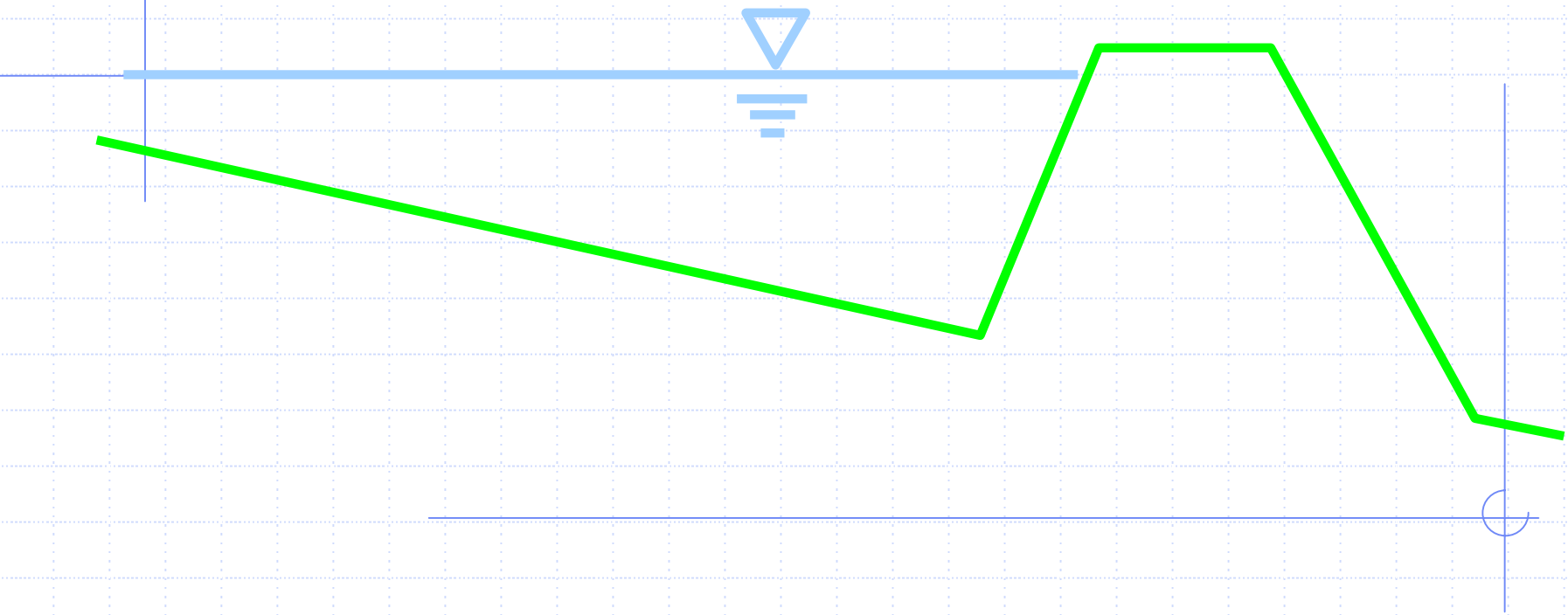
City of Springfield

Drainage Criteria Manual

Detention



aM Hydro Division

Basic Concepts

- Detention Reservoir Design
- Basic concepts
- Sizing/Siting
- Routing/Outlet structures
- Examples

Basic Concepts

- ***Continuity,*** $Q_{in} - Q_{out} = dS/dT$
- ***Energy Grade Line -The total energy at any point in the system (sum of the elevation, pressure head and velocity head)***
- ***Hydraulic Grade Line -The sum of the elevation and pressure head. The HGL is coincident with the water surface in free surface flow***

Basic Concepts

- ***Unit Hydrograph -The hydrograph resulting from one inch of constant intensity, uniformly distributed, excess rainfall***
- ***Abstractions -Any portion of rainfall that does not become runoff such as infiltration, interception, evaporation, transpiration or depression storage***
- ***Runoff Volume -The total volume of runoff expressed in acre-feet, inches over the watershed or cubic feet***

A Note on Probability

- ***A culvert with a design life of 50 years that is designed to carry a 50-year recurrence interval event has a 64% probability that its capacity will be equaled or exceeded during its design life***
- ***For an improvement with a design life of 2 years, designed for a 2-year recurrence interval, the probability of failure increases to 75%***

