URS

October 1, 2008

Ms. Vanessa Steigerwald Dick, Ph.D.
Ohio Environmental Protection Agency
Northeast District Office
2110 East Aurora Road
Twinsburg, Ohio 44087

Re: Stormwater Sampling and Analysis Plan
Akron Airdock, Akron, Ohio
Voluntary Action Program (VAP)

Dear Ms. Steigerwald Dick:

On behalf of Lockheed Martin Corporation (LMC) and Summit County Port Authority (SCPA), URS is submitting the enclosed *Stormwater Sampling and Analysis Plan* (Stormwater SAP) as part of the ongoing voluntary action at the Akron Airdock property. The SAP presents a program to collect confirmation stormwater samples from five locations within the Airdock property over the course of four, discrete storm events. The samples will be analyzed for polychlorinated biphenyls (PCBs) by a VAP-certified laboratory. We are submitting the SAP for your review and comments under technical assistance.

As we discussed at the August 28, 2008 meeting between Ohio Environmental Protection Agency (Ohio EPA), LMC, SCPA, and URS, the Stormwater SAP will be promptly implemented, weather permitting, following completion of the ongoing sewer sediment removal activities. The anticipated schedule to complete the sewer cleaning task is mid-October. Stormwater sample collection will then follow in accordance with the sampling conditions outlined in the SAP.

Because it will not be possible to complete the sampling program prior to the November 24, 2008 due date for submittal of the no further action letter (NFA), we are planning to submit the SAP as an element of an operations and maintenance plan (O&M Plan) as part of the overall Airdock remedy. We are in the process of preparing the O&M Plan, which also addresses other remedy elements such as risk mitigation measures for construction workers.

With respect to our recent discussion of analytical methods for PCBs, we inquired to TestAmerica Laboratories Inc. (TestAmerica) of North Canton (VAP CL0024) for the reporting limit for EPA Method 608 versus EPA Method 8082. TestAmerica reported that its current standard operating procedure under EPA Method 608 sets the reporting limit for PCBs in wastewater at 0.2 micrograms per liter (µg/L). This reporting limit is identical to that generated by TestAmerica when it analyzes PCBs

URS Corporation
36 East 7th Street, Suite 2300
Cincinnati, OH 45202
Tel: 513.651.3440
Fax: 513.651.3452
www.urscorp.com

under EPA Method 8082 "low level." Since TestAmerica is the only VAP-certified lab to have certification for the specific PCB of interest at the Airdock, Aroclor 1268, and the certification is based upon Method 8082, we are planning to submit the samples (one set of samples per station per event) to TestAmerica for analysis using Method 8082 "low level".

-oOo-

Please contact me if you have any questions or comments during your review of the Stormwater SAP or if further information is needed.

Sincerely,

URS Corporation

Jennifer J. Krueger, PG
Project Manager

Enclosure

Copy: Phil Rhodes, Ohio EPA, Division of Surface Water
Brad Heim, Lockheed Martin
Dave Gunnarson, Lockheed Martin
Steve Vardavas, Lockheed Martin
Norma Fox Horwitz, Summit County Port Authority
Terrence Finn, Roetzel & Andress

STORMWATER SAMPLING AND ANALYSIS PLAN

AKRON AIRDOCK, AKRON, OHIO

Prepared for:

LOCKHEED MARTIN CORPORATION
OCTOBER 1, 2008

JOB NO: 14947614

URS CORPORATION

STORMWATER SAMPLING AND ANALYSIS PLAN

Akron Airdock Facility
1210 Massillon Road
Akron, Ohio

October 1, 2008

PREPARED FOR:

LOCKHEED MARTIN CORPORATION
1210 Massillon Road
Akron, Ohio 44315

PRESENTED BY:

URS Corporation
Suite 2300
36 East Seventh Street
Cincinnati, OH 45202
Phone: 513-651-3440 / Fax: 513-651-3452

PREPARED BY:

John D. Priebe, P.E.
Senior Engineer

REVIEWED BY:

Jennifer J. Krueger, P.G.
Project Manager

CONTENTS

Section **Page**

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

1.0 INTRODUCTION

This Stormwater Sampling and Analysis Plan (SAP) has been prepared to address proposed post-remediation stormwater sampling activities at the Akron Airdock (Airdock) facility. The Airdock facility is a historic airship hangar located on the former Lockheed Martin Corporation (LMC) property at 1210 Massillon Road, Akron, Ohio.

The activities discussed in this plan are specific to the 19-acre parcel that includes the Airdock facility (also known as "Plant A"). A site aerial photograph illustrating the location of the Airdock parcel, surrounding properties, and other local drainage features is provided as Figure 1. The Airdock parcel is located in an industrial park south of the Akron Municipal Airport and north of U.S. Highway 224. The industrial park is owned by LMA Commerce LTD (LMA) and managed by Ohio Realty Advisors, Inc. Stormwater discharge from the northern portion of the industrial park, including the Airdock parcel, is currently permitted under the Ohio Environmental Protection Agency (Ohio EPA) *General Permit Authorization to Discharge Stormwater Associated with Industrial Activities* (General Permit, Ohio EPA Facility Permit Number 3GR00733*DG). The permittee is Valley Association Corporation (VAC), a corporation owned by LMA, Meggitt, and LMC.

