Frazier Avenue Detention Basin Rehabilitation

City of Des Moines

Loulou Dickey, Andrea McEachran, Sam Phillips

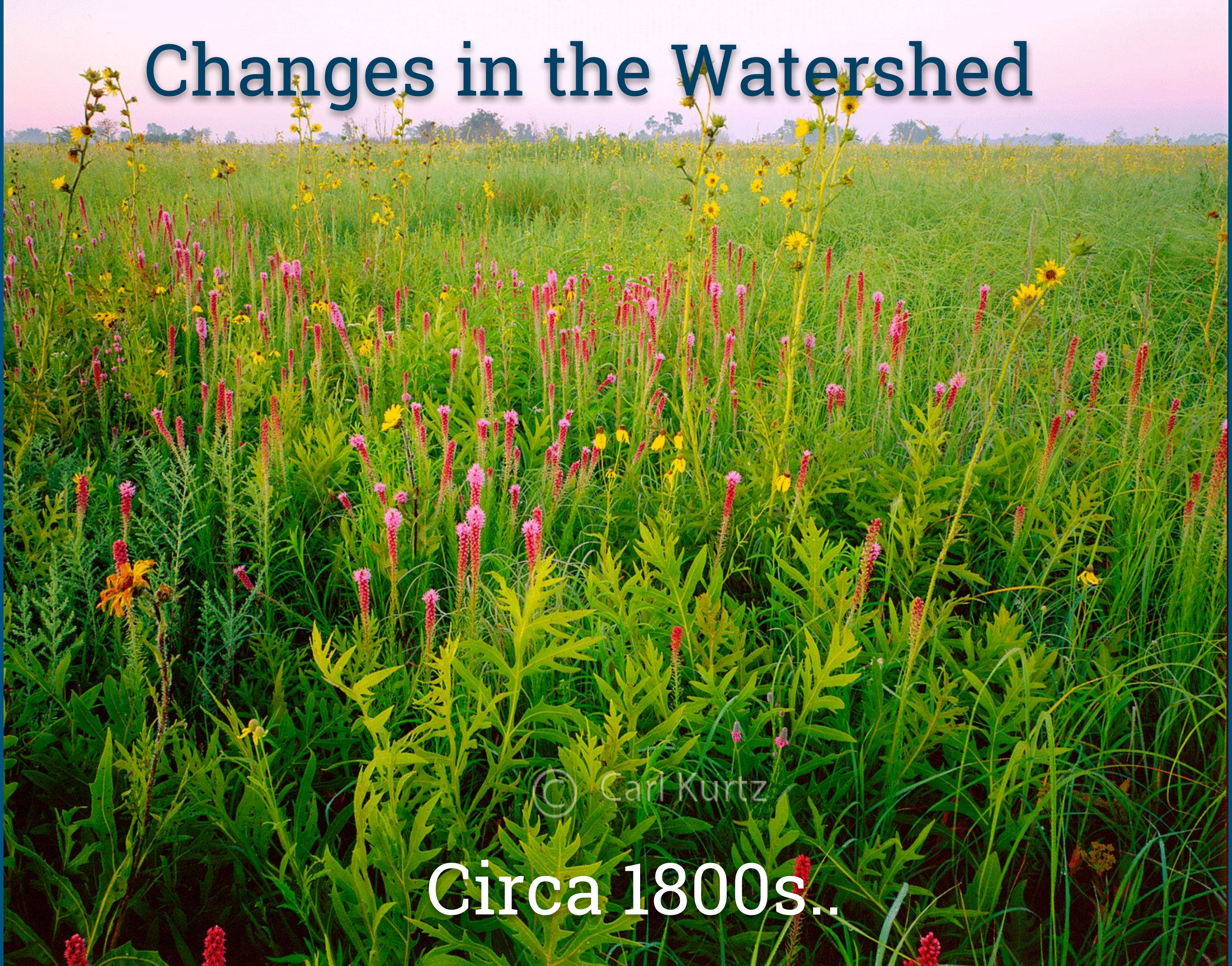
ABE 415

Spring 2018

Advisors and Collaborators

- ★ Jonathan Gano
  City of Des Moines Public Works Director
- ★ Dan Pritchard
  City of Des Moines Stormwater Group Leader
- ★ Keith Hubbard
  City of Des Moines Civil Engineer
- ★ Dr. Michael Perez
  Assistant Professor in Civil, Construction, and Environmental Engineering Department at Iowa State
- ★ Julie Perreault
  Easter Lake Watershed Coordinator

Changes in the Watershed

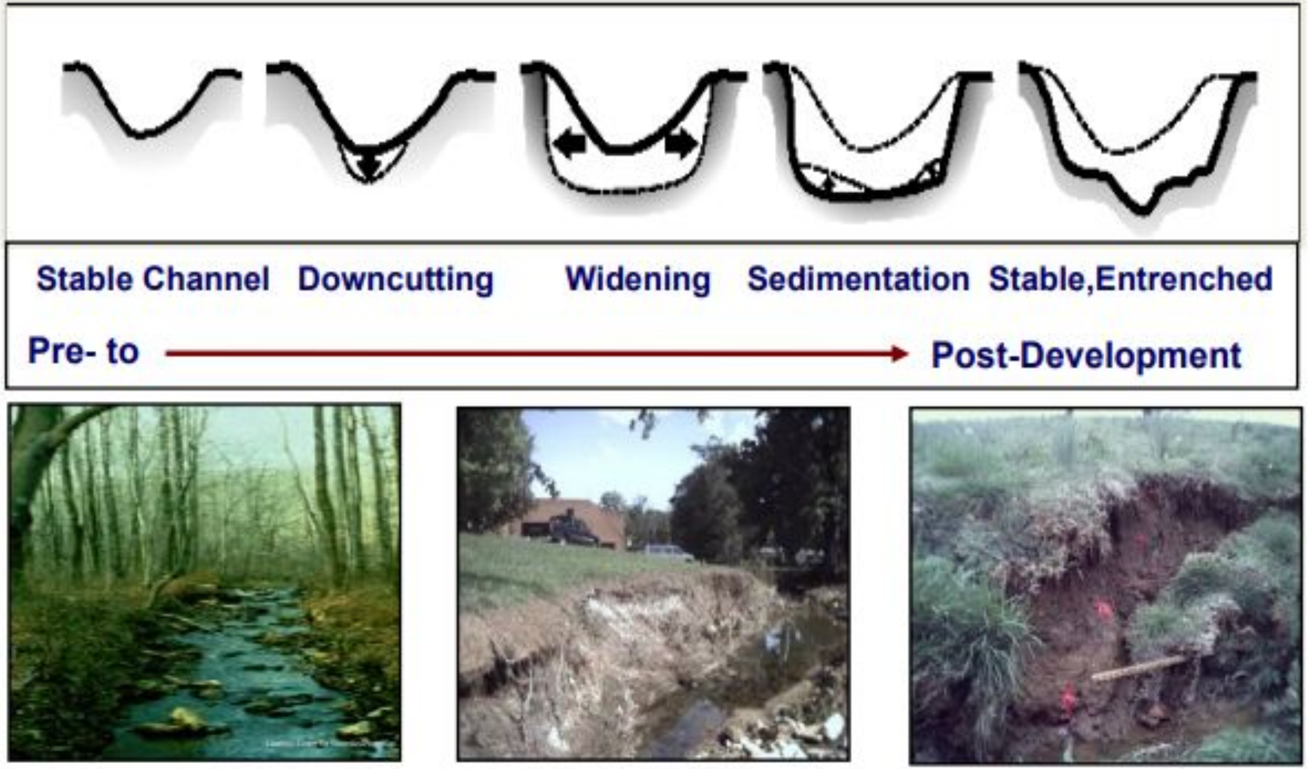


Circa 1800s..


