Part 1 - Introduction of Approaches to Natural Hazards Modelling

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Place: Hochschule Magdeburg-Stendal

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Natural hazards

Definition

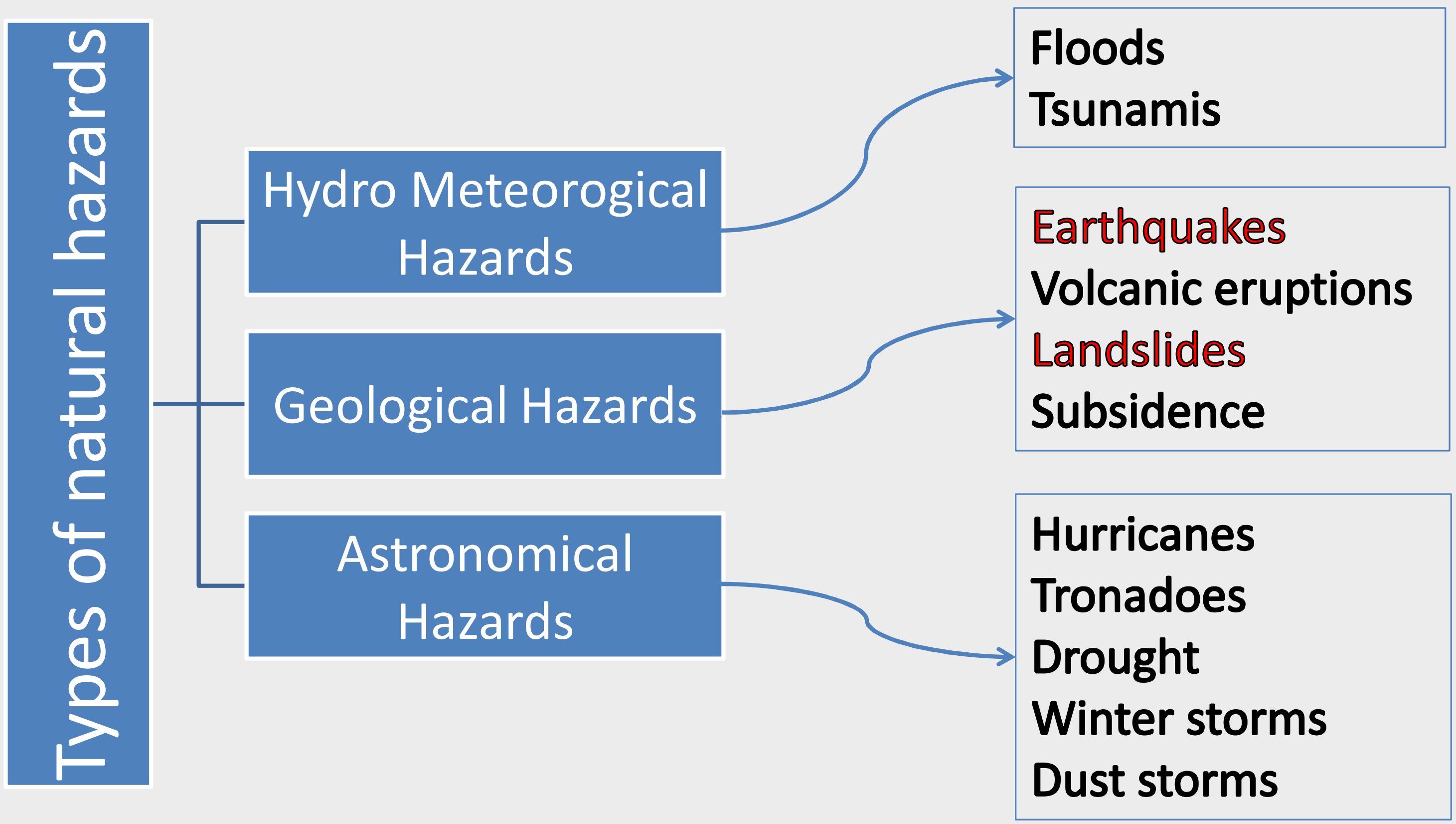
- Natural hazards are naturally occurring physical phenomena having atmospheric, geologic or hydrologic origin.
- Natural hazards are not entirely natural for people are also agents of disaster.

Hazards' Human Costs

- Every year natural disasters leave…
  - 4,000,000 homeless
  - 46,000 injured
  - 5520 dead
- These figures do not include the recent tsunami in Asia (273,000) and Hurricane Katrina (1000)

Source: The International Red Cross

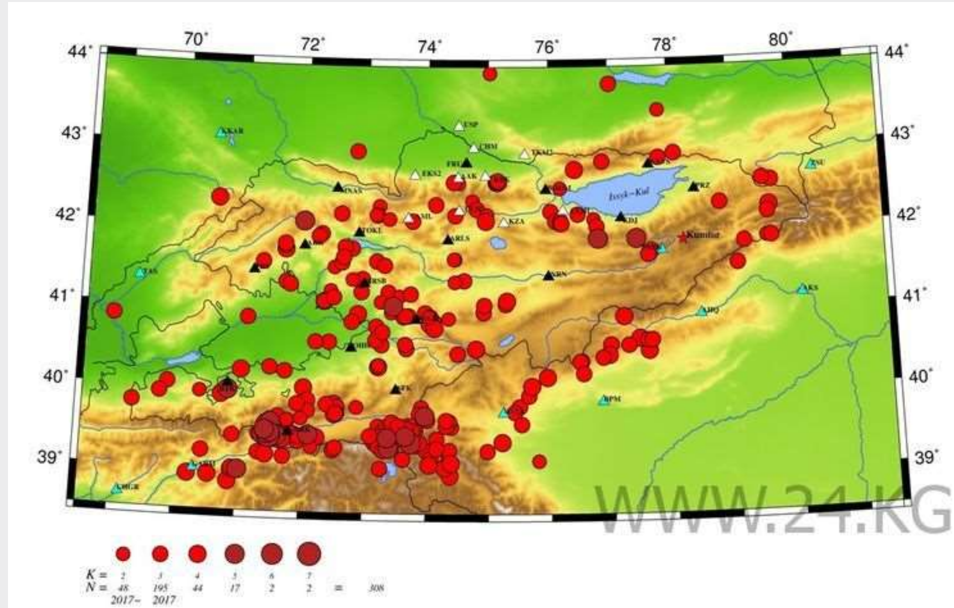
Types of natural hazards



Earthquake

Earthquake

- ❖ An earthquake is a shaking of the ground caused by sudden slippage of rock masses below or at the surface of the earth.
- ❖ It is a wave-like movement of the earth's surface.



In 2017, a total of 11,976 earthquakes were registered in Kyrgyzstan.
308 earth shocks reached 2-3 points or higher. There were no 6- and 7-point earthquakes.

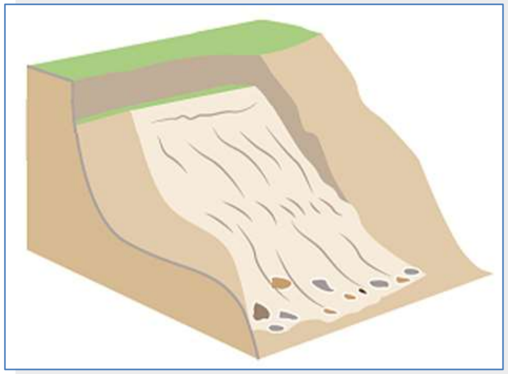
Landslide

Landslide

- ❖ A landslide is a massive outward and downward movement of slope-forming materials.
- ❖ The term landslide is restricted to movements of rocks and soil masses. These masses may range in sized from card to entire mountainsides.
- ❖ Their movements may vary in velocities.
- ❖ Landslide as a geological hazard is caused by earthquake or volcanic eruption.
- ❖ This initiated when a section of a hill slope or sloping section of a mountain is rendered weak to support its own weight.

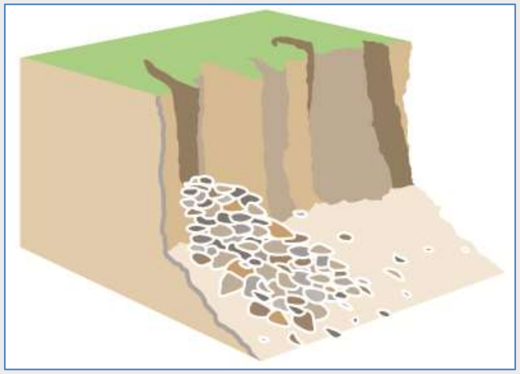
In 2017 a massive torrent of mud came down on the village of Ayu in Kyrgyzstan. It caused that 24 people were buried after 11 houses were hit by the landslide.