2.0 BACKGROUND

In 2003, the unusual non-liquid polychlorinated biphenyl (PCB) Aroclor 1268 was discovered to have been a component of the Airdock's original roof and siding. PCBs apparently were added to a bitumen layer of the roofing and siding material to serve as a fire retardant. Since the initial PCB discovery in 2003 and continuing to the present, LMC has successfully planned and implemented a multi-phased voluntary remediation program to manage the roofing and siding material that contains Aroclor 1268. These remedial activities are being conducted under two regulatory programs: the federal Toxic Substances Control Act (TSCA) and the Ohio EPA Voluntary Action Program (VAP).

In summary, remedial activities conducted external to the Airdock facility to date have included encapsulation of the roof with a rolled rubber membrane, replacement of the Airdock gutter system, and replacement of the Airdock's vertical siding. Remedial activities have also included a soil investigation and removal action to address isolated non-liquid PCB impacts to soil and pavement. Currently, a plan is being implemented to remove debris and sediment in the existing storm sewer system serving the Airdock facility parcel. These remedial activities are detailed in various documents including: *Akron Airdock PCB Exterior Remediation Strategy* dated June 22, 2007[1], *Akron Airdock Application for Risk-Based Cleanup of Soil* dated August 27, 2007[2], *Soil Excavation Plan* dated April 18, 2008[3], and *Storm Drain Debris Removal Plan* dated June 24, 2008[3].

Following completion of the storm sewer debris and sediment removal program, a post-remediation stormwater sampling program will be implemented. Implementation of the stormwater program is the subject of this SAP.

3.0 OBJECTIVE

The objective of this sampling program is to collect aqueous post-remediation sampling data that are representative of stormwater discharges from the 19-acre Airdock parcel, as required to meet VAP applicable standards and to satisfy requests from the Ohio EPA Division of Surface Water (DSW). The sampling data will be used to evaluate the effectiveness of the remediation activities relative to the current Lake Erie drainage basin surface water quality criterion for PCBs of 0.026 nanograms per liter (ng/L) for protection of human health and 0.12 ng/L for protection of wildlife. The sampling data will also be evaluated relative to the unrestricted use TSCA decontamination standard for PCBs in water of 0.5 micrograms per liter [µg/L] (40 CFR 761.79(b)(1)(iii).

4.0 SAMPLING LOCATIONS

Sampling is proposed from five locations, one from the western storm sewer and four from the eastern storm sewers, as described below.

A map illustrating the Airdock facility layout and drainage system is provided as Figure 2. Stormwater from the Airdock facility and the surrounding area drains through an underground storm sewer system to Haley's Ditch just beyond Triplett Boulevard, approximately 1 mile north of the Airdock facility. Three main sewers drain the Airdock parcel: (1) Plant A West (PAW) 48-inch, (2) Plant A West (PAW) 24-30-inch, and (3) Plant A East (PAE) 24-30-inch. PAW represents the storm sewers on the west side of the Airdock facility, and PAE represents those on the east side. As shown on Figure 2, both the PAE and PAW systems receive drainage from off-property buildings, Plant B and Plant E, respectively. The main sewer that runs beneath the airport property also receives flow from City of Akron storm sewers, as well as from other industrial and commercial properties downstream from the Airdock facility.

Each of the three sewers (PAW-48, PAW-24-30, and PAE-24-30) serving the Airdock facility parcel are subject to debris and sediment removal; however, only stormwater within the PAW-24-30 and PAE-24-30 sewers will be subject to sampling under this SAP. The PAW-24-30 sewer is representative of drainage for the entire western half of the symmetrical Airdock structure, while the PAE-24-30 sewer is representative of the drainage for the entire eastern half. The strategy of selecting these representative lines is consistent with the requirements for "Representative Discharge" contained in Part V.B.5. of the General Permit.

4.1 WESTERN SAMPLING (PAW) STRATEGY

Drainage from the western half of the Airdock facility is conveyed through PAW-24-30, which flows from south to north and includes several catch basins and manholes along the sewer. Available drawings indicate PAW-24-30 is isolated from Plant E drainage and therefore it is suitable for representative monitoring purposes.

4.1.1 West Side Representative Sampling Point

As shown on Figure 2, Manhole PAW-7 will be the only western sewer sampling point for the stormwater sampling program. Manhole PAW-7 is located within the 19-acre parcel (immediately prior to leaving the parcel) and is downstream of the western Airdock facility drainage area.

4.2 EASTERN SAMPLING (PAE) STRATEGY

Sample points on and around the eastern storm sewer PAE were chosen to investigate several conditions. The conditions and requisite sample points are: (1) a sample point representative of the eastern storm sewer as a whole, (2) multiple sample points to quantify potential off-property sources, and (3) a sample point to quantify conditions at the soil remediation site in the Southeast Area. The western area will not be sampled as extensively because it was not the primary location of remedial soil activities and off-site sources are not believed to contribute to the PAW sewer.

