Quantifying the Benefits of Micro Detention in Lenexa, Kansas

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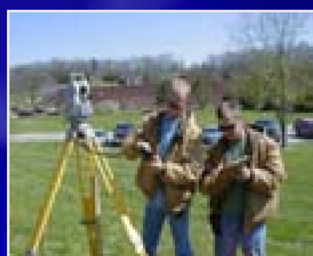


September 02, 2009

Project Team

Lenexa KANSAS

CDM

THE UNIVERSITY OF UTAH

INTUITION LOGIC

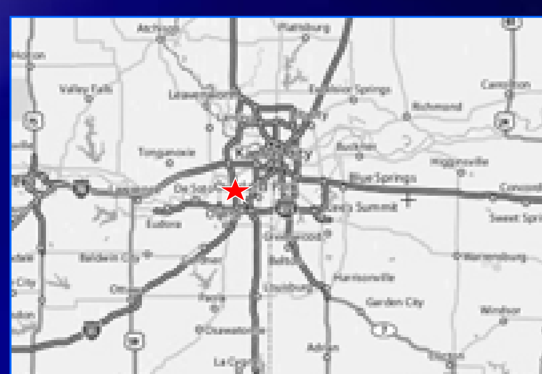
PBA

Today's Presentation

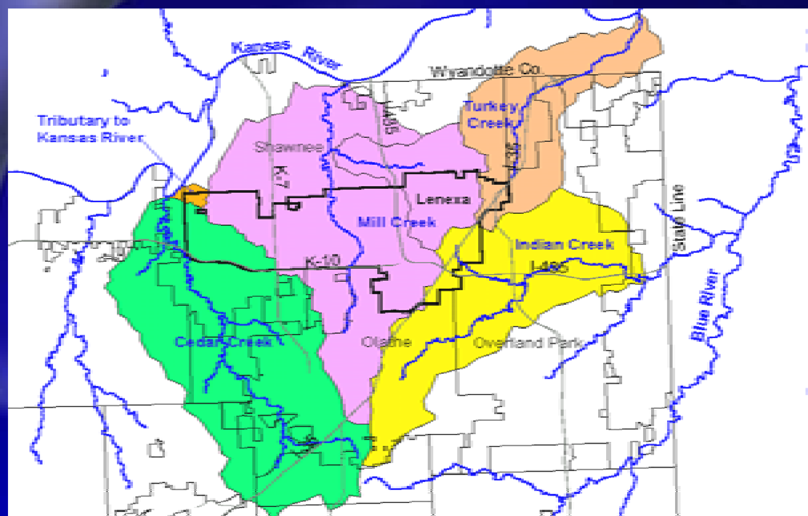
- Background Information
- Goals and Objectives
- Data Collection
- Methodology
- Results and Discussion
- Conclusion

Lenexa, Kansas

- Kansas City Metro Area – Population 1.8 million
- 45,000 residents
- 34 square miles
  - Two-thirds experiencing development pressure

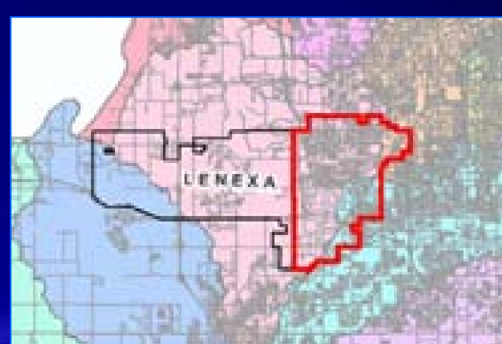


Lenexa's Watersheds



Project Study Area

- 15 square miles
- Spans three watersheds: Mill Creek, Indian Creek and Turkey Creek



Background

- The City of Lenexa, Kansas (City) has experienced steady growth over the last several years, with the majority of recent development occurring west of Interstate 435.
- The portion of the City east of Interstate 435 contains the majority of the original development.

