A GIS tool for mapping of pump storage potential in Norway

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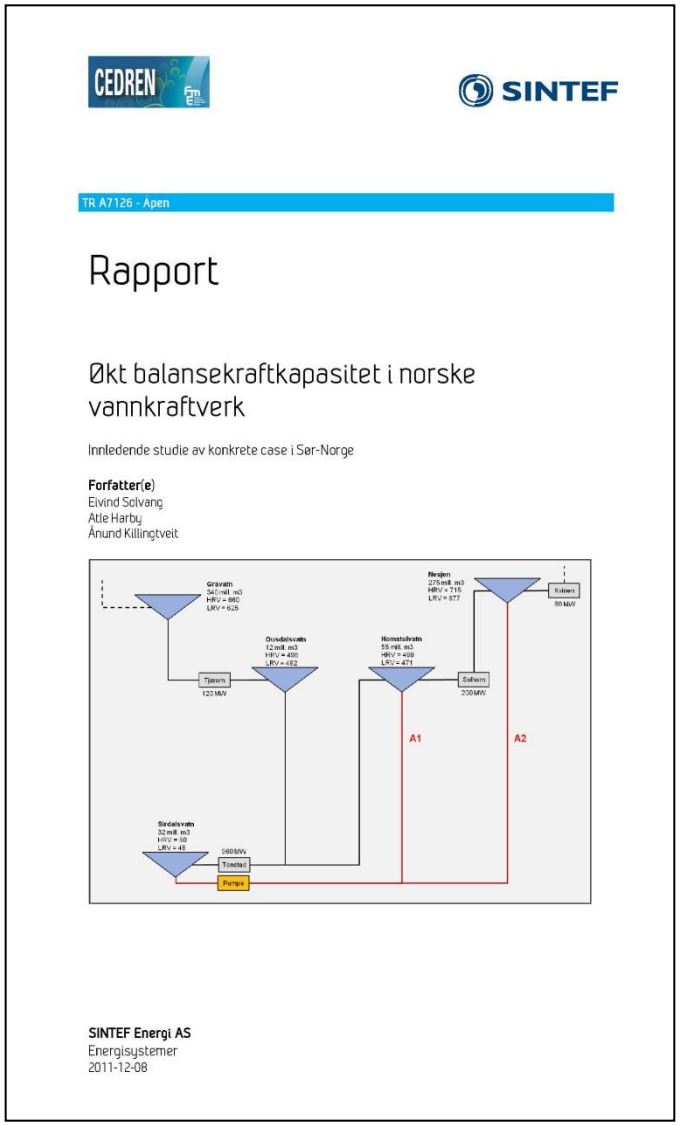
Background

- Large interest in Norway's potential for pumped storage hydropower (PSH) to develop renewable energy sources
- Pre-study from 2011 for southern Norway: selection of potential PSH connections based on expert knowledge
- GIS-tool: mapping for entire Norway based on documented selection criteria (first stage; no costs or reservoir interactions included)



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Rapport

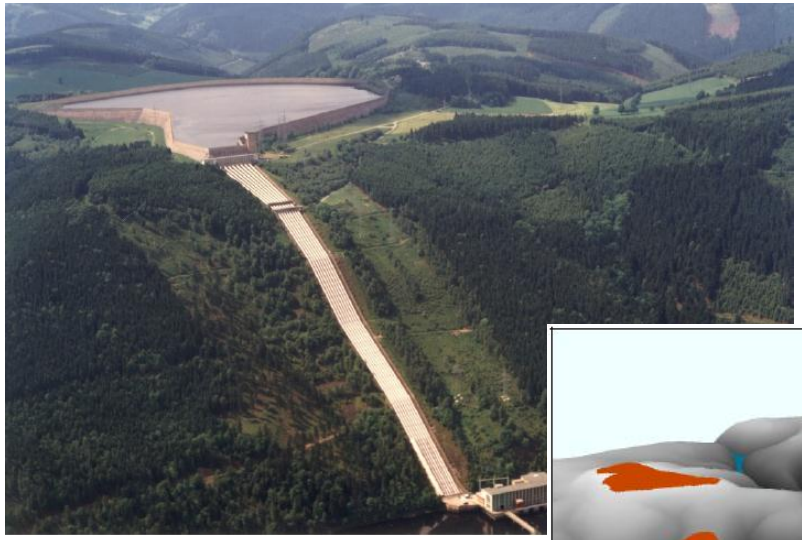
Økt balansekraftkapasitet i norske vannkraftverk

Innledende studie av konkrete case i Sør-Norge

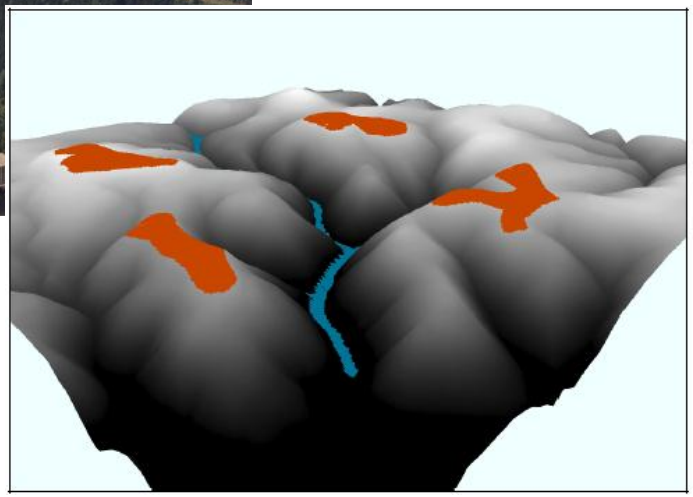
Forfatter(e)
Eivind Solvang
Atle Harby
Ånund Killingtveit

