JENSEN HUGHES

Advancing the Science of Safety

MODELING OF FLOODING FLOW RATES THROUGH FLOOR DRAIN NETWORKS USING MATHCAD

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PRESENTATION TOPICS

- Introduction
- Modeling Approach
- Sample Problem
- Summary

INTRODUCTION

PROBLEM DESCRIPTION

- Large internal flood events can quickly inundate areas of the plant and cause damage to safety related equipment
- Floor drains can help provide one means to help mitigate the accumulation of water
- Water that flows through floor drains can also overflow drain sumps and cause further water damage to rooms at lower elevations
- Treatment of floor drains varies across the industry
  - No credit for floor drains
  - Conservative estimate based on hydraulic calculations for flow in low head sewage and drainage systems
  - Design flow rate assumed

INTRODUCTION

PURPOSE OF ANALYSIS

- Provide a simple methodology to realistically estimate floor drainage flow rates where mitigation is critical
- Method of approach must be scalable and able to be implemented at different plants
- Not meant to be a time-consuming research project

MODELING APPROACH

OUTLINE OF METHODOLOGY

- The flow of water through floor drains involves a network of piping that combines into one or more drain headers that eventually lead to sumps
- flow resistances can be combined using series and parallel flow configurations, much like resistances can be combined for series and parallel electric circuits
- For an electric circuit, the electric current is proportional to the electric potential divided by the circuit resistance: I = E/R
- For fluid flow, the flow rate (analogous to current) is proportional to the square root of the pressure head (analogous to potential) divided by the square root of the resistance

$$\dot{Q} = C \cdot d^2 \cdot \sqrt{\frac{\Delta h}{K}}$$

$\dot{Q}$ ≡ Flow rate
C ≡ Conversion constant
d ≡ Pipe diameter
Δh ≡ Head of water above drain
K ≡ Flow resistance coefficient

MODELING APPROACH

SERIES AND PARALLEL FLOW NETWORKS

- Since flow networks offer resistances analogous to electrical circuits, it follows that similar relationships can be defined for summing flow resistances in series and in parallel

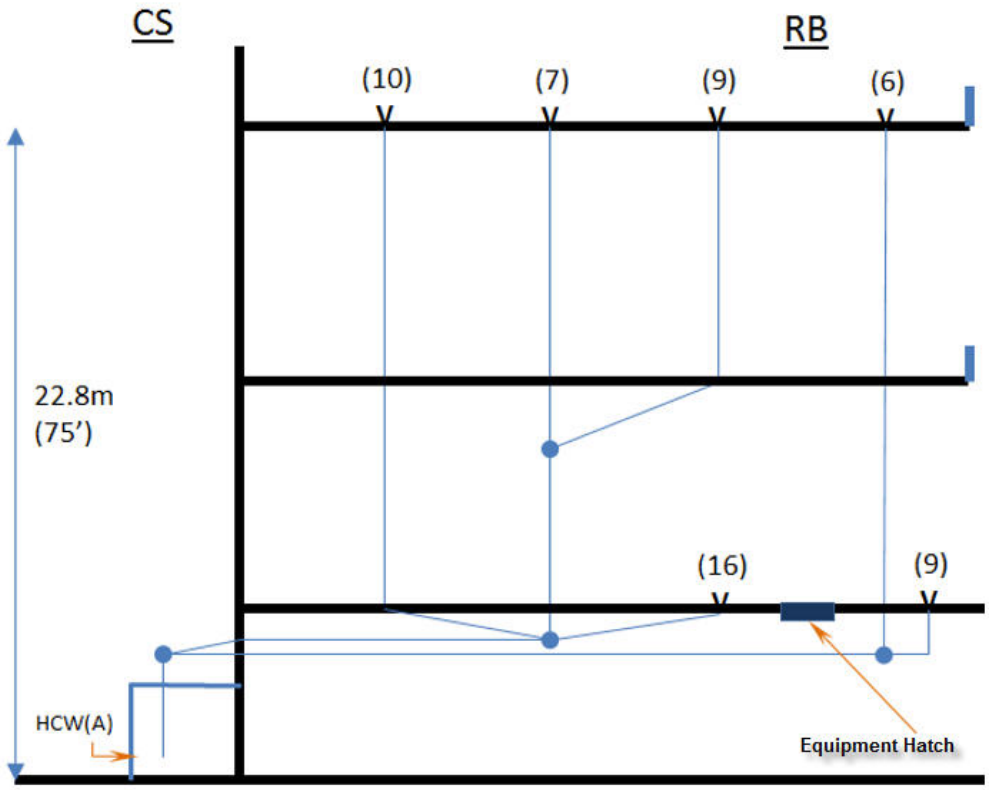
$$K_{series} = \sum K_i$$

$$K_{parallel} = \left[\frac{1}{\sum \left(\frac{1}{\sqrt{K_i}} \right)} \right]^2$$

