



# **“FIVE FEET HIGH AND RISING”**

## **Certifying the City of St. Louis Flood Protection System**

by

**Stephen Randolph, P.E., CPESC, CFM, LEED Green Assoc.  
Chicago, IL**

**IAFSM Conference, Springfield, IL  
March 8, 2017**



# “FIVE FEET HIGH AND RISING”

- Description of Flood Protection System
- Scope of Work
- Project Challenges
- Results
- Follow-up Projects
- Where are we now?



# STL FLOOD PROTECTION SYSTEM

Authorized in  
1955,  
Completed in  
1974

Protects 3,160  
acres -  
predominantly  
commercial  
and industrial,  
about 900  
people



MISSOURI

ILLINOIS



6.75 miles of  
floodwall, 4.25  
miles of levee,  
28 pump  
stations, 39  
closures

Sponsors – City  
of St. Louis,  
Metropolitan  
St. Louis Sewer  
District



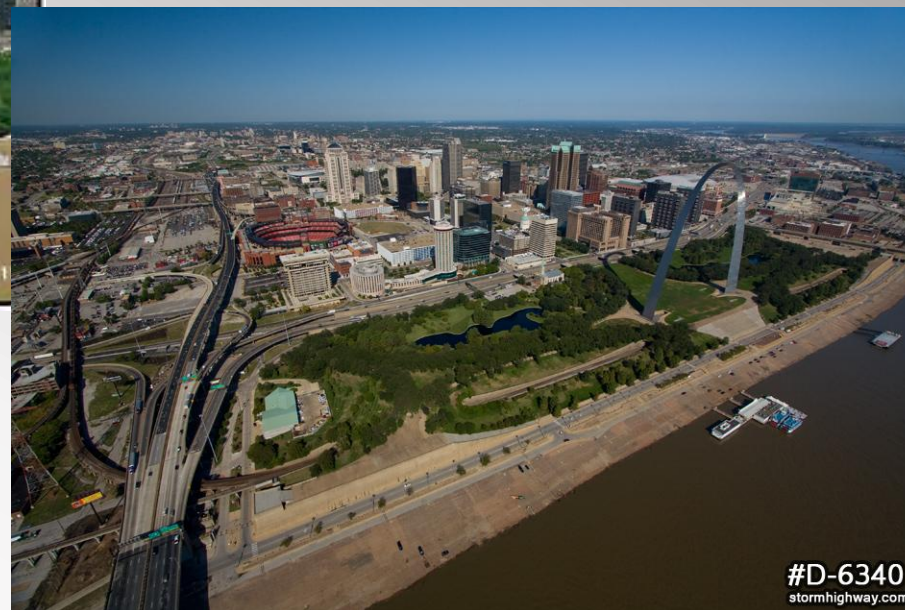
# STL FLOOD PROTECTION SYSTEM



Built to withstand a flood of 52' on the St. Louis gage.

Flood of record – 49.6'  
(August 1993)

Damages prevented  
\$680,000,000







# SCOPE OF WORK

## Hydraulics & Hydrology

- Freeboard analysis
  - Discharge-stage probability
  - Stage-discharge uncertainty
- Interior Drainage
  - Pump Stations
  - Relief wells

## Interior Drainage

- 44CFR65.10 deals with the issue of mapping it is not written specifically to deal with "re-"accreditation"
- Document that system elements are in working order and covered under documented O&M procedures.
- A new interior drainage study would not be needed.