SINTEF Energi AS
Energisystemer
2011-12-08

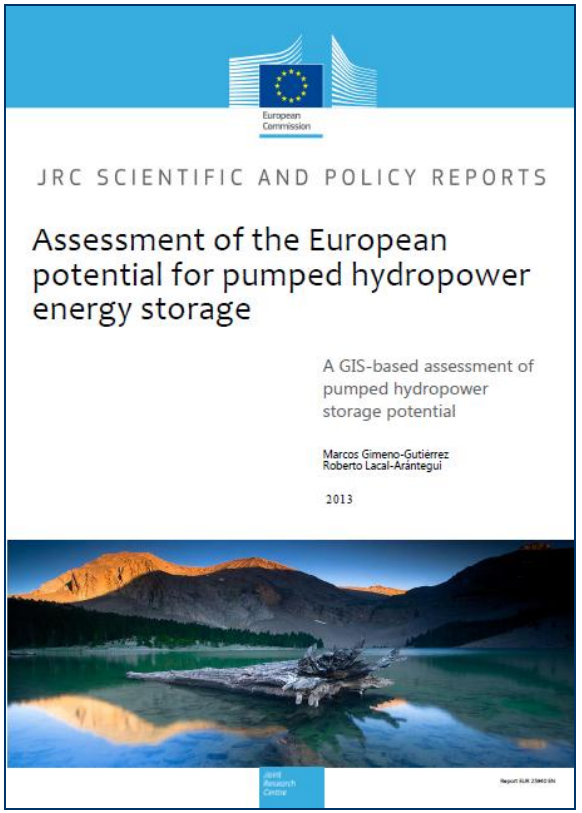
GIS mapping of PSH potential in Europe



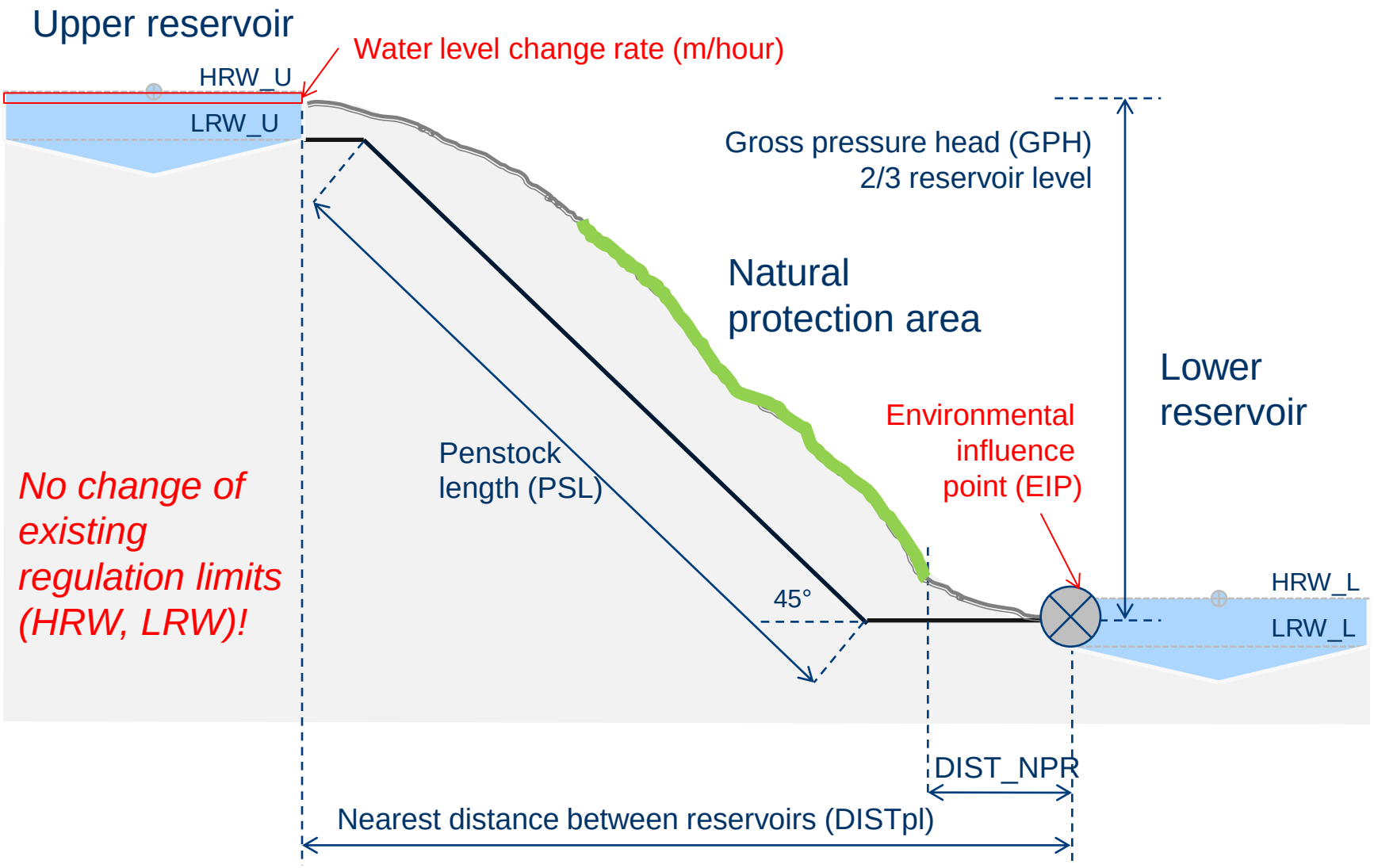
- Linking two existing reservoirs, or
- Transformation of one existing lake or reservoir to PHS by detecting a suitable site for a second reservoir



Schmidt et al. (2011);
Mapping of potential in Thüringen (Germany)



Norway:
Only linking of existing reservoirs, no construction of new ones



Scheme of a pumped hydropower storage reservoir pair

GIS mapping of PSH potential in Europe

Recommendations from a PSH GIS mapping workshop (Arántegui and Tzimas, May 2012)

Criteria	Scope			
	National	Region	County	Grid
Max distance between reservoirs (km)	20	20	20	20
Minimum head (m)	50 – 200	25 – 200	15 – 200	50 – 200
Topologies 1 & 2: minimum usable volume of existing reservoir (Hm^3), or hydropower installed capacity (MW)	1 Hm^3/ 10 MW	0.1 Hm^3/ 5 MW	0.05 Hm^3/ 1 MW	1 Hm^3/ 10 MW
Topology 2, assumed new reservoir size (m^2)	1 000	700	700	1 000
Topology 2, assumed new reservoir average depth (m)	10	7	7	10
Minimum distance to inhabited sites (m)	2 000	1 000	200	2 000
Minimum distance to existing transportation infrastructure (m)	100	100	0	100
Distance to national parks	2 000	1 000	500	2 000
Distance to Natura 2000 sites	200	100	50	200
Distance to special protection areas	200	100	50	200
Minimum distance to a UNESCO site (m)	2 000	1 000	500	2 000
Maximum distance to suitable grid connection (km)	20	20	10	20

Table 1: Proposed values for some of the criteria described, depending on the scope of the assessment. Minimum distances are between the new reservoir under assessment and the given feature[6].

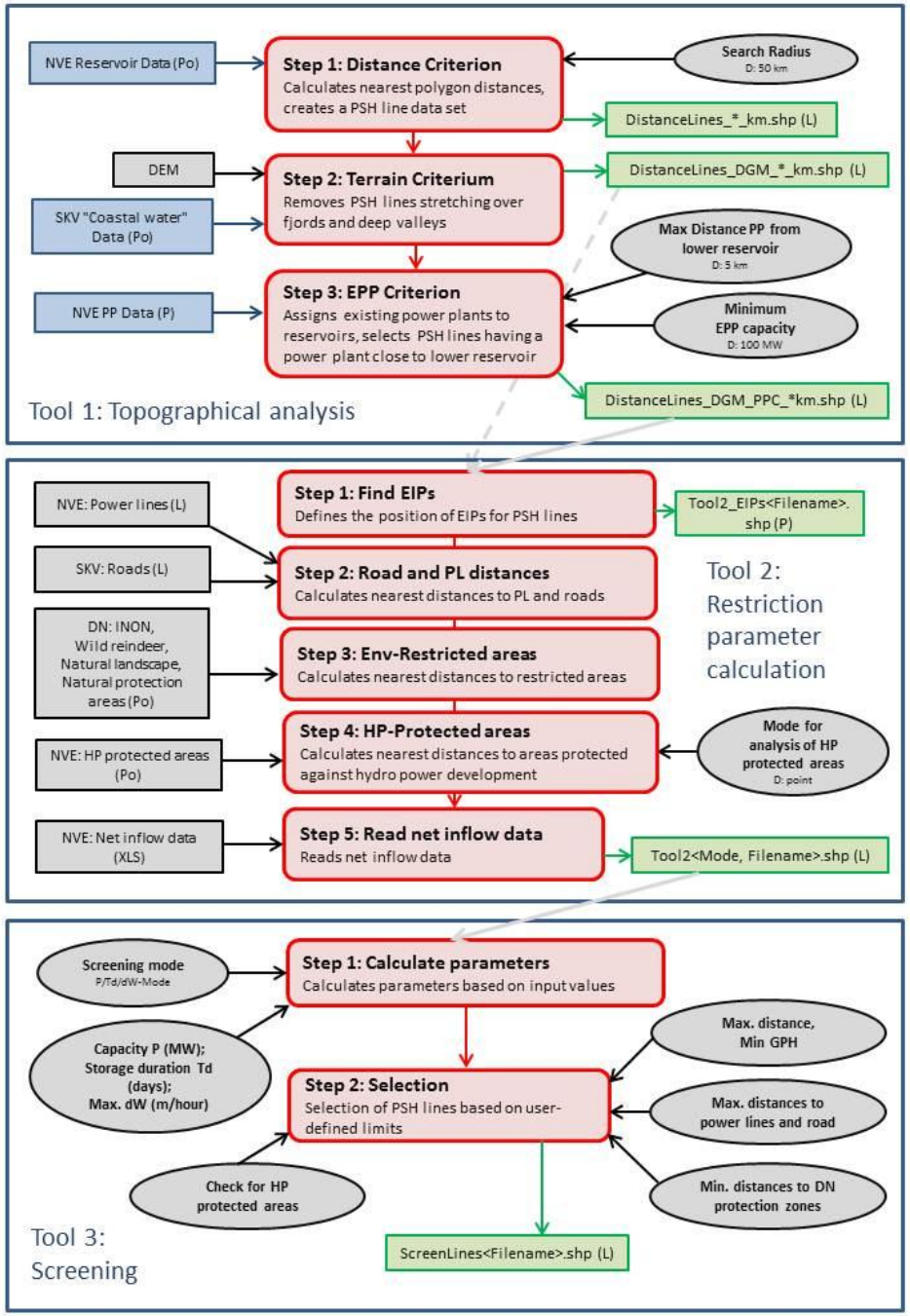
GIS Mapping Norway

Input data (maps) from the Norwegian Mapping Authority, NVE, and Environmental Agency