4.2.1 East Side Representative Sampling Point

The eastern storm sewer, PAE, runs parallel to the east side of the Airdock facility (see Figure 2). This storm sewer collects drainage from on-property and off-property sources, and flows from south to north. Downstream of the north end of the Airdock parcel, the storm sewer connects to the Airport main storm drain, where stormwaters are conveyed beneath the Airport property.

Because of the layout and configuration of the drainage system described above the most representative sample point for the eastern sewer is the northern-most accessible collection point along the sewer that remains within the bounds of the Airdock parcel. This point is the storm sewer manhole PAE-5 (also referenced as ST 5463, GPD survey, 2007). Manhole PAW-5 is located within the 19-acre parcel and is downstream of the eastern Airdock facility drainage area.

4.2.2 Off-Property Contribution Sampling Points

The Airdock parcel and the surrounding industrial facilities share common utilities, including the storm sewer system, and currently operate under an Ohio EPA General Permit (OHR000004) held by VAC. Consequently, several off-property storm sewers convey drainage through the Airdock eastern storm

sewer resulting in co-mingled stormwater discharge. In order to monitor for representative stormwater in the eastern storm sewer that originates at the Airdock facility, the potential contribution from off-property sources must also be monitored.

Suitable sample locations to monitor potential off-property sources were chosen by identifying 1) off-property storm sewers that ultimately connect to the PAE, and 2) available monitoring locations within the boundary of the Airdock parcel.

Two sample points were identified based on this criteria. These points are (from south to north): CB 1462 and ST 6536 (see Figure 2).

4.2.3 Southeast Area Sampling Point

Soil excavation and remediation for PCBs was completed on the southeastern side of the Airdock facility in June 2008. In order to monitor for the influence upon stormwater drainage from residual PCBs in soil, a suitable sample point was identified from this area. This point was required to be proximate to the soil excavation area, in the path of the stormwater drainage, and at a location that ultimately discharges to the PAE sewer. The proposed point is storm sewer manhole ST 6535 (see Figure 2).

4.3 SAMPLING STRATEGY LOCATION SUMMARY

The following table summarizes the five sampling points proposed for the stormwater sampling and analysis program.

Table 1

Proposed Stormwater Sampling Points

Sampling Area	Structure Name	Purpose	Invert (feet, msl)	Approximate Location
PAW	PAW-7	Representative – Main sewer, West Side	1035.1	From PAW-6: 350 feet north along PAW.
PAE	PAE-5 (ST 5463)	Representative – Main sewer, East Side	1036.0	From northeast corner Hydraulic Press Bldg: 90 feet north, 10 feet east.
PAE	CB 1462	Off-property contribution	1038.4	From PAE-1: 240 feet south along PAE
PAE	ST 6536	Off-property contribution	1037.3	From southeast corner Transformer Bldg: 75 feet south, 20 feet east.
PAE	ST 6535	Southeast Soil Remediation Area	Not Available	From southeast corner Transformer Bldg: 80 feet south, 5 feet east.

PAE = Plant A East Storm Sewer
PAW = Plant A West Storm Sewer
MSL = Mean Sea Level

5.0 SAMPLE COLLECTION FREQUENCY AND STORMWATER EVENT REQUIREMENTS

Stormwater samples will be collected from the proposed PAW and PAE sample locations during four discrete storm events. Consistent with NPDES guidance, one grab sample for each of the four storm events will be collected under the following conditions:

1. Sampling will occur during a storm event with at least 0.1 inch of precipitation (defined as a "measurable" event.
2. Sampling will not occur at a frequency greater than once every 72 hours.
3. Sampling will not occur unless there has been at least 72 hours of continuous dry weather immediately preceding the sampling event.
4. Grab samples will be collected from the five sample locations during approximately the first 30-minutes to 1-hour of storm water discharge (where possible).

The intention of the sample collection frequency and stormwater event requirements described above is to collect samples that are representative of runoff conditions from each area.

Ideally, the variance of the storm duration and total rainfall of a sampling event will not exceed 50 percent from the average or median storm event for the Arkon area. Based upon this criterion, total rainfall will be between 0.25 and 0.75 inches and a total duration will be between 5.6 and 16.8 hours. Further, in order to provide data that are representative of four discrete sampling events, it is desired that each of the four sampling events be conducted approximately 1 month apart (subject to the availability of a "measurable" storm event).

It is anticipated that these four discrete samples can be collected within a 1-year period. As described below, the team responsible for sampling will be expected to monitor the weather forecasts and anticipate when an appropriate event may occur. In the event that it is not possible to collect and analyze these samples within a 1-year period, the sampling conditions may be modified in order to meet the purpose of confirming attainment of VAP applicable standards within a reasonable timeframe.

6.0 SAMPLING METHODOLOGY

Grab samples during each "measurable" event will be collected from Manholes PAW-7, PAE-5 (T-5463), ST 6536, ST 6535, and CB 1462. Prior to sampling, the analytical schedule (Table 3) will be coordinated with the laboratory and a laboratory-supplied bottle order will be shipped to the sampling team.

