PIANC INTERNATIONAL WORSHOP

"Innovations in Navigation Lock Design"

In the framework of the PIANC Report n°106 - INCOM WG29

Presentations of the speakers

PIANC - http://www.pianc.org -

15-17 October 2009, Brussels, Belgium

Editor: Prof. Ph. RIGO, INCOM WG29 Chairman

PIANC BELGIUM - PIANC Workshop

INNOVATIONS IN NAVIGATION LOCK DESIGN

Presentations of the speakers

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Ir. Philippe Rigo
University of Liège – ANAST, Belgium

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PRESENTATION OF THE PIANC REPORT N°106 ON LOCKS

International Workshop, PIANC - Brussels, 15-17 Oct. 2009

INNOVATION IN NAVIGATION LOCK DESIGN

By INCOM – WG29 (2006-2009)

PIANC Workshop
15-16th October 2009

By Ph RIGO
Univ of Liege- ANAST
Belgium

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"Innovations in Navigation Lock Design"

PIANC Report n°106

Ph. Rigo
Chairman of INCOM WG29

and

E. Pechtold; P. Hunter; J. Bödefeld

PIANC WORKSHOP
– Innovation in Navigation Lock Design –

15th & 17th October 2009
in Brussels
(25th Anniversary of PIANC Belgian Section)

LOCK INNOVATIONS

The PIANC report n°106 (2009):

- Complement to PIANC 1986 report.
- Targets: innovations and changes occurring since 1986

NEW LOCK INNOVATIVE TOPICS

- Hydraulics (filling and emptying),
- Operations and Maintenance,
- Environmental,
- Design (concrete, foundation, gate,…),
- Construction Modes,
- Equipments,
- …..
- Design concept : Cost-Effective, Reliable,....

WG29 – Navigation Locks

- Locks are key structures for the development of commercial and leisure navigation in rivers and canals.
- Locks are also strategic infrastructure for port development.
- In low-lying countries, locks have an important function in flood defence.

Innovation applies to the big and fast…

New,
Cost-Effective
Reliable,….

GERMANY

PANAMA

… and the small and slow…

UK

Renovation
Rehabilitation

WG29 - LOCK INNOVATIONS

Major changes in design since 1986 concern:

- Maintenance and Operation aspects,
- New goals at the conceptual design stages of a lock
  - ➔ RELIABILITY , LIVE CYCLE COST, ...
- Renovation and rehabilitation of existing locks are also key issues for the future.

DESIGN AND OPTIMIZATION GOALS

Main design objectives governing the design of a lock are:

- Reliability - system, structures and operations,
- Reduced duration of a lock cycle times,
- Reduced water motions and mooring forces
- Avoid water resource problems (minimise water use)➔ Water Saving Basins
- Saltwater intrusion
- **Reduced life cycle cost**
- Minimizing energy use
- Avoid negative environmental impact
- Minimize impacts to navigation and local community
- Safety and Security

Early design stage

Key points at Early Design Stage are:

- Lock layout & Lock dimensions ,
- Life cycle of a lock ,
- Construction Modes or Methods,
- Layout of the hydraulic system,
- Lock structure concepts ,
- Salt water intrusion, Ice Control, Communication, Security and Safety, ...

DESIGN PRINCIPLES

1. "Risk based design" versus "Deterministic approach"

2. "Life cycle cost optimisation" versus "Least construction cost"

3. Use of "Numerical Modelling" as design tool (combined with physical model)

LAYOUT OF HYDRAULIC SYSTEM

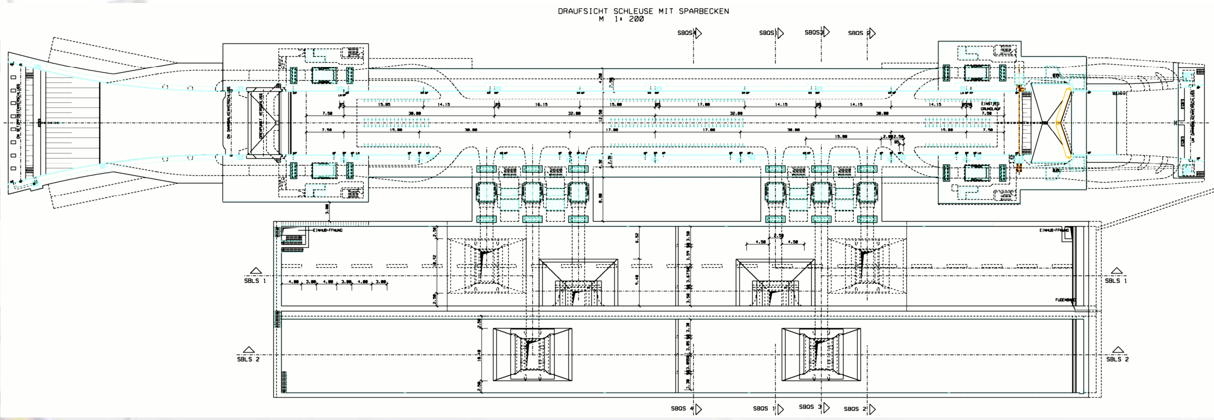
Hydraulic systems for filling and emptying locks can be divided into two types:

- ➔ *Through the heads*
- ➔ *Through longitudinal culverts*

Typical layouts of Longitudinal culvert system:

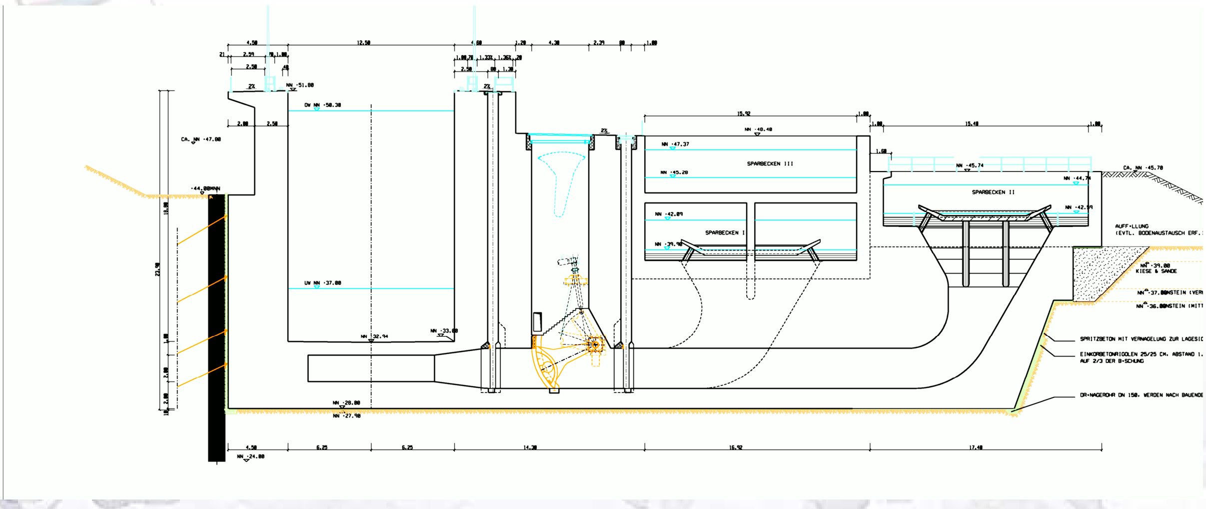
- *Wall culvert side port system*
- *Wall culvert bottom lateral system*
- *In-Chamber longitudinal culvert system (ILCS)*
- *Longitudinal culverts under the lock floor*
- *Dynamically balanced lock filling system*
- *Pressure chamber*

LAYOUT OF HYDRAULIC SYSTEM



Lock with Water saving basins located on the side of the lock
- Standard concept

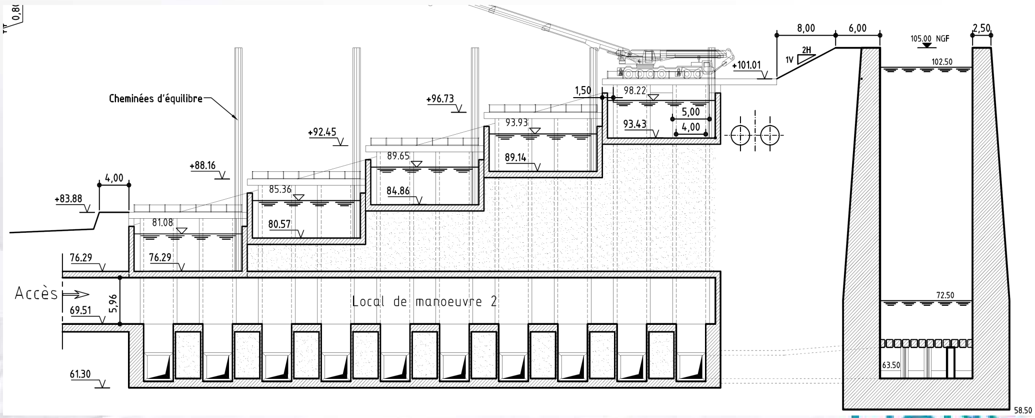
NEW LAYOUTS OF HYDRAULIC SYSTEM



Connection of pressure chamber to WSBs basins (upper) and to main chamber (lower)➔ Germany

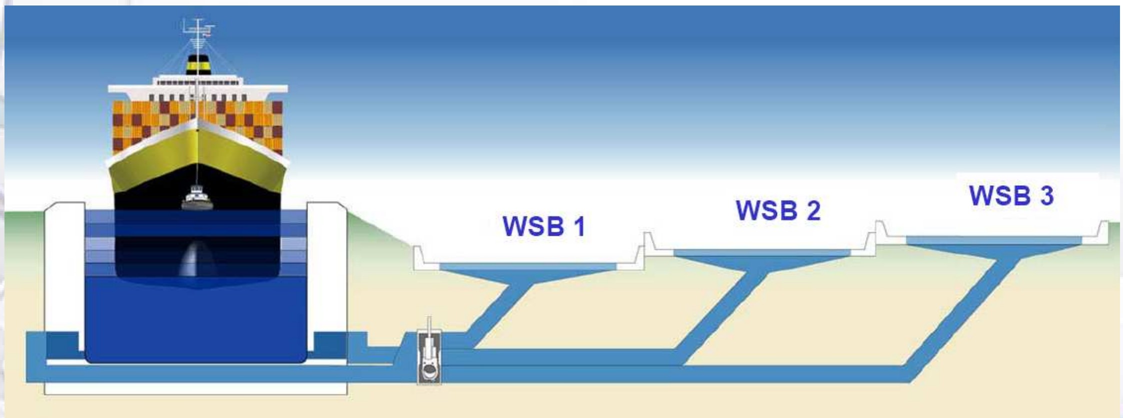
Water Saving Basins (WSBs)

Various types
of
Water Saving Basins.



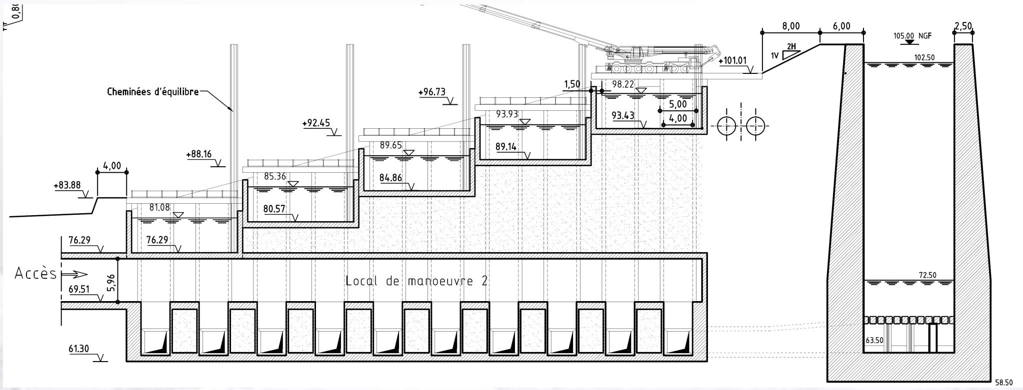
Water Saving Basin (WSB)

Locks with <u>separated WSBs</u> (located on one side or both sides of the lock, on a series of steps)



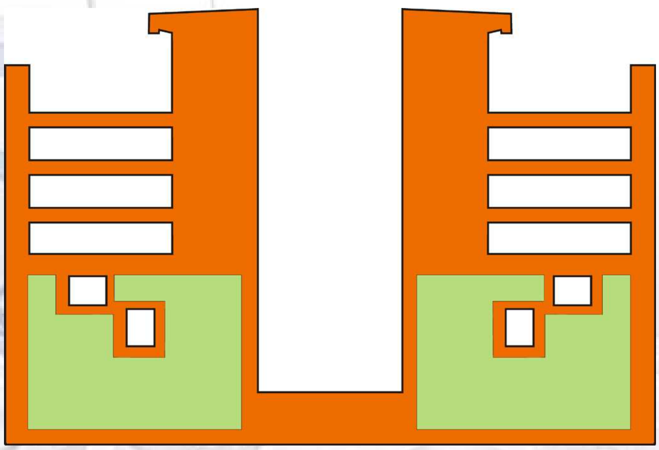
Water Saving Basins (WSBs)

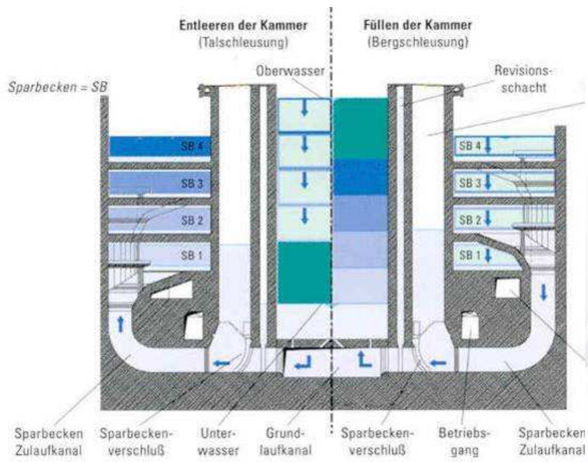
Cross-sections in a lock with 5 standard laterally located Water saving basins
(filling through the pressure chamber in the lock floor)



Integrated WSBs

The <u>integrated system</u> which integrates the WSBs in the two side walls, and makes the lock structure more stiff, compact and less land consuming.

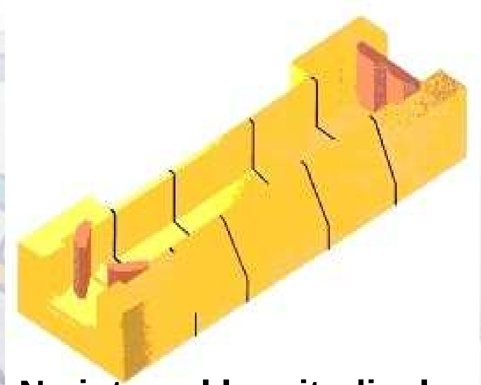




Lock sidewalls with integrated WSBs

Monolith LOCK

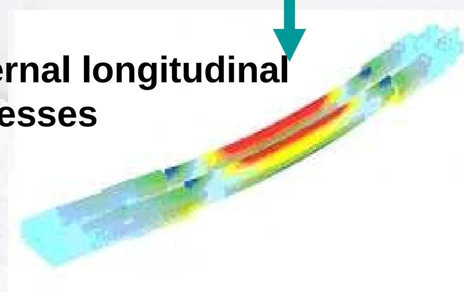
Standard Concept
With dilatation joints



No internal longitudinal stresses

Monolith Concept
Without dilatation joints

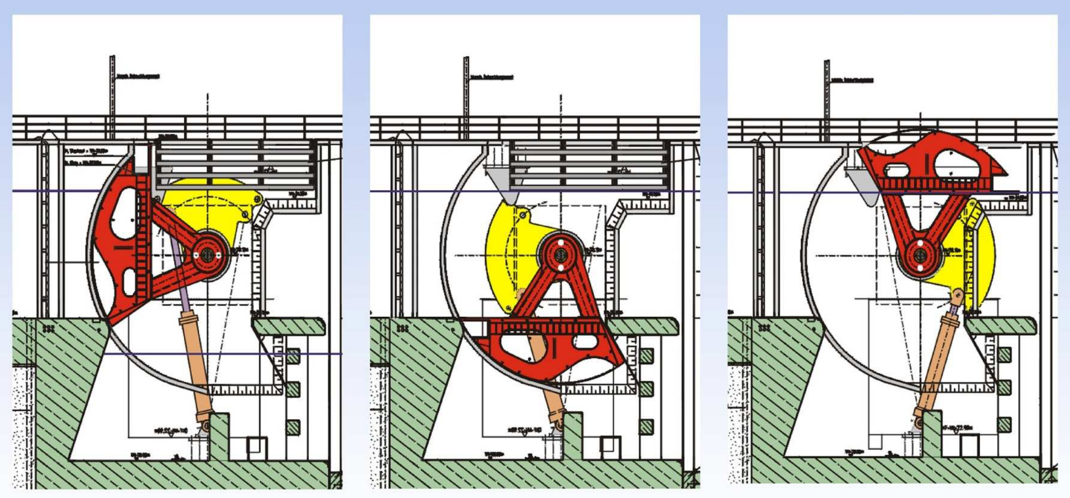
Internal longitudinal stresses



Complementarities between modeling

STEP	PHYSICAL MODEL	NUMERICAL MODEL
1	Definition of the problem	
	Identification of the essential acting forces	
2	Formulation of similarity requirements	Formulation of sets of equations
3	Formulation of boundary conditions	
4	Construction of a model	Development of a numerical solution scheme
5	Calibration of the model	
	Variation of roughness	Variation of coefficients
6	Measurements & solution	Calculation and solution
7	Optimization of the solution according to problem formulation	
	Model geometry variations	Variation of input data
8	Transfer of results from model to prototype	
	and examination by field measurements	

GATES AND VALVES



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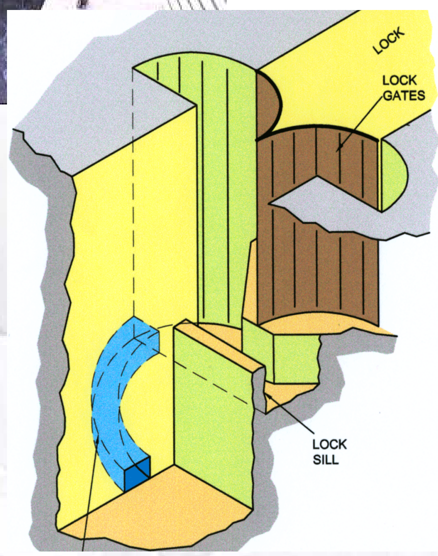
GATES AND VALVES

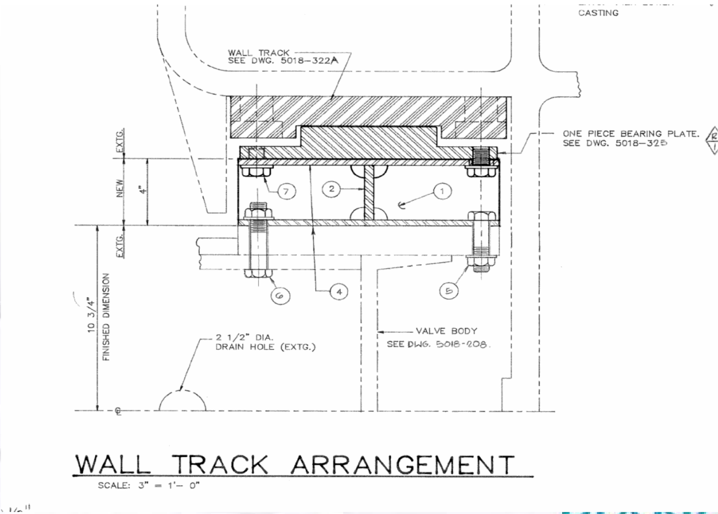


Mechanical devices

Actuator:

Sluice : Sliding vertical lift gate

UHMWPE : Ultra-high molecular weight polyethylene

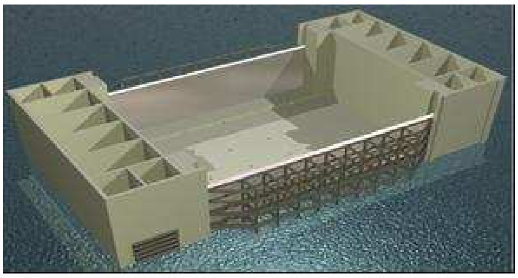


Construction Modes

The lock chamber is constructed on the ground surface.

When complete the soil is removed beneath the lock chamber and it is lowered into its final position.

➔ Prefabrication



InCom WG 29 CONCLUSIONS

Current Trade off problems in Lock Design:

➔"HIGH RELIABILITY" is often associated with "PROVEN TECHNOLOGIES" (in Lock Design)

If true ➔ Is it a the place for innovation in lock?

WG29 ➔ Yes. Innovation is required to reach highly reliable infrastructures, to reduce cost (construction mode), fulfil new requirements (fast locking), non standard dimension,…

Do not be afraid by innovation. ➔ Promote innovation.

➔**"RELIABILITY" versus "COST" (in lock design)**

Lock design is highly "Project Dependant".

Ex: "Panama Canal" versus the "Renovation of a small pleasure lock in Finland"

INNOVATIONS IN LOCK DESIGN

➔ FEW EXAMPLES

Magnetic Mooring System at KaiserLock Germany (*Cavotec Ltd*)

INNOVATION IN LOCK DESIGN

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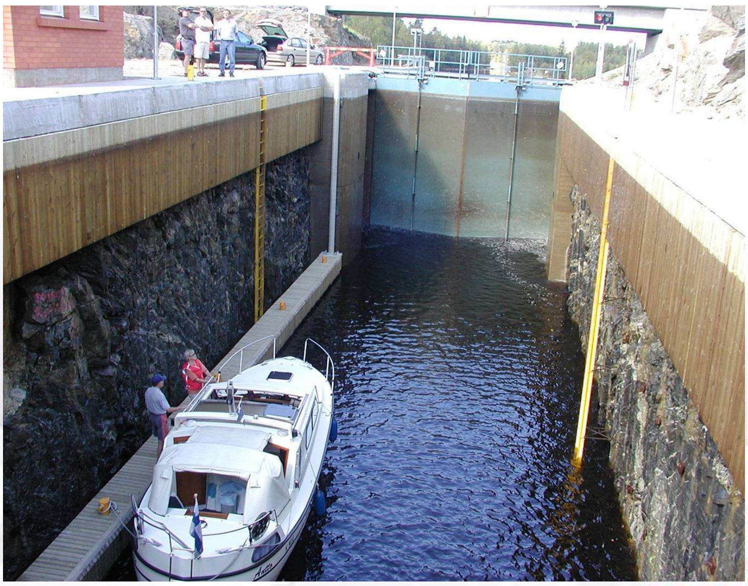
Locks Floating Pontoon (Fin)

INNOVATION IN LOCK DESIGN



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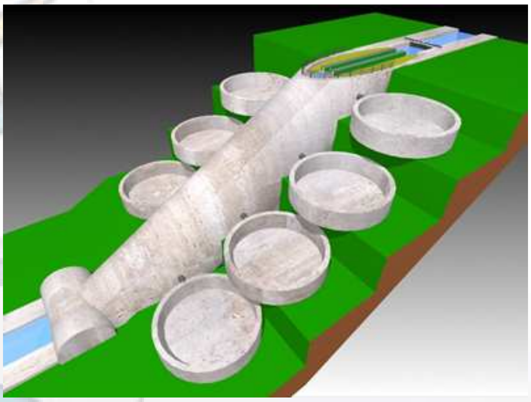
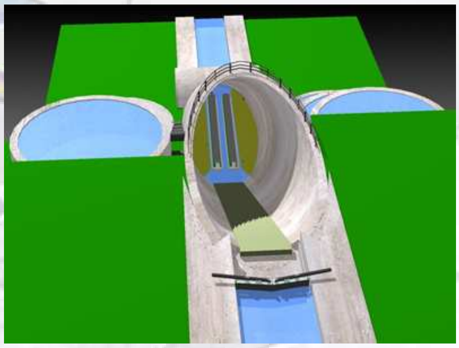
Dream to Reality ?

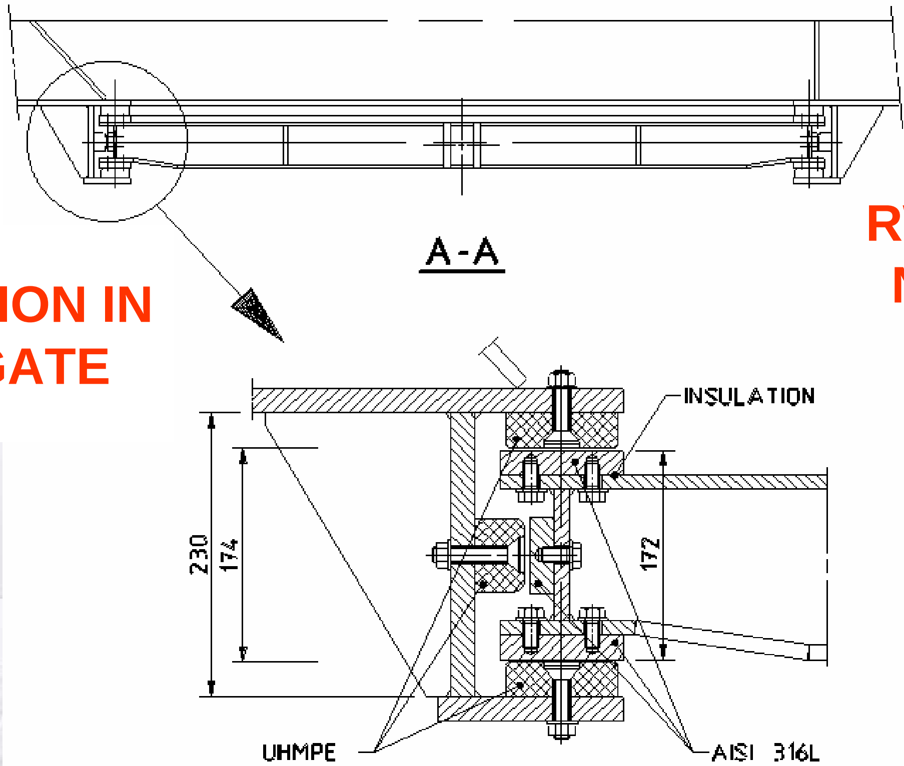




Diagonal
Lock
UK

Falkirk Wheel
UK

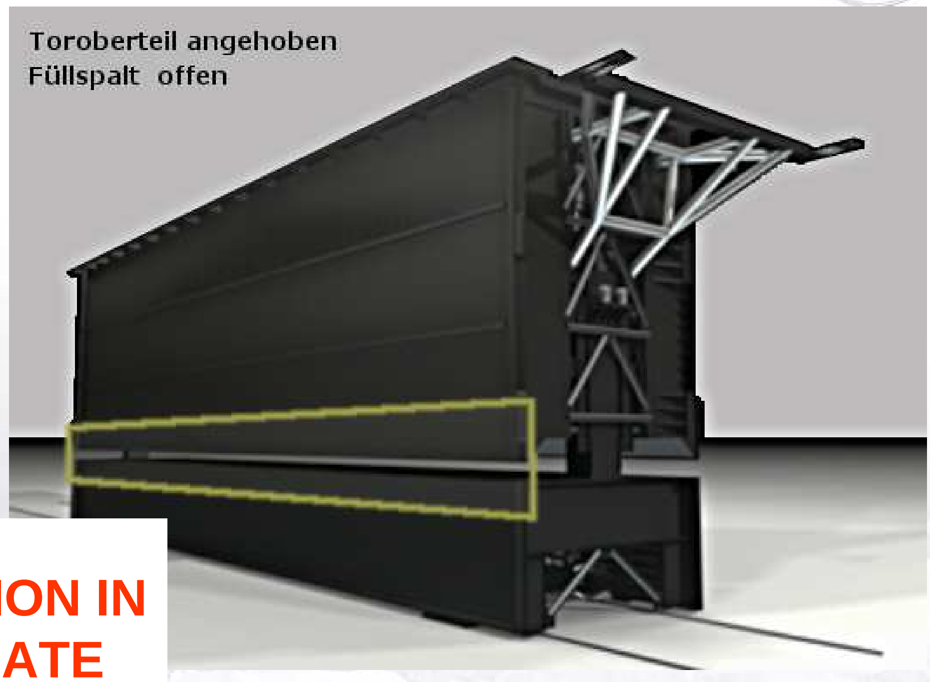
UHMPE sliding Gate/ Valves



INNOVATION IN
LOCK GATE

RWS
NL

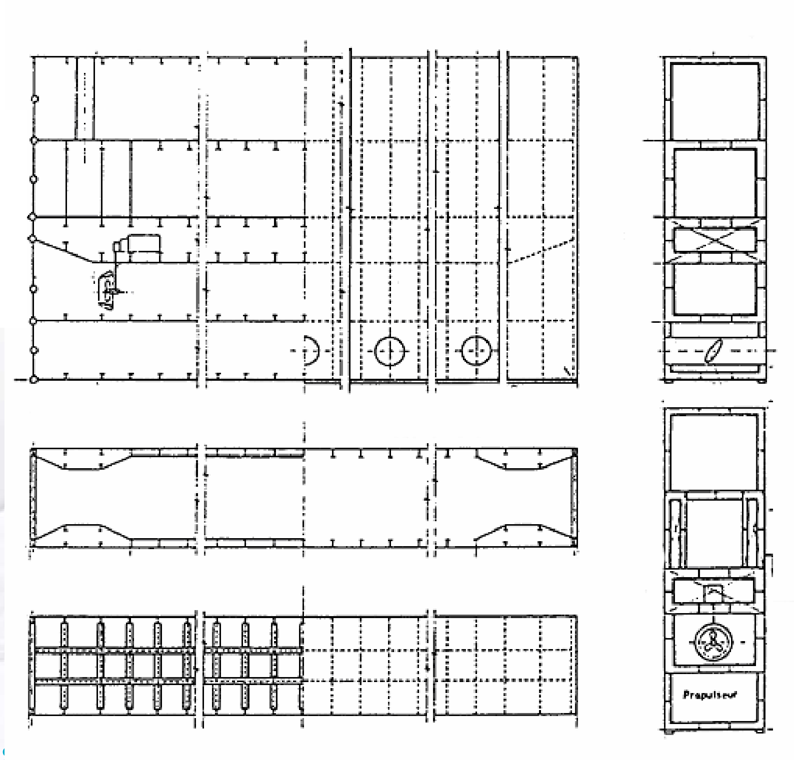
Kaiser lifting and sliding lock gate



INNOVATION IN LOCK GATE

Self-Propelled Floating Lock Gate (up to 70 m long)

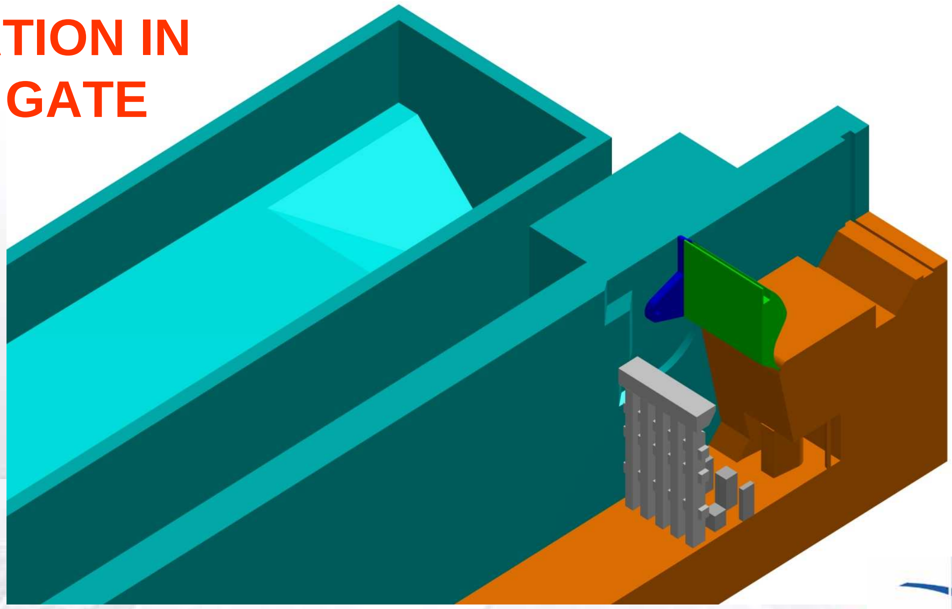
INNOVATIVE LOCK DESIGN



ANAST ULG (Belgium)

Promoting Innovation
➔ Lock in Bolzum (D)

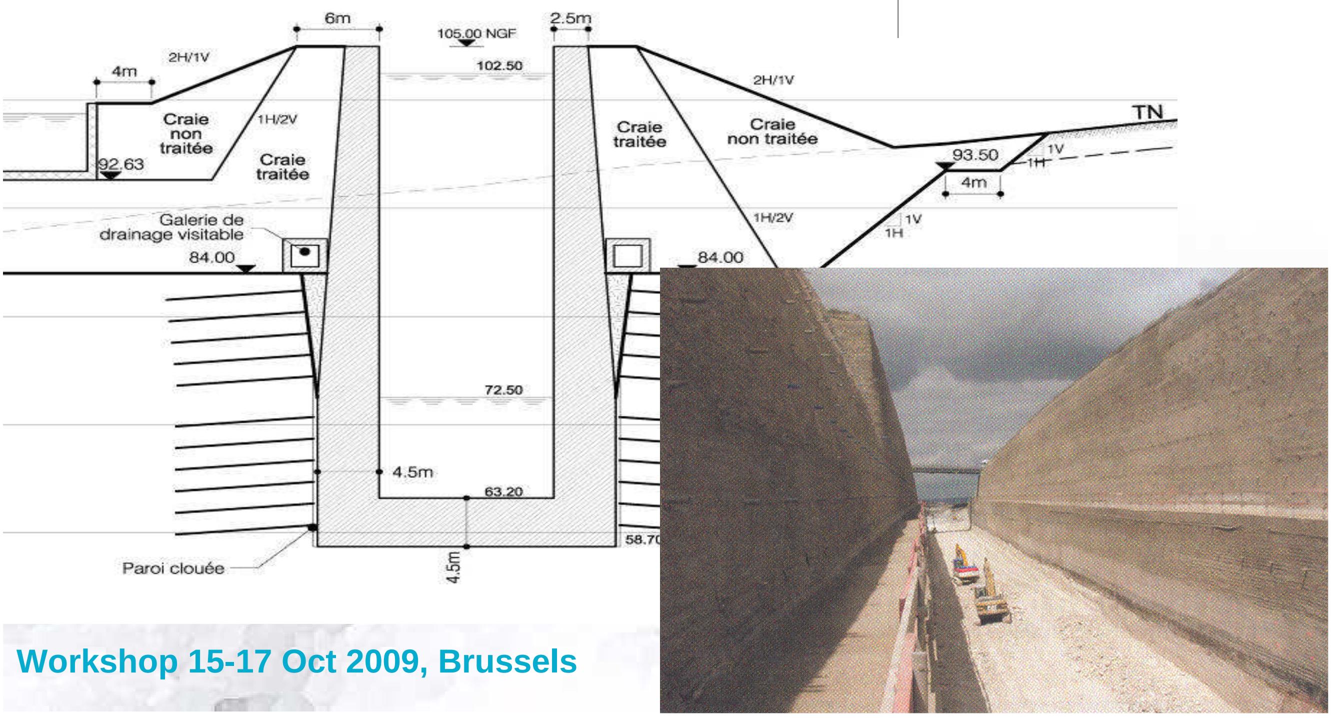
INNOVATION IN LOCK GATE



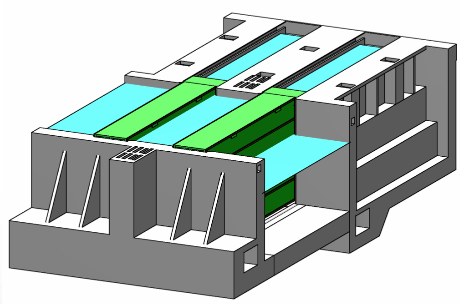
Setting

INNOVATIVE LOCK STRUCTURE

ARCADIS



Third lane of locks - Panama Canal



INNOVATION IN LOCK DESIGN

Workshop 15-17 Oct 2009, Brussels

PIANC Workshop 15-17th Oct 2009

PIANC REPORT N° 106

INLAND NAVIGATION COMMISSION

INNOVATIONS IN NAVIGATION LOCK DESIGN

2009

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WG29: Lock Innovations

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DALY Fabrice (Fr)
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HIJDRA Arjan (NL)
HIVER Jean-Michel (BE)
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PICHON N. (Fr) YP
RIGO Philippe (BE), Chair
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TARPEY Michael (USA, YP)
THORENZ Carsten (DE)
WONG Juan (Panama)
WU Peng (China)

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China, France, Panama, UK

Ir. Erwin Pechtold

Rijkswaterstaat, Ministry of Transport, Public Works and Water Management, The Netherlands

Paper 2
PROJECT REVIEWS

→ PROJECT REVIEWS

PIANC Workshop
15-16th October 2009

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Advisor Hydraulic structures

Rijkswaterstaat,
Ministry of Transport, Public Works
and Water Management,
The Netherlands

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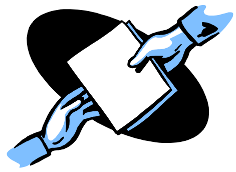
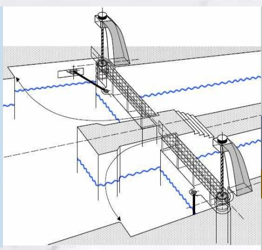
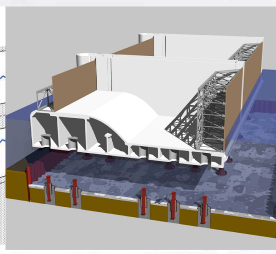
PROJECT REVIEWS



- A valuable asset of Report 106
  is the detailed collection of case studies.
- A selection of 56 projects worldwide containing facts, photographs and technical drawings.
- A summary is mentioned in the report.
- The full reviews are available on the enclosed DVD.
  (65 MB, 750 pages !!)


WG29 - LOCK INNOVATIONS

PROJECT REVIEWS

- Innovative features or unusual aspects.
- good view of type of innovations and state of technology.
- Illustrate the subjects covered in the report.

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WG29 - LOCK INNOVATIONS

PROJECT REVIEWS

- How to find these within report 106 ?

- Chapter 2
- Summary table (in the back of Chapter 2)
- List of files at DVD
- Contact the author or responsible organizations.

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SUMMARY TABLE (CHAPTER 2)

Project Reviews	Hydraulics: Filling and Emptying Systems	Hydraulics: Water Management (Water Saving Basins)	O & M: Energy Management	O & M: Life Cycle Cost	O & M: Maintenance	O & M: Vessel Operations and Impact	O & M: Silt and Debris Mitigation	Environmental: Environmental Concerns	Environmental: Salt Water Intrusion	Environmental: Ice Control	Environmental: Fish Mitigation	Design / Construction: Design Guidance	Design / Construction: Lock Size, Cycle & Capacity; Vessel Geometry, Lock cycle	Design / Construction: Struct Systems – Fdns, Lock Walls, approaches	Design / Construction: New Materials	Design / Construction: Gates – materials, systems, type	Design / Construction: Construction Means and Methods	Design / Construction: Renovation, Rehab & Size Modifications	Misc.: Lock Equipment	Misc.: Communications – 3D modeling	Misc.: Public Safety – Terrorism, Public Access
1 1-01 Kallo Sea Lock					PT	PT						PT					UT	UT			
2 1-03 Self-Propelled Floating Lock																AC					
3 1-04 High-Rise Navigation Lock	AC															AC					
4 1-05 Van Cauwelaert Lock							PT									PT		PT			
5 2-01 Tucurui Lock		PT											PT								
6 2-02 Lajeado Lock	PT												PT								
7 3-02 Grand Canal	PT												PT								PT
8 3-04 Jinjitan	PT																				PT
9 3-05 Mengli	PT																				
10 3-06 Qiaogong	PT																				PT
11 3-08 Three Gorges	PT												PT	PT		PT					
12 4-01 Juankoski Canal				PT		PT								PT			PT		PT		
13 4-02 Keitele	PT			PT	PT	PT							PT	PT							
14 4-03 Saarikoski																		PT			
15 4-04 Saimaa						PT	PT					PT				PT			PT		
16 5-01 Composite Miter Gates - Golbey				PT	PT							PT			PT	PT		PT			
17 5-02 Composite Vertical Lift Gate					NC										NC	NC					
18 5-03 Gate Protection - Rhone lock			PT			PT						PT		PT	PT	PT					
19 5-04 Horizontal Translation Gate												PT				PT					
20 5-05 Rhone Chautagne et Belley						UT						PT									
21 5-06 Rhone Locks Stoplogs Protection					PT														PT		
22 5-07 Seine-Nord Europe	PT	PT		PT												PT	UT				
23 5-08 Rhone Fish Ladder Lock	PT										UT										
24 5-09 Kembs Hydraulic Improvement	UT													UT		UT	UT				
25 6-01 Bolzum	PT													PT		PT					
26 6-02 Doerverden														NC							
27 6-03 Hohenwarthe														PT							
28 6-04 Uelzen II	PT													PT	PT	PT	PT				
29 6-05 Kaiserschleuse Bremerhaven	NC					PT								PT		NC			PT		
30 7-01 Caisson Method												PT					PT				
31 7-02 Lith Lock								PT						PT			PT				
32 7-03 Naviduct	PT				PT					PT							PT				
33 7-04 Oranje Locks																PT		PT			
34 7-05 Suspended Miter Gate															PT	PT					
35 7-06 Zuid-Willemsvaart												PT					PT				
36 7-07 Spiering lock - Composite Mitre Gate								UT							UT	UT					
37 8-01 Panama - New Locks	UT	PT		PT	PT	UT		PT	PT			PT	UT	UT							
38 9-01 Seville New Lock					PT		PT	NC				PT		PT		PT					
39 10-01 Avonmouth Lock Replacement					PT												PT	PT			
40 10-02 Cardiff	PT				PT				PT		PT			PT			PT				PT
41 10-03 Dalmuir Drop Lock	PT											PT	PT						PT		
42 10-04 Falkirk Wheel	PT		PT			UT				PT			NC	NC	NC	UT		PT			
43 10-05 Reverse Head Miter Gates								UT								UT			UT		
44 11-01 Braddock Lock and Dam																	PT				
45 11-02 Charleroi New Twin														NC			NC	UT			
46 11-03 Chickamauga Addition												PT									
47 11-04 Greenup	PT													NC	NC		NC	NC			
48 11-05 Inglis	NC							PT			PT			NC	NC		NC	NC	NC	PT	
49 11-06 Inner Harbor Navigation Canal														NC			NC	NC			
50 11-07 J.T Meyers														PT							
51 11-08 Kentucky Lock Addition														PT					PT		
52 11-09 Marmet	PT		PT			UT				PT				NC	AC	UT		PT			
53 11-10 McAlpine														PT			PT				
54 11-11 Olmsted Locks & Appr. Wall				UT	PT	UT	UT					UT		PT			PT			PT	
55 11-12 Troy Lock Rehab															PT		PT	PT			
56 11-13 Upper Miss-Locks 22 &25														NC			NC	NC			
	22	3	3	6	11	11	4	6	2	4	3	13	8	25	11	21	20	14	8	2	4

Impression of the Summary table

PT [1] Proven Technology (PT) – The feature has been built and validated by time and experience

UT [2] Unproven Technology (UT) – The feature has been built but it has not yet been validated by time and experience.

NC [3] New Concept (NC) – The feature is currently in the design process, but has not yet been built.

AC [4] Advanced Concept (AC) – the feature is been evaluated and/or tested in the research stage.

CATEGORIES

PT: Proven technology

UT: Unproven technology

NC: New Concept

AC: Advanced concept

PT	[1] Proven Technology (PT) – The feature has been built and validated by time and experience
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AREAS OF INNOVATION

Hydraulics	**O & M**	**Environ**	**Design / Construct**	**Misc**

Aspects:

- Hydraulics: Filling and emptying, water saving.
- Ops &Maintenance: Energy, LCC, Vessel ops & impact.
- Environmental: General, salt water, ice control, fish migration
- Design & Construct: Structure, materials, gates, construction methods.
- Miscellaneous: Lock equipment, communic,3D models, public safety

SOME TYPICAL EXAMPLES

These examples give a short overview
of the different types of locks
and of the different types of innovation
as can be found in the Chapter Project Reviews
and on the available DVD.

UK - Falkirk Wheel (10-04)

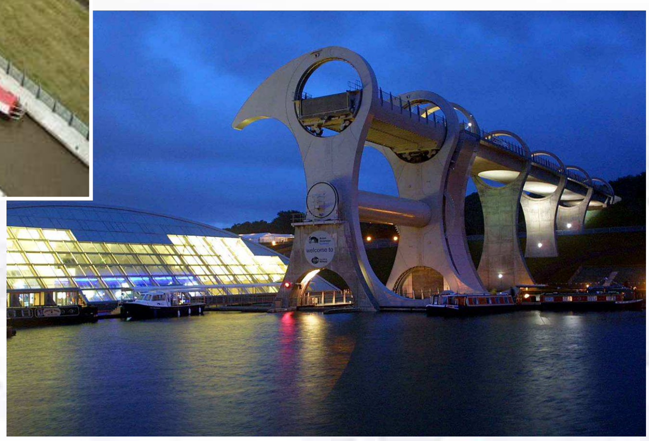
Areas of Innovation

Hydraulic	O & M	Environ	Design / Construct	Misc

Lock Dimensions

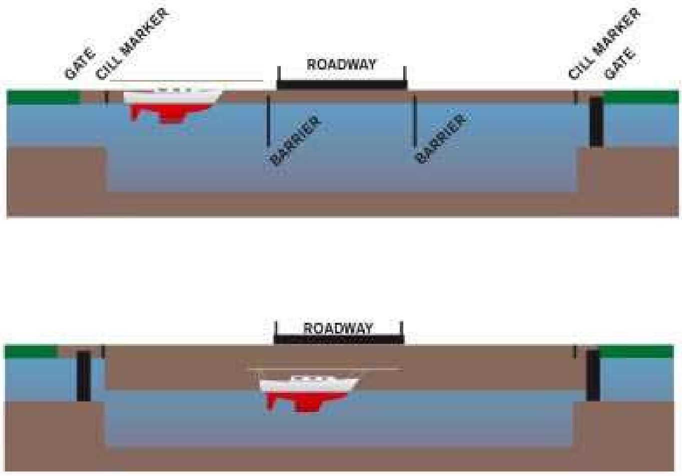
Length	22	Lift:	33.5m
Width:	6	Depth	1.5

D = 35 metres.



No actual lock (a ship lift), but characteristic for its principle, its aesthetic design and its multiple purpose, which includes tourism.

UK - Dalmuir Drop Lock (10-03)



Areas of Innovation

Hydraulic	O & M	Environ	Design / Construct	Misc

Lock Dimensions

Length		Lift:	
Width:		Depth	

An innovative use of existing techniques can be seen at the Drop Lock. Vessels are temporarily lowered, just to cross the road underneath.

FIN - Juankoski Canal (4-01)

Areas of Innovation

Hydraulic	O & M	Environ	Design / Construct	Misc

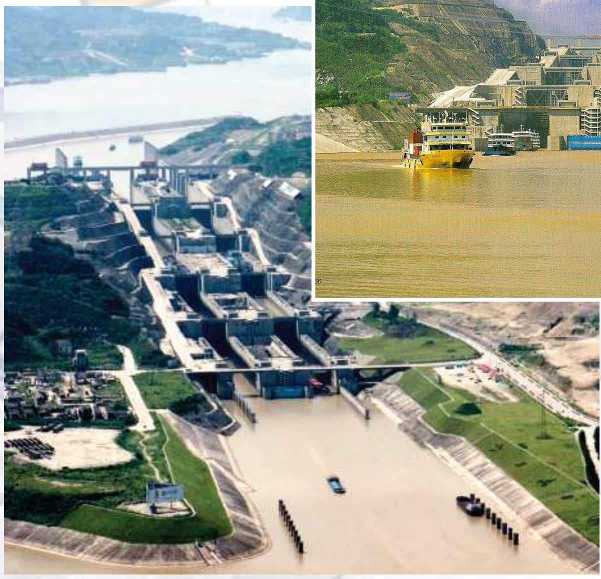
Lock Dimensions

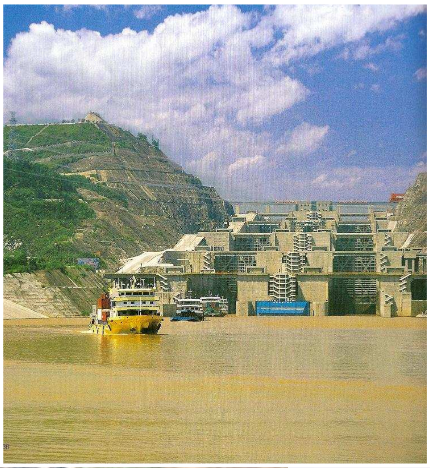
Length	35 m	Lift:	6 – 6.5 m
Width:	8 m	Depth	2.4 m

Where locks are built in rock, concrete walls do not always need to be used.

In those cases it is possible to use only a floating pontoon to moor the ships during lockage.

China – Three Gorges





Areas of Innovation

Hydraulic	O & M	Environ	Design / Construct	Misc

Lock Dimensions

Length:	1,621.0 m	Lift:	113.0 m
Width:	34.0 m	Depth:	5.0 m

With a total lift of 113 m and a max. water head of 45.2 m, the Three Gorges locks are in height the largest locks in the world.

Apart from its dimensions, also the Filling and Emptying system and the prevention of Cavitation are major innovative aspects.

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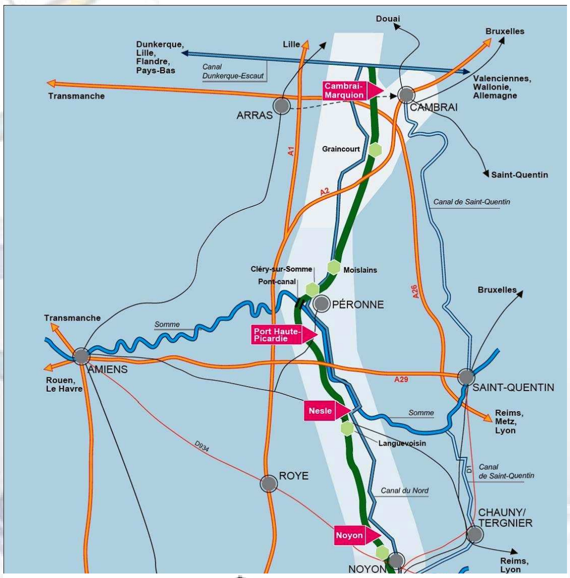
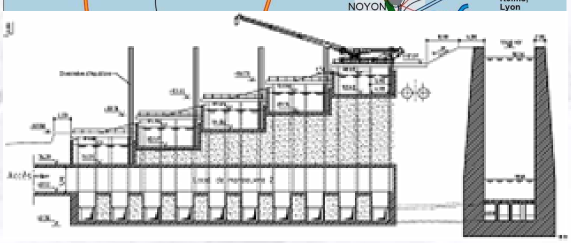
WG29 - LOCK INNOVATIONS

France - Seine-Nord Europe





Areas of Innovation

Hydraulic	O & M	Environ	Design / Construct	Misc

(Lock) Dimensions

Length	106 km	Lift:	15 – 30 m
Width:	12.5 m	Depth	

A new canal of 106 km long with 7 standardized locks will become an important connection between France and Northern Europe.

The major challenge in this project is the Water Resources Management.

- Water saving basins
- Pumping plants
- Watertight canal

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Panama - Canal Expansion

Areas of Innovation

Hydraulic	O & M	Environ	Design / Construct	Misc

Lock dimensions

Length	1281 m	Lift:	27m
Width:	55 m	Depth	18.3 m

Third Lock Project in Panama

- Three-step locks,
- Each with 3 water saving basins
- Side F/E system
- fresh and salt water on lock limits
- 365 / 24 / 7 uninterrupted use

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Belgium - Self Propelled Floating Gate

Areas of Innovation

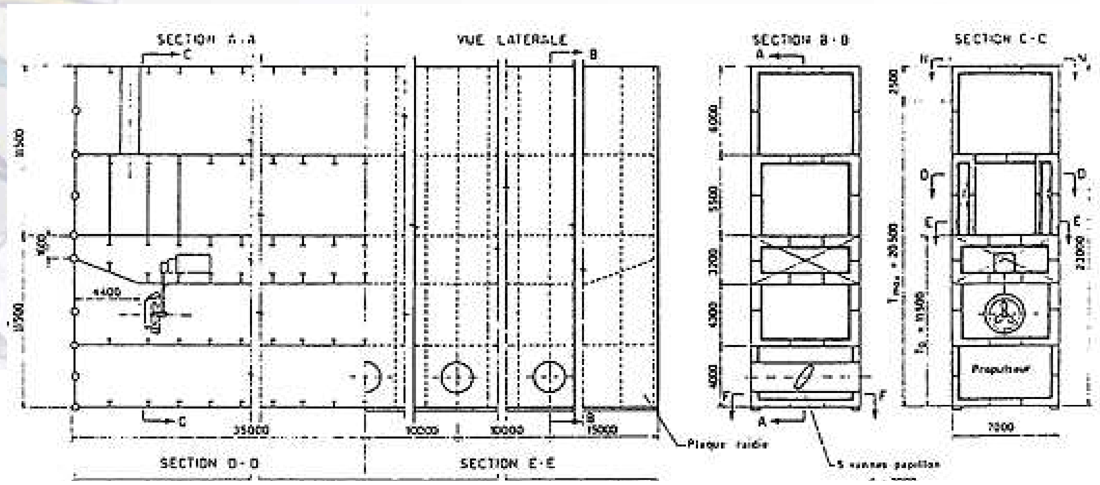
Hydraulic	O & M	Environ	Design/ Construct	Misc

Lock Dimensions

Length:	NA	Lift:	2-10 m
Width:	20 to 100 m	Depth:	10-20 m

Advanced Concept

An example of an Advanced Concept is the floating gate which is self propelled and thus actually a ship.



Germany

Hohenwarthe

Areas of Innovation

Hydraulic	O & M	Environ	Design / Construct	Misc

Lock Dimensions

Length:	190.0 m	Lift:	18.5 m
Width:	12.5 m	Depth:	4.0 m

An important example of structural innovations is the development of monolithic locks.

At the Hohenwarthe lock this solution is used for the 250 m long bottom plate.

Kaiserlock

Concept of magnetic mooring system

(also in use in N-Zealand)

Netherlands - Naviduct

Areas of Innovation

Hydraulic	O & M	Environ	Design / Construct	Misc

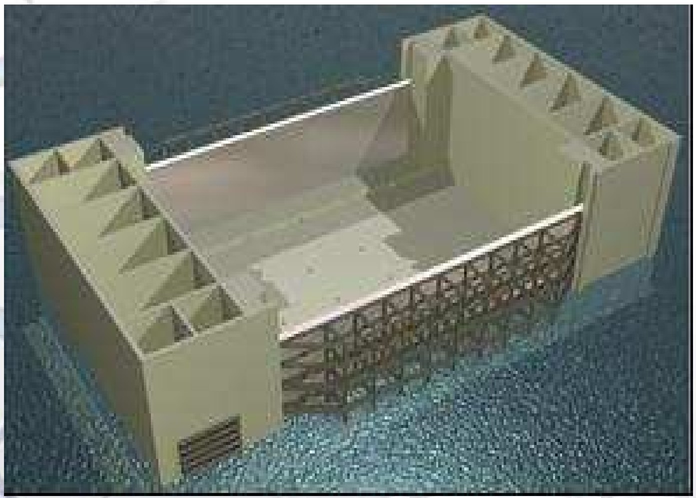
Lock Dimensions

Length	160 m	Lift:	
Width:	42 m	Depth	

Enkhuizen, the Netherlands.

A unique combination of a double navigation lock and an underpass for road traffic.

USA – Greenup Lock



Areas of Innovation

Hydraulic	O & M	Environ	Design / Construct	Misc

Lock Dimensions

Length	366 m	Lift:	
Width:	33.5 m	Depth	

Construction Methods in the wet

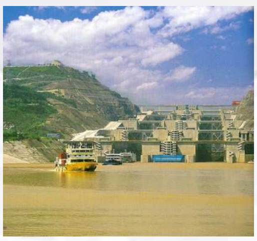
In the USA many different In the Wet construction methods are in use.
Among these are the Float-In and Lift-in techniques of precast elements.

WG29 - LOCK INNOVATIONS

Conclusion

- With Report 106 and its DVD a complete digital library on lock projects is available!
- A large diversity of innovative aspects is considered in the report.
- Why not a permanent and online PIANC database (Wikipedia like) ?