Common types of landslides

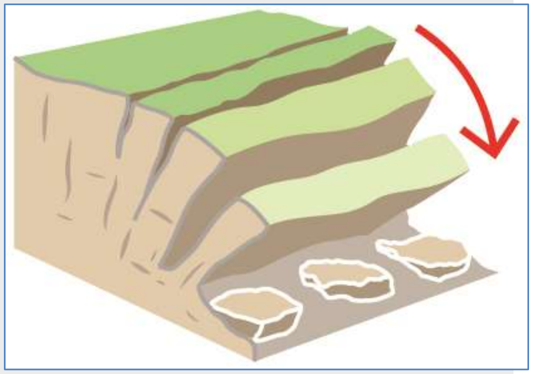


a) *Rotational slides* move along a surface of rupture that is curved and concave

b) *Translational slides* occurs when the failure surface is approximately flat or slightly undulated

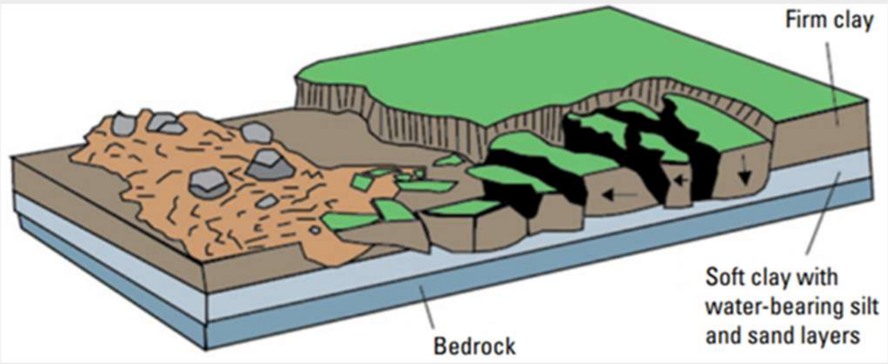


c) *Rotational slides* free falling of detached bodies of bedrock (boulders) from a cliff or steep slope



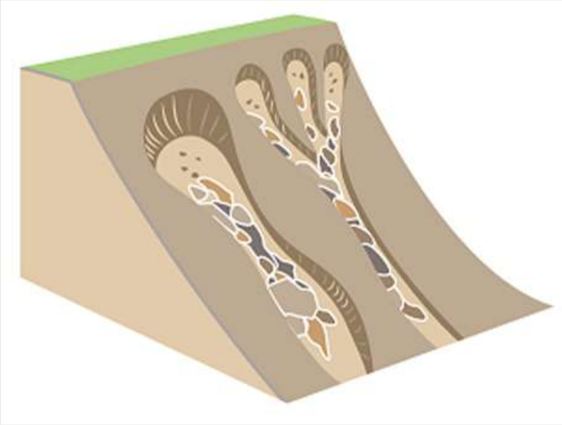
d) *Rotational slides* occurs when one or more rock units rotate about their base and collapse

Common types of landslides



e) *Lateral spreading* occurs when the soil mass spreads laterally and this spreading comes with tensional cracks in the soil mass

f) *Debris flow* down slope movement of collapsed, unconsolidated material typically along a stream channel



Mitigation strategies

- Hazard mapping
- Land use
- Retaining walls
- Surface drainage control works
- Engineered structures
- Increasing vegetation cover
- Insurance

a) Earthquake-Induced Landslide Models

Scoops3D

Scoops3D evaluates slope stability throughout a digital landscape represented by a digital elevation model (DEM). It provides the least-stable potential landslide for each DEM cell, as well the associated volumes and (or) areas.

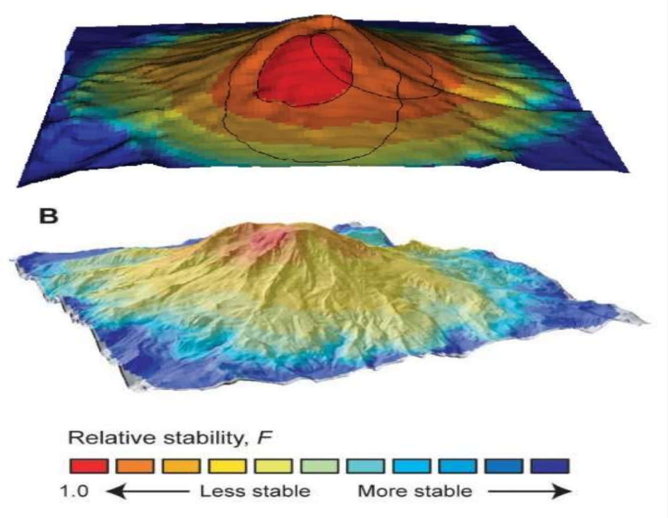
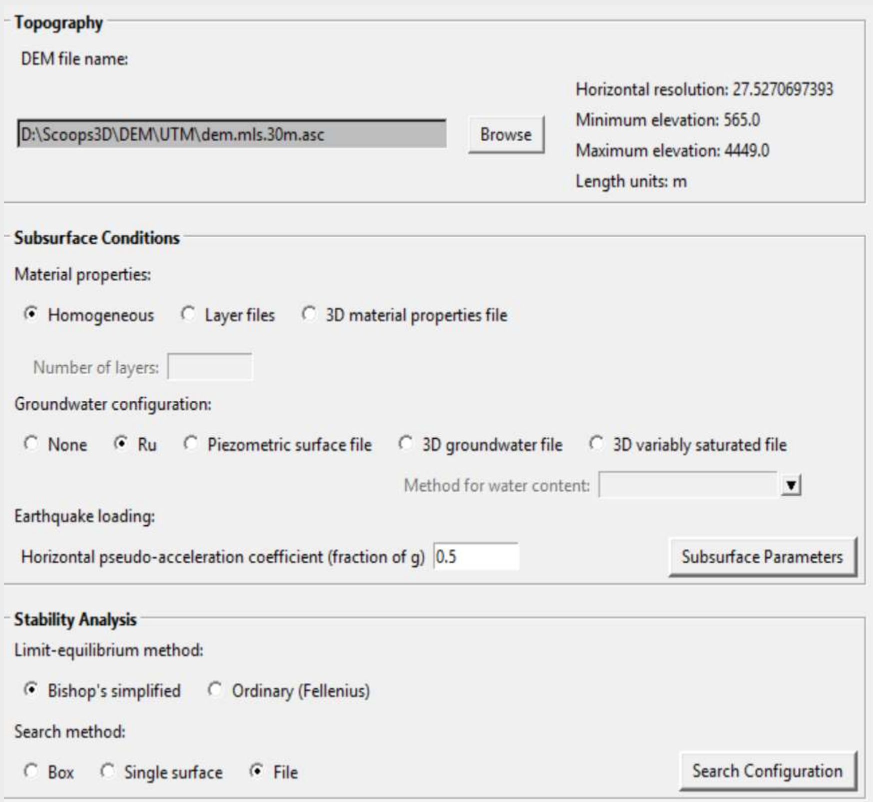


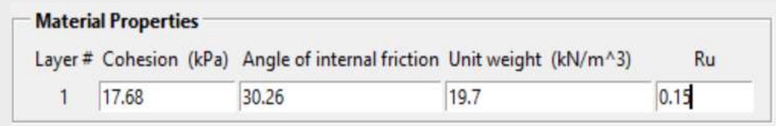
Table 1 – Recommended Horizontal Seismic Coefficients

Horizontal Seismic Coefficient, k_h	Description	
0.05 - 0.15	In the United States	
0.12 - 0.25	In Japan	
0.1	"severe" earthquakes	Terzaghi [4]
0.2	"violent, destructive" earthquakes	
0.5	"catastrophic" earthquakes	
0.1 - 0.2	Seed [2], FOS ≥ 1.15	
0.10	Major Earthquake, FOS > 1.0	Corps of Engineers [5]
0.15	Great Earthquake, FOS > 1.0	
½ to ⅓ of PHA	Marcuson [6], FOS >1.0	
½ of PHA	Hynes-Griffin [7], FOS > 1.0	

Eq. 0.8 refers to extreme earthquake

Input parameters





Layer	Depth (m)	Cohesion (kPa)	Angle of internal friction (°)	Unit weight (kN/m³)	Ru coefficient
L01	4.0	11.6	36.0	19.2	0.13
L02	5.2	11.3	32.3	19.2	0.10
L03	4.0	8.8	31.0	20.0	0.12
L04	2.0	40.0	23.0	19.1	0.26
L05	2.5	-	-	21.0	0.19
L06	4.3	16.7	29.0	19.6	0.12
Mean	3.7	17.7	30.3	19.7	0.15

$$R_u = \frac{u}{\gamma z}$$

u is the pore-water pressure (10 kPa);
γ is the unit weight of the soil;
z is the depth below ground