Sampling personnel will track weather patterns in anticipation of a "measurable" storm. The goal is to target and collect samples from a "measurable" event (i.e., minimum 0.1-inch precipitation event) within

the first 30 minutes to 1 hour of stormwater discharge. However, if this is impractical and the event qualifies as a "measurable" event, it is anticipated that the sampling will still be collected from this event. Precipitation patterns will be monitored using data from the Akron Fulton International Airport weather station. A rain gauge will placed within the property to monitor the actual event precipitation at the time of sampling.

The following sections describe the sampling methodology for collection of the stormwater samples.

6.1 STORMWATER SAMPLE COLLECTION

Grab samples will be collected from the PAW-24-30 sewer from surface access at Manhole PAW-7, and from the PAE-24-30 sewer at PAE-5 (ST 5463), ST 6536, ST 6535, and CB 1462. No confined space entry will be permitted or required to collect the stormwater samples. The sampling procedure will involve observation of stormwater flow through the manhole followed by sample collection of grab samples. Sample collection activities will involve lowering the laboratory-prepared containers attached to a pole into the manhole. The sampling device will be turned into the incoming flow and a representative sample will be collected. The sampler will attempt to position the container in the center of the stormwater flow path so that it is representative of the flow through the manhole and to avoid sediment within the base of the manhole, if any.

Following representative sample collection, the containers will then be raised to the surface and capped. The jars will be labeled with sample designation, time, date, and samplers initials prior to placement into a pre-chilled cooler.

Flow will be estimated at points PAW-7 and PAE-5 by measuring depth of water in the pipes during storm events, and using the included discharge estimate worksheets (Appendices B and C).

The following table details the sample collection order and pipe location, invert, diameter, and material information.

Table 2

Sample Point Collection Order and Location Characteristics

Collection Order	Sewer	Location Name	Diameter (inches)	Material
1	PAW	PAW-7	30	Brick
2	PAE	PAE-5 (ST 5463)	30	Brick
3	PAE	ST 6536	24	VCP
4	PAE	ST 6535	24	VCP
5	PAE	CB 1462	12	VCP

VCP = Vitrified Clay Pipe

6.2 MEASUREMENT OF FIELD PARAMETERS

Field parameters will be measured for each collected stormwater sample. At a minimum, these field parameters are anticipated to consist of pH, temperature, and specific conductivity. The parameters will be measured with a submersible instrument such as a Horiba U-10 or similar device. The instrument will be calibrated in accordance with the manufacturer's recommendations prior to each use and the information will be recorded in the field logbook.

7.0 SAMPLE PRESERVATION, SHIPPING, AND CHAIN-OF-CUSTODY

Samples will be placed in appropriate containers and preserved for shipment to the laboratory. A list of required parameters, test methods, and hold times for the stormwater monitoring program is provided in Table 3.

Table 3

Stormwater Sampling Analytical Schedule

Parameter	Test Method	Preservative	Maximum Hold Time
TSS	EPA 160.2	Cool 6ºC	7 days
PCBs	EPA 8082	Cool 6ºC	1 year
Field Parameters (temperature, pH, specific conductivity, etc.)	Calibrated field instrument	None required	Analyze immediately in field

TSS = Total suspended solids
EPA = United States Environmental Protection Agency

All samples will be transported in a cooler with ice and delivered under chain-of-custody. Chain-of-custody records will be maintained to document the custody of all samples from the time of collection until analysis.

Care will be taken in packing coolers. Bottles and ice will be packed in such a way as to minimize the chance of breakage. Each cooler shipped will be securely sealed to prevent opening in transit.

8.0 SAMPLE ANALYSIS AND DETECTION LIMITS

The samples will be analyzed by TestAmerica Laboratories, Inc. in North Canton, Ohio (TestAmerica). TestAmerica is certified for PCB analysis including Aroclor 1268 by the VAP certification laboratory program (CL0024). Level 3 quality control (QC) data reporting will be required under a laboratory affidavit. Samples will be analyzed for PCBs using EPA Method 8082. The analytical results will be summarized and reported by specific congener including Aroclor 1268. The VAP-certified laboratory reporting limit for the PCB analyses is 0.2 µg/L or 200 ng/L, which is consistent with VAP certified laboratory requirements.

9.0 EVALUATION OF RESULTS

Following receipt of the laboratory reports the data will go through a validation process to ensure that the reported results are of sufficient quality for the intended data use. Estimated concentrations reported by the lab that are below the VAP reporting limit of 0.2 μg/L, i.e. "J" flagged data, will be considered to be non-detectable.

After the validated results are available from the four discrete sampling events, the data will be reviewed and evaluated relative to sampling conditions and applicable standards. The evaluation will consider such factors as the:

- Consistency or variability of the analytical results over the sampling events, if applicable;
- Specific Aroclors detected at or above reporting limit, if any;
- Storm event characteristics (flow, duration, etc.);
- TSS levels; and
- Variability of sample results from the east and west sewer systems, if any.

