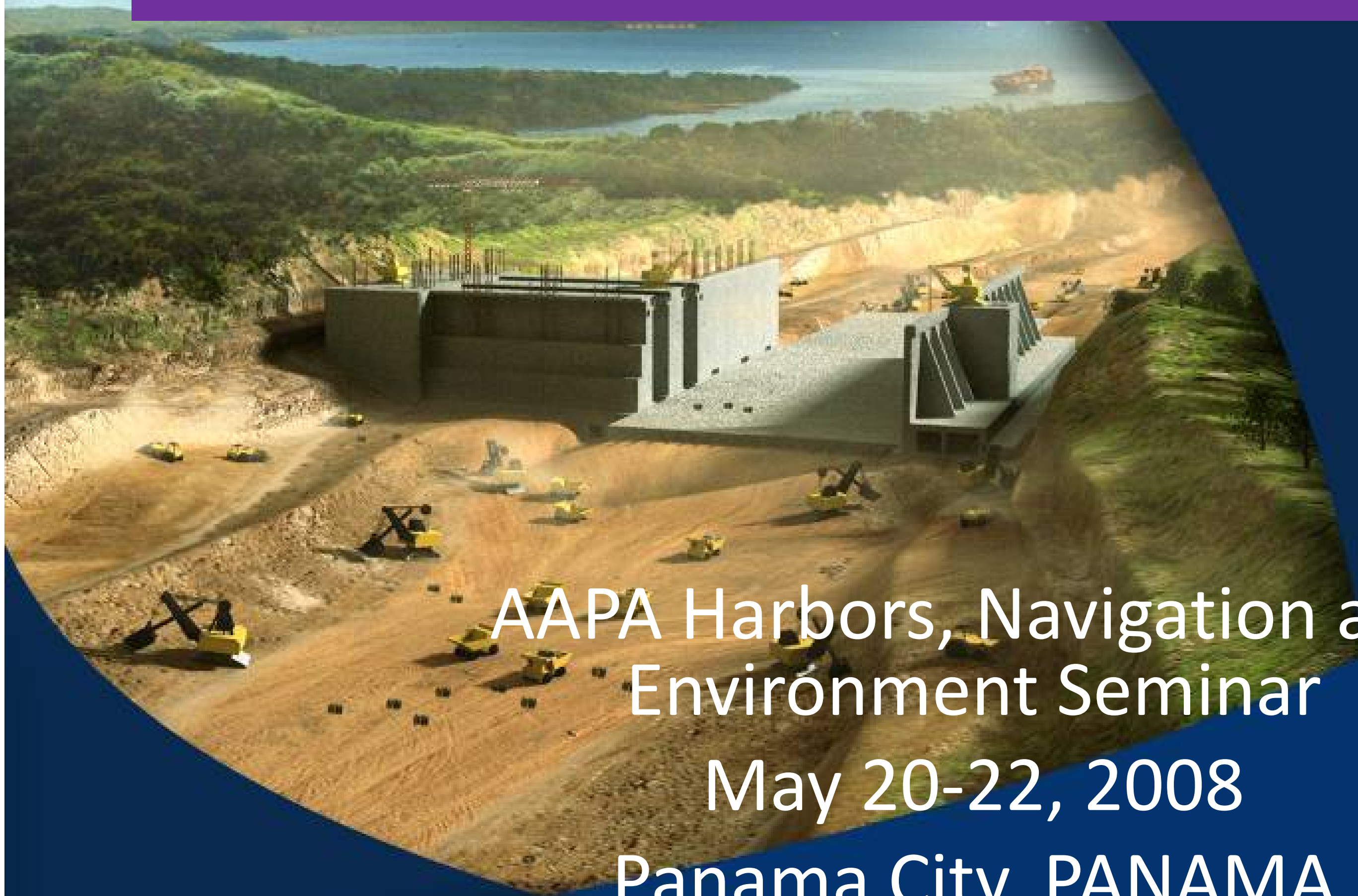
Lock Design For the Canal Expansion and Operational Considerations

