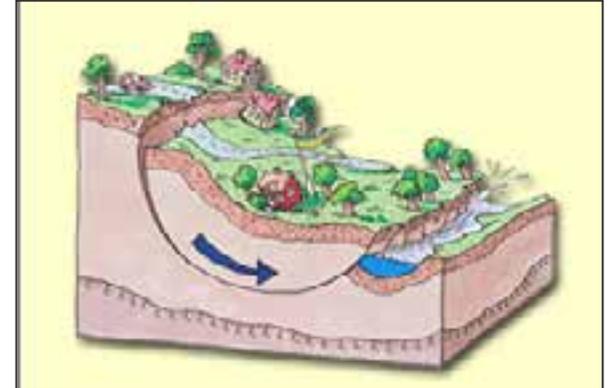
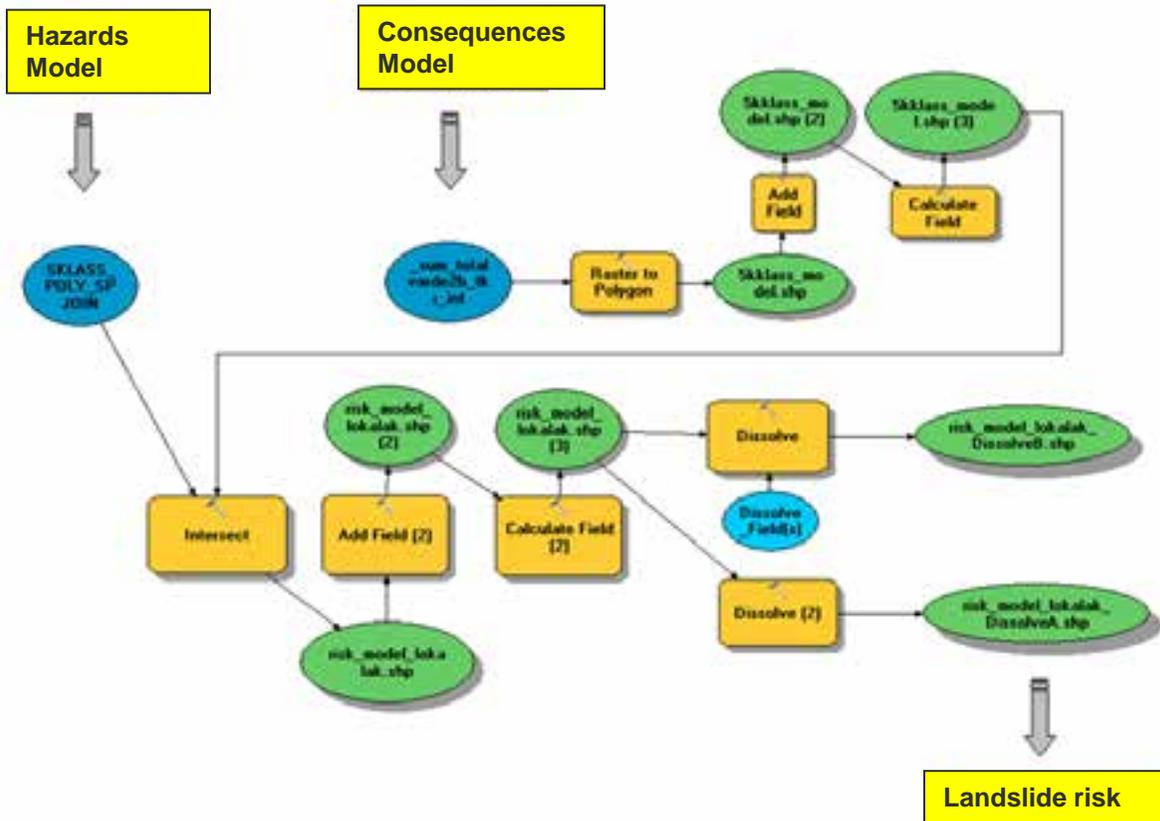
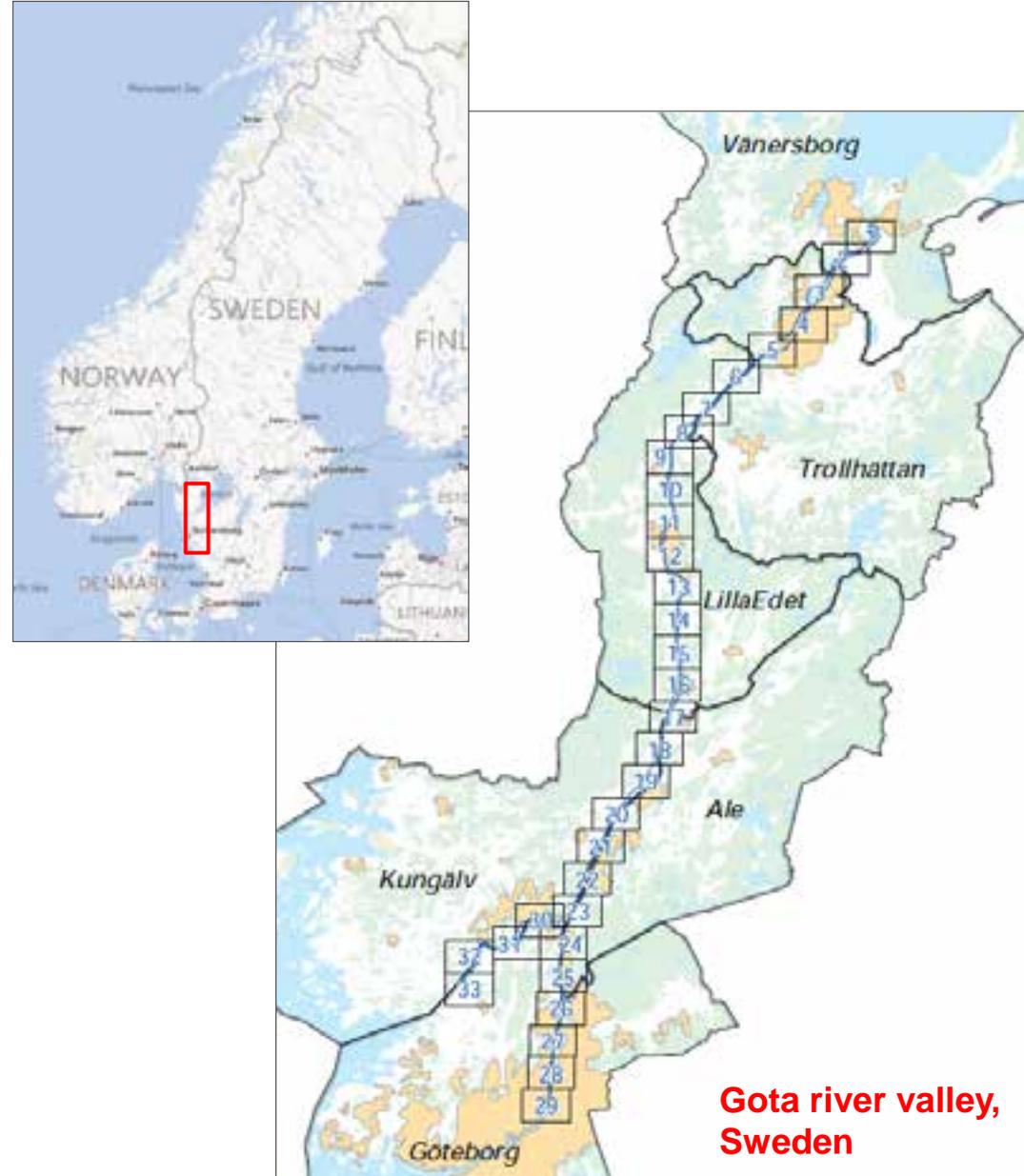


