ENGINEERING STUDIES AND H&H MODELING FOR FLOODWAY CONSTRUCTION PERMITTING

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Purpose of H&H Studies for IDNR/OWR

Compliance with

- **Part 3700 Rules (downstate)**
- **Part 3708 Rules (6-county Chicago metro area)**

Studies for IDNR/OWR Permitting may have different objectives (and different governing policies) than studies done for the Corps, FEMA, and others

What do Rules say about H&H analysis?

Part 3700 – Downstate

"Worst-case Analysis" The calculation of the maximum increases in flood heights, velocities and damages a project would cause due to conveyance and storage losses considering both the project alone and the combined effects of other existing construction and construction which could reasonably be anticipated to be proposed in the locality. Flood events up to and including the 100-year frequency flood shall be used in this analysis (see Section 3700.75 for exception).

Part 3708 – Northeast Illinois / Chicago Metro Area

Engineering calculations and supporting data shall be submitted showing that the proposed work will meet the permit criteria of Section 3708.70.

When is an H&H Analysis Required?

General Rule:

More developed area = More likely to require analysis

Work in Jurisdictional Floodways (or floodplains when a floodway is not delineated) involving:

- New Bridges or Culverts - and replacements
- New Levees or levee reconstruction which is
  - Riverward of existing alignment and/or
  - Higher than existing grades
- Channel Modification or Realignment
- Significant Re-grading including Fill

Agenda

1. Hydrologic Studies
   - Establishment of flow rates up to and including 1% chance (100-year) discharge

2. Hydraulic Studies
   - Computation of flows through floodway to determine
     - Conveyance Impacts
     - Storage Loss Impacts
     - Changes in Velocity

3. Upcoming Changes
   - Permit Fees
   - Possible Updates to Rules
   - Unsteady Flow Floodway Studies

Disclaimer

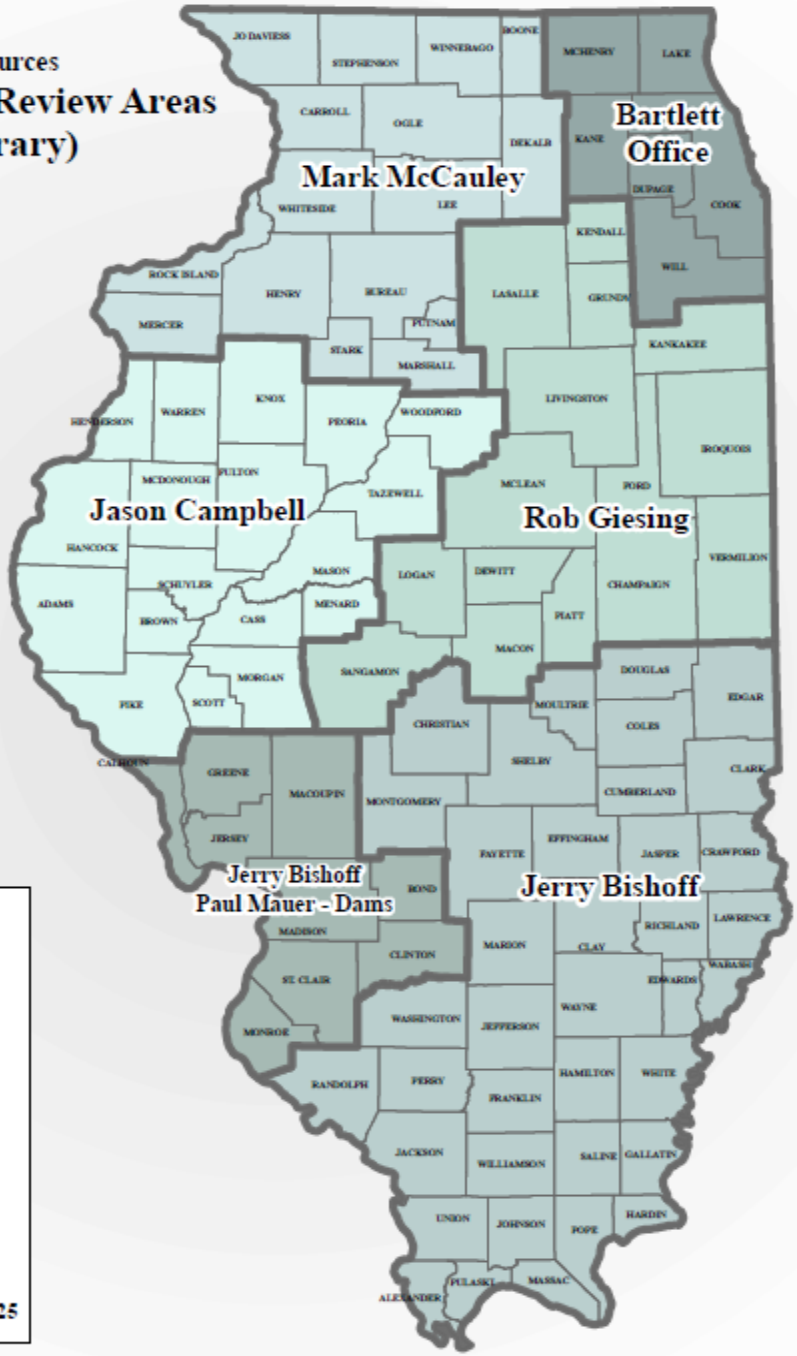
- The acceptability and appropriateness of any of the methods to be described will vary depending on the information available, project site characteristics, and the nature of the work being performed. The information described is not intended to be dictatorial as to what methods are to be used and what methods will be accepted.

- WHEN IN DOUBT – CONSULT WITH IDNR STAFF BEFORE TAKING ON AN H&H ANALYSIS

ILLINOIS DEPARTMENT OF NATURAL RESOURCES

Office of
Water Resources

Permit Review Areas (Temporary)



Legend

Springfield Office
Permit Reviewer
(217) 782-3863

- Jerry Bishoff
- Jason Campbell
- Rob Giesing
- Mark McCauley
- Paul Mauer - Dams in MetroEast Area

Barlett Office
Permit Reviewer
(847) 608-3100 Ext 2025

November 4, 2009

Hydrologic Studies

- Needed to determine 100-year discharge (at a minimum)
- IDNR/OWR Policy is to use "Best Available Information"

What is "Best Available Information"?