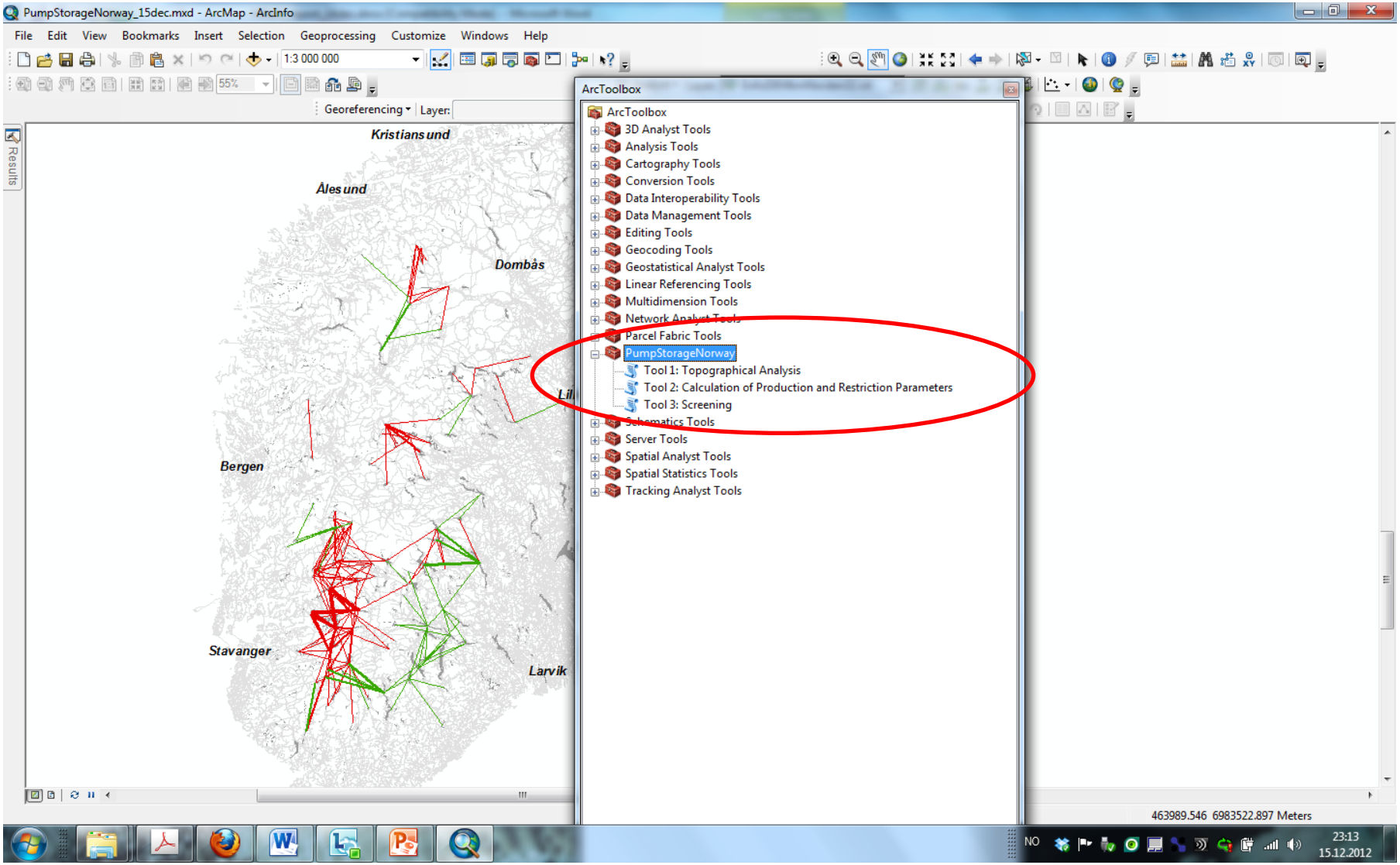
Norway has 905 existing reservoirs, 886 of them with a reservoir volume of >100 000 m^3

