE ACCESS ARRANGEMENTS. ORANGE COUNTY SCHOOL BOARD SHALL BE CONTACTED FOR SCHOOL BUSES RE-ROUTING.

35. ALL INLET ELEVATIONS ASSOCIATED WITH THE PROPOSED CURB INLETS ARE TO THE EDGE OF PAVEMENT ELEVATION.

36. ALL PIPE JOINTS SHALL BE WRAPPED WITH A FILTER FABRIC MATERIAL .

ABBREVIATIONS:

CONST.	CONSTRUCT	FL	FLOW LINE
C.M.U.	CONCRETE MASONRY UNIT	TBM	TEMPORARY BENCH MARK
DIP	DUCTILE IRON PIPE	STL	STEEL
EL. ELEV.	ELEVATION	RCP	REINFORCED CONCRETE PIPE
EXIST.	EXISTING	PVC	POLY VINYL CHLORIDE
FM	FORCE MAIN	SAN.	SANITARY
INV.	INVERT	N	NORTH
L.F.	LINEAR FEET	S	SOUTH
MH	MANHOLE	W	WEST
INL	INLET	E	EAST
PROP.	PROPOSED	NE	NORTHEAST
R/W	RIGHT OF WAY	NW	NORTHWEST
BM-1	BENCHMARK	SE	SOUTHEAST
BT	BURIED TELEPHONE	SW	SOUTHWEST
BE	BURIED ELECTRIC	AB-1	AUGER BORING
WM	WATER MAIN	ELEC	ELECTRIC
BFO	BURIED FIBER OPTIC	AH	AHEAD
BTV	BURIED TV	BK	BACK
OE	OVERHEAD ELECTRIC	LT	LEFT
OTV	OVERHEAD TV	RT	RIGHT

UTILITY COMPANIES AND CITY DEPARTMENT CONTACTS:

WATER
ORLANDO UTILITIES COMMISSION
3800 GARDENIA AVE.
ORLANDO, FL. 32839
ATTN: JIM BECK
PHONE: 407-434-2573

ELECTRIC
ORLANDO UTILITIES COMMISSION
6003 PERSHING AVENUE
PO BOX 3193
ORLANDO, FL. 32802
ATTN: STEWART C. DARY
PHONE: 407-434-4182

ELECTRIC
ORLANDO UTILITIES COMMISSION
- CHILLED WA
PO BOX 3193
ORLANDO, FL. 32802
ATTN: DAVE L. BRAMLETT
PHONE: 407-418-5025

PHONE
ATT / DISTRIBUTION
450 N. GOLDENROD ROAD
ORLANDO, FL. 32807
ATTN: RAY REGISTER
PHONE: 407-273-5084

COMMUNICATION
DELTACOM
1801 HILLYAR ROBINSON PKWY.
ANNISTON, AL 36207
ATTN: JOHN MCGRUFFEY
PHONE: 256-241-6438

COMMUNICATION
CENTURYLINK
700 W. MINERAL AVE.
ROOM UTD2734
LITTLETON, CO 80120
ATTN: GEORGE MCELVAIN
PHONE: 720-260-2514

COMMUNICATION
EMBARQ COMMUNICATIONS
420 PINEVIEW ST.
ALTAMONTE SPRINGS, FL 32701
ATTN: ROD JUDY
PHONE: 407-920-8981

COMMUNICATION
T W TELECOM
485 N. KELLER RD. SUITE 551
MAITLAND, FL 32751
ATTN: JIM SOWERS
PHONE: 407-215-6895

COMMUNICATION
SPRINT NEXTEL
201 E. PINE ST. SUITE 1306
ORLANDO, FL 32801
ATTN: MARK CALDWELL
PHONE: 407-838-5602

ORLANDO ORANGE COUNTY
EXPRESSWAY AUTHORITY
482 SOUTH KELLER ROAD
ORLANDO, FL 32810
ATTN: ERIC LEACH
PHONE: 407-806-4196

SEWER
CITY OF ORLANDO
WASTEWATER DIVISION
5100 L.B. McLEOD ROAD
ORLANDO, FL. 32811
ATTN: CHUCK SCHULTZ, P.E.
PHONE: 407-246-2213

TRAFFIC
CITY OF ORLANDO
400 S. ORANGE AVE, 8TH FLOOR
ORLANDO, FL. 32801
ATTN: SCOTT WALKER
PHONE: 407-246-2372

PARKS
CITY OF ORLANDO
1206 WEST COLUMBIA STREET
ORLANDO, FL. 32805
ATTN: JOHN PERRONE
PHONE: 407-246-2287

SURVEY
CITY OF ORLANDO
400 S. ORANGE AVE, 8TH FLOOR
ORLANDO, FL. 32801
ATTN: JOE STOKES JR, PSM
PHONE: 407-246-3319

STREETS AND DRAINAGE
STORMWATER UTILITIES BUREAU
400 S. ORANGE AVENUE
ORLANDO, FL 32801
ATTN: LISA HENRY
PHONE: 407-246-3646

SCHOOLS
ORANGE COUNTY PUBLIC SCHOOLS
TRANSPORTATION DEPARTMENT
5140 N. PINE HILLS ROAD
ORLANDO, FL. 32808
ATTN: WINNIE GERKEN
SAFETY MANAGER
PHONE: 407-521-2339, EXT. 7253
EXTENSION # 7253

GAS
TECO PEOPLES GAS
600 W. ROBINSON STREET
ORLANDO, FL. 32802
ATTN: DEBORAH FRAZER
PHONE: 407-420-6609

GAS
FLORIDA GAS TRANSMISSION CO.
2405 LUCIEN WAY, SUITE 200
MAITLAND, FL 32751
ATTN: JOSEPH E. SANCHEZ
PHONE: 407-838-7171

TRAFFIC CONTROL DEVICES
242 N. WESTMONTE DR.
ALTAMONTE SPRINGS, FL 32714
ATTN: BRIDGETT HACKETT
PHONE: 407-869-5300, #175

CABLE
BRIGHT HOUSE
844 MAGUIRE ROAD
OCOEE, FL. 34761-2916
PHONE: 407-532-8509
ATTN: MARVIN L. USRY, Jr.
CONSTRUCTION SUPERVISOR

REVISIONS			
DATE	DESCRIPTION	DATE	DESCRIPTION

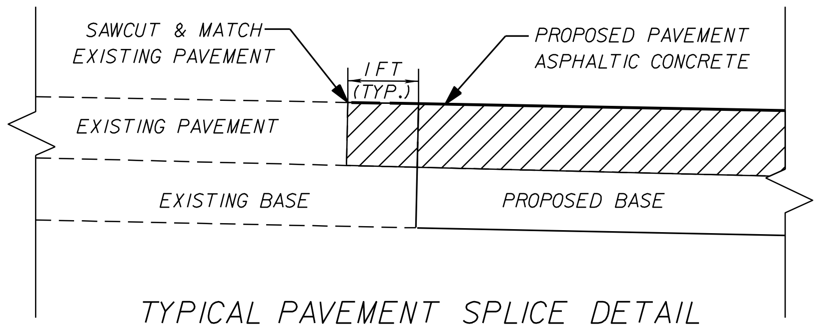
GTC Engineering Corporation
98 South Semoran Blvd, Orlando, FL 32807
Phone Number - 407.380.0402
Certificate of Authorization Number 6758
Claude L. Cassagnol, P.E. P.E. Number 35490

CITY OF ORLANDO

GTC PROJECT NO.		CITY OF ORLANDO PROJECT NO.
FLO 16.01	LAKE CONCORD ALUM TREATMENT & BAFFLE BOX	1461

GENERAL NOTES

SHEET NO. 2



TYPICAL PAVEMENT SPLICE DETAIL

N.T.S.

W. CONCORD STREET PAVEMENT REPLACEMENT

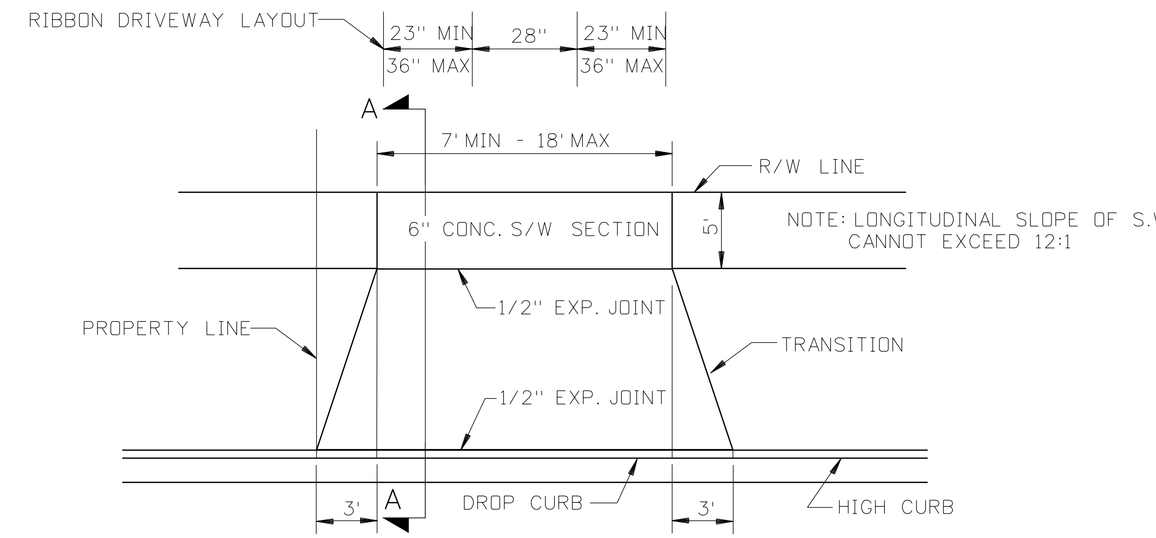
(1") FRICTION COURSE FC-9.5 (RUBBER)(TRAFFIC B)
(1½") TYPE SP-12.5 STRUCTURAL COURSE (TRAFFIC B)
(6") TYPE B-12.5 BASE
(12") TYPE B STABILIZATION LBR 40

