SECURING THE FUTURE
2 RIVERS, 1 STORY

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Kansas City District, USACE

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City of Manhattan, KS
OUTLINE

- Overview
- Where we’ve been
  - Historic Flooding
  - Original Design
- Where we’re going
  - A Tale of Two Rivers
    - Loading – H&H
    - Underseepage - Geotech
    - Structures
LEVEE CENTERLINE – EXISTING CONDITIONS

Historic Performance
- 1993 Record Flood
  - Near OT on Big Blue Reach
  - Peak Discharge: ~50% design
  - Pin boils and seepage along Big Blue and KS River reaches

2014 Final Feasibility Report
- Levee Raise along Big Blue River
- Underseepage Mitigation where necessary
- Gatewell Replacement
  - 5 Gatewells deemed structurally insufficient
WHERE WE’VE BEEN
HISTORIC KANSAS RIVER FLOODING

- Flood of June 1844 – Stage 40 feet
- Flood of July 1951 – Stage 33.4 feet
  - Inundated up to 30% of Manhattan
  - KS River above flood stage for 47 days
  - 300,000 cfs – KS River
  - 98,000 cfs – Big Blue River

<table>
<thead>
<tr>
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<th>Initial Federal Project Completed (yr)</th>
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2 Pump Stations
10 Drainage Structures
1 Stoplog Gap
3 Sand Bag Gaps
## FLOOD OF 1993

<table>
<thead>
<tr>
<th>USGS Sta.</th>
<th>Station Name</th>
<th>1903</th>
<th>1951</th>
<th>1993</th>
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<tbody>
<tr>
<td>6879500</td>
<td>Kansas River at Ogden (Upstream of Manhattan)¹</td>
<td>236,000</td>
<td>298,000</td>
<td>85,000</td>
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<tr>
<td>6887500</td>
<td>Kansas River at Wamego (Downstream of Manhattan)²</td>
<td>280,000</td>
<td>400,000</td>
<td>199,000</td>
</tr>
<tr>
<td>6887000</td>
<td>Big Blue River near Manhattan³</td>
<td>93,800</td>
<td>93,400</td>
<td>58,800</td>
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WHERE WE’VE BEEN

- Flood of 1993
- Recon Study (27 March 2003)
  - “berms and possibly some wells”…famous last words…
- Feasibility (Finished in 2015)
  - Milestones:
    - Alternatives Analysis
    - TSP Selection
    - Agency Decision
    - CW Review Board
    - ASA for CW Approval
- Authorization-Appropriation – Congress (2016)
- Pre-Construction Engineering and Design (2018-2021)
- Construction (2021-2024)
- Operations and Maintenance (On-going)
Feasibility Recommended Plan

- Investigated raises for ACE 1/300 (TSP) and 1/500 events
- Selected Plan included a levee raise along Big Blue River Reach, underseepage mitigation, and gatewell replacement
  - 48+ Relief wells, 2,000 linear feet of berms, 5 Gatewell Replacement

Final Design Features

- Raises along Big Blue and Kansas River: Sand drains/berms to mitigate stability issues
- Underseepage: 28 Relief Wells and 8,000 LF of Underseepage Berms
- Gatewells: 6 Total
  - 4 Strength modifications, 1 Replacement (Partial Betterment), 1 New Gatewell (100% Betterment)

Significant Design Changes

- Upstream KS River Raise – Now ties into high ground, completing the levee
- Relief Wells b/w STA 40+00 and 60+00, in-lieu of ponding area
- Less Relief Wells, More Seepage Berms
WHERE WE ARE: DESIGN FEATURES
Manhattan, KS FRM
Feasibility Proposed Features

Levee Raise – STA 131+00 to 270+00

- Relief Wells
- Underseepage Berms
- Ponding Ditch
- Gatewell Replacement
Manhattan, KS FRM
Final Design Features

- Relief Wells
- Underseepage Berms
- Ponding Ditch
- Gatewell Replacement
- Gatewell Modification
- Gatewell Raise Only
- New Gatewell
- Sandbag Gap Sill
- Stoplog Closure (UPRR)