Grey:
User-defined input parameters or data sets
Green:
Result files

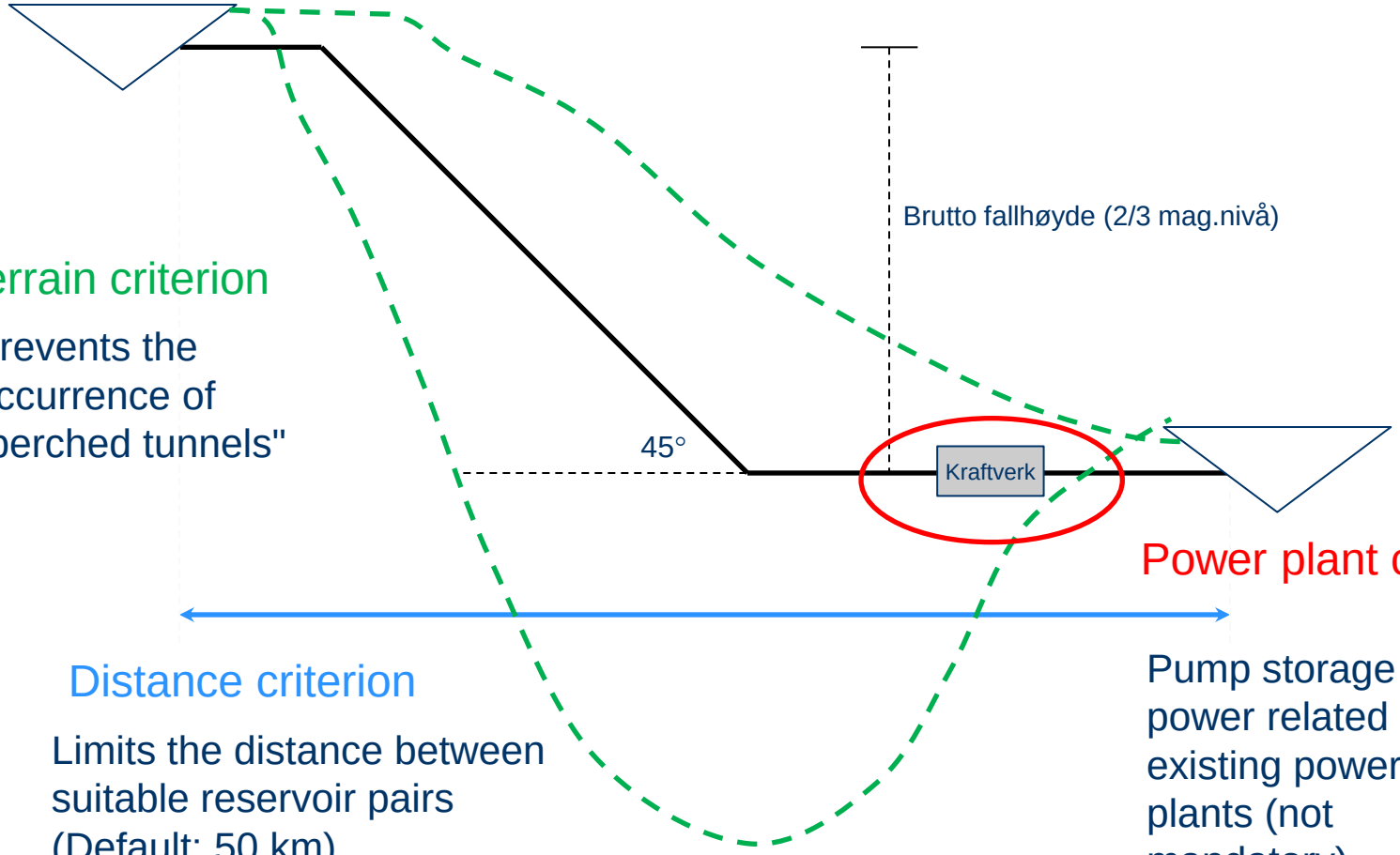
Flow chart



Python script tools, included into ArcGIS 10 geoprocessing toolbox



Tool 1: Topographical analysis



Terrain criterion

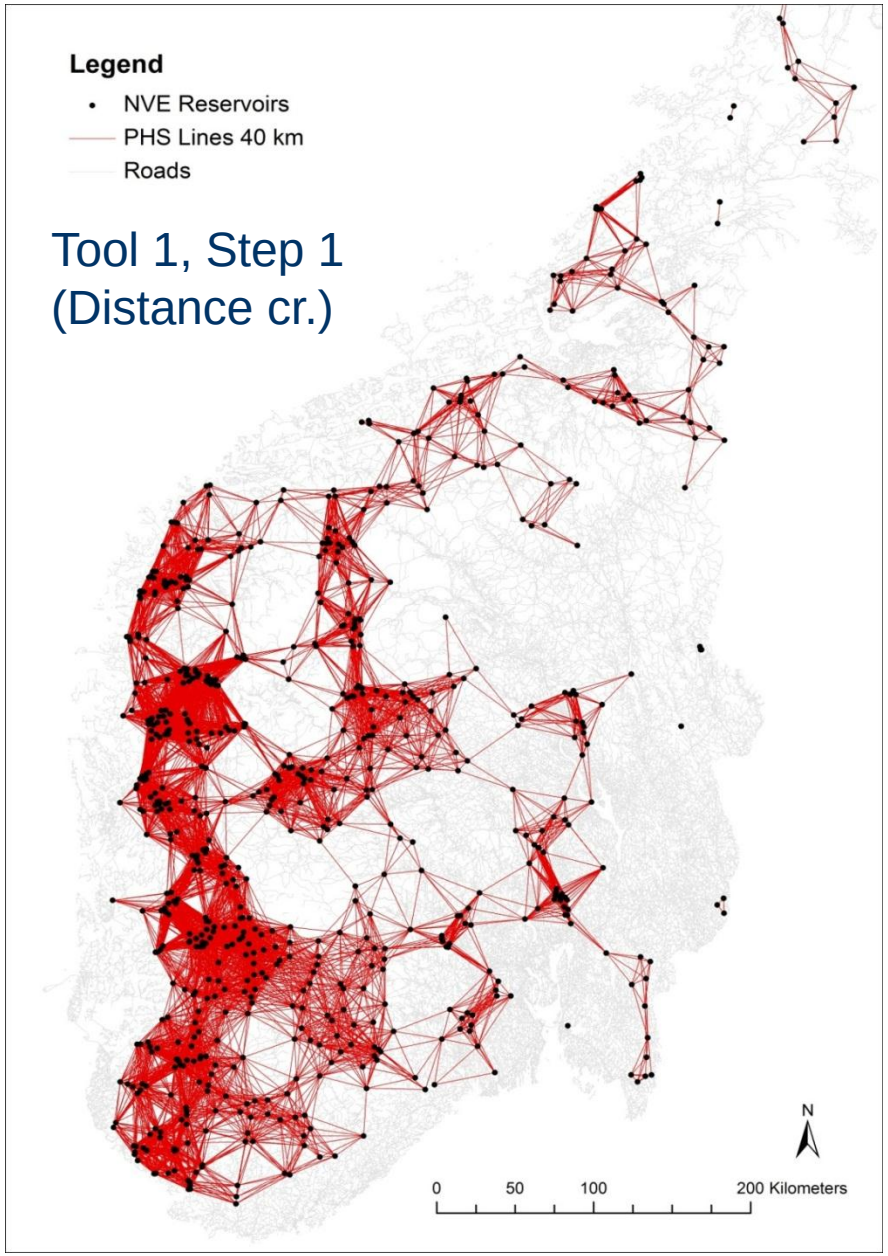
Prevents the occurrence of "perched tunnels"

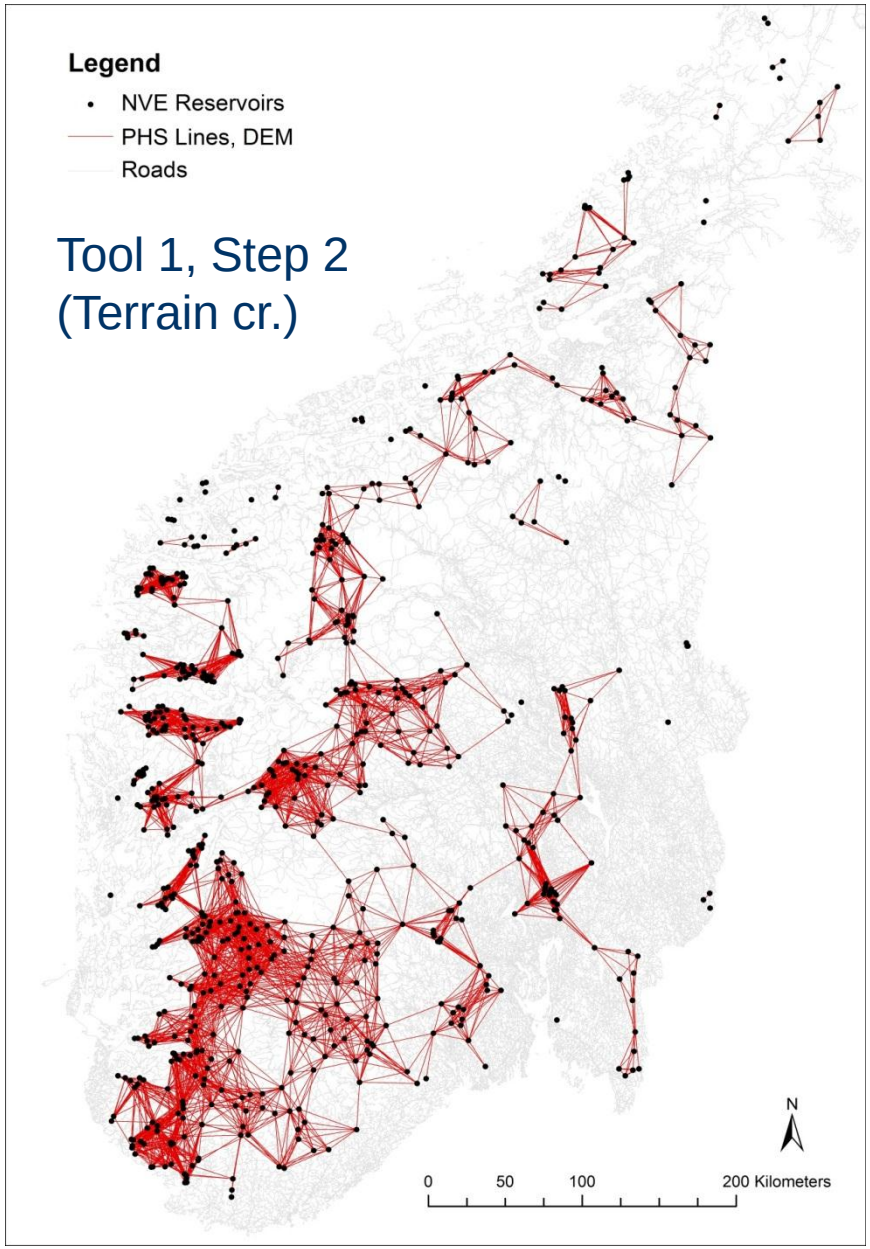
Power plant criterion

Pump storage power related to existing power plants (not mandatory)