Geoprocessing in landslide risk assessment and mapping



Mats Oberg, SGI
 ESRI International User Conference
 11 July 2013, San Diego

- Causes for landslides
- Risk = Probability of Hazard * Consequences
- ArcGIS for modelling and map production (Model Builder, Spatial Analyst, Data driven pages) in a 3 year project in Gota river valley, Sweden



Gota river valley, Sweden

Occurred landslides in Sweden



Surte 1950, 1 dead, 300 homeless, 30 damaged houses

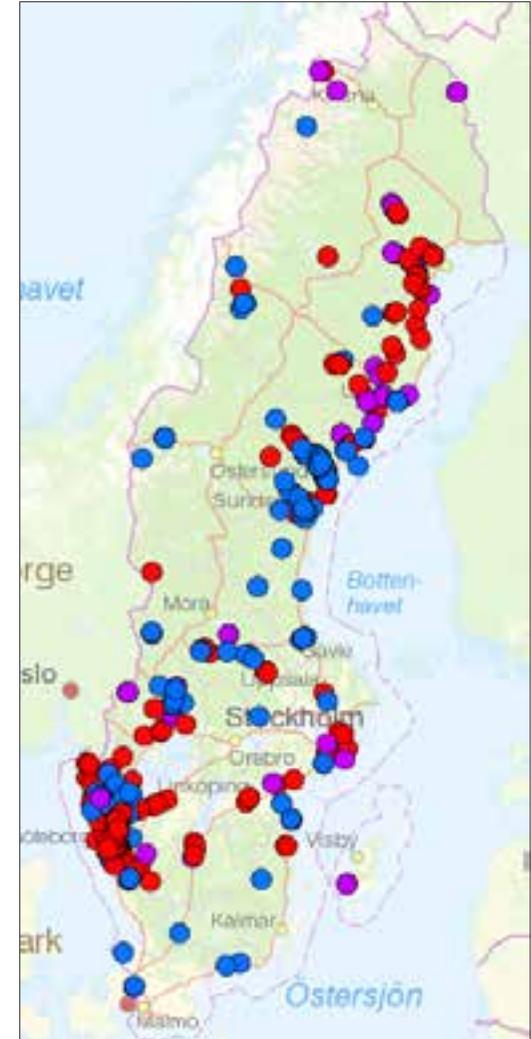


Tuve 1977, 9 dead, 300 injured



Småröd 2006, societal cost > 500 Mkr
Trigger: (improper) dumping of filling / earth masses

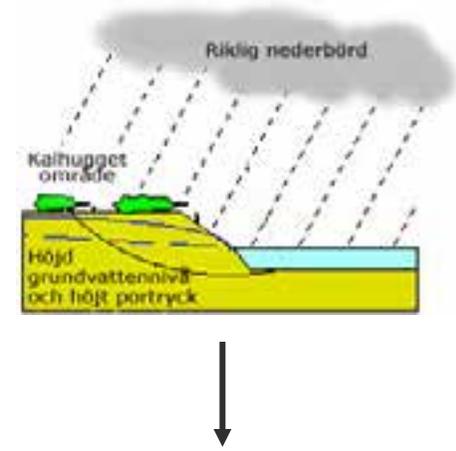
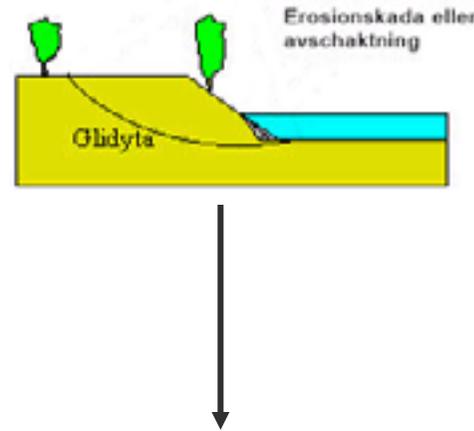
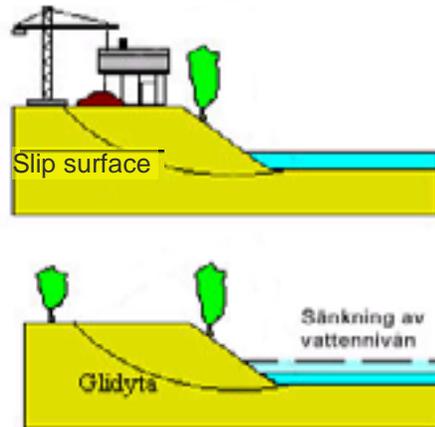
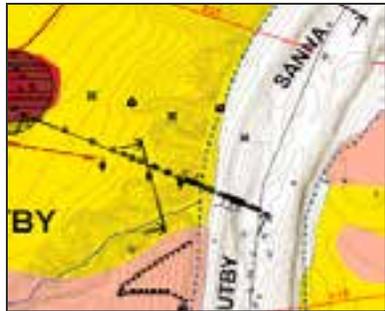
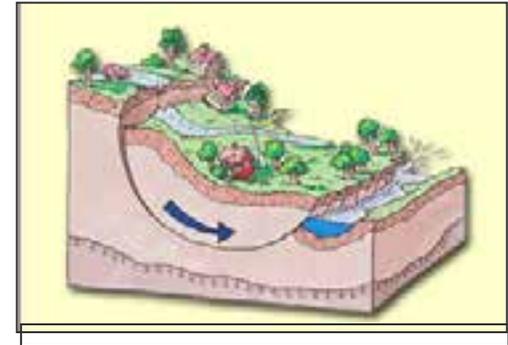
Geotechnical engineering - is the branch of civil engineering concerned with the engineering (technical) behavior of earth materials. Geotechnical engineering uses principles of soil mechanics and rock mechanics to investigate subsurface conditions and materials.



From <http://gis.swedgeo.se/skred/>
(~800, compare Norway >10.000)

Causes for landslides

- Soil geology and topography/geometry (slope) are two important parameters for assessment of the **preconditions** for landslide. Landslide **risk mapping/analysis** (probability of a hazard and consequences) is a more extensive task.



