ClimRunoff

- Funding from Norwegian Road Authority (Statens Vegvesen)
- Concerns about infrastructure due to climate change
  - More rain, more intense storms
  - More freeze-thaw cycles and increased winter runoff
  - Potential for road and rail closures and damage
- Focus on winter conditions and snowmelt
Current Culvert Sizing Methods

- Rational method \( Q = C i A \) is recommended for small areas (2 to 5 km\(^2\))
- Only four runoff coefficients listed by road authority
  - Impervious
  - Gravel
  - Agricultural
  - Green areas and forest
- Do not account for winter conditions or soil types
- Prior studies indicated the Rational method was insufficient for winter conditions and climate change
Winter in southern Norway

Jan 8, 2009
Winter in southern Norway

Jan 12, 2009
Winter in southern Norway

Feb 9, 2009
Winter in southern Norway

Feb 9, 2009
Winter in southern Norway

- Mild winters in coastal areas of southern Norway
- Probable winter changes from climate change:
  - Less snow, more rain
  - Snowpacks will be ‘ripe’ – close to 0°C
  - More frequent freeze-thaw cycles
  - Potentially more frozen soil due to less snowcover
  - More runoff due to frozen soils and ripe snowpacks
Modeling Approach

- Calibrated hydrologic model already used in project area, a 449 ha agricultural/forested watershed
  - LISEM: Limburg Soil Erosion Model (Netherlands)
  - No built-in snowmelt routing
- Snowmelt model chosen to provide input to LISEM
  - Utah Energy Balance Snowmelt Model (Utah State)
Utah Energy Balance Model

- Energy and mass balance approach

- **Snowpack**
  - Internal Energy $U$ (kJ/m$^2$)
  - Snow-Water Equivalent $W$ (m)
  - Snowpack Characteristics
    - $K_{sat}$: Hydraulic Conductivity
    - $L_c$: Liquid Holding Capacity
    - $\rho$: Snowpack Density

- **Turbulent Fluxes**
  - $Q_h$
  - $Q_e$
  - $E$

- **Net Energy in/out from Radiation**
  - $Q_{rad}$
  - Longwave & Shortwave Radiation (in/out)

- **Mass and Energy in from precipitation**
  - $Q_p$
  - $P_r$, $P_s$

- **Soil**
  - Ground Heat Flux $Q_g$

- **Mass and Energy removed by melting**
  - $Q_m$
  - $M_r$
Model Calibration

UEB Uncalibrated Snowpack Snow Water Equivalent and Measured SWE

Area-Averaged Measured W
UEB Model Results
UEB Calibrated Snowpack Snow Water Equivalent and Measured SWE
April 2009 Rainfall on Snow

- 25mm rain event on a ripe snowpack
  - 44mm of runoff due to snowmelt
- Output from UEB was input for LISEM
  - UEB output includes rainfall and snowmelt
- LISEM was roughly calibrated by reducing $K_{sat}$
  - Crude calibration due to lack of field/lab data
April 2009 Rainfall on Snow

Comparison of LISEM Results and Measured Outflow at E18

Poor estimation of timing and magnitude of $Q_{peak}$
April 2009 Rainfall on Snow

E18 Measured Discharge and LISEM Modelled Discharge at 2% Infiltration

Date
Discharge, Q (m$^3$/s)

LISEM Modeled Q
Measured Q
April 2009 Rainfall on Snow

E18 Measured Discharge and LISEM Modelled Discharge at 1% Infiltration

Discharge, Q (m³/s)

Date

Measured Q
LISEM Modeled Q
More research needed to:

- Characterize frozen soil
  - $K_{\text{sat}}$
  - macropores
- Model long-term climate change impacts to quantify the change in return period flow rates
Quick Clay
Quick Clay
Quick Clay
Quick Clay
Questions?

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