Avalanche Risk Estimation and Hazard Zoning in Iceland

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Workshop on probabilistic approaches in hazard mapping, BFW, Innsbruck, Austria, 27-28 February 2008


SATSIE meeting – Seyðisfjörður 2005

Photo: Emil Tómasson, February 2008

Outline

- Background of the current hazard mapping method in Iceland
- The Icelandic method of estimating risk
- Further developments

The background of hazard mapping in Iceland

- After a fatal avalanche accident 1974 in Neskaupstaður the first hazard maps were made by local authorities
  - no regulations
- The first laws were set in 1985 after an accident in Ólafsvík

1994-1995

- 36 people were killed in four avalanche accidents
- Many of them were in houses located in “safe” zones according to hazard maps at that time
- A discussion started of what is acceptable in terms of avalanche return periods and avalanche risk
- The government decided to provide funds for avalanche research, hazard mapping and defences/resettlement

What is acceptable?

Imagine an individual living in a house for 75 years, where the return period of avalanches is 300 years

- 20-25% probability of an avalanche hitting the house while he/she lives there
- Avalanche risk is much greater than any other factor, e.g. diseases or other accidents

New method

- In the years 1996-1999 a new method of hazard mapping was developed in Iceland
  - based on individual risk

Individual risk vs. return periods

- The severity of an avalanche event may depend on several other factors than its return period
- Is it possible to select acceptable return periods without estimating risk?
- How should one compare return periods of avalanches to slush flows, debris flows, rockfall?
- Individual avalanche risk is directly comparable to various risks – other natural disasters, traffic, disease

Acceptable risk

Defining acceptable risk should not be considered a technical problem

It is a political issue !

Risk – Annual probability of death

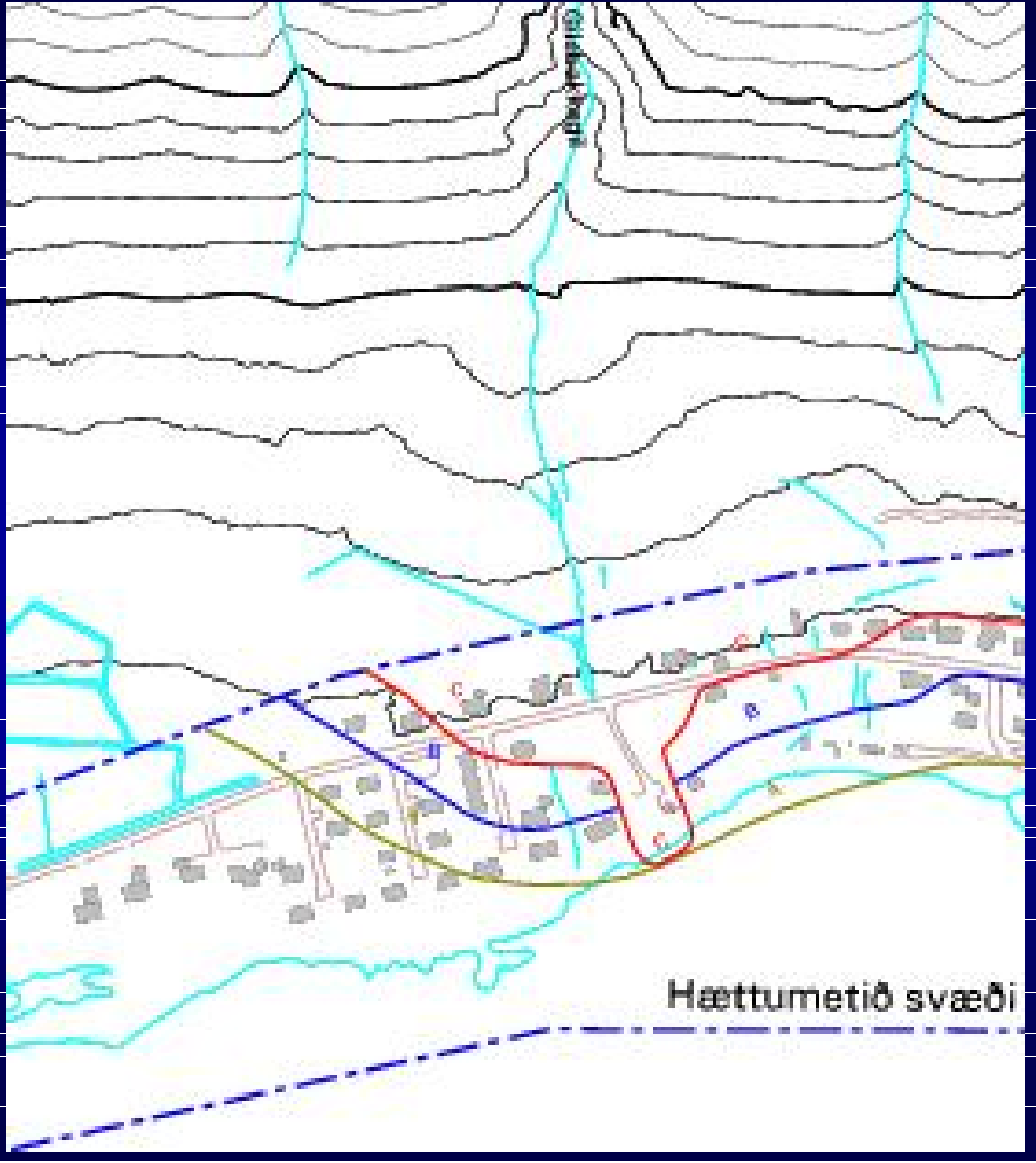
- Some risk factors
  - earthquakes in Iceland: 1 out of 1 000 000 ?
  - traffic: 1 out of 10 000
  - airplanes: 0.5 out of 1 000 000 trips
  - children 1–15 yr (all causes): 2 out of 10 000
  - avalanches 1900-2000 in avalanche prone villages in Iceland: 5–10 out of 10 000
- Acceptable risk by avalanches in Iceland
  - 0.2 out of 10 000 per year

Local risk

- Acceptable risk is defined by a regulation as 0.2 out of 10 000 per year for an individual inside an ordinary house
- We assume that any person stays only 75% of the time over a whole year in a particular house. Therefore, it is acceptable for a house to be located where the risk is 0.3 out of 10 000

Hazard zoning

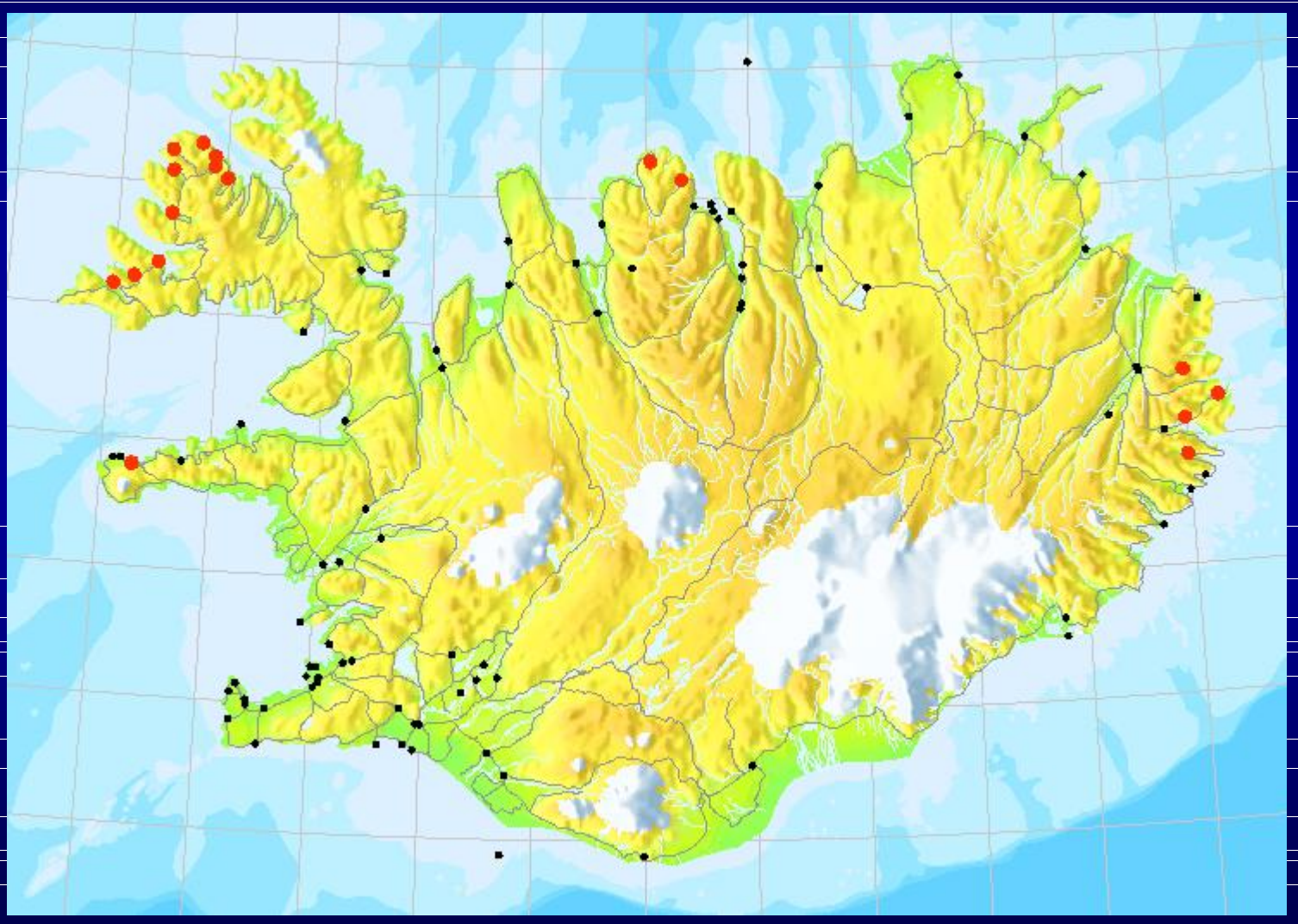
- Areas of unacceptable risk are classified into three categories:
  - Zone A 0.3-1.0 out of 10 000 per year
  - Zone B 1.0-3.0 out of 10 000 per year
  - Zone C > 3.0 out of 10 000 per year
- Local authorities are required to either defend or relocate settlements in C-zones


Hættumetið svæði

Authorities

- The Ministry of the Environment is responsible and provides funds
- The Icelandic Meteorological Office is responsible for
  - risk assessment
  - snow observations
  - evacuations
- Local authorities are responsible for building defense structures

Avalanche hazard zoning for 16 villages



Elements of risk calculations

- Transfer between paths – Runout indices
- Relative tail-shape of the runout frequency distribution
- Estimation of a base frequency
- Speed profiles and survival rate

