TECHNICAL RESOURCES CENTER - P.C.C.
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CPP Consorcio Post-Panamax

ACP
AUTORIDAD DEL CANAL DE PANAMA

Conceptual design to recycle water in Post Panamax locks

HYDRAULIC PART

ANNEXES

R-HY-002 B

Tractebel Development Engineering
TECHNUM
COYNE ET BELLIER
CNR PROJETS

in association with

IMDC
SBE
PORT OF ANTWERP
FITA AOSO

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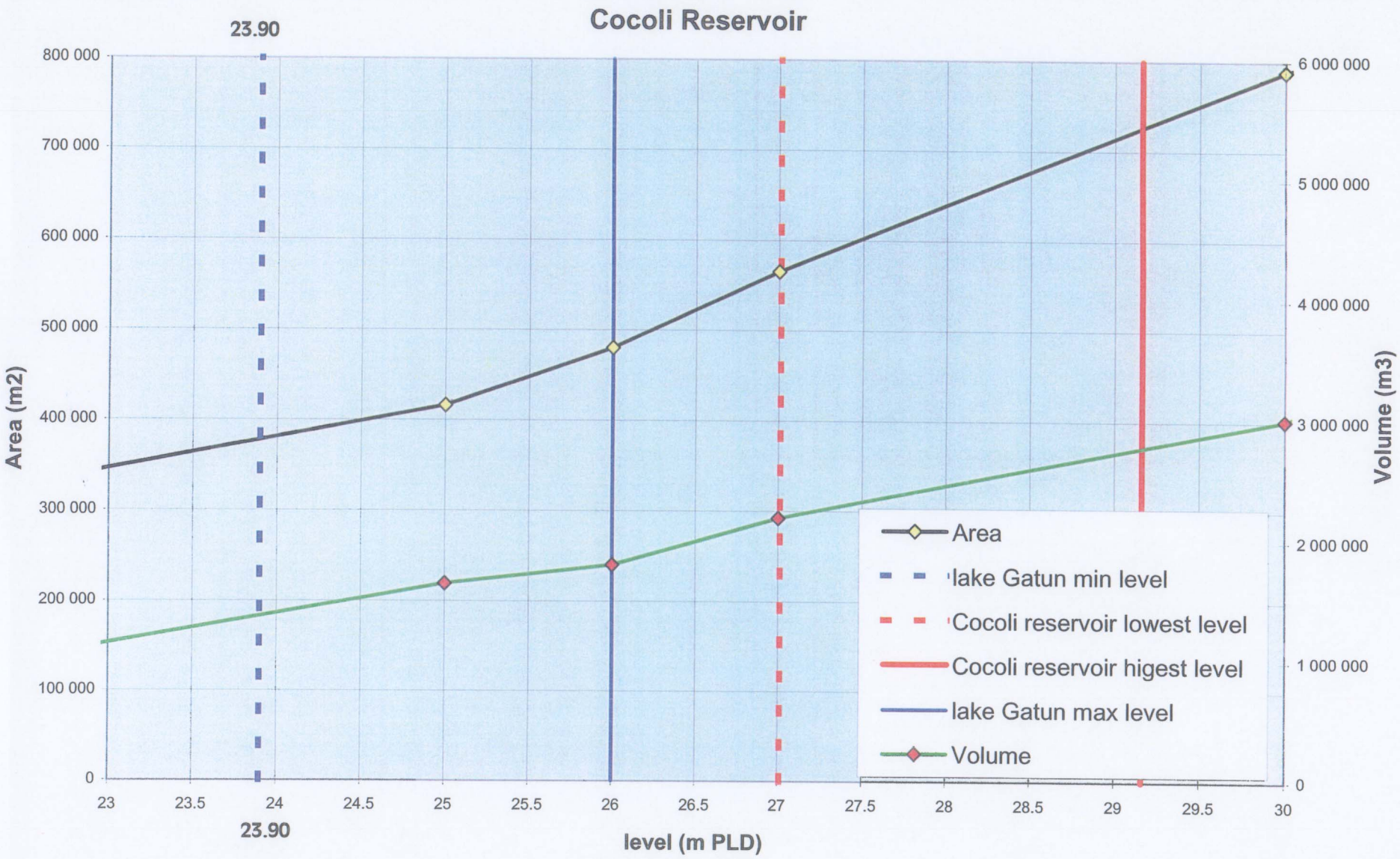
Annex 1

Area and capacity of the Cocoli reservoir versus ground level


Cocoli Reservoir
23.90
800 000
700 000
600 000
500 000
400 000
300 000
200 000
100 000
0
Area (m2)
6 000 000
5 000 000
4 000 000
3 000 000
2 000 000
1 000 000
0
Volume (m3)
23
23.5
24
24.5
25
25.5
26
26.5
27
27.5
28
28.5
29
29.5
30
23.90
level (m PLD)
Area
lake Gatun min level
Cocoli reservoir lowest level
Cocoli reservoir higest level
lake Gatun max level
Volume

Annex 2

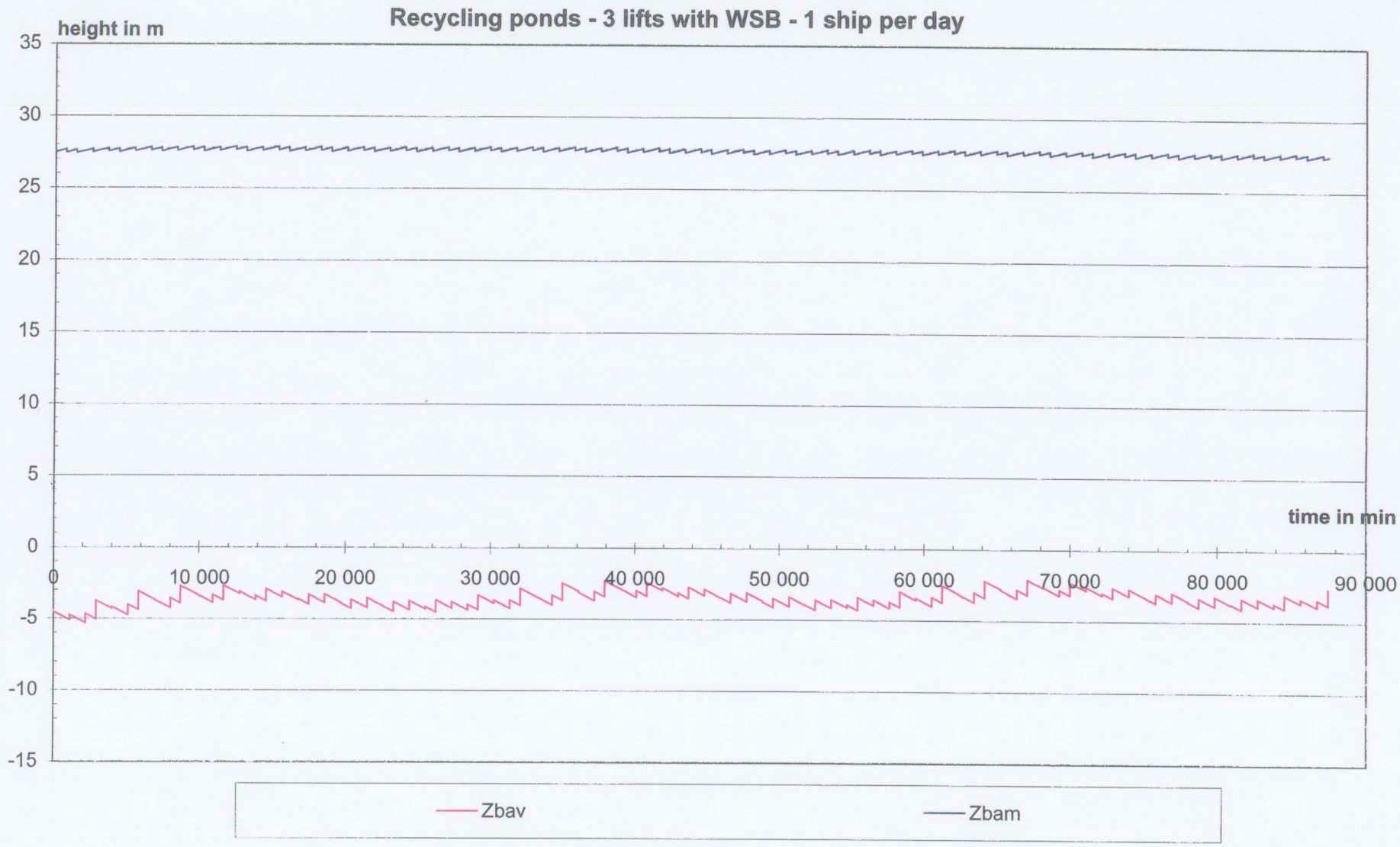
Drawing LO-001

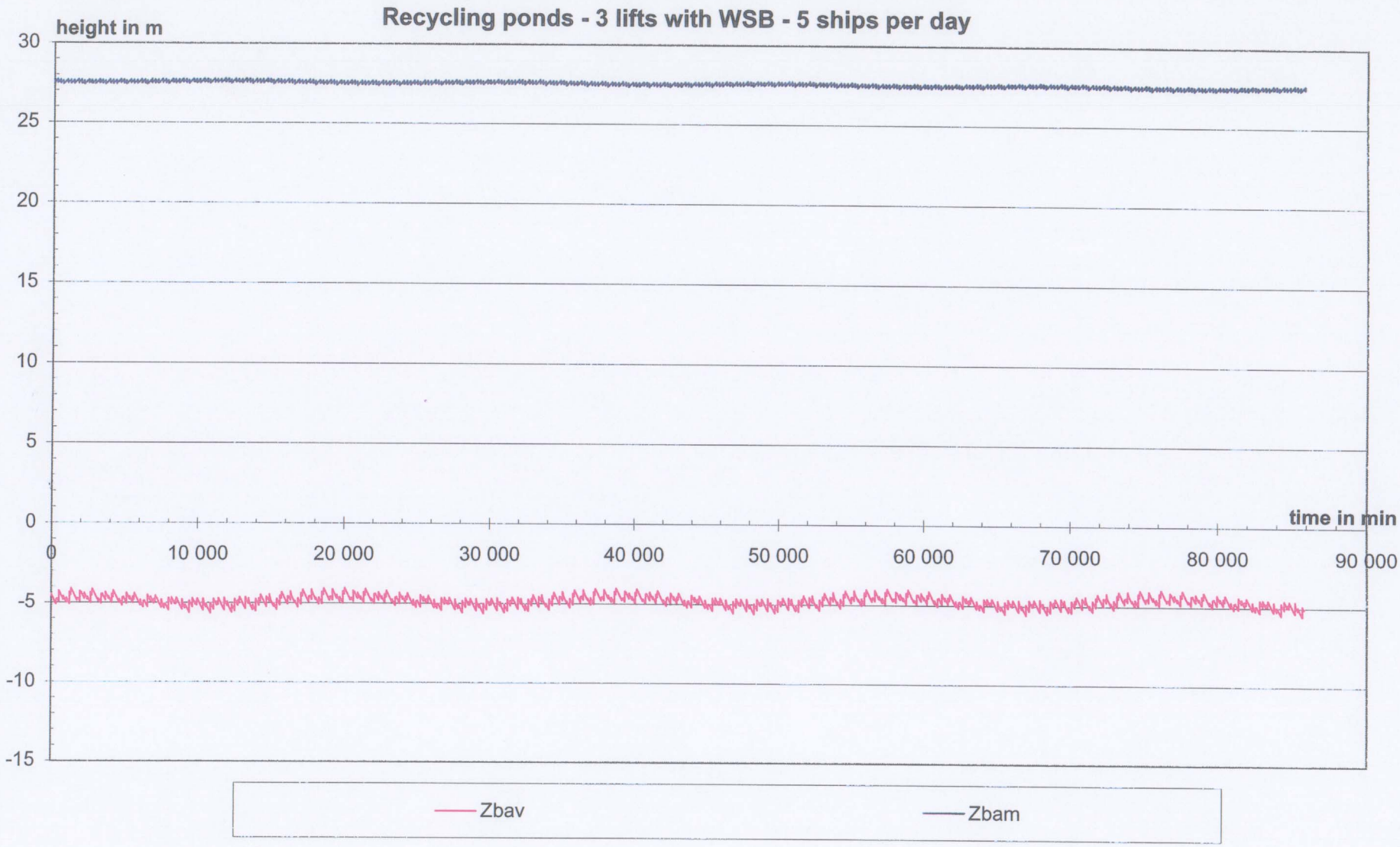
-

General Layout

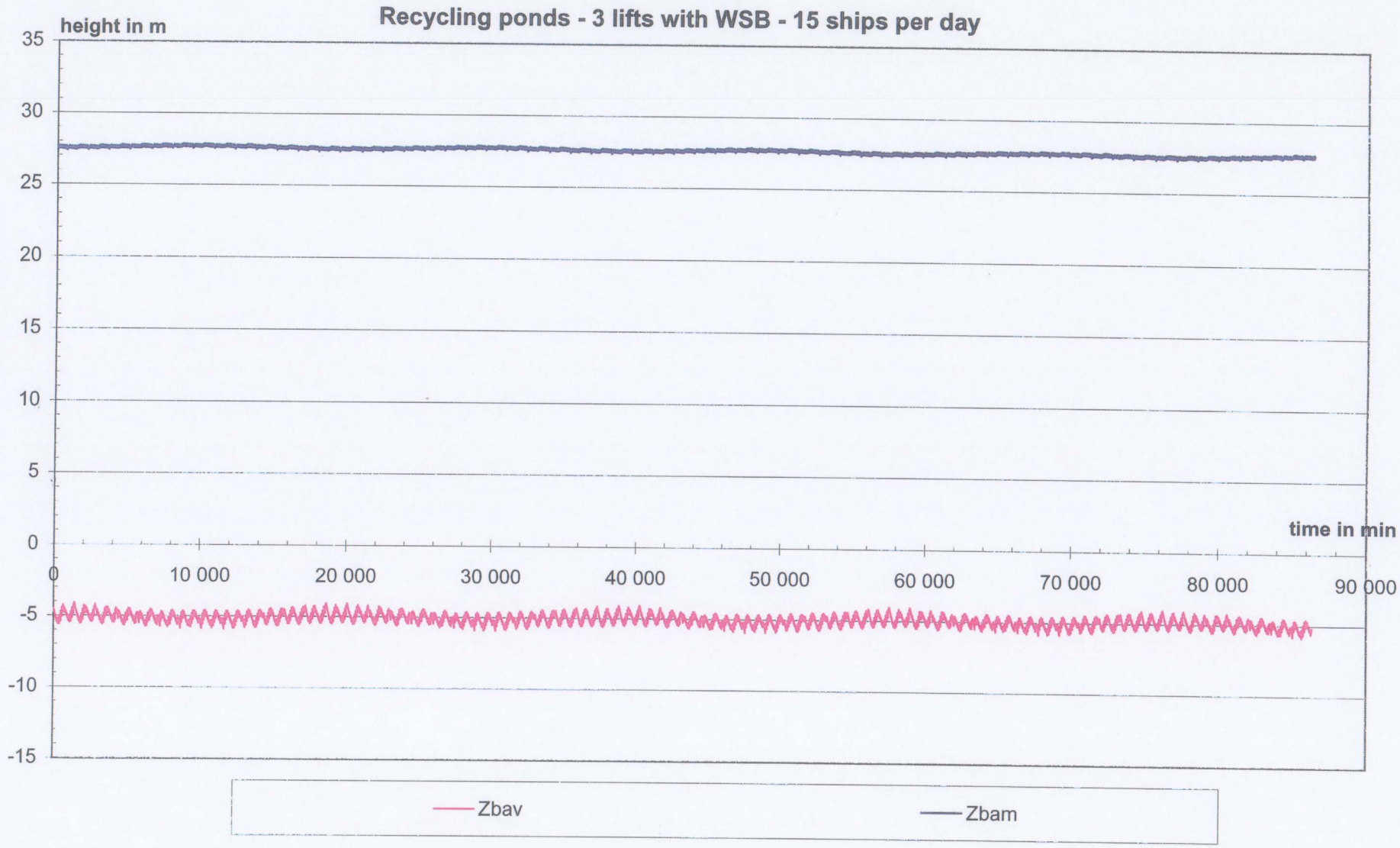
Annex 3

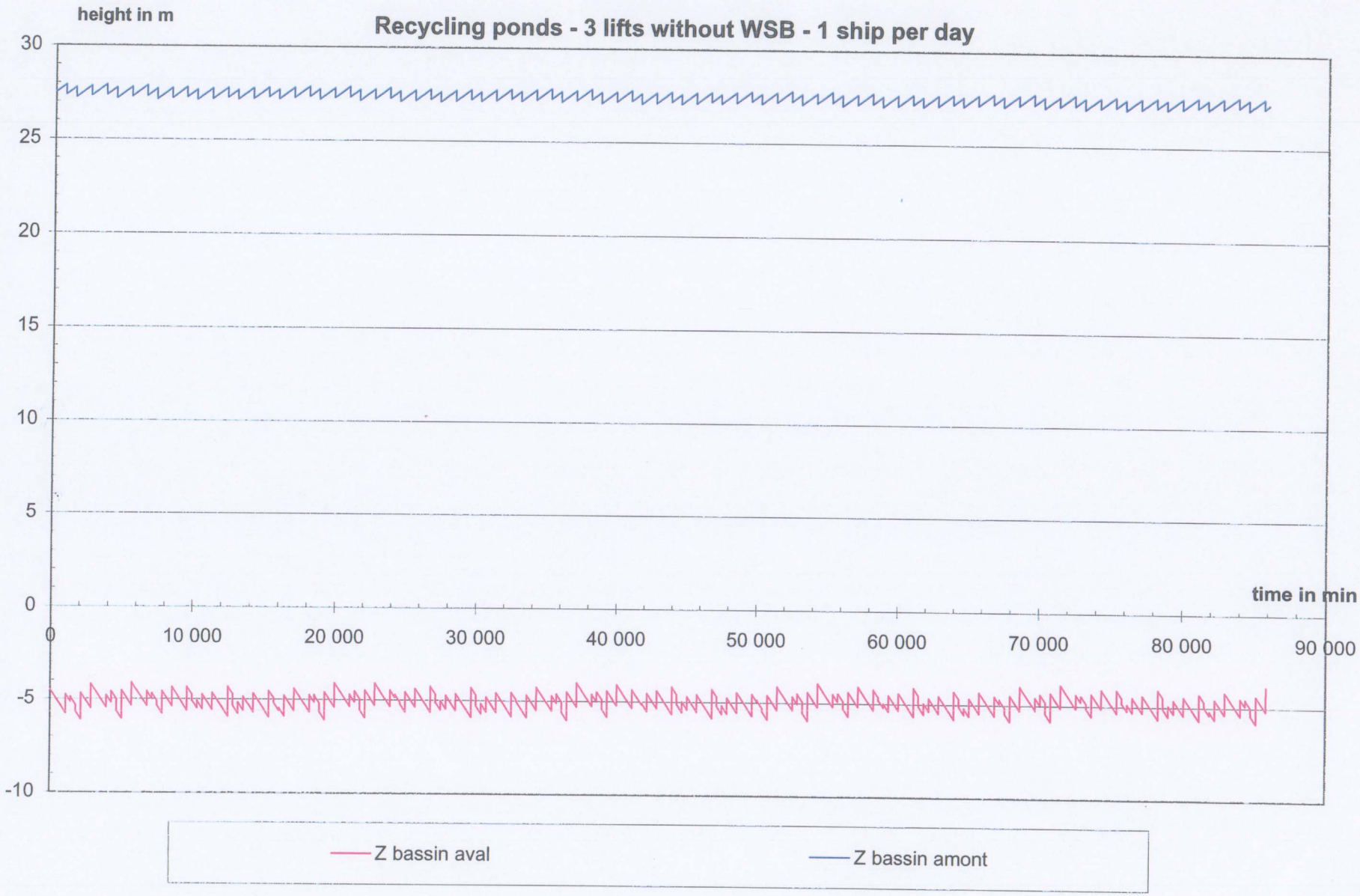
Ponds water level variation for the 3-lift locks system

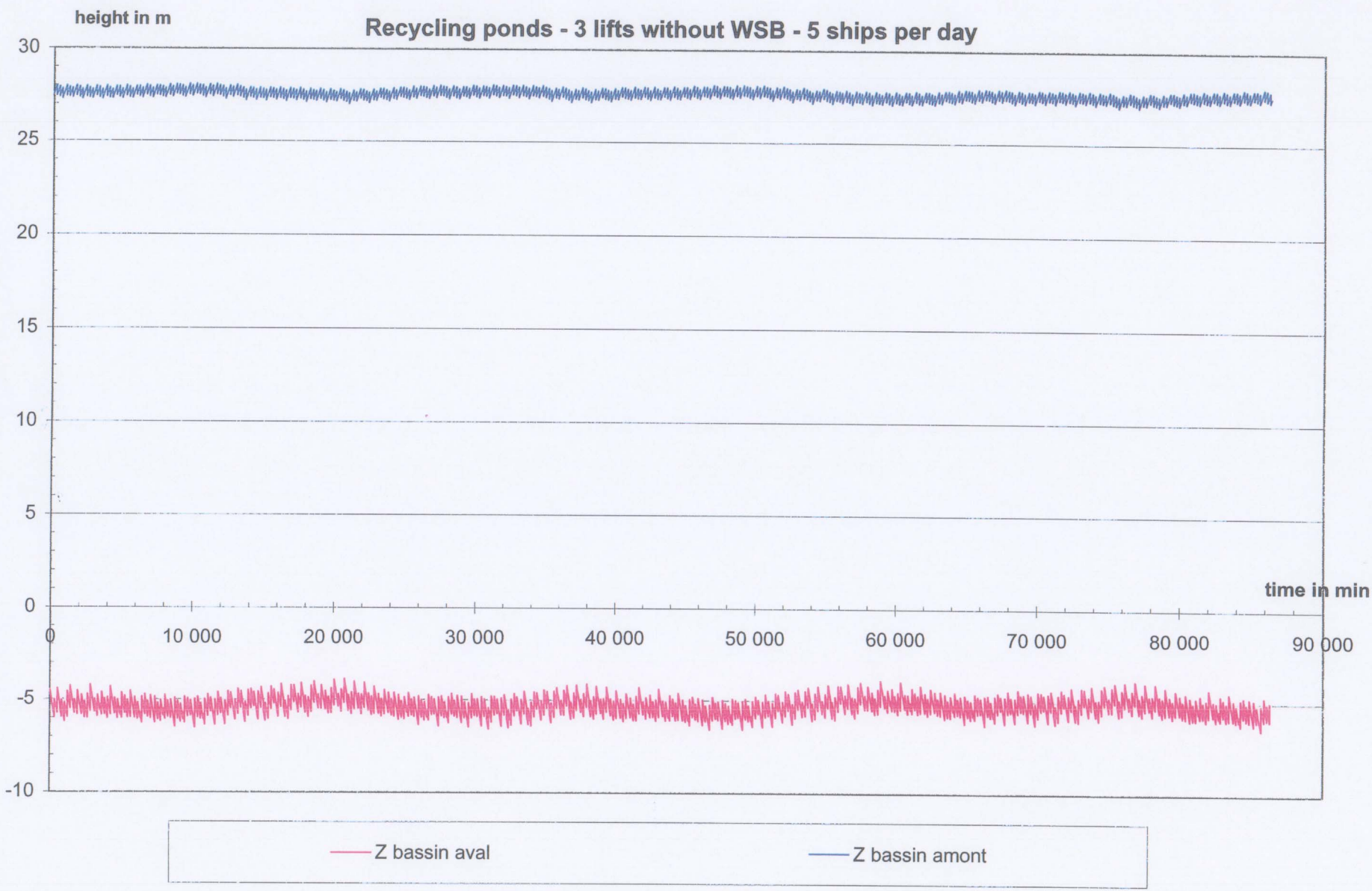

Recycling ponds - 3 lifts with WSB - 1 ship per day
height in m
35
30
25
20
15
10
5
0
-5
-10
-15
time in min
0
10 000
20 000
30 000
40 000
50 000
60 000
70 000
80 000
90 000
Zbav
Zbam


Recycling ponds - 3 lifts with WSB - 5 ships per day
height in m
30
25
20
15
10
5
0
-5
-10
-15
time in min
0
10 000
20 000
30 000
40 000
50 000
60 000
70 000
80 000
90 000
Zbav
Zbam

Recycling ponds - 3 lifts with WSB - 10 ships per day
height in m
30
25
20
15
10
5
0
-5
-10
time in min
0
10 000
20 000
30 000
40 000
50 000
60 000
70 000
80 000
90 000
Zbav
Zbam


Recycling ponds - 3 lifts with WSB - 15 ships per day
height in m
35
30
25
20
15
10
5
0
-5
-10
-15
time in min
0
10 000
20 000
30 000
40 000
50 000
60 000
70 000
80 000
90 000
Zbav
Zbam


height in m
Recycling ponds - 3 lifts without WSB - 1 ship per day
30
25
20
15
10
5
0
-5
-10
time in min
0
10 000
20 000
30 000
40 000
50 000
60 000
70 000
80 000
90 000
Z bassin aval
Z bassin amont


height in m
Recycling ponds - 3 lifts without WSB - 5 ships per day
30
25
20
15
10
5
0
-5
-10
time in min
0
10 000
20 000
30 000
40 000
50 000
60 000
70 000
80 000
90 000
Z bassin aval
Z bassin amont

height in m
Recycling ponds - 3 lifts without WSB - 10 ships per day
30
25
20
15
10
5
0
-5
-10
time in min
0
10 000
20 000
30 000
40 000
50 000
60 000
70 000
80 000
90 000
Z bassin aval
Z bassin amont

height in m
Recycling ponds - 3 lifts without WSB - 15 ships per day
30
25
20
15
10
5
0
-5
-10
time in min
0
10 000
20 000
30 000
40 000
50 000
60 000
70 000
80 000
90 000
Z bassin aval
Z bassin amont

Annex 4

Description of the recycling circuit components

Number of pumping networks	pumping scenario	locks configuration	Number of WSB	Component	Type	quantity	Lenght in m	Total lenght in m	Diameter in m	radius in m	deflection angle in deg	bars thickness in m	bars spacing in m	max flow rate in m3/s	max velocity in m/s
3 pumping networks	direct	3-lift	no WSB	Main culvert	concrete circular	1	2390	2390	2.9	/	/	/	/	20.0	3.0
				valve (upstream pumping station)	butterfly	1	/	/	2.9	/	/	/	/	20.0	3.0
				grid	circular bars	1	/	/	/	/	/	0.02	0.1	20.0	/
				bend	circular bend	1	/	/	2.9	2.9	90	/	/	20.0	3.0
						4					45				
						1					30				
			3 WSB	Main culvert	concrete circular	1	2390	2390	1.8	/	/	/	/	8.0	3.1
				valve (upstream pumping station)	butterfly	1	/	/	1.8	/	/	/	/	8.0	3.1
				grid	circular bars	1	/	/	/	/	/	0.02	0.1	8.0	/
				bend	circular bend	1	/	/	1.8	1.8	90	/	/	8.0	3.1
						4					45				
						1					30				
		2-lift	no WSB	Main culvert	concrete circular	1	2390	2390	3.2	/	/	/	/	25.0	3.1
				valve (upstream pumping station)	butterfly	1	/	/	3.2	/	/	/	/	25.0	3.1
				grid	circular bars	1	/	/	/	/	/	0.02	0.1	25.0	/
				bend	circular bend	1	/	/	3.2	3.2	90	/	/	25.0	3.1
						4					45				
						1					30				
			2 WSB	Main culvert	concrete circular	1	2390	2390	2.3	/	/	/	/	13.0	3.1
				valve (upstream pumping station)	butterfly	1	/	/	2.3	/	/	/	/	13.0	3.1
				grid	circular bars	1	/	/	/	/	/	0.02	0.1	13.0	/
				bend	circular bend	1	/	/	2.3	2.3	90	/	/	13.0	3.1
						4					45				
						1					30				
	semi direct	3-lift	no WSB	Main culvert	concrete circular	1	3470	3470	2.9	/	/	/	/	20.0	3.0
				valve (upstream pumping station)	butterfly	1	/	/	2.9	/	/	/	/	20.0	3.0
				grid	circular bars	1	/	/	/	/	/	0.02	0.1	20.0	/
				bend	circular bend	5	/	/	2.9	2.9	45	/	/	20.0	3.0
						1					30				
			3 WSB	Main culvert	concrete circular	1	3470	3470	1.8	/	/	/	/	8.0	3.1
				valve (upstream pumping station)	butterfly	1	/	/	1.8	/	/	/	/	8.0	3.1
				grid	circular bars	1	/	/	/	/	/	0.02	0.1	8.0	/
				bend	circular bend	5	/	/	1.8	1.8	45	/	/	8.0	3.1
						1					30				
		2-lift	no WSB	Main culvert	concrete circular	1	3470	3470	3.2	/	/	/	/	25.0	3.1
				valve (upstream pumping station)	butterfly	1	/	/	3.2	/	/	/	/	25.0	3.1
				grid	circular bars	1	/	/	/	/	/	0.02	0.1	25.0	/
				bend	circular bend	5	/	/	3.2	3.2	45	/	/	25.0	3.1
						1					30				
			2 WSB	Main culvert	concrete circular	1	3470	3470	2.3	/	/	/	/	13.0	3.1
				valve (upstream pumping station)	butterfly	1	/	/	2.3	/	/	/	/	13.0	3.1
				grid	circular bars	1	/	/	/	/	/	0.02	0.1	13.0	/
				bend	circular bend	5	/	/	2.3	2.3	45	/	/	13.0	3.1
						1					30				
	pond to pond	3-lift	no WSB	Main culvert	concrete circular	1	2500	2500	2.9	/	/	/	/	20.0	3.0
				valve (upstream pumping station)	butterfly	1	/	/	2.9	/	/	/	/	20.0	3.0
				grid	circular bars	1	/	/	/	/	/	0.02	0.1	20.0	/
				bend	circular bend	5	/	/	2.9	2.9	45	/	/	20.0	3.0
			3 WSB	Main culvert	concrete circular	1	2500	2500	1.8	/	/	/	/	8.0	3.1
				valve (upstream pumping station)	butterfly	1	/	/	1.8	/	/	/	/	8.0	3.1
				grid	circular bars	1	/	/	/	/	/	0.02	0.1	8.0	/
				bend	circular bend	5	/	/	1.8	1.8	45	/	/	8.0	3.1
		2-lift	no WSB	Main culvert	concrete circular	1	2500	2500	3.2	/	/	/	/	25.0	3.1
				valve (upstream pumping station)	butterfly	1	/	/	3.2	/	/	/	/	25.0	3.1
				grid	circular bars	1	/	/	/	/	/	0.02	0.1	25.0	/
				bend	circular bend	5	/	/	3.2	3.2	45	/	/	25.0	3.1
			2 WSB	Main culvert	concrete circular	1	2500	2500	2.3	/	/	/	/	13.0	3.1
				valve (upstream pumping station)	butterfly	1	/	/	2.3	/	/	/	/	13.0	3.1
				grid	circular bars	1	/	/	/	/	/	0.02	0.1	13.0	/
				bend	circular bend	5	/	/	2.3	2.3	45	/	/	13.0	3.1
2 pumping networks	direct	3-lift	3 WSB	Main culvert	concrete circular	1	2390	2390	2.1	/	/	/	/	11.0	3.2
				valve (upstream pumping station)	butterfly	1	/	/	2.1	/	/	/	/	11.0	3.2
				grid	circular bars	1	/	/	/	/	/	0.02	0.1	11.0	/
				bend	circular bend	1	/	/	2.1	2.1	90	/	/	11.0	3.2
						4					45				
						1					30				
	semi direct			Main culvert	concrete circular	1	3470	3470	2.1	/	/	/	/	11.0	3.2
				valve (upstream pumping station)	butterfly	1	/	/	2.1	/	/	/	/	11.0	3.2
				grid	circular bars	1	/	/	/	/	/	0.02	0.1	11.0	/
				bend	circular bend	5	/	/	2.1	2.1	45	/	/	11.0	3.2
						1					30				
	pond to pond			Main culvert	concrete circular	1	2500	2500	2.1	/	/	/	/	11:0	3.2
				valve (upstream pumping station)	butterfly	1	/	/	2.1	/	/	/	/	11.0	3.2
				grid	circular bars	1	/	/	/	/	/	0.02	0.1	11.0	/
				bend	circular bend	5	/	/	2.1	2.1	45	/	/	11.0	3.2

Annex 5

Drawing LO-002

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Lower reservoir to upper reservoir pipe
Longitudinal profile

Annex 6

Drawing LO-003

-

Lower reservoir to Gatun lake pipe
Longitudinal profile

Annex 7

Drawing LO-004

-

Pacific ocean to Gatun lake pipe
Longitudinal profile

Annex 8

Network curves

Annex 8.1.1
Pond to pond pumping - 3-lift locks system

Pond to pond pumping
3 identical pumping networks

General data

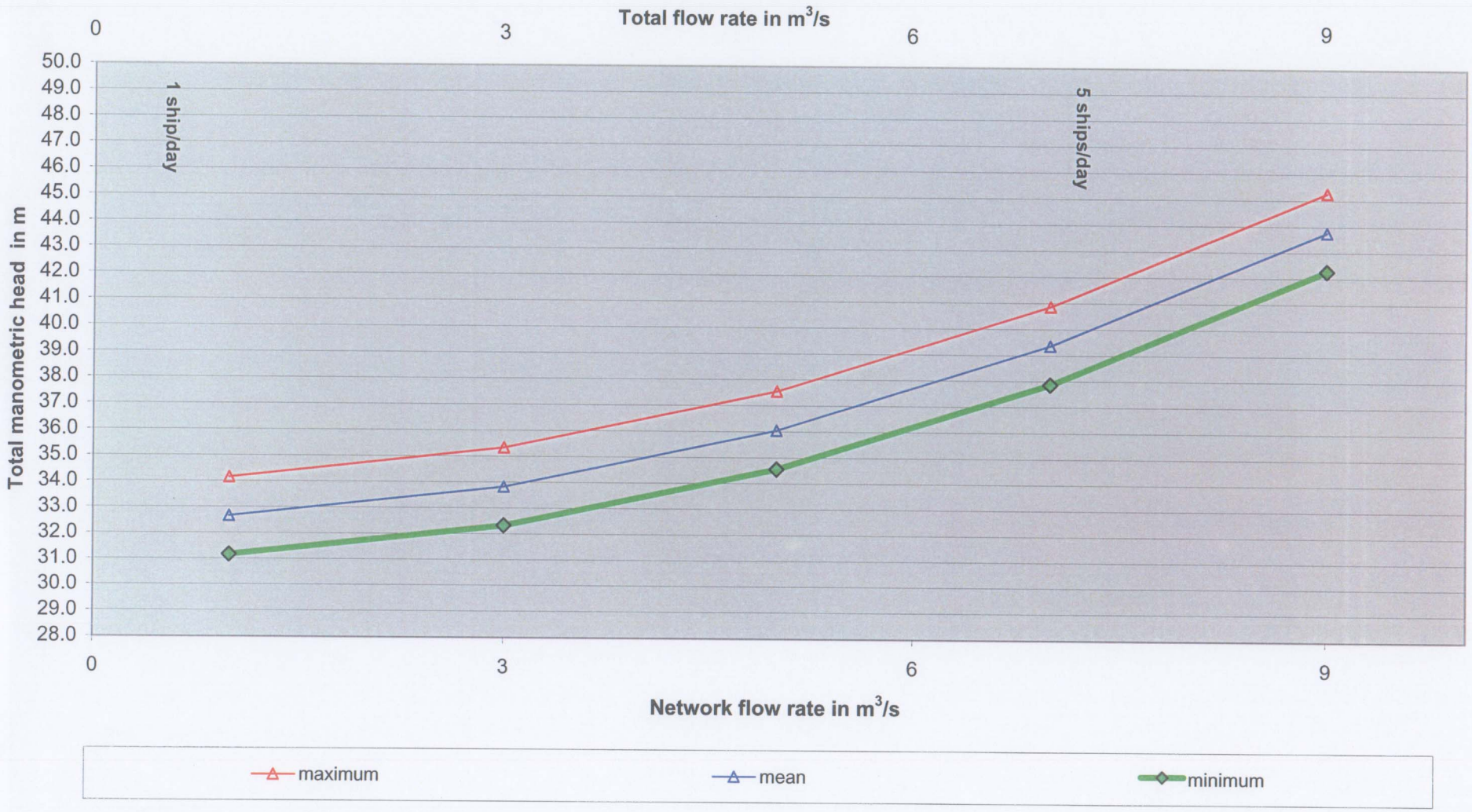
Number of lock chamber :	3
Number of WSB :	3
Pumping station flow rate range in m^3/s :	0 to 24
Pumping network flow rate range in m^3/s :	0 to 8
Number of pump per network :	1
Culvert diameter in m :	1.80

Network curves data

Flow rate in m^3/s	*Total head losses in m*	*Geometric head in m*			*Total manometric head in m*		
		minimum	*mean*	*maximum*	*minimum*	*mean*	*maximum*
1	0.2	31	32.5	34	31.2	32.7	34.2
3	1.3	31	32.5	34	32.3	33.8	35.3
5	3.6	31	32.5	34	34.6	36.1	37.6
7	6.9	31	32.5	34	37.9	39.4	40.9
9	11.3	31	32.5	34	42.3	43.8	45.3

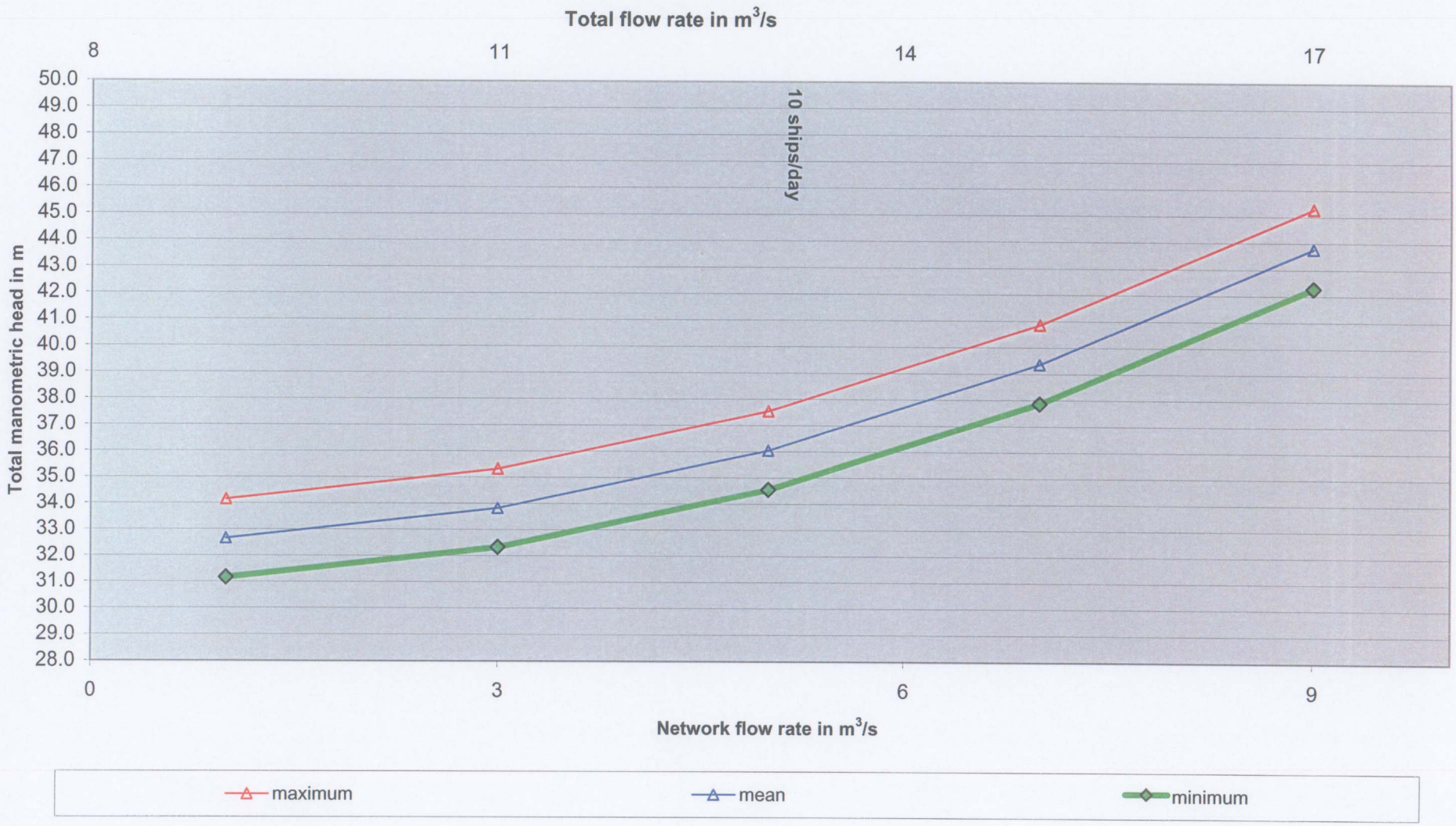
Pond to [illegible]nd pumping
3-lift locks system with WSB
3 identical pumping networks

Network curves - Pumping network N°1
Culvert diameter 1.80 m



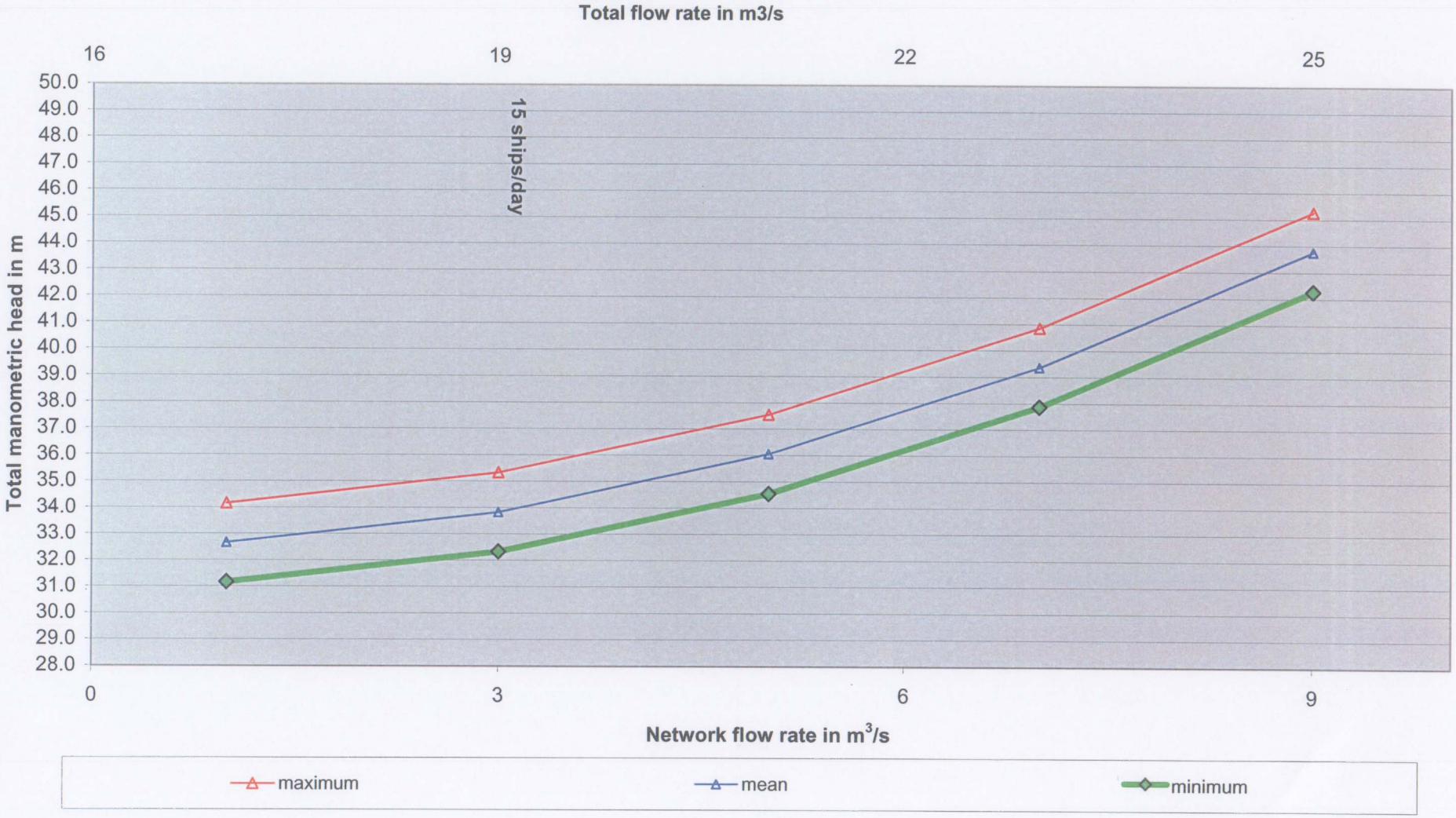
Pond to [illegible]nd pumping
3-lift locks system with WSB
3 identical pumping networks

Network curves - Pumping network N°2
Culvert diameter 1.80 m



Pond to [illegible]d pumping
3-lift locks system with WSB
3 identical pimping networks

Network curves - Pumping network N°3
Culvert diameter 1.80 m



Pond to pond pumping
2 identical pumping networks

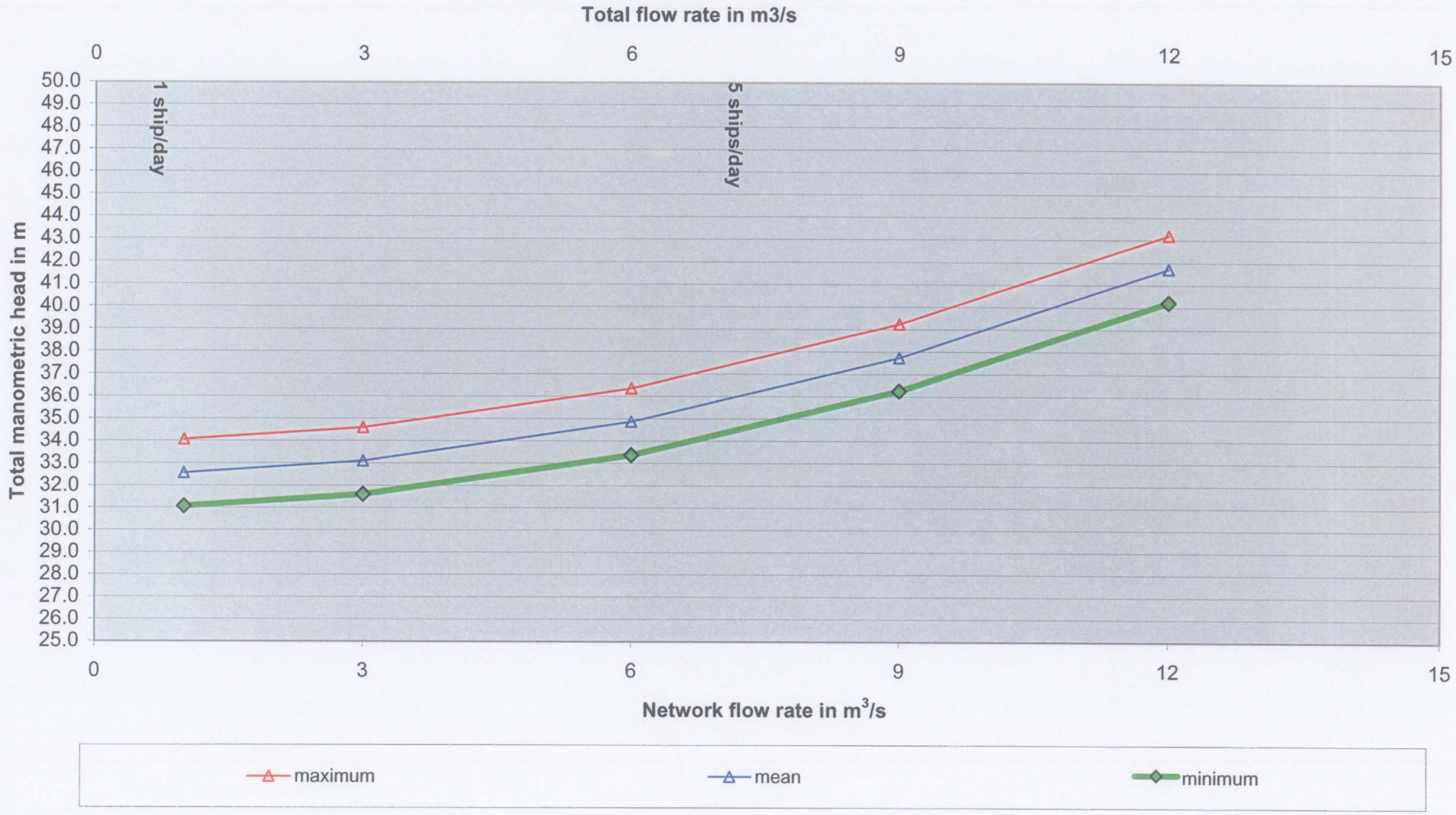
General data

Number of lock chamber :	3
Number of WSB :	3
Pumping station flow rate range in m^3/s :	0 to 22
Pumping network flow rate range in m^3/s :	0 to 11
Number of pump per network :	1
Culvert diameter in m :	2.10

Flow rate in m^3/s	*Total head losses in m*	*Geometric head in m*			*Total manometric head in m*		
		minimum	*mean*	*maximum*	*minimum*	*mean*	*maximum*
1	0.1	31	32.5	34	31.1	32.6	34.1
3	0.6	31	32.5	34	31.6	33.1	34.6
6	2.4	31	32.5	34	33.4	34.9	36.4
9	5.2	31	32.5	34	36.2	37.7	39.2
12	9.2	31	32.5	34	40.2	41.7	43.2

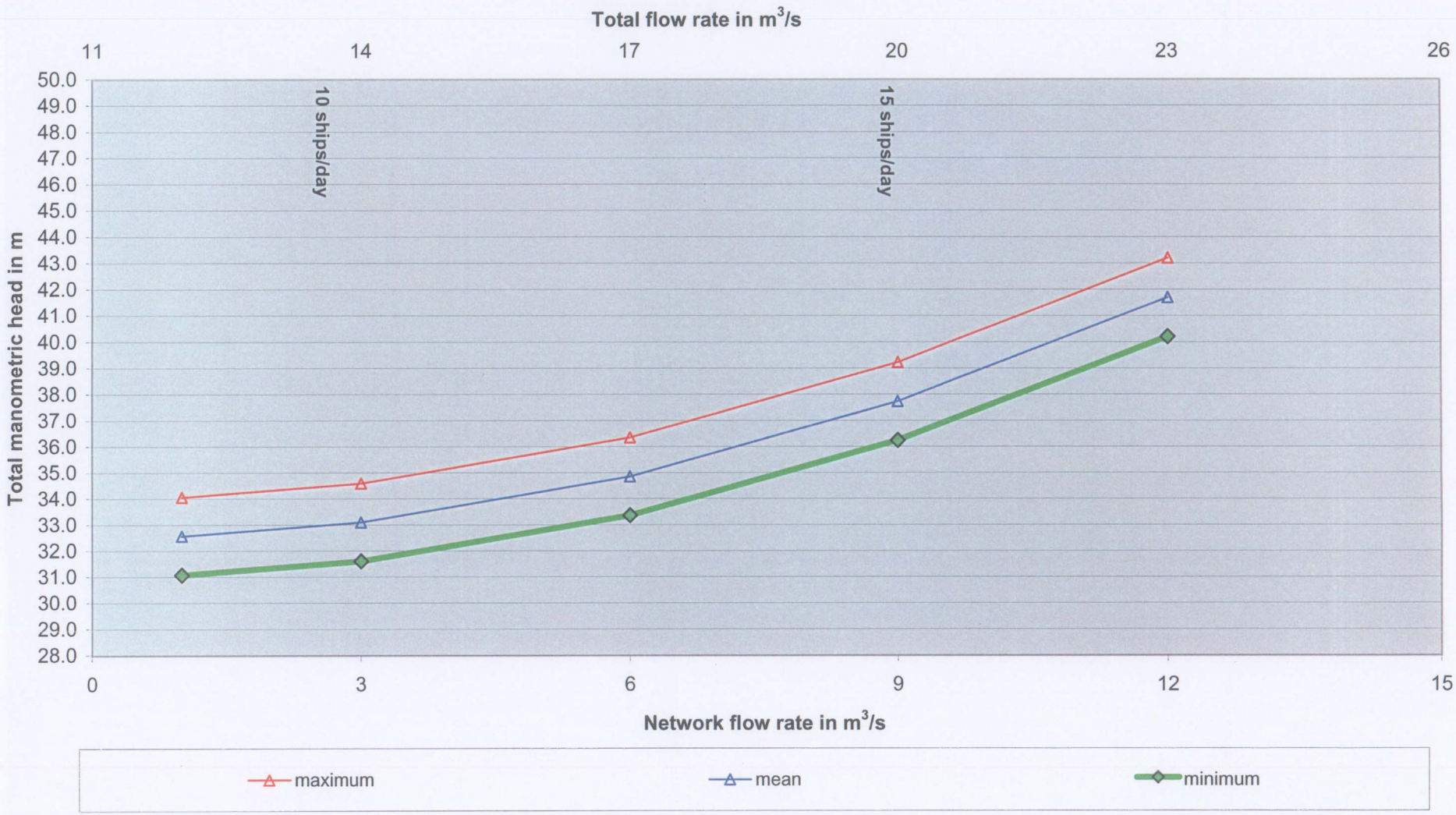
Pond to d pumping
3-lift locks system
2 identical pumping networks

Network curves - Pumping network N°1
Culvert diameter 2.10 m



Pond to [illegible]d pumping
3-lift locks system with WSB
2 identical pumping networks