Topography/geometry (land and in river)
 Geology, stratigraphy (for silt and clay)
 Hydrology

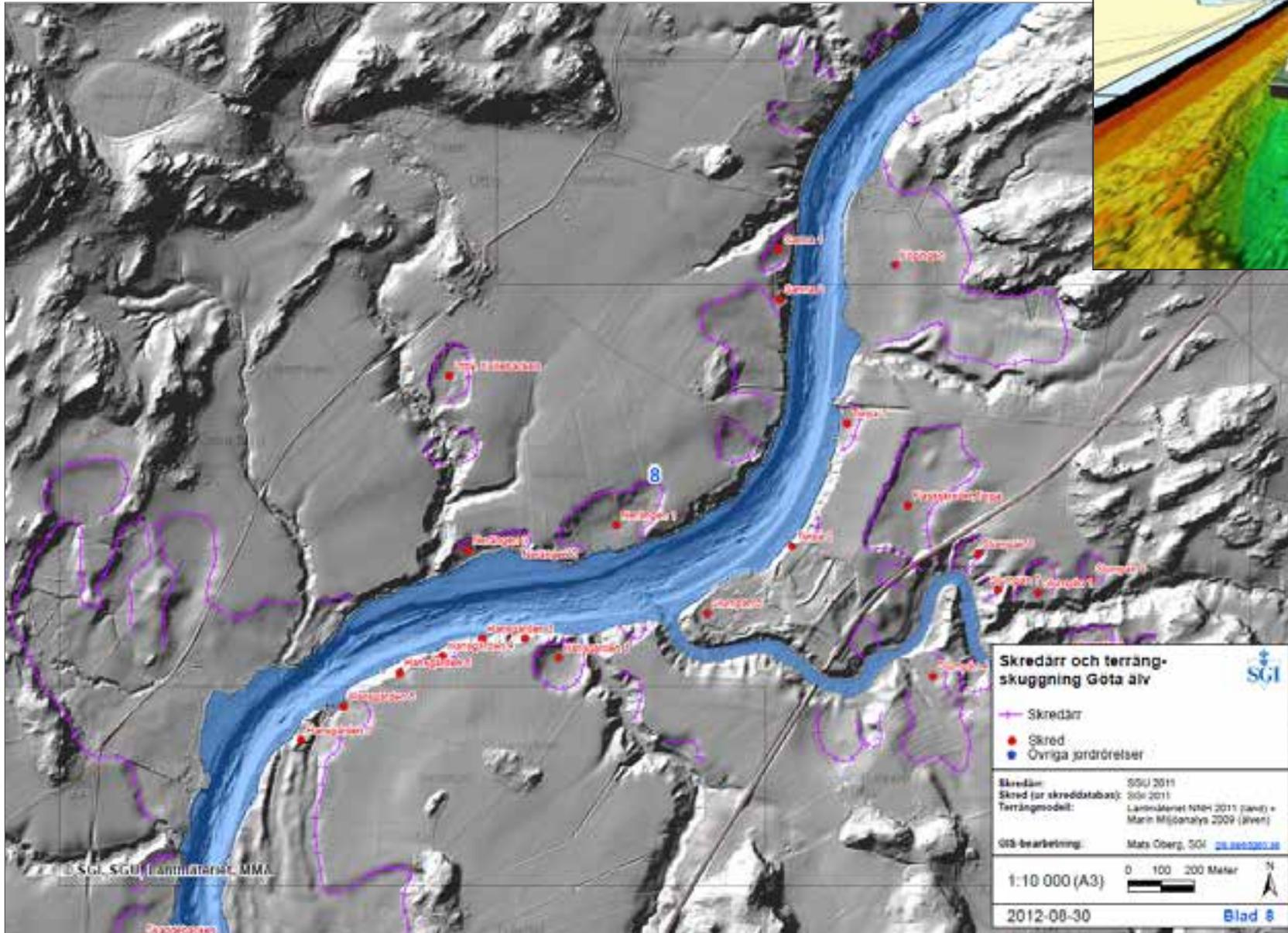
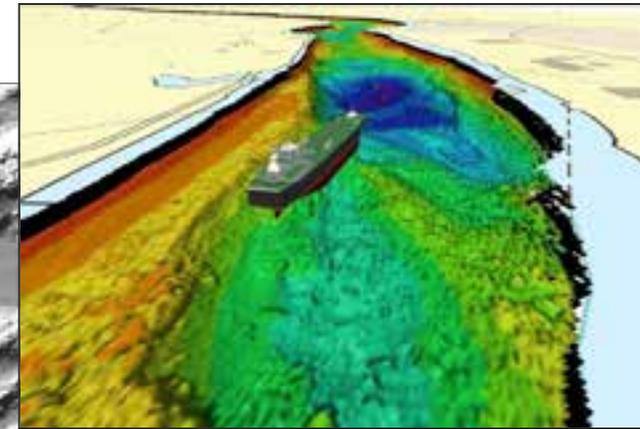
Soil mechanics - driving and resisting forces (which may change due to buildings/construction on land, change of the river's water level)

Erosion – changed flow in the river will affect the topography/geometry in the long term...

Precipitation/rain fall - can increase groundwater level and pore pressure in the soil (silt/clay)

Landslides is indeed a 3D problem...

Terrain model (land and in river)



Hillshade – standard ArcGIS 3D tool

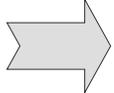
Risk = probability of Hazard occurrence * Consequences (vulnerability of exposed elements)

§ Landslide mapping of Göta river valley (some 200 km shoreline) with regard to climate changes. 3 year project. 40 reports incl. maps annex A3 1:10.000. Finished 31 March 2012.

Geotechnical evaluation and assessment based on field investigations (boreholes) and slope stability calculations

60 of 100MSEK

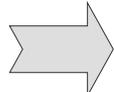
(~ 14 million \$)



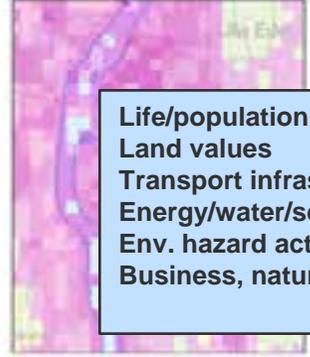
Probability of landslide



Data from Statistics Sweden, National Land Survey, National Road Adm., Communities, County Adm. etc.



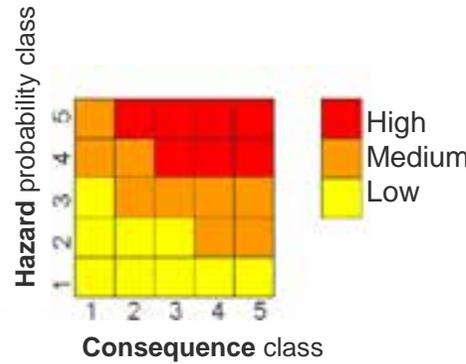
Consequences (in MSEK)