HUGHEY AVENUE PAVEMENT REPLACEMENT

(2") FRICTION COURSE FC-12.5 (RUBBER)(TRAFFIC C)
(2") TYPE SP-12.5 STRUCTURAL COURSE (TRAFFIC C)
(9") TYPE B-12.5 BASE
(12") TYPE B STABILIZATION LBR 40

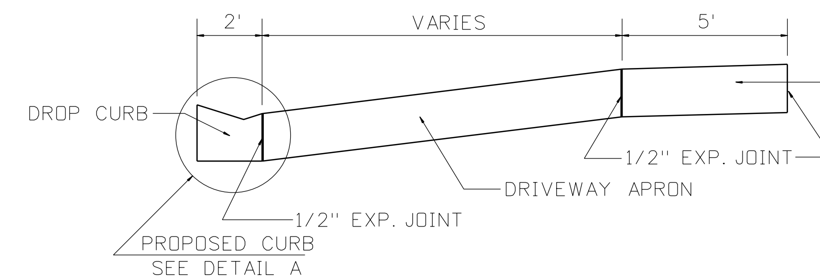
AMELIA STREET PAVEMENT REPLACEMENT

(2") FRICTION COURSE FC-12.5 (RUBBER)(TRAFFIC C)
(2") TYPE SP-12.5 STRUCTURAL COURSE (TRAFFIC C)
(9") TYPE B-12.5 BASE
(12") TYPE B STABILIZATION LBR 40



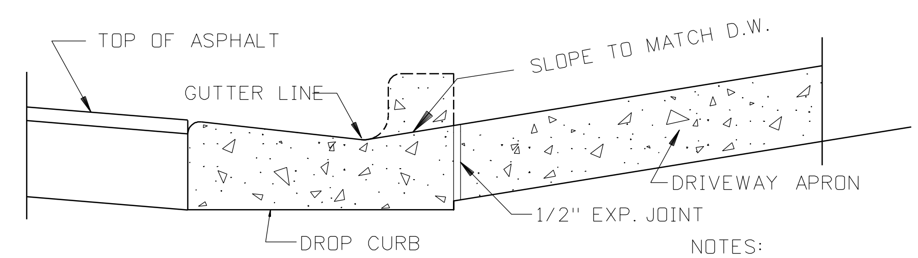
RESIDENTIAL DRIVEWAY APRON

N.T.S.



SECTION A-A

N.T.S.

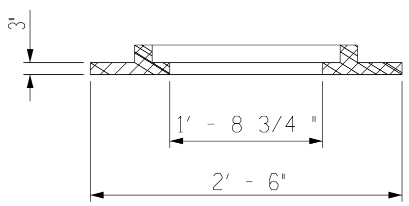


DETAIL A

N.T.S.

NOTES:

1. 3000 PSI CLASS 1 CONCRETE REQUIRED
2. EXISTING HIGH CURB SHALL BE REMOVED AND REPLACED WITH DROP CURB
3. 6" S.W. SECTION SHALL BE INSTALLED THROUGH DRIVEWAY



FRAME - TYPE II

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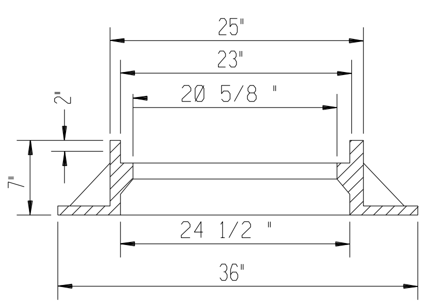

FRAME - TYPE I

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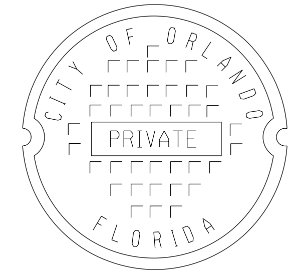

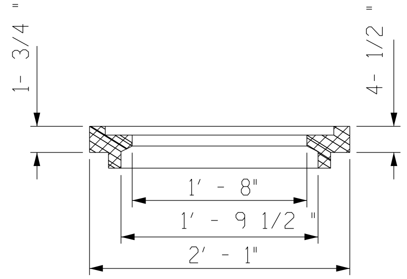

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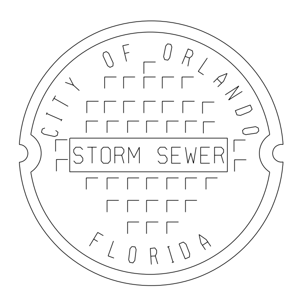
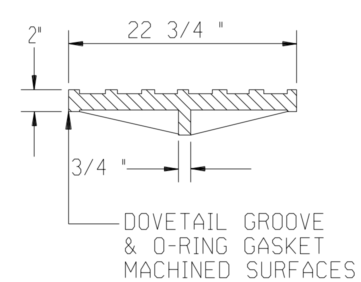


TYPICAL MANHOLE COVER

N.T.S.



MANHOLE FRAME & COVER:
(U.S.F. 420JT WITH CITY LOGO)
OR APPROVED EQUAL

REVISIONS			
DATE	DESCRIPTION	DATE	DESCRIPTION

GTC Engineering Corporation
98 South Semoran Blvd, Orlando, FL 32807
Phone Number - 407.380.0402
Certificate of Authorization Number 6758
Claude L. Cassagnol, P.E.
P.E. Number 35490

CITY OF ORLANDO

GTC PROJECT NO.		CITY OF ORLANDO PROJECT NO.
FLO 16.01	LAKE CONCORD ALUM TREATMENT & BAFFLE BOX	1461

STANDARD DRAWINGS AND DETAILS

SHEET NO. 3

SUMMARY OF PAY ITEMS

ITEM NUMBER	DESCRIPTION	UNIT	QUANTITY TOTAL PLANS	QUANTITY TOTAL FINAL
101-1	MOBILIZATION	LS	1	
102-1	MAINTENANCE OF TRAFFIC	LS	1	
104-14	PREVENTION, CONTROL AND ABATEMENT OF EROSION AND WATER POLLUTION	LS	1	
110-1-1	CLEARING & GRUBBING	LS	1	
110-4	REMOVAL OF EXISTING CONCRETE PAVEMENT	SY	96	
120-9	EXCAVATION, EMBANKMENT, AND GRADING	LS	1	
160-4	TYPE "B" STABILIZATION (12") (MIN. LBR 40)	SY	272	
285-709	BASE GROUP 09 (TYPE B-12.5) (6")	SY	160	
285-715	BASE GROUP 15 (TYPE B-12.5) (9")	SY	42	
334-1-12	TYPE SP ASPHALTIC CONCRETE (1 1/2") (TRAFFIC LEVEL B)	SY	160	
334-1-13	TYPE SP ASPHALTIC CONCRETE (2") (TRAFFIC LEVEL C)	SY	42	
337-7-30	ASPHALTIC CONCRETE FRICTION COURSE (RUBBER) (1" FC-9.5) (INCL. TACK COAT)	SY	160	
337-7-33	ASPHALTIC CONCRETE FRICTION COURSE (RUBBER) (2" FC-12.5) (INCL. TACK COAT)	SY	42	
425-2-91	MANHOLE (J-8) (<10')	EA	6	
425-3-82A	BAFFLE BOX	EA	1	
520-1-10	CONCRETE CURB & GUTTER (TYPE F)	LF	209	
522-1	CONCRETE SIDEWALK, 4" THICK (INCL. COMPACTION)	SY	24	
522-2-1	CONCRETE SIDEWALK, 6" THICK (INCL. COMPACTION)	SY	35	
522-2-2	CONCRETE SLAB	LS	1	
570-1-2	PERFORMANCE TURF, SOD	SY	330	
900-1	AS-BUILT PLANS (BLACK-LINE)	LS	1	
1050-11-211-1	1 " PVC	LF	230	
1050-11-211-2	1 1/2" POLYTUBING	LF	1,685	
1050-11-212A	4" SDR11 HDPE (DIRECTIONAL DRILL)	LF	1,598	
1050-11-212B	4" SDR11 HDPE	LF	67	
1050-113-24A	18" PVC SANITARY SEWER SDR 26	LF	50	
1060-11-222A	SANITARY MANHOLE (>10')	EA	1	

PAY ITEM FOOTNOTES

102-1 INCLUDE ALL ITEMS OF MAINTENANCE OF TRAFFIC INCLUDING, BUT NOT LIMITED TO, THE DESIGN OF THE MAINTENANCE OF TRAFFIC PLAN BY THE CONTRACTOR AND APPROVAL OF THE PLANS BY THE CITY OF ORLANDO. ALSO INCLUDES ALL TEMPORARY AND PERMANENT STRIPING, SIGNING, FLAGGERS, ETC. REQUIRED TO MAINTAIN TRAFFIC DURING CONSTRUCTION IN ACCORDANCE WITH THE MUTCD AND THE FDOT ROADWAY AND DESIGN STANDARDS, 2010 EDITION. ATTENTION IS DIRECTED TO THE 600 SERIES INDEX NUMBERS. NOTE THAT THE MAINTENANCE OF TRAFFIC PLAN SHOWN IN THE CONSTRUCTION PLANS IS FOR INFORMATION ONLY. FINAL PLAN TO BE SUBMITTED TO AND APPROVED BY THE CITY. THE MAINTENANCE OF TRAFFIC PLAN DONE BY THE CONTRACTOR SHALL BE SIGNED AND SEALED BY A PROFESSIONAL ENGINEER REGISTERED IN THE STATE OF FLORIDA.

104-14 INCLUDES THE COST OF ALL ITEMS REQUIRED FOR EROSION CONTROL INCLUDING, BUT NOT LIMITED TO SYNTHETIC BALES, TURBIDITY BARRIERS, SILT FENCES AND TEMPORARY GRASSING AS SHOWN IN THE PLANS OR AS DIRECTED BY THE ENGINEER. NOT AN FDOT PAY ITEM NUMBER.