Typical sources (in no particular order)

- Gage Records
- Flood Insurance Studies (FIS)
- Regression Equations
- Hydrologic Modeling

Gage Records

- Project site should be reasonable close to gage station
- Should have sufficient years of continuous record to obtain a significant 100-year discharge
  - Should not have significant changes in watershed characteristics during period of record (i.e. rural use converted to urban area)
- USGS Bulletin 17B procedures should be used
- SHOULD NOT BE USED TO SUPERSEDE OTHER DATA WITHOUT SUFFICIENT ANALYSIS FOR JUSTIFICATION

FEMA Flood Insurance Studies (FIS)

- Often (but not always) considered "best available"
- Wide variety of methods are used to determine discharges
- When to question FIS data…
  - Basin characteristics have changed dramatically from when the study was performed
  - Major flood control projects in place since study was done
  - Older study, used with outdated methods
- What about new studies in process of being adopted as regulatory models?
  - IDNR/OWR usually accepts a new study as "best available" once it has OWR approval

USGS Regression Equations

- Can be used for rural watersheds (<39% impervious areas)
- Current publication – USGS Scientific Investigations Report 2004-5103 "Estimating Flood-Peak Discharge Magnitudes and Frequencies for Rural Streams in Illinois"
  - Also in current IDOT Drainage Manual
- Streamstats website http://water.usgs.gov/osw/streamstats/illinois.html
- Adjustments necessary for
  - Urbanization (impervious areas)
  - Proximity to gages
- STREAMSTATS MAY NOT AUTOMATICALLY MAKE THESE ADJUSTMENTS

Hydrologic Modeling

When is it helpful?

- Areas that have no other study information
- Watershed characteristics have changed dramatically from when an existing study was performed
- Ideal for smaller watersheds where precipitation can be assumed constant over entire area

Hydrologic Modeling

Modeling Software

Staff currently most familiar with HEC-HMS and HEC-1

Note: Any software can be considered, but if it is not widely used, it may increase review time

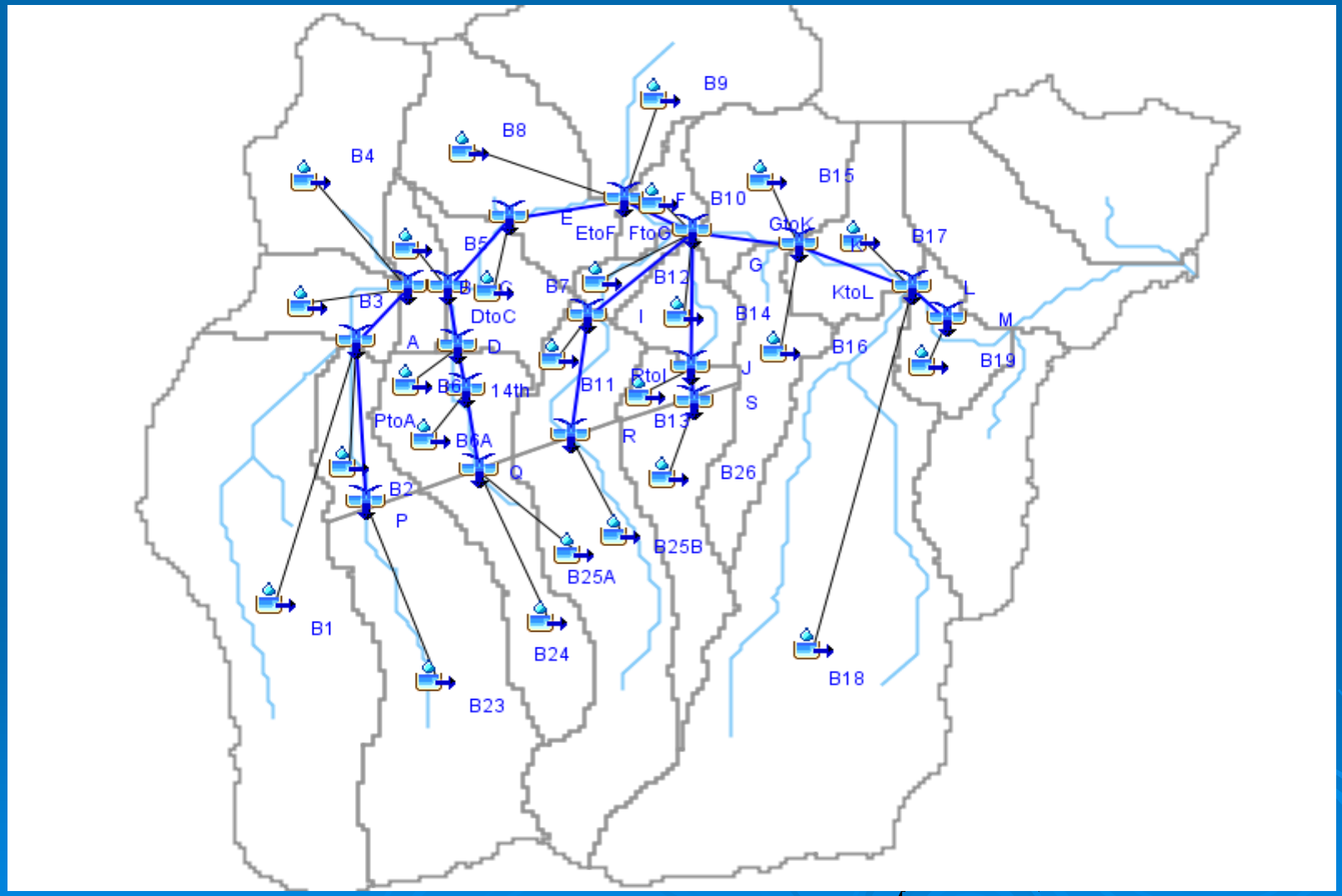
Technical Reference for the software may also need to be provided