Background

Background

- As a result, the detention basins located in eastern Lenexa have been designed using varying design requirements.
- In the early 1990s, the City of Lenexa, Kansas adopted the flood control standard which required developments to limit post-construction 1-percent-annual-chance flow rates to 2.79 cubic feet per second (cfs) per acre.

Background

- In addition, the majority of the basins are privately owned and operated, and until just recently, no regulatory mechanism was in place to inspect the detention basins or require regular maintenance.
- In 2003, the City adopted new requirements that were more specific to the region (APWA 5600).

Background

- The new standards removed the 1-percent-annual-chance requirement but included matching the 100-percent-annual-chance and 10-percent-annual-chance post-development flow rates to pre-development flow rates, as well as implementing best management practices (BMPs) to control the smaller rainfall events.
- In addition, the City passed an ordinance in 2007 that provided the authority to inspect privately owned detention basins and to require regular maintenance activities, with the goal of preserving the flood control benefits these basins provide to the citizens of Lenexa.

Background

- Many detention basins that have been specifically constructed to detain flood flows from local drainage in the past two decades have not been included as part of a city-wide flood hazard analysis. (Most recent Floodplain study was completed in 2000 by the city and Johnson County)

Background

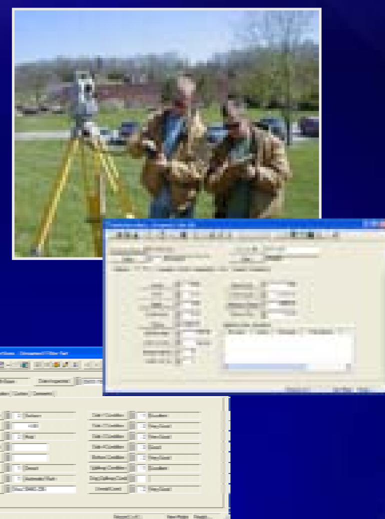
- Kansas Department of Health and Environment (KDHE) water quality status
  - Mill Creek Water Quality Status
    - Chloride, Fecal Coliform Bacteria (FCB) and Biology
  - Indian Creek Water Quality Status
    - Nitrate, Fecal Coliform Bacteria (FCB)
  - Turkey Creek Water Quality Status
    - Ammonia

