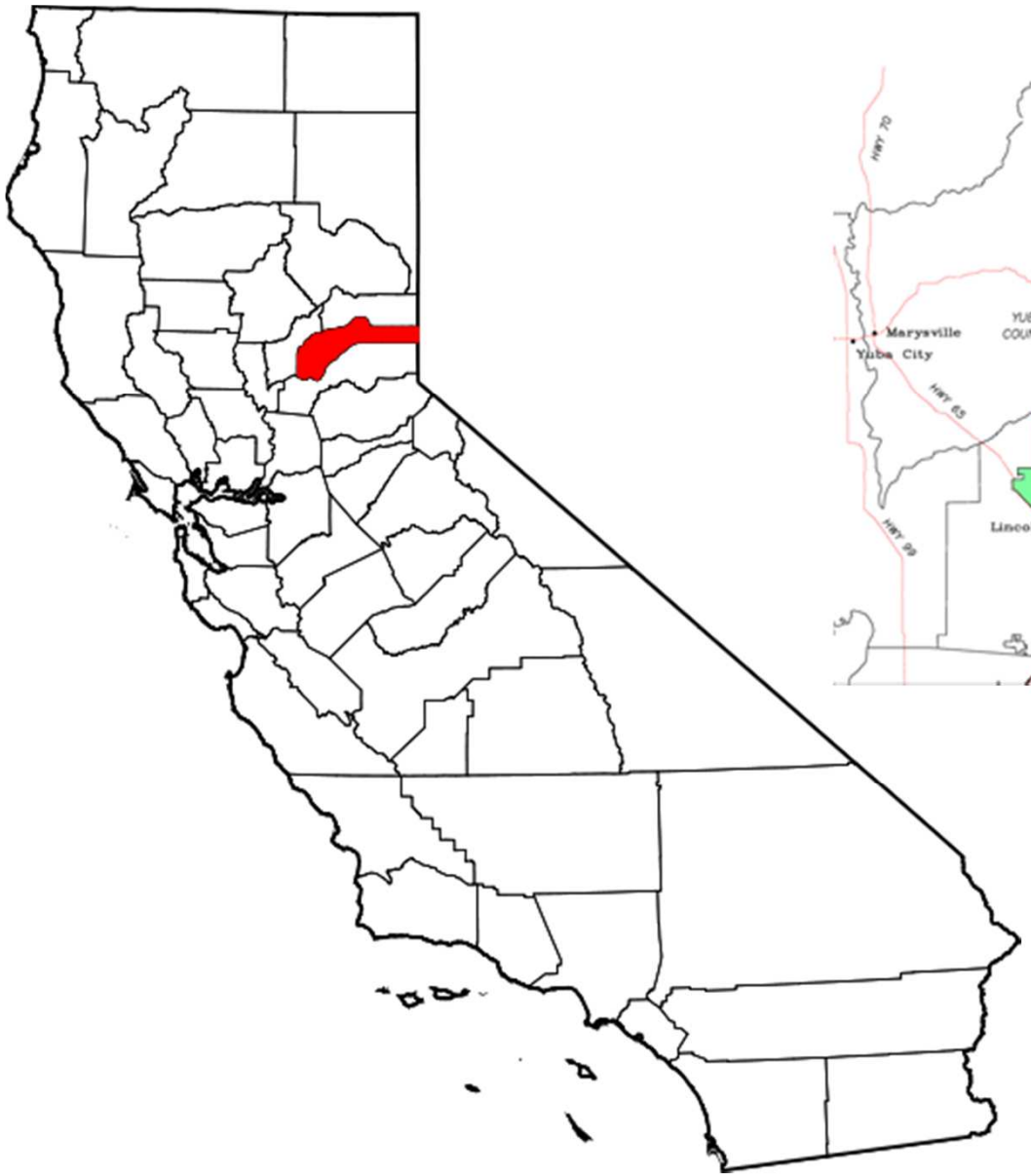
Irrigation: crops and water delivery

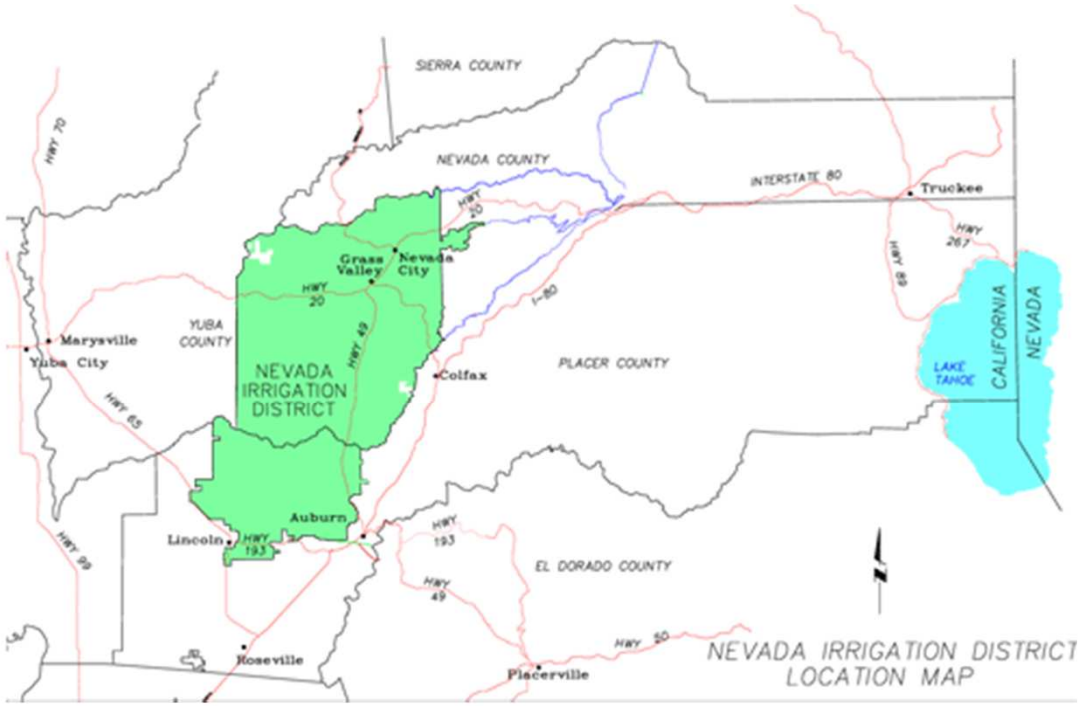
Irrigation and Drainage
CT4410

Maurits Ertsen

Water Resources Management

TU Delft
Technische Universiteit Delft





Nevada Irrigation District

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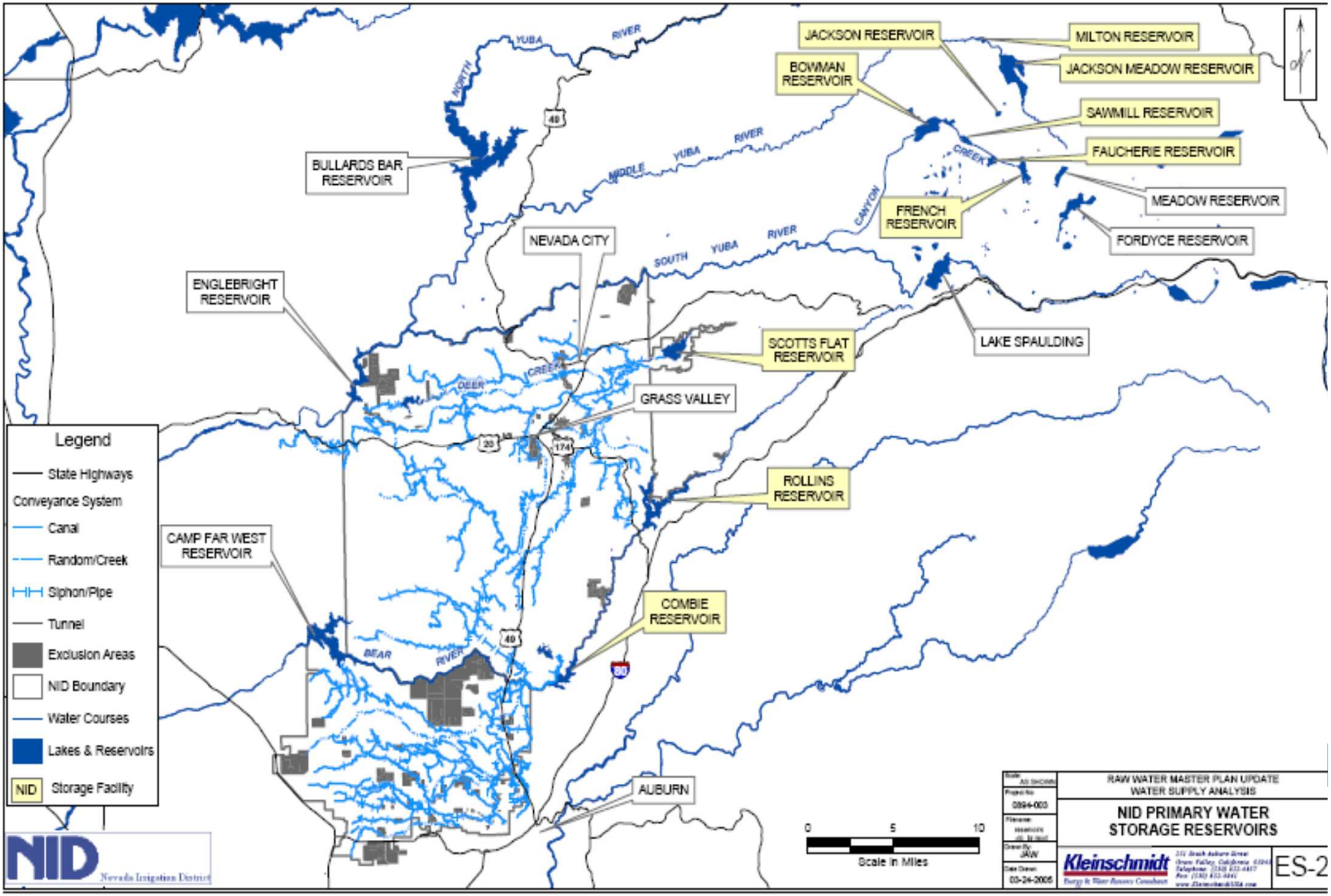
Transforming a ditch for mines to a ditch for irrigation