.. 2018


©1993 7-12
S. ALEXANDER #0.SU

Impacts of Urbanization



Source: All Images from GSWCC

Project Location: Easter Lake Watershed

EASTER|LAKE WATERSHED

Challenges

- High velocity flow degrades channel
- Lake depth decreased due to sediment deposition
- Residential flooding

Frazier Avenue Detention Basin

- Located in “headwaters” of the Easter Lake watershed
- Potential to reduce peak flow and velocity
- Potential to reduce sediment transport
- Currently outdated and degraded

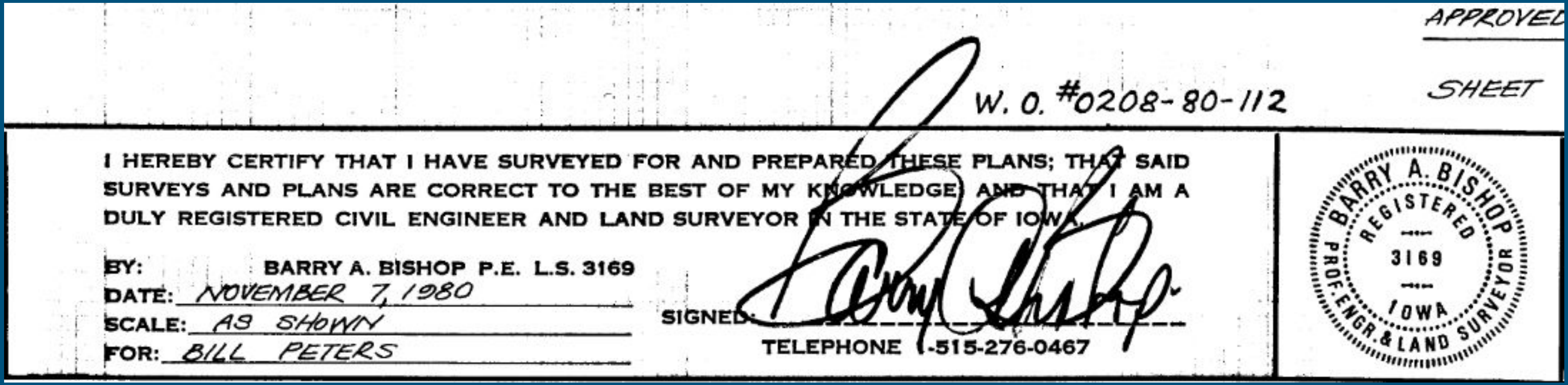
Table 1-1: Easter Lake Characteristics

IDNR Waterbody ID	IA 04-LDM-00490-L
8 Digit Hydrologic Unit Code (HUC)	07100008 (Basin=Des Moines, Subbasin=Lake Red Rock)
12 Digit HUC	071000081507 (Yeader Creek-Des Moines)
Location	Des Moines, Polk County, Iowa
Latitude/Longitude	41-54534 / -93.55538
Designated Uses	Primary Contact Recreation (Class AS)
	Aquatic Life Support (Class B(LW))
Receiving Waterbody	Yeader Creek and unnamed tributary
Maximum Depth* / Mean Depth*	21.2 feet / 8.1 feet
Lake Volume*	1,511 acre-feet
Length of Shoreline	35,300 ft (TMDL)
Watershed Area / Lake Surface Area	6,380 / 178* acres
Watershed / Lake Ratio	37:1
Lake Residence Time	0.28 years (TMDL)
TMDL Pollutants	Phosphorus, Sediment
Impaired Uses	A1 – primary contact recreation & B (LW) – aquatic life

ISU DF Study 2011

Project Background

- Assess and rehabilitate a stormwater detention basin within the Easter Lake Watershed
- Originally designed in 1980 by Bishop Engineering
- Privately owned - City of Des Moines gained possession in 2017



APPROVED

W. O. #0208-80-112

SHEET

I HEREBY CERTIFY THAT I HAVE SURVEYED FOR AND PREPARED THESE PLANS; THAT SAID SURVEYS AND PLANS ARE CORRECT TO THE BEST OF MY KNOWLEDGE; AND THAT I AM A DULY REGISTERED CIVIL ENGINEER AND LAND SURVEYOR IN THE STATE OF IOWA.