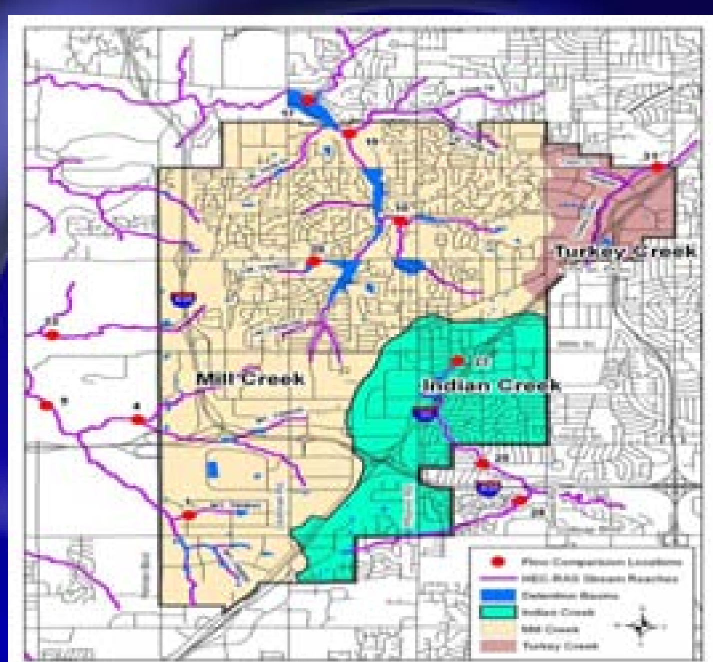
Project Goals and Objective

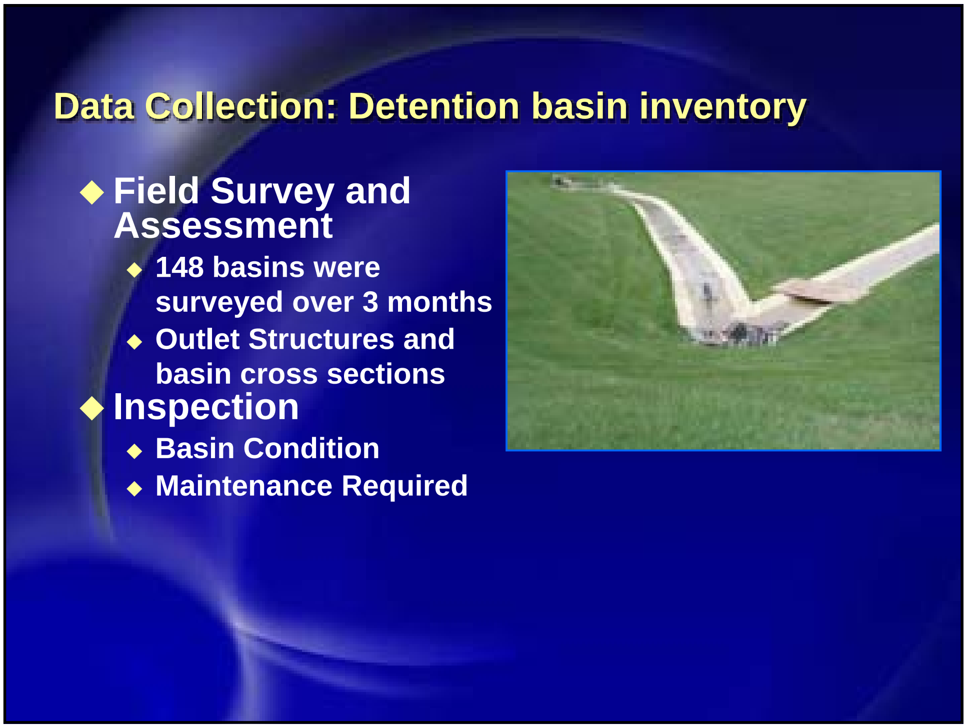
- Project key goals were to refine the floodplain boundaries and improve water quality, by considering new detention basins and/or retrofitting existing detention basins

Data Collection: Detention basin inventory

- GIS – identified 108 basins
- Field Reconnaissance – 18 additional basins
- Development Plan Review – 24 additional basins
- 2 basins are not in operation – identified by the city
- 148 Total Basins






Data Collection: Detention basin inventory
Field Survey and Assessment
148 basins were surveyed over 3 months
Outlet Structures and basin cross sections
Inspection
Basin Condition
Maintenance Required


Data Collection: Outlet Structures

Methodology: Hydrology

- Evaluate flow reduction obtained by basins using USACE HEC-HMS model.
  - Step 1 - Convert existing FEMA regulatory HEC-1 model to HMS
  - Step 2 - Refine converted HEC-HMS model to include additional subareas draining to 148 basins
  - Step 3 - Create updated existing HEC-HMS model to incorporate the 148 detention basins
  - Step 4 – Update HEC-RAS model
  - Step 5 – Evaluating water quality benefits