- High canals
- Continuous flow
- Reservoirs
- Water measurement in NID

The system


JACKSON RESERVOIR
MILTON RESERVOIR
BOWMAN RESERVOIR
JACKSON MEADOW RESERVOIR
SAWMILL RESERVOIR
FAUCHERIE RESERVOIR
BULLARDS BAR RESERVOIR
MEADOW RESERVOIR
FRENCH RESERVOIR
FORDYCE RESERVOIR
NEVADA CITY
ENGLEBRIGHT RESERVOIR
SCOTTS FLAT RESERVOIR
LAKE SPAULDING
GRASS VALLEY
ROLLINS RESERVOIR
CAMP FAR WEST RESERVOIR
COMBIE RESERVOIR
AUBURN
NORTH YUBA RIVER
MIDDLE YUBA RIVER
SOUTH YUBA RIVER
DEER CREEK
CANYON CREEK
BEAR RIVER
Legend
State Highways
Conveyance System
Canal
Random/Creek
Siphon/Pipe
Tunnel
Exclusion Areas
NID Boundary
Water Courses
Lakes & Reservoirs
NID Storage Facility
Nevada Irrigation District
0 5 10
Scale in Miles
RAW WATER MASTER PLAN UPDATE
WATER SUPPLY ANALYSIS
NID PRIMARY WATER STORAGE RESERVOIRS
Kleinschmidt
ES-2

Water measurement

- The miners inch
- Amount of water flowing through a surface of one square inch with a head of six inches.
- How many liters per second??

Controlling the canal

- What if a farmer does not needs his water?
- How to keep the constant head?

Water requirements

- How to determine water requirements?
- How to predict water demand?

Design problem

What cropping pattern do you take?

How correct is the ET calculation?

How correct is the ET and rainfall for the entire area?

How would you take into account "real" soil processes?

In other words: how to take into account heterogeneity?

Lankford (2004) discusses this.

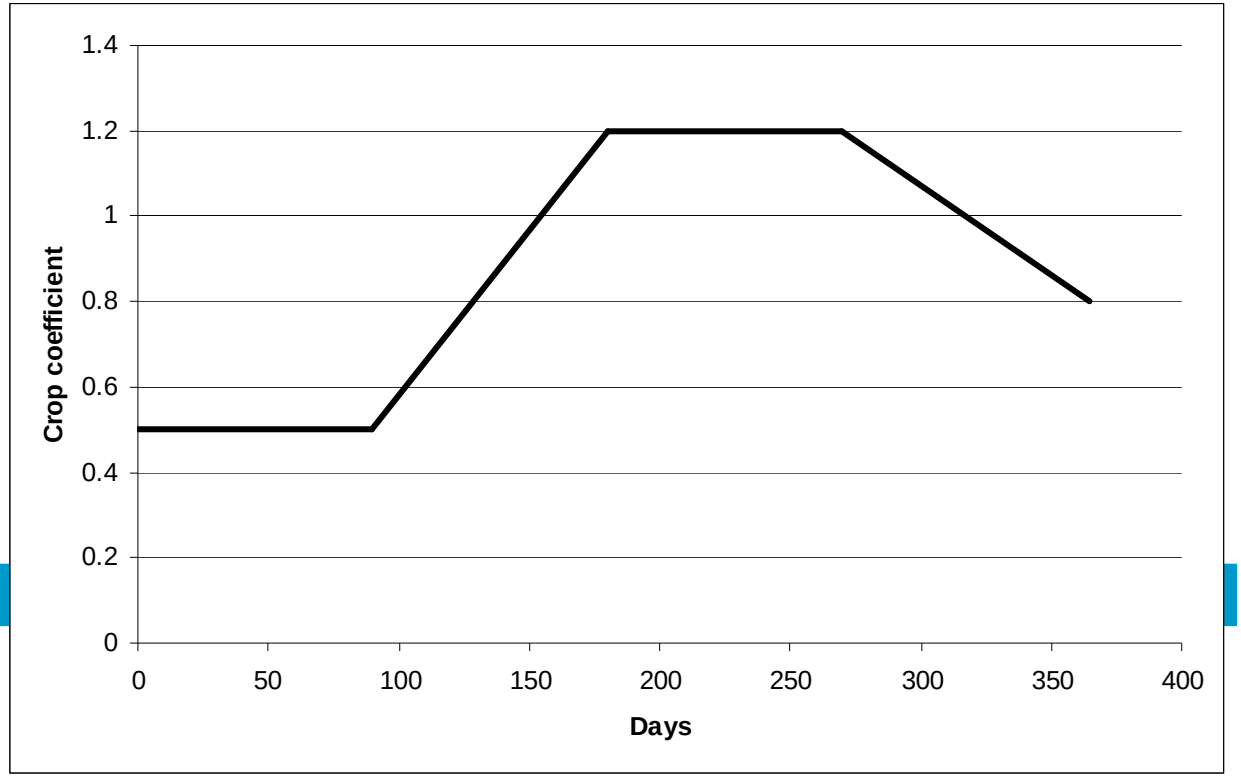
How to use remotely sensed ET in ***DESIGN*** ??

Blue beans

Start 1/1

Growth stage	*Length*	*Crop coefficient*	*Root depth*
	Days		*Meter*
Initial	90	0.5	2
Development	90		>>
Mid	90	1.2	2
Late	95	0.8	2
	365		

Crop water requirement calculation: example



Climate

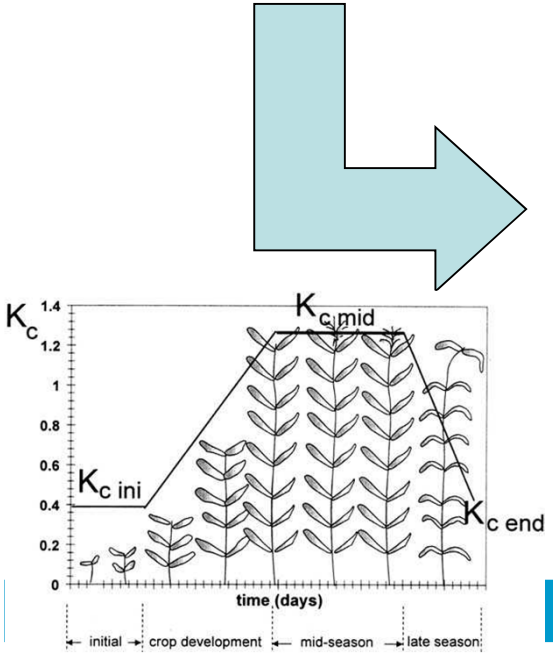
	Rain	*ETo*
	mm/stage	mm/day
Initial	90	5
Development	65	6
Mid	40	7
Late	80	5

Remarks:

Assuming all rain is effective

Simplifying development stage

Significant numbers??