BY: BARRY A. BISHOP P.E. L.S. 3169
DATE: NOVEMBER 7, 1980
SCALE: AS SHOWN
FOR: BILL PETERS

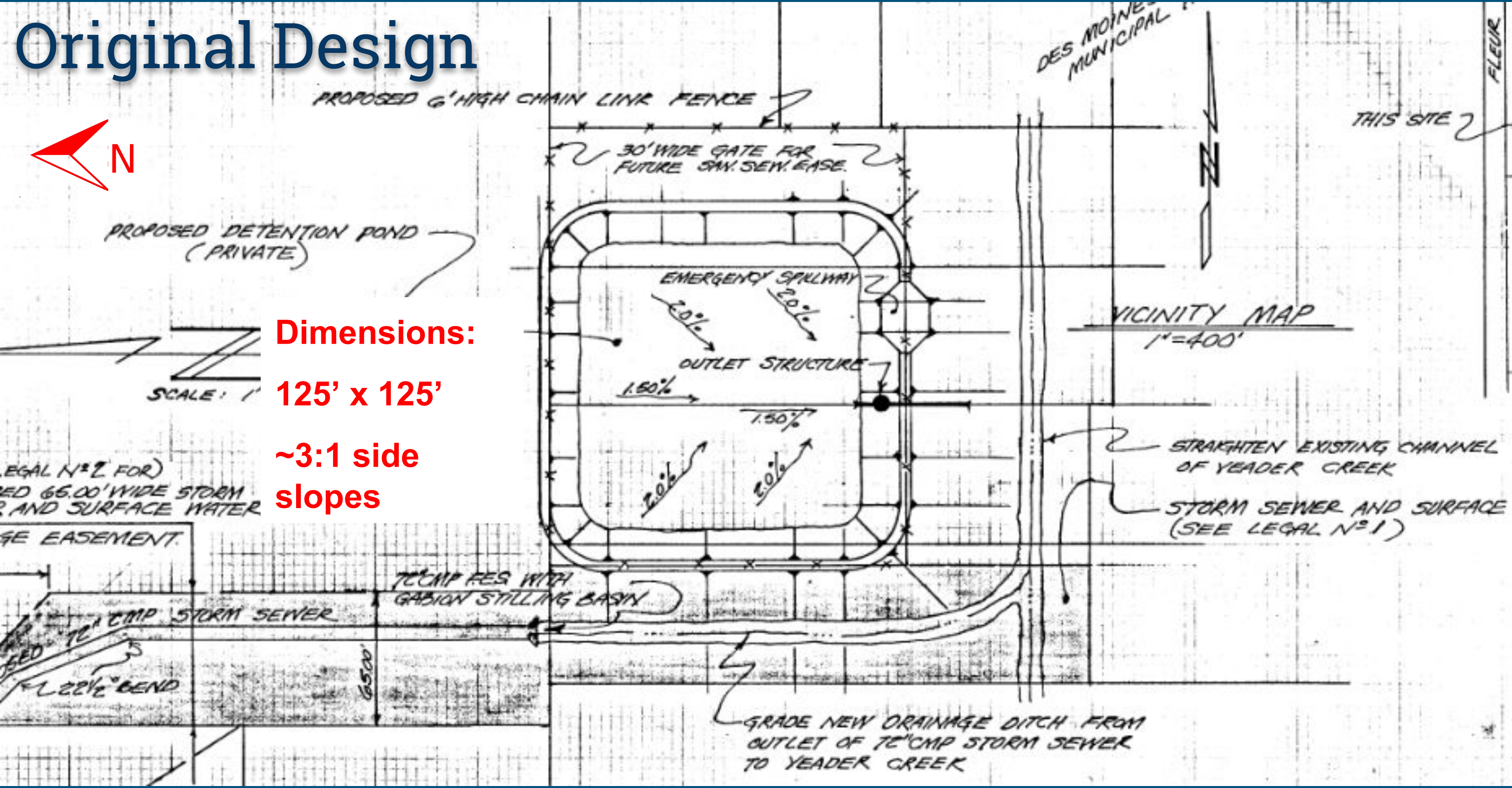
SIGNED: Barry A. Bishop

TELEPHONE 1-515-276-0467

BARRY A. BISHOP
REGISTERED
3169
IOWA
PROF. ENGR. & LAND SURVEYOR


Google Earth

Original Design

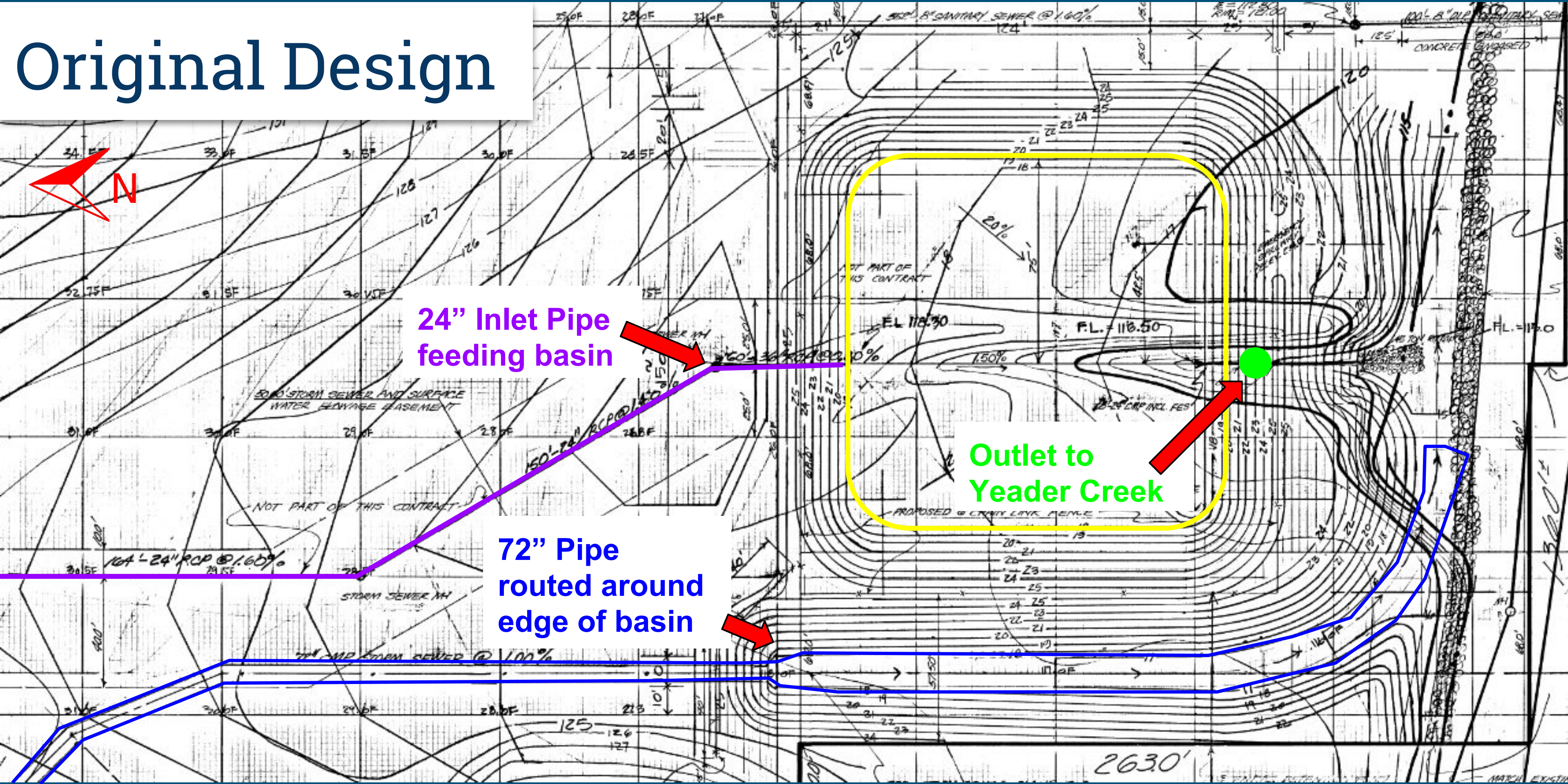


Dimensions:

125' x 125'

~3:1 side slopes

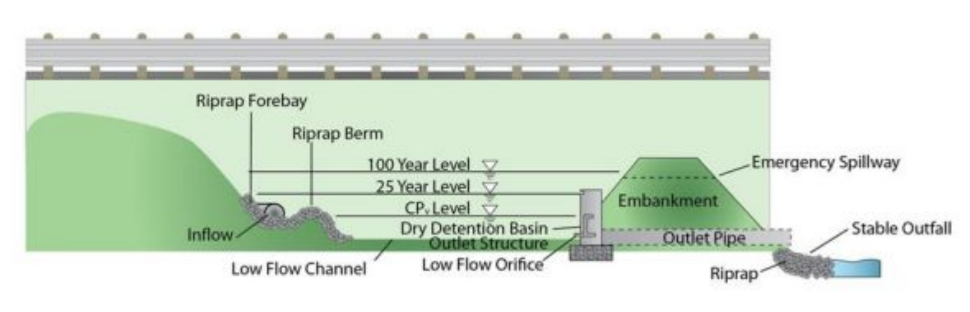
Original Design



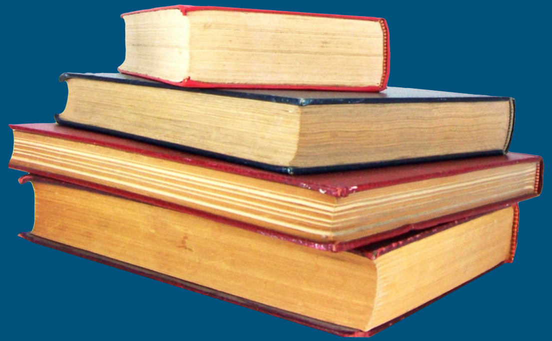
Current State of the Basin

What is a Detention Basin?

- ➢ Wet vs. Dry Basins
- ➢ Flood Control
  Collect water and release slowly using control structure
- ➢ Water Quality Improvements
  Remove sediment and phosphorus by impounding water
- ➢ Low Cost



Relevant Coursework



CE 372: Engineering Hydrology and Hydraulics

EM 378: Mechanics of Fluids

ABE 273: CAD for Process Facilities and Land Use Planning

ABE 431: Design and Evaluation of Soil and Water Monitoring Systems

Resources

IOWA STORM WATER EDUCATION PROGRAM

ISWEP

Iowa SUDAS

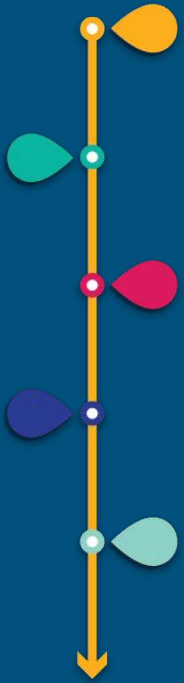
Statewide Urban Design and Specifications

I STATE

GDOT

Georgia Department of Transportation

Project Timeline



Task Name	Duration	Start	Finish	Predecessors
Determine Requirements / Establish Project	**31 days**	**Tue 2/13/18**	**Tue 3/27/18**	
Meet with the City of Des Moines	1 day	Tue 2/13/18	Tue 2/13/18	
Research	31 days	Tue 2/13/18	Tue 3/27/18	
Gather Data	**7 days**	**Wed 3/28/18**	**Thu 4/5/18**	
Area of Storm Sewersheds	7 days	Wed 3/28/18	Thu 4/5/18	1,2
Land Cover	3 days	Wed 3/28/18	Fri 3/30/18	1,2
Phosphorous and Sediment Concentrations	7 days	Wed 3/28/18	Thu 4/5/18	1
Calculations	**8 days**	**Fri 4/6/18**	**Tue 4/17/18**	
Volume and Flowrate of Stormwater Entering	4 days	Fri 4/6/18	Wed 4/11/18	5,6
Volume and Dimension of Ideal Basin	3 days	Thu 4/12/18	Mon 4/16/18	9
Outlet Orifice Sizing	4 days	Thu 4/12/18	Tue 4/17/18	9
Assessment of Current State of Basin	**3 days**	**Sun 4/15/18**	**Tue 4/17/18**	
Volume Considerations	3 days	Sun 4/15/18	Tue 4/17/18	
Outlet Considerations	3 days	Sun 4/15/18	Tue 4/17/18	
Share Current Results	**13 days**	**Wed 4/11/18**	**Fri 4/27/18**	
Write Report	10 days	Mon 4/16/18	Fri 4/27/18	
Create Presentation	6 days	Wed 4/11/18	Wed 4/18/18	
Present	1 day	Fri 4/20/18	Fri 4/20/18	17