Based on this evaluation, recommended response actions will be developed and proposed as appropriate. Such response actions may involve collection of additional samples at the current sampling locations or an expanded program to collect additional upstream data to identify potential contributing sources.

[1] Prepared by Lockheed Martin Corporation, 1210 Massillon Road, Akron, Ohio
[2] Prepared by Lockheed Martin Corporation, 1210 Massillon Road, Akron, Ohio
[3] Prepared by Arcadis, Project Reference B0038062.0000.

FIGURES

LEGEND

APPROXIMATE BOUNDARY OF 19-ACRE PARCEL

STORM SEWER LINE

N

0 1,000 2,000 Feet

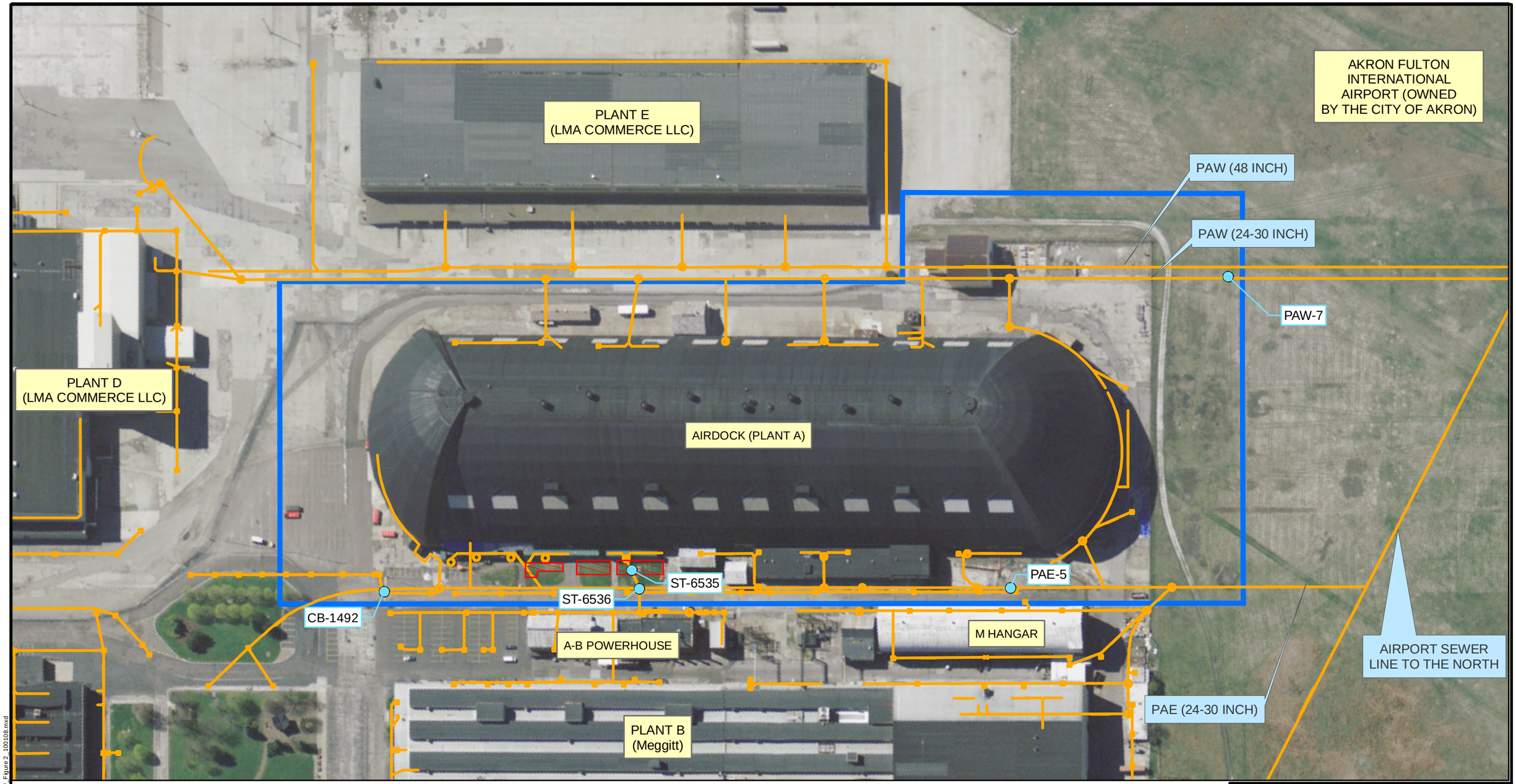
SOURCE: OSIP AERIAL PHOTOGRAPHY, 2006, AND SUMMIT COUNTY GIS, 2004.