CRW

mm/day

	Rain	**Eto**	**kc**	**Etg**	**Etn**
Initial	1.00	5	0.5	2.5	***1.50***
Development	0.72	6	0.85	5.1	***4.38***
Mid	0.44	7	1.2	8.4	***7.96***
Late	0.84	5	0.8	4	***3.16***

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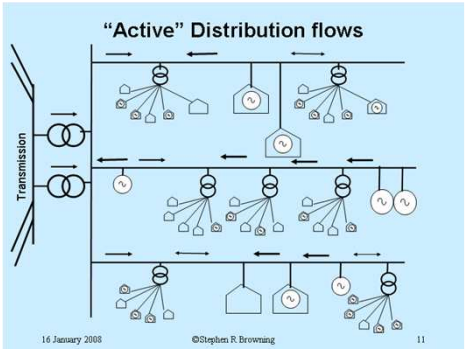
How to distribute that?



Flow for a farm of one hectare

	mm/day	m3/s	l/s
Continuous	8	0.0009259	1
Continuous during day	8	0.0018519	2
Every week for 10 hours	8	0.0155556	16
Every week for 1 hour	8	0.1555556	156
Every month for 1 hour	8	0.6666667	667

1. Suppose I have 10 farms, how much should my canal carry?
2. Suppose I have 1200 l/s, how many farms can irrigate at the same time?
3. In case 2, how large would my surface area per canal become?

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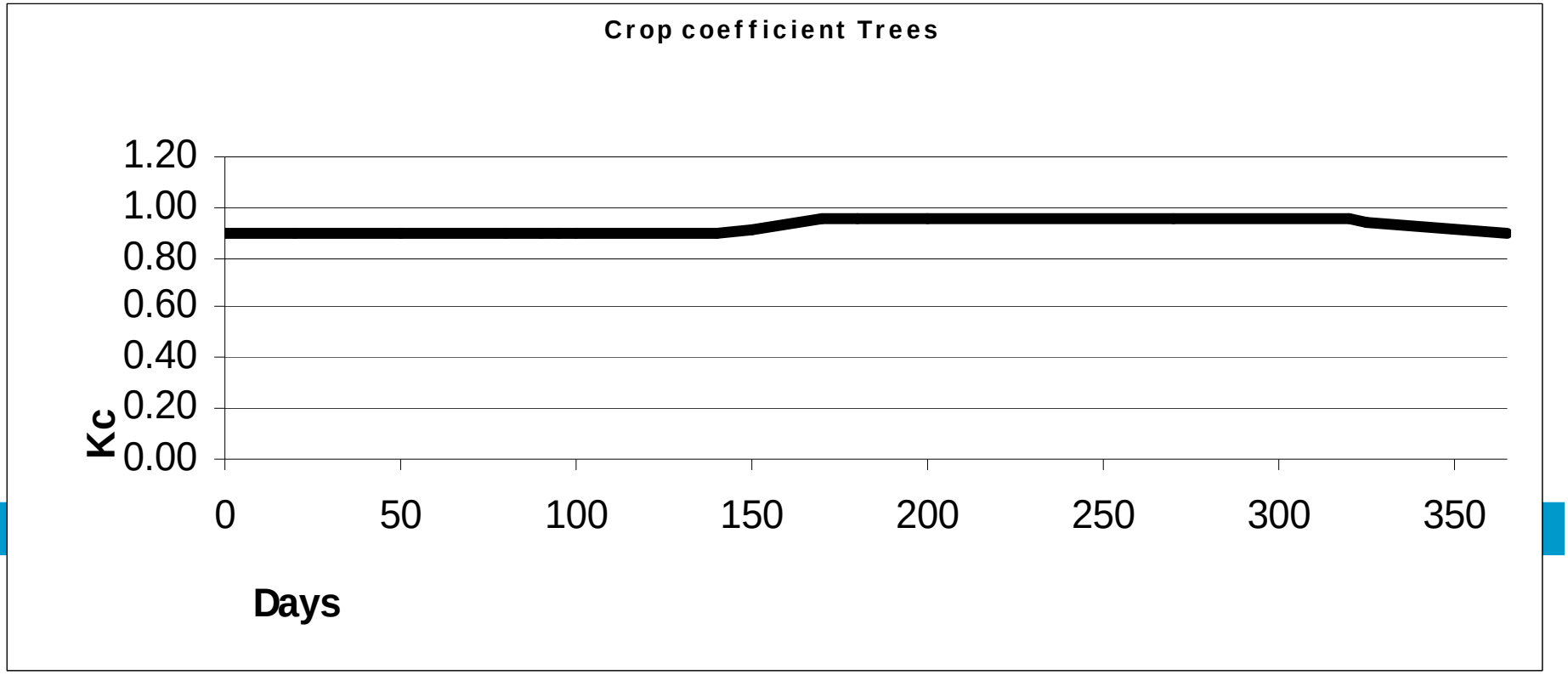
Your assignment

1. Calculate total water demand for a 1000 hectare area in the NID over a year.
2. Describe how this water would be supplied within the NID water delivery philosophy.
3. Calculate required canal flows at the intake for this 1000 hectare area.
4. Design the canal and outlets for this area, assuming that 20 farmers with each 50 hectares take water. Assume the canal being 10 kilometers long, with farm intakes evenly spread on one side.

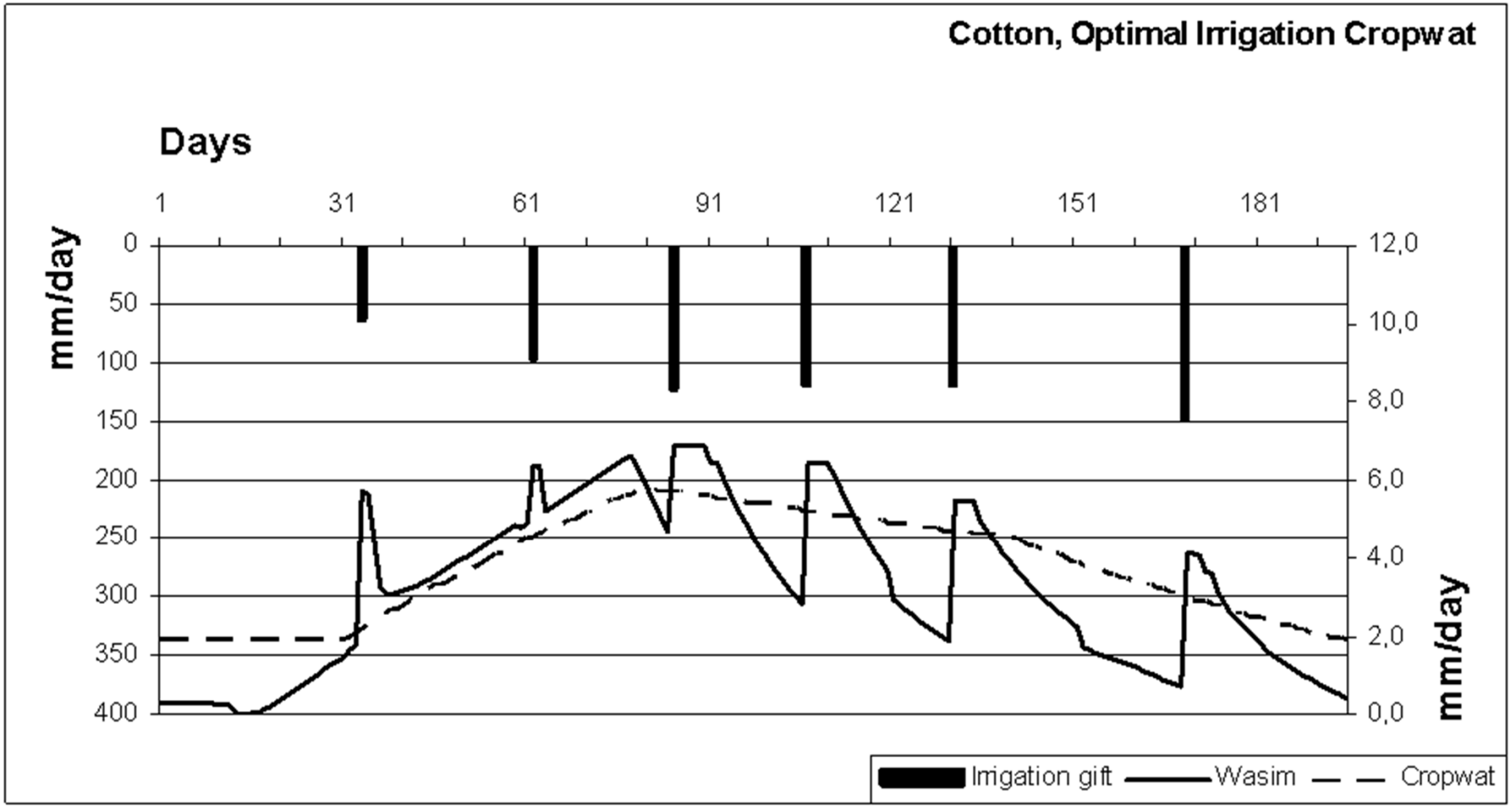
Example information

Trees ***35%*** ***of total area*** Start 1/4

Growth stage	***Length***	***Crop coefficient***	***Root depth***
	Days		*Meter*
Initial	140	0.9	2
Development	30		>>
Mid	150	0.95	2
Late	45	0.9	2
	365		