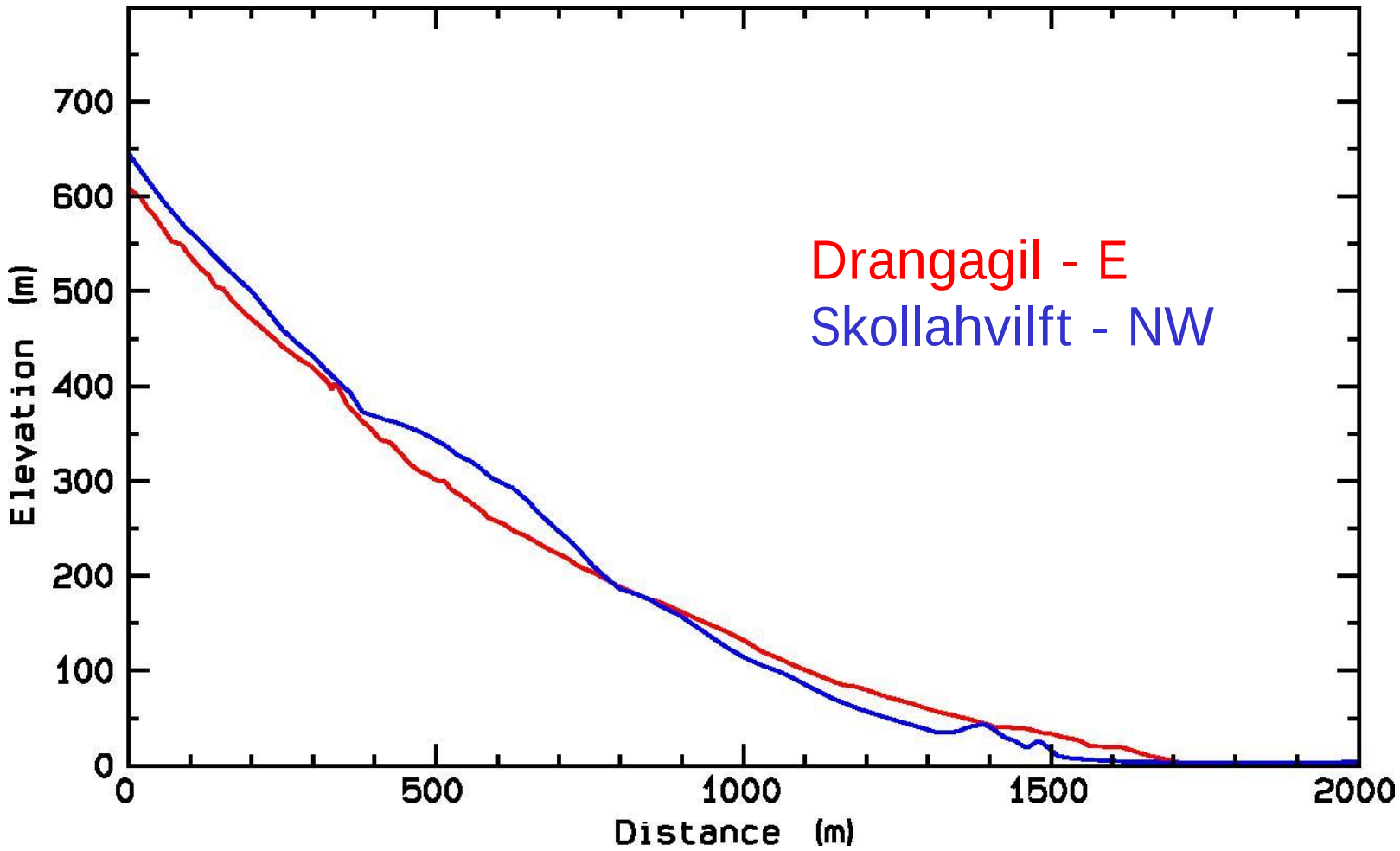
The standard path

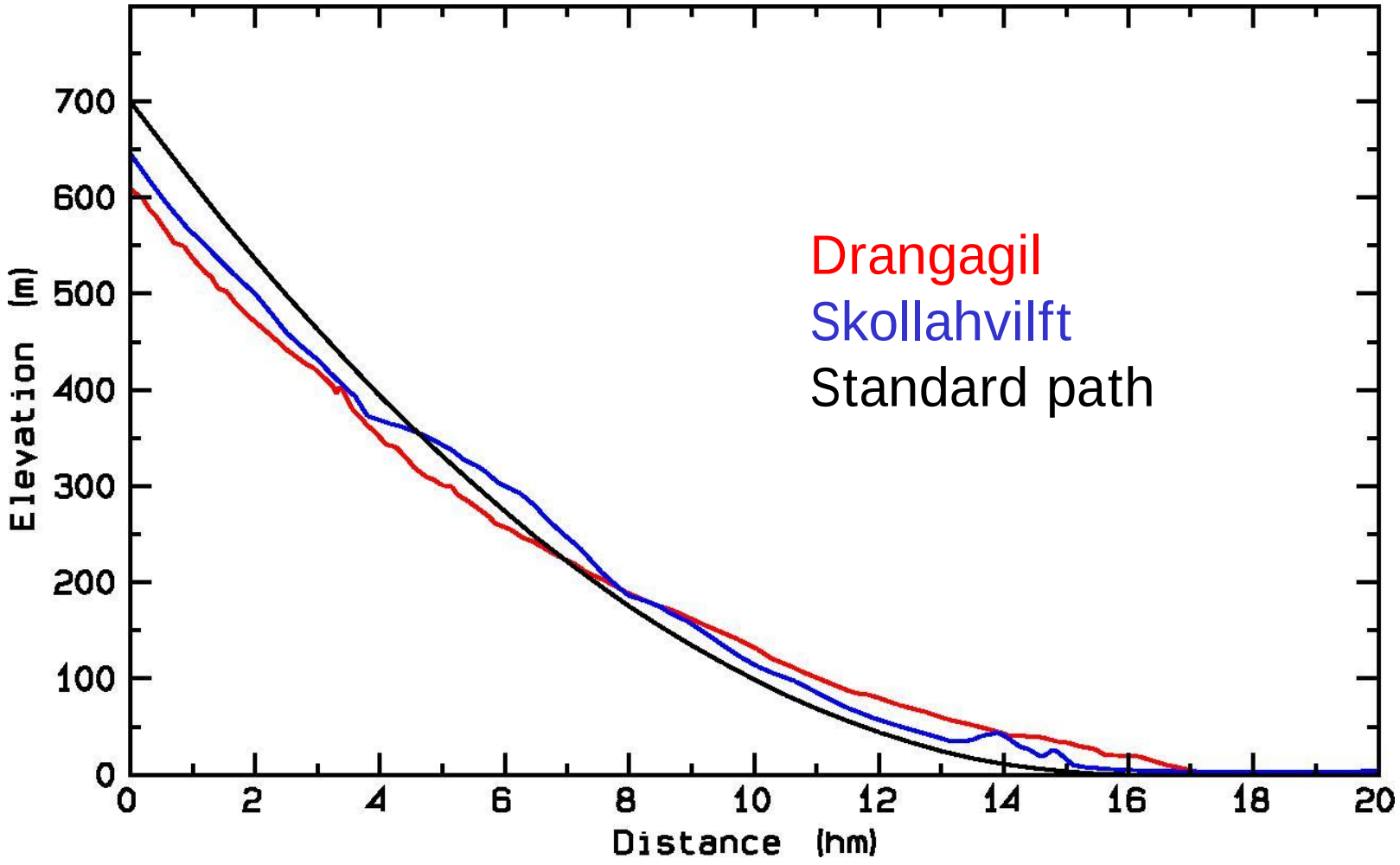
- Transferring avalanches between paths using a physical model
- The calculation of runout indices in a standard path

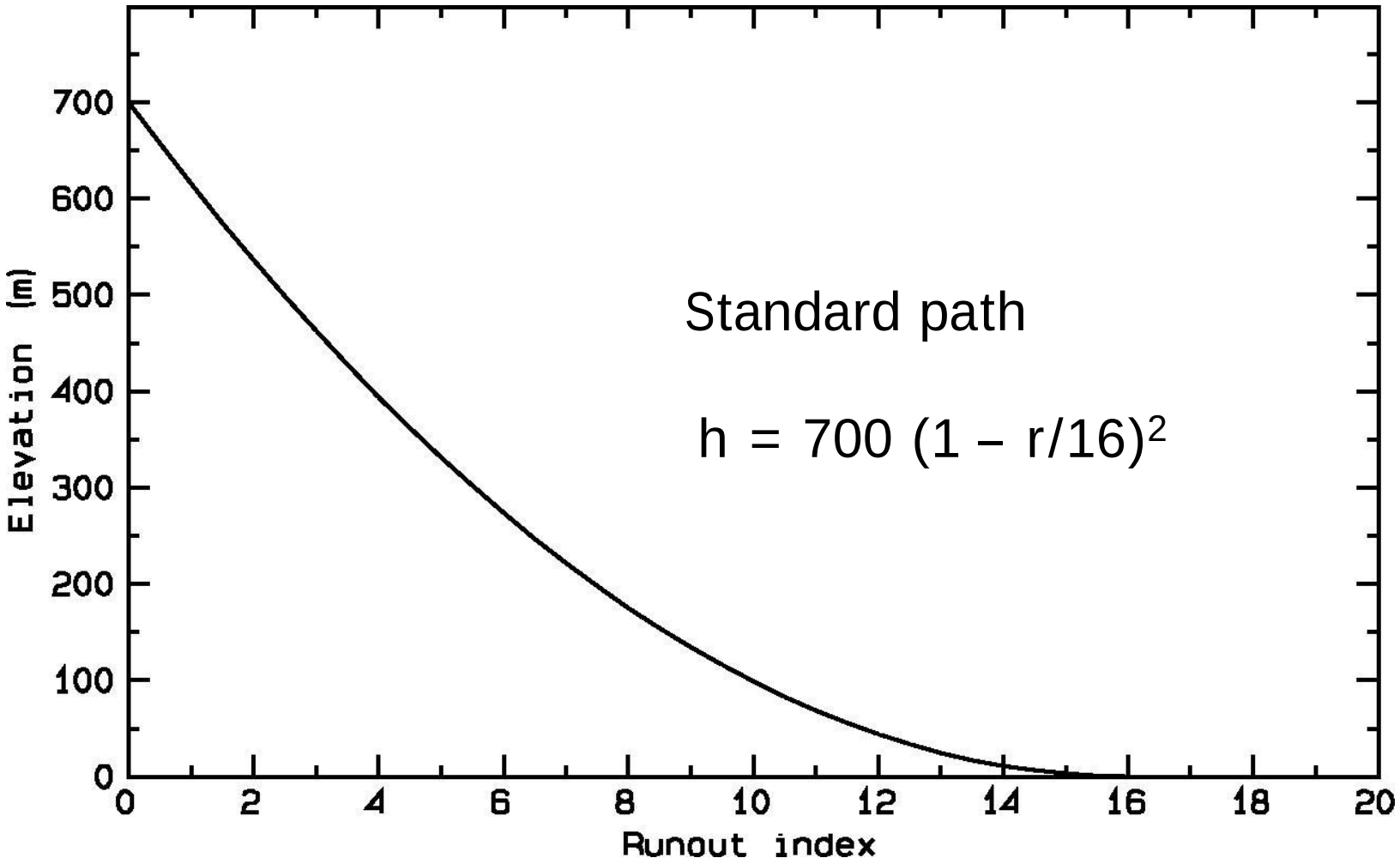
- Watching 50 independent standardized paths for 80 years can be considered like observing avalanches in a single path for 4000 years

Possible flaws

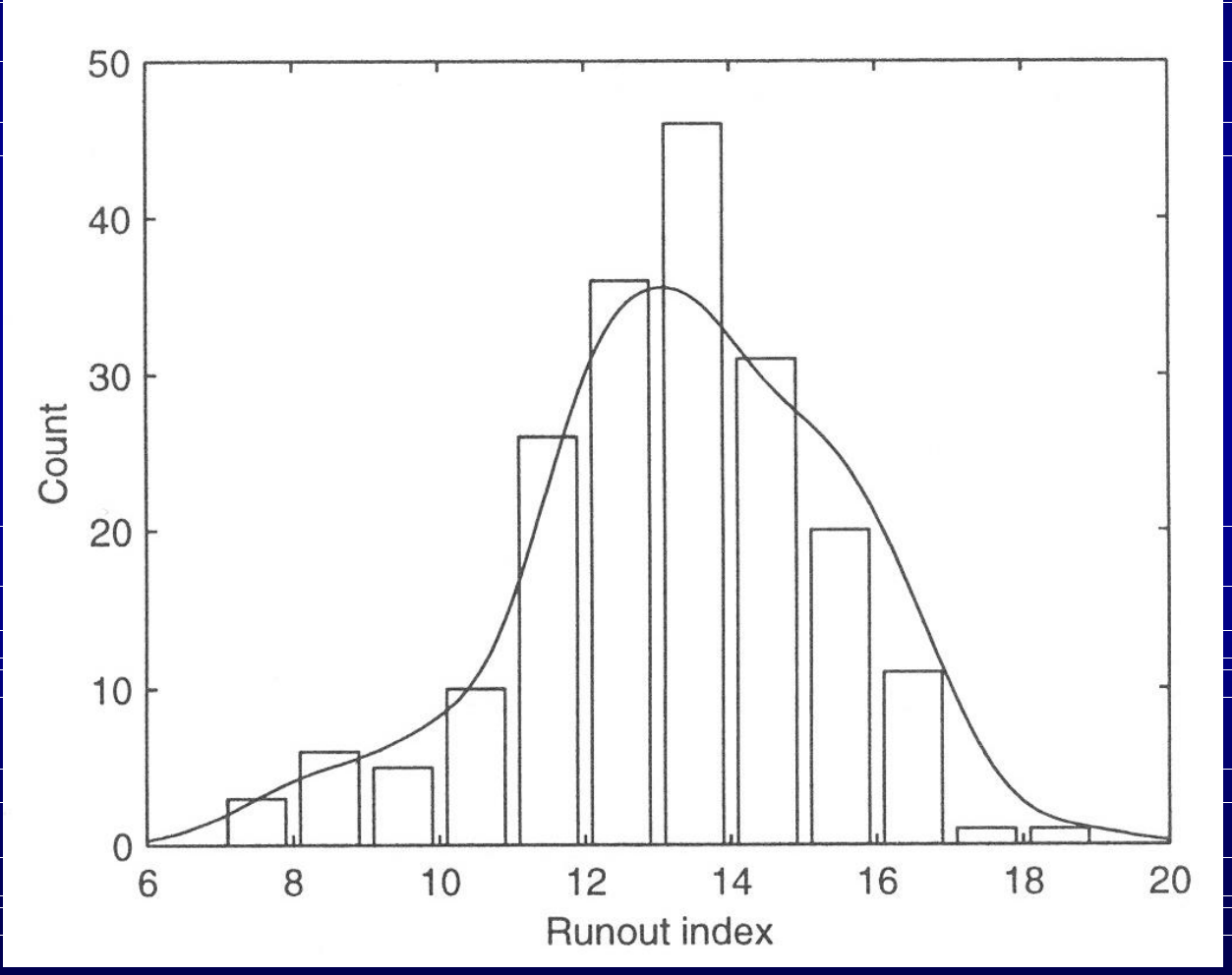
- Hillsides with frequent avalanches may have different shape of frequency distribution (FD) than low frequency hillsides
- Not all avalanches have been (accurately) recorded
- Different paths may have special characteristics (Climate, 2D landscape, PP of snow) affecting the relative shape of the local FD
- Climate change – The climate variability for the 20th century may not fully represent the 21st century