What to Include

Always document data and assumptions including…

- Basin Schematic
- Time of concentration
- Losses
- Excess Precipitation → Runoff relationship
- Storage-Discharge function for detention areas

Watershed Schematic



Watershed Schematic

- Appropriate model varies depending on the basin to be modeled

In general,

- Avoid excessive number of sub-basins
- Do not consider restrictive culverts or bridges – they can be made less restrictive in the future and this is easily permissible
- Public flood control projects should be modeled
- Private detention facilities should not be included
  - Do not want to be dependent on strictness and enforcement of local ordinance

Precipitation Model

- Precipitation depth should be obtained from the ISWS publication "Bulletin 70 – Frequency Distributions of Heavy Rainstorms in Illinois"
- Hyetograph should follow ISWS Circular 173 "Time Distributions of Heavy Rainstorms in Illinois" – commonly referred to as Huff distributions
  - Use recommended quartile for storm duration
- Determine critical duration event
  - Which duration event results in largest peak discharge?
- A 100-YEAR RAINFALL DOES NOT ALWAYS RESULT IN A 100-YEAR FLOOD – CRITICAL DURATION IS VERY IMPORTANT

Precipitation Losses

- Infiltration losses usually the only consideration
- Most common methods
  - SCS Curve Numbers
  - Green and Ampt
- Should consider that a storm event could occur on saturated or frozen ground which would increase runoff
- PRECIPITATION – LOSSES = RUNOFF

Computation of Runoff Hydrograph

- Need a mechanism to convert excess precipitation to runoff

- Time of concentration
  - NRCS "Urban Hydrology for Small Watersheds" a common resource
    - Sheet Flow
    - Shallow Concentrated Flow
    - Channel Flow
  - Many empirical formulas also exist
    - Acceptance will depend on appropriateness of application of an empirical formula and reasonableness of result

Computation of Runoff Hydrograph

- Unit Hydrograph Methods
  - SCS Dimensionless Unit Hydrograph
  - Clark Unit Hydrograph
    - For rural watersheds of up to 2.3 square miles – can use USGS Water-Resources Investigations Report 00-4184 “Equations for Estimating Clark Unit-Hydrograph Parameters for Small Rural Watersheds in Illinois”
  - Snyder Unit Hydrograph

Computation of Runoff Hydrograph

- Reach Routing Methods
  - Muskingum
  - Muskingum-Cunge
  - Modified Puls
  - Kinematic Wave

IF APPROPRIATE - DON'T FORGET ABOUT BASEFLOW IN THE STREAM AT THE ONSET OF A STORM EVENT

Example Scenario

An engineer is computing the 100-year discharge for a 2 square mile watershed. The engineer uses three methods to compute discharge and gets the following estimates:

- HEC-HMS using Clark Unit Hydrograph – 650 cfs
- HEC-HMS using SCS Unit Hydrograph – 900 cfs
- Regression with urbanization adjustment – 1,250 cfs

The methods and assumptions were reviewed. Input data was appropriate and no major errors were found in any of the computations. So, which discharge should be used for the 100-year?

What can be concluded about hydrologic studies for permitting?

- Estimating the peak flow rate requires considerable judgment on the part of the engineer and permit reviewer
- Under-estimating the discharge could endanger the public and/or cause damages if flooding were increased
- Over-estimating the discharge could create an unnecessary obstacle to regulatory compliance

MAY BE VERY BENEFICIAL TO GET FEEDBACK FROM IDNR BEFORE STARTING WORST-CASE HYDRAULIC ANALYSIS

Worst-Case Hydraulic Analysis

Intent of this requirement:

No unmitigated damages (or potential damages) due to increased flooding impacts

Flooding impact can be due to:

- Loss of Conveyance
- Increased velocities
- Reduced Storage

How can this be done?

Water surface profile computations

- Discharge which just overtops project (typically)
- 100-year discharge
- Other profiles, as appropriate for a specific project

Water Surface Profile Computation

Uniform Flow – flow depth and velocity does not change with channel distance (prismatic channel and floodplain cross-section for considerable distance)

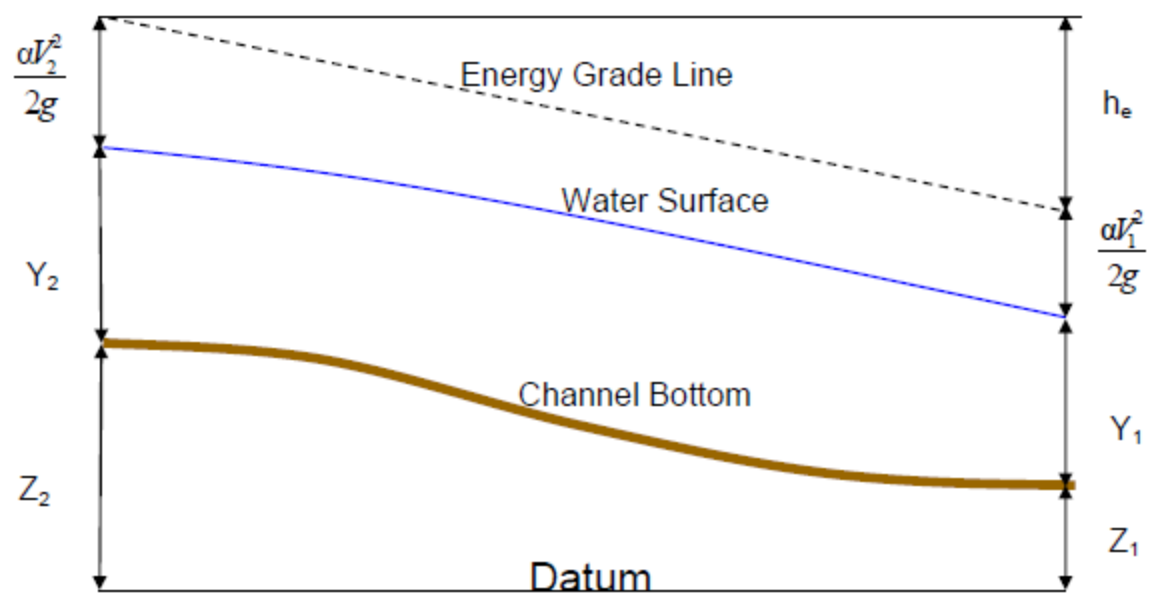
- **Manning's Equation**
- **Chezy Equation**