## Structural Analysis

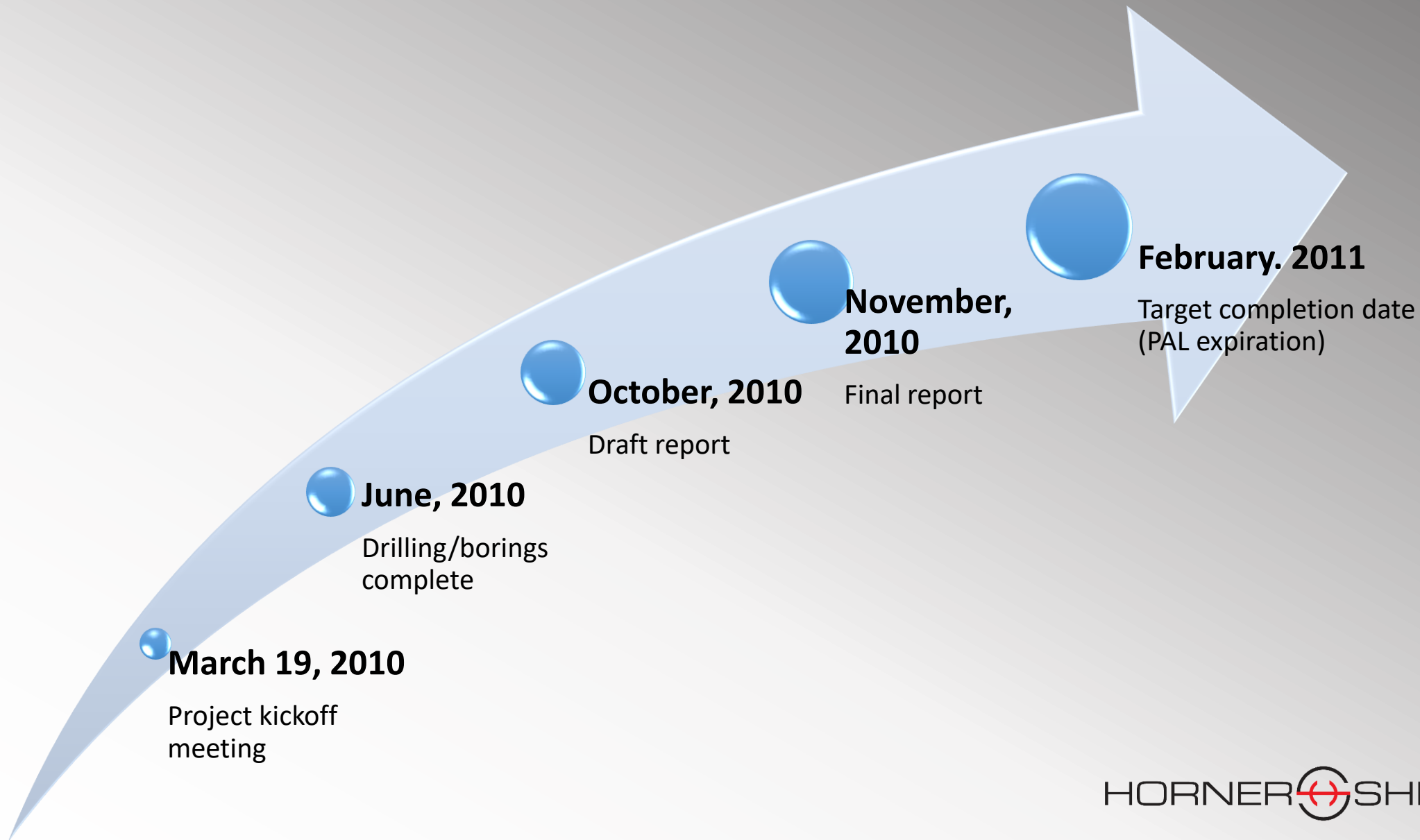
- Floodwalls
  - Strength analysis
  - Stability analysis
- Closure Structures (swing and panel gates)
  - Component analysis
  - Foundation analysis