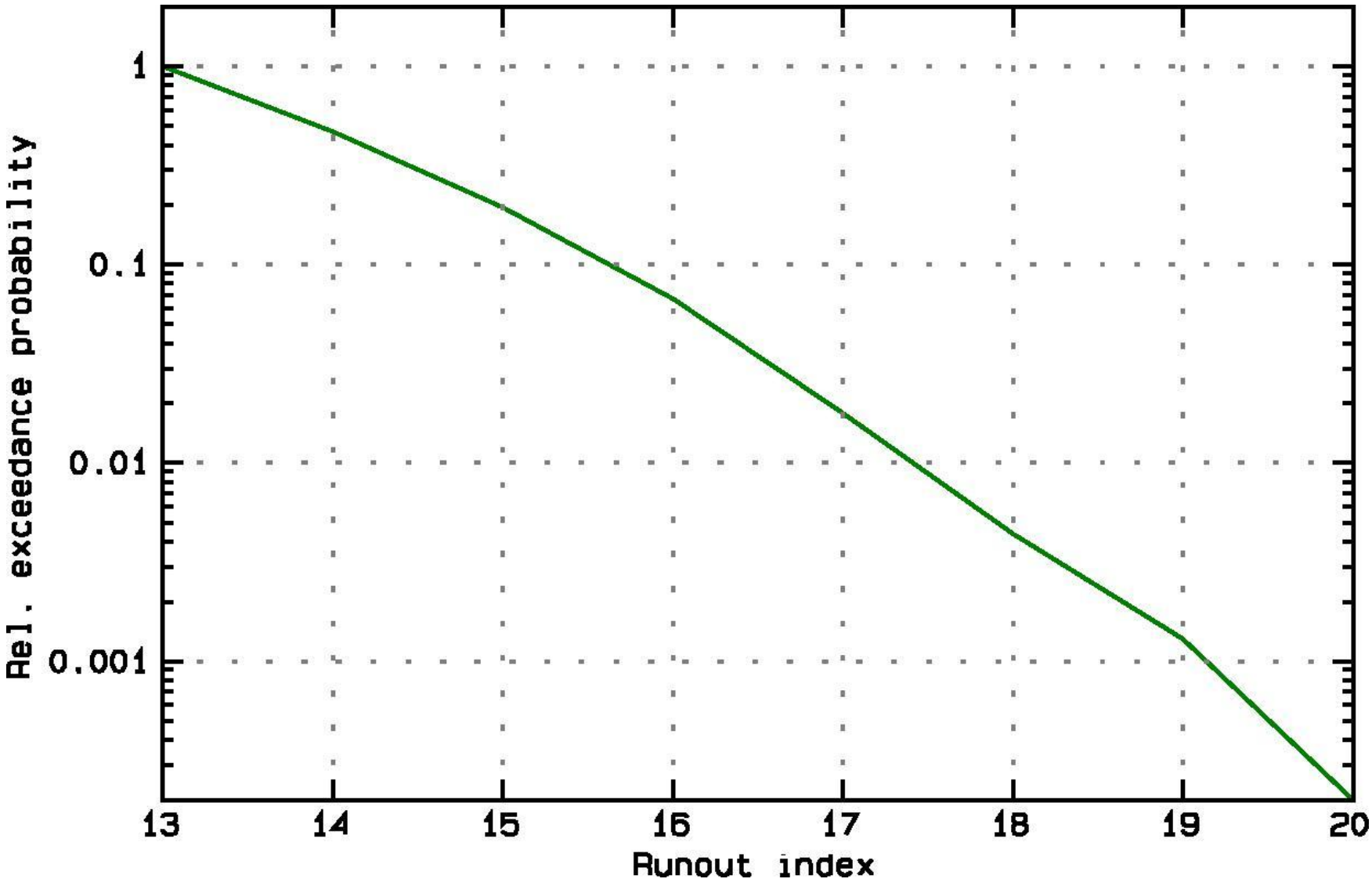

Drangagil - E
Skollahvilft - NW
Elevation (m)
0
100
200
300
400
500
600
700
0
500
1000
1500
2000
Distance (m)


Drangagil
Skollahvilft
Standard path
Elevation (m)
Distance (hm)
0
100
200
300
400
500
600
700
0
2
4
6
8
10
12
14
16
18
20

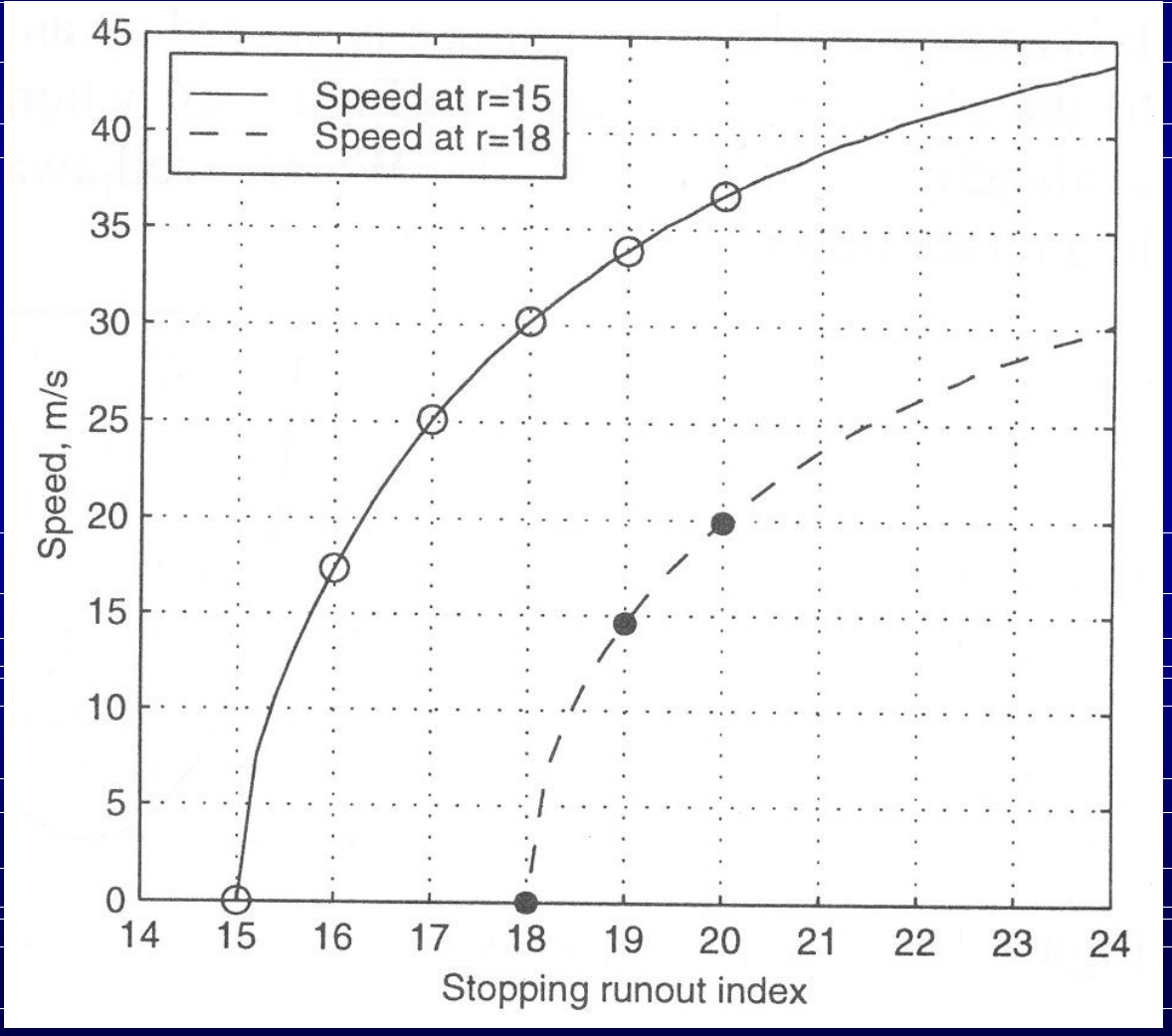

Standard path
h = 700 (1 – r/16)2
Elevation (m)
Runout index
0
100
200
300
400
500
600
700
0
2
4
6
8
10
12
14
16
18
20

196 Icelandic avalanches

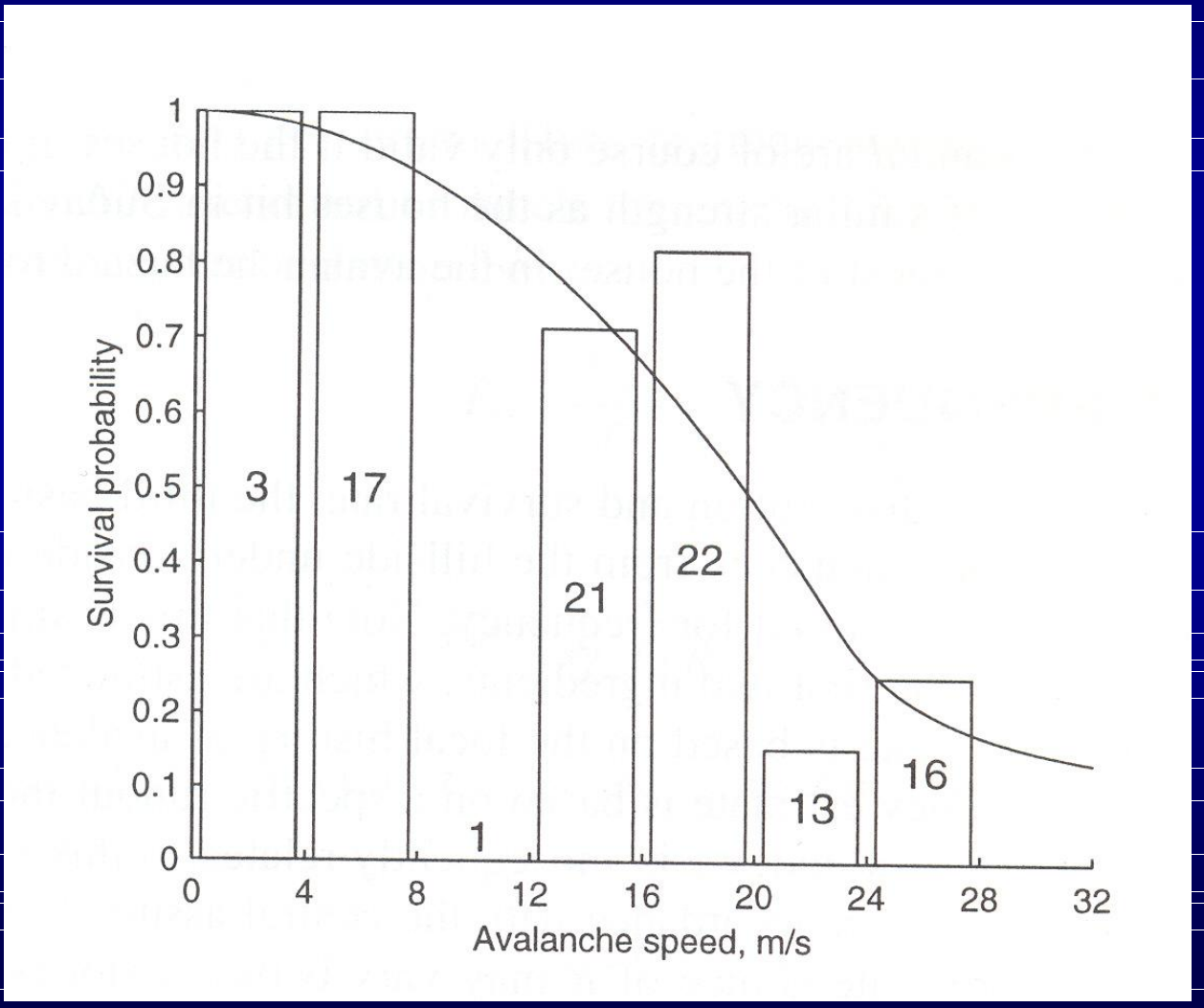



Rel. exceedance probability
1
0.1
0.01
0.001
13
14
15
16
17
18
19
20
Runout index