Network curves - Pumping network N°2
Culvert diameter 2.10 m



Pond to pond pumping
3 identical pumping networks

General data

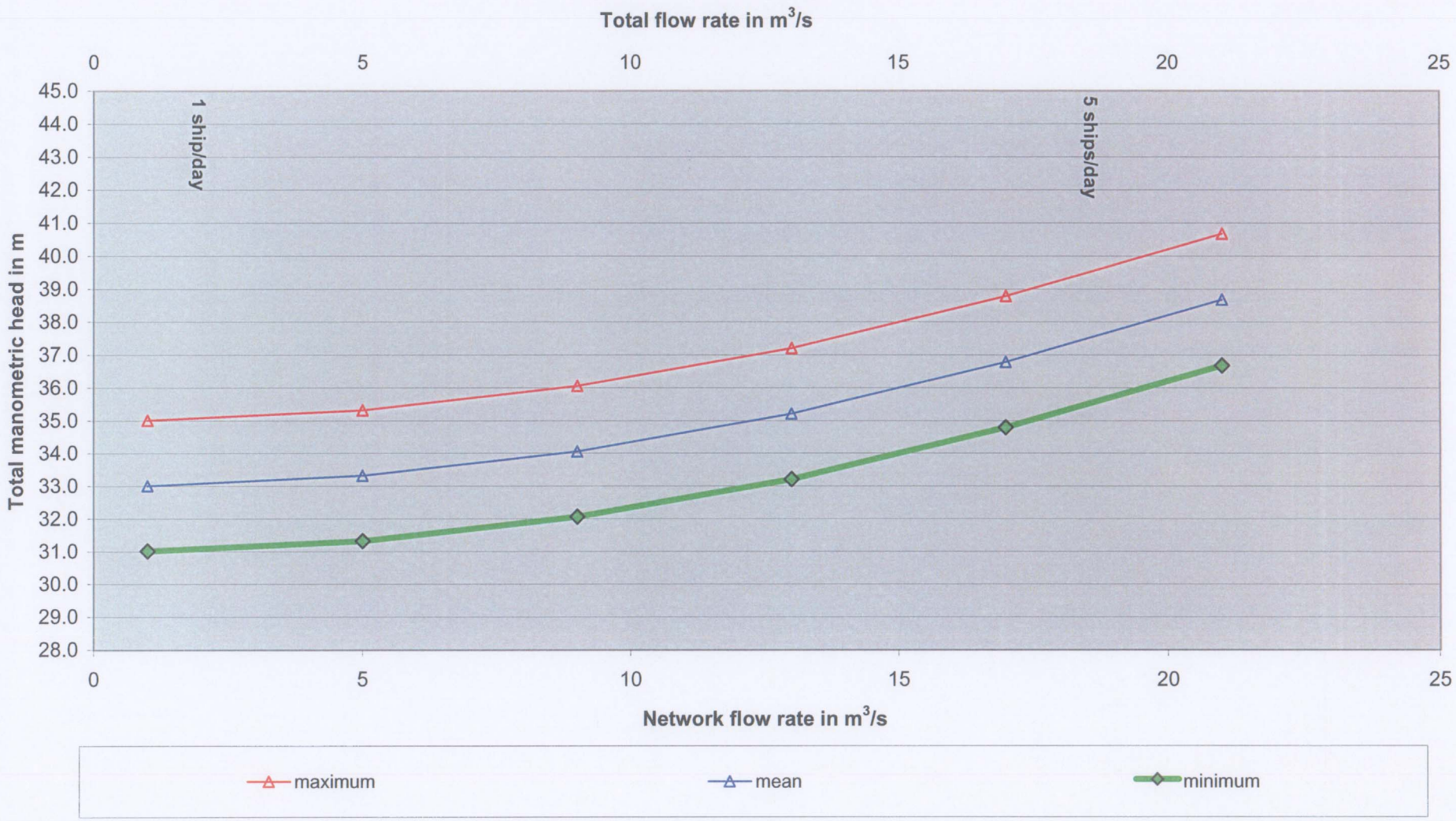
Number of lock chamber :	3
Number of WSB :	0
Pumping station flow rate range in m^3/s :	0 to 60
Pumping network flow rate range in m^3/s :	0 to 20
Number of pump per network :	1
Culvert diameter in m :	2.90

Network curves data

Flow rate in m^3/s	*Total head losses in m*	*Geometric head in m*			*Manometric head in m*		
		minimum	*mean*	*maximum*	*minimum*	*mean*	*maximum*
1	0.0	31	33	35	31.0	33.0	35.0
5	0.3	31	33	35	31.3	33.3	35.3
9	1.1	31	33	35	32.1	34.1	36.1
13	2.2	31	33	35	33.2	35.2	37.2
17	3.8	31	33	35	34.8	36.8	38.8
21	5.7	31	33	35	36.7	38.7	40.7

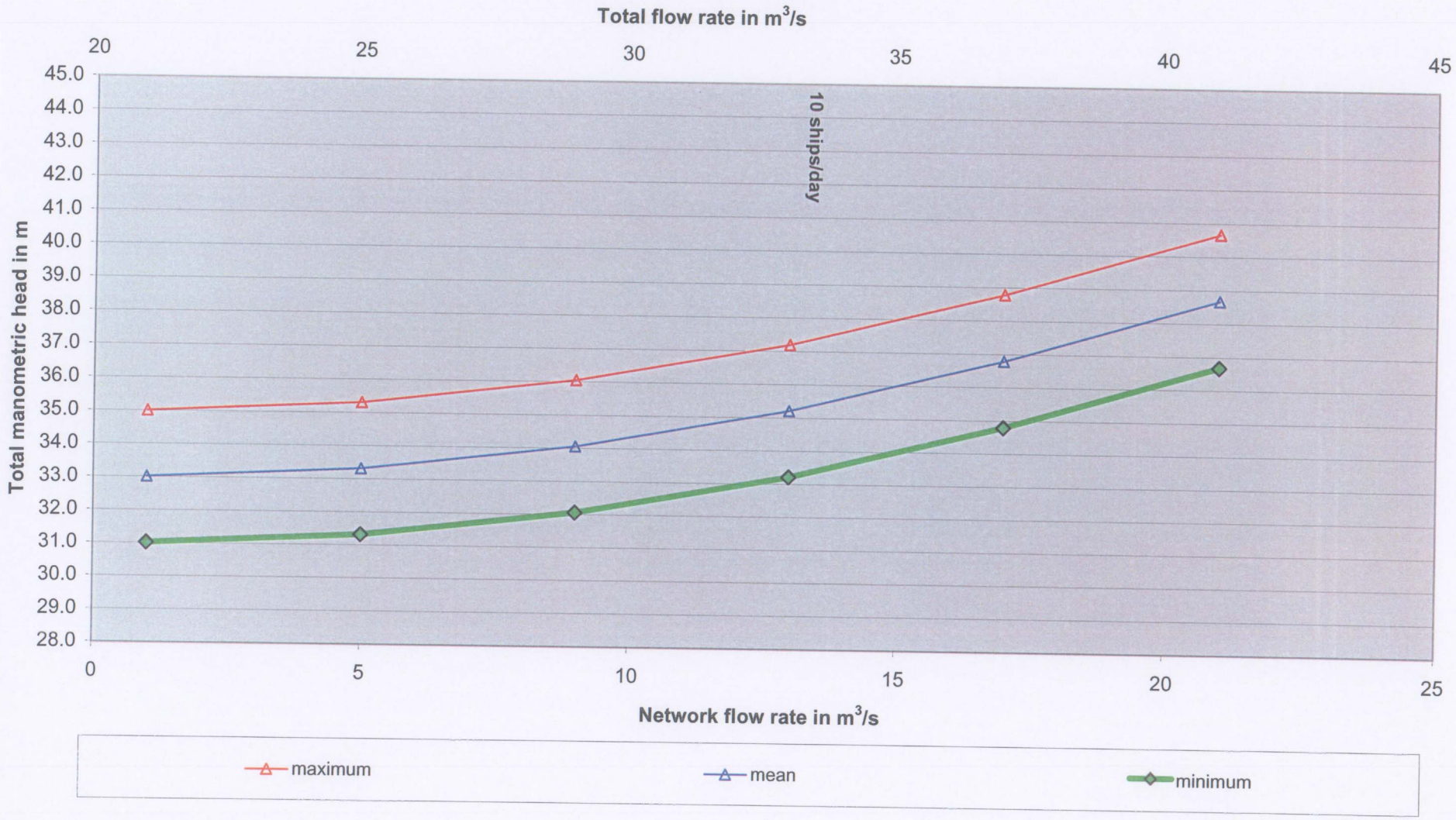
Pond to sea pumping
3-lift locks system without WSB
3 identical pumping network

Network curves - Pumping network N°1
Culvert diameter 2.90 m



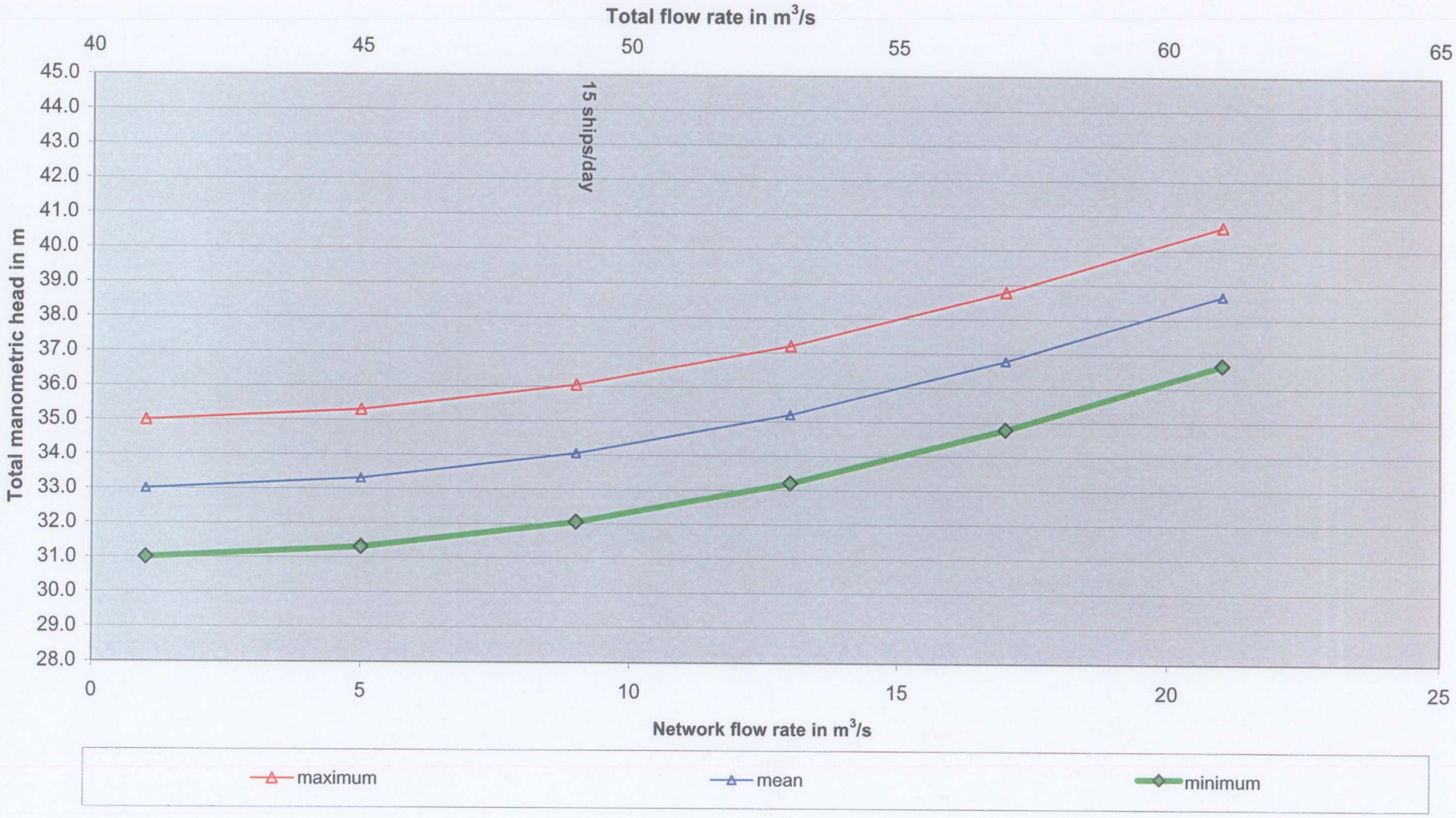
Pond to [illegible]d pumping
3-lift locks system without WSB
3 identical pumping networks

Network curves - Pumping network N°2
Culvert diameter 2.90 m



Pond to sea pumping
3-lift locks system without WSB
3 identical pumping networks

Network curves - Pumping network N°3
Culvert diameter 2.90 m



Annex 8

Network curves

Annex 8.1.2
Pond to pond pumping - 2-lift locks system

Pond to pond pumping
3 identical pumping networks

General data

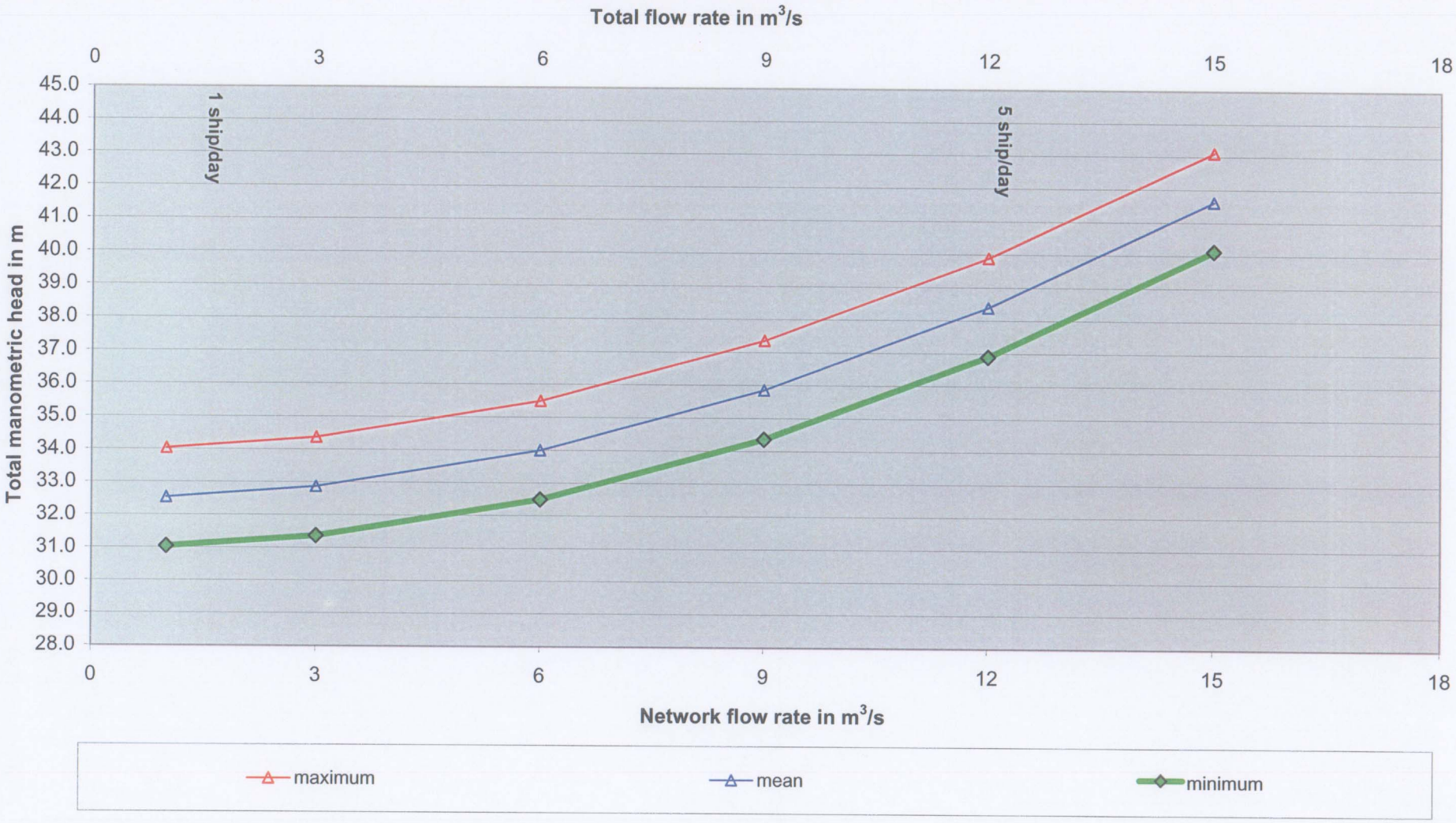
Number of lock chamber :	2
Number of WSB :	2
Pumping station flow rate range in m^3/s :	0 to 39
Pumping network flow rate range in m^3/s :	0 to 13
Number of pump per network :	1
Culvert diameter in m :	2.30

Network curves data

Flow rate in m3/s	*Total head losses in m*	*Geometric head in m*			*Manometric head in m*		
		minimum	*mean*	*maximum*	*minimum*	*mean*	*maximum*
1	0.0	31	32.5	34	31.0	32.5	34.0
3	0.4	31	32.5	34	31.4	32.9	34.4
6	1.5	31	32.5	34	32.5	34.0	35.5
9	3.4	31	32.5	34	34.4	35.9	37.4
12	5.9	31	32.5	34	36.9	38.4	39.9
15	9.1	31	32.5	34	40.1	41.6	43.1

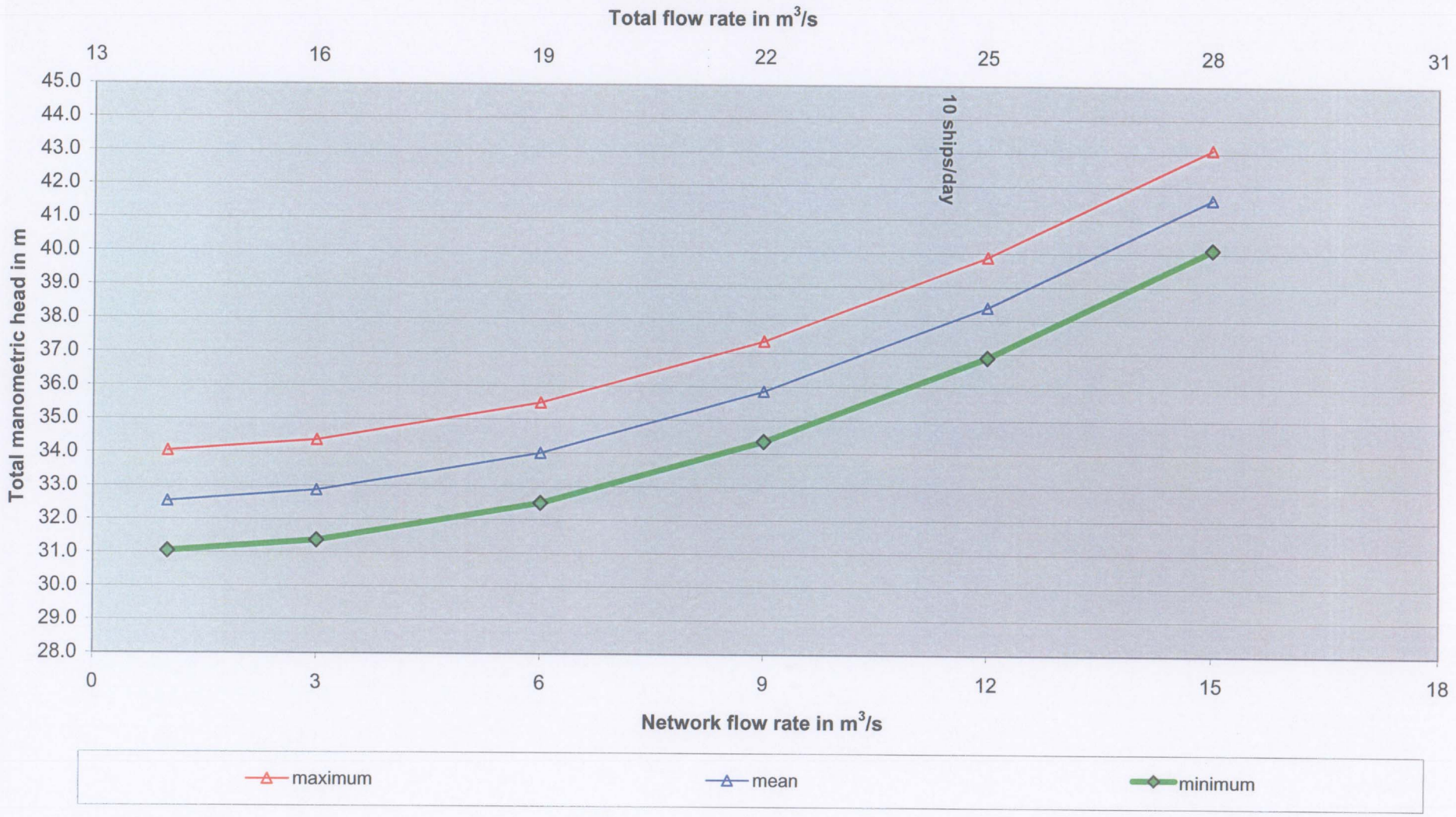
Pond to p d pumping
2-lift locks system with WSB
3 identical pumping networks

Nework curves - Pumping network N°1
Culvert diameter 2.30 m



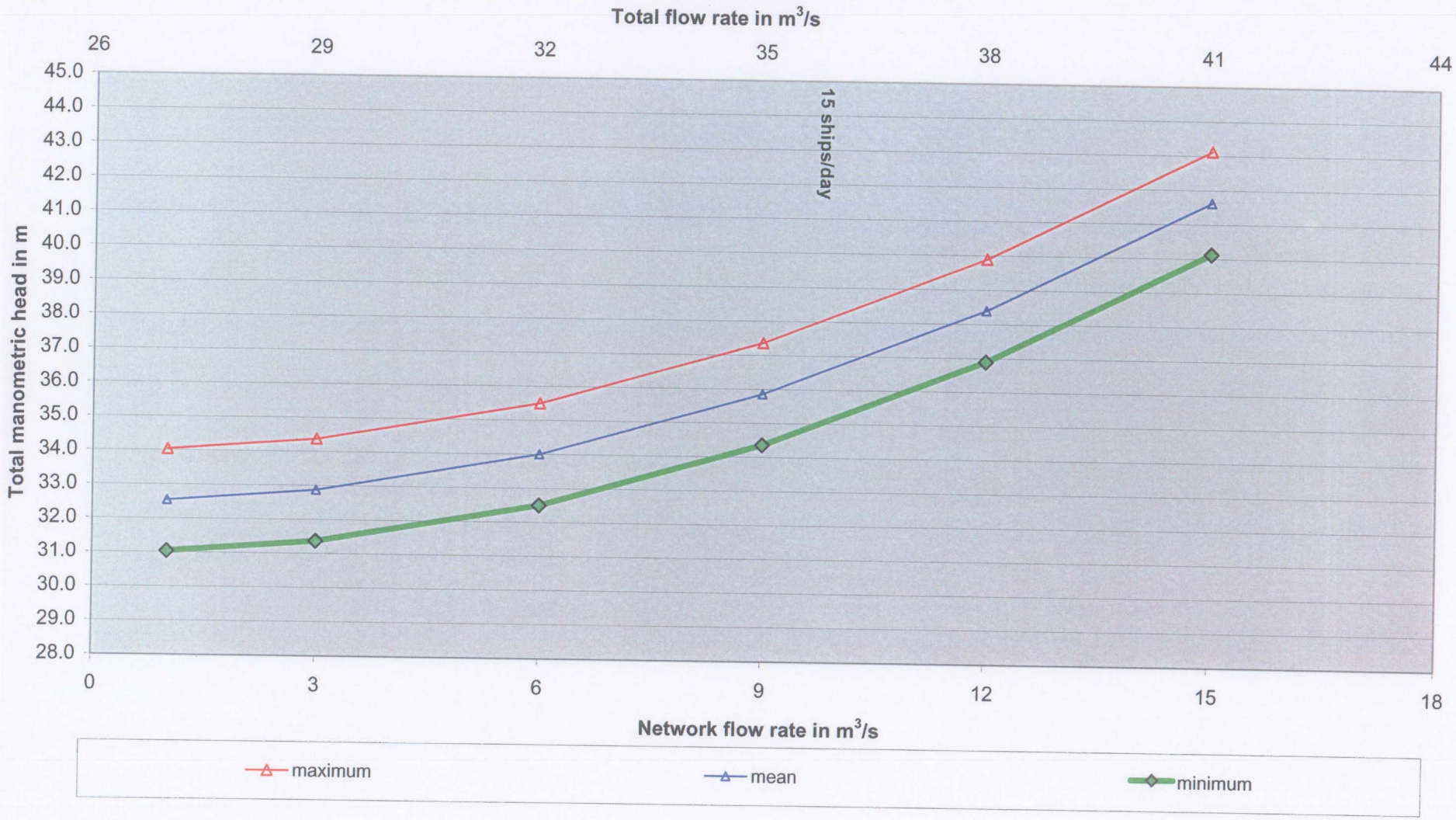
Pond to p d pumping
2-lift locks system with WSB
3 identical pumping networks

Nework curves - Pumping network N°2
Culvert diameter 2.30 m



Pond to p d pumping
2-lift locks system with WSB
3 identical pumping network

Nework curves - Pumping network N°3
Culvert diameter 2.30 m



Pond to pond pumping
3 identical pumping networks

General data

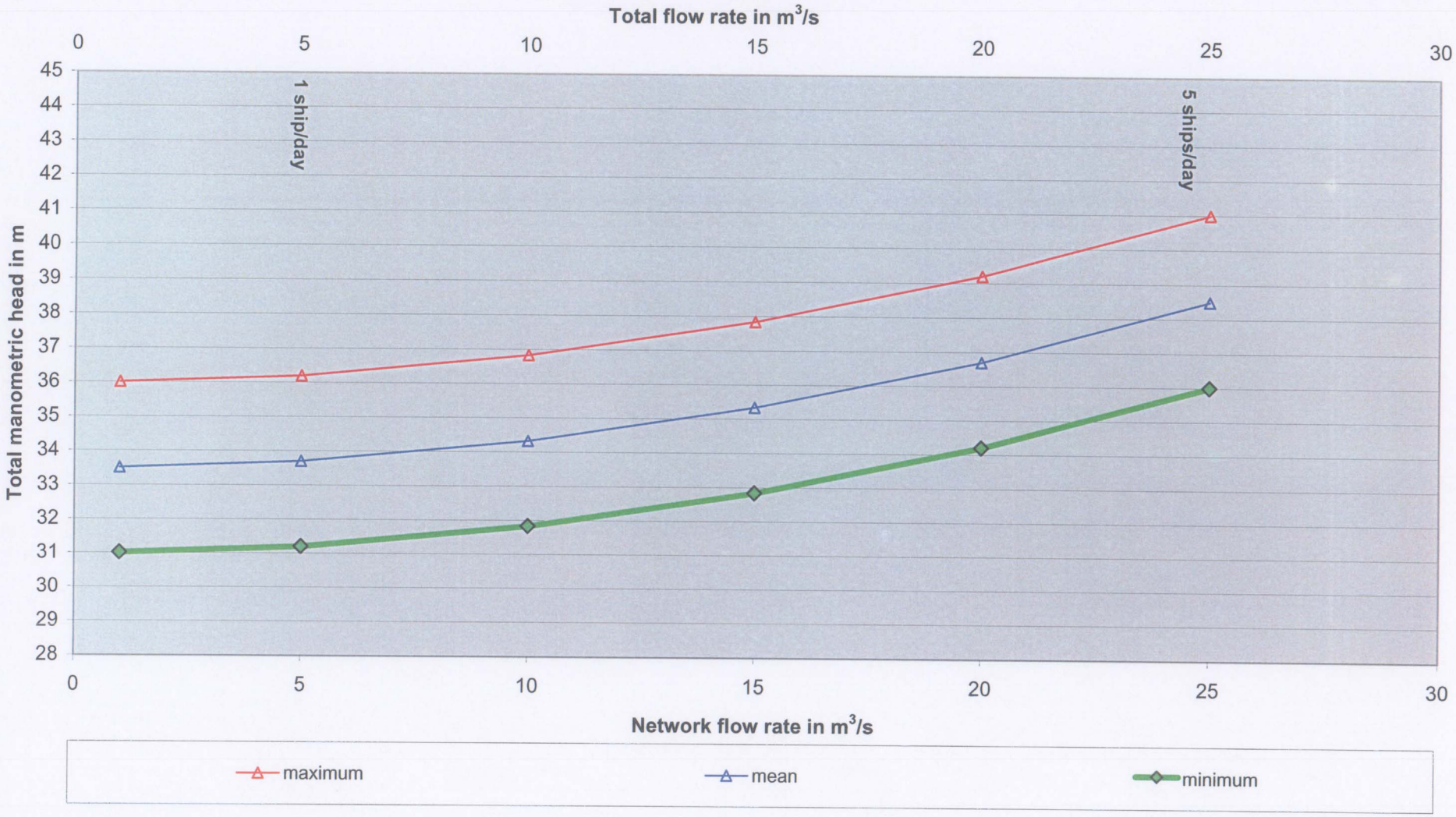
Number of lock chamber :	2
Number of WSB :	0
Pumping station flow rate range in m^3/s :	0 to 75
Pumping network flow rate range in m^3/s :	0 to 25
Number of pump per network :	1
Culvert diameter in m :	3.20

Network curves data

Flow rate in m3/s	*Total head losses in m*	*Geometric head in m*			*Manometric head in m*		
		minimum	*mean*	*maximum*	*minimum*	*mean*	*maximum*
1	0.0	31	33.5	36	31.0	33.5	36.0
5	0.2	31	33.5	36	31.2	33.7	36.2
10	0.8	31	33.5	36	31.8	34.3	36.8
15	1.8	31	33.5	36	32.8	35.3	37.8
20	3.2	31	33.5	36	34.2	36.7	39.2
25	5.0	31	33.5	36	36.0	38.5	41.0

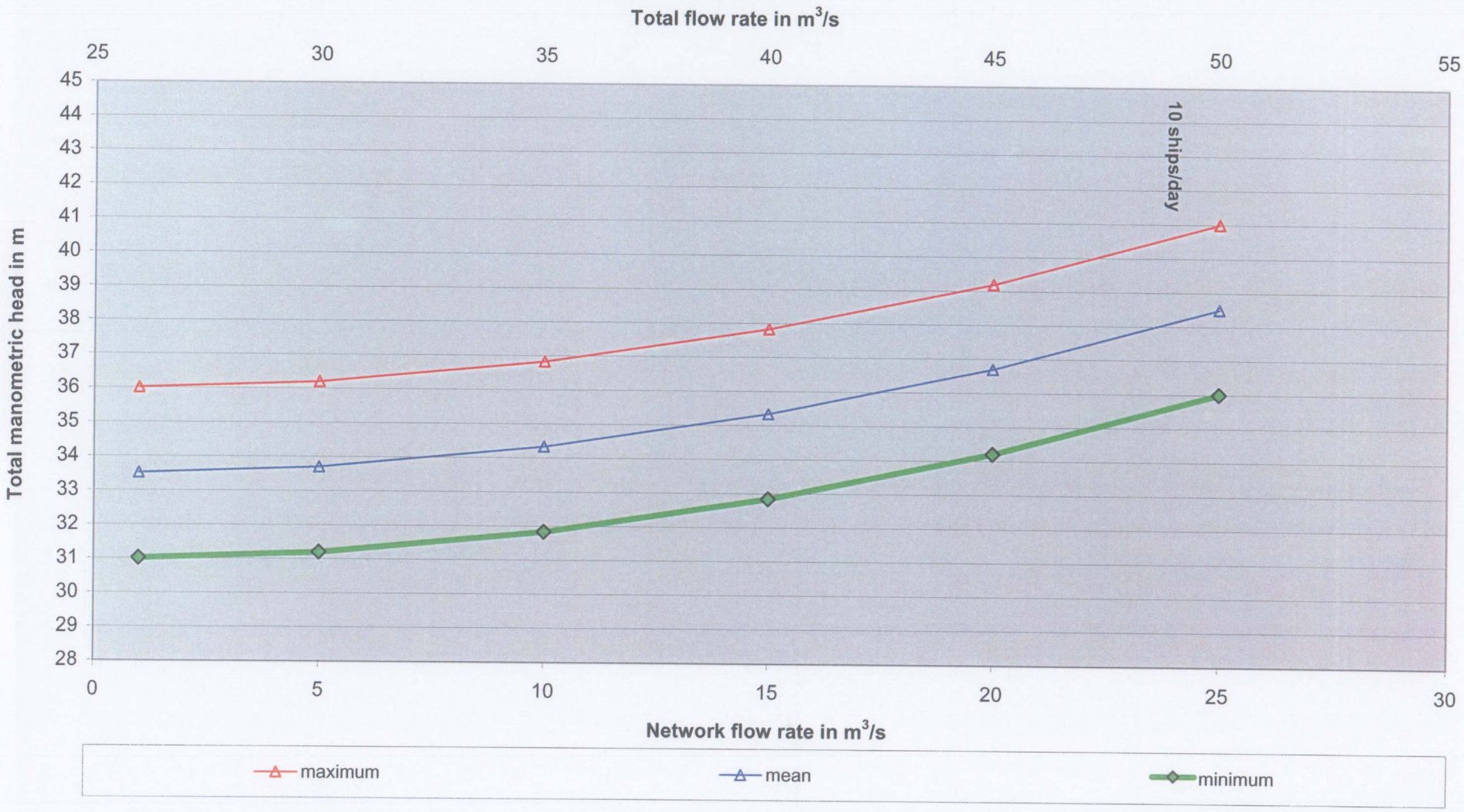
Pond to p d pumping
2-lift locks system without WSB
3 identical pumping networks

Nework curves - Pumping network N°1
Culvert diameter 3.20 m



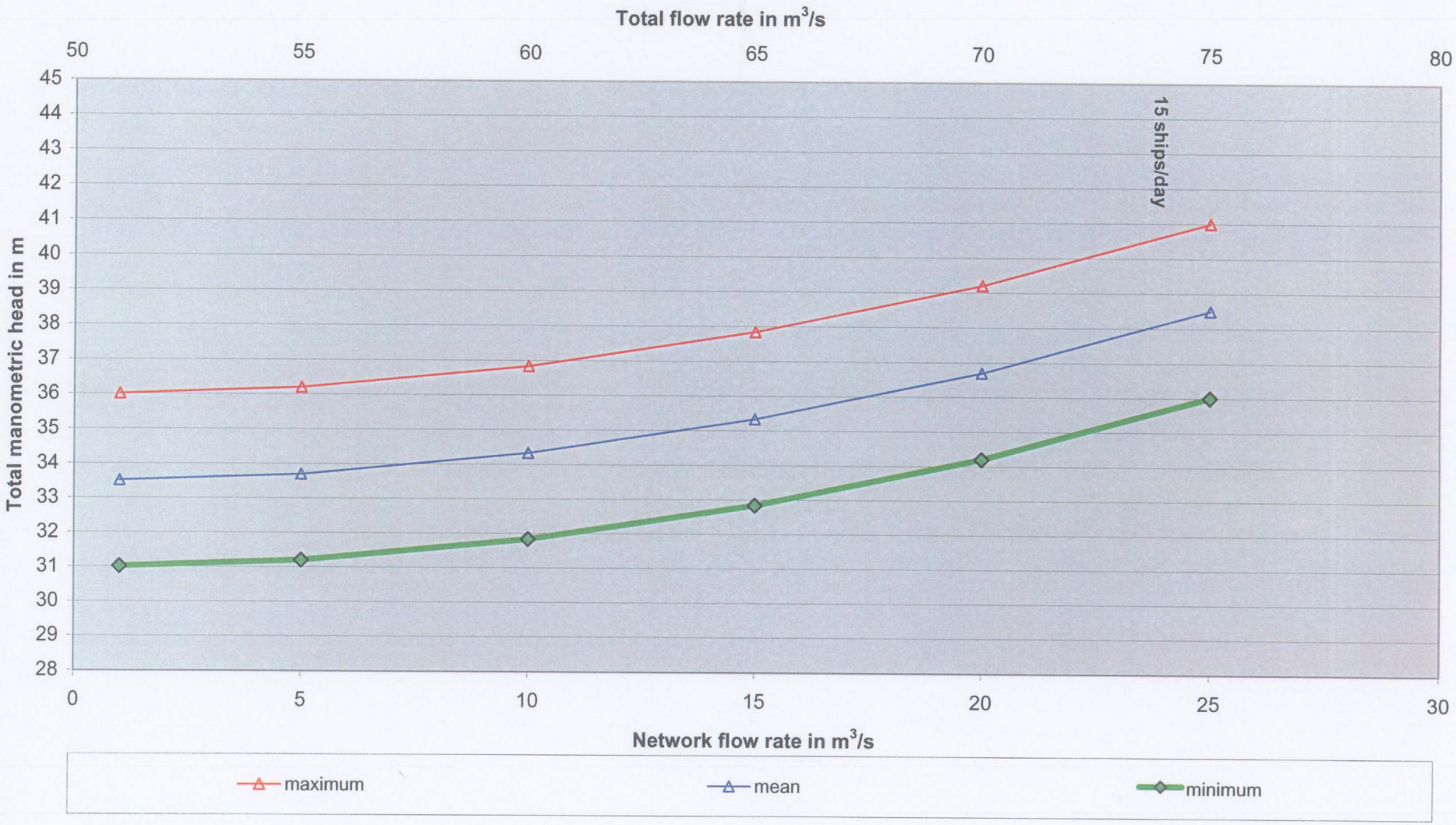
Pond to p d pumping
2-lift locks system without WSB
3 identical pumping networks

Nework curves - Pumping network N°2
Culvert diameter 3.20 m



Pond to p d pumping
2-lift locks system without WSB
3 identical pumping networks

Nework curves - Pumping network N°3
Culvert diameter 3.20 m



Annex 8

Network curves

Annex 8.2.1
Semi direct pumping - 3-lift locks system

Semi direct pumping
3-lift locks system with WSB
3 identical pumping networks

General data

Number of lock chamber : 3
Number of WSB : 3

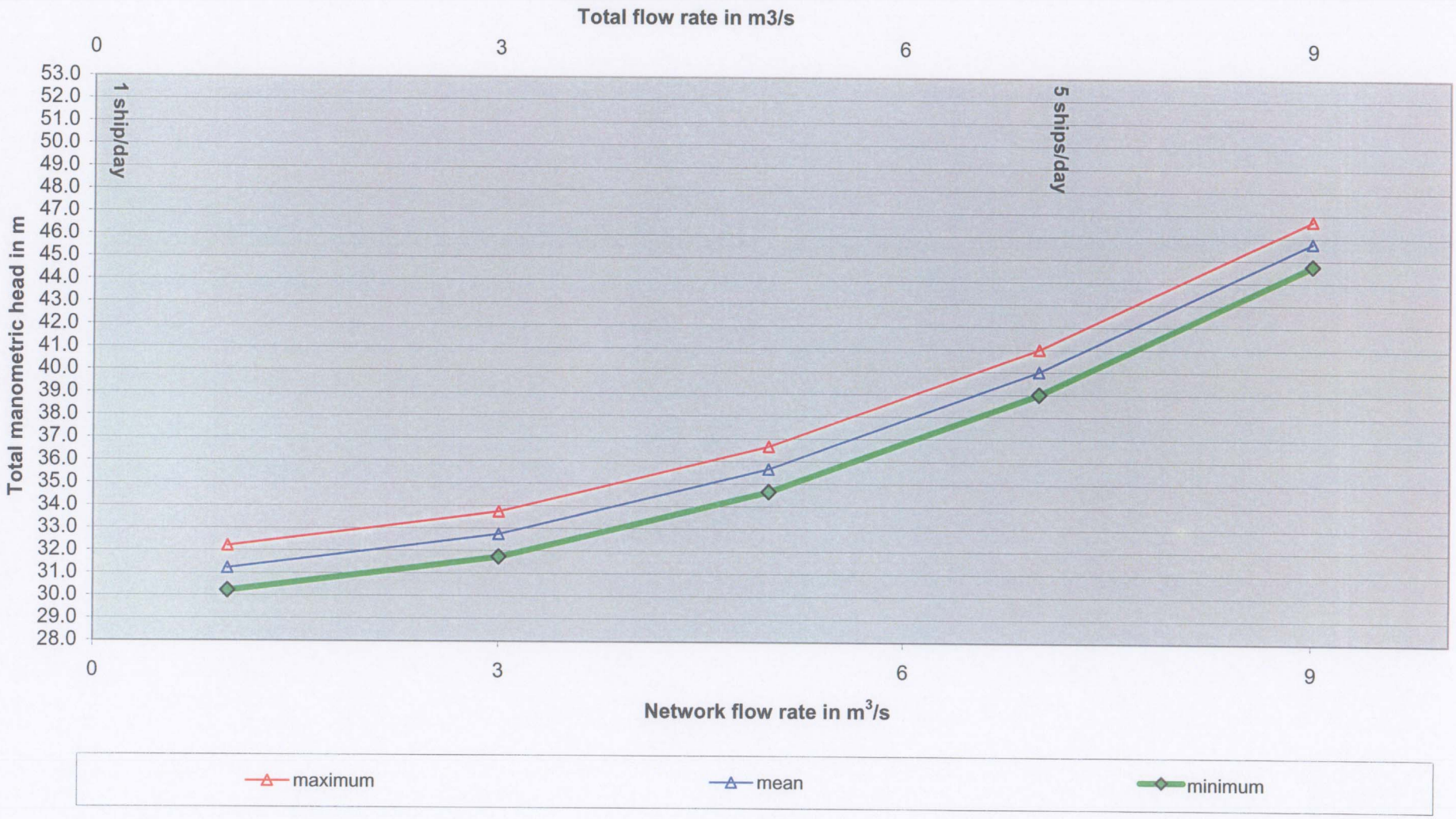
Pumping station flow rate range in m^3/s : 0 to 24
Pumping network flow rate range in m^3/s : 0 to 8
Number of pump per network : 1
Culvert diameter in m : 1.80

Network curves data

Flow rate in m^3/s	*Total head losses in m*	*Geometric head in m*			*Total manometric head in m*		
		minimum	*mean*	*maximum*	*minimum*	*mean*	*maximum*
1	0.2	30	31	32	30.2	31.2	32.2
3	1.7	30	31	32	31.7	32.7	33.7
5	4.7	30	31	32	34.7	35.7	36.7
7	9.0	30	31	32	39.0	40.0	41.0
9	14.8	30	31	32	44.8	45.8	46.8

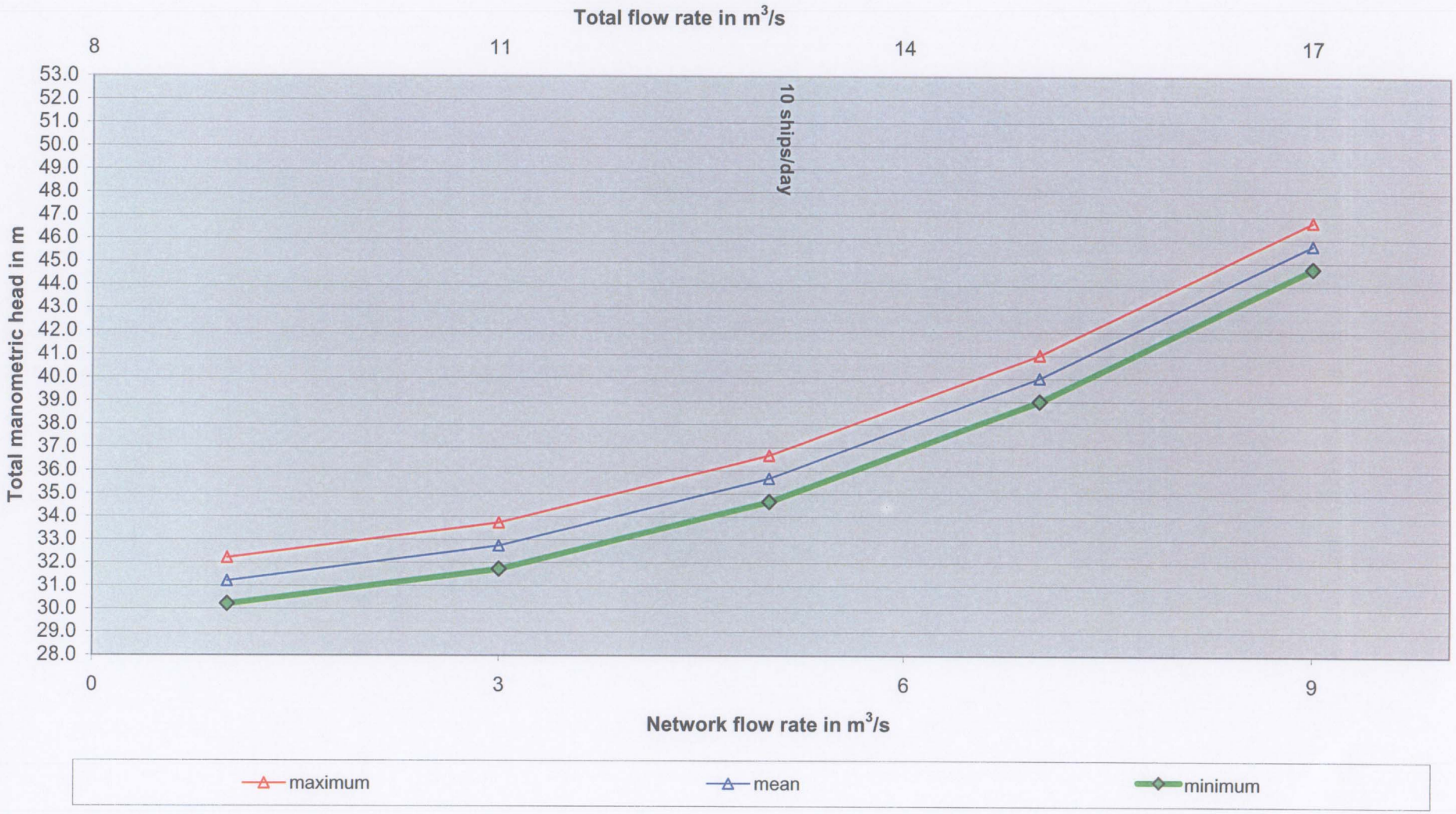
Semi dir pumping
3-lift locks system with WSB
3 identical pumping networks

Nework curves - Pumping network N°1
Culvert diameter 1.80 m



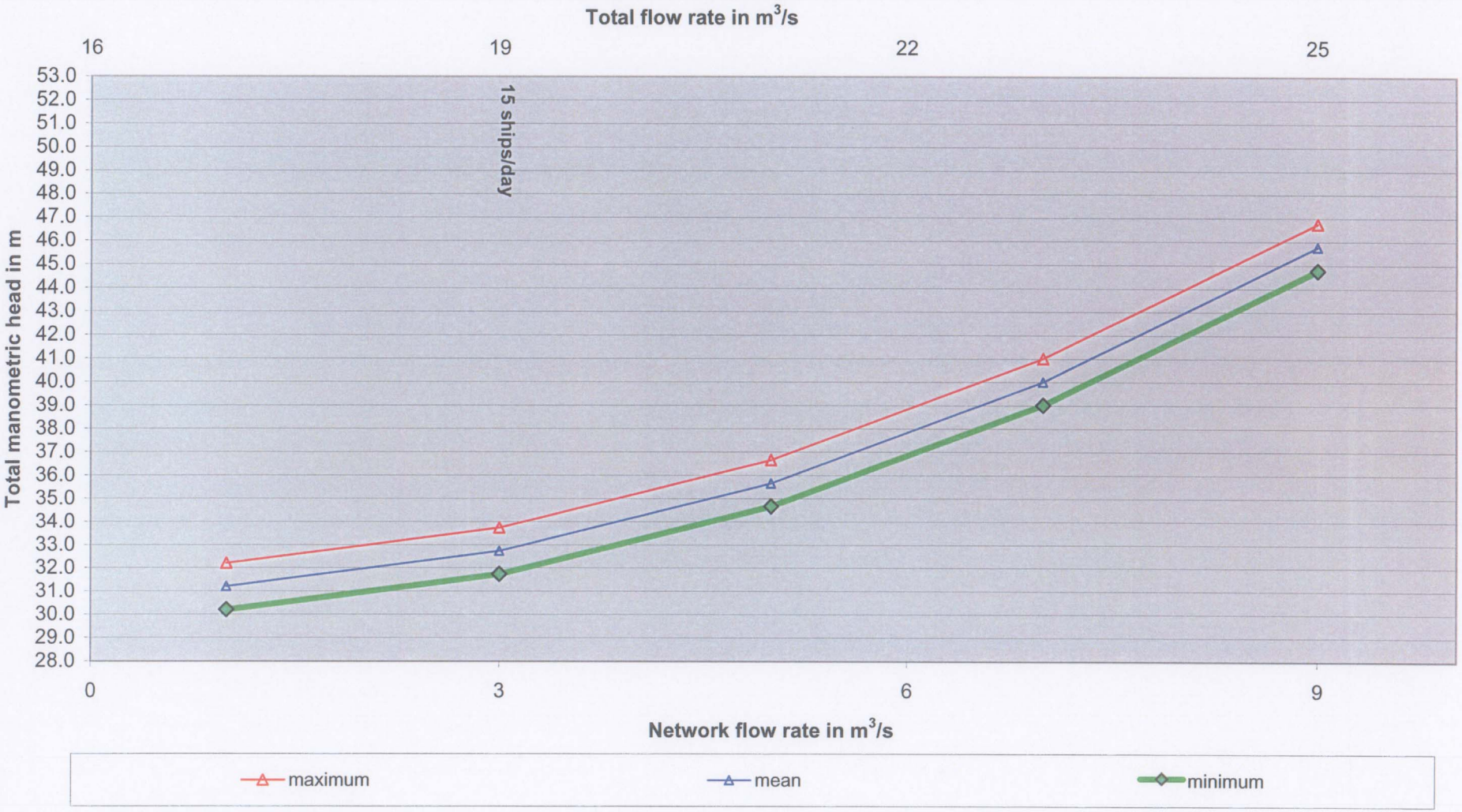
Semi di pumping
3-lift locks system with WSB
3 identical pumping networks

Nework curves - Pumping network N°2
Culvert diameter 1.80 m



semi dir pumping
3-lift locks system with WSB
3 identical pumping networks

Nework curves - Pumping network N°3
Culvert diameter 1.80 m



Semi direct pumping
3 identical pumping networks

General data

Number of lock chamber : 3
Number of WSB : 0

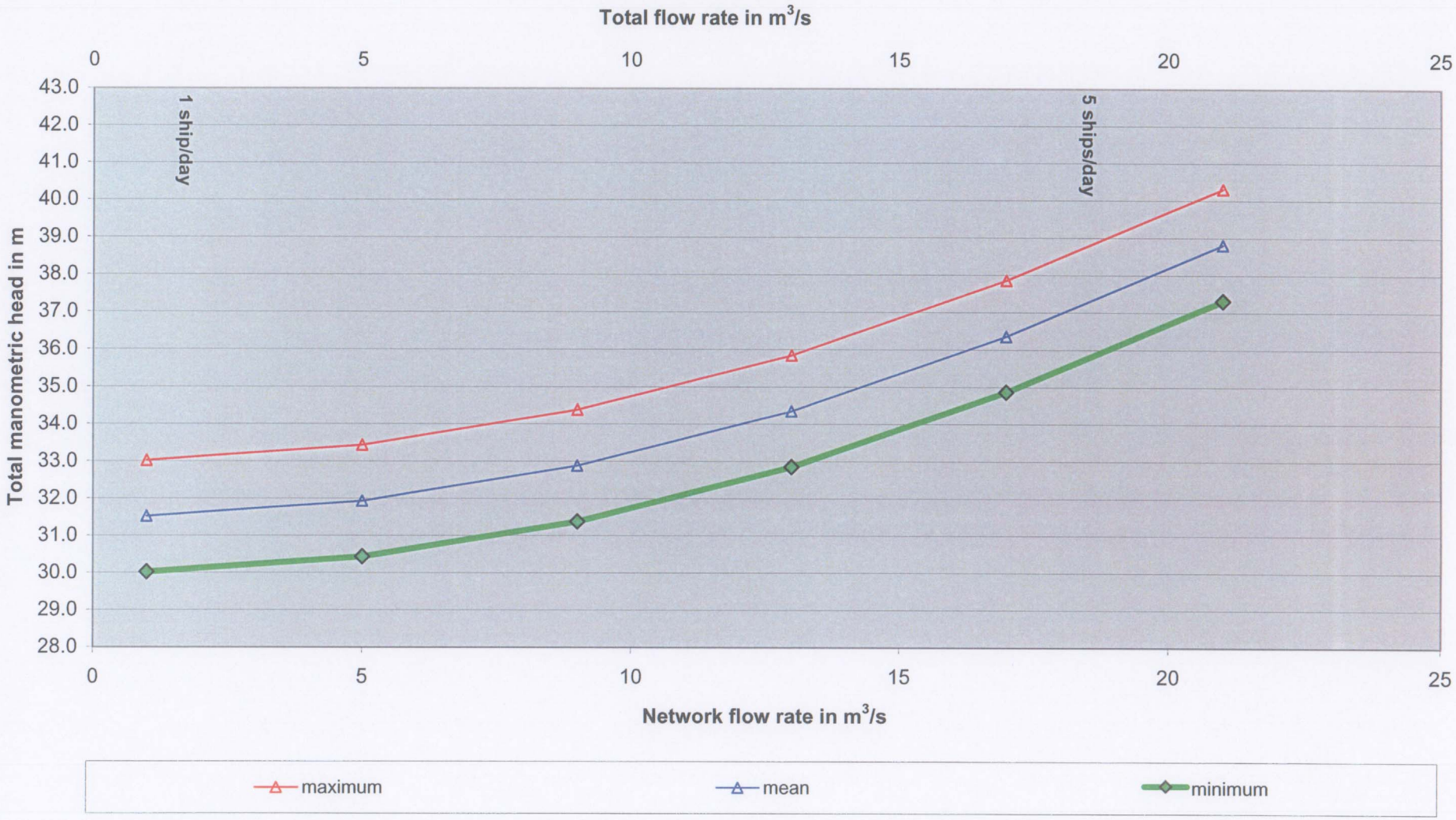
Pumping station flow rate range in m^3/s : 0 to 60
Pumping network flow rate range in m^3/s : 0 to 20
Number of pump per network : 1
Culvert diameter in m : 2.90

Network curves data

Flow rate in m3/s	*Total head losses in m*	*Geometric head in m*			*Total manometric head in m*		
		minimum	*mean*	*maximum*	*minimum*	*mean*	*maximum*
1	0.0	30	31.5	33	30.0	31.5	33.0
5	0.4	30	31.5	33	30.4	31.9	33.4
9	1.4	30	31.5	33	31.4	32.9	34.4
13	2.9	30	31.5	33	32.9	34.4	35.9
17	4.9	30	31.5	33	34.9	36.4	37.9
21	7.3	30	31.5	33	37.3	38.8	40.3