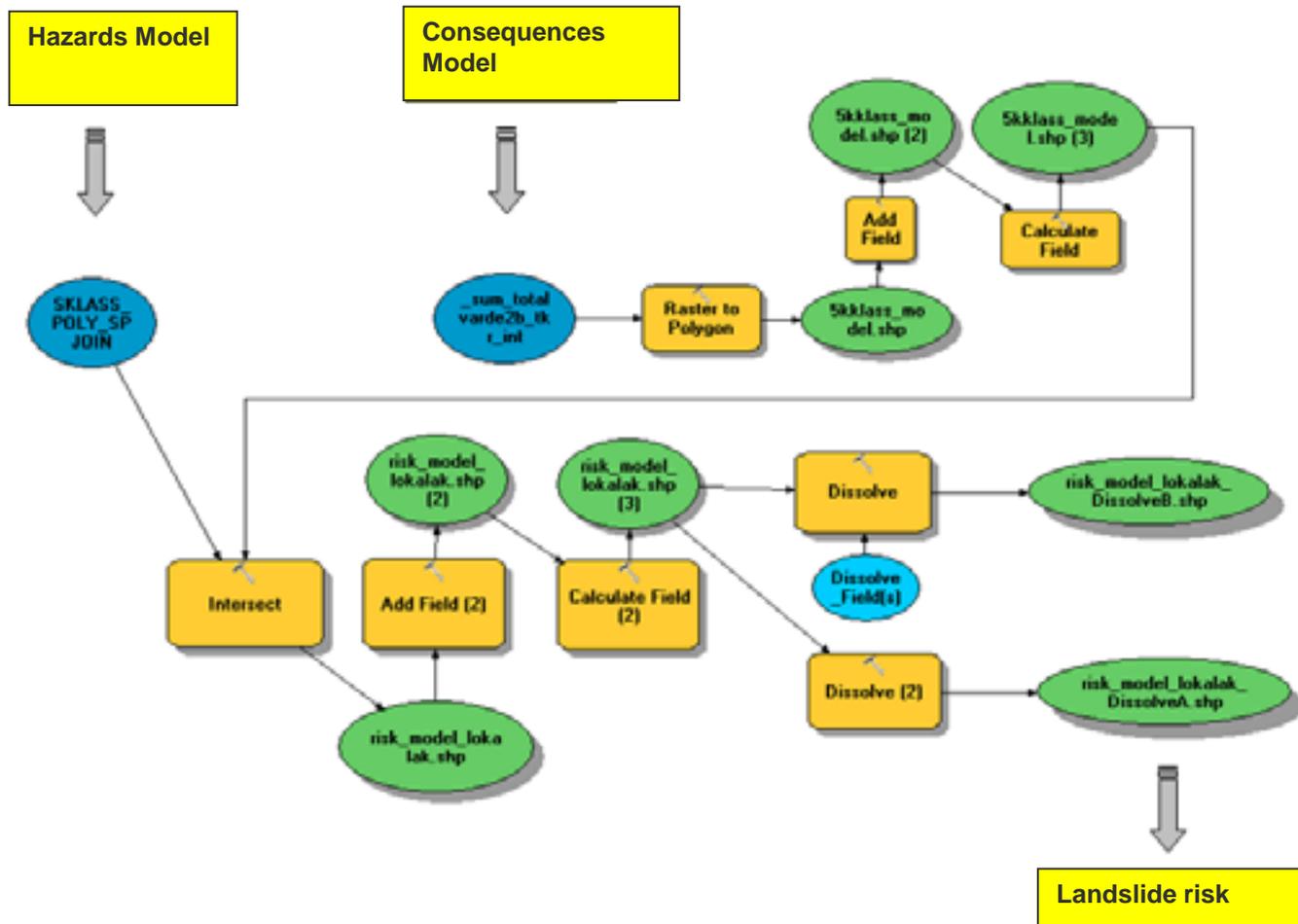
- Life/population
- Land values
- Transport infrastructure
- Energy/water/sewage
- Env. hazard activities
- Business, nature, culture

MSEK per 100m-square, i.e. a "cost" per each square

Risk



Risk model adopted to ArcGIS Model Builder



Screenshot:
C:/temp/camstudio_4Bintersect.avi
http://gis.swedgeo.se/dokument/camstudio_4Bintersect.avi
 USB...

Unmanageable (very time consuming) to do (once) without modelling it. There were constant changes in input data → must be able to run the model through again and again (approx. over 100 times)

Creation of probability classes (polygons)

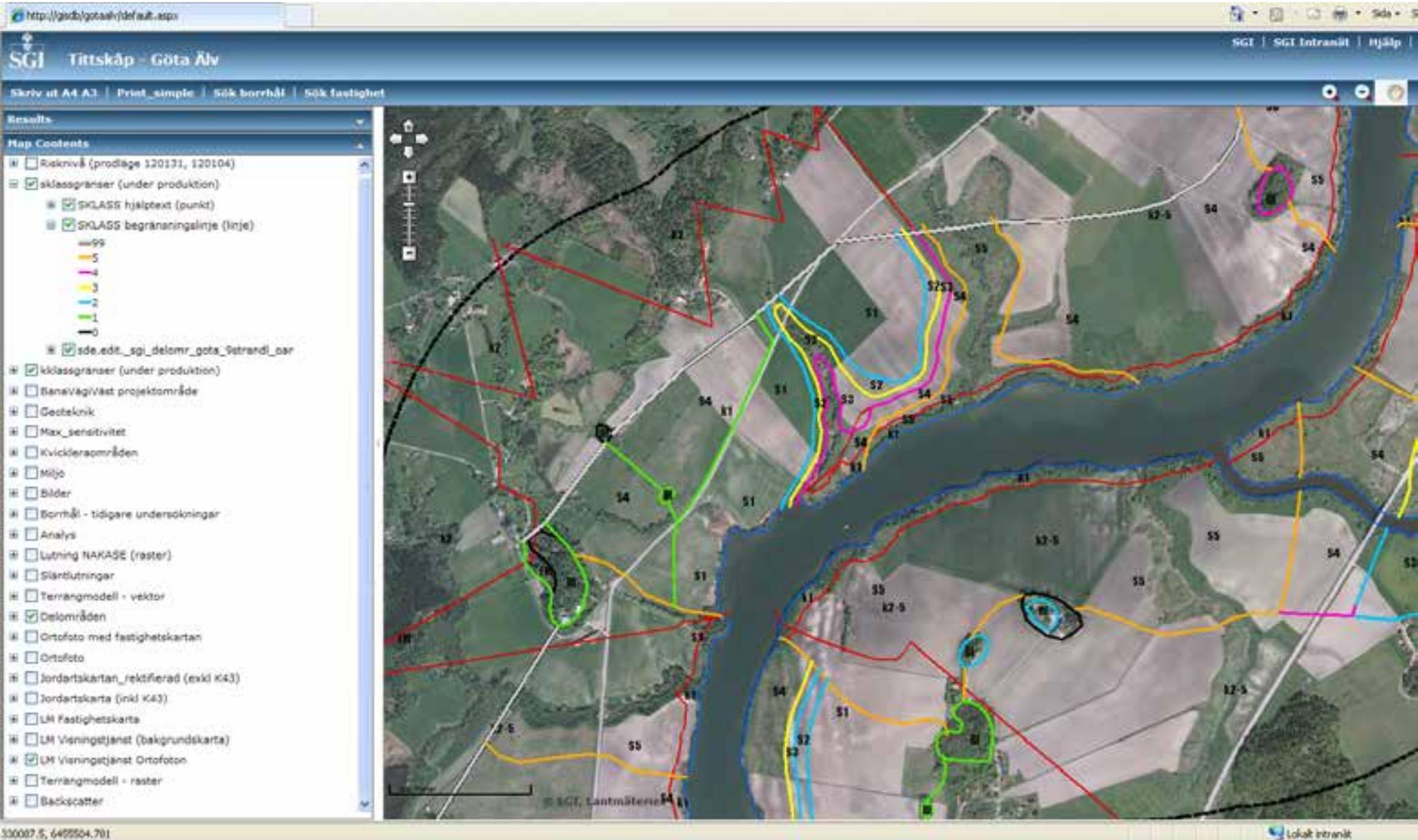
The screenshot displays a GIS application window titled "Edit SKLASS". The interface includes a "Map Contents" panel on the left with various layers checked, such as "edk_sklass", "KVICKLERAOMRÅDEN", "MAX_SENSITIVITET", "GBOTEKNIK", "BORRHÅL TIDIGARE UNDERSÖKNINGAR", "Delområden", "Analys (riskklasser mm äldre)", "Terrängmodell - vektor", "Jordartskartan (ej #43)", "LM fastighetskartan", "Lutning (raster)", "Ortofoto", and "LM Visningsönskt".