AKRON AIRDOCK FACILITY
AKRON, OHIO

FIGURE 1
SITE AERIAL PHOTOGRAPH

URS

2008-08-19 X:\projects\lockheed_akron\Airdock_RAP_1.1_100108.mxd



LEGEND

- Proposed Storm Sewer Sampling Location
- Approximate Airdock Boundary
- Location of Southeast Soil Remediation Area
- Storm Sewer
- Drainage Structure (Catch Basin or Manhole)

PAW = Plant A West Storm Sewer Line

PAE = Plant A East Storm Sewer Line

N

0 75 150 Feet

SOURCES: MODIFIED FROM SUMMIT COUNTY GIS, 2004 AND OSIP AERIAL PHOTOGRAPH, 2006

AKRON AIRDOCK FACILITY
AKRON, OHIO

FIGURE 2
STORM SEWER SYSTEM
WITH SAMPLING LOCATIONS

URS

2008-08-19 X:\projects\lockheed_akron\Airdock_RAP_Figure2_100108.mxd

APPENDICES

APPENDIX A

STORMWATER SAMPLING FORM

Stormwater Sampling Field Form

Project: Akron Airdock	**Project Number**:
Client: Lockheed Martin	**Location:** 1210 Massillon Road, Akron, Ohio
Sample ID: _____ **Sample Location** _____: **Sample Medium:** Stormwater	**Personnel**: _____/ . **Sample Date:** _____/_____/_____. **Sample Collection Time (ST):** _____

Storm Event and Sampling Point Information

Storm Event Start Time (ST):	**Precipitation at ST: inches/ source of data**
Weather Conditions at ST:	**Ambient Temperature at ST: ºF / source of data**
Storm Event Duration:	**Total Precipitation for Event (include source of data):**
Estimated Sampling Point Discharge Rate: cfs or gpm (circle one)	
Notes regarding flow character (turbulent, laminar, etc.):	

Water Quality Information

Instrument:		pH:		Color:	
Temperature(°F):		Oxidation-Reduction Potential (ORP) (mV):		Odor:	
Specific Conductance (mS/cm):		Total Dissolved Solids (mg/L):		Other:	

Sampling Information

Collection Method (describe):				
Sample Container	**Preservative**	**Analysis Required**	**Method Number**	**Laboratory**
250 ml Plastic	Chilled to 6ºC	Total Suspended Solids	EPA160.2	TestAmerica
2 – 1 Liter Amber Glass	Chilled to 6ºC	Total PCBs (unfiltered)	EPA SW-846 8082	TestAmerica

General Information

Sample Delivery or Shipment Method: _____

Date and Time Samples delivered to lab: _____

Laboratory Information:	TestAmerica Laboratories, Inc. 4101 Shuffle Drive NW North Canton, OH 44720 330-497-9396
Comments:	

URS CORPORATION

APPENDIX B

PAW FLOW ESTIMATE CALCULATION AND WORKSHEET

OBJECTIVE

The objective of these calculations is to provide an estimated full pipe flow value at manhole PAW-7 at the Akron Airdock site. This full flow value will be used by sampling personnel to estimate partial stormwater flow in the pipe at the PAW-7 test point using the attached worksheet.

METHODOLOGY

The calculation is performed by utilizing Manning's semi-empirical pipe flow formula. Partial flow is estimated by graphical method using a hydraulic characteristic graph for circular pipe flow (ratio of depth to diameter versus Q/Q_{full}), based on the theory of open channel flow. Units are BG standard.

ASSUMPTIONS

1. Manning's roughness coefficient "n" for brick ranges from 0.012 to 0.017 (Finnemore and Franzini, "Fluid Mechanics," McGraw-Hill 2002).
2. Manning's roughness coefficient "n" is taken as n=0.017 due to television pipe survey that determined the pipe in question was made of brick and mortar in semi-deteriorated condition.
3. Slope is estimated by dividing the change in vertical elevation between PAW-6 and PAW-7 inverts by the horizontal distance between the inverts.
4. Slope between PAW-6 and PAW-7 is assumed to be constant

CALCULATIONS

$$Q(cfs) = \frac{1.486}{n} A R_h^{2/3} S_0^{1/2}$$ (Manning's Equation)

where

- Q = *Flowrate (cfs)*
- n = *Manning's Roughness Coefficient*
- A = *Cross sectional area (ft^2)*
- R_h = *Hydraulic radius (cross section divided by wetted perimeter)(ft)*
- S_0 = *Pipe slope (ft/ft)*

$$D = 30\,inches = 2.5\ ft$$

$$A = \frac{\pi D^2}{4} = \frac{\pi (2.5)^2}{4} = 4.904\,ft^2$$

$$R_h = \frac{\pi r^2}{2\pi r} = \frac{r}{2} = \frac{D}{4} = \frac{2.5}{4} = 0.625\,ft$$

$$z_2 = 1035.60\,ft, z_1 = 1034.88\,ft, x_2 = 350\,ft, x_1 = 0\,ft$$

$$S_0 = \frac{\Delta z}{\Delta x} = \frac{1035.60 - 1034.88}{350} = \frac{0.72}{350} = 0.002\ ft/ft$$

Thus:

$$Q(cfs) = \frac{1.486}{n} A R_h^{2/3} S_0^{1/2}$$

$$Q(cfs) = \frac{1.486}{0.017}(4.904)(0.625)^{2/3}(0.002)^{1/2}$$

$$Q(cfs) = 14$$

CONCLUSIONS

The full pipe flow at PAW-7 is estimated at Q_{full} = 14 cfs. By using the ratio of measured depth to full diameter (y/D) and a provided hydraulic characteristic graph for circular pipe flow, the ratio of Q/ Q_{full} can be determined with the provided worksheet. Using this ratio, the partial flow in the pipe can subsequently be determined.