Scoops3D: Example

Scoops3Di

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MLS.eq0.8.scp - fine search #  71, 100.% complete,    129569 trial surfaces
       MLS.eq0.8.scp - Search node:  1969,  1753; fine search #  72 ,  10 % completed,
          129569 trial surfaces analyzed
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       MLS.eq0.8.scp - Search node:  1969,  1825; fine search #  72 ,  50 % completed,
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MLS.eq0.8.scp - fine search #  73, 100.% complete,    129572 trial surfaces
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 MLS.eq0.8_output\MLS.eq0.8_fos3d_out.asc
 MLS.eq0.8_output\MLS.eq0.8_ordfos3d_out.asc
 MLS.eq0.8_output\MLS.eq0.8_fosvol_out.asc
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 MLS.eq0.8_output\MLS.eq0.8_filtergrid_out.asc
 MLS.eq0.8.scp - Successful execution of Scoops3D version number 1.1
Date and Time: 09/11/2020  14:17:18
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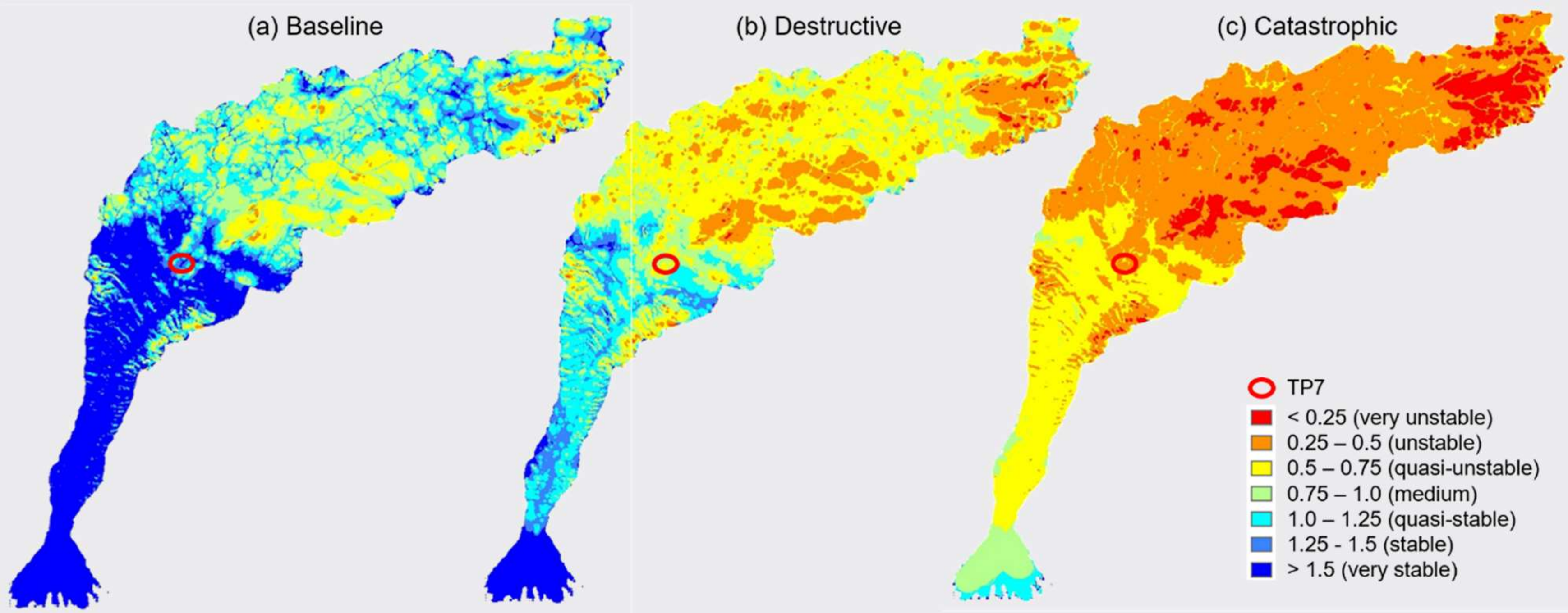
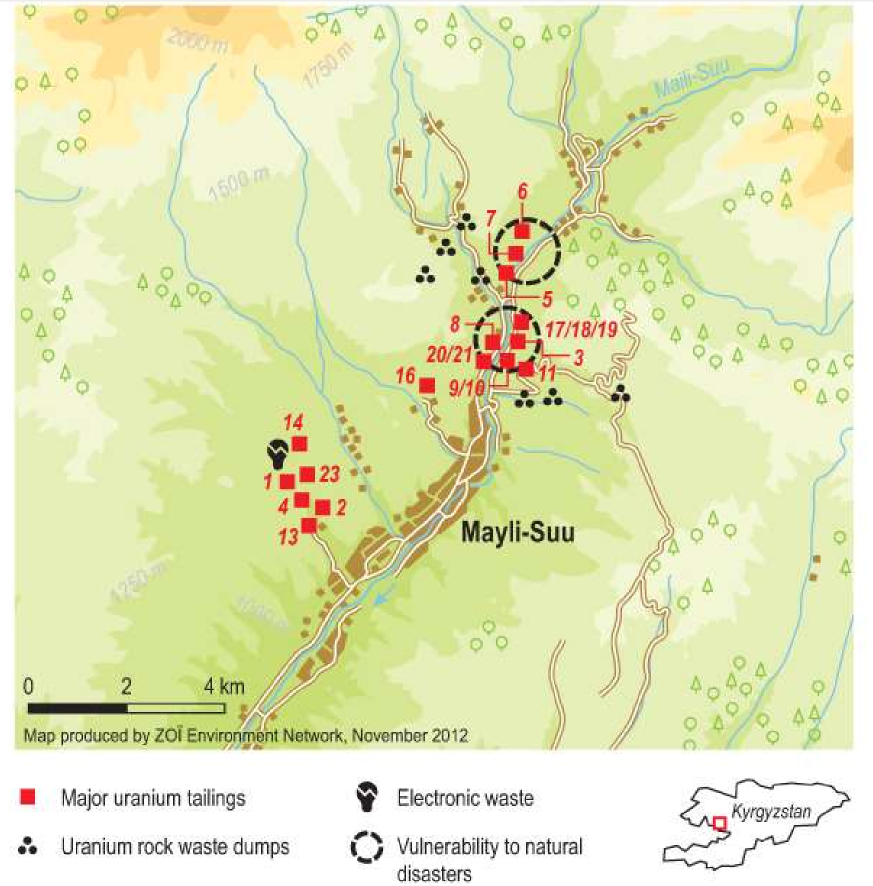
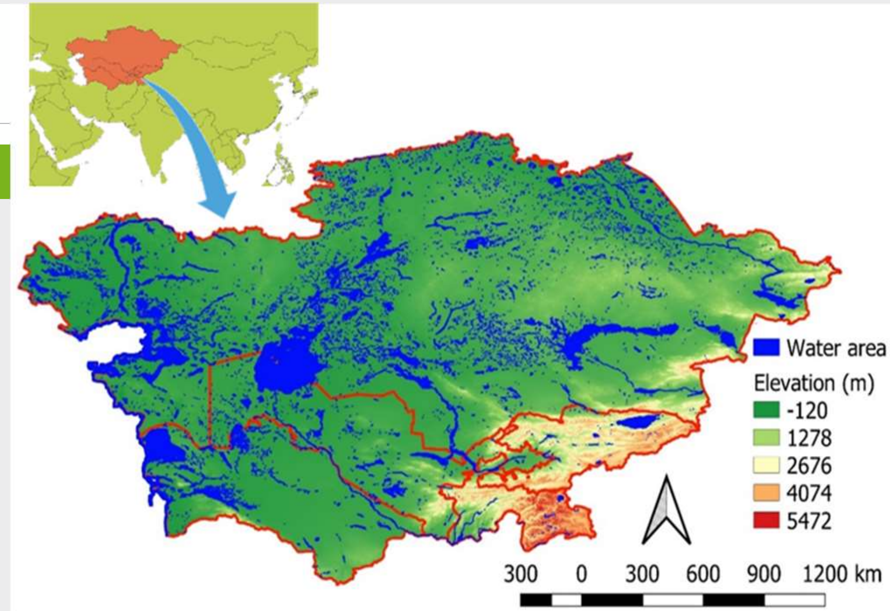
Maps of landslide susceptibility index



