# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge


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Prepared for:

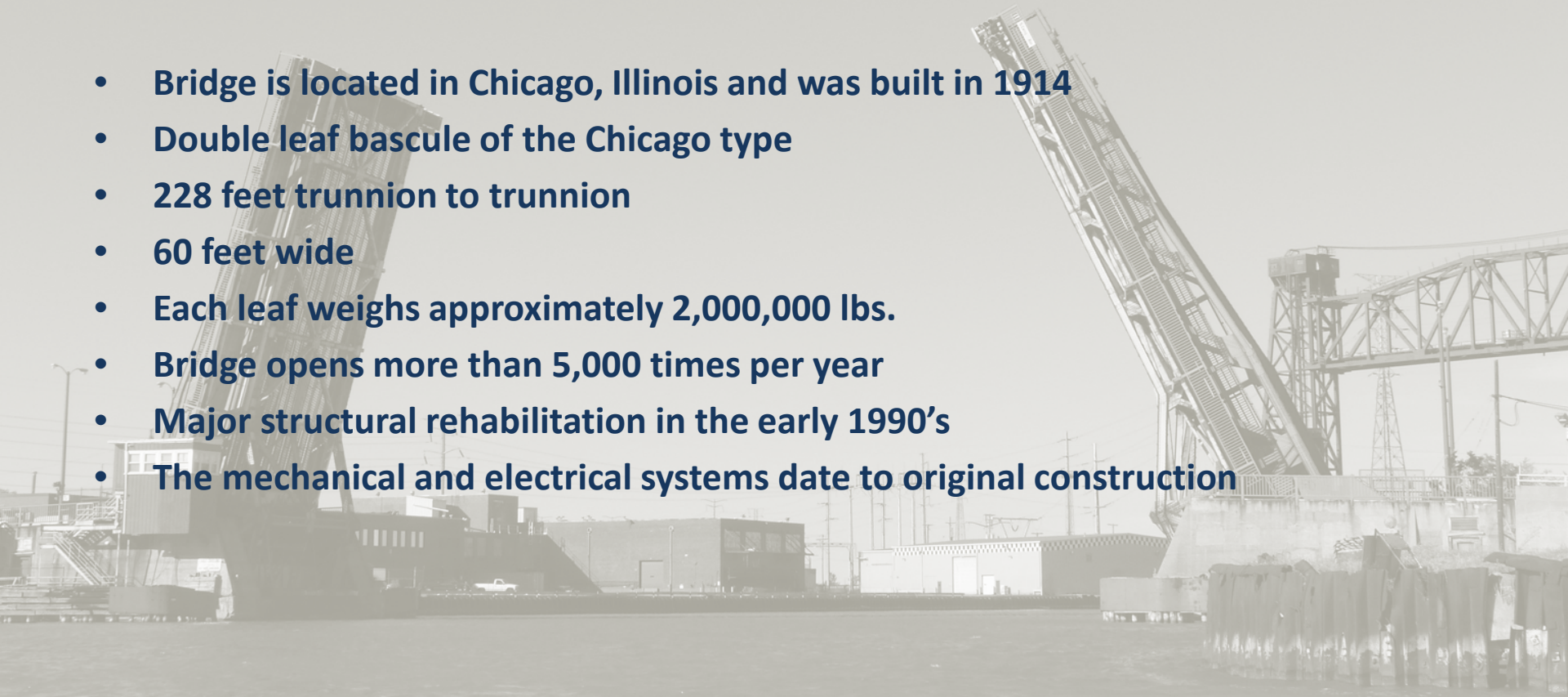
Western Bridge Engineers' Seminar

September 2015

# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

## Introduction

- Bridge is located in Chicago, Illinois and was built in 1914
- Double leaf bascule of the Chicago type
- 228 feet trunnion to trunnion
- 60 feet wide
- Each leaf weighs approximately 2,000,000 lbs.
- Bridge opens more than 5,000 times per year
- Major structural rehabilitation in the early 1990's
- The mechanical and electrical systems date to original construction



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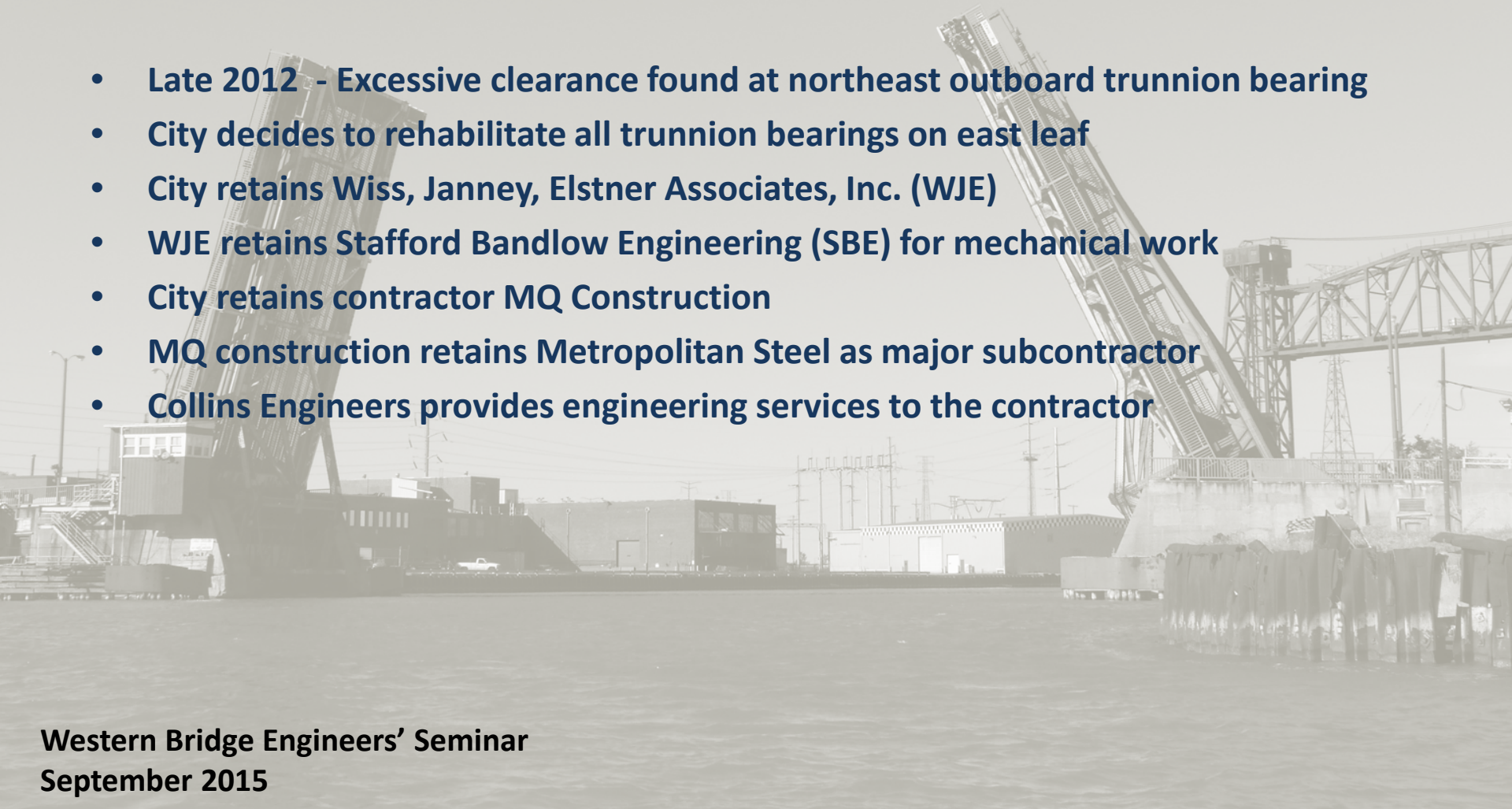
# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

## Background

- Late 2012 - Excessive clearance found at northeast outboard trunnion bearing
- City decides to rehabilitate all trunnion bearings on east leaf
- City retains Wiss, Janney, Elstner Associates, Inc. (WJE)
- WJE retains Stafford Bandlow Engineering (SBE) for mechanical work
- City retains contractor MQ Construction
- MQ construction retains Metropolitan Steel as major subcontractor
- Collins Engineers provides engineering services to the contractor



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# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

## Presentation Outline

- Mechanical Design for Bearing Rehabilitation
- Structural Design for Jacking
- Construction
- Inspection
- Emergency Work