Levee Raise – STA 10+00 to 80+00
Levee Raise – STA 131+00 to 270+00
LEVEE RAISE ~ 21,100 LINEAR FEET

<table>
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<tr>
<th>Station Start</th>
<th>Station End</th>
</tr>
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<tbody>
<tr>
<td>131+00</td>
<td>272+50</td>
</tr>
<tr>
<td>6+00</td>
<td>80+00</td>
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</table>

Oversteepened Crest– Upper KS River Reach

*NOTE – Toe Drain for Stability

Landside Levee Raise – Big Blue Reach
UNDERSEEPAGE MITIGATION MEASURES

28 Pressure Relief Wells

9,200 feet of Underseepage Berms
GATEWELL MODIFICATIONS

- Feasibility – 100% Replacement of 5 Gatewells
- Design
  - 4 Gatewells to be raised – no structural modifications needed
  - 2 Gatewells to be strengthened only
  - Requires excavation to expose exterior walls
  - 1 Gatewell to be replaced
  - 1 Newly constructed
LOADING: A TALE OF TWO RIVERS
Complex Hydrology

- Confluence of 2 Rivers
- Several constrictions and expansions
- Several Dams Upstream
  - Wilson, Kanopolis, Milford
  - Tuttle Creek
Surveyed TOL-0.5' Design Water Surface Profiles
UNDERSEEPAGE: A TALE OF TWO RIVERS
As documented in USACE WES – TM 3-434 (1956)
BACKWARDS EROSION PIPING OF FOUNDATION SANDS
<table>
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<tr>
<th>Analysis Method</th>
<th>Description</th>
<th>Pros</th>
<th>Cons</th>
</tr>
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<tr>
<td>Superposition</td>
<td>Analyze underseepage at any given point using a two dimensional analysis from each source. From closest source calculate $h_0$. From farthest source, calculate $h_0$. Add them together to get $h_0$ at the confluence area.</td>
<td>Superposition theory is sound logic. Simple to analyze using EM 1110-2-1913 methods. Takes into account levee intersection angle and “sharpness” of curvature.</td>
<td>Goes to infinity at confluence corner, and engineering judgment required. Analysis can predict excess heads greater than the driving head.</td>
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<td>Blocked Exit</td>
<td>Assume a blocked exit bisects the levee bend/confluence angle. Calculate $h_0$ at any point around the confluence using the blocked exit equations in EM 1110-2-1913.</td>
<td>Simple to analyze using EM 1110-2-1913 methods. Takes into account levee intersection angle and “sharpness” of curvature.</td>
<td>Goes to infinity at confluence corner, and engineering judgment required.</td>
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<td>Modified Tailwater</td>
<td>Calculate $h_0$ for a cross section adjacent to each source. Recalculate the lower $h_0$ using the higher $h_0$ as the tailwater. The recalculated $h_0$ applies at the confluence corner. Confluence effects assumed to end a distance equal to the effective seepage exit from the confluence corner.</td>
<td>Simple to analyze using EM 1110-2-1913 methods. Analysis always predicts an excess head at the corner between $h_0$ and $H$, and does not blow up in the corner.</td>
<td>Only works for 90 degree levee intersections. Assumes levee alignment is along theoretical alignment, and cannot take into account intersection “sharpness” of curvature</td>
</tr>
<tr>
<td>Seep/W Plan View Model</td>
<td>Set up a large plan view Seep/W model modeling boundary conditions as close as possible considering the levee intersection angle. Find $h_0$ at any point along the confluence area.</td>
<td>Can take into account levee intersection angle and “sharpness” of curvature.</td>
<td>Does not consider pressure relief through landward blanket. Requires large model. Entrance and exit conditions are approximate since model must be rectangular.</td>
</tr>
<tr>
<td>Modified Schmertmann</td>
<td>Schmertmann proposed multiple corrections in a 2000 ASCE publication for underseepage gradients along flow paths under embankments. One of those gradient corrections was for alignment changes. Schmertmann’s intent is to account for seepage concentrations at embankment alignment changes. The correction factor was modified here as a reduction factor on the head loss (to provide an increase in excess head) at an inside bend, as opposed to gradient.</td>
<td>Method is from published work. Method is simple and appears to take into account levee intersection angle and “sharpness” of curvature. Analysis always predicts an excess head at the corner between $h_0$ and $H$, and does not go to infinity in the corner.</td>
<td>Method is modified from its original intent. Method may be non-conservative for acute angles.</td>
</tr>
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<td>Intersection Angle</td>
<td>A relation between $h_0$ and intersection angle was established using the Modified Tailwater and Seep/W Plan View Model methods for a theoretical levee alignment. This relation is used to determine $h_0$–c for any intersection angle and takes “sharpness” of curvature into account using engineering judgment through a series of cases.</td>
<td>Analysis always predicts an excess head at the corner between $h_0$ and $H$, and does not go to infinity in the corner. Considers levee intersection angle and “sharpness” of curvature.</td>
<td>Engineering judgment used in developing model. May be overly conservative, especially for acute angles.</td>
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INTERSECTION METHOD
STRUCTURES: GATEWELLS
STRUCTURES – EFFICIENTLY ADDRESSING THE PROBLEM
STRUCTURES – EFFICIENTLY ADDRESSING THE PROBLEM
MANHATTAN’S PERSPECTIVE
KEY BENEFITS TO MANHATTAN