The central editing panel, titled "Editera SKLASS begränsningslinjer", contains the following sections:

- Edit:** A dropdown menu set to "SKLASS begräns".
- Create SKLASS begränsningslinje (linje):** A section with color-coded line styles.
- Edit SKLASS begränsningslinje (linje):** A section with various editing tools like pan, zoom, and delete.
- Edit SKLASS begränsningslinje (linje) Attributes:** A section with the text "No features selected" and a "Settings" button.

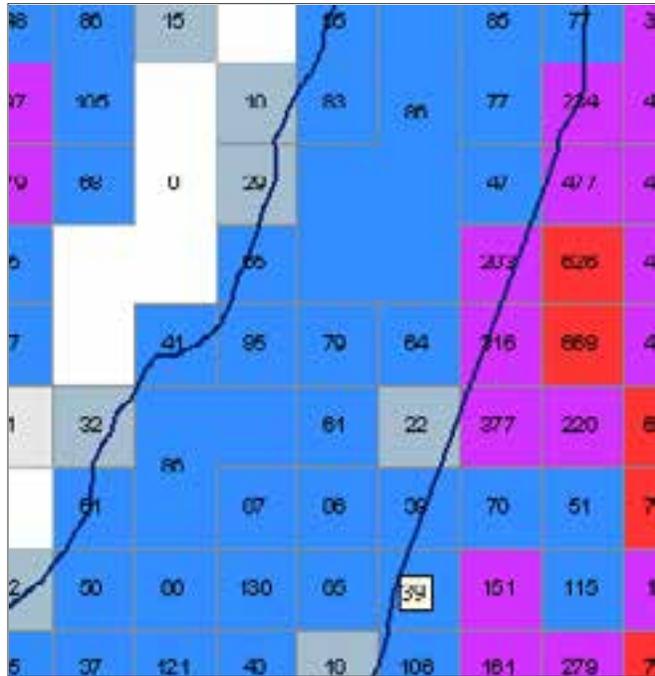
The main map area shows a topographic map with several colored polygons (green, red, blue, pink) representing different probability classes. A central panel displays a vertical profile of a slope with various parameters, including "V22870" and "V24250". An inset in the top right shows a cross-section of a slope with soil layers (Lag 1-5) and a failure surface.

Drawing of lines between the five probability classes is a qualified geotechnical engineering assessment – cannot be entirely automated! (however "Spatial Join" is used)



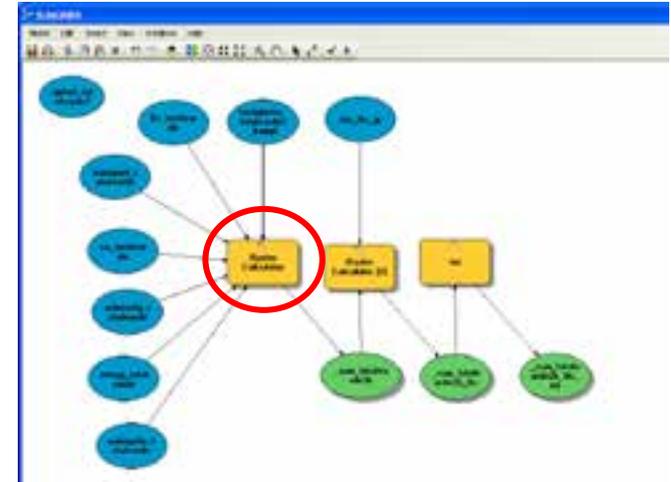
The geotechnical engineers web based viewer, some 100 layers/themes, a lot of symbology...

Creation of consequence classes (Raster Calculator à Raster2polygon)



GRIDCODE

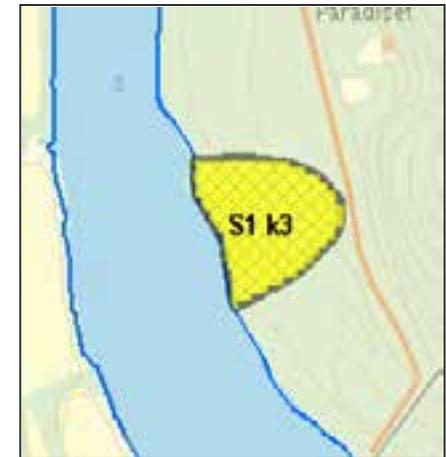
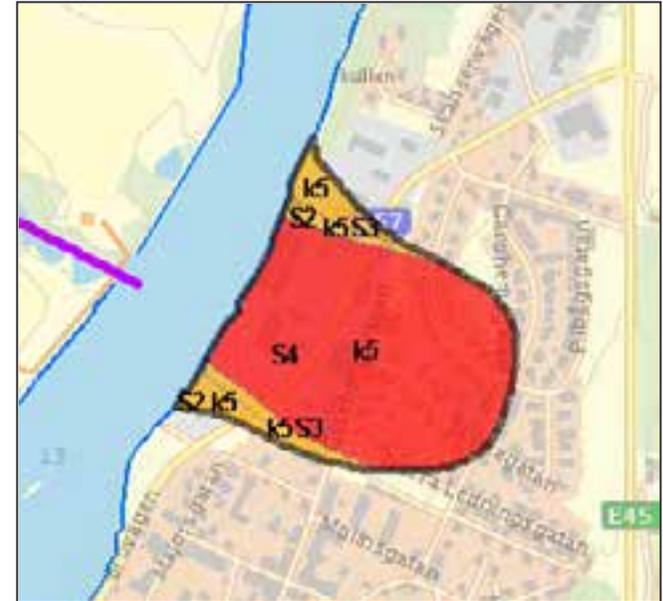
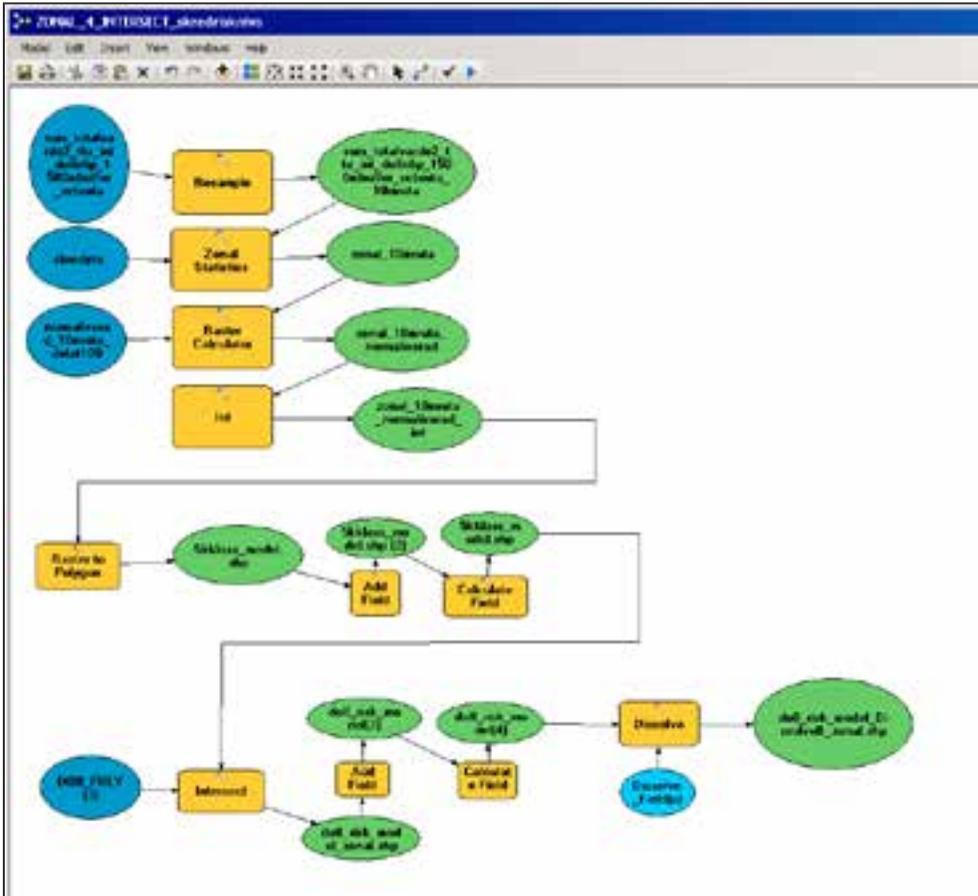
- 0
- 1 - 6
- 7 - 35
- 36 - 150
- 151 - 600
- > 600 MKR (~ 100 million \$)