First, a little warning: physical reality



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- Crop : COTTON
- Planting date : 1/10
- Calculation time step = 10 Day(s)
- Irrigation Efficiency = 100%
- Initial condition = 0% depletion

Date	ETo	Planted Area	Crop Kc	CWR (ETm)	Total Rain	Effect. Rain	Irr. Req.	FWS
	(mm/period)	(%)		(mm/period)				(l/s/ha)
1/10	50.76	100.00	0.35	17.77	12.17	11.87	5.90	0.07
11/10	51.83	100.00	0.35	18.14	13.82	13.24	4.90	0.06
21/10	52.63	100.00	0.35	18.42	17.10	15.75	2.67	0.03
31/10	53.11	100.00	0.44	23.56	21.59	19.12	4.44	0.05
10/11	53.24	100.00	0.61	32.66	26.63	22.83	9.84	0.11
20/11	53.01	100.00	0.78	41.52	31.49	26.35	15.18	0.18
30/11	52.41	100.00	0.95	49.97	35.52	29.22	20.75	0.24
10/12	51.49	100.00	1.12	57.84	38.32	31.16	26.68	0.31
20/12	50.29	100.00	1.20	60.35	39.75	32.07	28.28	0.33
30/12	48.54	100.00	1.20	58.24	39.84	32.07	26.17	0.30
9/1	48.03	100.00	1.20	57.63	39.86	32.26	25.38	0.29
19/1	47.50	100.00	1.20	57.00	39.51	32.19	24.81	0.29
29/1	46.75	100.00	1.20	56.10	38.52	31.64	24.46	0.28
8/2	45.80	100.00	1.20	54.96	36.75	30.49	24.47	0.28
18/2	44.70	100.00	1.14	50.97	34.22	28.73	22.24	0.26
28/2	43.48	100.00	1.03	44.84	31.01	26.41	18.43	0.21
10/3	42.21	100.00	0.92	38.93	27.33	23.68	15.25	0.18
20/3	40.94	100.00	0.81	33.28	23.45	20.72	12.56	0.15
30/3	39.71	100.00	0.70	27.95	19.68	17.79	10.16	0.12
9/4	19.42	100.00	0.62	12.08	8.55	7.86	4.22	0.10
Total	935.86			812.21	575.13	485.43	326.78	[0.19]

- Crop : COTTON
- Planting date : 1/10
- Calculation time step = 10 Day(s)
- Irrigation Efficiency = 100%
- Initial condition = 100% depletion

Date	ETo (mm/period)	Planted Area (%)	Crop Kc	CWR (ETm) (mm/period)	Total Rain (mm/period)	Effect. Rain (mm/period)	Irr. Req. (mm/period)	FWS (l/s/ha)
1/10	50.76	100.00	0.35	17.77	12.17	11.87	5.90	0.07
11/10	51.83	100.00	0.35	18.14	13.82	13.24	4.90	0.06
21/10	52.63	100.00	0.35	18.42	17.10	15.75	2.67	0.03
31/10	53.11	100.00	0.44	23.56	21.59	19.12	4.44	0.05
10/11	53.24	100.00	0.61	32.66	26.63	22.83	9.84	0.11
20/11	53.01	100.00	0.78	41.52	31.49	26.35	15.18	0.18
30/11	52.41	100.00	0.95	49.97	35.52	29.22	20.75	0.24
10/12	51.49	100.00	1.12	57.84	38.32	31.16	26.68	0.31
20/12	50.29	100.00	1.20	60.35	39.75	32.07	28.28	0.33
30/12	48.54	100.00	1.20	58.24	39.84	32.07	26.17	0.30
9/1	48.03	100.00	1.20	57.63	39.86	32.26	25.38	0.29
19/1	47.50	100.00	1.20	57.00	39.51	32.19	24.81	0.29
29/1	46.75	100.00	1.20	56.10	38.52	31.64	24.46	0.28
8/2	45.80	100.00	1.20	54.96	36.75	30.49	24.47	0.28
18/2	44.70	100.00	1.14	50.97	34.22	28.73	22.24	0.26
28/2	43.48	100.00	1.03	44.84	31.01	26.41	18.43	0.21
10/3	42.21	100.00	0.92	38.93	27.33	23.68	15.25	0.18
20/3	40.94	100.00	0.81	33.28	23.45	20.72	12.56	0.15
30/3	39.71	100.00	0.70	27.95	19.68	17.79	10.16	0.12
9/4	19.42	100.00	0.62	12.08	8.55	7.86	4.22	0.10
Total	935.86			812.21	575.13	485.43	326.78	[0.19]

- Crop : COTTON
- Planting date: 1/10

- Soil description : Medium
- Initial soil moisture depletion: 0%

- Application Timing:
  Irrigate when 100% of readily soil moisture depletion occurs.
- Applications Depths:
  Refill to 100% of readily available soil moisture.
- Start of Scheduling: 1/10

Date	TAM (mm)	RAM (mm)	Total Rain (mm)	Efct. Rain (mm)	ETc (mm)	ETc/ETm (%)	SMD (mm)	Interv. (Days)	Net Irr. (mm)	Lost Irr. (mm)	User Adj. (mm)
5/10	49.7	29.8	6.1	6.1	1.8	100.0%	2.7				
10/10	59.3	35.6	6.5	6.5	1.8	100.0%	5.1				
15/10	69.0	41.4	7.1	7.1	1.8	100.0%	7.1				
20/10	78.6	47.1	7.9	7.9	1.8	100.0%	8.3				
25/10	88.2	52.9	8.8	8.8	1.8	100.0%	8.7				
30/10	97.8	58.7	9.9	9.9	1.9	100.0%	8.0				
4/11	107.4	64.5	11.2	11.2	2.3	100.0%	7.4				
9/11	117.1	70.2	12.4	12.4	2.8	100.0%	7.9				
14/11	126.7	76.0	13.7	13.7	3.2	100.0%	9.4				
19/11	136.3	81.8	14.9	14.9	3.7	100.0%	12.0				
24/11	145.9	87.6	16.1	16.1	4.1	100.0%	15.5				
29/11	155.6	93.3	17.1	17.1	4.5	100.0%	20.3				
4/12	165.2	99.1	18.0	18.0	5.0	100.0%	26.2				
9/12	174.8	104.9	18.8	18.8	5.4	100.0%	33.4				
14/12	184.4	110.7	19.3	19.3	5.7	100.0%	42.1				
19/12	194.1	116.4	19.7	19.7	6.1	100.0%	52.2				
24/12	196.0	117.6	19.9	19.9	6.0	100.0%	62.6				
29/12	196.0	117.6	12.0	12.0	6.0	100.0%	80.6				
1/1	196.0	117.6	19.9	19.9	5.8	100.0%	78.4				
6/1	196.0	117.6	19.9	19.9	5.8	100.0%	87.5				
11/1	196.0	117.6	19.9	19.9	5.8	100.0%	96.4				
15/1	196.0	117.6	0.0	0.0	5.8	100.0%	119.5	106	119.5	0.0	
16/1	196.0	117.6	19.9	0.0	5.8	100.0%	5.8				
21/1	196.0	117.6	19.8	19.8	5.7	100.0%	14.6				
26/1	196.0	117.6	19.6	19.6	5.7	100.0%	23.5				
31/1	196.0	117.6	19.3	19.3	5.6	100.0%	32.5				
5/2	196.0	117.6	18.9	18.9	5.6	100.0%	41.6				
10/2	196.0	117.6	18.4	18.4	5.5	100.0%	50.9				
15/2	196.0	117.6	17.9	17.9	5.5	100.0%	60.5				
20/2	196.0	120.8	17.2	17.2	5.3	100.0%	70.1				
25/2	196.0	126.2	16.4	16.4	4.9	100.0%	79.0				
2/3	196.0	131.5	15.6	15.6	4.6	100.0%	87.2				
7/3	196.0	136.8	14.7	14.7	4.3	100.0%	94.8				
12/3	196.0	142.2	13.8	13.8	4.0	100.0%	101.8				
17/3	196.0	147.5	12.8	12.8	3.7	100.0%	108.3				
22/3	196.0	152.9	11.8	11.8	3.5	100.0%	114.4				
27/3	196.0	158.2	10.9	10.9	3.2	100.0%	120.0				
1/4	196.0	163.6	9.9	9.9	2.9	100.0%	125.2				
6/4	196.0	168.9	9.0	9.0	2.7	100.0%	130.0				
11/4	196.0	174.3	8.2	8.2	2.4	100.0%	134.4				
Total			573.5	553.7	812.2	100.0%			119.5	0.0	0.0