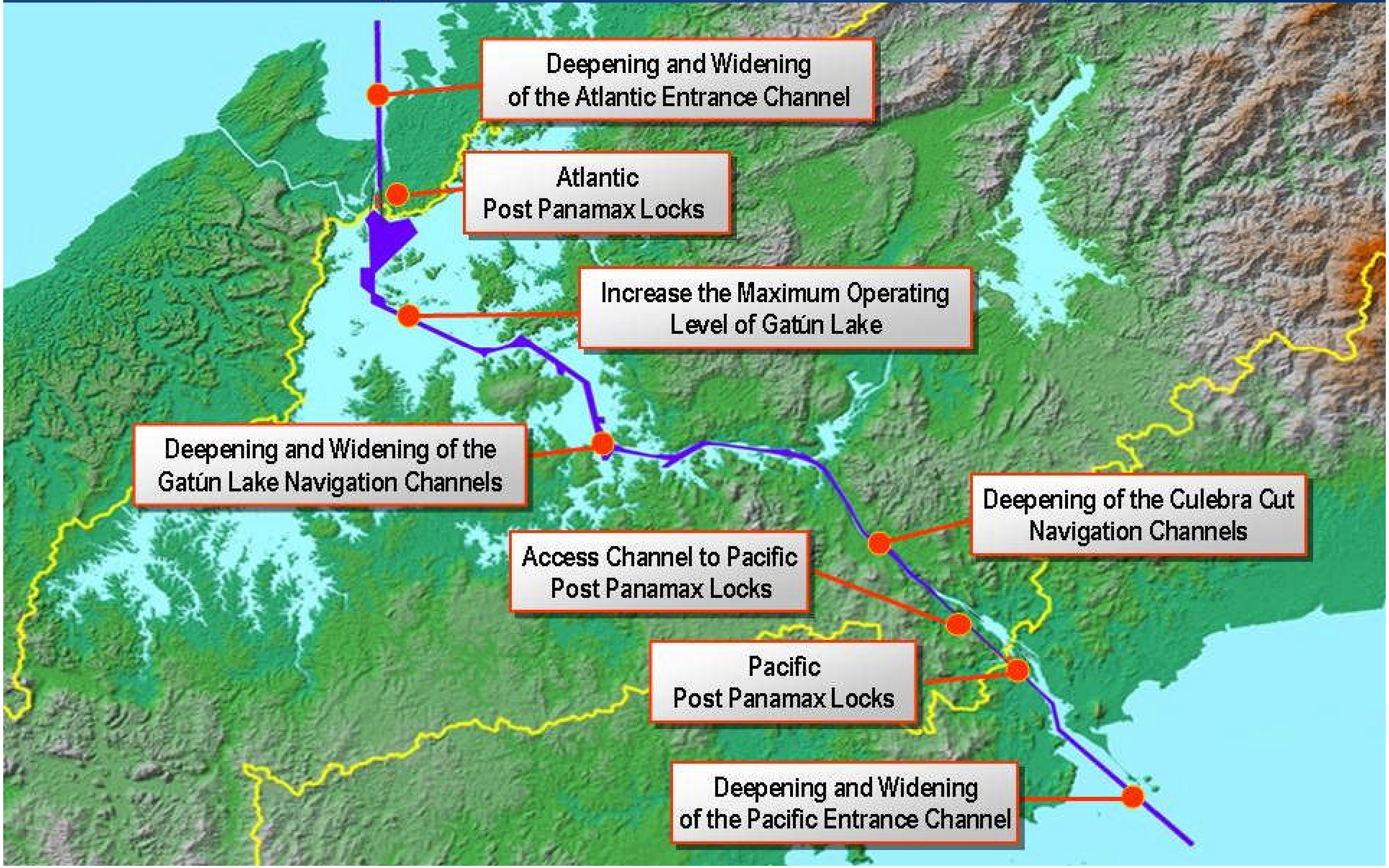


AAPA Harbors, Navigation and Environment Seminar

May 20-22, 2008

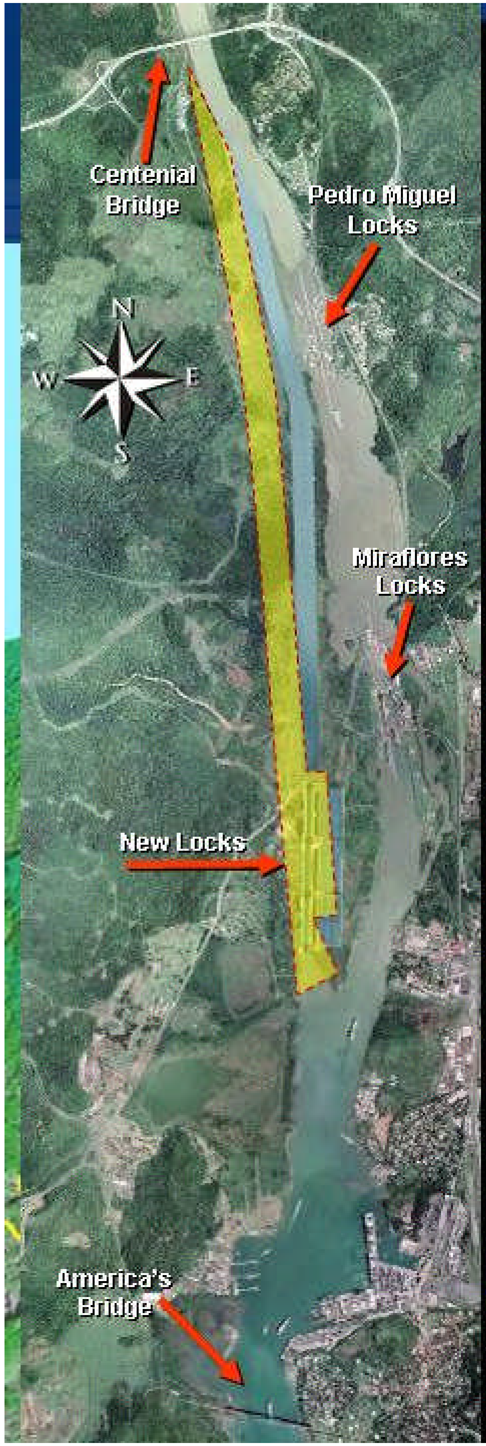
Panama City, PANAMA

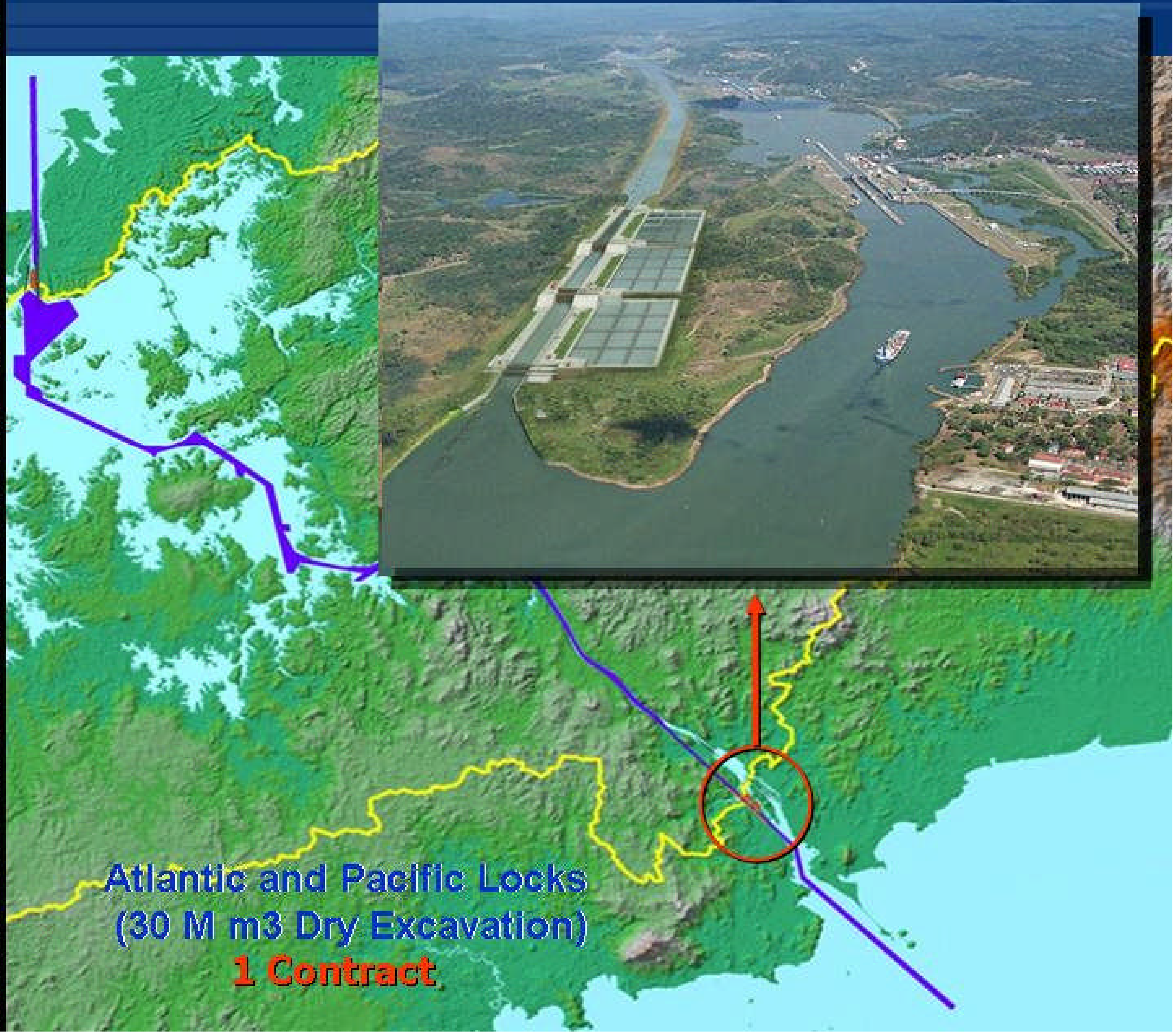
Canal Expansion Program Components



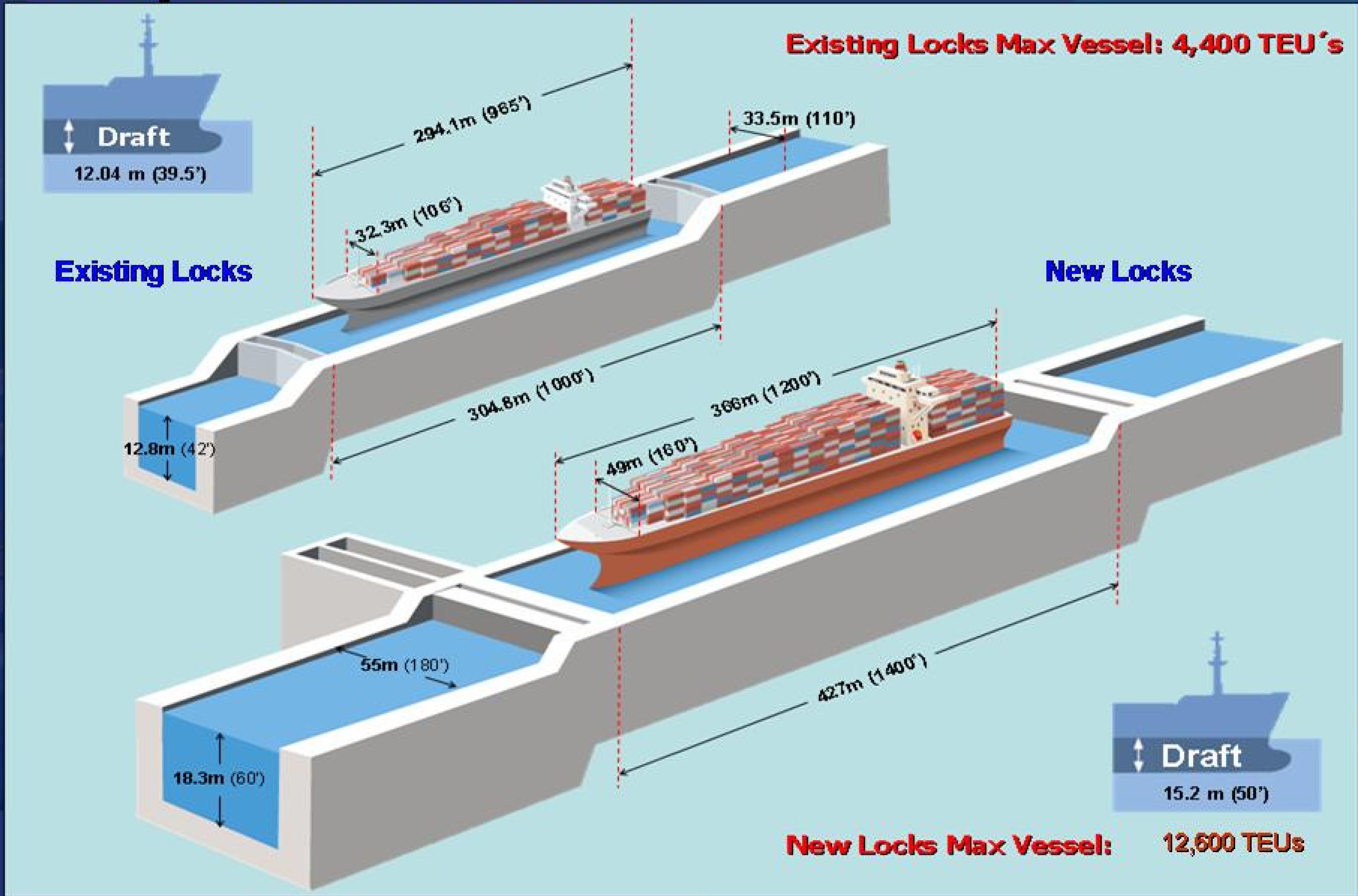
Post Panamax Locks

Post Panamax Locks