Distance criterion

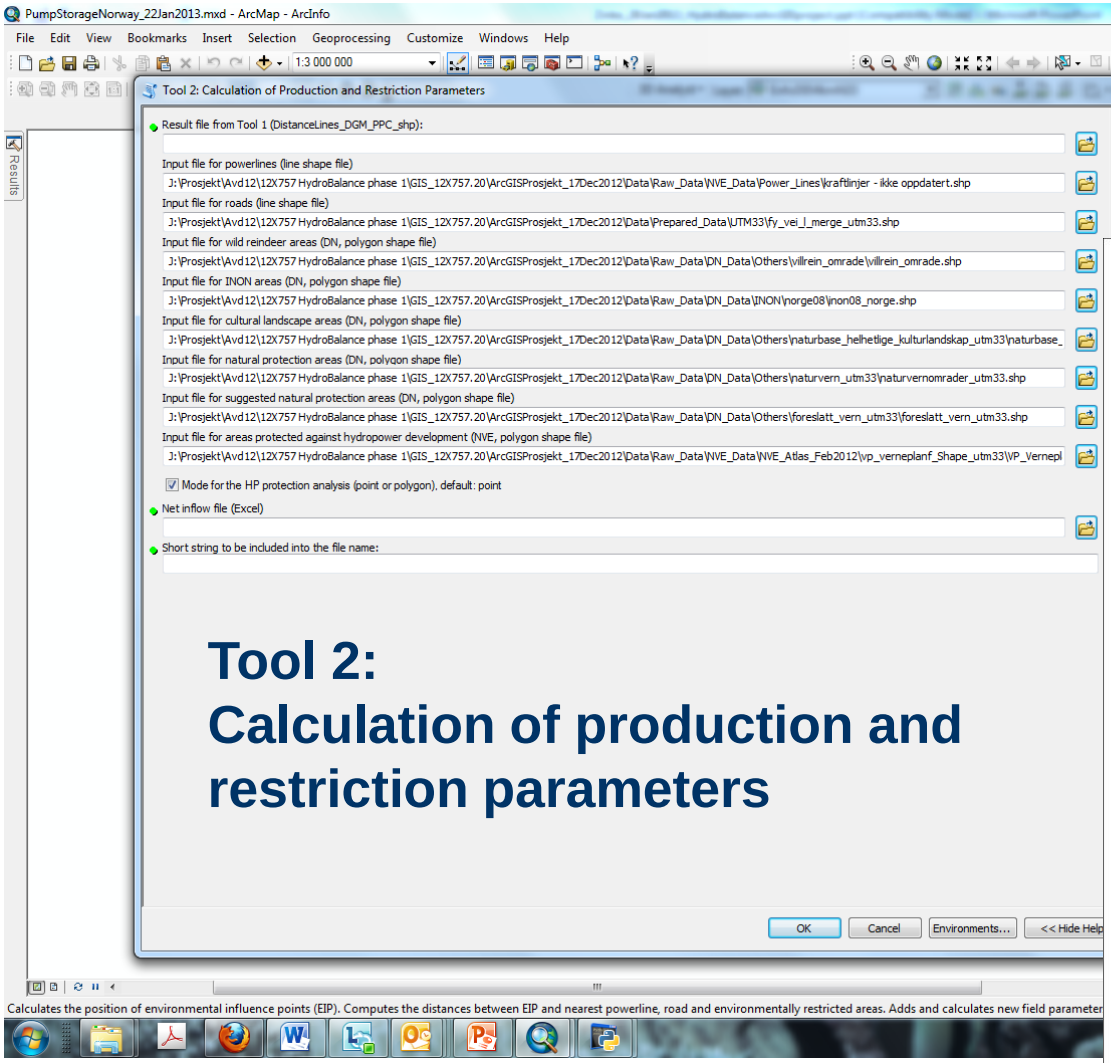
Limits the distance between suitable reservoir pairs (Default: 50 km)


Legend
NVE Reservoirs
PHS Lines 40 km
Roads
Tool 1, Step 1
(Distance cr.)
N
0
50
100
200 Kilometers

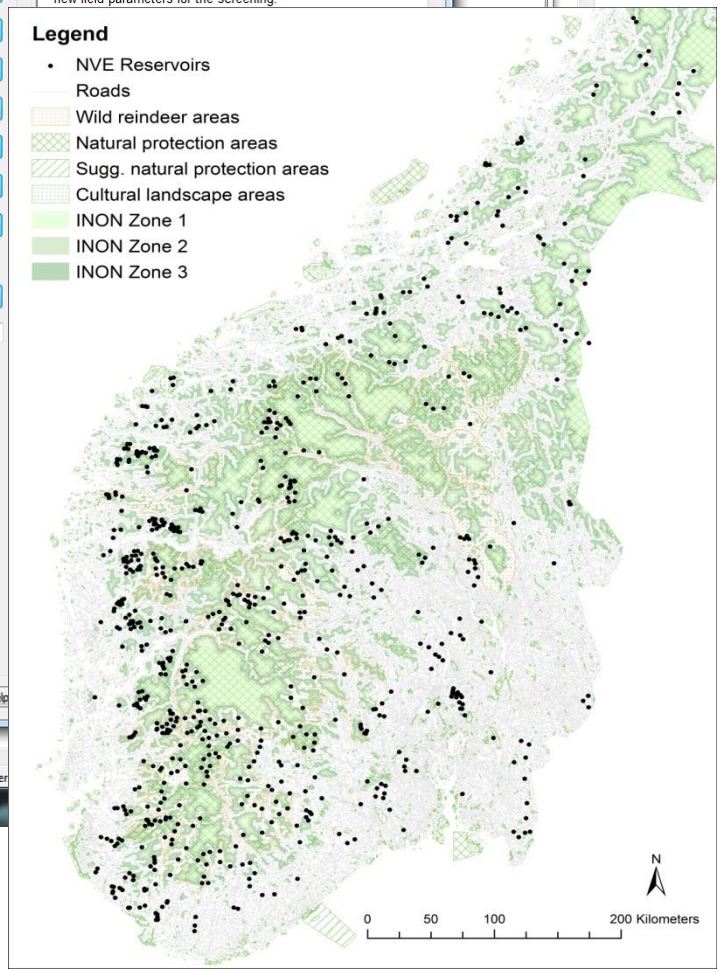

Legend
NVE Reservoirs
PHS Lines, DEM
Roads
Tool 1, Step 2
(Terrain cr.)
N
0
50
100
200 Kilometers

Tool 2 & 3: Production- and environmental related selection criteria

- There must be transmission capacities for the produced electricity.
- The water level changes (m/hour) in the upper reservoir and lower reservoir are limited because of environmental considerations (fish stranding etc.) and erosion issues.
- Protected areas (e.g. INON) should not be affected.



Tool 2:
Calculation of production and restriction parameters



User-defined parameters (can be varied in sensitivity tests)

Table 3: User-defined criteria and default values used in the present study

Criteria	Unit	Default	Note
Maximum distance between reservoirs	km	50	
Minimum head	m	50	
Minimum hydropower installed capacity	MW	100	
Maximum distance to roads	km	10	
Maximum distance to suitable grid connection	km	20	
Maximum rate of water level change in reservoirs	m/hour	0.13	Based on river data
Minimum distance to INON areas (not affected by heavy technical installations or constructions)	m	500	
Minimum distance to cultural landscape areas of high priority with biological and historical values	m	500	
Minimum distance to wild reindeer areas	m	2000	
Minimum distance to existing and suggested natural protection areas	m	500	