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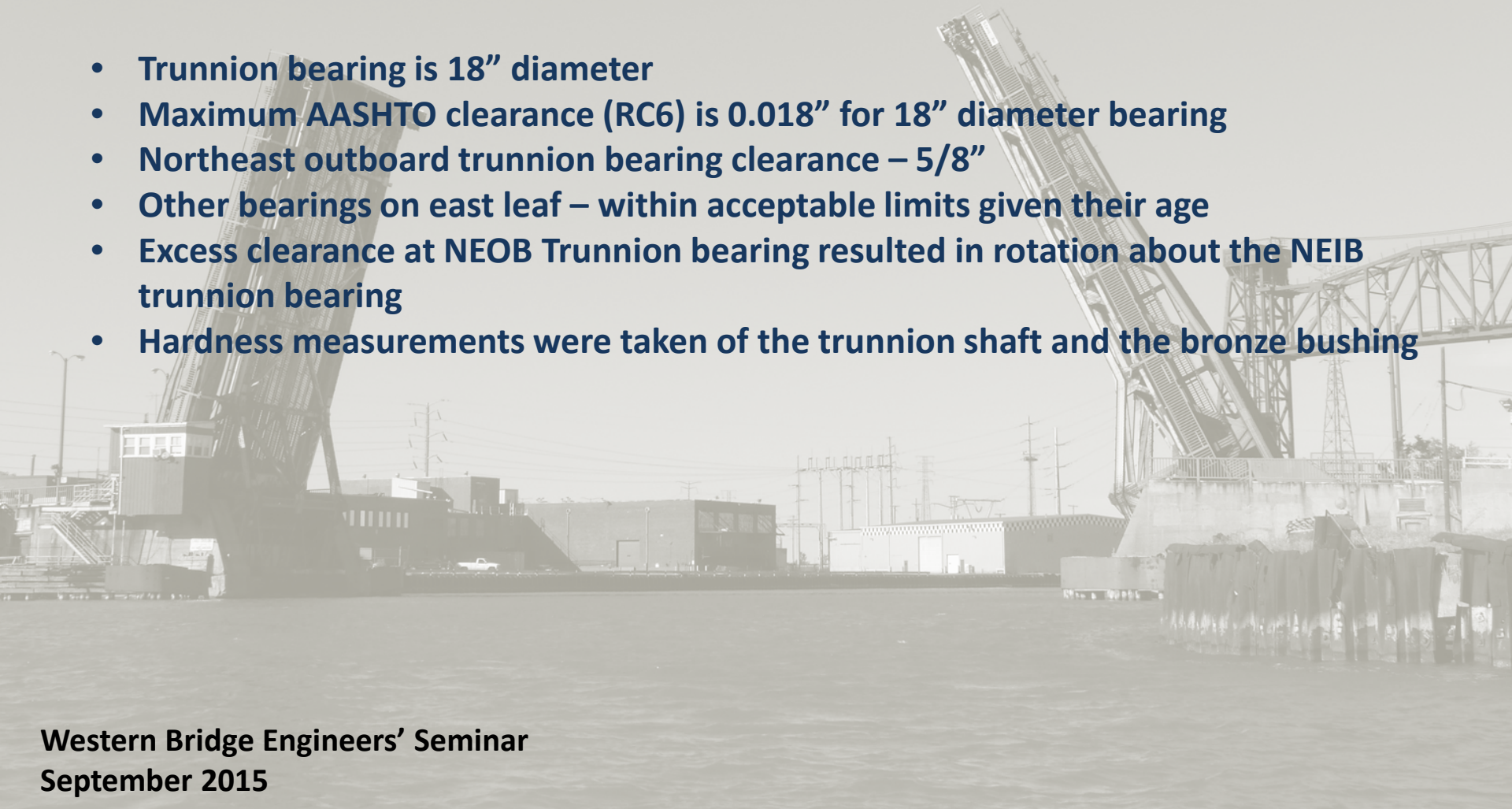
**Mechanical Design**
**Preliminary Information Obtained March 20, 2013**

- Trunnion bearing is 18” diameter
- Maximum AASHTO clearance (RC6) is 0.018” for 18” diameter bearing
- Northeast outboard trunnion bearing clearance – 5/8”
- Other bearings on east leaf – within acceptable limits given their age
- Excess clearance at NEOB Trunnion bearing resulted in rotation about the NEIB trunnion bearing
- Hardness measurements were taken of the trunnion shaft and the bronze bushing



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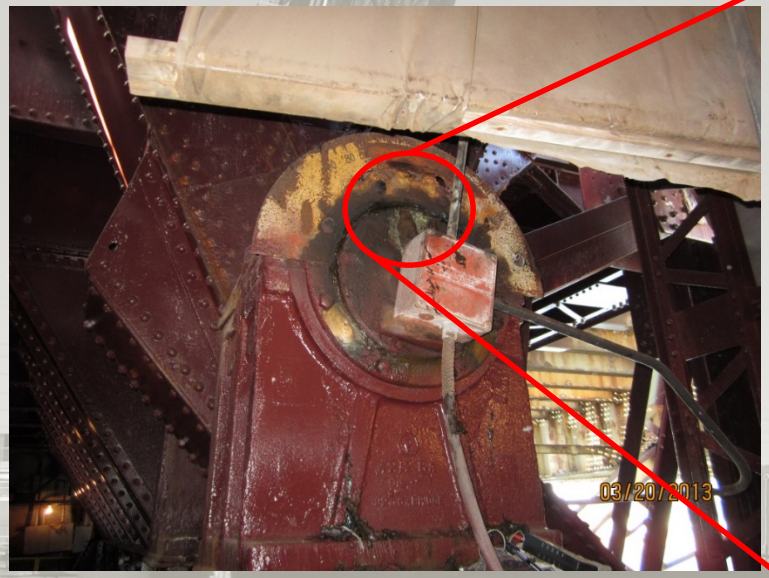
- **Excess Clearance**

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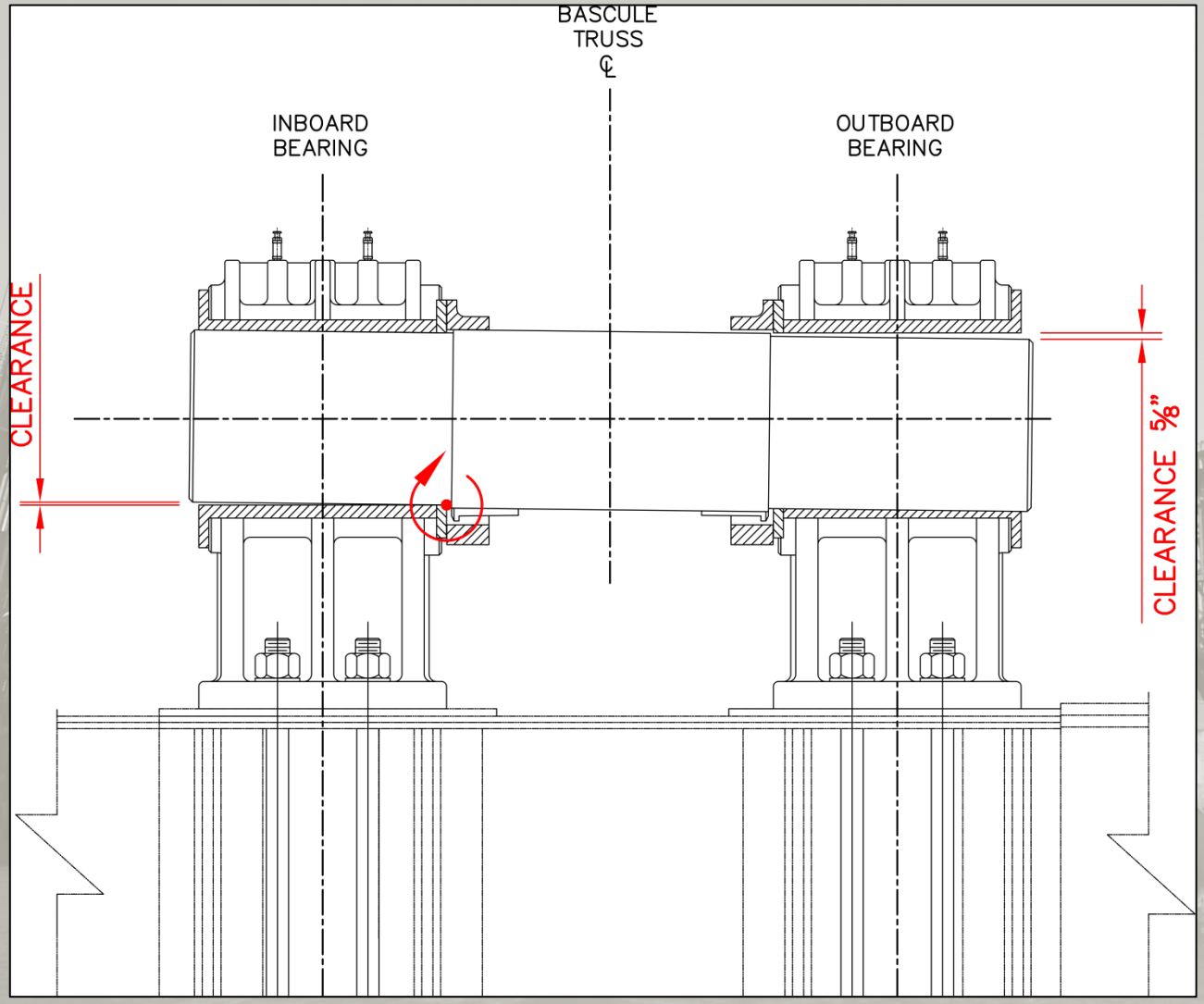


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# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