110-1-1 INCLUDES, BUT IS NOT LIMITED TO, THE COST OF REMOVAL AND DISPOSAL OF CONCRETE CURBS, STRUCTURES, WALLS, BRICK WALLS, VARIOUS TYPES OF FENCES, CAPPING WELLS, REMOVAL AND DISPOSAL OF SEPTIC TANKS AND DRAIN FIELDS, UNDERGROUND STORAGE TANKS, PAVEMENT, BASE, AND TRIMMING OF TREES AND SHRUBS AS REQUIRED TO CONSTRUCT THE PROJECT. INCLUDES THE COST OF SAWCUTTING CONCRETE DRIVEWAYS AND ANY TREE REMOVAL.

120-9 INCLUDES DREDGING AND GRADING AT LAKE CONCORD.

425-2-91 INCLUDES THE COST OF ALL INCIDENTAL ITEMS REQUIRED TO CONSTRUCT THE STRUCTURE, BUT NOT LIMITED TO THE COST OF GRADING, BRICK REPLACEMENT, INCIDENTAL ADDITIONAL PIPE AND ANY ADDITIONAL MATERIAL/METHOD NEEDED TO MAKE CONNECTIONS AS SHOWN IN THE PLANS OR AS DIRECTED BY THE ENGINEER.

425-3-82A INCLUDES THE COST OF INCIDENTAL ADDITIONAL PIPE, CONCRETE COLLARS (PER FDOT INDEX 280), AND ANY ADDITIONAL MATERIAL/METHOD NEEDED TO MAKE CONNECTIONS TO EXISTING PIPE WHERE EXISITING STRUCTURES ARE BEING REPLACED TO MATCH EXISTING REMAINING PIPE.

522-2-1 LOCATIONS OF DRIVEWAYS ARE APPROXIMATE AND SHALL BE FIELD ADJUSTED BY CONTRACTOR TO SUIT THE ACTUAL REQUIREMENTS AT THE TIME OF CONSTRUCTION AS DIRECTED BY THE ENGINEER.

522-2-2 28"x40"x6" CONCRETE SLAB AT STRUCTURE S-4 ALONG HUGHEY AVE. RIGHT SIDE.

1050-113-24A / 1060-11-222A INCLUDES, BUT IS NOT LIMITED TO, THE COST OF MAINTAINING EXISTING SEWAGE FLOW VIA PUMPS OR PUMP STORAGE TRUCKS. ALSO INCLUDES THE COST FOR REMOVAL OF EXISTING 18" & 10" VCP SANITARY SEWER PIPE AND PLUGGING & CONNECTING TO EXISTING SANITARY MANHOLE SM1.

1050-11-212A INCLUDES OFFSITE DISPOSAL OF DRILLING MUD AND WASTE PRODUCTS.

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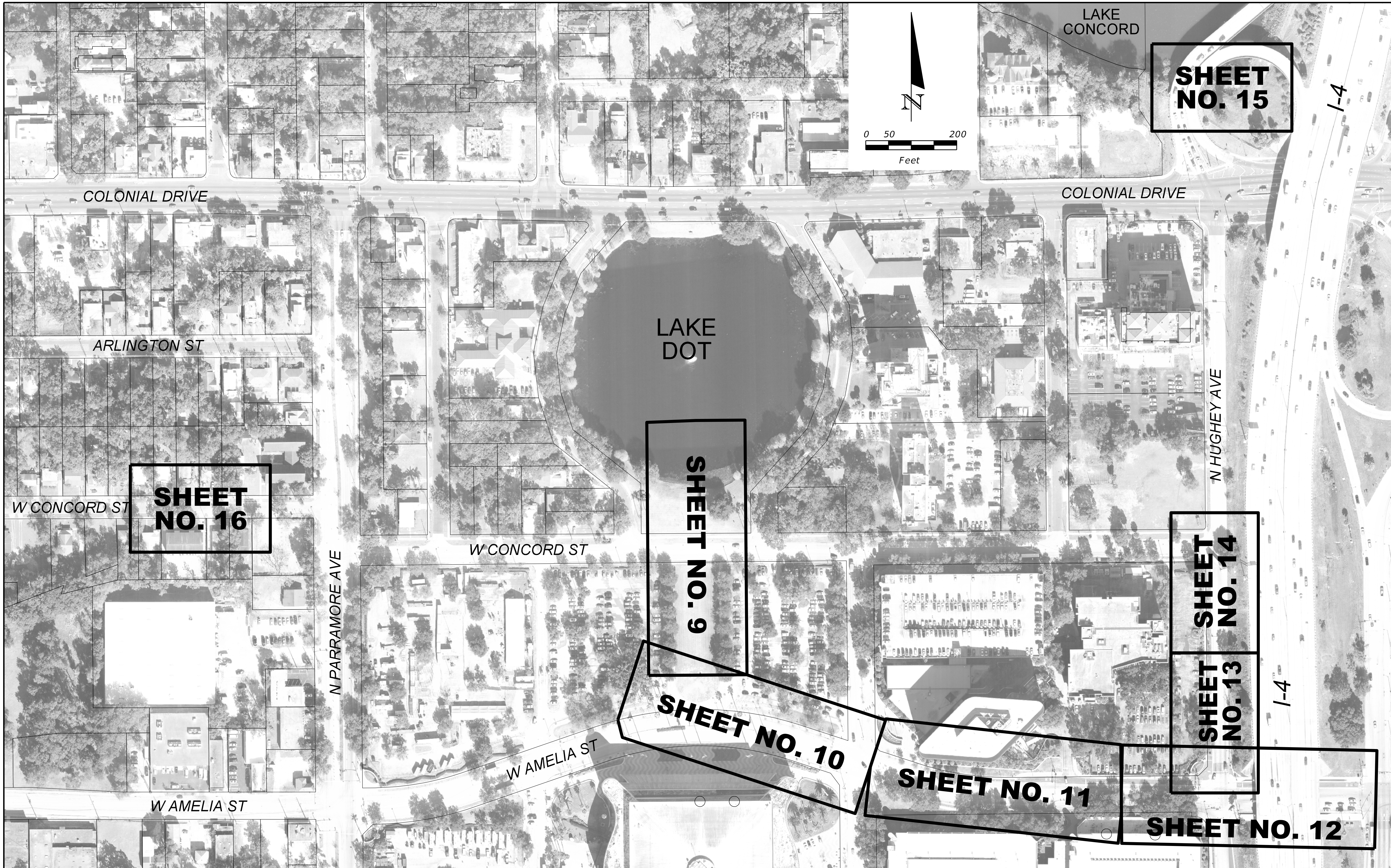
Claude L. Cassagnol, P.E. P.E. Number 35490

CITY OF ORLANDO

GTC PROJECT NO. FLO 16.01 | LAKE CONCORD ALUM TREATMENT & BAFFLE BOX | CITY OF ORLANDO PROJECT NO. 1461

SUMMARY OF PAY ITEMS



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PROJECT LAYOUT

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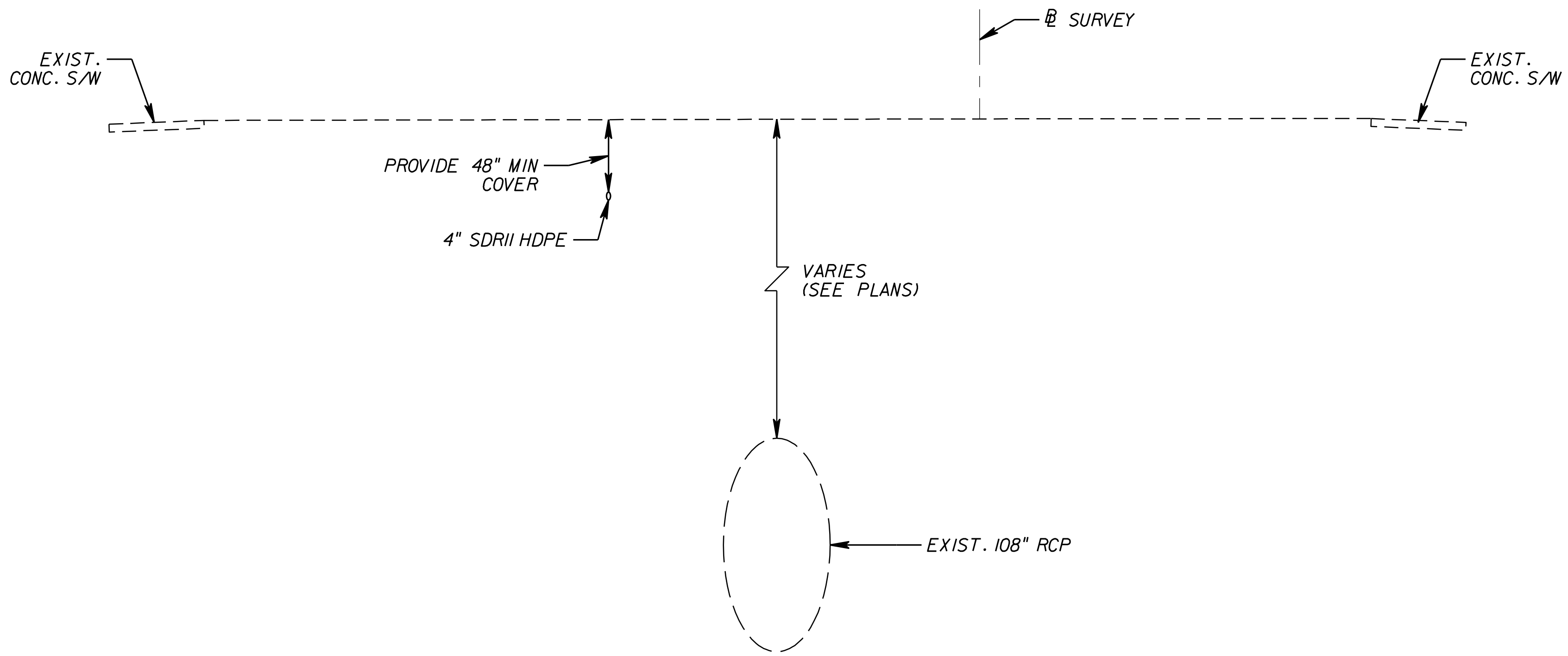