Criteria and Constraints

Criteria:

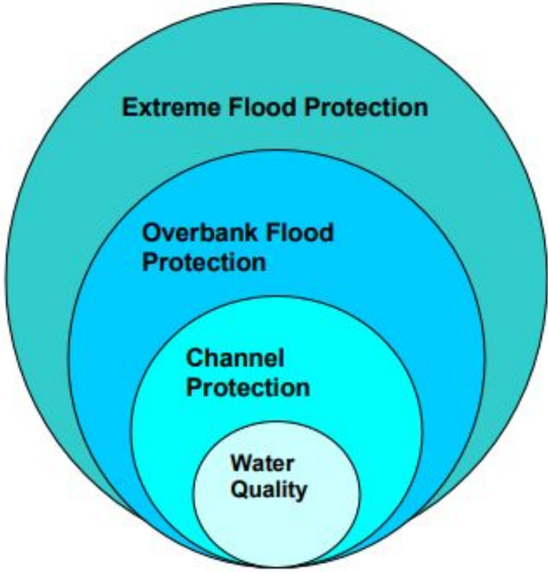
- Reduce peak discharge and velocity of flow into Yeader Creek
- Reduce sediment/phosphorus transport
- Use modern stormwater design standards
    - Unified sizing criteria
- Improve from old design
- City requested an educational and/ or recreational aspect

Constraints:

- Parcel size AKA property boundary
- Maximum allowed depth of 10 feet
- Topography of basin
- 72” pipe needs to be considered

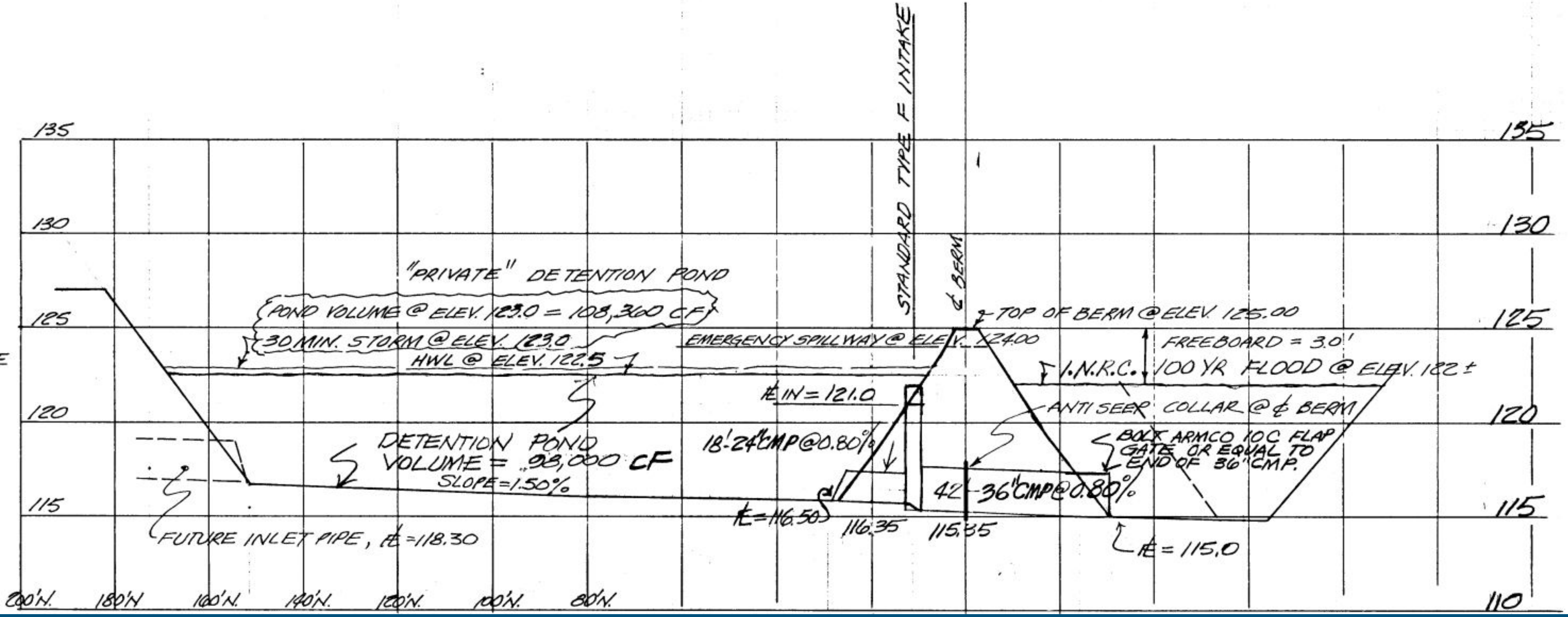
Unified Sizing Criteria

Sizing Criteria	Recommended Method
Water Quality Volume WQv (acre-feet) "first flush"	Treat the runoff from 90% of the storms that occur in an average year. For Iowa, this equates to providing water quality treatment for the runoff resulting from a rainfall depth of 1.25 inches or less. Goal is to reduce average annual post-development total suspended solids loadings by 80%. $WQv = [(Rv)(A)(P)]/12$ Rv = site runoff volume coefficient A = site drainage area (acres) P = design rainfall depth (90% cumulative frequency depth) (~ 1.25 inches)
Channel Protection Storage Volume Cpv 1-yr storm	Provide 24 hours of extended detention of the runoff from the 1-year 24-hr duration storm event to reduce bank-full flows and protect downstream channels from erosive velocities and unstable conditions.
Overbank Flood Protection Q_p	Provide peak discharge control of the 5-year storm event such that the post-development peak rate does not exceed the downstream conveyance capacity and/or cause overbank flooding in local urban watersheds. Some jurisdictions may require peak discharge control for the 2-yr storm event.
Extreme Flood Protection Q_f	Evaluate the effects of the 100-year storm on the stormwater management system, adjacent property, and downstream facilities and property. Manage the impacts of the extreme storm event through detention controls and/or floodplain management.



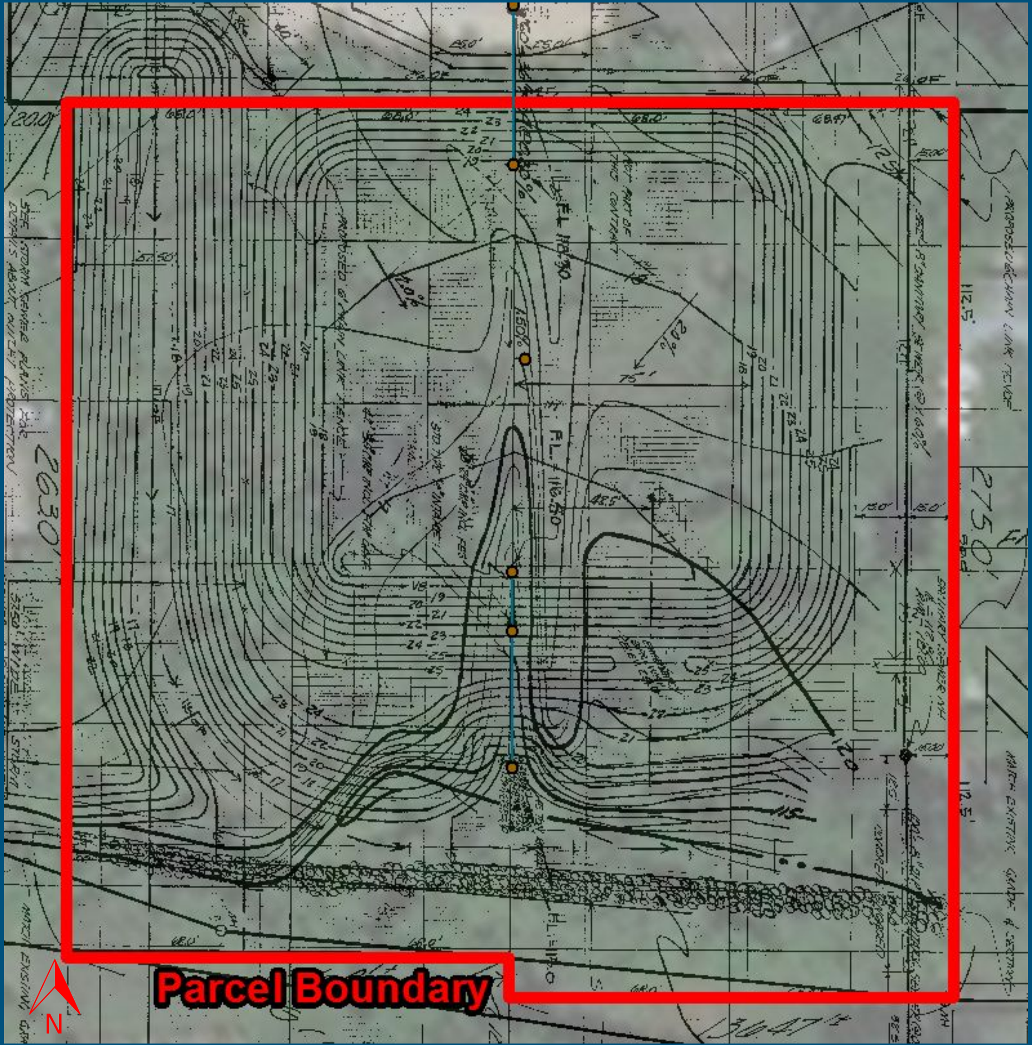
Source: Iowa Stormwater Management Manual