## Geotechnical Analysis

- Embankment Erosion
- Embankment & Foundation Stability
- Settlement Analysis



# ORIGINAL TIMELINE





# PROJECT CHALLENGES

High water

Several delays

Replacement  
gates

Affected  
Geotechnical  
& Structural  
timelines

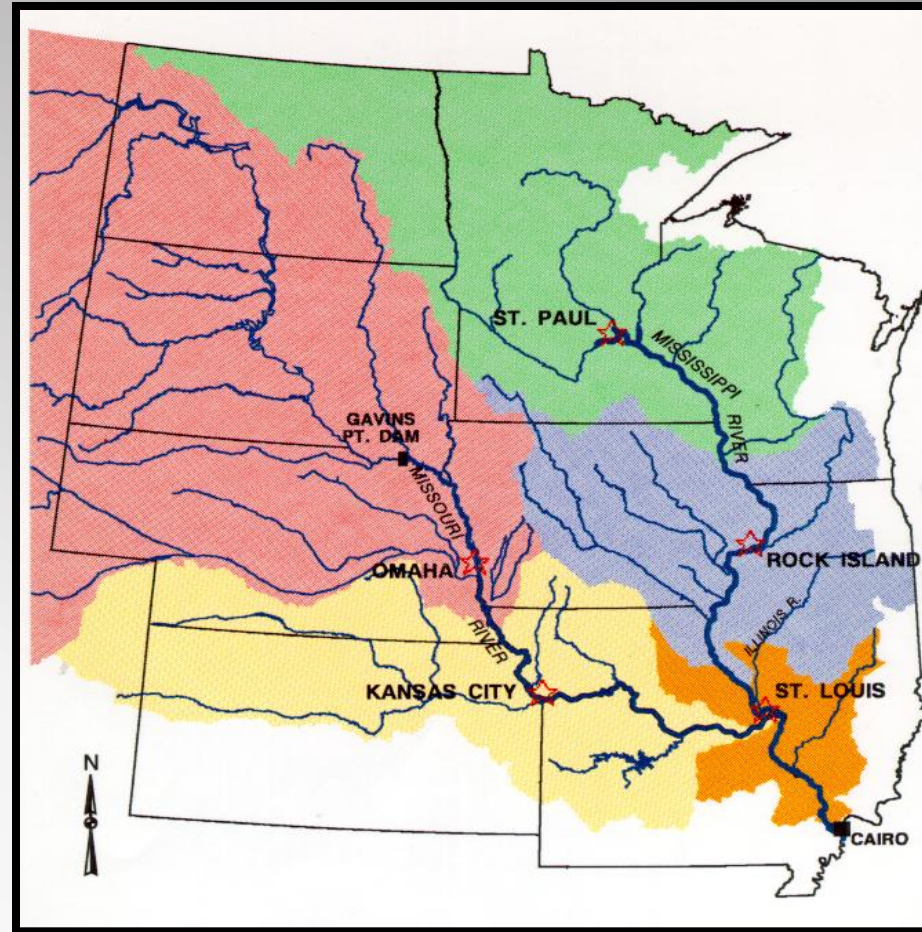


# HYDRAULICS & HYDROLOGY

Upper Mississippi  
River System Flow  
Frequency Study

Stage-discharge  
uncertainty

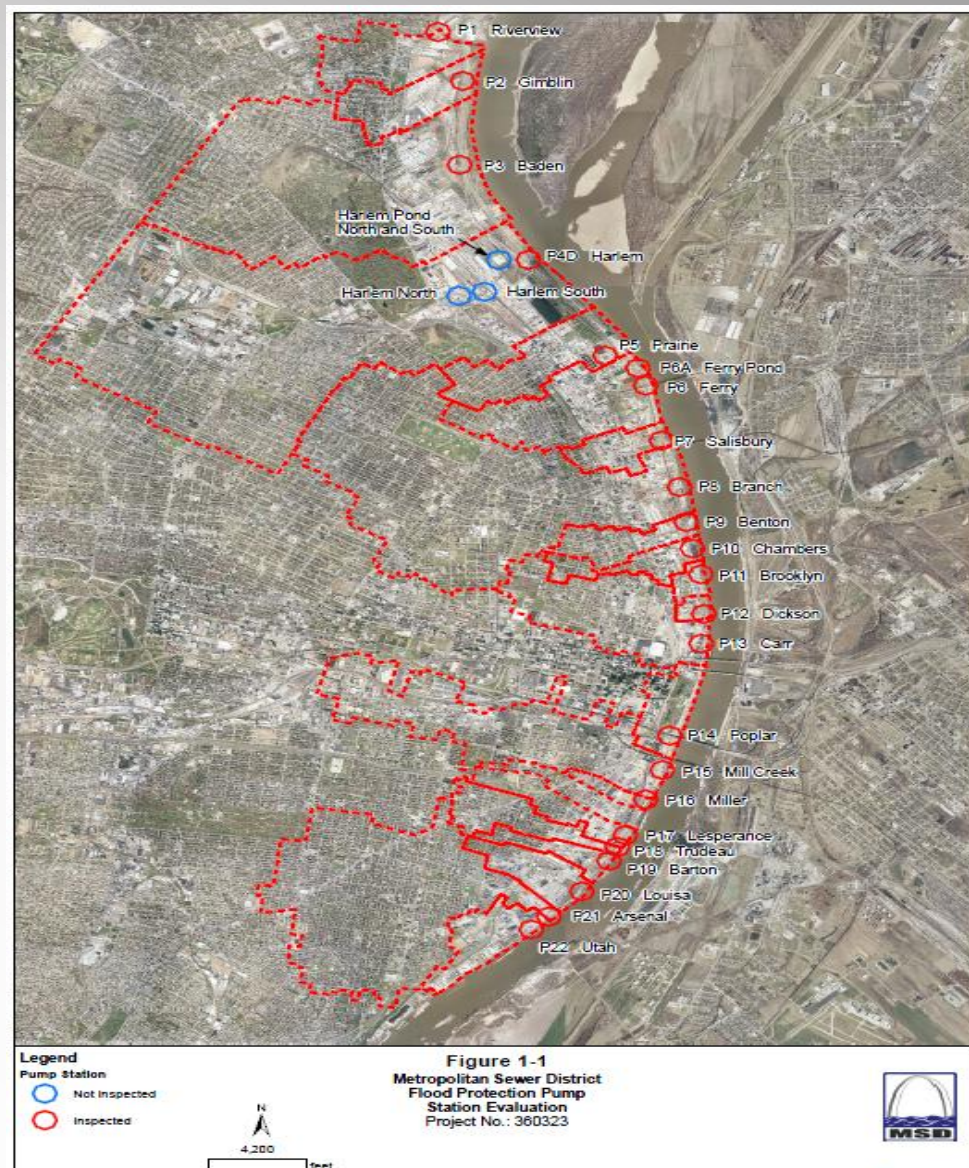
Discharge-stage  
probability







# PUMP STATION DRAINAGE AREAS





# H&H / INTERIOR DRAINAGE

MSD Pump  
Station  
Evaluation  
Report  
(2009)