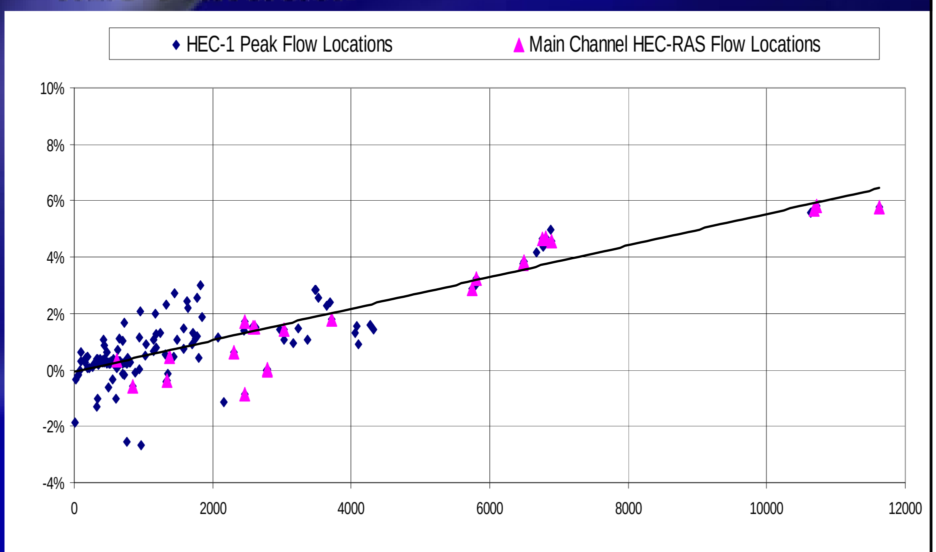
Methodology: Hydrology – Step 1

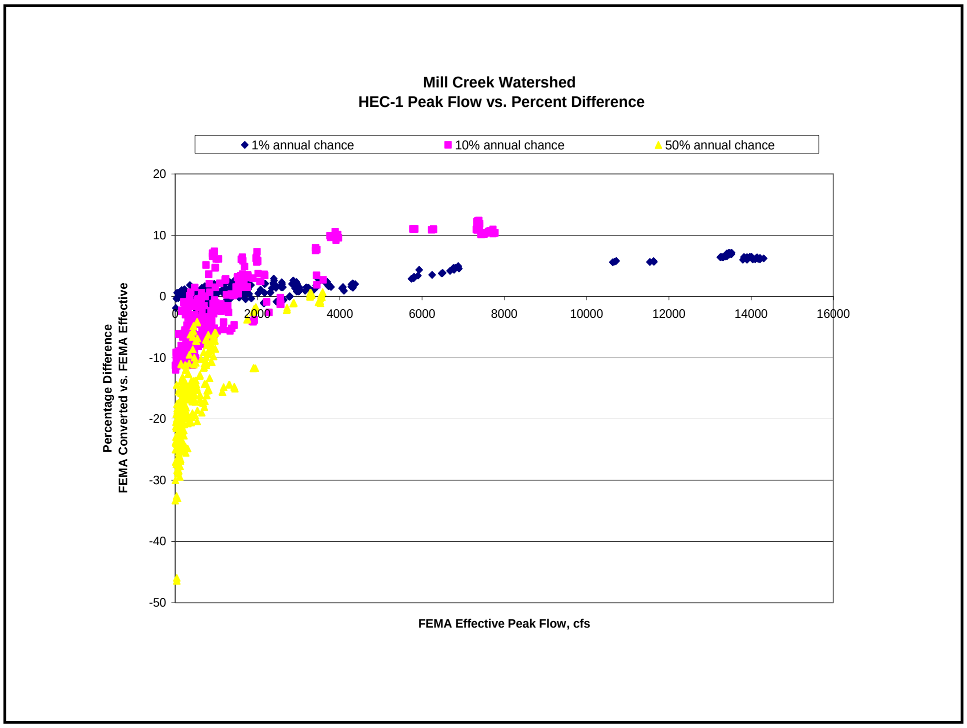
- Challenges Converting HEC-1 to HEC-HMS
  - Difference computation routines for routing methods
  - HEC-1 information imported into HEC-HMS was not geo-referenced.
  - 7% increase in peak flow at downstream point (approx. 0.25 feet increase in elevation)
- HEC-HMS more accurately calculates routed flow compared to HEC-1 routing methods.

Methodology: Hydrology Step 1: Difference between HEC-1 and HEC-HMS

- In HEC-HMS the flow depth for a given discharge is determined from the cross-sectional characteristics and then area, top width, and wave speed are computed for that depth using the cross-sectional data.
- In HEC-1 the discharge, area, top width, and wave speed are computed for 20 depths and stored in a table. During the routing process, area, top width, and wave speed are interpolated from the table for each discharge value.