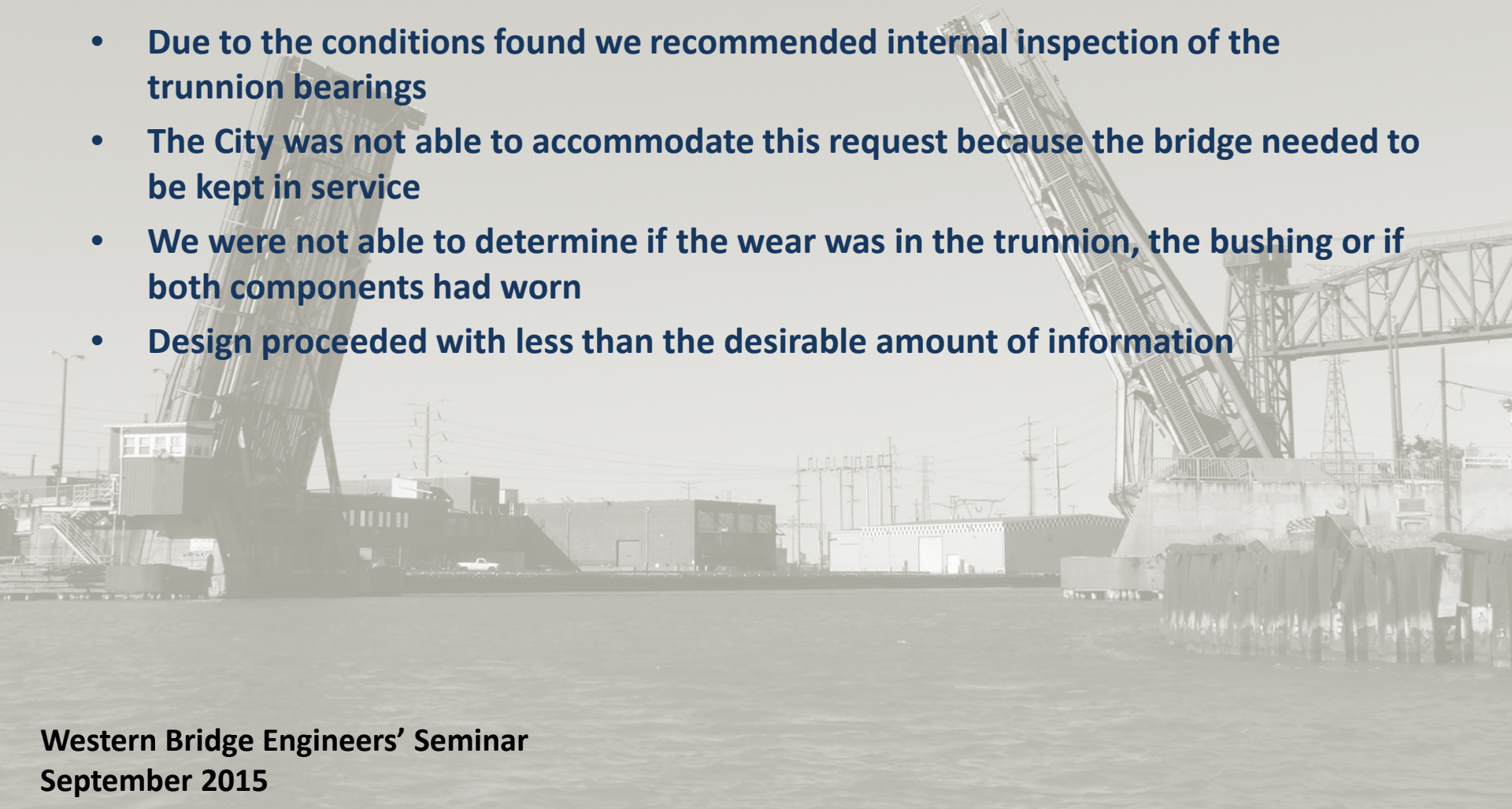
## Cause

- Lack of lubrication

# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

## Further Inspection Recommended

- Due to the conditions found we recommended internal inspection of the trunnion bearings
- The City was not able to accommodate this request because the bridge needed to be kept in service
- We were not able to determine if the wear was in the trunnion, the bushing or if both components had worn
- Design proceeded with less than the desirable amount of information



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# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

## The Initial Plan

- Field machine trunnion journals at four locations
- Replace bronze bushings at four locations
- Change lubrication system

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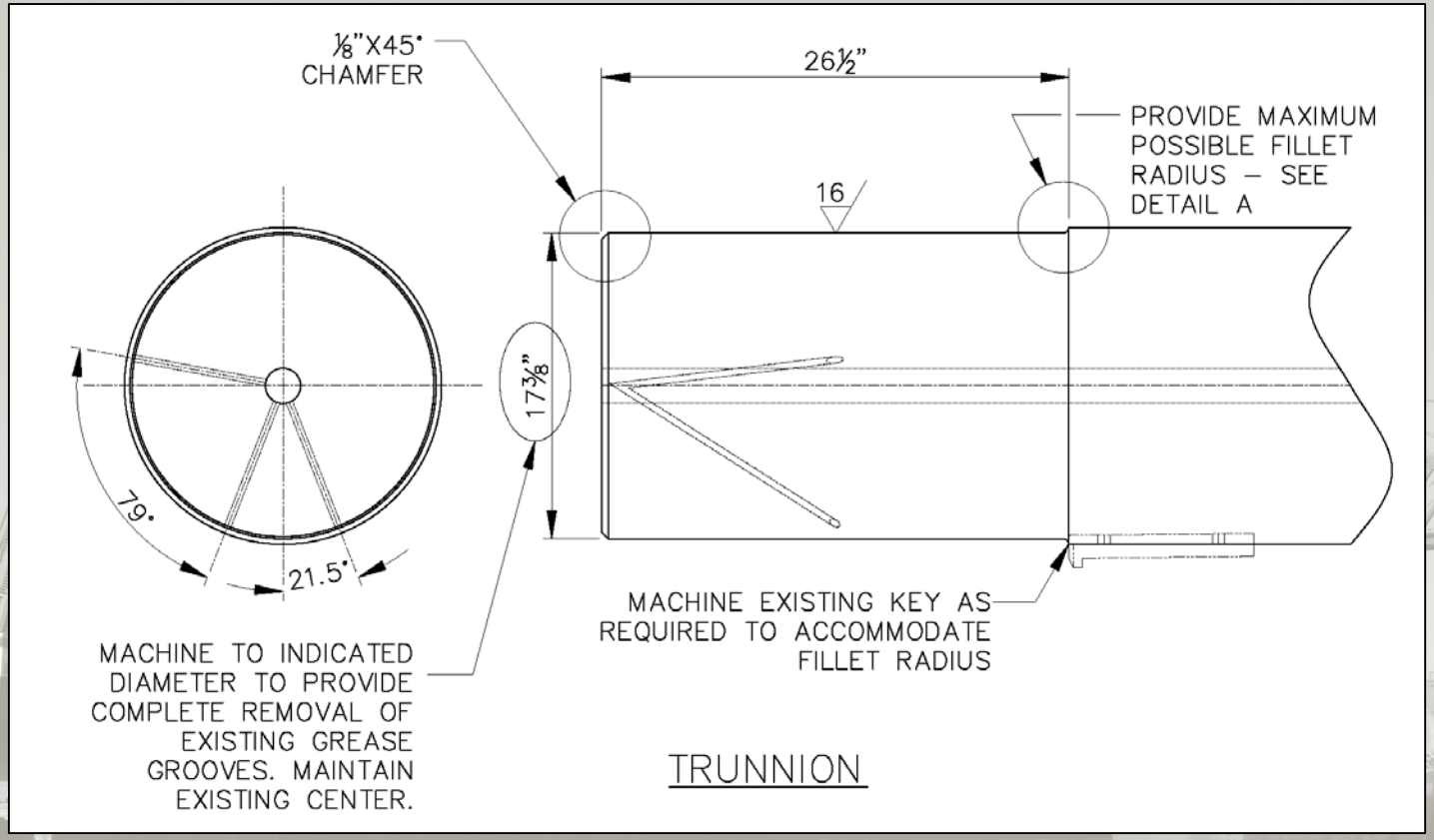
# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge




**Trunnion with single lube fitting supplying three grease grooves**

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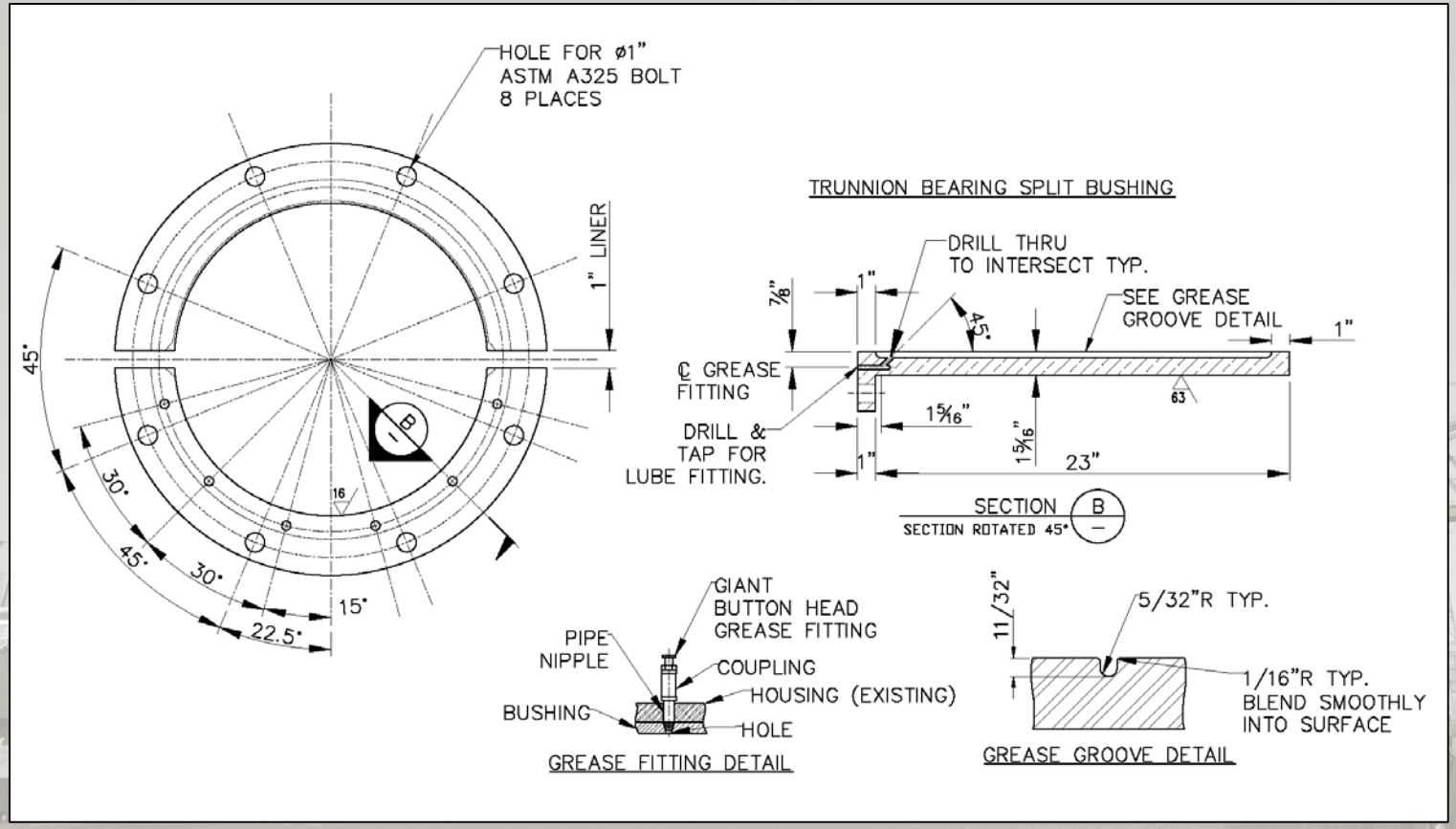
# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge




**Bushing with six grease grooves, each with a dedicated lube fitting**

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# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

## Trunnion Machining

- Remove a minimum of 3/8” on diameter to remove existing grease grooves
- Verify trunnion stress and fatigue
- Verify bearing pressure

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# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

## Trunnion Stresses

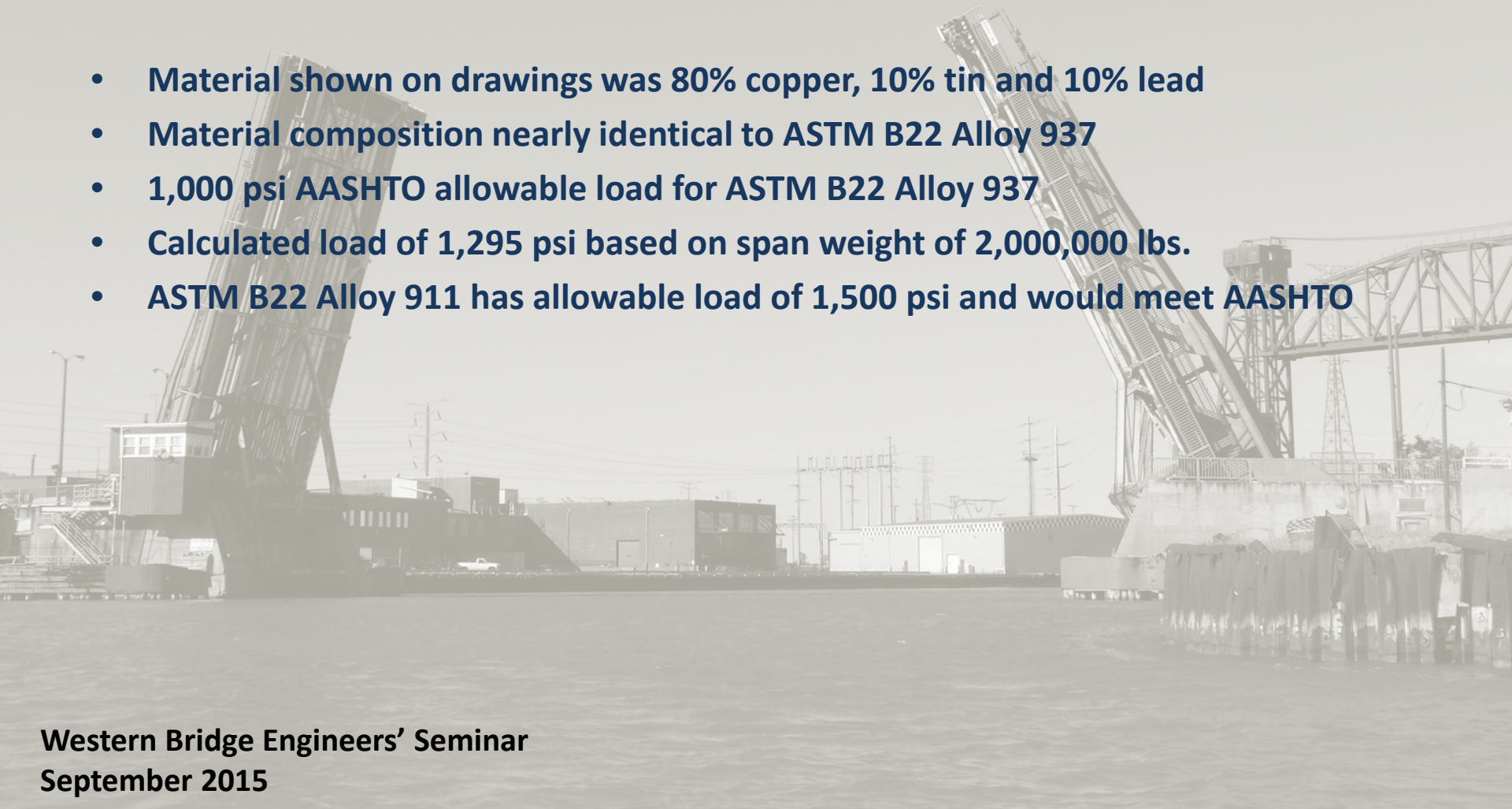
- Endurance limit for trunnion material is 16,146 psi
- Infinite fatigue life could not be achieved
- Fatigue life would likely be better than the initial fatigue life

| 92nd Street Bridge - Chicago, Illinois | | | | |
|---|---|---|---|---|
| Trunnion Geometry Versus Adjusted Fillet Stress | | | | |
| Journal Dia. (inches) | Material Removal (inches on dia.) | Fillet Radius (inches) | Stress at Fillet (psi) | Notes |
| 17.875 | 0 | .031 | 26,873 | Original diameter with 1/32" fillet |
| 17.875 | 0 | .057 | 23,207 | Original diameter with max possible fillet |
| 17.625 | .25 | .125 | 25,849 | |
| 17.625 | .25 | .182 | 23,525 | |
| 17.375 | .50 | .250 | 25,209 | |
| 17.375 | .50 | .307 | 23,913 | Recommended material removal |
| 17.125 | .75 | .375 | 25,251 | |
| 17.125 | .75 | .432 | 24,322 | |

# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

## Bushing Material Selection

- Material shown on drawings was 80% copper, 10% tin and 10% lead
- Material composition nearly identical to ASTM B22 Alloy 937
- 1,000 psi AASHTO allowable load for ASTM B22 Alloy 937
- Calculated load of 1,295 psi based on span weight of 2,000,000 lbs.
- ASTM B22 Alloy 911 has allowable load of 1,500 psi and would meet AASHTO

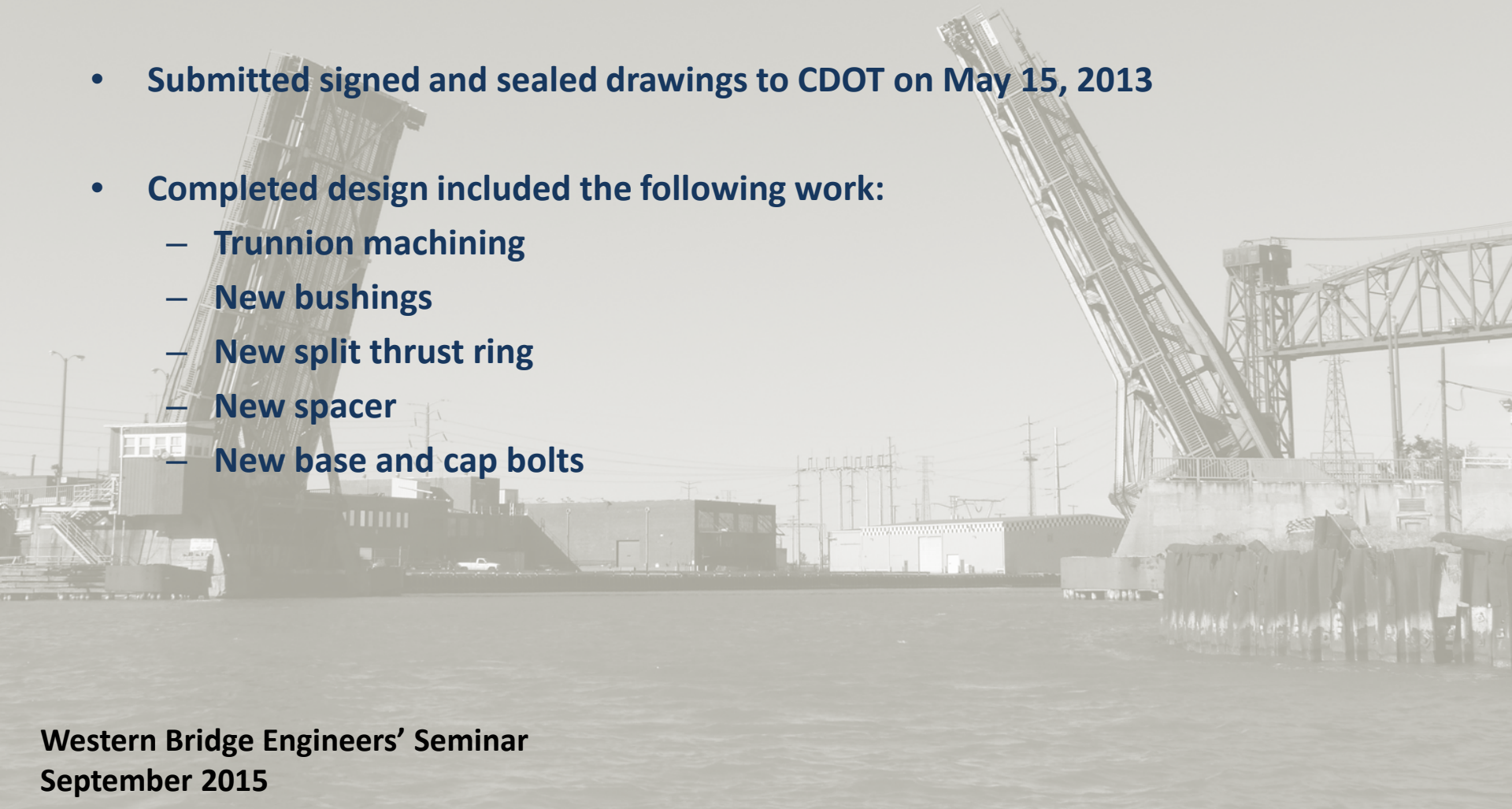


# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

## Bushing Material Selection

- Selected ASTM B22 Alloy 937
  - Similar to existing material which lasted nearly 100 years at other locations
  - High lead content is desirable in bronze bushing
  - Trunnion was too soft and not a good match for ASTM B22 Alloy 911