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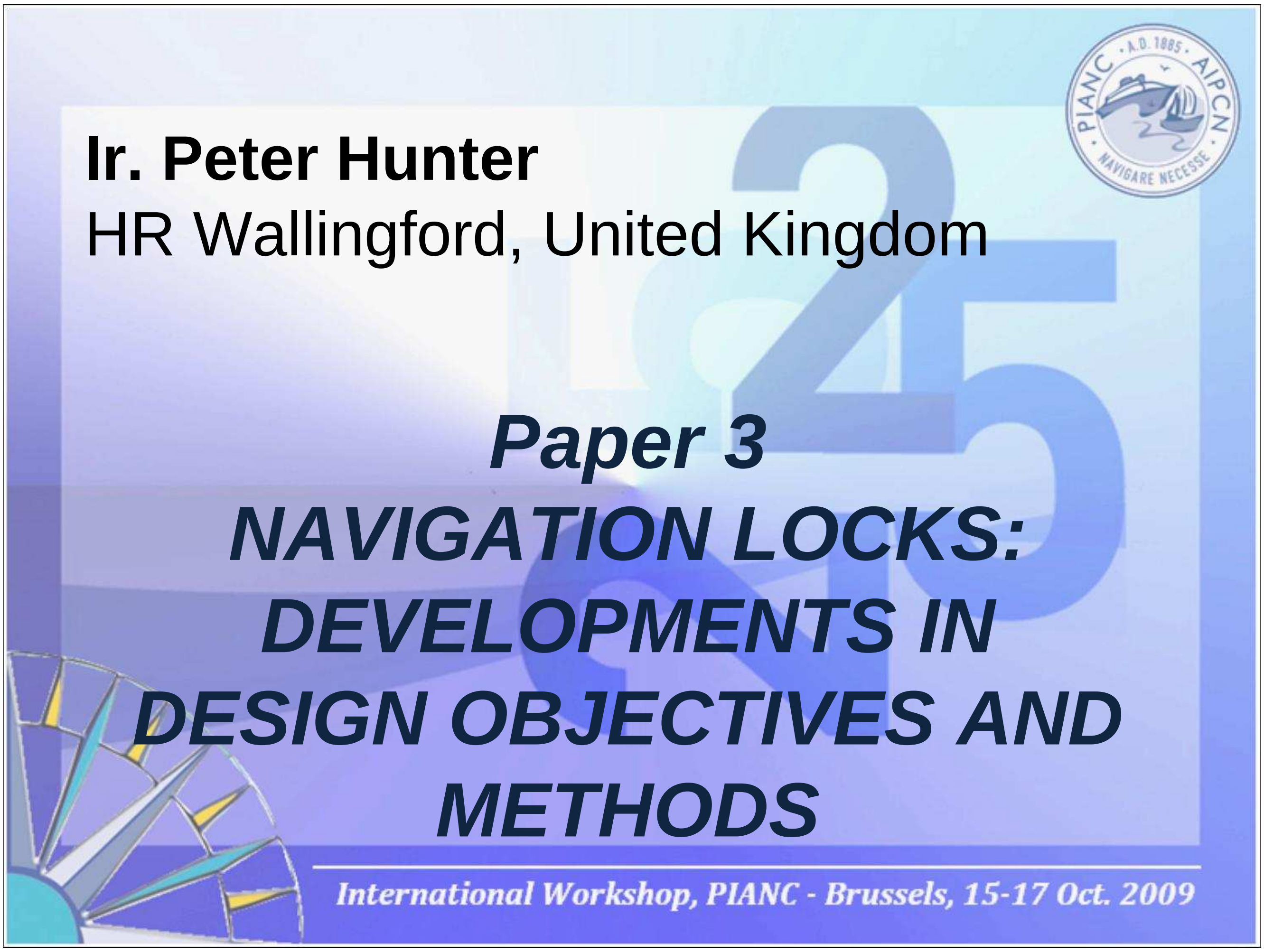
Ir. Peter Hunter
HR Wallingford, United Kingdom
Paper 3
NAVIGATION LOCKS: DEVELOPMENTS IN DESIGN OBJECTIVES AND METHODS
International Workshop, PIANC - Brussels, 15-17 Oct. 2009

PIANC Workshop
15-16th October 2009

Part 3: Navigation Locks: Developments in Design Objectives and Methods

Peter Hunter
HR Wallingford, U.K

HR Wallingford
Working with water

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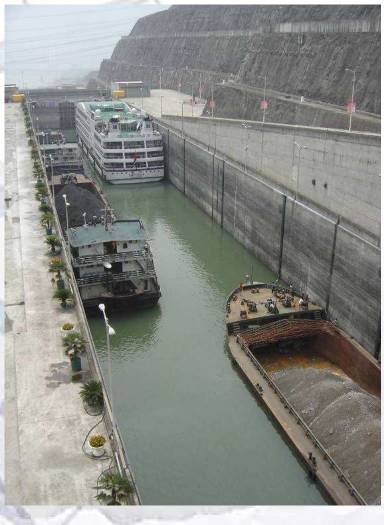
Locks: Design Objectives and Methods

- Economic and Financial Objectives
- Environmental Objectives
- Design Objectives
- Life Cycle Management
- Design Methods
- Safety

Locks: Project Objectives



Economic and Financial Objectives:

•allow larger ships

•increase capacity (e.g. of canal)

•reduce overall transport costs

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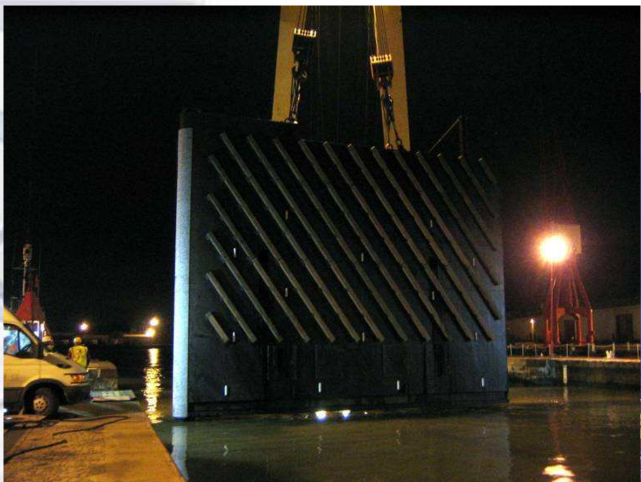
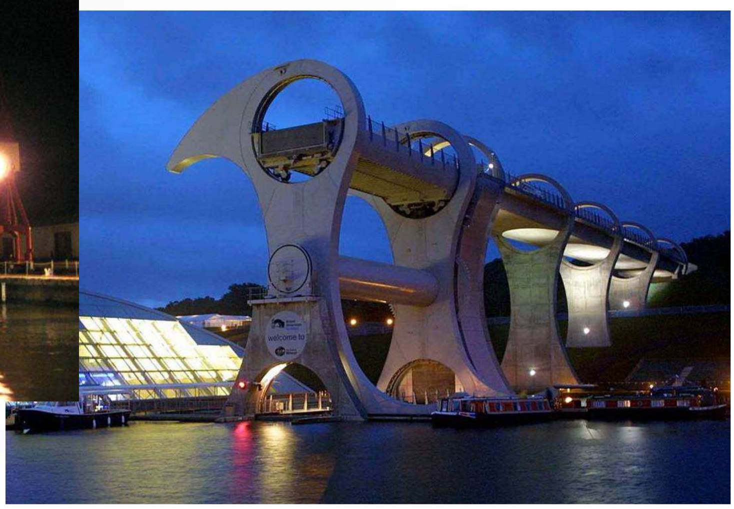
Other Economic and Financial Objectives:

- Reduce construction and maintenance costs
- Increase economic activity: tourism, leisure,





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Design Priorities

Design approach can have four different priorities:

- Design for lowest initial (construction) cost
- Design for minimum maintenance.
- Lowest whole life cost
- Best performance (fastest operation, least down-time)

Whose priorities?

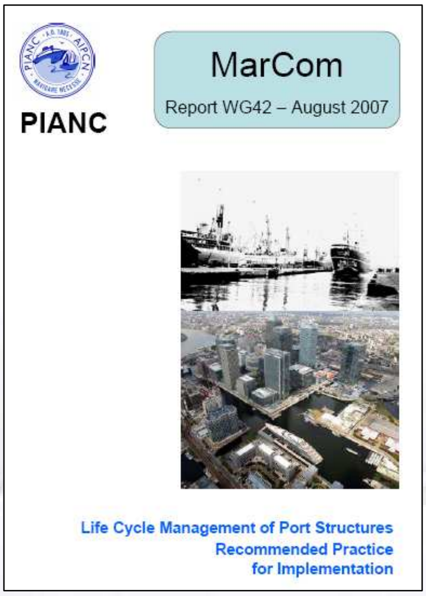
- Government - National interest: secure transport routes
- Owners - Profitability & Turnover
- Managers - Ship numbers, safe operations
- Employees - Rewarding employment, security
- Users - Efficiency, speed, safety, cost
- Community - Employment opportunities, environment

Main Design Objectives

Main design objectives and optimization goals that govern the design of a lock are:

- **Reliability - system, structures and operations,**
- **Faster cycle times,**
- **Reduced mooring forces**
- **Minimum water use**
- **Minimum Saltwater intrusion**
- **Reduced life cycle cost**
- **Minimised energy use**
- **Low *negative* environmental impacts**
- **Safety and Security**

Life Cycle Management



LCM is aimed at providing minimum Whole Life Costs.

dealt with in MarCom-WG42 Life Cycle Management of Port Structures (August 2007)

Life Cycle Management

- •Design for minimising operating & maintenance costs
- •Design for minimising downtime
- •Design for minimising whole life costs
- •Maintenance Management

SAFETY: Locks are safety-critical structures

Safety

Safety in design is increasingly important.

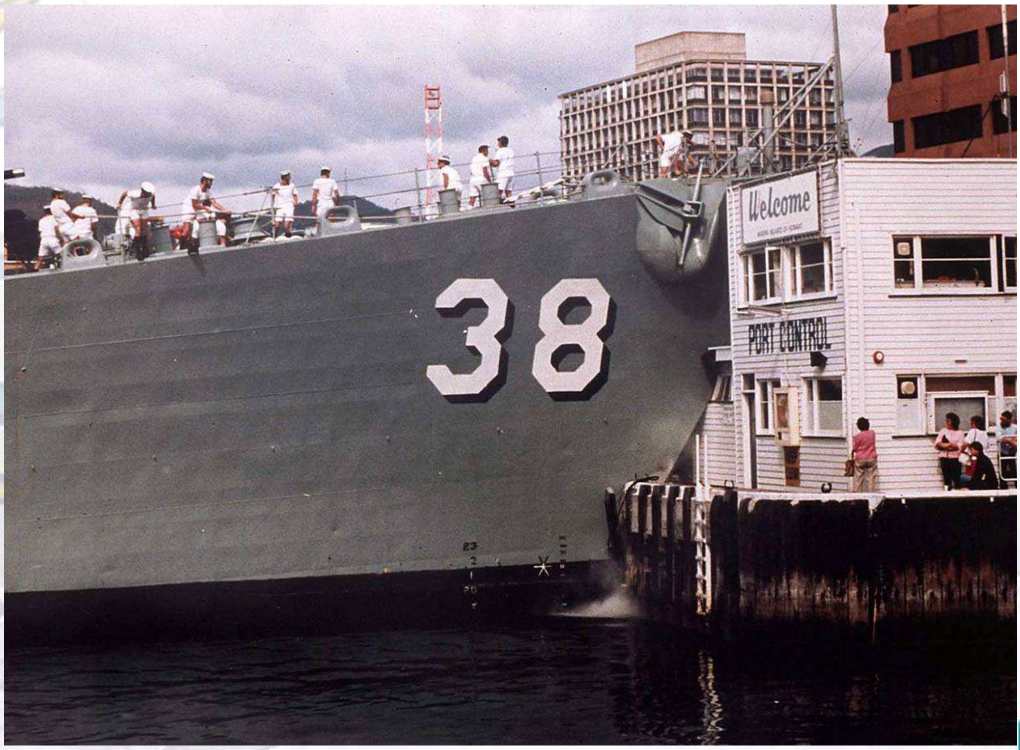
We are all more risk conscious, and are in a more litigious society.

The Report discusses protection of

- **People (users, operators, bystanders)**
- **Locks**
- **Ships**

Safety

Water Edge Safety



Safety: Public access – or not?

The Report includes Classification of types of water edge structure

with guidelines for suitable safety treatment for each category

Water Edge Safety Classification.

Description (SUMMARISED)
Class 1 • Water less than 0.5m depth • Minimal height above water. • No unaccompanied young children
Class 2 • Water depth between about 0.5m and 1.5m • Well-defined edge not more than about 2m above the water • Presence of people, walking or seated • No unaccompanied young children
Class 3 • Water more than about 1.5m deep • Well-defined edge not more than about 2m above the water • Unlikely to be near dwellings, bridges, weirs or locks • No unaccompanied young children
Class 4 • Water more than about 1.5m deep plus one or more additional haz as below o More than 2m above water o Fast-flowing water o Presence of vulnerable groups such as children o Presence of dwellings, schools etc

Design Methods

- “Risk based design” versus “Deterministic approach”
- “Minimum Whole Life Cost” versus “Least construction cost”
- Use of numerical modelling as design tool
- Use “Early Design Tools” for preliminary design stages

Design Methods

Design Tools:

Hydraulic Systems

Structural Design

Mechanical Design

Power and Controls

Codes and Standards

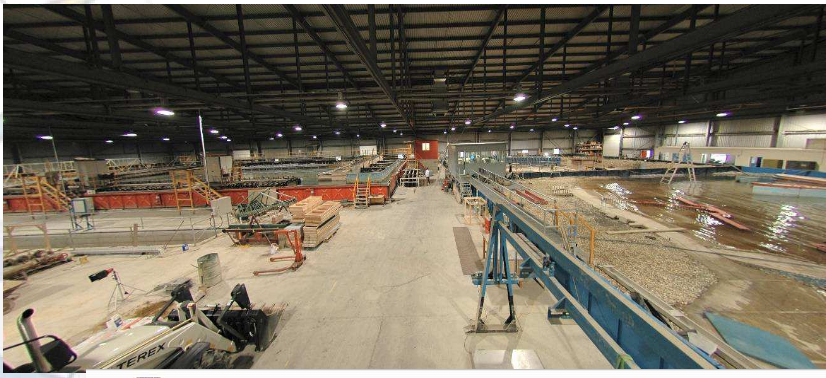
Codes and Standards:

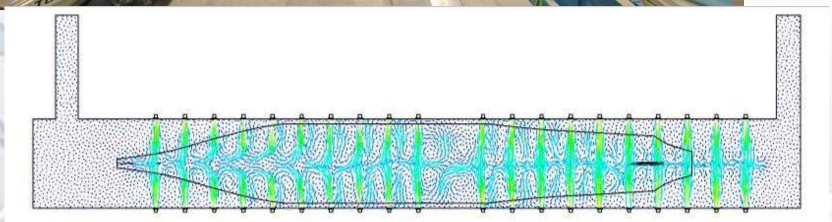
PIANC Report 106

PIANC 1986

Long list of other codes, standards and guides

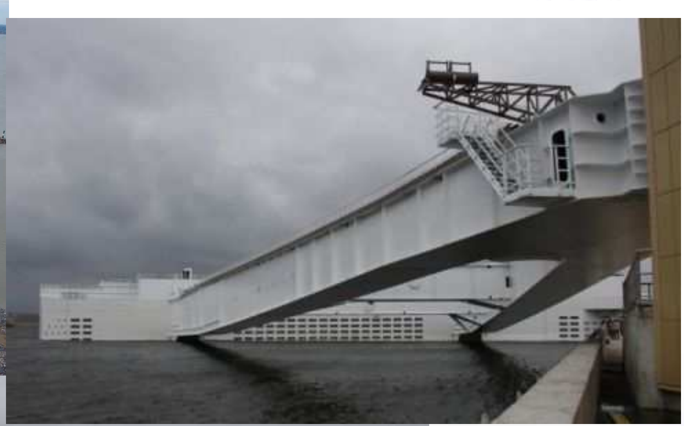
Design Methods





Inter-dependent Numerical and Physical modelling

Conclusion



Photos: Halcrow

HR Wallingford
Working with water

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You will be welcome at PIANC MMX

PIANC Congress 2010

Liverpool, UK

AGA	**10 May 2010**
Congress	**11–14 May 2010**

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Ir. Jorg Bödefeld

BAW, Germany

LOCK STRUCTURE

International Workshop, PIANC - Brussels, 15-17 Oct. 2009

PIANC Workshop
15-16th October 2009

Part 4: STRUCTURE

By J BÖDEFELD
BAW
GERMANY

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Technical aspects, principles and methodologies in design process

- What´s new ?
- Focus on structural design
- General remarks on safety concept
- Actual needs
- Actual possibilities
- Construction types

Safety Concept

Semi probabilistic approach

- partial safety factors (amplification / reduction)
- different load factors (permanent, traffic,...)
- different design situations (persistent, transient,...)
- different limit states (ULS, SLS)

Ultimate limit state

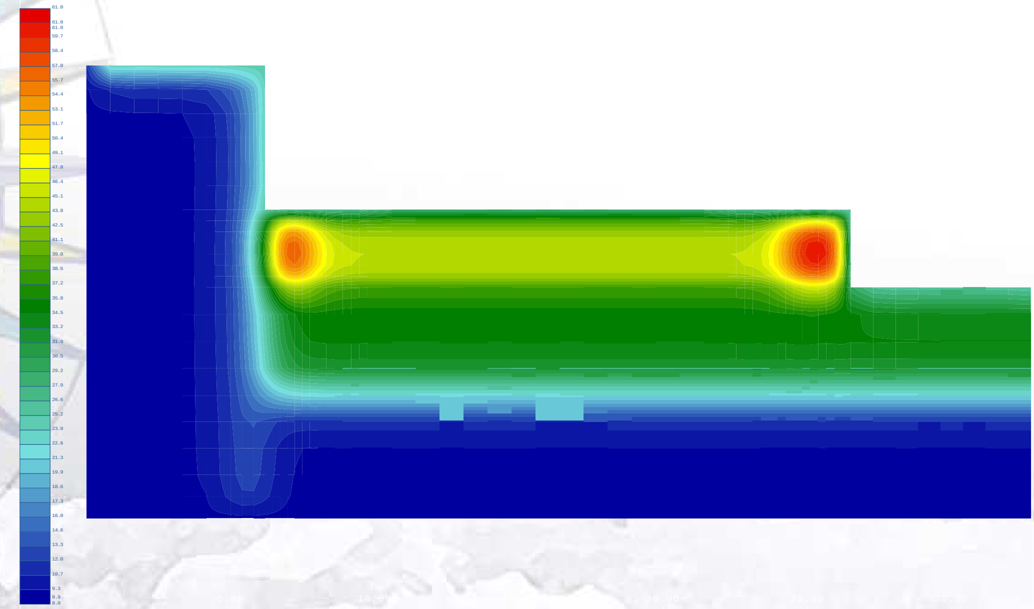
- **earthquake**
- **fatigue !**

Ultimate limit state

Serviceability limit state

- more important than before
- for concrete structures: crack width
- more time and effort (e.g. nonlinear analysis for thermal induced cracking)

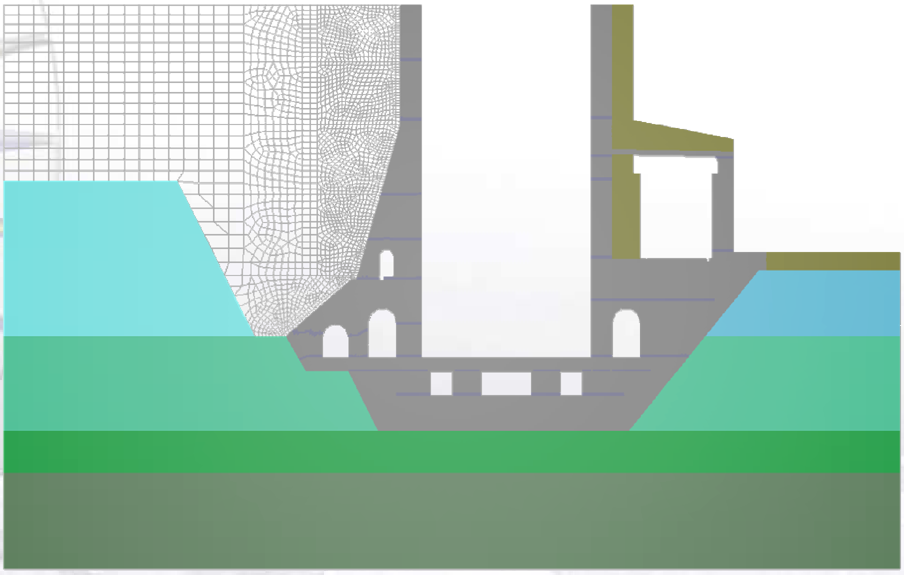
Serviceability limit state



Possibilities

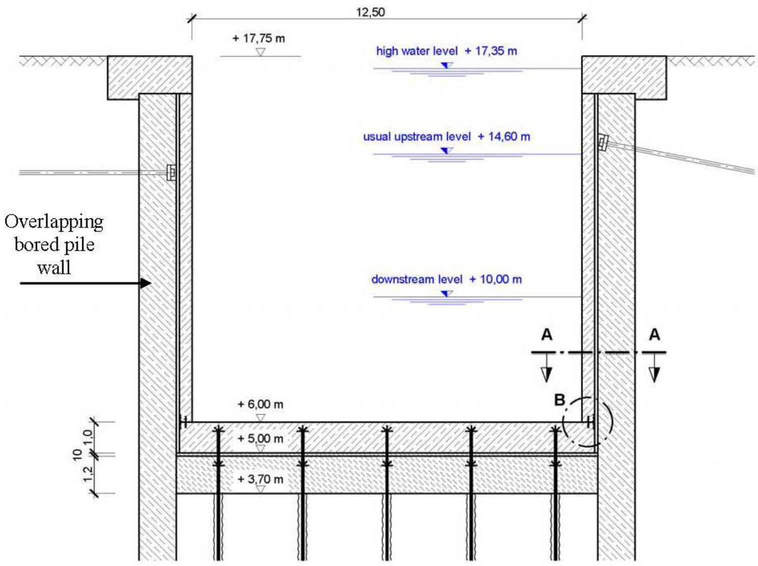
- numerical modeling (FEM, 2D, 3D)
- soil-structure-interaction
- seapage and groundwater modeling
- behaviour of material (e.g. for durability purposes frost-thaw-resistance of concrete)
- treatment of soil

Possibilities



Combination of excavation support walls and chamber walls

Tremie concrete slabs



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Layout of water saving basins

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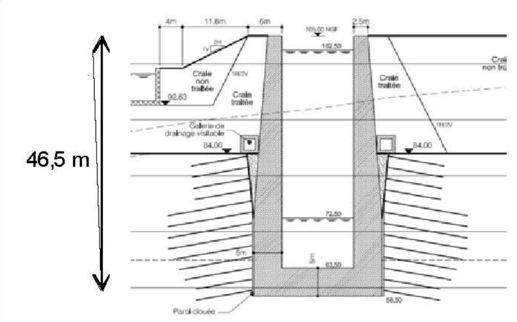
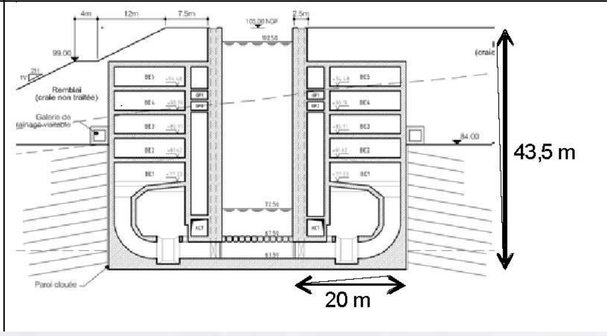
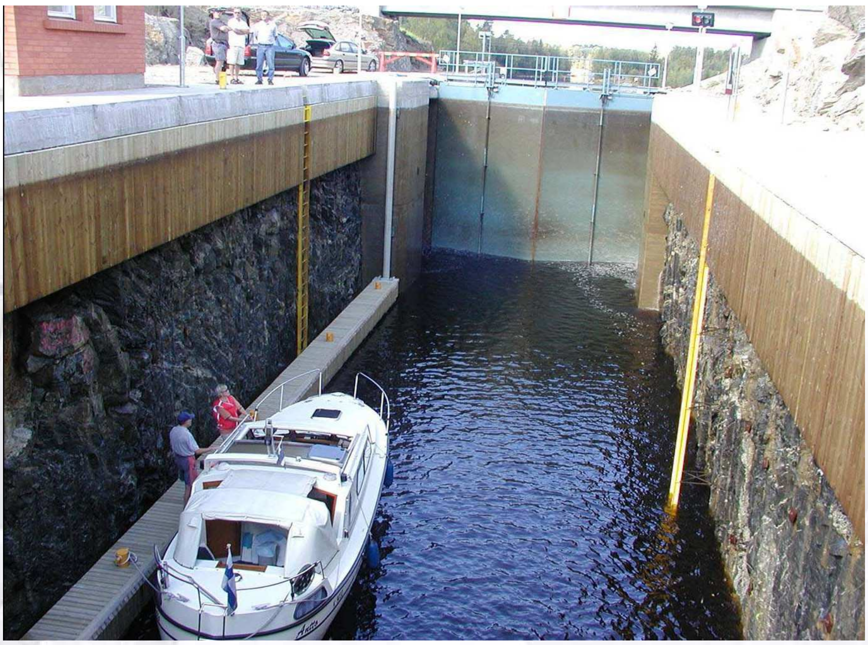
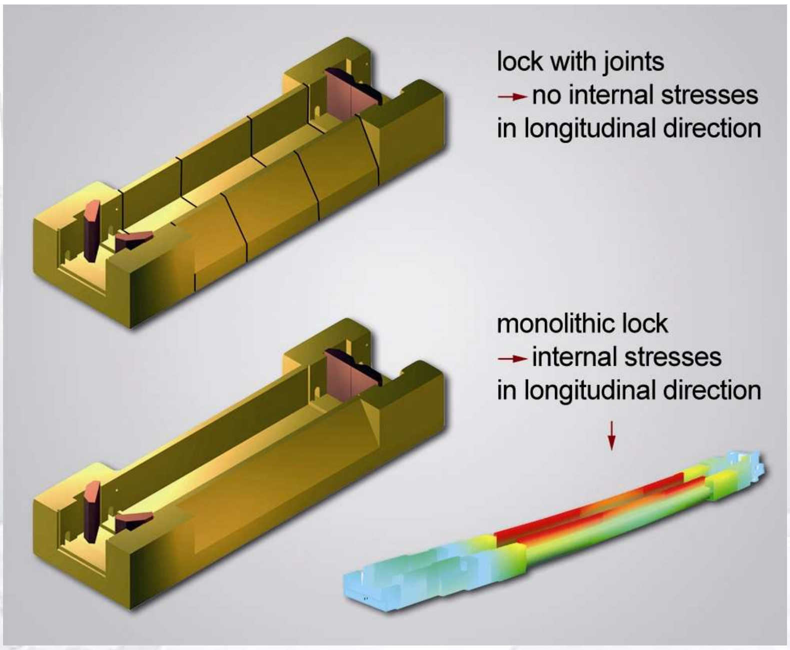
Layout of water saving basins

Chamber cross-sections – Comparative operation	
U-shaped chamber – Lock with separate water-saving basins	Lock with integrated water-saving basins
	

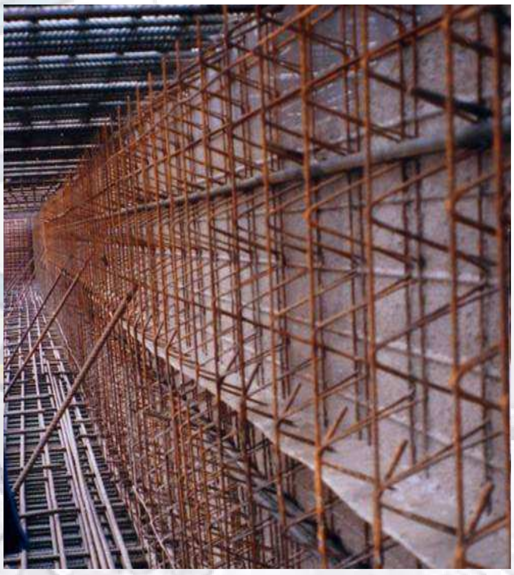
Locks in rock



Monolithic locks



Monolithic locks



Ir. Benoît Deleu
Voies navigables de France

Paper 4
THE LOCKS OF THE SEINE NORD EUROPE CANAL

International Workshop, PIANC - Brussels, 15-17 Oct. 2009

PIANC

The World Association for
Waterborne Transport Infrastructure

Seine Nord Europe Canal – Comparison of two lock concepts with water-saving basins and optimisation of chamber structure

PIANC Workshop
15-16th October 2009

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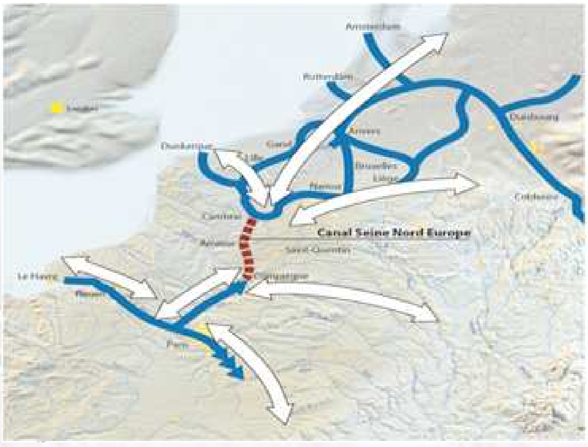
Presentation of the project

Seine-Nord Europe
Central link of the European Seine-Scheldt Waterway

- **Eliminate a major bottleneck** on the European high-capacity waterway network
- **Improve competitiveness of industry**
  - through the reliability and the reduced logistics costs of inland water transport
  - by offering **common access in Europe to 6 seaports** of the northern range (60% of Europe's exports/imports)
- **Contribute to regional development** in France and Europe, reinforcing the capacity of exchange in the corridor Le Havre-Paris-Amsterdam/Dunkirk



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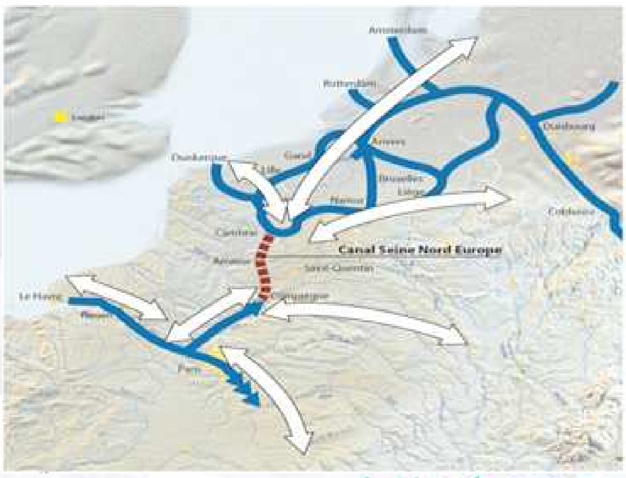
Seine-Nord Europe Canal

meeting challenges at the regional, national and European levels

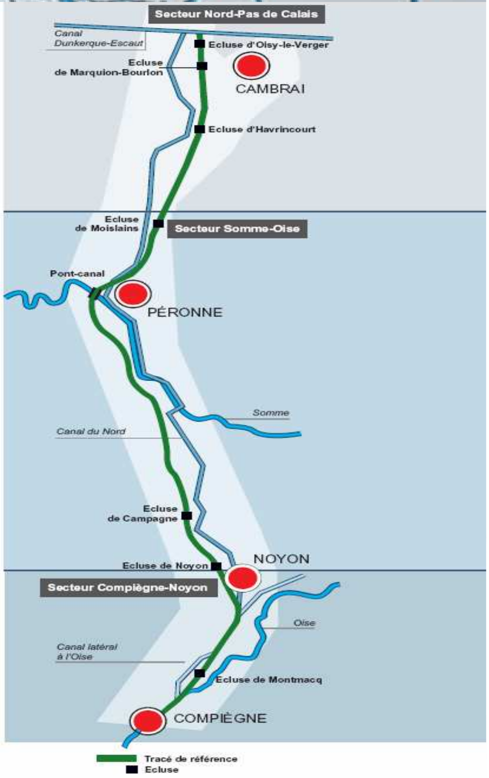
- develop **accessibility** of freight into the heart of large conurbations
- embody sustainable development issues in transport policies
  - by achieving a better **modal split** of freight movements
  - by contributing to a **reduction in greenhouse gases** and in the consumption of **non-renewable energy**
- tap the waterway's potential for **water transfer** and **tourism**



Main technical features of the project

The project consists of a canal **106 km long** (class Vb) from Compiègne to Aubencheul-au-Bac comprising:

- 8 pounds connected by 7 locks (single chamber) with water-saving basins
- 2 water storage reservoirs
- 3 aqueducts
- 59 other structures
- 55 million cubic metres of earthworks
- 2450 ha of land occupied by the canal
- 4 multimodal platforms and 7 loading / unloading quays
- 5 boat harbours + moorings for passenger vessels



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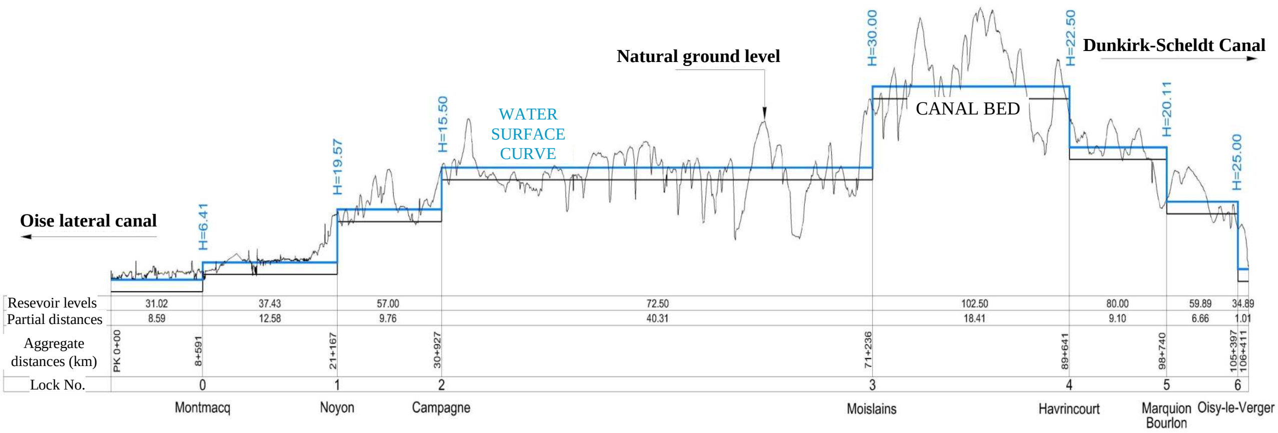
Longitudinal profile of the Seine-Nord Europe Canal



Optimised water management

Carefully controlled water supply

- maximum watertightness of the canal and recycling of lockages
- constitution of reserves (storage reservoirs)

Value added by water transfer

- transfer of 1 - 2 m^3/s from the Oise to guarantee water supply to the Lille conurbation (outside low-flow periods on the Oise)

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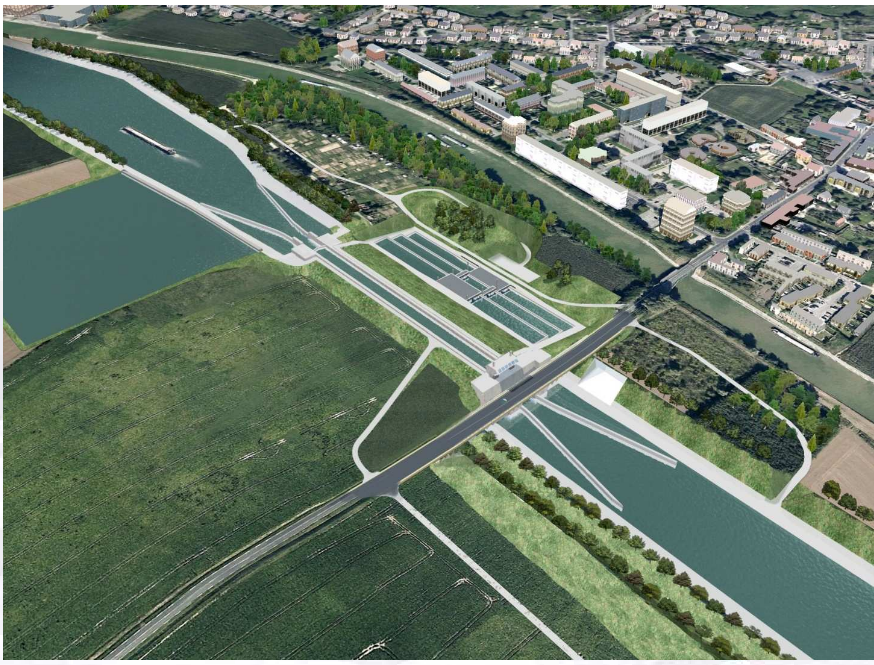
Image of a future lock



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Description of the locks

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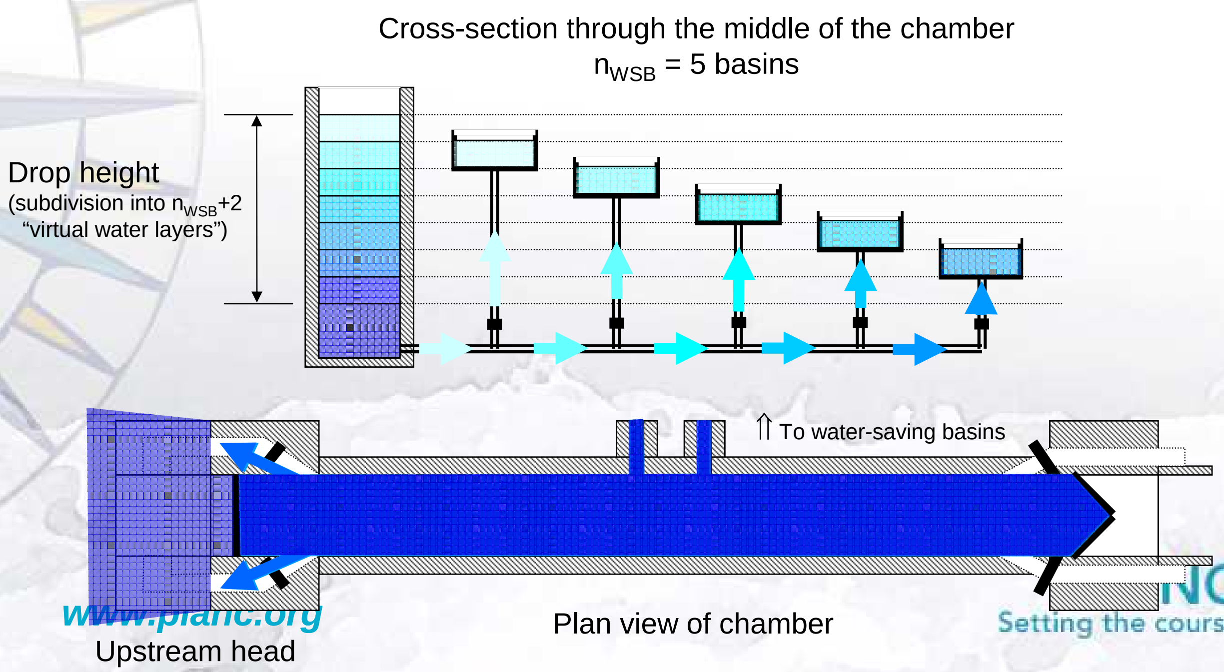
Operating principle of water-saving basins



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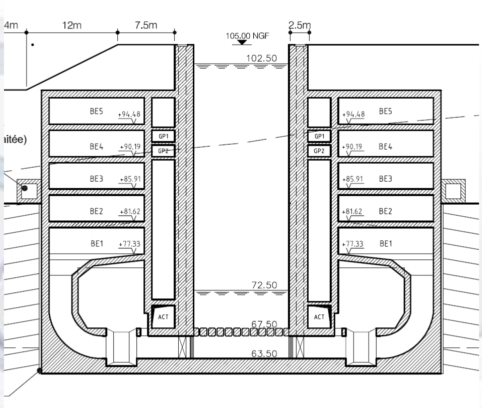
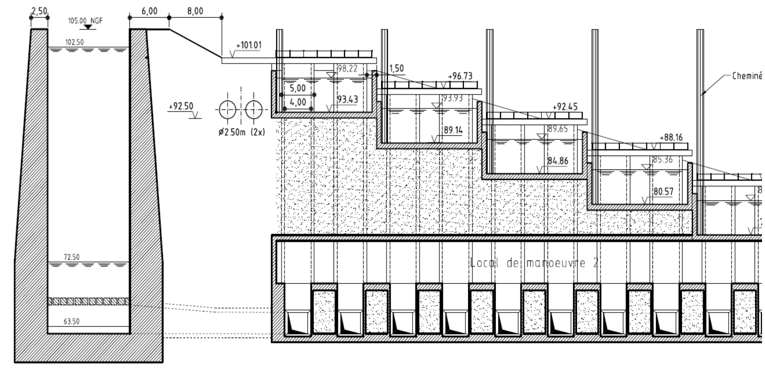
Comparison of two lock concepts



Integrated water saving basins



Separate water saving basins

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Comparison of a few key functions

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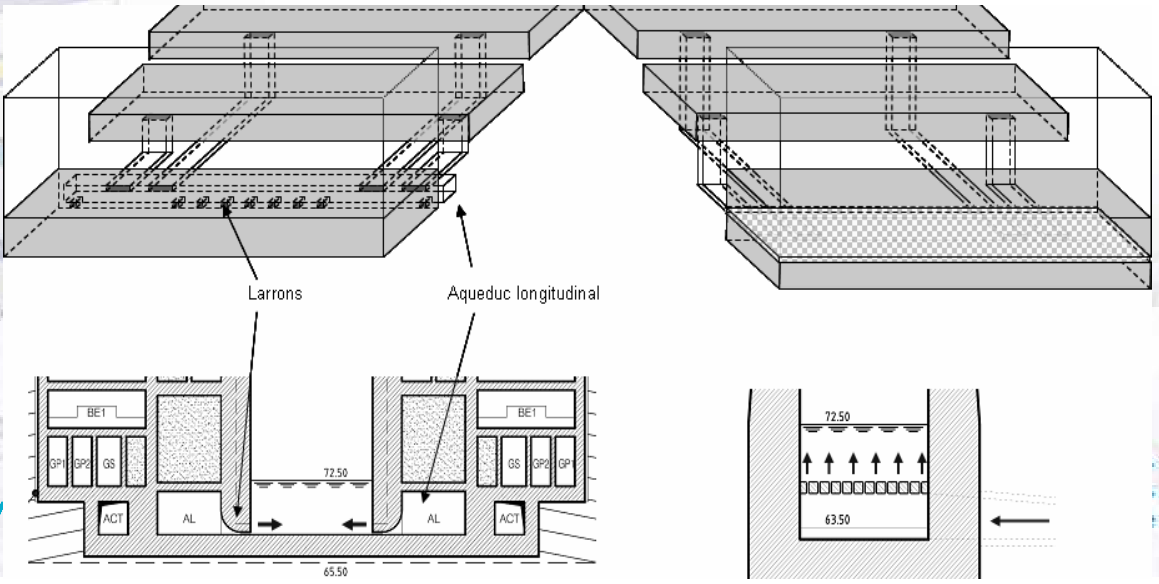
Water inlet methods to fill the chamber

Lateral inlet at the base of the side walls

System of longitudinal ducts + openings

Vertical inlet

System with perforated double apron



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Methods for introducing water into the chamber

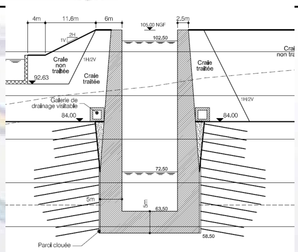
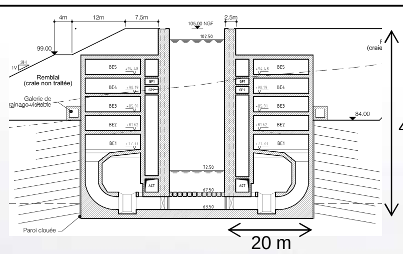
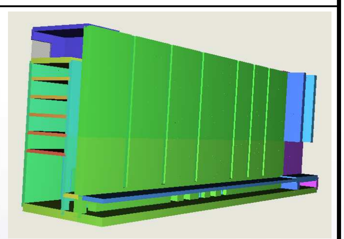
Lateral inlet at the base of the side walls System of longitudinal ducts + openings	Vertical inlet System with perforated double apron
Description: Longitudinal ducts: min. section 20 m² (4.00 m x 5.00 m) Openings (2.00 m x 0.25^{ht} m) : 2 x 30 units at regular intervals (every 4.00 m) Perfectly symmetrical arrangement of openings (jets face to face to dissipate energy) The longitudinal ducts homogenise flow rates through the openings and contribute to energy dissipation	Lower chamber under the perforated apron: height 3 m, width 12.50 m Perforated apron: 1100 perforations, section 0.20 x 0.20 m Water arrives from the WSB into the lower chamber possible dissymmetry A regulating zone in the chamber enables the incoming cross flows to be converted into longitudinal flows.
Advantages Reduced civil works: reduced foundation depth (~ 4.0 m) Simpler structure	Flow tranquillisation in the chamber at least equal and even better Downgraded mode with possible faulty gate
Drawbacks Widening of the base of the side walls in order to house the water ducts → less advantageous with an optimised U–shaped chamber Downgraded mode imposes complete non-use of a WSB level in the event of a faulty gate	Deepening of the structure Cost of the perforated double apron

Key functional components — Water-saving basins

	Integrated water-saving basins (WSB)	Separate water-saving basins
Height	Basins one on top of the other: impossible to match the volumes of water of the WSBs with those of the lock chamber Of the 4.30 m height of the layer of water to be saved, a height of 1.50 m is lost through: • the slab thickness (0.80 m) • a layer of water remaining in the WSB (0.20 min) • a layer of air (0.50 m) above the full basin	Possibility of matching the WSB water volumes exactly with those of their corresponding water layer in the lock chamber $H_{water} = H_{drop}/(n_{WSB} + 2) + 0.50$ m = 4.30 + 0.50
Length	~ length of chamber: 200 m Overflow pipes and and fall shafts at each end	Free length < chamber length (ease of water circulation): 184 m Overflow by running off the canal slopes
Width	Must make allowance for the space occupied inside the WSBs (water intake and bell-mouth of the upper basin) Resulting width required:	15.20 m

CANAL SEINE-NORD EUROPE

Comparative study of locks with separate or integrated water-saving basins
Operation of two types of reinforced concrete structure

U-shaped chamber (separate WSB)	Lock with integrated WSBs
46,5 m 	 43,5 m 20 m 
Chamber cross-section	Chamber cross-section ¼ chamber –3D view
Operation in pure planar deformation Contrast in rigidity between chambers / heads → vertical joint required	More complex operation: Rigidity of side walls + WSB in transverse plane competing with Rigidity of the WSBs in the horizontal plane → 3D modelling required with shell elements No contrast in rigidity between chamber / heads → monolithic structure

Lock with separate water saving basins – Optimisation of reference solution

Typical structure

- U – shaped or similar
- Structure with supported side walls, anchored by passive ties
- Structures with independent gravity side walls

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Structural design of lock chamber — The various structures

Distribution of concrete volumes (preliminary design reference solution)

Lock chamber	Length about 200 m, width 12.50 m Total height between 30 m and 46 m	43%
Headworks	Parallelepipedic gravity structures Width ~ 37 m, length 20 m (u/s) and 40 m (d/s)	25%
Gate chamber	Housed under the water-saving basins, in the middle Width 36 m, length between 50 m and 85 m	15%
Water-saving basins	3 to 5 basins per lock: 200 m x 16 m x 6.00^{ht}	8%
Miscellaneous	Linking water ducts, waiting quays	9%

→ Advantageous to optimise lock chamber

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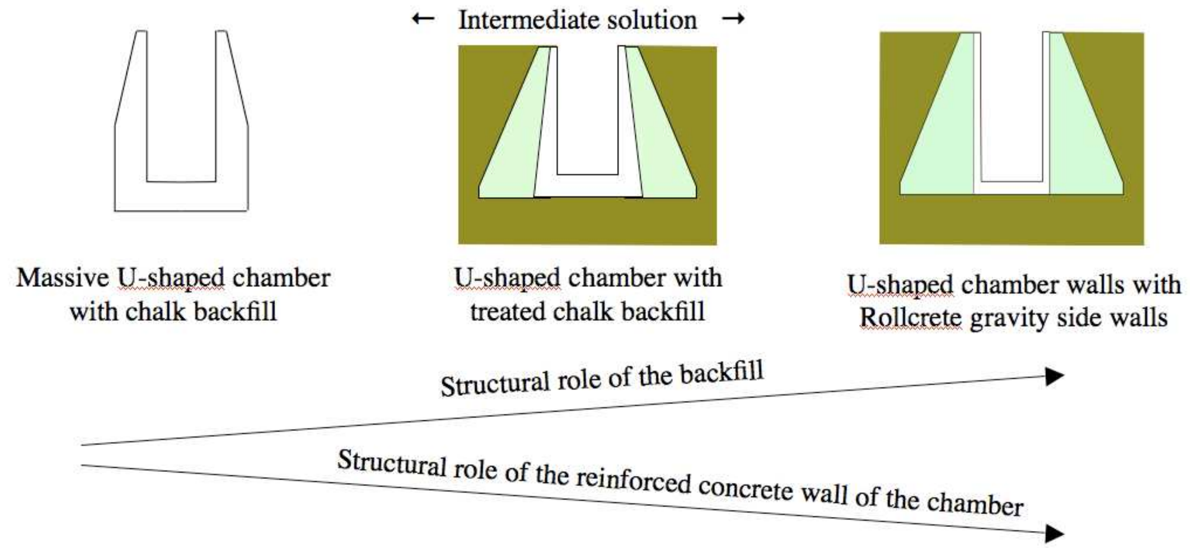
Structural design of lock chamber — Reference solution considered

Reference solution studied and selected
U-shaped structure with treated backfill (chalk - sand - silt)



Structural design of the lock chamber
Treated backfill: materials and method of use

- Hydraulic binder: cement or derivative (LSC binder)
- Binder content: maximum 5% – 6%
- Method of use: road-building technique, by layers:

  layer of levelled chalk, spreading of cement, mixing, compacting

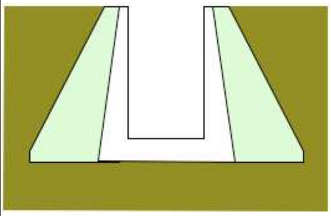
Calculation parameters considered for predesign:

- Non-treated chalk fill: f = 36°, C = 0, E_0 = 20 – 40 MPa
- Treated chalk fill: f = 38°, C = 150 kPa, E_0 = 200 – 400 MPa
- Requires, however, a study of the non-treated chalk fill solution

CANAL SEINE-NORD EUROPE

Structural design of lock chamber — Reference solution considered

U-shaped chamber structure with treated lateral backfill

U-shaped structure with treated lateral backfill		
	*Description :*	Change from self-stable structure to massive U-shape with the aim being to achieve a substantial reduction in lateral backfill thrust. Backfill reinforced with geogrids, geotextiles, rebars, welded mesh, tyres, gabions, etc. Solution with cement-treated in-situ chalk backfill
	Advantages:	• The reinforced concrete of the chamber remains structural but is has smaller cross-sections • Concrete inside the chamber is compressed • Excellent stiffness → little movement of head of side walls • Low-cost solution if backfill is made from treated chalk.
	Drawbacks:	• Few references of use in large massive structures (on the other hand, numerous references in road works) • Little information on fatigue behaviour so additional studies will be required
	Conclusion:	**Highly advantageous concept with treated chalk**

Structural design of the lock chamber
Treated backfill: advantages / drawbacks

Treated backfill (silt – sand – chalk)

Advantages :

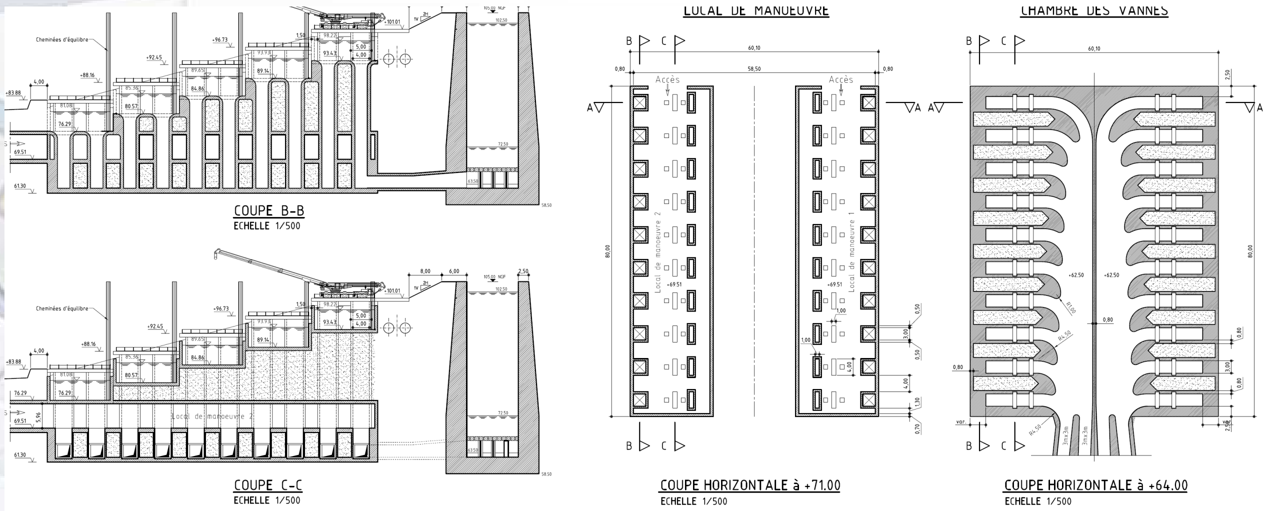
- Productive use made of a material widely available on the project site
- High modulus of deformability:
  - ➢ provides a good thrust block for the side walls *(when chamber is full)*
  - ➢ limits settlement *(foundation of water-saving basins)*
- Cohesion of the material limiting pressure on the side walls
- Low additional cost compared to the gains on the reinforced concrete sections of the chamber
- References from road-building techniques

Drawbacks:

- Restrictions on placing methods (sensitive to frost and bad weather)
- Few references of applications to massive structures
- Interference thrust on side walls during compacting and before setting
- Little is known about behaviour under cyclic stress conditions, cracking.