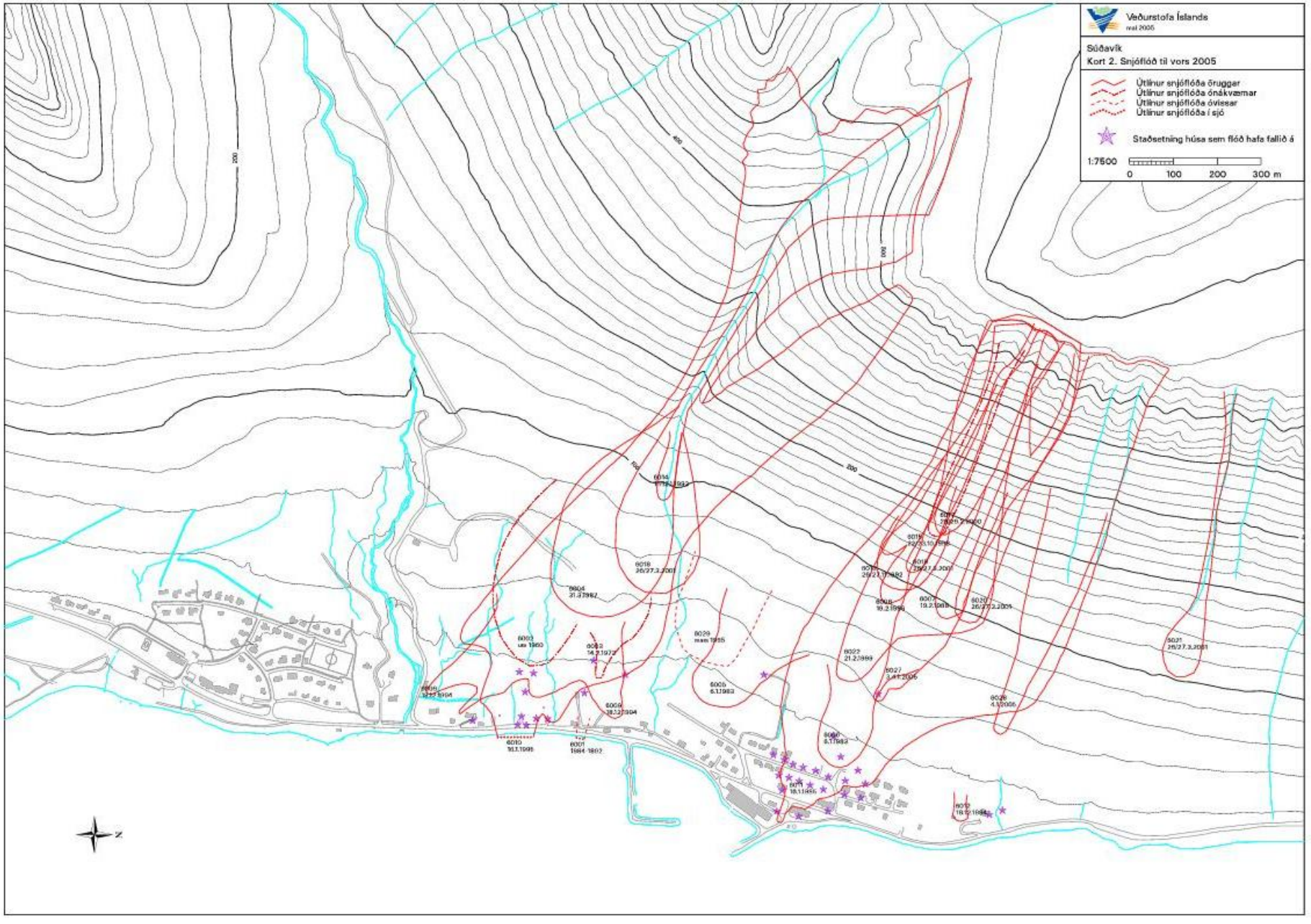
Speed profiles

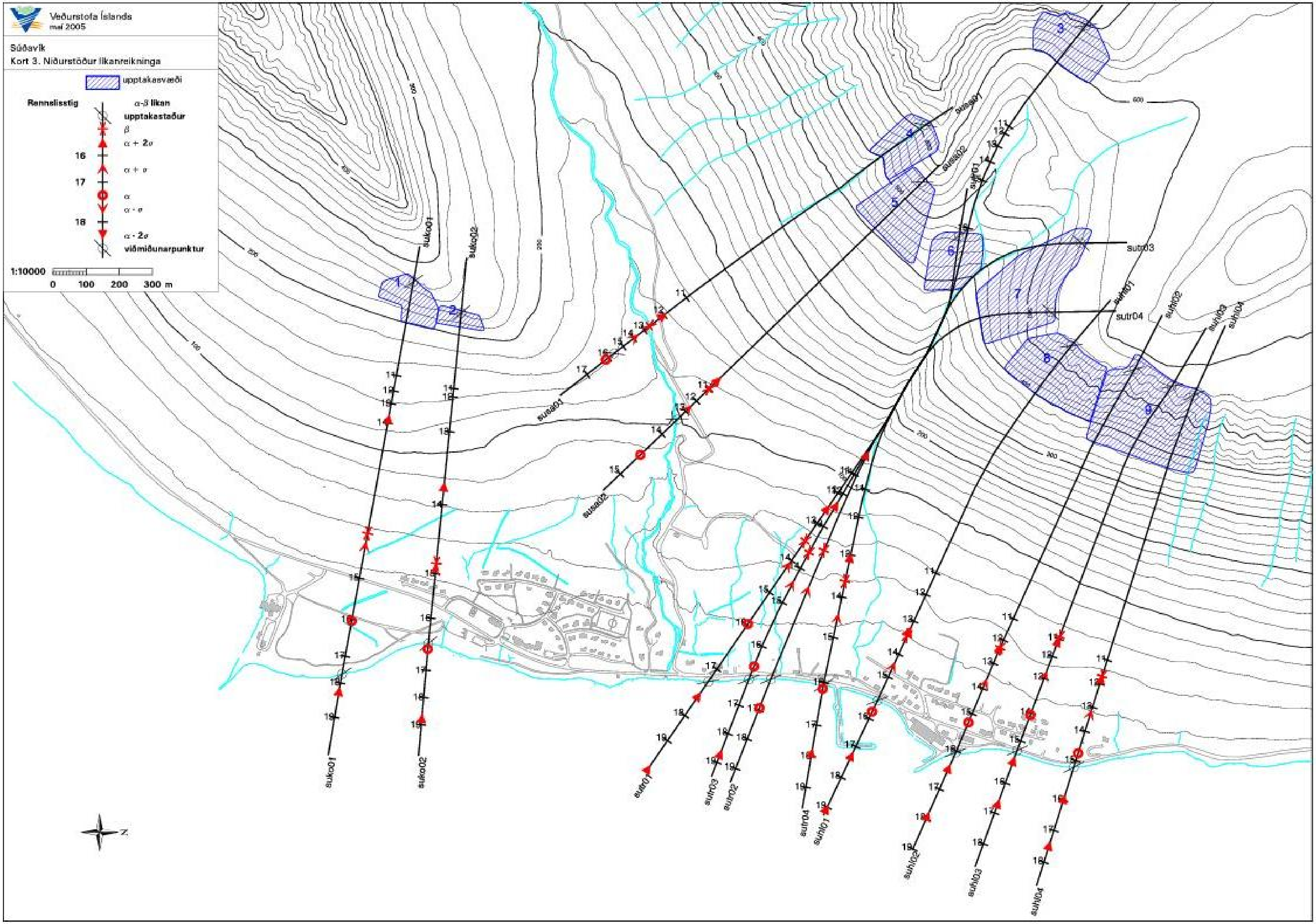


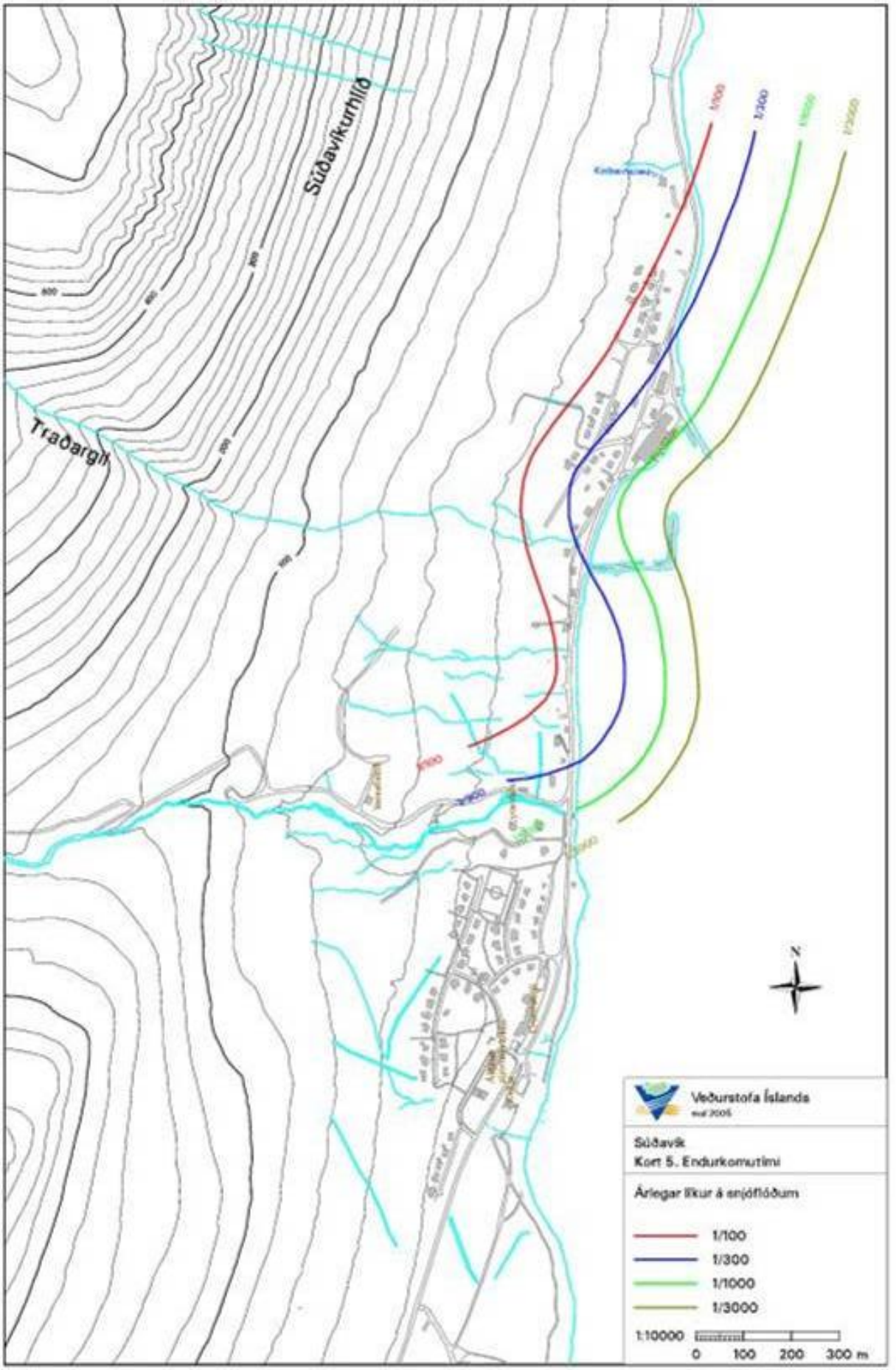
Survival rate

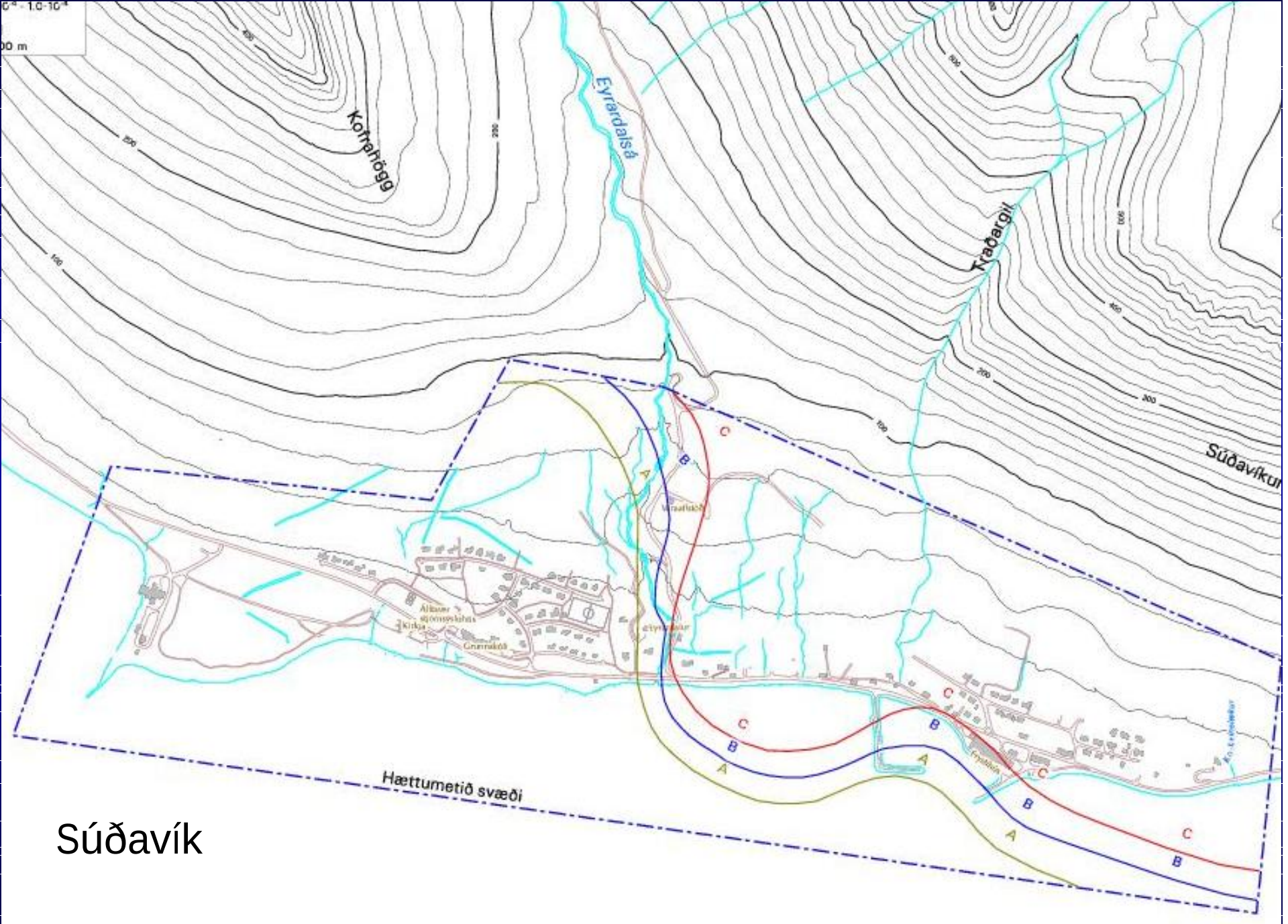


Súðavík


Veðurstofa Íslands
mai 2005
Súðavík
Kort 2. Snjóflóð til vors 2005
Útlínur snjóflóða óruggar
Útlínur snjóflóða ónákvæmar
Útlínur snjóflóða óvissar
Útlínur snjóflóða í sjó
Staðsetning húsa sem flóð hafa fallið á
1:7500
0 100 200 300 m
N