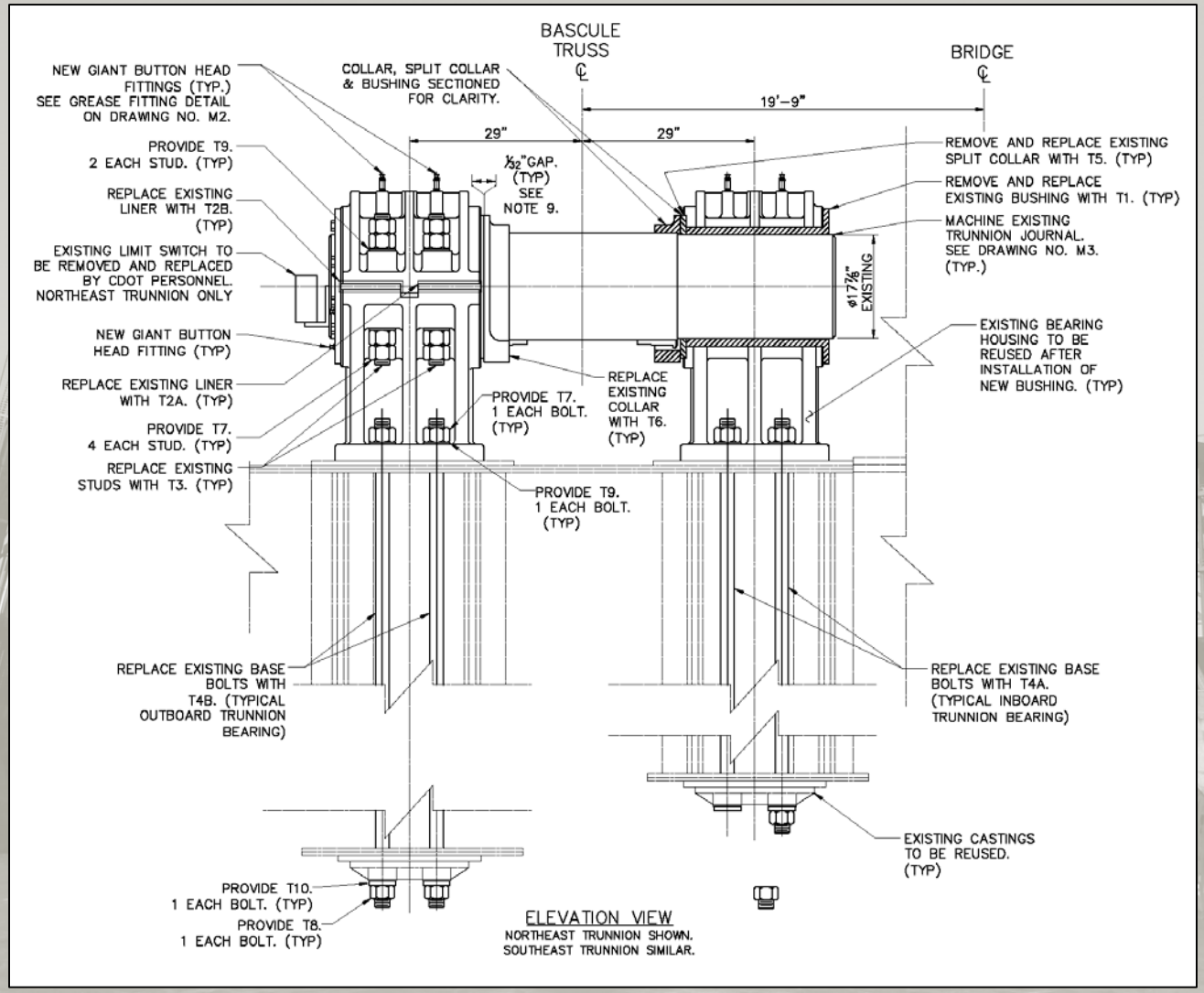
# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge



## Final Design

- Submitted signed and sealed drawings to CDOT on May 15, 2013
- Completed design included the following work:
  - Trunnion machining
  - New bushings
  - New split thrust ring
  - New spacer
  - New base and cap bolts

# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

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# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

## Alignment

- Intention was to restore original alignment
- Following notes were provided on the drawings:

***The purpose of the work shown on these drawings is to repair the sliding surfaces of the existing trunnion bearings on the east leaf of the bridge to extend the service life. It is presupposed that the original alignment of the bearings was satisfactory and that returning the bearings to the original position will result in satisfactory alignment. All work is based on returning the bearings to the same location and orientation following replacement of the bearing bushings. Following installation of the rehabilitated bearings, the alignment will be verified and any changes to the alignment will be directed by the engineer.***

# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

## Alignment

- Intention was to restore original alignment
- Following notes were provided on the drawings:

***Components that are disassembled as part of this work shall be match marked to ensure that they are returned to their original location unless directed otherwise by the engineer. Match marking to include all bearing assembly components, fasteners and shims.***

# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

## Alignment

- Intention was to restore original alignment
- Following notes were provided on the drawings:

***Install two tapered or straight dowel pins (at contractors discretion) in each bearing housing prior to removal of bearings so that bearings can be returned to their existing location. Dowels to have a maximum clearance of 0.002" with the mating hole and dowel shall extend completely through the bearing mounting surface.***

# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

## Alignment

- Intention was to restore original alignment
- Following notes were provided on the drawings:

***Remove bearing cap and survey elevation of bearing split line (with liners removed and surface cleaned) at two locations on each side of the trunnion. Survey prior to jacking and after jacking. Survey to +/- 0.001". Survey all bearings to a common level plane. Provide permanent marks at all survey points. Submit survey plan and results to the engineer for review.***

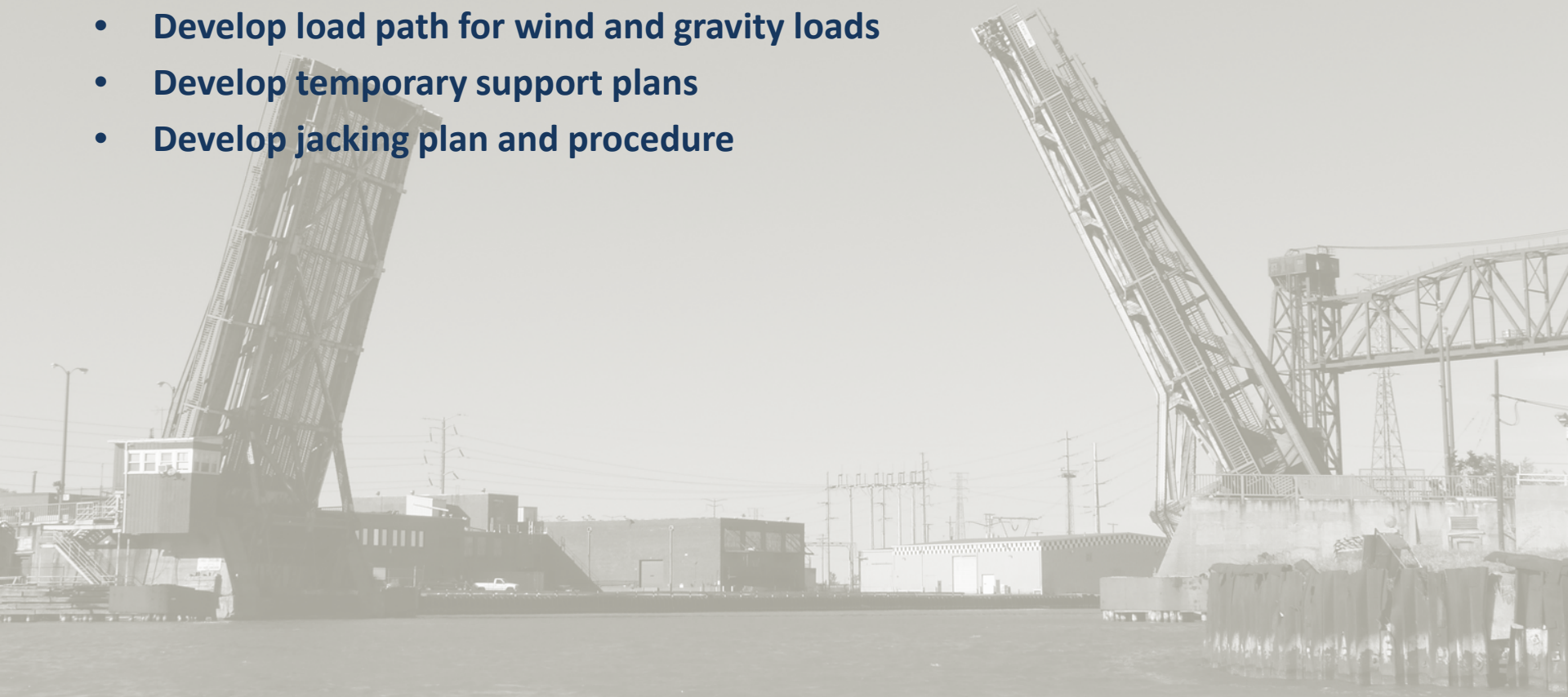
# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