USACE  
Design  
Memoranda

Recent TV  
Inspections  
and Cleaning  
of Toe Drains

Relief Wells  
Rehab and  
Replacement  
Project

Physical  
Inspections  
of Pump  
Stations





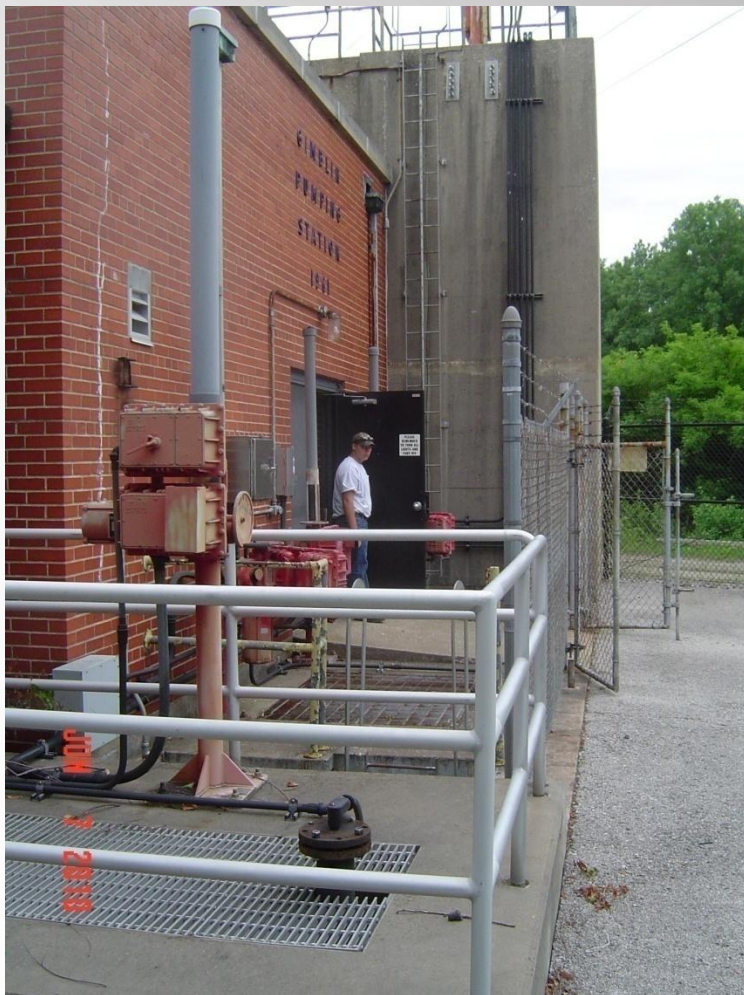
# PUMP STATION INSPECTIONS







# PUMP STATION INSPECTIONS







# PUMP STATION INSPECTIONS





# STRUCTURAL ANALYSIS

As-built  
drawings

USACE Design  
Memoranda

2009 Periodic  
Inspection  
Report

Development  
of  
Spreadsheet  
Tools

Physical  
Inspections of  
System  
Elements





# FLOODWALL INSPECTIONS







# FLOODWALL INSPECTIONS







# CLOSURE GATE INSPECTIONS







# CLOSURE GATE INSPECTIONS





# CLOSURE GATE INSPECTIONS





# GEOTECHNICAL ANALYSIS

Done by  
Shannon &  
Wilson

USACE  
Design  
Memoranda

2009  
Periodic  
Inspection  
Report

Original  
Construction  
Borings

Physical  
Inspections  
of System  
Elements





# LEVEE INSPECTIONS







# LEVEE INSPECTIONS





# SCOPE OF WORK

## Other Scope Items

- Operation, Maintenance, & Emergency Response Plans
- Certified As-Built Plans
- Probability of Failure and Consequences Failure Mode Analysis
- Submitted Draft Report in December, 2010



# RESULTS

## H & H Results

- Freeboard
- Interior drainage

## Structural Results

- Flood Walls
- Closure Structures
- Trigen Energy/Closure C-2

## Geotechnical Results

- Erosion, settlement
- Stability, Underseepage





# STRUCTURAL RESULTS

Trigen  
Energy

Former U.E.  
Plant





# STRUCTURAL RESULTS

Closure C-2  
panels and  
storage  
building  
sold for scrap.







# PROJECT CHALLENGES

**Moving target – FEMA policy changes**





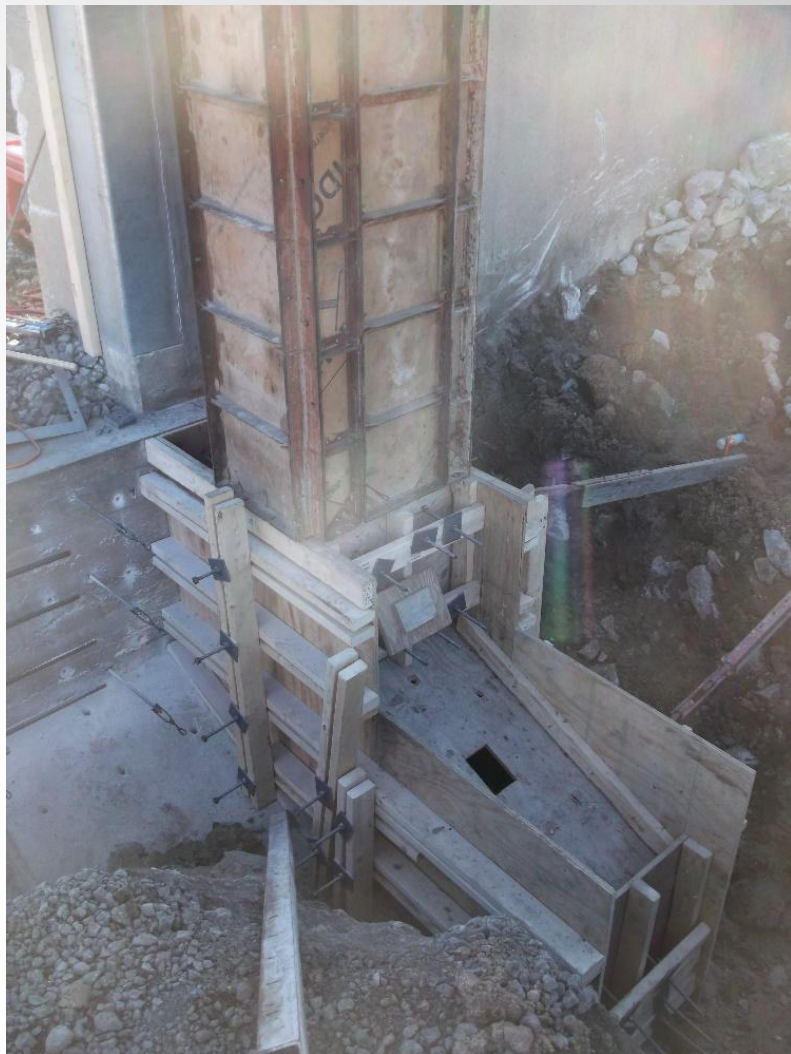
# FOLLOW-UP PROJECTS

- Abandoned Conduit Investigation
- New Closure C-2
- Riverview/Maline Creek Trench Drain
- Additional Swing Gates Analysis
- Trigen Plant Screen Well