Basic Concepts

- ***Time of Concentration - The time it takes for water to travel from the hydraulically most remote point in the watershed to the point of interest***
- ***Routing - The process of accounting for the effects of hydrograph translation and attenuation due to channel or reservoir storage***

Basic Concepts

- ***Recurrence Interval - 1/annual probability of an event being equaled or exceeded, synonymous with return period***
- ***Temporal Distribution - Distribution of rainfall with respect to time***
- ***Tailwater - Depth of water downstream of the pipe, channel or structure of interest, excess tailwater may have backwater effects reducing the system capacity***

Detention Design

- ***Why detention?***
- ***To meet regulations***
- ***To mitigate some of the impacts of urbanization***

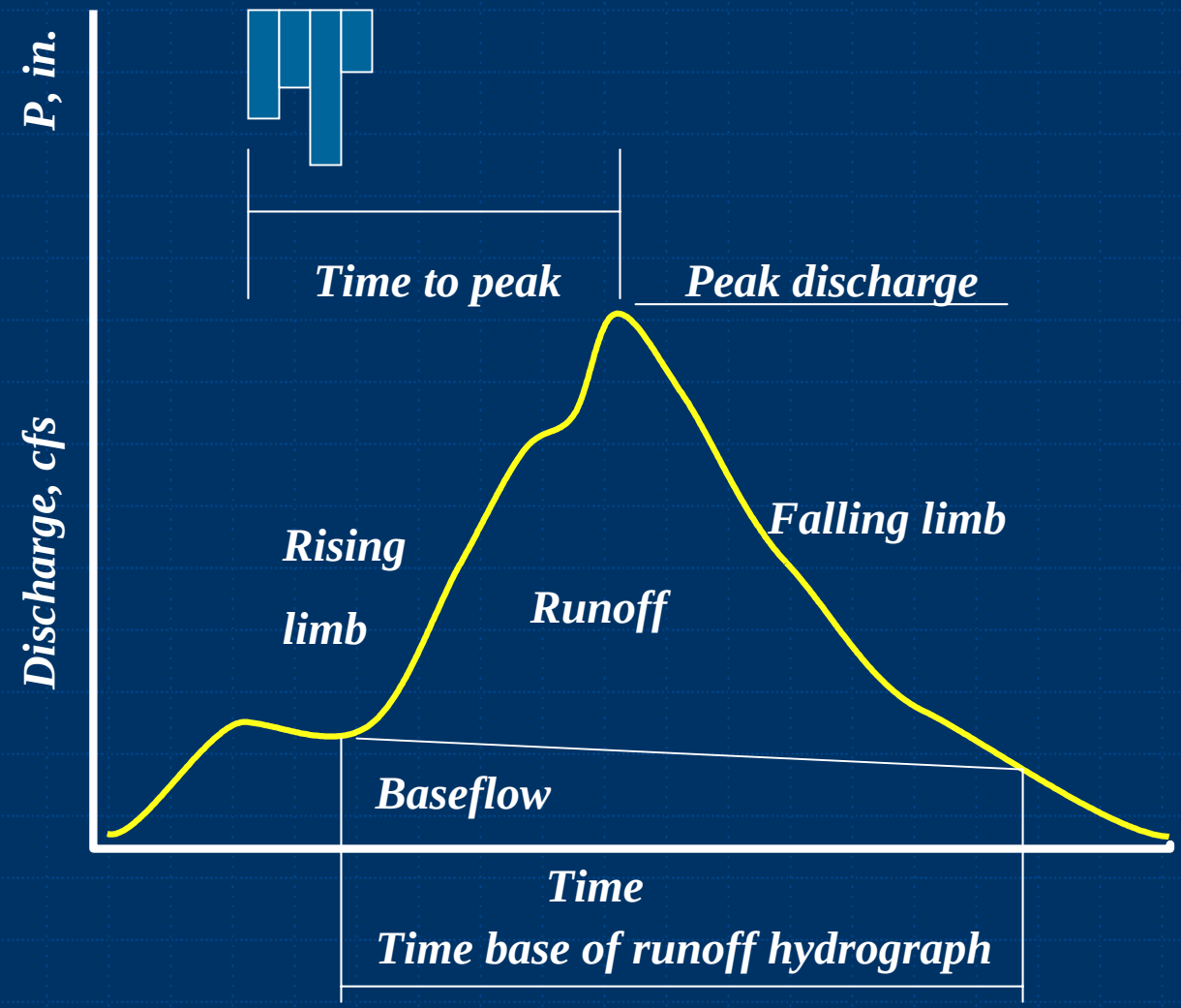
Missouri Water Law
Rule of Reasonable Use