## Alignment

- Intention was to restore original alignment
- Following notes were provided on the drawings:

***Contractor shall establish location and orientation of existing bushing bore relative to existing housing bore. Contractor to record measurements and submit to the engineer for review. It is intended that the relative orientations of the bores will be maintained with the new bushings.***

# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge



**Structural Challenge:**

- **Develop load path for wind and gravity loads**
- **Develop temporary support plans**
- **Develop jacking plan and procedure**

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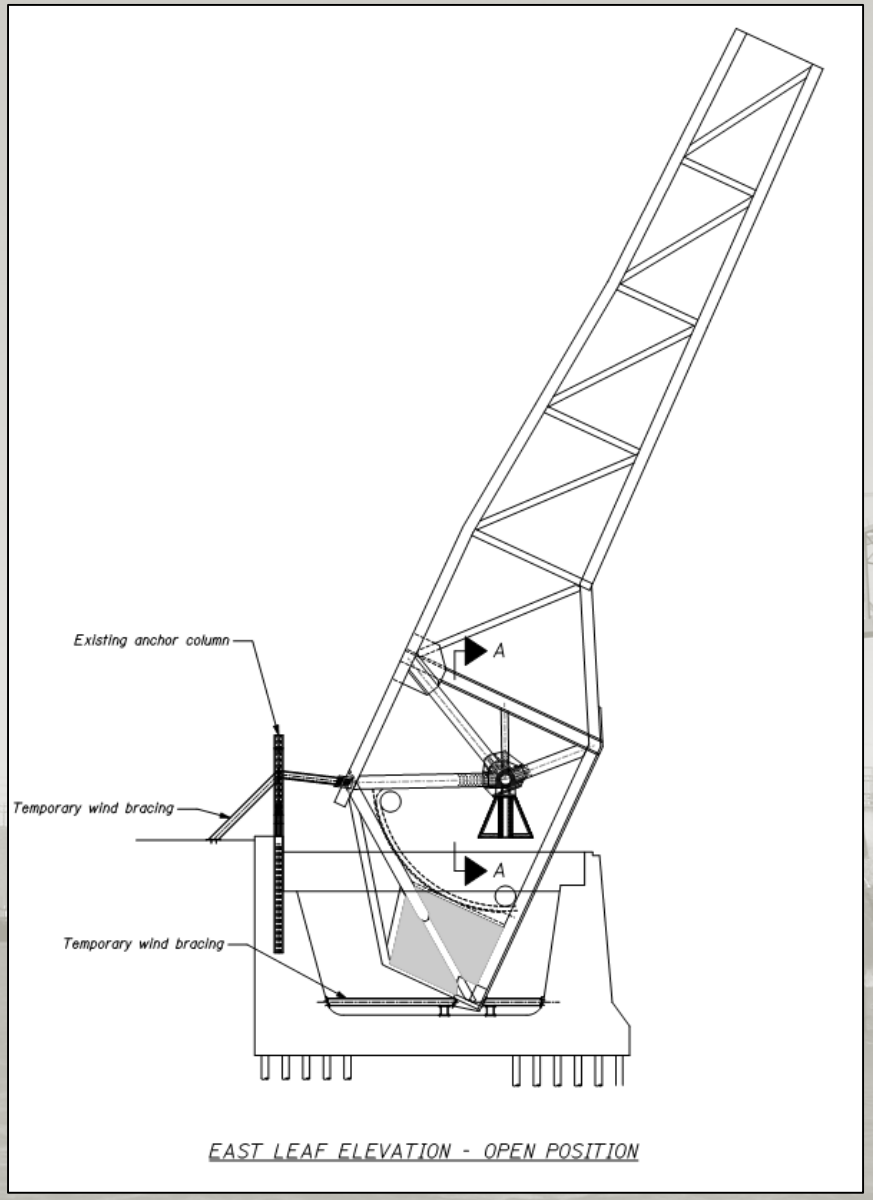
# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

**Structural Solution:**

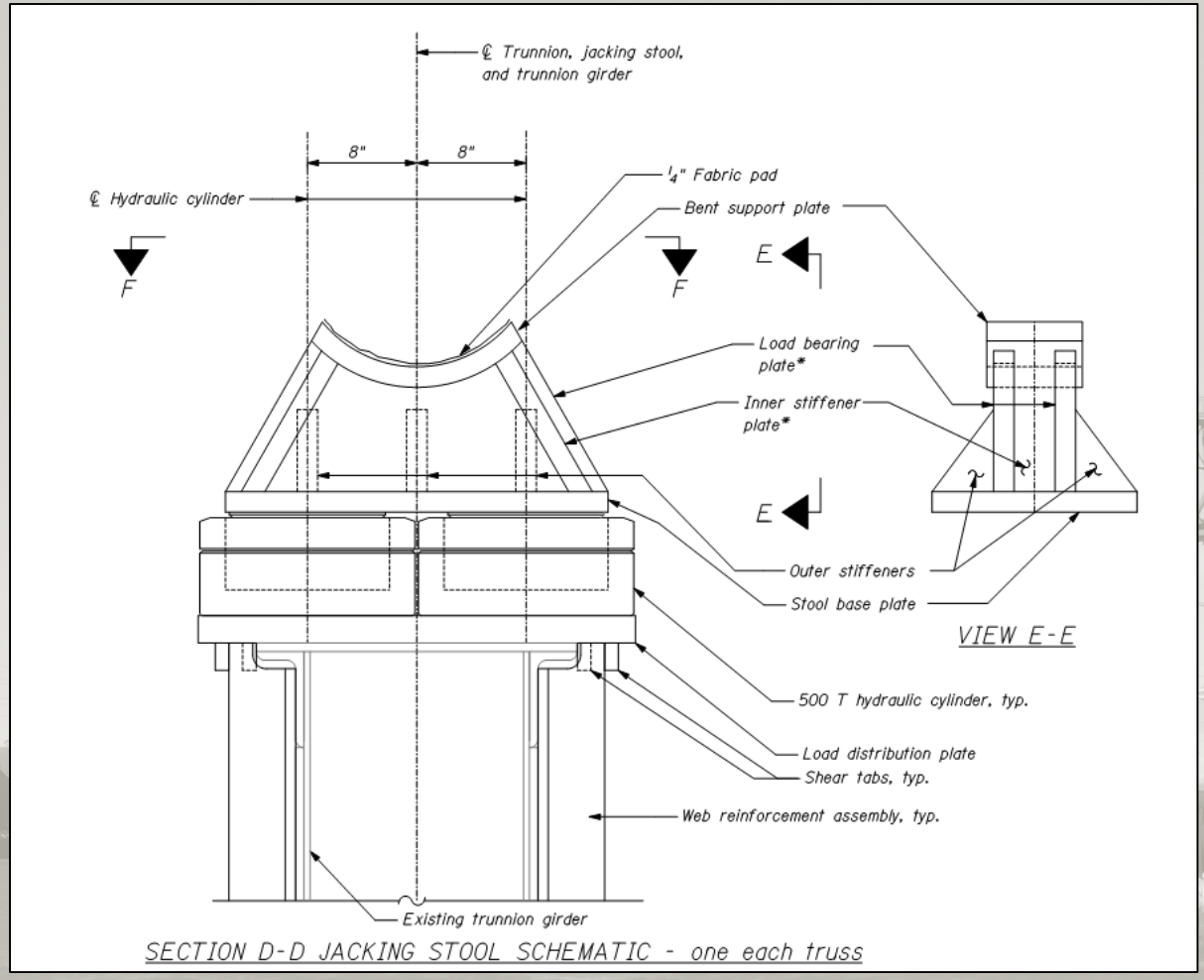
- Jack vertically from the trunnion girder
- Provide rotational stability
- Provide resistance to wind loads



# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

**Structural Solution:**

- Trunnion girder stiffeners
- Jacking saddles
- 500-ton locking collar rams
- Specialized jacking procedure
- Hydraulic manifold with lock-off ports

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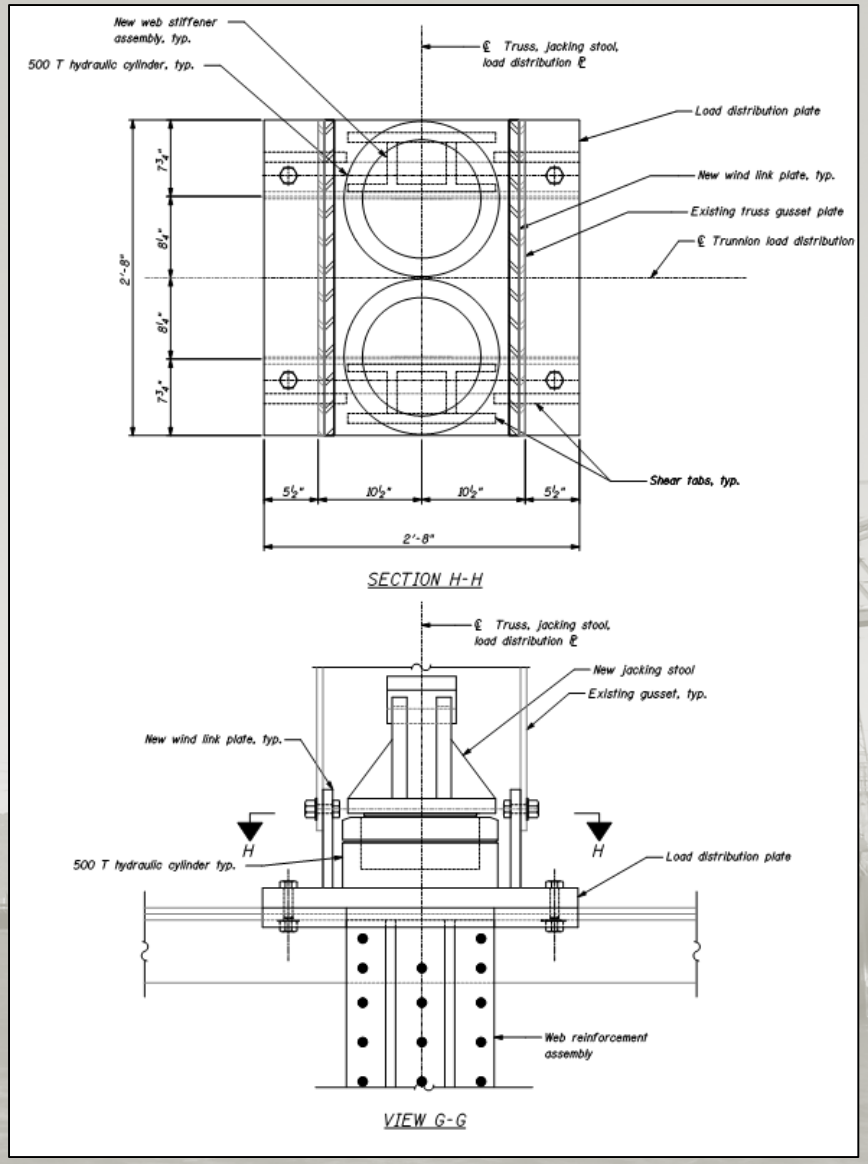
# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