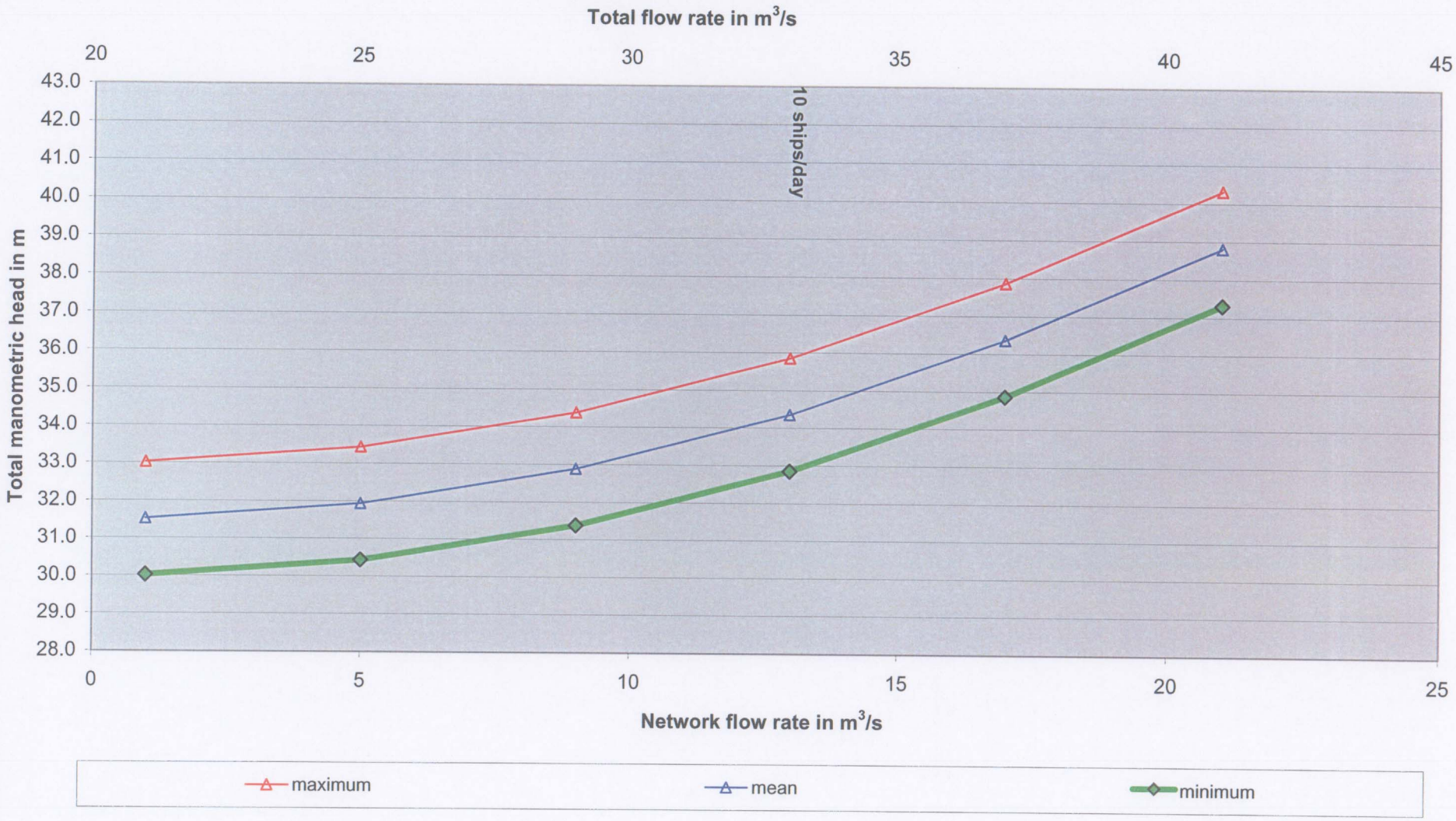
Semi dir pumping
3-lift locks system without WSB
3 identical pumping networks

Network curves - Pumping network N°1
Culvert diameter 2.90 m



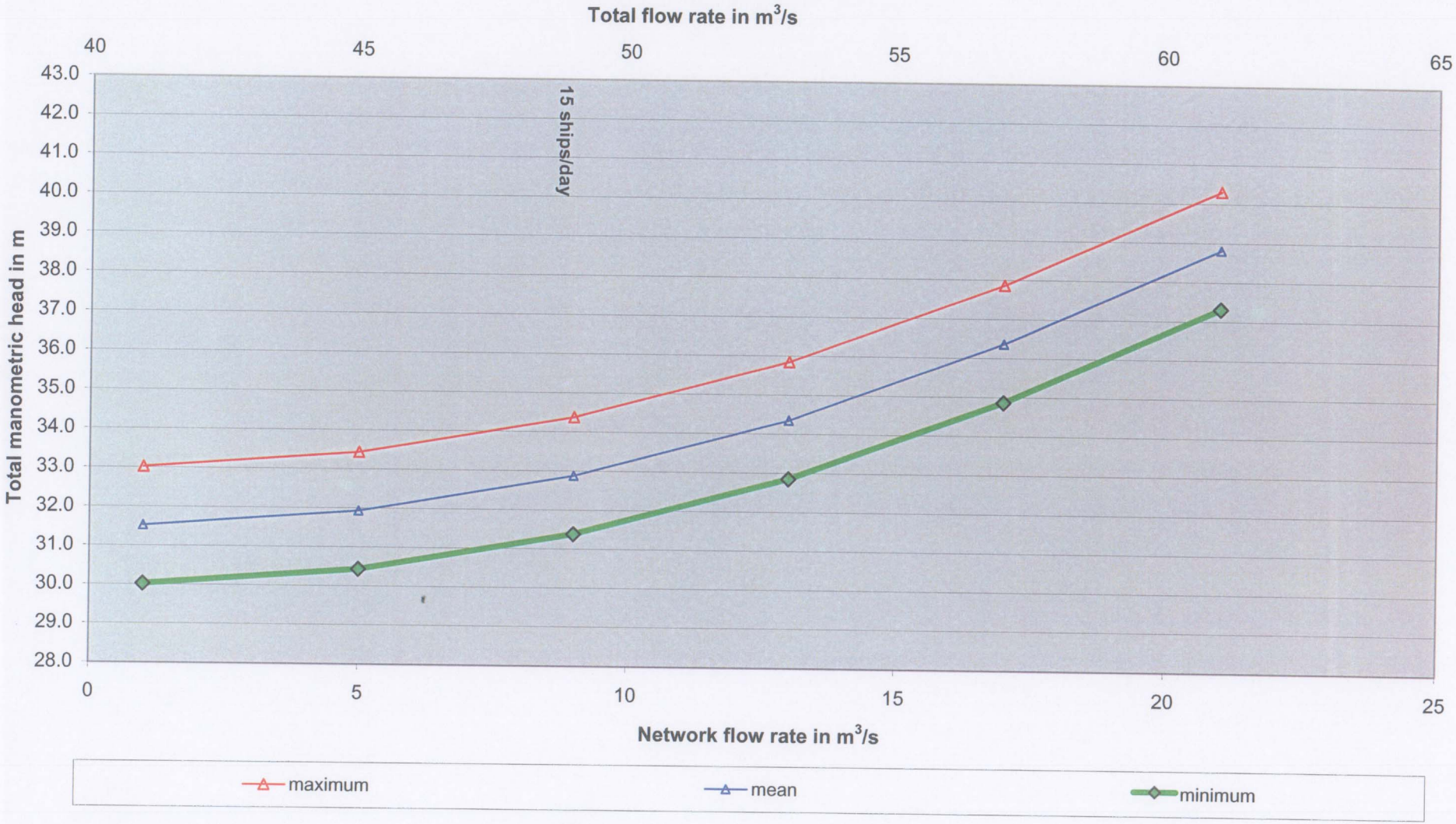
Semi di pumping
3-lift locks system without WSB
3 identical pumping networks

Network curves - Pumping network N°2
Culvert diameter 2.90 m



Semi dir. pumping
3 lift-locks system without WSB
3 identical pumping networks

Network curves - Pumping network N°3
Culvert diameter 2.90 m



Annex 8

Network curves

Annex 8.2.2
Semi direct pumping - 2-lift locks system

Semi direct pumping
3 identical pumping networks

General data

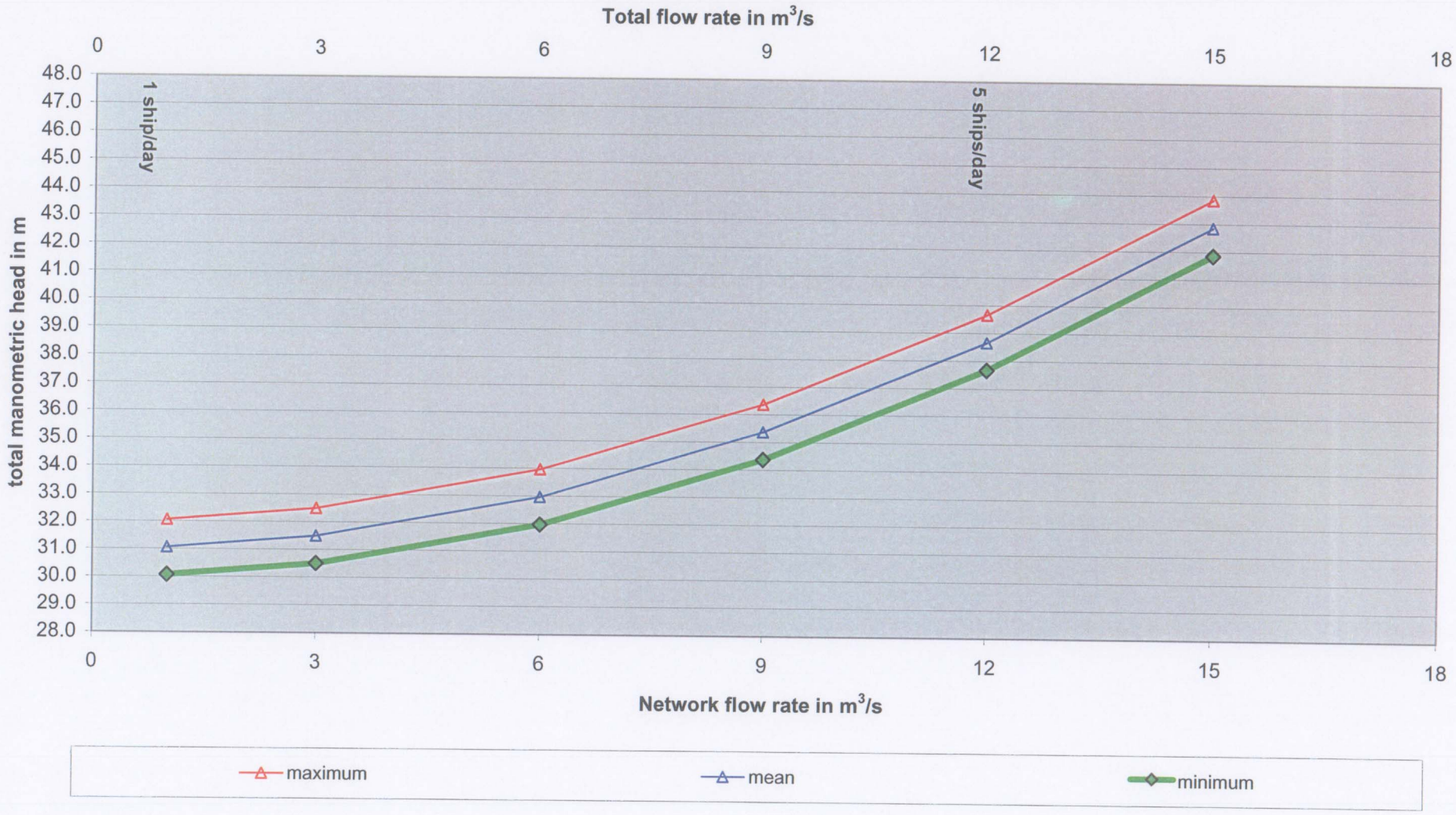
Number of lock chamber :	2
Number of WSB :	2
Pumping station flow rate range in m^3/s :	0 to 39
Pumping network flow rate range in m^3/s :	0 to 13
Number of pump per network :	1
Culvert diameter in m :	2.30

Network curves data

Flow rate in m^3/s	*Total head losses in m*	*Geometric head in m*			*Total manometric head in m*		
		minimum	*mean*	*maximum*	*minimum*	*mean*	*maximum*
1	0.1	30	31	32	30.1	31.1	32.1
3	0.5	30	31	32	30.5	31.5	32.5
6	2.0	30	31	32	32.0	33.0	34.0
9	4.4	30	31	32	34.4	35.4	36.4
12	7.7	30	31	32	37.7	38.7	39.7
15	11.9	30	31	32	41.9	42.9	43.9

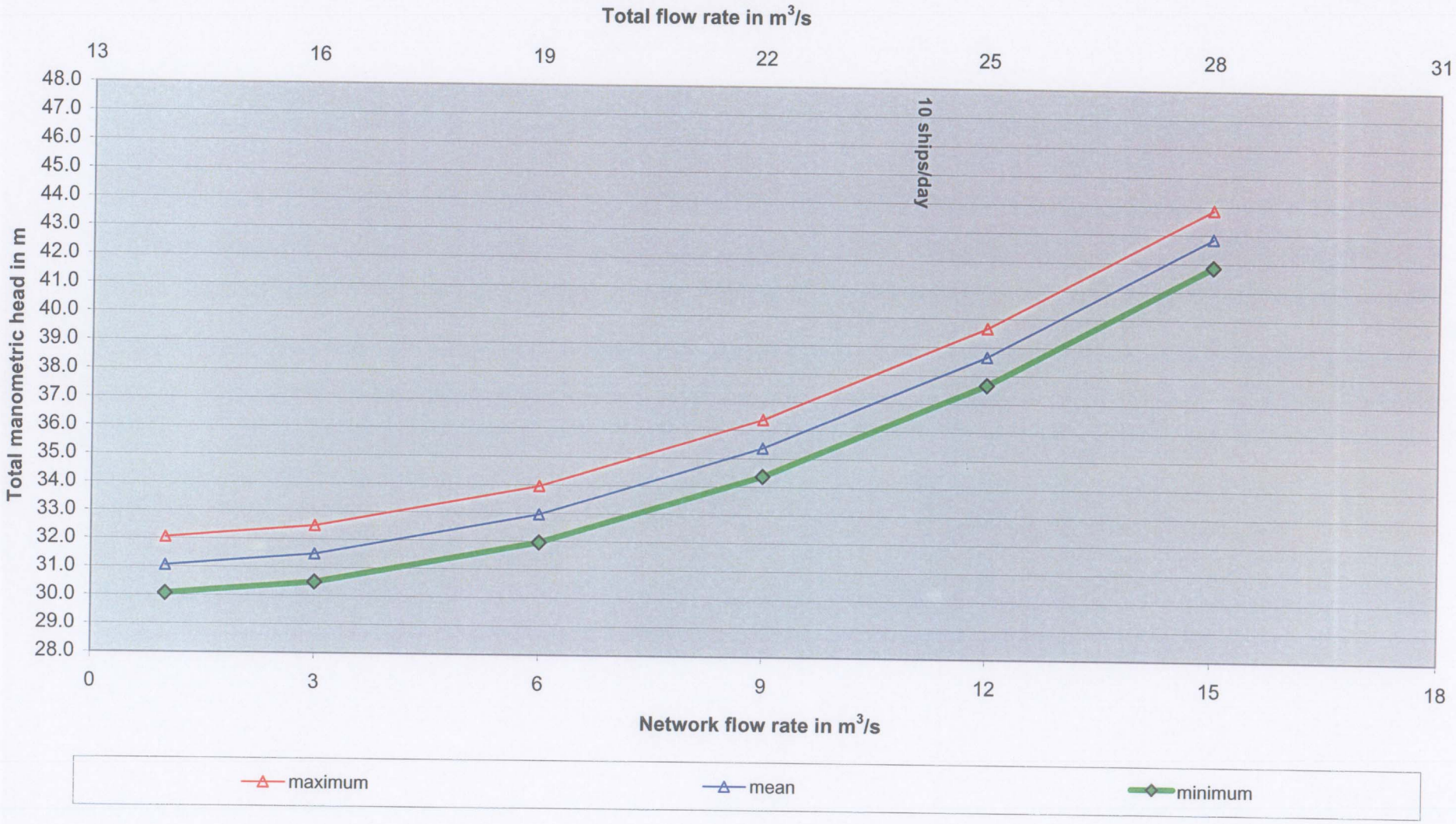
Semi di pumping
2-lift locks system with WSB
3 identical pumping networks

Network curves - Pumping network N°1
Culvert diameter 2.30 m



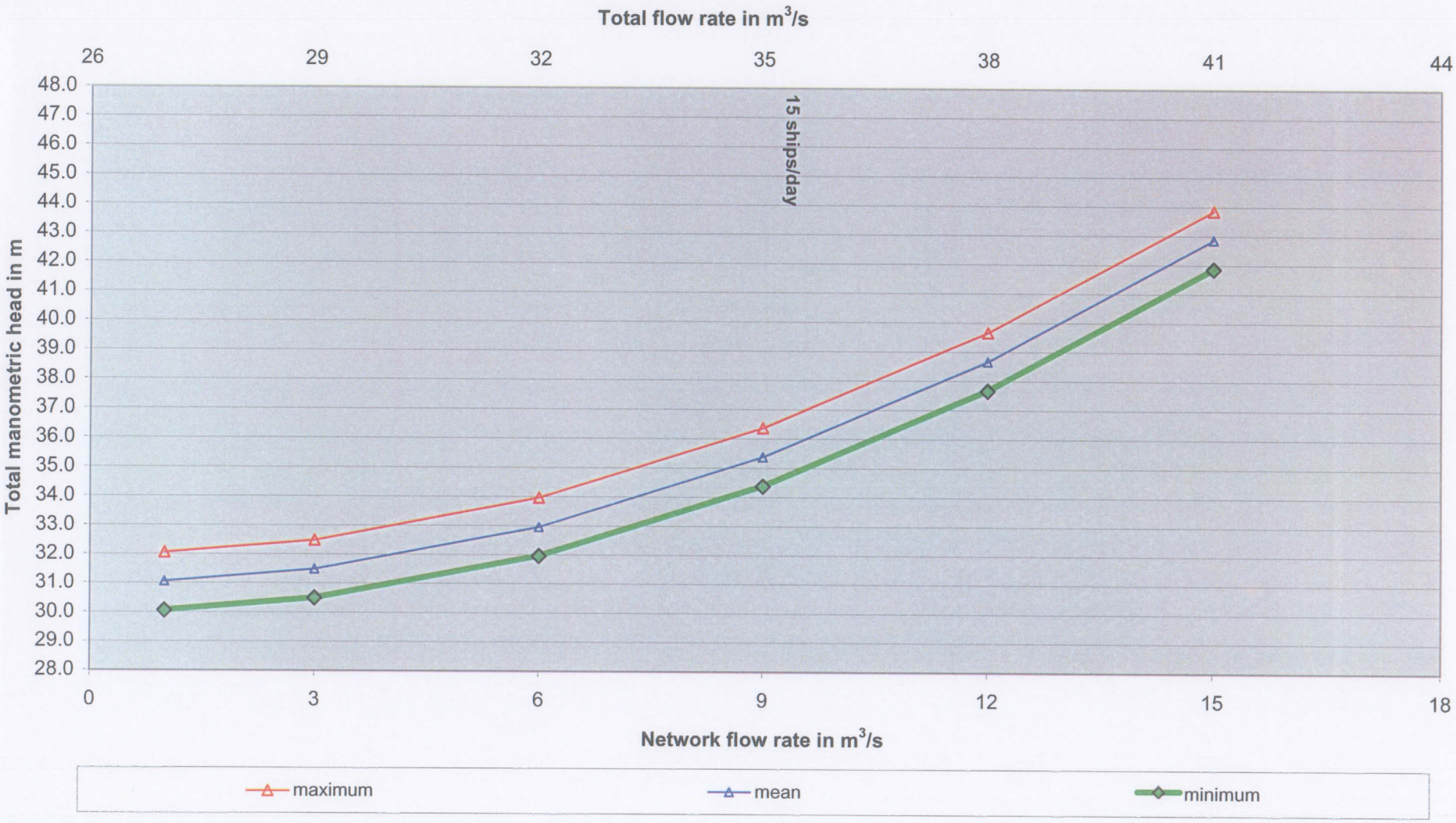
Semi dir[illegible] pumping
2-lift locks system with WSB
3 identical pumping networks

Network curves - Pumping network N°2
Culvert diameter 2.30 m



Semi di pumping
2-lift locks system with WSB
3 identical pumping networks

Network curves - Pumping network N°3
Culvert diameter 2.30 m



Semi direct pumping
3 identical pumping networks

General data

Number of lock chamber : 2
Number of WSB : 0

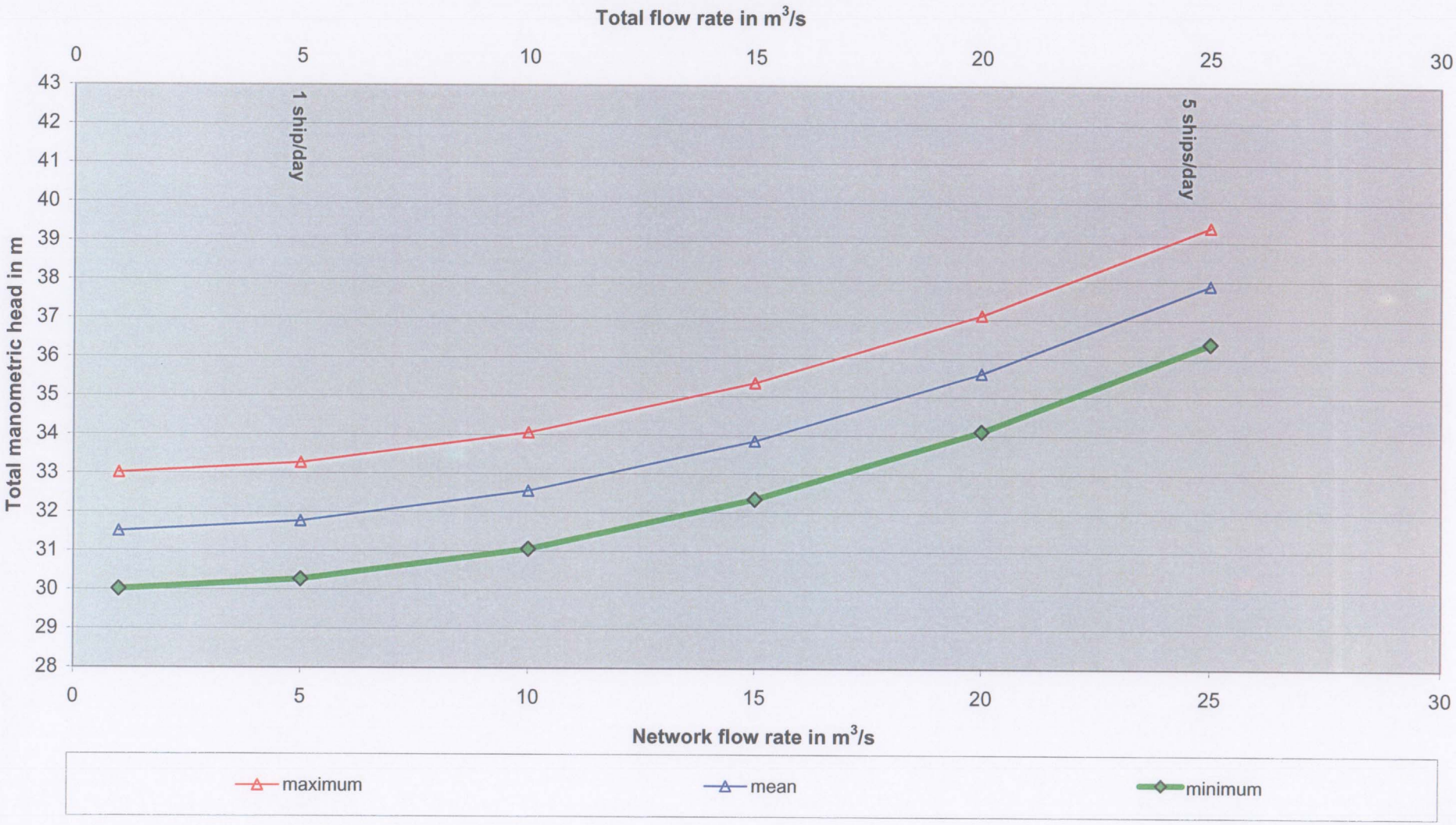
Pumping station flow rate range in m^3/s : 0 to 75
Pumping network flow rate range in m^3/s : 0 to 25
Number of pump per network : 1
Culvert diameter in m : 3.20

Network curves data

Flow rate in m3/s	*Total head losses in m*	*Geometric head in m*			*Total manometric head in m*		
		minimum	*mean*	*maximum*	*minimum*	*mean*	*maximum*
1	0.0	30	31.5	33	30.0	31.5	33.0
5	0.3	30	31.5	33	30.3	31.8	33.3
10	1.1	30	31.5	33	31.1	32.6	34.1
15	2.4	30	31.5	33	32.4	33.9	35.4
20	4.1	30	31.5	33	34.1	35.6	37.1
25	6.4	30	31.5	33	36.4	37.9	39.4

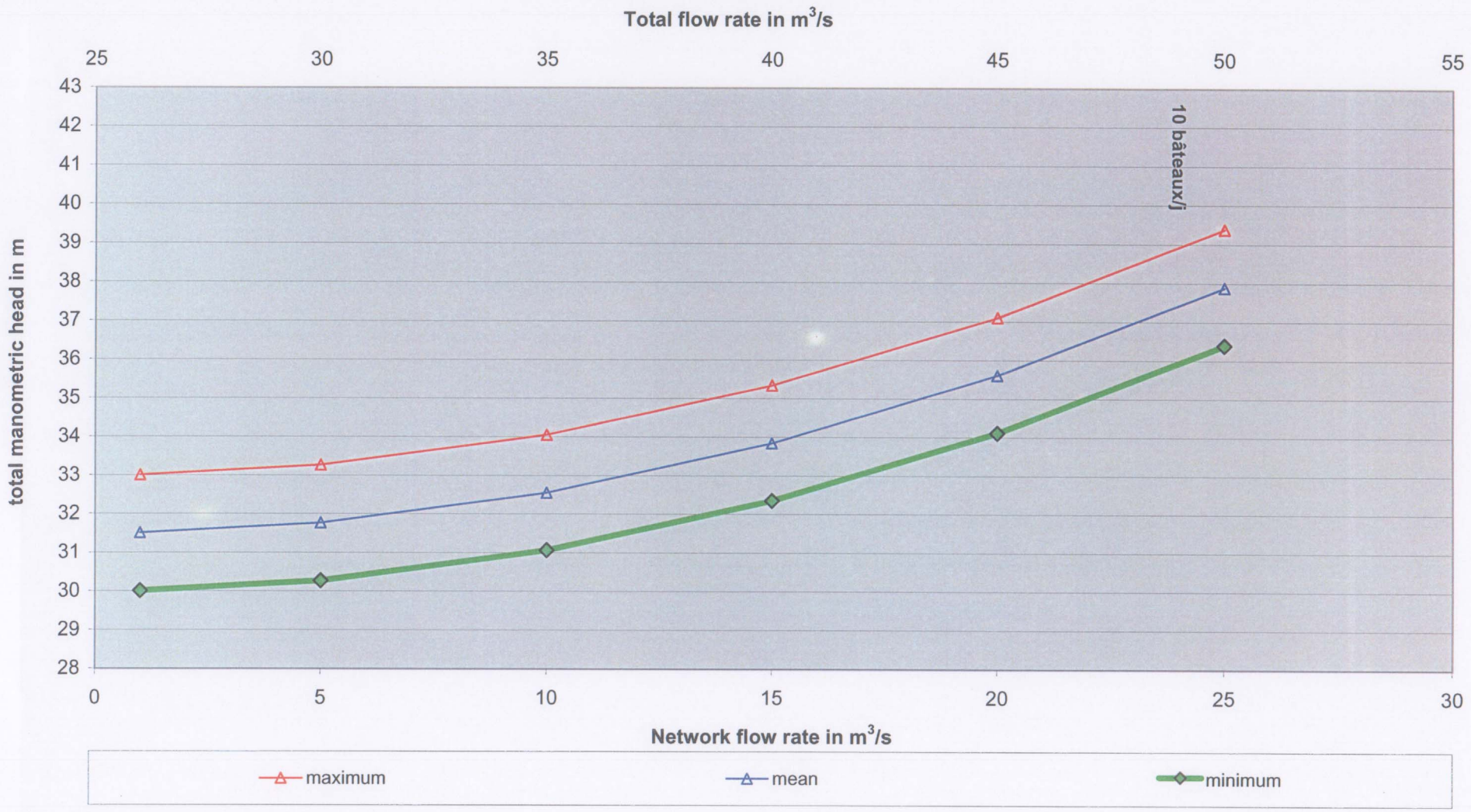
Semi di pumping
2-lift locks system without WSB
3 identical pumping networks

Network curves - Pumping network N°1
culvert diameter 3.20 m



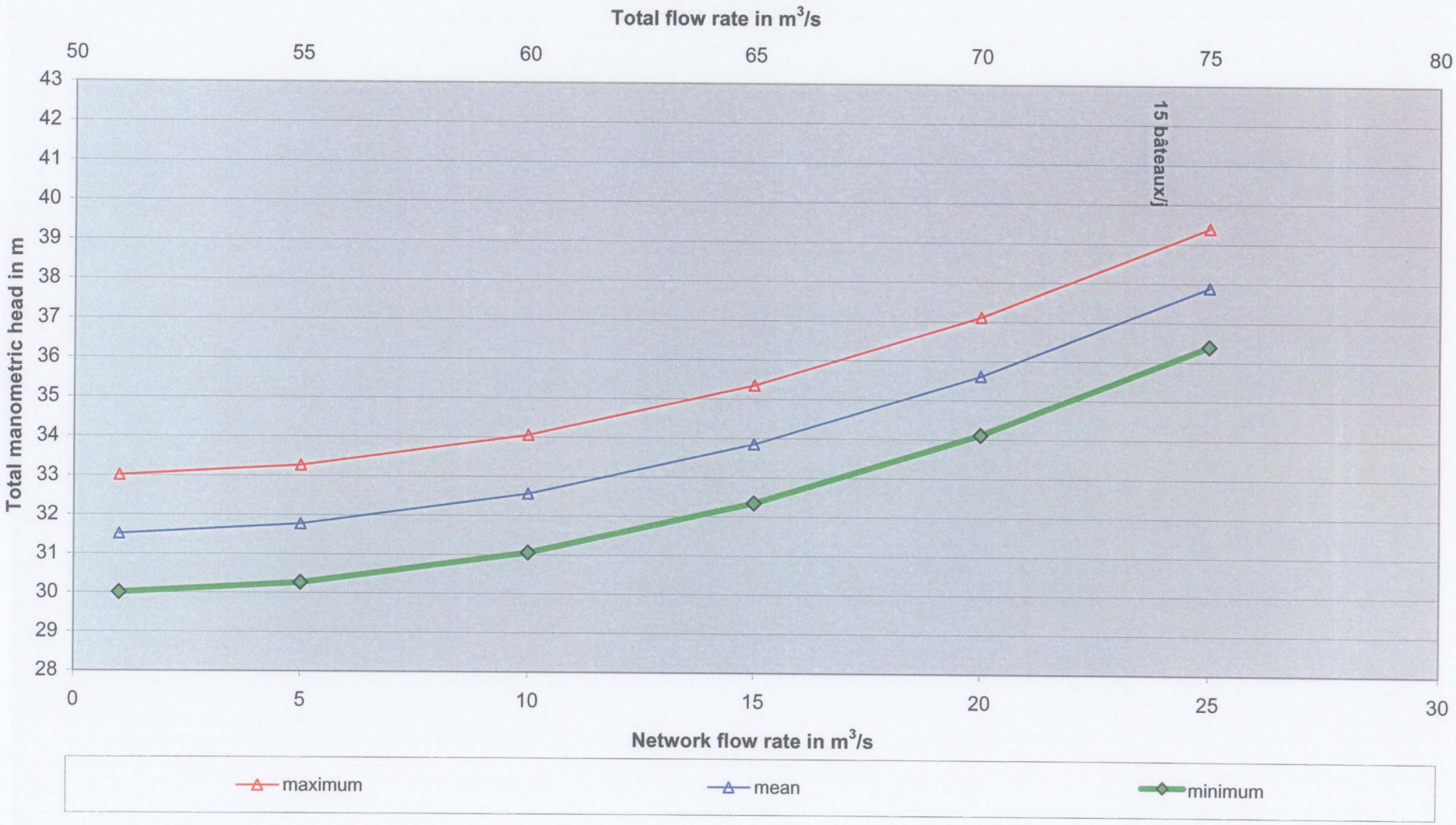
Semi dir[illegible] pumping
2-lift locks system without WSB
3 identical pumping networks

Network curves - Pumping network N°2
culvert diameter 3.20 m



Semi di[illegible] pumping
2-lift locks system without WSB
3 identical pumping networks

Network curves - Pumping network N°3
culvert diameter 3.20 m



Annex 8

Network curves

Annex 8.3.1
Direct pumping - 3-lift locks system

Direct pumping
3 identical pumping networks

General data

Number of lock chamber : 3
Number of WSB : 3

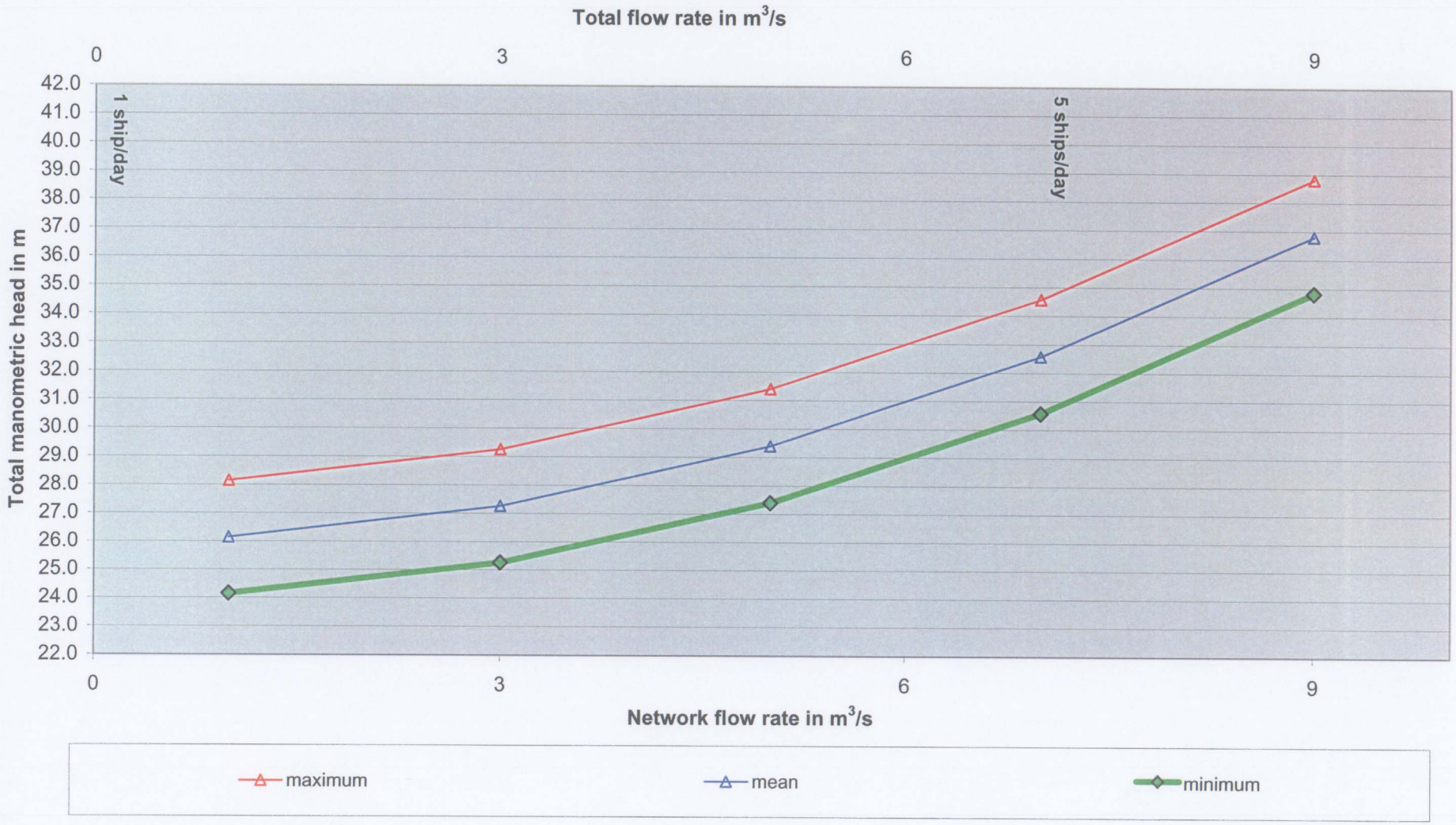
Pumping station flow rate range in m^3/s : 0 to 24
Pumping network flow rate range in m^3/s : 0 to 8
Number of pump per network : 1
Culvert diameter in m : 1.80

Network curves data

Flow rate in m^3/s	*Total head losses in m*	*Geometric head in m*			*total manometric head in m*		
		minimum	*mean*	*maximum*	*minimum*	*mean*	*maximum*
1	0.2	24	26	28	24.2	26.2	28.2
3	1.3	24	26	28	25.3	27.3	29.3
5	3.4	24	26	28	27.4	29.4	31.4
7	6.6	24	26	28	30.6	32.6	34.6
9	10.8	24	26	28	34.8	36.8	38.8

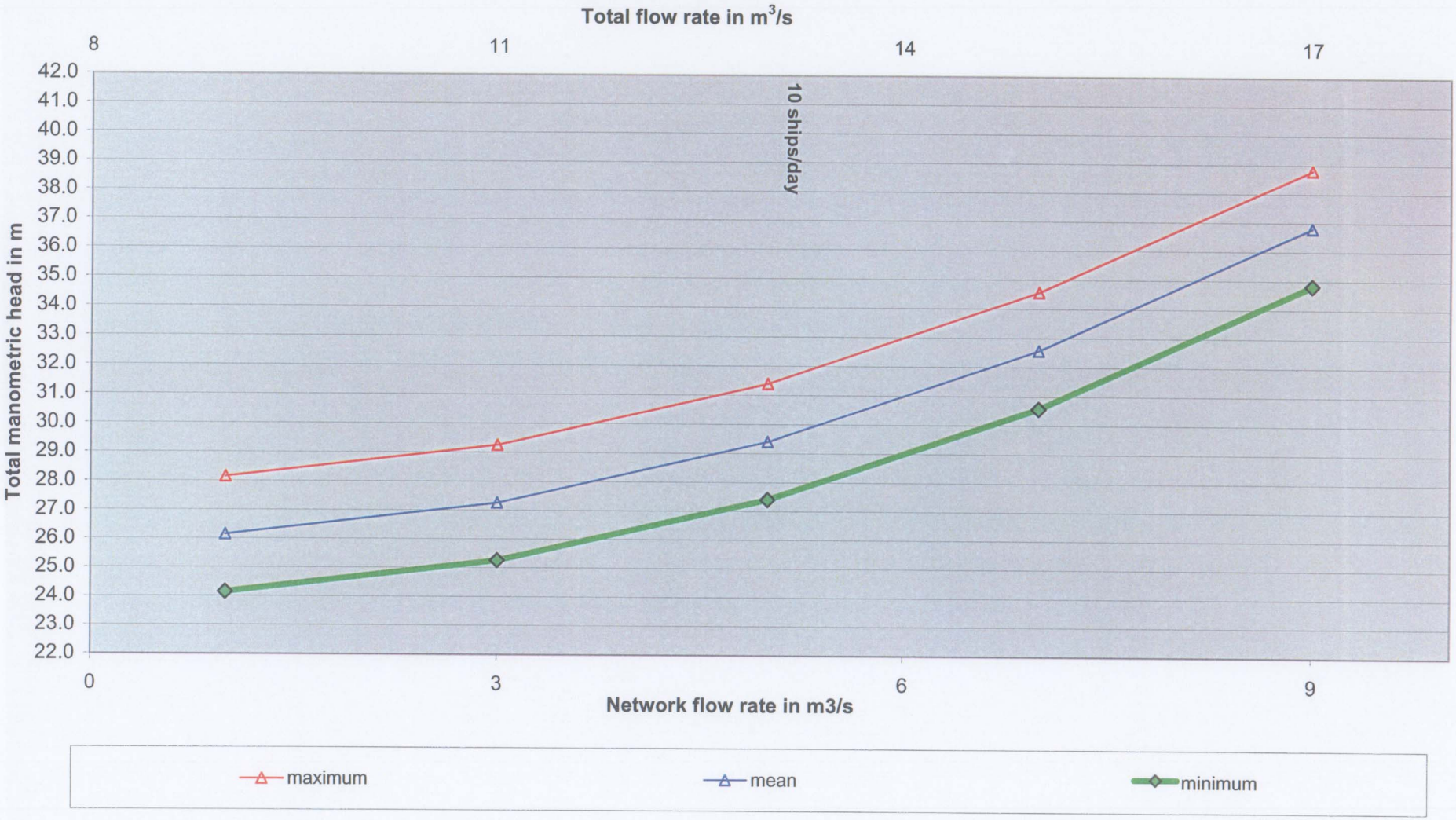
Direc umping
3-lift locks system with WSB
3 identical pumping networks

Network curves - Pumping network N°1
Culvert diameter 1.80 m



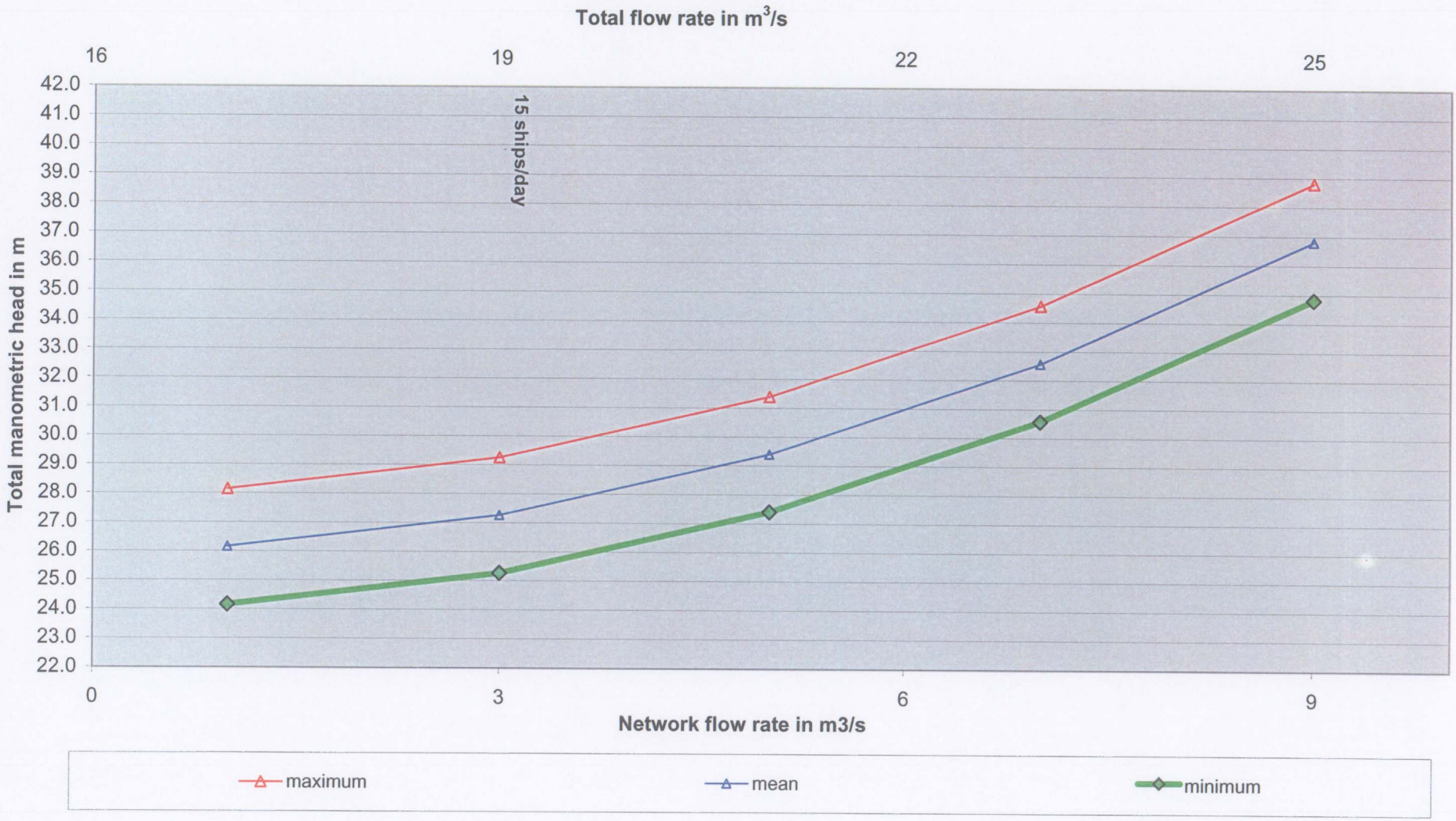
Direc. umping
3-lift locks system with WSB
3 identical pumping networks

Network curves - Pumping network N°2
Culvert diameter 1.80 m



Direc umping
3-lift locks system with WSB
3 identical pumping networks

Network curves - Pumping network N°3
Culvert diameter 1.80 m



Direct pumping
3 identical pumping networks

General data

Number of lock chamber : 3
Number of WSB : 0

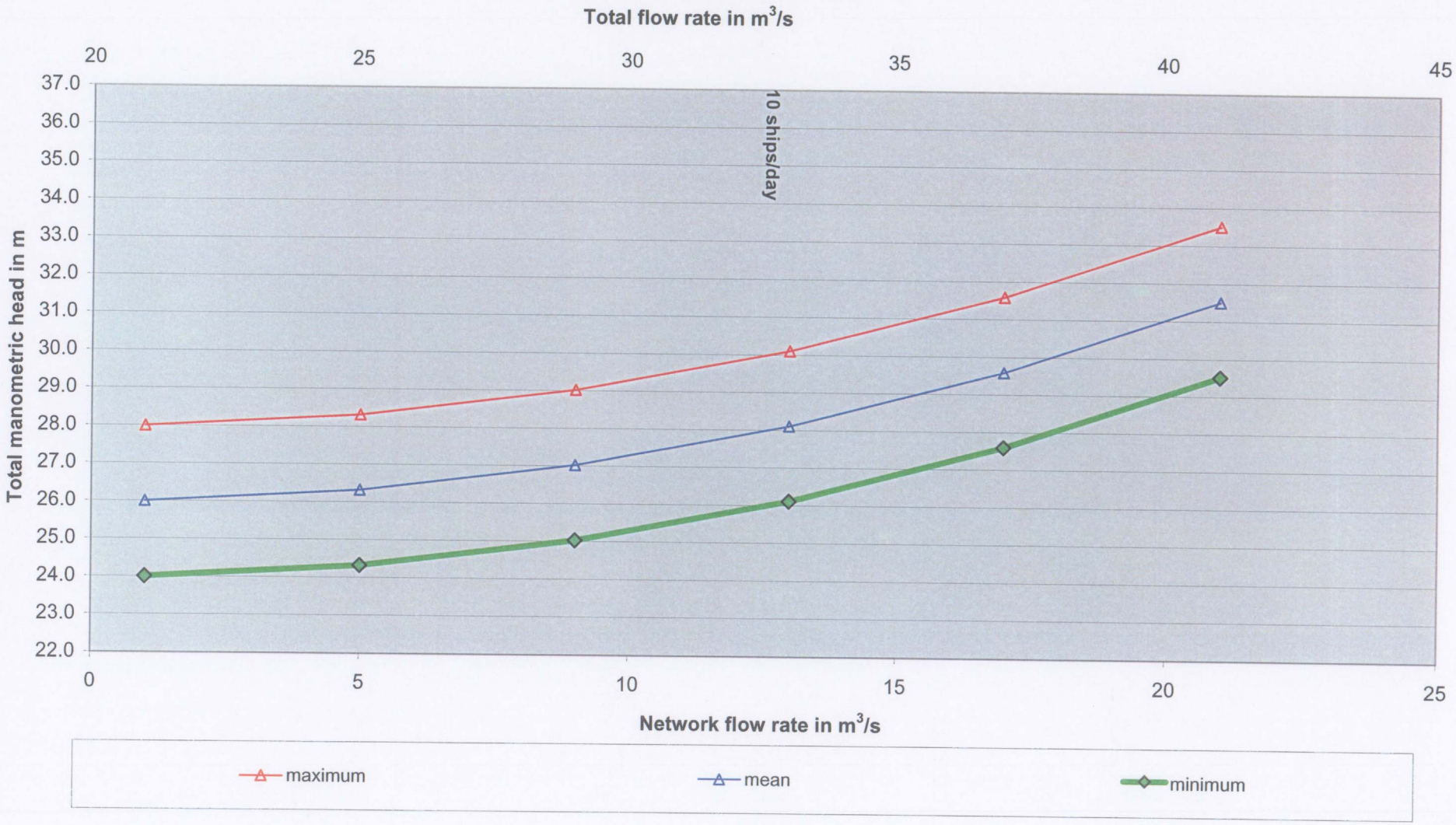
Pumping station flow rate range in m^3/s : 0 to 60
Pumping network flow rate range in m^3/s : 0 to 20
Number of pump per network : 1
Culvert diameter in m : 2.90

Network curves data

Flow rate in m^3/s	*Total head losses in m*	*Geometric head in m*			*total manometric head in m*		
		minimum	*mean*	*maximum*	*minimum*	*mean*	*maximum*
1	0.0	24	26	28	24.0	26.0	28.0
5	0.3	24	26	28	24.3	26.3	28.3
9	1.0	24	26	28	25.0	27.0	29.0
13	2.1	24	26	28	26.1	28.1	30.1
17	3.6	24	26	28	27.6	29.6	31.6
21	5.5	24	26	28	29.5	31.5	33.5

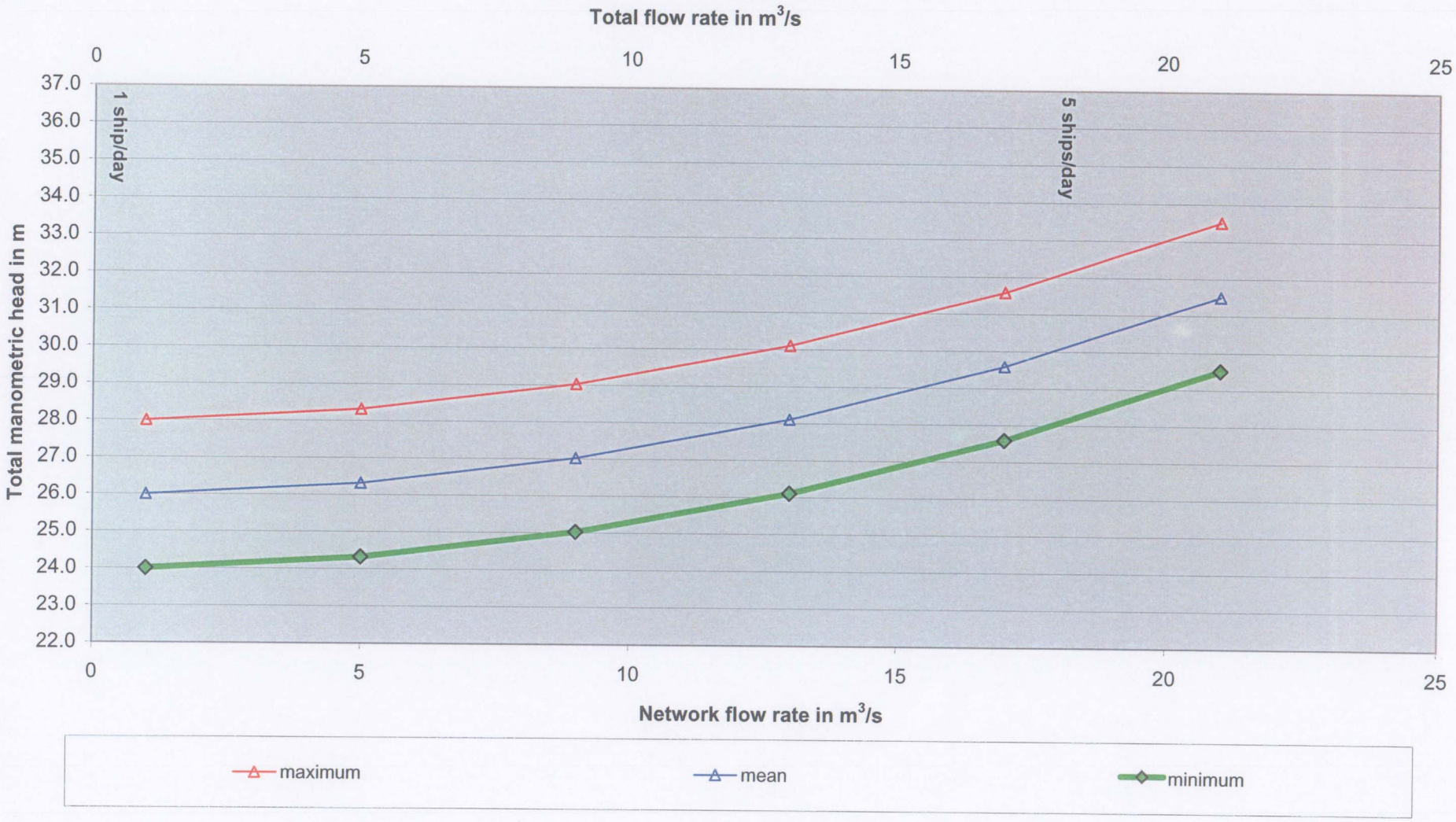
Direc. mping
3-lift locks system without WSB
3 identical pumping networks

Network curves - Pumping network N°2
Culvert diameter 2.90 m



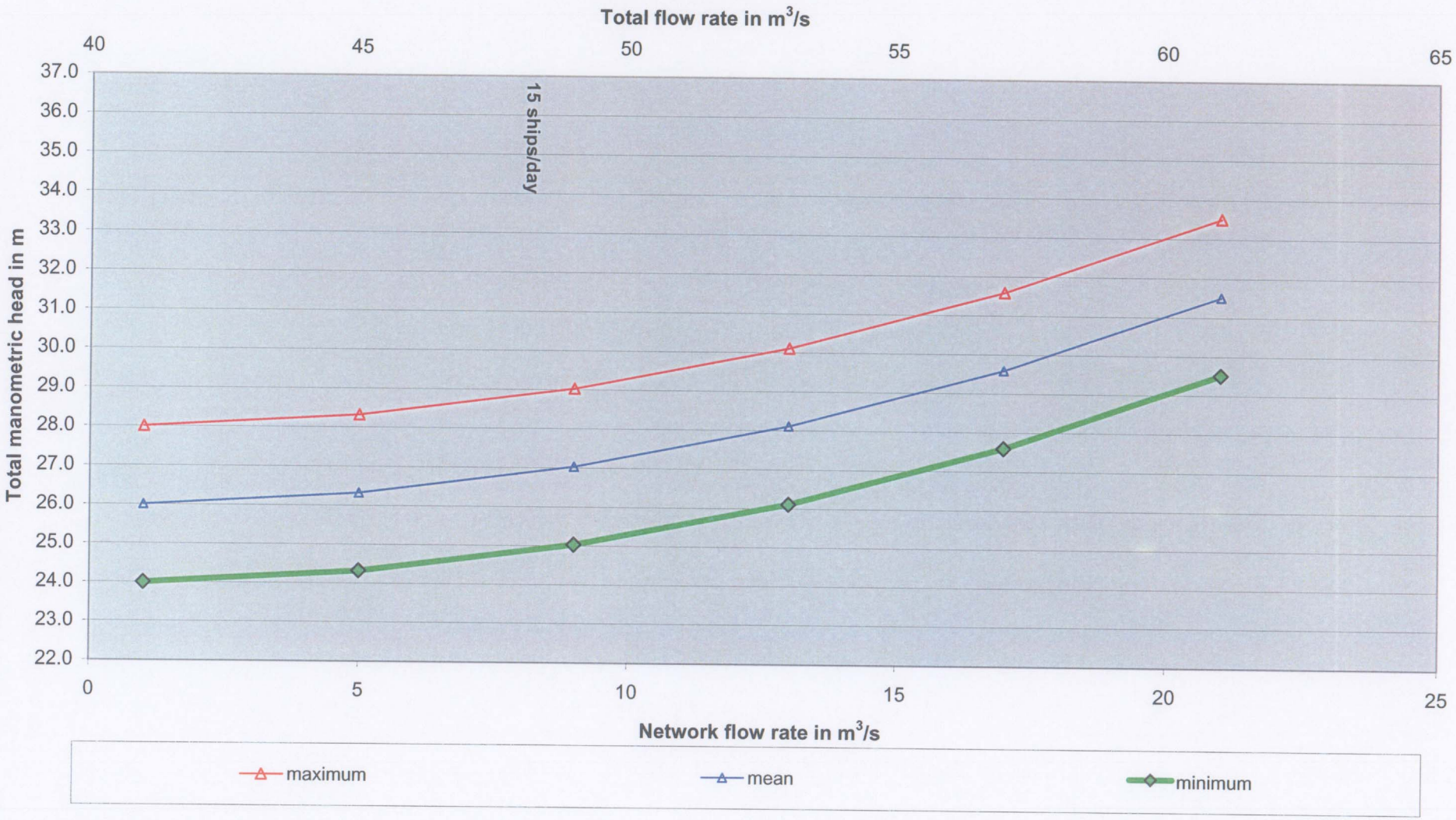
Direc mping
3-lift locks system without WSB
3 identical pumping networks