- ***Three tenets necessary to apply the rule of reasonable use***
  - ***Was the alteration necessary for the use of the property?***
  - ***Were reasonable steps taken to mitigate any adverse impacts?***
  - ***Does the utility of the alteration outweigh any potential harm?***

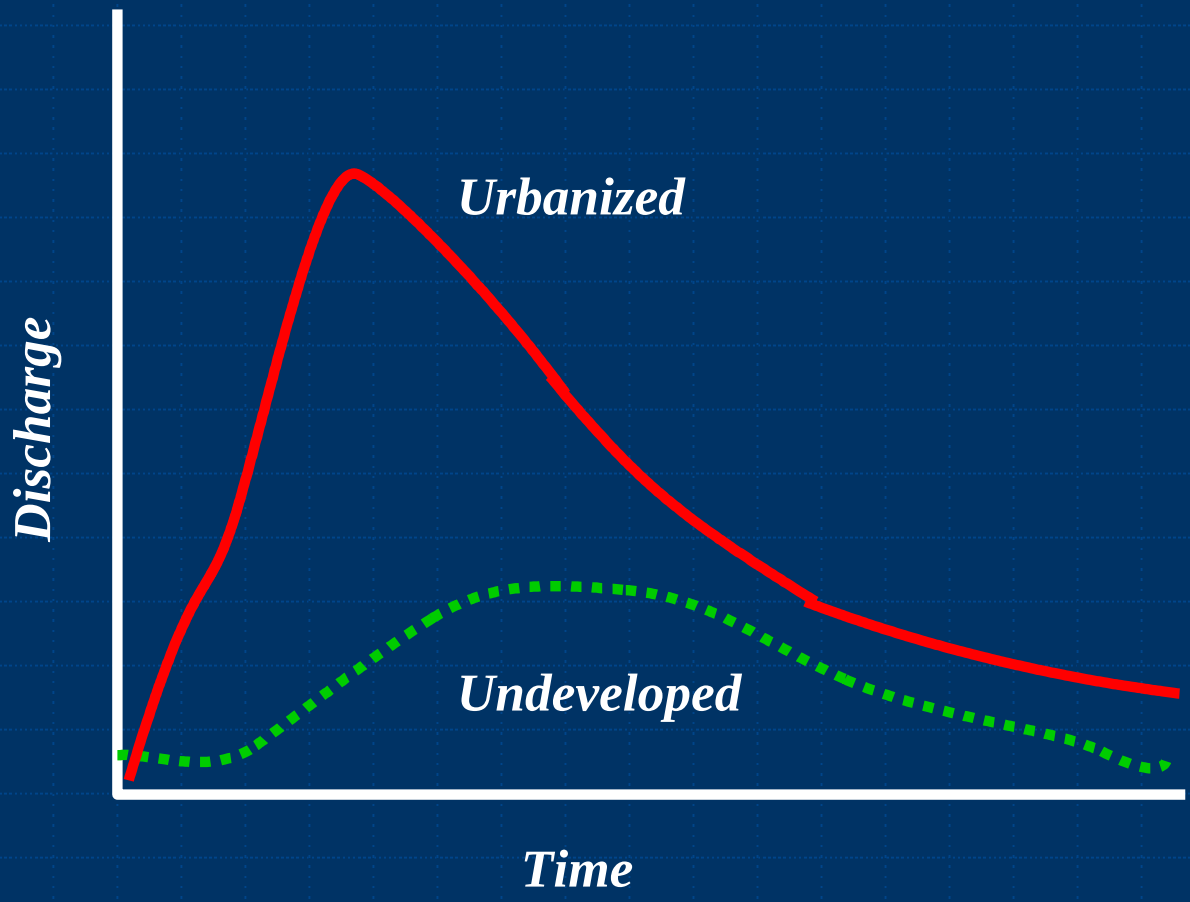
Impacts of Urbanization

- ***Greater volume of runoff***
- ***Faster time to peak***
- ***Greater peak discharge***
- ***Reduction in dry weather baseflow***
- ***Reduction in water quality***
- ***Increase in water temperature***