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- Crop : COTTON
- Planting date: 1/10
- Initial soil moisture depletion: 100%

- Application Timing:
  Irrigate when 100% of readily soil moisture depletion occurs.
- Applications Depths:
  Refill to 100% of readily available soil moisture.
- Start of Scheduling: 1/10

Date	TAM (mm)	RAM (mm)	Total Rain (mm)	Efct. Rain (mm)	ETc (mm)	ETc/ETm (%)	SMD (mm)	Interv. (Days)	Net Irr. (mm)	Lost Irr. (mm)	User Adj. (mm)
1/10	42.0	25.2	0.0	0.0	0.0	0.0%	42.0	0	42.0	0.0	
5/10	49.7	29.8	6.1	5.3	1.8	100.0%	1.8				
10/10	59.3	35.6	6.5	6.5	1.8	100.0%	4.2				
15/10	69.0	41.4	7.1	7.1	1.8	100.0%	6.2				
20/10	78.6	47.1	7.9	7.9	1.8	100.0%	7.4				
25/10	88.2	52.9	8.8	8.8	1.8	100.0%	7.7				
30/10	97.8	58.7	9.9	9.9	1.9	100.0%	7.0				
4/11	107.4	64.5	11.2	11.2	2.3	100.0%	6.5				
9/11	117.1	70.2	12.4	12.4	2.8	100.0%	7.0				
14/11	126.7	76.0	13.7	13.7	3.2	100.0%	8.5				
19/11	136.3	81.8	14.9	14.9	3.7	100.0%	11.0				
24/11	145.9	87.6	16.1	16.1	4.1	100.0%	14.6				
29/11	155.6	93.3	17.1	17.1	4.5	100.0%	19.3				
4/12	165.2	99.1	18.0	18.0	5.0	100.0%	25.3				
9/12	174.8	104.9	18.8	18.8	5.4	100.0%	32.5				
14/12	184.4	110.7	19.3	19.3	5.7	100.0%	41.1				
19/12	194.1	116.4	19.7	19.7	6.1	100.0%	51.3				
24/12	196.0	117.6	19.9	19.9	6.0	100.0%	61.7				
29/12	196.0	117.6	12.0	12.0	6.0	100.0%	79.7				
1/1	196.0	117.6	19.9	19.9	5.8	100.0%	77.5				
6/1	196.0	117.6	19.9	19.9	5.8	100.0%	86.5				
11/1	196.0	117.6	19.9	19.9	5.8	100.0%	95.5				
15/1	196.0	117.6	0.0	0.0	5.8	100.0%	118.6	106	118.6	0.0	
16/1	196.0	117.6	19.9	0.0	5.8	100.0%	5.8				
21/1	196.0	117.6	19.8	19.8	5.7	100.0%	14.6				
26/1	196.0	117.6	19.6	19.6	5.7	100.0%	23.5				
31/1	196.0	117.6	19.3	19.3	5.6	100.0%	32.5				
5/2	196.0	117.6	18.9	18.9	5.6	100.0%	41.6				
10/2	196.0	117.6	18.4	18.4	5.5	100.0%	50.9				
15/2	196.0	117.6	17.9	17.9	5.5	100.0%	60.5				
20/2	196.0	120.8	17.2	17.2	5.3	100.0%	70.1				
25/2	196.0	126.2	16.4	16.4	4.9	100.0%	79.0				
2/3	196.0	131.5	15.6	15.6	4.6	100.0%	87.2				
7/3	196.0	136.8	14.7	14.7	4.3	100.0%	94.8				
12/3	196.0	142.2	13.8	13.8	4.0	100.0%	101.8				
17/3	196.0	147.5	12.8	12.8	3.7	100.0%	108.3				
22/3	196.0	152.9	11.8	11.8	3.5	100.0%	114.4				
27/3	196.0	158.2	10.9	10.9	3.2	100.0%	120.0				
1/4	196.0	163.6	9.9	9.9	2.9	100.0%	125.2				
6/4	196.0	168.9	9.0	9.0	2.7	100.0%	130.0				
11/4	196.0	174.3	8.2	8.2	2.4	100.0%	134.4				
Total			573.5	552.8	810.4	99.8%			160.6	0.0	0.0

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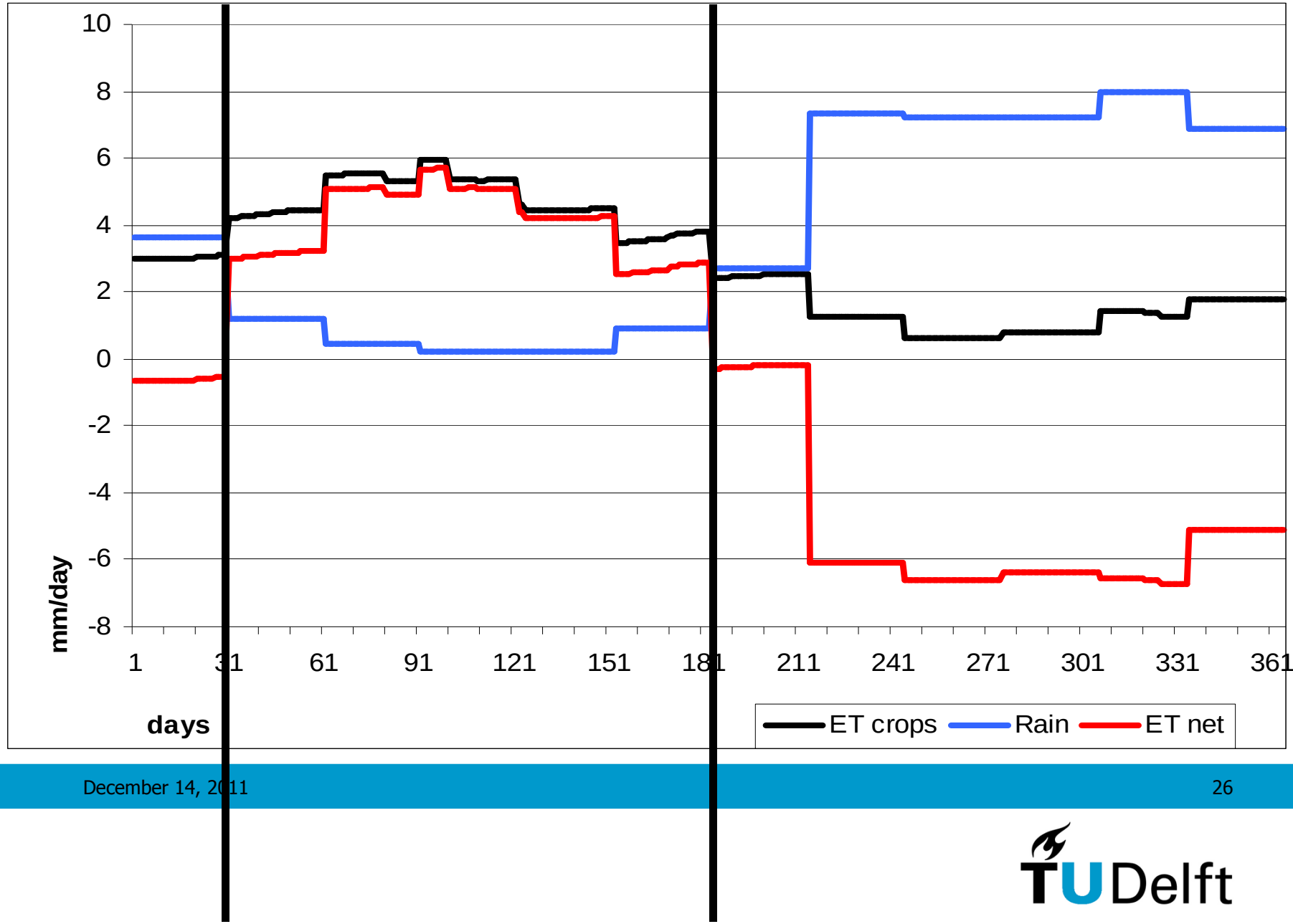
What did I do? Water requirements