Comparative study of locks with separate or integrated water-saving basins
Operation of two types of reinforced concrete structure

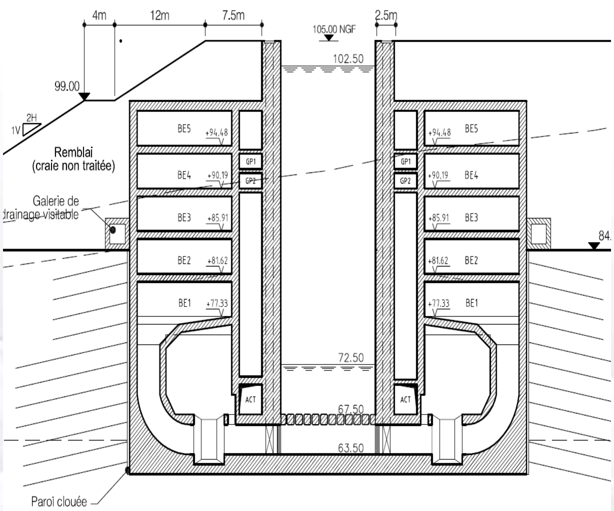
Lock chamber – separate gate chamber and water-saving basins
Preliminary design reference solution for SNE canal locks



Lock with integrated water saving basins – Optimisation of reference solution

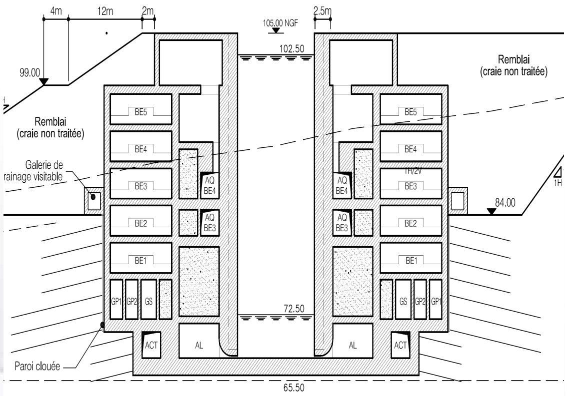
Lock chamber with integrated WSB – Solution n°1

- Water introduced through a double perforated floor
- Gates at the level of the lower room
- Single well for each water intake and each gate
- Gate operating room below the lowest water saving basin
- Butterfly type gates (operating room not high enough for vertical lift gates)
- Wells for basin isolation stop logs housed in the side walls
- Headworks by-pass ducts situated at the lower level against the lock chamber, entering the chamber in the middle (and not at the end)



Lock chamber with integrated WSB – Solution n°2

- Water introduced at the base ot the two side walls
- Gates situated at level n-1 in relation to water saving-basin n
- Certain wells, shared, situated between the basins and lock chamber



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Optimised solution selection

Solution n°1 appears to be the most attractive :

- Simplest hydraulic system
- Lowest hydraulic inertia : potential gain in lockage time
- Best guarantee of lock chamber stillness
- Cost not a decisive factor

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Comparison of the two optimised solutions

Comparison of the two optimised solutions

U-shaped chamber (separate WSB)	Lock with integrated WSBs
Advantages	Advantages
•Numerous references for this system •Lower construction costs (7%) •Smaller volumes of concrete for average drop heigths •More massive lock chamber structure, less elaborate and hence faster to build •Easier access to gates	• lock chamber stillness : slignt advantage thanks to the possibility of introducing water from adjacent reaches in the middle of the lock chamber •Simpler hydraulic circuit •Less environmental impact

Optimisation of construction methods for the solution using locks with separated water saving basins

Structural design of the lock chamber
Adaptation to the hydrogeological context of the site

Seven locks in all

Lock 0 and lock 1, both in the Oise valley,
specific in geotechnical terms, with the main differences being:
- apron foundations just at the top of the chalk formation
- presence of the water table at a high level

⇒ special construction methods required

Locks 2 – 3 – 4 – 5 and 6, built on the chalky plateau
Very similar geotechnical configurations characterised by:
- Cut relatively deeply into the chalk formation
- Presence of a water table at a low level with respect to the structure

⇒ Similar construction methods

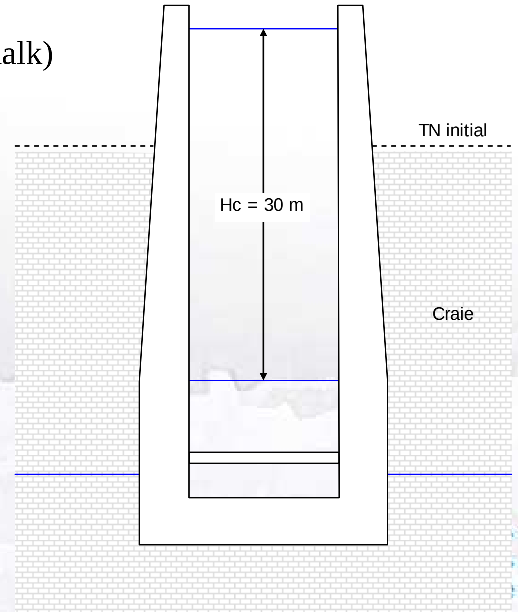
Construction method: Case of lock 3

Lock 3: main features

- Chalk of odd mechanical properties
  (apart from the first tree metres of weathered chalk)
- Low level water table

Solutions studied

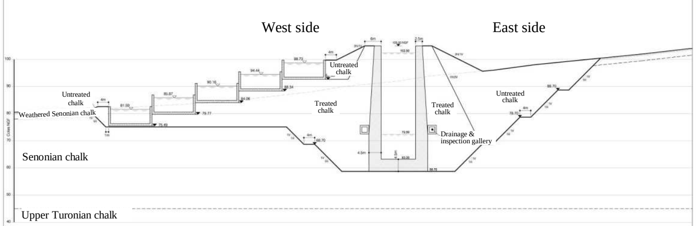
- Solution 1: large foundation pit with sloping sides
  - 1a: with lateral backfill using untreated chalk
  - 1b: with lateral backfill using treated chalk
- Solution 2: one nailed wall level (13 m height)
  - 2a: with lateral backfill using untreated chalk
  - 2b: with lateral backfill using treated chalk
- Solution 3: two nailed wall levels (24 m height)
  - 3a: with lateral backfill using untreated chalk
  - 3b: with lateral backfill using treated chalk



Construction method: Case of lock 3

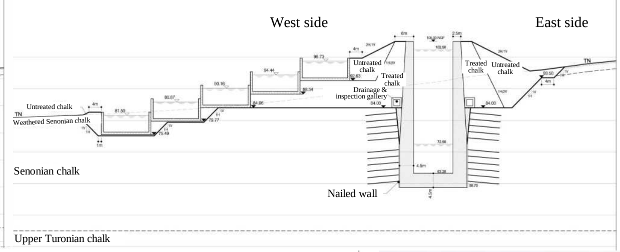
Solution 1b

- Large excavated foundation pit
- Treated chalk lateral backfill



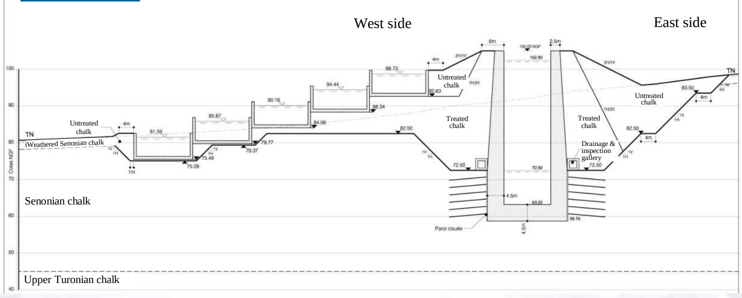
Solution 3b

- Nailed wall below el. 84.00 NGF
- Treated chalk lateral fill



Solution 2b

- Nailed wall below el. 72.50 NGF
- Treated chalk lateral fill



Construction method: Case of lock 3

Solution 1b: Large foundation pit with sloping sides and treated chalk lateral backfill
- High price
- Large footprint
- Very high treated backfill (more than 45 m)

→ sensitivity of the structure to this technique is too high

Solution 2b: Foundation pit with sloping sides for first 20 metres
Nailed wall (height 13 m)
Treated chalk lateral backfill (limited height of 28 m)

Advantages
- Price
- Drainage gallery set at the optimum elevation
- Reasonable sensitivity with respect ot the treated backfill
- Low height of nailed wall
- Smaller footprint

Construction method: Case of lock 3

Solution 3b: foundation pit with sloping sides for the first 8 metres
nailed wall (height 25 m)
lateral backfill using treated chalk (limited height 16 m)

Advantages:
- Price
- Limited volume of treated backfill
- Smaller footprint

Drawbacks :
- Large height of nailed wall
- Drainage gallery set at a relatively high elevation

Construction method: Case of lock 3

Construction costs per linear metre of lock chamber

Solutions	Relative cost per item					*Cost criterion ranking*
	Earthworks	Transport & dumping of surplus fill	Backfill	Concrete	Total	
1a: sloping foundation pit with chalk backfill	100	23	48	1170	1341	*6*
1b: sloping foundation pit with treated chalk backfill	90	22	225	860	1197	*4*
2a: nailed wall (h=13m) with chalk backfill	80	12	24	1118	1234	*5*
2b: nailed wall (h=13m) with treated chalk backfill	80	12	120	858	1070	*1*
3a: nailed wall (h=25m) with chalk backfill	92	9	24	1035	1160	*3*
3b: nailed wall (h=25m) with treated chalk backfill	92	9	110	879	1090	*2*

Optimised solution with treated backfill and nailed wall: 20% reduction in chamber cost

Summary of lock characteristics (single locks)

	Lock 0	Lock 1	Lock 2	Lock 3	Lock 4	Lock 5	Lock 6
	PK 8 (southern end)	PK 21	PK 30	PK 71	PK 89	PK 98	PK 105 (northern end)
	Montmacq	Noyon	Campagne	Moislains	Havrincourt	Marquion / Bourlon	Oisy le Verger
Fall height (m)	6.41	19.57	15.50	30.00	22.50	20.11	25.00

Chamber length	195 m
Whamber width	12.5 m
Mooring	5 m
Total volume of concrete for all 7 locks	1 million m^3
Total mass of steel reinforcement bars for all 7 locks	90 000 t
Total area of formwork for all 7 locks	830 000 m^2
Steel structures - 7 upstream gates, approx. 7 m x 7 m - 6 downstream gates, approx. 14 m x 13.5 m - 1 downstream gate, approx. 7 m x 13.5 m - 126 water duct gates 3.5 m x 3.5 m	5000 t

7 pumping stations with a total of 21 pumps with unit capacity ranging from 400 to 1900 kW
Installed capacity from 1.8 to 6.9 MVA per lock with a total of 28 MVA
Overall annual electricity consumption of 50 GWh (2013) rising to 87 GWh (2025)

Hydraulic simulations

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vnf voies navigables de France

Physical model of the 30 m lock - 1:25 scale

voies navigables de France

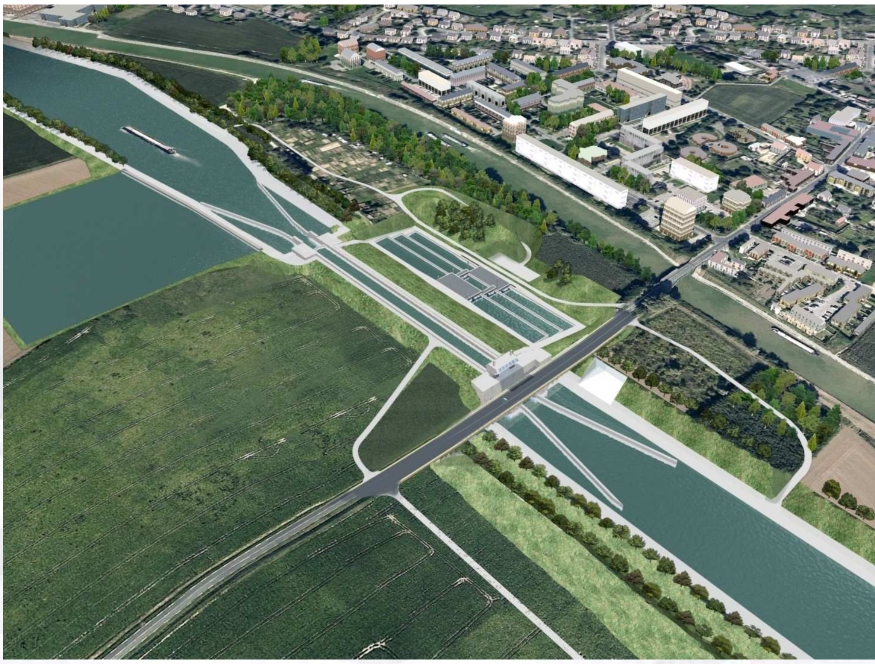
Results obtained in normal operation

- Filling time : of the order of 13 min 30s
- Longitidunal slope in the locks chamber remains at 0.1%
- Wave with a maximum amplitude of 1.15 m is observed in the water saving basins
- Downstream lockage wave remains less than 0.27 m high

CANAL SEINE-NORD EUROPE

voies navigables de France

Image of a future lock ?



Doubling of the locks

Doubling of locks: subject for in-depth study

- Traffic forecasts: 14 Mt by 2020 rising to 26 Mt by 2050
- Saturation will be reached 10 to 20 years after bringing the canal on stream

Allowance must be made for potential restrictions (geotechnical, land occupied) to lock doubling and/or subsequent lock doubling must be anticipated:

- oversizing of side wall when the ground thrust cannot be brought to bear,
- temporary underpinning of the upstream pound during canal doubling construction works,
- risks linked to the hydraulic gradient and to ground water flow,
- electro-mechanical equipment deferred for the second lock chamber.

Thank you very much for your attention

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Ir. Jerry Webb
US Army Corps of Engineers, USA

Paper 5, part A
INNOVATIONS IN LOCK EMPTYING AND FILLING SYSTEMS

International Workshop, PIANC - Brussels, 15-17 Oct. 2009

INNOVATIONS IN LOCK EMPTYING & FILLING SYSTEMS

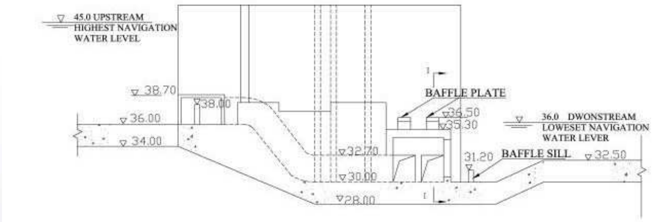
(Based on InCom WG29 – Version 20b – Final Report)

Jerry Webb, P.E., D.WRE
US Army Corps of Engineers

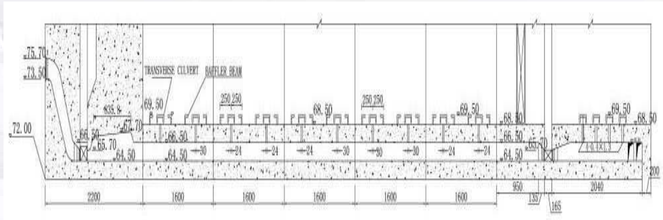
- Layout of Hydraulic Systems
  - Types of Hydraulic Systems
  - New Concepts in Hydraulic Systems
  - Selection Guidelines
  - Water Saving Concepts
- Technical Aspects of Lock Design
  - Developments in Hydraulic Analysis
  - Hydraulic Aspects of Design

LAYOUT OF HYDRAULIC SYSTEMS

- Two Types of Hydraulic Systems
  - “Through the Heads”

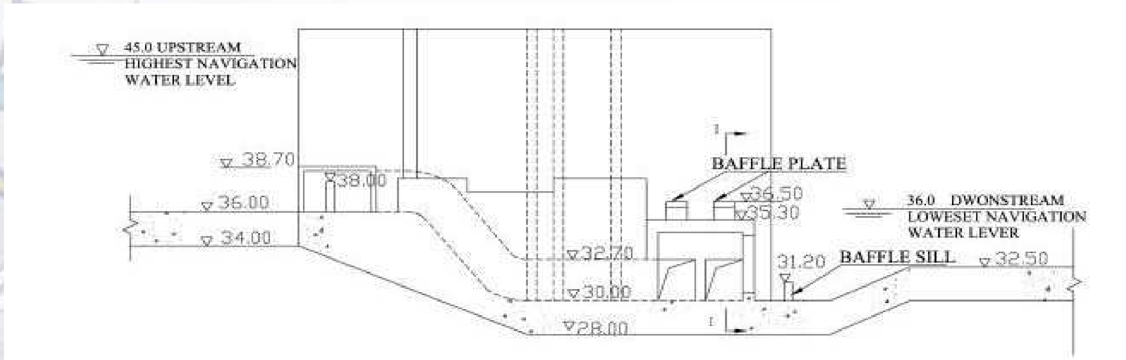


  - “Through Longitudinal Culvert”



TYPES OF HYDRAULICS SYSTEMS

- “Through the Heads” System
  - Short culvert in heads
  - Gates with integrated valves
  - Use lock gates as valves



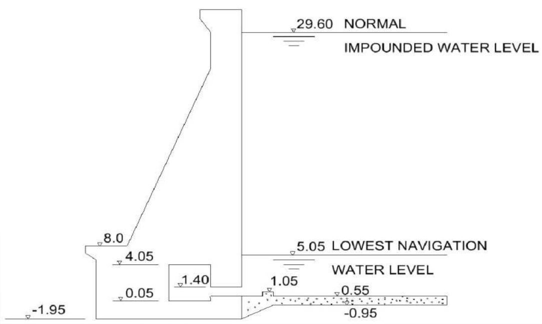
Filling system through the head and with short culvert system with a complex energy dissipation chamber (Fig. 4.12)

TYPES OF HYDRAULIC SYSTEMS

- "Through the Heads" System
  - Use may induce dangerous currents and waves within the lock
  - Solutions:
    - Lock can be operated with a very slow valve schedule
    - Lock can be equipped with an energy dissipation system to reduce the current and waves
    - Lock can be monitored continuously to avoid safety hazards, so that a lock keeper can bypass the automated filling/emptying mode
- Filling/Emptying procedure should be carefully planned and validated before use

TYPES OF HYDRAULIC SYSTEMS

- "Through Longitudinal Culvert" System
  - Asymmetric distribution of flow along the length of the lock chamber
    - Wall culvert side port system
    - In Chamber Longitudinal Culvert System (ILCS)

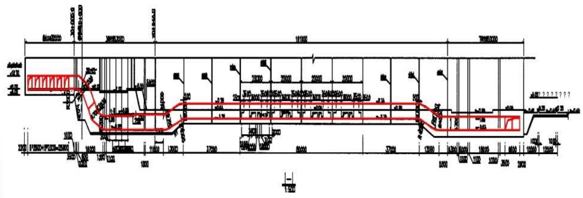


Wall Culvert Side Port System (Fig. 4.13)

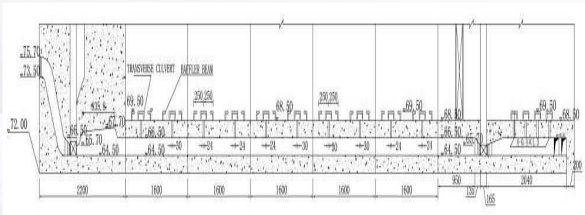
In Chamber Longitudinal Culvert System (ILCS) (Fig. 4.16)

TYPES OF HYDRAULIC SYSTEMS

- "Through Longitudinal Culvert" System
  - Asymmetric distribution of flow
    - Wall culvert bottom lateral system
    - Wall culvert bottom longitudinal system
    - Longitudinal culverts under the lock floor



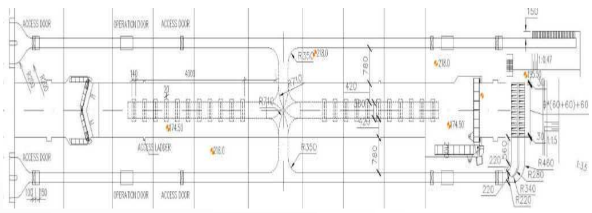
Wall Culvert Bottom Lateral System (Fig. 4.14)



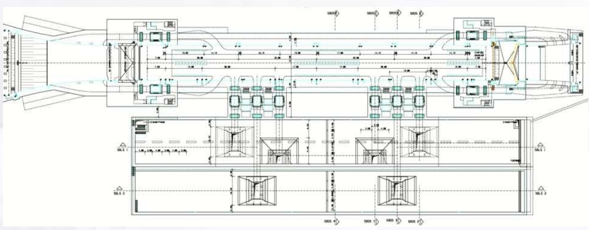
Longitudinal Culverts Under the Lock Floor (Fig. 4.18)

TYPES OF HYDRAULIC SYSTEMS

- "Through Longitudinal Culvert" System
  - Symmetric distribution of flow along the length of lock chamber
    - Dynamically balanced lock filling system
    - Pressure chamber



Dynamically Balanced Lock Filling System (Fig. 4.19)



Pressure Chamber Filling System under Lock Floor (Fig. 4.20)

TYPES OF HYDRAULIC SYSTEMS

- Longitudinal culvert systems can be divided into three categories, as follows, based on complexity :

Complexity Categories of Longitudinal Culvert Systems (Table 4.9)

Complexity	Hydraulic Systems
1. Simple longitudinal culvert systems	- Wall culvert side port system - In Chamber longitudinal system system (ILCS)
2. More complex longitudinal culvert systems	- Wall culvert bottom later system - Longitudinal culverts under the lock floor - Wall culvert bottom longitudinal system - Longitudinal culverts under the lock floor
3. Very complex longitudinal culvert systems	- Dynamically balanced lock filling system - Pressure chamber under the floor

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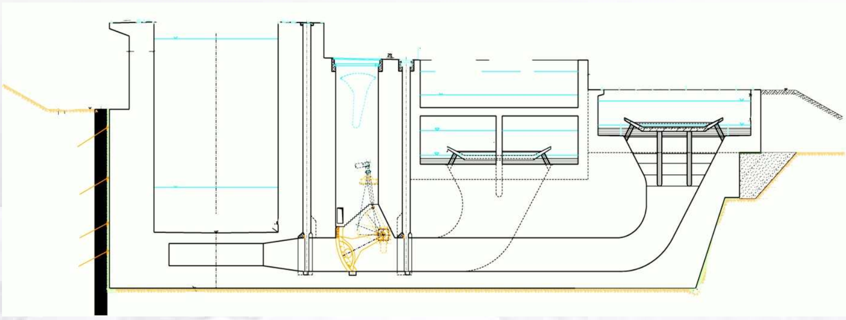
LAYOUT OF HYDRAULIC SYSTEMS

- New Hydraulic System Concepts (Developed after 1986)
  - Pressure chamber system
    - Connected to main chamber through arrays of nozzles
    - Results in a smooth filling of the chamber and a short filling time
    - Has proven very effective, particularly in combination with water saving basins



Connection of Pressure Chamber to Water Saving Basins (Fig. 4.21)

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NEW CONCEPTS

- Pressure chamber system (cont'd)
  - When designed, it is important to balance the number and diameter of the nozzles against the size of the chamber and the culverts.
  - If there are too few nozzles, flow into the chamber will be uneven, causing turbulence on the water surface.
  - System should be balanced so the hydraulic loss for the filling process is governed by the nozzles in the floor rather than the hydraulic losses in the inlet, culverts or pressure chamber.

NEW CONCEPTS

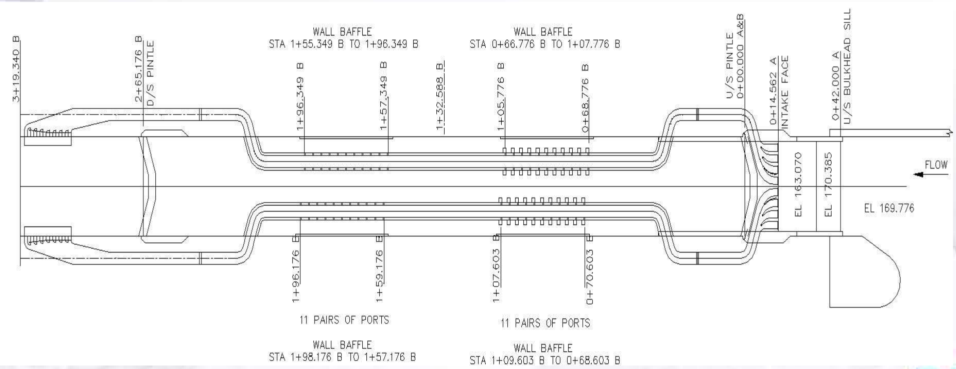
- Pressure chamber system (cont'd)
  - Nozzle size should be estimated using the following ratio of cross-sectional areas:

$$\alpha = \sum_{nozzles} A_{nozzle} / \sum_{culverts} A_{culvert}$$

  - When α is small (<1), the filling process is slower but smoother.
  - When α is larger (>1.5), the filling process is faster but rougher.
  - Rule of thumb: $A_{pressure\ chamber} \geq A_{feeding\ culverts}$
  - Studies have shown that smaller values of α provide the best results (Minden, Germany).

NEW CONCEPTS

- In-chamber Longitudinal Culvert System (ILCS)
  - Design Philosophy: Develop a system that performs almost as efficiently as the side-port filling and emptying system
  - Culverts in the chamber walls are replaced by culverts in the floor of the chamber.



In-Chamber Longitudinal Culvert System (ILCS) – Marmet Lock (Fig. 4.15)

NEW CONCEPTS

- In-chamber Longitudinal Culvert System (cont'd)
  - Allows for alternative lock wall construction, such as RCC or in-the-wet construction
  - Optimized port extensions and wall baffles can provide a uniform distribution of flow into the chamber during filling. They can also assist in energy dissipation.

In-chamber Longitudinal Culvert System (ILCS) – Marmet Lock (Fig. 4.16)

NEW CONCEPTS

- In-chamber Longitudinal Culvert System (cont'd)
  - Can result in significant savings under specific conditions, such as a construction in rock
  - Investigations show that increasing water depth in the chamber allows for a slight improvement in operation speeds.

SELECTION GUIDELINES

- When selecting a filling and emptying system, five factors should be taken into consideration:
  - lift height
  - filling/emptying times
  - lock chamber sizes
  - permissible investments for the lock
  - maximal forces on the vessel
- Generally, the admissible forces on the vessel and the filling time govern.
- Additionally, it is necessary to determine a balance among *lift, safety, cost* and *efficiency.*
  - Lift and safety are determined by the specific project and hawser forces, and cannot be changed. Therefore, cost and efficiency must be balanced.

SELECTION GUIDELINES

- A good filling/emptying system should follow five principles:
  - Filling time should be as short as possible (based on the specified capacity and construction costs).
  - Water movement and turbulence in the chamber must be limited. The forces on the vessels and thus in the hawsers must not exceed established criteria.
  - Entrapment of large air bubbles in the filling system must be avoided.
  - Cavitation should be avoided if economically possible; otherwise adequate protective measures must be taken.
  - Currents in lock approaches should be reduced to a minimum so that there will be no adverse effect on vessels waiting to lock or maneuvering in the approaches.

SELECTION GUIDELINES

- Two, simple approaches for determining most efficient hydraulic system:
  - Lock lift height
  - M coefficient (Chinese Code, 2001)
    - To be covered in another presentation

- Lift height (H) Approach
  - Design is based on the lift height, following the table below:

• Low lift height	H < 10m
• Intermediate lift	10m < H < 15m
• High lift	15m < H

  - **Note:** This classification was derived for inland waterway navigation and is not valid for seagoing vessels and sea locks.

SELECTION GUIDELINES

- “Low lift locks”
  - A through the heads system or simple longitudinal culvert system may be used (Level 1, Table 4.9).
  - A short culvert system may require an advanced energy dissipation chamber if a short filling time is required.
  - The filling process is not balanced along the chamber length.
- “Intermediate lift locks”
  - A wall culvert side port system and simple longitudinal culvert system may be suitable (Level 1 or 2, Table 4.9).
    - Wall culvert side port system; longitudinal culverts under the floor with side outlets; longitudinal culverts under the floor with top outlets
  - The filling process is better balanced along the chamber length.

SELECTION GUIDELINES

- “High lift locks”
  - Require a more complex/advanced culvert system (level 2 or 3, Table 4.9)
    - “Two sections dynamically balanced” lock filling system; “four sections dynamically balanced” lock filling system; “pressure chamber” system for locks with WSBs
  - It is necessary that the filling process is as symmetric in relation to the chamber as possible.

SELECTION GUIDELINES

- Factors unaffected by lock lift height analysis:
  - Overall lock size (length x width)
    - Complex systems could be inappropriate due to cost
  - Lock dimensions
  - Flow variations
    - How fast flow velocity is changing during the locking
    - Tend to lead to waves in the chamber
    - Can induce longitudinal forces against vessel and miter gates, or transverse forces against hull of the vessel
  - Transverse forces, caused by the following processes, can be major problems:
    - Asymmetric filling system/operation
    - Asymmetric position of vessel
    - Jets which directly touch the hull

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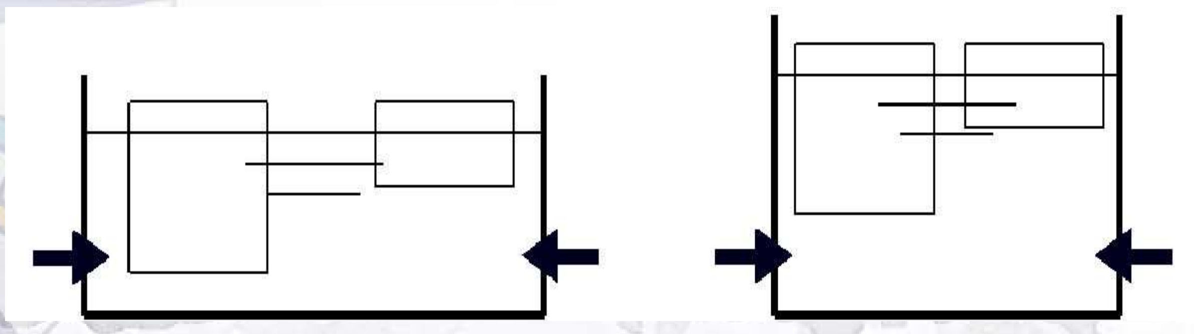
SELECTION GUIDELINES

- Transverse Force Example: The locks below have the same cross sectional area. However, the flow of water into the lock causes direct transverse forces on a vessel in one configuration, but not on the other.



Impact of the wall culvert side port system (bad configuration on the left, better one on the right) (Fig. 4.23)

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SELECTION GUIDELINES

- Additional Selection Criteria
  – If leveling is not carried out uniformly over the entire length of the lock chamber, longitudinal loads will also act on the vessels.
    - With wall culverts and even longitudinal culverts, discharge is not uniformly distributed along the lock length.
    - Uniform distribution can be enhanced by using bigger culverts and, more significantly, by using symmetric systems.
  – Dimensioning of the culverts is also influenced by the need to limit cavitation and wear in the culverts.
    - Although flow speed is not a sufficient criterion, many countries place limitations on the average flow speed allowed in the culverts.
    - Cavitation is largely influenced by the pressure field and the shape of the hydraulic system.

SELECTION GUIDELINES

- Additional Selection Criteria (cont'd)
  – For locks with a deep and perforated bottom (longitudinal culverts under lock floor, pressure chamber below floor, etc), flow enters the lock vertically through small holes in the floor.
    - If the volume of water beneath the floor is great and there are a great number of holes distributed regularly throughout the surface of the floor, water is transferred uniformly by the bottom of the lock chamber into the lock chamber.
    - Only very small waves are generated even when the rate of flow varies during the locking. Moored ships are not heavily loaded in the longitudinal and transverse directions.

WATER SAVING CONCEPTS

- Determination of Saving Needs and Selection of the Water Saving System
  - Defined during the studies of water resources management taking into account the following:
    - Assumed traffic
    - Evaporation
    - Infiltration
    - Canal watertightness
    - Climate changes
  - The global water saving system of the lock is a combination or choice of different systems:
    - Pumping
    - Water Saving Basins (WSBs)
    - Intermediate gate inside the chamber
    - Twin synchronized locks (parallel locks)
    - Lock ladder

WATER SAVING CONCEPTS

- To select the best water saving system, the various systems have to be designed and optimized simultaneously by a technical and economic assessment in relation with the existing lift height and the energy cost.
- The main choice criteria for selecting a system or a combination of systems are:
  - Construction cost
  - Operation cost
  - Energy saving and environmental cost
  - Filling time and traffic
  - Available space
  - Influence on water level in the upper and lower reaches

WATER SAVING CONCEPTS

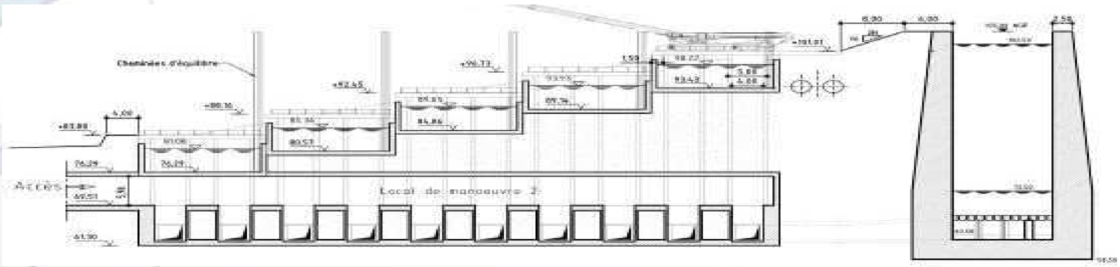
- Examples of Criteria Use:
  - Twin synchronized locks can be accepted only if they are economically justified by the traffic.
  - An intermediate gate may be a good solution only if a significant number of lockages are to be made with small boats.
  - A lock ladder has many advantages over a single lock, but it increases the number of gates and ship operations (mooring, etc.), therefore lowering the traffic capacity.
  - Although water saving basins lead to high initial investment, complex structure, numerous gates, and longer filling/emptying times, they are best when the need for water saving is permanent and larger than a minimum value (case-specific) because of reasons of life cycle cost, energy saving, and environmental cost.

WATER SAVING BASINS

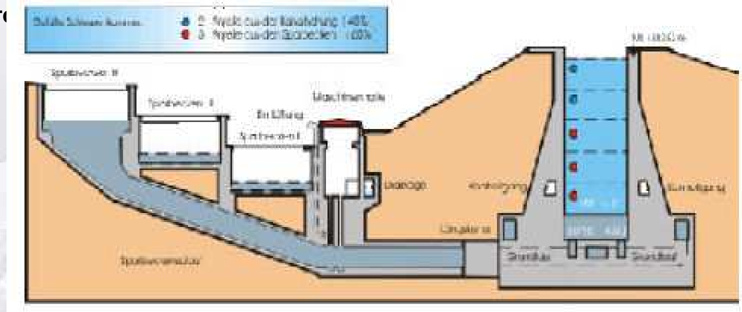
- Historic Use
  - Locks with integrated water saving basins were first built in 1928 in Germany. They are still in operation with no major problems reported.

- Recent Examples
  - 3rd lane of the Panama Canal (proposed)
  - Seine Nord Europe Canal (proposed)
  - Uelzen, Germany (2006)
  - Hohenwarthe, Germany (2003)
  - Rothensee, Germany (2001)
  - Rhine-Main-Danube (RMD): 20-30 years of successful use

WATER SAVINGS BASINS



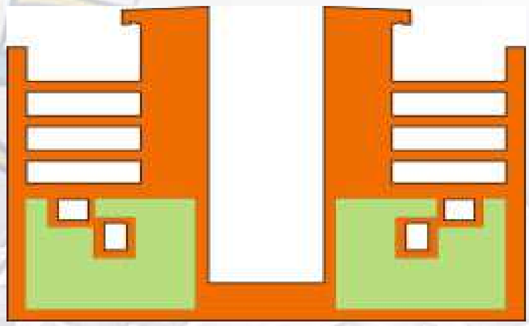
Example of a lock with separated WSBs in France (Seine Nord Europe);
Cross section thr... mber (Fig. 4.27)

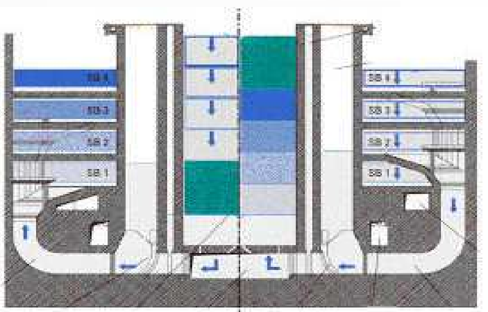


Rothensee Lock (2001 – Mittellandkanal) (Fig. 4.26)

WATER SAVING BASINS

Uelzen I Lock (1976 – Elbe-Seiten Canal) before construction of Uelzen II (Fig. 4.26)





Cross-sections of lock sidewalls with integrated saving basins,
Uelzen II lock with 4 integrated water saving basins and different concrete compositions (Fig. 4.28)

WATER SAVING BASINS

- A lock with water saving basins (WSBs) better fits to filling/emptying systems with longitudinal culverts and inlets on the sidewalls or even distributed through the floor because the successive openings/closures of valves induce significant discharge and therefore higher risk of disturbance of the water level on the lock chamber (balancing waves along the lock chamber).

WATER SAVING BASINS

- Key Points for Optimization of Water Saving Basin Design
  - Optimization of the basin dimensions and parameters:
    - n: Number of saving basins
    - m: $\frac{\text{Area of saving basin}}{\text{Area of chamber}}$
    - e: Pressure head difference when closing valves

    The values of these parameters determine the water saving rate.

  - Hydraulic optimization in order to decrease the filling time
    - The most significant improvements of such a system relate to the design of the global hydraulic system, especially through optimization by numerical and physical models
      - Example: Studying the synchronization of the valve openings and closures
    - Numerical models make it possible to test a large number of configurations
      - Number of WSBs, diameters and positions of culverts, etc.

WATER SAVING BASINS

- Key Points for Optimization of Water Saving Basin Design (cont'd)
  - Division into symmetrical half saving-basins to facilitate the maintenance and reduce the impact in case of a problem (closure of ½ basin versus 1 basin). That may be a useful solution if a short filling time is required.
    - In this case, half basins can be placed symmetrically on both sides of the lock.
  - It is better to have multiple culverts between a basin and the chamber for reliability reasons and to avoid a high degradation of performance during the maintenance of a valve or a culvert. With multiple culverts per basin the water distribution along the axis can be enhanced and thus faster filling can be achieved (for a higher building cost).

WATER SAVING BASINS

- The choice of hydraulic filling system (i.e. through the heads system, simple longitudinal culvert system, etc.) must be done considering the real water lift height between 2 basins. However, when the use of the WSBs is economically relevant, that also means that the lock lift height is rather important and that a reduced filling time is expected.
- Thus an advanced and performing hydraulic system is generally needed.

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PIANC
Setting the course

HIGH RISE NAVIGATION LOCK USING WSBs

- Traditionally, the maximum lift height of a lock is considered to be limited at 25, 30, or 45m due to the hydraulic aspects, mainly cavitation.
- If WSBs are used, there is no limit for the lock height. Locks of 100 or 150m can be considered if the filling and emptying of each WSB is studied to avoid cavitation.
  - Cavitation limits the height of the saving basins but not their number and therefore the total lift height of a lock.
    - Example: A lock of 100m lift height with 6 water saving basins is similar for cavitation and hydraulic aspects to a series of four locks of 25m lift height.

Ir. Wu Peng
Planning and Design Institute for Water Transportation, China

Paper 5, part B
DISCUSSION ON FILLING AND EMPTYING SYSTEMS

International Workshop, PIANC - Brussels, 15-17 Oct. 2009

PIANC InCom – Work Group 29

Discussion on Filling and Emptying Systems

Wu Peng
Chief-engineer of PDI (Planning and Design Institute for Water Transportation)
China

Hydraulic system discussion

★ A GOOD F/E SYSTEM

★ SOME EXAMPLES

-- PARTIAL DISTRIBUTED SYSTEM

-- DOUBLE DITCHES ENERGY DISSIPATION SYSTEM

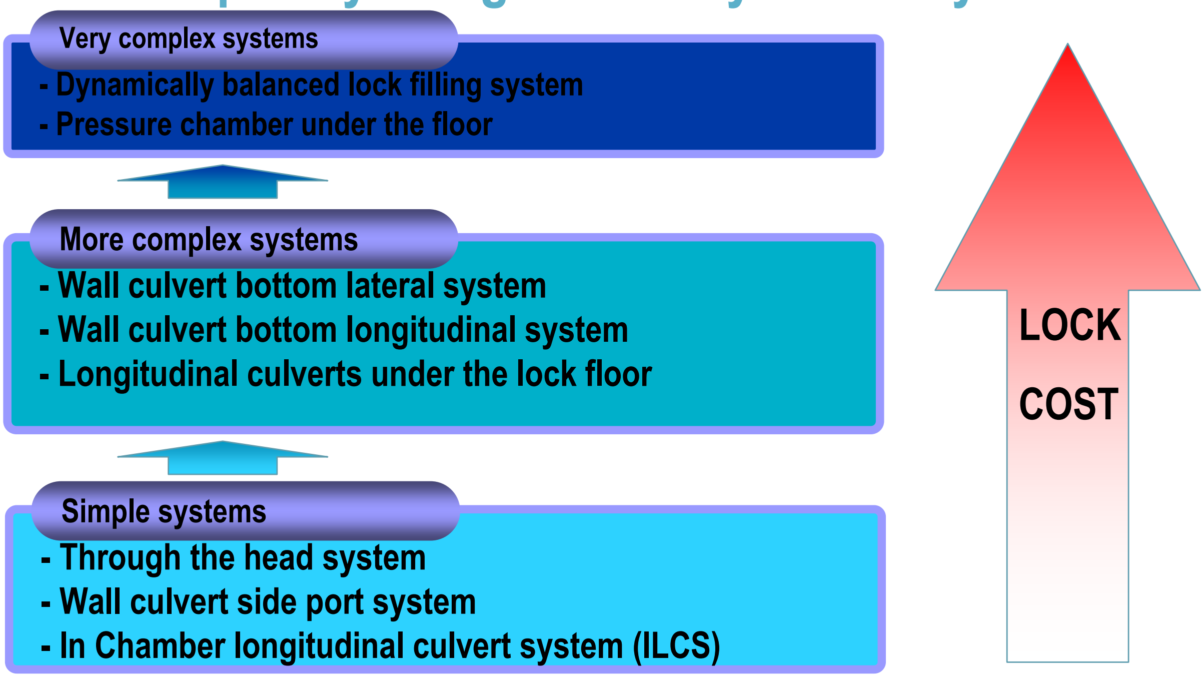
-- ENERGY DISSIPATION FOR SIDE PORT SYSTEM

★ A GOOD F/E SYSTEM

A Good Filling and Emptying System

- could provide proper filling time (not as short as possible)
- Lock cost could be lower

Complexity categories of hydraulic systems



Factors which influence the hydraulic efficiency:

- Lift height
- Permissible hawser forces
- Lock dimensions (lock chamber length, width and submergence)

Chinese code

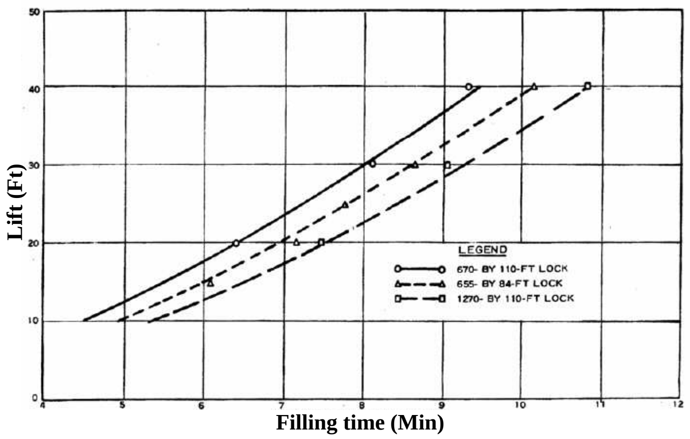
DWT of vessels	3000t	2000t	1000t	500t	300t	100t	50t
longitudinal horizontal components (kN)	46	40	32	25	18	8	5
Transverse horizontal components (kN)	23	20	16	13	9	4	3

Dutch criteria

VESSEL Class	Hawser force criteria (o/oo of total ship displacement)	
	In filling	At emptying or filling with floating bollards
CEMT Class III	1.50	2.00
CEMT Class IV	1.10	1.50
CEMT Class Va	0.85	1.15

USA: Allowable hawser force is 5t

USACE EM1110-2-1604 Figure D-5(side port system)



Coefficient $M = T/H^{1/2}$ for side port system

Lift height (m)	Chamber length/chamber width		
	6.09	7.8	11.5
6.10m	2.59	3.28	3.77
9.14m	2.35	2.84	3.37
12.19m	2.15	2.58	3.09

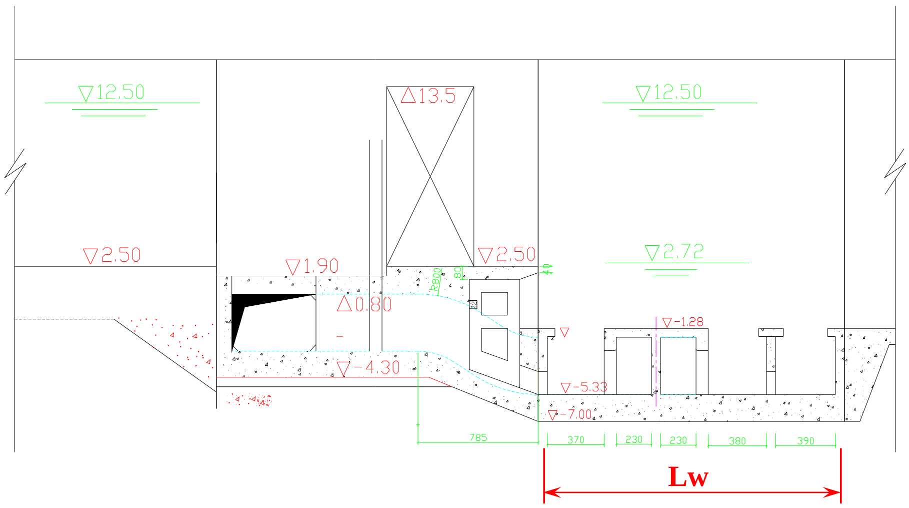
★ Example 1: Partial Distributed System

A hybrid system combined by through head system and through longitudinal culvert system.

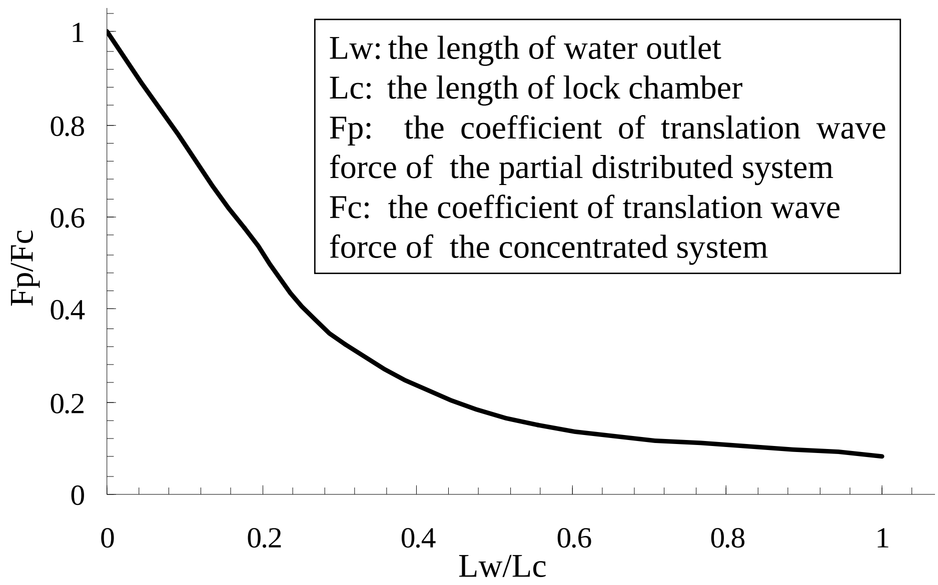
Through head system can be used for locks with very low lift height (≤7m).

This system could be used to locks with low or intermediate lift height (about 10m).

Hydraulic system discussion

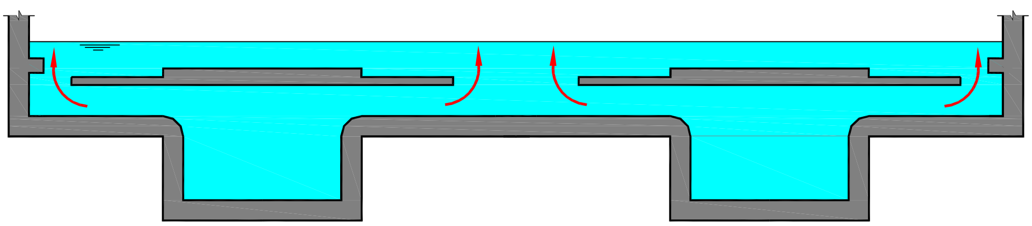


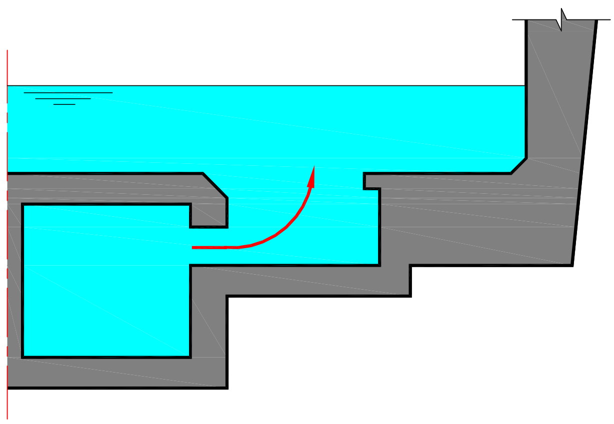
Hydraulic system discussion



★ Example 2: Double Ditches Energy Dissipation System

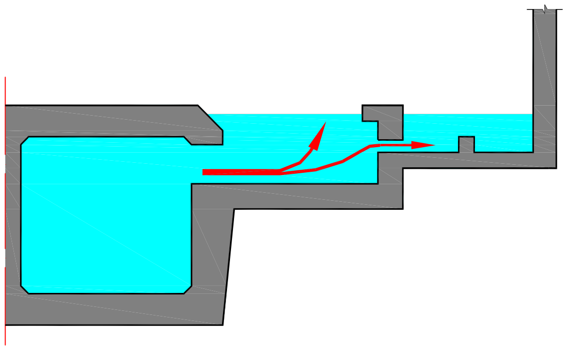
To avoid dangerous currents at the outlets of filling and emptying system, measures should be taken for energy dissipation. Double ditches are effective system for energy dissipation.



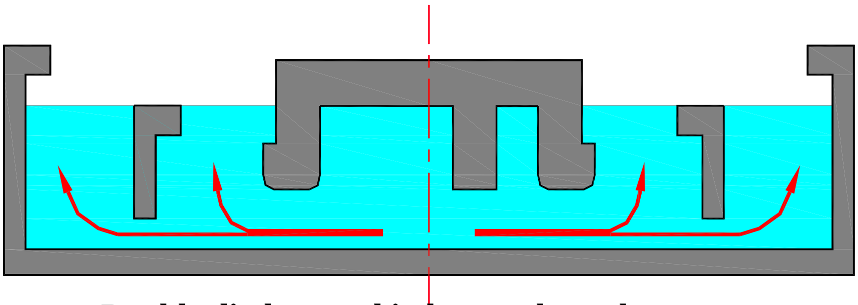


In-chamber Longitudinal Culvert System

Hydraulic system discussion



Double ditches used in ILCS system



Double ditches used in bottom lateral system

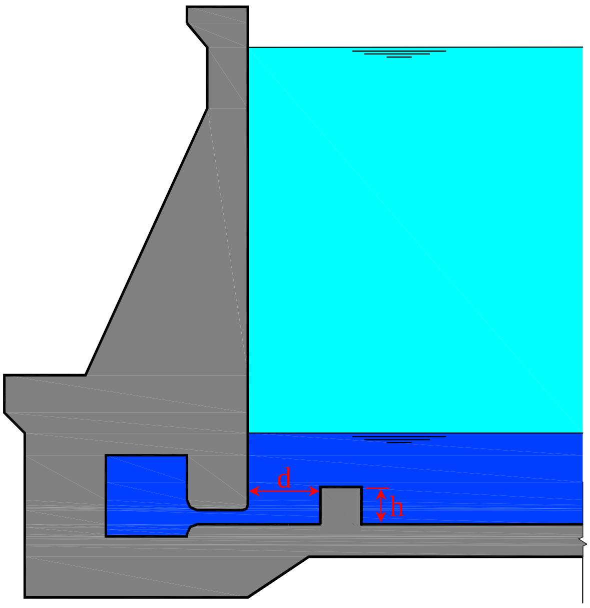
Hydraulic system discussion

Compared with one ditch system the filling time was shortened. Using the same filling time, the maximum transverse hawser force of the double ditches system is small.

	Filling time	Max. transverse hawser force
Single ditch	9min	56 kN
Double ditches	9min	11.2 kN
Permissible transverse hawser force 20 kN		

★ Example 3: Energy Dissipation for Side Port System

For side port system enough submergence is required to prevent direct action of the port jets against the bottom of the vessel. But in many cases a little more submergence will lead to much cost.

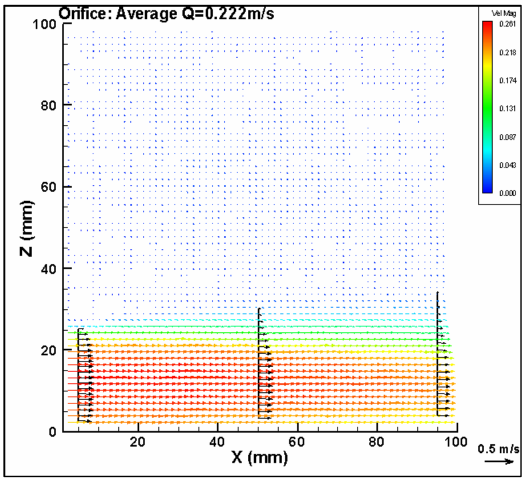


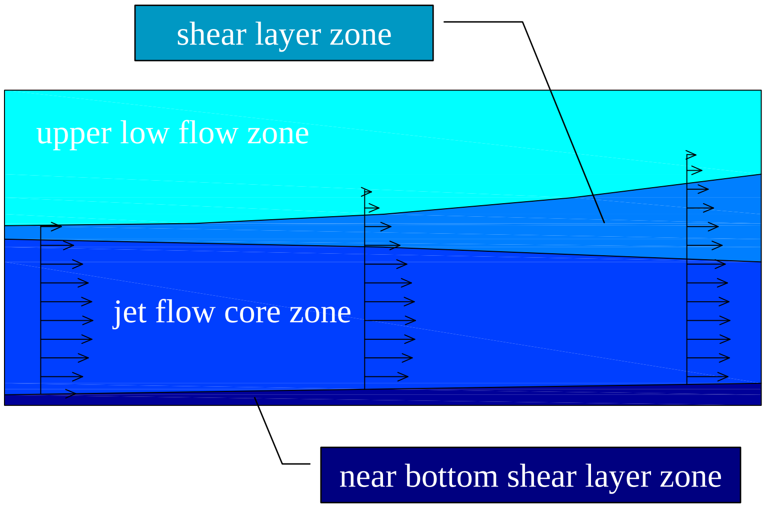
If port deflectors was arranged in chamber the jet into the chamber was spread by the deflectors evenly and the hydraulic condition was improved.

Side port system with port diflectors

Hydraulic system discussion

Flow distribution without deflectors





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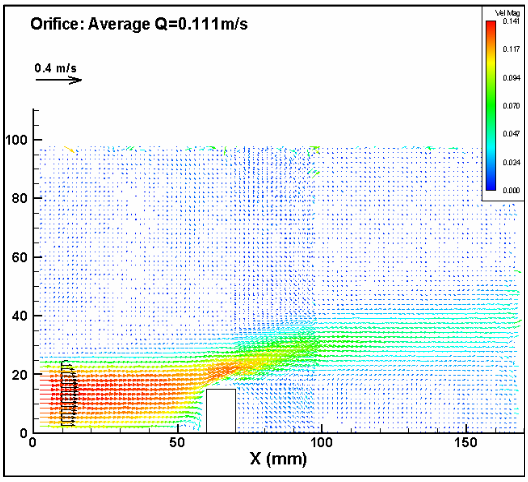
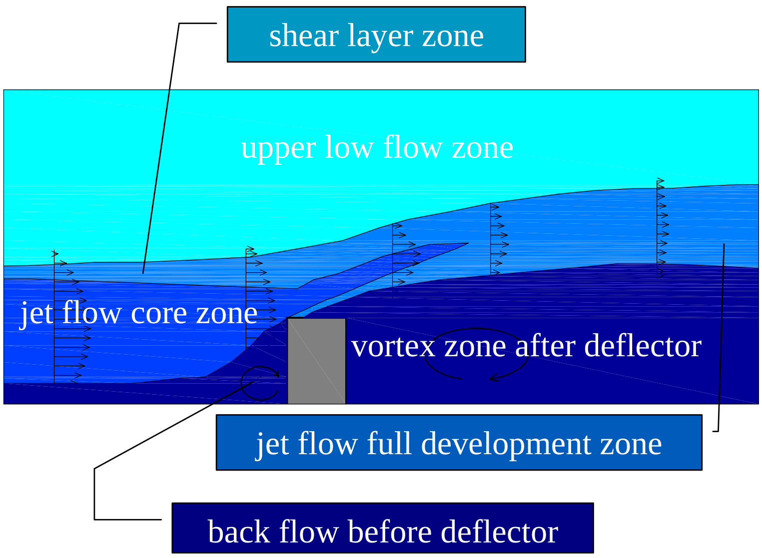
Hydraulic system discussion

Flow distribution with deflectors





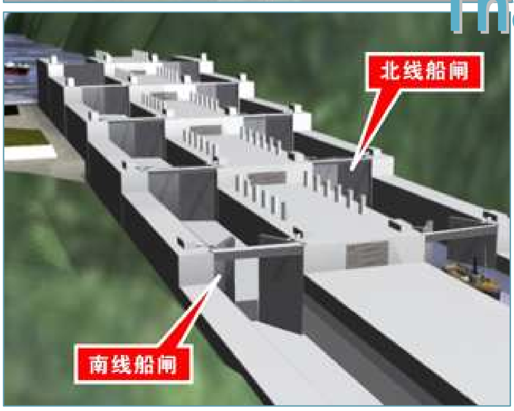
PIANC– Oct. 2009 – Brussels - "Innovations in Navigation Lock Design"

Hydraulic system discussion

- In design stages, the selection of proper hydraulic system need enough knowlege and experience.
- There is no one-size-fits-all approach.
- As the development of hydraulic simulation, we can validate all possible measures to make asymmetric system more balanced and more efficient.

Hydraulic system discussion


Thanks!