- Manhattan is a River City – confluence of the Kansas River and the Big Blue River.
- Levee protects 1,500 acres of land within Manhattan, including:
  - 1,412 Homes
  - 231 Commercial Properties
  - 53 Public and 37 Industrial Structures
  - 3 miles of Railroad, 4 state bridges, and the Water & Wastewater Plants
- Disruption to entire City if flooded.
PROGRESS TO GET HERE

- 1931 – Report to Congress on Kansas River Flooding
- 1961 – Original Levee Built
- 1993 – Major Flooding, Weaknesses Revealed
- 2004 – New Hydrology for Upper Mississippi Basin
- 2011 – Separate Levee Raise, Select Reach, for FEMA Levee Certification
- 2014 – Final Feasibility Report for Proposed Modifications
- 2015 – Approval by Chief of Engineers (Washington DC)
- 2019 – City and Corps Sign Project Partnership Agreement
- 2021 - Ready to Bid
CITY’S ROLE DURING DESIGN

- Design Input and Liaison
- Acquire Lands and Easements
- Acquire Borrow Site
- Relocate Utilities (Ours and Others)
- Railroad Coordination
- Permitting Support – KDOT and Counties
- Betterments – Requests and Planning
LANDS AND EASEMENTS

- City acquired.
- Standardized types
- Portion of Costs Creditable.
- SMH Consultants (Manhattan) provided integrated services
- Included a 20 acre Borrow Site for 260,000 cubic yards
MANY STEPS & MANY PARTNERS SEAL THE DEAL

- Ownership and Title Research – Charlson & Wilson
- Field Surveys and Property Corners – SMH Consultants
- Public & Land Owner Engagement – City, SMH
- Design Coordination and Construction Limits – Corps, City, SMH
- Draw Easements and Write Legals – SMH
- Appraisals & Review – Simmons Co & Valbridge Property Advisors
- Make Offers and Negotiate – SMH
- Contracts and Settlements – SMH, Legal, Title Co
- Condemnation – in 2 Counties
UTILITY RELOCATIONS

- City Relocations: Sewer, Water, Water Supply, Well Field, Communications
- Going “Up and Over”
- Olsson provided Design, being Bid with Corps’ Project

- Other Coordination: High Pressure Gas Line, High Voltage Electrical, Regional Fiber Optic Communications Linkages, Power Poles, etc.
LESSONS LEARNED

- Question Assumptions
  - Updated H&H modeling increased resilience of the system
  - Relief Wells reduced by 40% ~$2M in savings
  - Gatewells Modifications versus Replacements ~$2-5M in savings

- Models are only tools
  - Complex system: Coincident flooding, Independent sources, Several constrictions
  - Underseepage at the confluence: 3D Effects not modeled well by any one tool

- Involve Stakeholders
  - City and Construction Personnel involved early in the process
QUESTIONS, COMMENTS, OR DISCUSSION

Thank you for your attention.