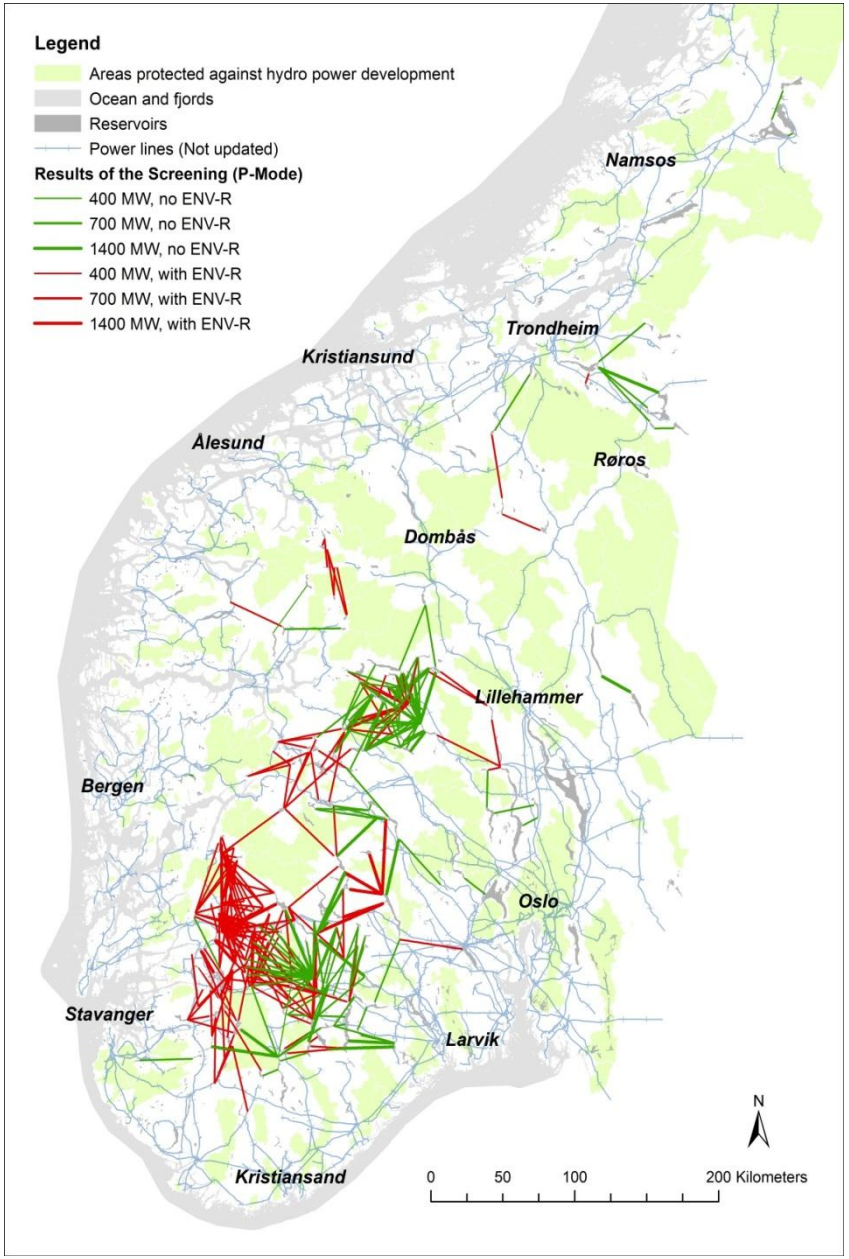
Distances with respect to EIP. Update and expert assessment necessary!

Tool 3: Screening

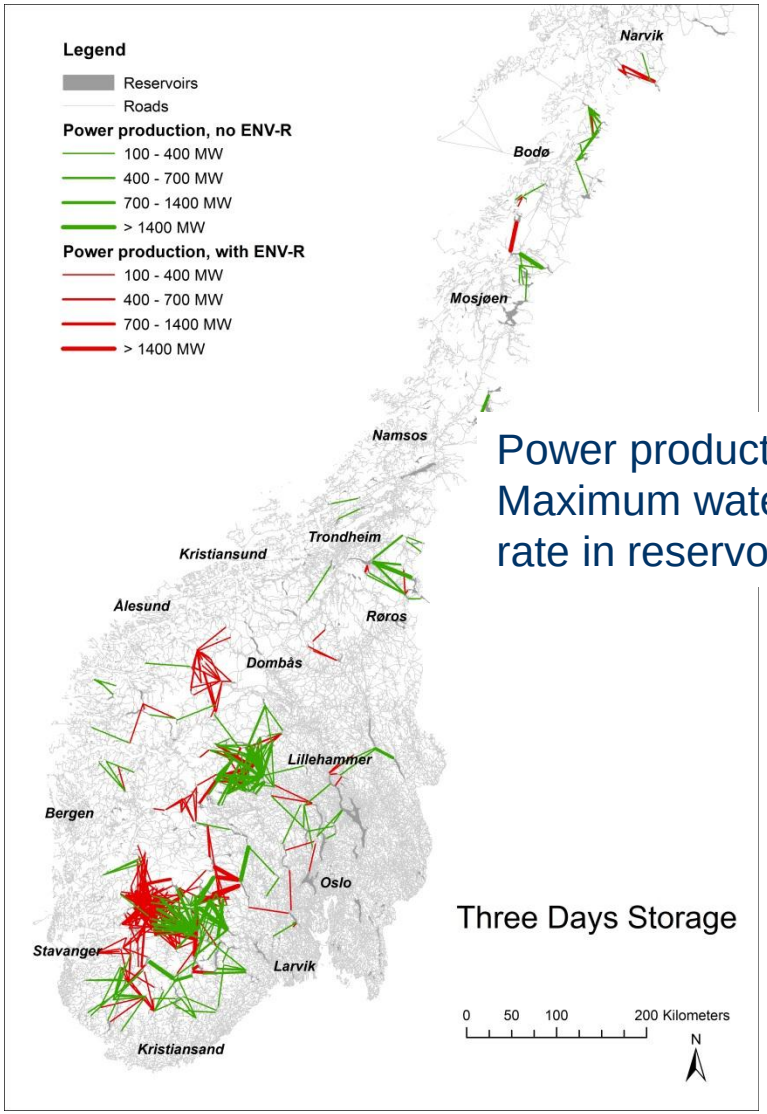
Some screening results

P-Screening-Mode

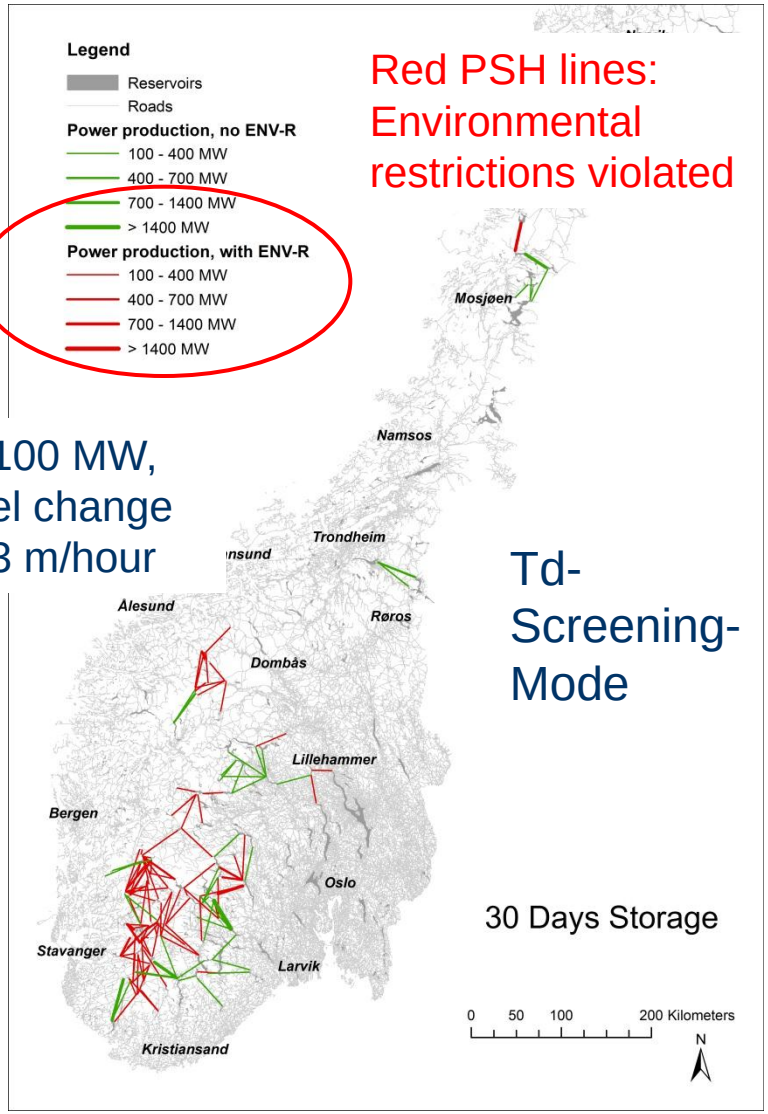
PSH potential for power production of 400, 700 and 1400 MW,
minimum storage duration one day,
maximum water level change rate in reservoir 0.13 m/hour