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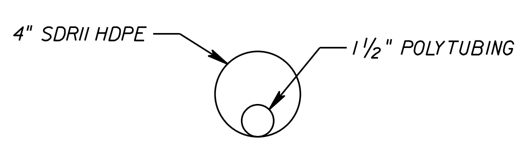

DETAIL 'A'
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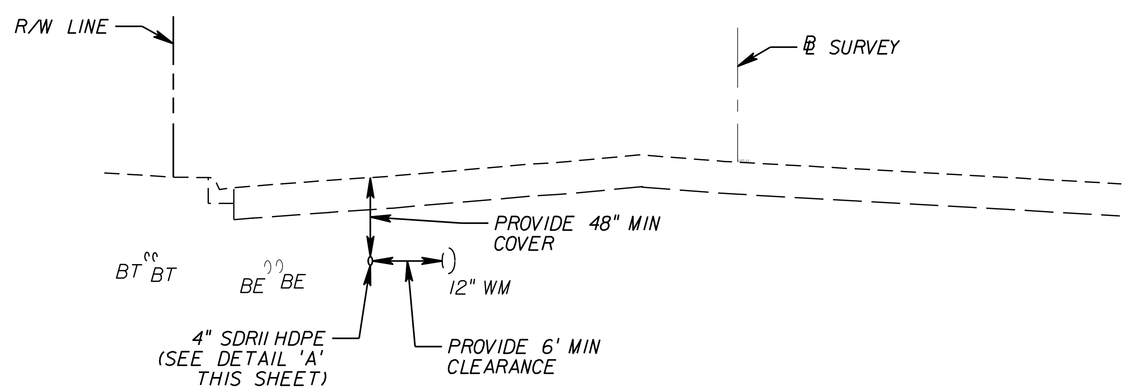

TYPICAL SECTION
AMELIA STREET
STA. 12+00.00 TO STA. 24+00.00

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TYPICAL SECTIONS

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SUMMARY OF DRAINAGE STRUCTURES

PROPOSED STRUCTURE	DESCRIPTION	PROPOSED TOP ELEV	PROPOSED COORDINATES	PROPOSED PIPES AND INVERTS	PROPOSED STATION AND OFFSET	ACTUAL TOP ELEV	ACTUAL COORDINATES	ACTUAL PIPES AND INVERTS	ACTUAL STATION AND OFFSET
S-1	TYPE J-8 MANHOLE	112.19	N 1532834.250 E 532032.024	CONST. 4" SDR11 HDPE (INV 108.44 N) CONST. 4" SDR11 HDPE (INV 108.44 E)	STA 12+04.00, 36.00' LT B SURVEY 1				
S-2	TYPE J-8 MANHOLE	106.69	N 1532683.477 E 532623.513	CONST. 4" SDR11 HDPE (INV 102.45 W) CONST. 4" SDR11 HDPE (INV 102.45 E)	STA 18+10.00 ,26.71' LT B SURVEY 1				
S-3	TYPE J-8 MANHOLE	104.74	N 1532693.998 E 533220.535	CONST. 4" SDR11 HDPE (INV 100.91 W) CONST. 4" SDR11 HDPE (INV 101.41 N)	STA 60+41.16, 23.25' RT CL CONST. HUGHEY AVE.				
S-4	TYPE J-8 MANHOLE	104.66	N 1532742.708 E 533218.810	CONST. 4" SDR11 HDPE (INV 100.33 S) 3'X2' HOLE IN BOTTOM OF STRUCTURE	STA 60+89.89, 21.91' RT CL CONST. HUGHEY AVE.				
S-5	TYPE J-8 MANHOLE	101.77	N 1533141.818 E 533215.865	3'X2' HOLE IN BOTTOM OF STRUCTURE	STA 64+89.01, 22.08' RT CL CONST. HUGHEY AVE.				
S-6	TYPE J-8 MANHOLE	102.18	N 1533226.189 E 532028.780	CONST. 4" SDR11 HDPE (INV 94.87 S) CONST. 4" SDR11 HDPE (INV 94.87 NW)	STA 54+27.00, 23.25' LT B SURVEY 2				
S-7	BAFFLE BOX	100.08	N 1533278.288 E 530930.381	CONNECT EXIST. 18" RCP (INV 92.56 N) CONNECT EXIST. 24" RCP (INV 91.76 S) CONNECT EXIST. 66" RCP (INV 88.18 W) CONNECT EXIST. 72" RCP (INV 87.67 E)	STA 72+77.39, 3.34' RT CL CONST. CONCORD ST.				

SUMMARY OF SEWER

PROPOSED STRUCTURE	DESCRIPTION	PROPOSED TOP ELEV	PROPOSED COORDINATES	PROPOSED PIPES AND INVERTS	PROPOSED STATION AND OFFSET	ACTUAL TOP ELEV	ACTUAL COORDINATES	ACTUAL PIPES AND INVERTS	ACTUAL STATION AND OFFSET
SAN-1	SANITARY MANHOLE	99.89	N 1533288.138 E 530912.958	CONST. 18" PVC SDR26 (INV 89.06 E) CONST. 18" PVC SDR26 (INV 89.06 W)	STA 72+60.00, 6.56' LT CL CONST. CONCORD ST.				

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CITY OF ORLANDO

GTC PROJECT NO. FLO 16.01

LAKE CONCORD ALUM TREATMENT & BAFFLE BOX

CITY OF ORLANDO PROJECT NO. 1461

SUMMARY OF DRAINAGE STRUCTURES AND SEWER

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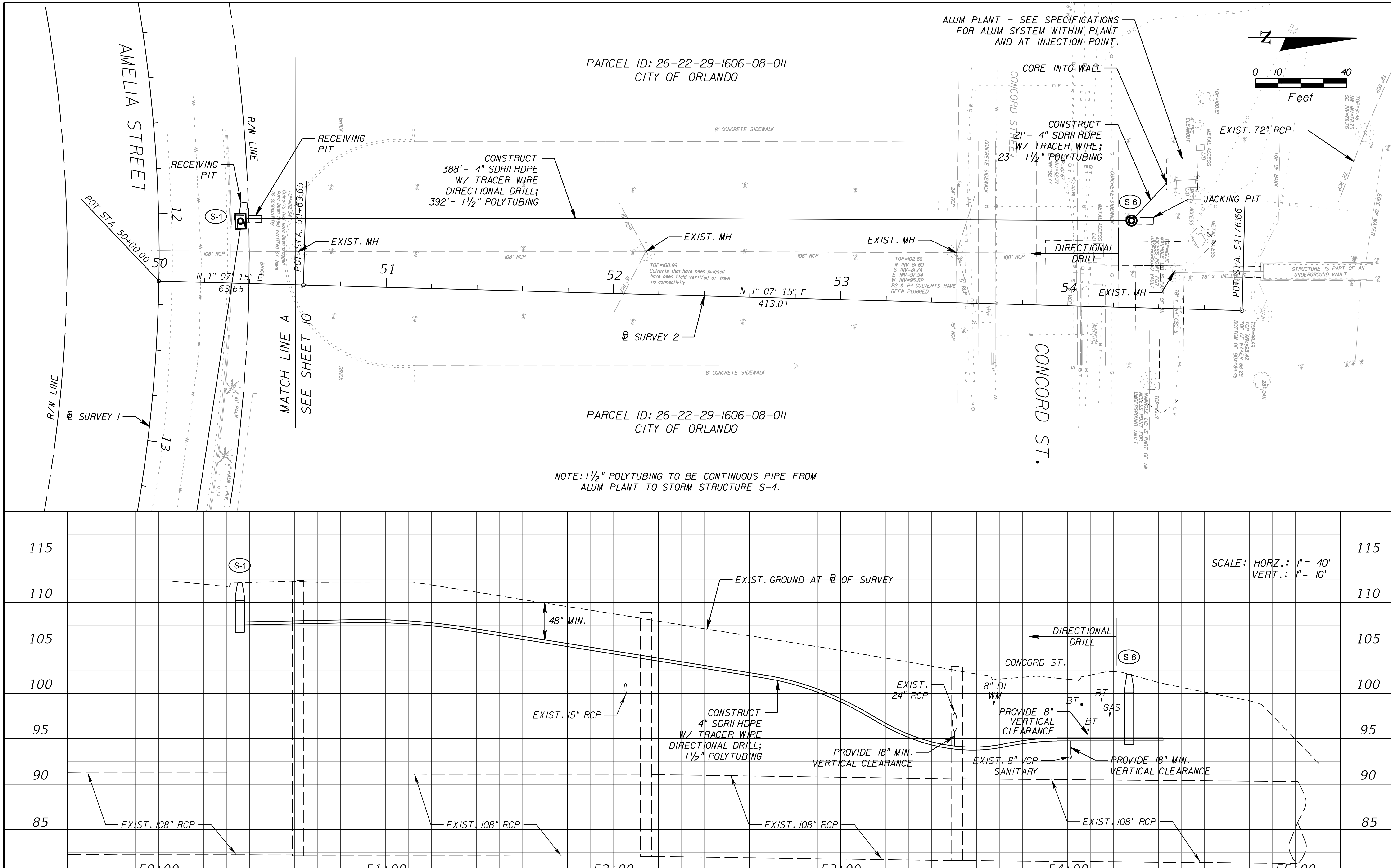

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PLAN AND PROFILE
STA. 50+00.00 TO STA. 55+00.00