Methodology: Hydrology: HEC-1 to HEC-HMS Conversion





Methodology: Hydrology – Step 2

- GIS data and development plans used to determine contributing areas to detention basins.
  - Percent Impervious and CN updated
  - Time of concentration recomputed
  - Additional Routing added
- Converted Refined HEC-HMS model was created

Methodology: Hydrology – Step 3

- Added storage nodes into HEC-HMS model for each of the 148 detention basins
  - Use elevation-area information from GIS
  - Use elevation-discharge information from HEC-RAS and hydraulic calculations
- Existing with detention model was created
- The Peak flows computed from the Exiting with detention model was compared with the HEC-1 model
- Peak Flows are reduced at most of the locations and increased at some of the locations

Hydrology: Step 3

- Peak flow Increase
  - 5 minute computation time in HEC-1 and 1 minute computation time in HEC-HMS
  - Update in Percent Imperviousness
  - Drainage area difference between the models
- Peak flow decrease
  - Mill Creek and Indian Creek detention basin performance averaged 24 and 23 percent for the 1% annual chance
  - Turkey Creek detention basin performance averaged 34 percent reduction for 1% annual chance

Methodology: Step 4:Hydraulics – Floodplain Refinement

- Reduced flows were input into HEC-RAS model to estimate floodplain elevations.
- Compared resulting floodplain elevations with FEMA model
  - Mill Creek:
    - WSE Increase – 286 of 489
    - WSE Decrease – 193 of 489
  - Indian Creek:
    - WSE Increase – 28 of 100
    - WSE Decrease – 70 of 100
  - Turkey Creek:
    - WSE Increase – 36 of 62
    - WSE Decrease – 25 of 62

Results And Discussion: Hydrology and Hydraulics

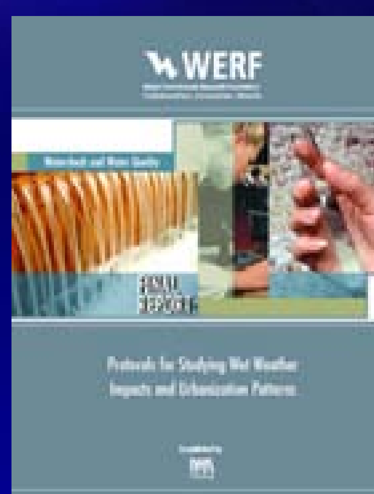
- Compared newly computed Water Surface Elevation (WSE) with the Lowest Adjacent Grade (LAG) surveyed.
  - Mill Creek :The LAG for the existing 31 buildings was compared to the Existing with Detention 1-percent-annual-chance water surface elevation. Comparing the LAG with Existing with Detention water surface elevations resulted in an additional nine buildings found to be outside the floodplain.
  - Indian Creek : one additional building found to be outside the floodplain.
  - No building found to be outside the floodplain.

Step 5: Water Quality

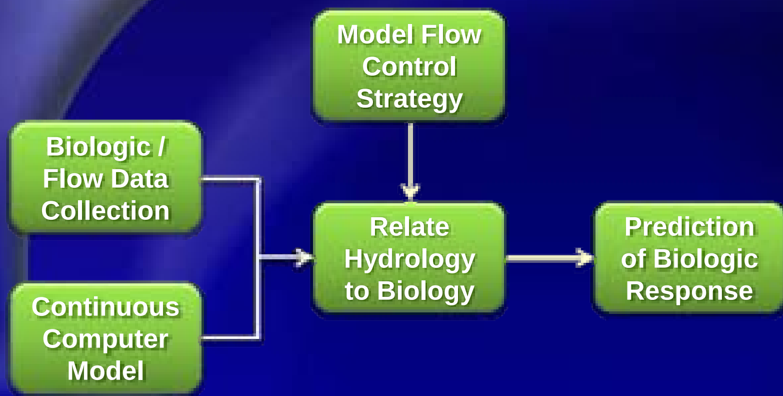
- Estimate instream response to biological diversity after modifying existing detention basins to capture and detain smaller storm events

Step 5: Water Quality

- Water Environment Research Foundation (WERF) Protocols for Studying Wet Weather Impacts and Urbanization Patterns (Pomeroy *et al., 2008)*