SAMPLE PROBLEM

REACTOR BUILDING FLOOR DRAINS

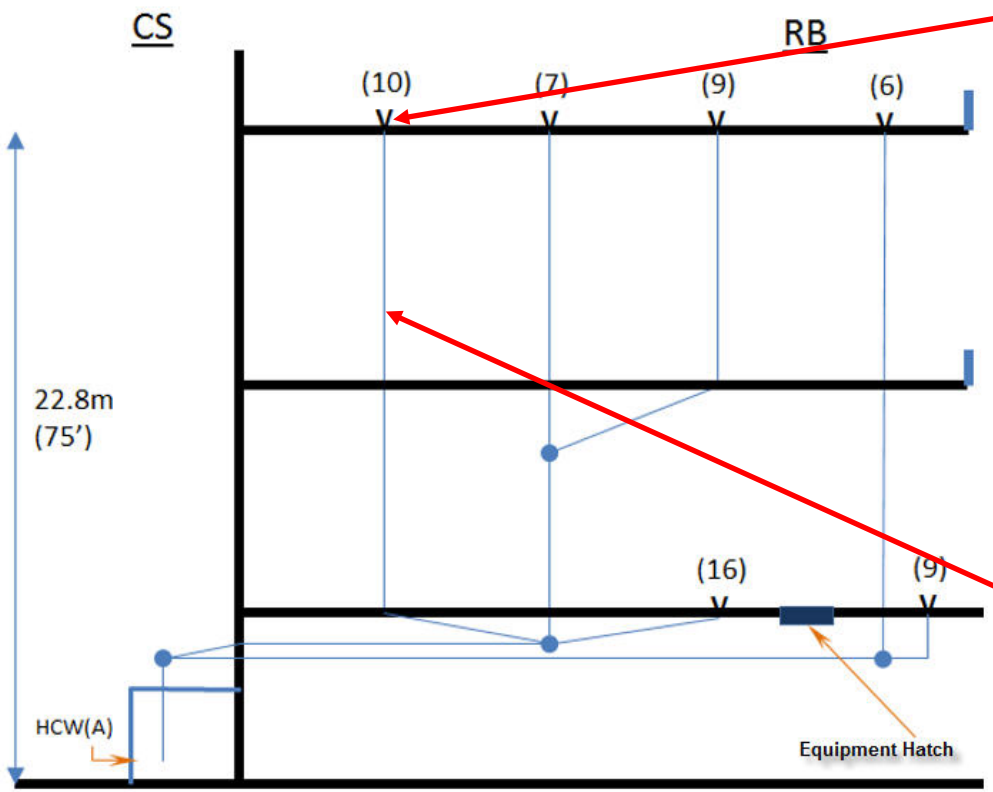
- Develop schematic of floor drain network using simple geometry and connections