Veðurstofa Íslands
maí 2005
Súðavík
Kort 3. Niðurstöður líkanreikninga
upptakasvæði
Rennslisstig
α-β líkan
upptakastaður
β
α + 2σ
16
α + σ
17
α
α - σ
18
α - 2σ
viðmiðunarpunktur
1:10000
0 100 200 300 m
suko01
suko02
susa01
susa02
sutr01
sutr02
sutr03
sutr04
suhl01
suhl02
suhl03
suhl04
1
2
3
4
5
6
7
8
9


Súðavíkurhlíð
Traðargil
1/100
1/300
1/1000
1/3000
N
Veðurstofa Íslands
Súðavík
Kort 5. Endurkomutími
Árlegar líkur á snjóflóðum
1/100
1/300
1/1000
1/3000
1:10000
0
100
200
300 m


Eyrardalsá
Kofrahögg
Kraðargil
Súðavíkur
Hættumetið svæði
C
B
A

Súðavík

Súðavík

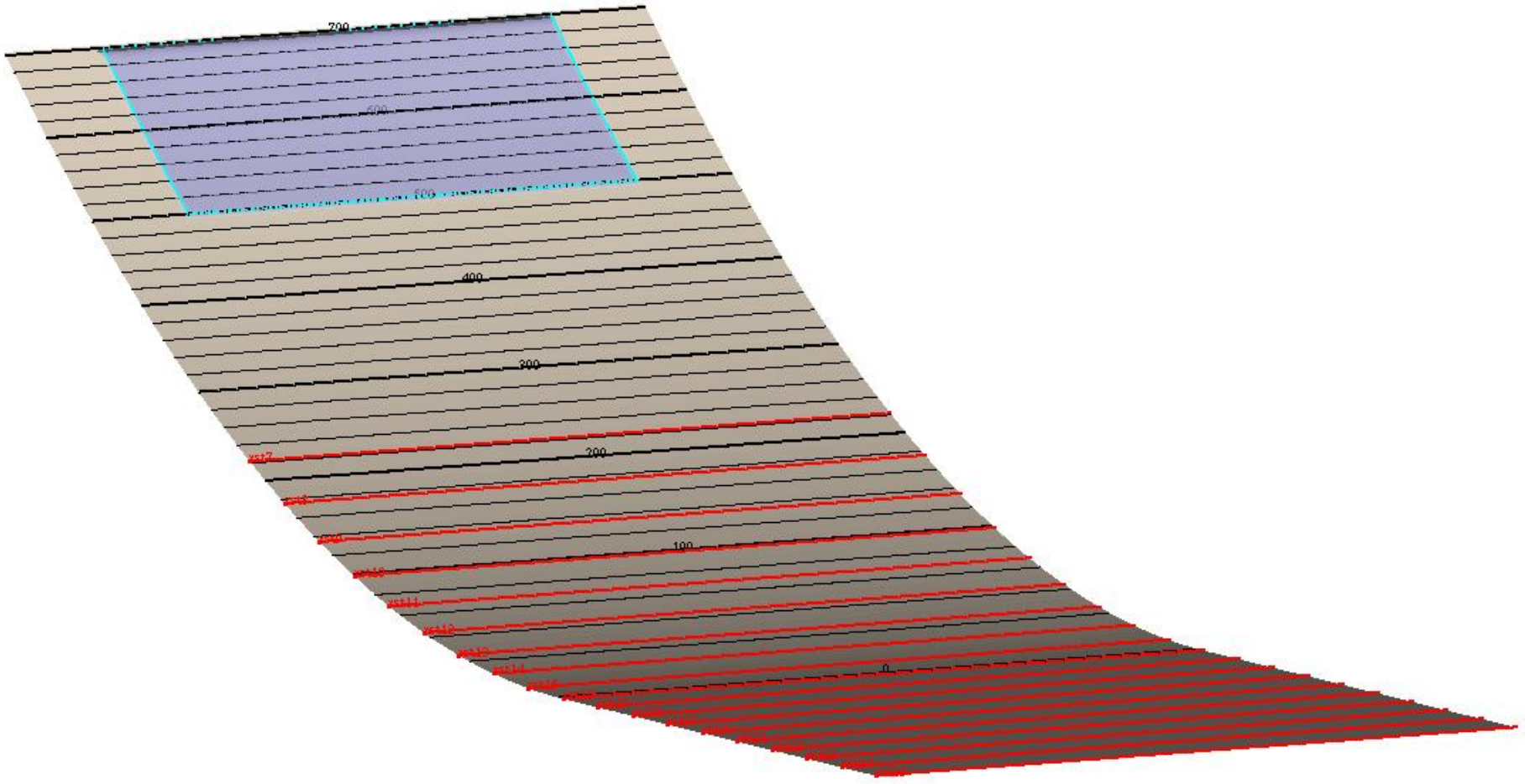
Further developments

- Calculation of 2D runout indices
- Reevaluation of the shape of the runout frequency distribution
- Define better the survival rate function
- Integration of the total risk
- Comparison between countries

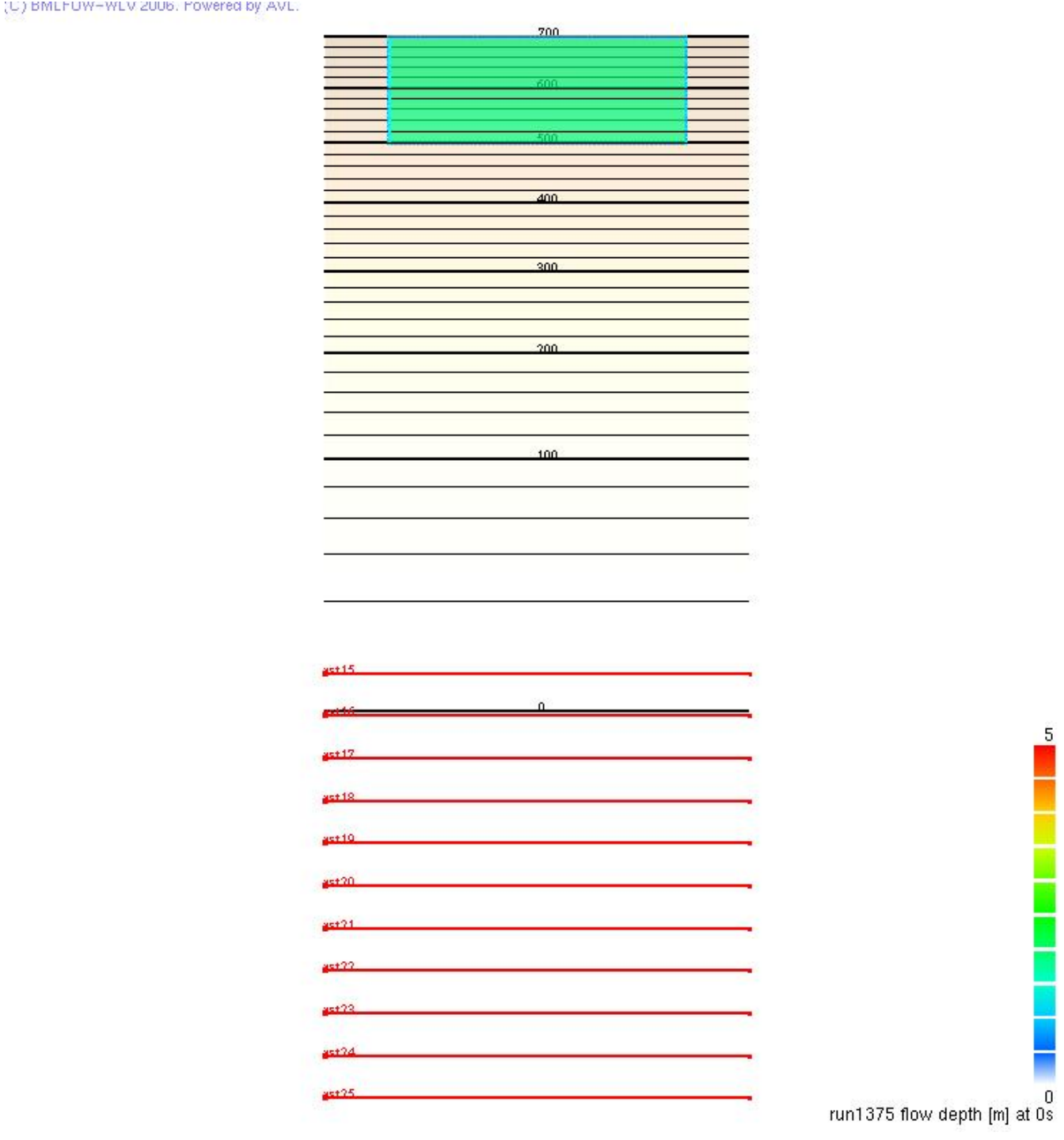
2D runout indices

- The runout index scale has been used extensively at IMO
- Flow-line models only consider the geometry of the path in the downstream direction
- In reality topographical features such as gullies and ridges strech along avalanche paths and affect the runout of avalanches
- It is possible to use 2D models to estimate 2D runout indices for hazard mapping