PAW Flow Calculation Worksheet

Required Equipment:

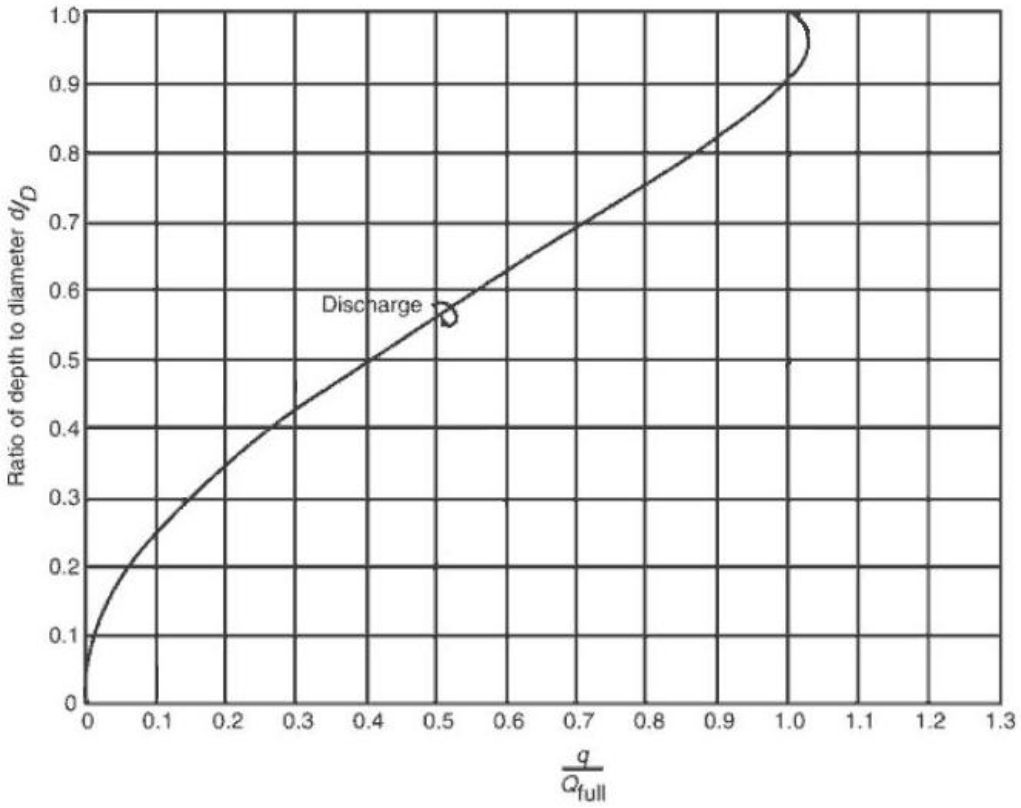
- **Staff Gauge / Water Depth Measurement Device**
- **Calculator**

Method:

(A) Record Water Depth Reading (in inches): ☐

(B) Divide Depth Reading **(A)** by 30 inches: ☐ ÷ 30 = ☐

(C) Use value found in **(B)** on the vertical axis of the chart below. Read horizontally across the chart from left to right until you reach the discharge line, then read vertically down to the proportion full flow value. Record that number here:



(D) Multiply value found in **(C)** by 14cfs: ☐ x 14 = ☐ Result is in cubic feet per second (cfs)

(E) Record discharge result **(D)** on Sampling Field Form

APPENDIX C

PAE FLOW ESTIMATE CALCULATION AND WORKSHEET

OBJECTIVE

The objective of these calculations is to provide an estimated full pipe flow value at manhole PAE-5 (ST 5463) at the Akron Airdock site. This full flow value will be used by sampling personnel to estimate partial stormwater flow in the pipe at the PAE-5 test point using the attached worksheet.

METHODOLOGY

The calculation is performed by utilizing Manning's semi-empirical pipe flow formula. Partial flow is estimated by graphical method using a hydraulic characteristic graph for circular pipe flow (ratio of depth to diameter versus Q/Q_{full}), based on the theory of open channel flow. Units are BG standard.

ASSUMPTIONS

1. Manning's roughness coefficient "n" for brick ranges from 0.012 to 0.017 (Finnemore and Franzini, "Fluid Mechanics", McGraw-Hill 2002).
2. Manning's roughness coefficient "n" is taken as n=0.017 due to television pipe survey that determined the pipe in question was made of brick and mortar in semi-deteriorated condition
3. Slope is estimated by dividing the change in vertical elevation between PAE-4 and PAE-5 inverts by the horizontal distance between the inverts.
4. Slope between PAE-4 and PAE-5 is assumed to be constant.