SAMPLE PROBLEM

FLOW RESISTANCE ESTIMATES

- Develop constituent flow resistances from the top down



$$K_{B2a} := \left(\frac{1}{\frac{10}{\sqrt{K_{dm}}}} \right)^2$$

$$K_{dm} := \left(2K_{elbow} + K_{p1} + K_{ent}\right)$$

$$K_{ent} := 0.5$$

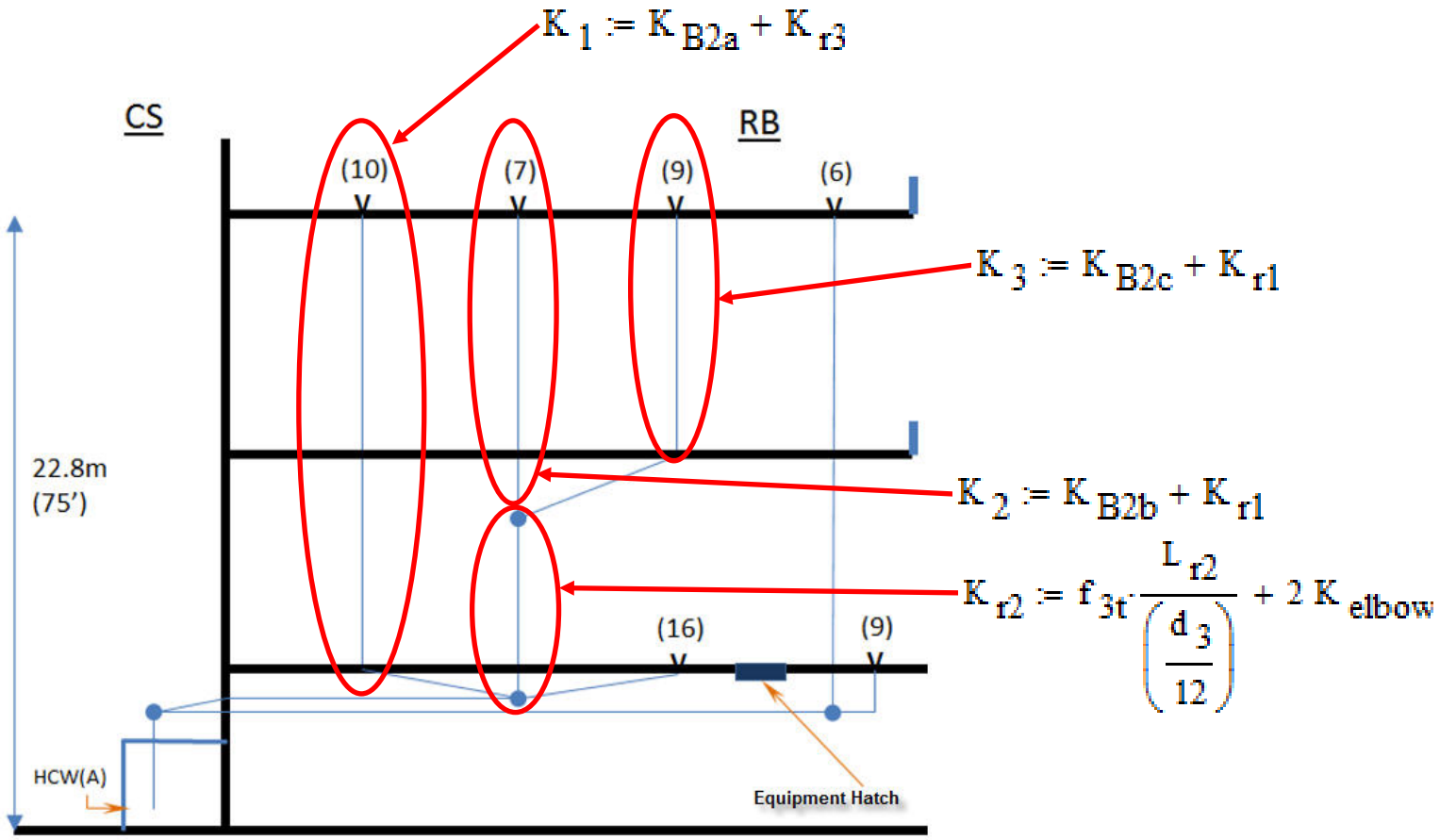
$$K_{elbow} := 30 \cdot f_{3t}$$

$$K_{p1} := f_{3t} \cdot \frac{L_{d1}}{\left(\frac{d_3}{12}\right)}$$

$$K_{r3} := f_{3t} \cdot \frac{L_{r3}}{\left(\frac{d_3}{12}\right)} + 2\,K_{elbow}$$