Achieve Better Performance



Property Boundary!

Biggest constraint



Design Process

ArcGIS

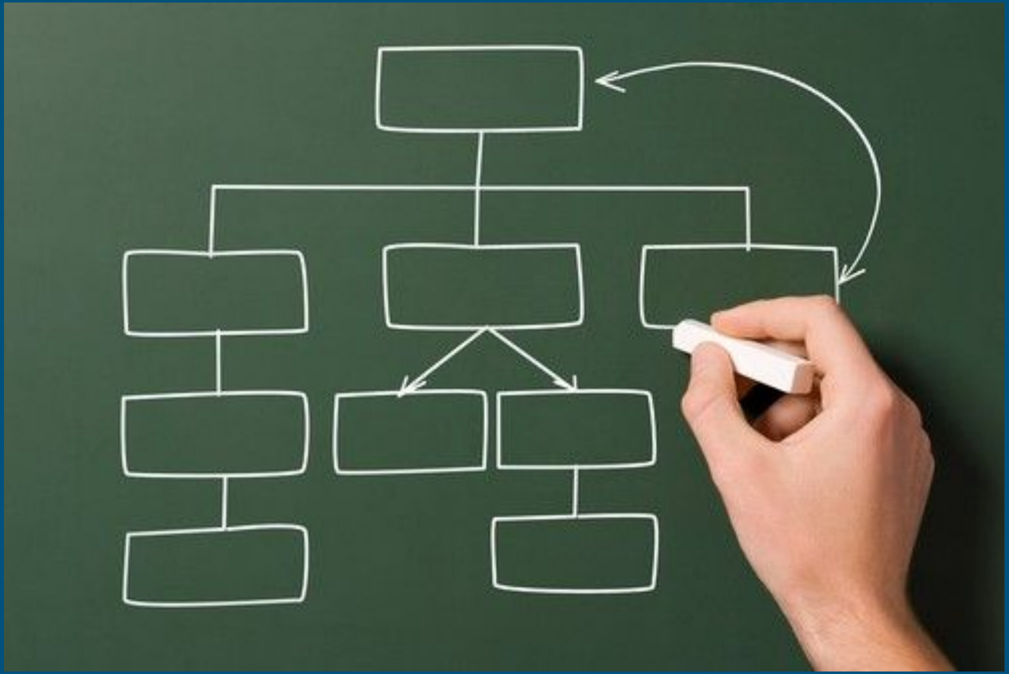
- Storm sewershed
- Land cover
- Average slope
- Flow lengths

TR-55 Method

- Curve numbers
- Runoff volume
- Time of concentration

AutoCAD Civil 3D

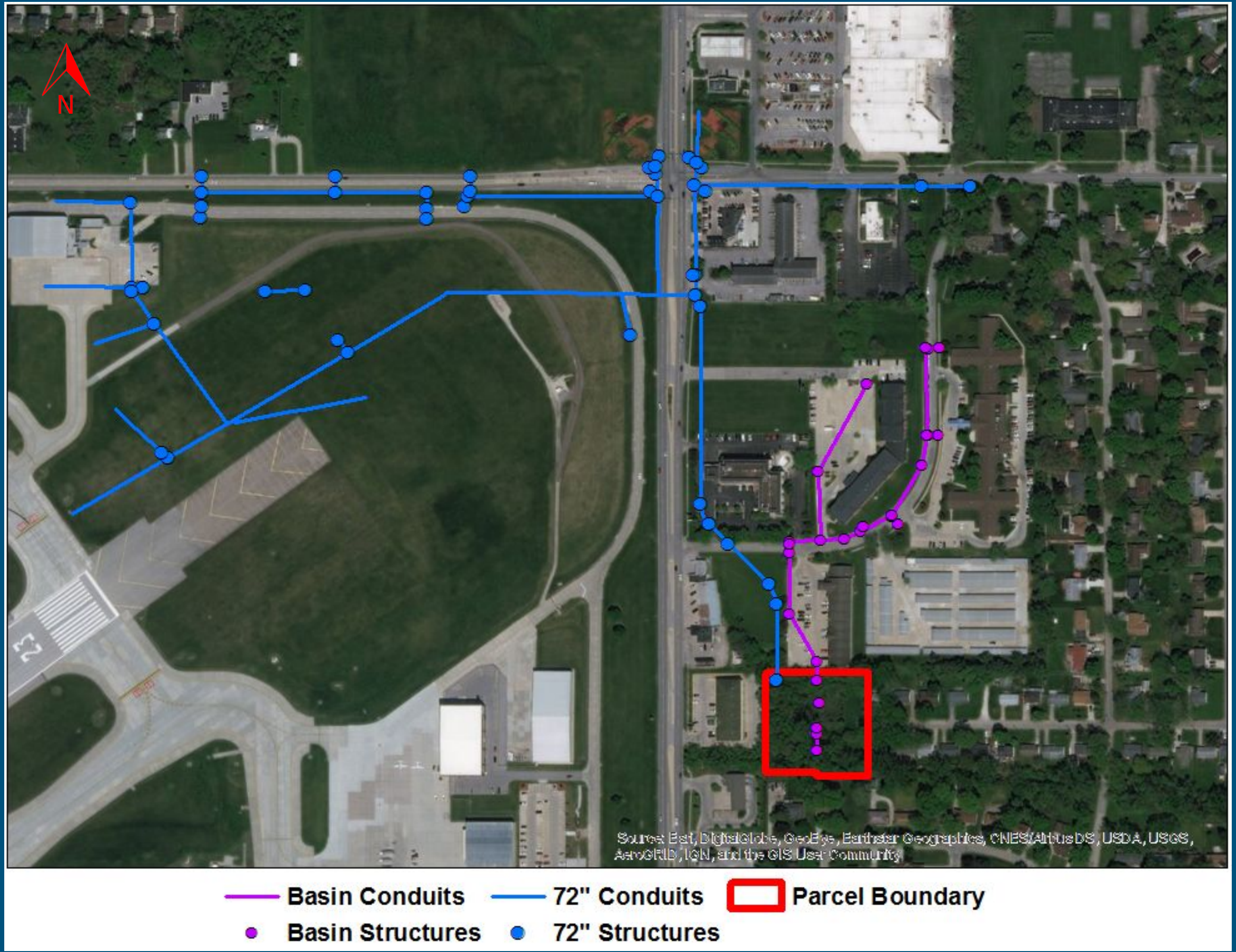
- Basin geometry
- Route storms
- Hydrographs
- Peak flows
- Outlet design