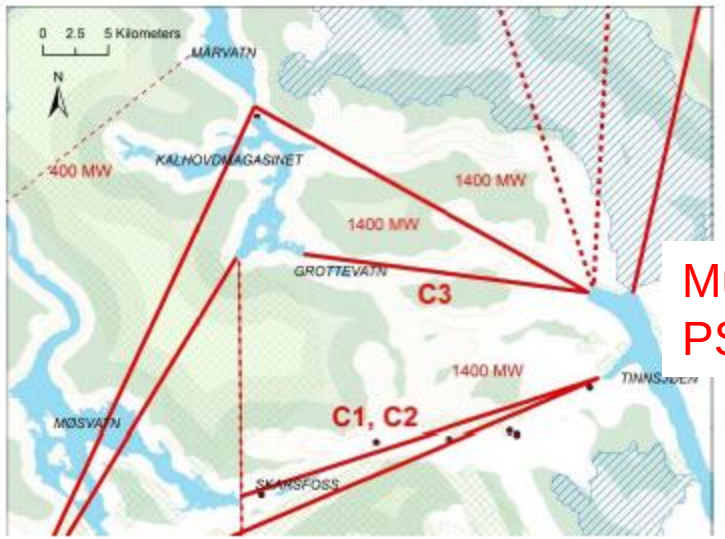
PSH connections for three and 30 days storage



Power production >100 MW,
Maximum water level change rate in reservoir 0.13 m/hour



Performance test example: Tinnsjø (C1)



Multiple PSH lines

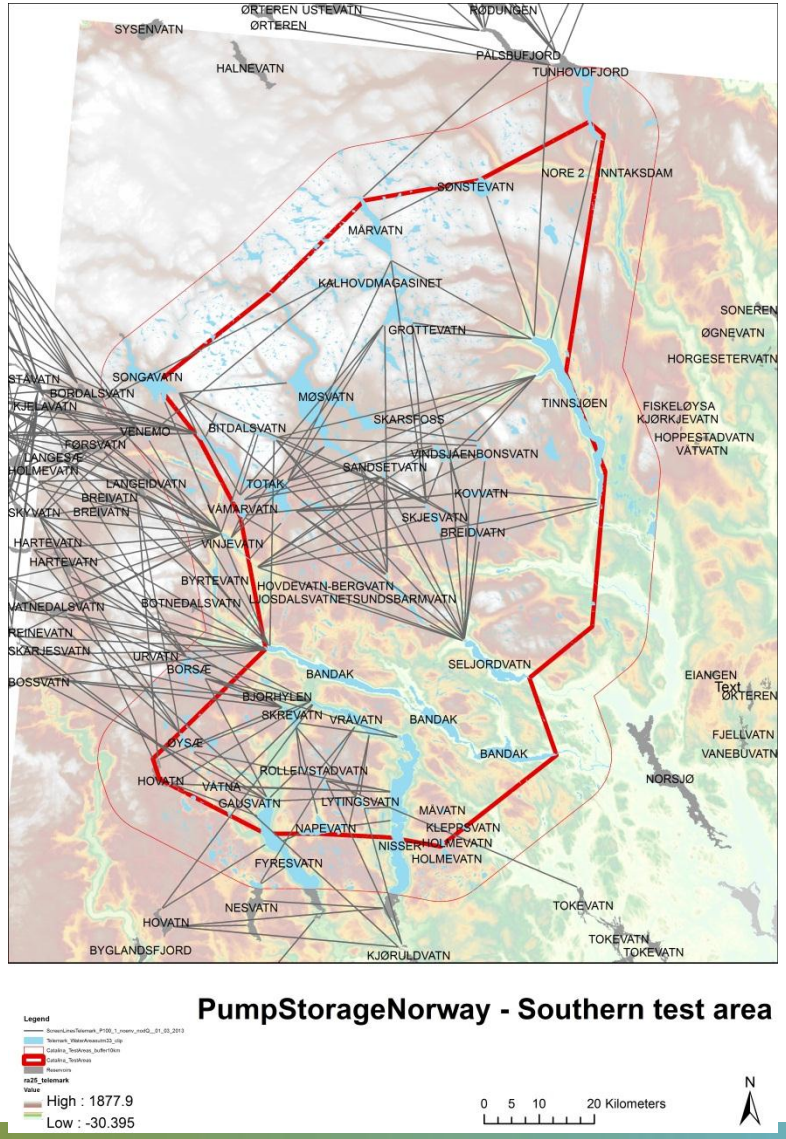
Figure 6: The Møsvatn-Tinnsjø-Kallhovd/Mår area with the PSH cases suggested by Solvang et al. (2012, left) and the GIS-screening results obtained using the P-Mode for 400, 700 and 1400 MW. Dashed lines: PSH lines which are in conflict with the environmental restriction zones.

Different net inflow rates, depending on assumptions

Table 8: Net inflow from the reservoirs for Case C1

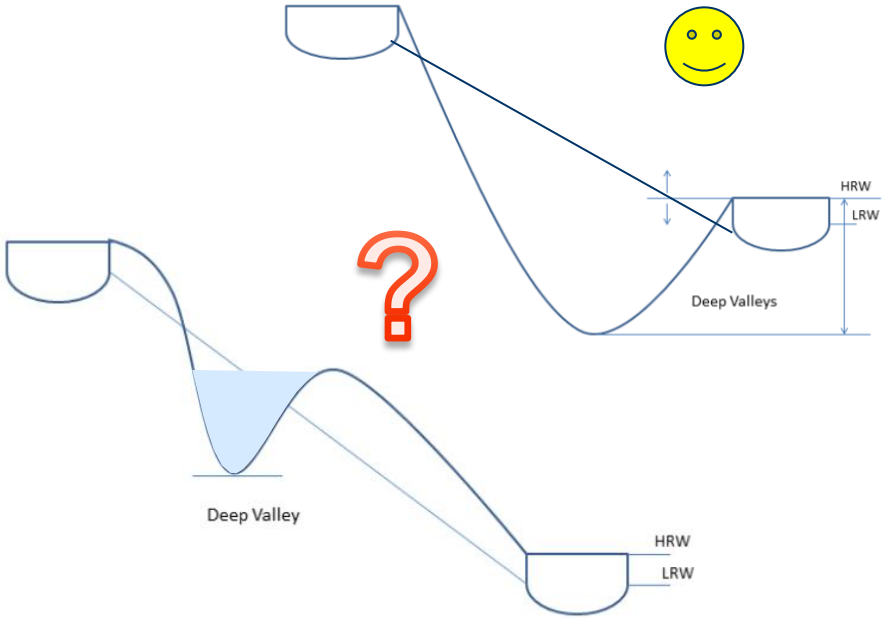
		Upper Reservoir: Møsvatn		Lower Reservoir: Tinnsjø	
		Solvang et al. (2012)	Arnesen (2013)	Solvang et al. (2012)	Arnesen (2013)
Other inflow	m^3/s			99.7	
Other discharge	m^3/s	87.1		150.2	
Net inflow	**m^3/s**	**-87.1**	**-90.5**	**-50.5**	**-130.6**