# C-2 STOPLOG STRUCTURE







# TRIGEN PLANT SCREEN WELL







# TRIGEN PLANT SCREEN WELL





# WHERE ARE WE NOW?

## FEMA New Approach - 2013

**Nov.-Jan., 2015**

City completes last remediation project. Certification report submitted to FEMA.

**May, 2015**

FEMA review letter.

**April, 2016**

Initiate process to respond to comments

**June, 2016**

Levee Analysis and Mapping Plan (LAMP)





# LEVEE ANALYSIS & MAPPING PLAN



**Levee Analysis and Mapping Plan**  
*St. Louis Flood Protection System*  
City of St. Louis  
Missouri

*November 29, 2016*

*Final*



**RiskMAP**  
Increasing Resilience Together

- The Project's goal is to prepare a work plan on how FEMA should analyze and map the flood risk behind the St. Louis Flood Protection System using FEMA's Levee Mapping and Analysis Procedures (LAMP) for non-accredited levees.
- The Agency understands that the City of St. Louis is performing the required analysis and gathering documentation to gain accreditation for the St. Louis Flood Protection System. However, at this point in time FEMA must move forward to create a work plan to update the flood risk behind the levee, in keeping with its mission.



# QUESTIONS?





# QUESTIONS?



# "FIVE FEET HIGH AND RISING"

## Certifying the City of St. Louis Flood Protection System

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Stephen Randolph, P.E., CPESC, CFM, LEED Green Assoc.  
St. Louis, Missouri

ASFPM National Conference, San Antonio, TX  
May 24, 2012





# PROJECT CHALLENGES

Revised schedule due to high river levels

<u>milestone</u>	<u>original due date</u>	<u>revised due date</u>
drilling complete	June 10, 2010	<b>September 24, 2010</b>
100% of boring logs to City	July 24, 2010	<b>October 8, 2010</b>
geotechnical lab testing complete	August 24, 2010	<b>October 8, 2010</b>
draft report due to City	October 24, 2010	<b>December 8, 2010</b>
final report due to City	November 24, 2010	<b>January 8, 2010</b>







# FLOODWALL INSPECTIONS







# ABANDONED CONDUIT INVESTIGATION



Mound City Electric Plant







# RIVERVIEW/MALINE CREEK TRENCH DRAIN

- Underseepage gradient exceeded current and original design criteria.
- Site of sand boils during 1993 flood.
- Uncooperative property owner.
- Intense review by USACE.