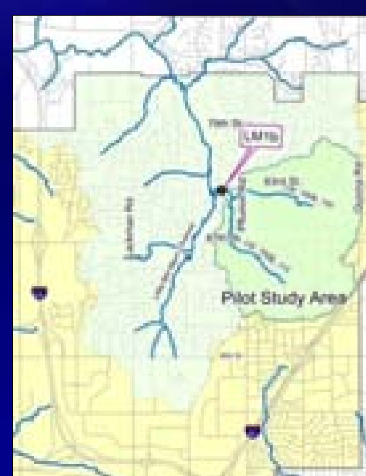


Step 5: Water Quality



Step 5: Water Quality : Pilot Study Area

- 1,017 acres (1.6 sq. mi.)
- Mill Creek Watershed: chloride, fecal coliform bacteria, and biology have been identified as water quality impairment
- ~ 90 percent developed
- 11% commercial/ institutional, 56% residential, rest is mixed land use

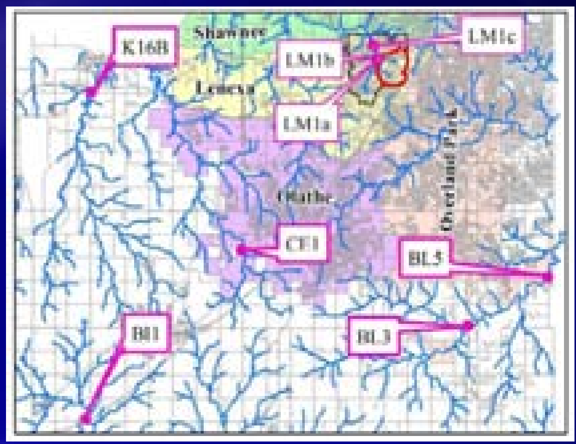


Step 5: Water Quality: Pilot Study Area

- Total of 20 detention basins
- 30% of study area drains to detention basin

Step 5: Water Quality: Biology and Flow Data Collection

- Biology samples collected at eight sites
- Discharge measured at five sites
- Calibrated model results used at three sites



Step 5: Water Quality: Calculation of Biologic Metrics

- Macro-invertebrate samples were collected during spring and summer 2007 by USGS at eight locations
- Samples used to calculate the Kansas Biotic Index
  - Pollution tolerance index
  - A higher index indicates a community more tolerant of organic pollution exerting oxygen demands in the stream setting

Step 5: Water Quality: KBI Values for Sampling Locations

Site	KBI	Rating
LM1a	3.0	Moderate Impact
LM1b	2.9	Moderate Impact
LM1c	3.0	Moderate Impact
KI6b	2.4	Slight Impact
CE1	2.3	Slight Impact
BL3	2.1	Slight Impact
BL5	2.0	Slight Impact
BI1	2.2	Slight Impact

***KBI RATING SCALE*[1]**	
KBI Score	***Rating*[2]**
$\leq$ 1.50	No Impact
1.51 – 2.50	Slight Impact
2.51 – 3.50	Moderate Impact
$\geq$ 3.51	High Impact

[1] Adapted from Table 10 in Huggins and Moffett 1988
[2] Impact from nutrient and oxygen demanding pollutants

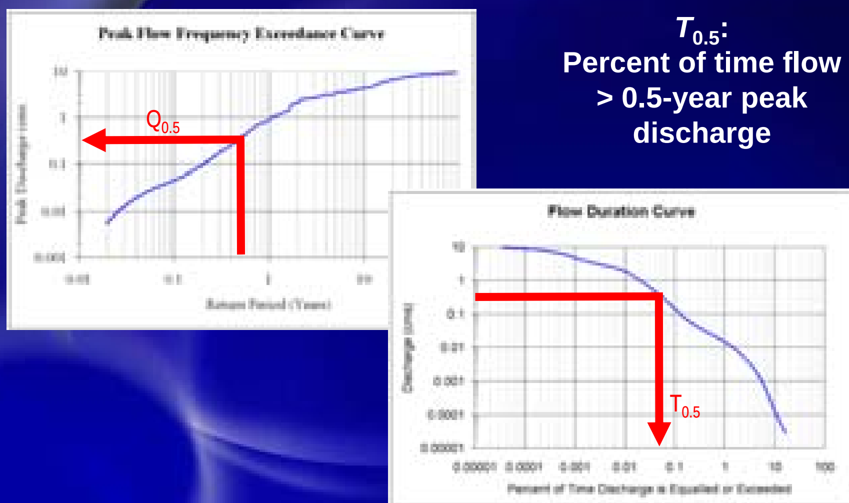
Step 5: Water Quality: Calculation of Hydrologic Metrics