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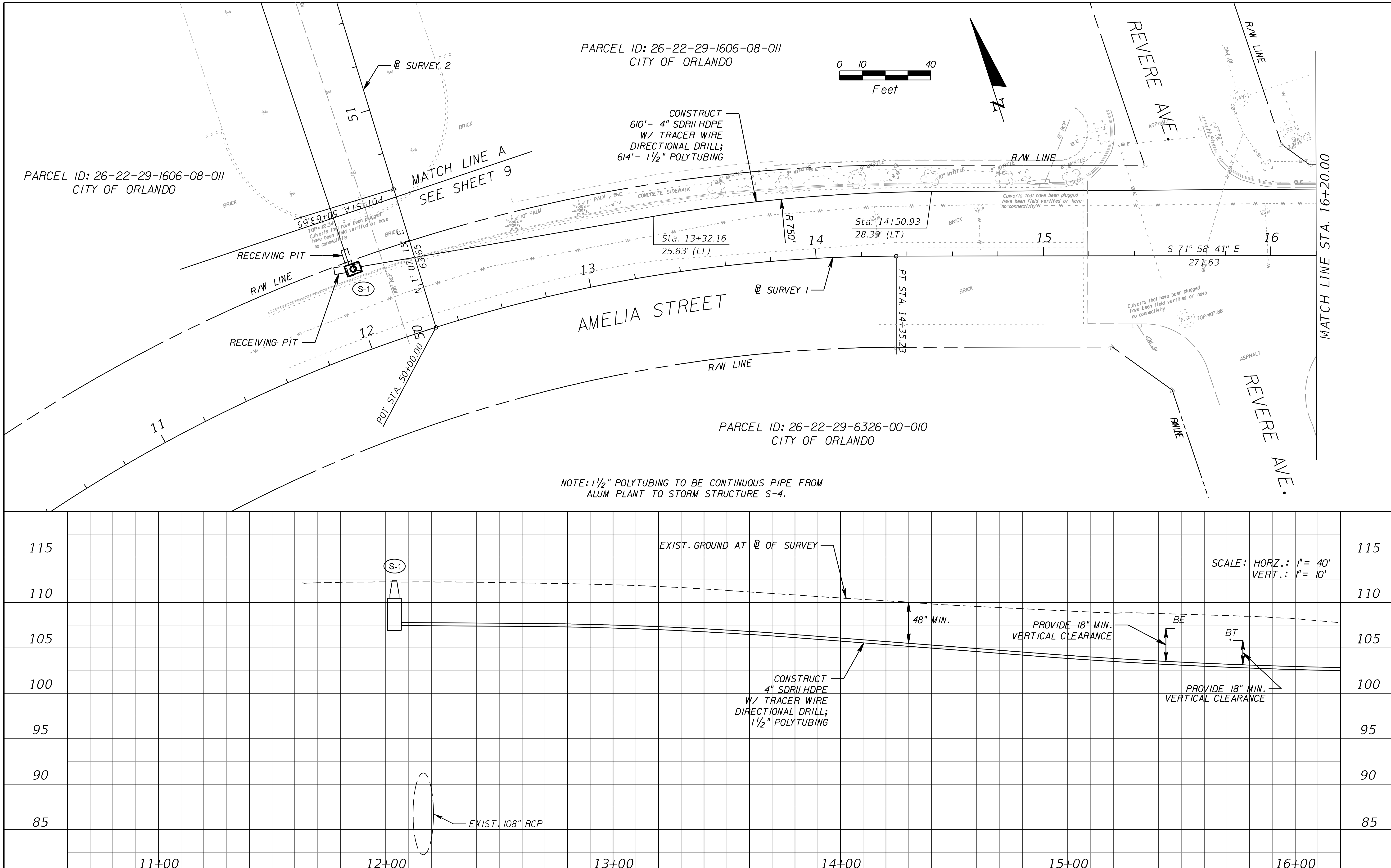

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PLAN AND PROFILE
STA. 11+00.00 TO STA. 16+20.00

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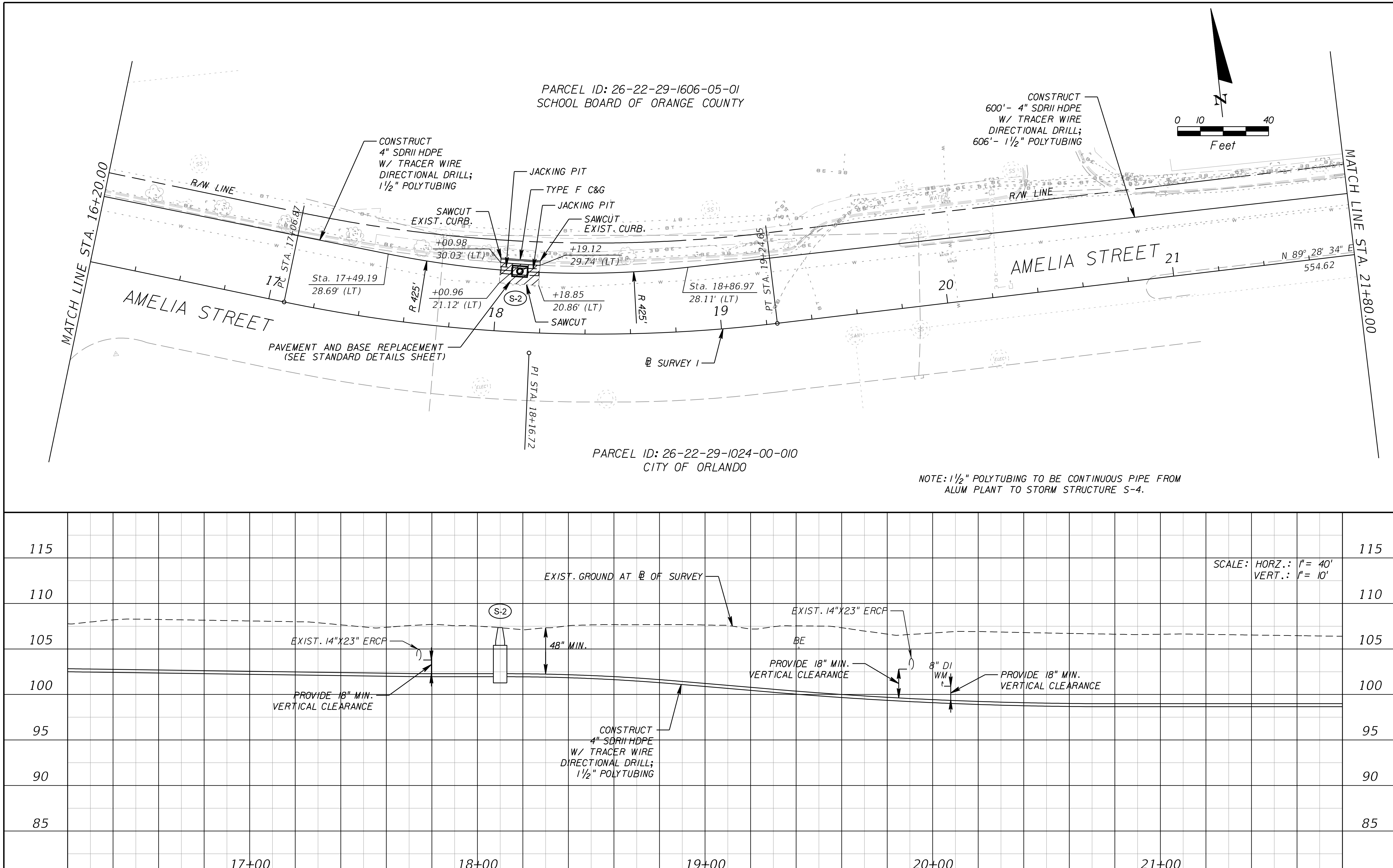

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PLAN AND PROFILE
STA. 16+20.00 TO STA. 21+80.00

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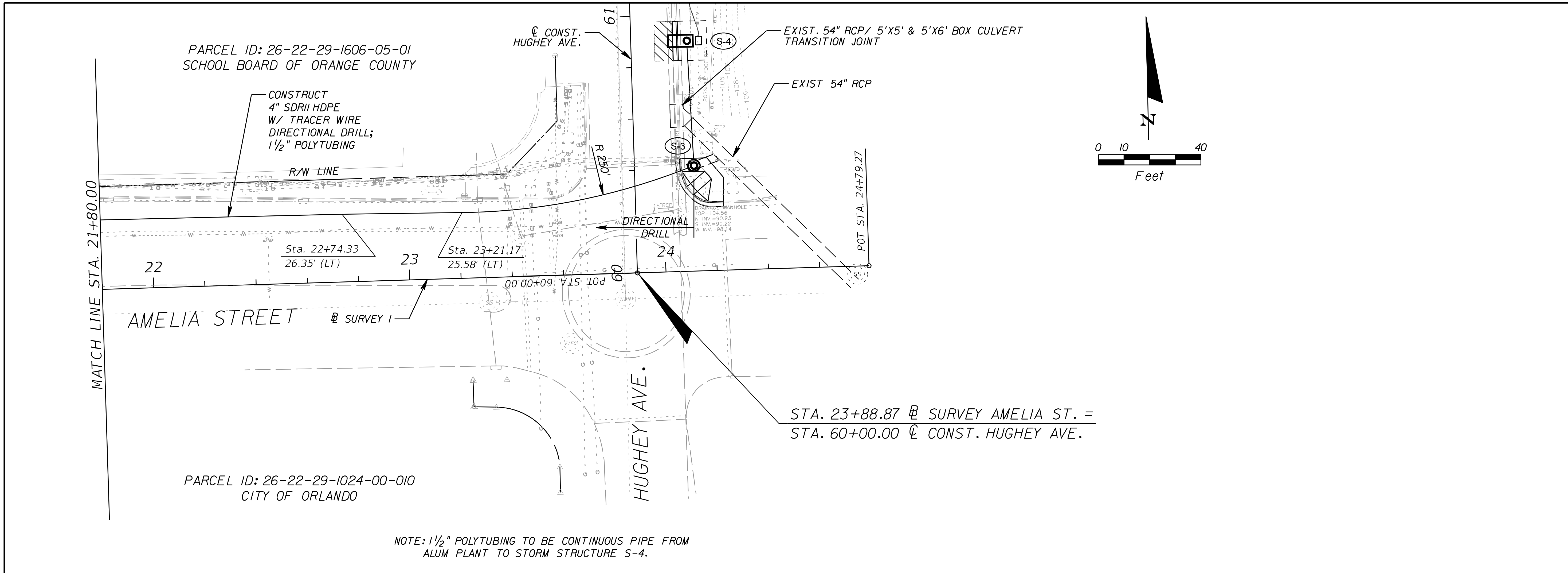