Network curves - Pumping network N°1
Culvert diameter 2.90 m



Direc. mping
3-lift locks system without WSB
3 identical pumping networks

Network curves - Pumping network N°3
Culvert diameter 2.90 m



Annex 8

Network curves

Annex 8.3.2
Direct pumping - 2-lift locks system

Direct pumping
3 identical pumping networks

General data

Number of lock chamber : 2
Number of WSB : 2

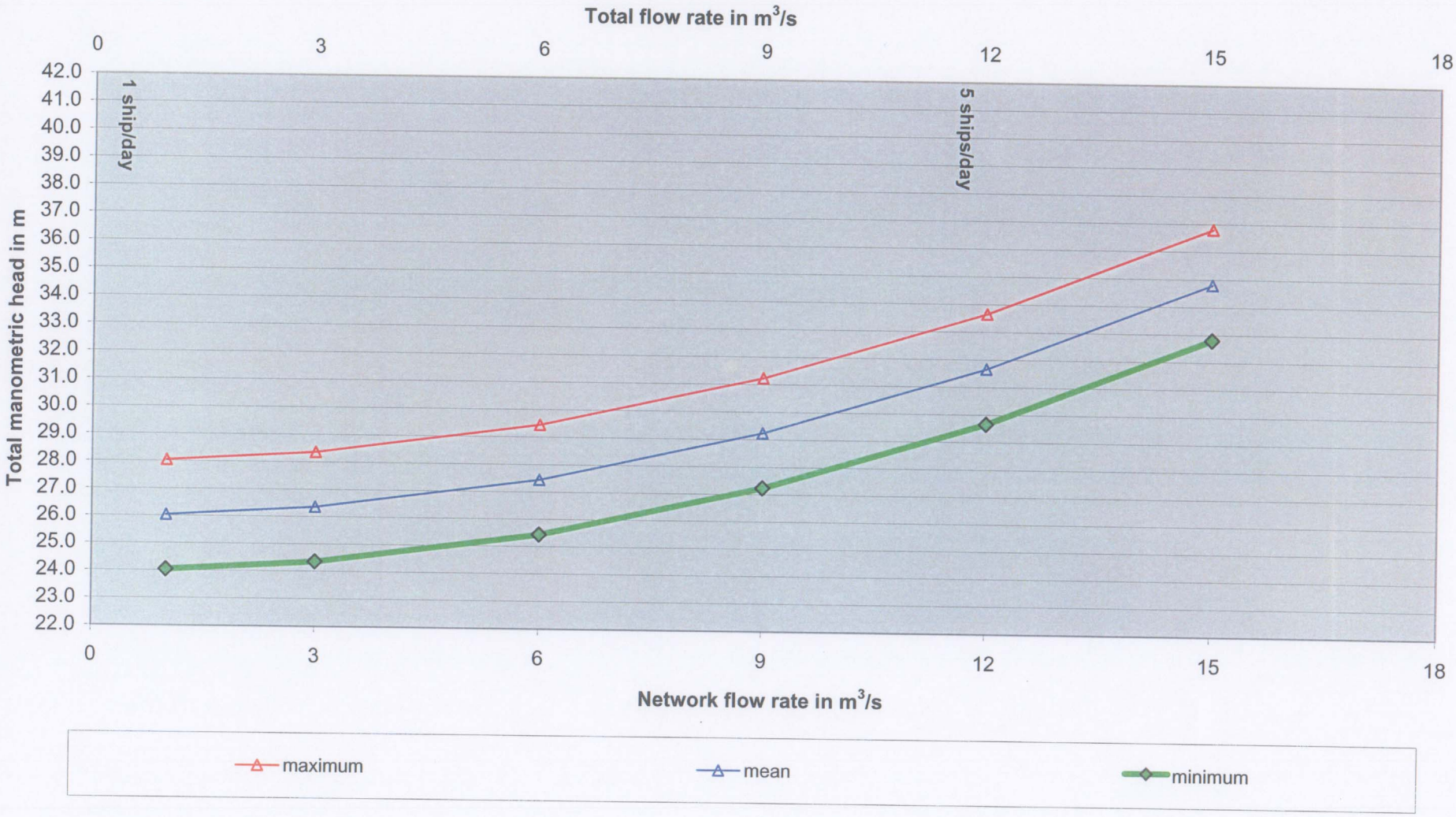
Pumping station flow rate range in m^3/s : 0 to 39
Pumping network flow rate range in m^3/s : 0 to 13
Number of pump per network : 1
Culvert diameter in m : 2.30

Network curves data

Flow rate in m^3/s	*Total head losses in m*	*Geometric head in m*			*total manometric head in m*		
		minimum	*mean*	*maximum*	*minimum*	*mean*	*maximum*
1	0.0	24	26	28	24.0	26.0	28.0
3	0.4	24	26	28	24.4	26.4	28.4
6	1.4	24	26	28	25.4	27.4	29.4
9	3.2	24	26	28	27.2	29.2	31.2
12	5.7	24	26	28	29.7	31.7	33.7
15	8.8	24	26	28	32.8	34.8	36.8

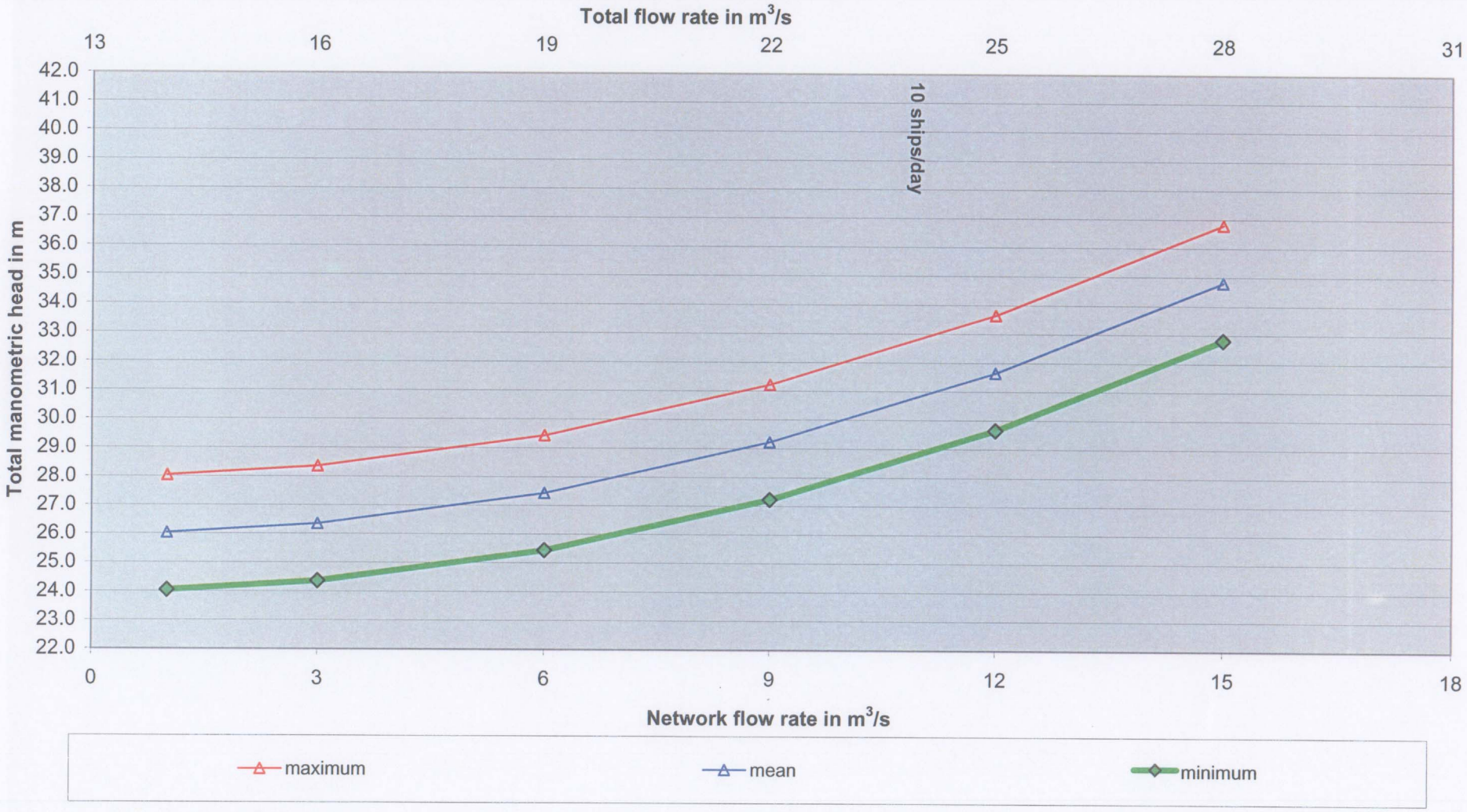
Direc mping
2-lift locks system with WSB
3 identical pumping networks

Network curves - Pumping network N°1
culvert diameter 2.30 m



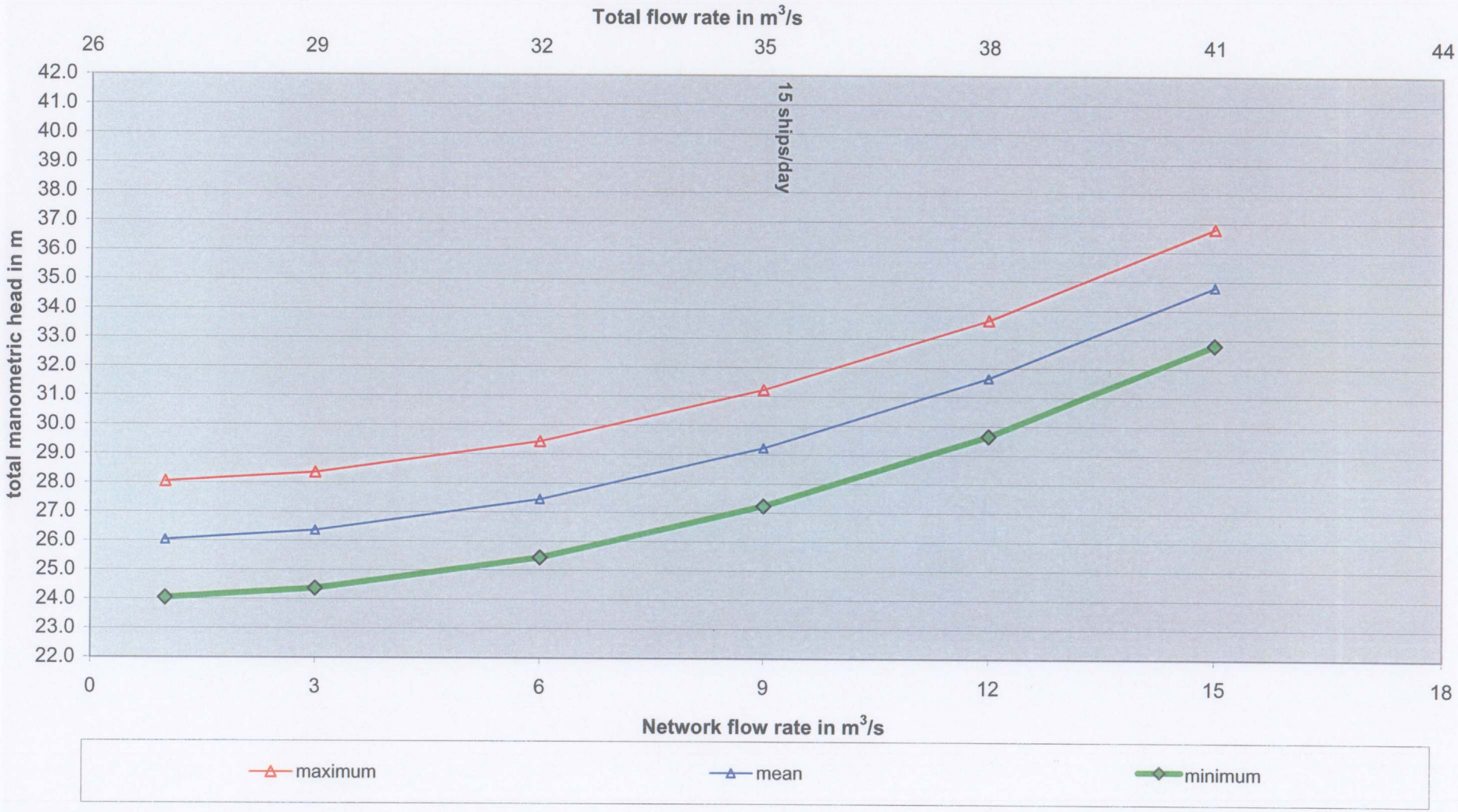
Direc mping
2- lift locks system with WSB
3 identical pumping networks

Network curves - Pumping network N°2
culvert diameter 2.30 m



Direc mping
2-lift locks system with WSB
3 identical pumping networks

Network curves - Pumping network N°3
culvert diameter 2.30 m



Direct pumping
3 identical pumping networks

General data

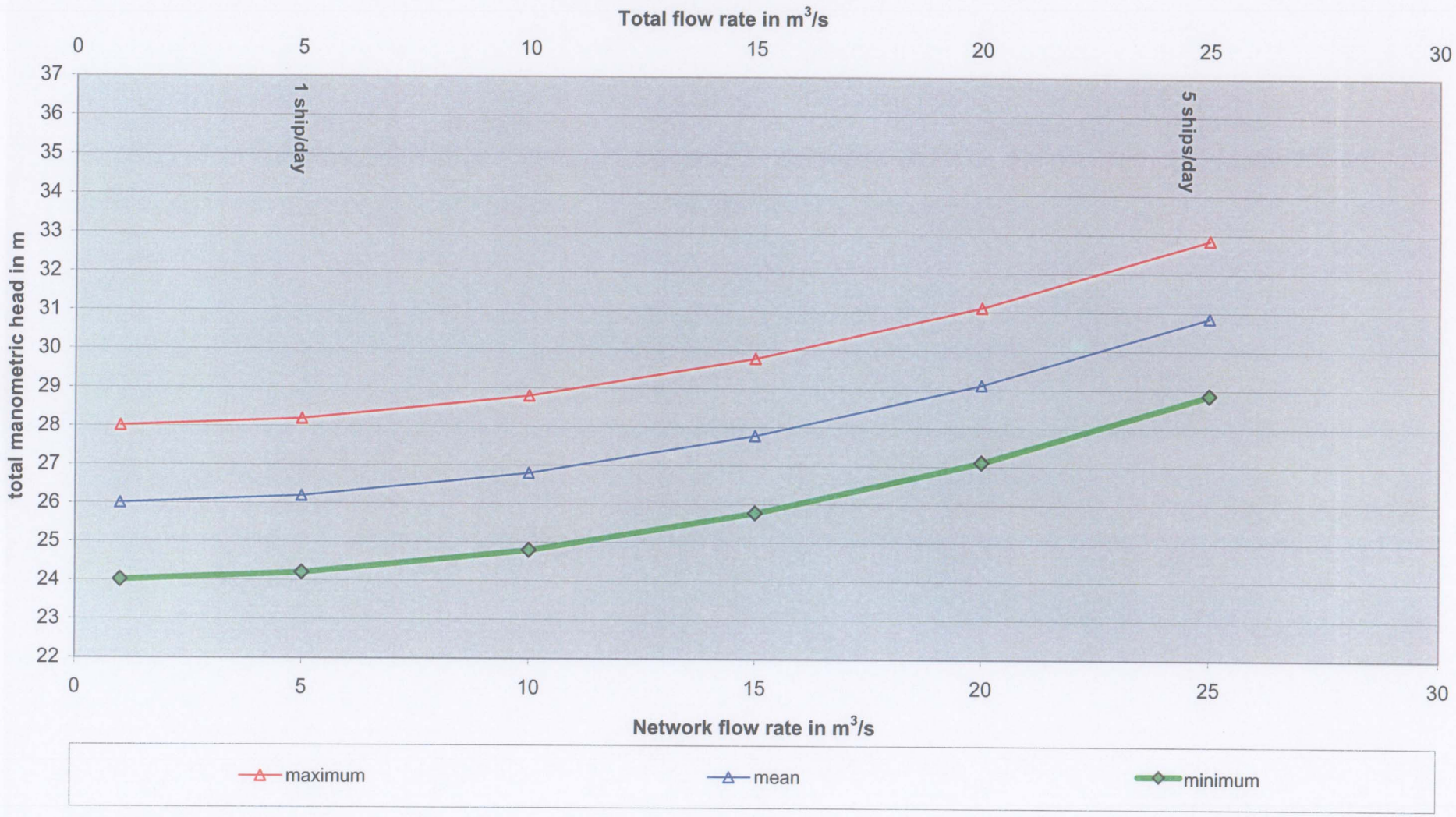
Number of lock chamber :	2
Number of WSB :	0
Pumping station flow rate range in m^3/s :	0 to 75
Pumping network flow rate range in m^3/s :	0 to 25
Number of pump per network :	1
Culvert diameter in m :	3.20

Network curves data

Flow rate in m3/s	*Total head losses in m*	*Geometric head in m*			*total manometric head in m*		
		minimum	*mean*	*maximum*	*minimum*	*mean*	*maximum*
1	0.0	24	26	28	24.0	26.0	28.0
5	0.2	24	26	28	24.2	26.2	28.2
10	0.8	24	26	28	24.8	26.8	28.8
15	1.8	24	26	28	25.8	27.8	29.8
20	3.1	24	26	28	27.1	29.1	31.1
25	4.9	24	26	28	28.9	30.9	32.9

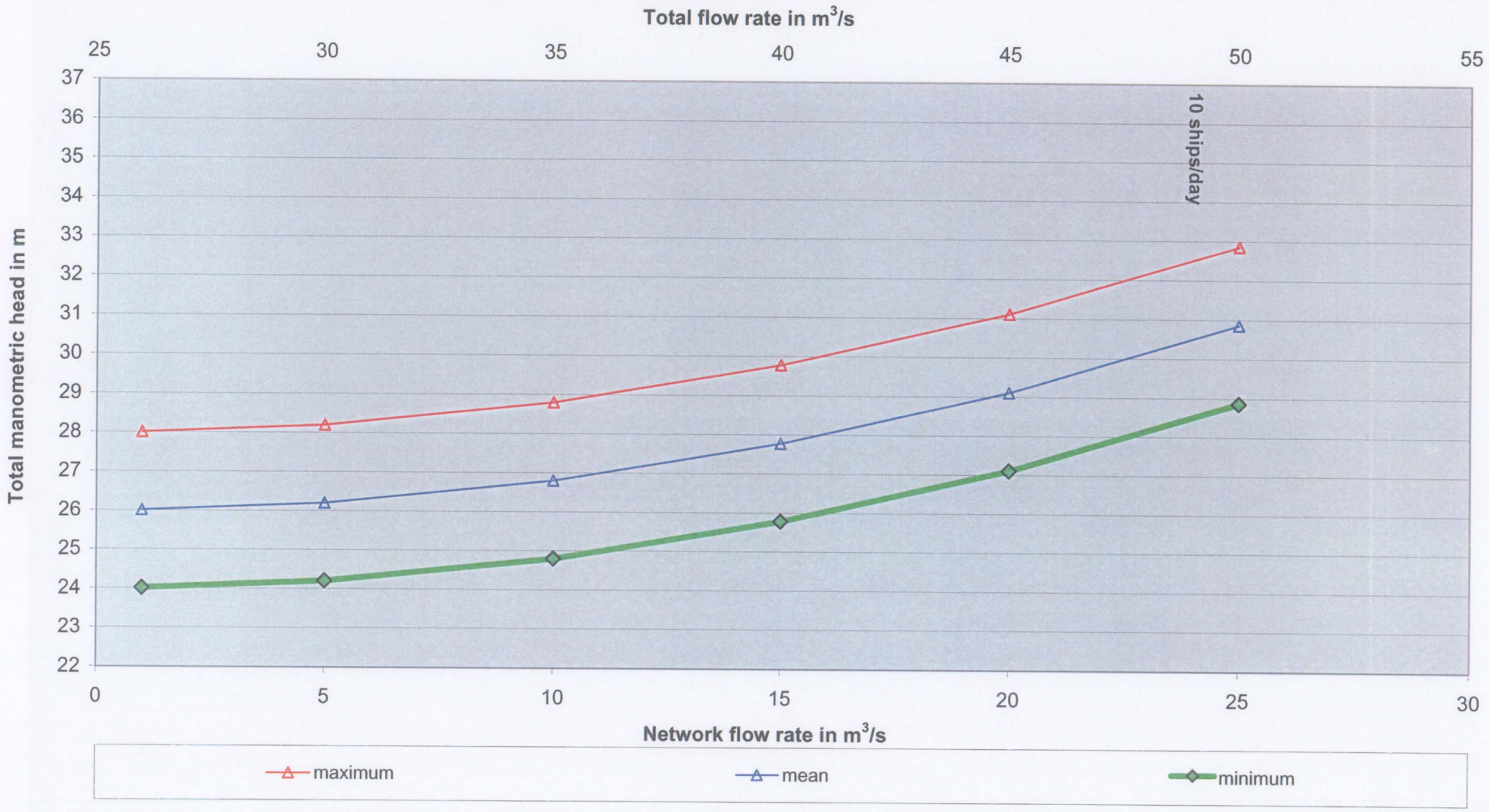
Direc umping
2-lift locks system without WSB
3 identical pumping networks

Network curves - Pumping network N°1
Culvert diameter 3.20 m



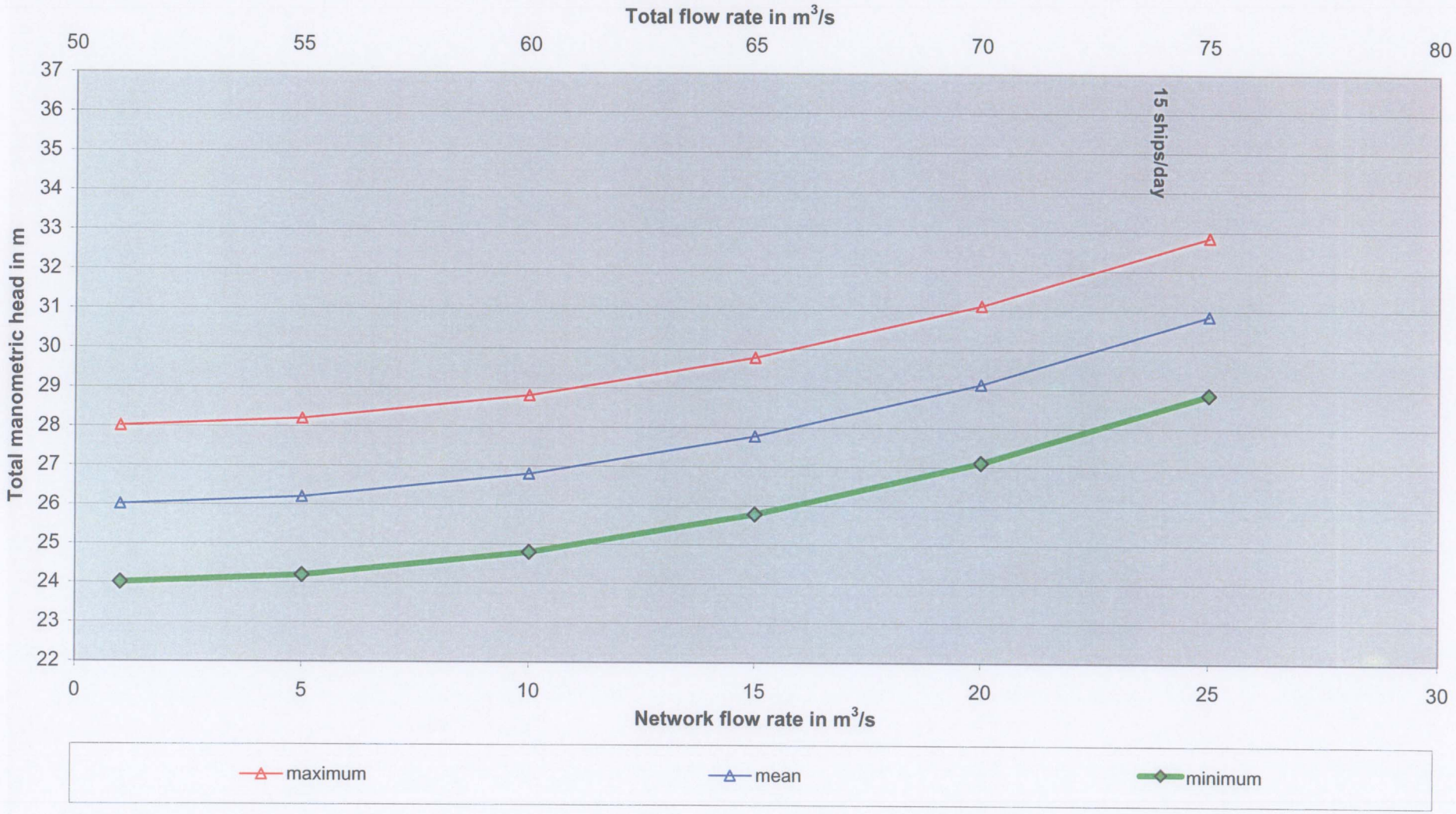
Direc mping
2-lift locks system without WSB
3 identical pumping networks

Network curves - Pumping network N°2
Culvert diameter 3.20 m



Direc umping
2-lift locks system withou WSB
3 identical pumping networks

Network curves - Pumping network N°3
Culvert diameter 3.20 m



Annex 9

Roughness culvert sensitivity

Annex 9

Roughness culvert sensitivity

Direct pumping
3 identical pumping networks

General data

Number of lock chamber :	2
Number of WSB :	0
Pumping station flow rate range in m^3/s :	0 to 75
Pumping network flow rate range in m^3/s :	0 to 25
Number of pump per network :	1
Culvert diameter in m :	3.20
Culvert absolute roughness in mm :	0.025

Network curves data

Flow rate in m3/s	*Total head losses in m*	*Geometric head in m*			*Total manometric head in m*		
		minimum	*mean*	*maximum*	*minimum*	*mean*	*maximum*
1	0.0	24	26	28	24.0	26.0	28.0
5	0.2	24	26	28	24.2	26.2	28.2
10	0.7	24	26	28	24.7	26.7	28.7
15	1.6	24	26	28	25.6	27.6	29.6
20	2.8	24	26	28	26.8	28.8	30.8
25	4.4	24	26	28	28.4	30.4	32.4

Direct pumping
3 identical pumping networks

General data

Number of lock chamber :	2
Number of WSB :	0
Pumping station flow rate range in m^3/s :	0 to 75
Pumping network flow rate range in m^3/s :	0 to 25
Number of pump per network :	1
Culvert diameter in m :	3.20
Culvert absolute roughness in mm :	0.1

Network curves data

Flow rate in m3/s	*Total head losses in m*	*Geometric head in m*			*Total manometric head in m*		
		minimum	*mean*	*maximum*	*minimum*	*mean*	*maximum*
1	0.0	24	26	28	24.0	26.0	28.0
5	0.2	24	26	28	24.2	26.2	28.2
10	0.8	24	26	28	24.8	26.8	28.8
15	1.8	24	26	28	25.8	27.8	29.8
20	3.1	24	26	28	27.1	29.1	31.1
25	4.9	24	26	28	28.9	30.9	32.9

Direct pumping
3 identical pumping networks

General data

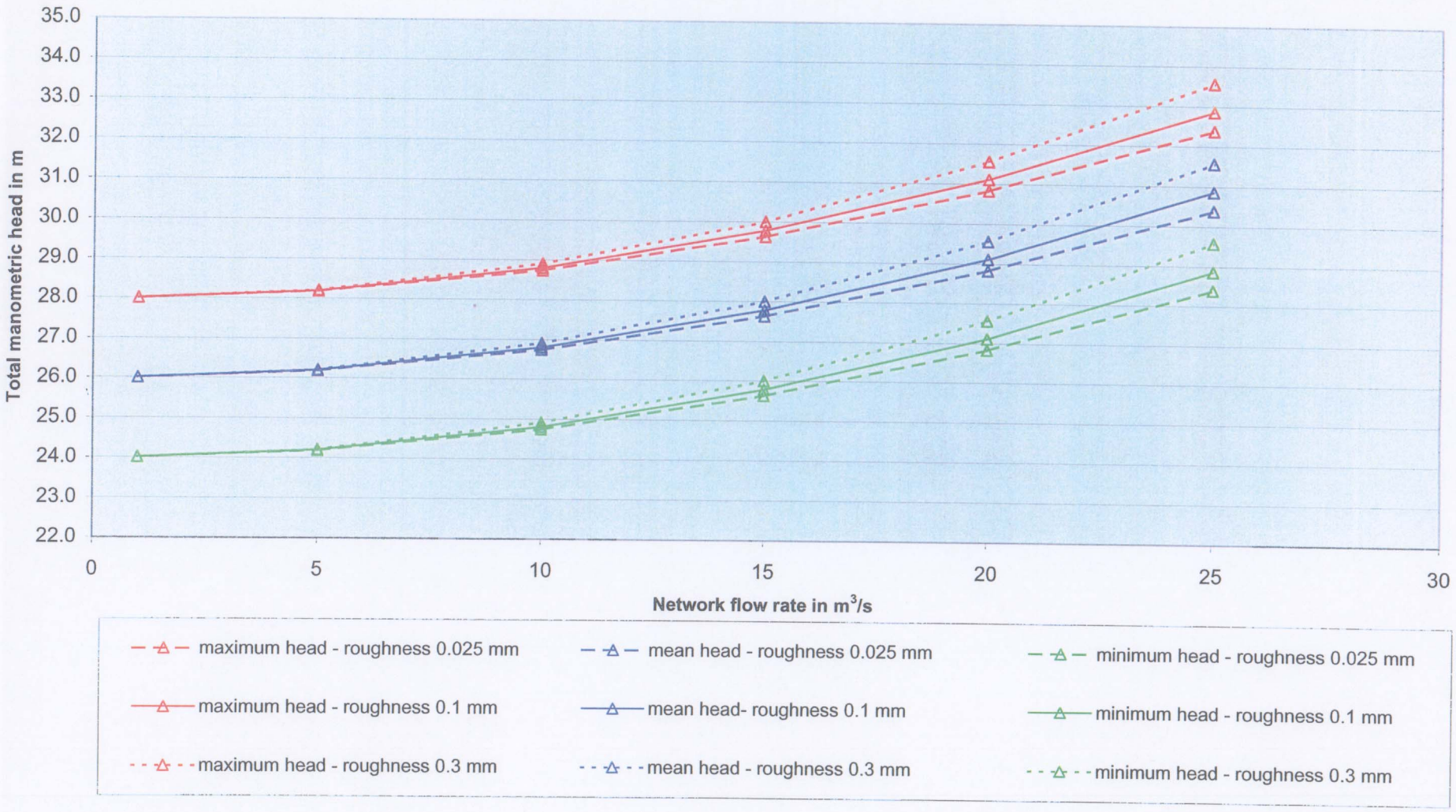
Number of lock chamber :	2
Number of WSB :	0
Pumping station flow rate range in m^3/s :	0 to 75
Pumping network flow rate range in m^3/s :	0 to 25
Number of pump per network :	1
Culvert diameter in m :	3.20
Culvert absolute roughness in mm :	0.3

Network curves data

Flow rate in m3/s	*Total head losses in m*	*Geometric head in m*			*Total manometric head in m*		
		minimum	*mean*	*maximum*	*minimum*	*mean*	*maximum*
1	0.0	24	26	28	24.0	26.0	28.0
5	0.2	24	26	28	24.2	26.2	28.2
10	0.9	24	26	28	24.9	26.9	28.9
15	2.0	24	26	28	26.0	28.0	30.0
20	3.6	24	26	28	27.6	29.6	31.6
25	5.6	24	26	28	29.6	31.6	33.6

Dispositif de pompage direct
écluse à 2 sas sans bassin d'épargne
3 réseaux de pompage identiques

Network curves for one pumping network
Culvert diameter 3.20 m



Annex 10

Modification of pumps number in pumping networks

Pond to pond pumping
3 identical pumping networks

General data

Number of lock chamber :	2
Number of WSB :	0
Pumping station flow rate range in m^3/s :	0 to 75
Pumping network flow rate range in m^3/s :	0 to 25
Pump flow rate range in m^3/s :	0 to 25
Number of pump per network :	1
Culvert diameter in m :	3.20

Network curves data

Flow rate in m3/s	*Total head losses in m*	*Geometric head in m*			*Manometric head in m*		
		minimum	*mean*	*maximum*	*minimum*	*mean*	*maximum*
1	0.0	31	33.5	36	31.0	33.5	36.0
5	0.2	31	33.5	36	31.2	33.7	36.2
10	0.8	31	33.5	36	31.8	34.3	36.8
15	1.8	31	33.5	36	32.8	35.3	37.8
20	3.2	31	33.5	36	34.2	36.7	39.2
25	5.0	31	33.5	36	36.0	38.5	41.0

Pond to pond pumping
3 identical pumping networks

General data

Number of lock chamber : 2
Number of WSB : 0

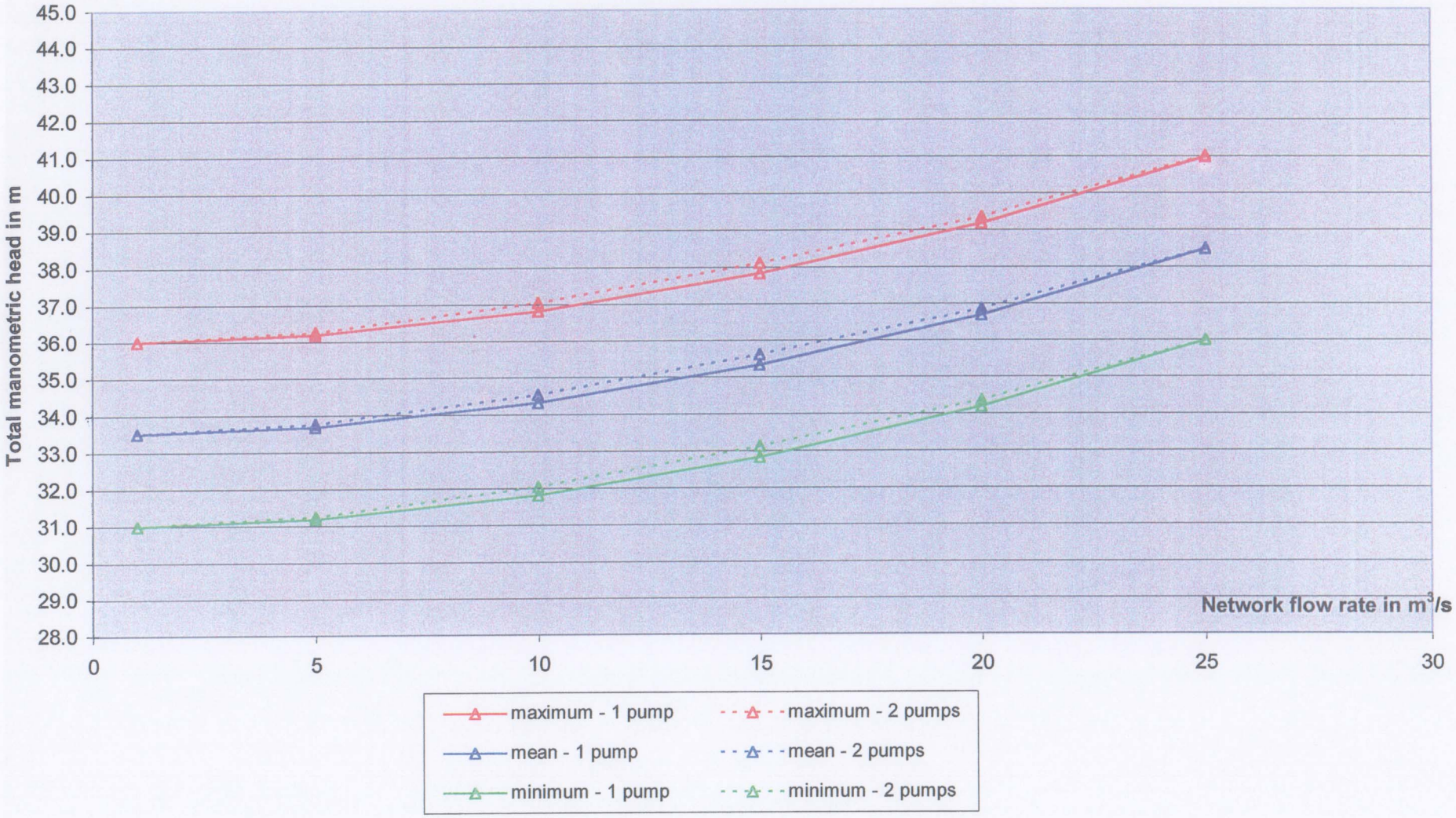
Pumping station flow rate range in m^3/s : 0 to 75
Pumping network flow rate range in m^3/s : 0 to 25
Pump flow rate range in m^3/s : 0 to 12.5
Number of pump per network : 2
Culvert diameter in m : 3.20

Network curves data

Flow rate in m3/s	*Total head losses in m*	*Geometric head in m*			*Manometric head in m*		
		minimum	*mean*	*maximum*	*minimum*	*mean*	*maximum*
1	0.0	31	33.5	36	31.0	33.5	36.0
5	0.3	31	33.5	36	31.3	33.8	36.3
10	1.1	31	33.5	36	32.1	34.6	37.1
15	2.1	31	33.5	36	33.1	35.6	38.1
20	3.4	31	33.5	36	34.4	36.9	39.4
25	5.0	31	33.5	36	36.0	38.5	41.0

Pond to pc pumping
2-lift locks system without WSB
3 identical pumping networks

Network curve for 1 and 2 pumps per pumping networks
Culvert diameter 3.20 m



Annex 11

Drawings LO-005, LO-006, LO-007, LO-008

-

Connection between reservoirs and lock chambers Longitudinal profiles of filling and emptying culverts