- $T_{0.5}$ hydrologic metric is a strong predictor of biotic richness (Booth et al., 2004; Pomeroy et al., 2008).
- The $T_{0.5}$ metric is the percent of time that the flow is greater than the peak flow of the 0.5-year storm for the simulation period
- Indicator of stream flashiness

Step 5: Water Quality: Calculation of Hydrologic Metrics

- The period of flow record from October 2003 to September 2005
- Discharge measured at five sites
- Calibrated model results used at three sites

Step 5: Water Quality: **Calculation the $T_{0.5}$**



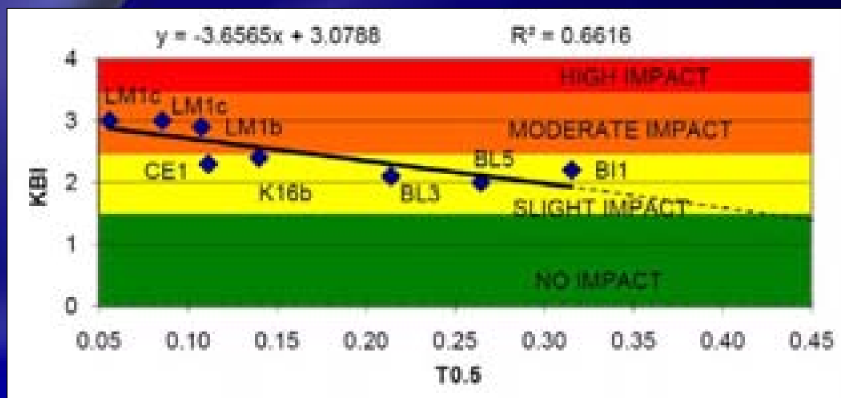
$T_{0.5}$:
Percent of time flow > 0.5-year peak discharge

Step 5: Water Quality: Calculation of Hydrologic Metrics

$T_{0.5}$ for Sampling Locations

Site	***$T_{0.5}$, Existing With Detention***
LM1a	0.056
LM1b	0.108
LM1c	0.085
K16b	0.140
CE1	0.111
BL3	0.214
BL5	0.264
Bl1	0.315

Step 5: Water Quality: Relate Hydrology to Biology



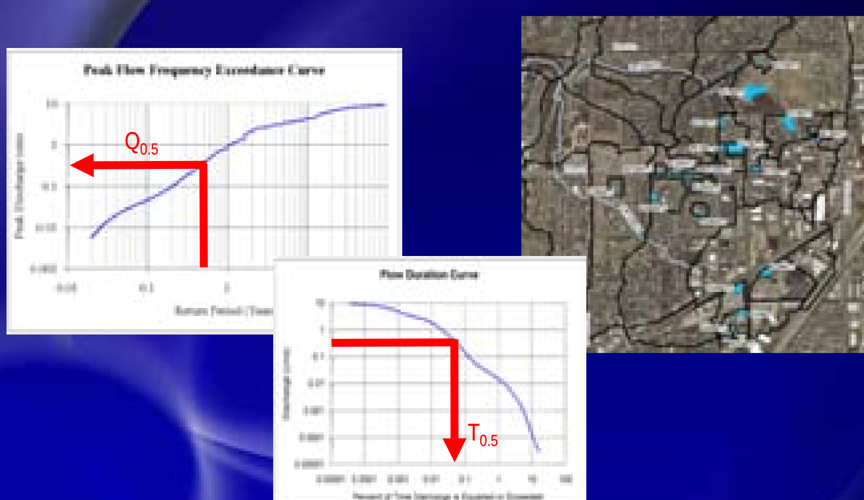
Step 5: Water Quality: Proposed Flow Control Strategy