ArcGIS

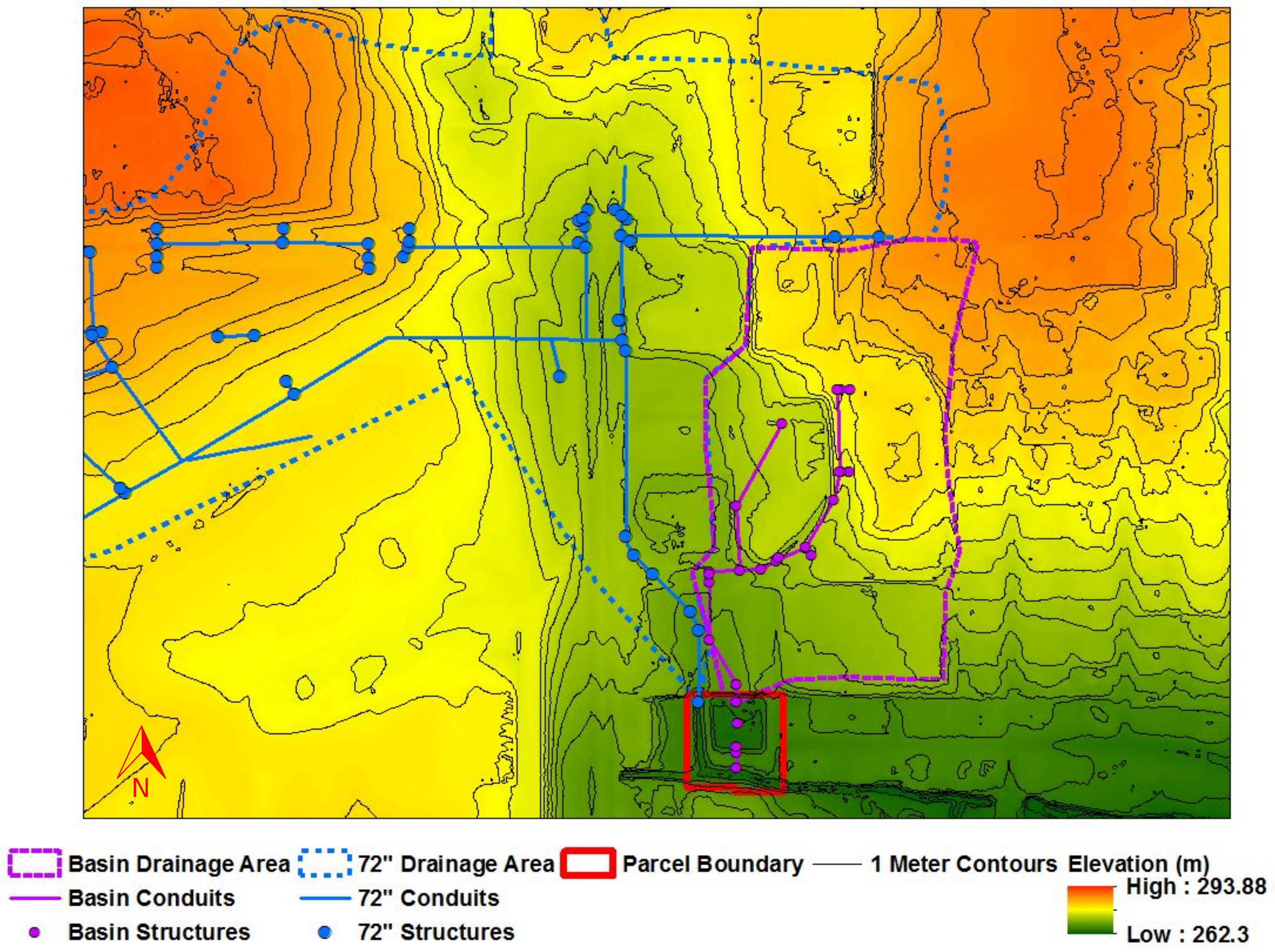
- Isolate sewer network

GIS data provided by City of Des Moines



ArcGIS

- ➢ Delineate drainage areas
- ➢ Calculate average slopes
- ➢ Measure flow length from most remote area

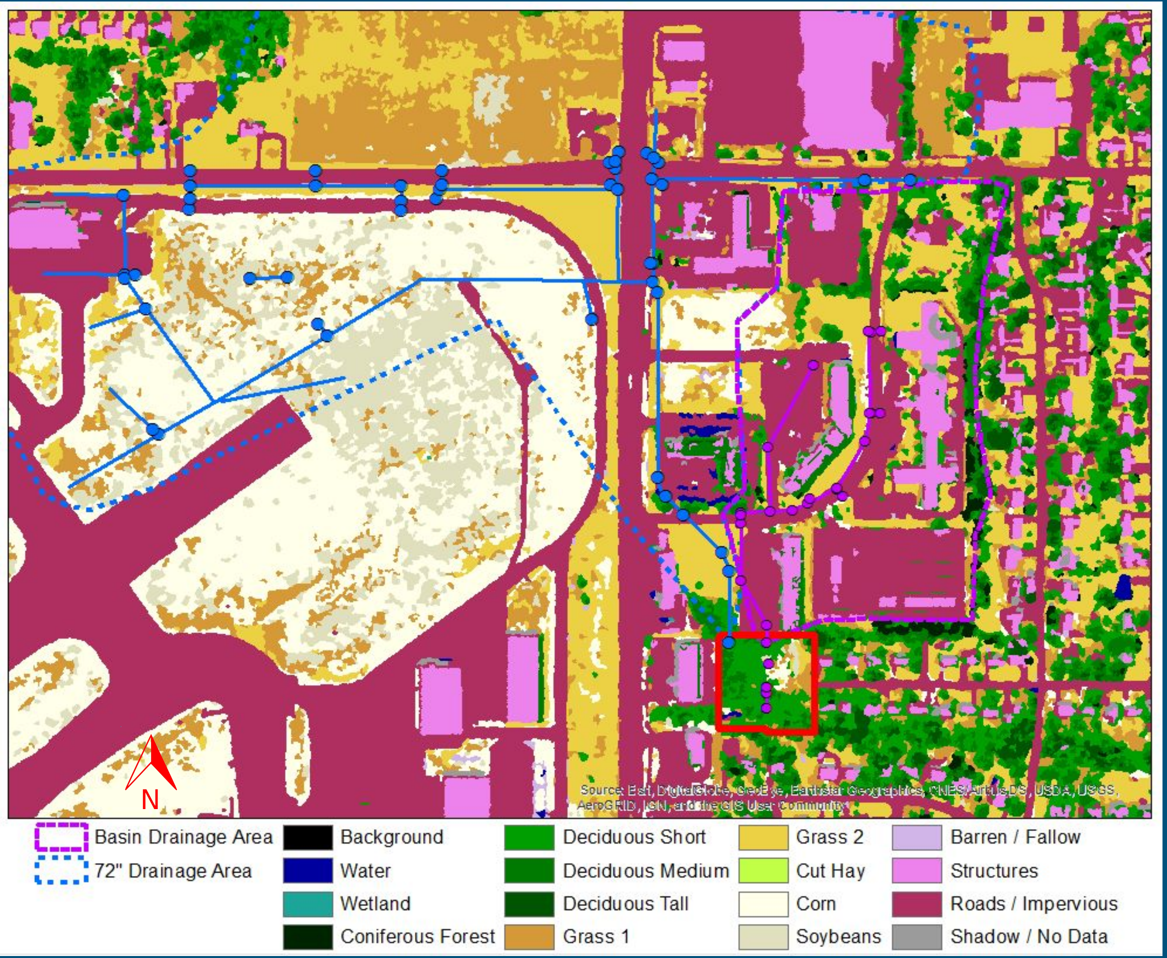


ArcGIS:

➢ Quantify land cover areas to calculate NRCS curve number

Pre-Development Land Cover			
Cover Type/Condition			**Curve Number**
Prairie			71
Total Area	18.83	acres	
Curve Number			**71**

Post-Development Land Cover			
Cover Type/ Condition			**Curve Number**
Open Space (grass, lawns, etc)			
Good	8.1	acres	74
Impervious Areas (roads, roofs, etc)	10.7	acres	98
Total Area	**18.8**	**acres**	
Composite CN			**88**