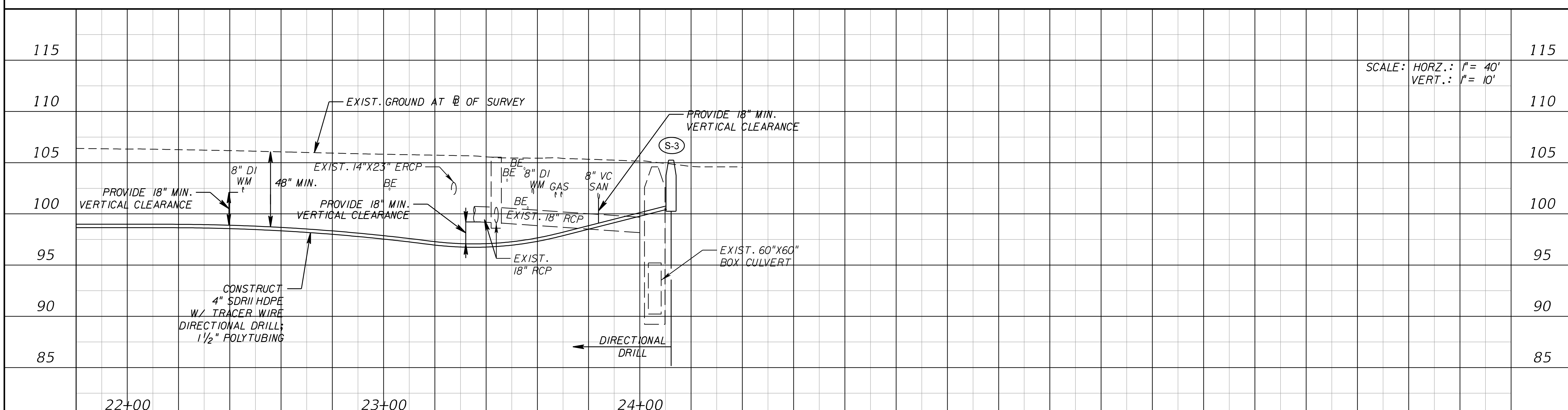

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PLAN AND PROFILE
STA. 21+80.00 TO STA. 24+79.32

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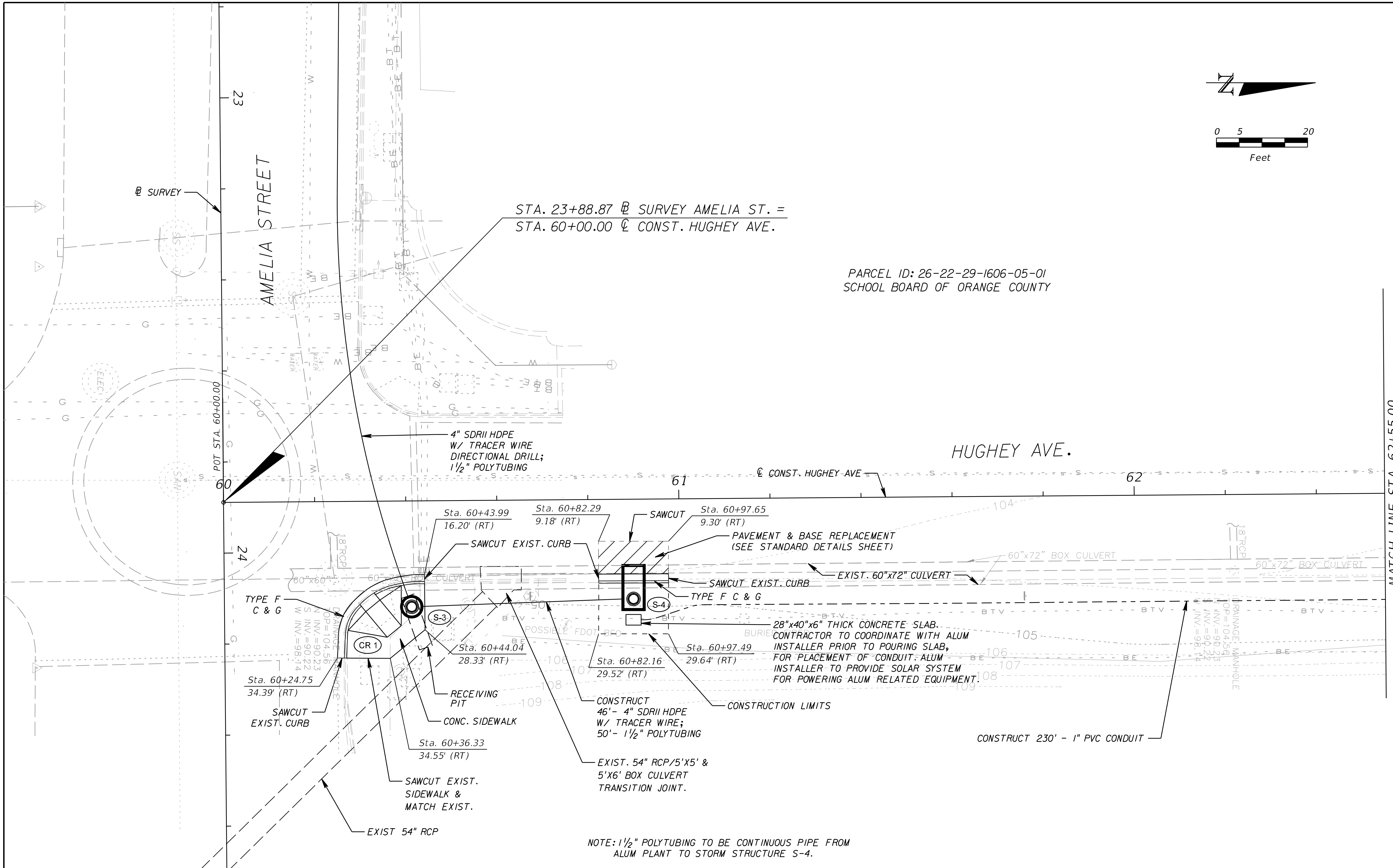

NOTE: 1 1/2" POLYTUBING TO BE CONTINUOUS PIPE FROM ALUM PLANT TO STORM STRUCTURE S-4.

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PLAN SHEET HUGHEY AVENUE

SHEET NO. 13

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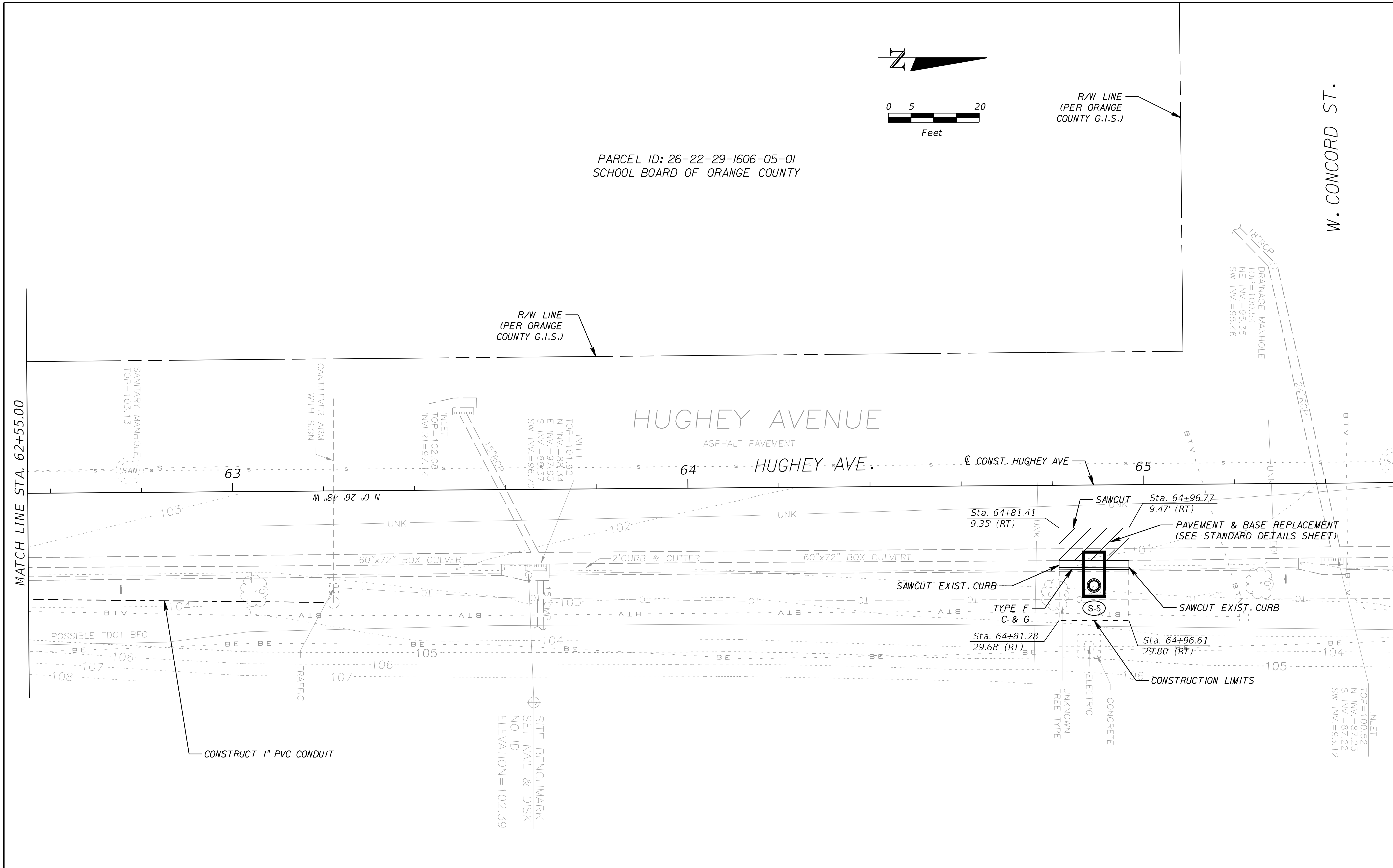