b) Transport Models

Overview map

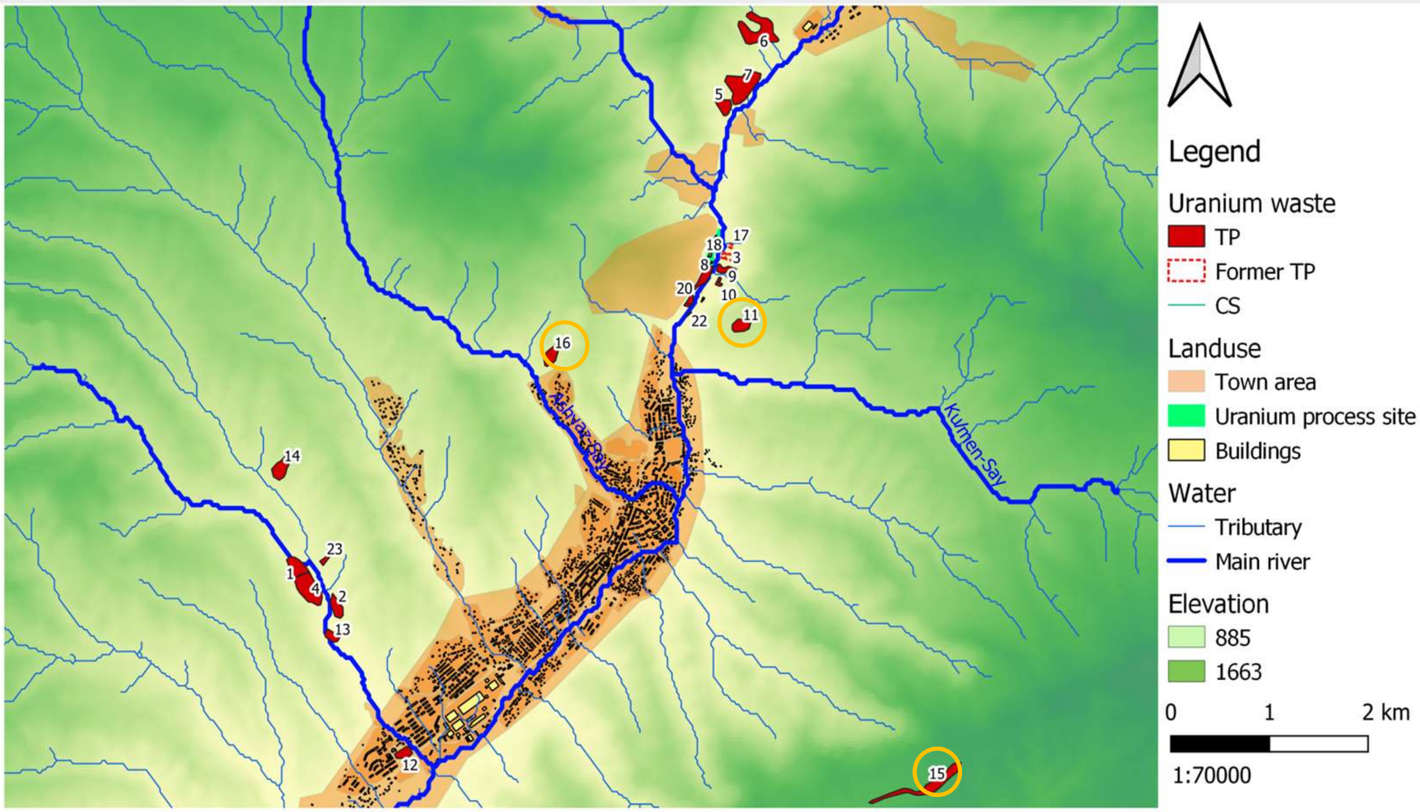




- Basin: Mailuu-Suu
- Town: 23.000 population
- Distance: 25 km to Kyrgyz-Uzbek border
- Radiation: 100 – 300 nSv/h (cosmic 50 – 150 nSv/h)

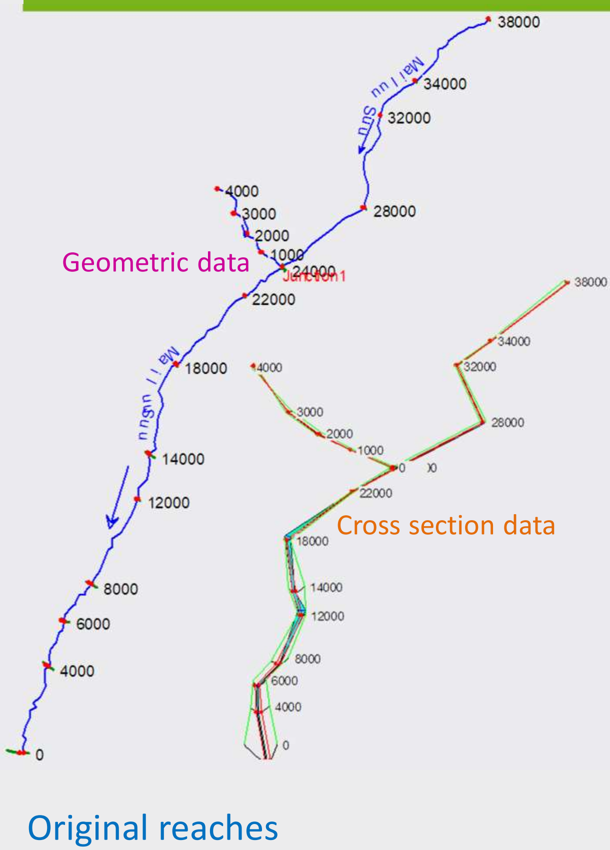
Tailings ponds

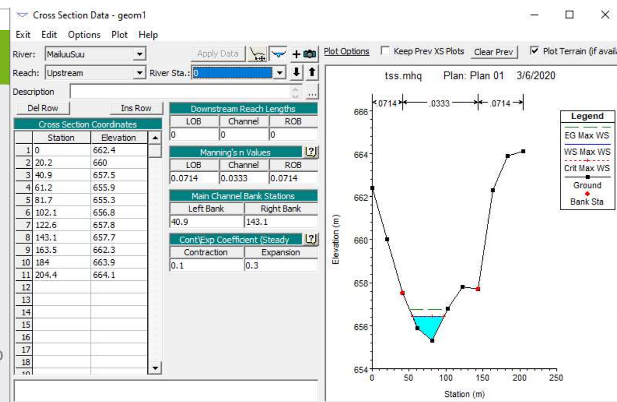
- 14 out of 23 tailings ponds were included;
- 6 ponds were remediated or classified into rock wastes;
- 3 ponds are not in the reach of river.



Tailings ponds	Neighbouring reach	Volume (m^3)
1	T3000	84000
2	T2000	65000
4	T3000	115000
5	S32500	111000
6	S33500	150000
7	S33000	600000
8	S31000	90000
9	S31000	115000
10	S31000	50000
12	S24000	2000
13	T2000	40000
14	T4000	99000
19	S31000	2000
23	T3000	25000
3	S31000	Remediation
17	S31000	Destroyed
18	S31000	Remediation
20	S30500	No tailings
21	S30500	No tailings
22	S30500	No tailings
11	Remote location	70000
15	Remote location	47000
16	Remote location	303000