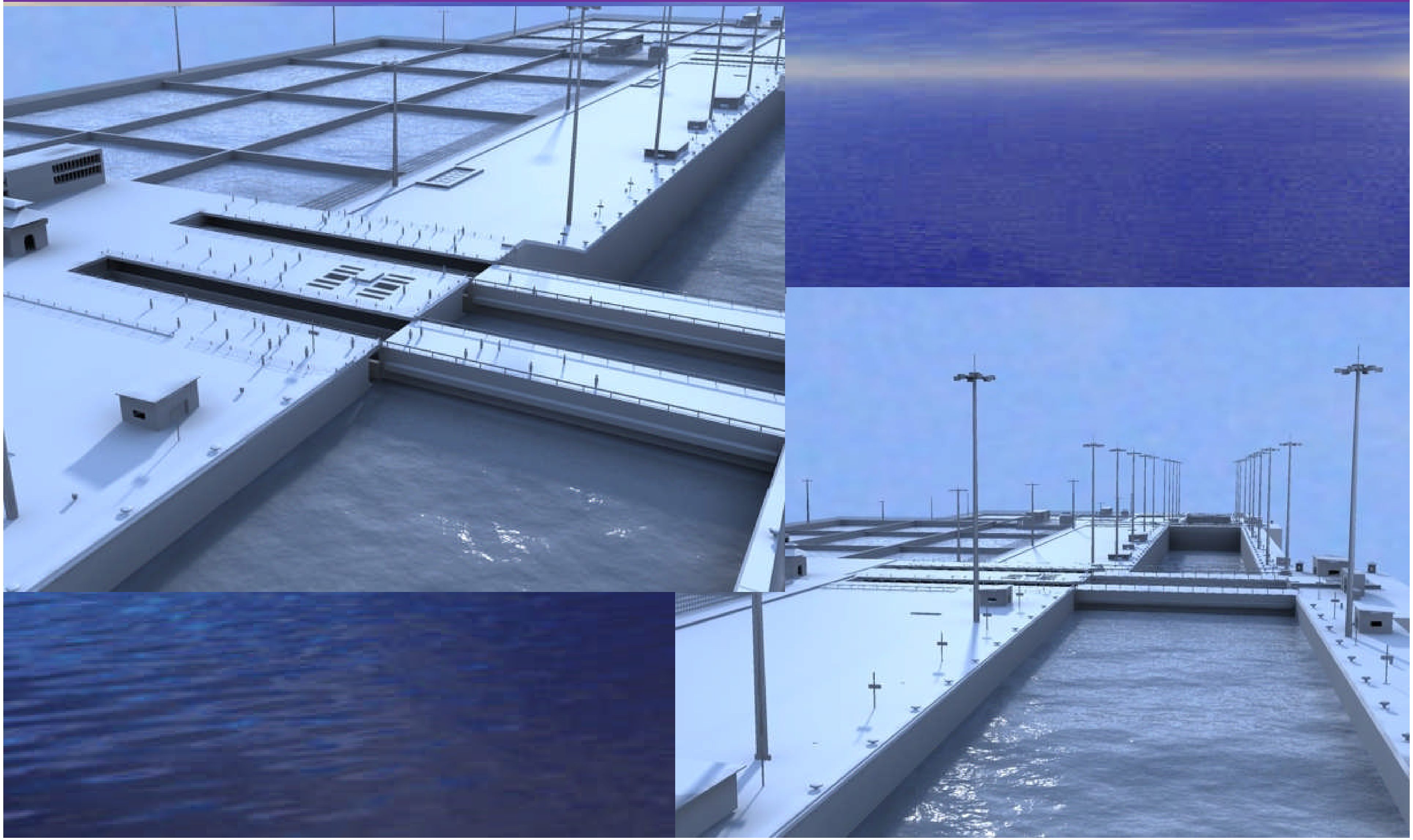




Dimension of Locks and Post-panamax vessels



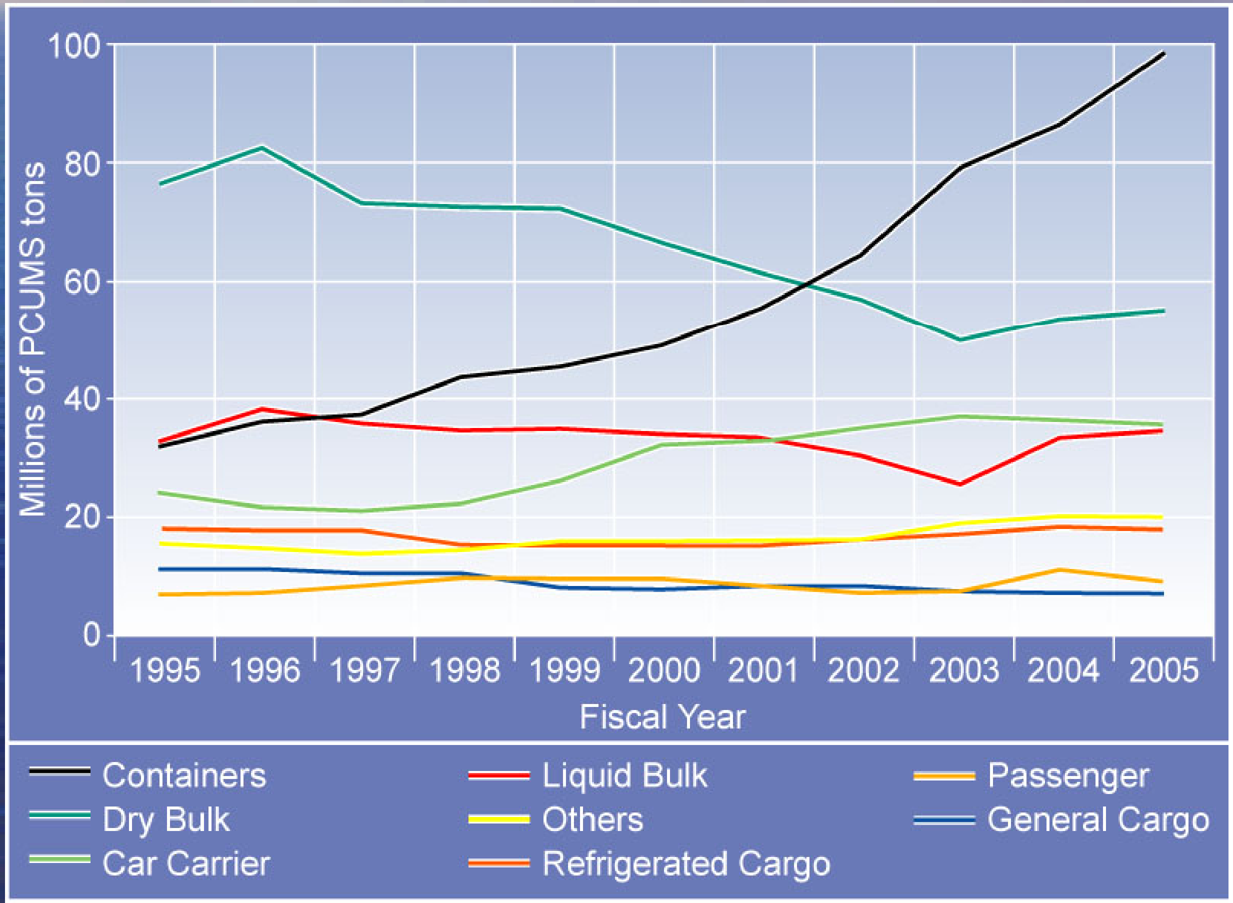
Concept drawing of the new locks



As it used to be: 9.14 m (30 ft)

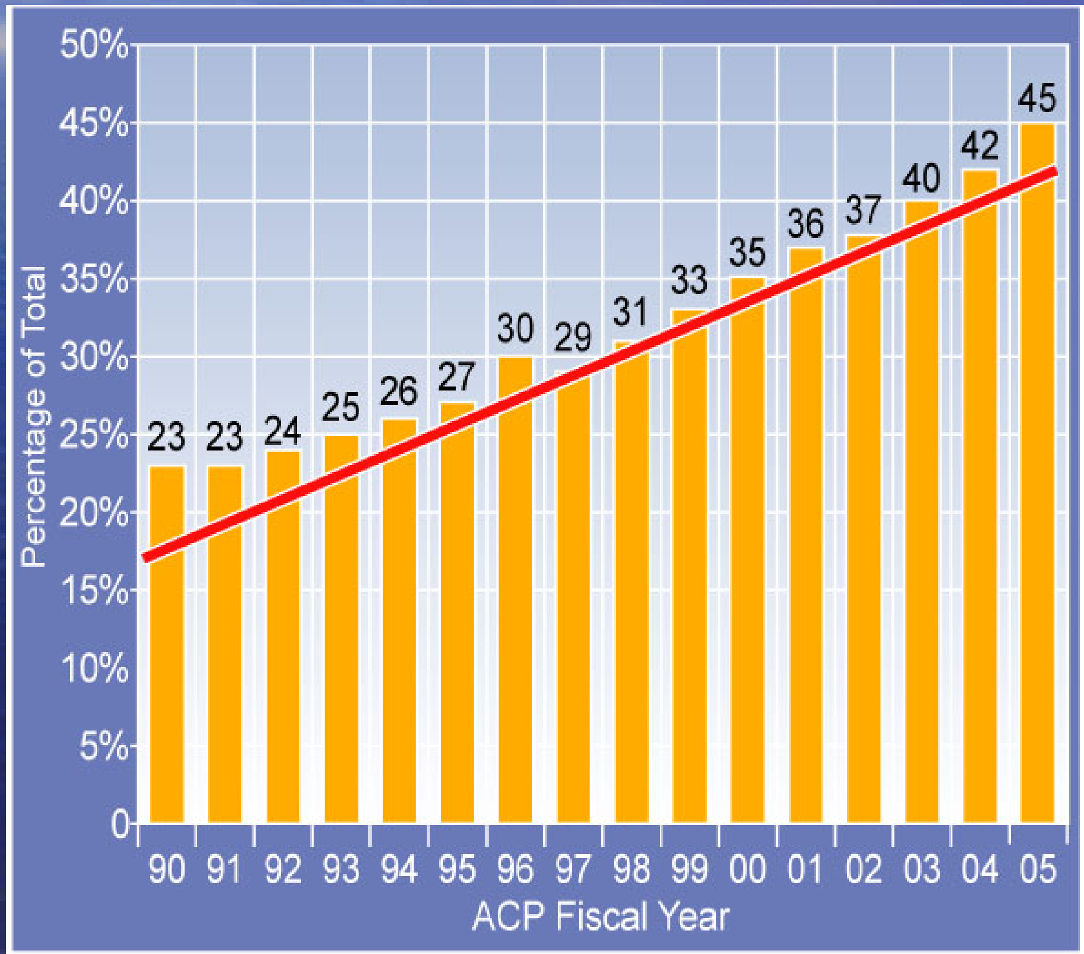
Canal's traffic evolution

Containerized cargo has recently become the fastest growing market segment in the Canal