Gradually Varied Flow – flow depth and velocity changes with channel distance (but varies at a slow rate)

- **Direct Step Method**
  - **Can be used for artificial channels (spillways, canals, etc.) with constant cross-section**
- **Standard Step Method**
  - **Ideal for natural channels with changes in alignment and cross-section**

MAJORITY OF HYDRAULIC STUDIES USE STEADY FLOW, STANDARD STEP METHOD

Standard Step Method



Uses Conservation of Energy (Bernoulli)

- **Method used by HEC-RAS (Steady Flow)**
- **Computes head loss between two sections and iterates to find correct water surface at next cross-section**
- **Does not compute IMPACTS due to loss of storage**

Types of Hydraulic Models

Encroached:

Regulatory model is used with floodway encroachment lines established

- **Place cross-sections, with encroachments, at location of proposed development (existing and proposed)**
- **Evaluate base model versus developed model**
- **No-rise condition is the standard (encroachment has taken the allowable increases)**

Non-encroached:

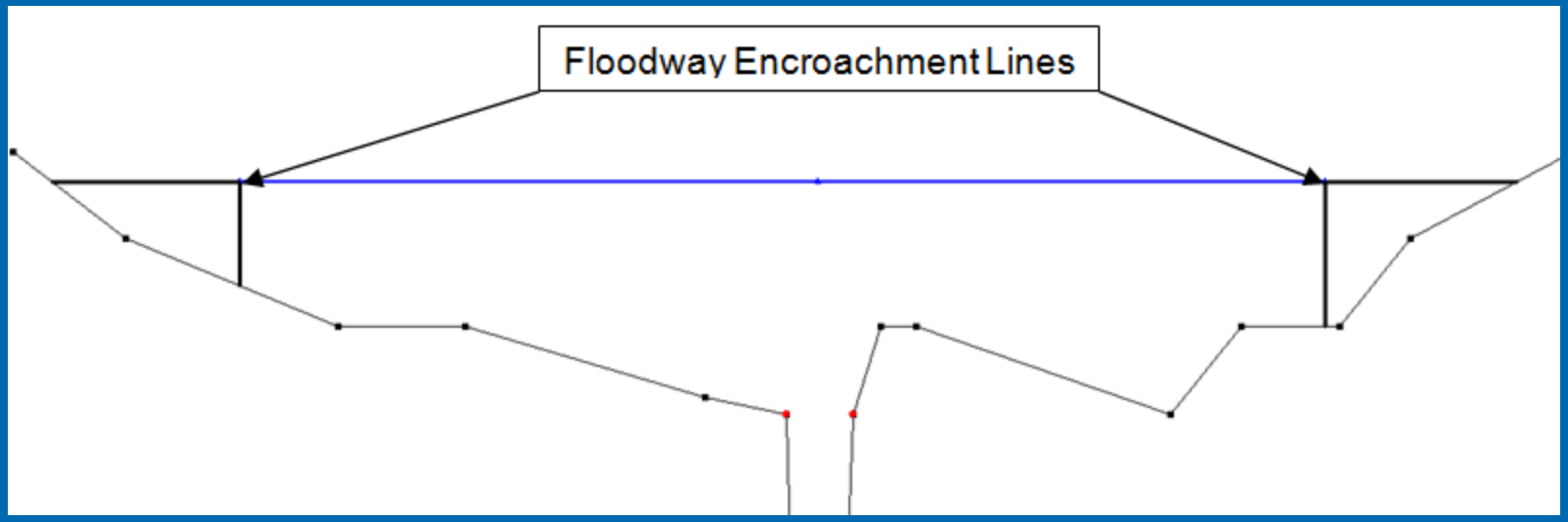
Regulatory model or model developed by the engineer

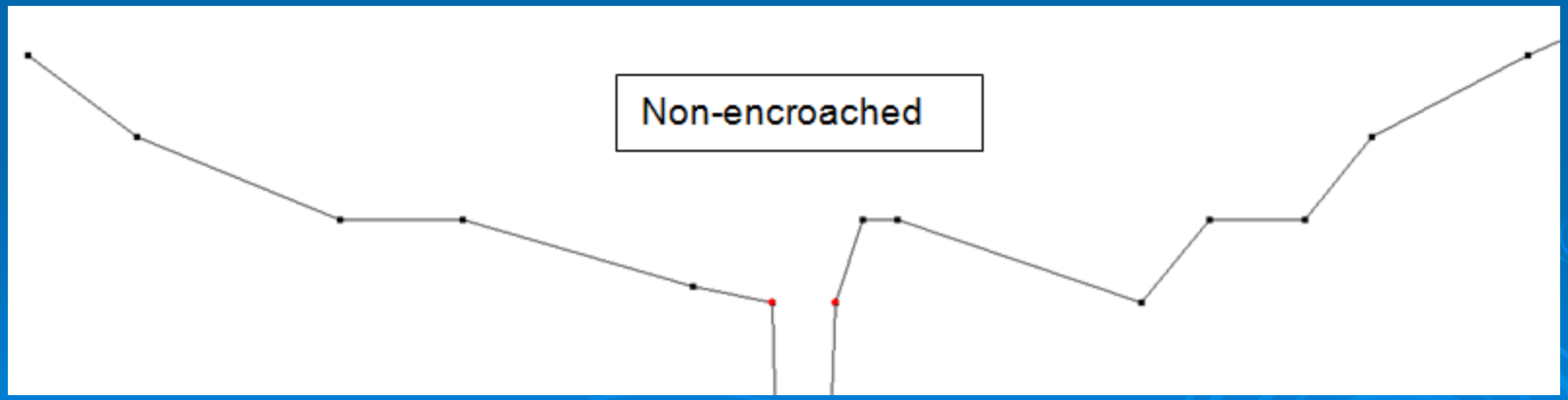
- **Proposed versus natural**
- **Must consider cumulative effects**