Annex 12.1

Connection between reservoirs and lock chambers

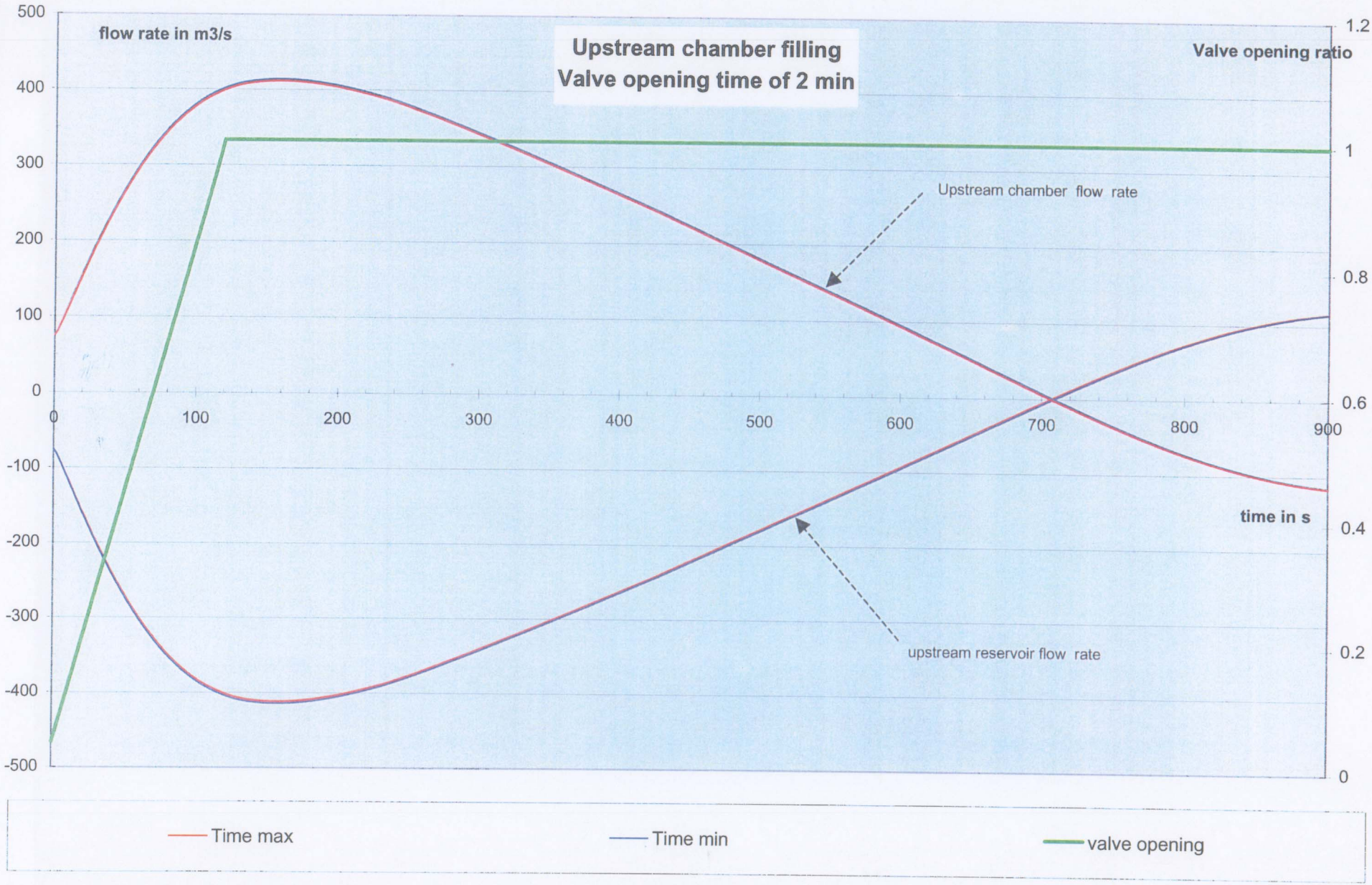
-

Graphics flow rate versus time and water level versus time

3-lift locks system

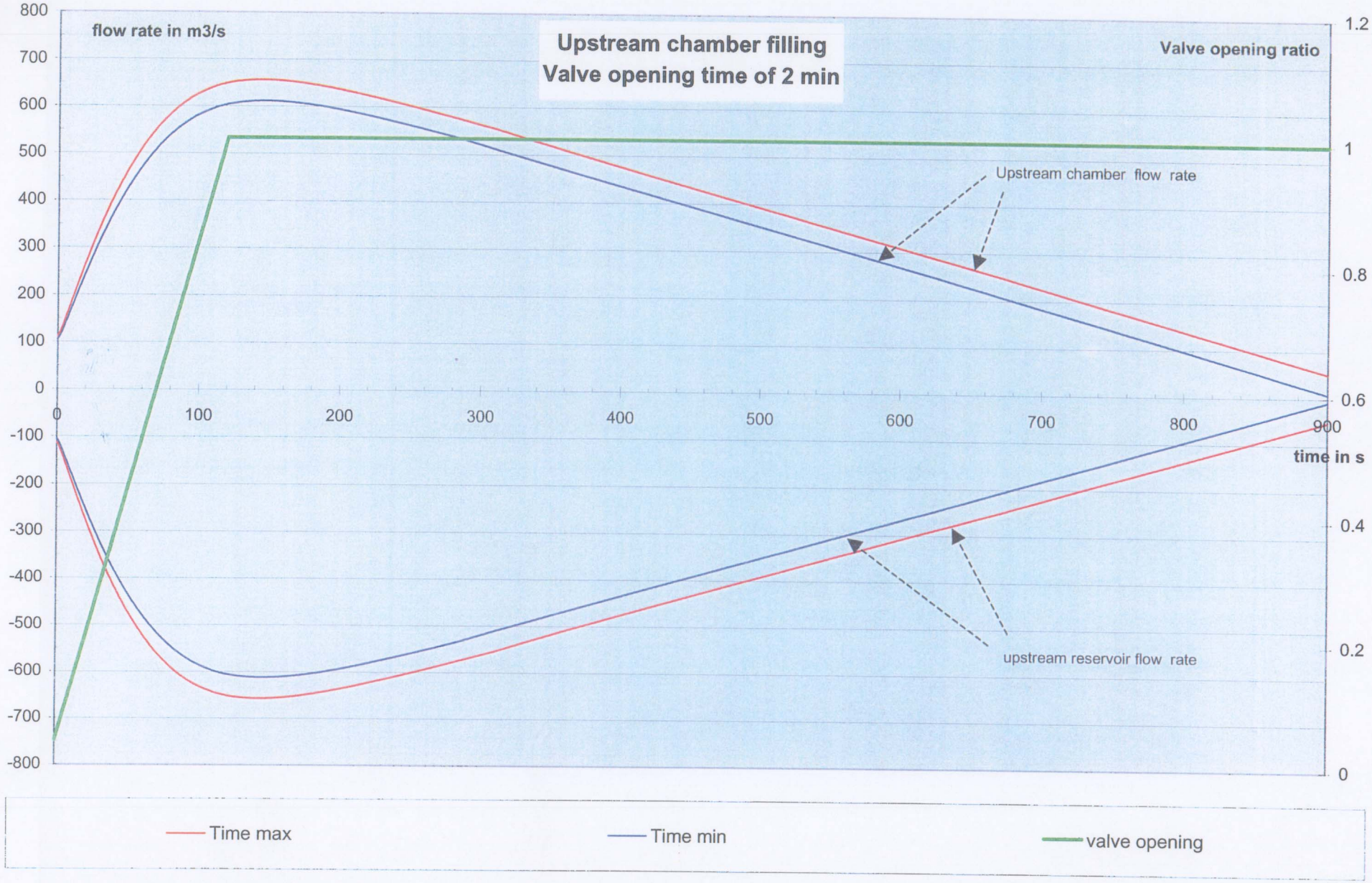
3 steps locks with WSB

Annex 12.1



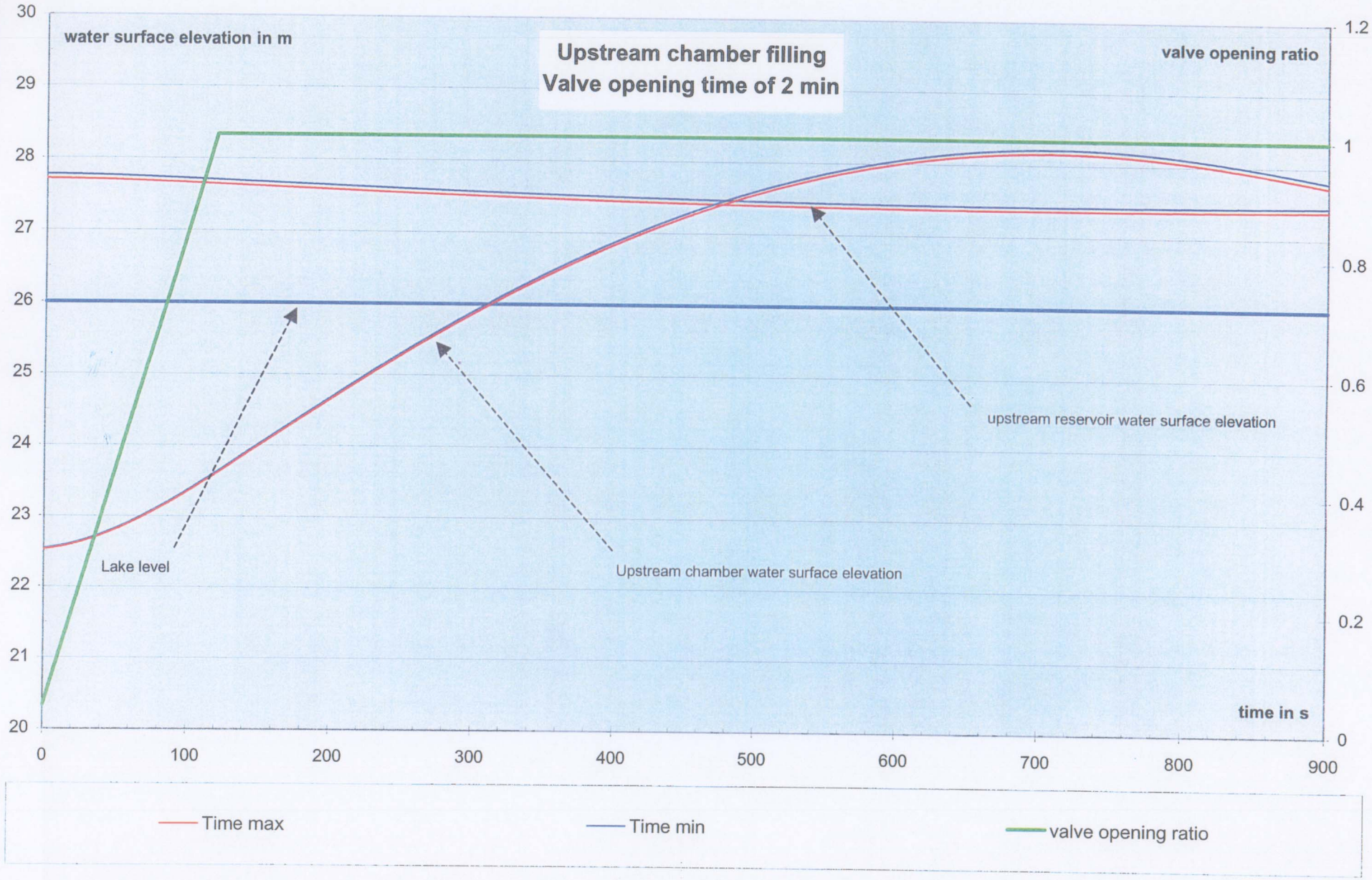
3 step locks without WSB

Annex 12.1



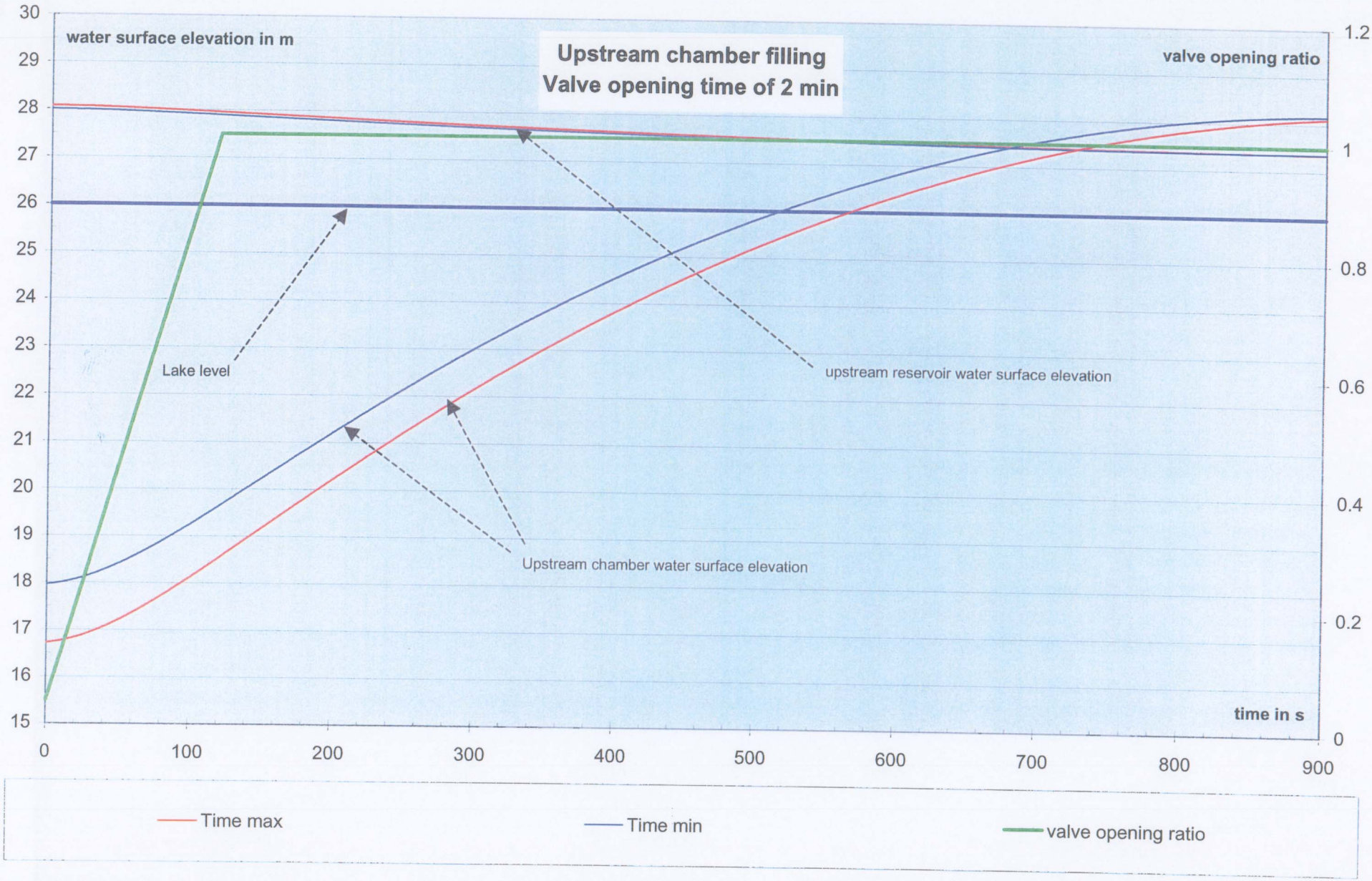
3 step locks with WSB

Annex 12.1



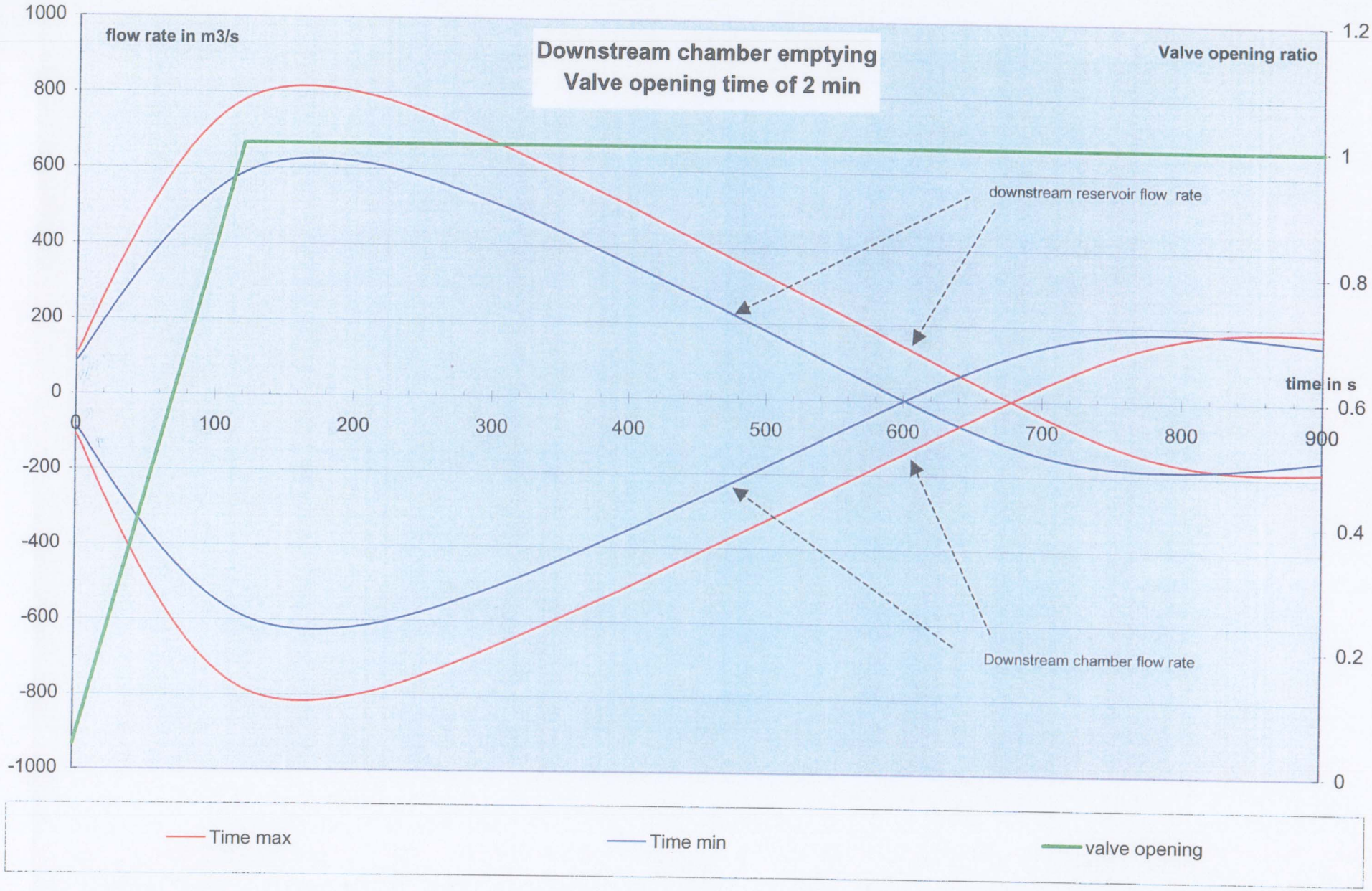
3 step locks without WSB

Annex 12.1



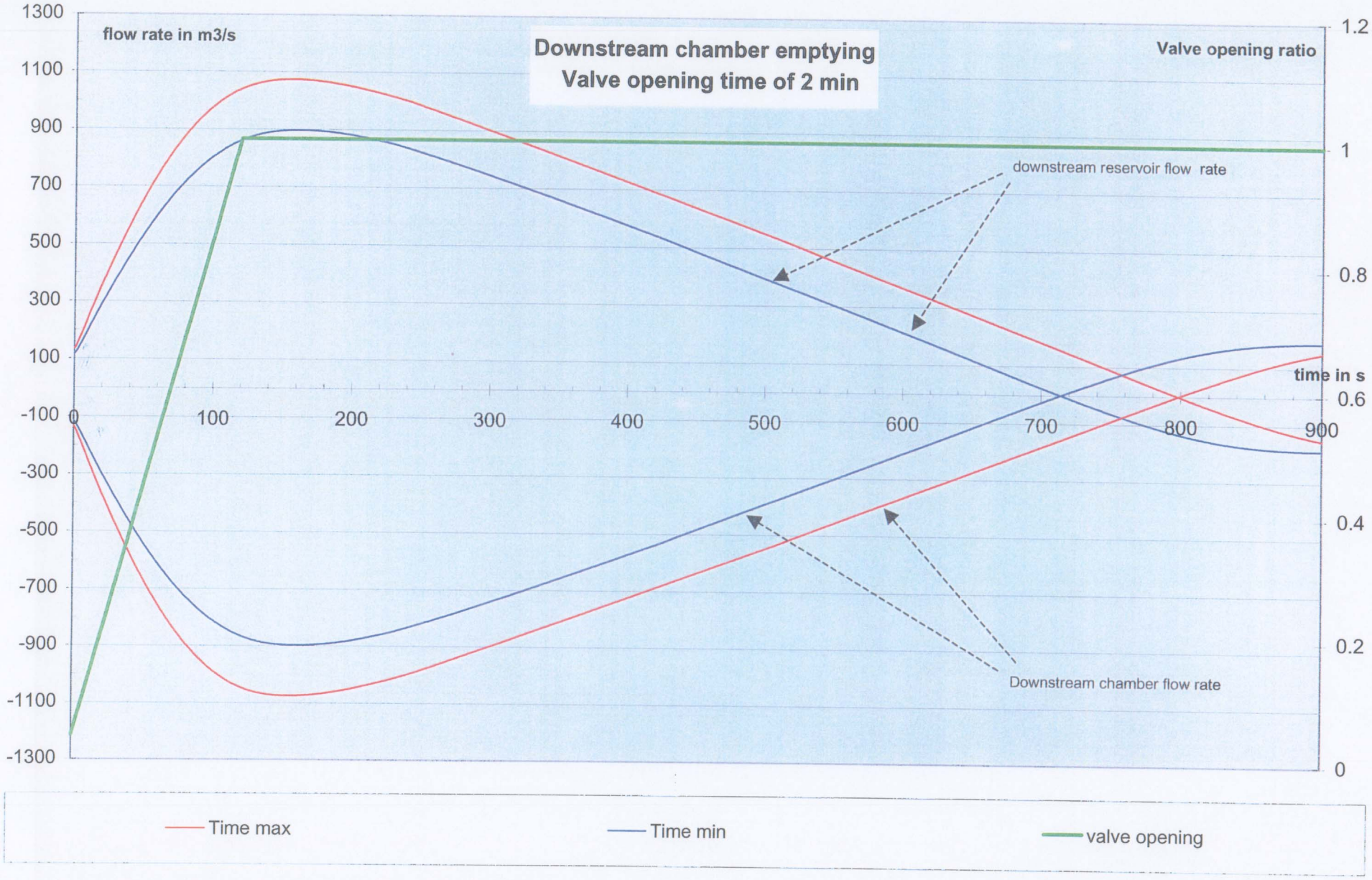
3 step locks with WSB

Annex 12.1



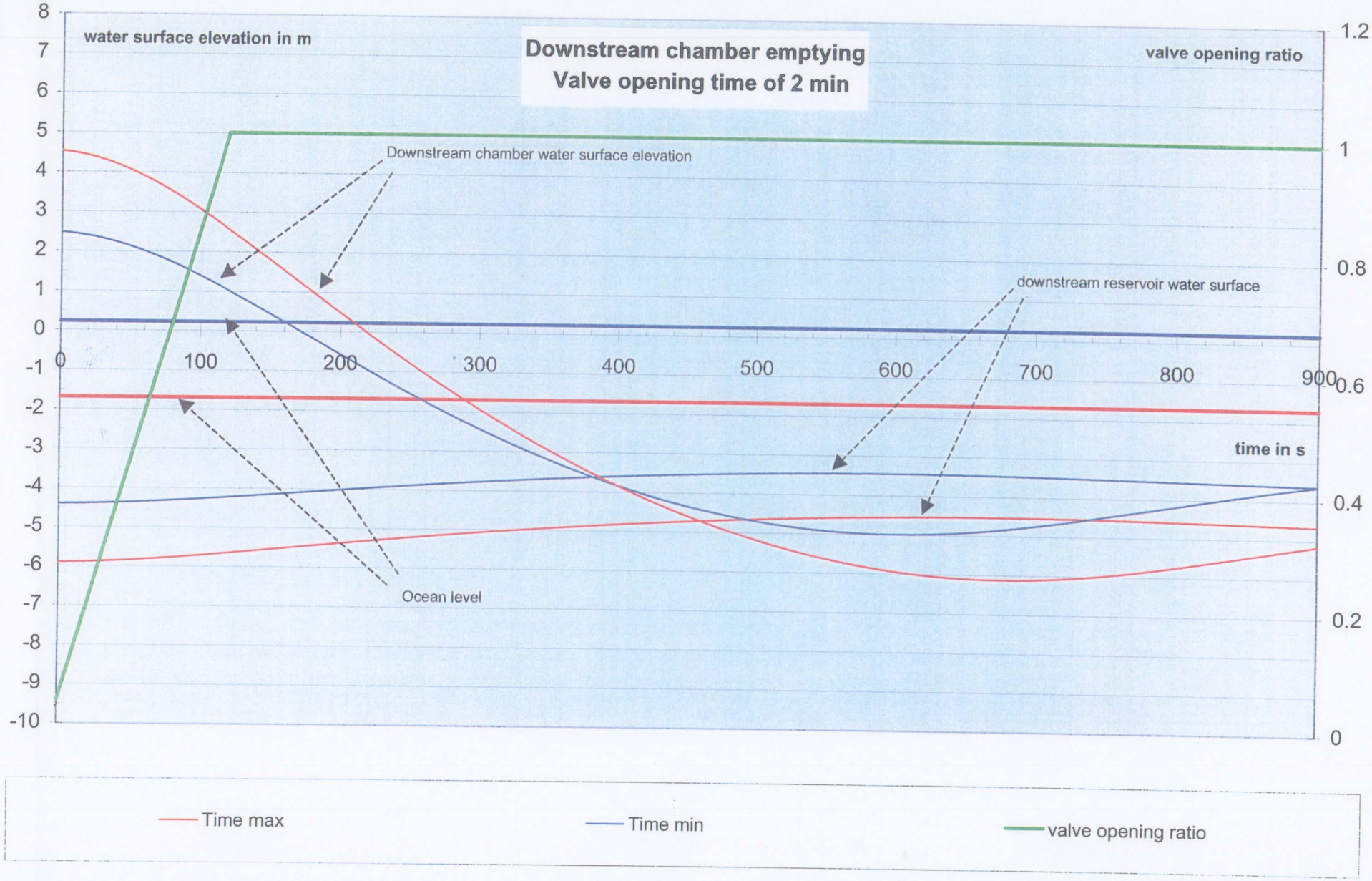
3 step locks without WSB

Annex 12.1



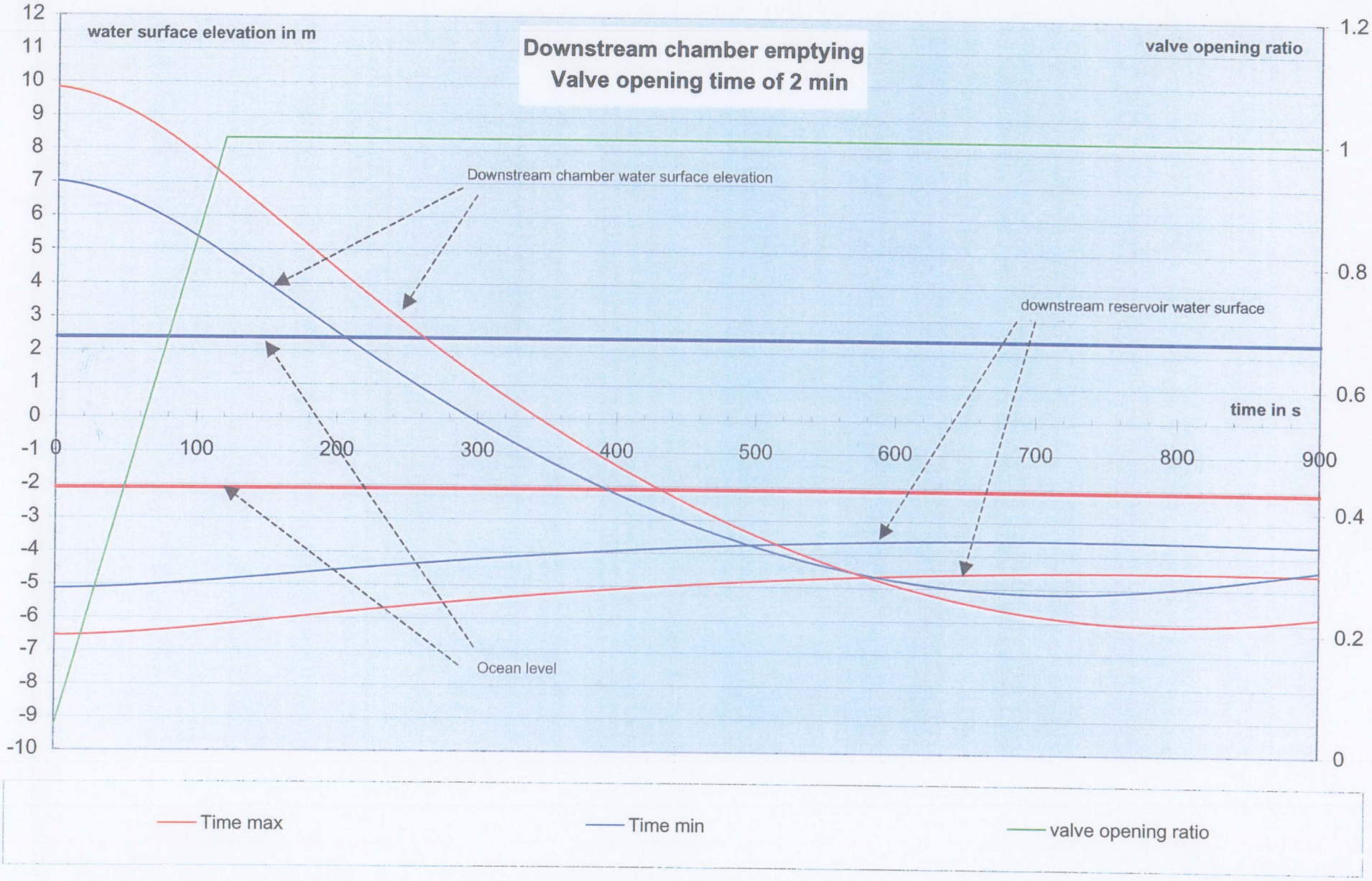
3 step locks with WSB

Annex 12.1



3 step locks without WSB

Annex 12.1



Annex 12.2

Connection between reservoirs and lock chambers

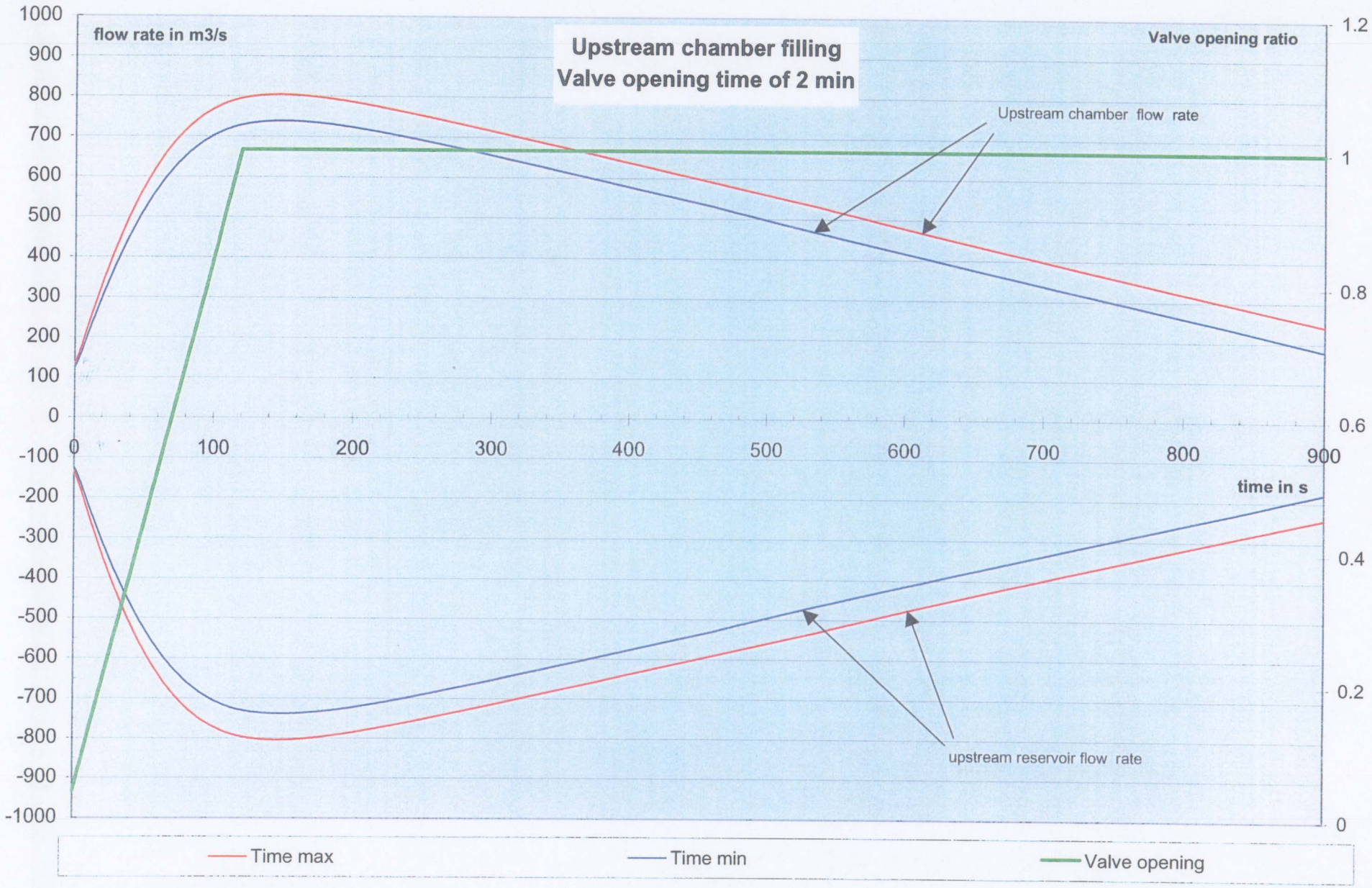
-

Graphics flow rate versus time and water level versus time

2-lift locks system

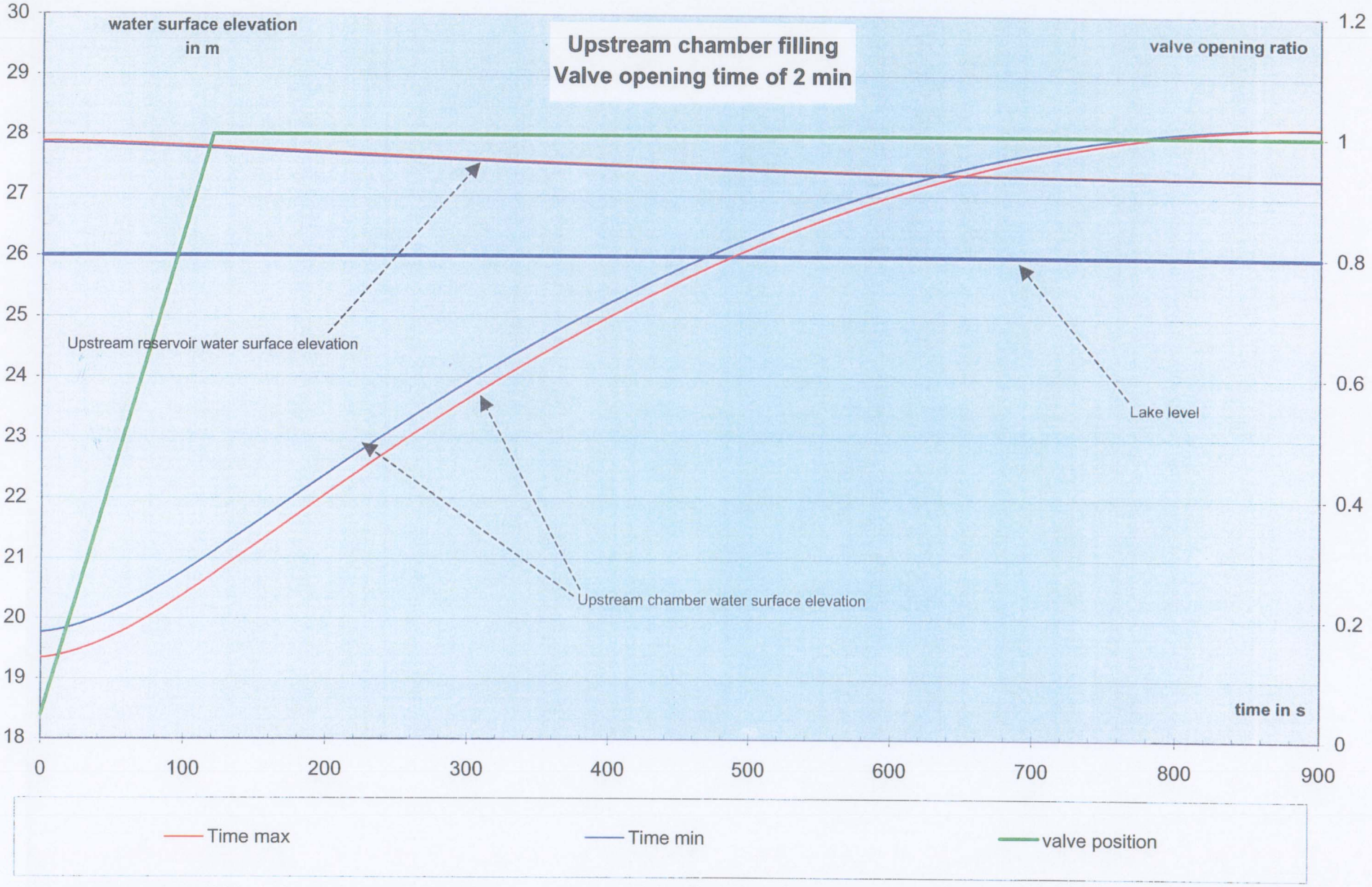
2 step locks without WSB

Annex 12.2



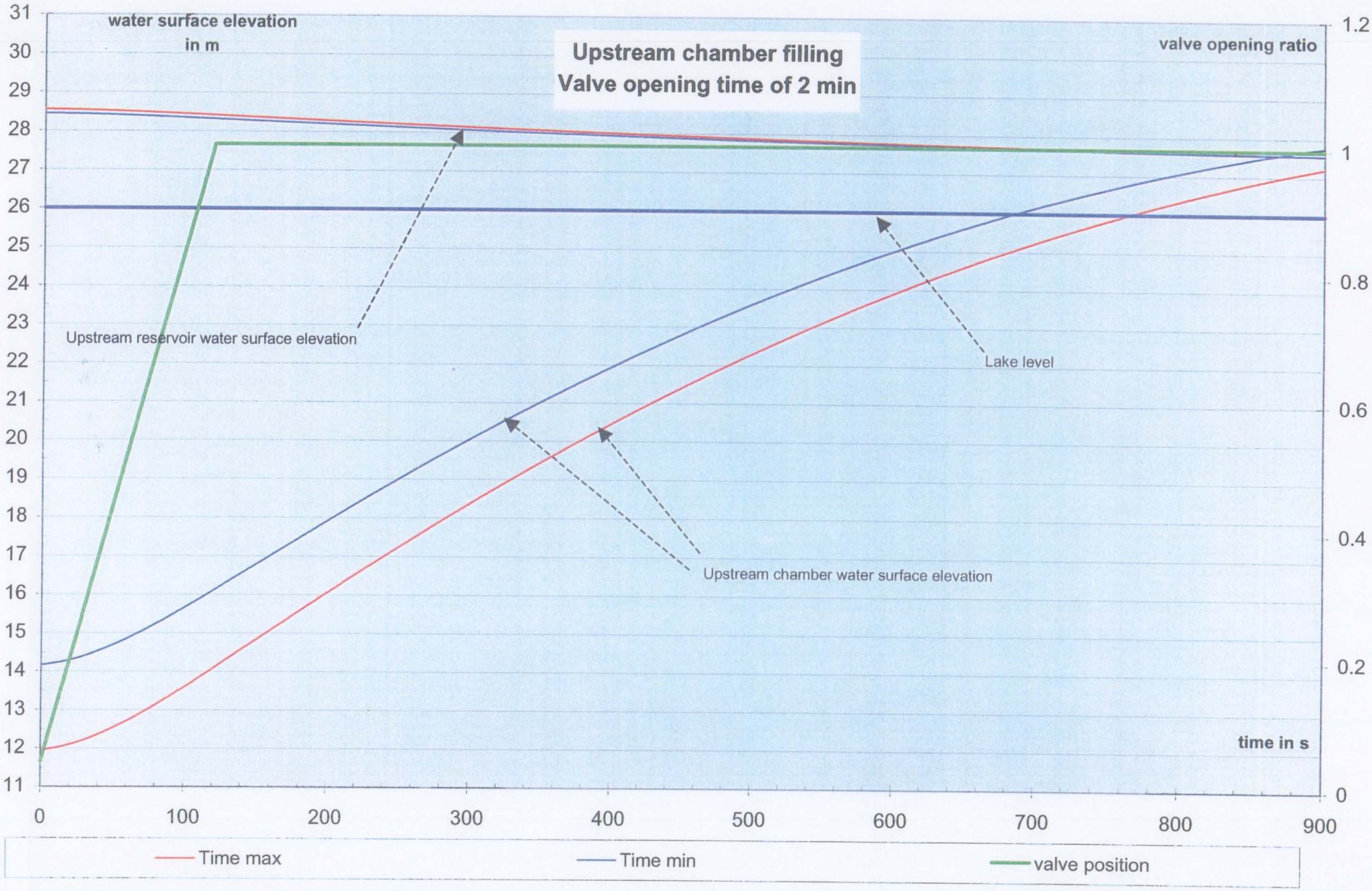
2 step locks with WSB

Annex 12.2

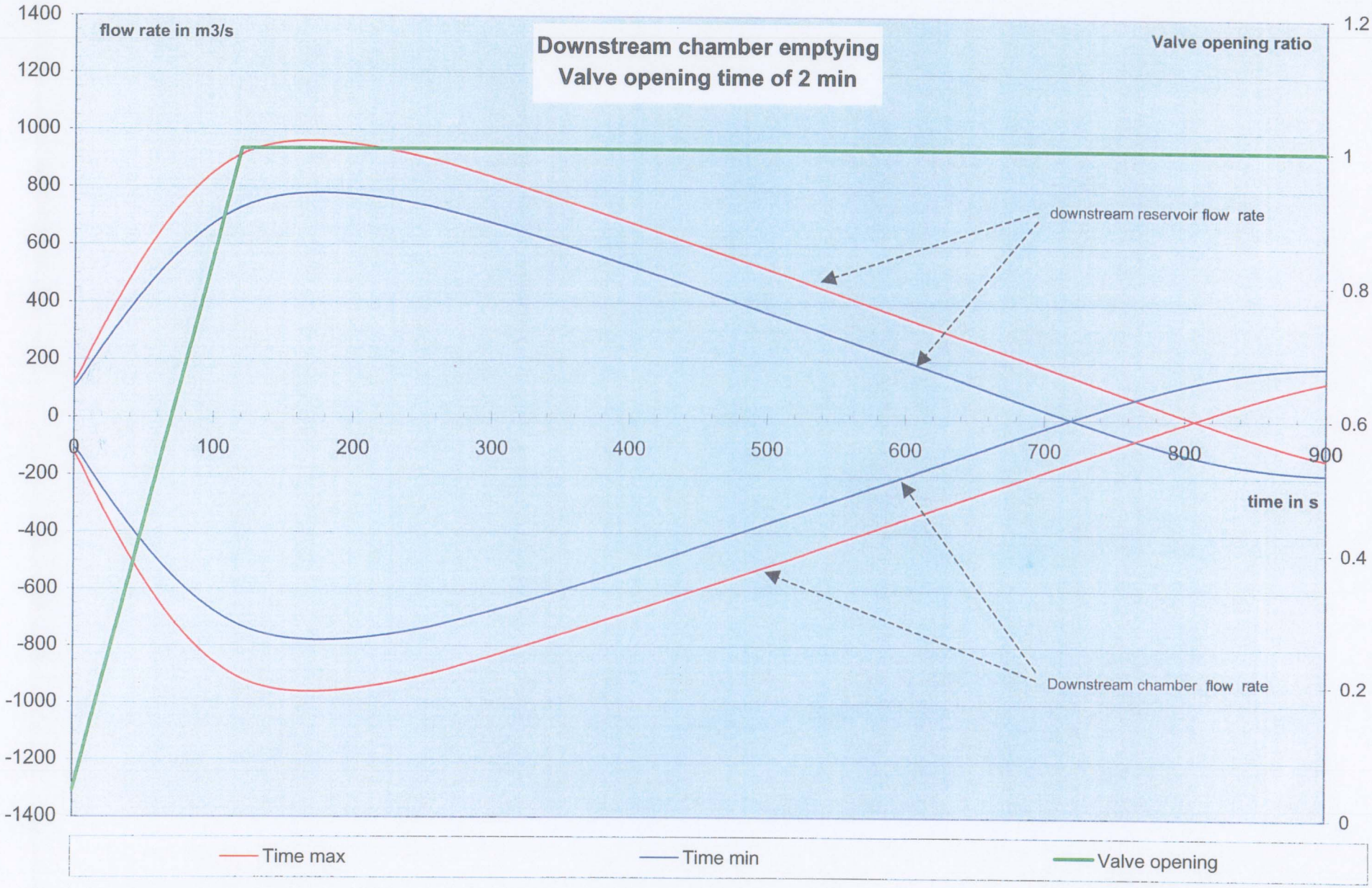


2 step locks without WSB

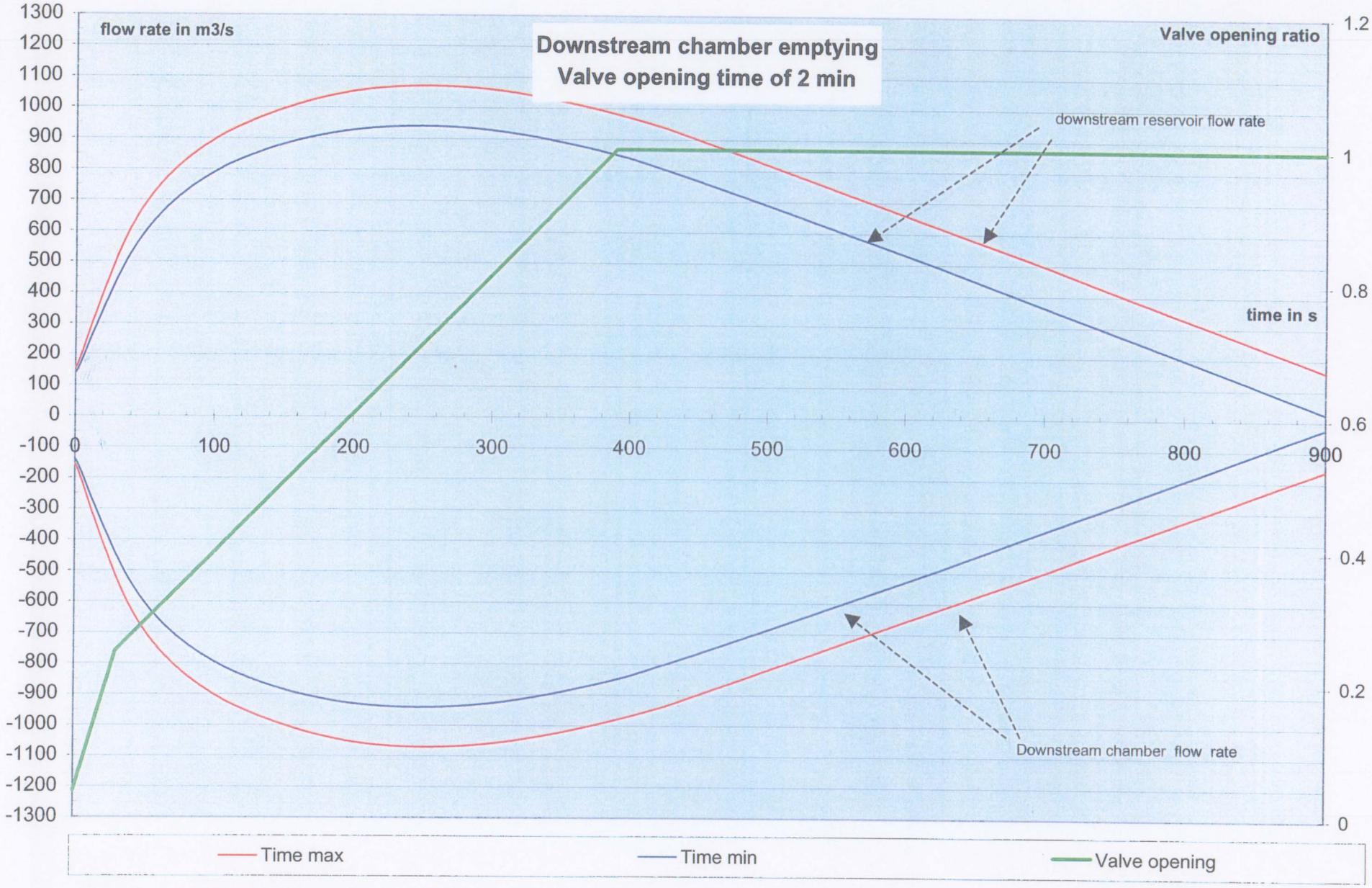
Annex 12.2



2 step locks with WSB

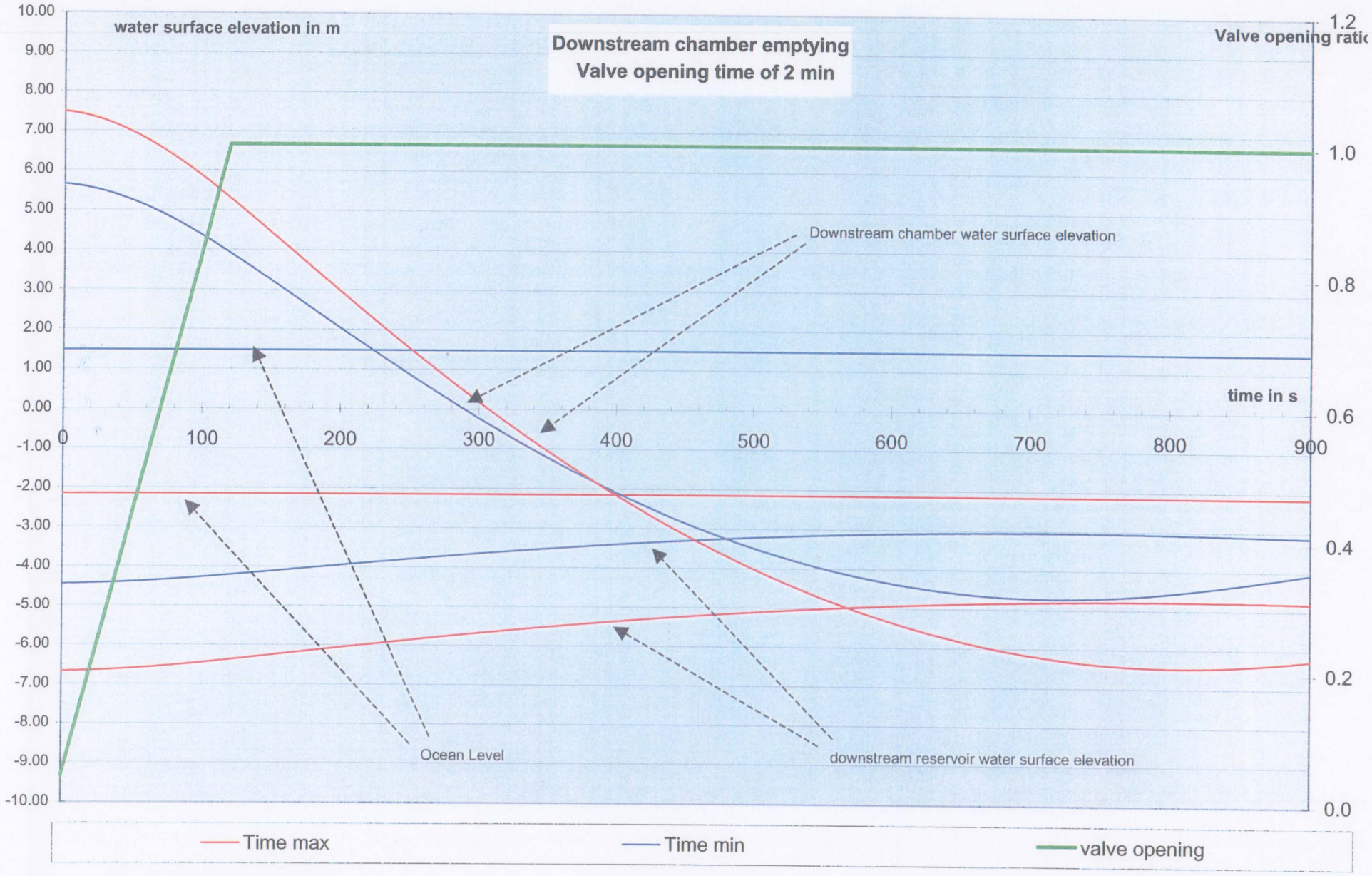


2 step locks without WSB



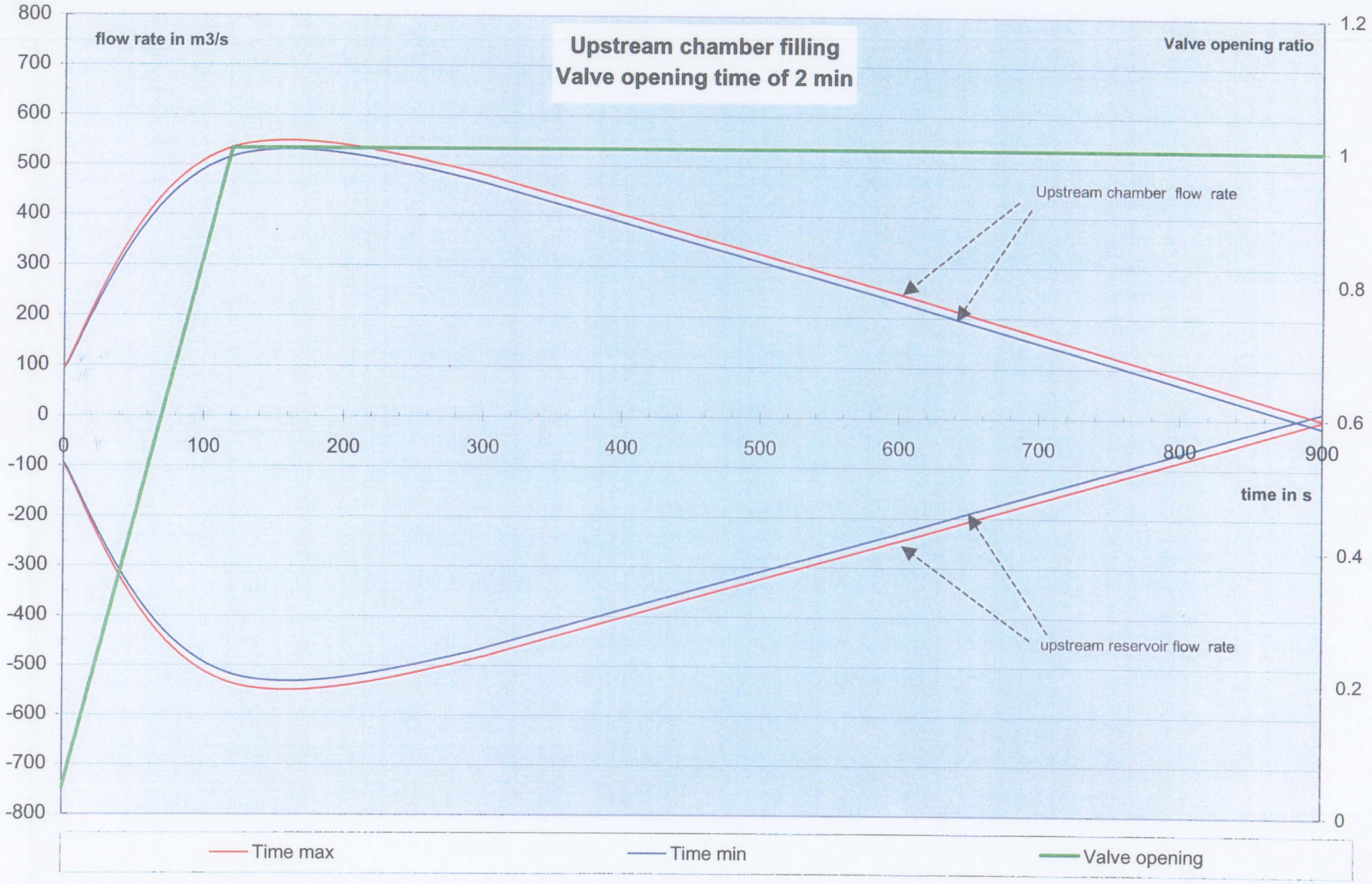
2 step locks with WSB

Annex 12.2



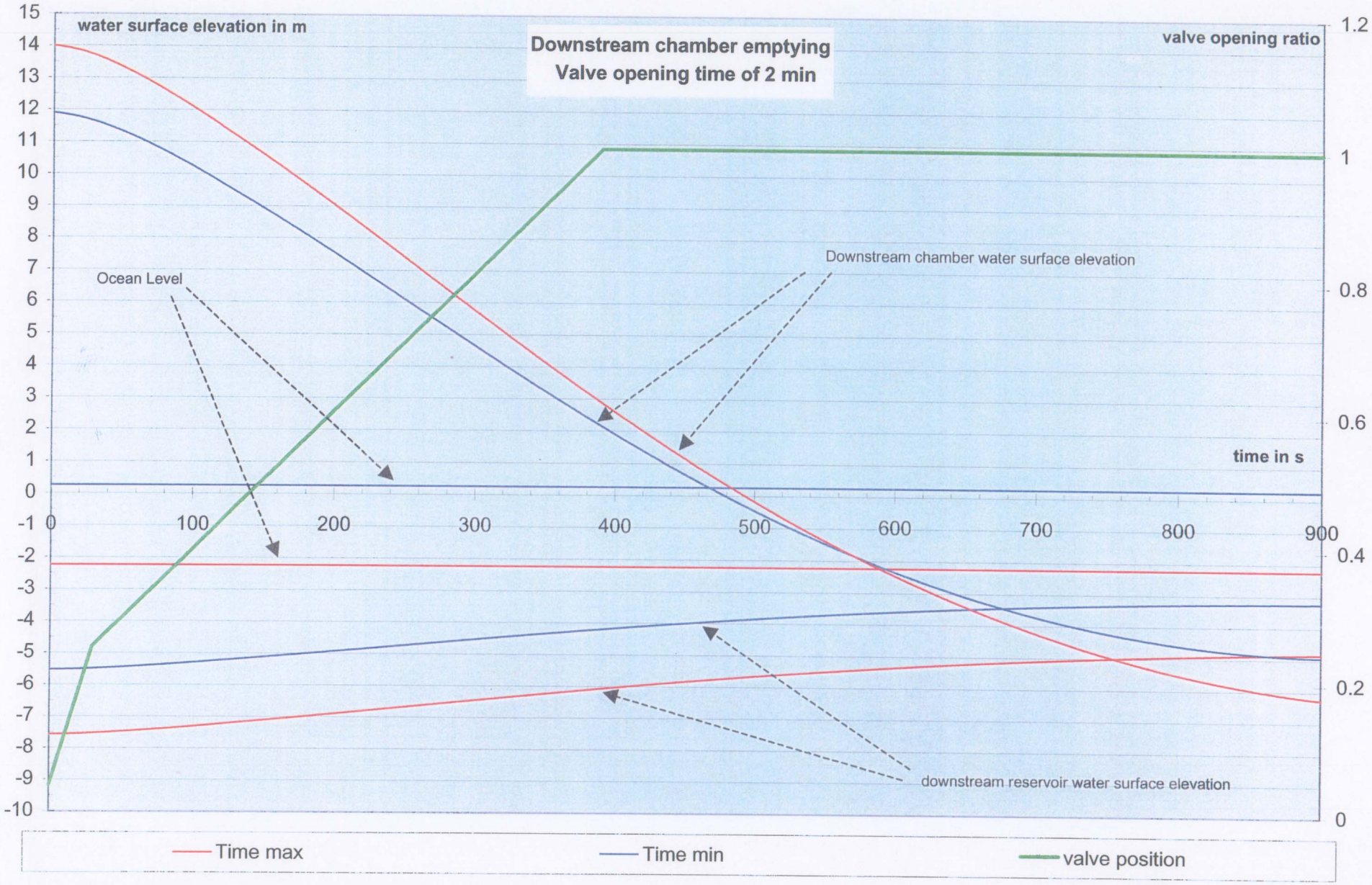
2 step locks with WSB

Annex 12.2



2 step locks without WSB

Annex 12.2



List of annexes - part 2

Annex 13 : Total manometric height - Network discharge

Annex 14-1 : ALSTOM Pump curves
Annex 14-2 : Pump - Hydraulic head – global curves
Annex 14-3 : Pump - Torque – global curves

Annex 15 : TMH - discharge in one network - Functioning point of the Electro -pumps

Annex 16 : Longitudinal profile of pumping networks

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Annex 17-2 : Pump cutout – Pump stop on proper inertia – Valve closure in 30 sec - Cavitation simulation – Point A
Annex 17-3 : Pump cutout – Pump stop on proper inertia – Valve closure in 30 sec - Cavitation simulation – Point B
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Annex 18-6 : Pump cutout – Pump stop on proper inertia – Valve closure in 30 sec - Short inclined surge shaft - optimization – Point E
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Annex 19-1 : Pump cutout – Pump stop on proper inertia – Valve closure in 30 sec – Long inclined surge shaft D=3.20 m – Valve pressure

Annex 19-2 : Pump cutout – Pump stop on proper inertia – Valve closure in 30 sec – Long inclined surge shaft D=3.20 m – Connection with surge shaft

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Annex 19-8 : Pump cutout – Pump stop on proper inertia – Valve closure in 30 sec - Long inclined surge shaft D=3.20 m – Point F

Annex 19-9 : Pump cutout – Pump stop on proper inertia – Valve closure in 30 sec - Long inclined surge shaft D=3.20 m – Point G

Annex 20-1 : Pump cutout – Pump stop on proper inertia – Valve closure in 30 sec – Long inclined surge shaft D=3.20 m Surge chamber 100 m² – Valve pressure

Annex 20-2 : Pump cutout – Pump stop on proper inertia – Valve closure in 30 sec – Long inclined surge shaft D=3.20 m Surge chamber 100 m² – Connection with surge shaft

Annex 20-3 : Pump cutout – Pump stop on proper inertia – Valve closure in 30 sec - Long inclined surge shaft D=3.20 m Surge chamber 100 m² – Point A

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Annex 20-5 : Pump cutout – Pump stop on proper inertia – Valve closure in 30 sec - Long inclined surge shaft D=3.20 m Surge chamber 100 m² – Point C

Annex 20-6 : Pump cutout – Pump stop on proper inertia – Valve closure in 30 sec - Long inclined surge shaft D=3.20 m Surge chamber 100 m² – Point D

Annex 20-7 : Pump cutout – Pump stop on proper inertia – Valve closure in 30 sec - Long inclined surge shaft D=3.20 m Surge chamber 100 m² – Point E

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Annex 21-1 : Pump cutout – Pump stop on proper inertia – New closure law – Long inclined surge shaft D=3.20 m Surge chamber 100 m² – Valve pressure

Annex 21-2 : Pump cutout – Pump stop on proper inertia – New closure law – Long inclined surge shaft D=3.20 m Surge chamber 100 m² – Connection with surge shaft

Annex 22-1 : Pump cutout – Pump stop on proper inertia – Valve closure in 30 sec – Vertical surge shaft – Valve pressure

Annex 22-2 : Pump cutout – Pump stop on proper inertia – Valve closure in 30 sec – Vertical surge shaft – Connection with surge shaft

Annex 22-3 : Pump cutout – Pump stop on proper inertia – Valve closure in 30 sec - Vertical surge shaft – Point A

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Annex 22-6 : Pump cutout – Pump stop on proper inertia – Valve closure in 30 sec - Vertical surge shaft – Point D

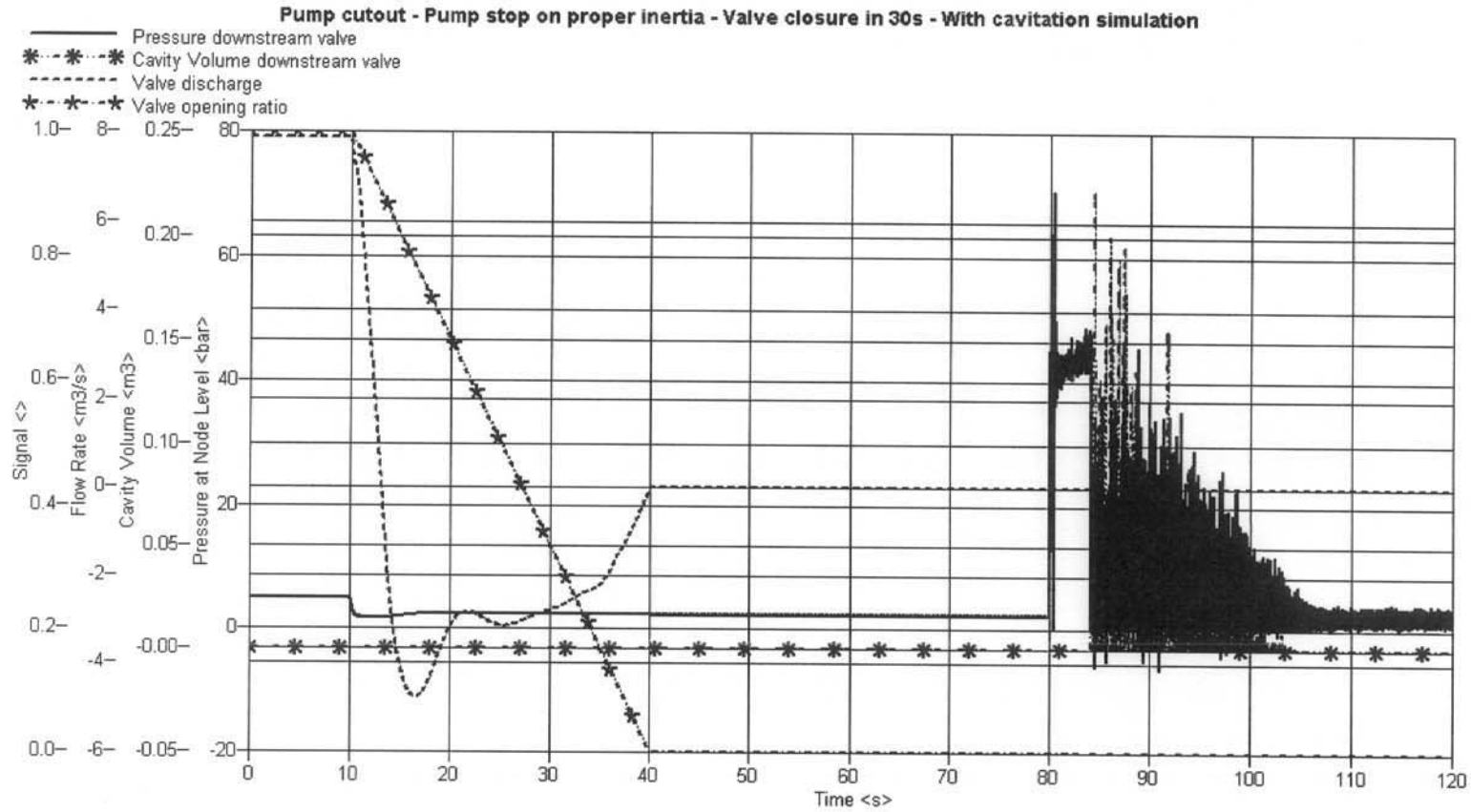
Annex 22-7 : Pump cutout – Pump stop on proper inertia – Valve closure in 30 sec - Vertical surge shaft – Point E

Annex 22-8 : Pump cutout – Pump stop on proper inertia – Valve closure in 30 sec - Vertical surge shaft – Point F

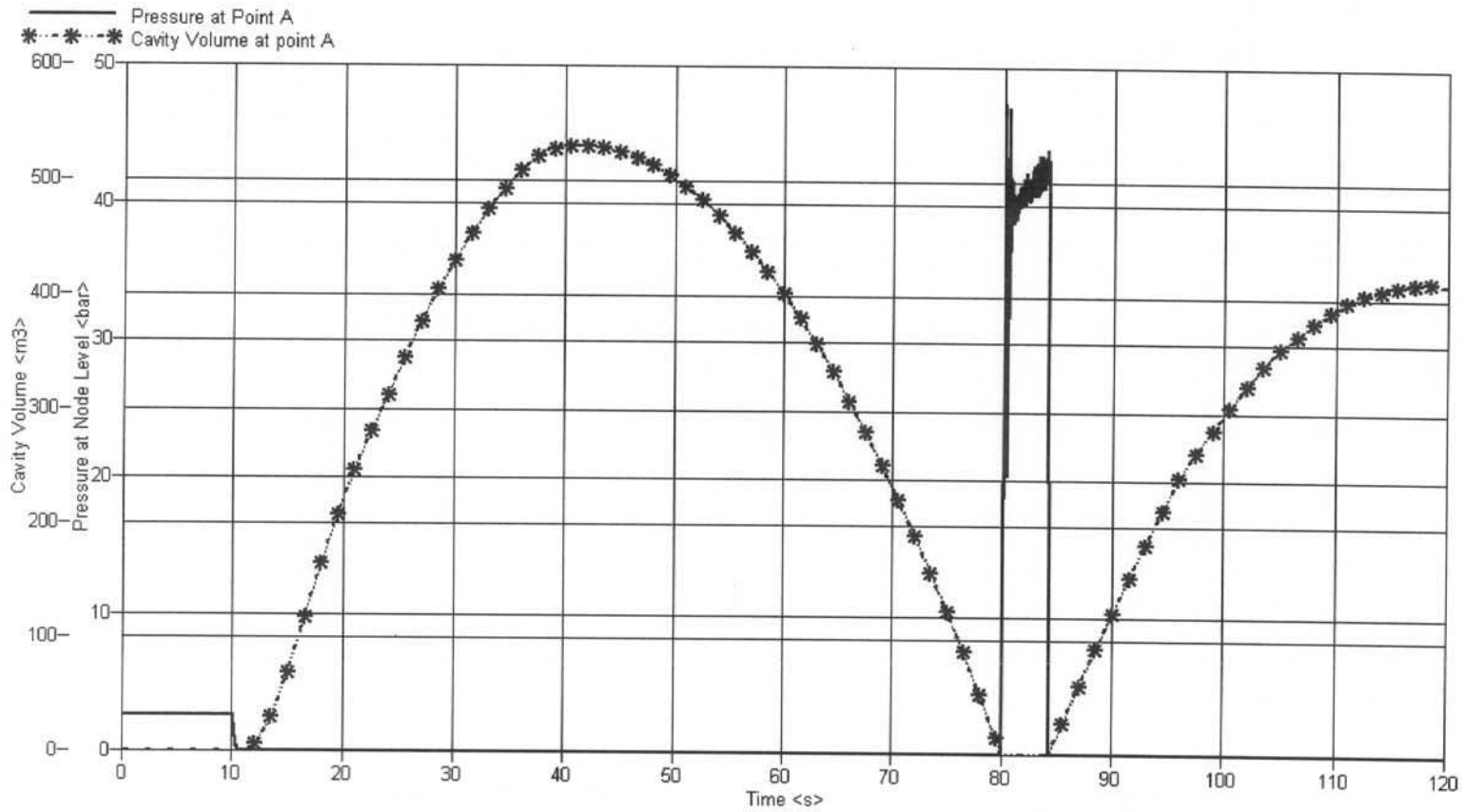
Annex 17

Pump cutout – Pump stop on proper inertia – Valve closure in 30 sec - Cavitation simulation