Use of Panamax vessels

Vessels with a beam of over 100' have been increasing dramatically over the past 20 years



Present conditions

Picking up tugs approaching locks & line handlers boarding party

Approaching the lock guide wall with tug assist

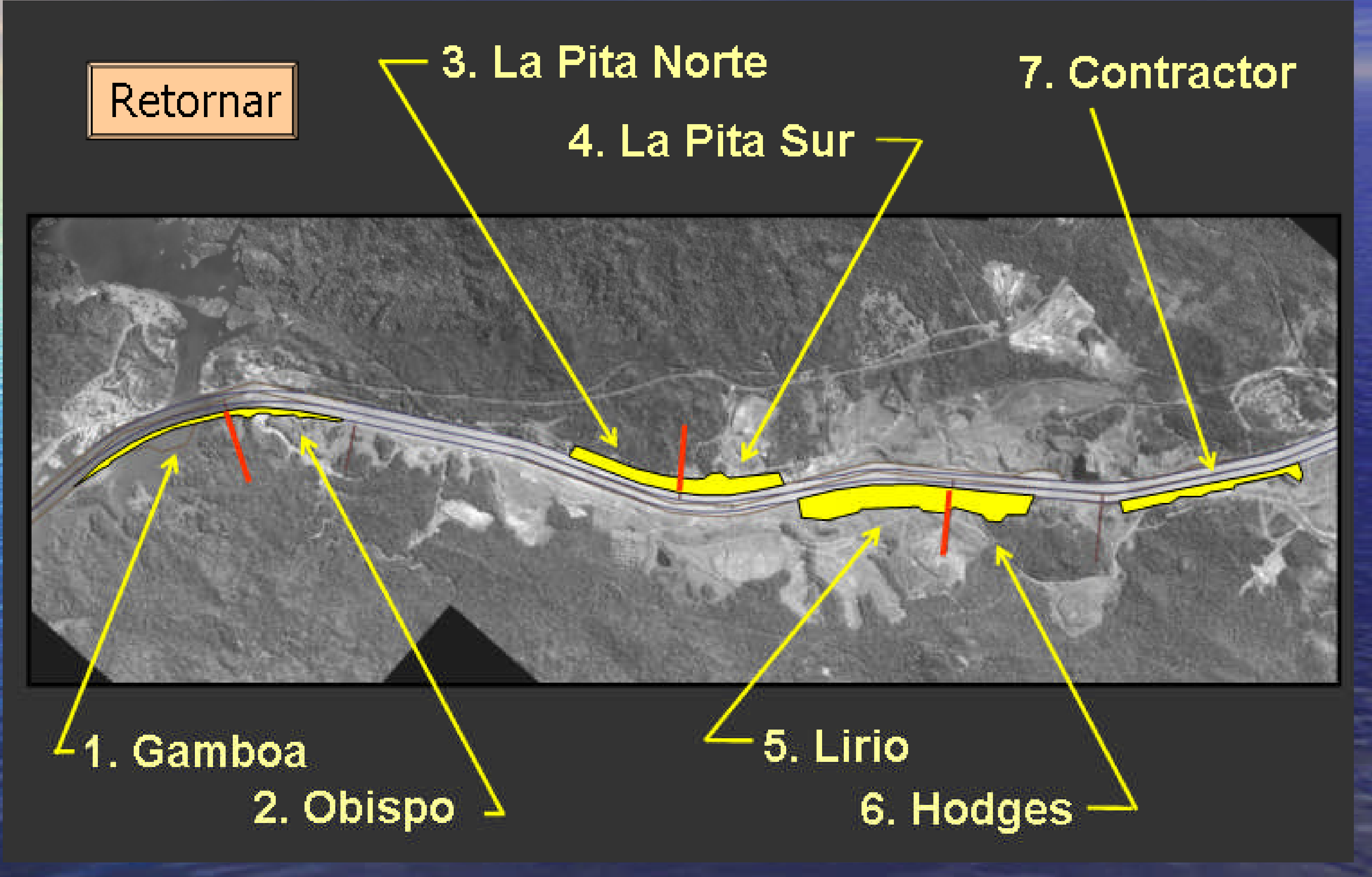
Getting the lines on the locomotives & lining up on the guide wall

Moving into the chamber with locomotives keeping the ship aligned

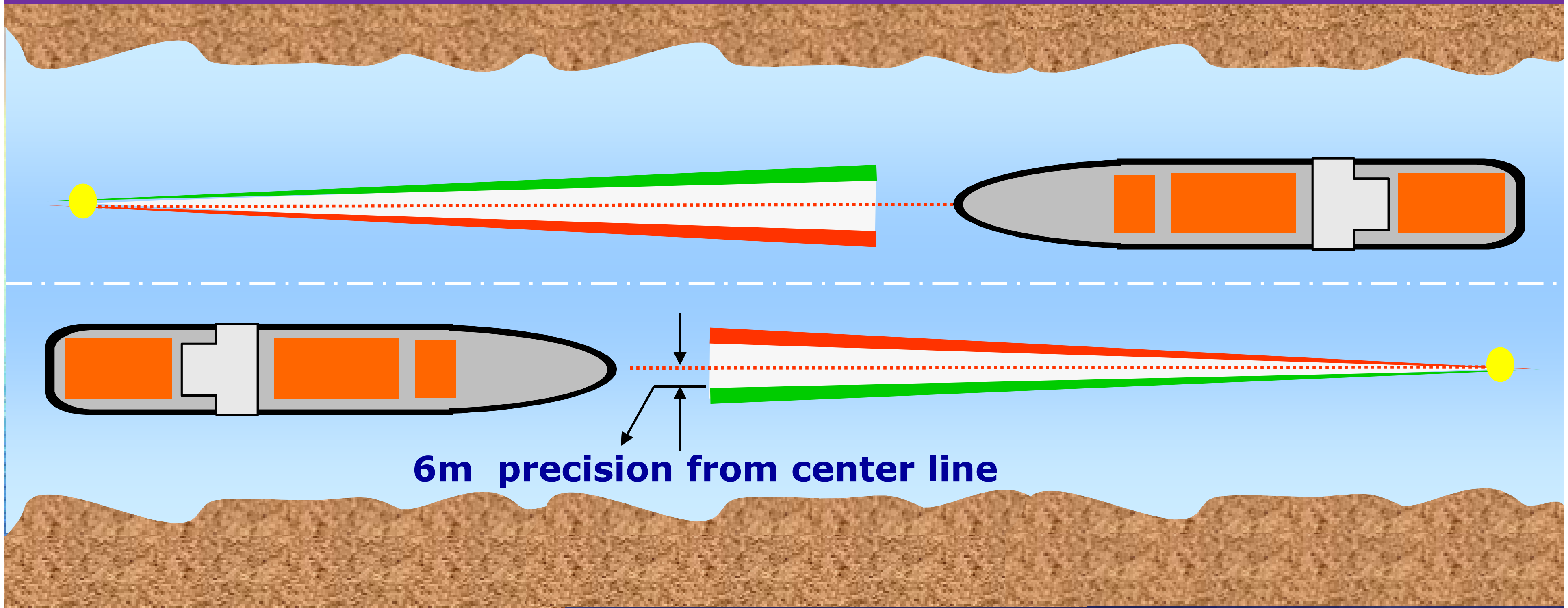
Locking through in the chamber – keeping the chamber busy with follow-up ships

Moving into the Cut and transiting after leaving the locks – efficiency improvements