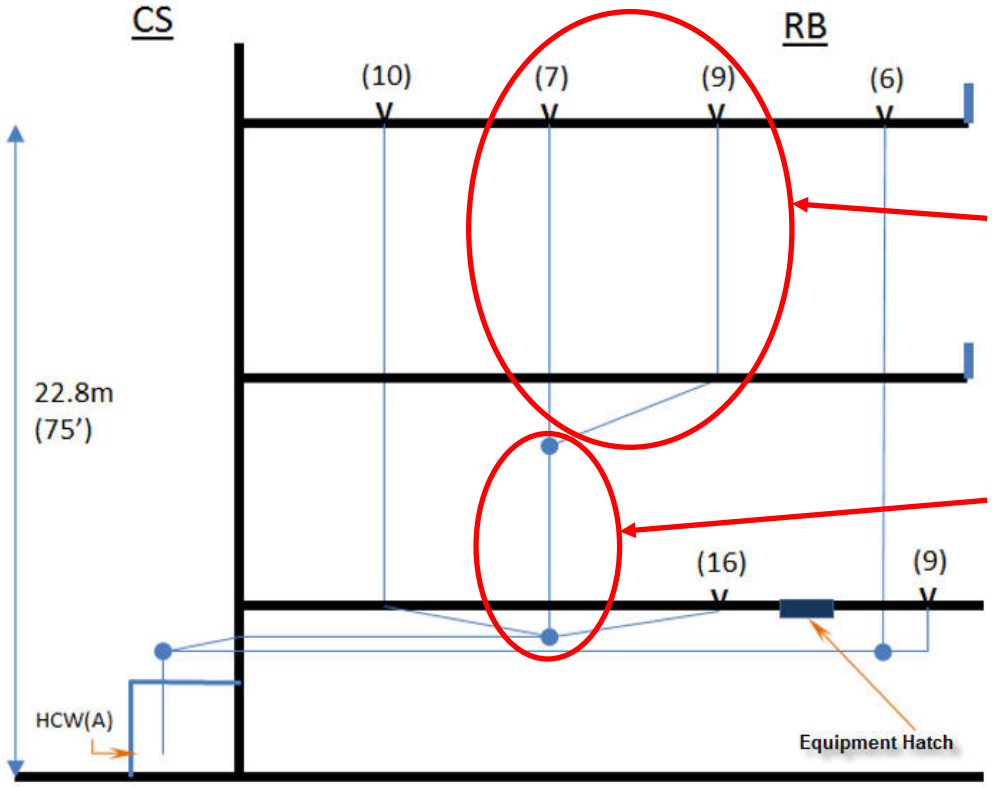
SAMPLE PROBLEM

MODEL FLOW RESISTANCES IN SERIES



SAMPLE PROBLEM

MODEL FLOW RESISTANCES IN SERIES AND PARALLEL

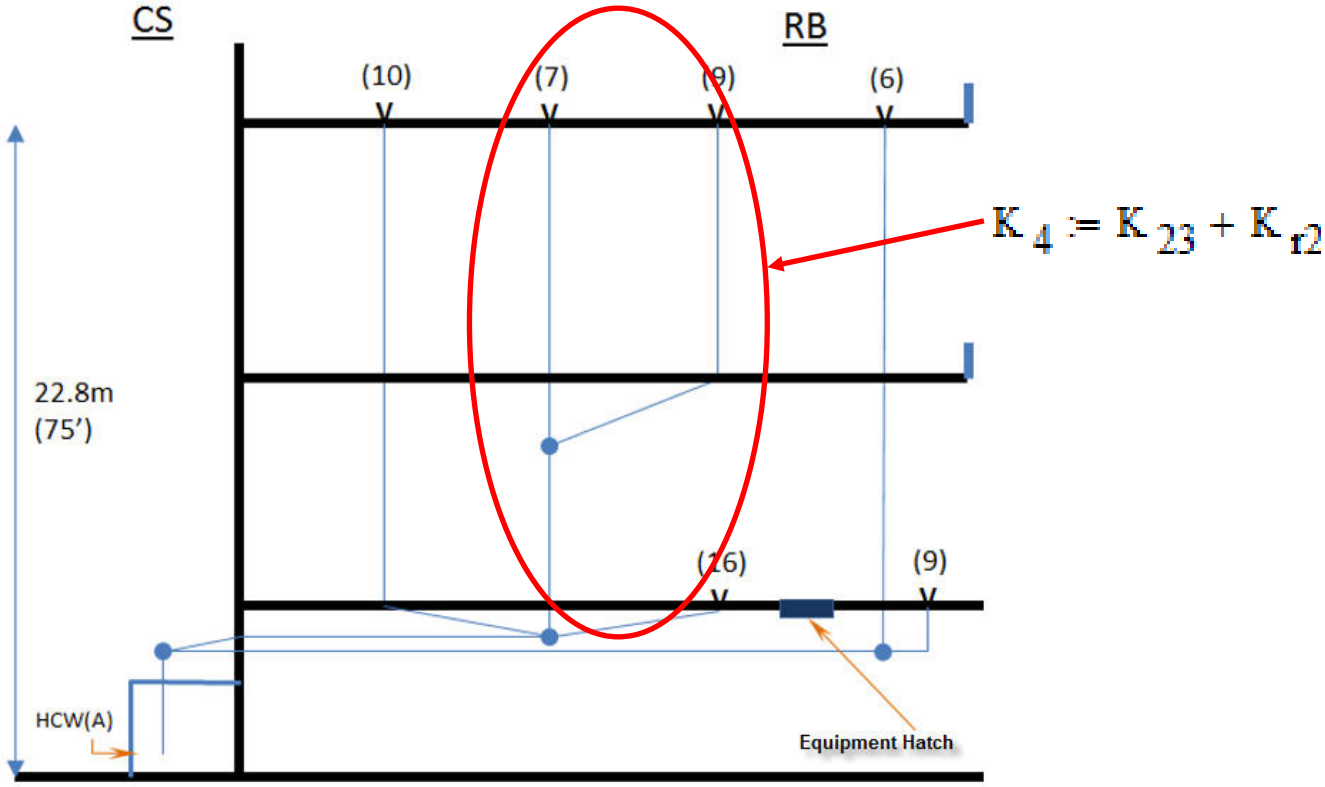


$$K_{23} := \left(\frac{1}{\frac{1}{\sqrt{K_2}} + \frac{1}{\sqrt{K_3}}} \right)^2$$