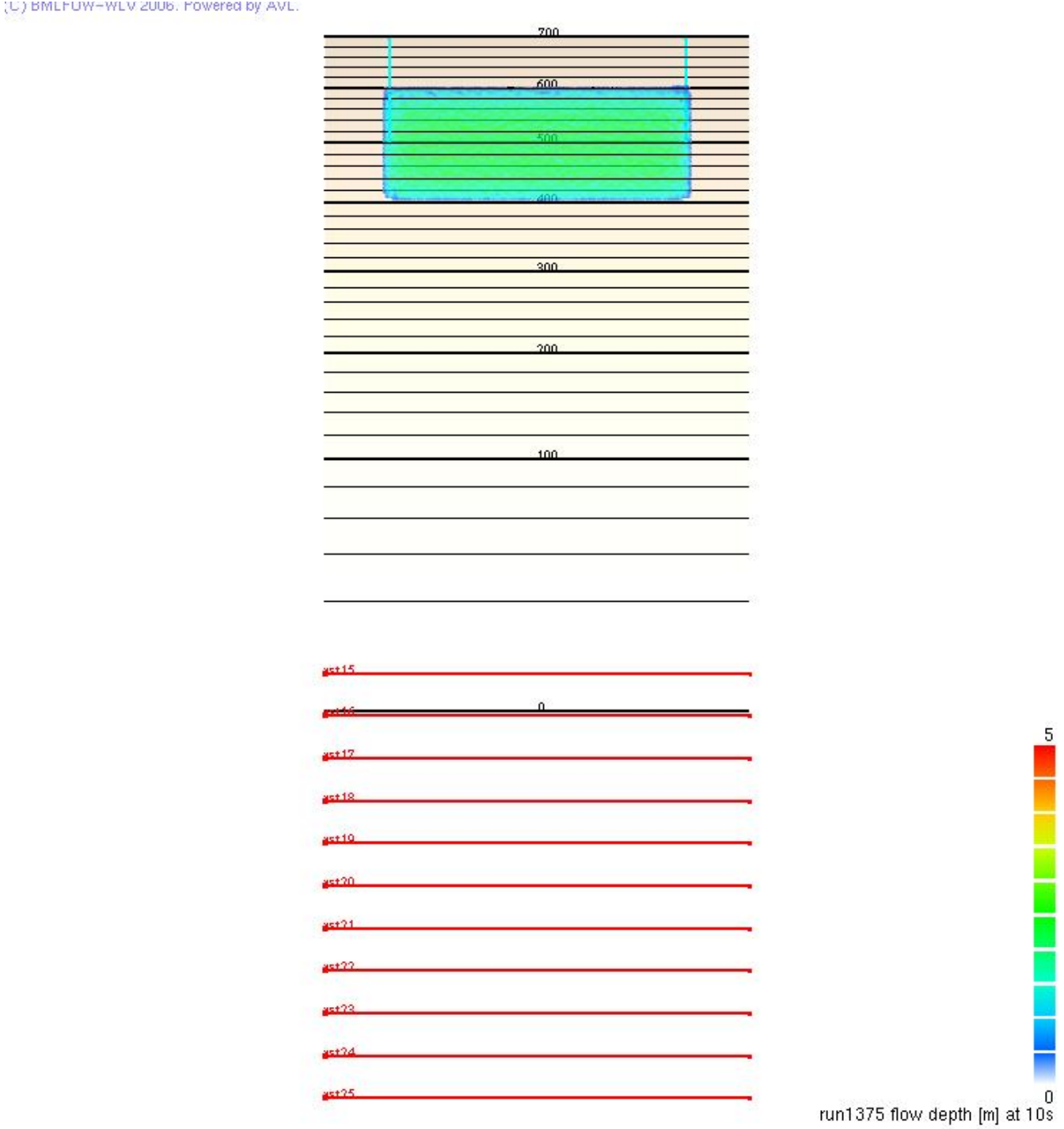
2D standard path



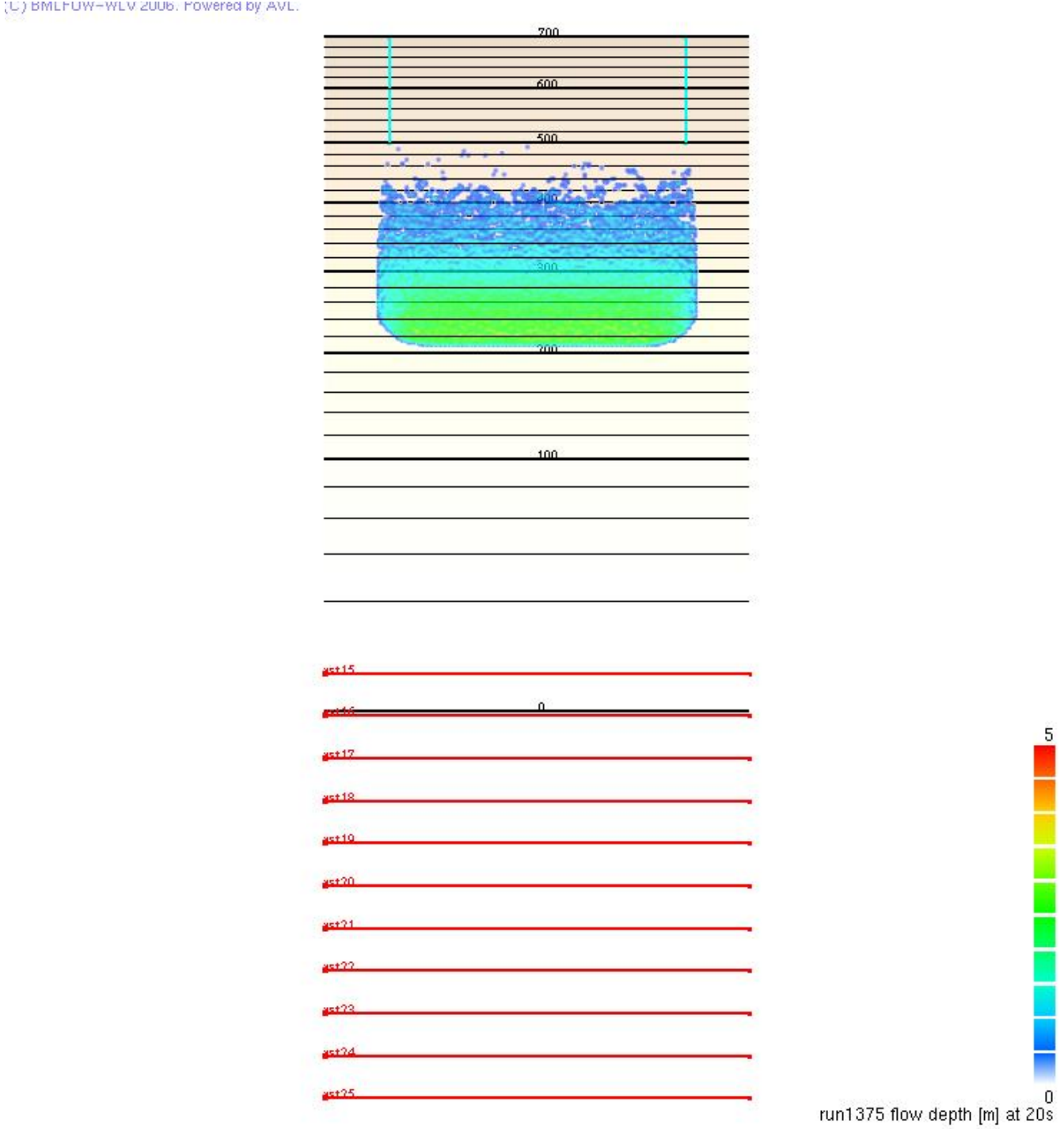
0 s


(C) BMLFLOW-WLV 2006. Powered by AVL.
700
600
500
400
300
200
100
0
gst15
gst16
gst17
gst18
gst19
gst20
gst21
gst22
gst23
gst24
gst25
5
0
run1375 flow depth [m] at 0s

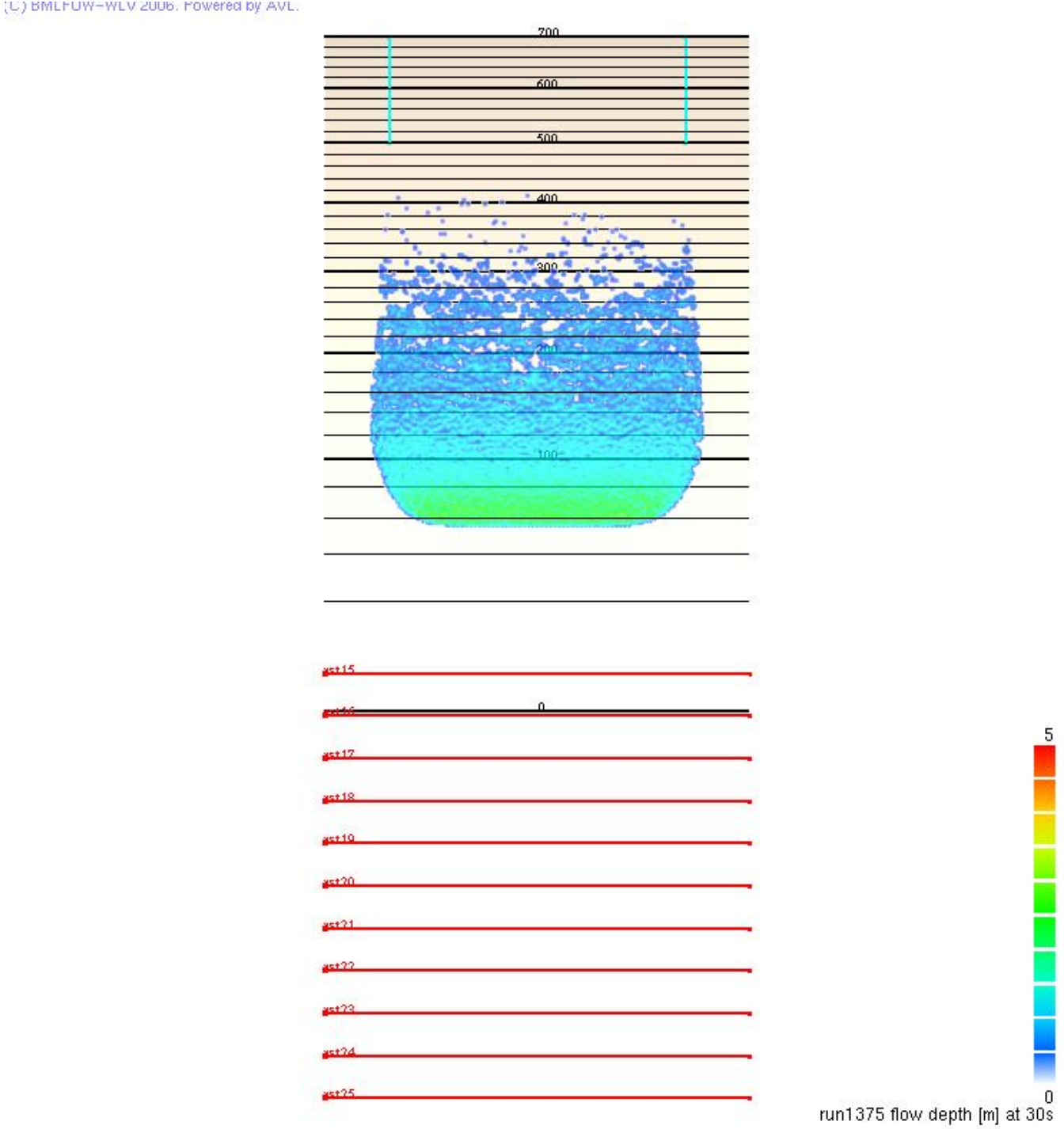
10 s


(C) BMTFLOW-WLV 2006. Powered by AVL.
700
600
500
400
300
200
100
0
gst15
gst16
gst17
gst18
gst19
gst20
gst21
gst22
gst23
gst24
gst25
5
0
run1375 flow depth [m] at 10s

20s


(C) BMLFLOW-WLV 2006. Powered by AVL.
700
600
500
400
300
200
100
0
gst15
gst16
gst17
gst18
gst19
gst20
gst21
gst22
gst23
gst24
gst25
5
0
run1375 flow depth [m] at 20s

30s


(C) BMLFLOW-WLV 2006. Powered by AVL.
700
600
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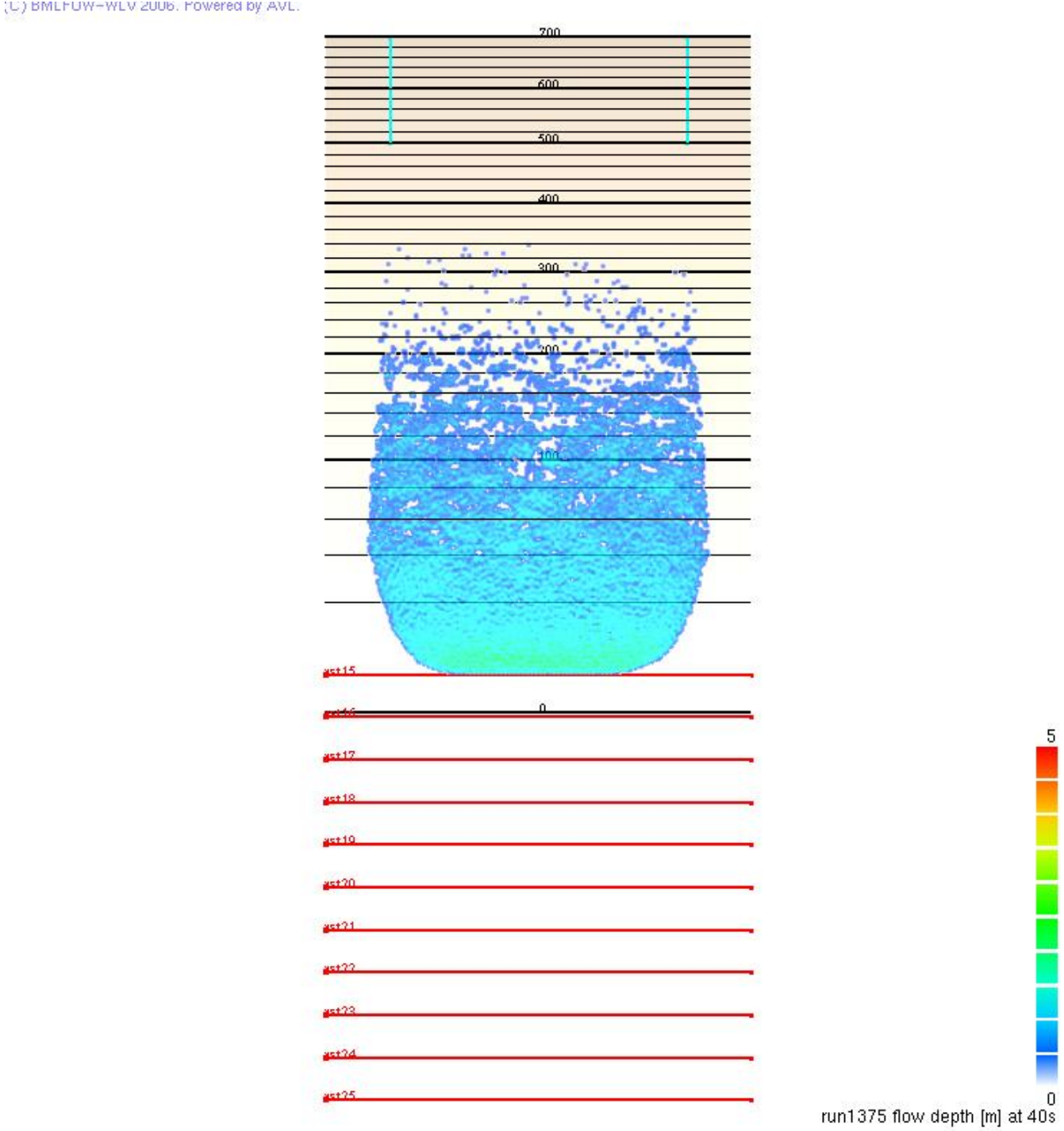
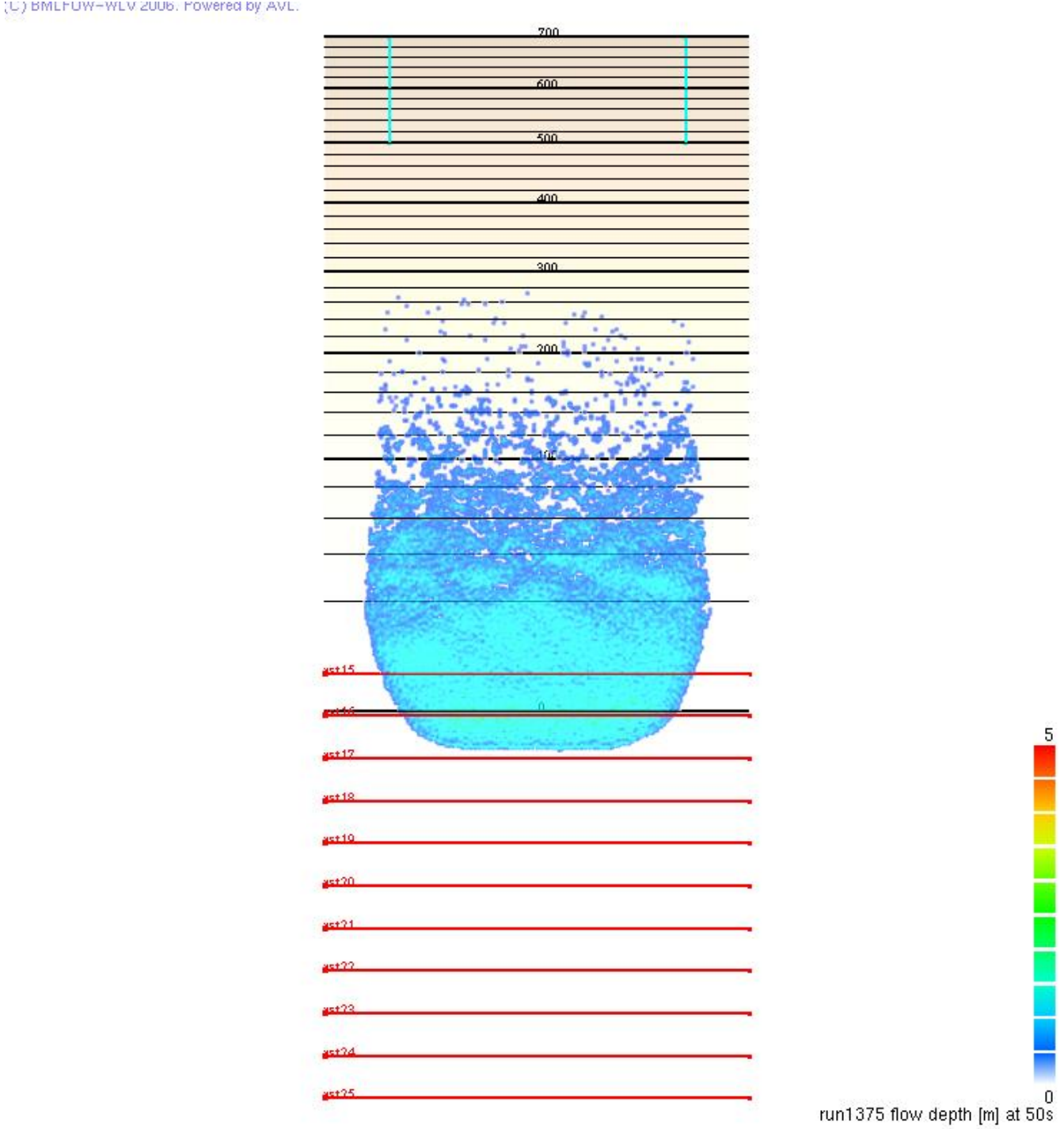
300
200
100
0
gst15
gst16
gst17
gst18
gst19
gst20
gst21
gst22
gst23
gst24
gst25
5
0
run1375 flow depth [m] at 30s