Spatial Analyst Raster calculator (Map Algebra) – an invaluable tool!



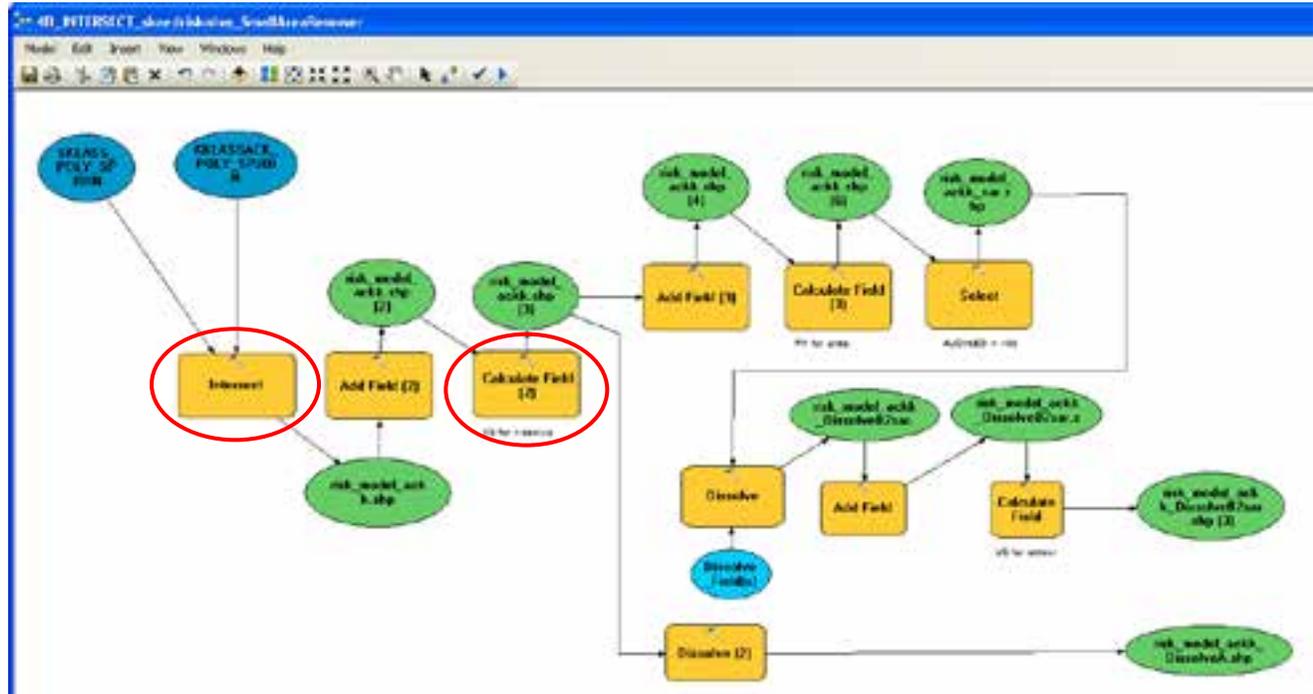
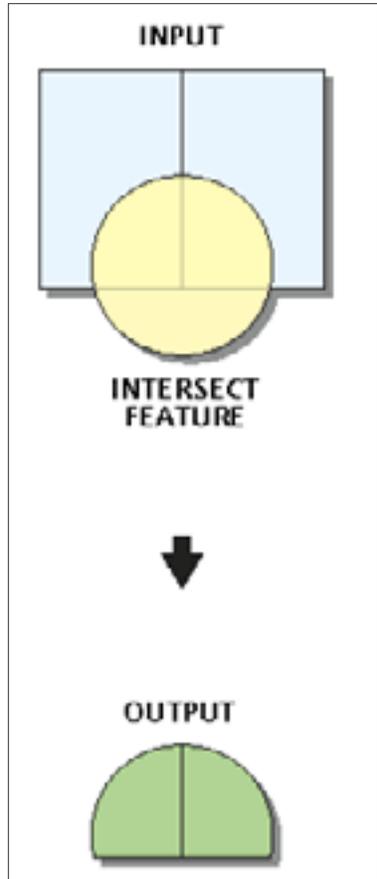
Spatial Analyst ZONAL statistics: the sum of costs under a defined ("known") landslide area



Over 90% of consequence cost (in this area) is related to:
life cost, transport infrastructure and land values

INTERSECT, one of many ArcGIS Tools which was used

```
Dim output
IF (([sklasstext] = "S5") AND ([kklasstext] = "k2" OR [kklasstext] = "k3" OR [kklasstext] = "k4" OR [kklasstext] = "k5")) OR (([sklasstext] = "S4") AND ([kklasstext] = "k3" OR [kklasstext] = "k4" OR [kklasstext] = "k5")) THEN
output = "HÖG"
ELSEIF
...
...
```