$$K_{r2} := f_{3t} \cdot \frac{L_{r2}}{\left(\frac{d_3}{12} \right)} + 2\,K_{elbow}$$

SAMPLE PROBLEM

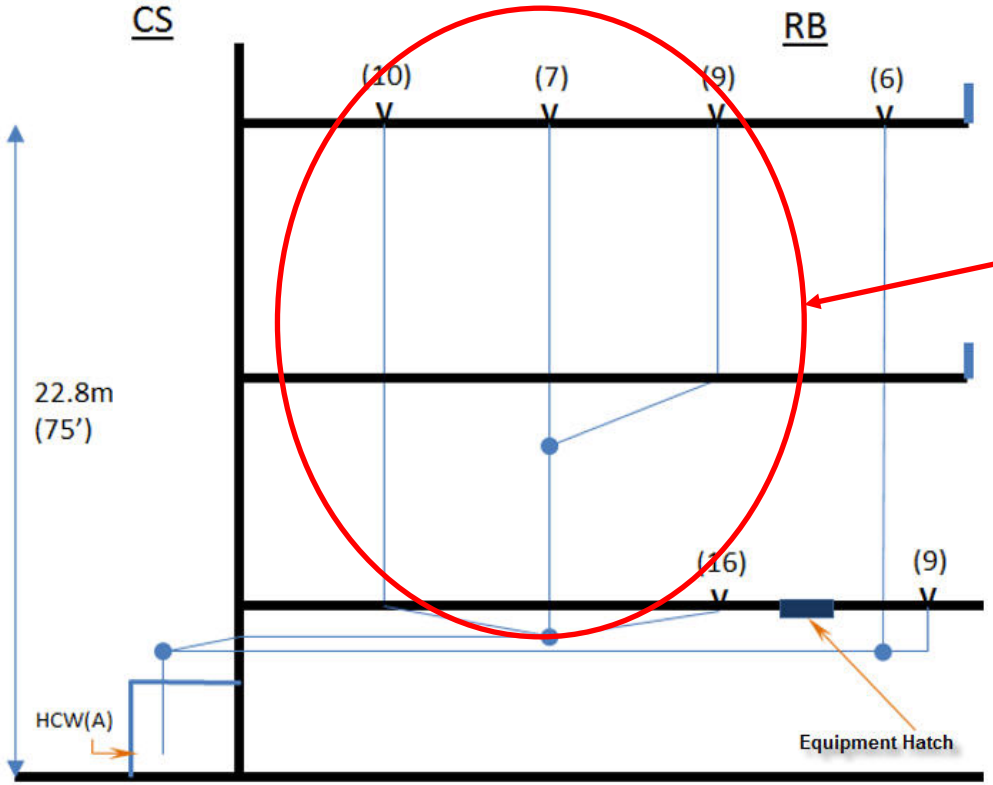
COMBINE SERIES AND PARALLEL SEGMENTS



$$K_4 := K_{23} + K_{r2}$$

SAMPLE PROBLEM

CONTINUE COMBINING FLOW BRANCHES



$$K_{14} := \left(\frac{1}{\frac{1}{\sqrt{K_1}} + \frac{1}{\sqrt{K_4}}} \right)^2$$