40s


(C) BMLFLOW-WLV 2006. Powered by AVL.
700
600
500
400
300
200
100
0
gst15
gst16
gst17
gst18
gst19
gst20
gst21
gst22
gst23
gst24
gst25
5
0
run1375 flow depth [m] at 40s

50s


(C) BMLFLOW-WLV 2006. Powered by AVL.
700
600
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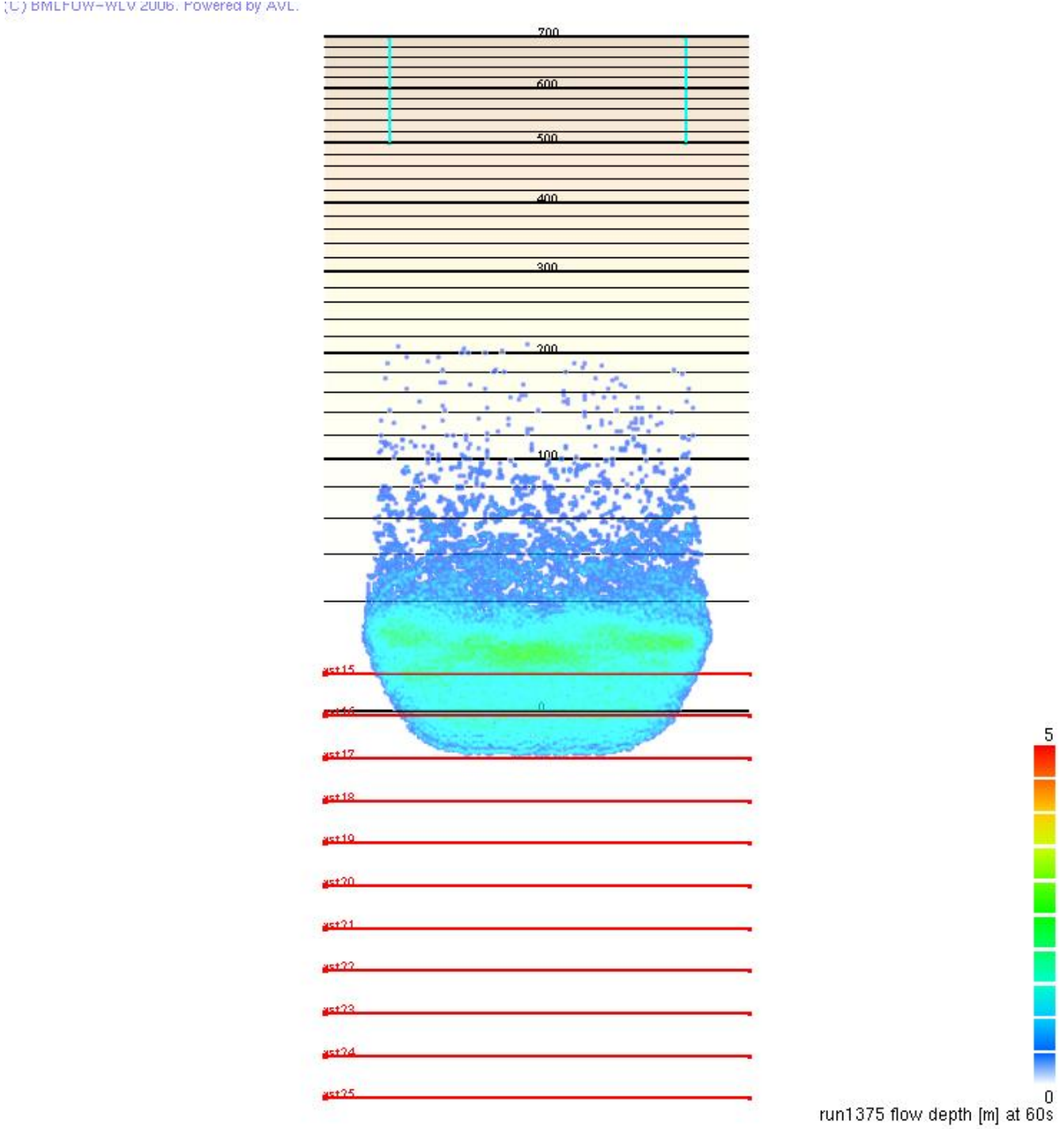
200
100
0
gst15
gst16
gst17
gst18
gst19
gst20
gst21
gst22
gst23
gst24
gst25
5
0
run1375 flow depth [m] at 50s

60s


(C) BMLFLOW-WLV 2006. Powered by AVL.
700
600
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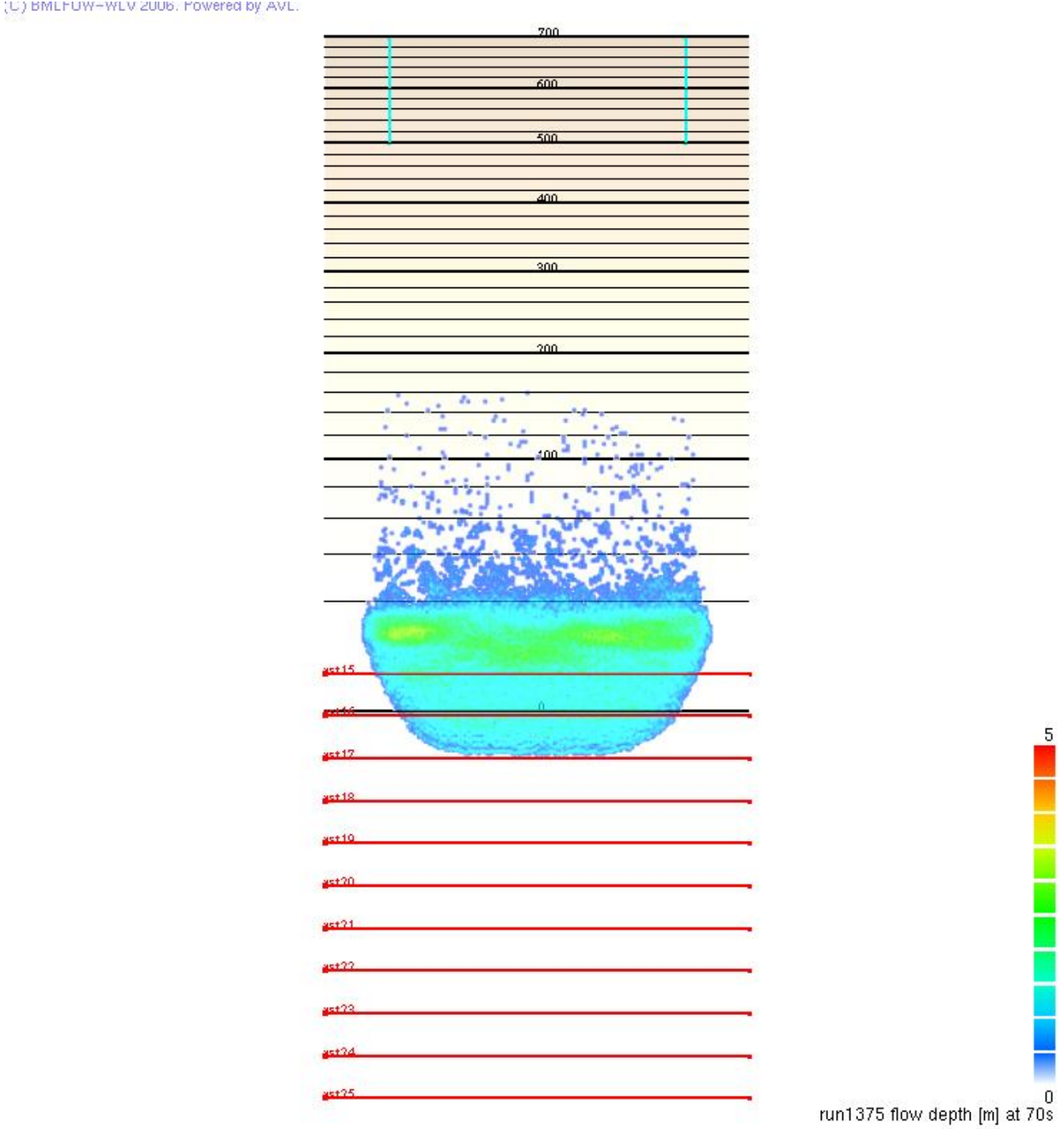
200
100
0
gst15
gst16
gst17
gst18
gst19
gst20
gst21
gst22
gst23
gst24
gst25
5
0
run1375 flow depth [m] at 60s

70s


(C) BMLFLOW-WLV 2006. Powered by AVL.
700
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100
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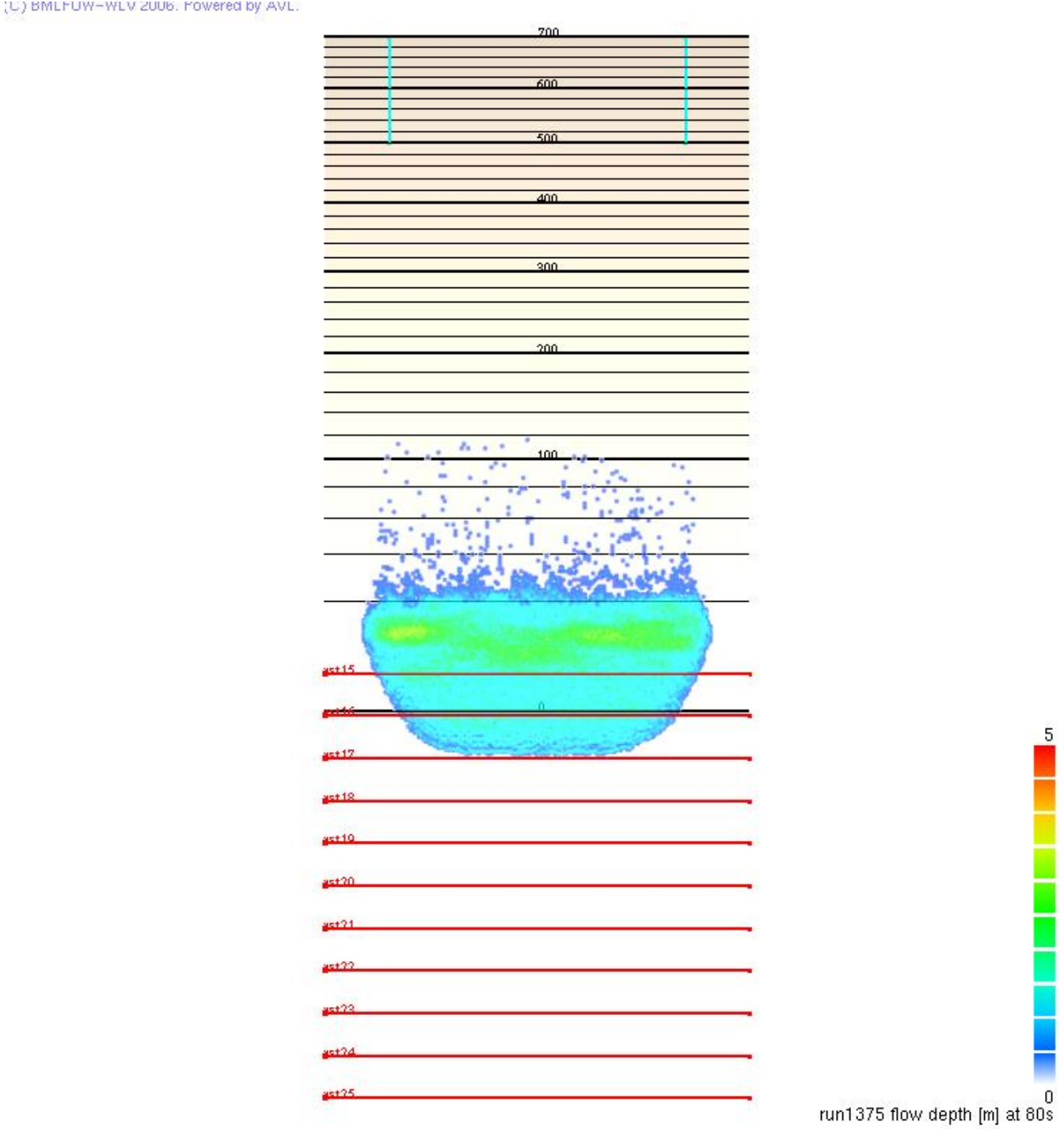
gst15
gst16
gst17
gst18
gst19
gst20
gst21
gst22
gst23
gst24
gst25
5
0
run1375 flow depth [m] at 70s