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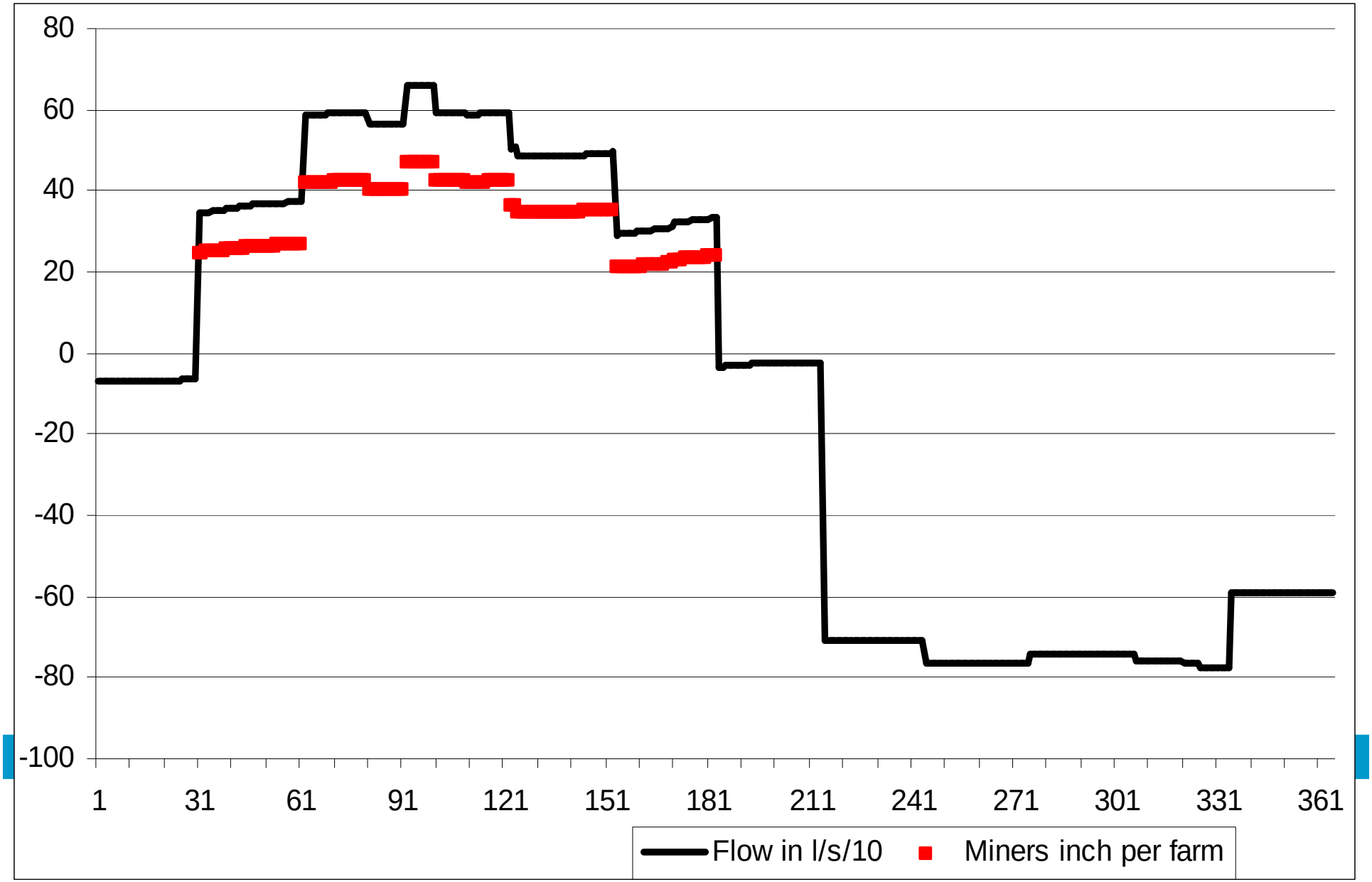
Water need in l/s and miners inches/farm



So why start per April 1??

- What if a farmer is an early vegetable grower?
- What if it does not rain in April?
- What if … ?

And the canal?

I know I will have fluctuating flows and that there is a need to maintain the same water level. So, one uniform flow calculation will not suffice. And I probably need some kind of water level control, and perhaps some spills.

Canal calculation

Not that straightforward designing a fitting canal and structures

canal	AB
L	10000
H control	0.64
y	0.64
A	2.97
Q	0.66
m	1
v	0.22
R	0.51
s	0.0001
k	35
b	4
n	6.3

Q increases:

canal	AB
L	10000
H control	0.71
y	0.71
A	3.34
Q	0.8
m	1
v	0.24
R	0.56
s	0.0001
k	35
b	4
n	5.6

Q decreases:

canal	AB
L	10000
H control	0.47
y	0.47
A	2.10
Q	0.4
m	1
v	0.19
R	0.39
s	0.0001
k	35
b	4
n	8.5