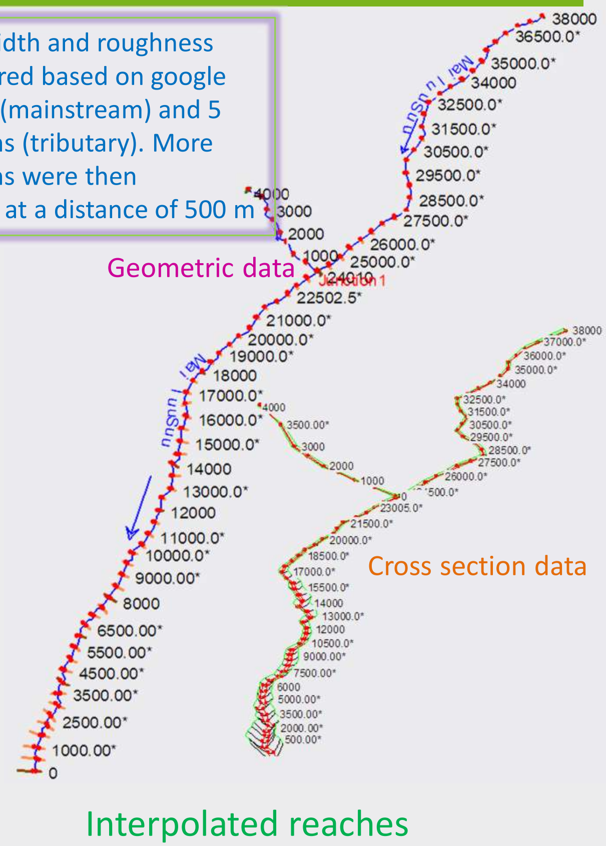
Hec-Ras and geometric data



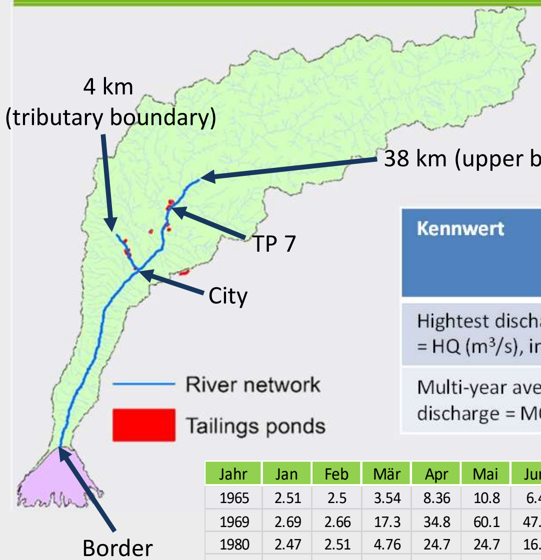


Reach	Elevation	Slope	Depth	Width		Roughness		
				Water	Channel	Left bank	Water	Right bank
km	m	m/m	m	m	m	$s*m^{-1/3}$	$s*m^{-1/3}$	$s*m^{-1/3}$
Mainstream								
38 km	1108.3	0.0172	0.3	12.5	52.5	0.100	0.033	0.050
34 km	1039.4	0.0172	0.5	20.4	49.5	0.063	0.033	0.062
32 km	1004.9	0.0134	0.6	24.4	48.0	0.045	0.033	0.068
28 km	951.5	0.0121	0.6	27.4	56.1	0.048	0.033	0.071
24 km	903.2	0.0121	0.7	28.8	67.9	0.064	0.033	0.071
22 km	879.0	0.0101	0.7	29.5	73.8	0.071	0.033	0.071
18 km	838.7	0.0101	1.0	35.2	97.5	0.067	0.033	0.071
14 km	798.4	0.0101	1.3	40.9	121.1	0.063	0.033	0.071
12 km	778.3	0.0101	1.4	43.8	132.9	0.061	0.033	0.071
8 km	738.0	0.0101	1.7	49.5	156.5	0.056	0.033	0.071
6 km	717.9	0.0101	1.8	52.3	168.4	0.054	0.033	0.071
4 km	697.7	0.0106	2.0	55.2	180.2	0.052	0.033	0.071
Border	655.3	0.0000	2.2	102.2	204.4	0.071	0.033	0.071
Tributary								
4 km	1074.4	0.0478	0.3	1.6	6.4	0.100	0.033	0.100
3 km	1026.6	0.0491	0.3	2.7	8.1	0.100	0.033	0.100
2 km	977.5	0.0280	0.6	7.4	14.8	0.100	0.033	0.100
1 km	949.5	0.0463	1.1	12.7	27.8	0.100	0.033	0.100
Junction	903.2	0.0000	0.9	22.1	37.8	0.100	0.033	0.100

Elevation, width and roughness were measured based on google earth for 13 (mainstream) and 5 cross sections (tributary). More cross sections were then interpolated at a distance of 500 m

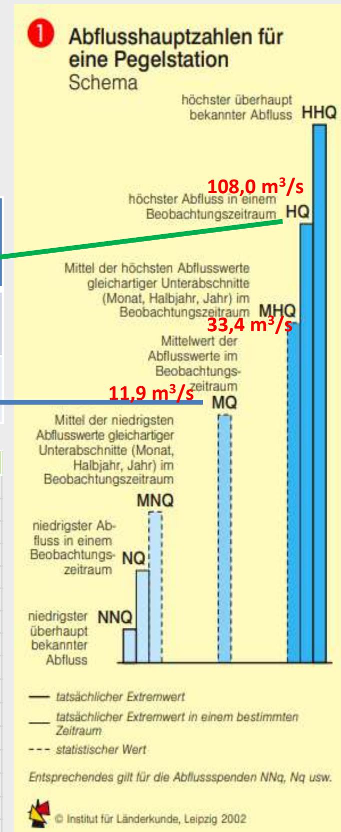


Discharge & dispersion coefficient



Kennwert	Mailuu-Suu city	Upper boundary (38 km)	Tributary boundary (4 km)
Hightest discharge = HQ (m^3/s), in 1969	108,0	65,6	0,95
Multi-year average discharge = MQ (m^3/s)	11,9	7,2	0,10

Jahr	Jan	Feb	Mär	Apr	Mai	Jun	Jul	Aug	Sep	Okt	Nov	Dez	Mittelwert	Max
1965	2.51	2.5	3.54	8.36	10.8	6.4	4.18	3.25	3.16	5.03	10.9	5.5	5.5	10.9
1969	2.69	2.66	17.3	34.8	60.1	47.5	23.9	11.2	6.36	8.91	8.35	4.26	19.0	60.1
1980	2.47	2.51	4.76	24.7	24.7	16.7	8.03	4.46	3.57	3.24	3.31	3.41	8.5	24.7
1985	2.9	3.8	7	31.1	31.5	21.3	10.7	5.1	4.1	4	3.8	3.7	10.7	31.5
1986	2.5	2.5	2.8	9.2	14.2	11.7	8	4.9	3.6	4.6	3.6	4.3	6.0	14.2
1987	3.9	4.7	12.2	34.2	42	32.1	22.5	13.8	7.5	8.2	9.6	5.9	16.4	42.0
1988	6.2	5	8.1	24.7	47.2	37.5	17.5	7.4	5.3	4.8	4.5	3.5	14.3	47.2
1989	3.3	2.2	5.1	11.5	18.9	14.3	9.2	4.9	3.2	3.4	3	3	6.8	18.9
2009					37.6	30	16.5	9.2	6.4	4.8	4.9	4	14.2	37.6
2010	3.7	4.7	16	38.8	37.2	43.7	22	11.7	7.2	4.9	4.3	3.9	16.5	43.7
2011	3.4	3.5	6	17	21.9	12.5	6.4	4.4	3.8	4.5	8.6	8	8.3	21.9
2012	4.2	4.8	10	37.5	35.5	41.5	15.5	8.3	4.8	4.4	4.3	4.3	14.6	41.5
2013	4.6	5.4	18.5	25	29.7	26	8	3.8	6.2	5.3	4.5	4.4	11.8	29.7
2014	3.2	3.9	12.5	31.5	33.2	16	8.5	3.2	2.9	3.6	4.5	5.1	10.7	33.2
2015	5	8	16.5	38.5	44.1	23	11.2	5.6	5	7.2	9.3	7.7	15.1	44.1
Mean	3.6	4.0	10.0	26.2	32.6	25.3	12.8	6.7	4.9	5.1	5.8	4.7	11.9	33.4



- The transport model bases on the advection-dispersion equation (ADE).

$$\frac{\partial c}{\partial t} + U\frac{\partial c}{\partial x} = D\frac{\partial^2 c}{\partial x^2} - \frac{wc}{h}$$

- The dispersion coefficient of the suspended sediment is mathematically described by Fick's law.

The equation for model computed dispersion coefficients is:

$$D = m\ 0.011\frac{u^2 w^2}{y u^*} \quad (19\text{-}1)$$

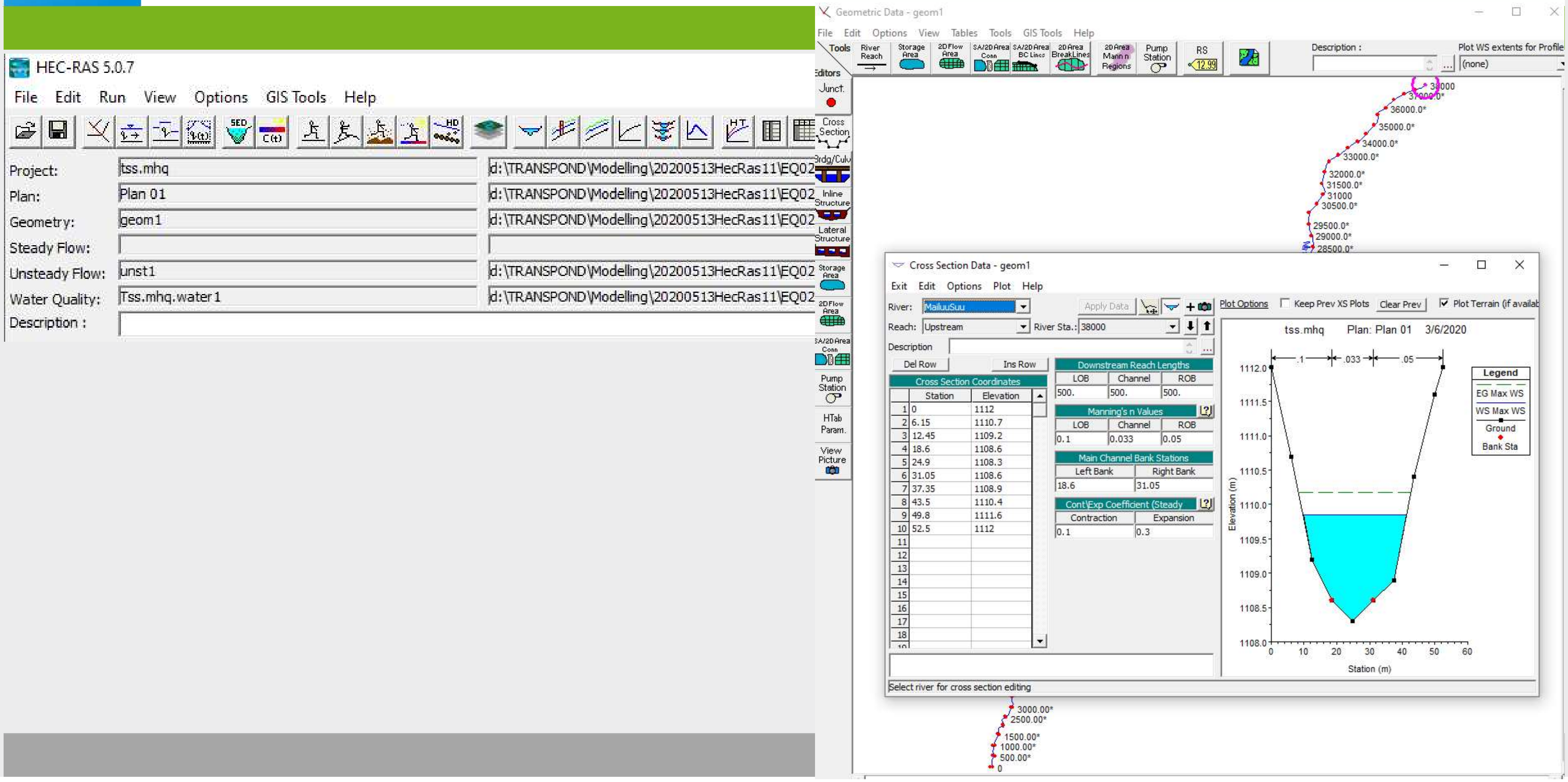
m	=	user assigned multiplier	(unitless)
u	=	face velocity	(m/s)
w	=	average channel width	(m)
y	=	average channel depth	(m)
u*	=	shear velocity	(m/s)

and shear velocity is computed as: (19-2)

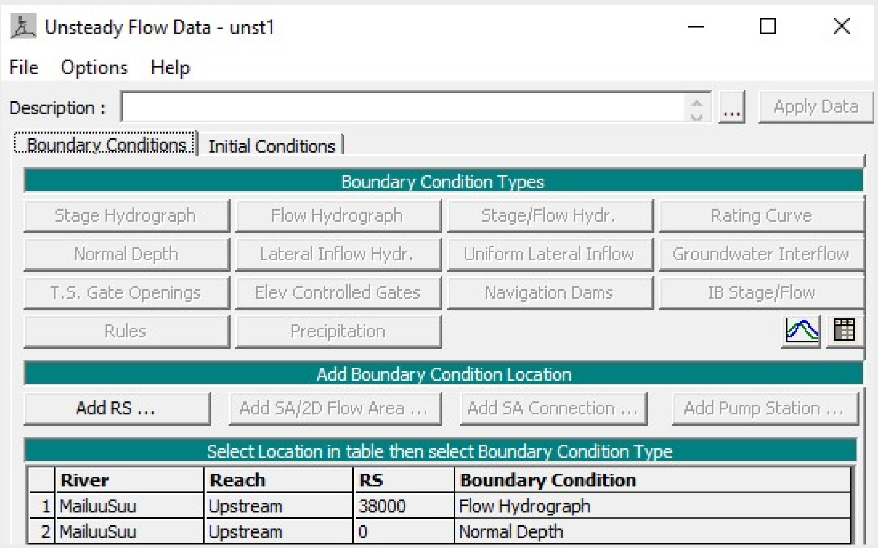
$$u^* = \sqrt{gdS}$$

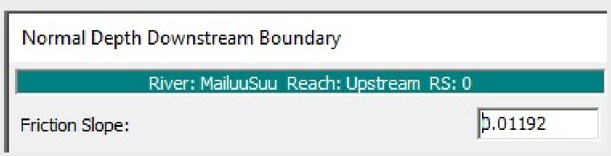
g	=	gravitational constant	(9.81 m/s^2)
d	=	average channel depth	(m)
S	=	friction slope	(unitless)