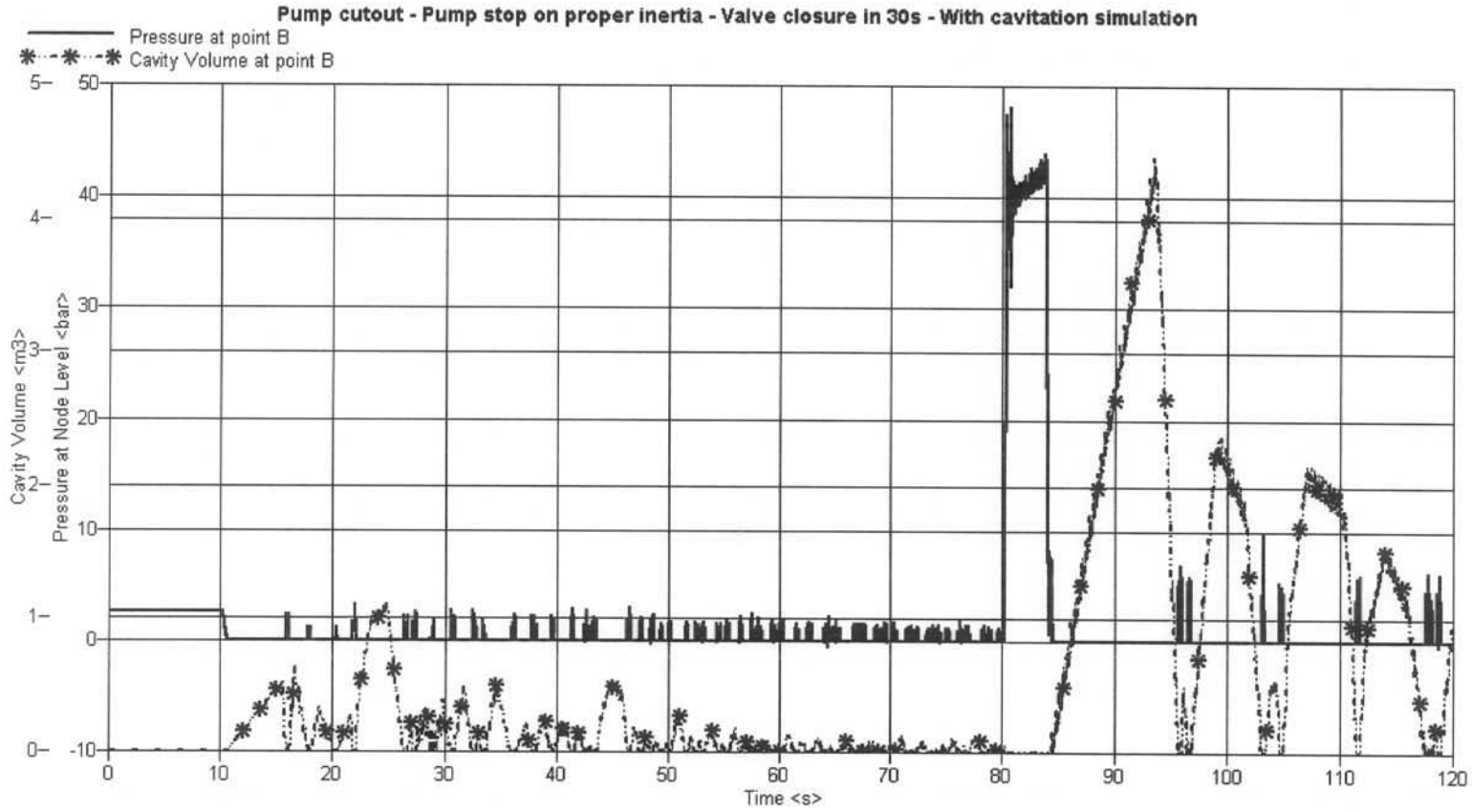
Annex 17.1


Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation simulation
Pressure downstream valve
Cavity Volume downstream valve
Valve discharge
Valve opening ratio
Signal <>
Flow Rate <m3/s>
Cavity Volume <m3>
Pressure at Node Level <bar>
Time <s>

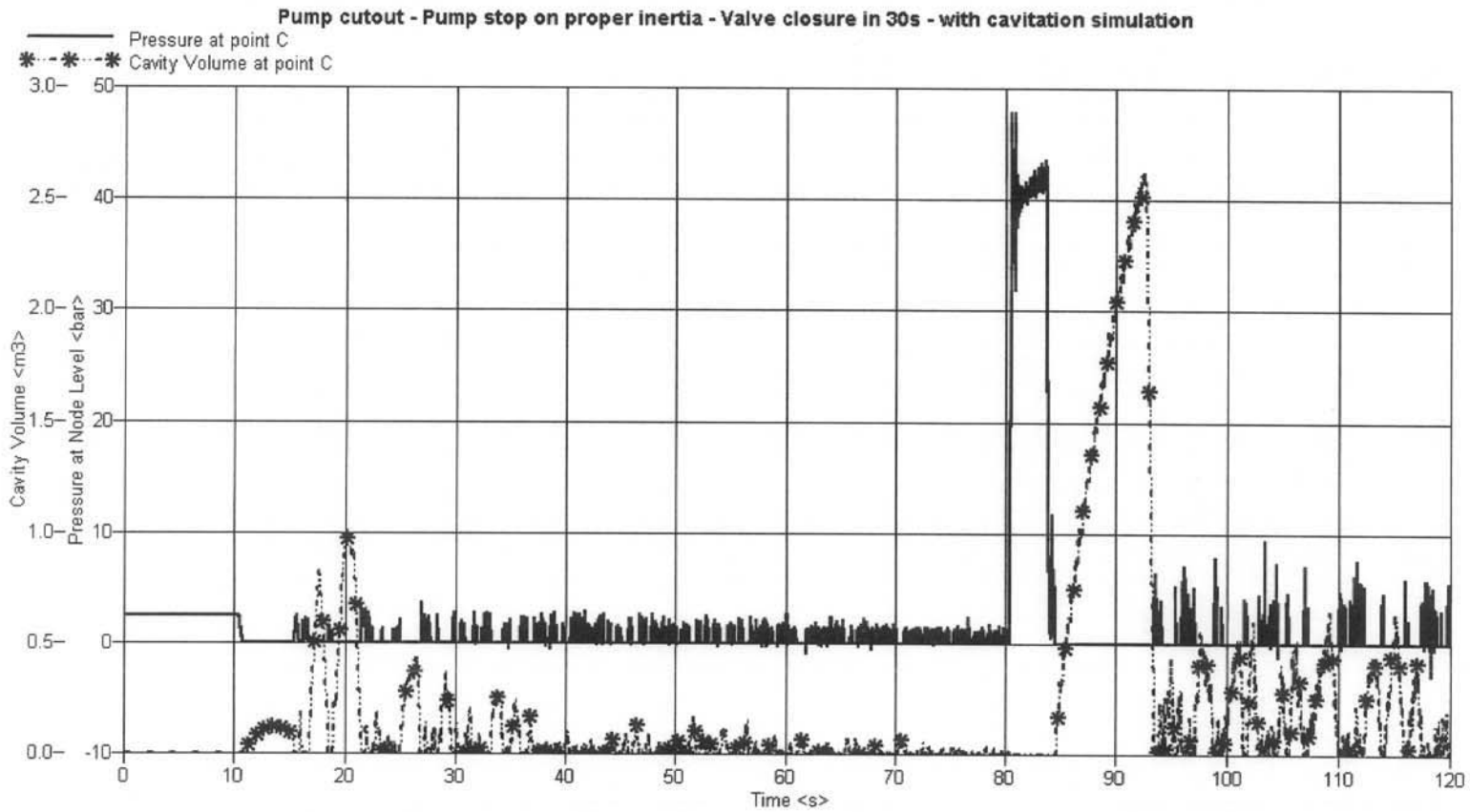
Annex 17.2


Pressure at Point A
Cavity Volume at point A
Cavity Volume <m3>
Pressure at Node Level <bar>
Time <s>
600
500
400
300
200
100
0
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
110
120

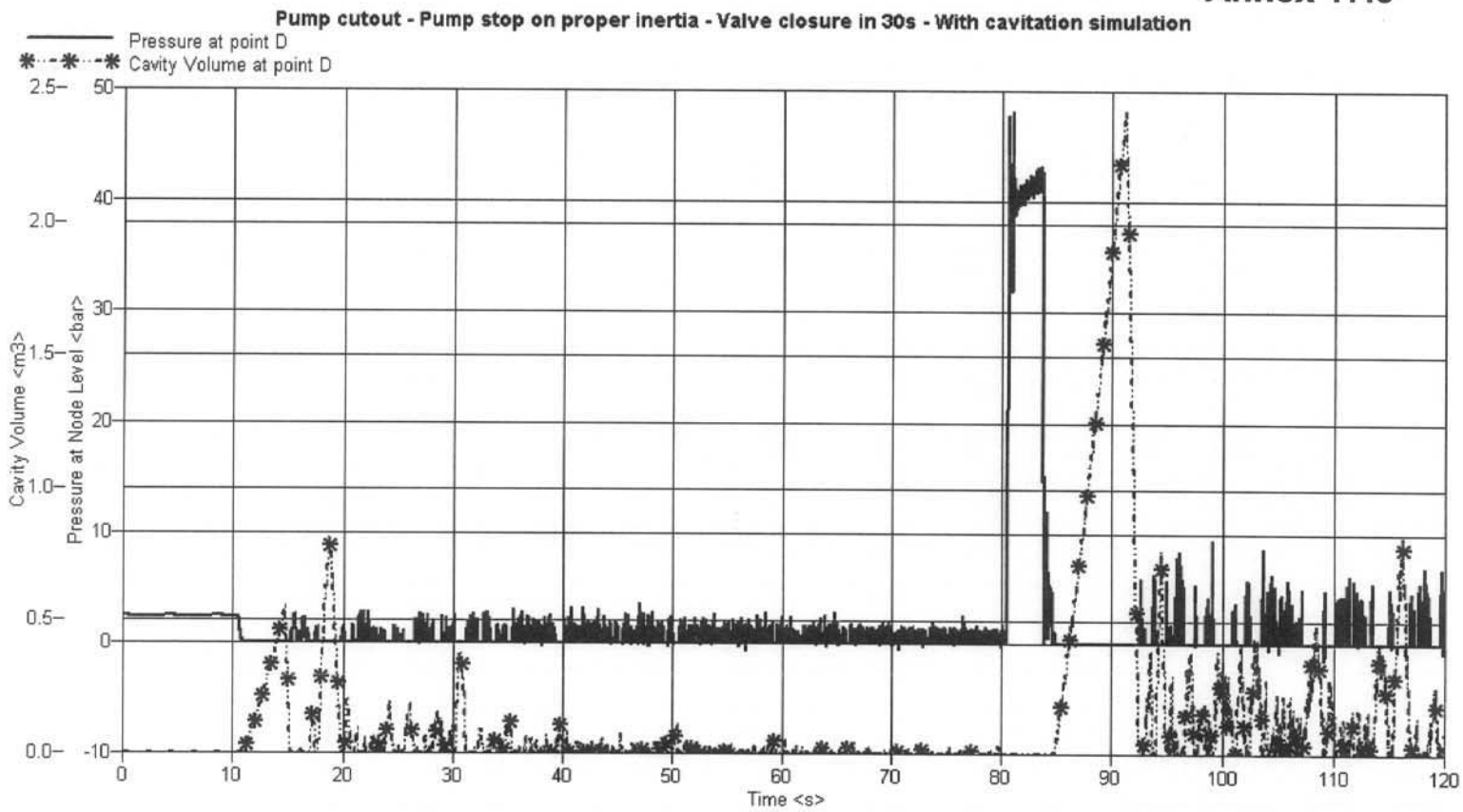
Annex 17.3


Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation simulation
Pressure at point B
Cavity Volume at point B
Cavity Volume <m3>
Pressure at Node Level <bar>
Time <s>
5
4
3
2
1
0
50
40
30
20
10
0
-10
0
10
20
30
40
50
60
70
80
90
100
110
120

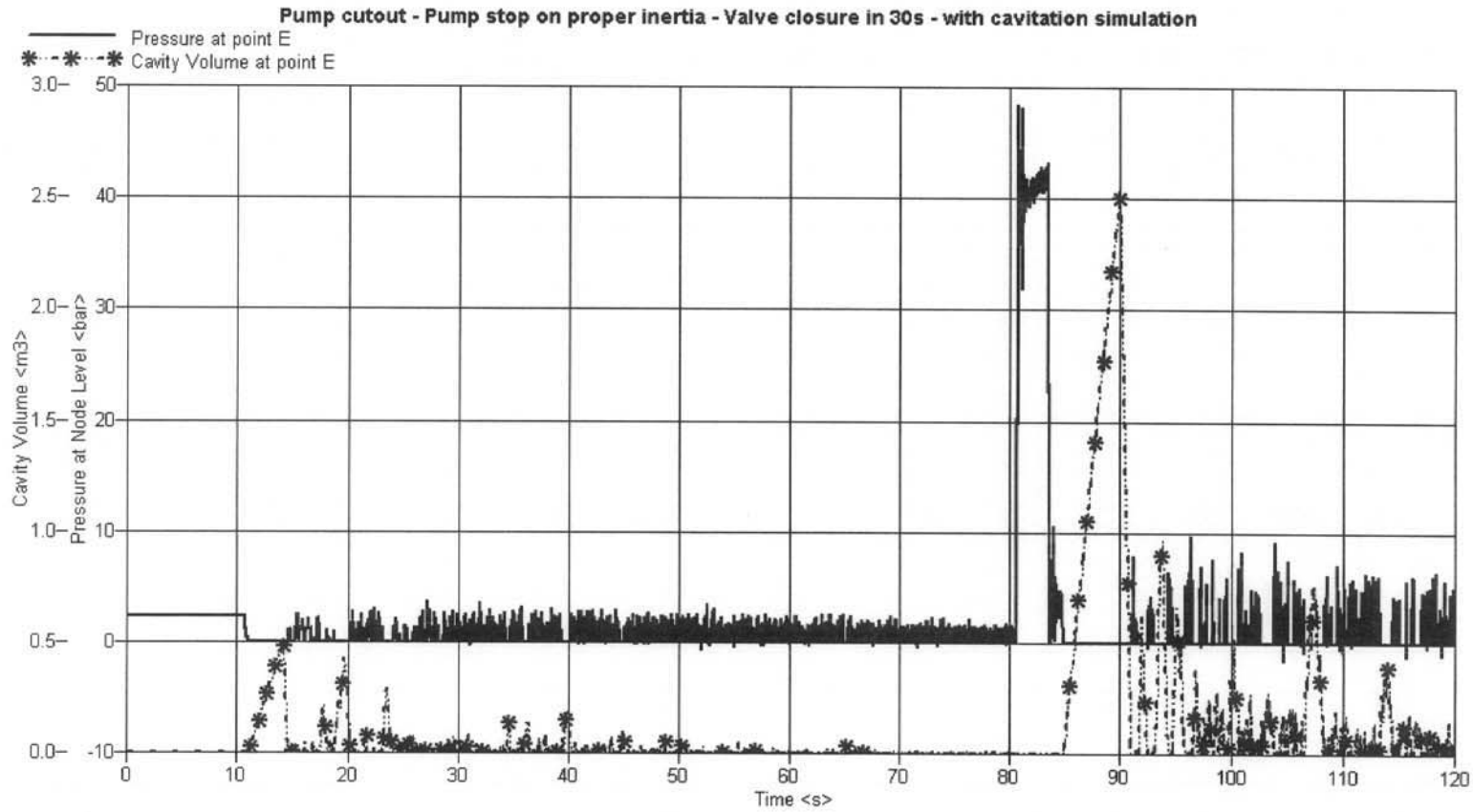
Annex 17.4


Pump cutout - Pump stop on proper inertia - Valve closure in 30s - with cavitation simulation
Pressure at point C
Cavity Volume at point C
Cavity Volume <m3>
Pressure at Node Level <bar>
Time <s>
3.0
2.5
2.0
1.5
1.0
0.5
0.0
50
40
30
20
10
0
-10
0
10
20
30
40
50
60
70
80
90
100
110
120

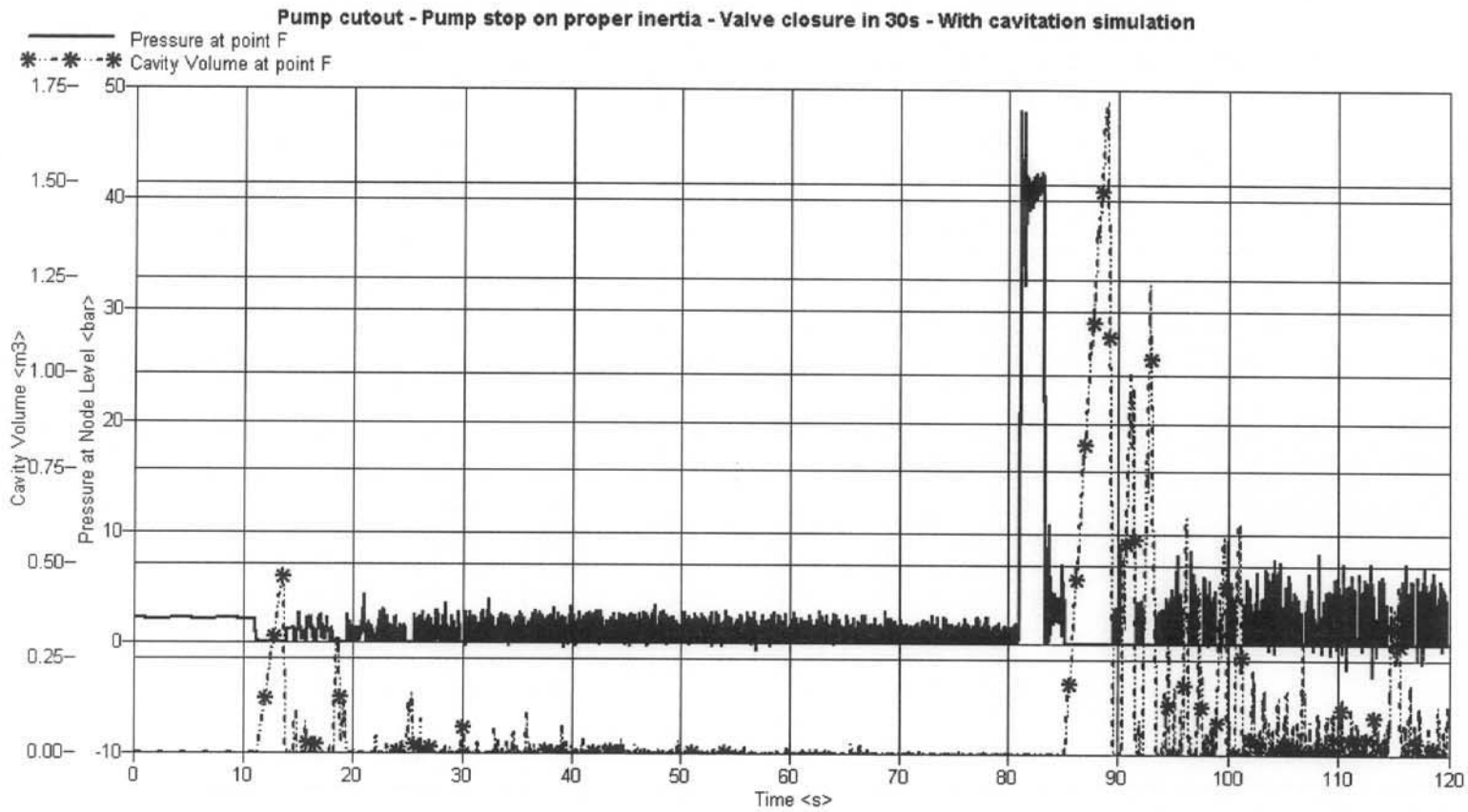
Annex 17.5


Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation simulation
Pressure at point D
Cavity Volume at point D
Cavity Volume <m3>
Pressure at Node Level <bar>
Time <s>
2.5
2.0
1.5
1.0
0.5
0.0
50
40
30
20
10
0
-10
0
10
20
30
40
50
60
70
80
90
100
110
120

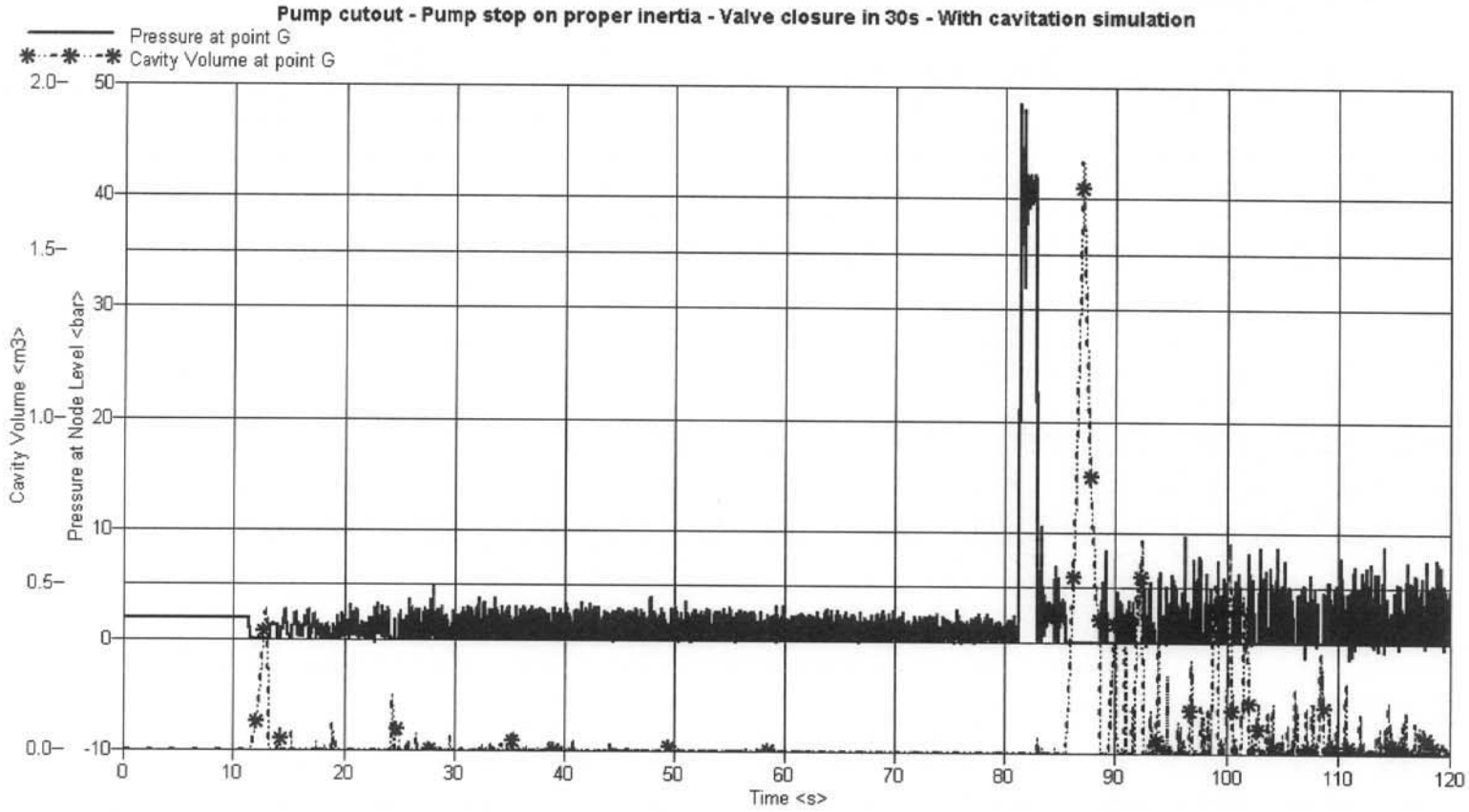
Annex 17.6


Pump cutout - Pump stop on proper inertia - Valve closure in 30s - with cavitation simulation
Pressure at point E
Cavity Volume at point E
Cavity Volume <m3>
Pressure at Node Level <bar>
Time <s>
3.0
2.5
2.0
1.5
1.0
0.5
0.0
50
40
30
20
10
0
-10
0
10
20
30
40
50
60
70
80
90
100
110
120

Annex 17.7


Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation simulation
Pressure at point F
Cavity Volume at point F
Cavity Volume <m3>
Pressure at Node Level <bar>
Time <s>
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
50
40
30
20
10
0
-10
0
10
20
30
40
50
60
70
80
90
100
110
120

Annex 17.8

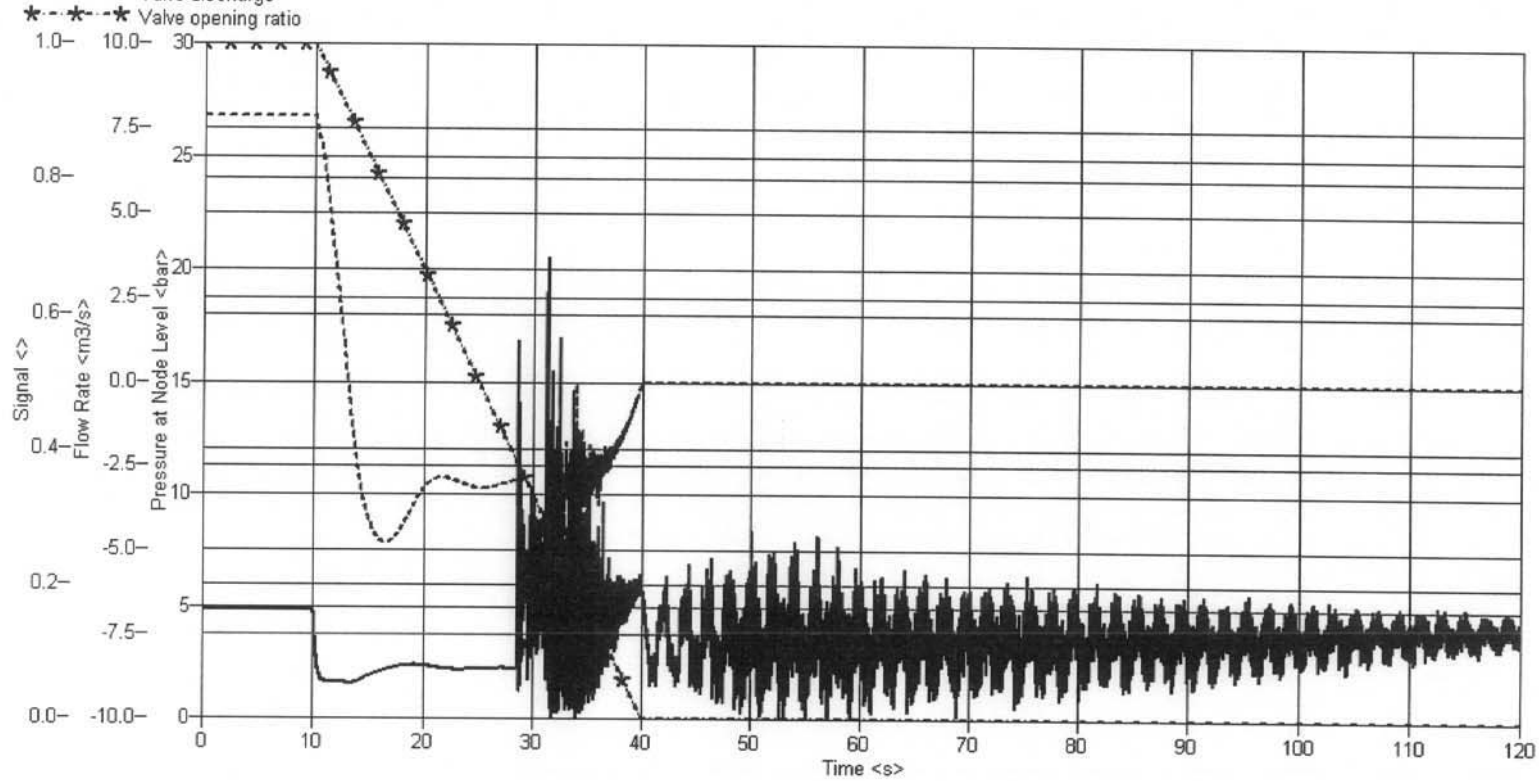

Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation simulation
Pressure at point G
Cavity Volume at point G
Cavity Volume <m3>
Pressure at Node Level <bar>
Time <s>
2.0
1.5
1.0
0.5
0.0
50
40
30
20
10
0
-10
0
10
20
30
40
50
60
70
80
90
100
110
120

Annex 18

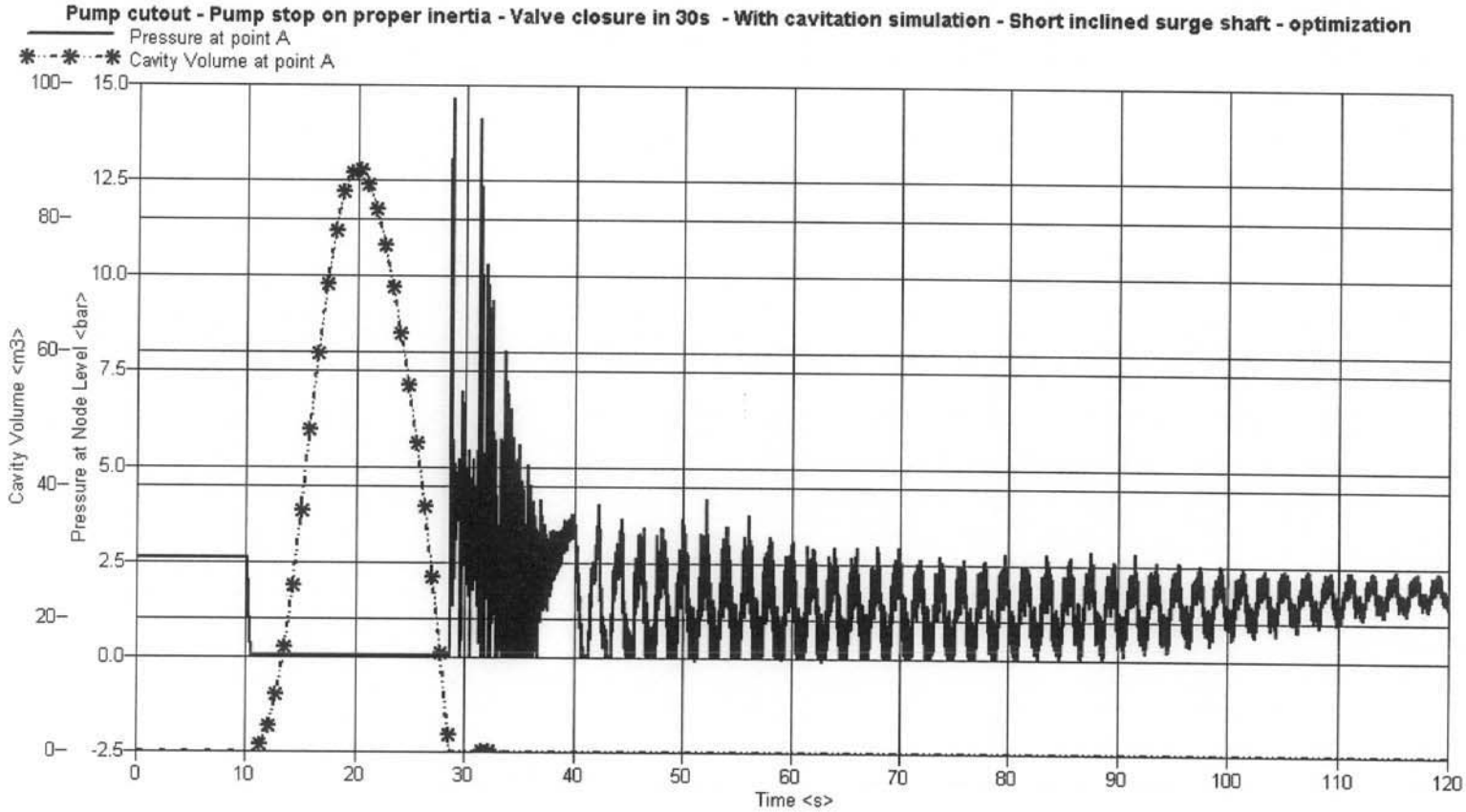
Short inclined surge shaft - optimization

Annex 18.1

Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation simulation - Short inclined surge shaft - optimization

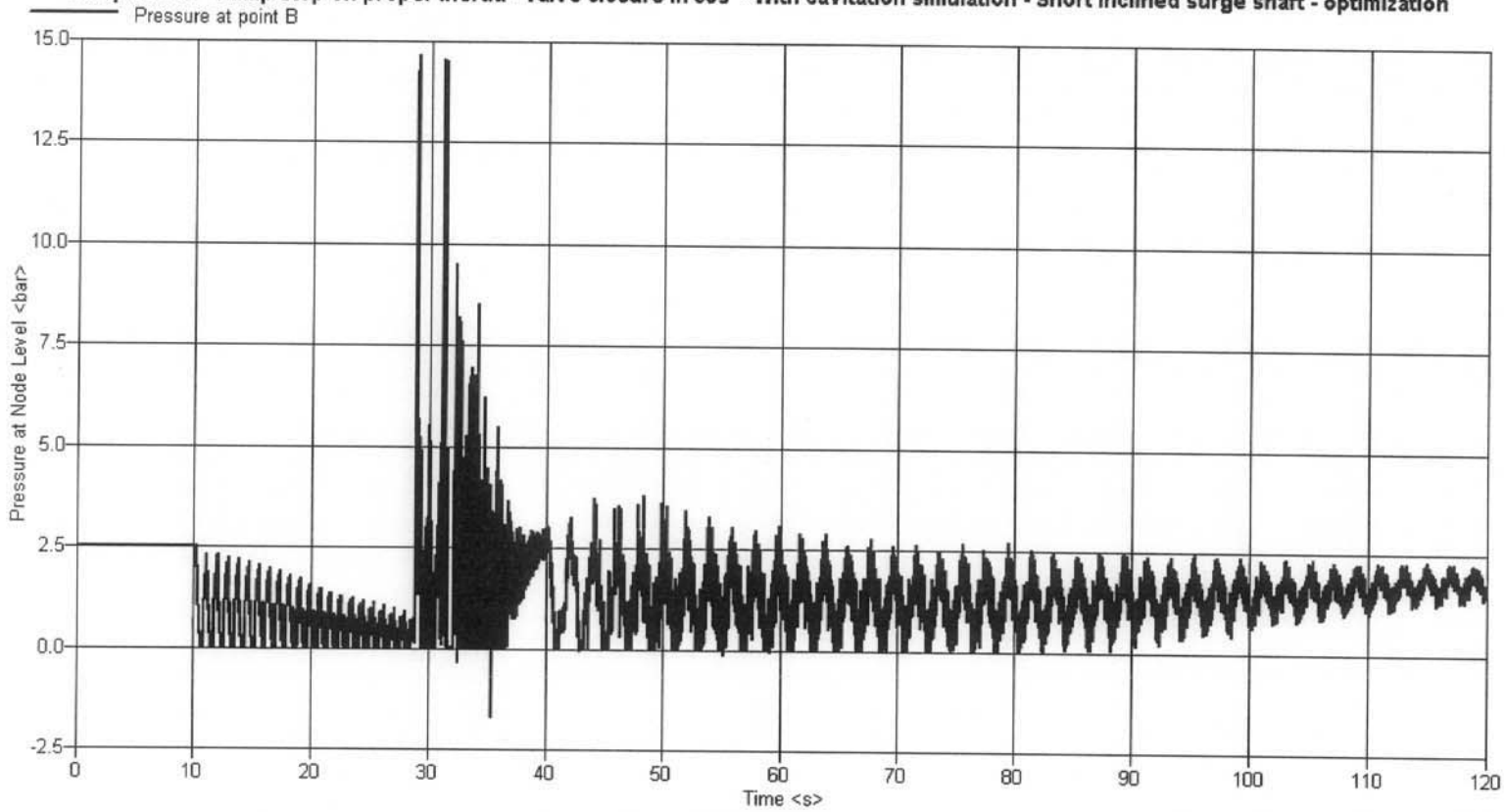


Annex 18.2


Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation simulation - Short inclined surge shaft - optimization
Pressure at point A
Cavity Volume at point A
Cavity Volume <m3>
Pressure at Node Level <bar>
Time <s>
100
80
60
40
20
0
15.0
12.5
10.0
7.5
5.0
2.5
0.0
-2.5
0
10
20
30
40
50
60
70
80
90
100
110
120

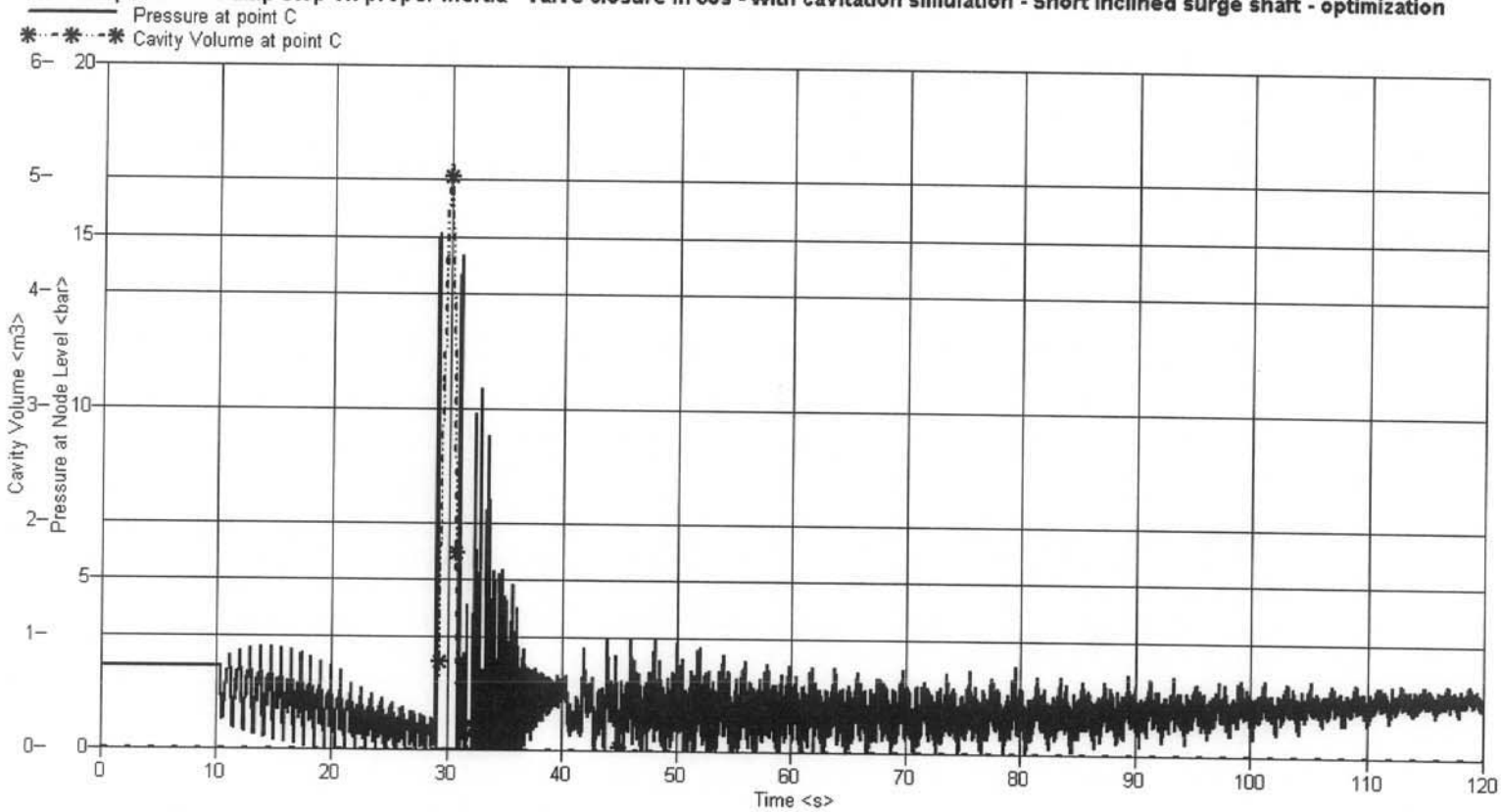
Annex 18.3

Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation simulation - Short inclined surge shaft - optimization

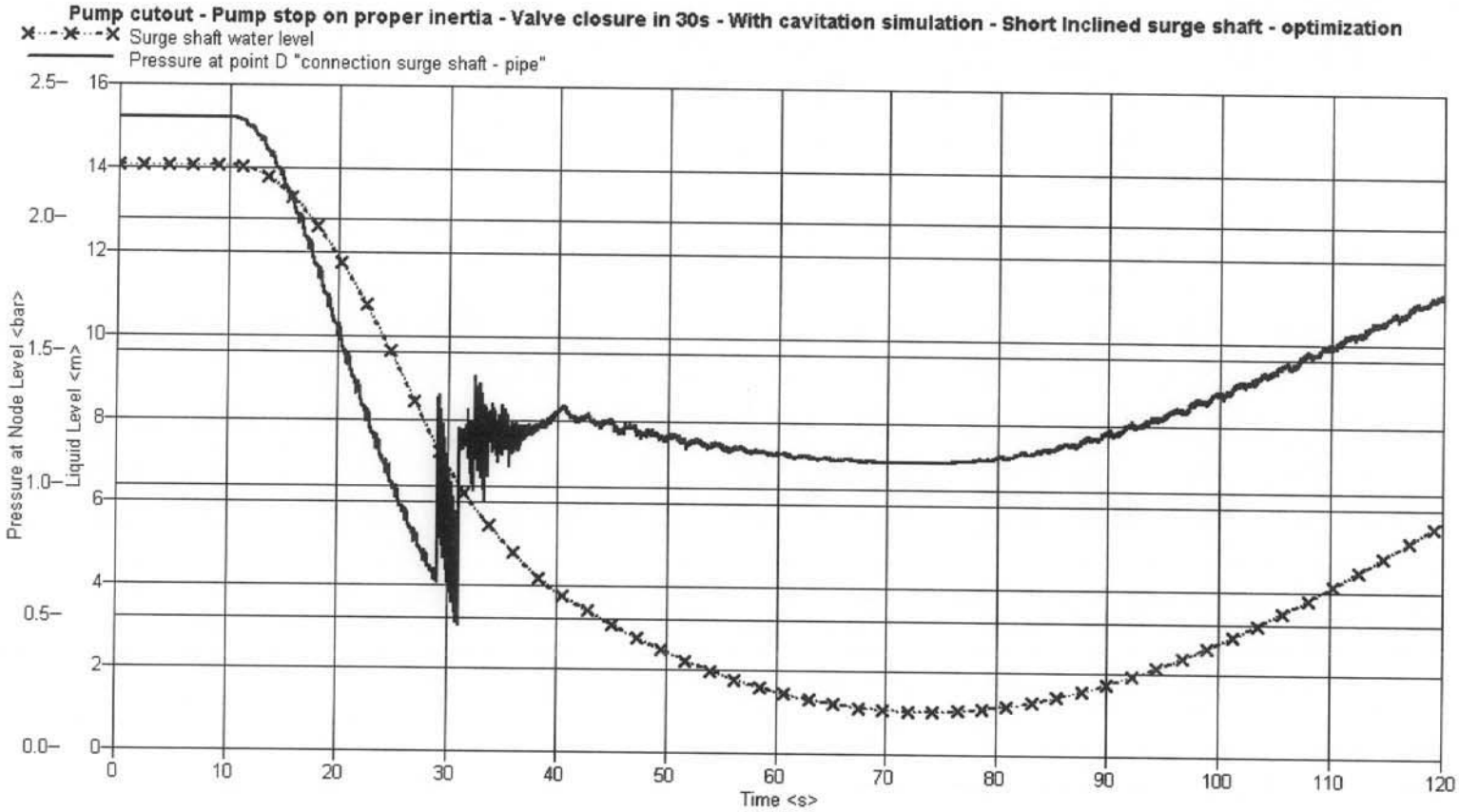


Annex 18.4

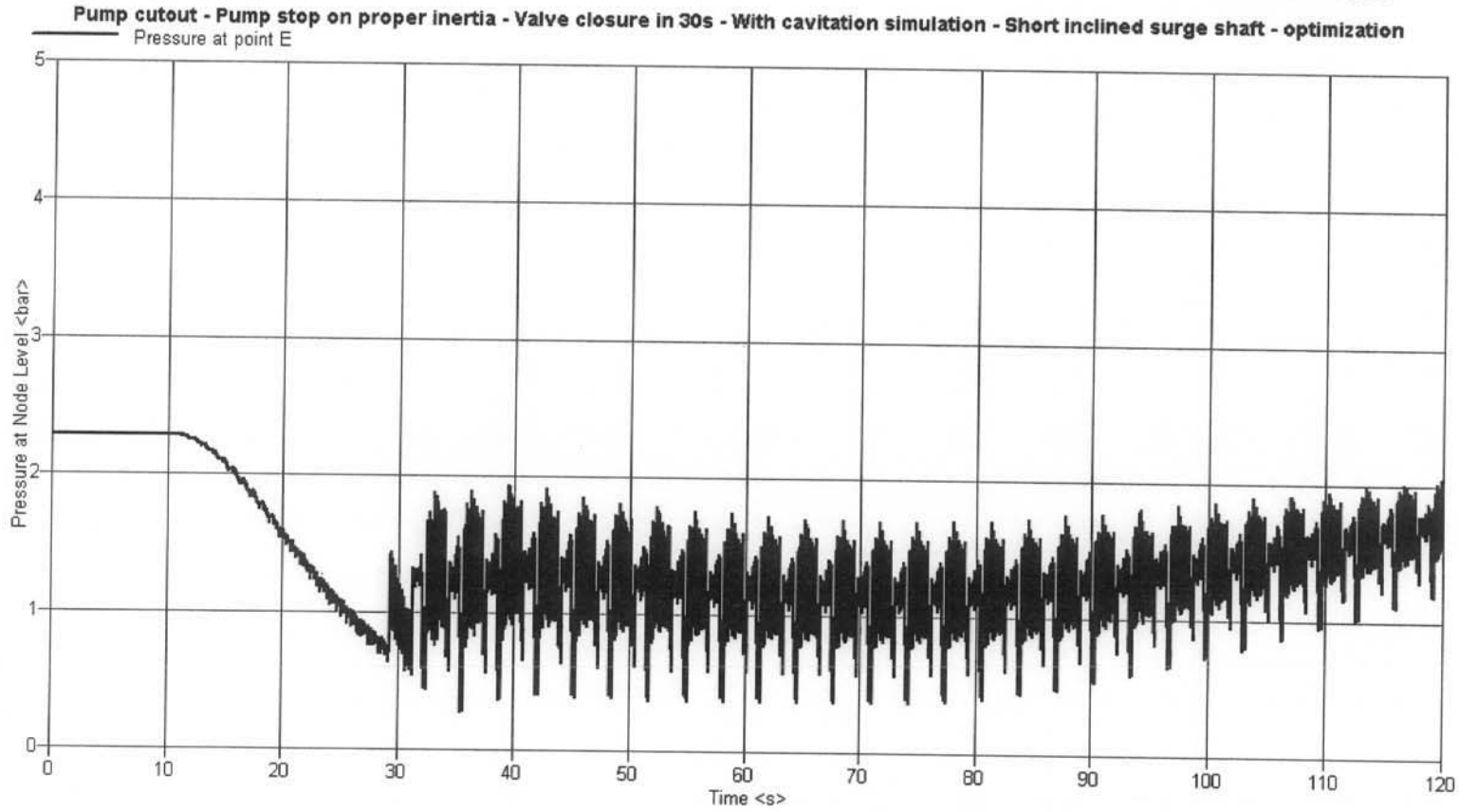
Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation simulation - Short inclined surge shaft - optimization



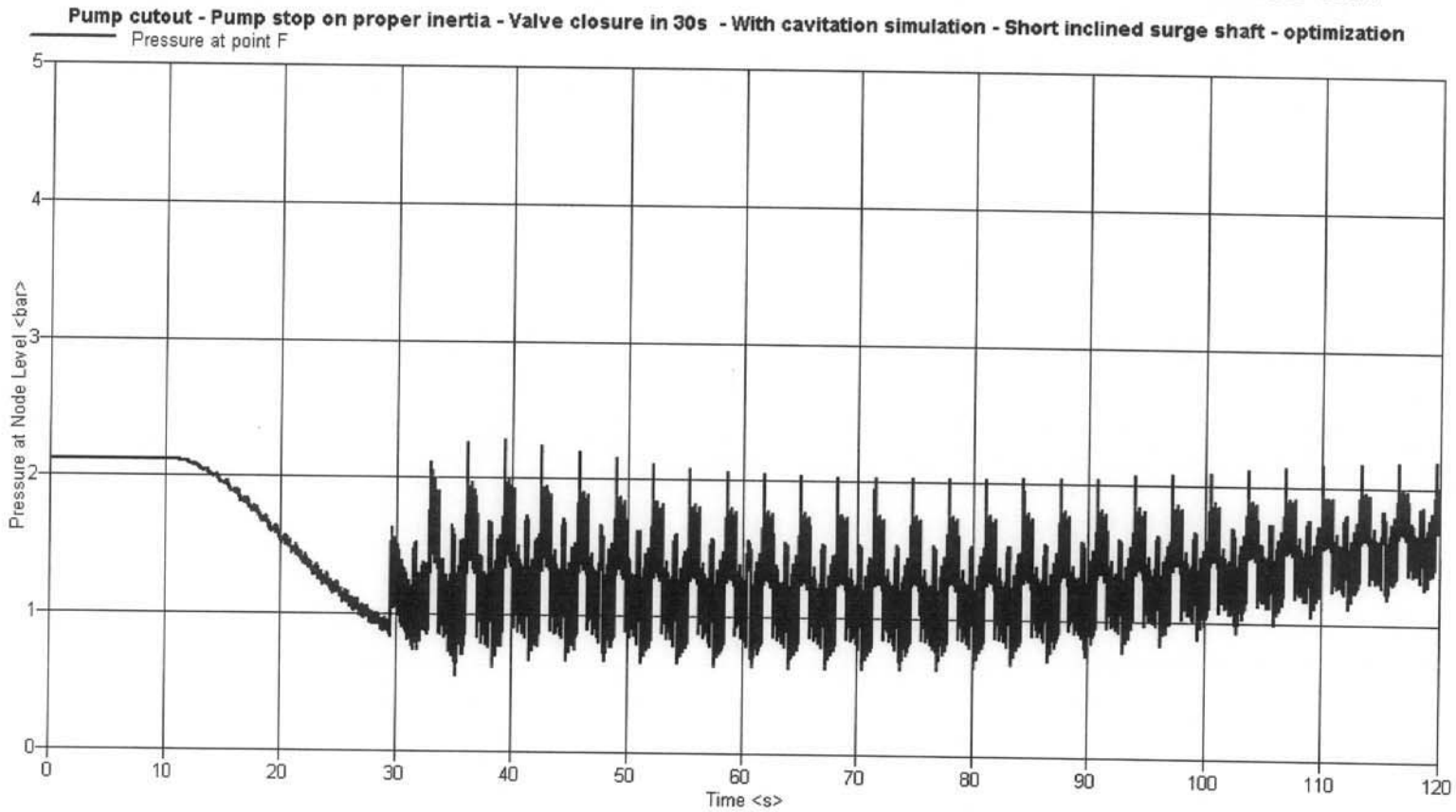
Annex 18.5


Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation simulation - Short inclined surge shaft - optimization
Surge shaft water level
Pressure at point D "connection surge shaft - pipe"
Pressure at Node Level <bar>
Liquid Level <m>
Time <s>
2.5
2.0
1.5
1.0
0.5
0.0
16
14
12
10
8
6
4
2
0
0
10
20
30
40
50
60
70
80
90
100
110
120

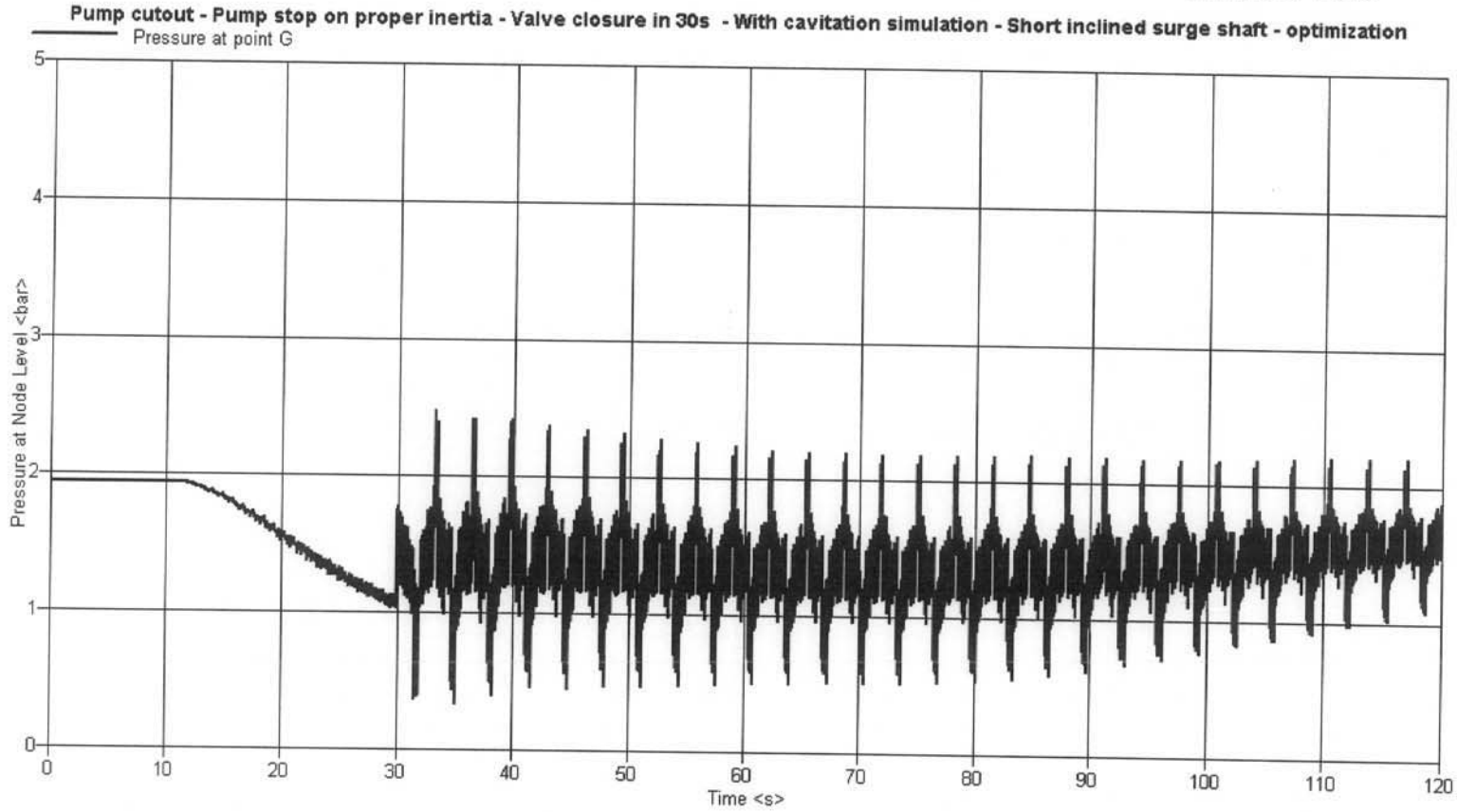
Annex 18.6


Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation simulation - Short inclined surge shaft - optimization
Pressure at point E
Pressure at Node Level <bar>
Time <s>
0
1
2
3
4
5
0
10
20
30
40
50
60
70
80
90
100
110
120