- Retrofit situation ~ primarily built out
- Detention basins retrofit to detain WQv and release it over 40 hours
  - Maximize water quality benefits to address TMDLs
  - Provide flow control to reduce erosion potential
- Preserve existing 1 percent-chance-annual peak release rate

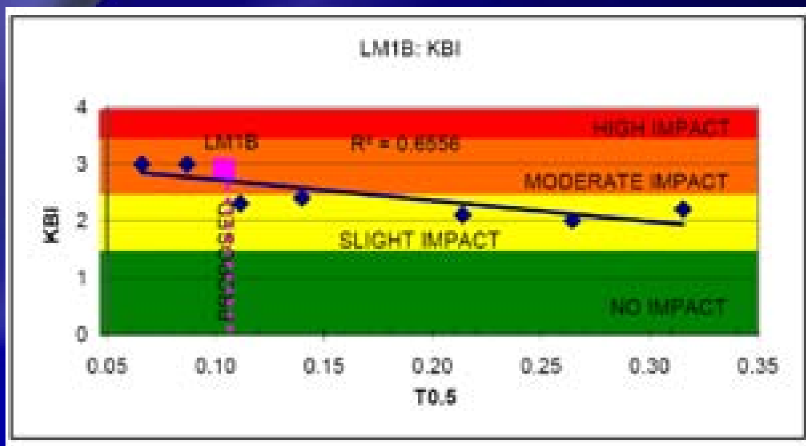
Step 5: Water Quality: Proposed Flow Control Strategy

Detention Basin ID	Modified Outlet Structure (Y/N)	New Storage Volume Added (Y/N)	Additional Comment
E27SEb_1	Yes	Yes	100% WQv is captured
E27SEb_2	No	No	100% WQv is captured in E27SEb_1
E34NEc_1	Yes	Yes	100% WQv is captured
E34NEc_2	Yes	No	100% WQv is captured
E34NWa_1	Yes	Yes	100% WQv is captured
E34NWa_2	Yes	Yes	100% WQv is captured
E34NWb_1	Yes	Yes	100% WQv is captured
E34NWb_2	Yes	No	100% WQv is captured
E34SEb_1	Yes	No	100% WQv is captured
E34SEb_2	Yes	No	100% WQv is captured
E34SEb_3	No	No	100% WQv is captured in E34SEb_1
E27SEd_1	No	No	Retrofit not feasible
E27SEd_2	Yes	No	100% WQv is captured
E27SEc_1	Yes	Yes	100% WQv is captured
E27SEc_2	No	No	Basin is recommended for closure
E27SEc_3	No	No	100% WQv is captured in E27SEc_4
E27SEc_4	Yes	Yes	100% WQv is captured
E27SWd_1	Yes	Yes	100% WQv is captured
E27SWd_2	Yes	Yes	80% WQv is captured
E27SWd_3	Yes	Yes	100% WQv is captured

Step 5: Water Quality: Calculate Hydrologic Metrics: Proposed Control Strategy



Step 5: Water Quality: Relate Hydrology to Biology



Conclusions

- The model refinements that were made to account for existing detention facilities in the study area reduced the estimated 1-percent-annual-chance floodplain elevations in some locations.
- As a result, 10 buildings within the East Lenexa Detention Study Area were removed from the 1-percent-annual-chance floodplain limits.

Conclusions

- Proposed flow control strategy did not show significant benefit to biology from a hydrologic perspective
- Retrofitting basins that capture 30 percent of tributary area did not provide significant benefit to biology from a hydrologic perspective
- Other practices including LID techniques may also be needed to show greater improvement

Thank you

Questions?