CALCULATIONS

$$Q(cfs) = \frac{1.486}{n} A R_h^{2/3} S_0^{1/2}$$ (Manning's Equation)

where

- Q = *Flowrate (cfs)*
- n = *Manning's Roughness Coefficient*
- A = *Cross sectional area (ft^2)*
- R_h = *Hydraulic radius (cross section divided by wetted perimeter)(ft)*
- S_0 = *Pipe slope (ft/ft)*

$D = 30\,inches = 2.5\ ft$

$$A = \frac{\pi D^2}{4} = \frac{\pi (2.5)^2}{4} = 4.904\,ft^2$$

$$R_h = \frac{\pi r^2}{2\pi r} = \frac{r}{2} = \frac{D}{4} = \frac{2.5}{4} = 0.625\,ft$$

$$z_2 = 1036.1\,ft, z_1 = 1035.8\,ft, x_2 = 247\,ft, x_1 = 0\,ft$$

$$S_0 = \frac{\Delta z}{\Delta x} = \frac{1036.1 - 1035.8}{247} = \frac{0.3}{247} = 0.001\ ft/ft$$

Thus:

$$Q(cfs) = \frac{1.486}{n} A R_h^{2/3} S_0^{1/2}$$

$$Q(cfs) = \frac{1.486}{0.017}(4.904)(0.625)^{2/3}(0.001)^{1/2}$$

$$Q(cfs) = 10$$

CONCLUSIONS

The full pipe flow at PAE-5 is estimated at Q_{full} = 10 cfs. By using the ratio of measured depth to full diameter (y/D) and a provided hydraulic characteristic graph for circular pipe flow, the ratio of Q/ Q_{full} can be determined with the provided worksheet. Using this ratio, the partial flow in the pipe can subsequently be determined.

PAE Flow Calculation Worksheet

Required Equipment:

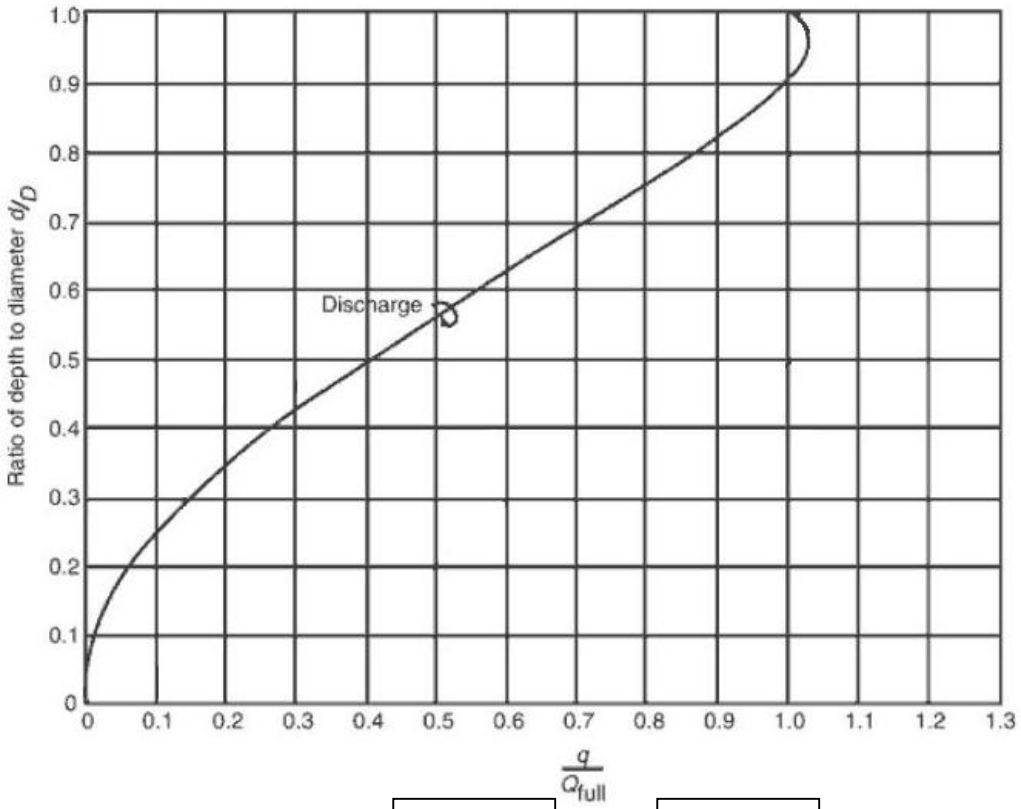
- **Staff Gauge / Water Depth Measurement Device**
- **Calculator**

Method:

(F) Record Water Depth Reading (in inches): ☐

(G) Divide Depth Reading **(A)** by 30 inches: ☐ ÷ 30 = ☐

(H) Use value found in **(B)** on the vertical axis of the chart below. Read horizontally across the chart from left to right until you reach the discharge line, then read vertically down to the proportion full flow value. Record that number here:



(I) Multiply value found in **(C)** by 10cfs: ☐ x 10 = ☐ Result is in cubic feet per second (cfs)

(J) Record discharge result **(D)** on Sampling Field Form