Data Driven Pages ArcGIS10

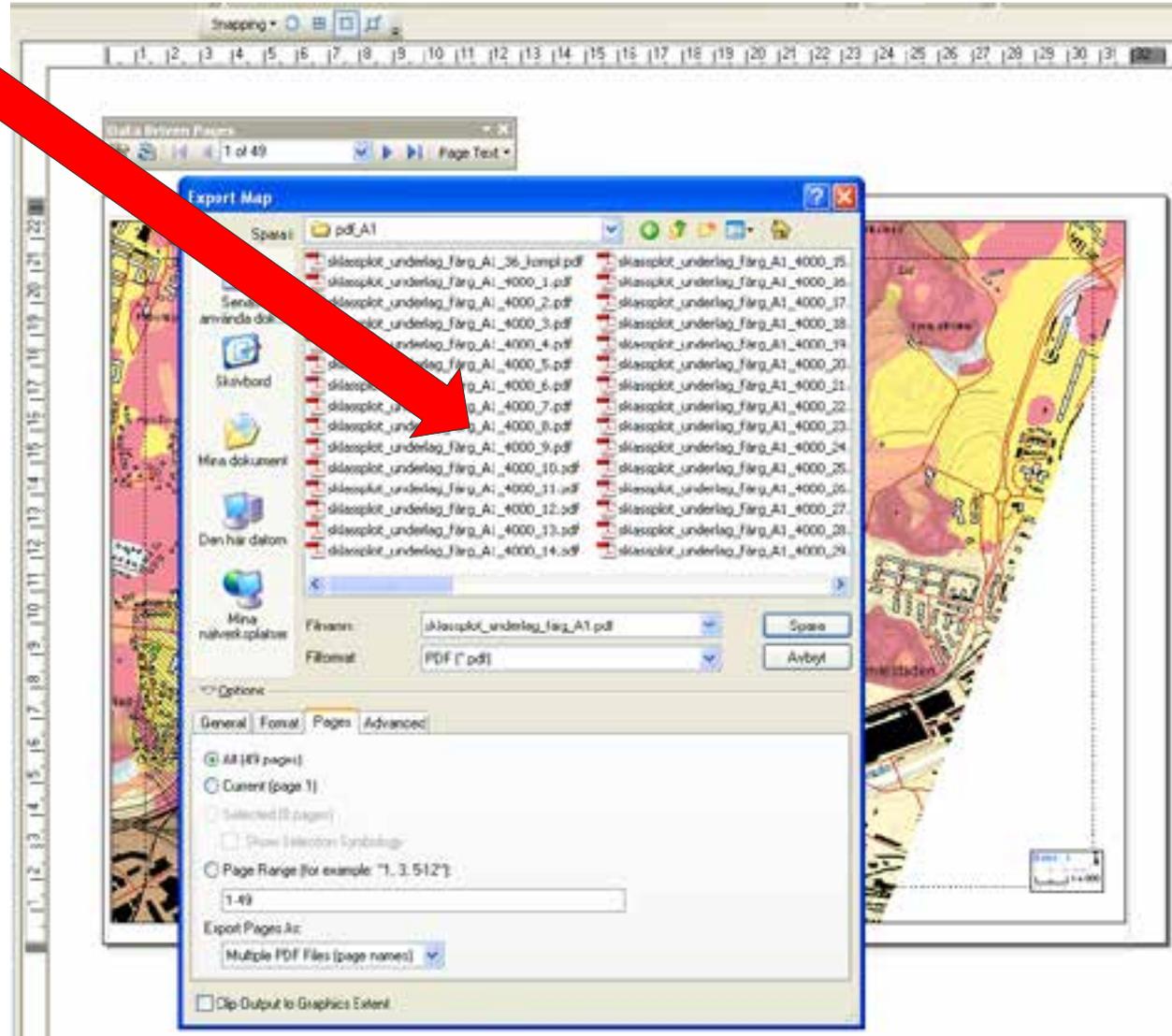
Very useful for creating PDF map series (e.g. 1:4000, 1:10,000, etc.)

§ Generate a large number of pdf's referenced to a fixed grid

§ Apply dynamic text such as Page Number, Date, values in an attribute field etc.

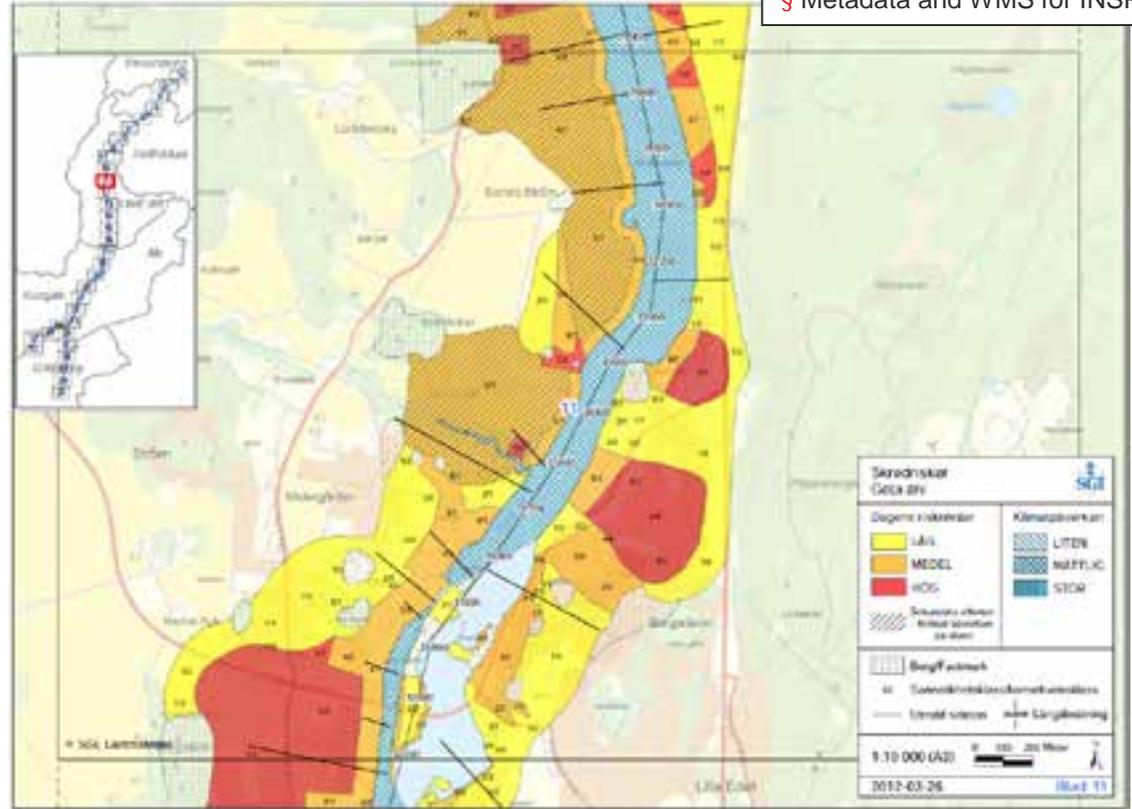
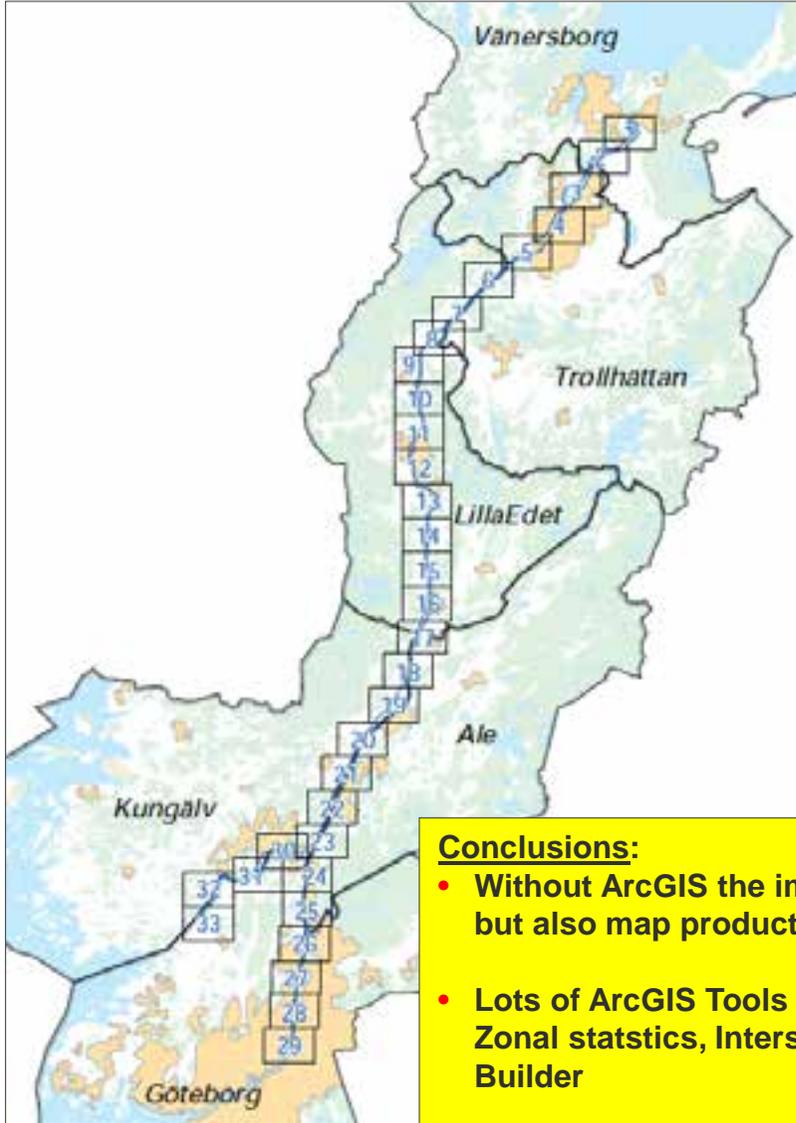
[Can autogenerate grids]