Map of the Gaillard Cut Straightening

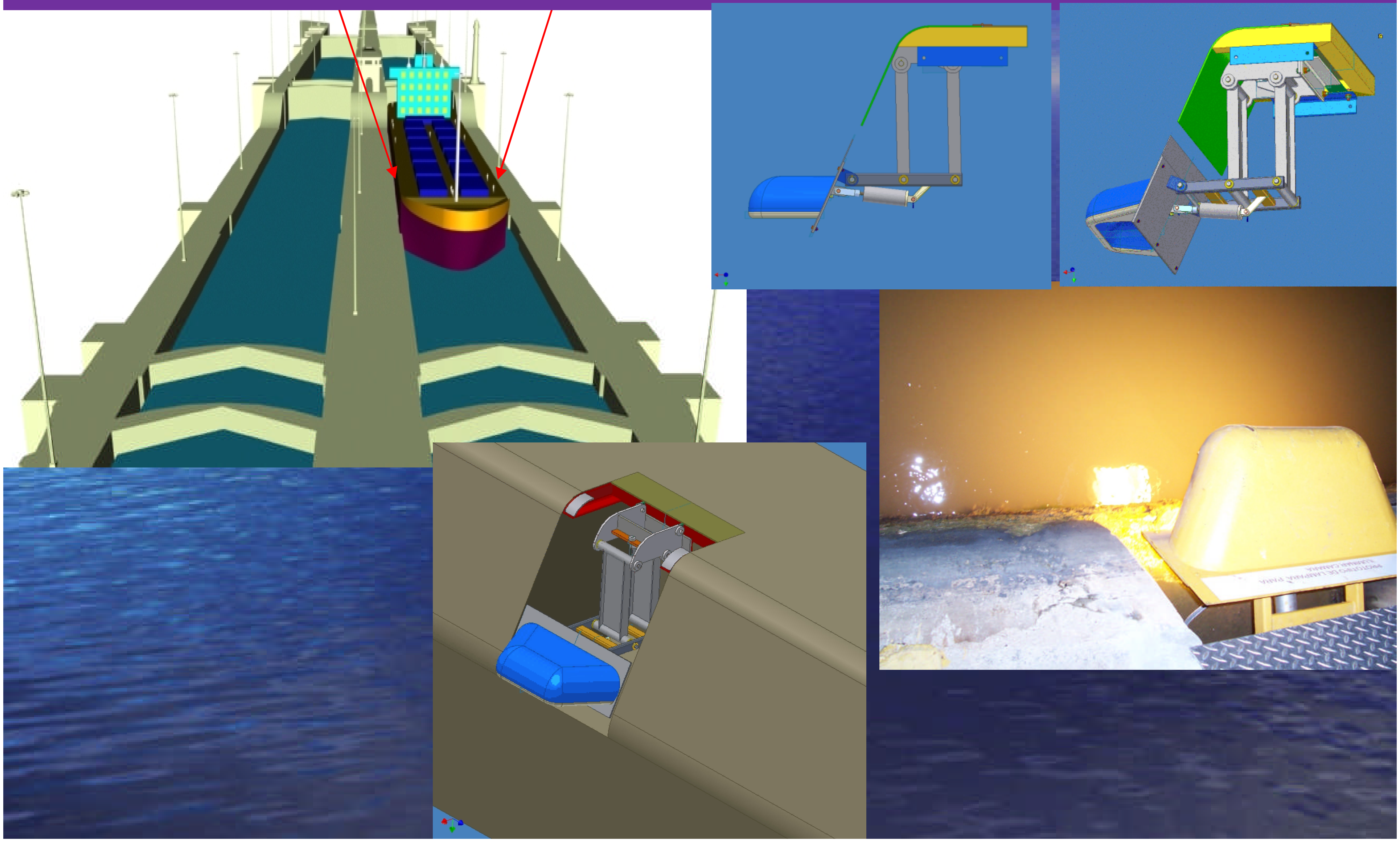


Minimum Off Axis Distance from Center Line Through the use of PEL Sector Light

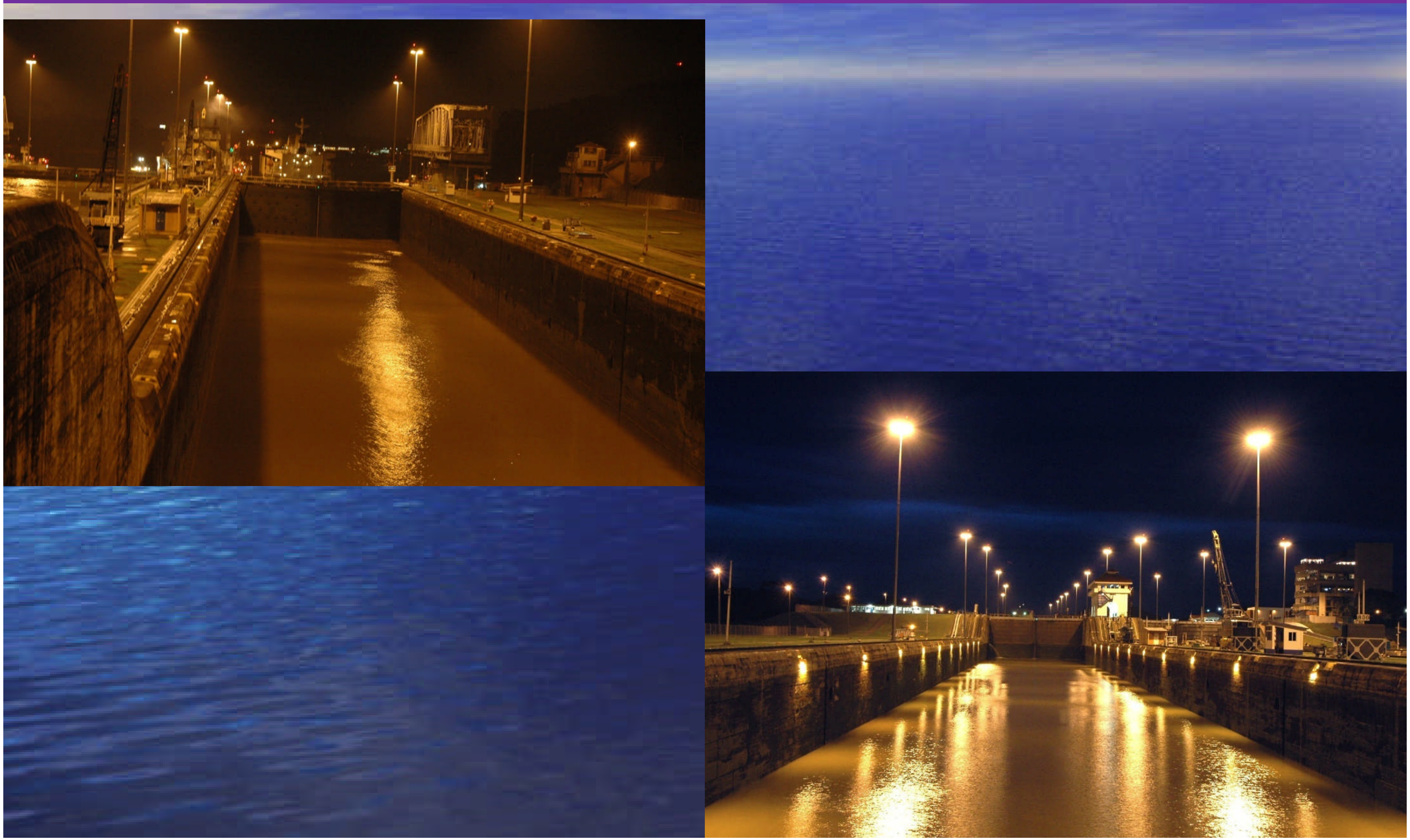


PEL Sector Light

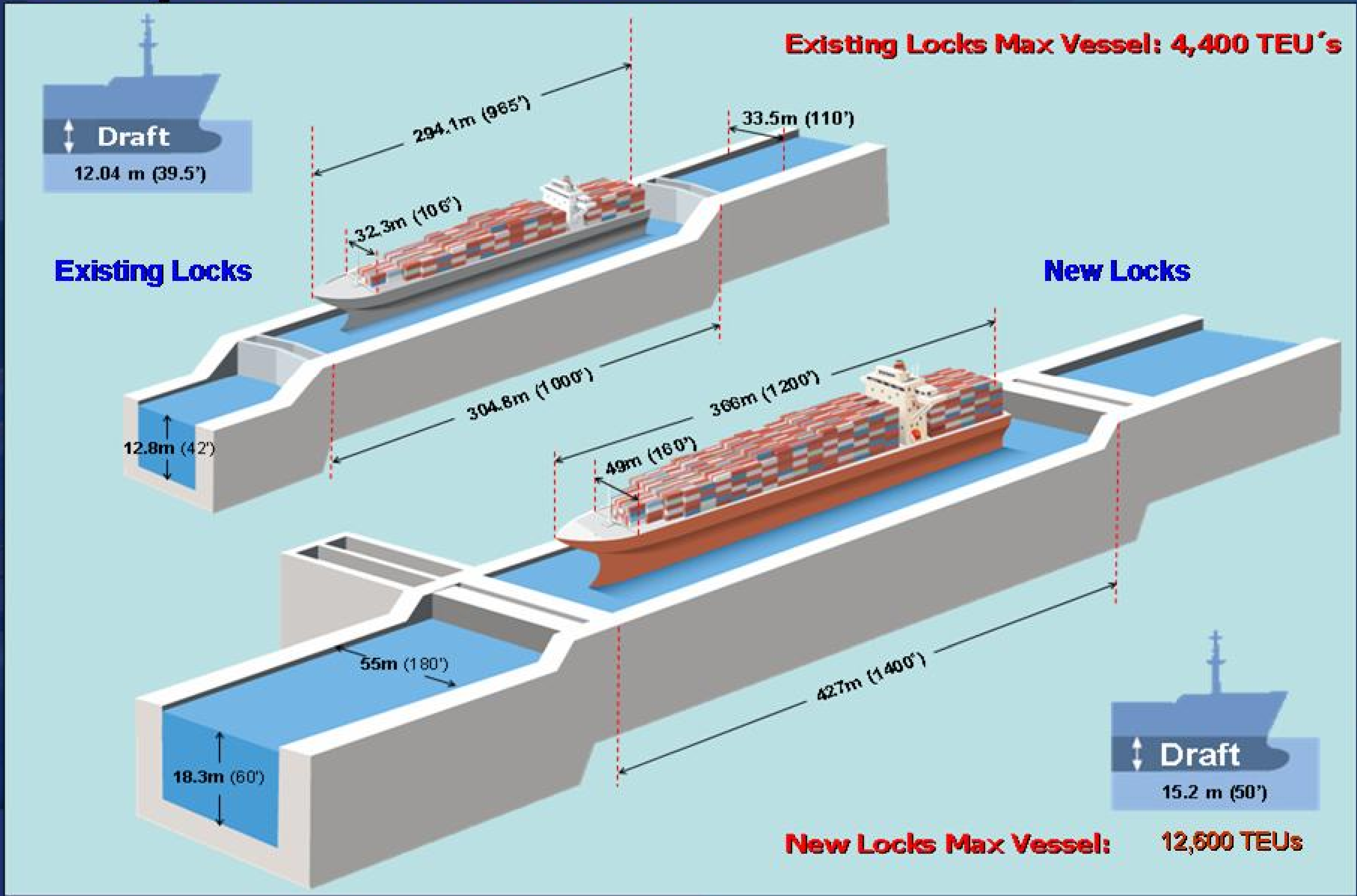
Increasing night operations through improved illumination in the locks for night operations