Ir. Juan Wong H.
Panama Canal Authority, Republic of Panama

Paper 6
THE PANAMA'S THIRD SET OF LOCKS PROJECT

International Workshop, PIANC - Brussels, 15-17 Oct. 2009

The New Locks of the Panama Canal

PIANC Workshop
Innovation in Navigation Lock Design

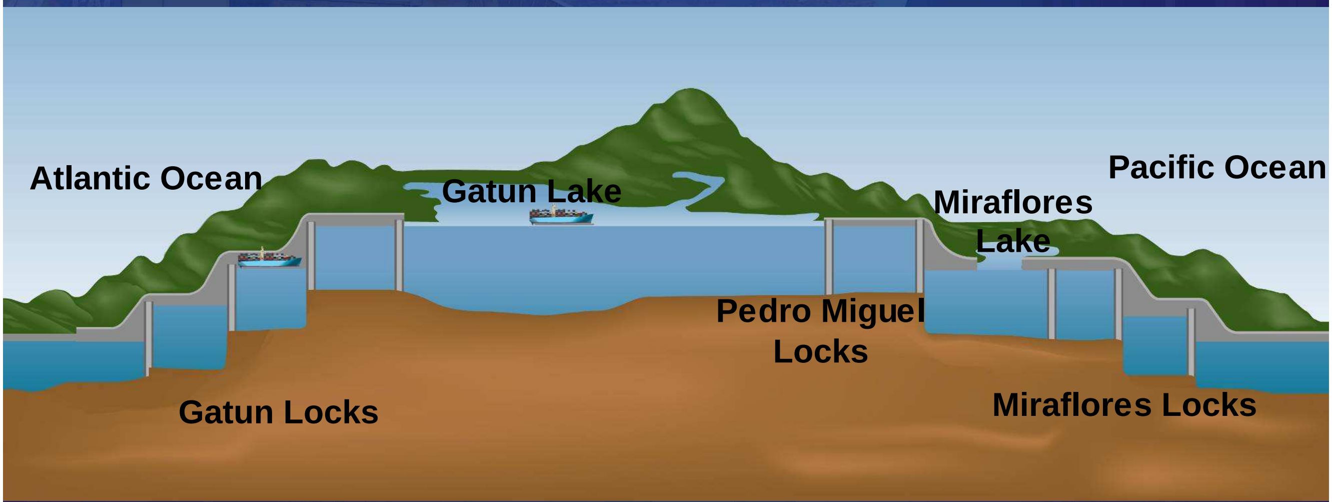
Juan Wong H.
Project Manager Third Set of Locks Pacific
Panama Canal Authority
16 October, 2009

The Panama Canal Expansion Program

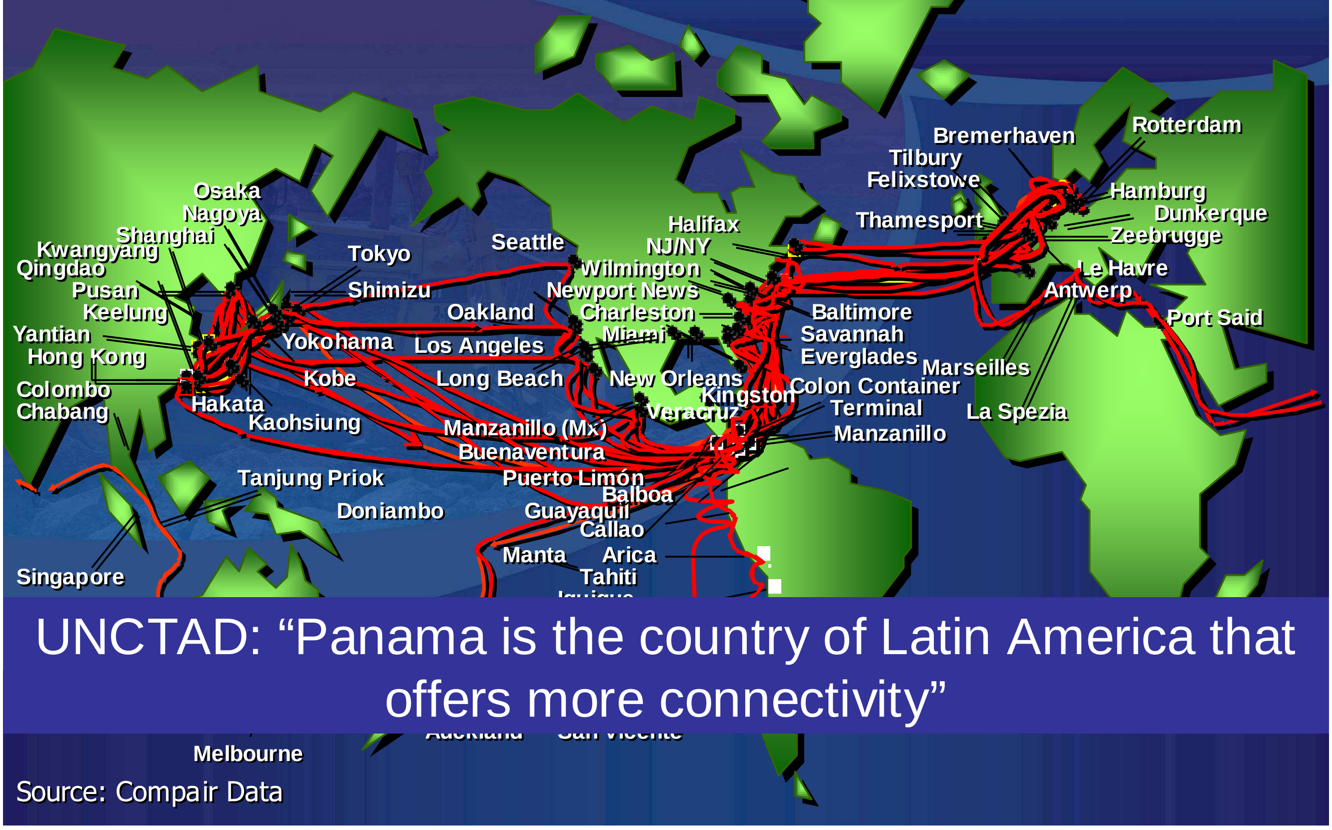
- The Panama Canal Market and Capacity
- Expansion Program
- Third Set of Locks Contracting
- New Locks Features
- Project Management

The Panama Canal

- The Panama Canal opened in August 15, 1914
- This waterway is approx. 50 miles (80 km) long between the Atlantic and Pacific Oceans
- Gatun Lake is 85 feet (26 m) above sea level
- The water used to raise and lower vessels in each set of locks comes from Gatun Lake by gravity (approx. 52 million of gallons per transits)



37 Liners Services employing Container utilize the Panama Canal in 2008

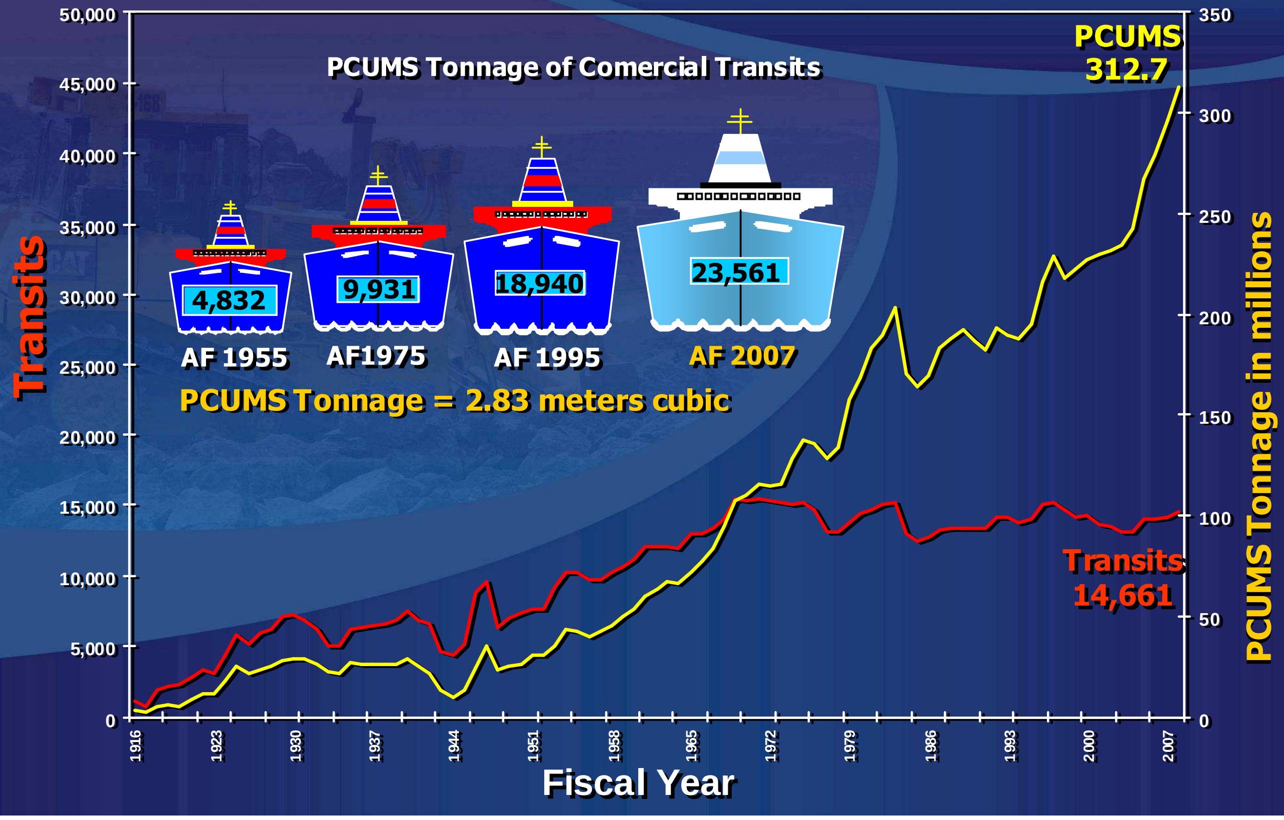


UNCTAD: “Panama is the country of Latin America that offers more connectivity”

Source: Compair Data

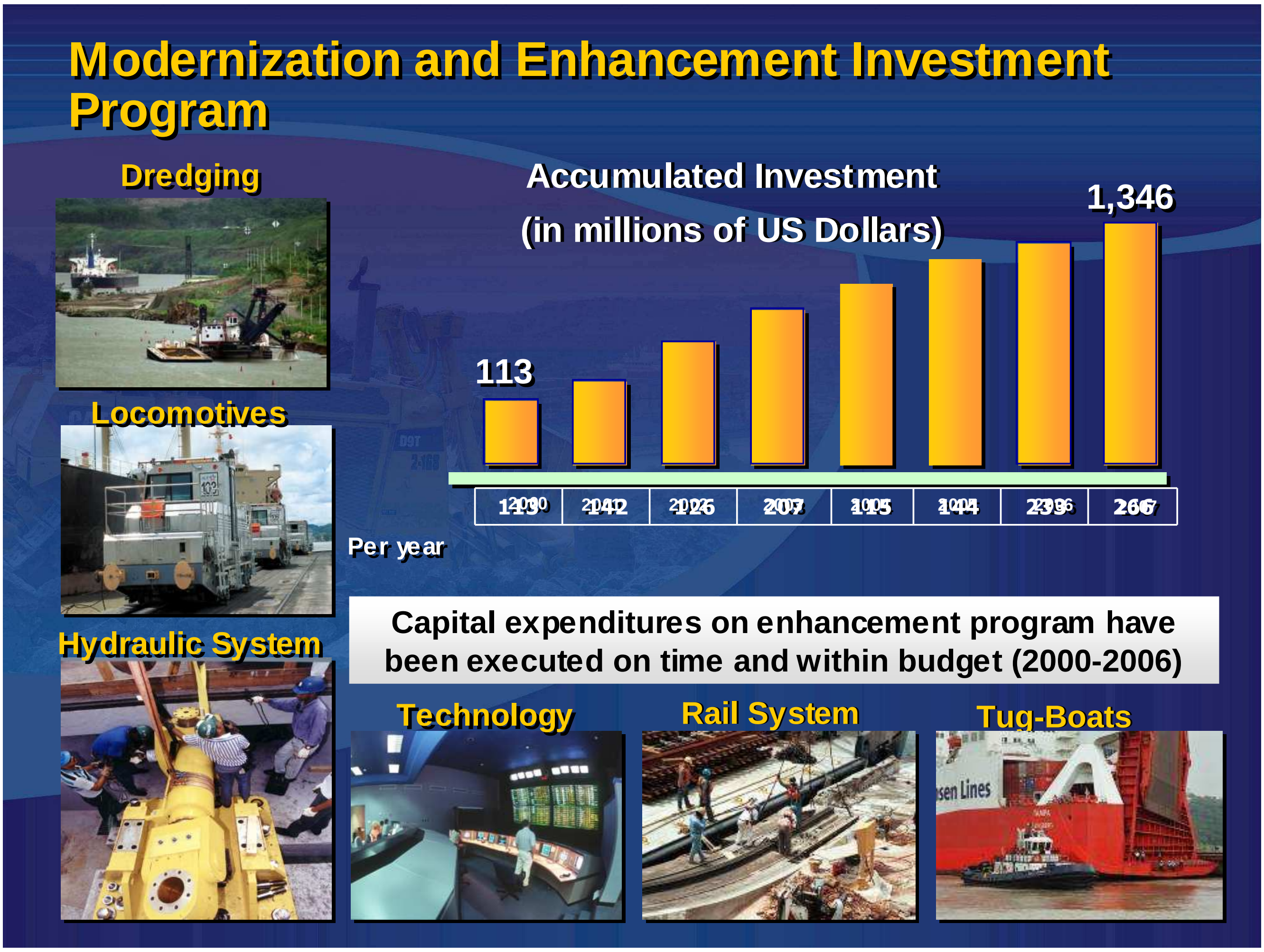
Transits vs Tonnage PCUMS

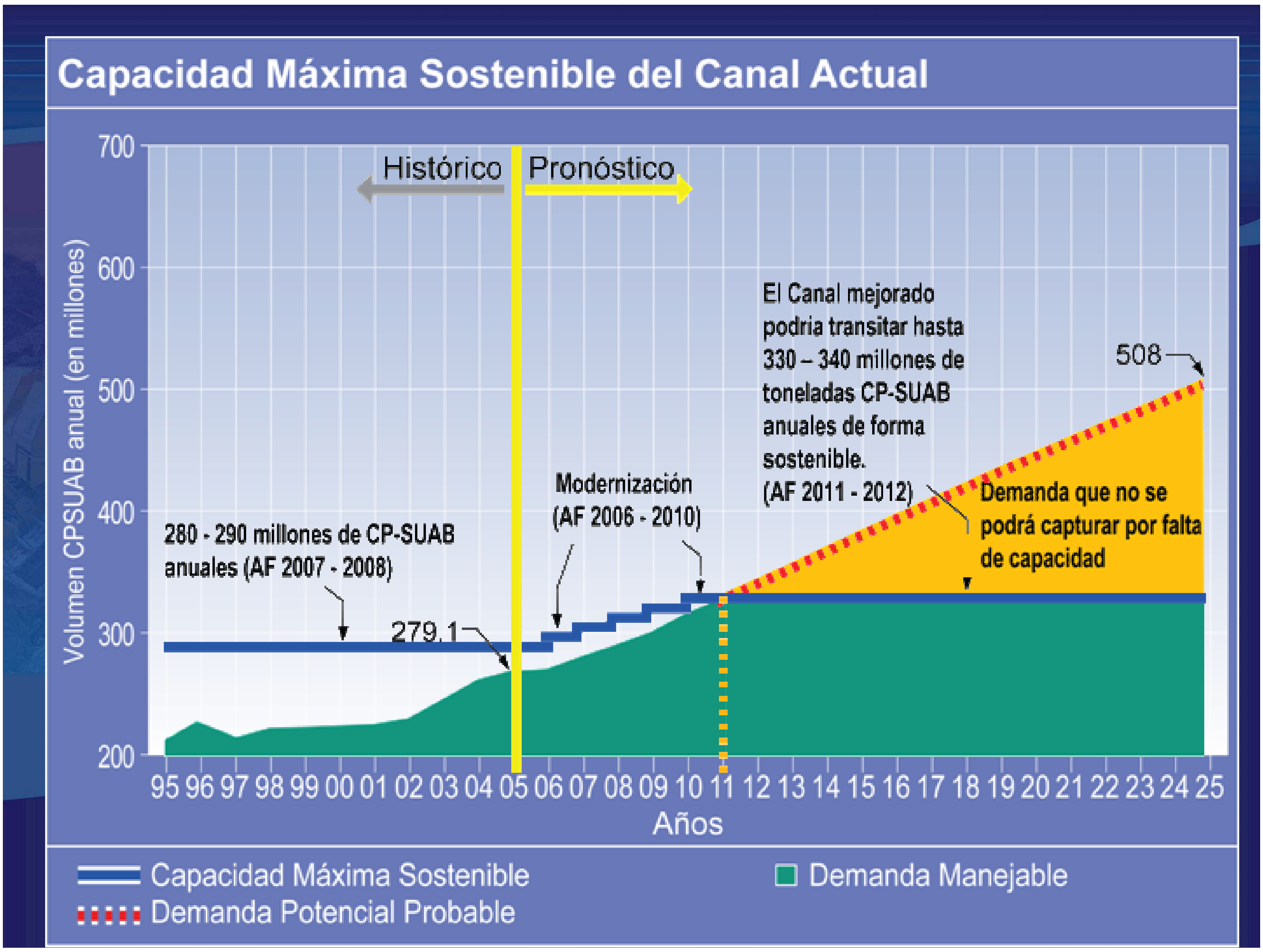
FY1915 - FY2006



Market Segments

Segments	2006		2007	
Containers	$503M	49%	$682M	56%
Dry bulk	170M	17%	163M	13%
Car Carriers	100M	10%	106M	9%
Liquid bulk	91M	9%	107M	9%
Others	59M	6%	61M	5%
Refrigerated	53M	5%	57M	5%
Passenger ships	26M	3%	26M	2%
General Cargo	25M	2%	25	2%

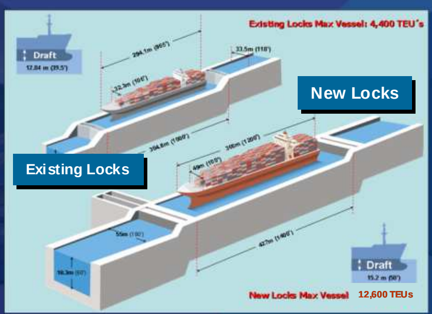

Modernization and Enhancement Investment Program
Dredging
Locomotives
Hydraulic System
Accumulated Investment
(in millions of US Dollars)
113
1,346
113
142
126
207
115
144
239
266
Per year
Capital expenditures on enhancement program have been executed on time and within budget (2000-2006)
Technology
Rail System
Tug-Boats


Capacidad Máxima Sostenible del Canal Actual
Histórico
Pronóstico
Volumen CPSUAB anual (en millones)
700
600
500
400
300
200
El Canal mejorado podría transitar hasta 330 – 340 millones de toneladas CP-SUAB anuales de forma sostenible. (AF 2011 - 2012)
508
Modernización (AF 2006 - 2010)
Demanda que no se podrá capturar por falta de capacidad
280 - 290 millones de CP-SUAB anuales (AF 2007 - 2008)
279.1
95 96 97 98 99 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Años
Capacidad Máxima Sostenible
Demanda Potencial Probable
Demanda Manejable

The Panama Canal Expansion Program

Capital Expenditures ($ millions)

New locks



Water saving basins

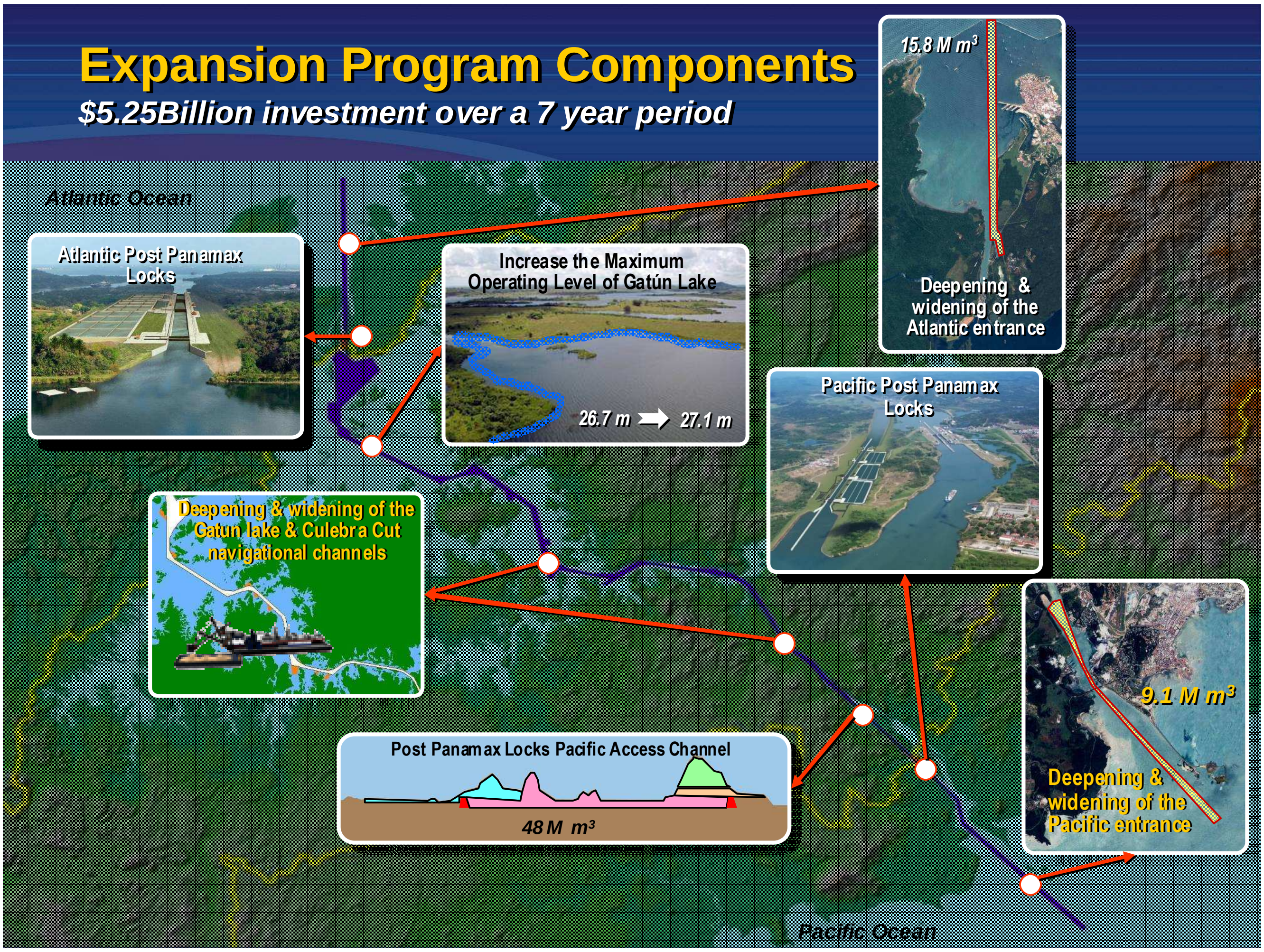
Access channel for new locks

Improvements to the existing navigational channel

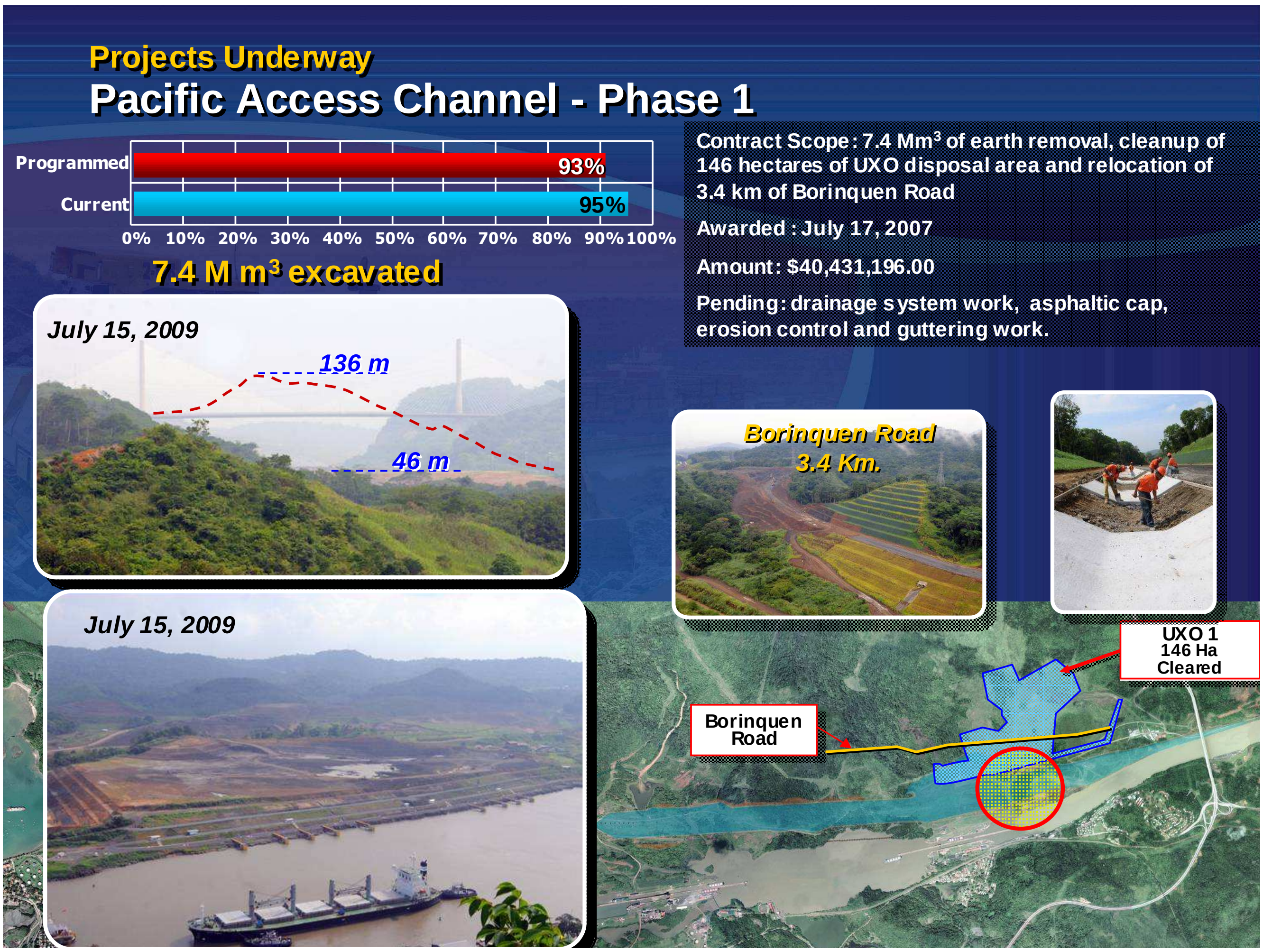
Improvements to the water supply

Component	$ millions
New locks	2,730
Water saving basins	620
Access channel for new locks	820
Improvements to the existing navigational channel	290
Improvements to the water supply	260
Inflation during construction	530
Total investment	5,250

The investment of each component includes contingency



Expansion Program Components
$5.25Billion investment over a 7 year period
Atlantic Ocean
Atlantic Post Panamax Locks
Increase the Maximum Operating Level of Gatún Lake
26.7 m → 27.1 m
15.8 M m³
Deepening & widening of the Atlantic entrance
Pacific Post Panamax Locks
Deepening & widening of the Gatun lake & Culebra Cut navigational channels
9.1 M m³
Deepening & widening of the Pacific entrance
Post Panamax Locks Pacific Access Channel
48 M m³
Pacific Ocean



Projects Underway
Pacific Access Channel - Phase 1
Programmed
Current
93%
95%
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
7.4 M m³ excavated
Contract Scope: 7.4 Mm³ of earth removal, cleanup of 146 hectares of UXO disposal area and relocation of 3.4 km of Borinquen Road
Awarded : July 17, 2007
Amount: $40,431,196.00
Pending: drainage system work, asphaltic cap, erosion control and guttering work.
July 15, 2009
136 m
46 m
July 15, 2009
Borinquen Road
3.4 Km.
UXO 1
146 Ha
Cleared
Borinquen Road

Projects Underway

Pacific Access Channel - Phase 2

6.7 M m³ excavated

Progress (%)	
Programmed	92%
Current	79%

Projects Underway

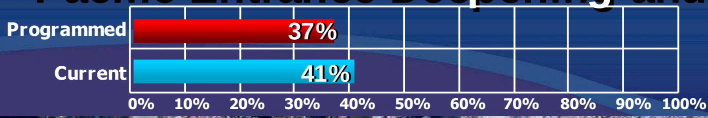
Pacific Access Channel - Phase 3

Progress (%)	
Programmed	16%
Current	26%

Awarded: December 16, 2008
Company: Constructora MECO, S.A.
Excavation: 8.0 M m³
Clearing 190 ha of UXO area

1.034 M m³ excavated
178 hectares cleared

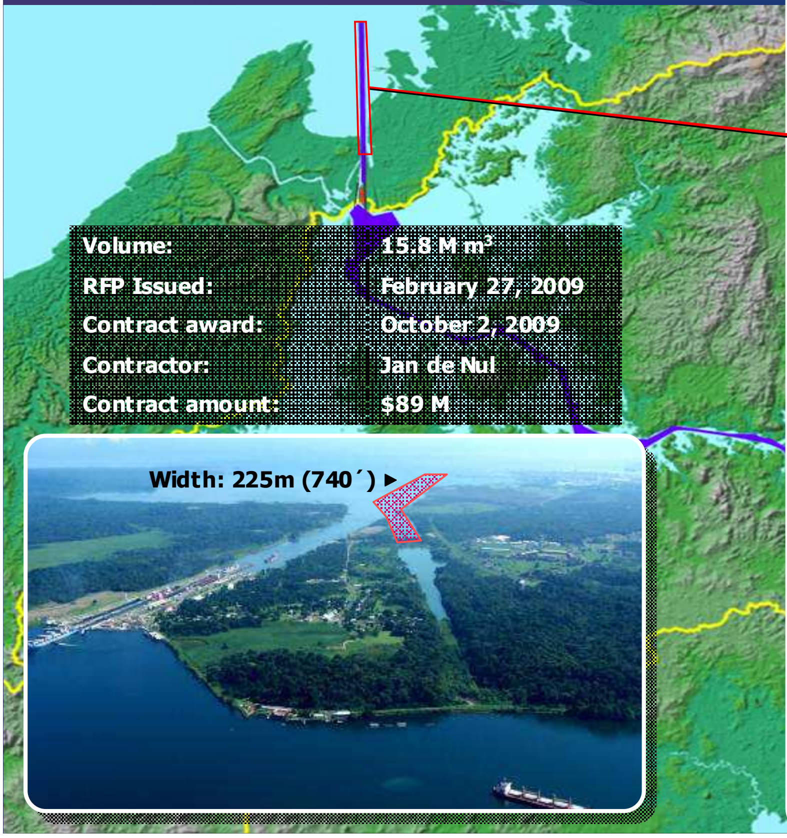
Projects Underway
Pacific Entrance Deepening and Widening (9.1 M m³)



4.04 M m³ dredged

Projects Underway
Gatun Lake & Culebra Cut Dredging Areas

Atlantic Entrance Deepening & Widening



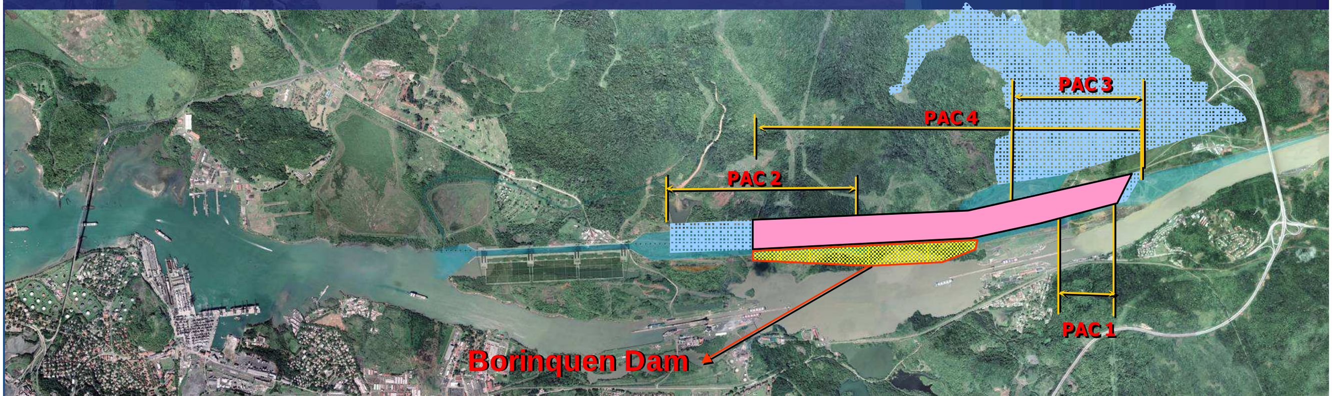
Volume:	15.8 M m³
RFP Issued:	February 27, 2009
Contract award:	October 2, 2009
Contractor:	Jan de Nul
Contract amount:	$89 M

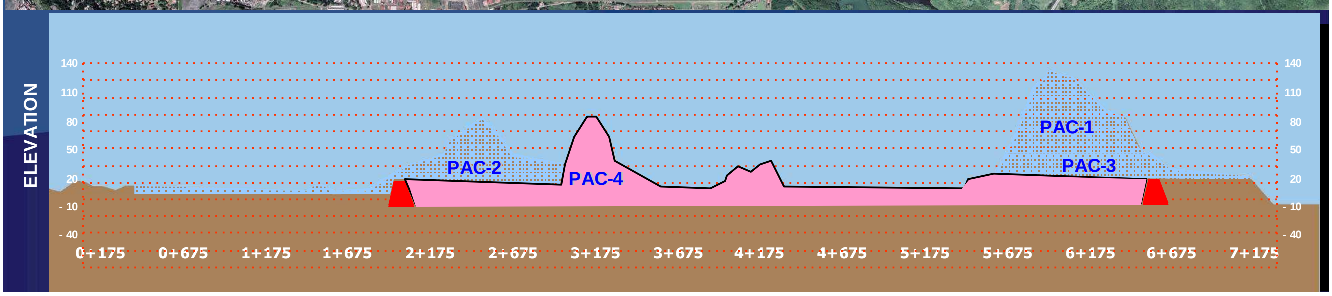
Pacific Access Channel - Phase 4

27 M m3 of Dry Excavation

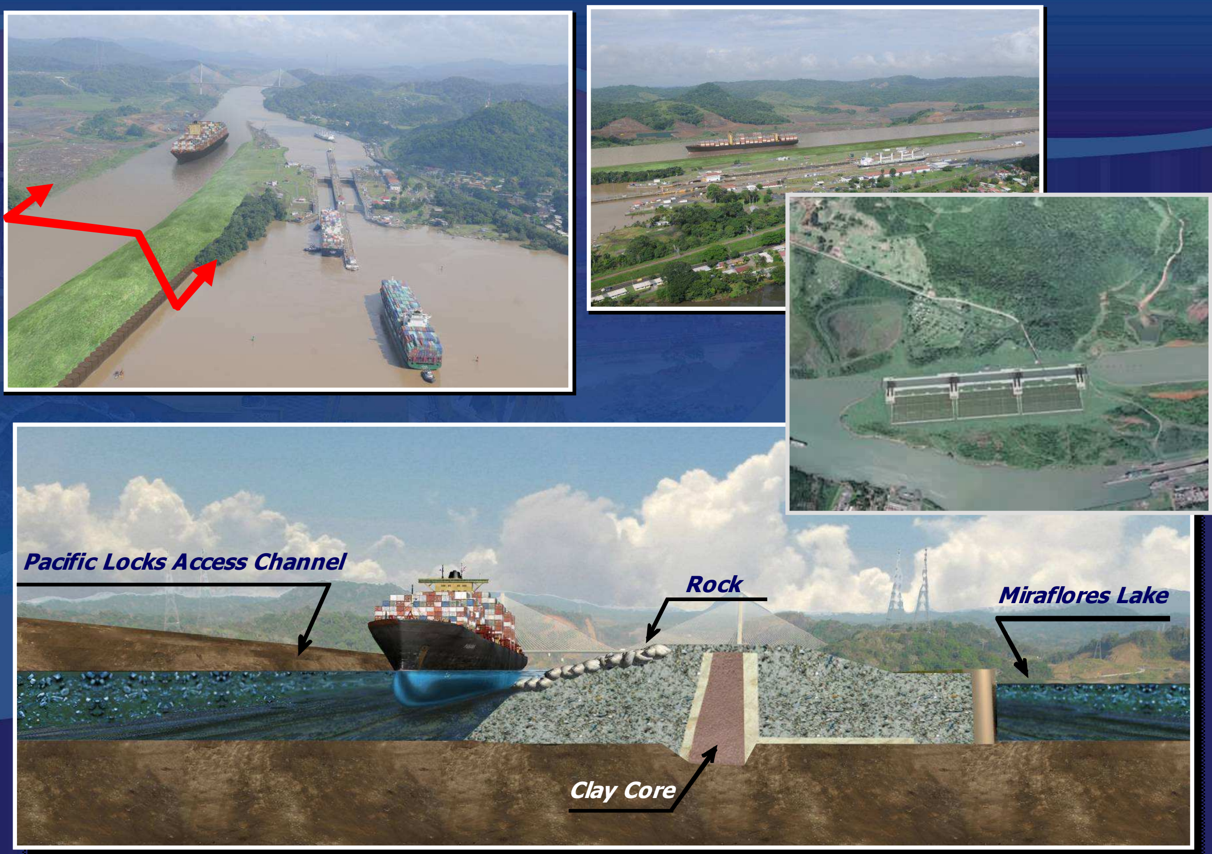
Tender Documents published on July 31, 2009

- Site Visit: August 25, 2009
- Pre tender Meeting: August 26, 2009
- Submit Technical Proposal: August 31, 2009
- Bid Opening (Price): October 30, 2009





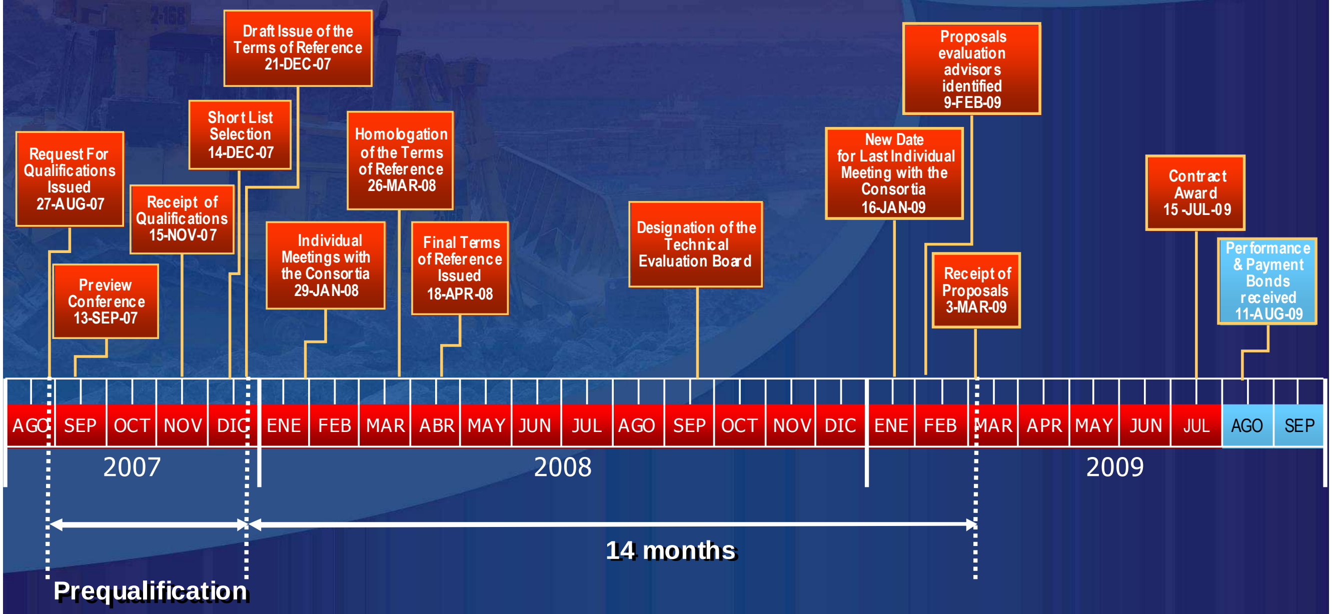
Borinquen Dam



ACP

Third Set of Locks contract award

Locks Design and Construction Timeline of the Contracting Plan



Prequalified Consortia

Consortium	Members	Designers	Gate fabricators
C.A.N.A.L.	ACS Servicios, Comunicaciones y Energía, S.L. – Leader	Sener Ingeniería y Sistemas	ACS Servicios, Comunicaciones y Energía, S.L.
	Acciona Infraestructuras, S.A.	Haskoning Nederland BV	
	Fomento de Construcciones y Contratas, S.A.	Mott Macdonald Limited	
	Hochtief Construction AG	Hochtief Consult	
	Constructoras ICA S.A. de C.V.		
Bechtel, Taisei, Mitsubishi Corporation	Bechtel Internacional, Inc. – Leader	Bechtel Internacional, Inc. – Leader	Wuchang Shipyard
	Taisei Corporation		
	Mitsubishi Corporation		
Grupo Unidos por el Canal	Sacyr Vallehermoso S.A. – Leader	Montgomery Watson Harza (MWH) – Leader	Heerema Fabrication Group
	Impregilo S.p.A.		
	Jan de Nul n.v.	IV-Groep	
	Constructora Urbana, S.A.	Tetra Tech	
Atlántico-Pacífico de Panamá	Bouygues Travaux Publics – Leader	AECOM – Leader	ALSTOM Hydro Energia Brasil
	Bilfinger Berger		
	VINCI Construction Grands Projets		
	Construcoes e Comercio Camargo Correa S.A.		
	Construtora Andrade Gutierrez S.A.		
	Construtora Queiroz Galvao S.A.		
	ALSTOM Hydro Energia Brasil		
	BARDELLA Ind. Mecánicas		

Consortia that submitted proposals on March 3, 2009

Consortium	Members	Designers	Gate fabricators
C.A.N.A.L.	ACS Servicios, Comunicaciones y Energía, S.L. – Leader	Sener Ingeniería y Sistemas	ACS Servicios, Comunicaciones y Energía, S.L.
	Acciona Infraestructuras, S.A.	Haskoning Nederland BV	
	Fomento de Construcciones y Contratas, S.A.	Mott Macdonald Limited	
	Hochtief Construction AG	Hochtief Consult	
	Constructoras ICA S.A. de C.V.		
Bechtel, Taisei, Mitsubishi Corporation	Bechtel Internacional, Inc. – Leader	Bechtel Internacional, Inc. – Leader	Wuchang Shipyard
	Taisei Corporation		
	Mitsubishi Corporation		
Grupo Unidos por el Canal	Sacyr Vallehermoso S.A. – Leader	Montgomery Watson Harza (MWH) – Leader	Heerema Fabrication Group
	Impregilo S.p.A.	IV-Groep	
	Jan de Nul n.v.	Tetra Tech	
	Constructora Urbana, S.A.		
A… P… P…	Bouygues Travaux Publics – Leader		

Locks Design and Construction Bidding Process

Opening of Price Envelopes - July 8, 2009

Autoridad del Canal de Panamá
Contrato de Diseño y Construcción del Tercer Juego de Esclusas
Design and Construction of the Third Set of

Licitación RFP-76161

Fecha de apertura de sobres de precio: 08-Jul-09 9:00 A.M.

Proponentes precalificados	Puntos Propuesta Técnica (55%) Máx 5,500	Propuesta de Precio Base (40%)	Puntos Precio Base Máx 4,000	Propuesta de Precio de Partida Provisional (5%)	Puntos Partida Provisional Máx 500	Total Propuesta de Precios	Total Puntos Propuesta de Precios (45%) Max 4,500	Total de Puntos (100%) Máx 10,000	Orden de Mejor Valor
Bechtel, Taisei, Mitsubishi Corporation	3,789.5	$ 4,185,983,000.00	2,980.3	$ 93,836,670.00	-	$ 4,279,819,670.00	2,980.3	6,769.8	2
Consorcio C.A.N.A.L.	3,973.5	$ 5,981,020,333.00	2,085.9	$ -	500.0	$ 5,981,020,333.00	2,585.9	6,559.4	3
Grupo Unidos por el Canal	4,088.5	$ 3,118,880,001.00	4,000.0	$ 102,751,383.00	-	$ 3,221,631,384.00	4,000.0	8,088.5	1
Partida Asignada - ACP		$ 3,481,000,000.00							

Calcular resultado

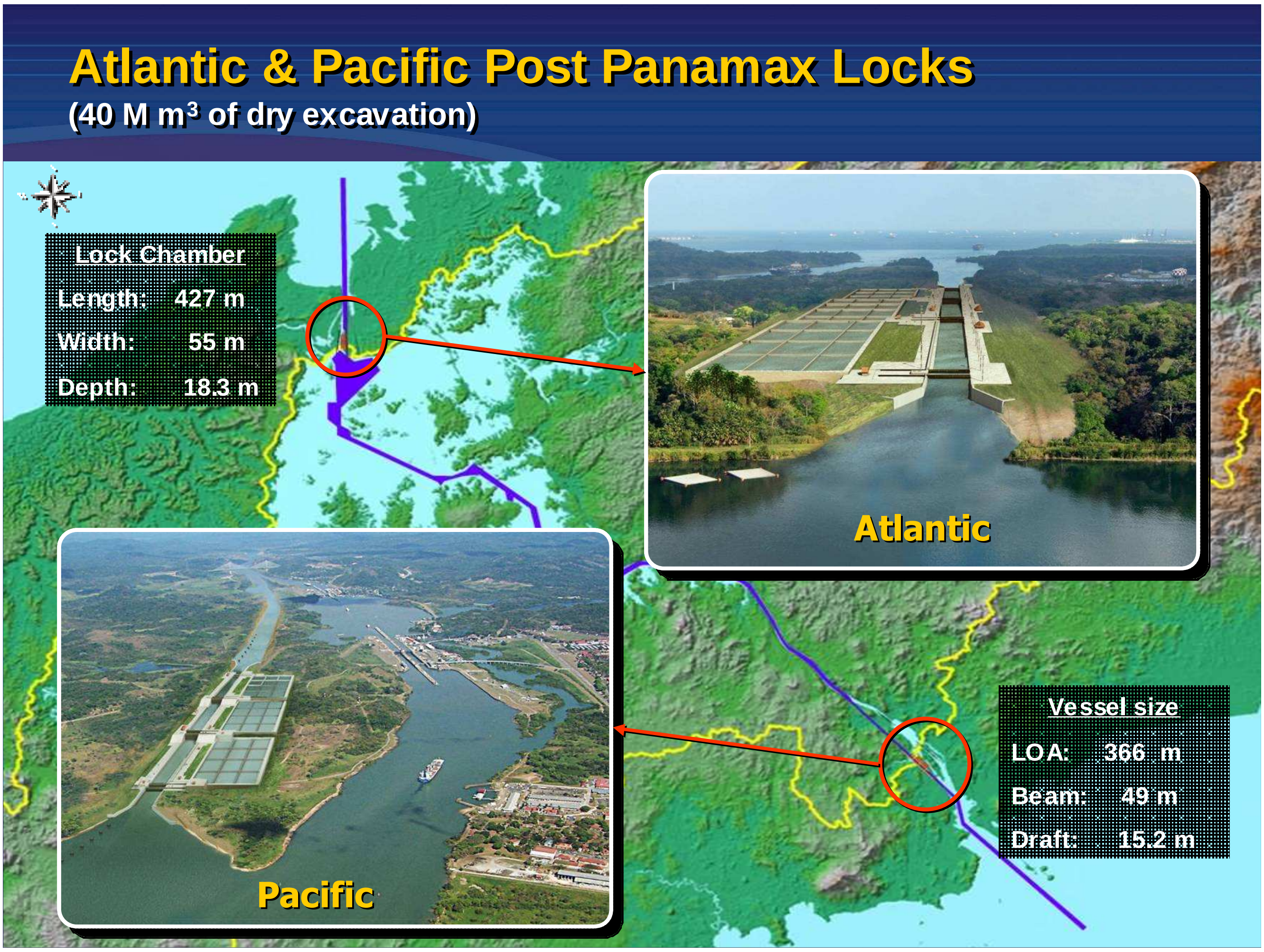
New Locks features

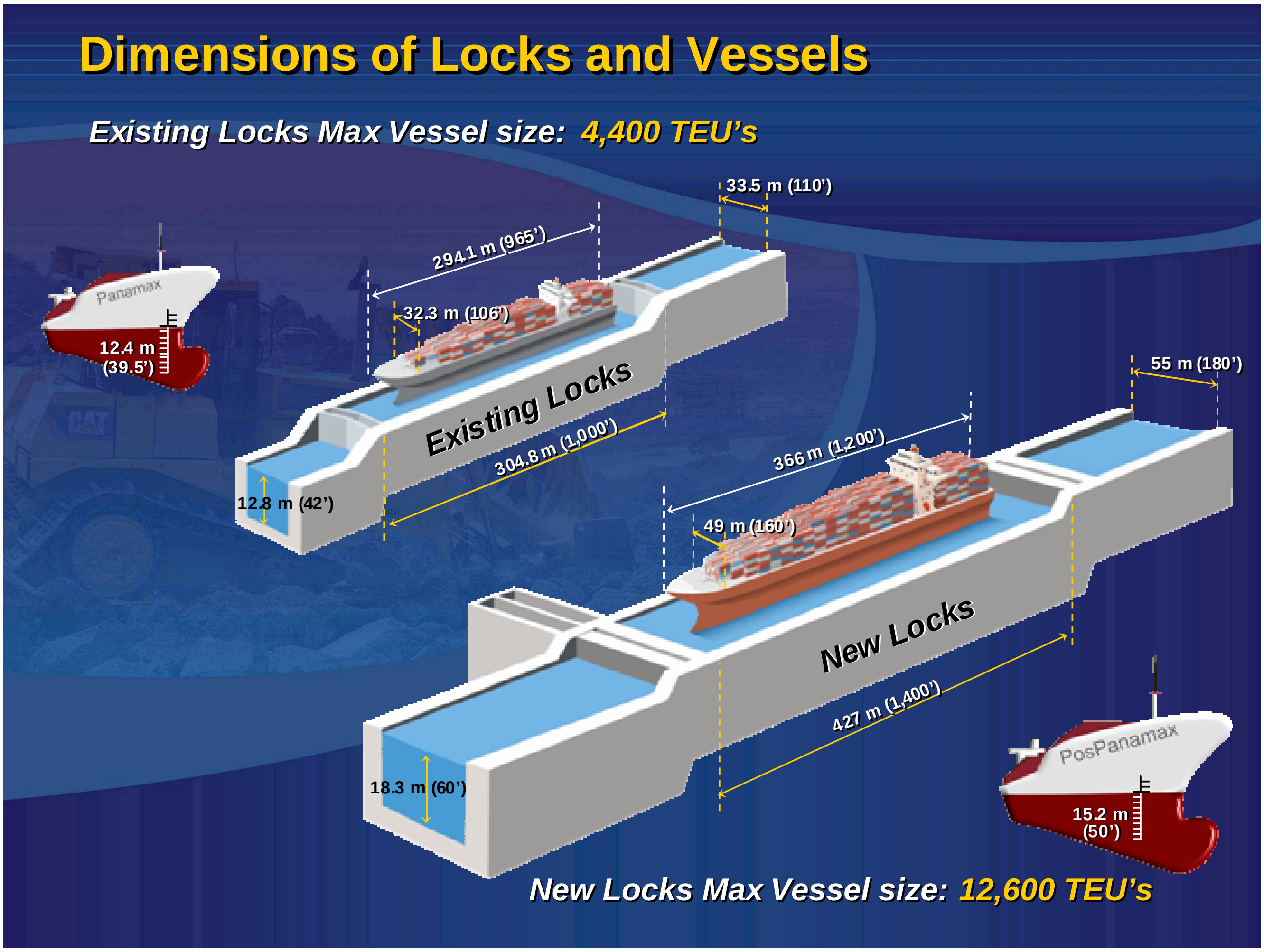
Main functions and objectives Third Set of Locks

- Larger locks for post-panamax vessels
- Throughput minimize F-E times
- Safe smooth filling and emptying lock chambers
- Environmental preserve Gatun Lake as source of fresh water for human consumption
- High reliability third lane locks
- Water efficient
- Benefit/Cost analysis alternatives
- Life cycle cost optimization
- Durable infrastructure

Project concept and execution of Third Set of Locks project

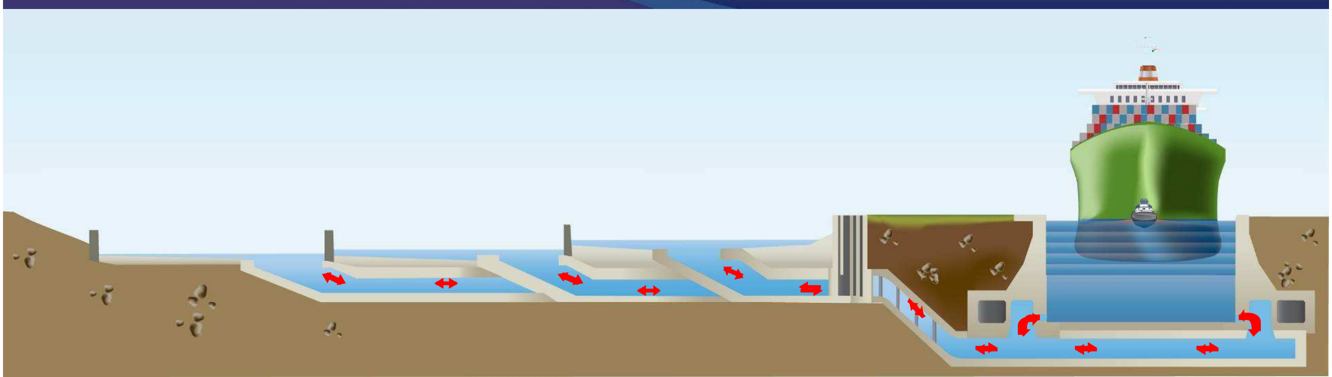
- Conceptual design
- Numerical and physical F-E models
- Performance based contract specifications
- Design and build contract
- Technical evaluation of proposals
- Selection based on best value
- Final design by Contractor
- Requires optimization of F-E system numerical model and validation physical model
- Commissioning F-E performance


Atlantic & Pacific Post Panamax Locks
(40 M m³ of dry excavation)
Lock Chamber
Length: 427 m
Width: 55 m
Depth: 18.3 m
Atlantic
Pacific
Vessel size
LOA: 366 m
Beam: 49 m
Draft: 15.2 m

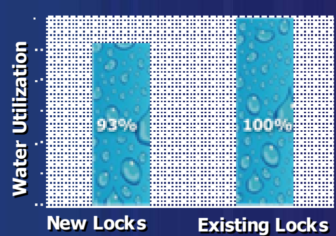

Dimensions of Locks and Vessels
Existing Locks Max Vessel size: 4,400 TEU's
33.5 m (110')
294.1 m (965')
32.3 m (106')
Panamax
12.4 m (39.5')
Existing Locks
304.8 m (1,000')
12.8 m (42')
55 m (180')
366 m (1,200')
49 m (160')
New Locks
427 m (1,400')
18.3 m (60')
PosPanamax
15.2 m (50')
New Locks Max Vessel size: 12,600 TEU's

GUPC Locks Design – Pacific Locks

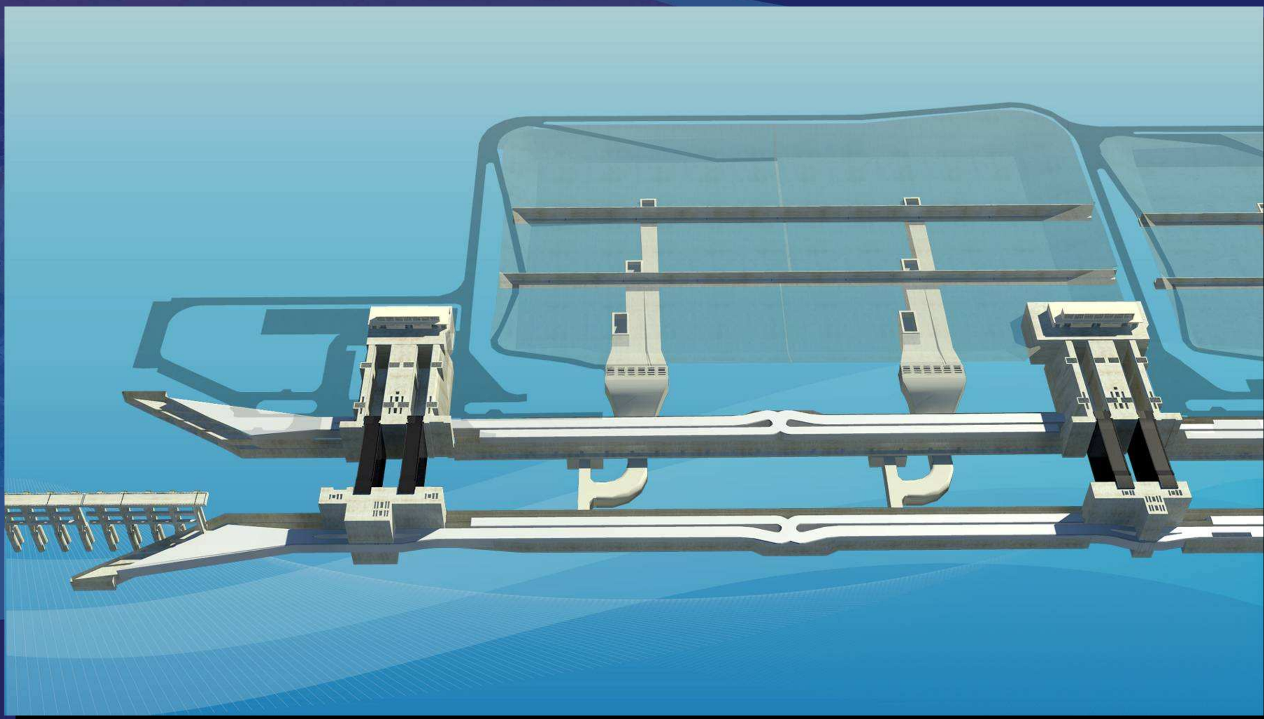
Post-Panamax Locks Operation GUPC's Proposal



With the water saving basins
the new locks will use 7% less water
than the existing locks

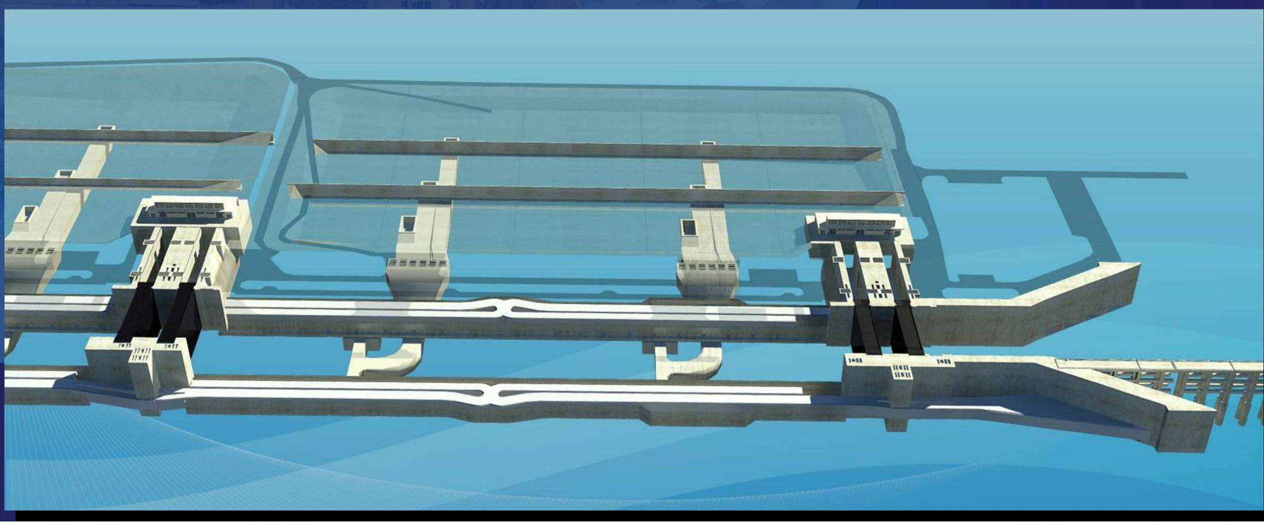


Hydraulic Filling and Emptying System
Upper Chamber and water Intakes



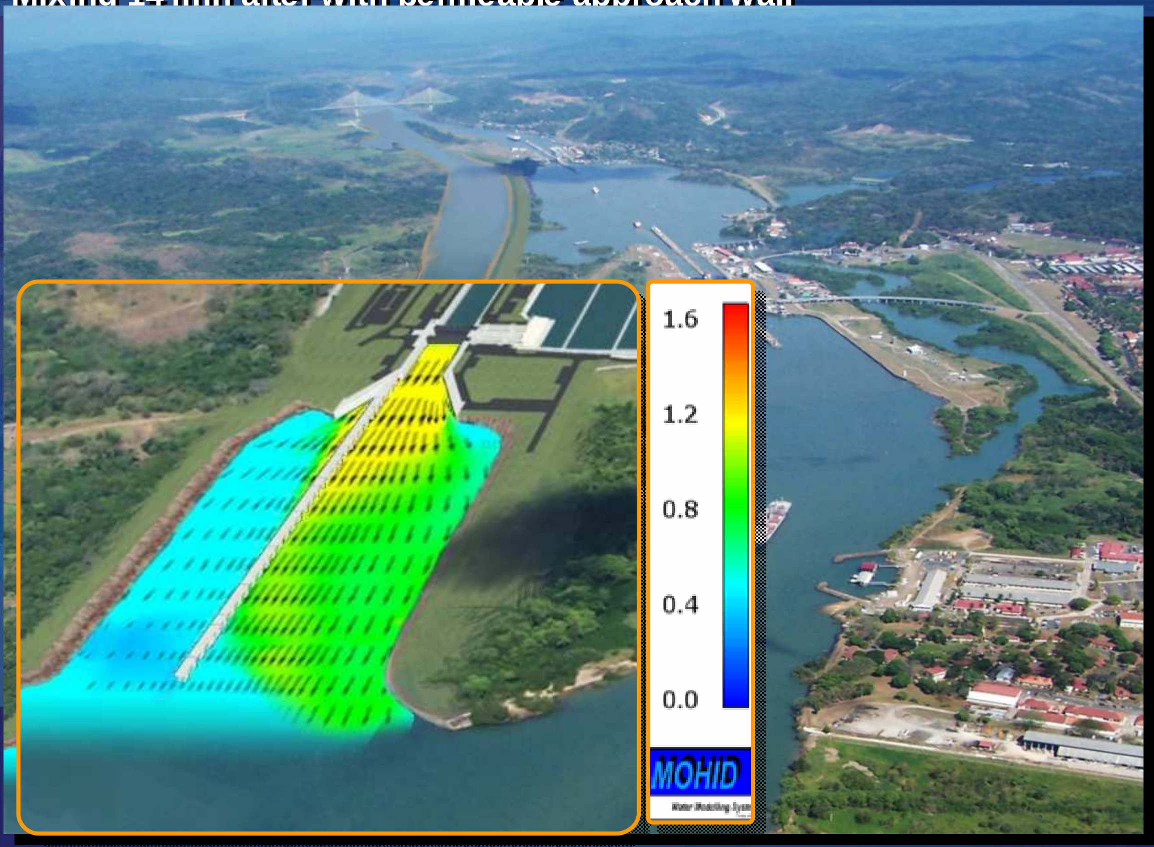
GUPC Tender Design Meets or Exceeds ACP's Performance Requirements

- Filling and Emptying System times – improved throughput
- Chamber Hawser Forces
- Permeable Approach Structure
- Approach Channel Current Velocities
- Culvert water flow velocities
- Water Saving percentage



Peak Surface longitudinal Velocity

Mixing 14 min after with permeable approach wall



F-E system final design next steps

- Contractor to optimize numerical model runs and finalize F-E system design
- Validate F-E system with contractor's physical model prior to construction of F-E system
- Final F-E system acceptance with commissioning and take over performance tests

ACP

Program Management

Administration

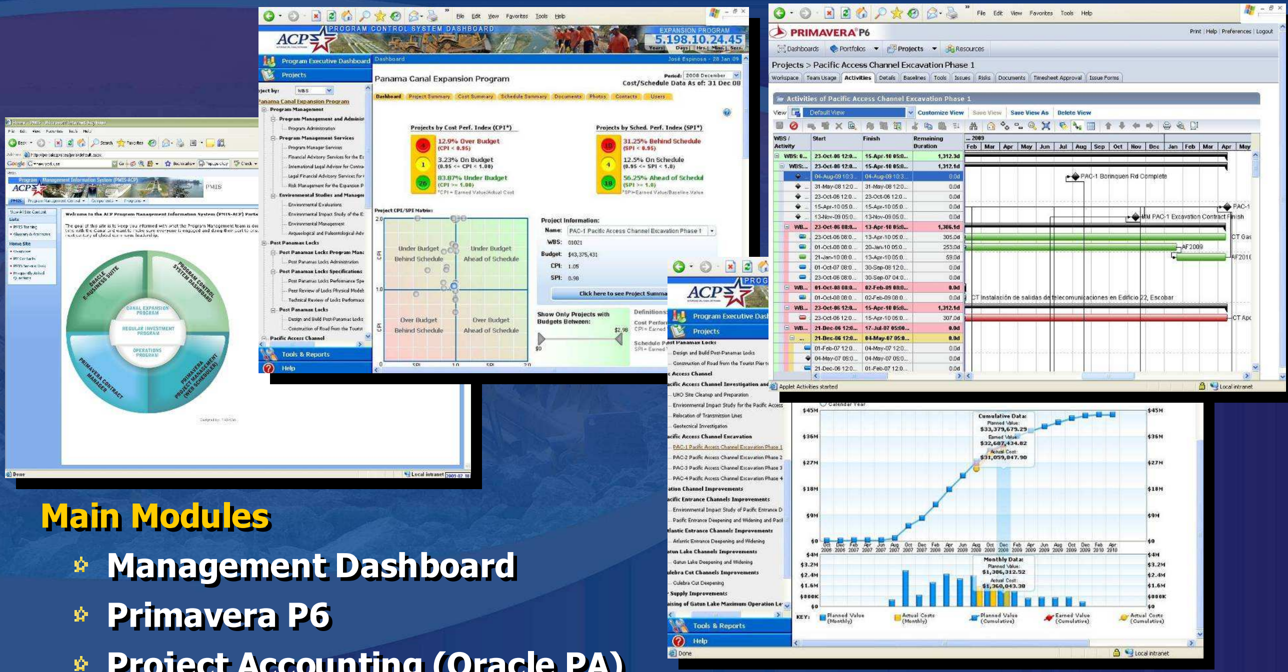
Secured Financing for Expansion Program – December 9, 2008

The $2.3 billion financing package will cover a portion of the $5.25 billion total cost of the project and will be allocated as follows:

FINANCING:	European Investment Bank (EIB)	$ 500 M
	Japan Bank for International Cooperation (JBIC)	$ 800 M
	Inter-American Development Bank (IDB)	$ 400 M
	International Finance Corporation (IFC)	$ 300 M
	Corporación Andina de Fomento (CAF)	$ 300 M
	Subtotal:	$2,300 M
	ACP:	$ 2,950 M
	Total:	$ 5,250 M

The negotiated financing structure includes favorable provisions for the ACP including a 20-year amortizing period with a 10-year grace period.