Floodway Encroachments

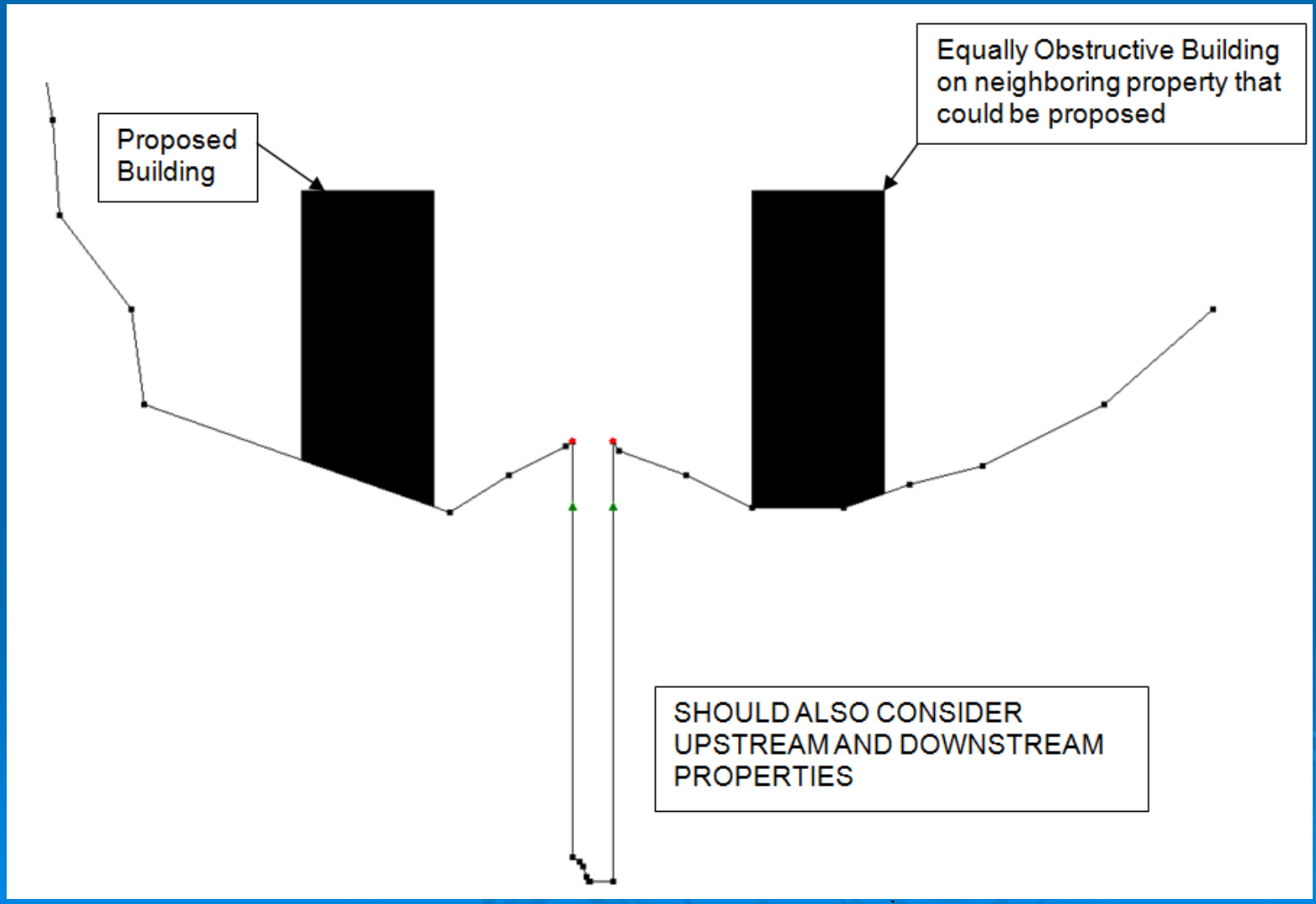
Floodplain is encroached until either:

- **Flood height increases by 0.1 ft**
- **Velocity is increased by 10%**
- **Storage volume is reduced by 10%**


Floodway Encroachment Lines


Non-encroached

What is meant by "Cumulative Effects"



Hydraulic Modeling Considerations

- Boundary Conditions
- Reach Lengths
- Number and Placement of Cross-sections
- Channel and Overbank Roughness
- Flow Transitions

Boundary Conditions

- Normal Depth – specify an initial slope to estimate losses using Manning's Equation
- Known Water Surface – should be used when a regulatory model is used. Profile elevation should correspond to discharge value used to establish the water surface elevation