Annex 18.7


Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation simulation - Short inclined surge shaft - optimization
Pressure at point F
Pressure at Node Level <bar>
Time <s>
0
1
2
3
4
5
0
10
20
30
40
50
60
70
80
90
100
110
120

Annex 18.8

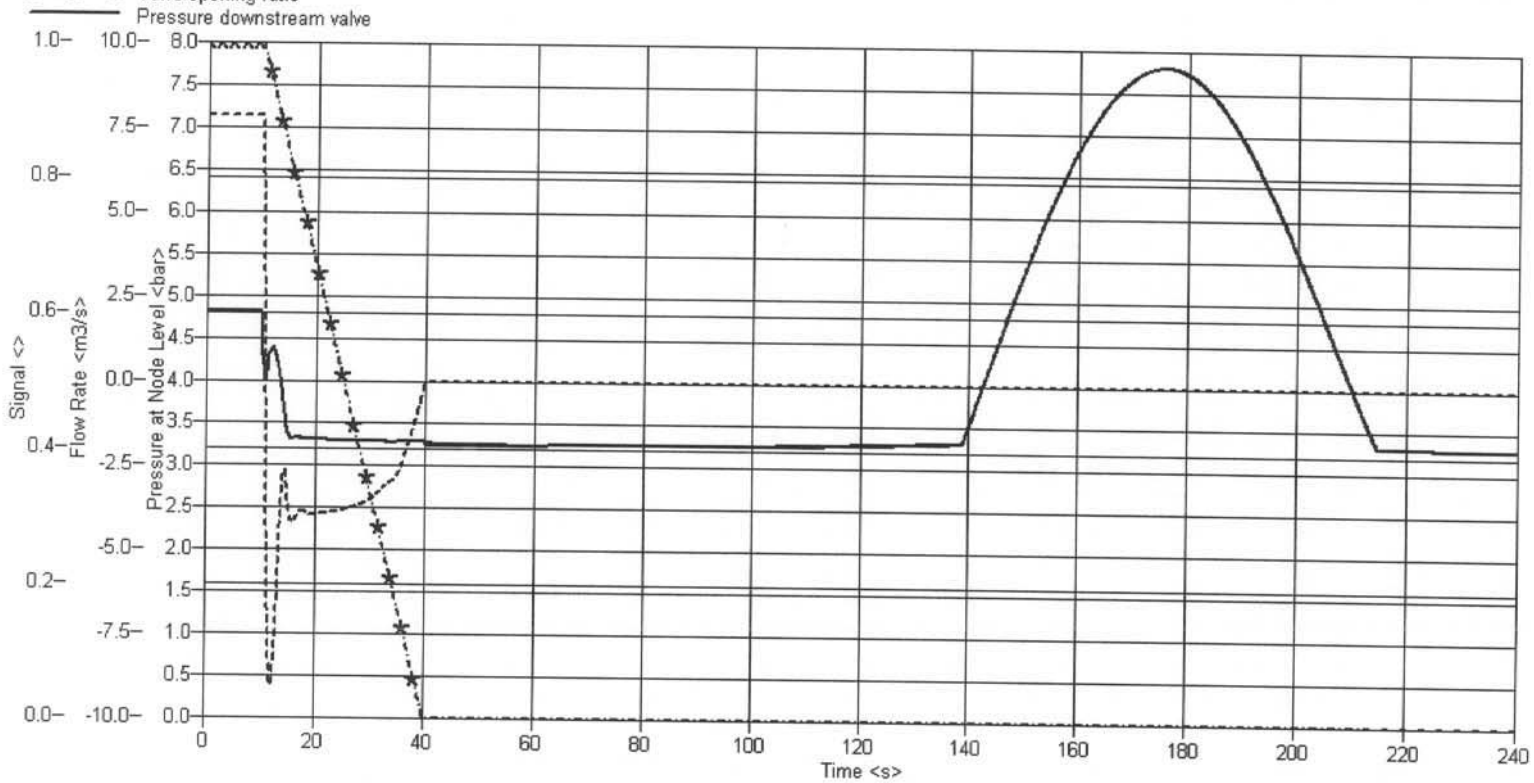

Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation simulation - Short inclined surge shaft - optimization
Pressure at point G
Pressure at Node Level <bar>
Time <s>
0
1
2
3
4
5
0
10
20
30
40
50
60
70
80
90
100
110
120

Annex 19

Long inclined surge shaft

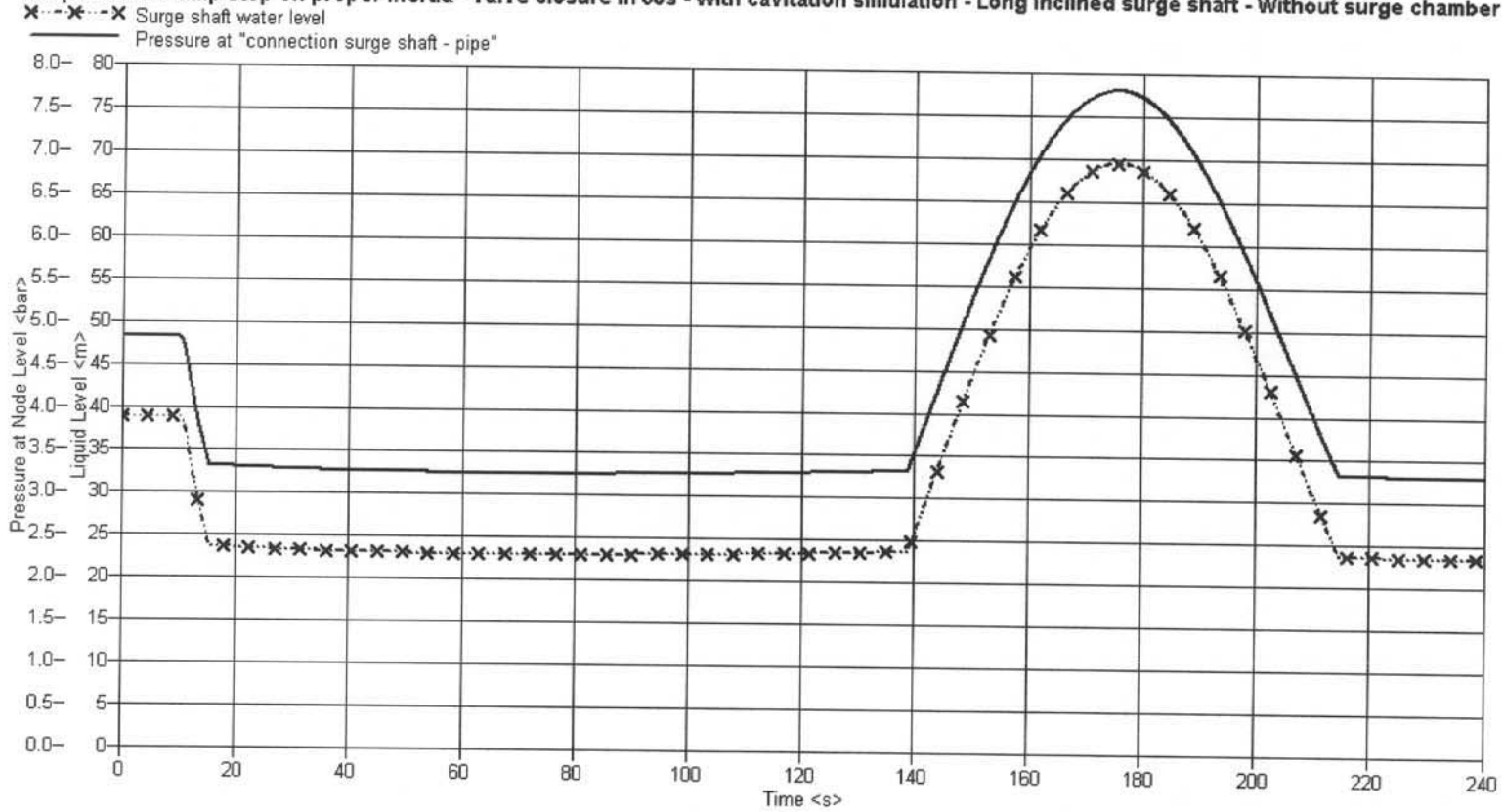
Annex 19.1

Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation simulation - Long inclined surge shaft - Without surge chamber



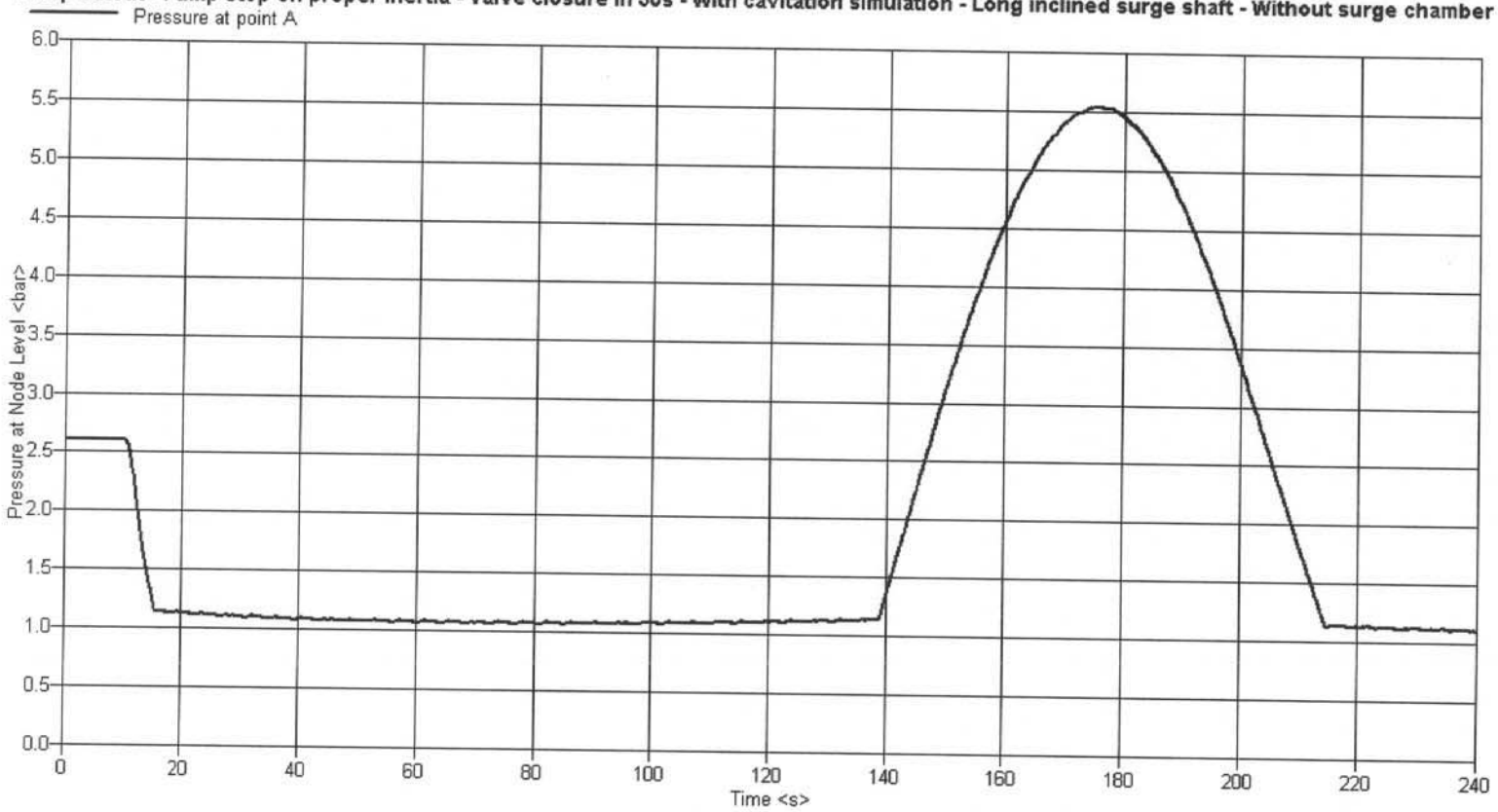
Annex 19.2

Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation simulation - Long inclined surge shaft - Without surge chamber



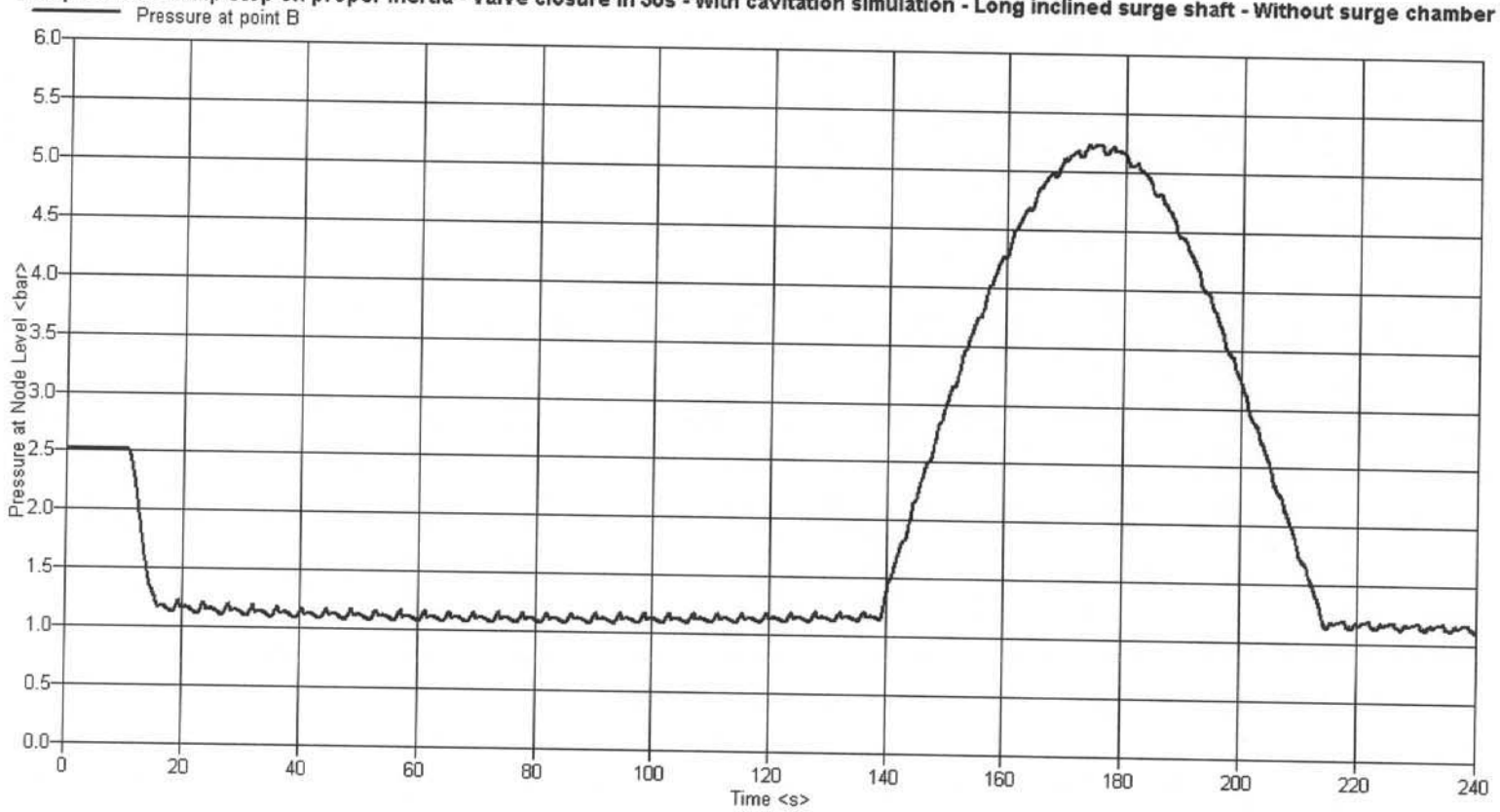
Annex 19.3

Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation simulation - Long inclined surge shaft - Without surge chamber



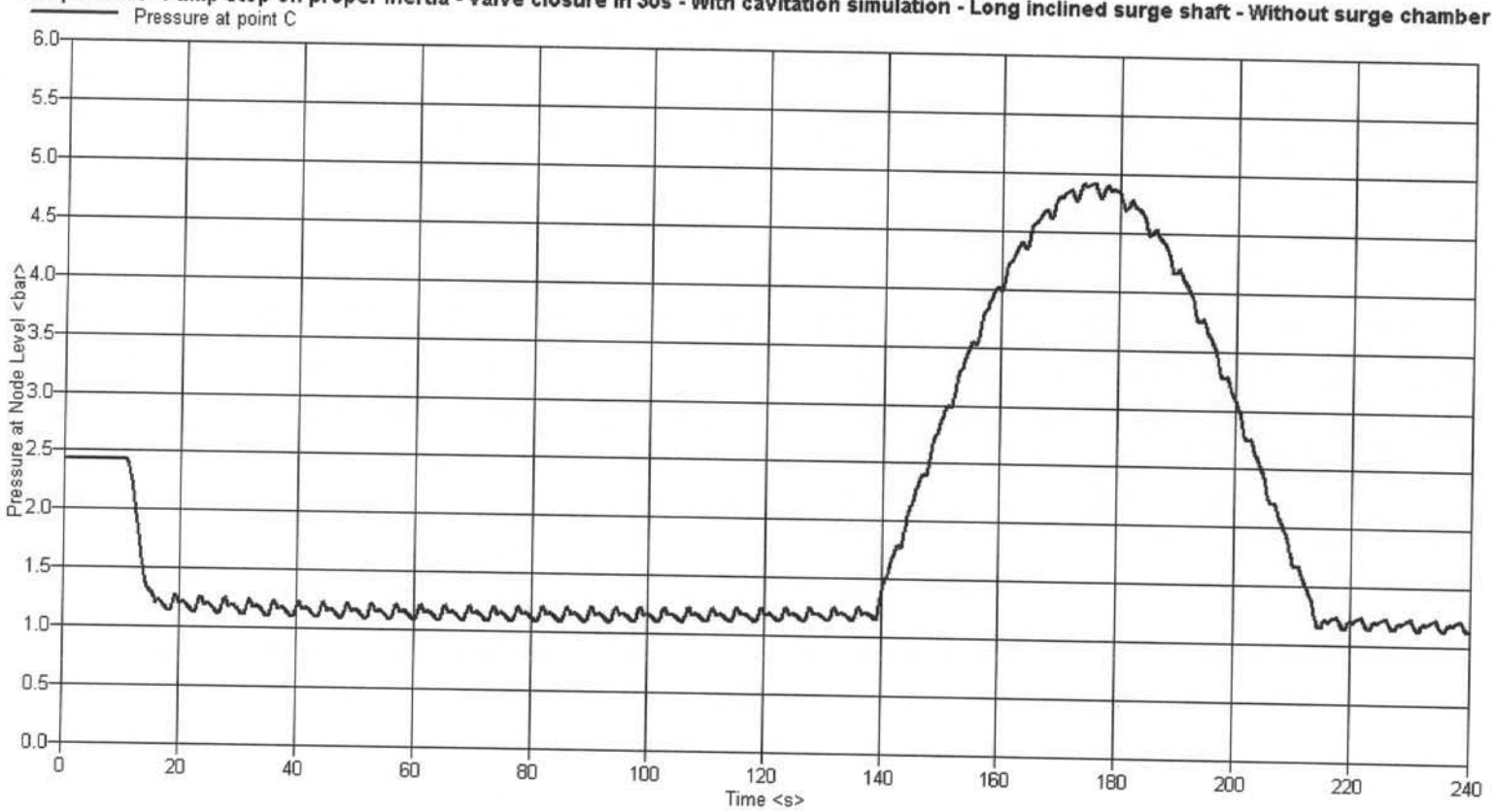
Annex 19.4

Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation simulation - Long inclined surge shaft - Without surge chamber



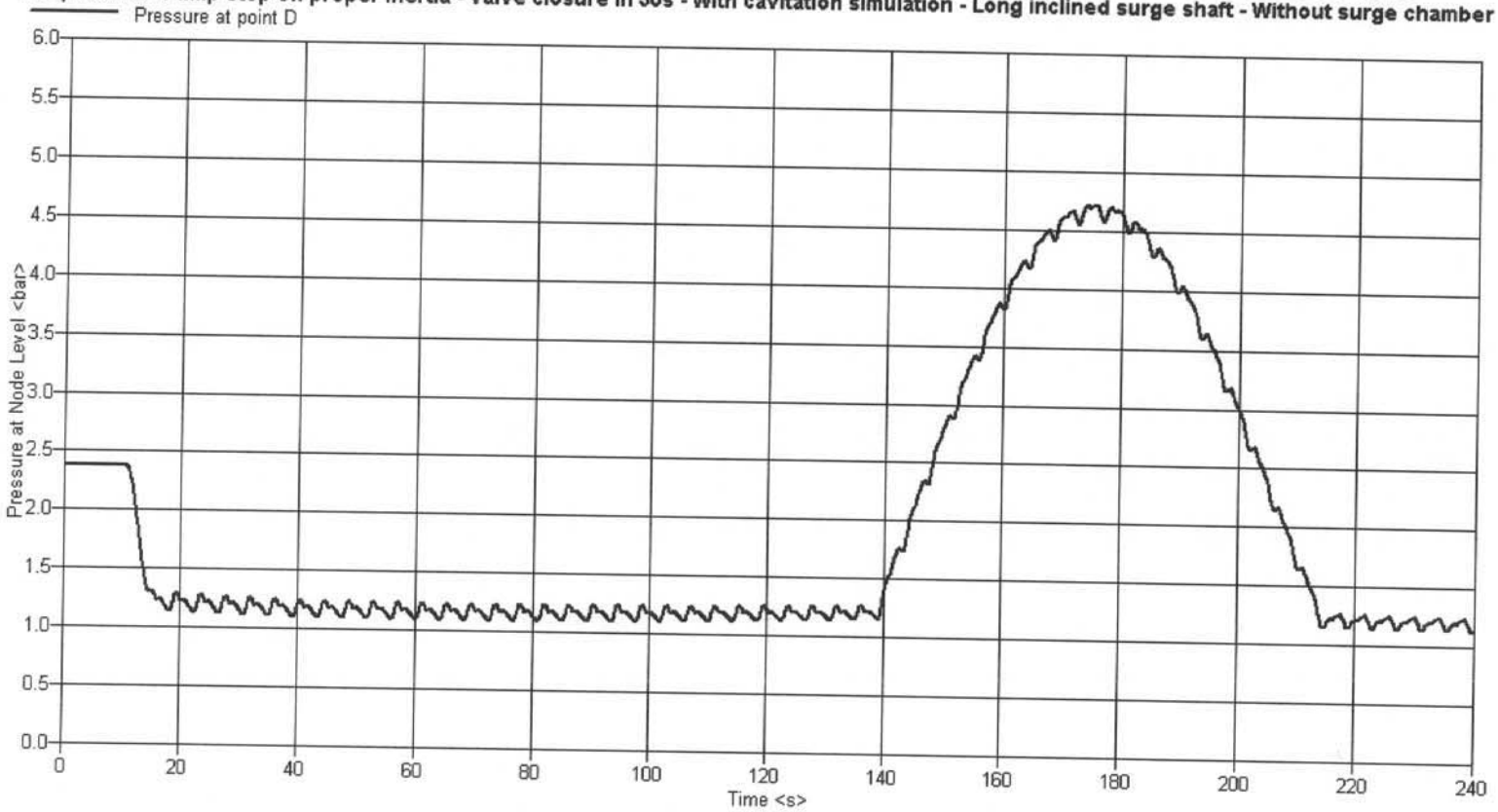
Annex 19.5

Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation simulation - Long inclined surge shaft - Without surge chamber



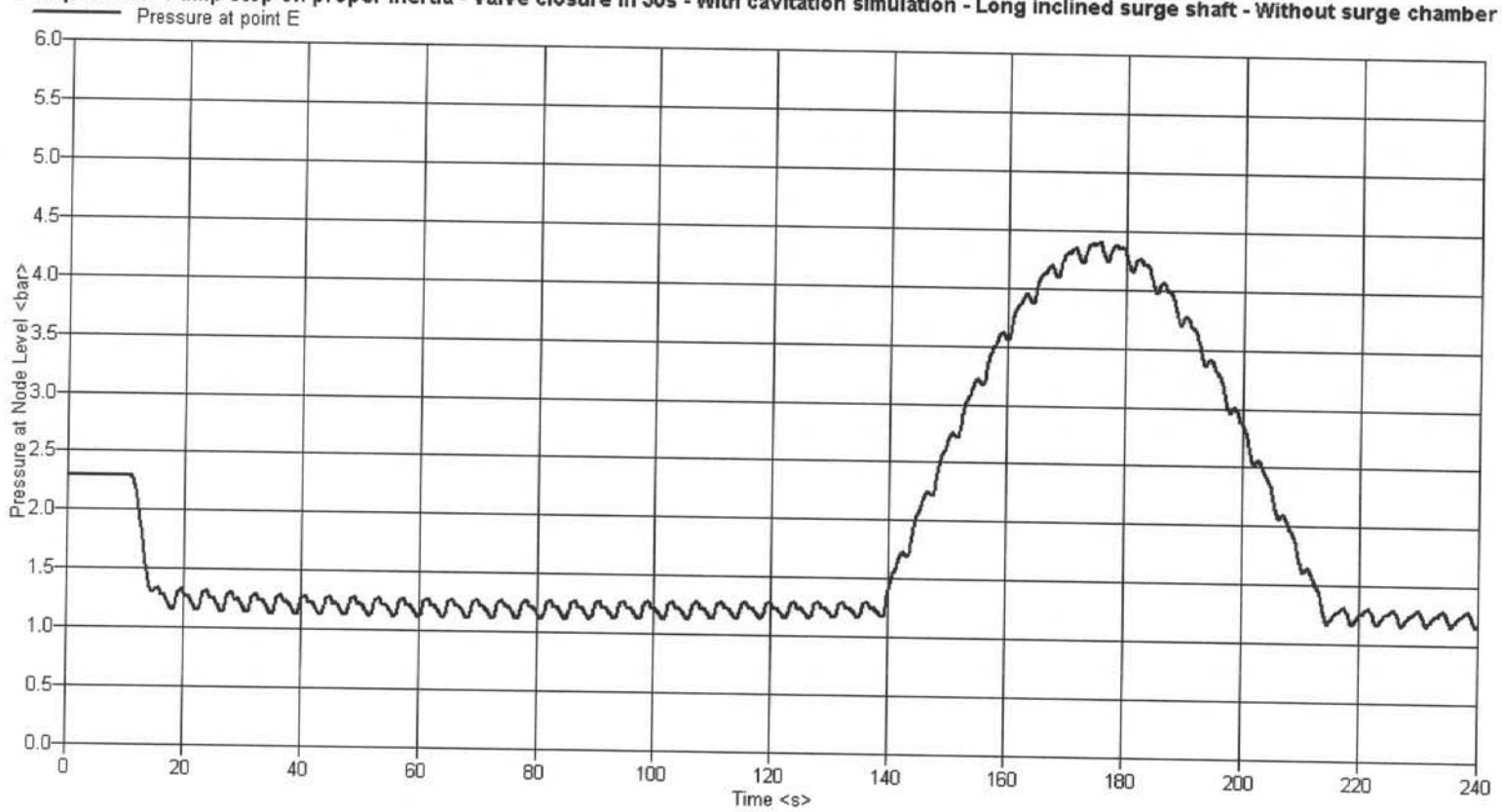
Annex 19.6

Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation simulation - Long inclined surge shaft - Without surge chamber



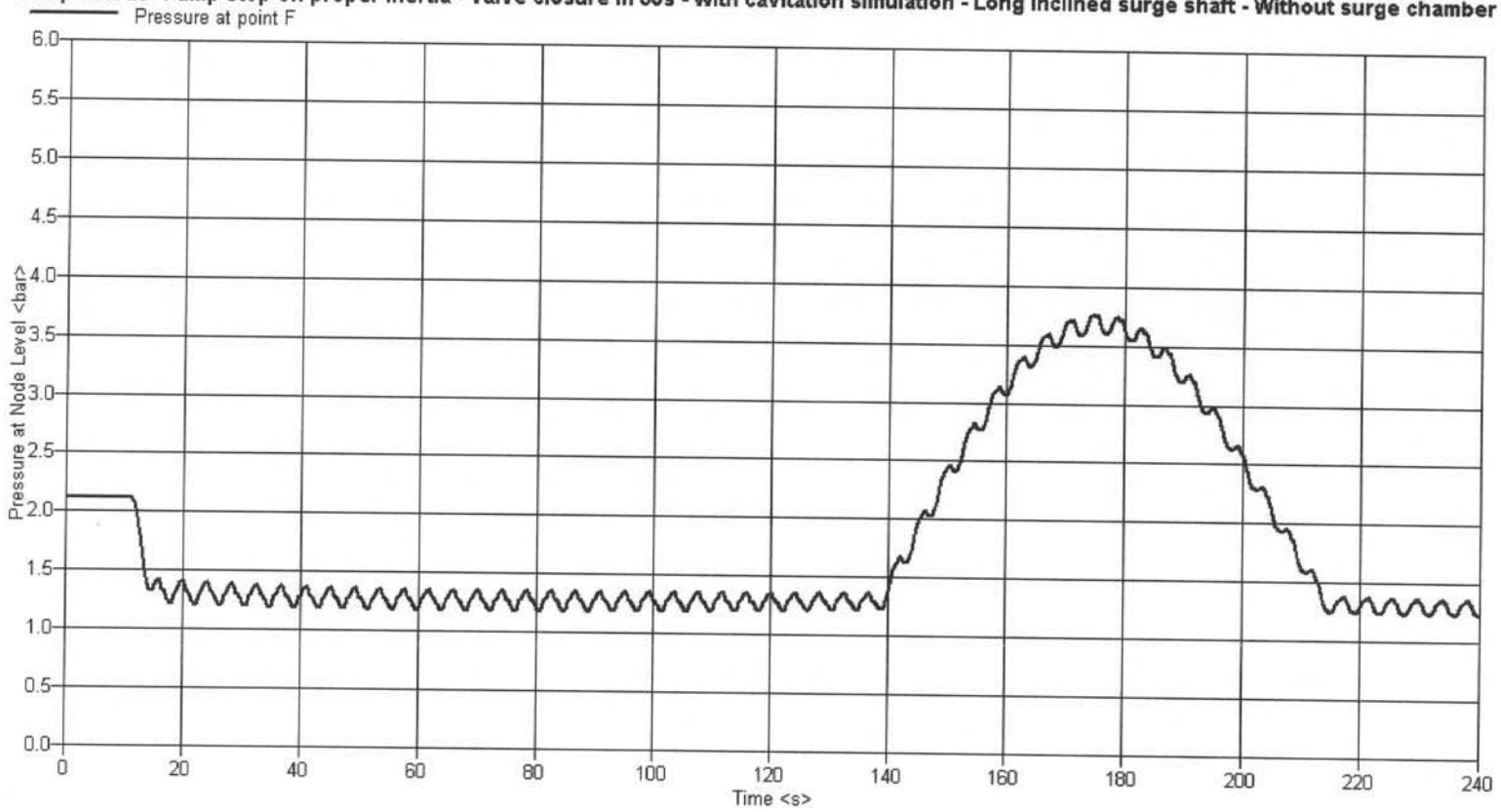
Annex 19.7

Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation simulation - Long inclined surge shaft - Without surge chamber



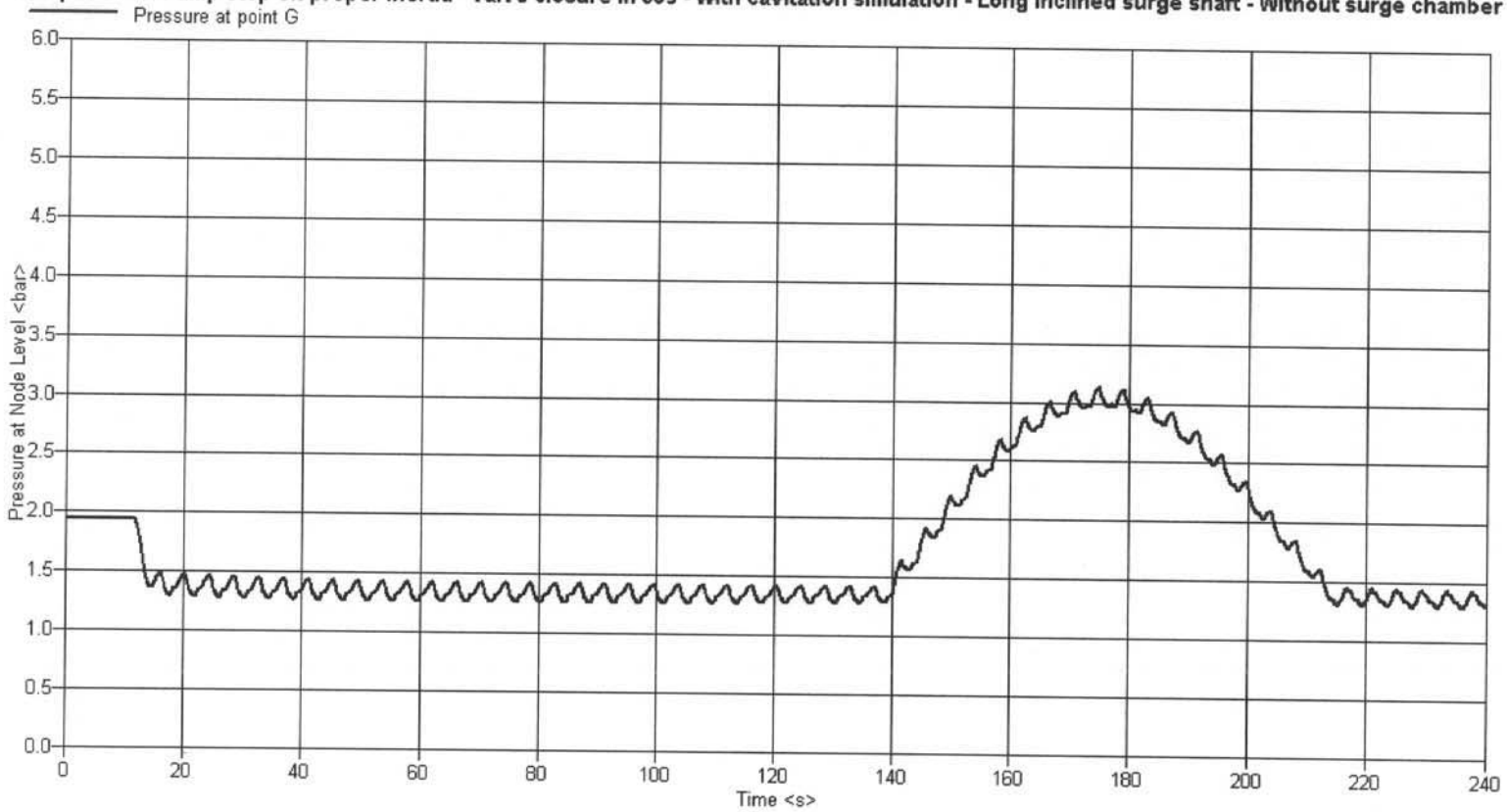
Annex 19.8

Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation simulation - Long inclined surge shaft - Without surge chamber



Annex 19.9

Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation simulation - Long inclined surge shaft - Without surge chamber

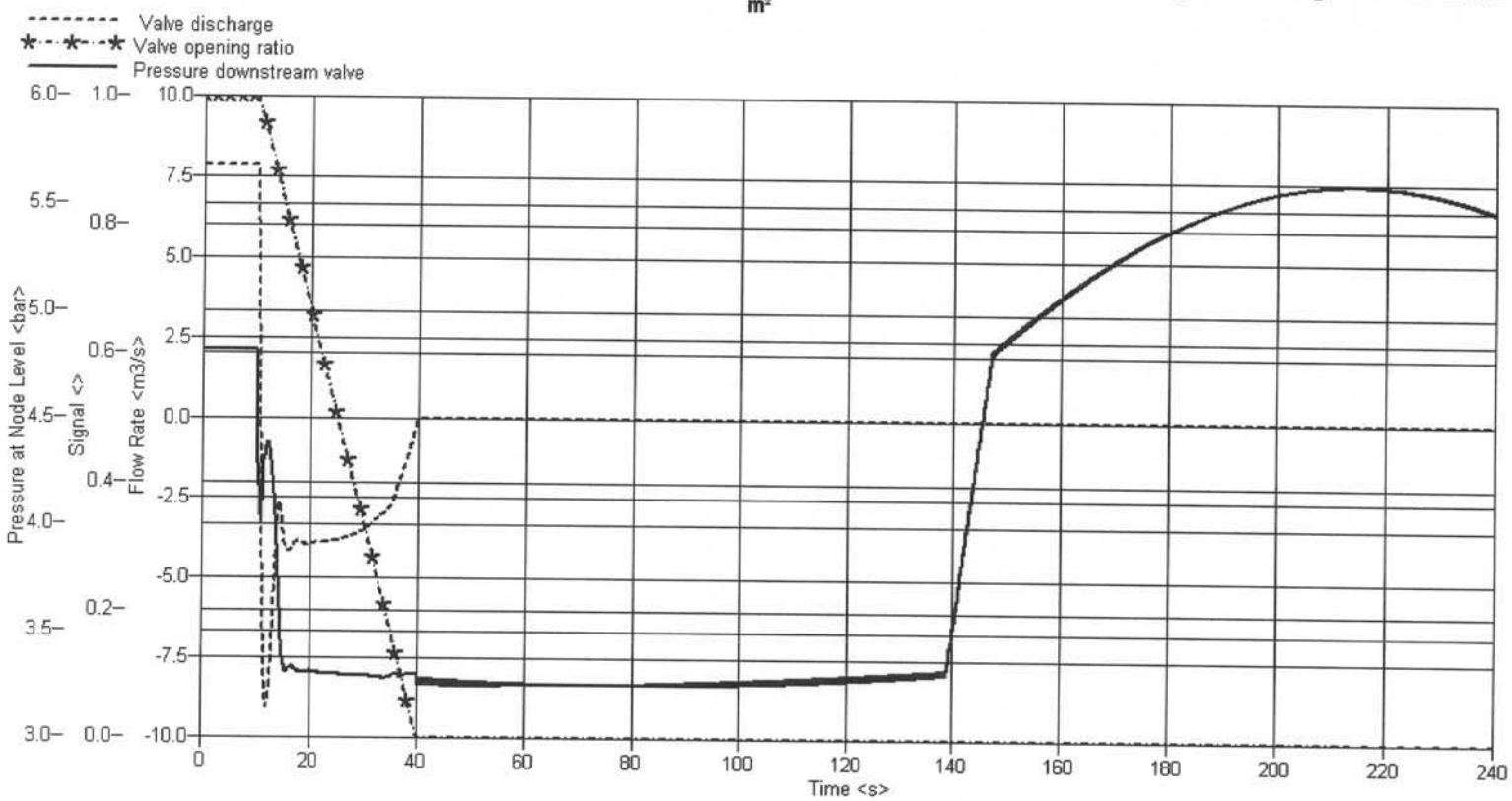


Annex 20

Long inclined surge shaft D=3.20 m Surge chamber 100 m²

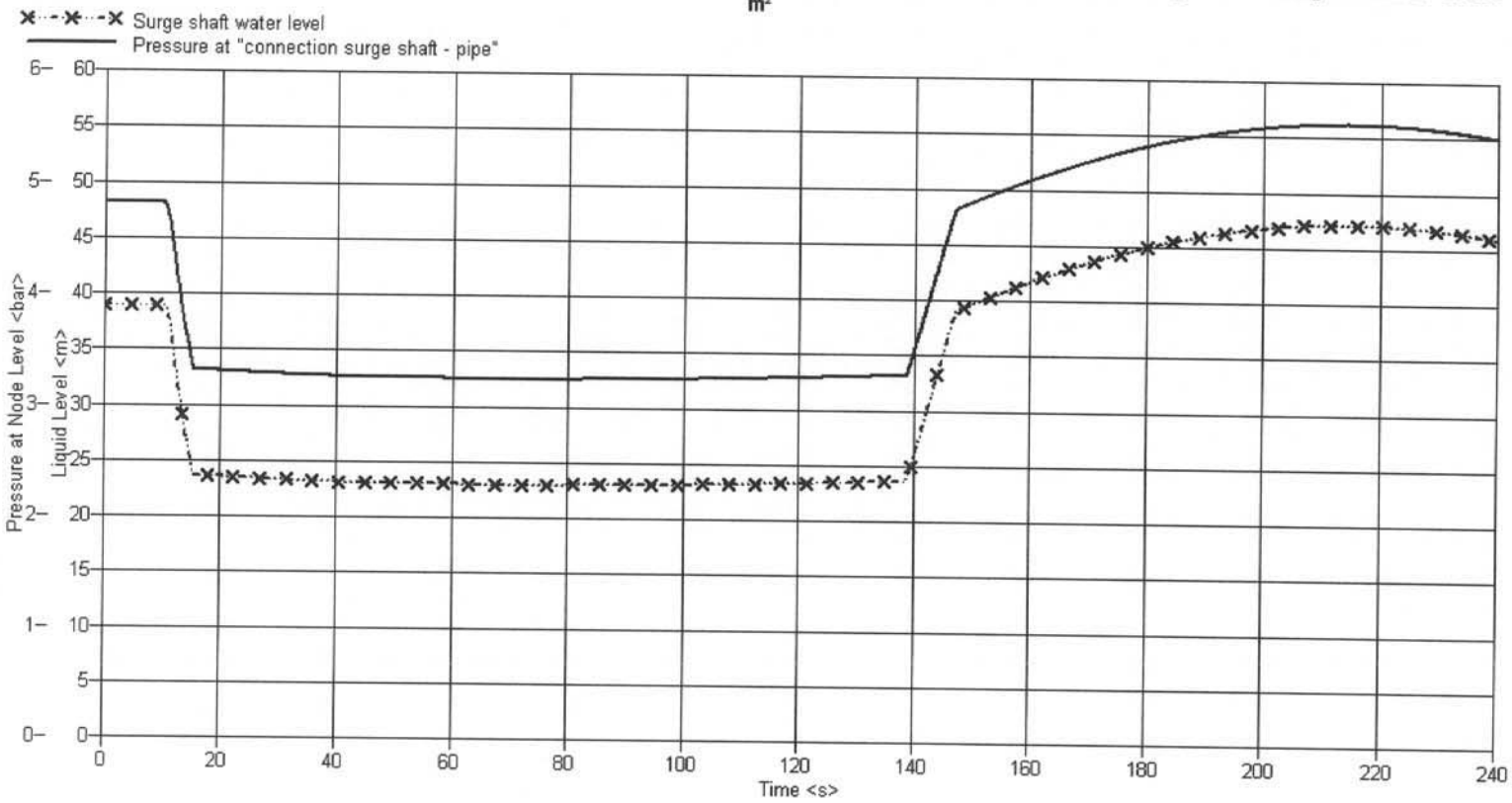
Annex 20.1

Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation simulation - Long inclined surge shaft - Surge chamber of 100 m²



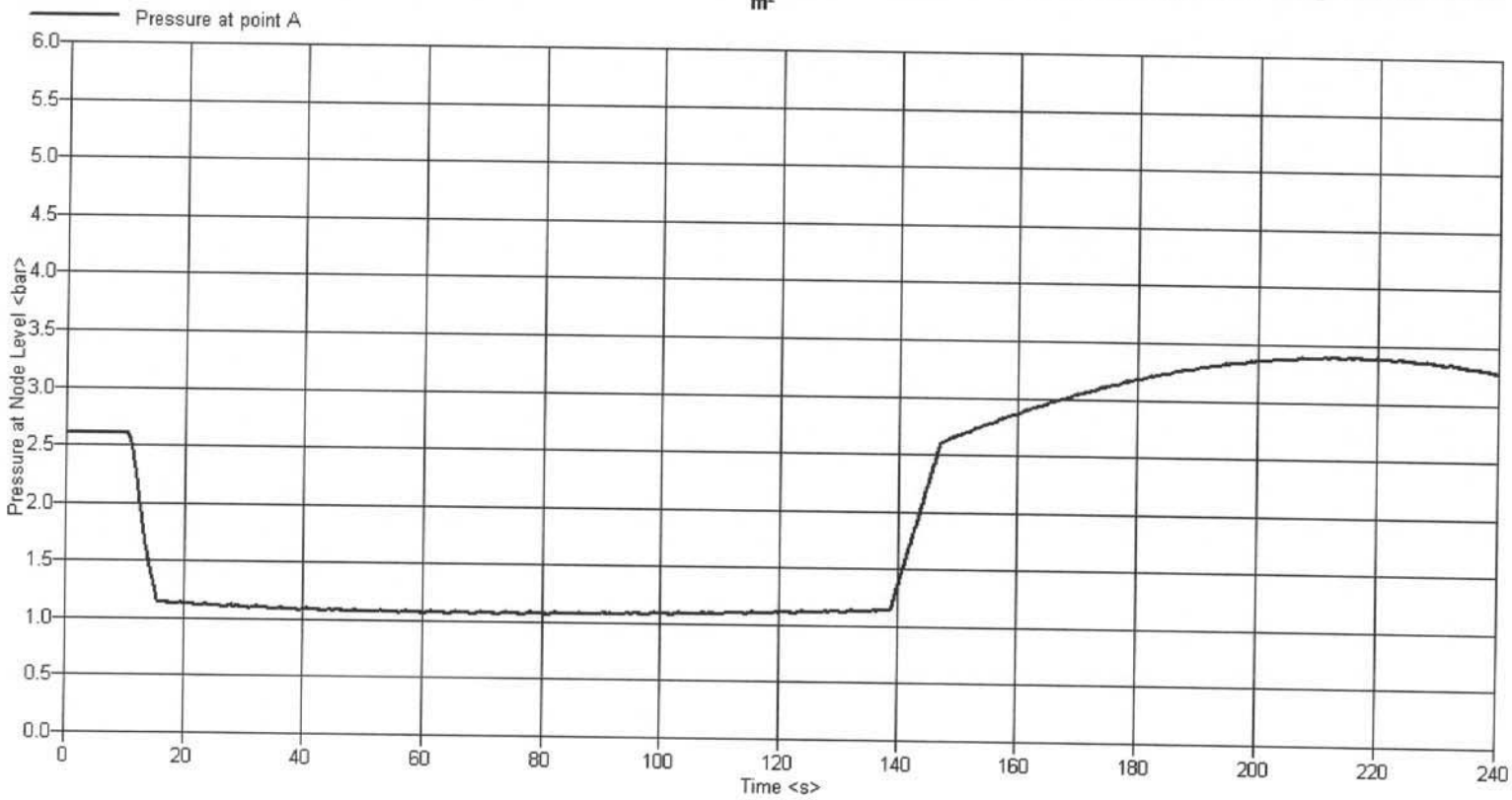
Annex 20.2

Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation simulation - Long inclined surge shaft - Surge chamber of 100 m²



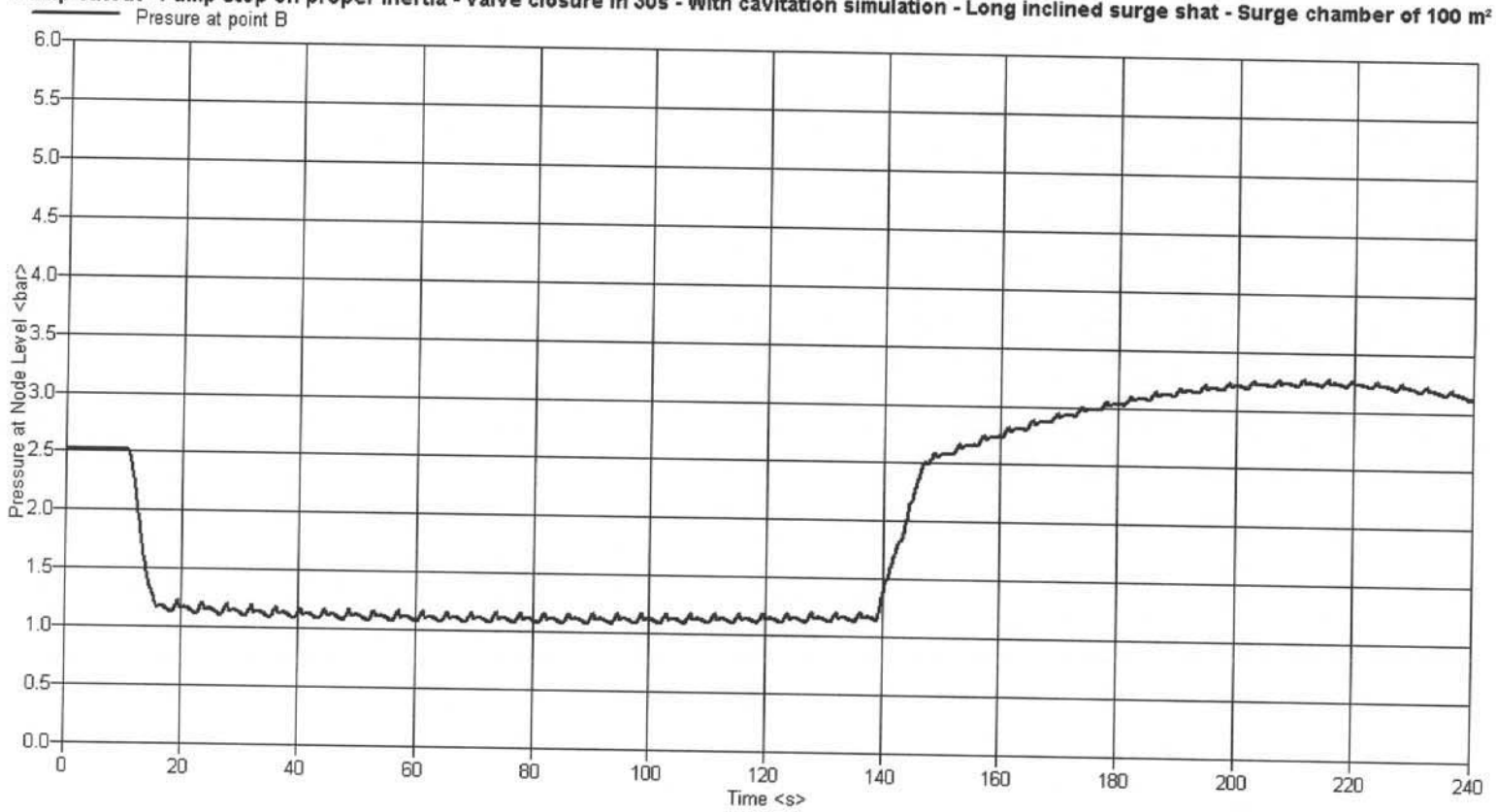
Annex 20.3

Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation simulation - Long inclined surge shaft - Surge chamber of 100 m²



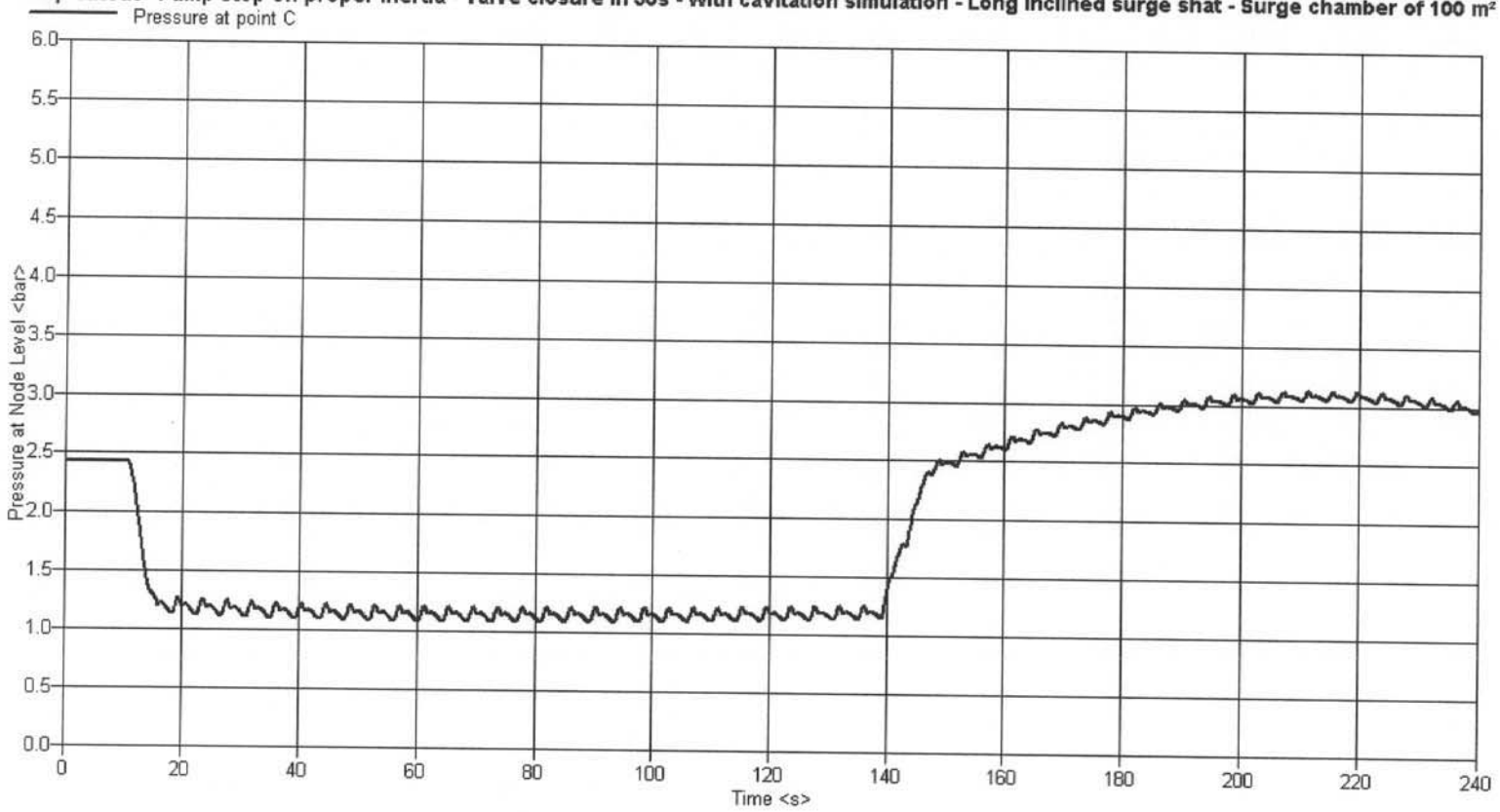
Annex 20.4

Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation simulation - Long inclined surge shat - Surge chamber of 100 m²