Source: TR 55 manual Table 2-2a

TR-55 Method

Calculations done in Google Sheets

$$S = \frac{1000}{CN} - 10$$

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

$$I_a = 0.2S$$

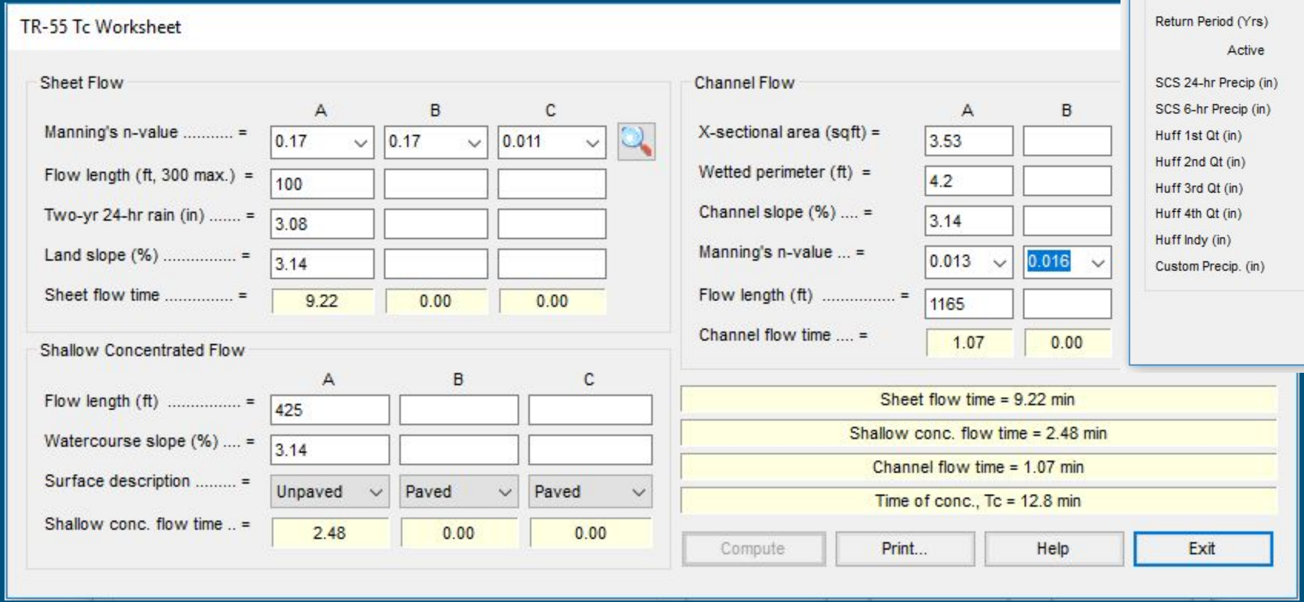
$$\text{Target flow} = \frac{\text{Volume}}{\text{day}}$$

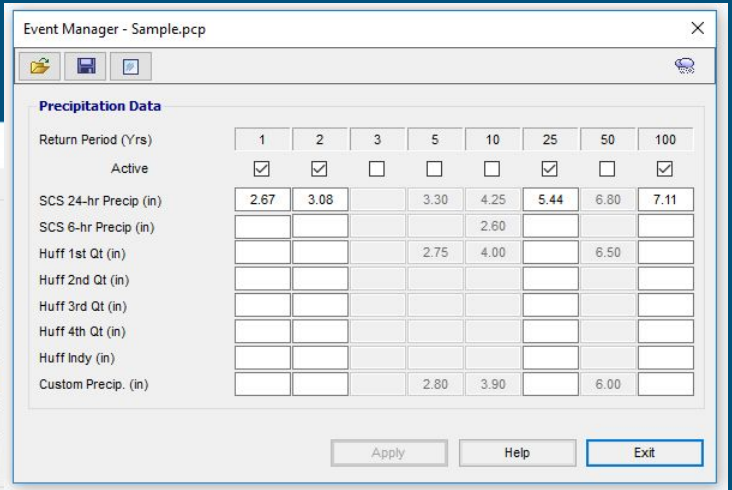
Runoff Volume Computation				
	1.25 in	1-yr	25-yr	100-yr
	WQ_v	CP_v	Q_p	Q_f
Rainfall (P)	**1.25**	**2.65**	**5.37**	**7.1**
Potential retention (S)	1.405	1.405	1.405	1.405
Initial abstraction (Ia)	0.28	0.28	0.28	0.28
Runoff (Q)	0.4	1.49	3.99	5.65
Volume (ft^3)	**27,035**	**101,653**	**272,621**	**386,517**
Target Flow (cfs)	**0.31**	**1.18**	**1.95**	**4.47**

Time of Concentration		
Sheet Flow	4.03	min
Shallow Concentrated Flow	4.01	min
Open Channel Flow	2.48	min
Total Time	**10.52**	**min**

AutoCAD Civil 3D - Hydraflow Analysis

Useful to double check our calculations
Software uses TR 55 method





AutoCAD Civil 3D - Hydraflow Analysis

- Input watershed characteristics
- Calculate Q_{peak}
- Compare Pre-Developed to Post-Developed

Peak Flowrate (ft^3/s)					
	1.25 inch	1-yr	5-yr	25-yr	100-yr
Pre-Development	0.10	6.56	11.85	34.05	53.65
Post-Development	10.77	41.50	56.36	107.51	147.23

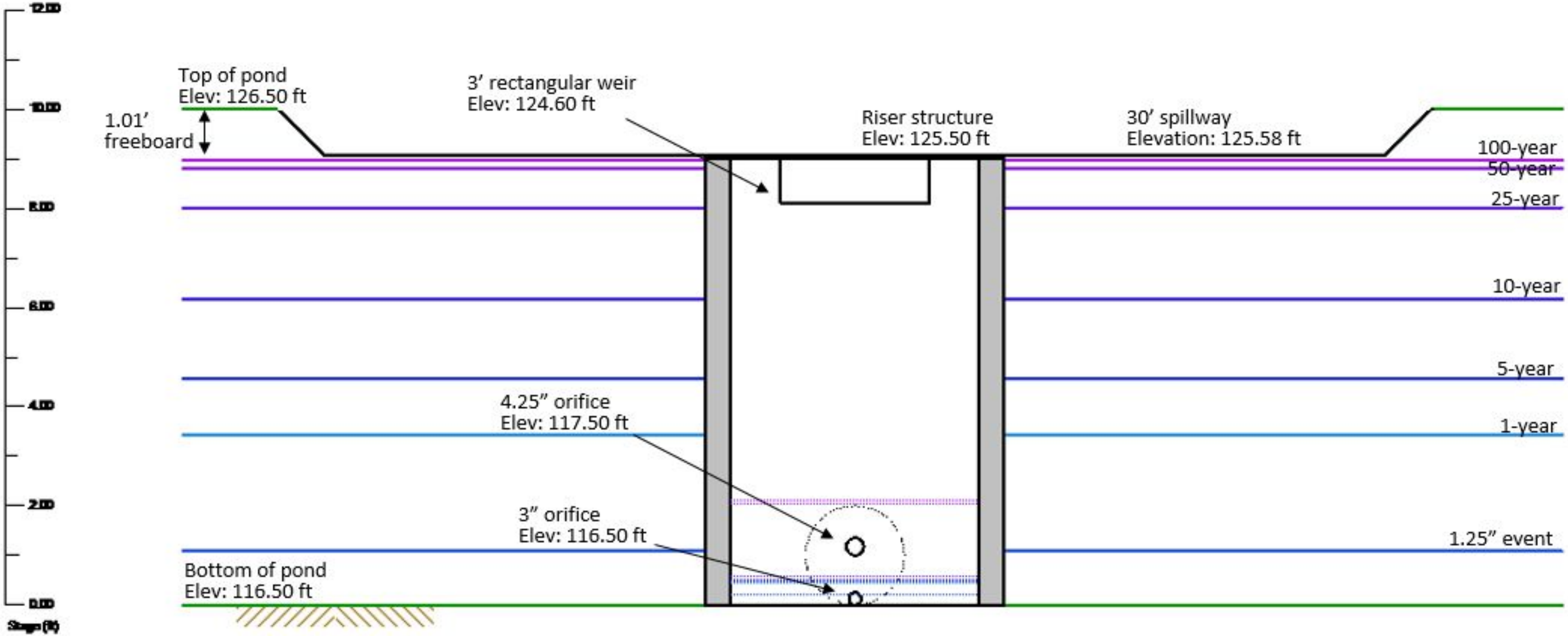
AutoCAD Civil - Hydraflow Analysis

- Input basin geometry from original design
- Route storm events through basin
- Calculate storage volumes
- Model old control structure and flow rates
- Design new control structure
- Calculate target flow rates to dewater basin over 24 hours for each event
- Iterate until control structure meets criteria
- Compare flow rates out of new and old control structures