Administration
Program Management Integrated System



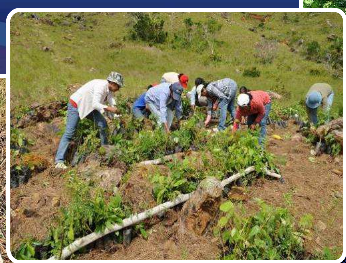
Main Modules

- Management Dashboard
- Primavera P6
- Project Accounting (Oracle PA)
- Primavera Contract Manager (Document Control)
- Risk Analysis (Primavera Pert Master and @Risk)
- Cost Estimates (Heavy Bid and Timberline Estimating)

CH2MHILL ACP

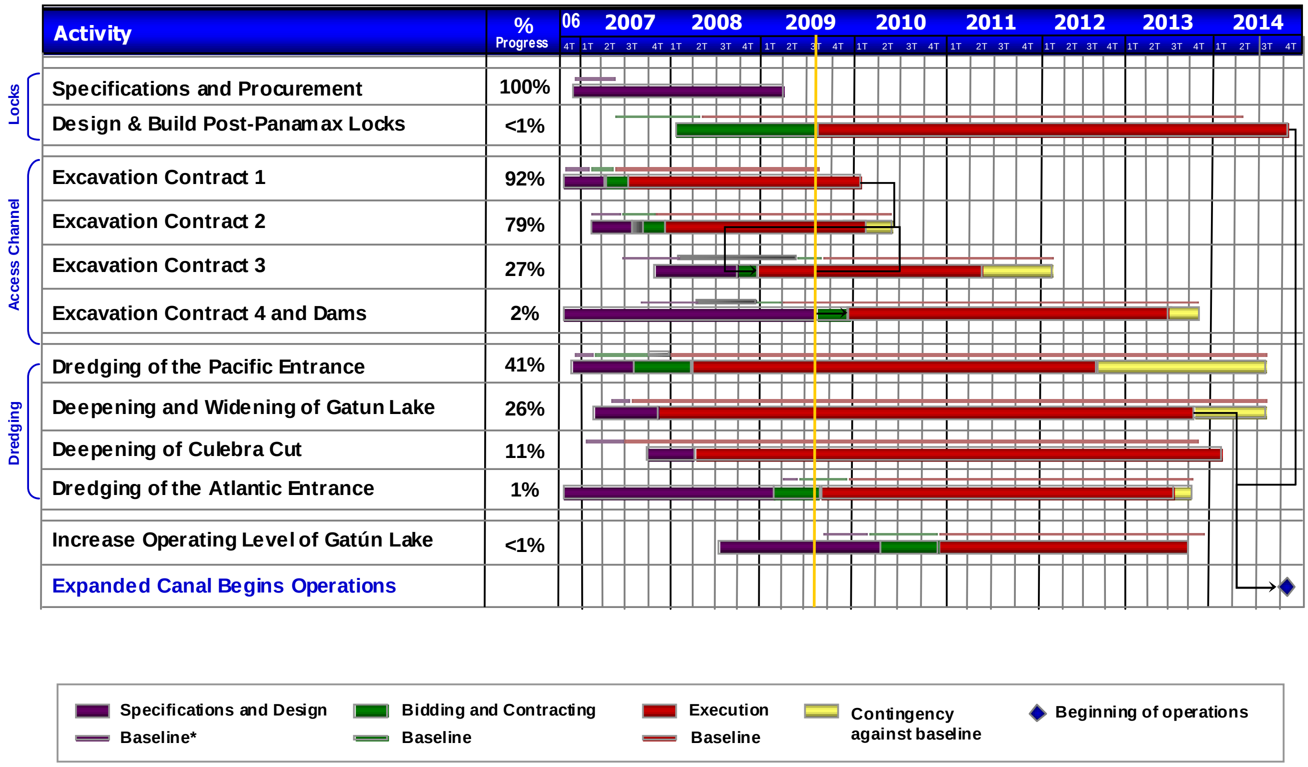
Administration
Environmental and Social Monitoring and Control

- Environmental Impact Assessment
- Ecological Compensation paid to ANAM
- Wildlife Rescue Plan
- Archeological Rescue
- Paleontological Resources Studies
- Reforestation
- Air and Water Quality Monitoring
- Noise and vibrations monitoring
- Meetings with communities according to project advance
- Report and inspection by independent consultant
- Inspections by ANAM



Summary Schedule of Main Projects with Baseline and Contingency

as of July 31, 2009*



* Baseline from December 31, 2006 including contingency.

www.pancanal.com

The Panama Canal's Third Set of Locks Project

Juan Wong H.
Panama Canal Authority, Panama, Republic of Panama

ABSTRACT: One of the world's greatest engineering achievements, the Panama Canal plays a vital role in world shipping. But, eventhough at the time of their construction the dimensions of the existing locks set the standard that defined the 'Panamax' size container ships and bulk carriers, today's locks are nearing their maximum throughput capacity in spite of all the infrastructure improvements of past decades. To accommodate growing traffic demand, particularly by containerships in the route between Northeast Asia and ports on the US East Coast, and also to accommodate post-Panamax ships, the Panama Canal has started executing its ambitious expansion plan, which is scheduled for completion by 2014.

The Panama Canal conducted more than 120 studies that were analyzed and integrated into the decision making process to select the most suitable, efficient, and effective alternatives that would enable the optimization of the Third Set of Locks Project. The studies for the Panama Canal Capacity Expansion Program are described in full in the Panama Canal Master Plan 2005-2025 and in the Proposal for the Canal Expansion approved on October 22, 2006 through national referendum. The Master Plan and summaries of the most relevant studies can be found at http://www.pancanal.com/eng/plan/index.html.

The Panama Canal is the country's main economic asset. The Panama Canal Authority (ACP), the agency in charge of administering the waterway, is carrying forward a program to expand the Canal's throughput capacity in terms of vessel number, vessel size and to double cargo capacity. An expanded Canal would be the cornerstone on which the long term sustainability of the national economy would be built, guaranteeing the continuity of its commitment to serve world trade while promoting the development of an international logistics hub in Panama.

1 THE PANAMA CANAL EXPANSION

The Panama Canal Expansion Program involves six main projects, mainly: 1) the construction of two set of locks at the Atlantic and Pacific ends of the Canal; 2) the dry excavation of an access channel connecting the Gaillard (Culebra) Cut to the new Pacific locks; 3) dredging of the existing navigational channels of the Atlantic Ocean entrance; 4) dredging of the existing navigational channels Pacific Ocean entrance, 5) dredging the Gatun Lake and Gaillard Cut fresh water navigational channels; and 6) raising the level of Gatun lake through modifications to existing land based infrastructure. Overall the activities of the Expansion Program will span over the 80 kilometers of the Panama Canal.

The access channel to link the new Pacific Locks with Gaillard Cut, the narrowest channel section in the Panama Canal, will be about 6.1 kilometers long. It will require the removal of 47 million cubic meters of earth and rock and the construction of earthen dams. This new channel will bypass the present Pedro Miguel Locks, Miraflores Lake and Miraflores Locks and will operate at Gatun Lake elevation, an average of 26 meters above sea level.

Work on the Panama Canal Expansion began on September 3, 2007 when ground was broken in Paraiso Hill highlighting the start of the first of the dry excavation work contract awarded to the lowest bidder of ten that tendered. The local construction firm bid $40.4 million. This first contract of four of the Pacific access channel (PAC-1) involves the removal of 7.4 Mm^3 of earth, road rerouting and drainages and the clearing of 146 hectares of unexploded ordnance. Progress to date 90%.

The second dry excavation contract (PAC-2) was awarded in December 2007 to an international firm for $25.8 million. This contract requires 7.5 Mm³ of earth and rock removal and a 3.5 km diversion of a small river and road rerouting and drainages as well. Progress 84% to date.

The third dry excavation contract (PAC-3) was awarded in December 2008 for $36.7 million to remove 8.0 Mm³ of material and the clearing of 190 hectares of unexploded ordnance (UXO's). Progress to date 31%.

The fourth dry excavation (PAC-4) tender documents for prequalification received in September 2009 and are being evaluated. Its design indicates a total dry excavation of approximately 27 Mm³, additional 2.8 Mm³ to fill and construct a 2.3 Km long earthen dam.

The contract for the dredging of the Pacific Entrance which encompasses the widening and deepening of the navigation channel leading to the new locks was awarded in April 2008 for $177 million. There are approximately 9.1 Mm³ of material to be dredged along a 14.3 km of channel. The channel has been designed to be a minimum of 225 meters wide at the prism line and at a minimum depth of 15.5 meters at Mean Low Water Springs. This project advances in accordance to its schedule achieving 46% progress thus far and is expected to be completed by September 2012 or earlier.

The tender documents for the dredging of the Atlantic entrance navigation channel leading to the new locks was awarded in September 2009 for $89.6 million. The contract will encompass 15Mm³ of dredging over 13.9 kilometers of channel and approximately 0.8 Mm³ of dry excavation.

In-house ACP personnel are performing dredging work required to adequate the Canal's freshwater inland navigational channels, to date 5.8 Mm³ of material has been dredged progress 22%.

Figure 1 – Map of the Panama Canal expansion program

2 THE THIRD SET OF LOCKS

The Panma Canal Authority ACP evaluated many configurations and technical options to increase Canal capacity. After conducting a series of market studies the ACP decided to divide Canal trade into segments which established different tariffs for the commodities transported by the different types of vessels passing through the Panama Canal. Results of the studies indicated that containerized cargo trade between Northeast Asia and the U.S. East Coast showed the highest levels of demand growth. Additionally, studies highlighted that in the transoceanic routes the trend is to use post-Panamax containerships to take advantage of the economies of scale which allows them to carry more containers in larger vessels.

Among the alternatives considered were a sea level canal, shiplifts/synchrolifts and different channel alignments. Using expert workshops and multi-criteria analyses, it was concluded that constructing two new sets of locks would be the best option, considering initial investment, maintenance, environmental impact, and technological risk.

Lock configurations of one, two and three sets of consecutive chambers were analyzed. The three-level configuration proved to be the best option regarding initial investment, operational efficiency, ease of maintenance, environmental impact, and water utilization.

One set of locks will raise/lower vessels on the Atlantic end of the Canal, east of the existing Gatun Locks, and the other set of locks will raise/lower vessels on the Pacific end, southwest of the existing Miraflores Locks. Each facility will be comprised of three consecutive lock chambers, which will use gravity force to move water to lift the vessels from one ocean to an average height of 26 meters at lake level and lower them back to ocean level on the opposite end. Each chamber will be accompanied by three lateral water-saving basins for a total of nine water-saving basins per lock.

Each lock chamber will be 427 m to 458 m long, 55 m wide and 18.3 m deep as a minimum, to allow the transit of vessels up to 49 meters in beam, and overall length of up to 366 meters and a draft up to 15.2 meters in tropical fresh water, which corresponds to a 12,000 TEU nominal capacity containership loaded with 19 container rows across deck.

The new locks will also allow the transit of Capesize dry-bulk carriers and Suezmax tankers displacing 150,000 to 170,000 tons. These new lock dimensions will allow the transit of vessels carrying more than twice the cargo currently transported by 'Panamax' vessels.

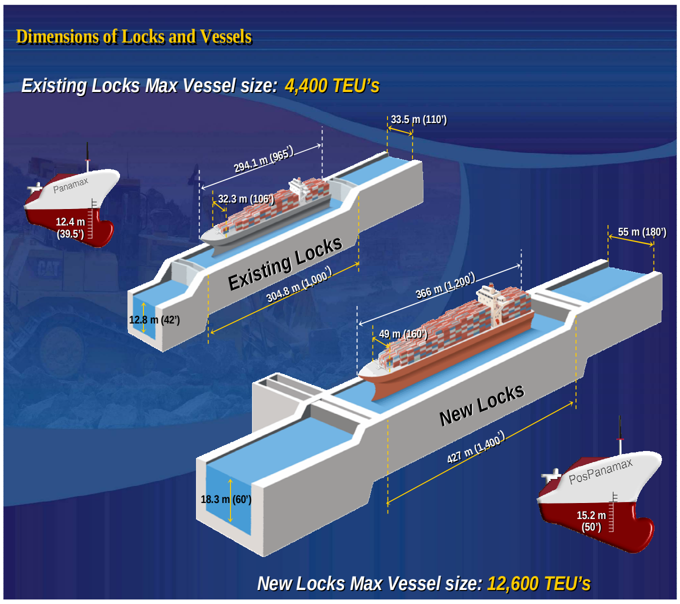


Figure 2 – Comparative Panamax and Post-Panamax vessels and locks

The new locks will incorporate proven technology used in the operation and maintenance of post-Panamax locks in Europe. These new locks will also incorporate technology upgrades used in the existing Canal such as chamber lighting and satellite vessel tracking system.

All potential lock gate types were studied and narrowed down to sector, miter and rolling gates. It was concluded that rolling or horizontal sliding gates would be the best option since these are the type of gates used in Europe for similar size locks, the gate recesses allows for dry dock gate maintenance and repair *in situ*, and require less chamber length. To increase system reliability, the rolling gates will be placed in pairs at each end of the lock chambers, for a total of eight gates per lock.

Many existing and potential vessel positioning systems were evaluated and compared. The towing locomotives presently used at the Panama Canal for Panamax size vessels, was not considered appropriate to handle post-Panamax vessels because of the number -up to 16 locomotives- and capacity –over 70 tons- required and the increased construction costs for lock walls to withstand the forces exerted by the locomotives proved unpractical.

After having successfully performed a series of lockage tests with tugboats in the existing Gatun and Miraflores locks, the ACP decided that the new Third Set of Locks will use tugboats to position vessels during lockages, as used in other post-Panamax locks in Europe. The Canal will expand its existing fleet by acquiring commercially available tugs.

The water-saving or reutilization basins have been used successfully in locks in Germany for almost a century. These water-saving basins or pools will provide an effective system for reducing water usage in the new locks. Different combinations of lock steps and number of basins –one to six- were analyzed as part of the studies conducted by the ACP. The combination of three steps and three water-saving basins per chamber yields the best relation of water consumption, construction cost, and system throughput, while maintaining Gatun Lake's water quality as a fresh water ecosystem with water suitable for human consumption.

Figure 3 – Three-step locks with three water-saving basins and rolling gates

Water will be moved by gravity to fill and empty the lock chambers and water-saving basins. Two longitudinal culverts which flow via a central connector to a secondary culvert which acts as a manifold with 20 side ports open along the bottom of each lock chamber wall. The culverts will have split culverts with double valves for increased system reliability and ease of maintenance.

Model tests were conducted by the Consorcio Post-Panamax, a Belgium-French consortium, to ensure the proper and optimal behavior of the new locks filling and emptying system, water slopes in the lock chambers, hydraulic performance in the culverts, water-saving basins, intakes and discharges that make up the system. A tank model navigation test was also conducted to assess ship behavior using different approach, exit, lock-to-lock, density currents, vessel assistance and maneuverability scenarios.

The selected contractor will perform the final design of the lock filling and emptying system and validate the design with its own physical model prior to construction. The finished lock will have to meet filling and emptying times and performance established for final acceptance tests.

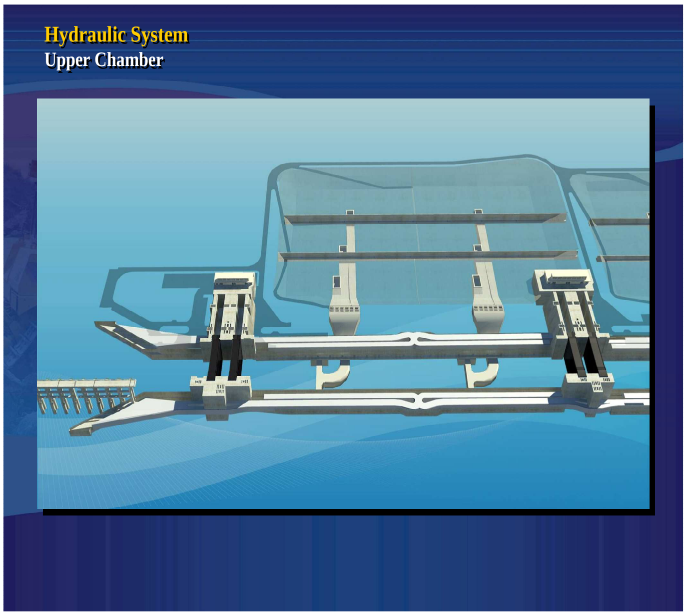


Figure 4 – Third set of locks filling and emptying system

3 LOCKS CONTRACTOR SELECTION

On March 3, 2009 three of the four pre-qualified worldwide Consortia for the design and construction of the Third Set of Locks, submitted bids for this element of the Expansion Program. These Consortia are formed by top ranked global construction firms. The evaluation process was completed and bids were opened in July 2009. The selection of the winning consortia was be based on a best value concept with 55% of the weight being assigned to the technical proposal and the remaining 45% to the price offered.

The design and construction of the two locks complexes is expected to take 62 months. This project represents the critical path of the Expansion Program and all attention focuses on facilitating its completion so that operations of the new locks system can begin in 2014.

Consorcio	Puntaje Técnico (Máximo 5,500)	Propuesta de precio en dólares	Puntaje de precio (Máximo 4,500)	Total de puntos (Máximo 10,000)
Bechtel, Taisei Mitsubishi Corporation	3789.5	$4,185,983,000	2,980	6,770
C.A.N.A.L.	3973.5	$5,981,020,333	2,586	6,559
Grupo Unidos por el Canal	4088.5	$3,118,880,001	4,000	8,089
Partida Asignada – ACP		$3,481,000,000		

Figure 5 – Result of technical and price evaluation

4 ENVIRONMENT AND FINANCE

In total, the expansion program will require approximately the excavation of some 147 million cubic meters of earth and rocks, 1.1 million tons of cement, 350,000 metric tons of steel, placing 5.2 million cubic meters of concrete, 20 million kilograms of explosives, 320 million liters of diesel fuel, the need of up to 10 dredgers and hundreds of large heavy equipment such as loaders, trucks, drills and cranes, rock crushers, conveyor systems, and batching plants.

To carry forward the aggressive schedule, the ACP has carried out a corporate organizational restructuring that focuses on two main drivers: project management and operations. The ACP also, immediately upon referendum approval, undertook budget preparation and submittal to start work without delay, devoted its engineering resources to the design of all expansion program projects, except for the locks, performed final Environmental Impact Assessments, trained its key personnel, developed sophisticated project scheduling and document controls systems, enhanced its contract/claims management processes, hired and developed construction safety and industrial hygiene, environmental, risk management and legal staff to insure it posses the skills, knowledge and competence required to manage the expansion program. The ACP has also contracted renown international firms to assist in critical program areas, such as program management, dam and locks engineering, physical modeling, financing, legal contract counsel, risk assessment and management, insurance brokerage, process auditors, communications and graphics documentation, and environmental audits, among others.

Required environmental impact assessments for all facets of the expansion program have been completed to comply with the requirements of the Panama's National Environmental Authority (ANAM) and the Ecuador Principles. The environmental plans being executed include wildlife rescue and relocation, prospective archeological investigations and salvage of any findings, mitigation measures, reforestation and environmental compensation.

The plan studied and selected options to ensure adequate quantity and quality of water supply to satisfy future water demand, first for human, municipal and industrial consumption in the watershed area and Panama and Colon metropolitan areas, and secondly for projected water requirements to operate the expanded canal with the Third Set of Locks.

The total program cost to expand the capacity of the waterway is estimated at US$5.25 billion. About 60% of the funds will be provided by the Canal's ongoing operations. The ACP has secured financing for the remaining amount, up to a total of $2.3 billion, with five multilateral financing agencies. The loans are for 20 years with an initial 10-year grace period to cover the construction period and startup operations.

Figure 6 – Financial plan for expansion program

5 IMPACT ON MARITIME TRADE AND BENEFITS FOR PANAMA

The maritime industry is adjusting its fleet to take advantage of the new trade routes and increased capacity of ship sizes the Third Set of Locks project will allow through the Panama Canal. Once the Expansion Program is completed it is expected that 98% of the world's fleet, by vessel dimensions, will be able to fit in the new locks. In particular, at least 96% of the world's container vessel fleet will fit through the expanded Canal. Moreover, more than 1,100 of present day post-Panamax container ships with capacities between 5,000 and 12,600 TEU's, totaling more than 8 million TEU fleet capacity and averaging 8,000 TEU's per ship, will be able to transit through the expanded Panama Canal.

U.S. East Coast ports in New York, New Jersey, Virginia, South Carolina, Florida, Georgia are already implementing plans to expand its infrastructure to receive post-Panamax container vessels that may transit to and from Asia's northeast ports through the expanded Panama Canal. Main improvements include dredging deeper navigation channels, increasing berth space, purchasing new post-Panamax cranes, and increasing yard, rail and road capacities.

The Panama Canal is the country's most valuable asset and the expansion program will become the driving force that will further spread out the economic boom the country is experiencing, particularly in a wide range of maritime services and port development, to help Panama become the maritime hub of the Americas and support the growth of maritime trade in the region.

Due to the magnitude of the expansion project, both the ACP and contractors will need to increase their labor forces, which will also help to create more jobs in the service and related sectors. A comprehensive training program to ensure the availability of skilled, certified labor for the expansion and other ongoing mega-projects in Panama has been launched nationwide.

The expansion project will generate up to 8,000 direct employments, of which, by Panamanian law, at least 90% must be citizens of Panama. The ACP estimates that for each direct expansion job, a further five will be created in the service and related sectors, therefore more than 40,000 industry jobs may be created during the peak of the expansion program works. Training of labor is underway in a national program to prepare the workforce to ensure the quantity and quality of certified personnel is available for the expansion and other major projects taking place in Panama.

With the expansion of the Panama Canal, the country is taking advantage of its geographic position along one of the main maritime trade routes by establishing itself as a logistics center for Latin America. In this regard Panama is expanding its spectrum of services as a platform for transportation and distribution which includes expanding its port and railroad installations and supporting businesses. Infrastructure investments plans in Panama's ports on both the Pacific and Atlantic ends of the Canal, are geared to handle, when completed, more then 8 million TEU's, thus making this system of ports the leader in container transshipment in Latin America.

Numerous maritime services firms and others interested in the distribution of their products from this advantageous geographical position are establishing operations in Panama to benefit from the growth of this major hub of the Americas. The trans-isthmus railroad is fit to transport some 500,000 containers each year, and its continuous expansion program will allow it to reach 750,000 per year at up to 32 daily trains.

Panamanian Copa Airlines, one of the largest in Latin America, will offer an air-maritime cargo transport option from its operations center at the Tocumen international airport, increasing Panama's potential as a distribution platform for time sensitive products.

Progress of the Third Set of Locks Project may be followed in the Panama Canal's web site: www.pancanal.com.

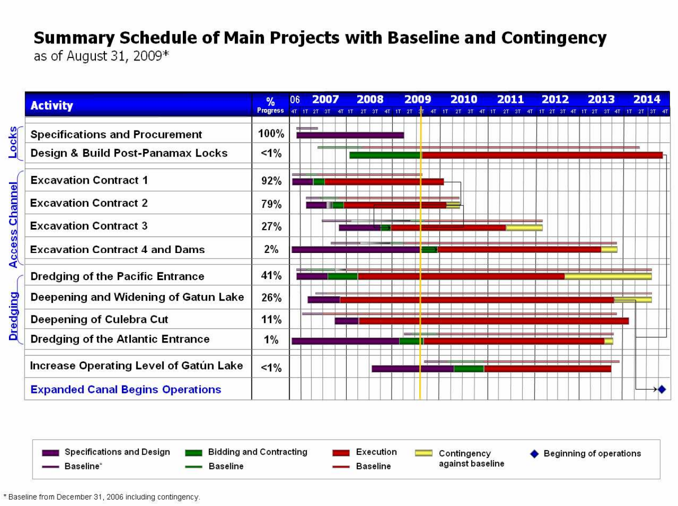


Figure 7 – Work schedule for Panama Canal expansion program

REFERENCES

Panama Canal's Third Set of Locks Project Master Plan (2006) available at www.pancanal.com

Monthly and quarterly Third Set of Locks Project Reports, available at www.pancanal.com

Ir. Marc Sas
IMDC, Belgium

SALINITY AND LOCKS

International Workshop, PIANC - Brussels, 15-17 Oct. 2009

PIANC

IMDC International Marine & Dredging Consultants

The World Association for
Waterborne Transport Infrastructure

Salinity and Locks

Marc Sas
International Marine and Dredging Consultants
(Belgium)

PIANC Workshop
15-16th October 2009

PIANC
Setting the course

Salinity and Locks

1. Salinity and nautical aspects
2. Salinity and the environment
3. Salinity and sedimentation
4. Mitigating measures

Salinity and Locks

1. Salinity and nautical aspects
2. Salinity and the environment
3. Salinity and sedimentation
4. Mitigating measures

Salinity and Locks

Innovations in Navigation Lock Design
Brussels 15-17/10/2009
Marc Sas

1. Salinity and nautical aspects

- Salinity differences causes density currents
- Major phenomena :
  - Spilling (leveling of the chamber)
  - Exchange current (opening of the doors)
- They have impact on the navigation :
  - What you see is NOT what you get
  - Asymmetric flow distribution in the tail bay/ access channel of the lock
  - Increased hawser forces

Salinity and Locks

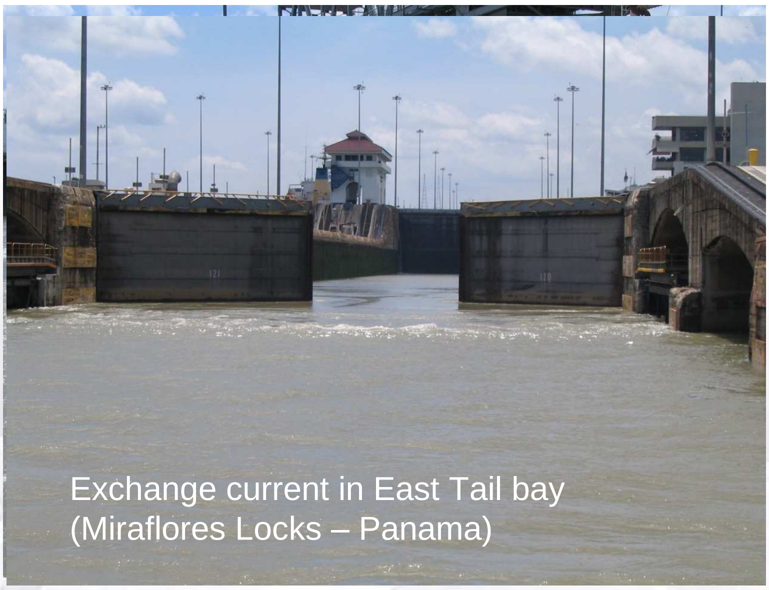
1. Salinity and nautical aspects

Spill in East Tail bay (Miraflores Locks – Panama)

Salinity and Locks

Innovations in Navigation Lock Design
Brussels 15-17/10/2009
Marc Sas

1. Salinity and nautical aspects



Exchange current in East Tail bay (Miraflores Locks – Panama)

Salinity and Locks

1. Salinity and nautical aspects

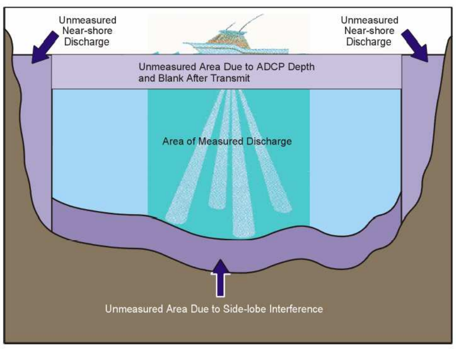
Study approach

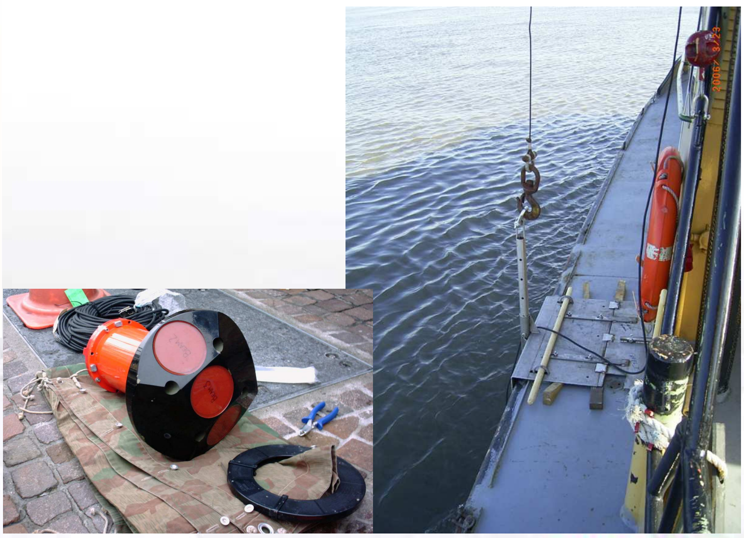
- Data collection
  - To better understand flow and salt exchange between chamber and the ocean during leveling (spilling) and after opening the gates (density current);
  - To determine the velocities caused by density currents that effect ship navigation;
- 3D Modeling of present situation
  - Set-up, validation and results
- 3D Modeling of future situation
  - Set-up, scenarios and results

Salinity and Locks

1. Salinity and nautical aspects

Current Measurements - ADCP





Salinity and Locks

1. Salinity and nautical aspects

Salinity Measurements – rapid drop SiltProfiler

High Frequency (100 Hz)

Wireless (acquisition & transmission)

Freefall Profiling

3 Silt sensors:

- 1 Seapoint BS sensor (0-700 mg/l)
- 2 Transmittance Extinction Sensors (500-5000 mg/l & 5000 – 35000 mg/l)

CTD sensor + backup sensor

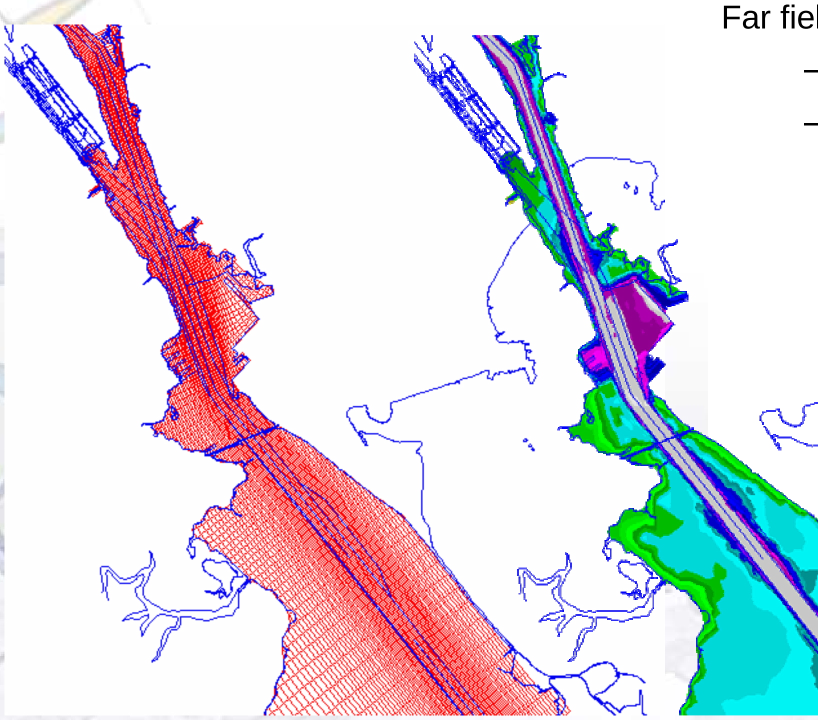
Salinity and Locks

1. Salinity and nautical aspects

Study approach

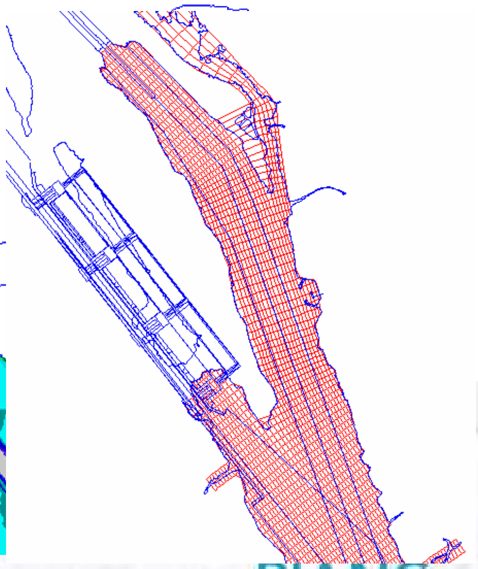
- 3D Modeling of present situation (Set-up, validation and results)
  - far field model (global hydrodynamics)
  - Near field (density currents)

Salinity and Locks



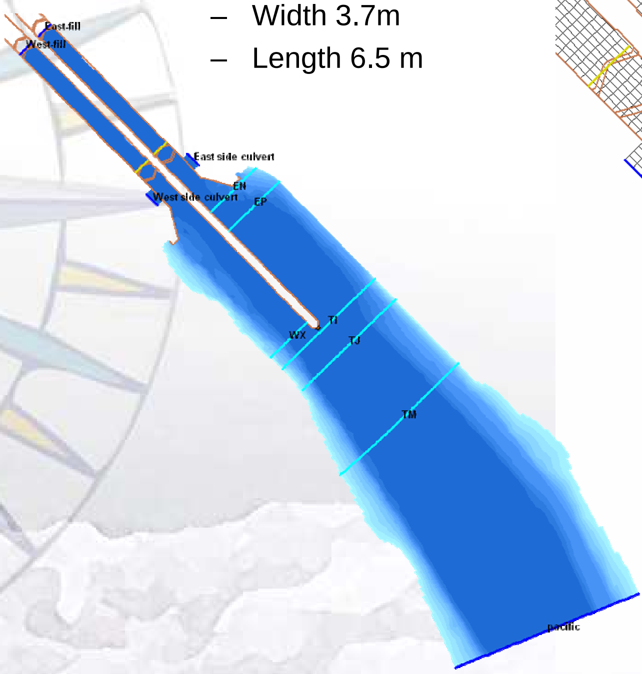
Far field Grid cells:

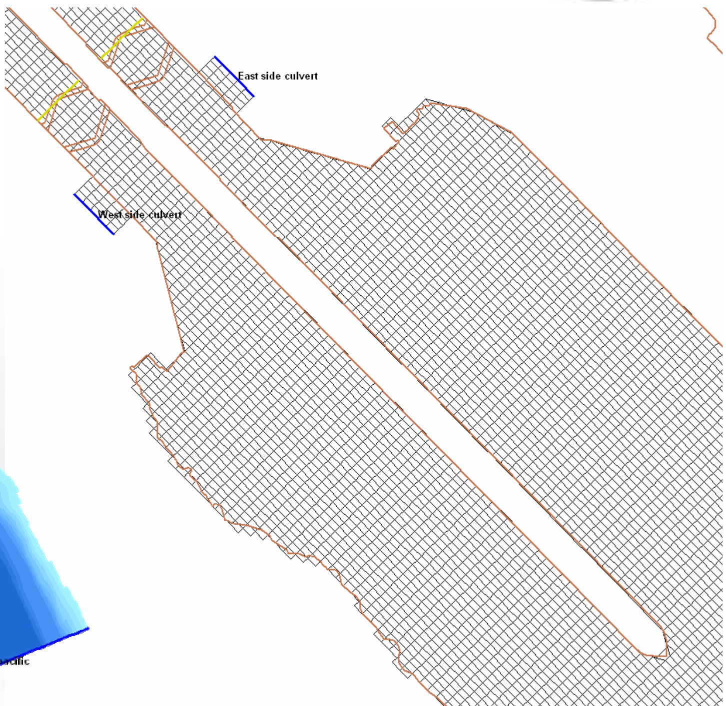
- Width : 20m in channel
- Length : 40m – 80m



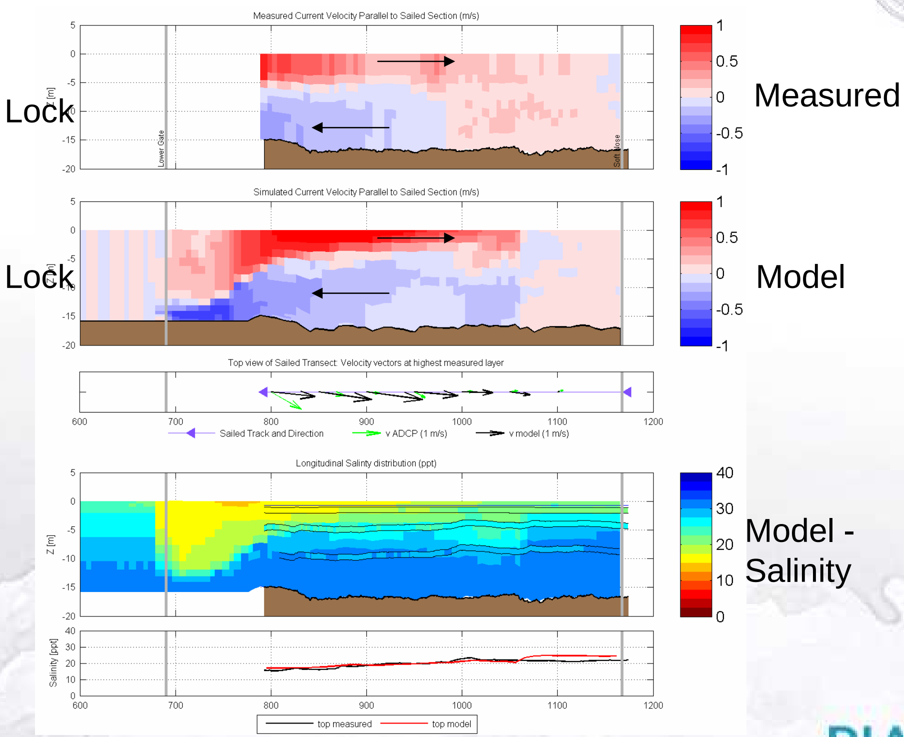
Salinity and Locks

- Near field :Grid cells:
  - Width 3.7m
  - Length 6.5 m





Salinity and Locks



Salinity and Locks

1. Salinity and nautical aspects

Study approach

- 3D Modeling of future situation (Set-up, scenarios and results)
- Focus on alternative designs of the tail bay and the centre wall

Salinity and Locks

1. Salinity and nautical aspects

- Base line scenarios
- To study the effect of the permeability of the center wall
- Invisible wall <u>without</u> and <u>with</u> Water Saving Basins

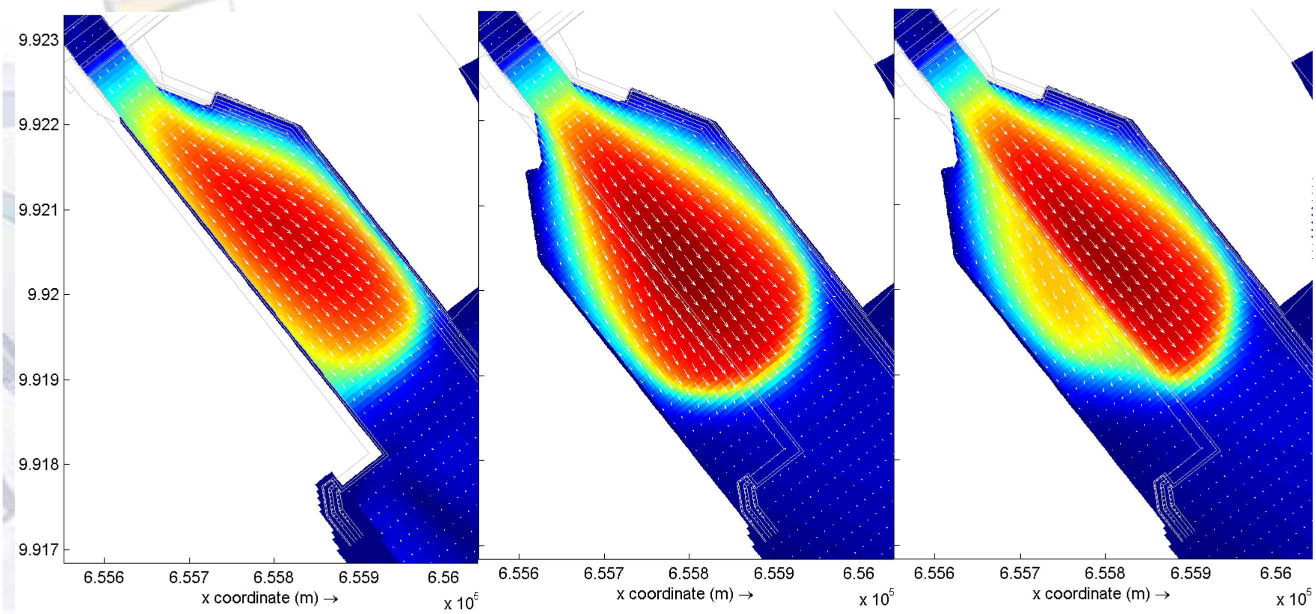
closed center wall no center wall invisible center wall

Salinity and Locks

Innovations in Navigation Lock Design
Brussels 15-17/10/2009
Marc Sas

1. Salinity and nautical aspects

closed center wall no center wall invisible center wall



Salinity and Locks

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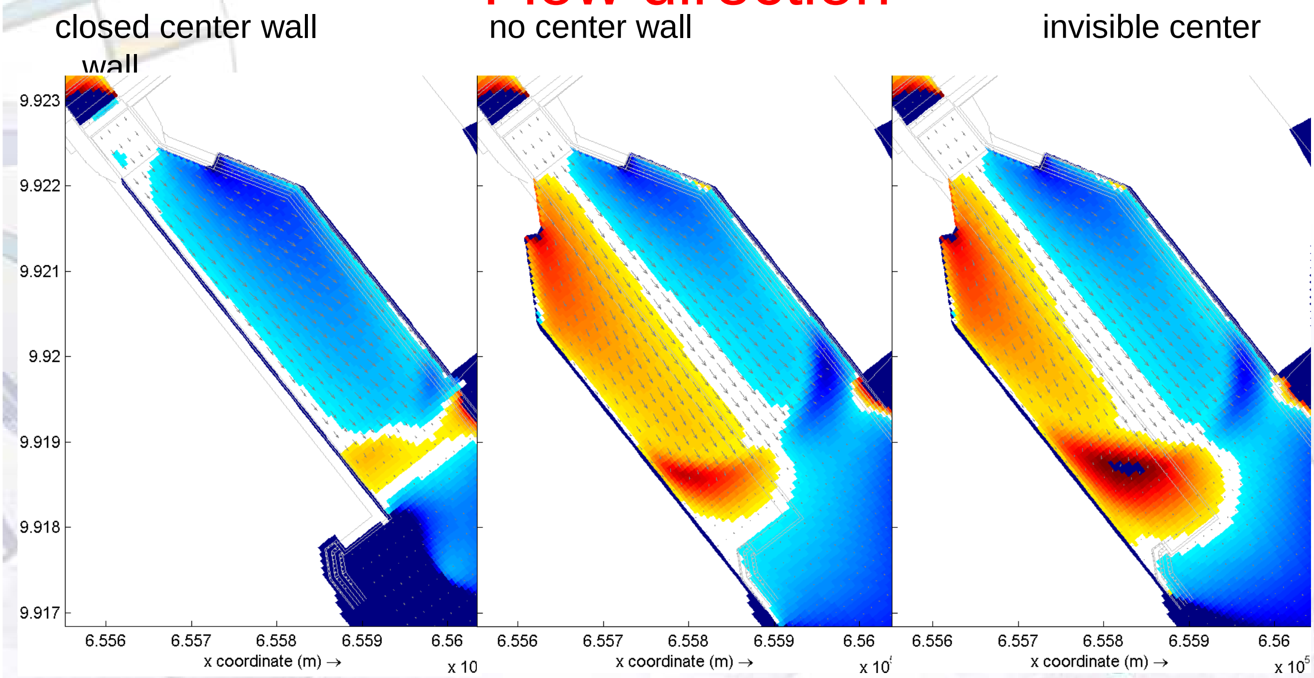
1. Salinity and nautical aspects

Flow direction



Salinity and Locks

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1. Salinity and nautical aspects
2. Salinity and the environment
3. Salinity and sedimentation
4. Mitigating measures

Salinity and Locks

2. Salinity and the environment

Salt water intrusion from sea locks into inland waterways induces problems :

- Surface water (drinking, agriculture, industry, ecosystem)
- Examples :
  - Saline intrusion into Gatun lake (from the Pacific)(Panama)
  - Saline intrusion into canal Gent-Terneuzen (the Netherlands)

Salinity and Locks

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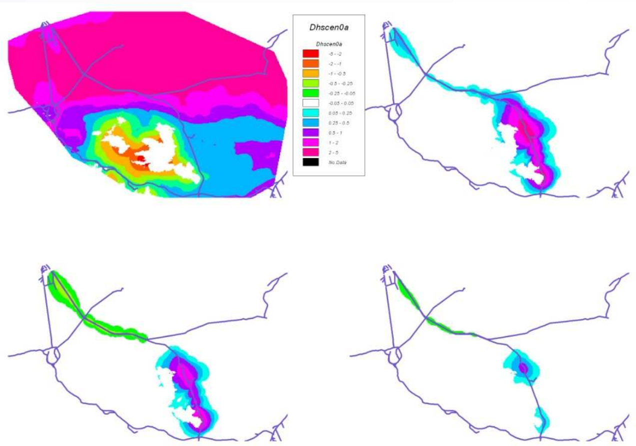
2. Salinity and the environment

Salt water intrusion from sea locks into inland waterways induces problems :

- Groundwater (drinking, agriculture, industry, ecosystem)
- Example :
  Seine-Scheldt West canal study



Salinity and Locks

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3. Salinity and sedimentation

– Density currents entrain fine sediments into the lock chamber
  Examples :
  – Deposition of mud on the doors (e.g. rolling gates Zandvliet/Berendrecht)
– Density currents entrain fine sediments in the access channels tot the locks, and are responsible (in general) for more than 50% of the sedimentation rate (see PIANC WG 43 on Minimisation of harbour Siltation)
  Examples :
  – Kallo lock (river Scheldt – Belgium) :
    - o tidal filling : 20%
    - o Eddy : 10%
    - o Density currents : 70%

Salinity and Locks

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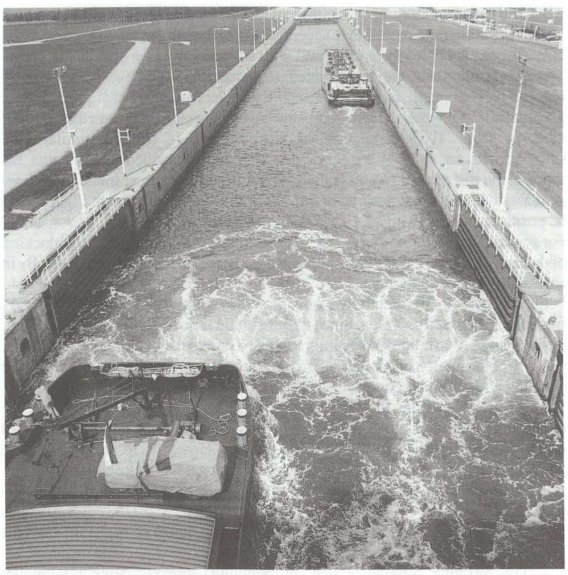
4. Mitigating measures

- Pumping back the saline lockage prism
- Use of air bubble curtain (Volkerak locks – the Netherlands, Kerstma et al.)



Salinity and Locks

4. Mitigating measures

- Gravitational discharge of saline water via receptor basin (Terneuzen, PIANC 1986)

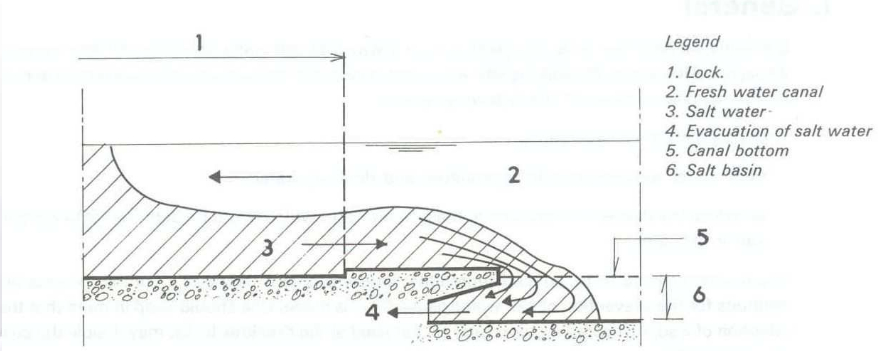


Fig. 2 - System of Terneuzen: Selective withdrawal of salt water intruded in the fresh water canal

Salinity and Locks

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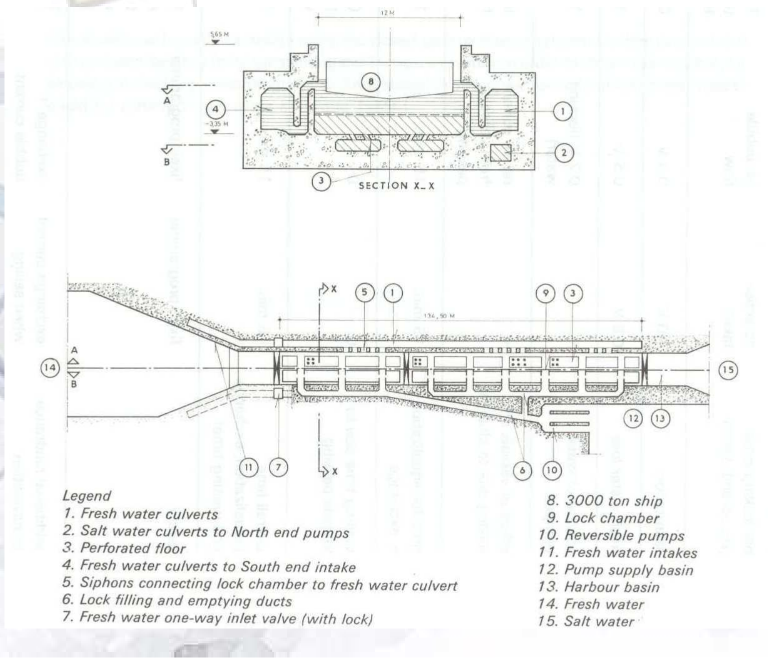
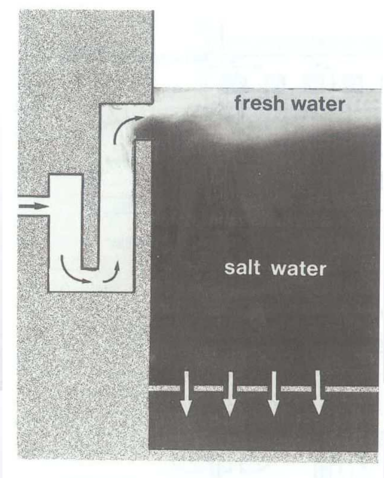
4. Mitigating measures

- Complete lock chamber exchange (Dunkirk - France, Kreekrak and Krammer – the Netherlands) (PIANC 1986, Kerstma et al.)