Resultant Improved Night Lighting in Present Locks

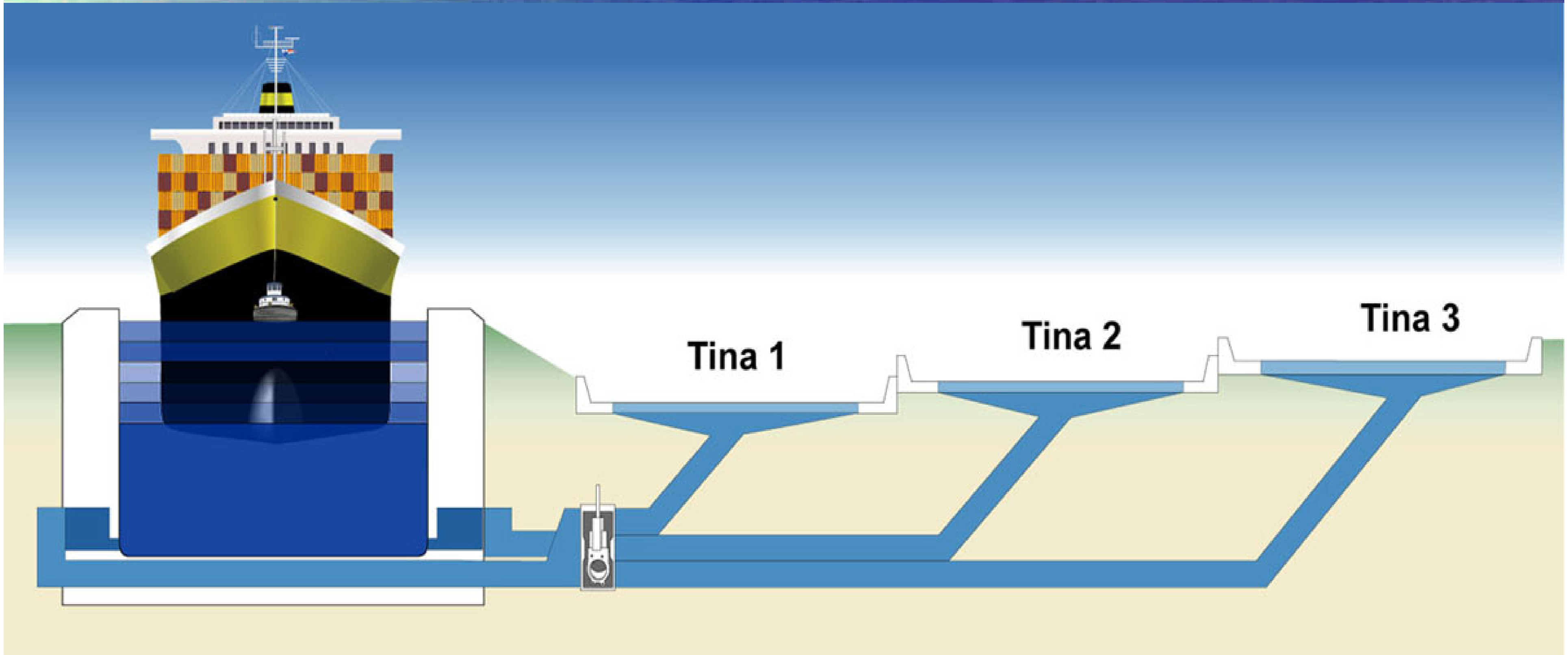


Dimension of Locks and Post-panamax vessels



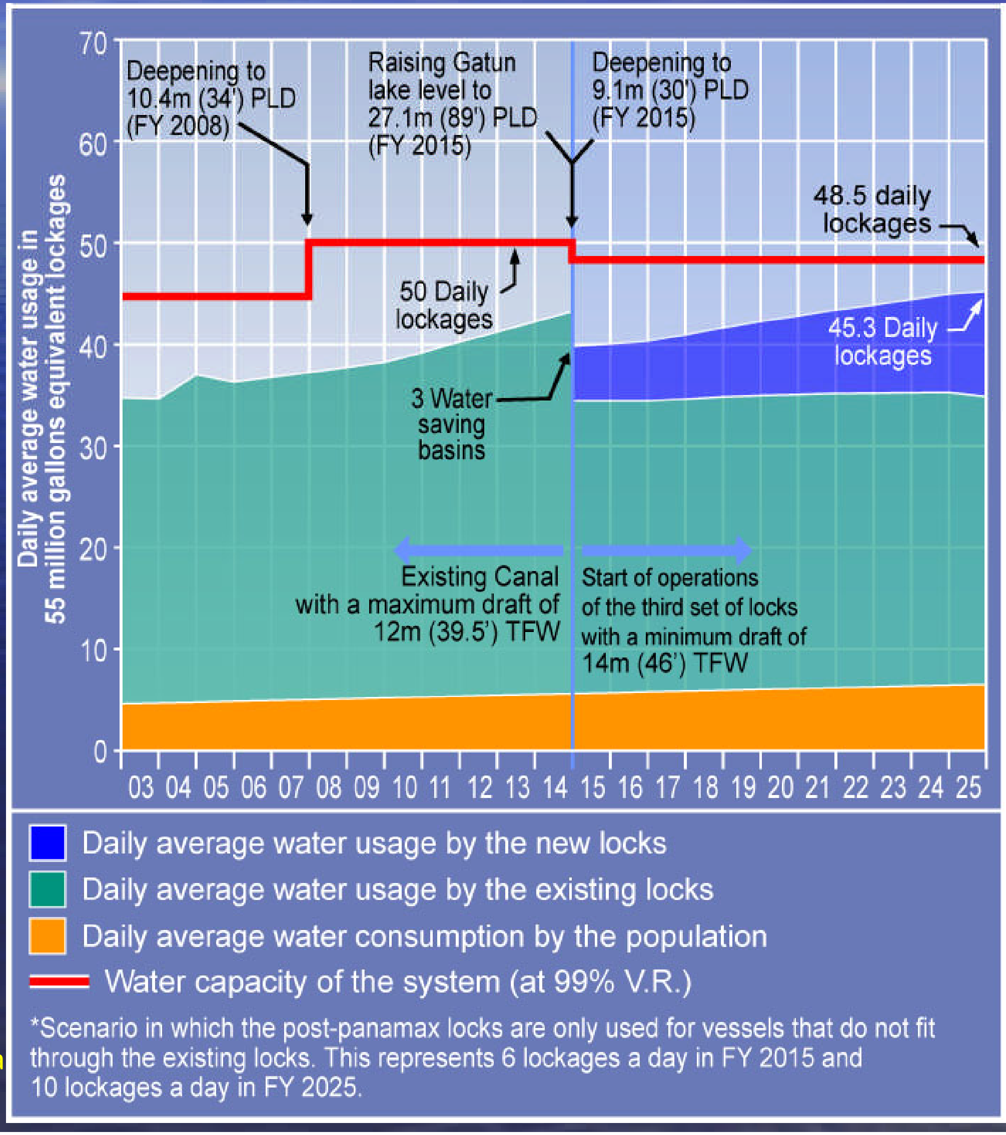
Water saving basins

The new locks will transit twice as much cargo with less water



Maximizing the utilization of the existing Canal's watershed

The expanded Canal will provide enough water for municipal and industrial uses and for the operation of the Canal beyond 2025



Panama Cana

Physical Model of the Filling-Emptying System For Panama Canal's Third Set of Locks

Consorcio Post-Panamax

Compagnie Nationale du Rhone, Lyon

Position of ship in lock

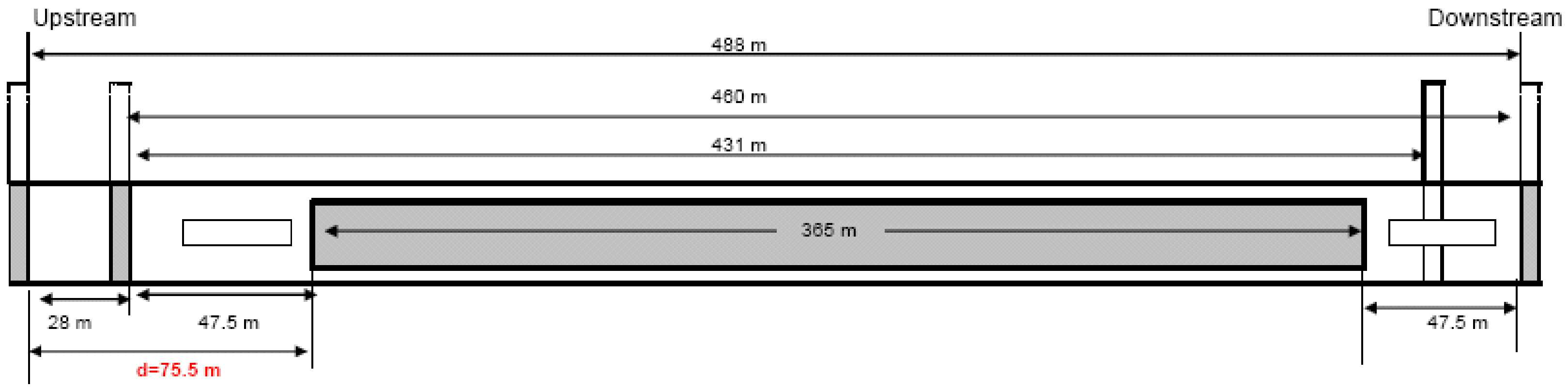


Figure 5-8: Ship centred in the middle chamber considering the standard filling phase (1A) (d=75.5 m)
Ship centred in the chamber considering the non standard emptying phase (2C) (d=75.5 m)