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PLAN SHEET
HUGHEY AVENUE

SHEET NO. 14

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PLAN SHEET
LAKE CONCORD AT I-4 RAMP

SHEET NO. 15

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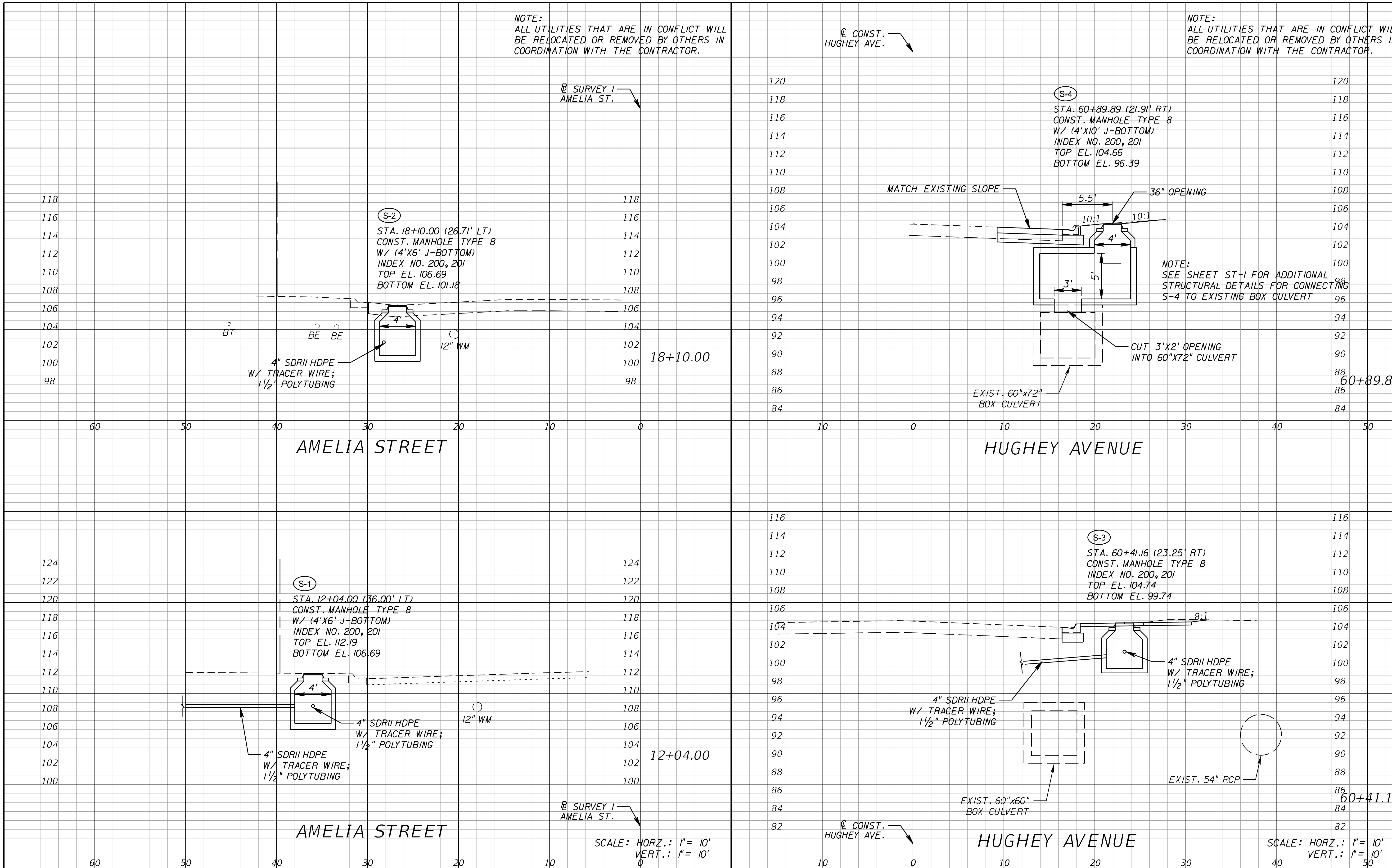

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DRAINAGE STRUCTURE SHEET

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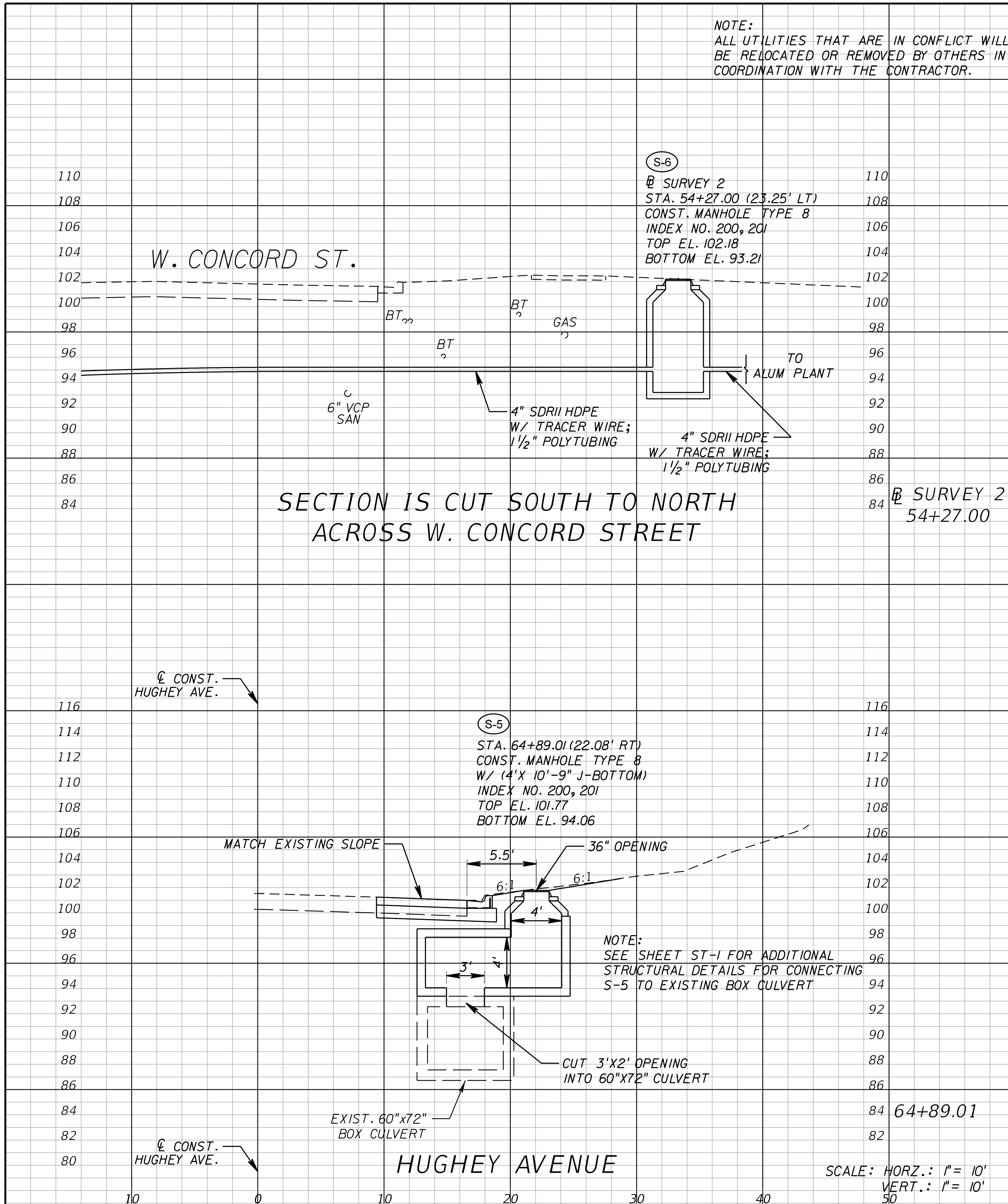