Reach Lengths

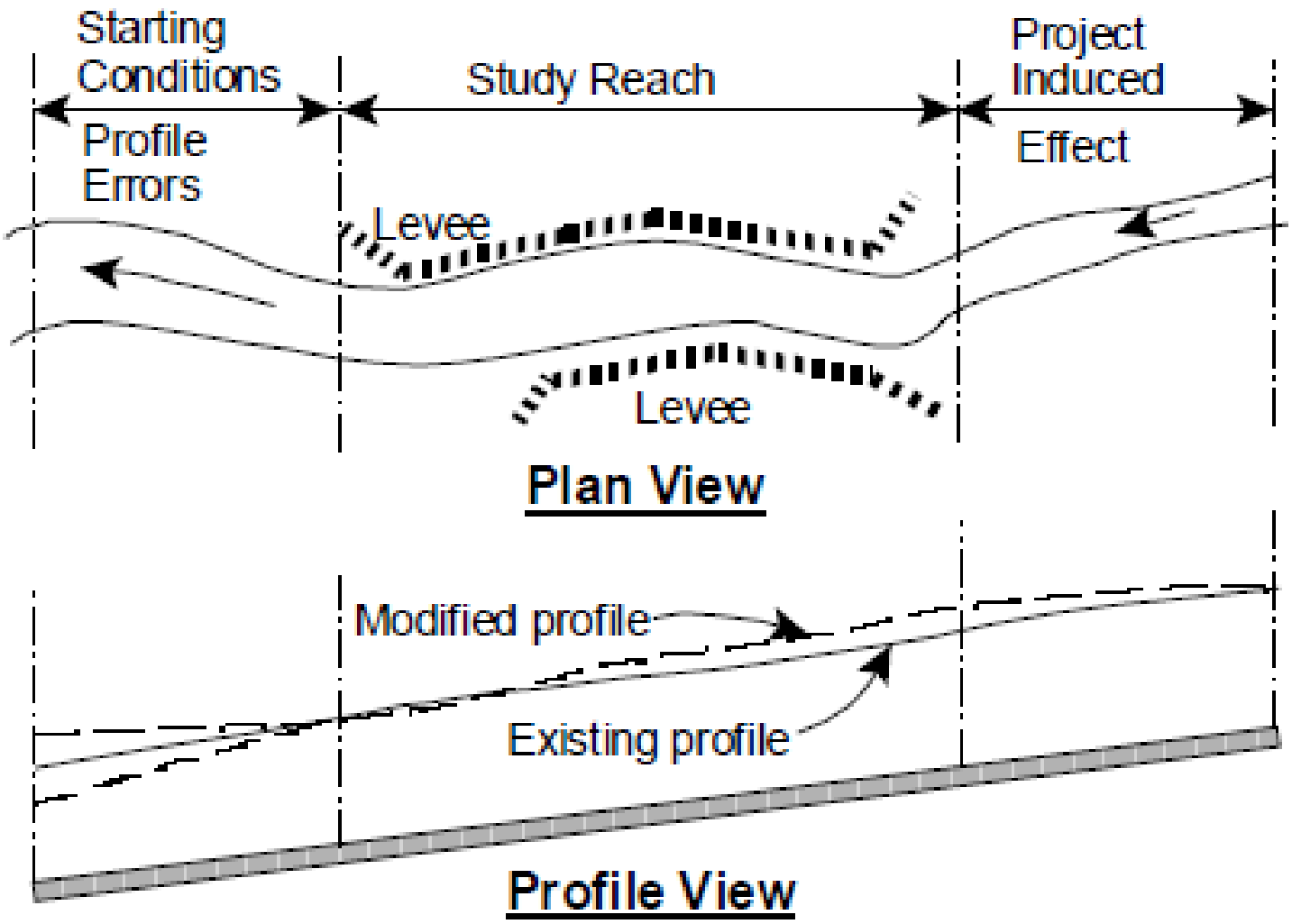
Downstream

Must extend far enough downstream of project to minimize effect of any error is estimate of boundary conditions

Upstream

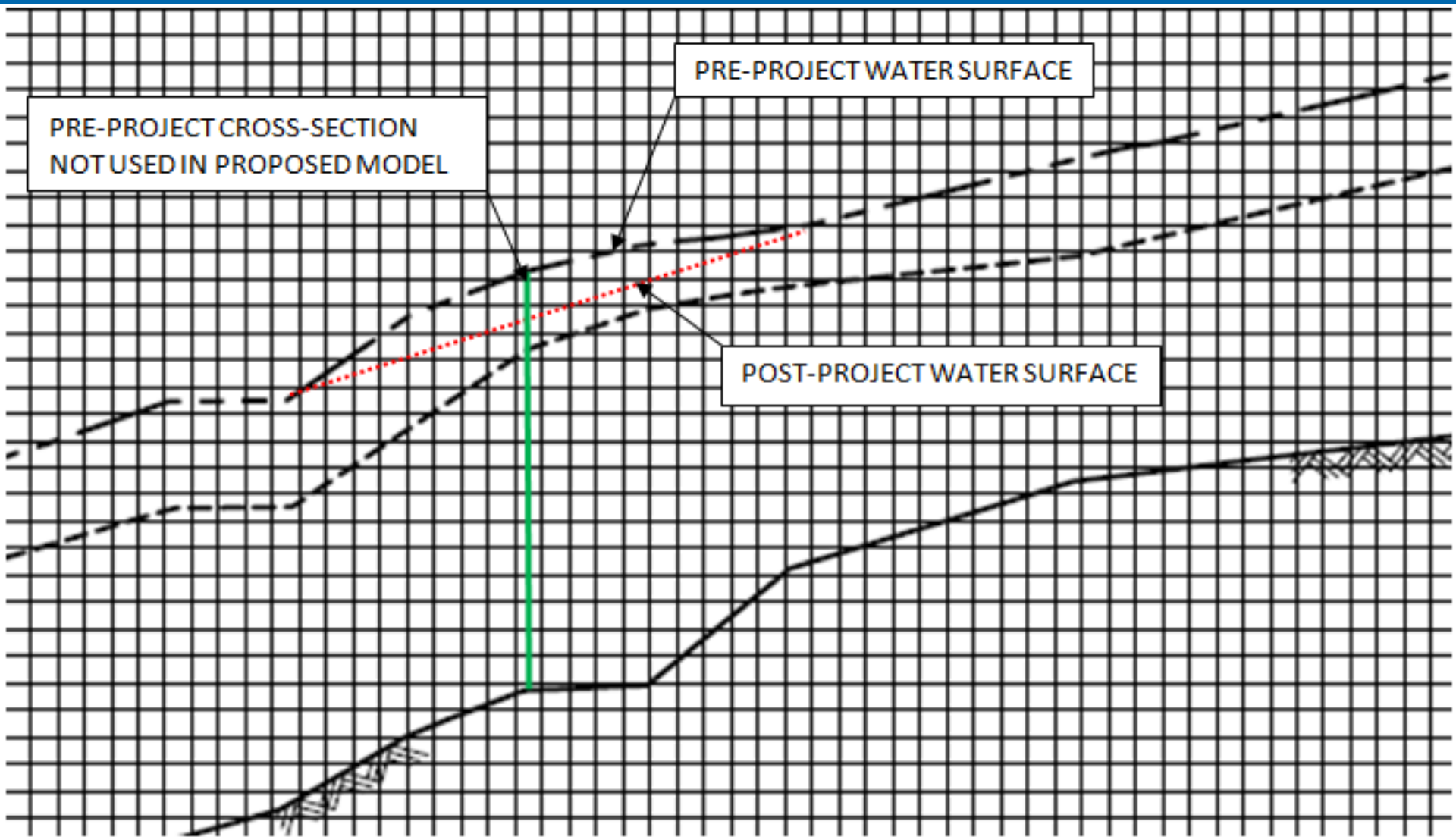
Must extend far enough upstream of project so that full extent of impacts from project is known