PIANC
Setting the course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EXPERTISE IN WATER

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Paper 7
MOORING FORCES AND SHIP BEHAVIOUR IN NAVIGATION LOCKS

Mooring forces and ship behaviour in navigation locks

Tom De Mulder

Flemish Authorities
Mobility and Public Works Department
Flanders Hydraulics Research
Antwerp, Belgium

Hydraulic design of F/E system

a.o.:

- **Limit F/E time**
- **Respect hawser force criterion**

✓limit 'turbulence'

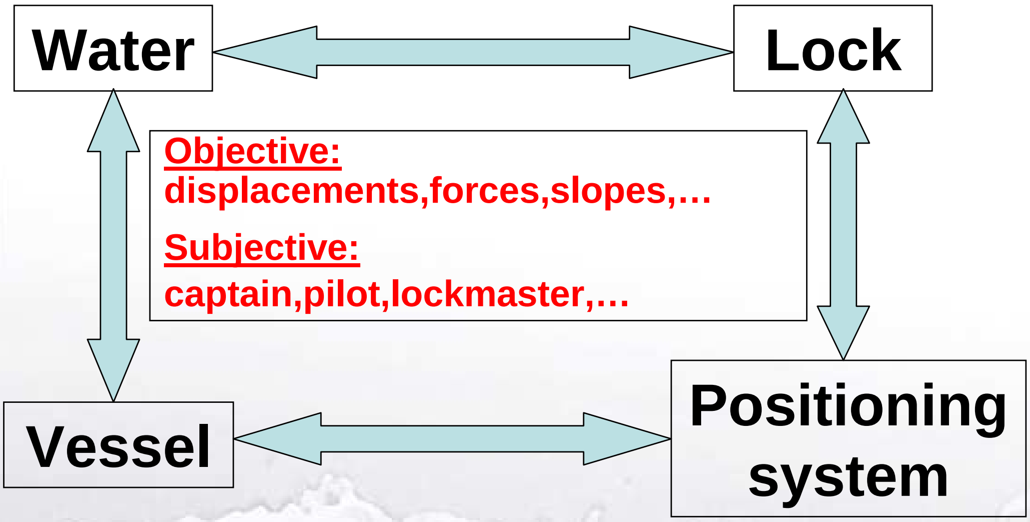
✓prevent line damage/break

✓limit ship motion

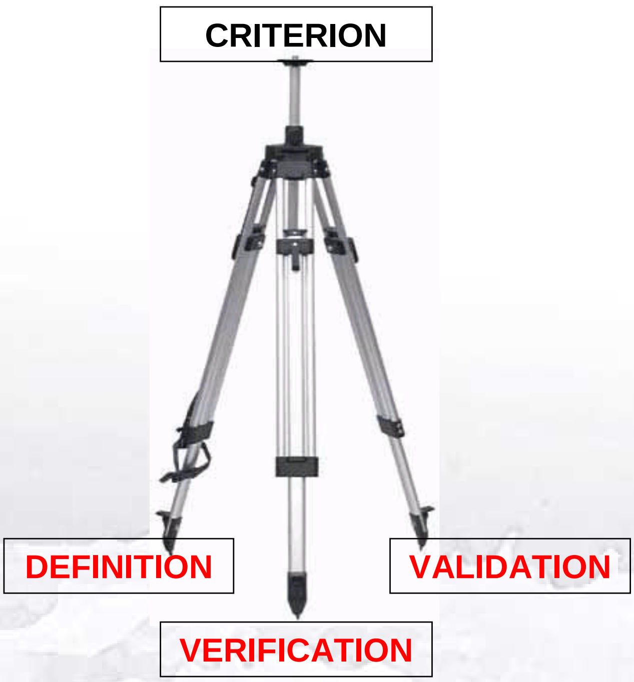
➔ safety and comfort

➔ objective and subjective

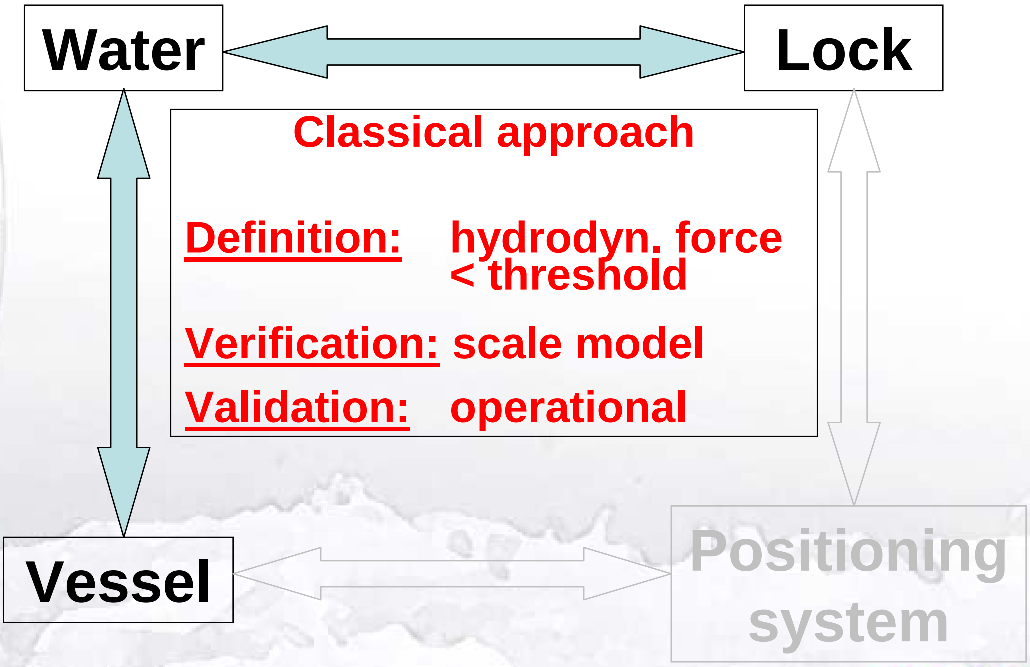
Hawser force criterion



Hawser force criterion



Hawser force criterion

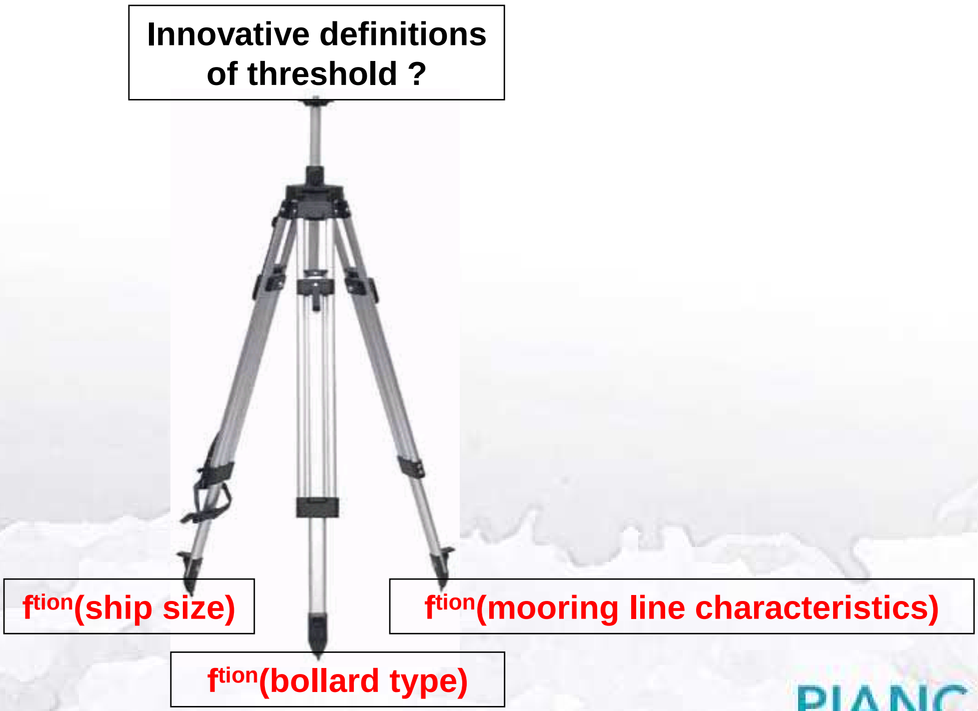


Hawser force criterion

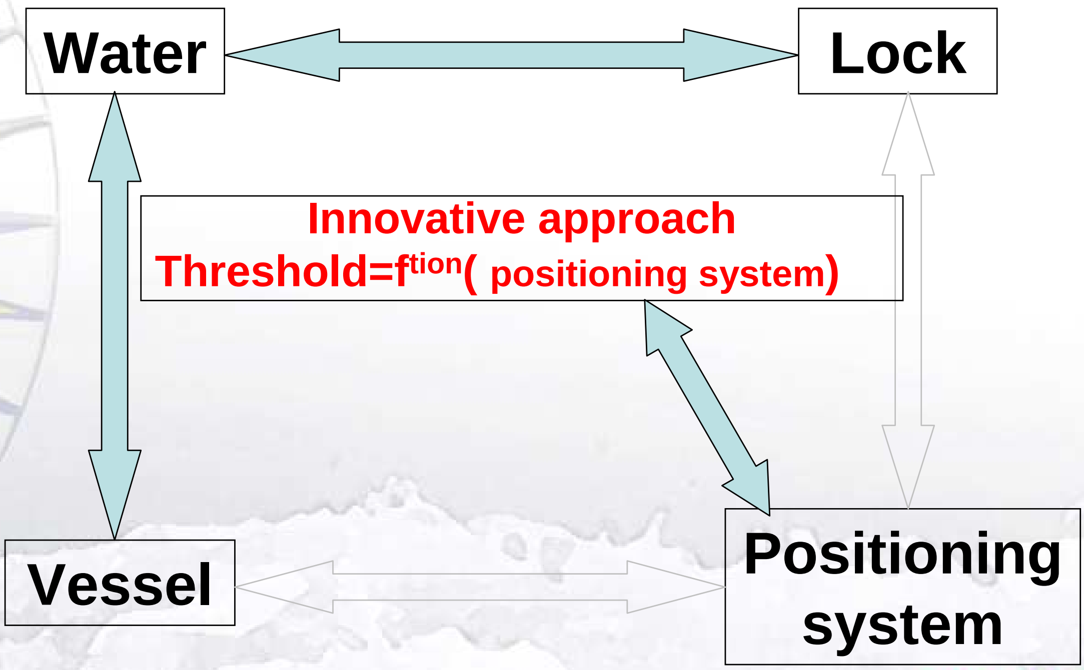
Innovative approaches ?

Pandora opening the box (J.W. Waterhouse, 1896)

Hawser force criterion



Hawser force criterion



Hawser force criterion

Threshold for hydrodynamic force

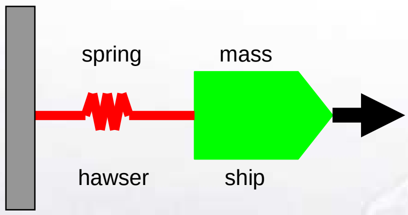
$$\text{threshold} = \sum_{\text{mooring lines}} \frac{T_u \cos(\theta_i)\cos(\phi_i)}{f_s \cdot f_m}$$

T_u = minimum tensile strength

f_s = safety factor w.r.t. T_u

f_m = dynamic magnification factor

θ_i, ϕ_i = line orientation



cf. H.-W. Partenscky (1986) ; A. Vrijburcht (1994) ; T. De Mulder (2007)

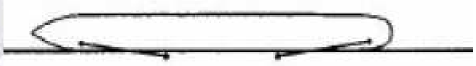
Hawser force criterion

Threshold for longitudinal hydrodynamic force

A. Vrijburcht (1994) ; Rijkswaterstaat (2000)

VESSEL Class	Hawser force criteria (°/oo of total ship displacement)	
	In filling	At emptying or filling with floating bollards
CEMT Class III	1.50	2.00
CEMT Class IV	1.10	1.50
CEMT Class Va	0.85	1.15

inland navigation



Hawser force criterion

Thresholds for hydrodynamic forces/moments

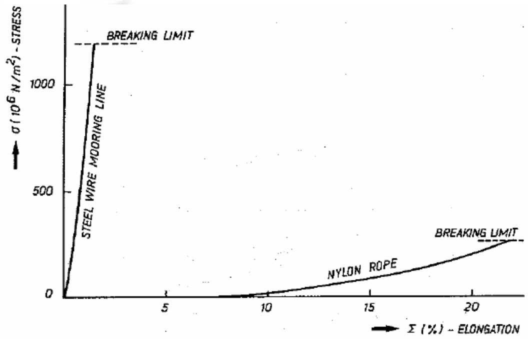
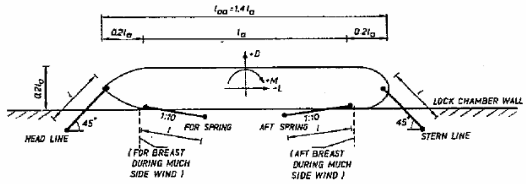


FIG. 1 STRESS-ELASTIC STRAIN RELATIONSHIP FOR STEEL WIRE AND NYLON MOORING ROPES



A. Vrijburcht (1977)

FIG. 2 STANDARDISED SITUATION AND DIMENSIONS MOORED SHIP

criteria in ‰

ship's size tons DW	rope's type	rope T_{pr}/T_u (pre-tension)	long. force x	transv. force y	moment z_1	moment z_2	moment z_3
40,000	steel	0.15	0.24	0.14	0.075	0.050	0.025
40,000	steel	0.10	0.15	0.10	0.051	0.034	0.017
40,000	nylon	0.20	0.26	0.20	0.102	0.068	0.034
40,000	nylon	0.10	0.14	0.10	0.051	0.034	0.017
80,000	steel	0.15	0.21	0.12	0.066	0.044	0.022
80,000	steel	0.10	0.13	0.085	0.044	0.029	0.015
80,000	nylon	0.20	0.22	0.16	0.087	0.058	0.029
80,000	nylon	0.10	0.115	0.08	0.043	0.029	0.015
120,000	steel	0.15	0.19	0.11	0.060	0.040	0.020
120,000	steel	0.10	0.12	0.08	0.041	0.027	0.014
120,000	nylon	0.20	0.205	0.16	0.081	0.054	0.027
120,000	nylon	0.10	0.105	0.08	0.040	0.027	0.013

ocean-going vessels 120,000 DWT

long. forces of 0.10 à 0.20‰

Hawser force criterion

Validation: Hydrostatic force ~ water surface slope

Measurements (FHR/APA, 2007) in Berendrecht lock (L x W=500m x 68m)

Hawser force criterion

Innovative verification tools ?

SCALE MODELS

IN SITU MEASUREMENTS

NUMERICAL MODELS

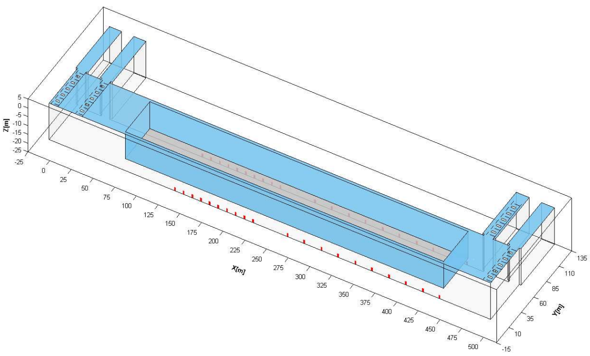
Hawser force criterion

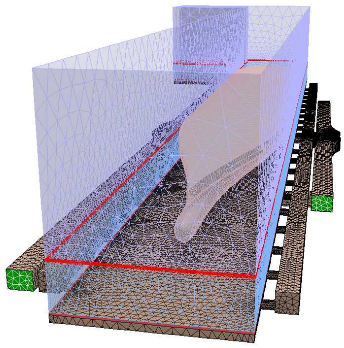
Numerical tools for verification of criterion

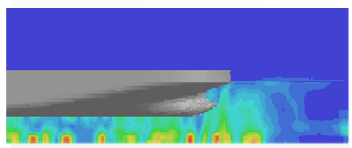
1D/2D Shallow Water Equations

3D Reynolds-Averaged Navier-Stokes (Computational Fluid Dynamics)

+ Fluid Structure Interaction (optional)







CPP/CNR/FHR/Modelys (2007)

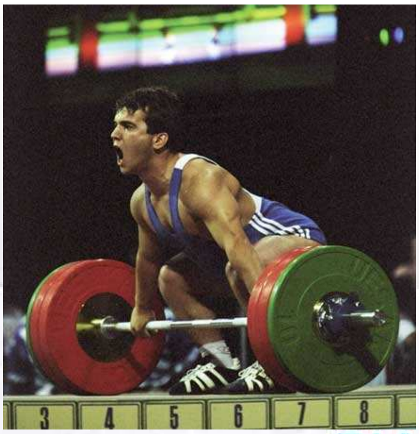
Hawser force criterion

Numerical tools for verification of criterion

1D/2D Shallow Water Equations

3D Reynolds-Averaged Navier-Stokes (Computational Fluid Dynamics)

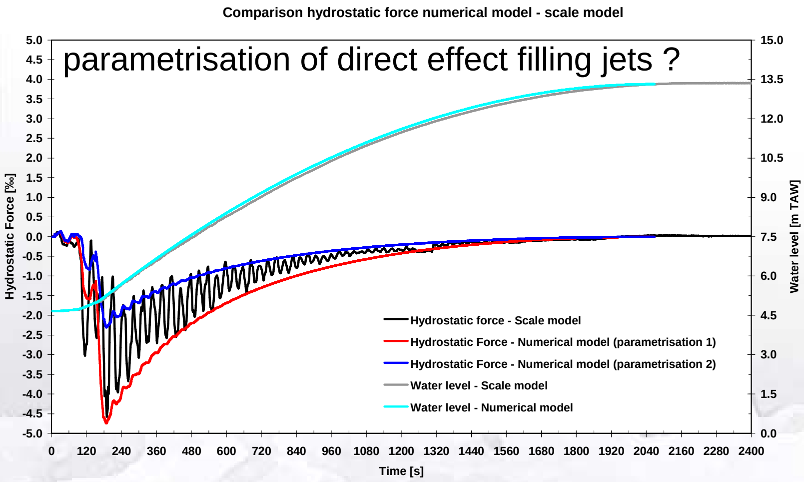
+ Fluid Structure Interaction (optional)



Hawser force criterion

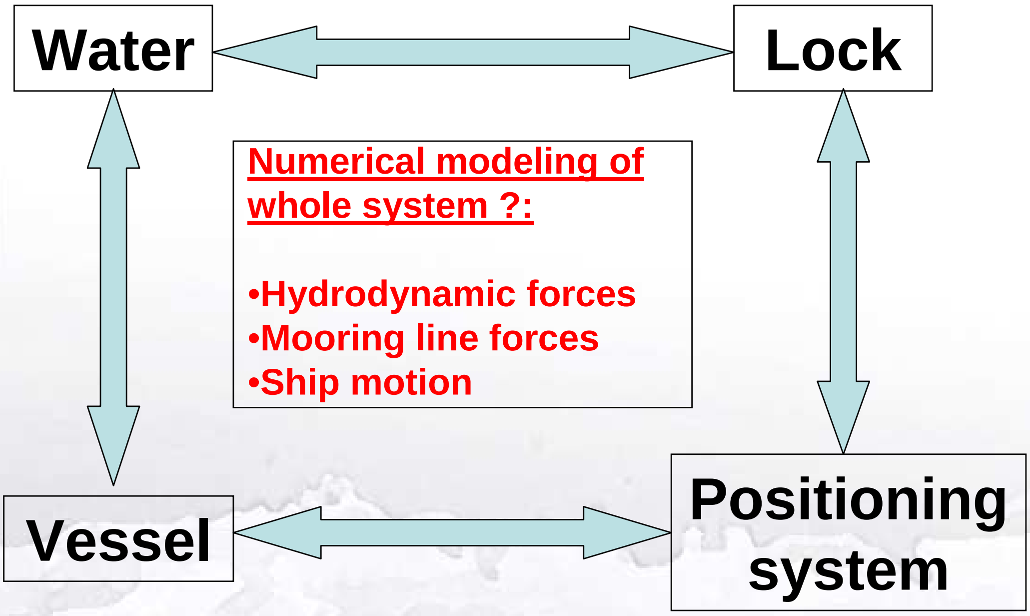
Numerical tools for verification of criterion

- Longitudinal forces / slopes = ±OK



- Transversal forces / slopes ?!

Mooring forces and ship behaviour



Mooring forces and ship behaviour

Numerical modeling of whole system ?

Daidalos and Ikaros (C.P. Landon, 1799)

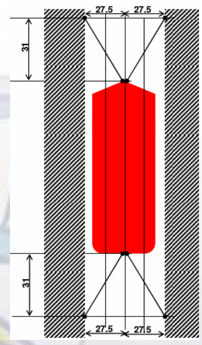
Mooring forces and ship behaviour

Numerical modeling of whole system ?

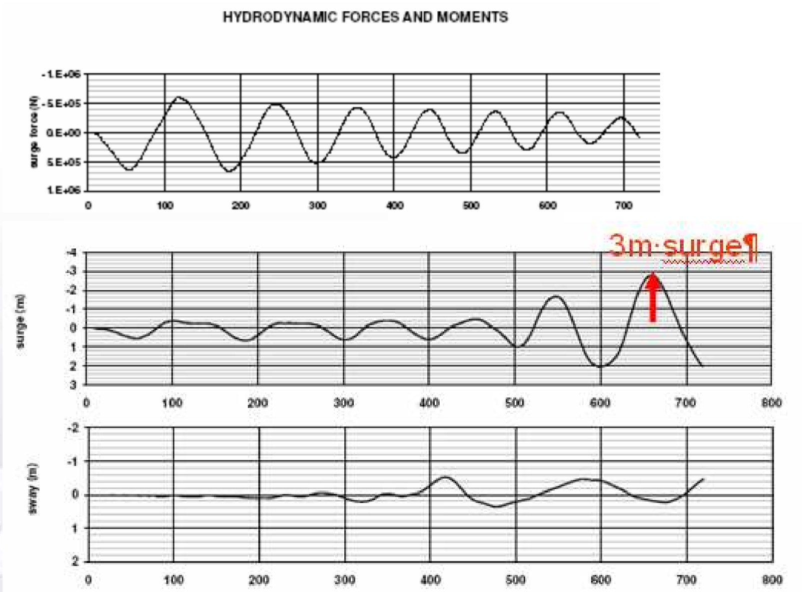
- Ship at (off-shore or port) terminal exposed to wind waves
- Application to ship moored in (shallow and confined) navigation lock !?

Mooring forces and ship behaviour

Numerical modeling of whole system ?



CPP/FHR/Univ.Gent (2007)

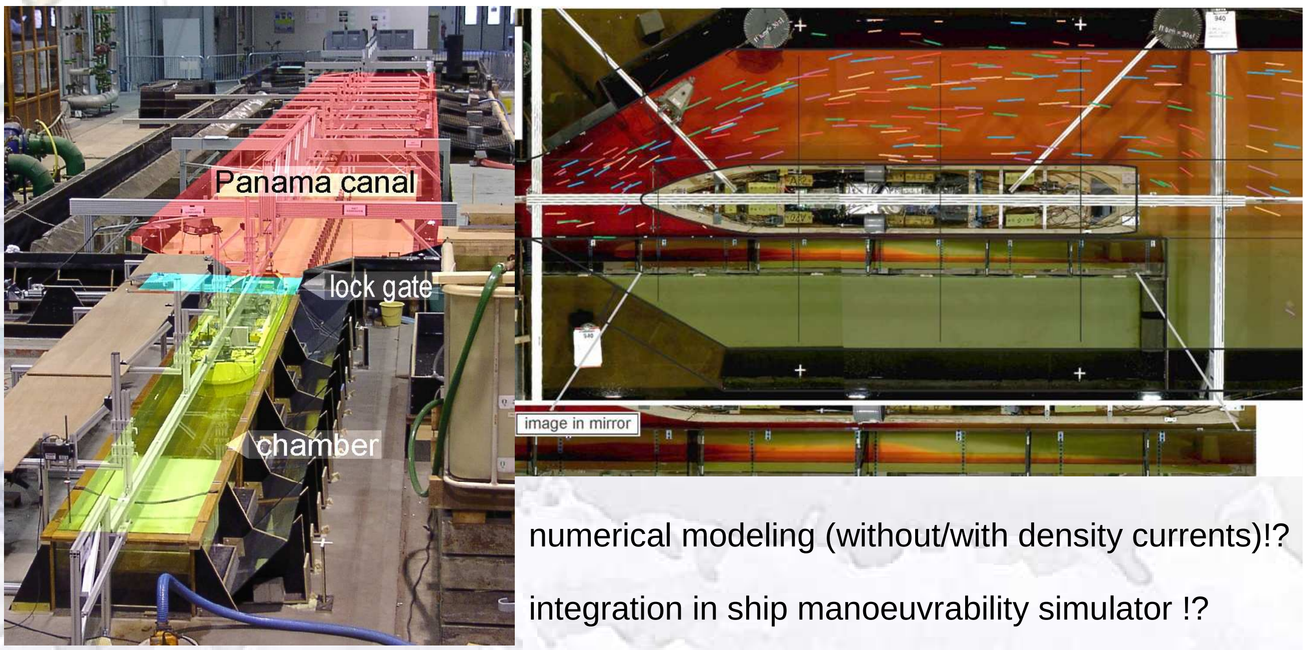


Mooring forces and ship behaviour

Numerical modeling of whole system

- Large number of (often uncertain) parameters !?
- Results sensitive to choice of (some) parameters !?
- Computational effort !?

Ship behaviour sailing in/out lock



numerical modeling (without/with density currents)!?

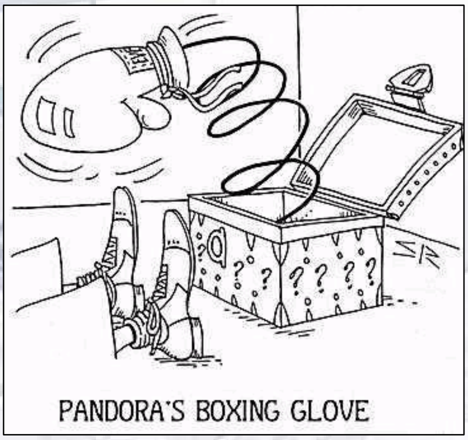
integration in ship manoeuvrability simulator !?

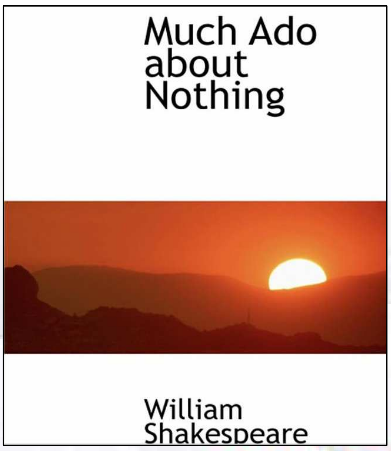
CPP/FHR (2008)

Mooring forces and ship behaviour

- Notwithstanding numerous innovations…
- …still not fully understood
- More efforts needed for in situ observations/measurements:
  - ➔ validation data for (more or less sophisticated) models
  - ➔ above all for gaining insight !!!

Mooring forces and ship behaviour





Ir. Sam X. Yao

Ben Gerwick INC., San Francisco, CA, USA

Ir. John Clarkson

US Army Corps of Engineers, Huntington, WV, USA

Paper 8
IN-THE-WET CONSTRUCTION

International Workshop, PIANC - Brussels, 15-17 Oct. 2009

In-the-Wet Construction

John Clarkson
US Army Corps of Engineers
Huntington District
and
Sam Yao
(mistakenly not listed in WF29 report, he wrote this section of the report)
Ben C. Gerwick, Inc.

In-the-Wet Construction

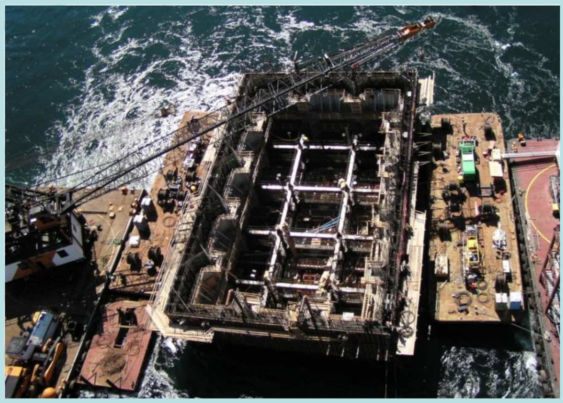
First used in the offshore oil industry
and immersed tunnels

Immersed tube tunnels
(Float-In)

Offshore drilling platforms
(Float-In)

In-the-Wet Construction

Also in bridge construction



Float-in Construction of Tacoma-Narrows Bridge Pier

Lift-in Construction of Confederation Bridge Deck

What is "In-the-Wet" Construction?

An innovative method of **prefabricating** precast concrete (or steel) **modules on land, transport** and placing them in rivers as the in-situ **form** into which underwater concrete and **mass concrete** are directly placed. Therefore, a lock or a dam may be constructed **without use of a cofferdam**.

Float-In vs. Lift-In

Float-In

Lift-In

Why In-the-Wet Construction?

A Recent Development in Construction of Locks and Dams

- **Minimizes impact to existing navigation** traffic as much of the work is prefabricated off site and no cofferdam is required.
- **Especially beneficial for expanding existing locks.**

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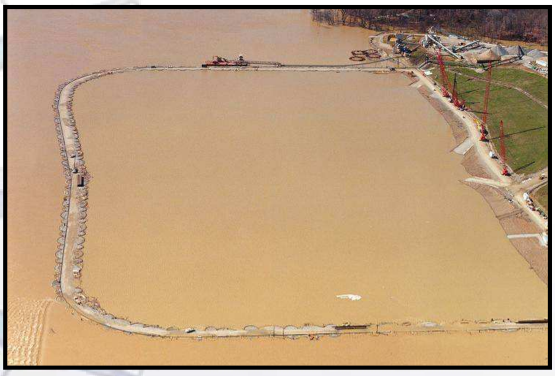
Setting the course

In-the-Wet Construction

Advantages of In-the-Wet Construction



Conventional Lock Construction with Cofferdam

- **Risk of floods overtopping** the cofferdam
- Risks of having severe scour and suspended sediments

Innovative Lock Construction without Cofferdam

- No Cofferdam leads to **shortened On-Site construction schedule**
- No Cofferdam results in cost and time savings

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In-the-Wet Construction

Advantages of In-the-Wet Construction

- **Maximize Off-site Fabrication**

- **Improve Quality Control of Concrete Elements**

- Minimize Marine Work

- Cost Reduction

Greater Flexibility in Construction Process

- **Off-season work** - **Schedule reduction On-Site**

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In-the-Wet Construction

Disadvantages of In-the-Wet Construction

- In-the-Wet technology is relatively **new so it lacks many "rules of thumb"** of past experience.
- Many of the new details have to be developed by the designers or contractors; may require a **steep learning curve** for the first time users.
- There may be **limited** pool of **available contractors**.
- In-the-Wet technology **may have less flexibility** during construction.
- Particular attention needs to be paid to the **connection and tolerances between each pre-constructed element.**
- Since a cofferdam is not used the substructures or **foundations are not visible**.

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What is Float-in-Construction? 1/3

- **Constructed in a dry dock** or similar structure and **floated to the construction site**.
- The **modules** are usually **thin-shell floating structures** with internal ballasting compartments.
- Once the float-in modules are **transported** to and precisely positioned over the site, they are **lowered** down to a **prepared foundation by means of ballasting**.

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Float-In Advantages 2/3

Float-in method has several major advantages over lift-in method:

- It **avoids heavy lift equipment** which sometimes represents a substantial portion of the project cost.
- The float-in modules can be **made as large as practical** without any concern for equipment capacity. Thus, it **minimizes marine work and underwater joints**.
- Use of large modules generally leads to **shorter on-site construction time and lower cost.**

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Float-In Limitations 3/3

In general, the float-in method is used effectively where the environmental constraints are not too severe, and the size and configurations of the prefabricated modules are favorable.

- The float-in constructability is severely **limited by** river conditions, such as **draft and river flow velocity, 1-2 m/s.**
- A **launching system** for loading out the float-in modules from a **casting yard into river – A significant cost factor**.
- A **sophisticated** positioning system and complex **set-down** process (e.g., **ballasting/deballasting**).
- **Underwater tie-in** of the float-in modules to their **foundation may be complex**.

What is Lift-in Construction? 1/3

In general, the lift-in method is usually efficient when a large number of prefabricated modules have to be installed on site or where environmental conditions impose restrictions on the float-in method

- **Preferred where limited draft and higher river velocity.**
- The prefabricated modules do not float. They are **transported on barges** and installed at project sites with **heavy lift equipment.**
- Auxiliary guiding systems (e.g. **mooring and position guides**) are often used in order to position the modules within **acceptable tolerance**.

Lift-In Advantages

- Since the lift-in modules are not required to float over water, their fabrication is **substantially simpler than the float-in modules.**
- Lift–in construction is largely independent of river level - **draft,** but is constrained by river flow velocity, with a normal upper limit of **2 to 3 meters per second**.

Lift-in Limitations

- The size and configuration of lift-in modules **is limited by availability of heavy lift equipment** in the local region
- **Cost of heavy lift equipment** and equipment utilization rate
- Smaller modules - **Underwater joining** of multiple lift-in modules is **complex and costly**

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Setting the course

Examples of Innovative In-the-Wet Projects

Greenup Float-In

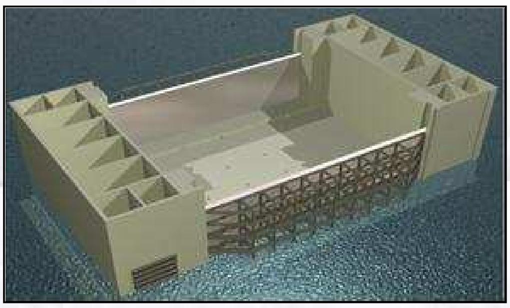
The Greenup plan of improvement includes a 183 m (600 ft) extension of the existing 183 m (600 ft) auxiliary lock to provide an overall length of 366 m (1200 ft), extension of the lock approach walls, filling and emptying system improvements, installation of a miter gate quick change out system for faster repairs to the lock miter gates and environmental mitigation. Extension of the auxiliary lock will be accomplished by lengthening the lock chamber with float-in concrete sections. This technique will utilize a dry dock at R.C. Byrd Locks and Dam to construct a concrete shell base raft. After the base raft is complete, the raft will be floated to a fit-out area at Greenup Locks and Dam where the walls are constructed on the base raft. The structure is then transported, positioned, and ballasted so that it will sink to its final position.

Areas of Innovation

Hydraulic	O & M	Environ	Design / Construct	Misc

Lock Dimensions

Length	366 m	Lift:	9.1 m
Width:	33.5 m	Depth	4.6 m



J.T. Meyers – Float-In

*This project extends an existing lock from 34 m to 366 m using **float-in construction for the approach walls and supplemental thru sill filling system** for newly extended chamber.*

Areas of Innovation

Hydraulic	O & M	Environ	Design / Construct	Misc

Lock Dimensions

Length	366 m	Lift:	5.5 m
Width:	34 m	Depth	4.9 m

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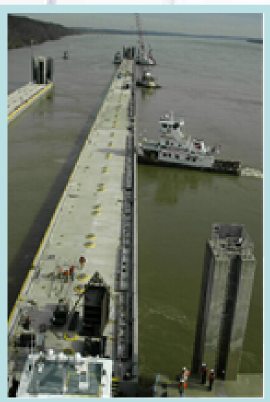
Setting the course

Olmsted Lock and Dam – Floating Walls

*Expensive and deep foundations, high seismic design loads, **large water level fluctuations** and **heavy bed loads** provided an impetus to develop a floating solution for the Olmsted Approach walls. A floating structure that is only anchored at each end instead of continuously or intermediately along the length as is typical for fixed structures would meet this goal. A structure that floats would also **never be submerged;** thus eliminating the requirement to wash mud from the structure.*



Areas of Innovation

Hydraulic	O & M	Environ	Design / Construct	Misc

Lock Dimensions

Length	366 m	Lift:	7.9 m
Width:	33.5 m	Depth	12.5 m

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Kentucky Lock – Float-In

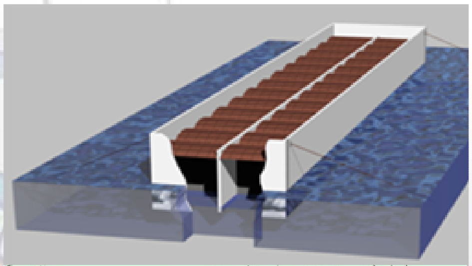
This project adds a new 366 m chamber adjacent to an existing 183 m chamber. ***Construction utilizes an innovative float-in cofferdam.***

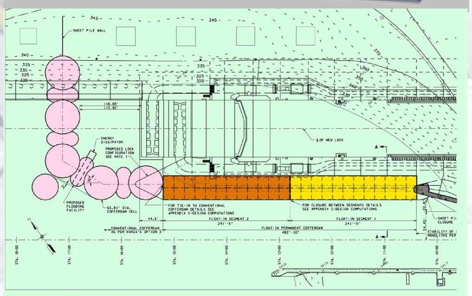
Areas of Innovation

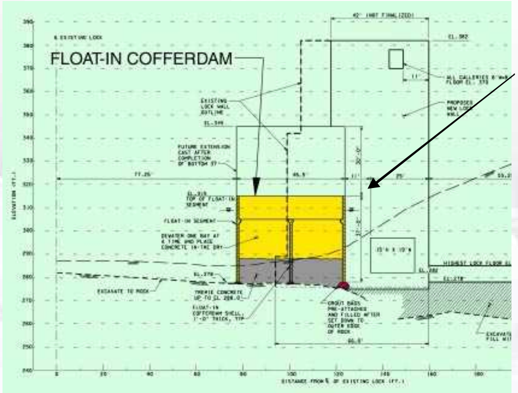
Hydraulic	O & M	Environ	Design / Construct	Misc

Lock Dimensions

Length	366 m	Lift:	17.4 m
Width:	34 m	Depth	5.2 m







An integrated cofferdam into monolithic construction

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Charleroi - Lift-In

Replacement and expansion of existing 17 m x 220 m and 17 m x 110 m locks with two new lock chambers, each 26 m x 220m, done while maintaining traffic through the locks. Two innovative features highlighted:

Jump-form Construction

Local Cofferboxes
Internally braced local cofferboxes will be used to construct many of the lock wall monoliths. The cofferboxes will be used to ***dewater local areas*** *for* ***conventional construction*** *of these lock monoliths.*

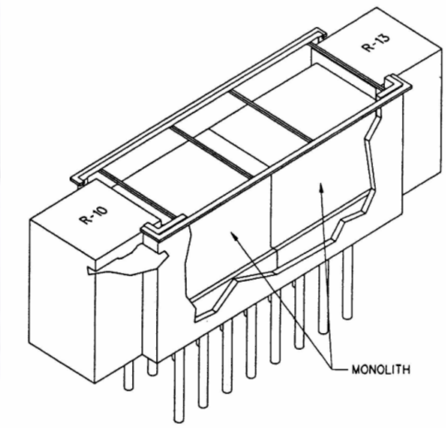
The cofferboxes will be composed of HZ kin piles, AZ sheet piling, internal bracing and a tremie concrete seal.

Areas of Innovation

Hydraulic	O & M	Environ	Design / Construct	Misc

Lock Dimensions

Length	220 m	Lift:	6 m
Width:	26 m	Depth	



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Caisson Method (7-01)

While ***technically not In-the-Wet, it is built without a cofferdam****. The lock chamber is constructed* ***on the ground surface.*** *When complete, the* ***soil is removed beneath*** *the lock chamber and it is* ***lowered into its final position.***

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Lith (7-02)

A new lock chamber built to replace a small existing lock. The lock chamber is ***built on the ground*** *surface and the ground beneath is then removed to* ***lower the chamber*** *to its final elevation.*

Areas of Innovation

Hydraulic	O & M	Environ	Design / Construct	Misc

Lock Dimensions

Length	200 m	Lift:	4.7 m
Width:	18.5 m	Depth	

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Two Examples of Float-In and Lift-In with More Detail

Braddock
Float-In

Chickamauga
Lift-In

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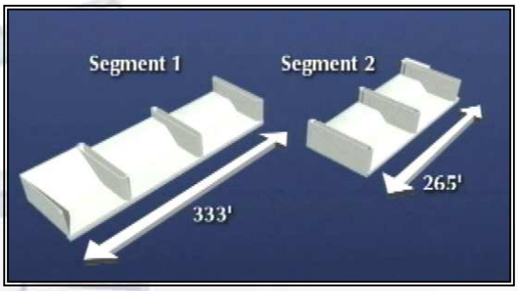
WG29 - LOCK INNOVATIONS – FLOAT-IN

Innovations in the Braddock Dam Design



- Two 11,000 tons precast concrete float-in segments
- A unique two-stage cast & launch system for two segments
- Tow the segments 27 miles to the site through two locks
- A unique positioning system to install the float-in segments on site to a tolerance of 50 mm
- A high performance underwater grouting and tremie concrete

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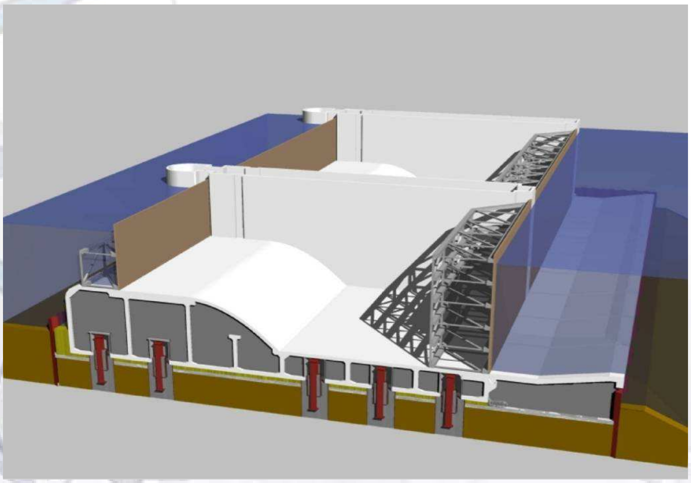
WG29 - LOCK INNOVATIONS

Construction Sequence

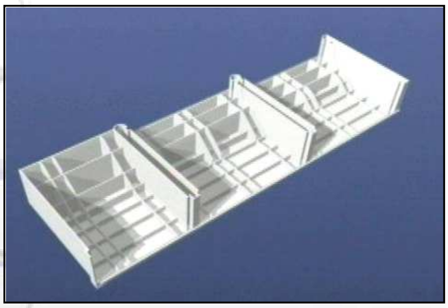


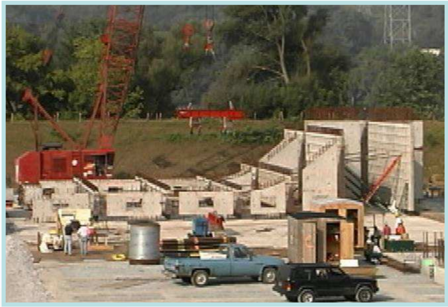
- Precast Dam Segment
- Tow the Dam segment to the site and Position it over Drilled Shafts
- Ballast down the segment and place underbase grout
- Place tremie concrete
- Dewater the dam segment and place concrete infill

WG29 - LOCK INNOVATIONS

WG29 - LOCK INNOVATIONS

Prefabrication and Outfitting





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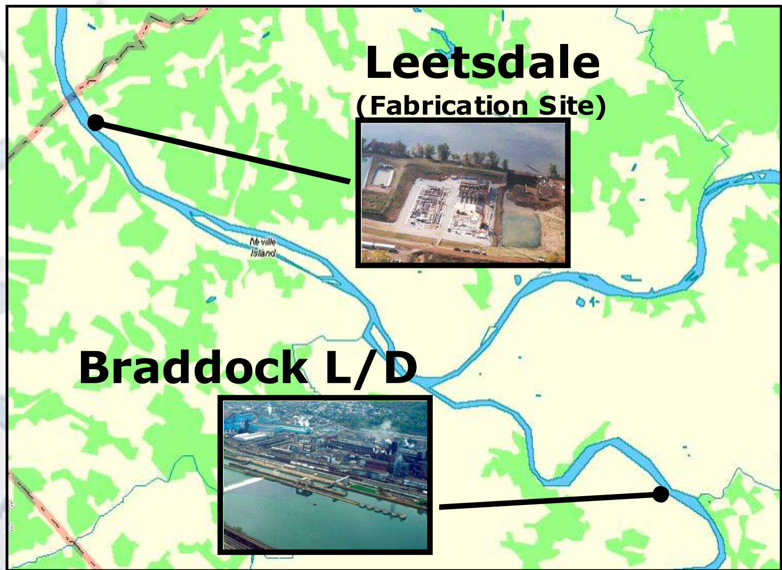
WG29 - LOCK INNOVATIONS



Towing the Segment
42 km from the fabrication
to the lock/dam site

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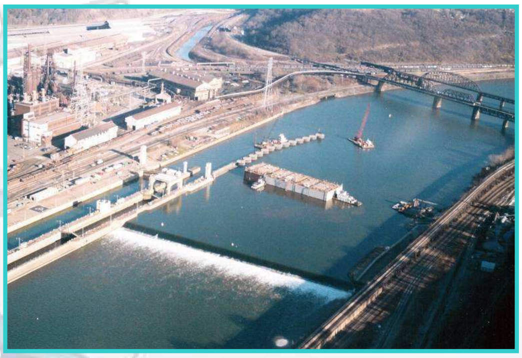
WG29 - LOCK INNOVATIONS

Installation of Segment 1 on June 18, 2002



Positioning the Segment

- Mooring Anchors and Winches
- Horn Guides
- Hydraulic Rams
- Flat Jacks on Top of Drilled Shafts Foundation

Set-down Operations

- Sequential Ballasting and De-ballasting
- Grouting of the Shear Pin Connection on Top of Drilled Shafts

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WG29 - LOCK INNOVATIONS

Underwater Grouting and Tremie Concrete Seal

Grouting the Foundation 2000 m3 Of Underbase Grout under Water

Placing 10,500 m3 Mass Tremie Concrete and 8,000 m3 Concrete Fill within the Float-in Segments

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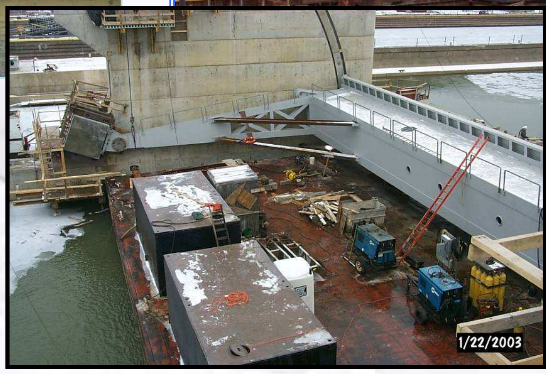
WG29 - LOCK INNOVATIONS

Pier Construction and Gate Installation



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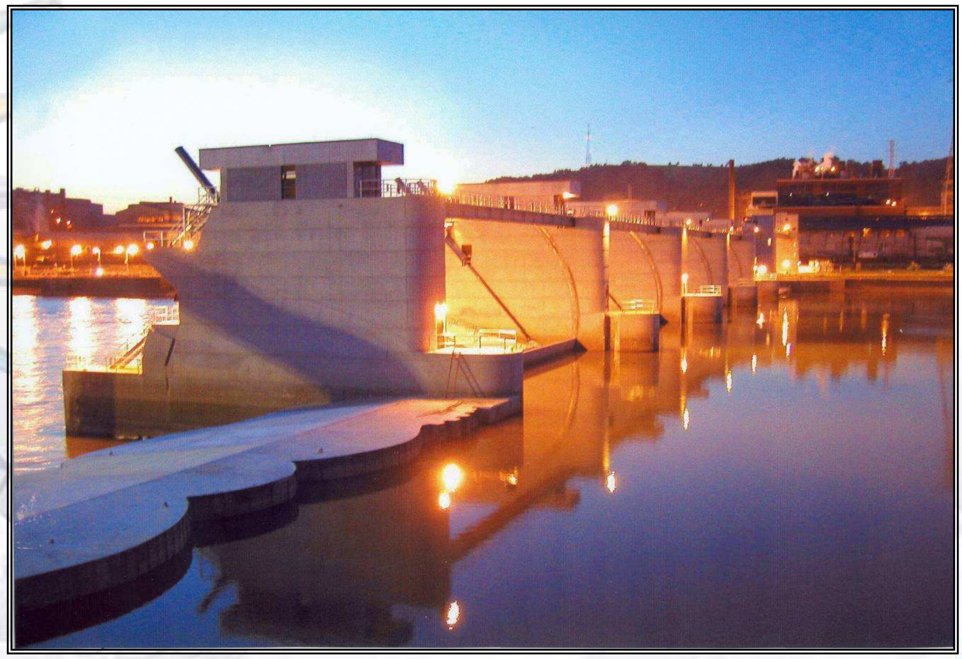
In-the-Wet Construction

Project Completion - August 2004



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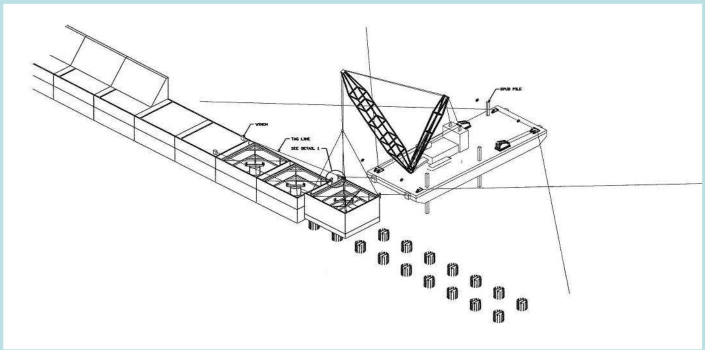
Lift-In Construction

Chickamauga (11-03)

Lock renovation and expansion using lift-in construction techniques to work with difficult geological conditions and to maintain operation during construction.

Areas of Innovation

Hydraulic	O & M	Environ	Design / Construct	Misc



Lock Dimensions

Length	183 m	Lift	14.8 m
Width	34 m	Depth	5.2 m

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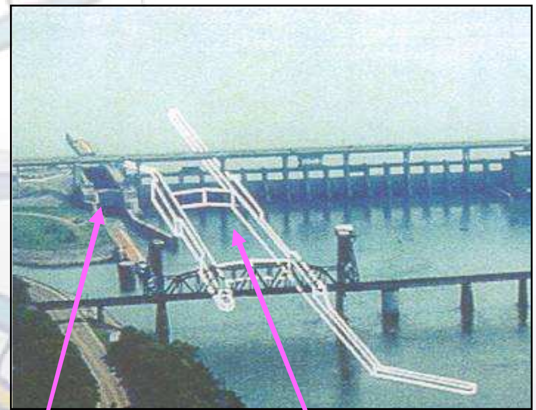
In-the-Wet Construction

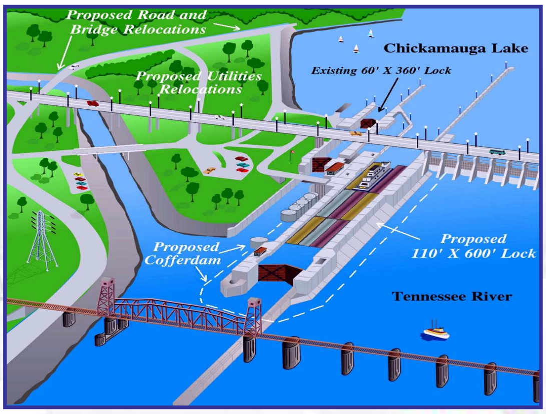
The Old and New Chickamauga Locks



Old Lock
(18m by 110m)

New Lock
(34m by 183m)

- The Old Lock is plagued with AAR and scheduled for demolition by 2014.
- The New Lock is Located downstream of the Chickamauga Dam Spillway and Adjacent to the old lock.



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In-the-Wet Construction

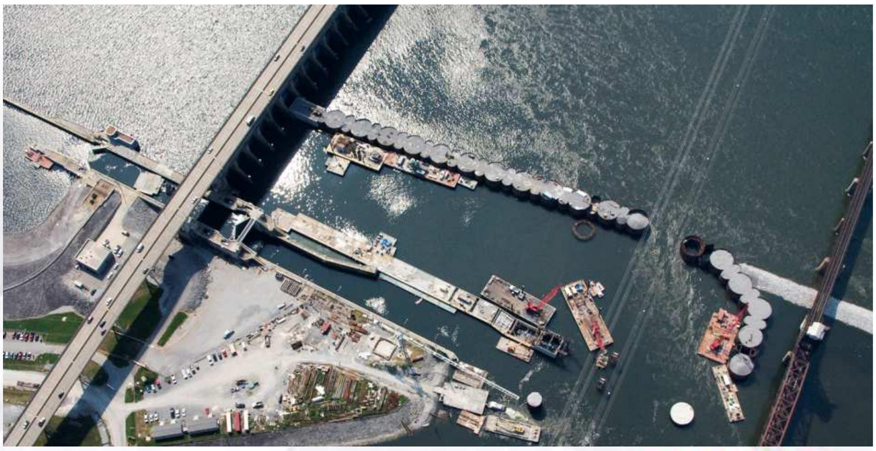
Project Challenges with Landward Cofferdam

- Maintain Navigation During Lock Construction
- Limited Width for Cofferdam – Stability of Cells
- Difficult Geologic Conditions

  Sloping Rock Formations

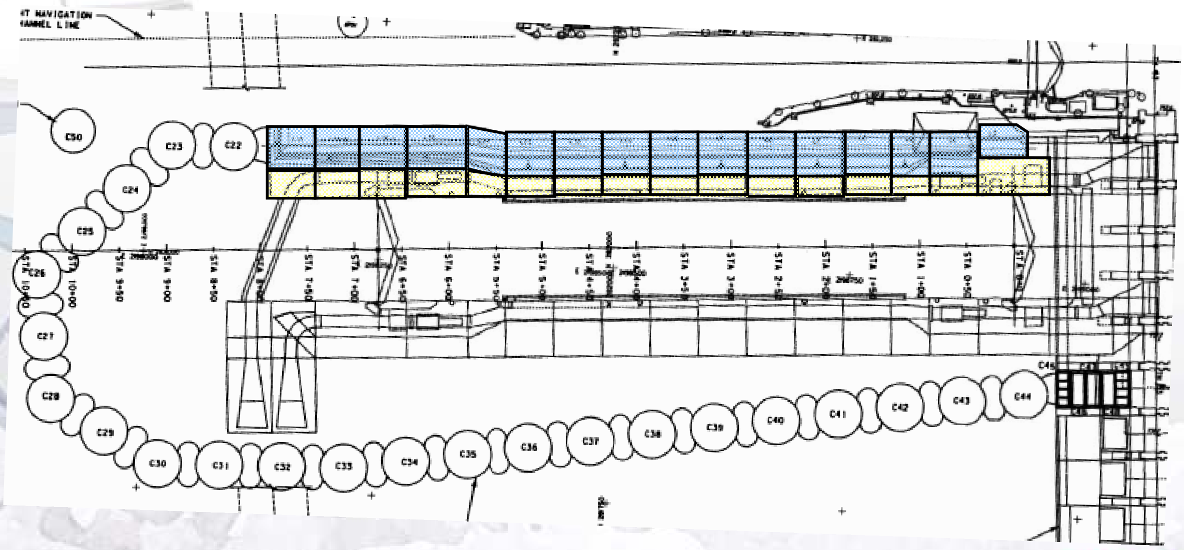
  Embedded Clay Seams

  Solution Cavities



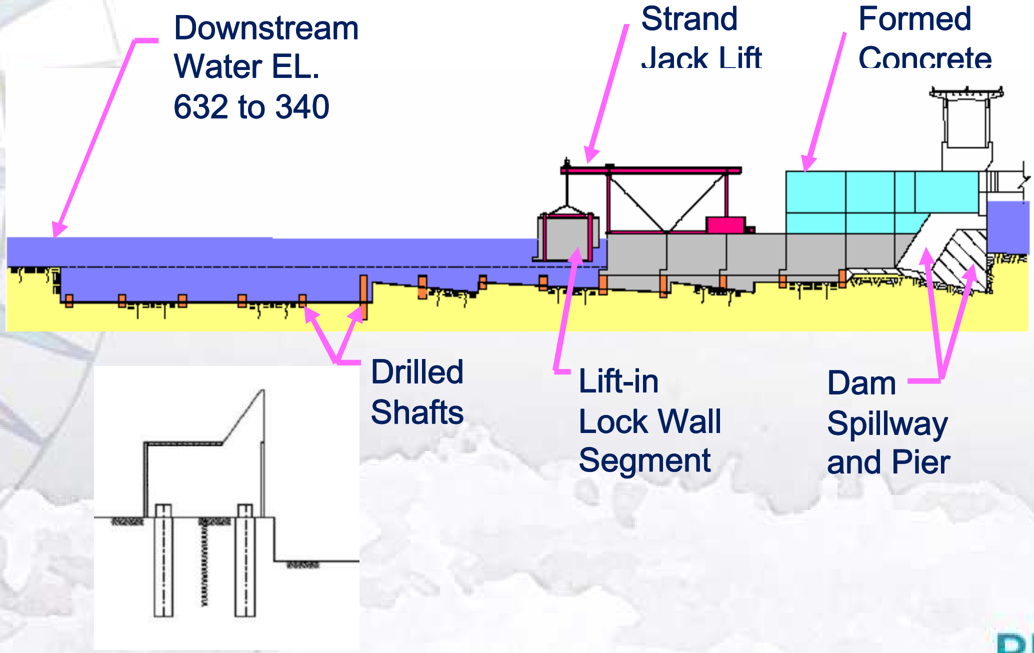
Innovative Lift-in Cofferdam Design

- **In-the-Wet Construction of the Segmental Cofferdam**
- **In-the-Dry Construction of the Integral Lock Wall**



In-the-Wet Construction

Lift-in Construction Sequence



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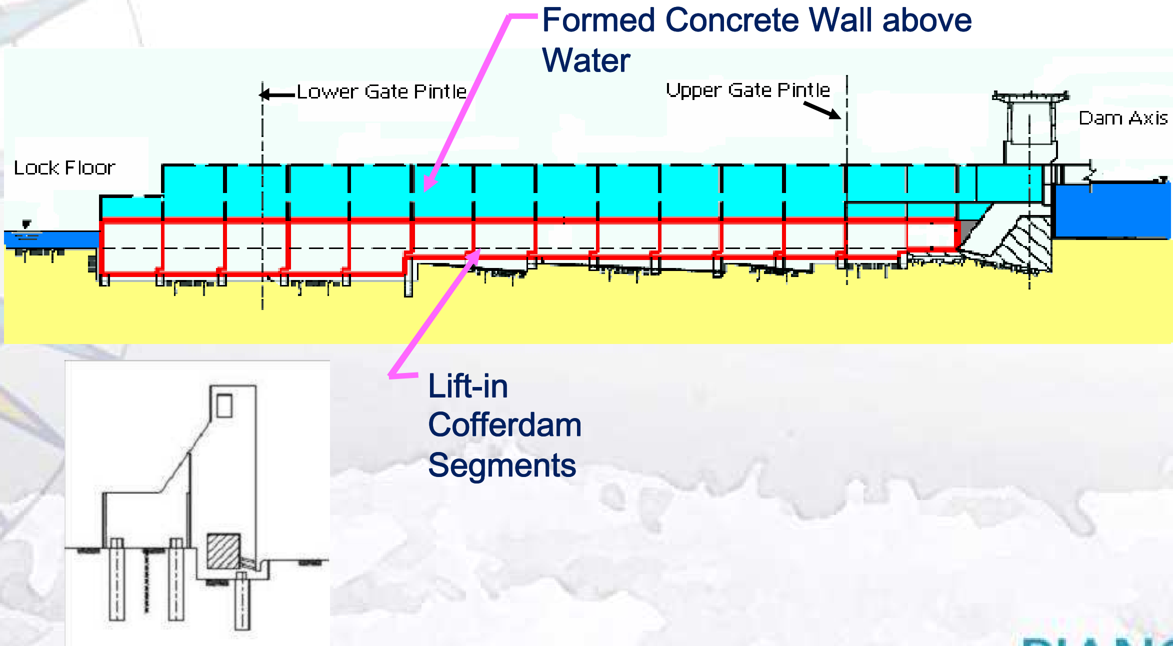
In-the-Wet Construction

Lift-in Construction Sequence



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In-the-Wet Construction

Advantages of the Segmental Lift-in Construction of Chickamauga Lock Cofferdam and Lock Wall

- Cofferdam stability with limited width and under Complex and Uncertain Geologic Conditions
- Navigation traffic during construction of the new lock
- No Landward Cofferdam Demolition
- Less Rock Excavation
- Little adverse environmental impact
- Cost Savings

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In-the-Wet Construction

Drilled Shaft Installation and Testing Under Water

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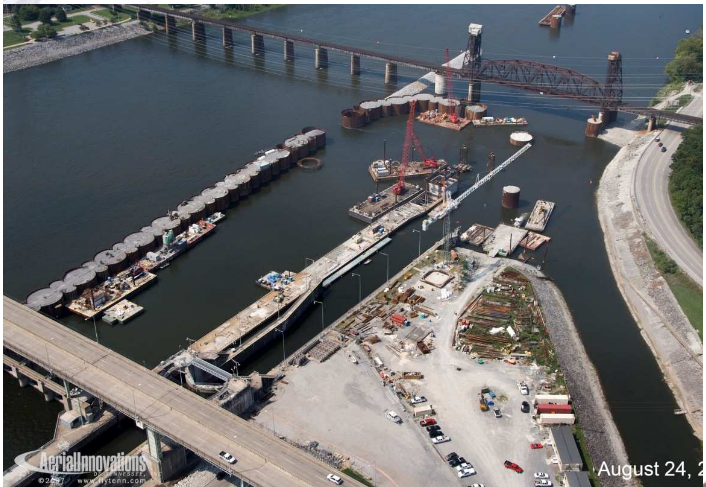
In-the-Wet Construction

Precast Lock
Segments on Barges

A typical Box Cofferdam Segment is 16-m by 14-m by 7-m in size

In-the-Wet Construction



Towing a Lift-in Cofferdam Box Segment to the Site

Positioning and Jacking the Box Segment

In-the-Wet Construction

Place Tremie Concrete Seal

Dewater The Box Cofferdam

In-the-Wet Construction

Placing Tremie Concrete Infill and Grouting the Foundation

Completion of the Cofferdam by 3/2010

In-the-Wet Construction

Comparison with Conventional Methods

- Many engineering solutions for the innovative in-the-wet construction have to be identified, evaluated, and carefully developed from concepts to details.
- In some cases, it is advantageous to combine the conventional method and the innovative In-the-Wet method in the same project and take advantage of both methods to deal with the risks and complexity in various parts of the project.