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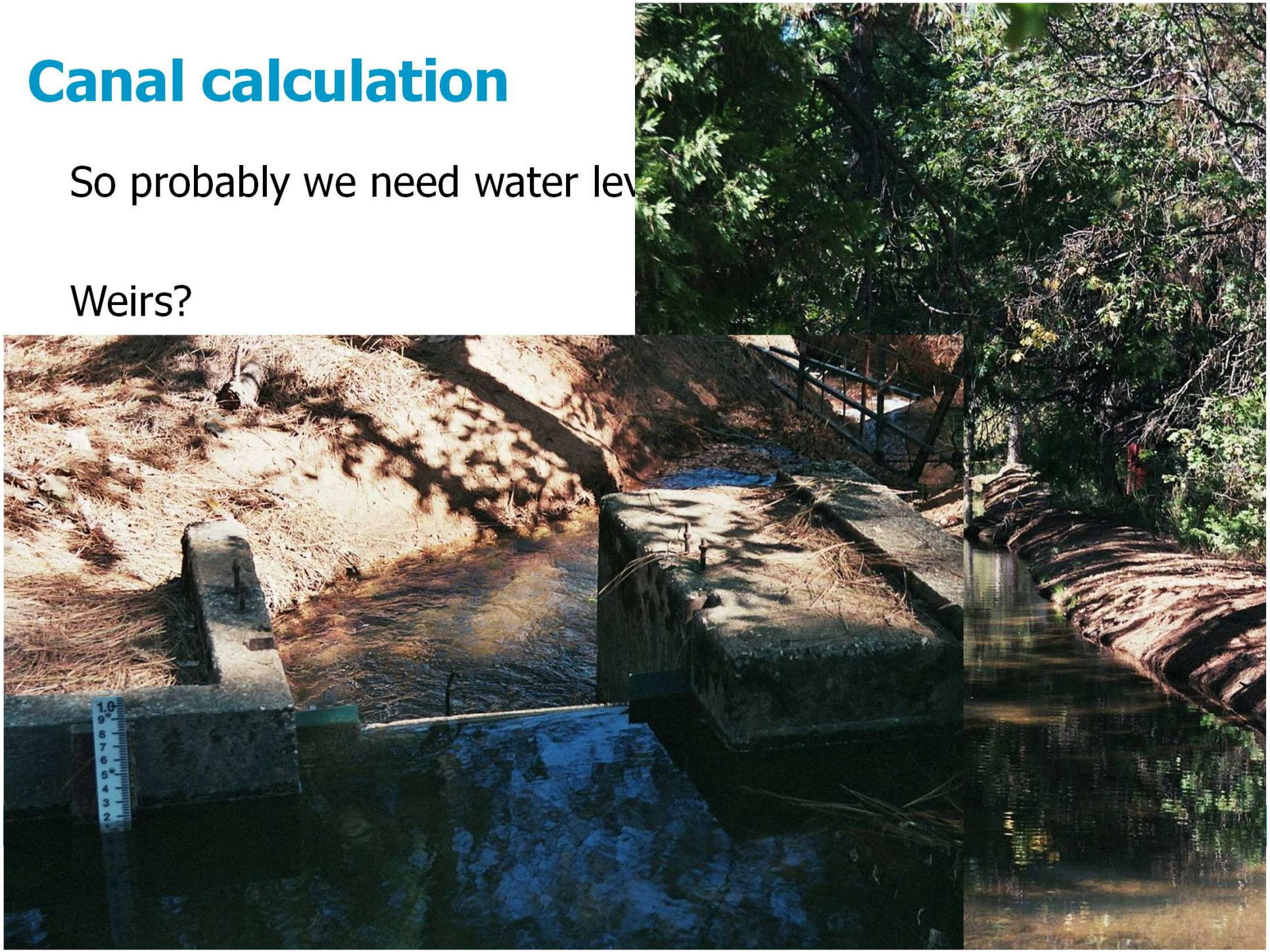
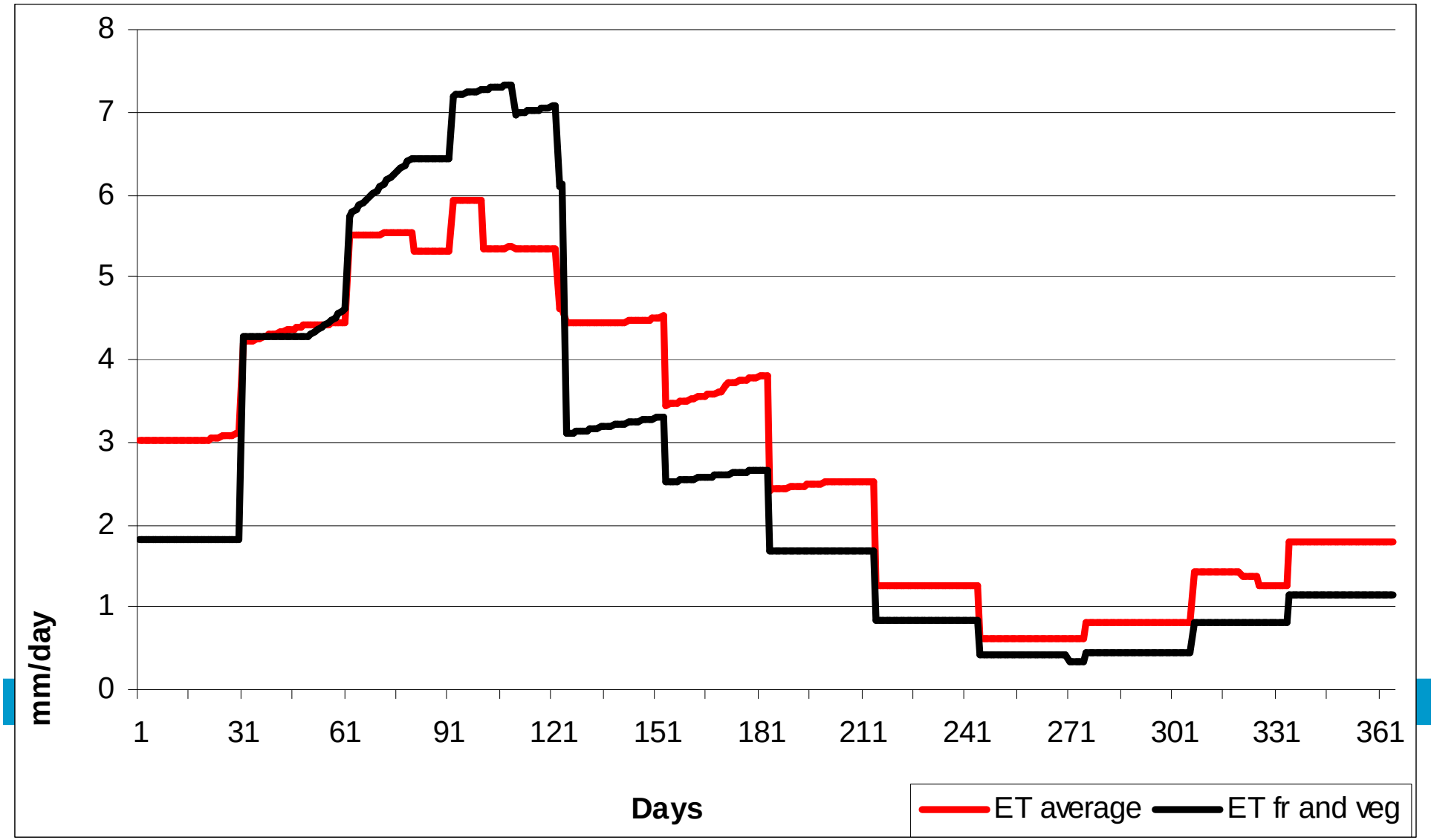
Canal calculation

So probably we need water lev

Weirs?



And what if I have farmers with only fuit and vegetables????



What did I do?