# RIVERVIEW/MALINE CREEK TRENCH DRAIN





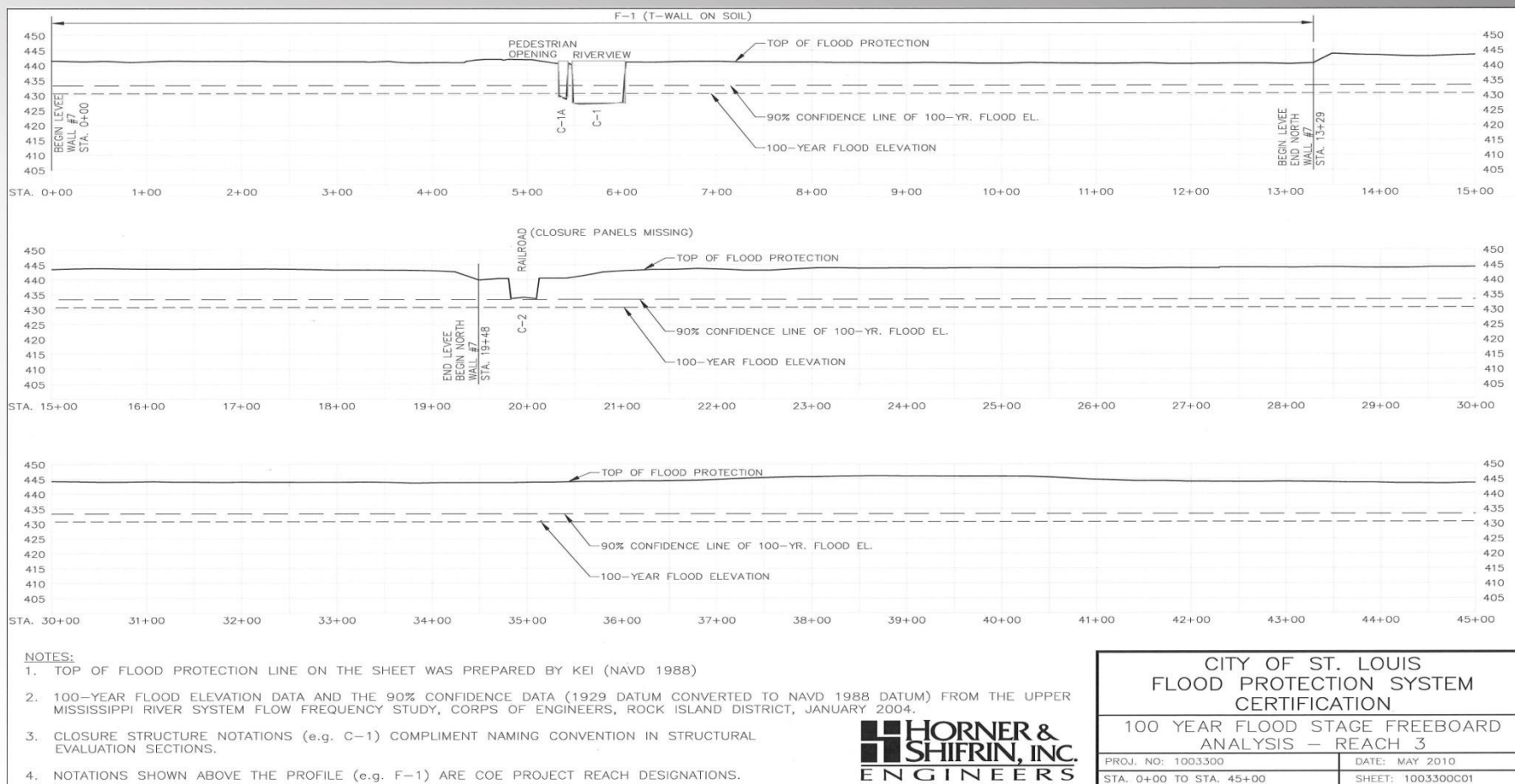


# TRIGEN PLANT SCREEN WELL

- Cooling water tunnel potential breach.
- Initial idea was to fill with grout.
- Owner preferred to keep tunnel open.
- Not enough freeboard in screen well.
- Access to site was difficult.



# H&H RESULTS





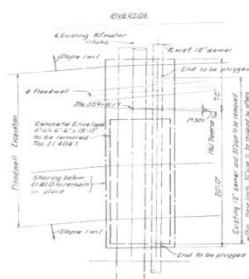
# ABANDONED CONDUIT INVESTIGATION



LOCATION MAP  
SCALE: N.T.S.

## LEGEND

BLACK TEXT AND LINE WORK IS FOR INFORMATIONAL PURPOSES ONLY AND IS TAKEN FROM THE ORIGINAL FLOODWALL CONSTRUCTION PLANS (JANUARY 1966).  
RED TEXT AND LINE WORK IS FOR WORK TO BE DONE UNDER THIS CONTRACT.



DETAIL  
SCALE: 1"=1'-0"



SITE PLAN  
SCALE: 1"=20'

## NOTES

- CONDUITS ARE OF UNKNOWN ORIGIN AND USAGE. IT IS POSSIBLE THAT THEY ARE STILL ACTIVE. USE CAUTION WHEN CUTTING INTO THEM. CONTRACTOR SHOULD BE PREPARED TO CLOSE AND/OR REPAIR CONDUIT IMMEDIATELY IF IT IS DETERMINED TO BE ACTIVE.
- UNDERGROUND FACILITIES, STRUCTURES, AND UTILITIES HAVE BEEN PLOTTED FROM AVAILABLE SURVEYS AND RECORDS. THEREFORE, THEIR LOCATION MUST BE CONSIDERED APPROXIMATE ONLY. THERE MAY BE OTHERS, THE EXISTENCE OF WHICH IS PRESENTLY NOT KNOWN. THE CONTRACTOR SHALL NOTIFY OWNER IN ADVANCE OF CROSSING OVER OR UNDER ANY UTILITIES SHOWN ON THE PLANS. THE CONTRACTOR SHALL NOTIFY THE OWNER IMMEDIATELY UPON DISCOVERY OF ANY UTILITY NOT SHOWN ON THE PLANS.
- THE ORIGINAL FLOODWALL DRAWING IS PROVIDED FOR INFORMATIONAL PURPOSES ONLY. PIPES, FACILITIES AND WORK DESCRIBED ON THE PLANS MAY OR MAY NOT BE ACCURATE.
- EXCAVATIONS ON LANDSIDE OF FLOODWALL TO BE LOCATED BY CITY OF ST. LOUIS STREET DEPARTMENT. CONTRACTOR TO LOCATE CONDUIT ON RIVERSIDE OF FLOODWALL PRIOR TO GROUTING.
- CONDUITS SHALL BE GROUTED ACCORDING TO USACE SPECIFICATIONS.
- SAFETY PROVISIONS SHALL CONFORM TO U.S. DEPARTMENT OF LABOR (OSHA) AND ALL OTHER APPLICABLE FEDERAL, STATE AND CITY LAWS, ORDINANCES AND CODES.
- THE CONTRACTOR SHALL HAVE THE SOLE RESPONSIBILITY TO DETERMINE THE CONSTRUCTION MEANS AND METHODS FOR SHORING AND BRACING OF TRENCHES, AS REQUIRED TO FURNISH SAFE AND ACCEPTABLE WORKING CONDITIONS. SHEETING, SHORING AND BRACING SHALL BE DESIGNED IN ACCORDANCE WITH THE FEDERAL OCCUPATIONAL SAFETY AND HEALTH ACT (OSHA).
- SOIL SAMPLING WAS DONE FOR THIS SITE. A COPY OF THE SOIL ANALYSIS IS ON SHEETS AC2 & AC3.
- EMC TRAIL IS TO REMAIN OPEN DURING CONSTRUCTION. COORDINATE W/ BKE ST. LOUIS, ROBIN FRANKEL, (314) 863-3373.