Reach Length



Number and Placement of Cross-sections

- The number and placement of cross-sections influences the level of confidence in the results
- Consistency between pre-development and post-development models are necessary for a good comparison


PRE-PROJECT WATER SURFACE
PRE-PROJECT CROSS-SECTION
NOT USED IN PROPOSED MODEL
POST-PROJECT WATER SURFACE

Channel and Overbank Roughness

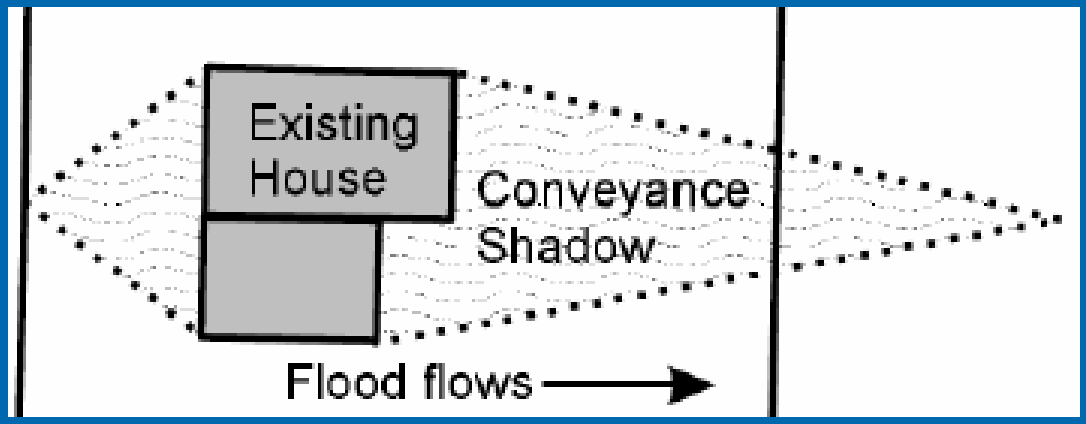
- Typically uses Manning's 'n' value
- Should be consistent between pre-development and post-project models

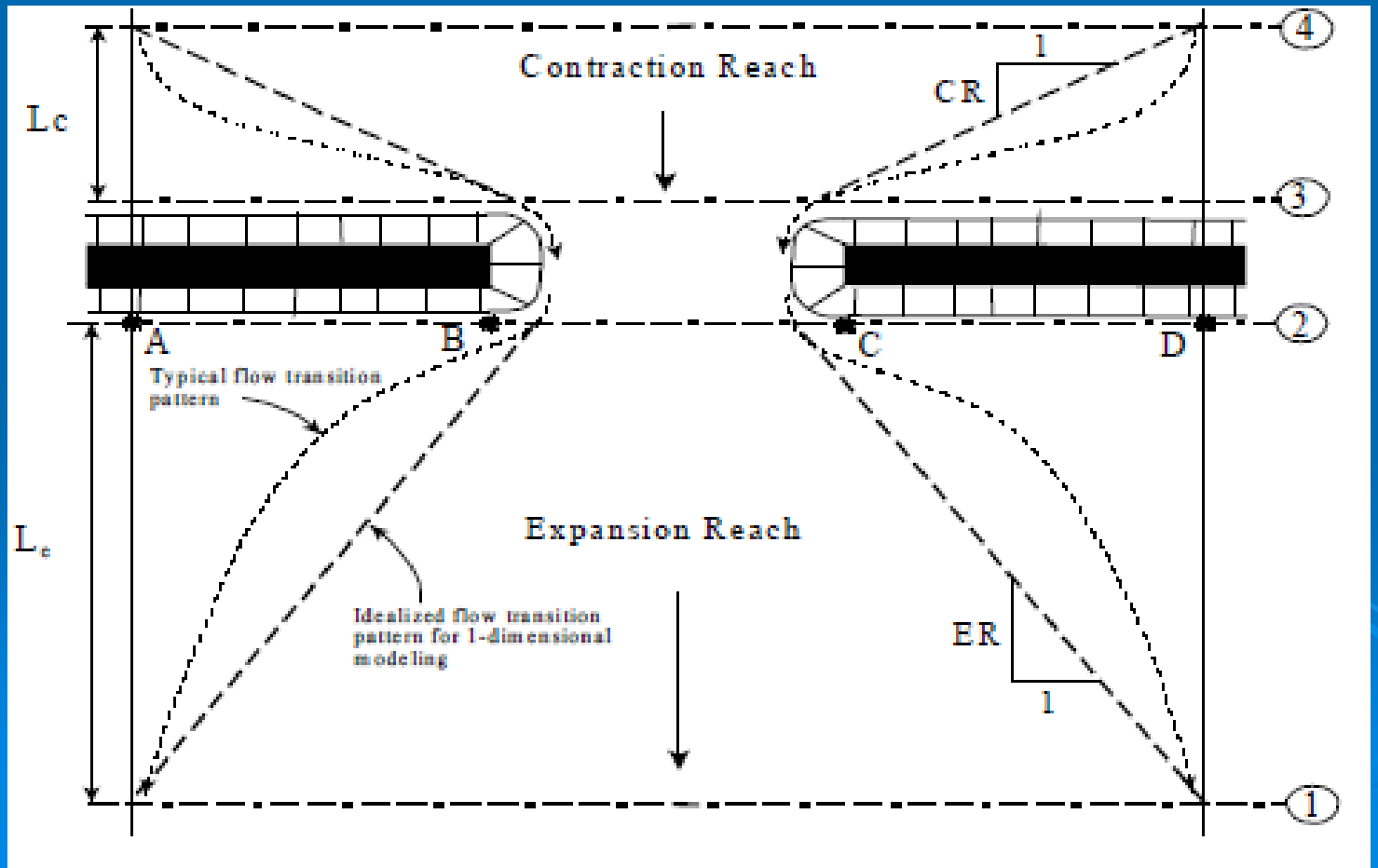
  Exceptions:

  - Permanent change in overbank land use (e.g. pavement)
  - Formal maintenance agreement by unit of government – usually requires a binding resolution – ONLY CONSIDERED FOR OVERBANKS

Flow Transitions

- Hydraulic Shadows
- Bridge and Culvert expansion and contractions
  - Adjust velocity head coefficients
  - Ineffective flow in contraction and expansion areas
- Channel Excavation Transitions
  - 6:1 horizontal transition rate
  - 10:1 vertical transition rate


Existing
House
Conveyance
Shadow
Flood flows


Contraction Reach
Lc
CR
1
4
3
2
A
B
C
D
Typical flow transition pattern
Le
Expansion Reach
Idealized flow transition pattern for 1-dimensional modeling
ER
1
1

Channel Excavation

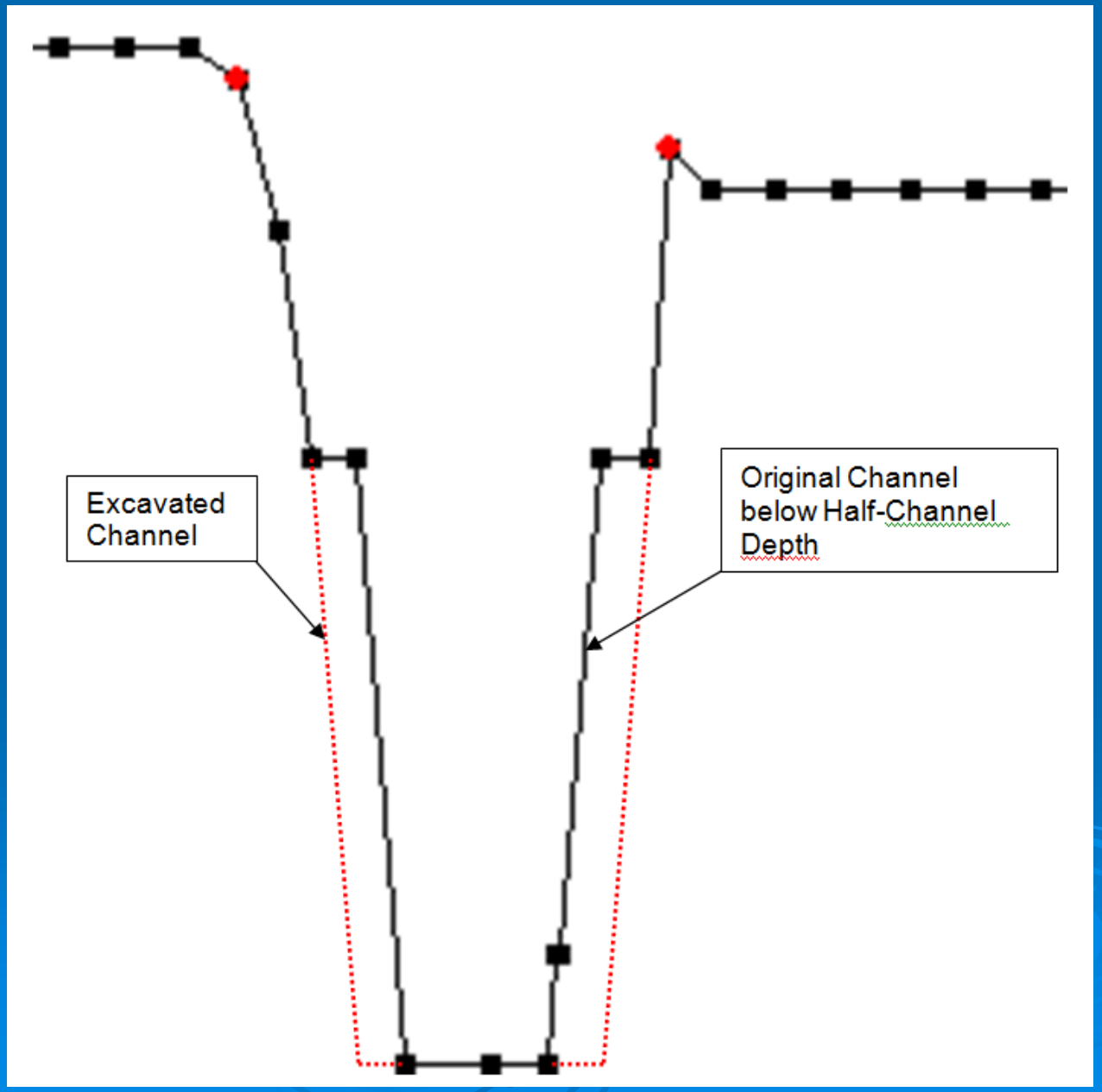
Reasons for Channel Excavation

- **Compensatory Conveyance**
- **Compensatory Storage**
- **Bridge or Culvert Crossings**

Guidelines for Channel Excavation

- **If there is any widening – excavation below half-channel depth is not considered effective to storage or conveyance**

WHAT DOES THAT MEAN?


Excavated Channel
Original Channel below Half-Channel Depth

Compensatory Conveyance and Storage Guidelines

- **Guidelines:**
  - **Must be free draining if compensating for storage**
  - **Must be located at interval in which conveyance or storage was lost (i.e. between the 10-year and 100-year)**
  - **Must ensure no re-filling with restrictive covenant**

  IF AN ENCROACHED PORTION OF FLOODPLAIN IS USED FOR MITIGATION – A LOMR IS ALSO NEEDED

Floodway Storage Losses

- If a water surface is lowered, more water may be going downstream than in the pre-project condition
- Must consider loss of storage
  - If storage loss is more than 10% in an unencroached model - will need to mitigate losses
  - Any floodway storage loss in an encroached model will require mitigation

Possible Changes Ahead

- Application and Permit Fees
- Conversion of Statewide Permits to General Permits
  - Application submittal would always be required
- Unsteady Floodways

Questions