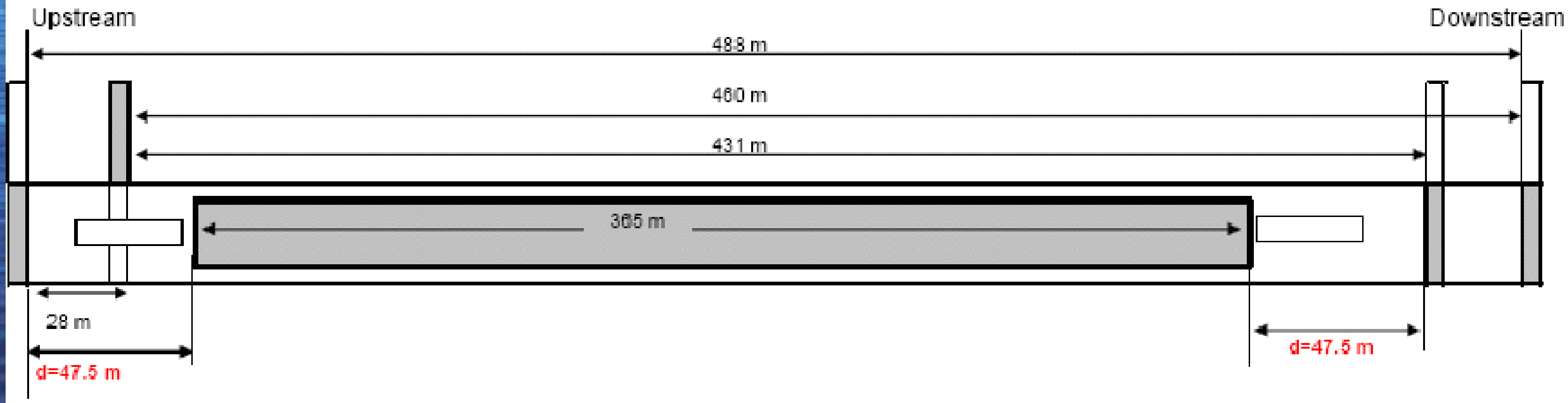
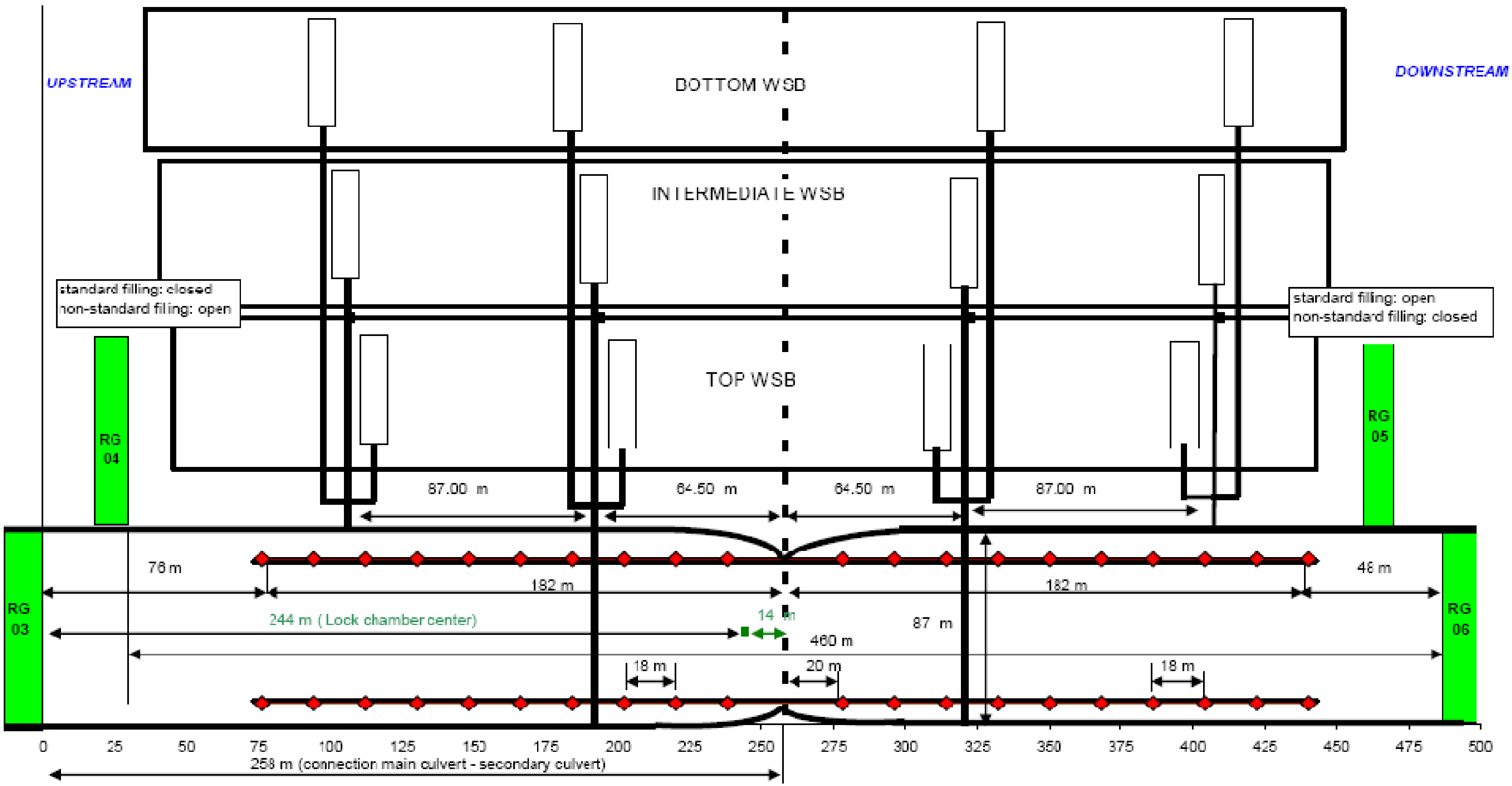


Figure 5-9: Ship centred in the middle chamber considering the standard emptying phase (2A) (d=47.5 m)
Ship centred in the chamber considering the non standard filling phase (1C) (d=47.5 m)

Optimization studies : system retained for physical model study



Presentation of the model

Retained geometric scale: $E_l = 1/30$

Froude similarity

Reynolds number must be > 4 000

Deduced scales:

→ Velocity scale $E_V = 1/5.47 = E_l^{1/2}$

→ Discharge scale $E_Q = 1/4\,929 = E_l^{5/2}$

→ Time scale $E_t = 1/5.47 = E_l^{1/2}$

→ Force scale $E_F = 1/27\,000 = E_l^3$

Presentation of the model

Model sizes (example):

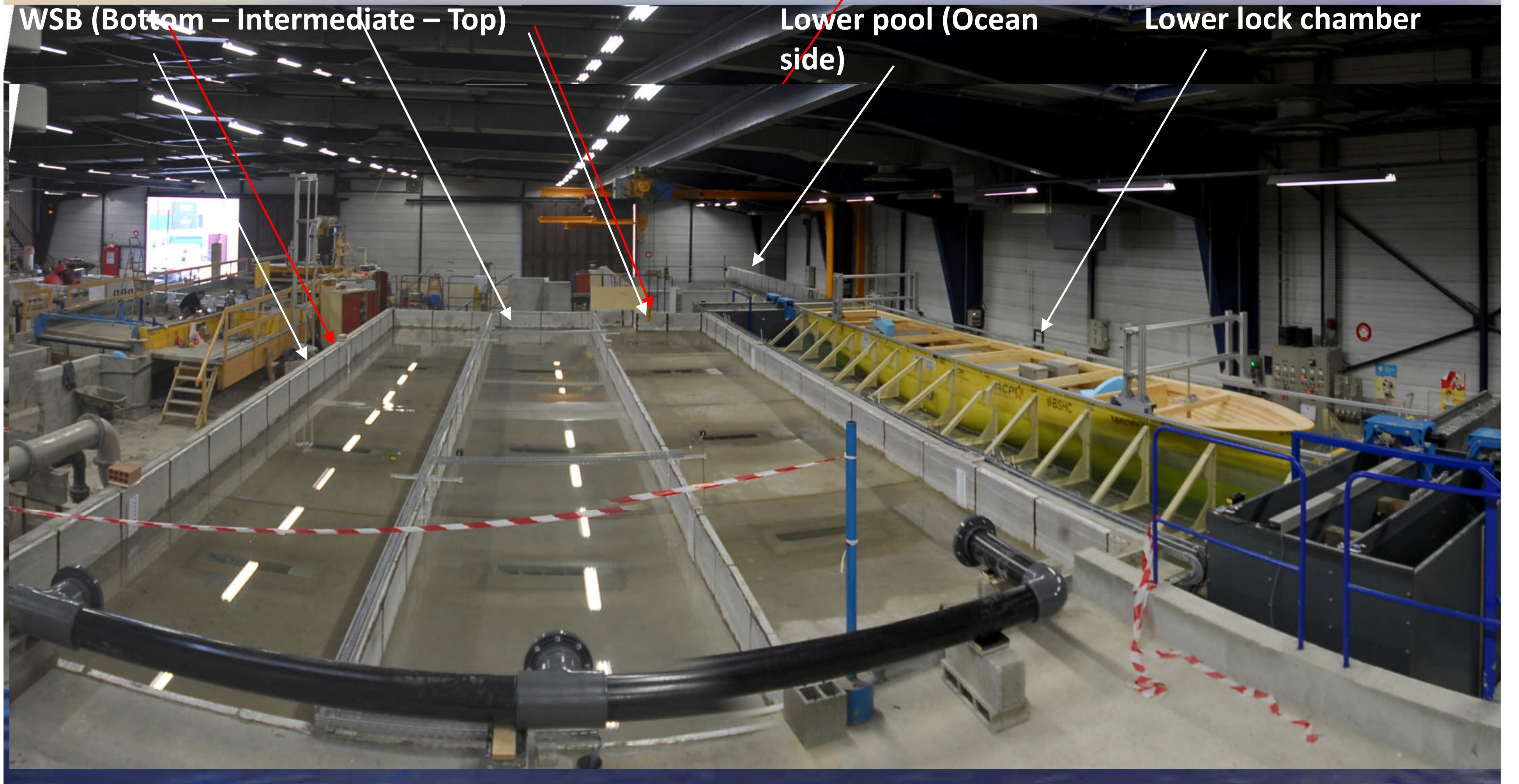
- **Lock chamber (460 x 55 m) → 15.30 m x 1.80 m**
- **Ship model (366 x 49 m) → 12.20 m x 1.62 m**
- **Velocity of 7 m/s → 1.3 m/s**
- **Discharge of 500 m^3/s → 100 l/s**
- **F/E operations of 10 minutes → 2 minutes**