## GROUTING SPECIFICATIONS — 36" PIPE

- CUT THE PIPE AT A DISTANCE AT LEAST 5 FEET FROM THE FLOODWALL.
- CONSTRUCT A WOODEN FORM AT EACH CUT END OF THE PIPE. THE FORMS WILL ACT AS BLUEHEADS DURING GROUT PLACEMENT. LEAVE THE FORMS IN PLACE AND FILL PIPE WITH A NON-SHIRMING GROUT MIX (S&K RIVER SAND GROUT W/ INTERPLAST).
- THE RIVERSIDE FORMS SHOULD BE BUILT AT LEAST 18" TALLER THAN THE LANDSIDE FORMS TO CREATE A NET HEAD ACTING FROM RIVERSIDE TO LANDSIDE. THE FORMS SHOULD PROVIDE AT LEAST 1 FOOT OF COVER IN ALL DIRECTIONS FROM THE CUT ENDS OF THE CONDUIT.
- THE NOZZLE OF THE GROUTING HOSE SHOULD BE FED FROM THE LANDSIDE OF THE WALL TO THE RIVERSIDE THROUGH THE REMAINING SECTION OF CONDUIT, ALLOWING THE RIVERSIDE FORMS TO BE FULLY FILLED. BEFORE BACKING THE NOZZLE OUT OF THE LANDSIDE OF THE CONDUIT, THE LANDSIDE FORMS SHALL BE FULLY FILLED.
- THE NOZZLE SHOULD BE BACKED OUT OF THE CONDUIT SLOWLY FROM THE RIVERSIDE TO THE LANDSIDE WHILE PUMPING CONTINUES AND A VENT PIPE SHOULD BE PLACED FROM THE TOP OF THE CONDUIT AND UP BEYOND THE TOP OF THE FORMS TO ALLOW ANY ENTAPPED AIR TO ESCAPE. THE RIVERSIDE FORMS HAVE BEEN SEEN, THE HOSE SHOULD BE BACKED OUT SLOWLY WHILE PUMPING CONTINUES.
- SHOULDER FORMS SHALL BE FULLY FILLED WITH GROUT. ALL EXCAVATIONS SHALL BE BACKFILLED WITH GROUT. ALL EXCAVATIONS SHALL BE BACKFILLED WITH GROUT. ALL EXCAVATIONS SHALL BE BACKFILLED WITH GROUT. ALL EXCAVATIONS SHALL BE BACKFILLED WITH GROUT.
- ALTERNATIVELY, THE EXCAVATION MAY BE BACKFILLED WITH A FLOWABLE FILL MIXTURE TO AT LEAST 1 FOOT BELOW EXISTING GRADE. BACKFILLING TO THIS ELEVATION WILL ALLOW FOR THE PLACEMENT OF UP TO 1 FOOT OF SOIL BACKFILL.