In-the-Wet Construction

Conclusions

- The in-the-wet construction method, in many cases, has demonstrated significant advantages over the conventional cofferdam method.
- The float-in construction is preferred when the environmental/river conditions are not restrictive
- The float-in is preferred when the casting/launching systems are available and economical, and structural size/configuration are favorable.

Conclusions (Cont.)

- The lift-in construction is preferred when lift equipment is available to install a large number of prefabricated modules
- The lift-in is preferred where environmental and river conditions impose severe restrictions on the float-in construction.
- The in-the-wet method may be combined with the conventional method to take advantage of both methods to deal with the risks and complexity in a project.

Ir. Philippe Rigo
University of Liège – ANAST, Belgium
Ir. Thomas Gernay
University of Liège, Belgium

Paper 9, Parts A & B
LOCK GATES
INNOVATIVE CONCEPTS
- SHIP IMPACTS

International Workshop, PIANC - Brussels, 15-17 Oct. 2009

PIANC - InCom Work Group 29

Lock Gate and Ship Impact

- Report n°106, 2009 -

Prof. Philippe Rigo
Chairman WG29

T. Gernay, V.Herbillon, A. Thiry

University of Liege, Belgium

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Lock Gate and Ship Impact

Part A: LOCK GATES – INNOVATIVE CONCEPTS

Ph. Rigo, V.Herbillon, A. Thiry (ANAST)

Part B: SHIP IMPACT

T. Gernay (FNRS)

University of Liege, Belgium

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LOCK GATES – INNOVATIVE CONCEPTS

1. - LOAD AND STRENGTH ASSESSMENT

Load and strength are linked when structural engineers design lock gates and valves, first at the early design stage (to assess weight and cost) and later at the final design stage (construction drawings).

Nowadays most difficult issues issues concern :

➔ Seismic effect on lock gate

- additional loads (external and internal)
- behavior during gate motion
-

➔ Ship collision on lock gates

The challenge for the next years is to identify relevant and cost/effective specifications and requirements.

LOCK GATES – INNOVATIVE CONCEPTS

2. - MECHANİCAL PARTS: SEALS, BEARİNGS, HYDRAULİC CYLİNDERS, OPERATİNG EQUİPMENT

The main points about the mechanical parts (see Table 1 in Report):

- The key points to consider during the design of mechanical parts is the Gate Operation.
- Operating machinery is critical locks equipment because this equipment is subjected to intensive operation.
- Lock availability depend mainly on the machinery performance and reliability.

LOCK GATES – INNOVATIVE CONCEPTS

2. - MECHANİCAL PARTS: SEALS, BEARİNGS, HYDRAULİC CYLİNDERS, OPERATİNG EQUİPMENT

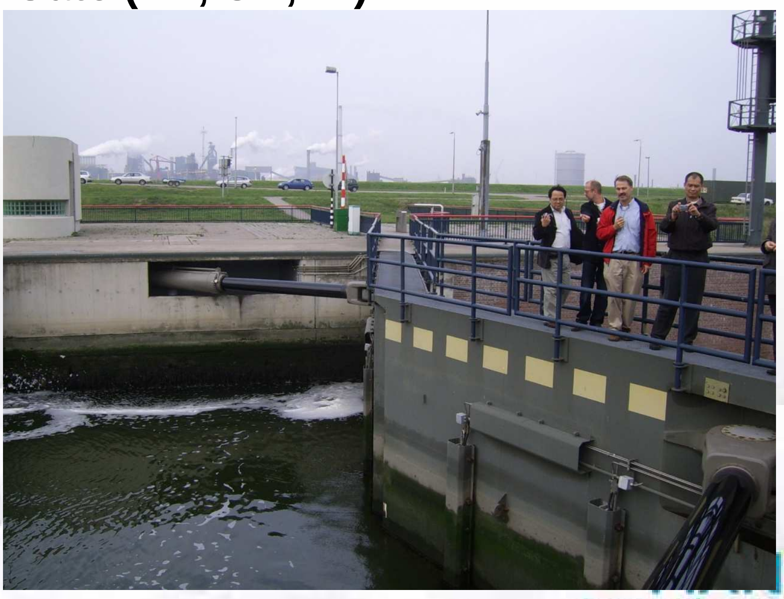
Electromechanical actuators, using a capsulated threaded pin (Germany)

Mitre gate at Uelzen II

3- NEW INNOVATIVE GATE CONCEPTS

a- Folded Plate for gates (Germany) – see previous page

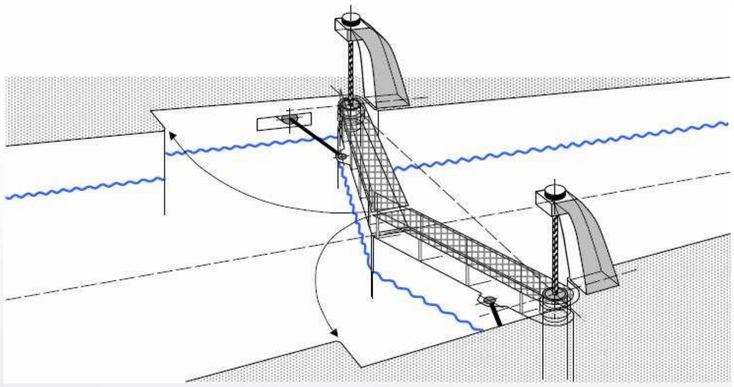
b- Reversed Mitre Gate (NL, UK, …)



Reverse Mitre Gate (IJmuiden-NL)

NEW INNOVATIVE GATE CONCEPTS

c- Suspended Mitre Gates (NL)



Suspended Mitre Gate

Mitre gates supported only at their top hinges

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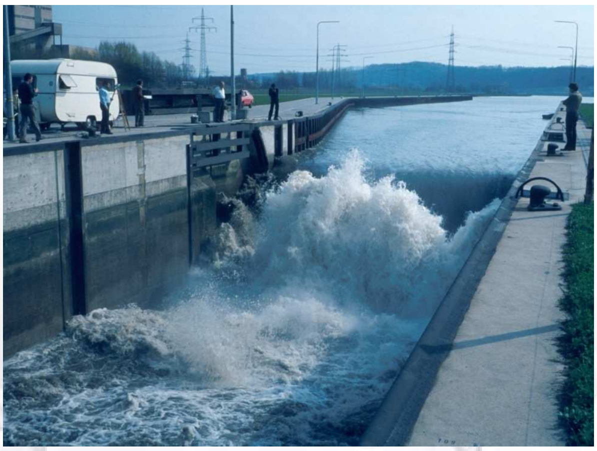
NEW INNOVATIVE GATE CONCEPTS

d- Rotary Segment Lock Gate (horizontal axis) - Germany



Lisdorf Lock – Flood discharge through the lock

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NEW INNOVATIVE GATE CONCEPTS

e- ***Vertical-axis Sector Gates***
(Germany, Finland, Japan, …)

NEW INNOVATIVE GATE CONCEPTS

f) COMPOSITE LOCK GATES

CETMEF (France) ➔ vertical lift arch gate with composite materials.

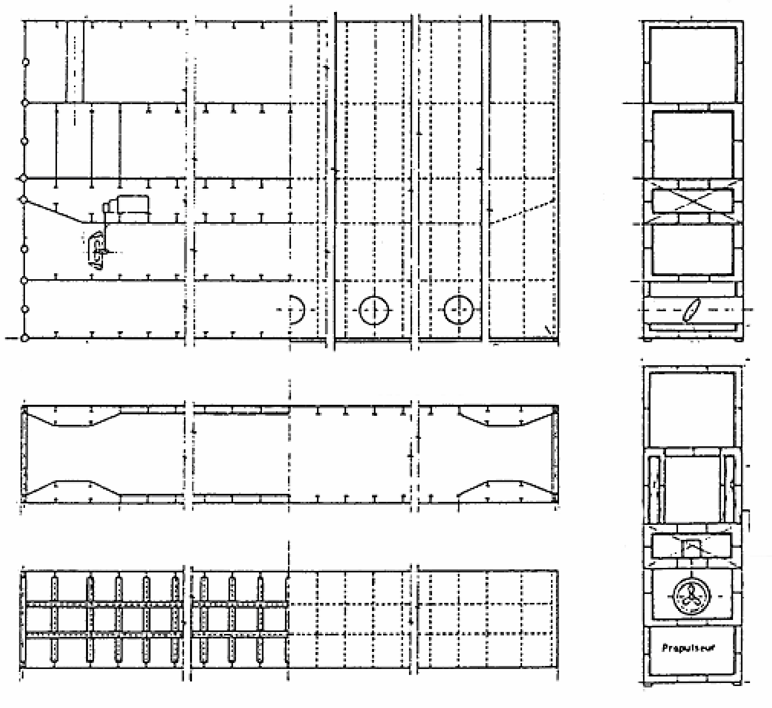
RWS - the "Spieringsluis" ➔ high strength synthetic composite material to reduce the higher maintenance costs of wooden or steel gates.

<u>Main advantages of composite arch gates are:</u>

- **No corrosion;**
- **Good resistance to aging in damp environment;**
- **Finishing paint useless, ➔ reducing maintenance costs;**
- **Lightness, easing transportation and fitting of the gate;**
- **Lightness reducing purchasing and maintenance of machinery;**

NEW INNOVATIVE GATE CONCEPTS

g) Self-propelled floating lock gates

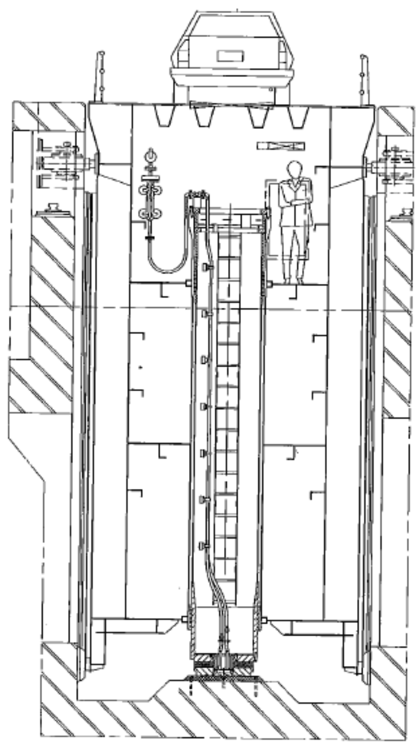


Maritime locks
➔ Cost savings

ANAST -ULG

NEW INNOVATIVE GATE CONCEPTS

h- Sliding gate – Hydrojet (NL)

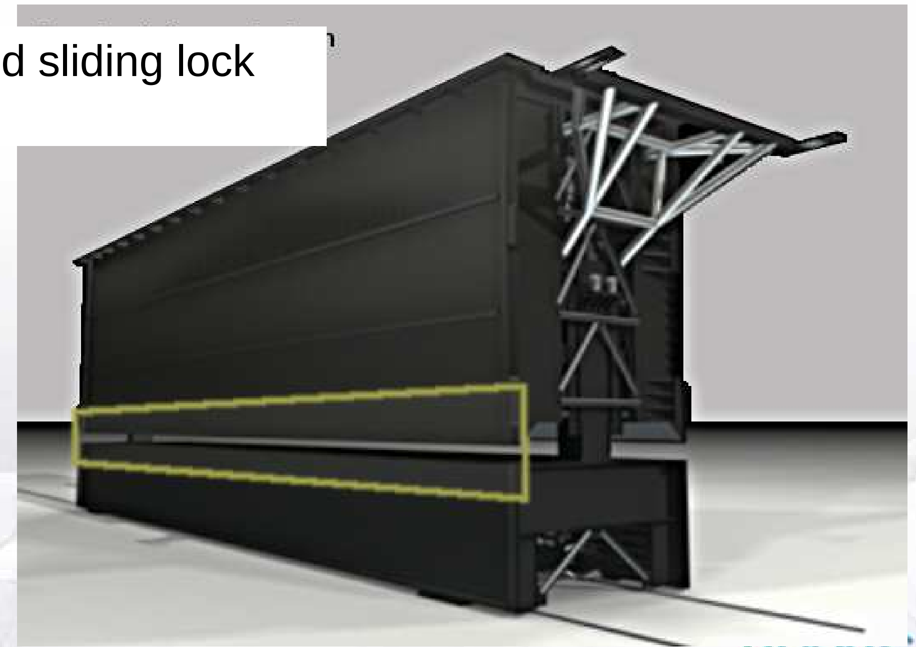


Hydrojet
Oranje lock (NL)

NEW INNOVATIVE GATE CONCEPTS

i) Rolling gates with integrated filling/emptying system

Kaiser lifting and sliding lock gate



LOCK GATES – INNOVATIVE CONCEPTS

4. – GATE TIGHTNESS, LININGS and SEALS

➔ *The "come back" of sliding gates/valves*

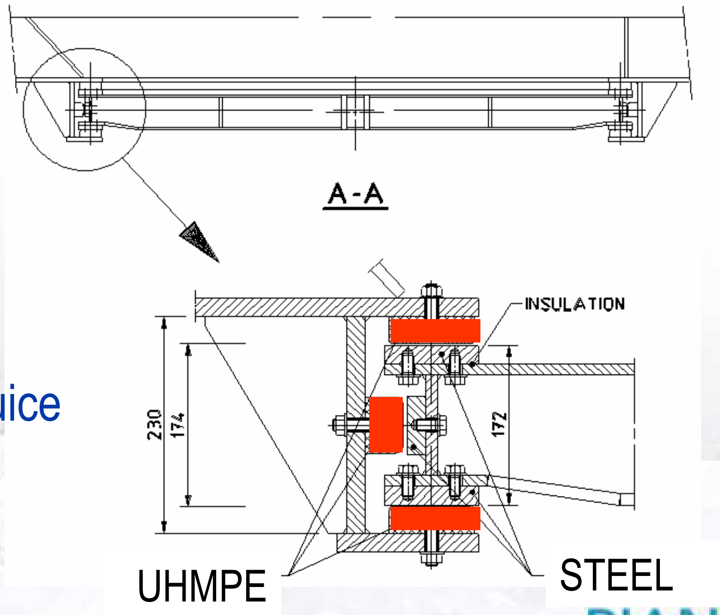
In the Netherland, Germany, Panama, etc.

UHMPE (ultra-high molecular weight polyethylene) is nowadays considered a reliable teachnology and a very durable material to be used for sliding gate and lock filling and emptying valves.

LOCK GATES – INNOVATIVE CONCEPTS

5. – VALVES for FILLING/EMPTYING SYSTEM

Use of UHMPE



UHMPE sliding Gate sluice (Naviduct, NL)

LOCK GATES – INNOVATIVE CONCEPTS

5. – VALVES for FILLING/EMPTYING SYSTEM

➔ USE of UHMPE (ultra-high molecular weight polyethylene)

Sliding lift gate with UHMPE is based on a high mechanical performance sliding material with a low friction coefficient.

The material provides both guiding and sealing functions.

UHMWPE has the following characteristics:

- **low friction coefficient (< 0.2);**
- **low wear index (wear < 4 mm in 35 years – working life);**
- **maximum stress (6 N/mm²)**

UHMPE is nearly a standard solution for such contacts in the modern Dutch vertical lift gate sluices e.g. see as the valves of the Naviduct Enkhuizen (NL)

LOCK GATES – INNOVATIVE CONCEPTS

6. – CORROSION : PREVENTION and PROTECTION

a) In the last decade, costs associated with maintenance of infrastructure have increased dramatically due to the development of more stringent environmental regulations.

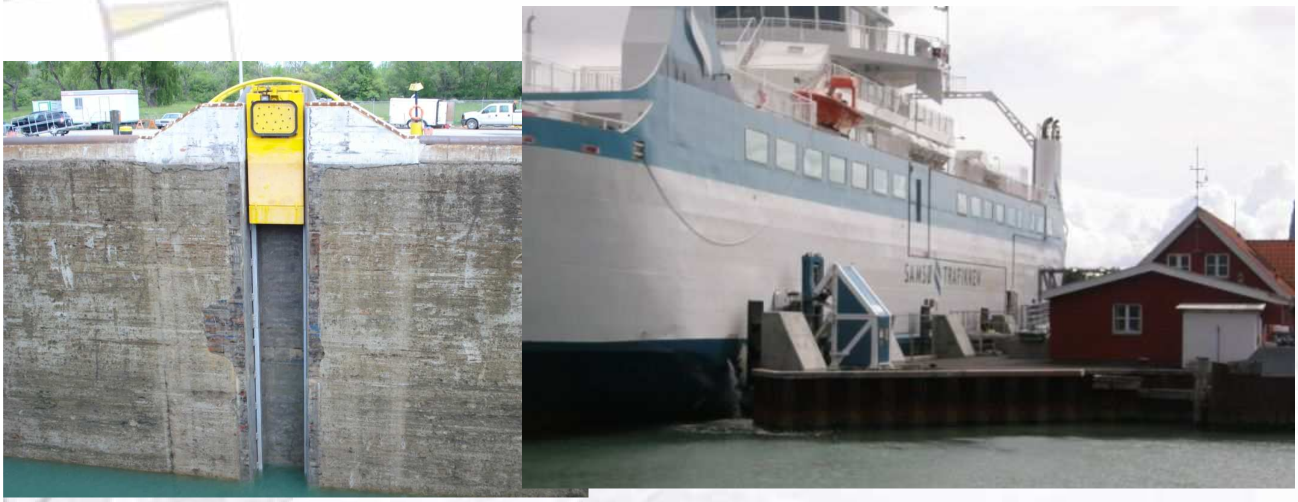
b) Durability and economic maintainability are both directly proportional to corrosion preventive measures taken.

c) Corrosion prevention of metal, which should be considered at the design stage, must not be confused with corrosion protection, which is regarded as an other item to consider but at the building stage.

LOCK GATES – INNOVATIVE CONCEPTS

7. – GATE EQUIPEMENT

Magnetic automatic innovative mooring systems



Magnetic Mooring System at KaiserLock (*Cavotec Ltd*)

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PIANC InCom – Work Group 29

Part b: Ship Impact

- Report n°106, 2009 -

Thomas Gernay
Aspirant du F.R.S.-FNRS

University of Liege, Belgium

Plan

1. **Introduction**
2. **Ship impact analysis: state of art**
   a) Empirical approach
   b) Analytical-Rational approach
   c) FEM, quasi-static analysis
   d) FEM, dynamic analysis
3. **One example: “Seine-Escaut Est”**
4. **Conclusion**

Introduction

New project: recommendations?

1. **Define a "vessel impact" design criterion (ship weight and speed)**
   Panama canal:
   - 160,000 t
   - 0.5 m/s
   - With no loss of water tightness and the global resistance
     => consistent with the project

2. **Protective measures VS gate designed to sustain ship impact**

WG29 – LOCK GATE AND SHIP IMPACT

Introduction

3. **Gate = ship stopping device**
   Structure must combine sufficient <u>flexibility</u> with sufficient <u>load bearing capacity</u> to successfully <u>absorb the kinetic energy</u>

Analysis to perform to design the gate structure?

a) Empirical approach
b) Analytical-Rational approach
c) FEM, quasi-static analysis
d) FEM, dynamic analysis

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State of art: empirical approach

- Methods based on empirical data and practice experience
- Very simple way to evaluate an order of magnitude
- Use it as a rule of thumb

→ more detailed analysis must be performed

State of art: analytical approach

Analytical models (Le Sourne)

Hypothesis – Approximations:

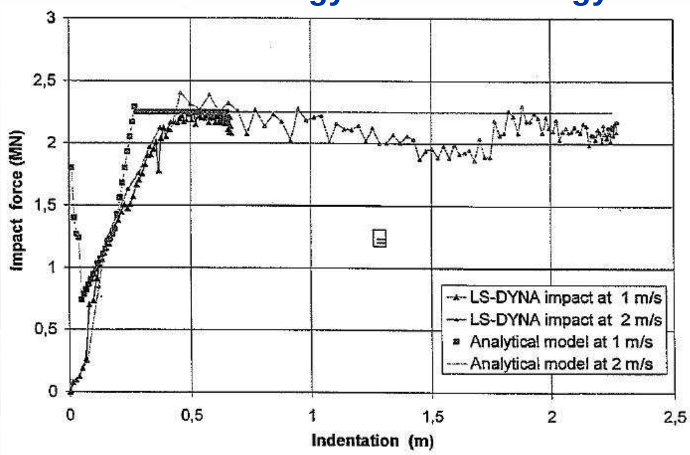
- Analytical model → simplifications
- Totality of the energy dissipated by the gate
- No change in the contact
- No dynamic effect (vibrations, ...)

Numerical studies have validated these assumptions for simple cases

State of art: analytical approach

The impact force – indentation relationship can be obtained

Kinetic energy ↔ Strain energy



Impact forces comparison (Le Sourne) – Dynamic analysis VS analytical model

WG29 – LOCK GATE AND SHIP IMPACT

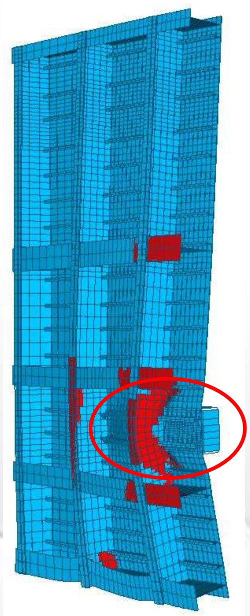
FEM, quasi-static analysis

Finite Elements Methods
Neglect the dynamic effects → quasi-static analysis

One possibility:
Simple model of the bow of the ship
→ ex: perfectly stiff rectangular element

No evolution of the contact
between the bow and the gate

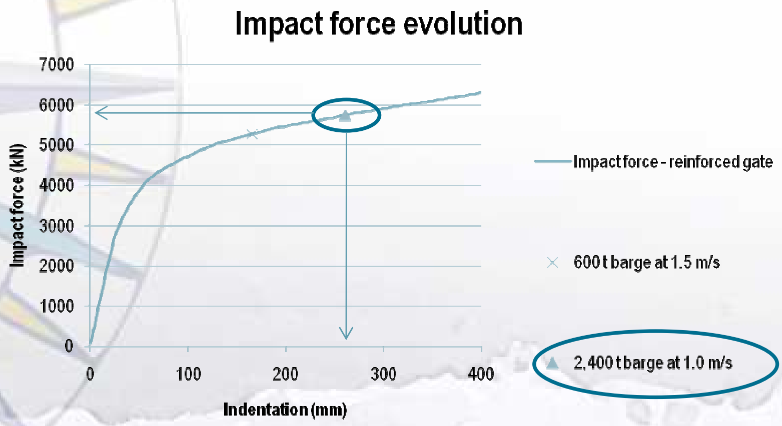
Load *Fimpact* on the bow increased
until equalization of the energies

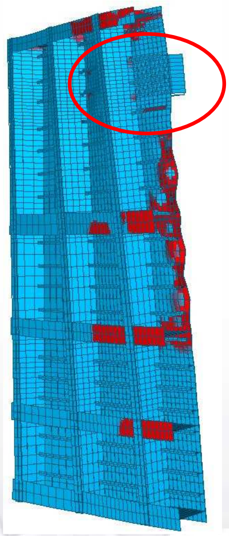


Lock gate simply supported on three sides

WG29 – LOCK GATE AND SHIP IMPACT

FEM, quasi-static analysis





⇒ *Indentation 26 cm and impact force 5,75 MN (energy: 1,20 MJ)*

WG29 – LOCK GATE AND SHIP IMPACT

FEM, dynamic analysis

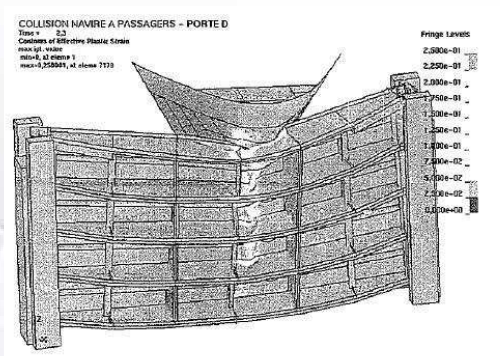
LS-DYNA

✓ **Possibility of modeling the deformable bow of the ship**

⇒ **Giving an initial position and speed, the contact can be considered**

✓ **Dynamic effects taken into account**

... But highly time-consuming



Passenger ship impact: effective plastic strains at t=2,3 sec.

Which analysis perform?

Empirical: gives an order of magnitude of the impact strength

Analytical: very effective and time-saver for gate structure with plane geometry but must be correctly applied (assumptions to validate)

FEM, quasi-static: gives good results when a dynamic analysis can't be performed

FEM, dynamic: accurate but time consuming. Using it for few cases can offer reference results to validate assumptions made in other methods

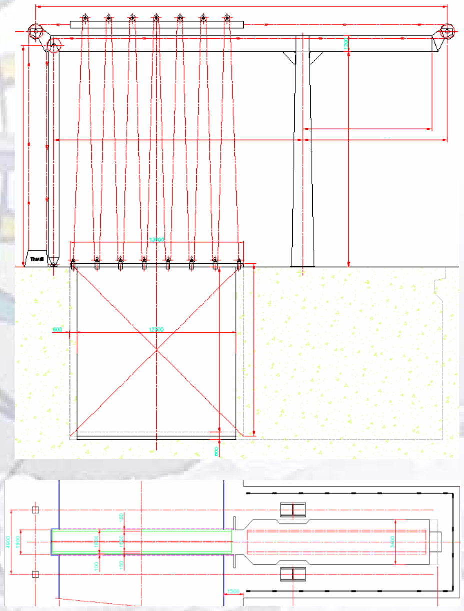
One example: "Seine-Escaut Est"

Lock gate designed for the "Seine-Escaut Est project" in Belgium

Downstream lock gates: length 13.7 m ; height 13.6 m
Gates suspended and manoeuvred by lateral movement

WG29 – LOCK GATE AND SHIP IMPACT

One example: "Seine-Escaut Est"



First, optimization of the structure considering hydrostatic load cases

→ Elastic design

Total weight: 51.4 t

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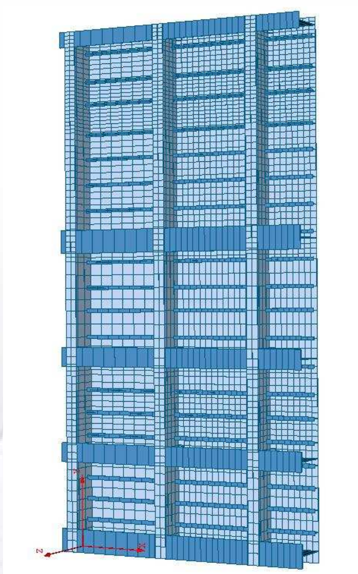
One example: "Seine-Escaut Est"

Then, analysis of the ship impact

It was decided to perform a FEM quasi-static analysis using the *FINELG* software



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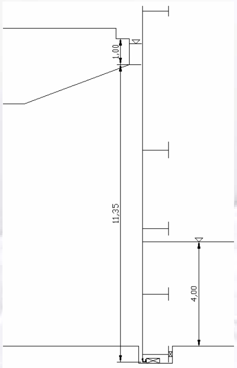
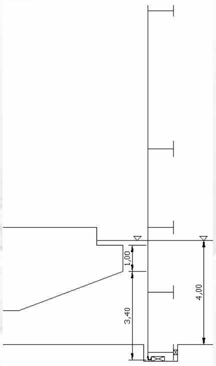
FEM, quasi-static analysis – example

Analysis of 3 scenarios

1. Upstream water level (U.W.L.) without any hydrostatic load
2. Upstream water level with hydrostatic service load (7.50 m)
3. Downstream water level (D.W.L.) without any hydrostatic load

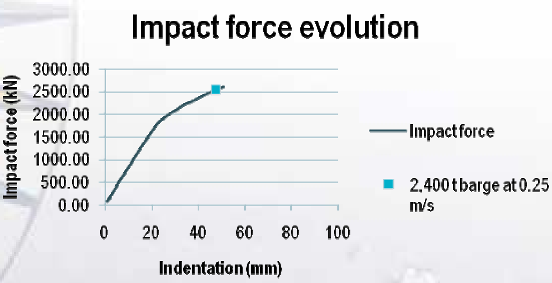


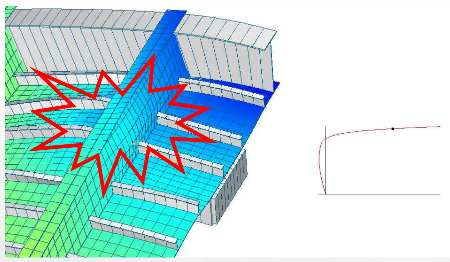


FEM, quasi-static analysis – example

U.W.L. with the initially optimized structure

Low thickness of the frames and girders (slenderness ratio: Hugues' criteria for T-elements)





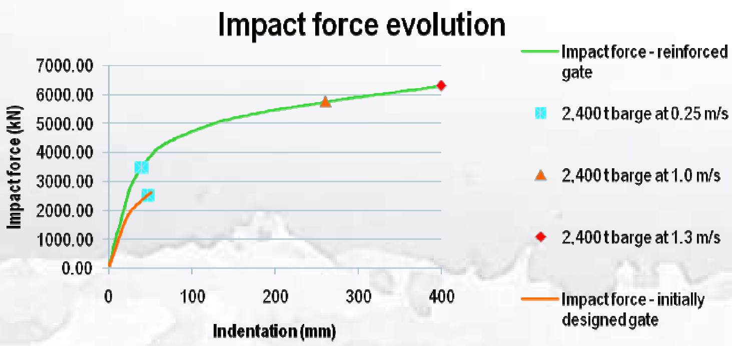
- ⇒ Buckling of the central frame
- ⇒ Fragile behavior – sudden collapse – low capacity for energy dissipation
- ⇒ Choice of reinforcing the structure

FEM, quasi-static analysis – example

Reinforcing the structure

Aim: avoid instability phenomenon – increase ductility

Dimensions of frames and girders increased (slenderness ratio: EN class 1)
Total weight: 51.4 t → 68.7 t (+34%)



⇒ By using class-1 sections for frames and girders, we improve the gate behaviour in case of ship impact

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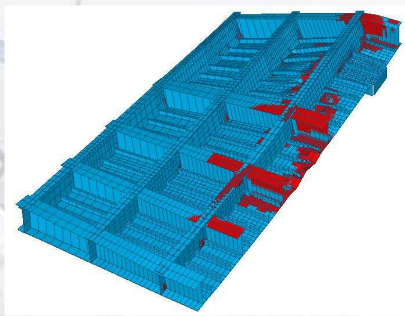
FEM, quasi-static analysis – example

Reinforced gate

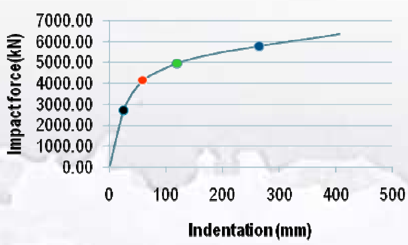
Ductile behaviour – very significant capacity for energy dissipation

Initially optimized structure: 0,08 MJ
Reinforced structure: 2 MJ (i.e. a 2,400 t barge at 1.3 m/s)

Global plastic failure mechanism



Yielding at the collapse stage (amplified x6)



Apparition of successive plastic hinges in the girders

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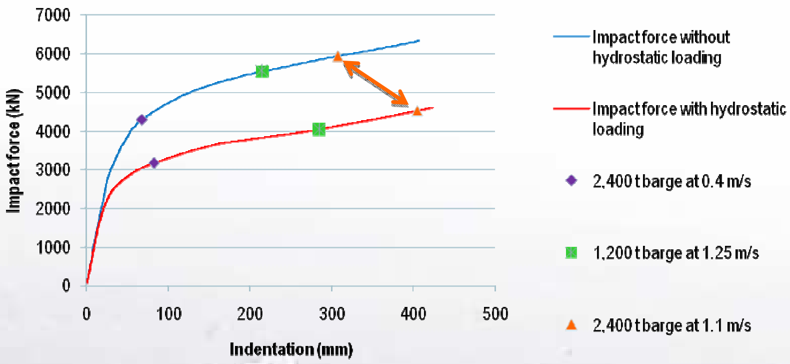
FEM, quasi-static analysis – example

U.W.L., taking into account the hydrostatic loads



The global behaviour of the gate is identical but the structure is more deformable because previously submitted to a stress field

⇒ **Neglecting the hydrostatic load leads to underestimate the deformation and the yielding of the structure – but overestimate the impact force**

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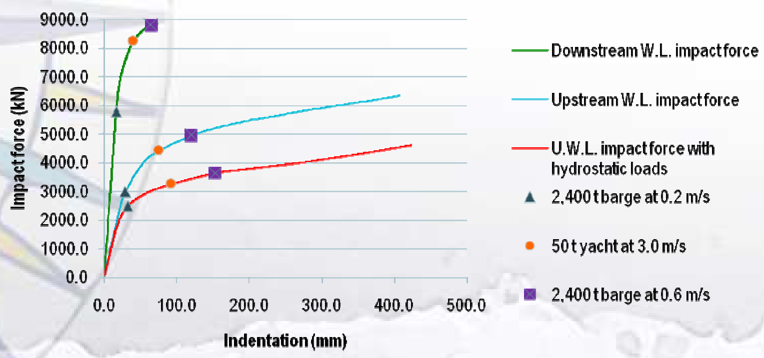
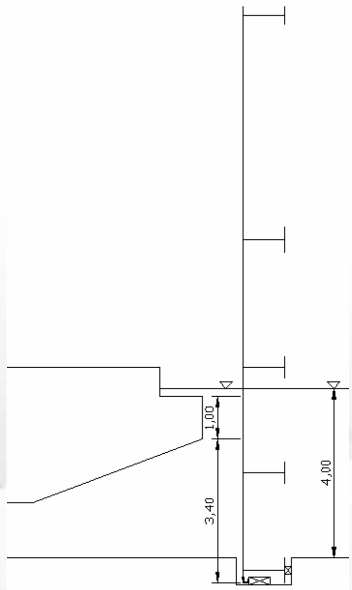
FEM, quasi-static analysis – example

Impact at downstream water level

Highly stiffened impact zone





⇒ **Very different behaviour of the gate (fragile) because of the impact zone**

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FEM, quasi-static analysis – example

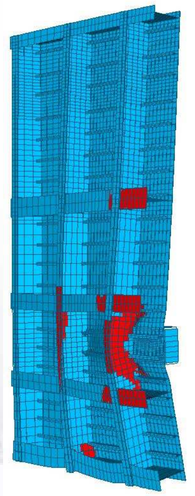
Strain concentration in the impact zone leads to a fragile, sudden collapse

Transverse stiffness << Longitudinal stiffness

⇒ **No propagation of yielding**

⇒ **No global plastic failure mechanism**

⇒ **Collapse for a small indentation and low energy dissipation (0,5 MJ)**



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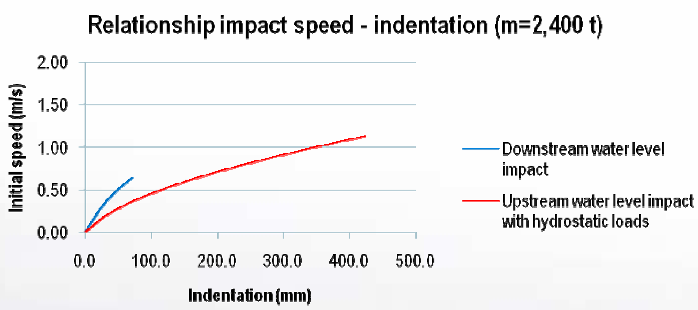
FEM, quasi-static analysis – example

Results



Impact of a 1,200 t barge at 0.8 m/s (384 kJ)	U.W.L. without hydrostatic loads	U.W.L. with hydrostatic loads	D.W.L.
Impact force	4,845 kN	3,550 kN	8,706 kN
Indentation (only due to the impact)	11.1 cm	13.9 cm	5.9 cm
Number of plastic hinges in frames and girders	2 girders	3 girders	1 frame

FEM, quasi-static analysis – example

Conclusion:

1. Aim: to design a gate able to resist the ship impact by itself
2. To dissipate energy, it needs ductility (avoid instability)
3. Ductility of the elements can be achieved by using EN class-1 cross sections (increasing dimensions of frames and girders)
4. Ductility of the gate requires a good propagation of yielding, which can be achieved by a good design of the stiffness ratios in the potential impact zones

FEM, quasi-static analysis – example

- Lock gates: elastic design considering hydrostatic loading
- Impact analysis: increase the dimensions of the frames and girders
- Recommendation: new constraint in the optimization software to obtain optimized solutions considering impact strength
- Then, comparison (cost): reinforced solution VS elastic optimum solution coupled with protective measures against ship impact

PIANC InCom – Work Group 29

Thank you

Prof. Philippe Rigo , Chairman WG29
V Herbillon , A Thiry (ANAST)

Thomas Gernay
Aspirant du F.R.S.-FNRS

University of Liege, Belgium

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Ir. Carsten Thorenz
BAW; Federal Waterways Research Institute, Germany

Paper 10
COMPUTATIONAL FLUID DYNAMICS – STATE OF THE ART

Computational Fluid Dynamics
- State of the art -

Dr.-Ing. Carsten Thorenz
Federal Waterways Research Institute (BAW)

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Coloured Fluid Dynamics
- State that it is art ?-

Dr.-Ing. Carsten Thorenz
Federal Waterways Research Institute (BAW)

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Classification of numerical models

- 1D-models: networks of filling and emptying systems (full lock cycles, mass balance computations)
- 2D-models, depth averaged: Inlet-outlet areas, maybe chamber sloshing (lock cycles)
- 3D-models with single fluid phase: Special parts of the filling-emptying system
- **3D-models with multiple fluid phases: Flow in chamber, water saving basins, inlet-outlet areas**

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One dimensional models

- Momentum equation solved for only a single direction at each regarded point
- Geometry is reduced to "linear" objects
- Averaging over cross sections
- Heavily based on the knowledge of characteristic parameters (loss coefficients)
- Applicability can be doubted if pipe length between objects is too small

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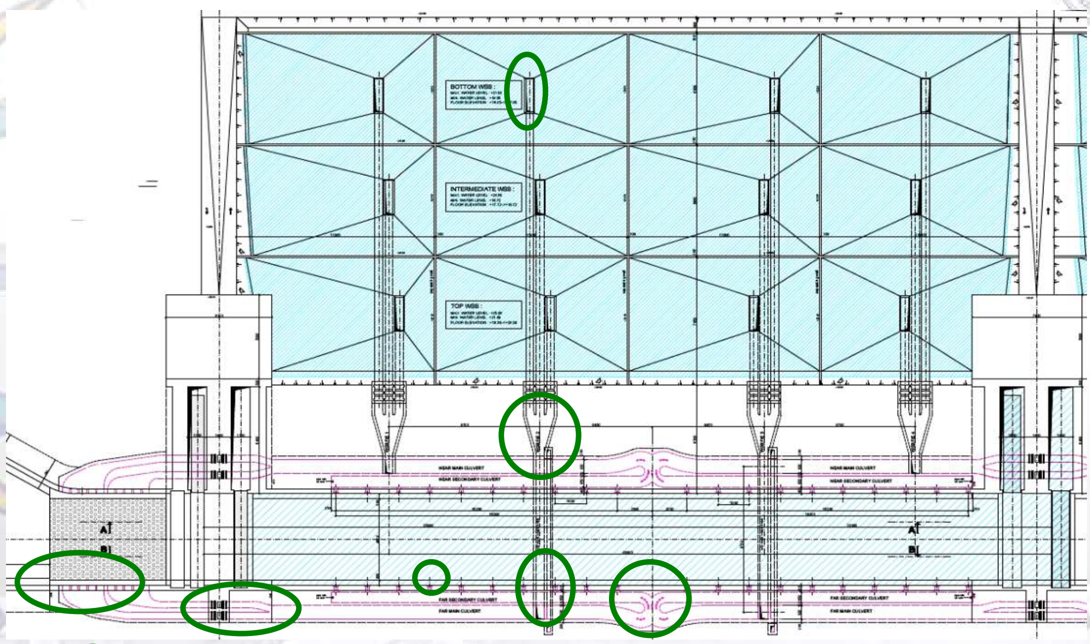
Example: Panama Canal Locks (by ACP)



Hydraulic loss coefficient must be calculated/measured

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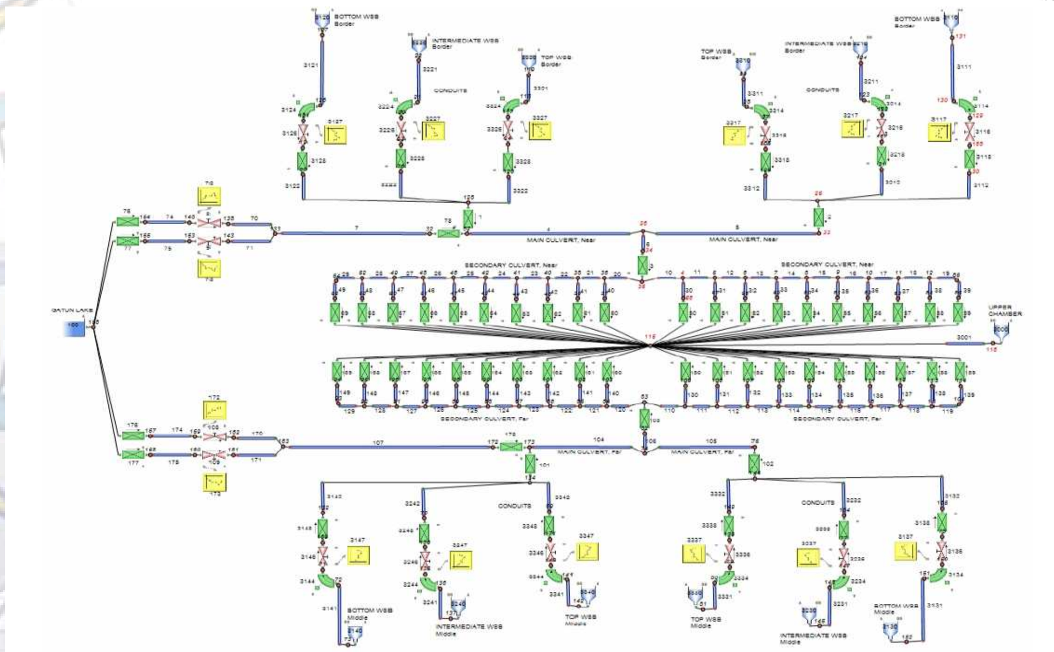
Example: Panama Canal Locks



Network model of the lock

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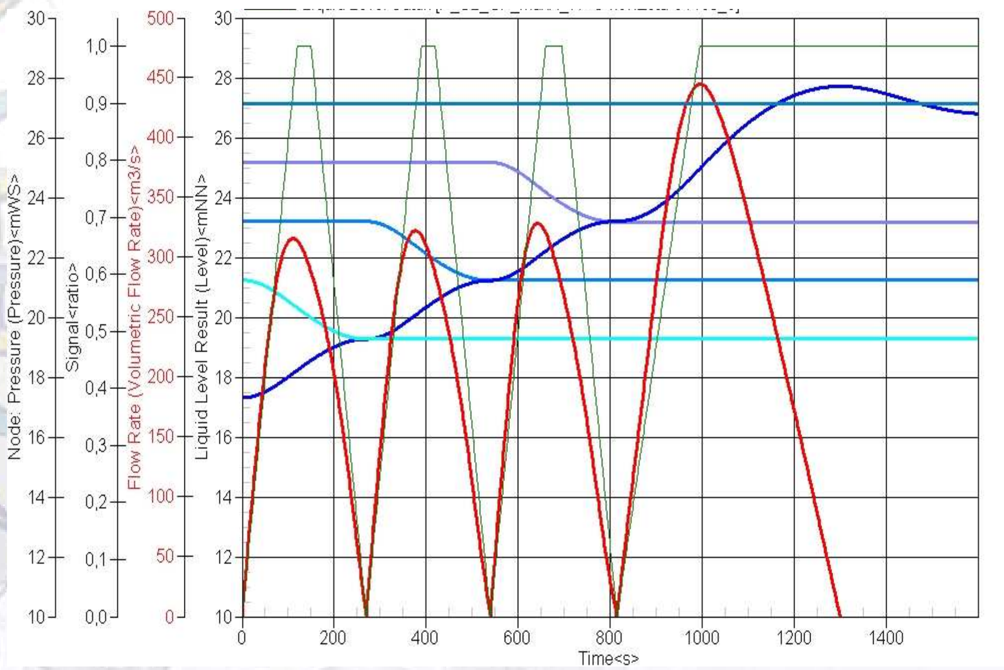
Example: Network model results



Resulting plot with valve schedules (green), flowrate (red), waterlevels (blue)

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One dimensional models

- Can reproduce the large scale dynamics of a filling/emptying system
- Easy to simulate large number of variants
- Parameters have to be evaluated very, very carefully!

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Two dimensional models

- Momentum equations solved for two directions
- Depth averaged (“Shallow water equations”)
- Detailed information in the horizontal plane
- Geometry is no longer completely “parameterized” but part of the model

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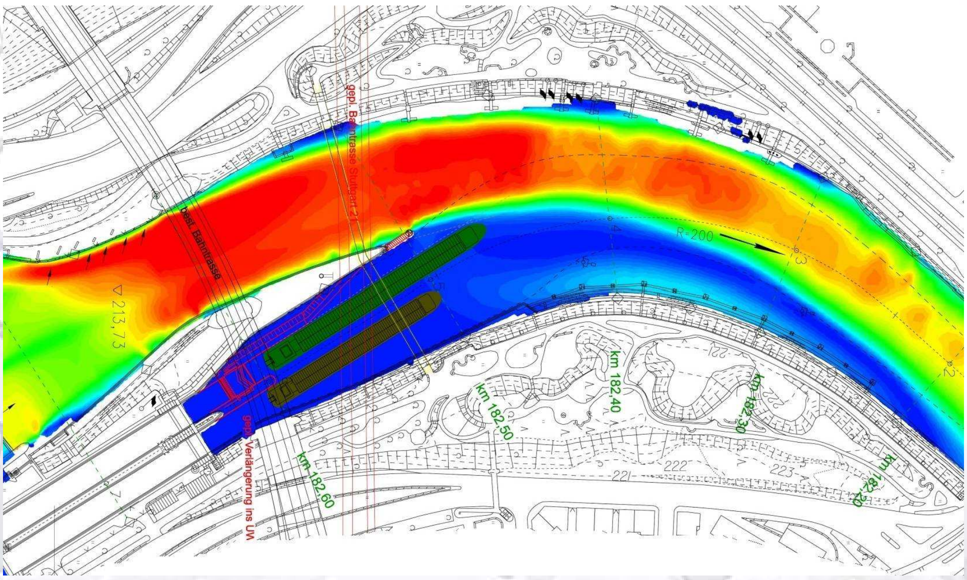
Two dimensional models



Large scale flow modelling
downstream of a weir

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Two dimensional models

- Only applicable if vertical fluid acceleration is negligible
- Gives good results for approach areas, rivers and canals
- Sometimes applied for simulating sloshing in the lock chamber
- Much more “fluid physics” are computed by the numerics, less dependent on parameters

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Three dimensional models

- Detailed reproduction of the geometry, which has to be discretized
- Impact of geometry on the flow is no longer parameterized, solution of 3D momentum equations
- Without free water surface: Culverts, bends, …
- With free water surface: Chamber, water saving basins, inlets, outlets
- With moving objects: Valves, ship in chamber

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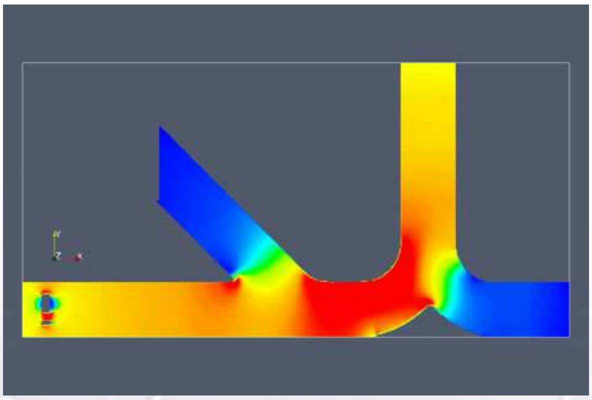
Possible lock modeling strategy

- 3D-CFD model (or hydraulic model) for local loss coefficients



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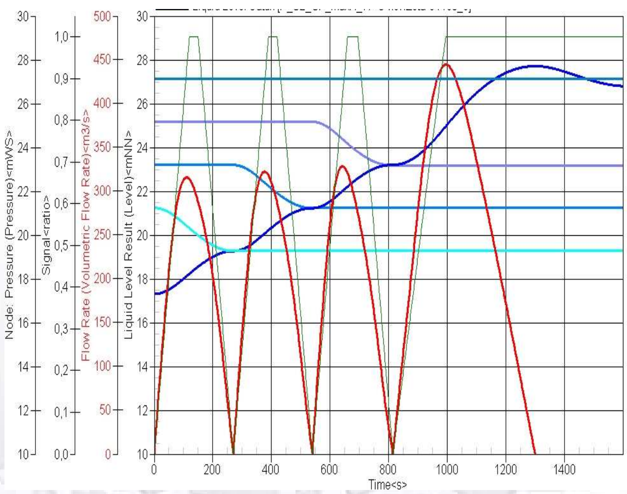
Possible lock modeling strategy

- 3D-CFD model (or hydraulic model) for local loss coefficients
- 1D-network model for the lock complex



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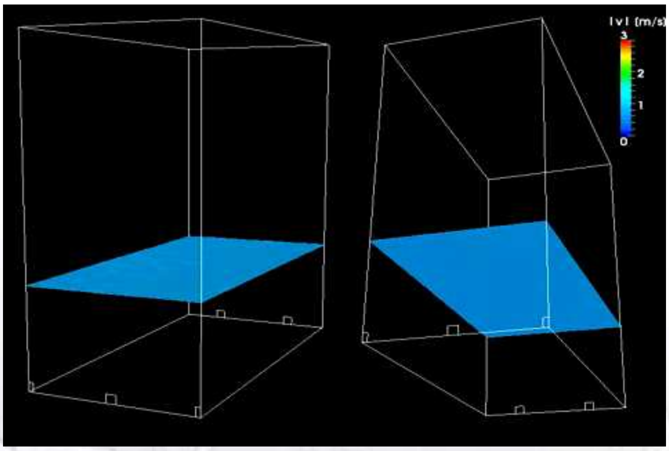
Possible lock modeling strategy

- 3D-CFD model (or hydraulic model) for local loss coefficients
- 1D-network model for the lock complex
- 3D-CFD model (or hydraulic model) for flow in inlet/outlet, chamber, …



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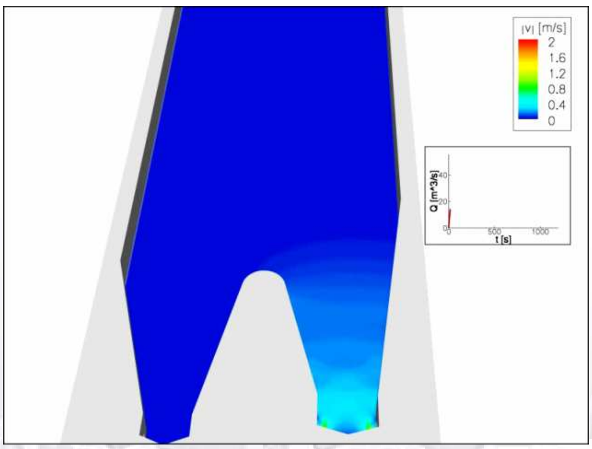
Possible lock modeling strategy

- 3D-CFD model (or hydraulic model) for local loss coefficients
- 1D-network model for the lock complex
- 3D-CFD model (or hydraulic model) for flow in inlet/outlet, chamber, …
- 2D-CFD model (or 3D-CFD or hydraulic model) for flow in approach areas, adjacent rivers or canals



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Strategies for code development

➨ **In-house developments**

Accumulation of knowledge
Requires highly skilled experts
Typical for universities

➨ **Cooperational development with partners**

Possibility to steer developments
Larger base of developers / users
Typical for research institutions

➨ **Externally developed codes**

„Take it or leave it“

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Troubles with 3D models

- Choice of turbulence model is difficult
- Impact of grid resolution is not negligible
- Different scales can be problematic
- Moving parts are difficult to handle for complex geometries

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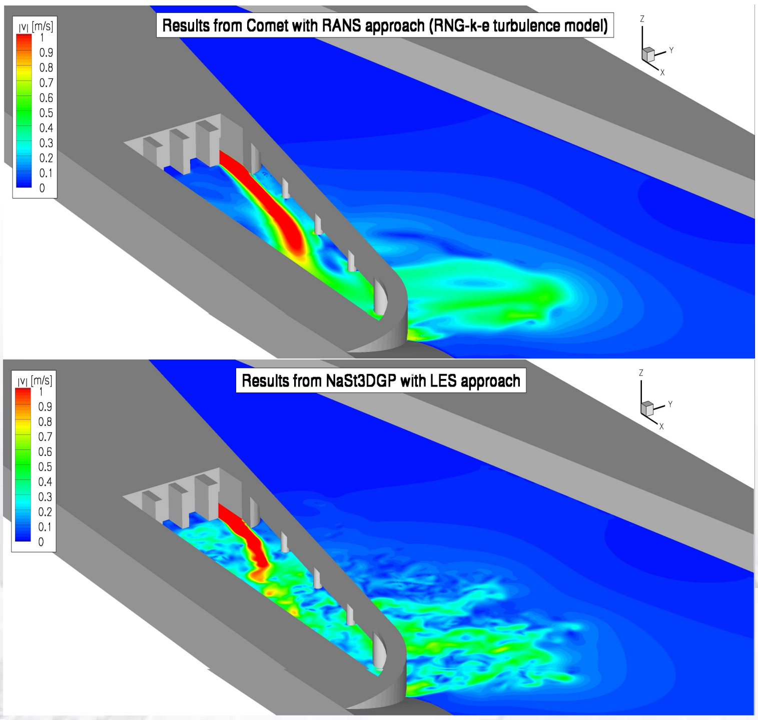
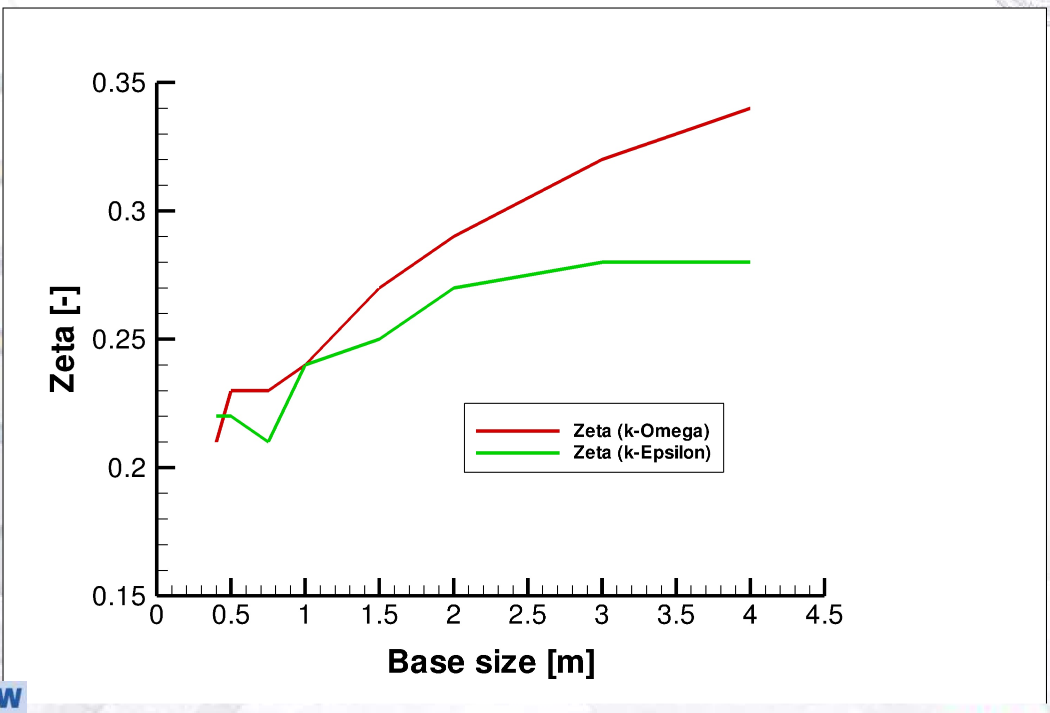
Turbulence modeling

- Detailed reproduction of microscopic fluid movement is not possible
- Real energy dissipation process (large eddies >> small eddies >> heat) can not be modelled
- Replacement for the missing dissipation: Turbulence models add artificial viscosity
- Which turbulence model to choose?