Assumptions

- Assumed homogeneous mixture of land use throughout watershed
    - Could be broken up into sub-basins, although not clear where boundaries would be
- Soil data accuracy at scale of project - used hydrologic group C
- No channelized flow in “Pre-Development” analysis
- Used 24” for storm sewer pipe diameters, assumed concrete
- Manning’s n values based on best estimate of land cover and pipe conditions
- Slope of storm sewer equal to ground slope
- No survey yet - topography could be limiting factor in the future

Proposed New Outlet Structure



Front View (looking downstream)

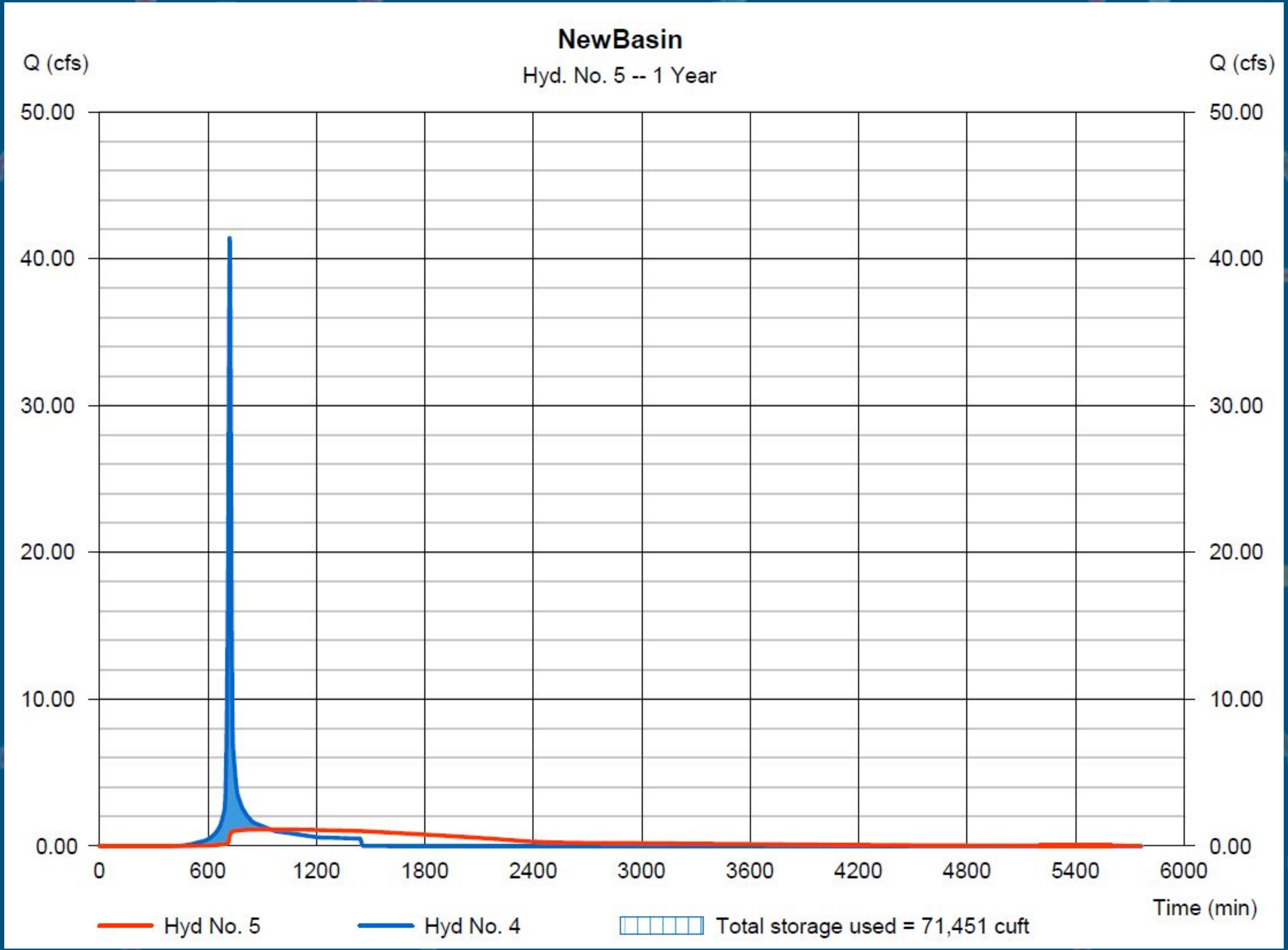
Results

Peak Flow Rates (ft^3/s)					
	1.25 inch	1-yr	5-yr	25-yr	100-yr
	WQv	CPv	Qp	-	Qf
Pre-Development	0.10	6.56	11.85	34.05	53.65
Post-Development	10.77	41.50	56.36	107.51	147.23
Target Dewatering Rate	0.33	1.25	1.70	3.34	4.65
Old Control Structure	1.64	9.60	11.88	28.39	85.52
Proposed New Control Structure	0.24	1.13	1.36	1.89	10.20

Peak Flow Rate Reductions

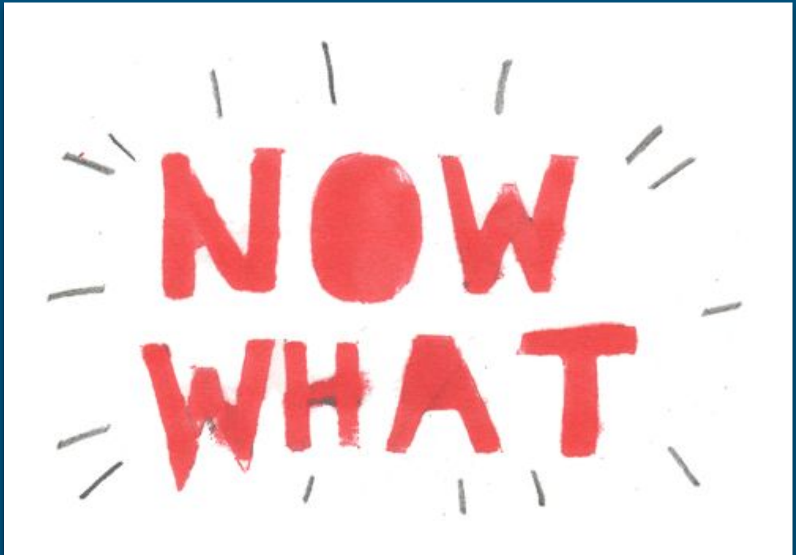
Old vs. New Control Structure					
Percent Reduction	85%	88%	89%	93%	88%

Post-Development vs. New Control Structure					
Percent Reduction	98%	97%	98%	98%	93%


NewBasin
Hyd. No. 5 -- 1 Year
Q (cfs)
Q (cfs)
50.00
40.00
30.00
20.00
10.00
0.00
0
600
1200
1800
2400
3000
3600
4200
4800
5400
6000
Time (min)
Hyd No. 5
Hyd No. 4
Total storage used = 71,451 cuft

Future Considerations

- Use survey data to refine design
- Address 72” pipe with designed channel
- Analysis of effects downstream
- Include recreational/educational elements
- Produce construction plan
- Potential beginning of construction
- Upstream practices to reduce flow



Questions?

Sources

"Design Standards Chapter 7 - Detention Practices." Iowa Storm Water Management Manual, Iowa Department of Natural Resources, www.iowadnr.gov/Environmental-Protection/Water-Quality/NPDES-Storm-Water/Storm-Water-Manual.

"Urban Hydrology for Small Watersheds." Technical Release 55, www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044171.pdf.

"Chapter 2: Stormwater." Iowa Statewide Urban Design and Specifications, www.iowasudas.org/manuals/manual.cfm?manual=design.


BBC
THANKS