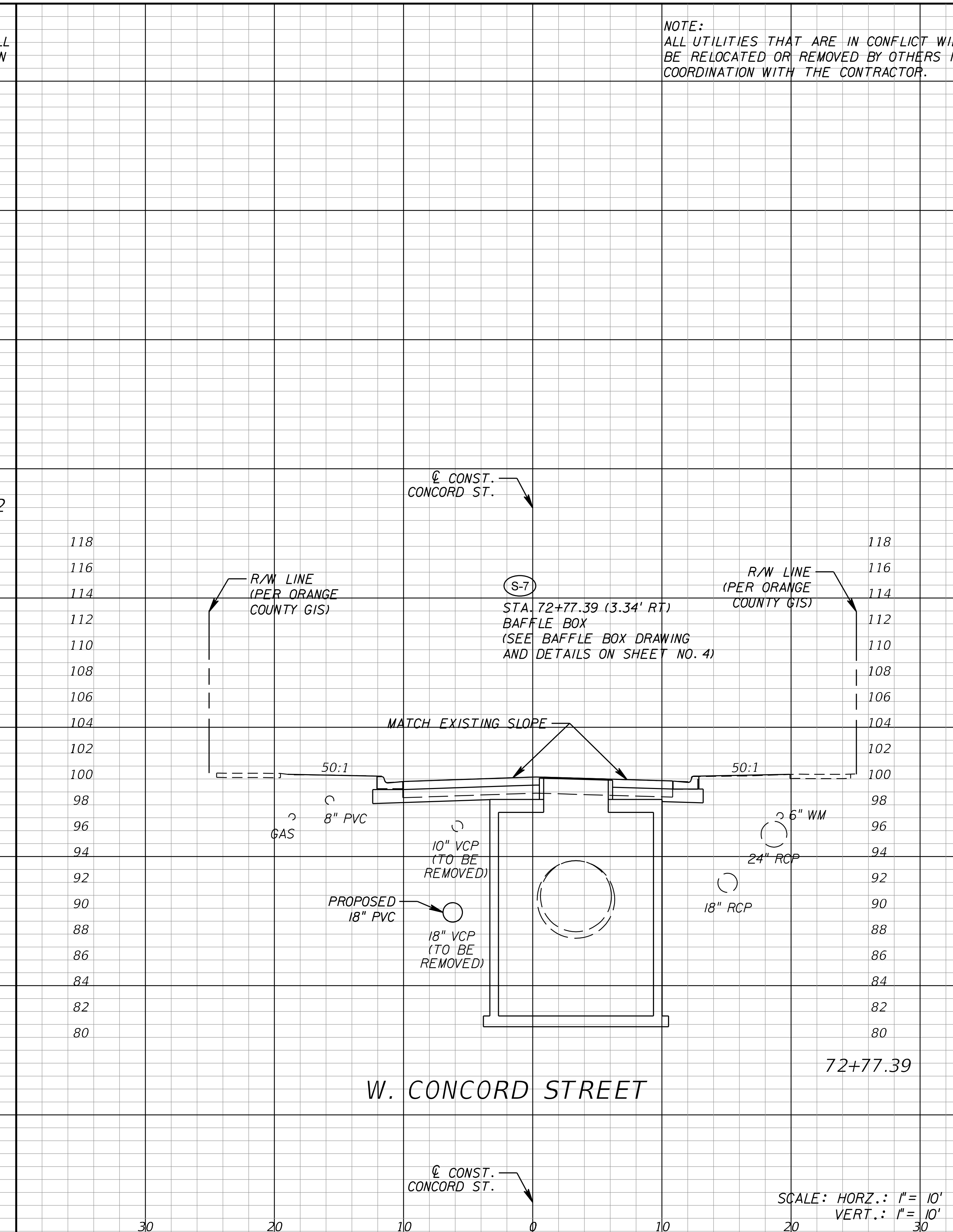

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LAKE CONCORD ALUM TREATMENT & BAFFLE BOX
CITY OF ORLANDO PROJECT NO.: 1461

DRAINAGE STRUCTURE SHEET

SHEET NO. 18

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APPENDIX B

CHARACTERISTICS OF UNTREATED RUNOFF SAMPLES COLLECTED FROM THE HUGHEY AVENUE STORMSEWER SYSTEM

Characteristics of Untreated Runoff Samples Collected from the Hughey Avenue Stormsewer

Site	Date Collected	Event Rainfall (in)	pH (s.u.)	Alkalinity (mg/L)	Cond (µmho/cm)	Ammonia N (µg/L)	NOx-N (µg/L)	Diss. Org. N (µg/L)	Part. N (µg/L)	Total N (µg/L)	SRP (µg/L)	Diss. Org. P (µg/L)	Part. P (µg/L)	Total P (µg/L)	Turbidity (NTU)	Color (Pt-Co)	TSS (mg/L)	Total Al (µg/L)	Total Cd (µg/L)	Total Cr (µg/L)	Total Cu (µg/L)	Total Fe (µg/L)	Total Mn (µg/L)	Total Ni (µg/L)	Total Pb (µg/L)	Total Zn (µg/L)
Upstream - Raw	7/22/15	0.60	7.49	52.8	124	130	164	442	689	1,424	43	25	216	284	16.0	20	92.8	1,786	0.49	15	111	1,728	31	3	17	59
Upstream - Raw	7/28/15	0.74	7.52	52.0	151	151	145	464	495	1,256	61	40	143	244	46.8	23	73.2	3,993	0.01	7	22	1,285	16	3	9	55
Upstream - Raw	8/31/15	1.38	7.06	47.0	107	163	142	308	467	1,080	28	38	49	115	12.3	11	38.4	839	0.01	3	24	536	9	1	6	69
Upstream - Raw	9/8/15	1.29	7.36	33.4	153	33	286	477	88	884	98	56	258	412	124	10	81.4	7,190	0.01	9	21	1,133	14	3	10	71
Upstream - Raw	9/25/15	1.42	7.03	50.6	127	3	387	101	131	622	45	37	109	191	12.0	25	66.6	1,072	0.01	3	12	345	6	1	1	82
Upstream - Raw	5/3/16	0.99	7.02	69.8	91	260	410	397	186	1,252	111	64	126	301	26.4	44	53.2	953	0.06	4	31	1,017	56	2	5	129
Upstream - Raw	6/7/16	1.12	7.73	127	153	7	606	207	813	1,633	40	26	489	555	214	35	295	7,482	1.00	29	67	3,524	47	4	33	69
Upstream - Raw	7/12/16	0.59	6.97	56.4	80	328	307	264	385	1,284	78	30	89	197	9.5	35	36.4	737	0.40	18	24	655	17	1	1	22
Upstream - Raw	10/11/16	1.25	6.81	32.8	99	127	92	54	131	404	49	35	105	189	6.6	15	38.2	512	0.60	13	11	433	8	1	1	58
Upstream - Raw	12/8/16	0.21	7.17	101	291	3	40	1,006	2,012	3,061	97	115	593	805	20.2	93	78.8	489	0.15	21	34	624	22	1	21	189
Minimum Value:		**0.21**	**6.81**	**32.8**	**80**	**3**	**40**	**54**	**88**	**404**	**28**	**25**	**49**	**115**	**6.6**	**10**	**36.4**	**489**	**0.01**	**3**	**11**	**345**	**6**	**1**	**1**	**22**
Maximum Value:		**1.42**	**7.73**	**127**	**291**	**328**	**606**	**1,006**	**2,012**	**3,061**	**111**	**115**	**593**	**805**	**214**	**93**	**295**	**7,482**	**1.00**	**29**	**111**	**3,524**	**56**	**4**	**33**	**189**
Geometric Mean:		**0.85**	**7.21**	**57.0**	**129**	**49**	**200**	**285**	**351**	**1,132**	**59**	**42**	**164**	**282**	**25.1**	**25**	**69.0**	**1,507**	**0.08**	**9**	**28**	**885**	**18**	**2**	**6**	**70**
																		Class III Criterion:	**0.16**	**49**	**5**	**1,000**	**-**	**26**	**1.3**	**67**

Highlighted cells indicate values which were BDL; the listed value is 1/2 of the MDL.

APPENDIX C

CHARACTERISTICS OF ALUM TREATED RUNOFF SAMPLES COLLECTED FROM THE HUGHEY AVENUE STORMSEWER SYSTEM

Characteristics of Alum Treated Runoff Samples Collected from the Hughey Avenue Stormsewer

Site	Date Collected	Event Rainfall (in)	pH (s.u.)	Alkalinity (mg/L)	Cond (µmho/cm)	Ammonia N (µg/L)	NOx-N (µg/L)	Diss. Org. N (µg/L)	Part. N (µg/L)	Total N (µg/L)	SRP (µg/L)	Diss. Org. P (µg/L)	Part. P (µg/L)	Total P (µg/L)	Turbidity (NTU)	Color (Pt-Co)	TSS (mg/L)	Total Al (µg/L)	Total Cd (µg/L)	Total Cr (µg/L)	Total Cu (µg/L)	Total Fe (µg/L)	Total Mn (µg/L)	Total Ni (µg/L)	Total Pb (µg/L)	Total Zn (µg/L)
Treated	7/22/15	0.60	6.89	34.4	78	200	136	303	69	709	3	18	32	53	2.0	18	3.6	131	0.24	1	6	125	7	1	5	49
Treated	7/28/15	0.74	6.77	44.8	114	198	99	390	97	784	4	37	31	72	2.4	21	5.0	124	0.01	1	7	197	12	1	1	48
Treated	8/31/15	1.38	6.81	34.2	67	92	202	196	95	585	3	16	17	36	2.4	10	7.0	177	0.01	1	11	59	3	1	2	68
Treated	9/8/15	1.29	6.86	31.8	72	106	137	216	23	483	4	47	11	62	4.3	7	6.6	454	0.01	2	11	82	4	1	1	61
Treated	9/25/15	1.42	6.80	38.2	155	176	149	34	75	434	4	31	11	46	1.6	18	8.7	93	0.01	2	9	137	7	1	1	40
Treated	5/3/16	0.99	7.24	66.8	125	295	412	184	48	938	14	43	24	81	12.9	24	12.7	454	0.01	2	15	328	24	1	3	51
Treated	6/7/16	1.12	7.65	72.8	133	32	263	63	24	382	4	21	25	50	2.1	24	2.2	69	0.30	11	4	61	3	1	1	8
Treated	7/12/16	0.59	6.73	39.0	115	191	239	163	55	648	14	26	28	68	1.7	21	4.0	73	0.10	15	8	315	14	1	1	4
Treated	10/11/16	1.25	6.38	27.7	72	41	80	103	67	291	3	31	9	43	3.1	12	3.6	118	0.50	8	6	148	4	1	1	14
Treated	12/8/16	0.21	6.87	72.0	247	3	36	656	524	1,219	12	67	20	99	8.9	57	32.0	107	0.01	12	9	299	4	1	2	21
Minimum Value:		**0.21**	**6.38**	**27.7**	**67**	**3**	**36**	**34**	**23**	**291**	**3**	**16**	**9**	**36**	**1.6**	**7**	**2.2**	**69**	**0.01**	**1**	**4**	**59**	**3**	**1**	**1**	**4**
Maximum Value:		**1.42**	**7.65**	**72.8**	**247**	**295**	**412**	**656**	**524**	**1,219**	**14**	**67**	**32**	**99**	**12.9**	**57**	**32.0**	**454**	**0.50**	**15**	**15**	**328**	**24**	**1**	**5**	**68**
Geometric Mean:		**0.85**	**6.89**	**43.5**	**109**	**83**	**145**	**171**	**69**	**595**	**5**	**31**	**19**	**58**	**3.2**	**18**	**6.3**	**143**	**0.04**	**3**	**8**	**146**	**6**	**1**	**2**	**27**
																		Class III Criterion:	**0.16**	**49**	**5**	**1,000**	**-**	**26**	**1.3**	**67**

Highlighted cells indicate values which were BDL; the listed value is 1/2 of the MDL.