80s


(C) BMLFLOW-WLV 2006. Powered by AVL.
700
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100
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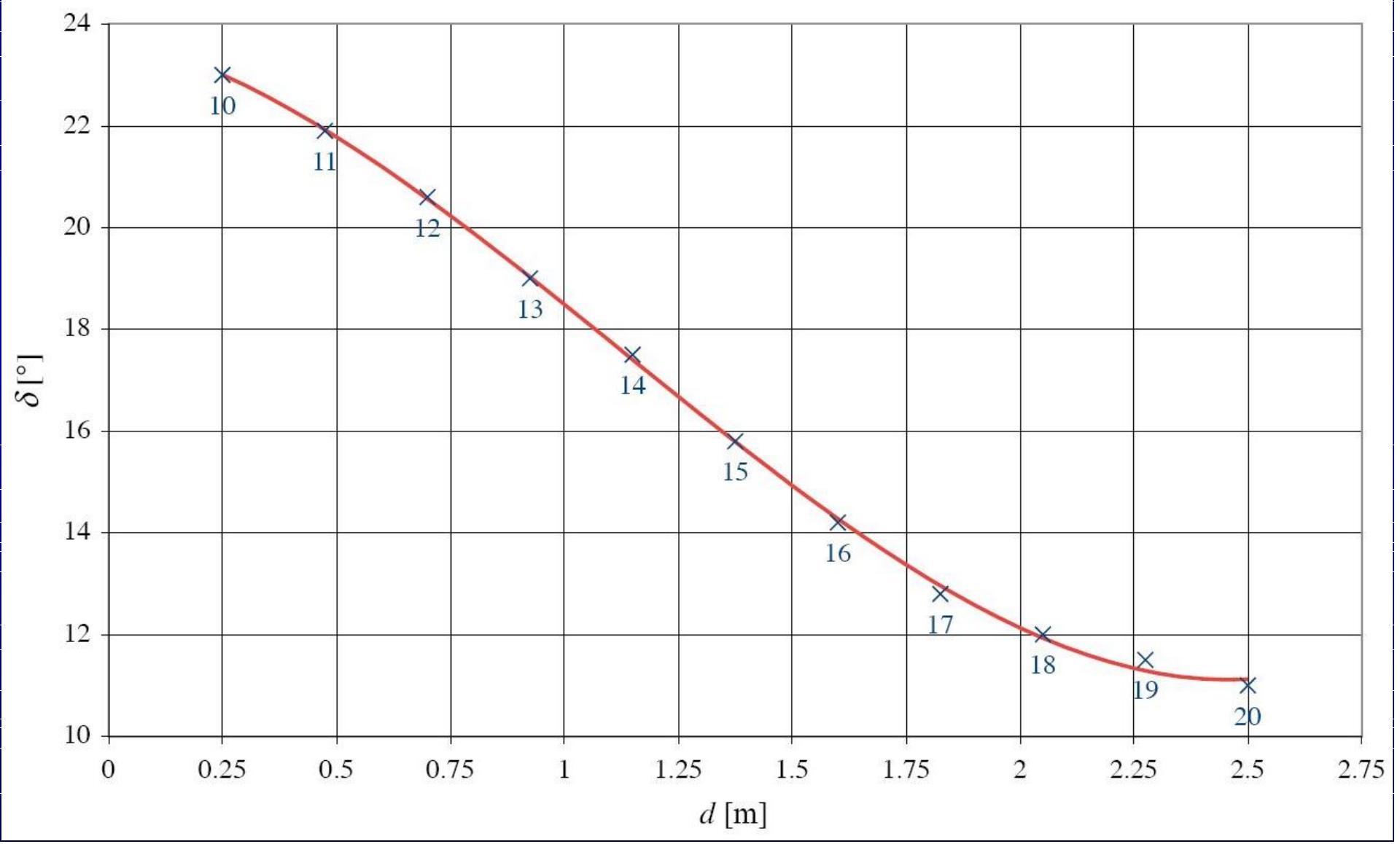
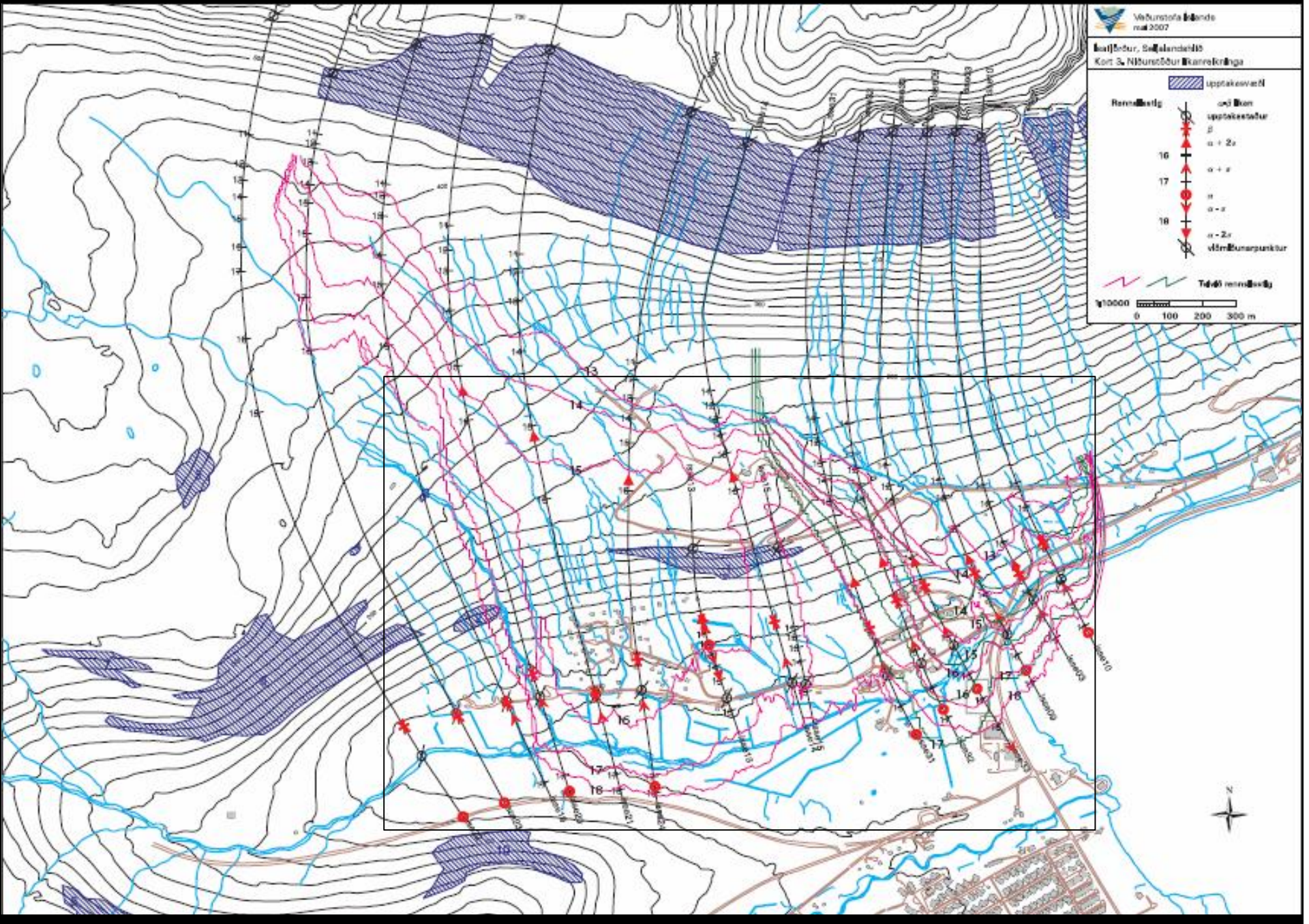
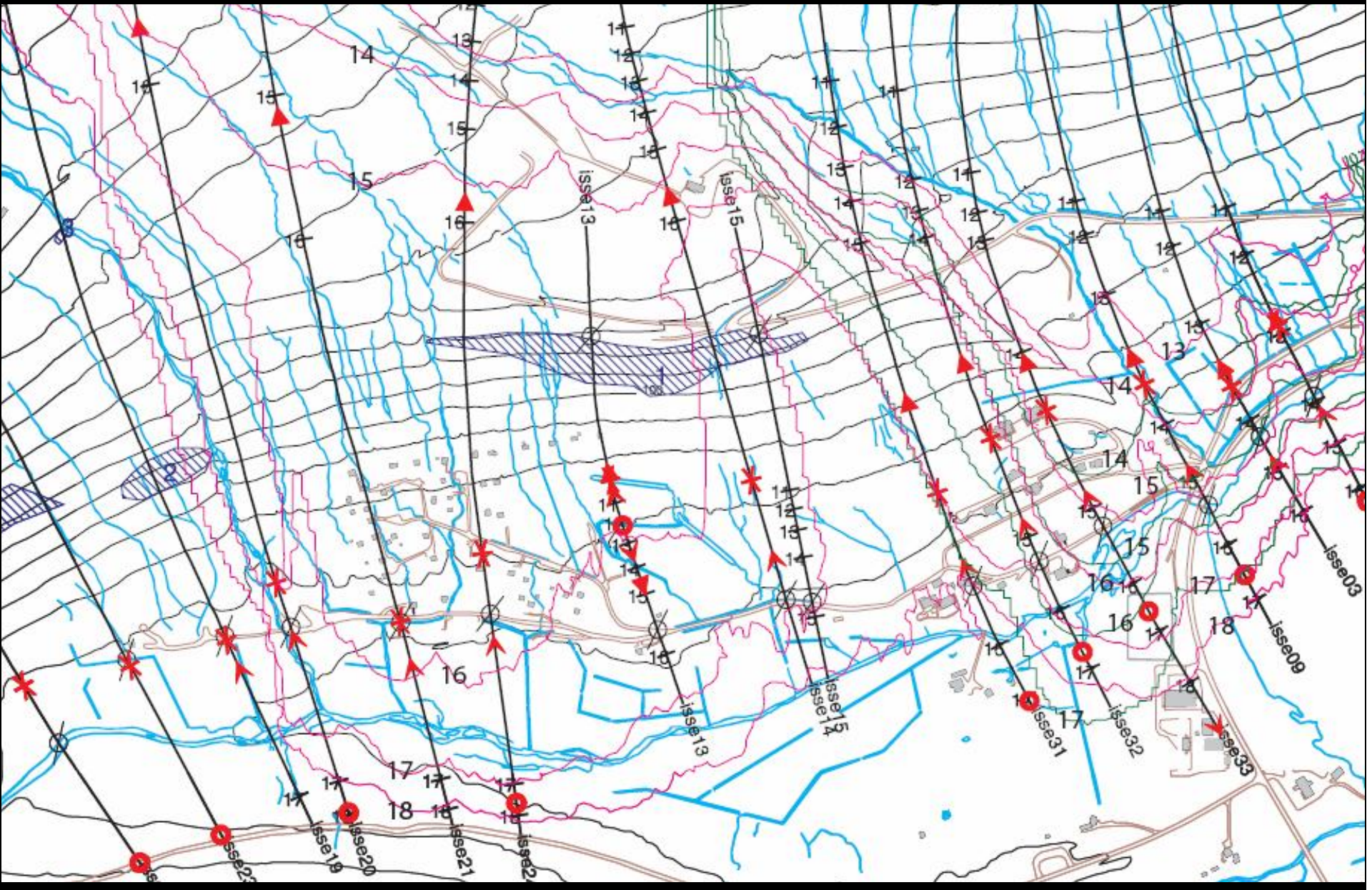
gst15
gst16
gst17
gst18
gst19
gst20
gst21
gst22
gst23
gst24
gst25
5
0
run1375 flow depth [m] at 80s

δ-d axis


24
22
20
18
16
14
12
10
δ [°]
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
2.75
d [m]
10
11
12
13
14
15
16
17
18
19
20


upptakesvæði
upptakestraumur
0
16
17
18
1:10000
0 100 200 300 m
N


isse13
isse15
isse14
isse31
isse32
isse33
isse09
isse03
isse19
isse20
isse21