Turbulence model: RANS or LES?



Necessary grid resolution



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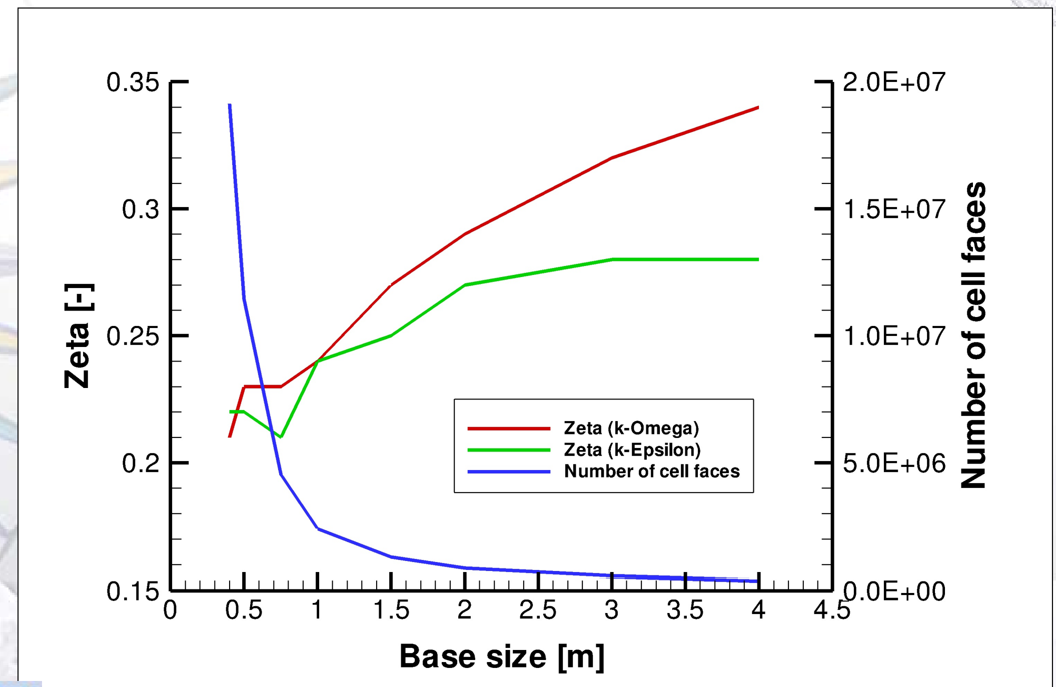
Necessary grid resolution



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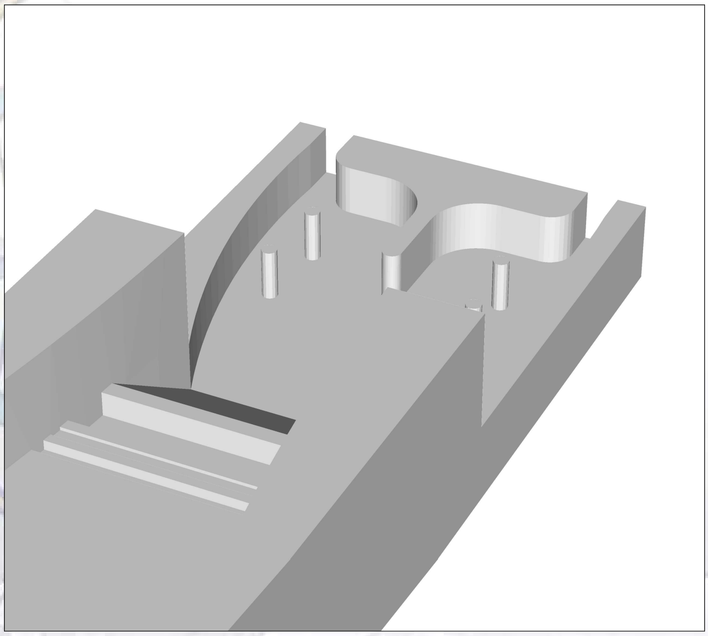
Example for scale problems …



Proposed inlet configuration for new lock

- ***Complex shape***
- ***Based on laboratory studies for other locks***

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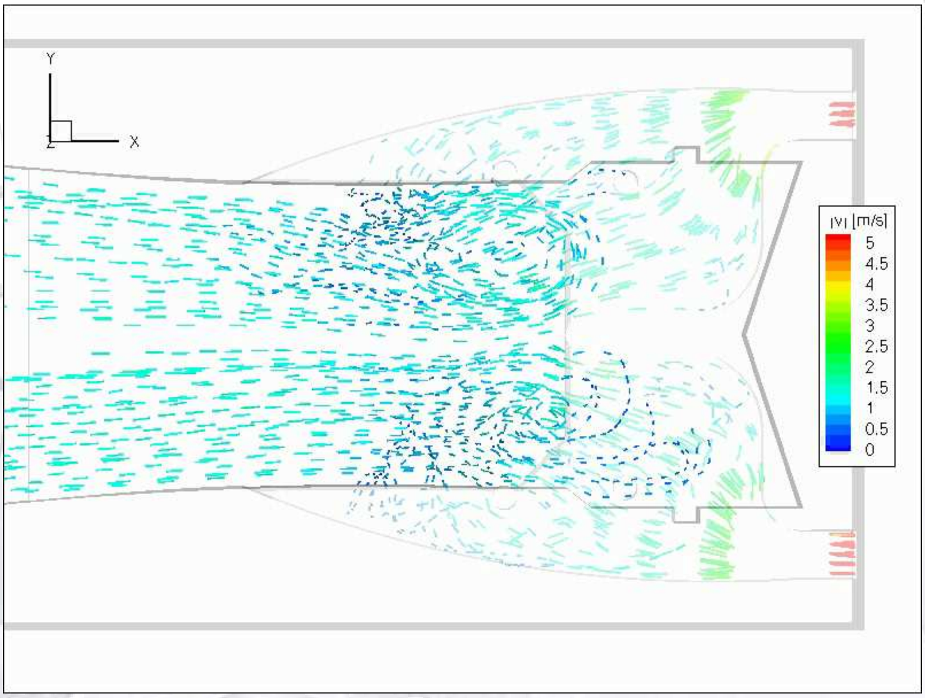
Simulation results for the inlet



Concrete is translucent in this case…

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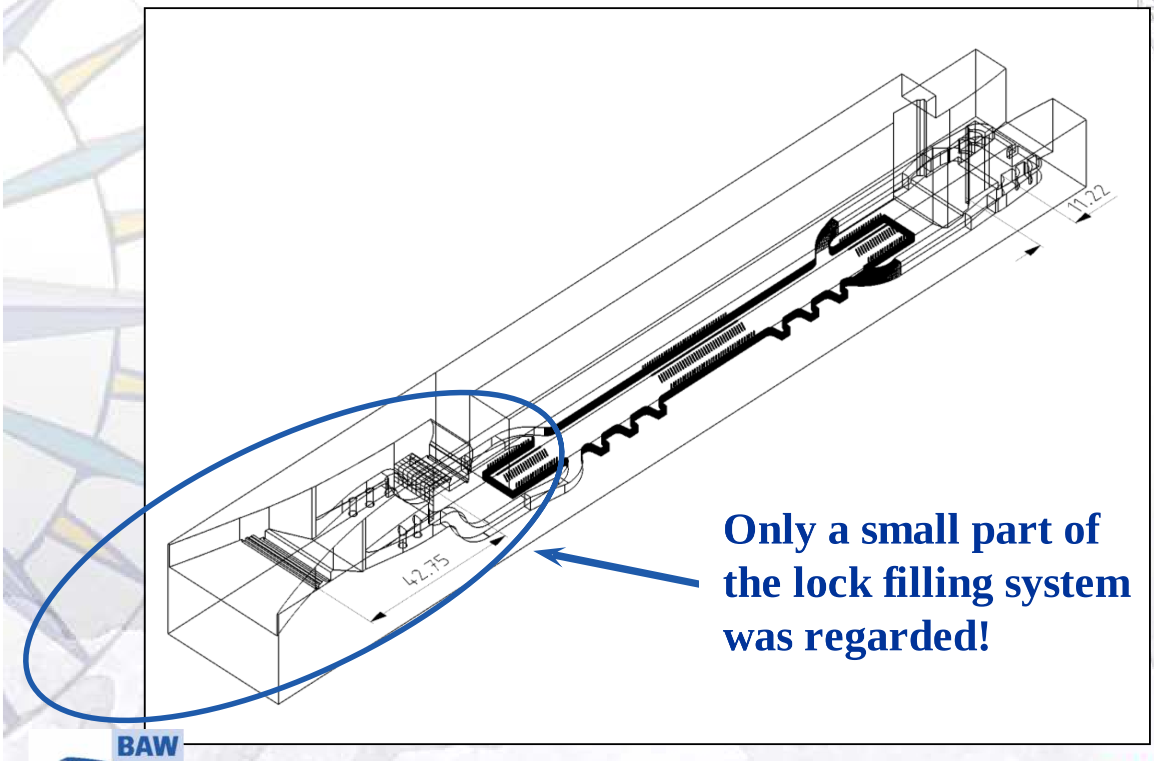
Is this the whole story?

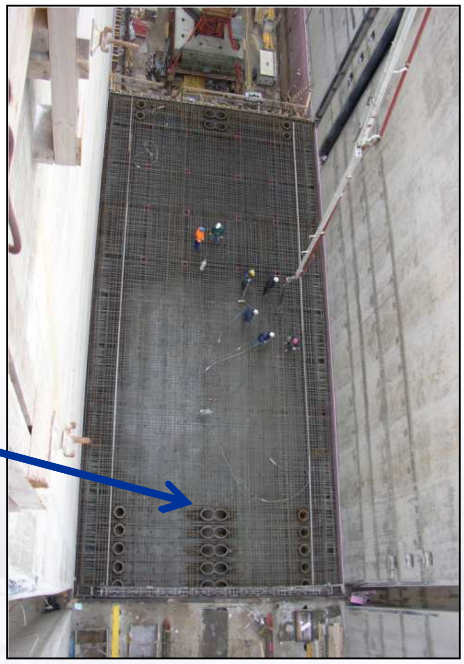


Only a small part of the lock filling system was regarded!

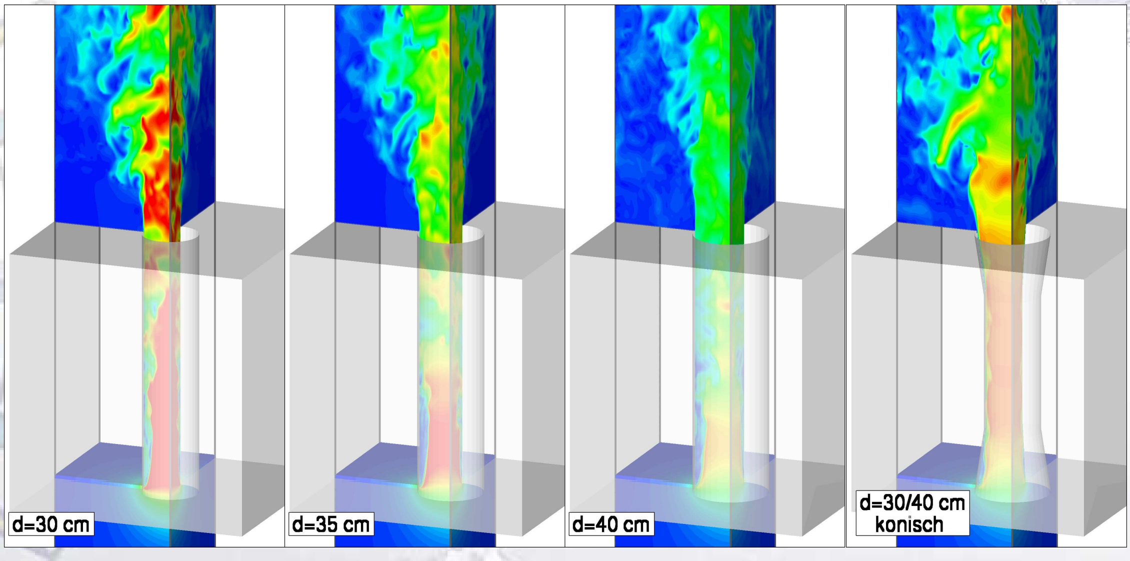
Filling and emptying system

Filling of the lock chamber from below, through a multitude of nozzles

(Picture: Lock Uelzen II).



Simulation of different nozzles



- Grid-convergence for 5 mm resolution at the edge
- Total system size is ~200 m ...

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Further considerations

- Grid resolution inlet area: ~12 cm
- Simulated time: several minutes

- Grid resolution nozzles: ~0,5 cm
- Simulated time: 30 s

- ~ 400 nozzles in the chamber floor

⇒ Computing all of the lock in „nozzle resolution“ requires multiple magnitudes more CPU-power ...

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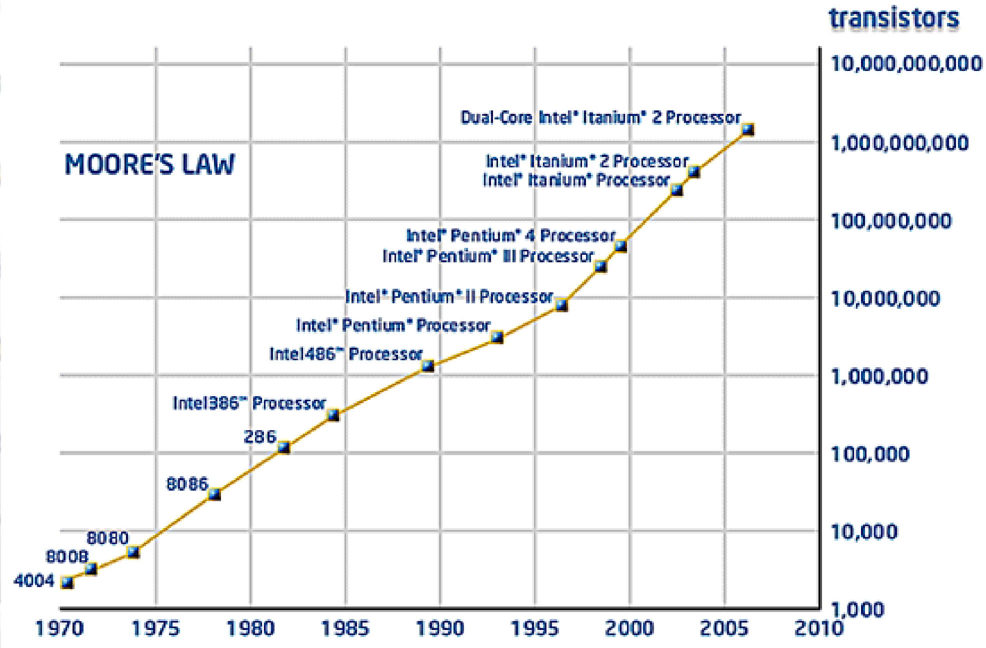
Development of CPU resources



(Intel corp. 2007)

Simply wait another decade?

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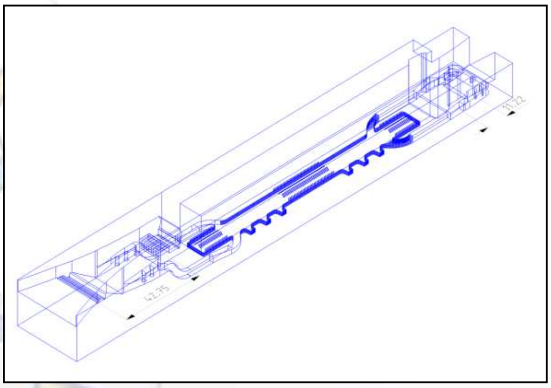
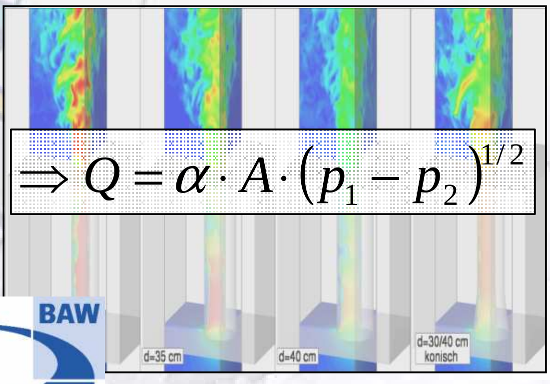
Possible solution





$$\Rightarrow Q = \alpha \cdot A \cdot \left(p_1 - p_2\right)^{1/2}$$

Use more computing power

+

Equivalent replacement models for the nozzle flow

⇒ introduce „coefficient“ based physics into the 3D model

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Conclusions

- Many aspects of the flow in and around locks can be computed
- (Currently) it is necessary to couple different models to get the “whole thing”
- Uncertainties (grid resolution, turbulence models) must be considered and tested for
- Ask about the quality, maybe have multiple (good) modellers (and compare the results)
- **Don’t simply trust pretty pictures**

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Ir. Jean-Michel Hiver
Service Public Wallon (Belgium)

Panel of experts

Ir. Olivier Cazaillet, SOGREAH, France
Ir. Sébastien Roux, CNR, France
Ir. Michael Tarpey, US Army, USA
Ir. Carsten Thorenz, *BAW, Germany*

Paper 11
NUMERICAL SIMULATIONS AND EXPERIMENTAL MODELS: HOW TO CHOOSE? and Discussion

International Workshop, PIANC - Brussels, 15-17 Oct. 2009

Numerical simulation and experimental models:

How to choose?

prof. ir. J-M HIVER

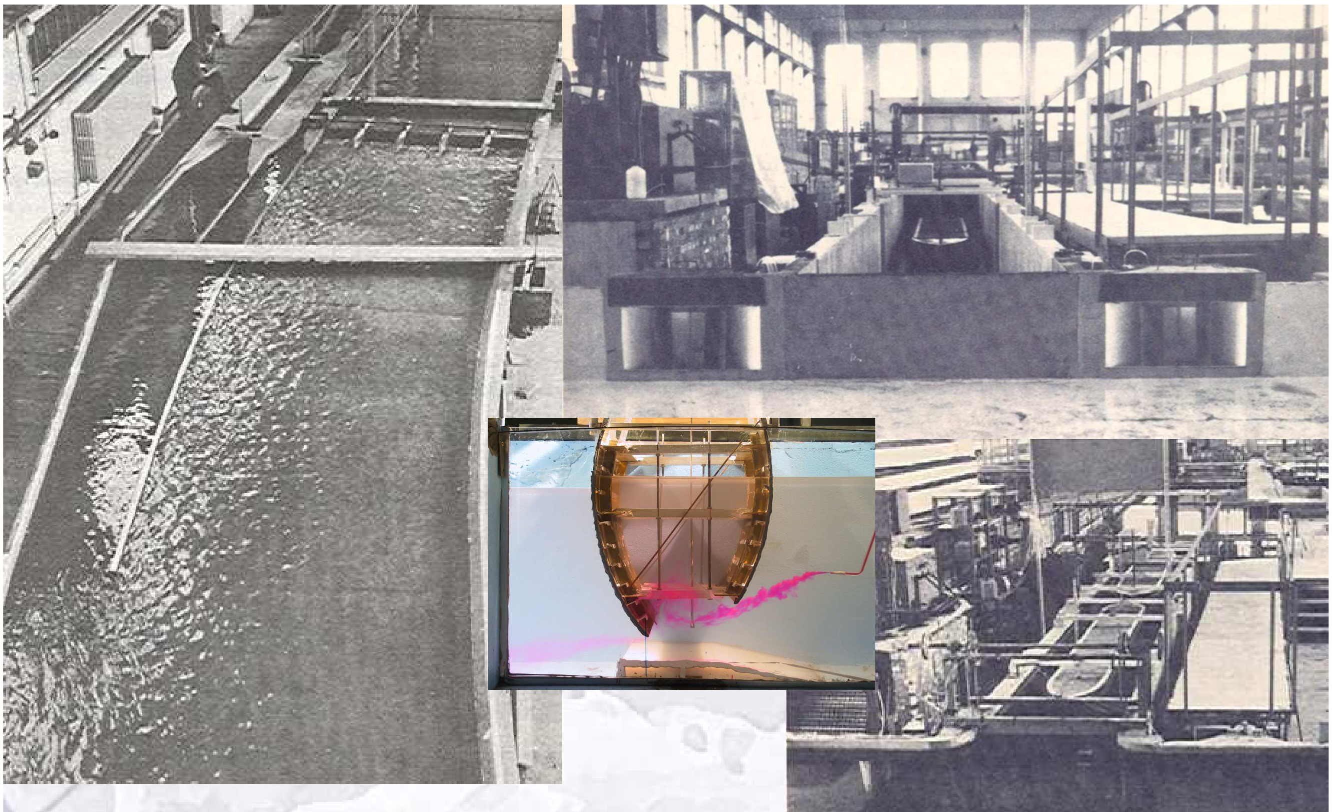
Hydraulics design for navigation locks

- In the chamber
  - ✓ Filling-emptying system
  - ✓ Flow in chamber and culverts
  - ✓ Water surface slope and forces acting on the ships (mooring design)
  - ✓ Turbidity current, salinity
- For the mechanical equipments
  - ✓ Valves design, head losses determination, air-entraining, vortices, cavitation
  - ✓ Gates sollicitations, operations
  - ✓ Flow induced forces and vibrations
- Upstream and dowstream the lock
  - ✓ Near field: currents, eddies in the inlet
    design of the navigation approach-harbours to the lock
  - ✓ Far field: dowstream and upstream lockage waves
    bank protection
    interaction navigation-bank,
- Eco-hydraulic
  - ✓ Fish migration
  - ✓ Hydropower and green energy

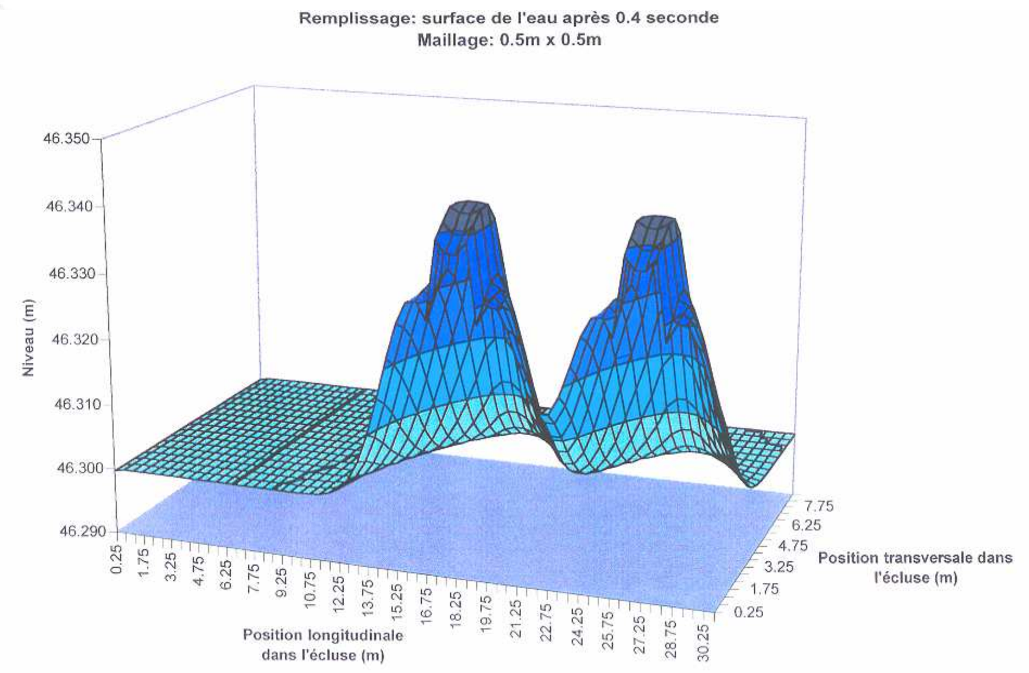
Hydraulic tools

- Analytical model — exact mathematical solution for simplified equations
- Numerical model — approximative solution, domain and boundaries conditions
- Physical model — reduced scale model, approximative solution
- Test model — simple conceptual physical model (no scale)
- Field measurements

Introduced the concept of Composite modelling



Physical modelling …outdated approach ?



Numerical modelling… absolutely confidence ?

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Thus…

- Why to maintain costly facilities test hall !
- But, how to improve an efficient mean of communication to present the real-world situation?

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Acknowledgements

- The market shares of the numerical models have increased in the last century against the physical models.
- Less experimental activities have been noticed.
- Nevertheless, physical models are *in fine* guarantying the precision of the design results.
- Physical models vs. numerical models: strengths and weakenesses.

Conceptual comparison between hydraulic and numerical models to engineering problems

Step	Hydraulic model	Numerical model
1	Definition of	the problem
	Identification of the	essential acting forces
2	Formulation of similarity requirements	Formulation of a set of equations
3	Formulation of	boundary conditions
4	Construction of a model	Development of a numerical scheme
5	Calibration and	validation
6	Measurements converge to solution	Calculations converge to solution

Limiting factors

- **Concerning the physical modelling :**

1st limiting factor	-compromise to choice the similarity
2d limiting factor	-influence of the sufarce tension
3th limiting factor	-effect of the distorsion
4th limiting factor	-effect of the sedimentology time and turbulence generated by bottom morphology

- **Concerning the numerical modelling :**

1st limiting factor	-complexity of the equations -sediment transport processes -turbulence effect
2d limiting factor	- numerical models are global and physical models are local
4th limiting factor	-interferences introduced by the simplifications of equations -interferences introduced by the algoritmic developments
4th limiting factor	-calibration and validation difficulties

Principal and practical limiting factors

HYDRAULIC MODEL	NUMERICAL MODEL
Principal	**limitations**
Model size (laboratory)	Storage capacity
Discharge (pumping capacity)	Computational speed
Energy head (pumping capacity)	Incomplete set of equations
Model laws	Turbulence hypothesis
Practical	**limitations**
Minimum model scale (surface tension, viscosity, roughness,…)	In simplified set of equations: -accuracy of assumed relationships -availability of coefficients
Model size (upper limitation)	Space and time resolution
Measuring methods and data collection	Numerical stability and convergence
Availability of boundary and initial conditions	Availability of boundary and initial conditions

Hydraulic or numerical model
Decision criteria

- Principal limiting factors
- Required accuracy
- Simplicity
- Cost and time requirements
- Flexibility
- Intuitive power
- Credibility
- Feedback to nature (calibration possibilities)
- Prognostic capabilities

Type of model	Hydraulic model	Numerical model
River and tidal models with fixed bed	Local problems, complex geometry	Large scale problems, simple geometry
River and tidals models with movable bed	Bedload transport, erosion ans deposition problems	Suspended load transport (bed load transport for very simple geometry)
River and tidal models for transport processes	Near-field problems	Far-field problems
Lake and reservoir models	Detailed questions, fundamental experiments	Mainly used
Harbour and coastal models	Mainly used	Wave pattern for simple geometry
Models of hydraulic structures: -Discharge characteristics -Energy dissipation -Erosion -Flow forces -Vibrations -Cavitation	 Complex geometry Complex geometry Necessary Complex geometry Neccessary Necessary	 Simple geometry Simple geometry Simple geometry
Pipe flow models	Local problems, complex geometry, sediment transport	Mainly used

1. The contribution of analytical, numerical and experimental modelling

A comparison of experimental and numerical models shows at first glance that both type of model have very much in common. Each must be preceded by a conceptual phase, in which the physical relationships are identified which are to be simulated by the model.

2. Comparison between each models, limitations

The effort in constructing a hydraulic physical model is comparable to the effort of working out a solution scheme for the numerical model. Both methods must make use of certain simplifications and approximations and have to be adapted to the real situation in nature – in the one case by adapting the empirical coefficients, in the other case by changing the model roughness.

3. Decision making process

The most important role in the decision making process is played undoubtedly by the limiting factors of either of model and the negative effects in modelling.

Because these two types of model lead to approximate solutions, when using them one has to know how approximate the solution is, that is, it's precision. One way to know is to use all three types of models, and to combine them so as to avoid their main shortcomings.

4. Contribution for pluridisciplinary expertise and public relation

Physical model is an efficient mean of communication that allows to present the real-world simulation, helps learning about the processes involved and convince of the relevance of works wich improve multidisciplinary approach.

Hydraulic studies

METHODOLOGY

- Physical modelling
- Field measurement
- Numerical modelling

Composite modelling to optimize the methodology and reduce the parasite effects generated by physically and numerically approach

1st Example
Lanaye 4
Filling-emptying system for a lock

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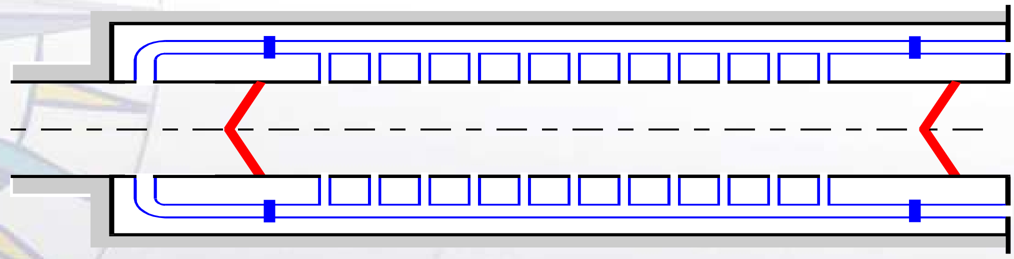
Filling and emptying systems

Longitudinal culverts with branch culverts



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Numerical model elements

- **Culverts, branches and valves**
  - Pressure pipes
- **Lock chamber**
  - Open-channel flow (SWE), 1D and 2D
- **Coupled modelling**
- **Boundary conditions**
  - Upstream and downstream water levels

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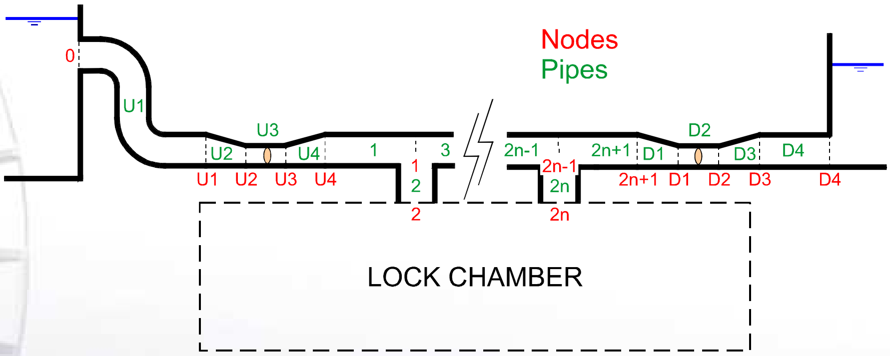
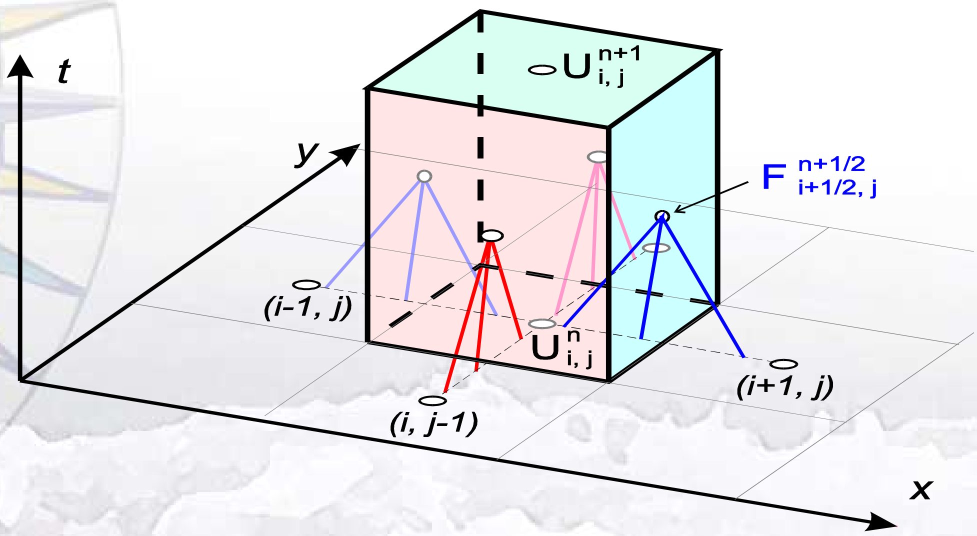
Pipes modelling

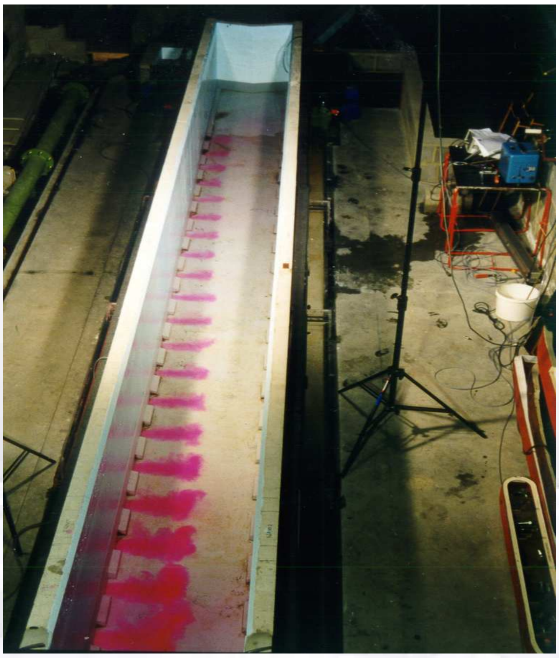


- Elements: pipes and nodes
  - Unknown: head H, velocity V
  - Mass continuity at nodes
  - Energy equation on pipes
  - BC: Upstream, downstream and chamber water levels

SWE integration
Finite volume scheme



Filling visualisation (Scale model)



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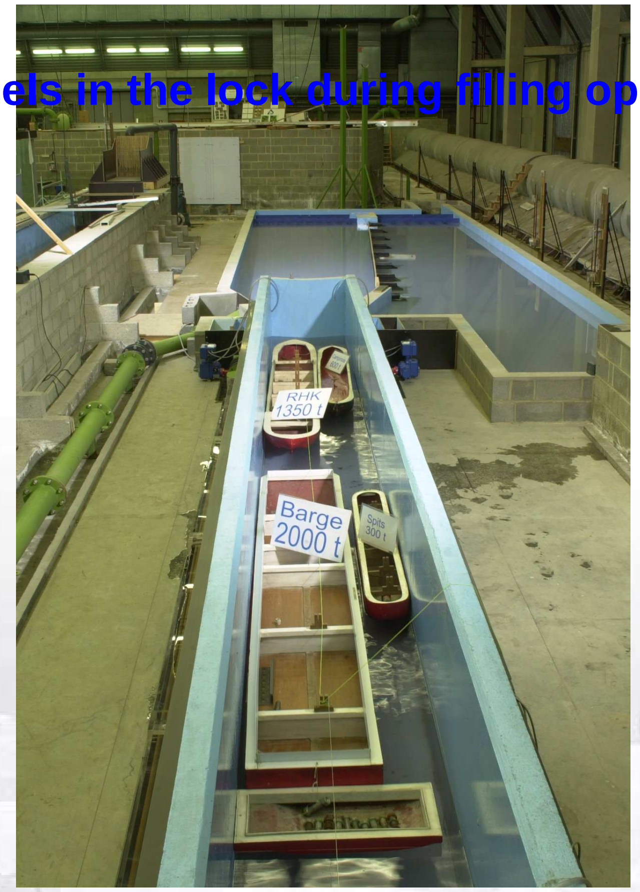
Vessels in the lock during filling operation



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Lanaye IV study

- Comparison with scale model
  - Adapted valve diameter
- Comparison with Lanaye III Lock
  - On-site measurements
  - Adapted culvert layout
  - Numerical model validation
- Lock 225 m x 25 m
  - 2D model of chamber : optimisation

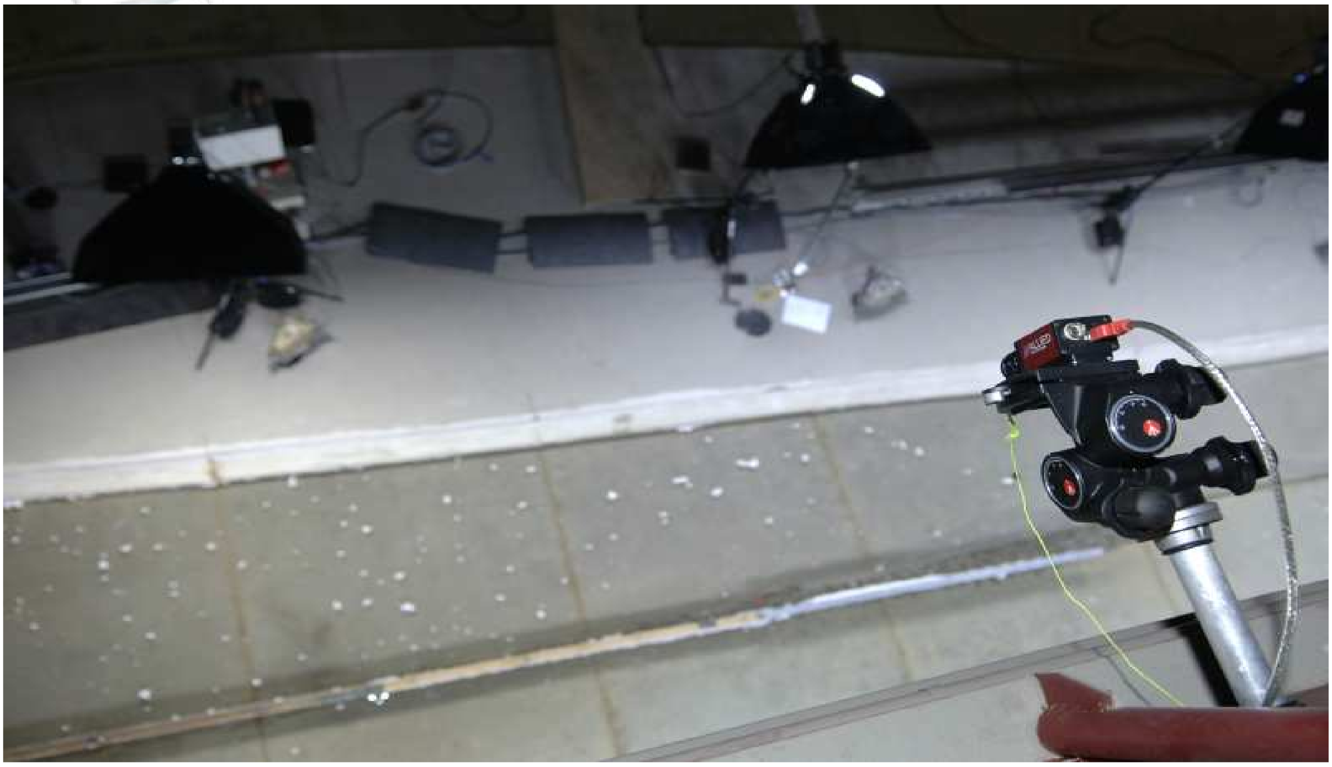
2d Example
Ivoz-Ramet complex
Upstream and dowstream harbours

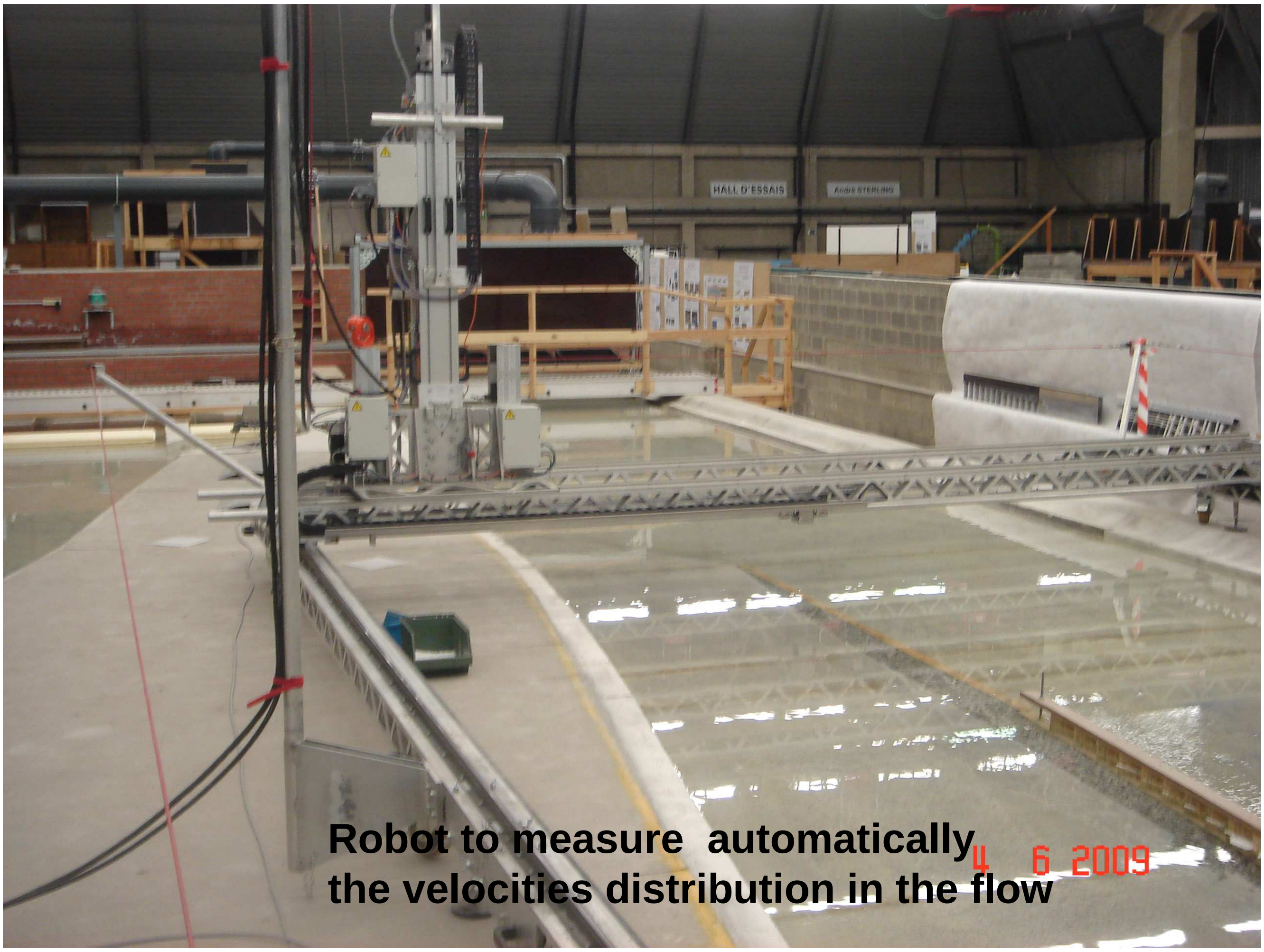
Methodology

- Stream evaluation
  - Physical model 1/50
  - Numerical model TELEMAC 2D
- Navigation simulation
  - Numerical simulator (ALKYON)
- Impacts on the river
  - Waterprofiles – 1D modelling
  - Waves generated by the lock operations – 1D unsteady numerical model

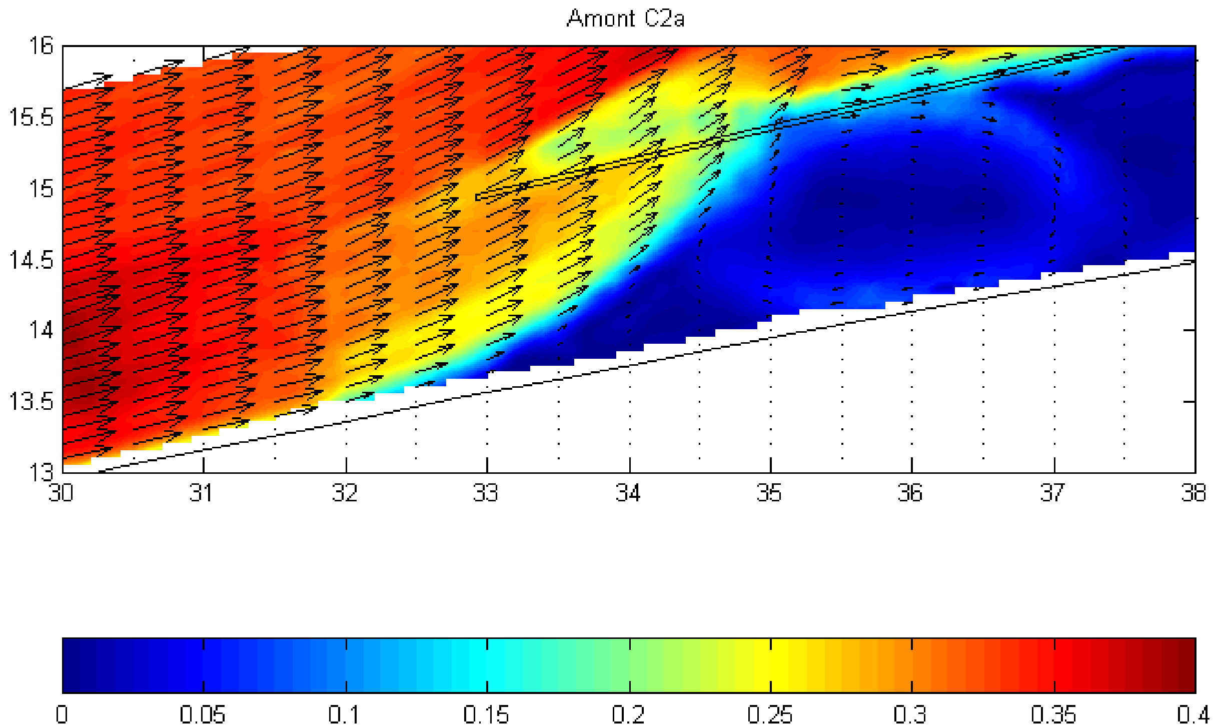
Physical model

Video streamlines measurements



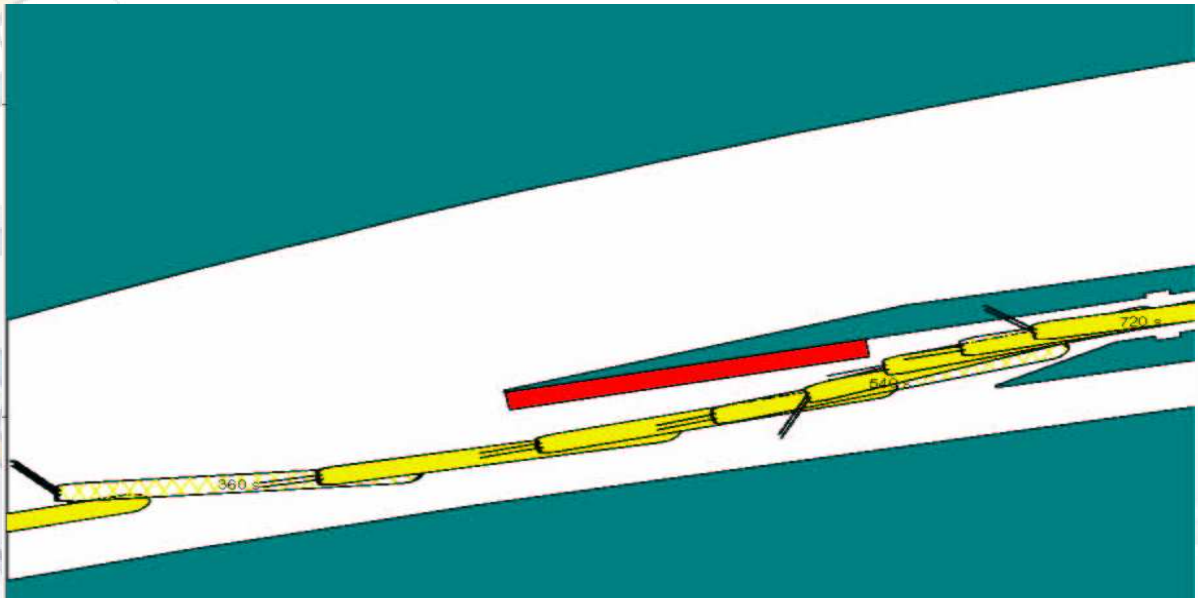


Robot to measure automatically the velocities distribution in the flow



Upstream wall

Simulation navigation (ALKYON)



The multi-approach study of the ports layout for the new lock enabled the design of a adequate solution regarding both navigation fluidity and safety with only insignificant impact on flood levels

Hydraulic studies Recommendations

Improvement of the numerical scheme neighbourhood of the structures

Numerical modelling

Physical modelling

Management of the boundaries conditions

Geographical spreading
Unsteady flow simulations

3D modelisation for complex situations
Public relations

Composite modelling
Conclusions

The most common theoretical combination during the design process is :

- Analytical models at early design stage, so as to know the feasibility of widely different solutions;
-Numerical models at detailed design stage to get a refined solution;
-Physical models for final design stage to confirm interactions.

The added values of the composite modelling are the limitation of the parasite effects, guaranty the precision and accurate way of the design, flexibility, cost efficiency, teaching and efficient mean of communication which improve multidisciplinary approach.

Thank you for your attention

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Waterborne Transport Infrastructure

PIANC Workshop
15-16th October 2009

O.Cazaillet Sogreah

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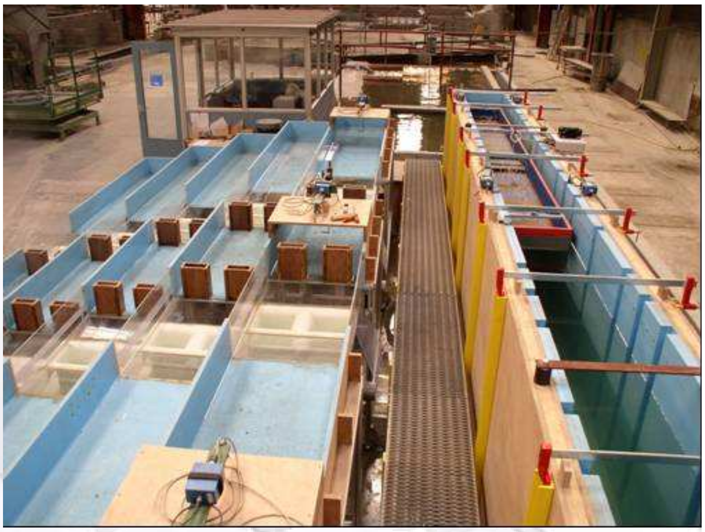
Canal Seine Nord Europe Moislains Lock



Canal Seine Nord Europe Moislains Lock

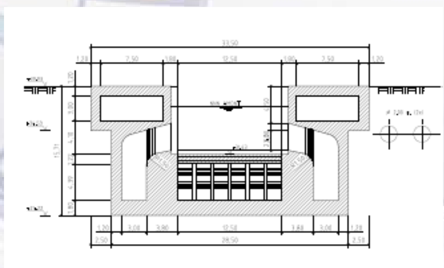
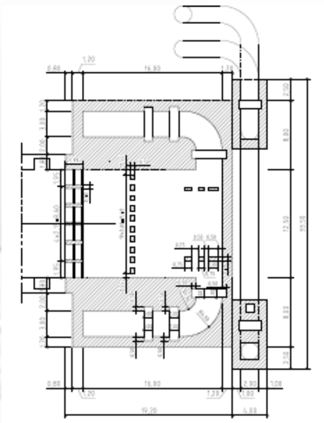
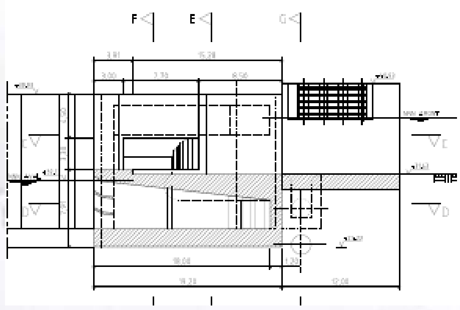
Moislains Lock Seine Nord Europe Canal (lift height 30 m)
L=195 m B=12.5 m 5 saving basins
Filling and emptying Time

	1D Math. model	Scale model (1/25)	Difference	%
Filling	13' 24"	12' 53"	**- 31"**	4%
Emptying	14'	13' 14"	**- 46"**	5.5%

Canal Seine Nord Europe Moislains Lock

Montmacq Lock Seine Nord Europe Canal (lift height 6.41 m)
L=220 m B=12.5 m no saving basin
Comparison of 1D mathematical models

	Software 1	Software 2	Difference	%
Filling	449 s	495 s	**46'**	10%

Ir. Philippe Rigo
University of Liège – ANAST, Belgium

CONCLUSIONS

International Workshop, PIANC - Brussels, 15-17 Oct. 2009

CONCLUSIONS

PIANC Workshop
15-16th October 2009

By Ph RIGO
Univ of Liege- ANAST
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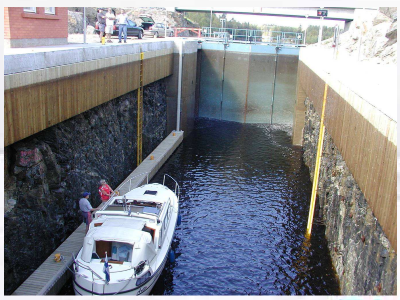
PIANC WORKSHOP
– Innovation in Navigation Lock Design –

15th & 17th October 2009
in Brussels
(25th Anniversary of PIANC Belgian Section)



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NEW LOCK INNOVATIVE TOPICS

- Hydraulics (filling and emptying),
- Operations and Maintenance,
- Environmental,
- Design (concrete, foundation, gate,…),
- Construction Modes,
- Equipments,
- …..
- Design concept : Cost-Effective, Reliable,....

WG29 - LOCK INNOVATIONS

Major changes in design since 1986 concern:

- Maintenance and Operation aspects,
- New goals at the conceptual design stages of a lock
  - ➔ RELIABILITY , LIVE CYCLE COST, ...
- Renovation and rehabilitation of existing locks are also key issues for the future.

Workshop 15-17 Oct 2009, Brussels

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WG29: Lock Innovations

BODEFELD Jorg (DE)
BOS Jan (NL)
CLARKSON John (USA)
DALY Fabrice (Fr)
FERNANDEZ (Spain)
HIJDRA Arjan (NL)
HIVER Jean-Michel (BE)
HOLM Olli (Fin)
HUNTER Peter (UK)

Support Groups:
US, NL, BE, Fr, Brazil

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TARPEY Michael (USA, YP)
THORENZ Carsten (DE)
WONG Juan (Panama)
WU Peng (China)

Corresponding members:
China, France, Panama, UK

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And tomorrow ?

1) <u>LOCK PROJECT REVIEWS</u>

- ➔ Continue to feed a database with new project reviews (on voluntary base) –
- ➔ Stored on PIANC web site or .... ?
- ➔ For free ?
  - ➔ No, need to cover web site management expenses
  - ➔ Company can afford to be mentioned in this international database

And tomorrow ?

2) 2nd PIANC Int. Workshop on Locks

- ➔ When? Maybe 2 years
- ➔ Where ? Wait for proposal
- ➔ Need scientific/organisation board. Who is volunteer ? Maybe WG29 members ?
- ➔ Topics ? : Lock + Barrier & Navig weir

PIANC Workshop 15-17th Oct 2009

PIANC REPORT N° 106

INLAND NAVIGATION COMMISSION

INNOVATIONS IN NAVIGATION LOCK DESIGN

2009

Technical visit at the Van Cauwelaert and Berendrecht Locks in Antwerpen on Saturday 17th October 2009

- 8:00 am: BRUSSELS -> ANTWERPEN
  by private bus
  departure from Crown Plaza Hotel
- 13:00 pm: ANTWERPEN -> BRUSSELS
  by private bus
  arrival at Crown Plaza Hotel

International Workshop, PIANC - Brussels, 15-17 Oct. 2009

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