[Grid may be rotated, have a set overlap etc]



Final map products

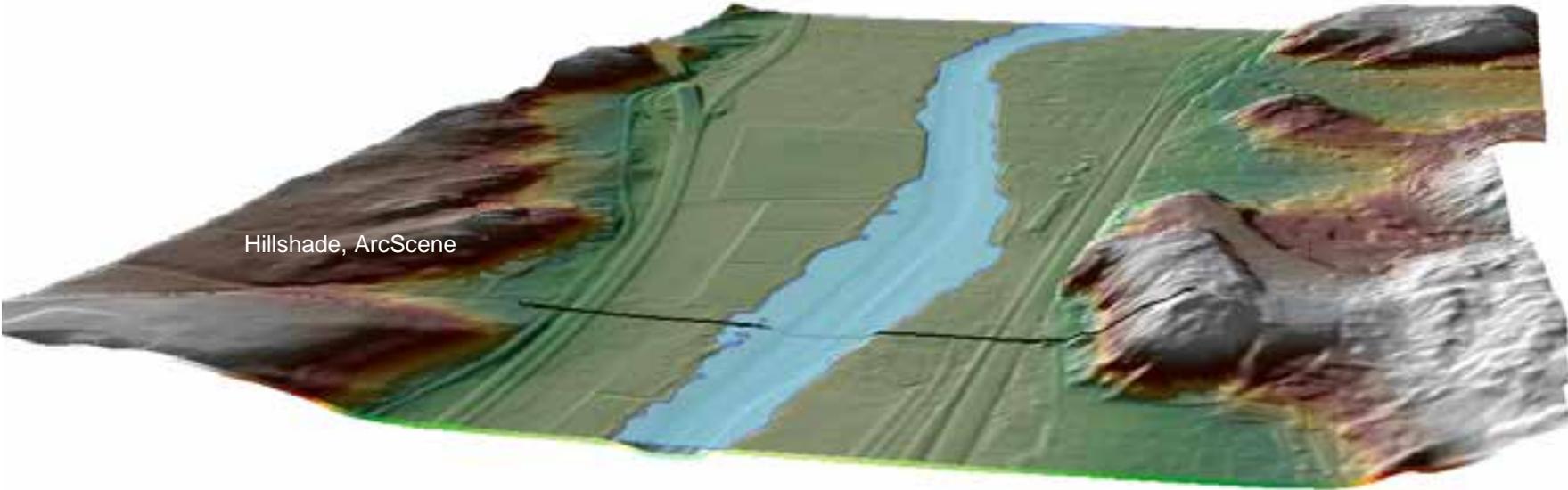
- § 33 sheets A3 1:10.000 pdf
- § WebGIS map applications
- § Metadata and WMS for INSPIRE



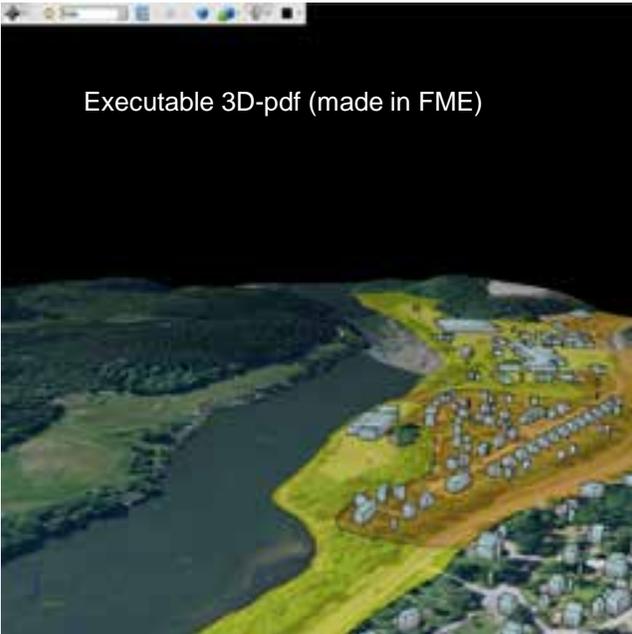
- Conclusions:**
- Without ArcGIS the implementation of the landslide risk assessment/mapping (particularly modelling but also map production) would – in practice - have been impossible!
 - Lots of ArcGIS Tools were used (web editing, Spatial join, Clip/Merge/Dissolve, Raster calculator, Zonal statistics, Intersect, hillshading, 3D profiles, Data driven pages etc) and implemented in Model Builder
 - The cost to lower the risk in all red and some orange areas is estimated to 6000 MSEK ~ 1 billion \$...

3D visualization, some examples

Hillshade, ArcScene



Executable 3D-pdf (made in FME)



Executable 3D model (coming soon on gis.swedgeo.se)



- +
 - WebGIS map applications
 - § Metadata and WMS for INSPIRE