Testing and suggestions for improvements/development

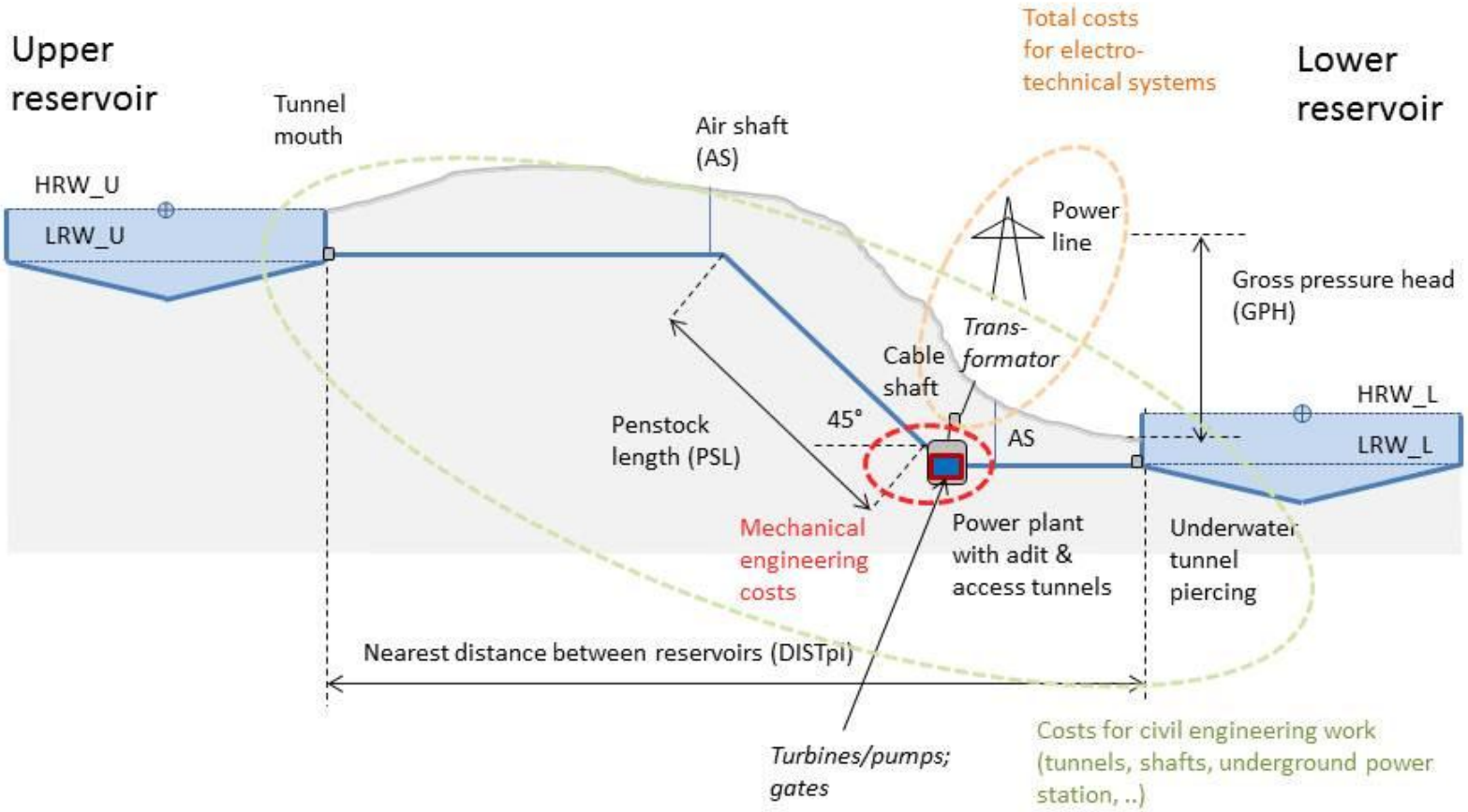


Master thesis C. Cortinez (2013):

- ❑ Suggestions for improvements of some algorithms (e. g. terrain criterion)
- ❑ Inclusion of a simplified cost estimation as additional selection criterion for a test region in Telemark

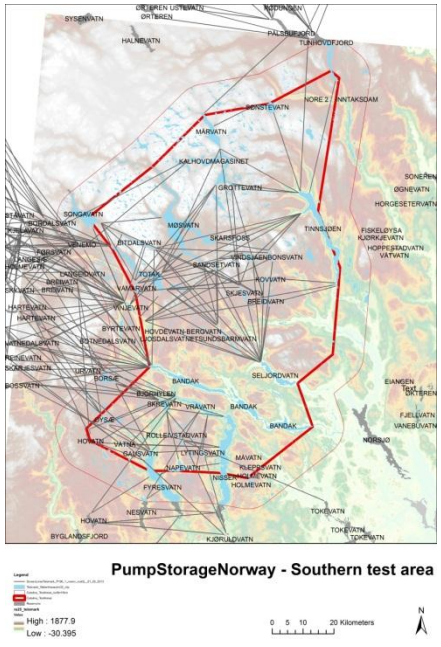


Cost estimation



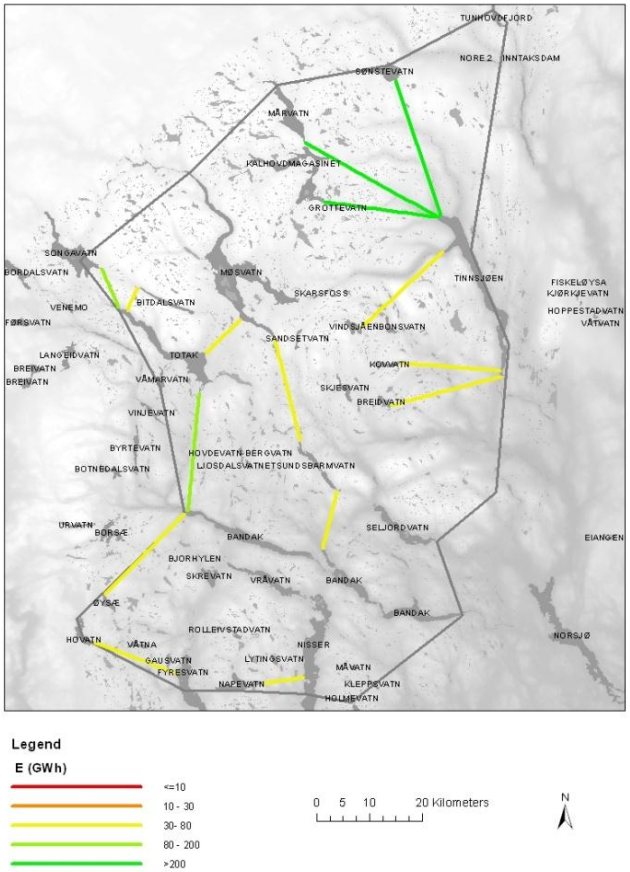
NVE Guidelines for cost estimates; with some simplifications

Testing and suggestions for improvements/development

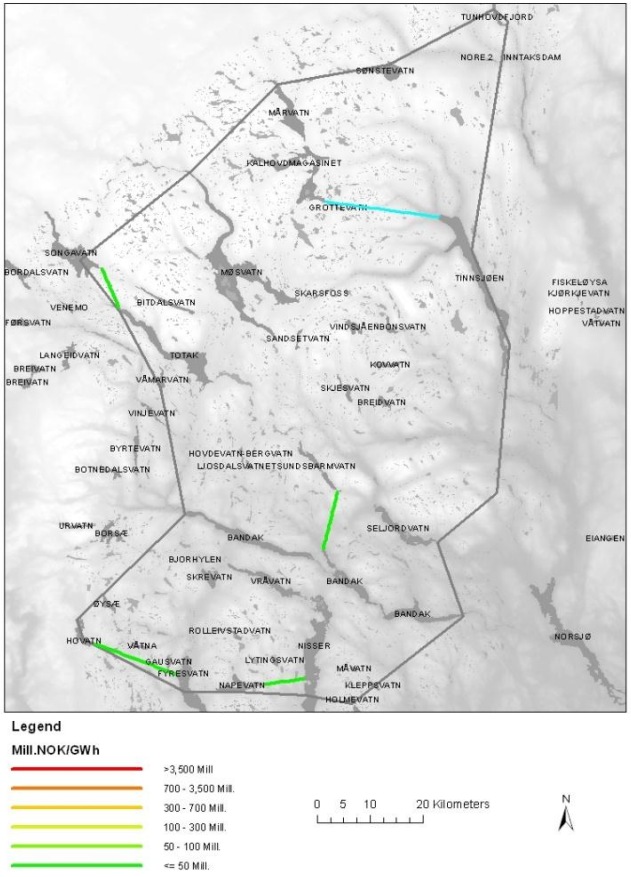


$$E = \rho g \eta \cdot GPH \cdot V$$

E = total potential energy storage (GWh)
GPH = gross pressure height
V = volume



Establish a minimum E to clip out lines with very low energy storage potential.



Choose the best GWh/NOK for each reservoir

C. Cortinez (2013)

Conclusions

- The GIS tool showed high PSH potential in the mountains in the southern part of Norway, some relevant sites in Central Norway, few in North-Norway.
- Results are highly depending on net inflow due to existing power plants and reservoir interactions.
- Many of the PSH connections are in conflict with environmental restrictions. Further investigations of environmental restrictions are needed (expert assessment)!
- Suggested improvements and new routines for cost calculation and selection in case of multiple reservoir connections need to be implemented into the GIS tool.

Thank you!

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