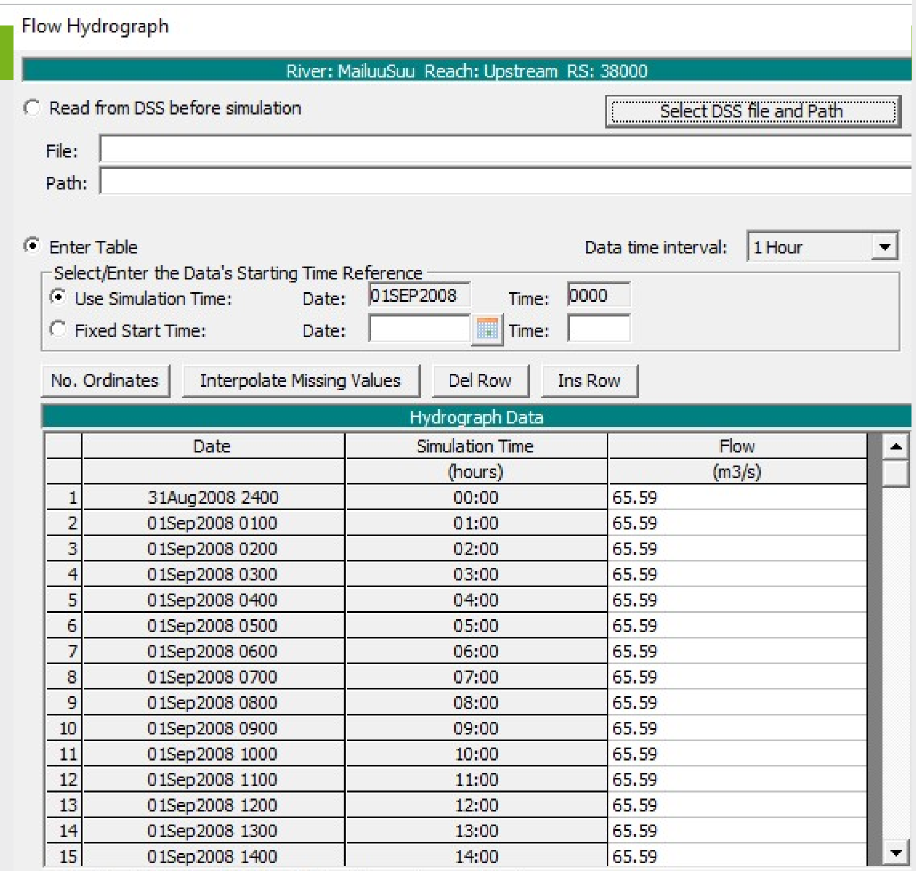
Example: Geometric profile



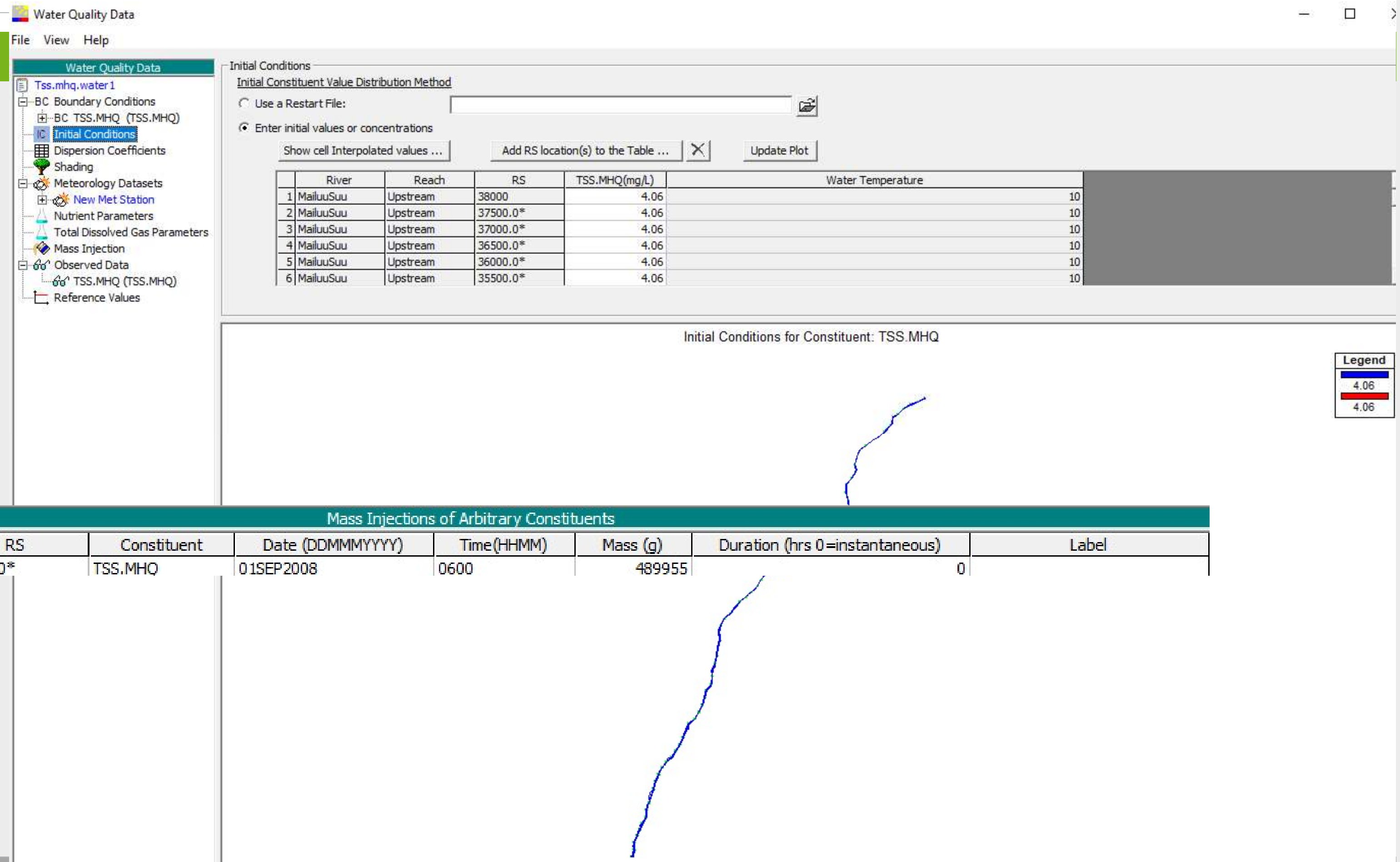
Example: Flow simulation







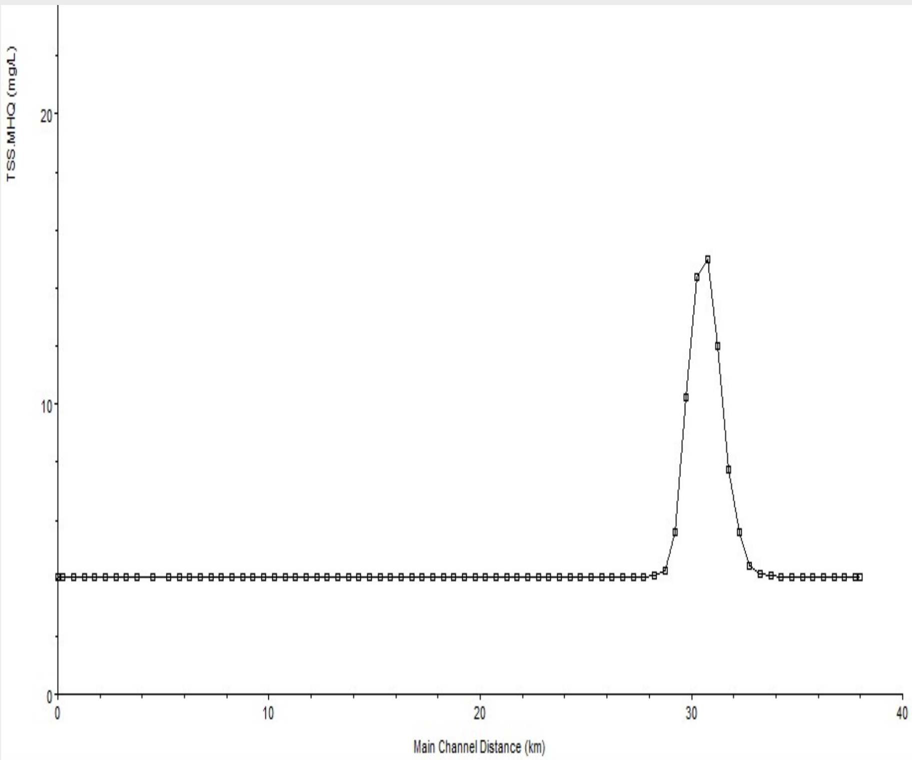
Example: Transport simulation

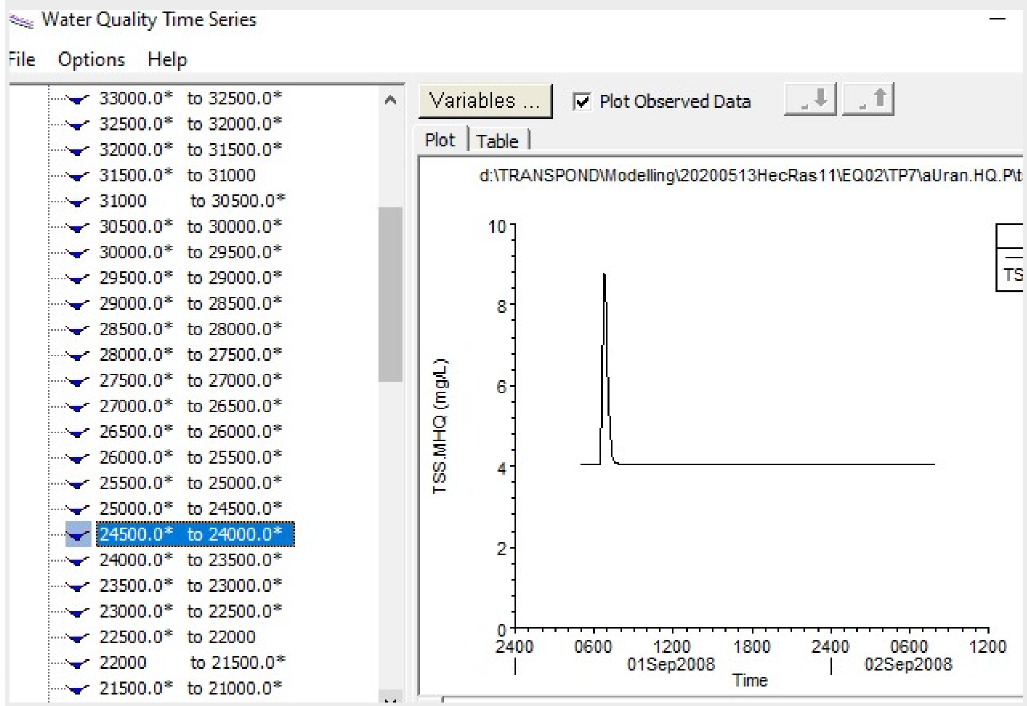


Mass Injections of Arbitrary Constituents

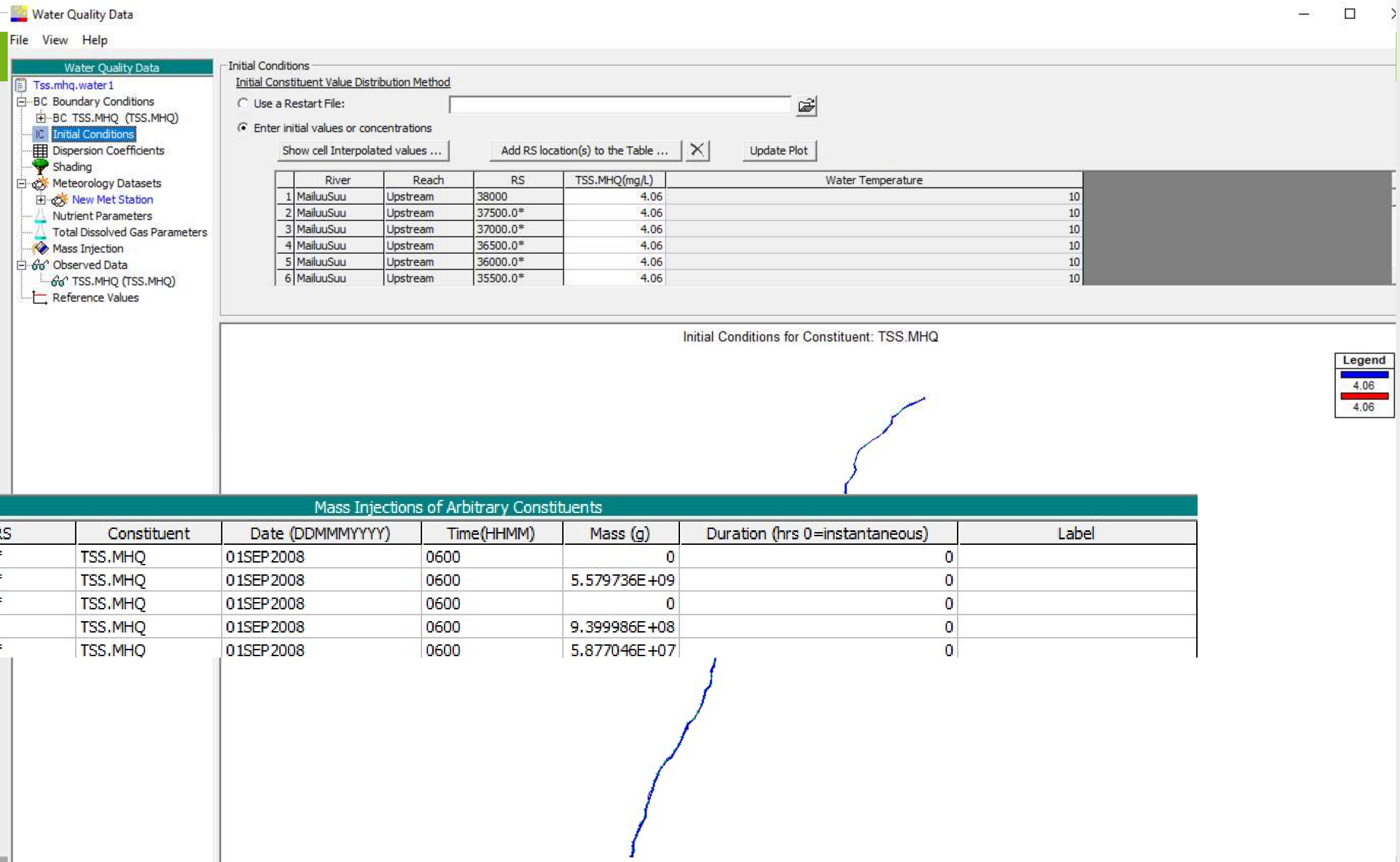
	River	Reach	RS	Constituent	Date (DDMMMYYYY)	Time(HHMM)	Mass (g)	Duration (hrs 0=instantaneous)	Label
1	MailuuSuu	Upstream	33000.0*	TSS.MHQ	01SEP2008	0600	489955	0	

Example: Results of single river section and time





Example: Release of multiple ponds

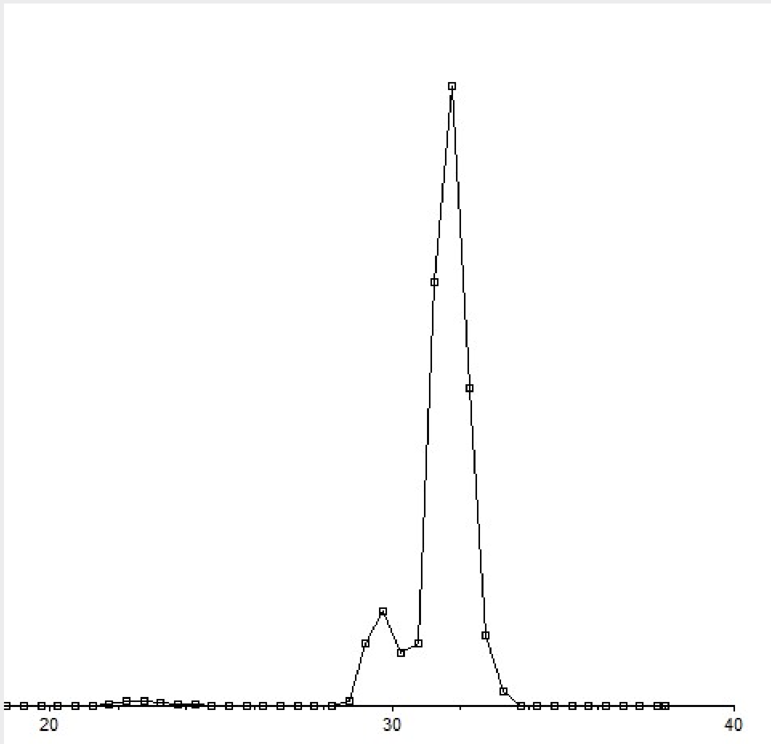


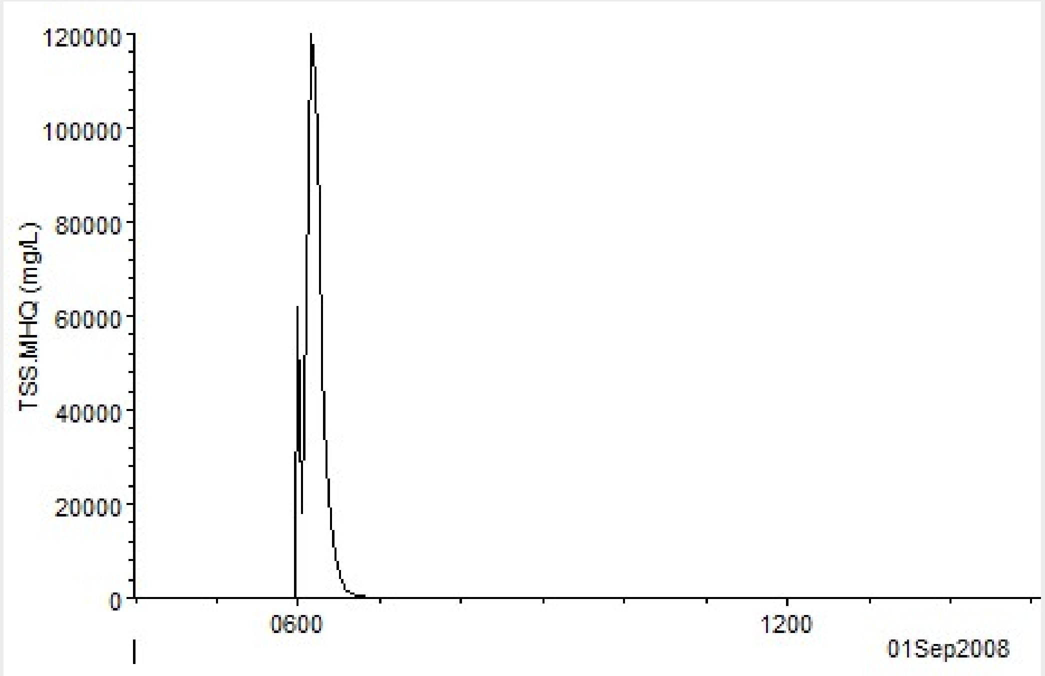
	River	Reach	RS	TSS.MHQ(mg/L)	Water Temperature
1	MailuuSuu	Upstream	38000	4.06	10
2	MailuuSuu	Upstream	37500.0*	4.06	10
3	MailuuSuu	Upstream	37000.0*	4.06	10
4	MailuuSuu	Upstream	36500.0*	4.06	10
5	MailuuSuu	Upstream	36000.0*	4.06	10
6	MailuuSuu	Upstream	35500.0*	4.06	10

Mass Injections of Arbitrary Constituents

	River	Reach	RS	Constituent	Date (DDMMMYYYY)	Time(HHMM)	Mass (g)	Duration (hrs 0=instantaneous)	Label
1	MailuuSuu	Upstream	33500.0*	TSS.MHQ	01SEP2008	0600	0	0	
2	MailuuSuu	Upstream	33000.0*	TSS.MHQ	01SEP2008	0600	5.579736E+09	0	
3	MailuuSuu	Upstream	32500.0*	TSS.MHQ	01SEP2008	0600	0	0	
4	MailuuSuu	Upstream	31000	TSS.MHQ	01SEP2008	0600	9.399986E+08	0	
5	MailuuSuu	Upstream	24000.0*	TSS.MHQ	01SEP2008	0600	5.877046E+07	0	

Example: Results of multiple ponds





Thank you for your attention
Time for questions

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To be continued: Part 2 - A Case Study