## Structural Solution:

- Wind-lock plates
- Bearing plate shear tabs

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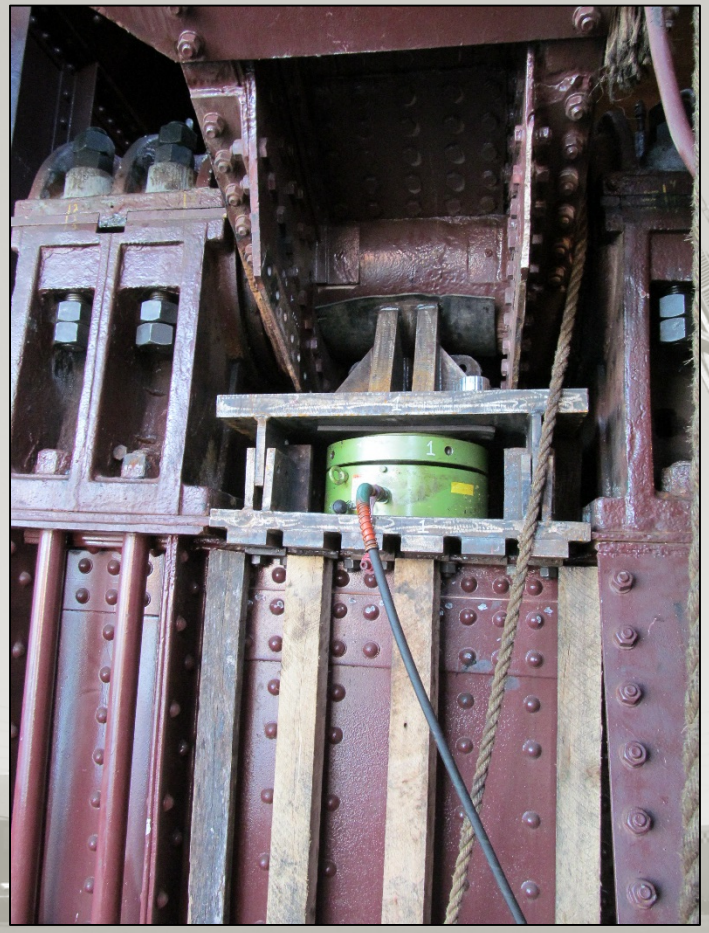
# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge



Jacking saddle with jack

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# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge


Up-close view of jacking saddle with jack

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# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

Counterweight Strut

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# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

## Construction

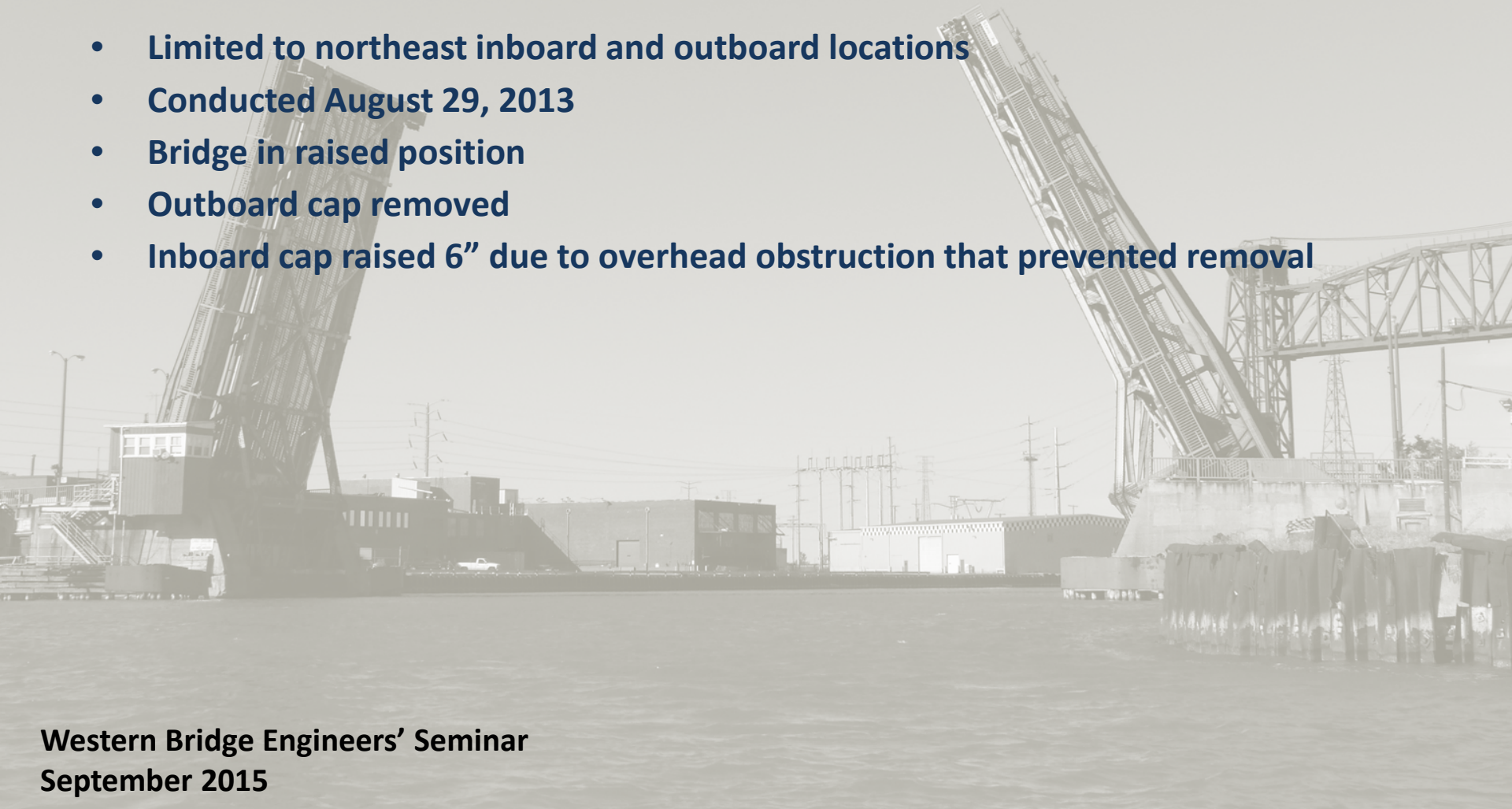
- Contractor retained prior to completion of design
- Construction had to be completed by September 27, 2013 to avoid conflicts with other city projects
- Work would be completed during a 10 week roadway closure
- Long lead time items ordered in late April with extra stock allowance for machining
  - Bronze bushings
  - Split collars

# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

## Delays

- The Project encountered numerous delays
- By August it was apparent that the work could not be completed on time
- The schedule could not be changed
- CDOT decided to replace the bushing at the northeast outboard location only
  - Location with excessive clearance
  - No trunnion bearing housing removal
  - No trunnion journal machining
- SBE and WJE tell CDOT that this is not a good plan
- SBE and WJE agree to assist CDOT
- SBE and WJE insist on trunnion bearing cap removal for internal inspection

# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge



## Inspection

- Limited to northeast inboard and outboard locations
- Conducted August 29, 2013
- Bridge in raised position
- Outboard cap removed
- Inboard cap raised 6” due to overhead obstruction that prevented removal

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# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

Outboard bearing after cap removal - trunnion journal covered with lubricant

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# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

Outboard trunnion journal after removing lubricant – severe corrosion with scaling and pitting

Diameter was measured and ranged from 17.842” on an unworn surface to 17.554” at the inboard end of the trunnion journal.

Taper due to wear and corrosion was 0.288” over length of journal.

# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

Outboard trunnion journal – grease groove nearly worn away at inboard end

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# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

Outboard trunnion journal – close up of pitting

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# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

Outboard bearing – fractured steel collar

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# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

Inboard trunnion journal - generally good to fair condition

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# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

Inboard trunnion journal – close up of inboard end with light scoring and bronze embedment

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# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

## Inspection Conclusions

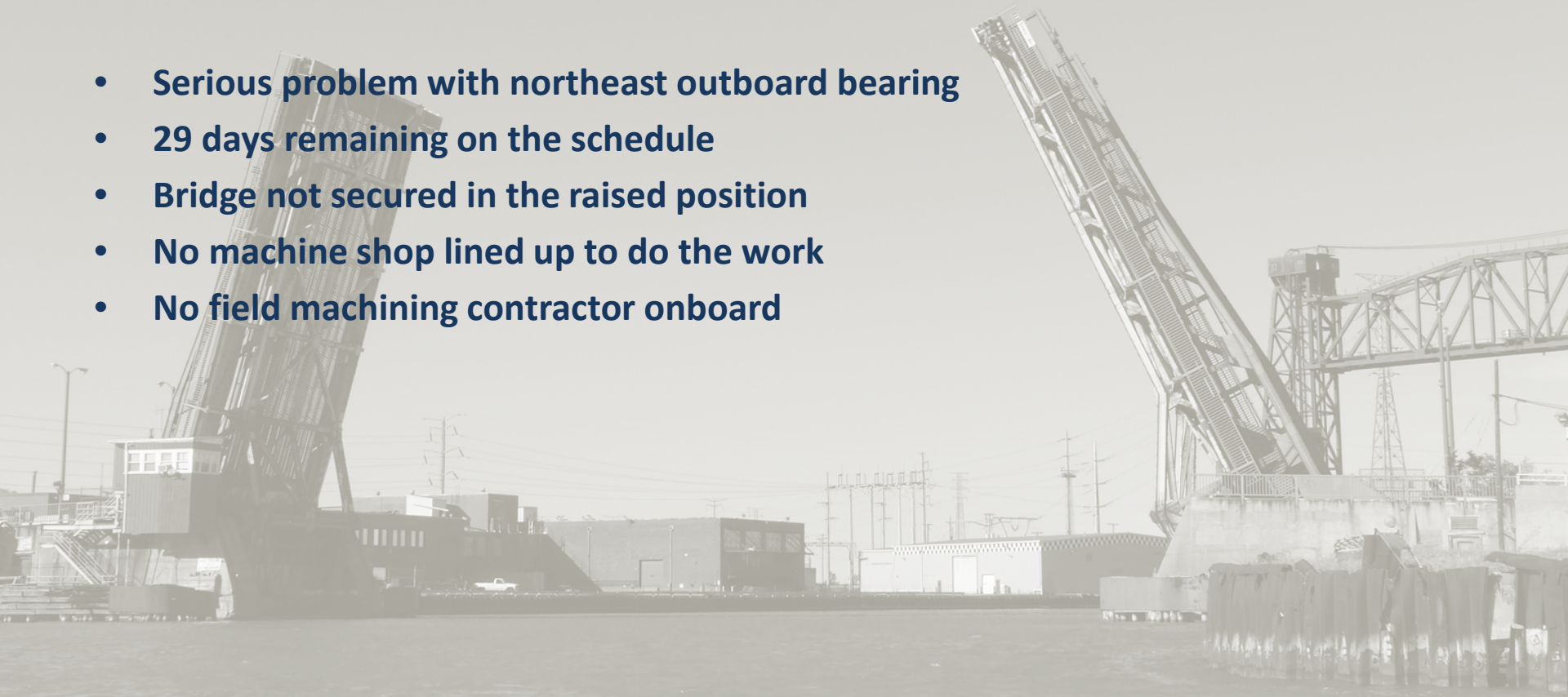
- Northeast outboard trunnion bearing
  - Trunnion journal not suitable for continued service
  - Trunnion journal machining required
  - New bushing required
  - New steel collar required
  - Design drawings provide a suitable basis for this work
- Northeast inboard trunnion bearing
  - Trunnion journal is acceptable for continued service
  - Damage at inboard end is due to poor alignment
  - Alignment will be corrected and load redistributed when outboard bearing is rehabilitated

# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

## Inspection Recommendations

- Rehabilitate northeast outboard bearing based on rehabilitation plans dated May 15, 2013
- Take detailed clearance and alignment measurements at northeast inboard bearing as a baseline prior to jacking the bridge
- Remove southeast inboard and outboard bearing caps for inspection of the trunnion journals
- Take detailed clearance and alignment measurement at the southeast inboard and outboard bearings

# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge



## Emergency Work

- Serious problem with northeast outboard bearing
- 29 days remaining on the schedule
- Bridge not secured in the raised position
- No machine shop lined up to do the work
- No field machining contractor onboard

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# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

## Getting the Work Done in 29 Days

- SBE proposes the following:
  - SBE lead the coordination effort required for the trunnion rehabilitation work
  - Contractor to focus on work required to secure bridge in raised position
- CDOT and WJE agree that this is a viable approach with the best chance of success
- Long lead time materials on hand gave us a chance to complete the work
- We needed:
  - A company to complete the field machining
  - A machine shop with the capability and capacity to complete the work

# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

**Field Machining**

- Mountain Machine Works of Auburn, Maine
- Recent experience on a more complex field machining job
- They agreed to do it!!

**Machine Shop**

- Initially we thought Smedberg Machine of Chicago would do the work
  - Relatively small shop
  - Located within a few miles of the bridge
- Further discussion revealed that they could not meet the schedule
  - Agreed to do some of the smaller parts
  - Agreed to assist with field measurement and fitting of steel collar as required
- G&G Steel said they could meet the schedule
  - Confidence in their ability
  - 620 miles from the bridge
  - Need to get it right the first time to meet schedule

**Everything was in place and we were ready to go**

# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

## Construction Time Line

**September 16, 2013 - East leaf jacked and secured in fully open position**

**September 16, 2013 - Bearing removed from bridge and transported to G&G Steel**


**Bearing after removal - Note poor condition of the bearing**

# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

## Construction Time Line

**September 16 - 17, 2013 - Field machining equipment set up and aligned**


**Field machining – Machine set up and aligned**

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# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

## Construction Time Line

**September 17, 2013 - Bearing arrives at G&G Steel and first chips are cut in the field**


**Field machining- Initial cut**

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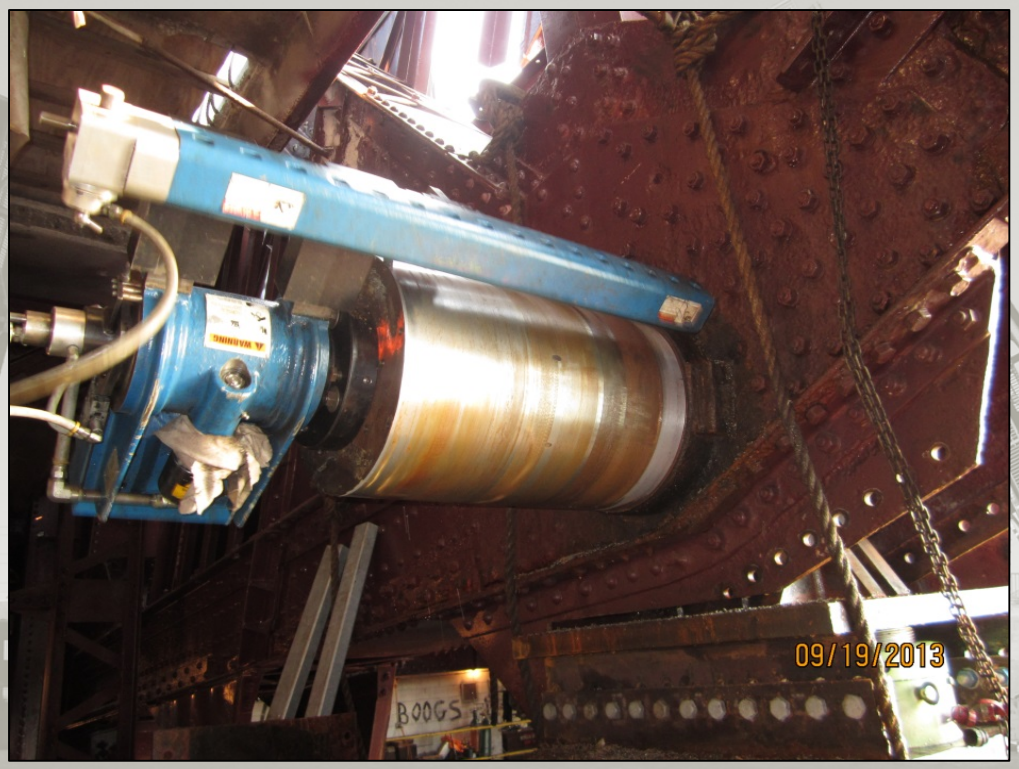
# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

## Construction Time Line

**September 19, 2013 - Grease grooves removed from trunnion journal, rough machining complete**




**Field Machining - Grease grooves removed, rough cut complete**

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## Construction Time Line

**September 20, 2013 - SBE personnel on-site at G&G to inspect work progress**

**September 20, 2013 - Final trunnion OD determined and bushing ID provided to G&G**


**Field machining – Dimensions on shaft**

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# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

## Construction Time Line

**September 21, 2013 - Polishing of trunnion journal completed and Mountain Machine Works demobilizes.**


**Field machining – Trunnion journal complete**

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# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

## Construction Time Line

**September 24, 2013 - Rehabilitated bearing arrives on-site and installed on bridge**


**Trunnion bearing base and bushing at installation**

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# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

## Construction Time Line

**September 25 – 26, 2013 – Bearing alignment and installation of bolts**

**September 26 , 2013 – Removal of jacks and struts used to secure bridge in open position**

**September 26, 2013 – Initial operation of bridge following bearing rehabilitation**

**September 27, 2013 – Shimming of live load supports and clean-up**

**September 27, 2013 – Bridge opened to vehicular traffic on schedule**

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# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge

## Conclusions

- Project did not go as originally envisioned
- Project was successful
  - Everyone involved with the project was satisfied with the work
  - Project was completed within the original schedule
- Improvements were made to the design of the bearing
- Lubrication is no longer an issue
- The bearings on the east leaf of the bridge will provide reliable long term service

# Replacement of Trunnion Bearing, 92nd Street Bascule Bridge


## Acknowledgements

- City of Chicago Department of Transportation
- Wiss, Janney, Elstner Associates, Inc.
- Collins Engineers
- MQ Construction
- Metropolitan Steel
- Smedberg Machine
- Mountain Machine Works
- G&G Steel


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