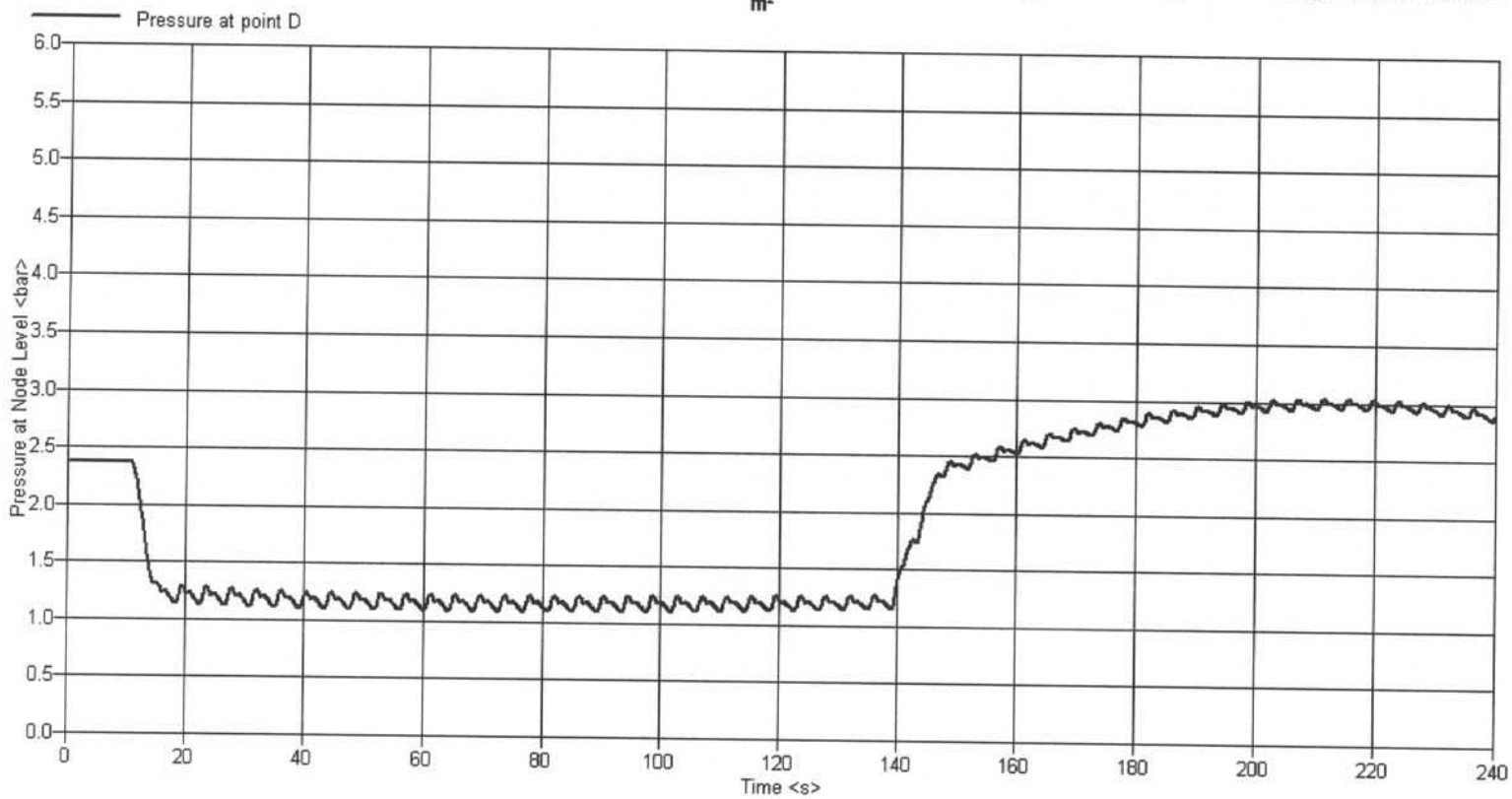
Annex 20.5

Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation simulation - Long inclined surge shat - Surge chamber of 100 m²



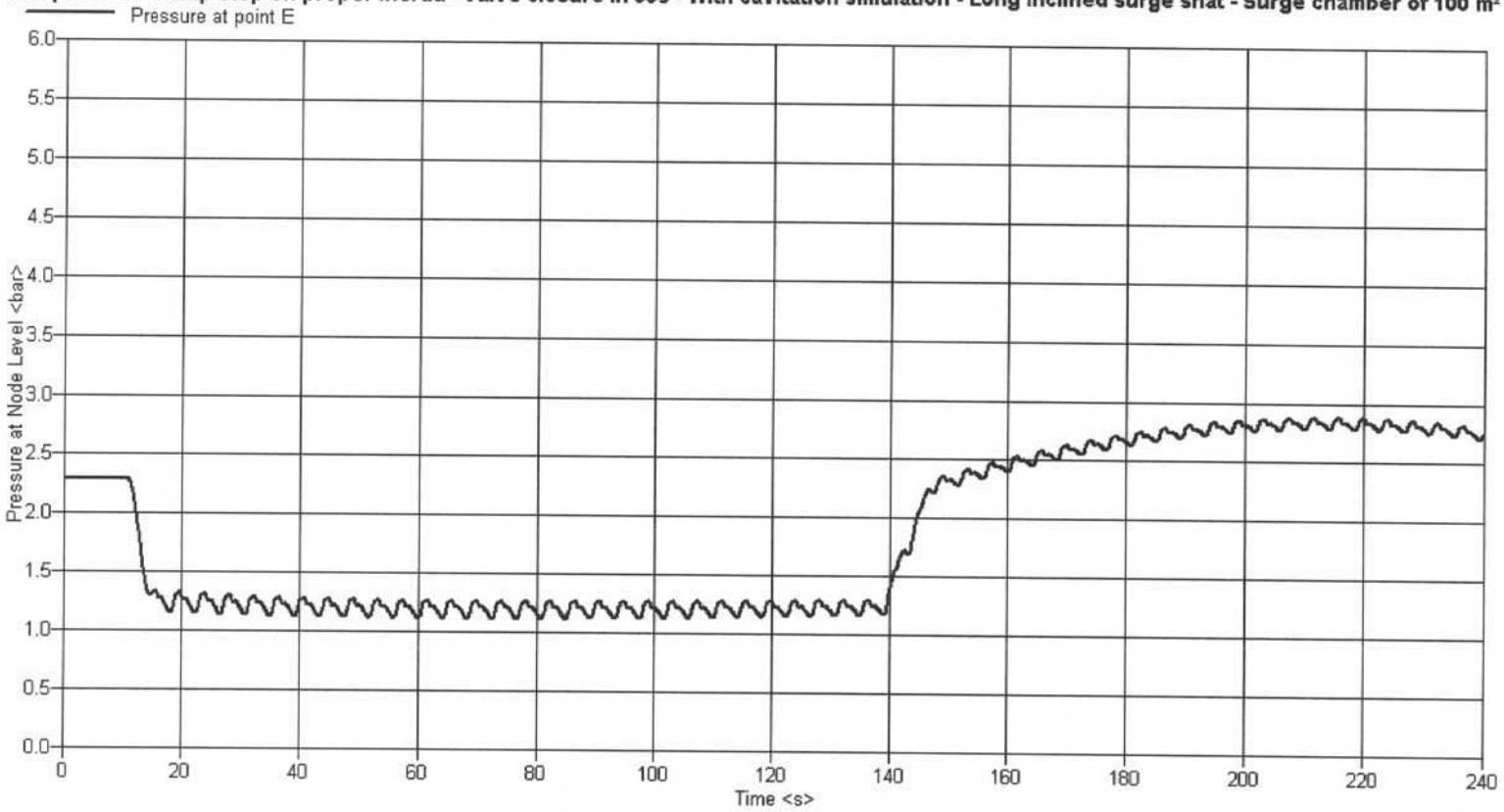
Annex 20.6

Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation simulation - Long inclined surge shaft - Surge chamber of 100 m²



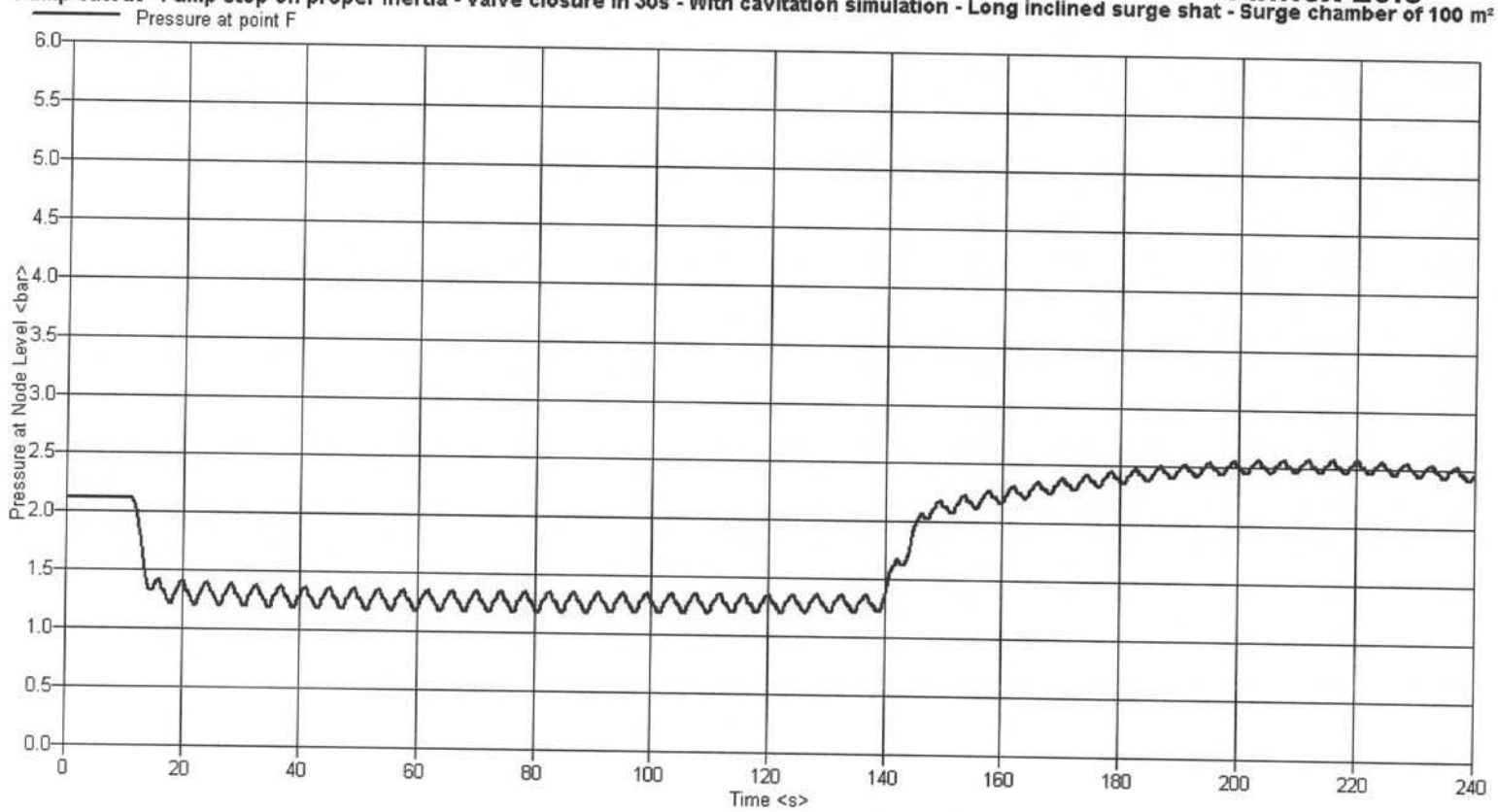
Annex 20.7

Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation simulation - Long inclined surge shat - Surge chamber of 100 m²



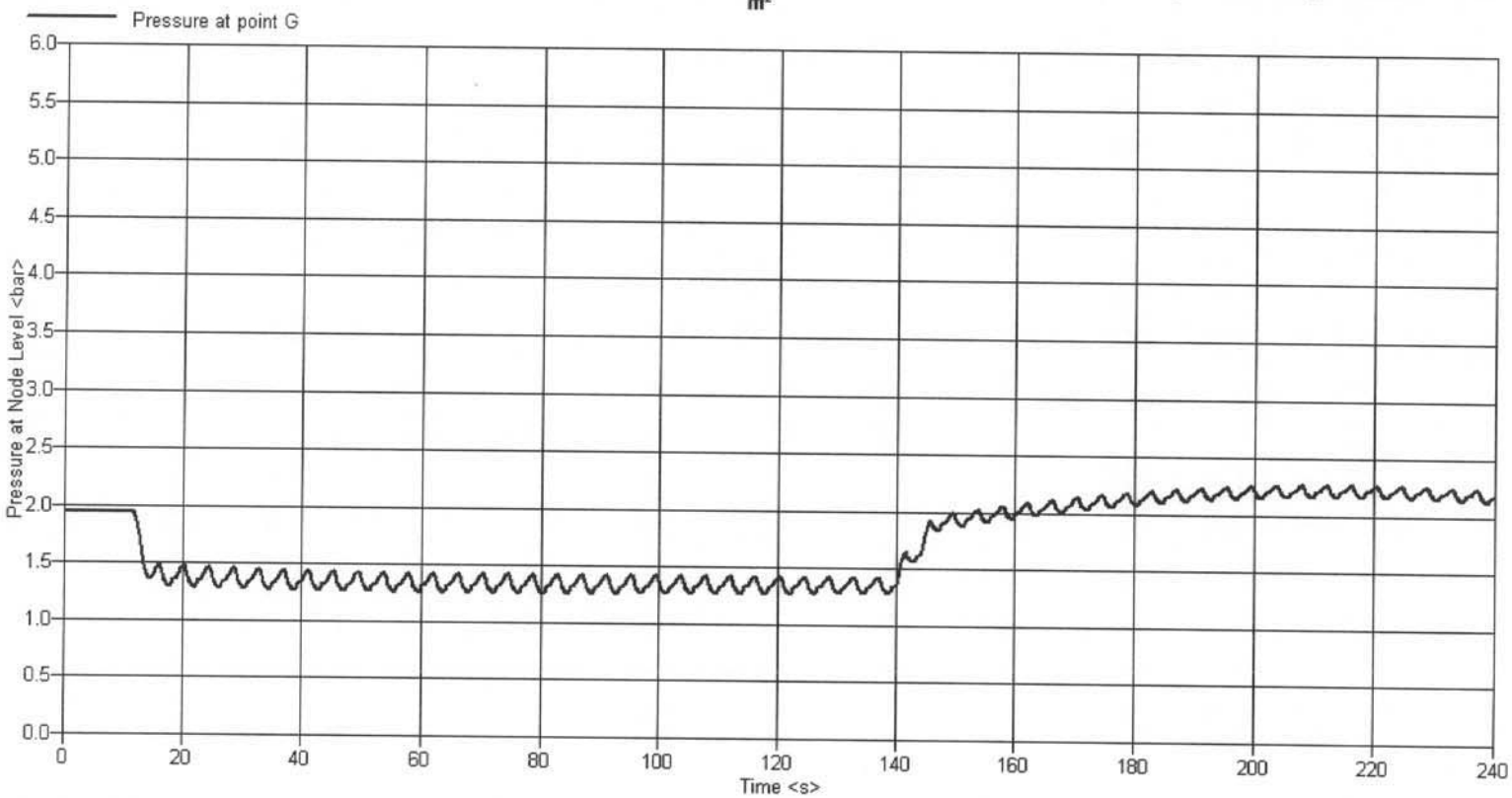
Annex 20.8

Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation simulation - Long inclined surge shat - Surge chamber of 100 m²



Annex 20.9

Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation simulation - Long inclined surge shaft - Surge chamber of 100 m²

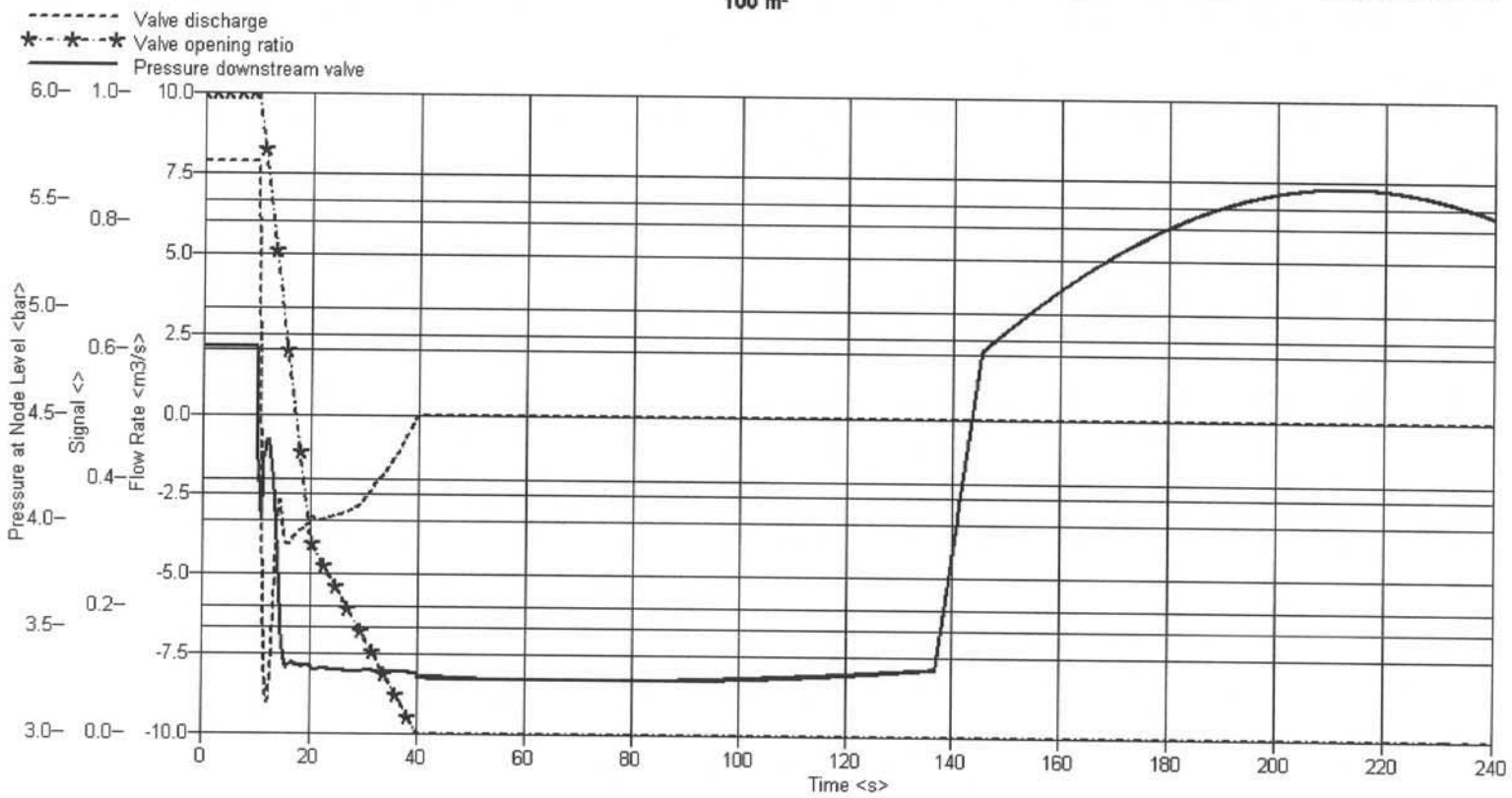


Annex 21

Long inclined surge shaft D=3.20 m Surge chamber 100 m²
New closure law

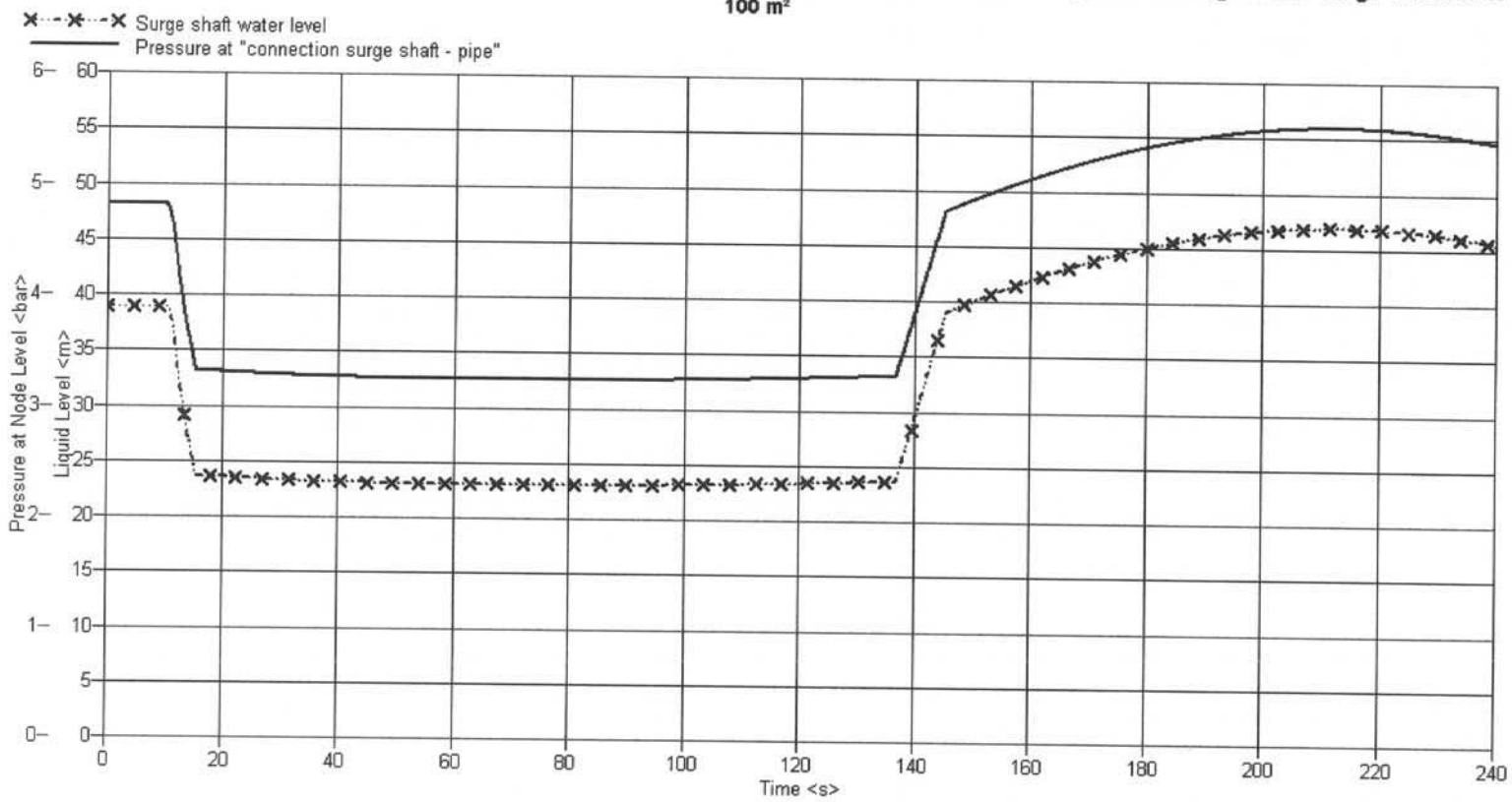
Annex 21.1

Pump cutout - Pump stop on proper inertia - New law of valve closure - With cavitation simulation - Long inclined surge shaft - Surge chamber of 100 m²



Annex 21.2

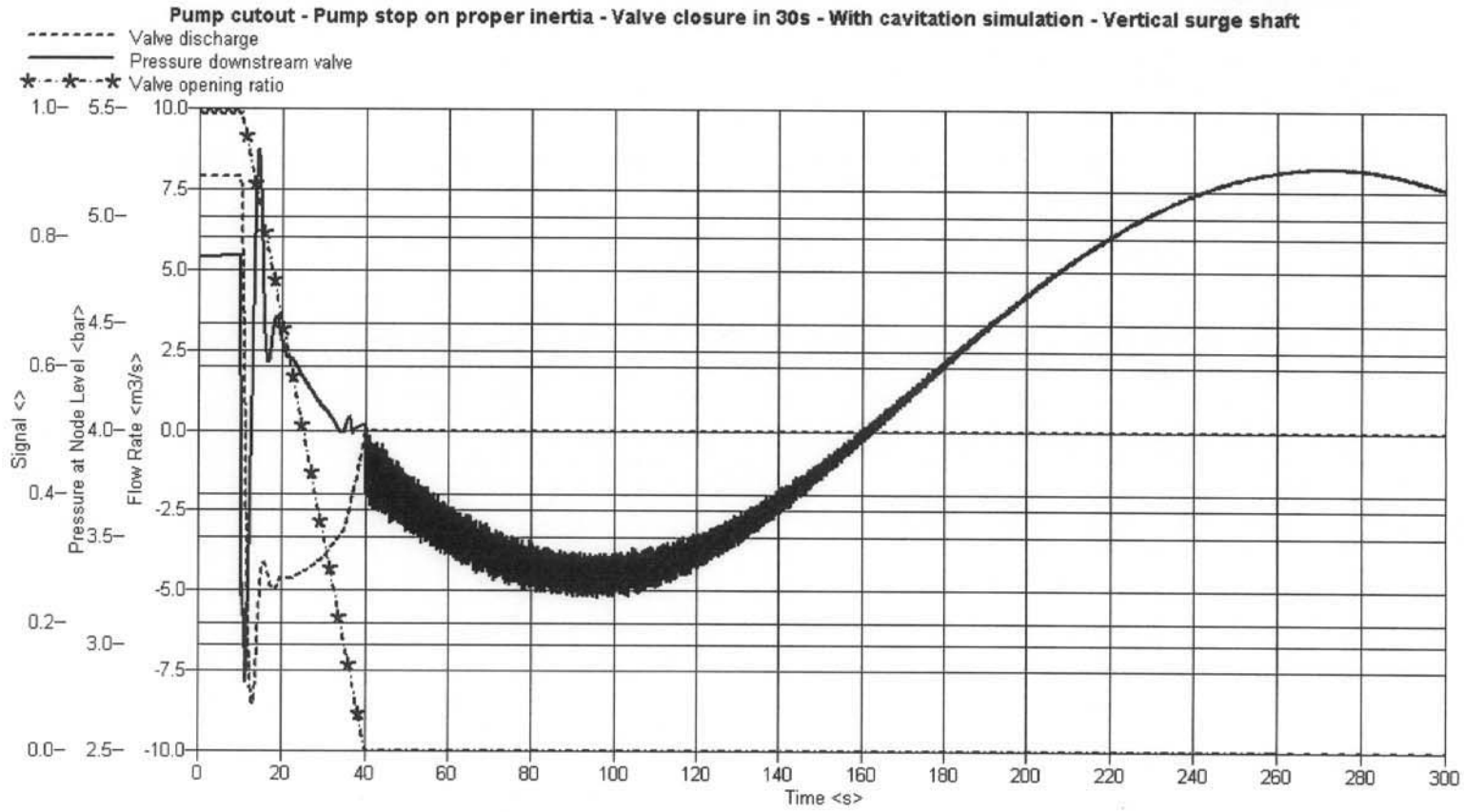
Pump cutout - Pump stop on proper inertia - New law of valve closure - With cavitation simulation - Long inclined surge shaft - Surge chamber of 100 m²



Annex 22

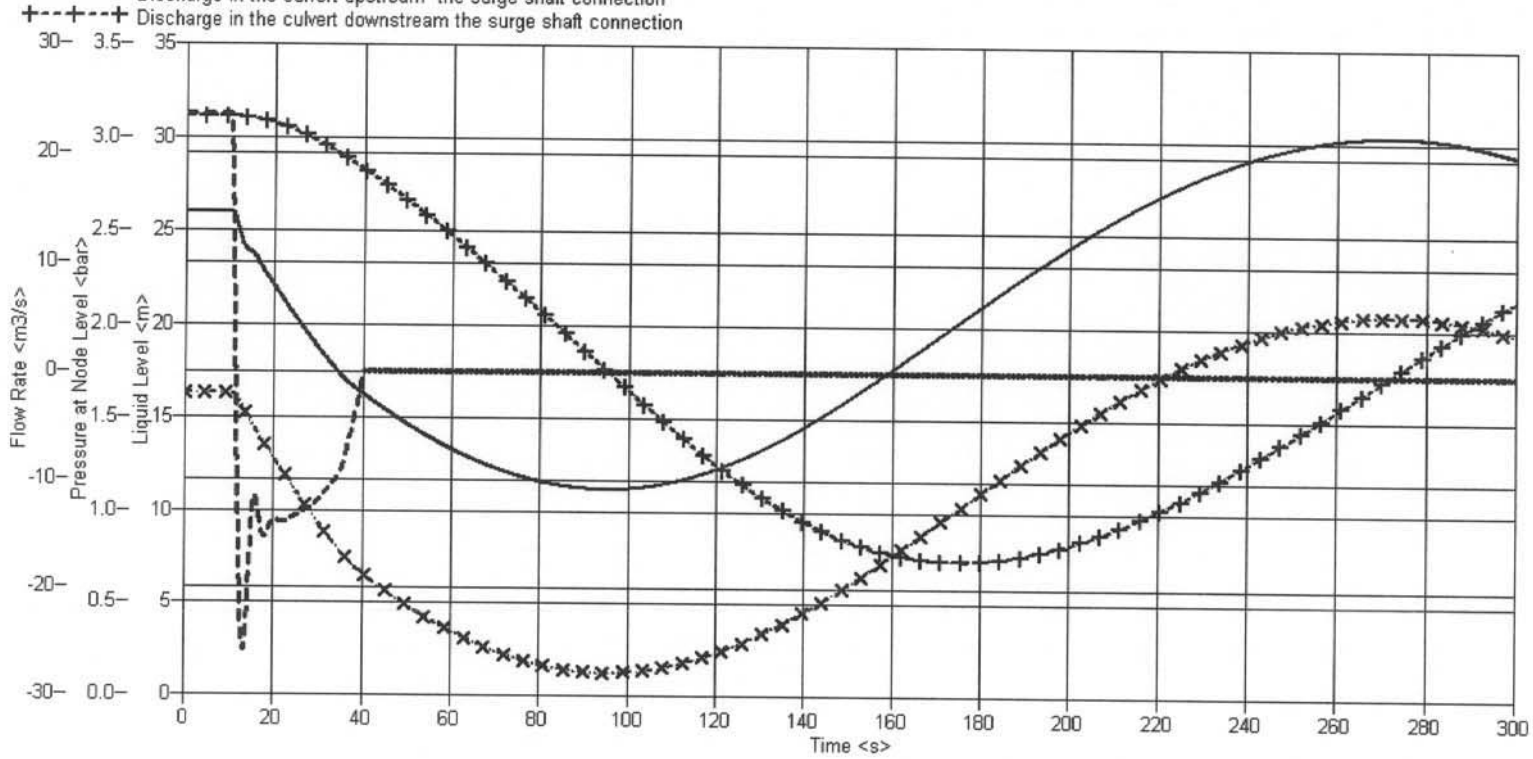
Vertical surge shaft

Annex 22.1

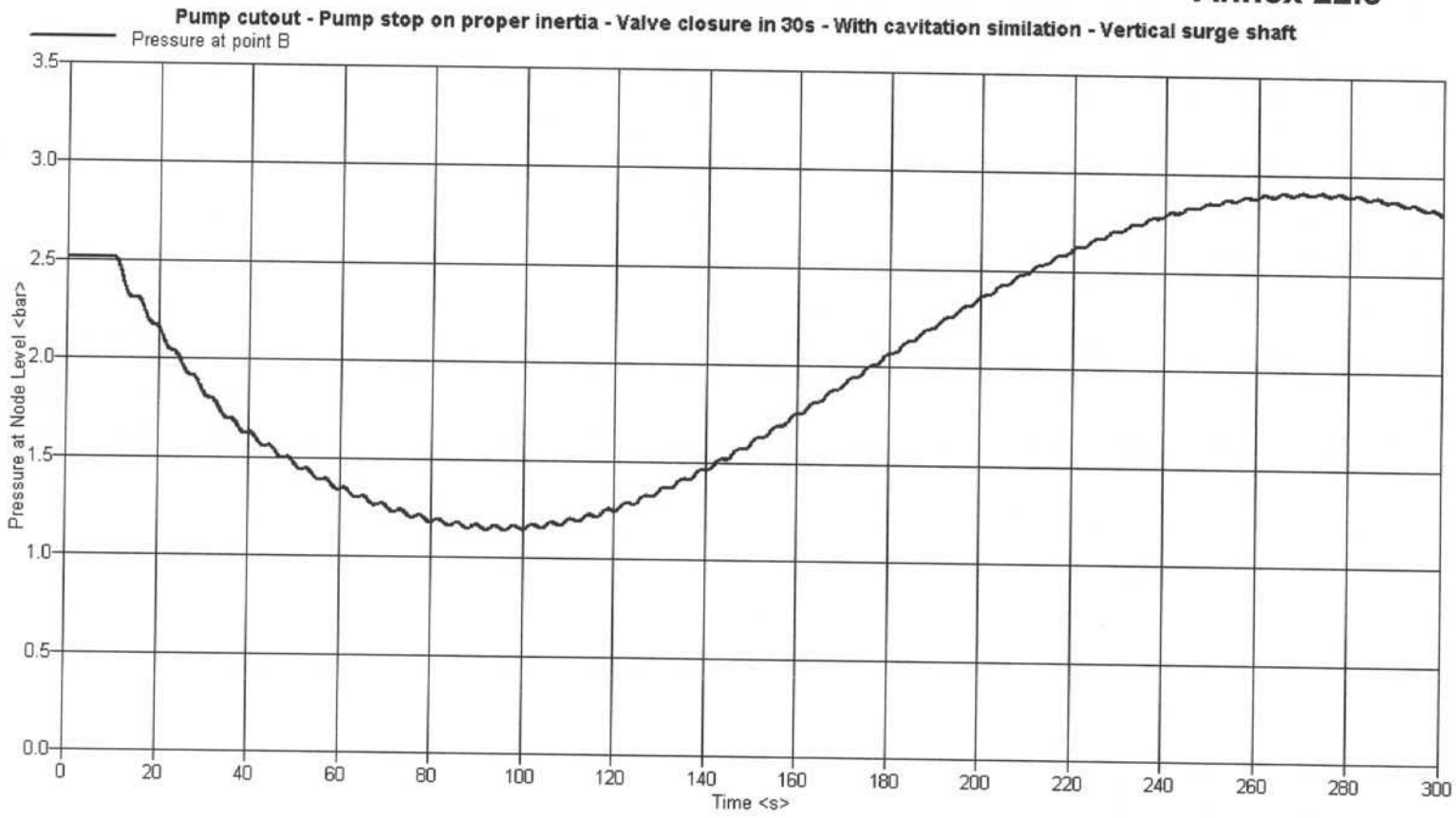

Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation simulation - Vertical surge shaft
Valve discharge
Pressure downstream valve
Valve opening ratio
Signal <>
Pressure at Node Level <bar>
Flow Rate <m3/s>
Time <s>

Annex 22.2

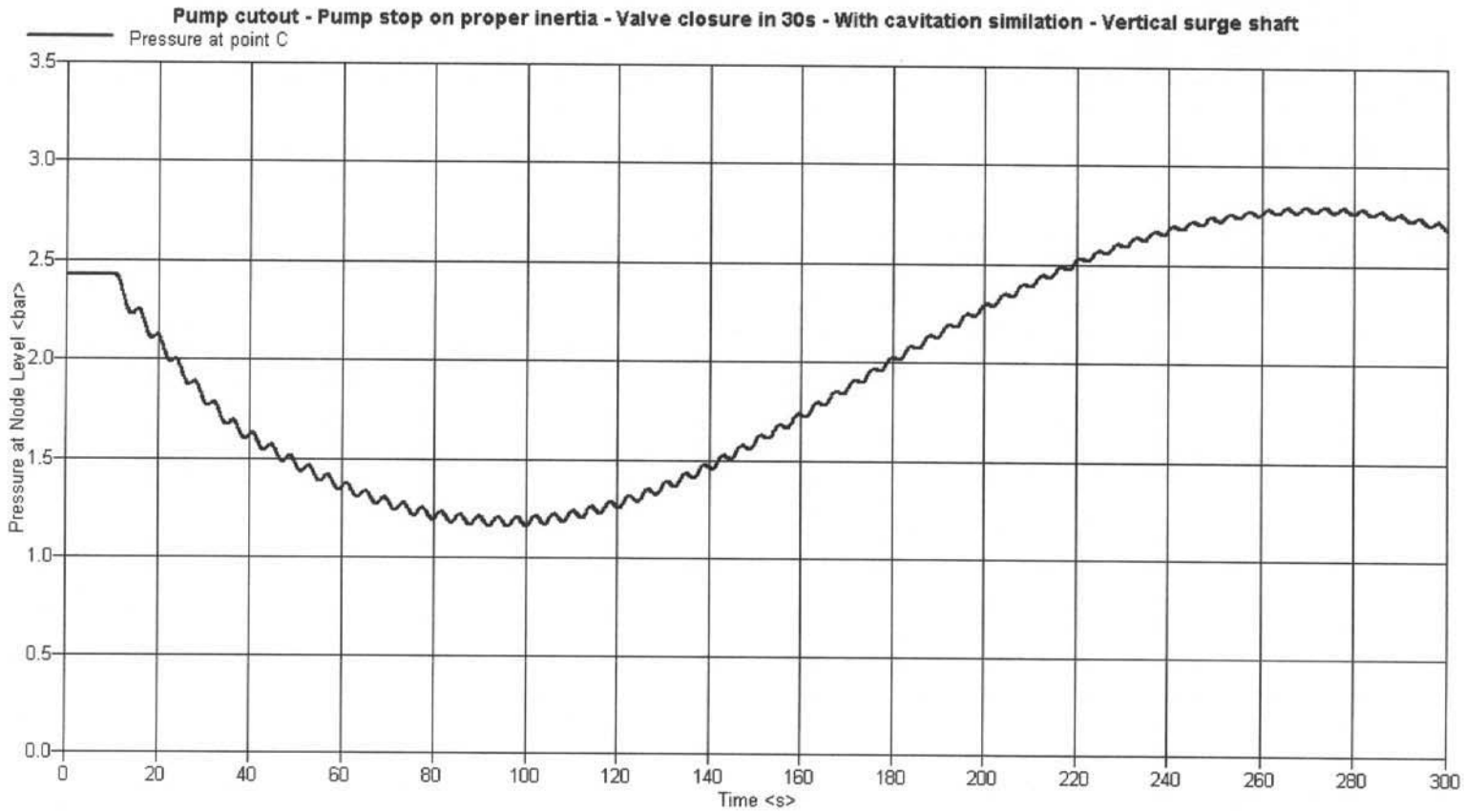
Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation simulation - Vertical surge shaft



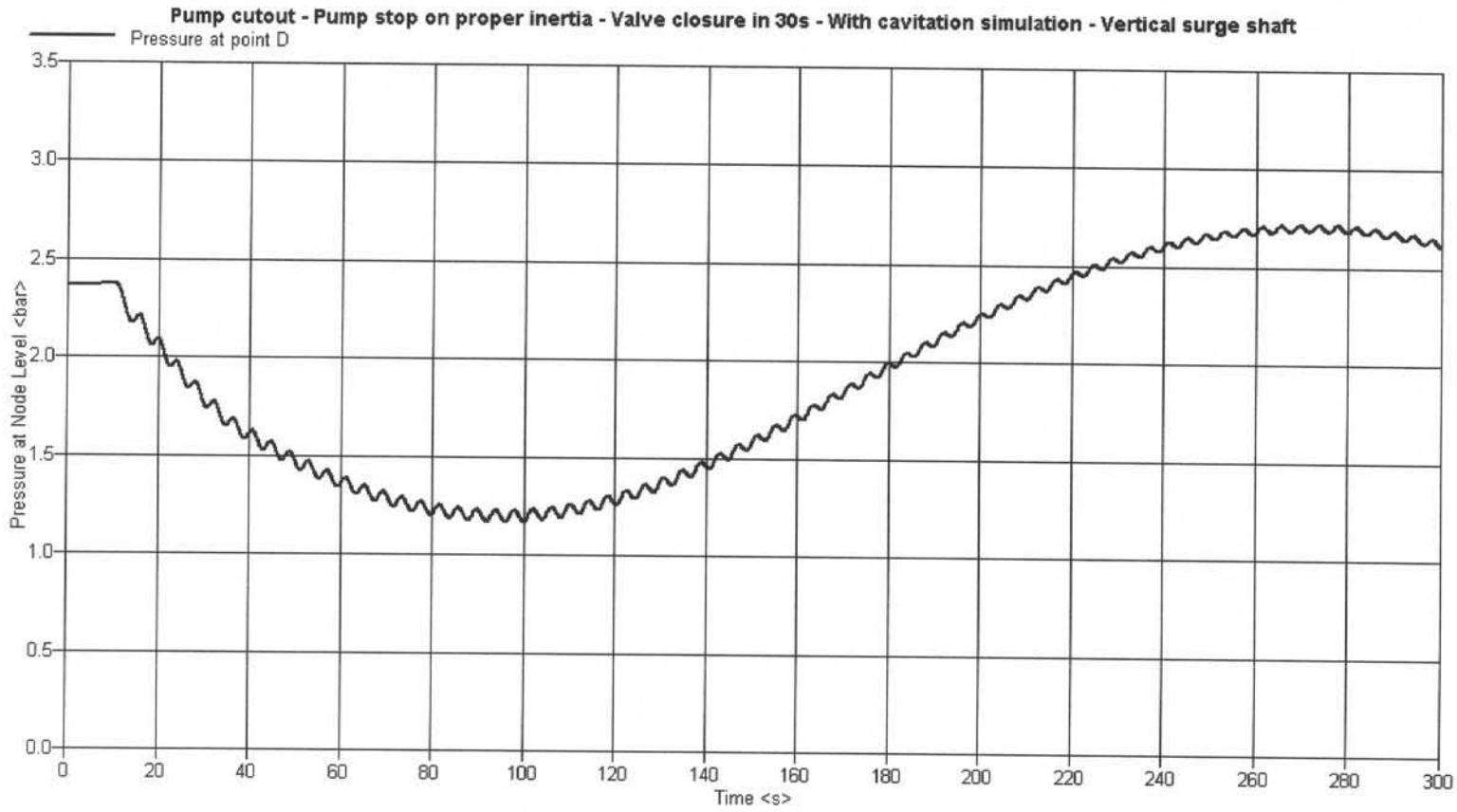
Annex 22.3


Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation similation - Vertical surge shaft
Pressure at point B
Pressure at Node Level <bar>
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
Time <s>

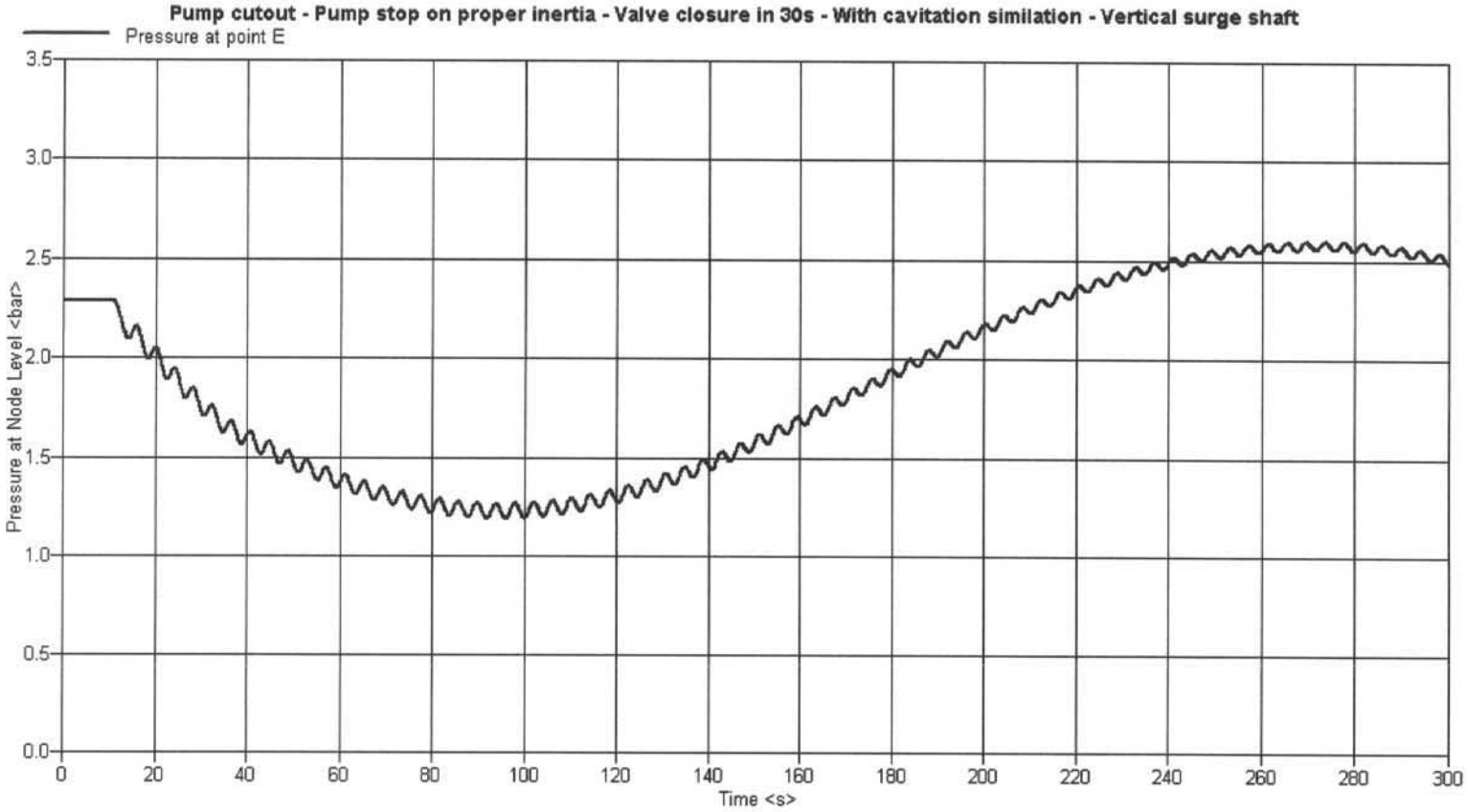
Annex 22.4


Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation similation - Vertical surge shaft
Pressure at point C
Pressure at Node Level <bar>
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
Time <s>

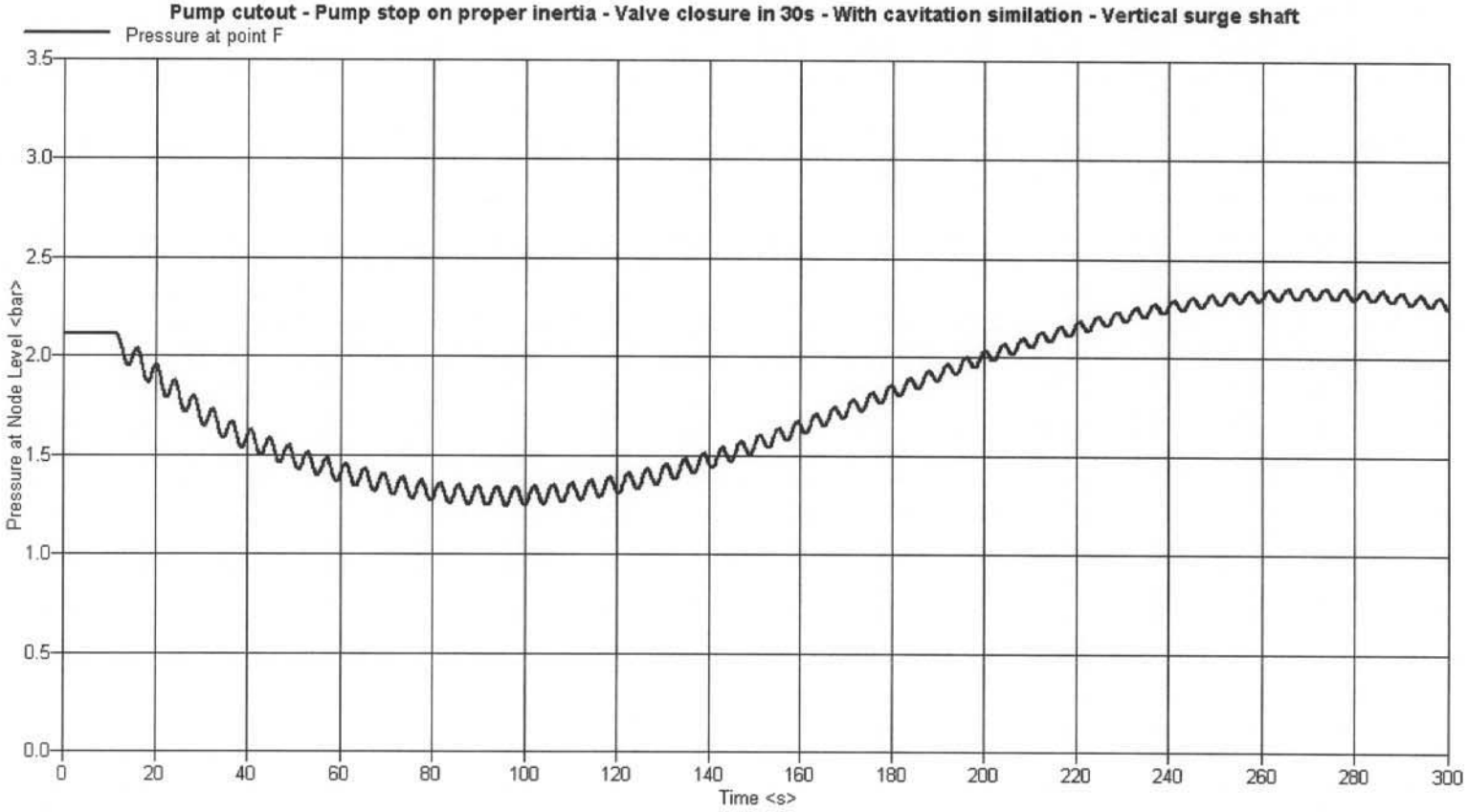
Annex 22.5


Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation simulation - Vertical surge shaft
Pressure at point D
Pressure at Node Level <bar>
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
Time <s>

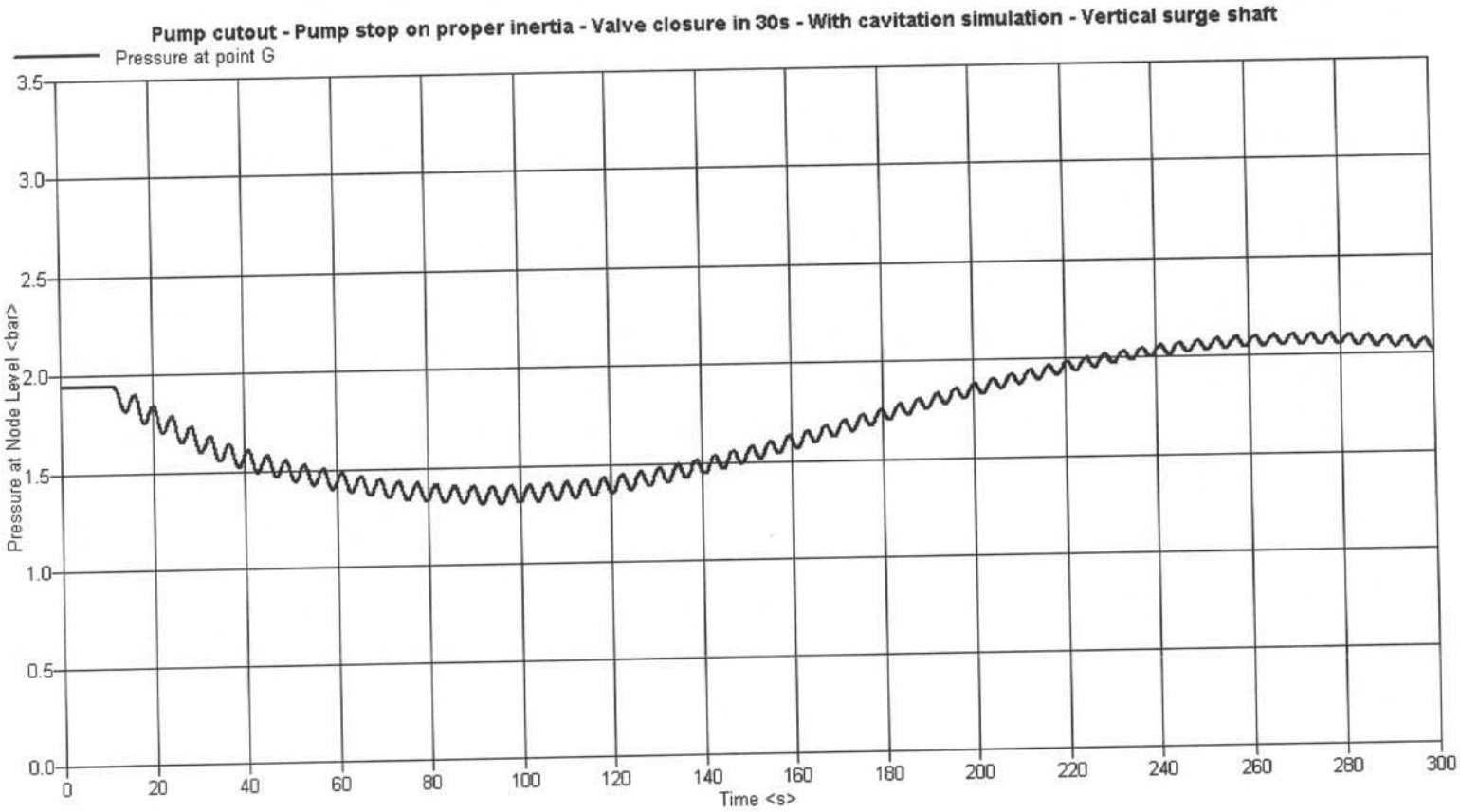
Annex 22.6


Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation similation - Vertical surge shaft
Pressure at point E
Pressure at Node Level <bar>
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
Time <s>

Annex 22.7


Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation similation - Vertical surge shaft
Pressure at point F
Pressure at Node Level <bar>
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
Time <s>

Annex 22.8


Pump cutout - Pump stop on proper inertia - Valve closure in 30s - With cavitation simulation - Vertical surge shaft
Pressure at point G
Pressure at Node Level <bar>
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
Time <s>