SAMPLE PROBLEM

OVERALL FLOW RESISTANCE COEFFICIENT

- Continue combining flow resistances until overall flow coefficient is derived

$$K_1 := K_{B2a} + K_{r3}$$

$$K_2 := K_{B2b} + K_{r1}$$

$$K_3 := K_{B2c} + K_{r1}$$

$$K_4 := K_{23} + K_{r2}$$

$$K_{23} := \left(\frac{1}{\frac{1}{\sqrt{K_2}} + \frac{1}{\sqrt{K_3}}} \right)^2$$

$$K_{14} := \left(\frac{1}{\frac{1}{\sqrt{K_1}} + \frac{1}{\sqrt{K_4}}} \right)^2$$

$$K_5 := K_{14} + K_{r4}$$

$$K_6 := K_{B2d} + K_{r3} + K_{r4}$$

$$K_{56} := \left(\frac{1}{\frac{1}{\sqrt{K_5}} + \frac{1}{\sqrt{K_6}}} \right)^2$$

$$K_{B2A} := K_{56} + K_{r5}$$

resistance coefficient for network of floor drains from B2 leading to HCW(A)

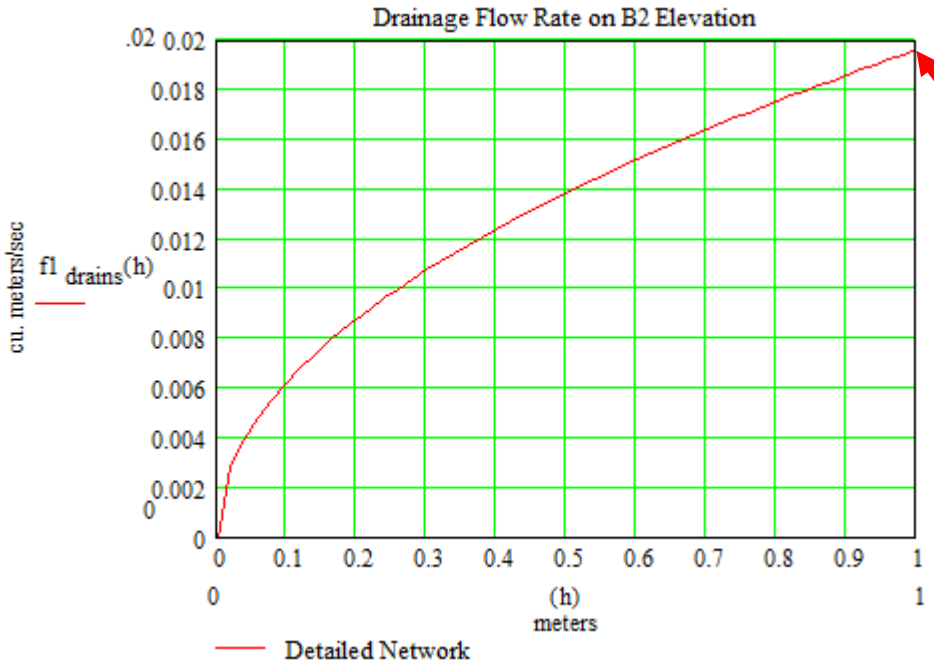
$$K_{B2A} = 5.317$$

SAMPLE PROBLEM

FLOOR DRAIN NETWORK FLOW RATE

- Flow rate is dependent on head of water above opening of floor drain

$$fl_{drains}(h) := \left(d^2 \cdot \sqrt{\frac{h}{K_{B2A}}} + d^2 \cdot \sqrt{\frac{h}{K_{B2B}}} \right) \cdot 3.478 \cdot 10^{-6} \quad (m^3/s)$$



~310 gpm at water height of 1 m (drain dia. of 3”)

SUMMARY

INSIGHTS GAINED FROM STUDY

- Flow networks analogous to electrical networks, but with square root dependency
- Resistance coefficients are based on a particular diameter of pipe, so ensure coefficients are scaled to be consistent with the same diameter
- Network models are constructed based on simplistic assumptions
- Although methodology is simplistic, it can still be time consuming to construct
- This detailed treatment should only be used for risk-significant scenarios where time for flood mitigation is critical

QUESTIONS?

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