Runoff Hydrograph



Impacts of Urbanization



Types of Detention

- ***Detention / Retention***
- ***Wet / Dry***
- ***On line / Off line***
- ***Regional / Site specific***

Types of Flood Control Storage

- ***Detention temporarily stores runoff. Runoff either gravity drains or is pumped from the facility***
- ***Retention stores runoff until it either evaporates or infiltrates***
- ***Wet detention maintains a permanent pool***
- ***Dry detention drains or is pumped dry***

Types of Flood Control Storage

- ***An on line facility is on the main drainage channel***
- ***Off line detention is located off of the main channel and generally has a diversion structure to route runoff from the main stream to the reservoir***
- ***Regional detention provides storage for several tracts of land***
- ***Site specific detention requires each tract of land to provide detention as it develops***

Regional Detention

- ***Advantages -***
  - ***More effective flood control***
  - ***Requires watershed planning***
  - ***More cost effective***
  - ***Single large structure has less maintenance requirements than several small structures***
- ***Disadvantages -***
  - ***Timing of construction***
  - ***Collection of fees***
  - ***Land availability in developed areas***
  - ***Requires watershed planning***

Site Specific Detention

- ***Advantages -***
  - ***Perceived equity in system***
  - ***Relatively easy to regulate***
- ***Disadvantages -***
  - ***Multiple small structures pose a maintenance problem***
  - ***Area of effective flood control limited to immediately downstream of structure***

Site Selection Issues

- ***Proximity to flood prone areas***
- ***Land availability***
- ***Land ownership***
- ***Gravity inflow & outflow***
- ***Existing structures***
- ***Lateral constraints***
- ***Vertical constraints***

1.1 Detention Requirement

- "... post-development peak runoff rate for all land development must be no greater than the pre-development peak runoff rate for the design storms listed in this chapter."
- Basins must be safe, maintainable, enhance the environment and provide aesthetic value to the community
- Multipurpose use is encouraged

1.2 Payment in Lieu of Detention

- "engineer can show that constructing a detention basin will provide no downstream benefits and no existing downstream drainage problems will be impacted, a payment in lieu of constructing detention may be acceptable."
- Requires signed and sealed application
- Does not waive water quality requirements

1.3 Design Spreadsheets

- Detention volume estimation
  - Modified FAA method
  - Hydrograph methods
- Stage-Storage computations for various geometries
- Outlet structure rating computations for various outlets

2.0 Types of Detention

- Dry
- Extended
- Wet
- In-Line
- Off-Line

3.0 Hydrologic & Hydraulic Design

Table DET-1, Design Methods

Detention Design Method	Acceptable Volume (cubic feet [ft^3])	Approx. Acceptable Impervious Area Added
Tabular Method (Section 3.1.1)	< 5,000 ft^3	½ acre
Simplified (Modified FAA) Method (Section 3.1.2)	<20,000 ft^3	2 acres
Hydrograph Method (Section 3.1.3)	Any size	Any amount

3.1.1 Tabular Method

- Applicable for volumes less than 5000 ft^3.
- Criteria listed in Table DET-2
- Table DET-2 is also applicable to determine the required volume for payment in lieu of detention

3.1.1 Tabular Method Criteria

- Flow rates determined using Rational Method
- Low-flow orifice limited to 1-year peak flow rate, minimum 6” diameter
- Overflow spillway for 100-year flow rate ABOVE the required volume
- Turf reinforcement or sod preferred for overflow spillways
- 6 inches of freeboard above 100-year water surface required.

3.1.2 Simplified Method

- Applicable for volumes less than 20,000 cubic feet
- Modified FAA Method
- Spreadsheet available to assist with computations

3.1.3 Hydrograph Methods

- Detention basins larger than 20,000 cubic feet
- Methods
  - SCS Dimensionless Unit Hydrograph
  - Kinematic wave hydrograph generation

3.2.1 Peak Flow Attenuation

- 1-yr, 10-yr and 100-yr events must be analyzed
- Analysis conditions
  - Condition 1, Pre-project
  - Condition 2, Post-project
  - Condition 3, Fully urbanized w/no upstream detention unless previously approved (100-yr only)
- Downstream conditions may warrant spillway capacity greater than the 100-yr