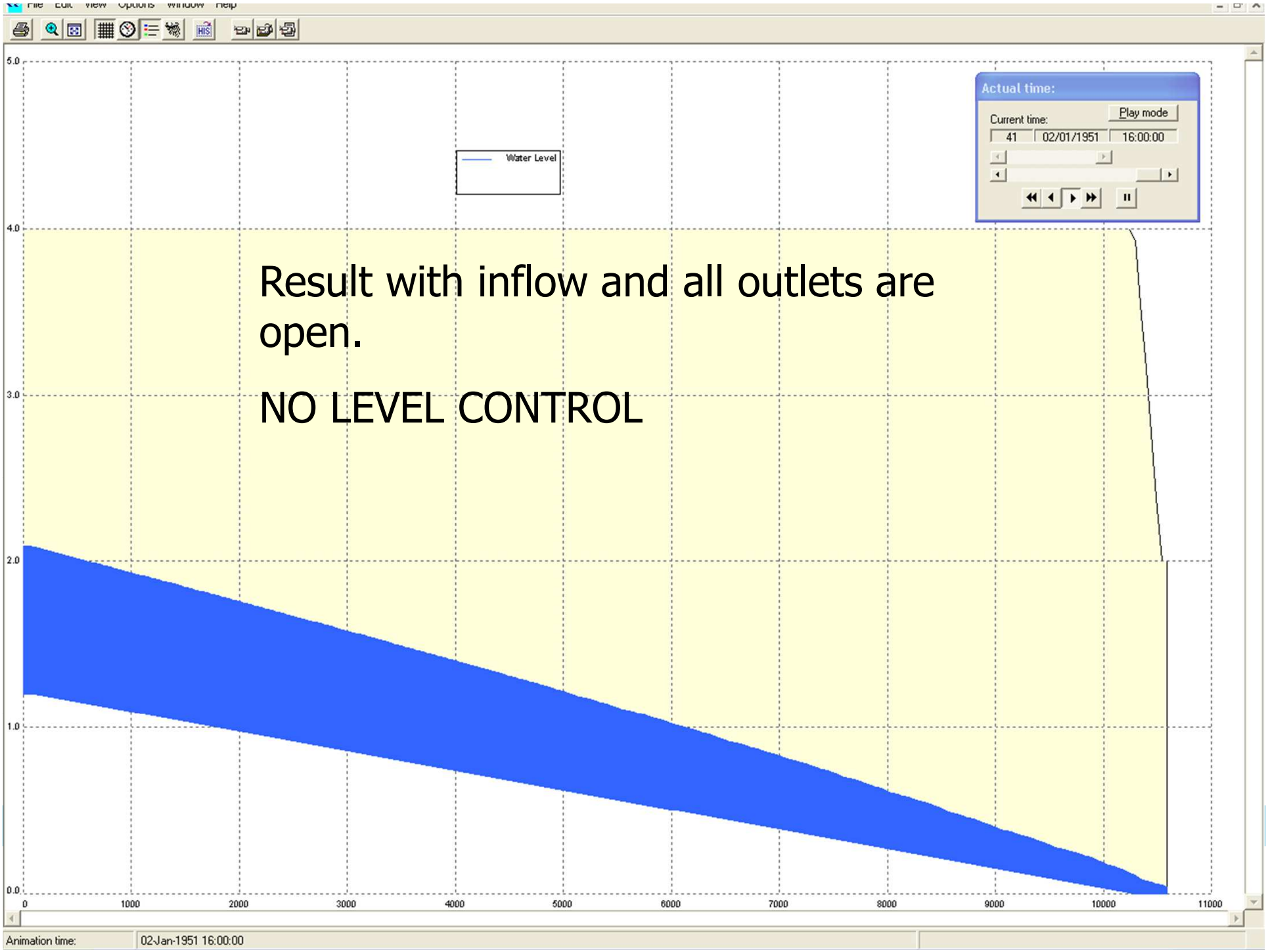
Design discharge of 1 m3/s

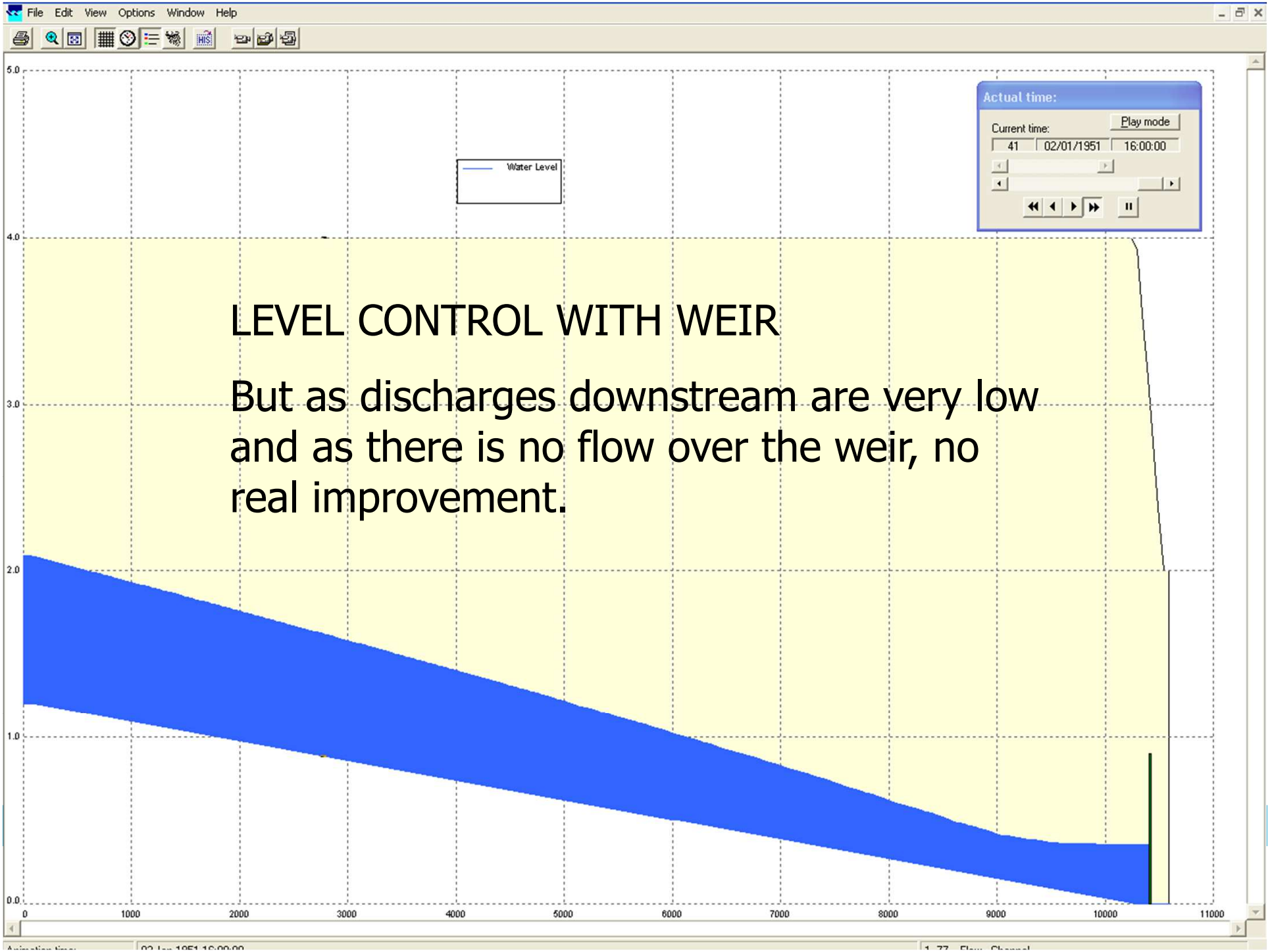
Water depth of 1 meter, bed width of 2 meters

Slope of 1 in 10000

Side slope of 1

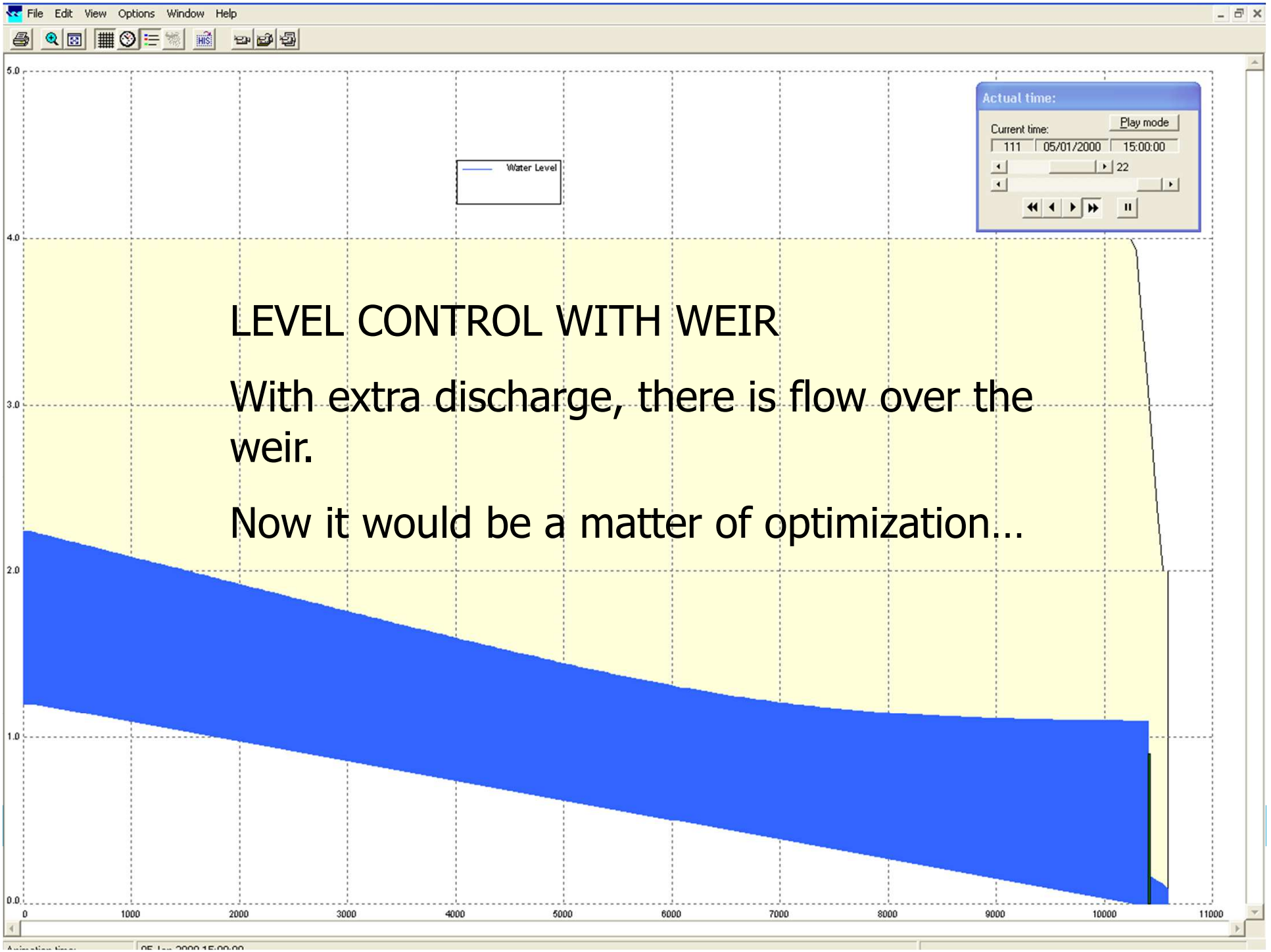
Roughness of about 45 (Strickler)


Water Level
Actual time:
Current time:
Play mode
41
02/01/1951
16:00:00
Result with inflow and all outlets are open.
NO LEVEL CONTROL
5.0
4.0
3.0
2.0
1.0
0.0
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
Animation time:
02-Jan-1951 16:00:00



LEVEL CONTROL WITH WEIR

But as discharges downstream are very low and as there is no flow over the weir, no real improvement.



LEVEL CONTROL WITH WEIR

With extra discharge, there is flow over the weir.

Now it would be a matter of optimization…