## GROUTING SPECIFICATIONS — 6'x12' BOX

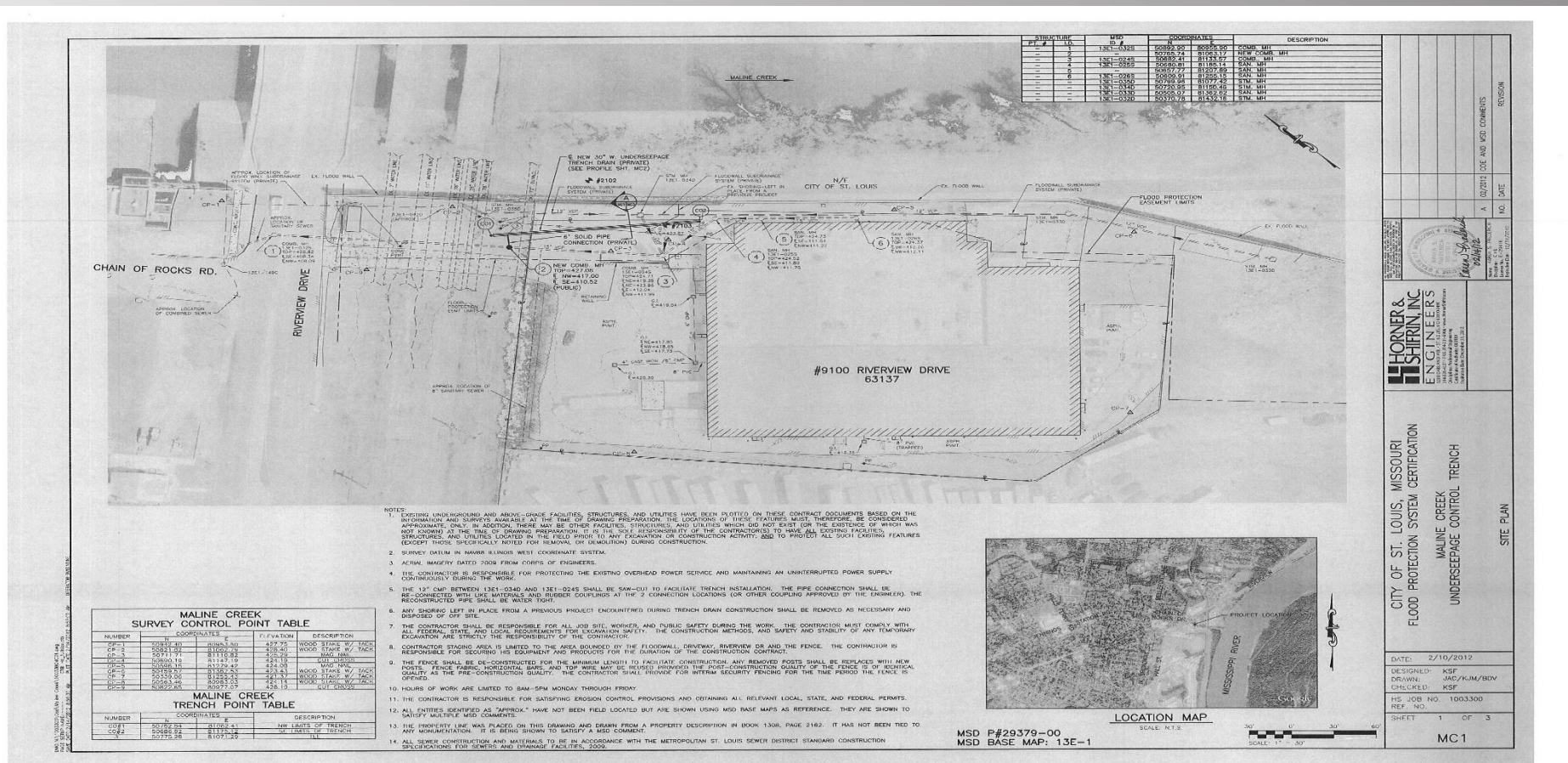
- GROUT/FILL TO BE 3000 PSI CONCRETE.
- FILL BOX/CONDUIT TO COVER ANY OR ALL LATERALS BY 1.0'.
- ANY CONNECTING LATERALS SHALL BE PLUGGED AND FILLED FOR A DISTANCE OF 10' FROM THE BOX/CONDUIT.
- ALLOW CONCRETE MIX TO CURE FOR A MINIMUM OF 48 HOURS BEFORE BACKFILLING.
- THE EXCAVATION MAY BE BACKFILLED WITH EITHER THE PREVIOUSLY EXCAVATED SPILLS OR A FLOWABLE FILL MIXTURE. IF THE EXCAVATION IS BACKFILLED WITH THE SPILLS, IT SHALL BE BACKFILLED IN MAXIMUM 6" LOOSE LIFTS AND TAMPED WITH A JUMPING JACK COMPACTOR FOR A MINIMUM OF FOUR PASSES.
- ALTERNATIVELY, THE EXCAVATION MAY BE BACKFILLED WITH A FLOWABLE FILL MIXTURE TO AT LEAST 1 FOOT BELOW EXISTING GRADE. BACKFILLING TO THIS ELEVATION WILL ALLOW FOR THE PLACEMENT OF UP TO 1 FOOT OF SOIL BACKFILL.

		REGION	
NO.		DATE	
CITY OF ST. LOUIS FLOOD PROTECTION SYSTEM CERTIFICATION ABANDONED CONDUITS STA. 357+25 AND STA. 360+00		SHEET 1 OF 3	
DATE: MAY 2011		AC1	
DESIGNED: SR			
DRAWN: JAC			
CHECKED: SR			
HS JOB NO. 10033300			
REF. NO.			





# CREEK TRENCH DRAIN





# INTERIOR DRAINAGE RESULTS

An analysis of the USACE Design Memorandums and the ASCE Journal article by the Chief of Hydraulics, showed that pump station capacity was provided to allow removal of storm runoff as quickly as it would arrive at the line of protection with storms coincidental with gate closing stage, or for storms coincident with the design flood, thereby with sufficient capacity to make flood storage volume unnecessary.



# PROJECT CRITERIA

- FEMA vs. USACE

FEMA 65-10 – Design Criteria “vague”

→ Closures - “according to sound engineering practice”

Embankment & Foundation Stability –

→ “analyses that evaluate levee embankment stability must be submitted”





# PROJECT CRITERIA

- FEMA vs. USACE

USACE – EC 1110-2-6067

➡ Closures – EM 1110-2-2105

➡ Embankment & Foundation Stability –

➡ EM 1110-2-1902



# ABANDONED CONDUIT INVESTIGATION



Mound City Electric Plant



# ABANDONED CONDUIT INVESTIGATION

## . CSI St. Louis

- Monsanto Acid Sewer
- Anheuser-Busch Molasses Line
- Mound City Electric Plant





# ABANDONED CONDUIT INVESTIGATION



Foot of Angelrodt Street







# ABANDONED CONDUIT INVESTIGATION



Foot of Angelrodt Street



# HORNER & SHIFRIN, INC.

## FIRM OVERVIEW

- Founded in 1933
- Offices in St. Louis, Springfield, and Poplar Bluff, MO, and O'Fallon, Chicago, and Rochester IL.
- 90 Employees, 42 Full-Time P.E.'s
- Full-Service Engineering Firm:
  - Mechanical
  - Electrical
  - Plumbing
  - Civil
  - Structural
  - GIS/Survey
  - Environmental
  - Transportation
  - Construction Administration





# CONCLUSION



# QUESTIONS?