3.2.3 Outlet Works Design

- Must restrict the post-project release rates to less than or equal to the pre-project rates
- Design frequencies 1-yr, 10-yr, and 100-yr
- Critical duration analysis required

3.3.1 Detention Volume Estimation

- Direct hydrograph subtraction
  - Typical final volume = 1.5 –2 times the direct subtraction volume
- Modified FAA Method
- Hydrograph Volumetric Method
- Rule of thumb 0.35 acre-feet of storage required for each acre of impervious area

3.3.2 Outlets

- Orifices
- Weirs
  - Broad-crested
  - Sharp-crested
  - Vertical Slots
  - Slots with sloping sides
- Culverts
- Risers

3.3.3 Reservoir Routing

- Level-pool/Modified Puls Routing
- Numerous computer programs available
- Suitable for spreadsheet computations

4.0 Final Design Considerations

- Potential for multiple use
  - Recreational facilities must be at or above the 2-year stage in the reservoir
- Basins to be located at the natural low point of the site
  - Must discharge to the natural drainage location

4.3 & 4.4 Grading and Geometry

- Utilize natural contours to the maximum extent practical
- Maximum slopes 4H:1V
- Minimum 1% grade in bottom of basin
- Concrete low-flow channel required for 2-year greater than 5 cfs
- Hard improvements required to control 2-yr through 10-yr discharge

4.3 & 4.4 Grading and Geometry

- Sod or turf reinforcement may be acceptable for velocities less than 4 ft/s
- Water quality grading should consider a gradual expansion at the inlet and gradual contraction at the outlet to avoid short-circuiting flow.

4.5 Embankments & Cut Slopes

- Maximum of 4H:1V
- Minimum of 1 ft. of freeboard between the top of embankment and the 100-yr water surface elevation
- Increase embankment heights by 5% to allow for settlement
- MDNR Dam Safety criteria may control

4.6 Linings

- Impermeable linings may be required if there is potential to increase ground water levels and adversely impact adjacent properties
- Permeable linings are encouraged where practical to encourage ground water recharge

4.7 Inlets

- Inlets to the detention facility must incorporate energy dissipation to reduce erosion
- Forebays or sediment traps are required at all inflow points.
- Access must be provided for maintenance of sediment traps

4.8 Outlet Works

- Outlets must be sized and designed to release the specified flow rates without structural or hydraulic failure
- Insufficient erosion protection can lead to structural failure
- Trash racks must not interfere with hydraulic capacity and must be protective of public safety

4.10 Vegetation

- Planting plan required
- Plantings function of:
  - Use
  - Frequency and duration of inundation
  - Soil types
  - Native or non-native plants
- Trees and shrubs are not recommended for dam or embankment slopes

4.11 Operation & Maintenance

- Consider landscaping that discourages entry
- Easements for access and maintenance are required
- Permanent ponds should have provisions for completely draining the facility for maintenance
- Permanent pools may require aeration to minimize odors and other nusiances
- Secondary uses that are incompatible with sediment deposits should not be planned unless maintenance provisions are included

4.11 O & M cont'd

- French drains are discouraged in areas where high sediment loads are expected
- Underground detention must provide multiple access points of sufficient size for entry to remove sediment and debris
- Permanent pools should be of sufficient depth as to discourage excessive aquatic vegetation
- Trash rack designs should consider aesthetics and maintenance

4.11 O & M cont'd

- To minimize maintenance, outlet structures should be designed with no moving parts
- The use of sharp plates for weirs is discouraged due to potential for damage, vandalism and accidents
- Forebays and sediment traps are to be cleaned on a regular basin, at a minimum when the trap is ¾ full of sediment

4.12 Access

- All-weather, stable access to the bottom, inflow, forebay, and outlet works areas shall be provided for maintenance vehicles
- Maximum grades should be 10 percent, and a solid driving surface of gravel, rock, concrete, or gravel-stabilized turf should be provided

4.13 Geotechnical

- Geotechnical considerations may include issues related to embankment stability, geologic hazards, seepage, and other site-specific issues
- It may be necessary to confer with a qualified geotechnical engineer during both design and construction, especially for larger detention and retention storage facilities.

4.14 Environmental Permitting

- U.S. Army Corps of Engineers 404 permit
  - Wetlands
  - Waters of the United States
- Missouri Department of Natural Resources 401 Water Quality Certification
- NPDES permit