Presentation of the model

Upper pool (Gatun lake side)

Rolling gates & gates recesses

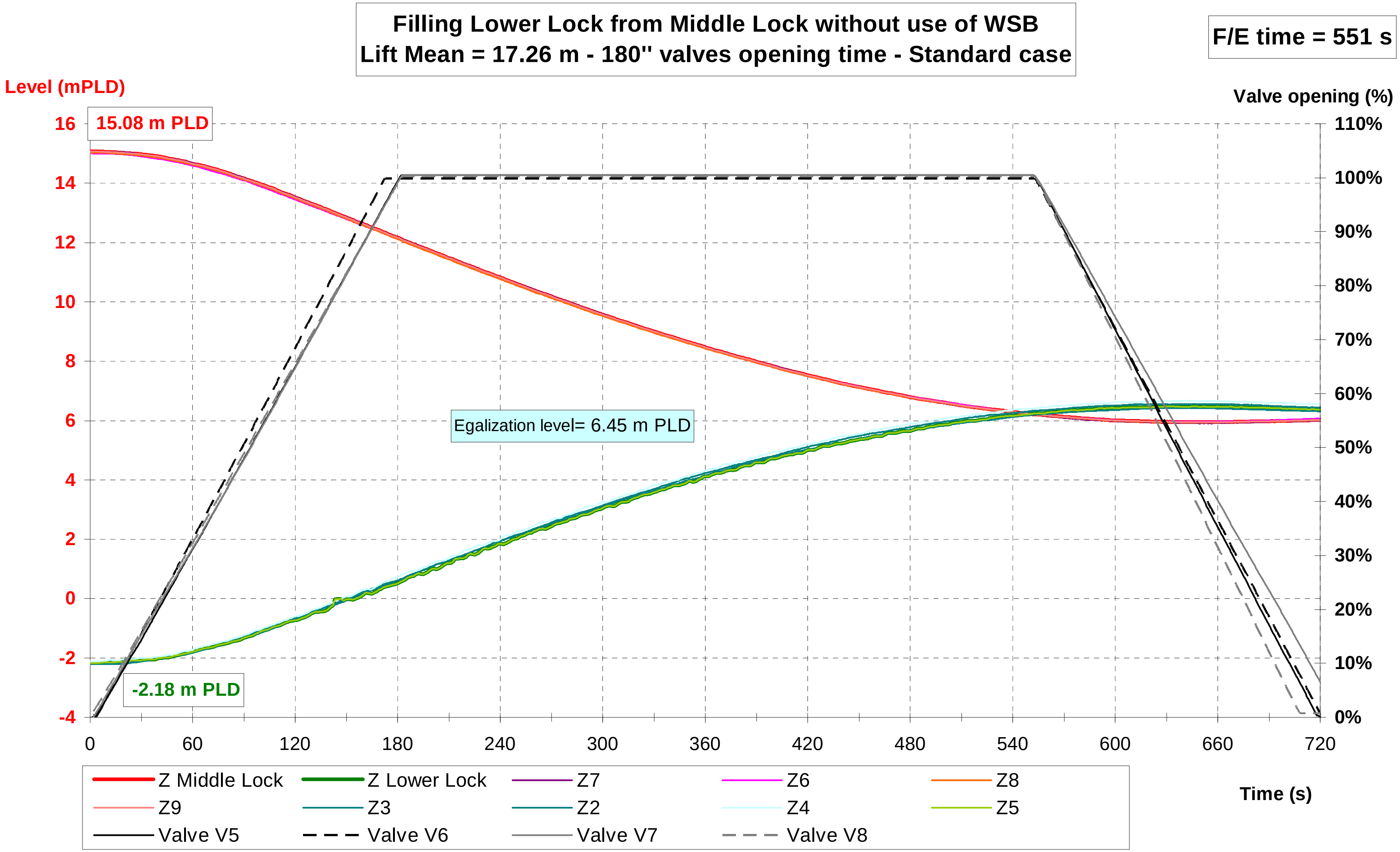
Presentation of the model



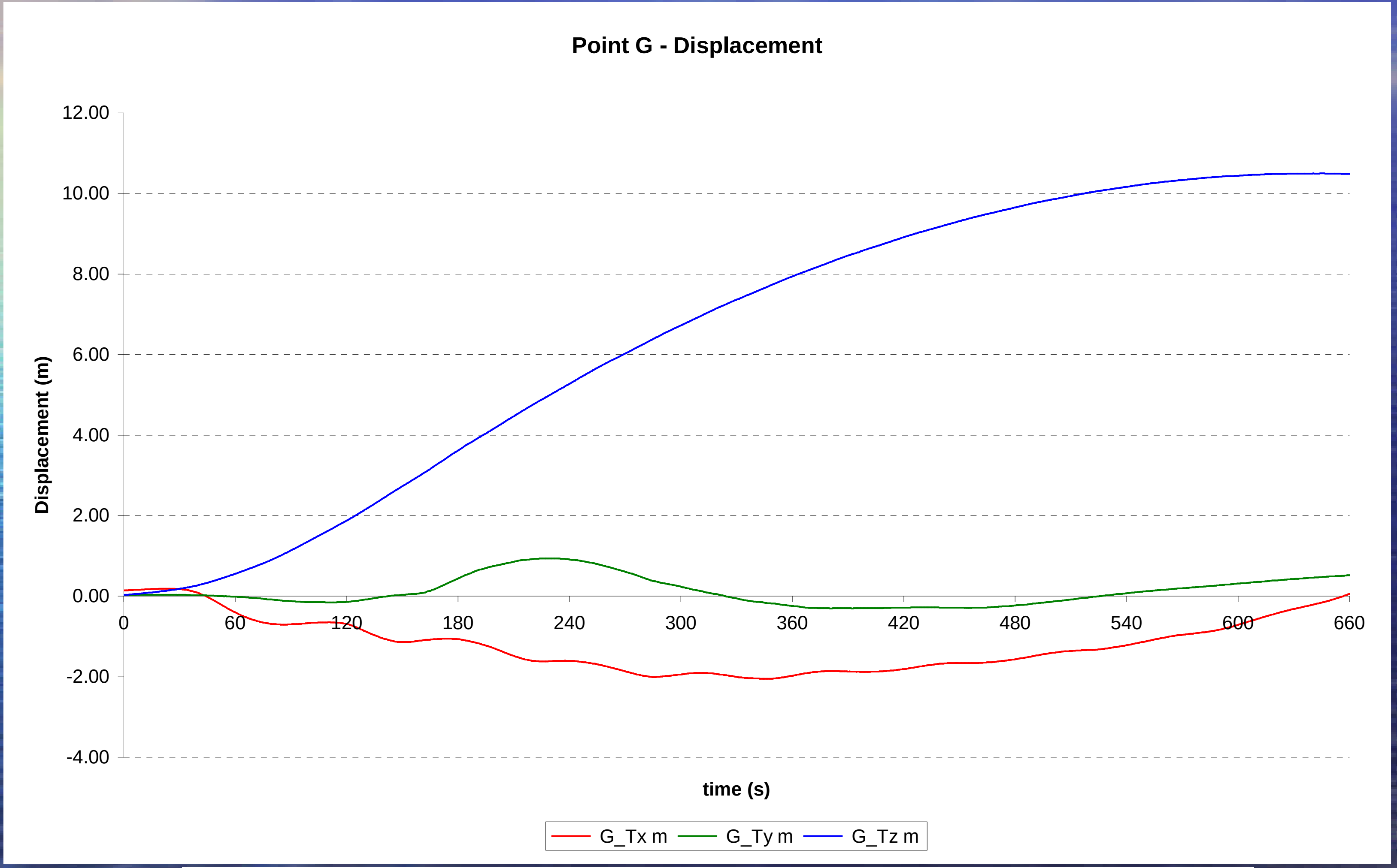
Measurements carried out

- Filling/Emptying times,
- Hawser forces,
- Water levels & water slope in the lock chambers,
- Velocity & flow rate in the main culverts & ports,
- Pressure downstream of the valves,
- Valves position,
- Ship motions when free to move.

Data recorded on physical model



Example of ship motion measurements

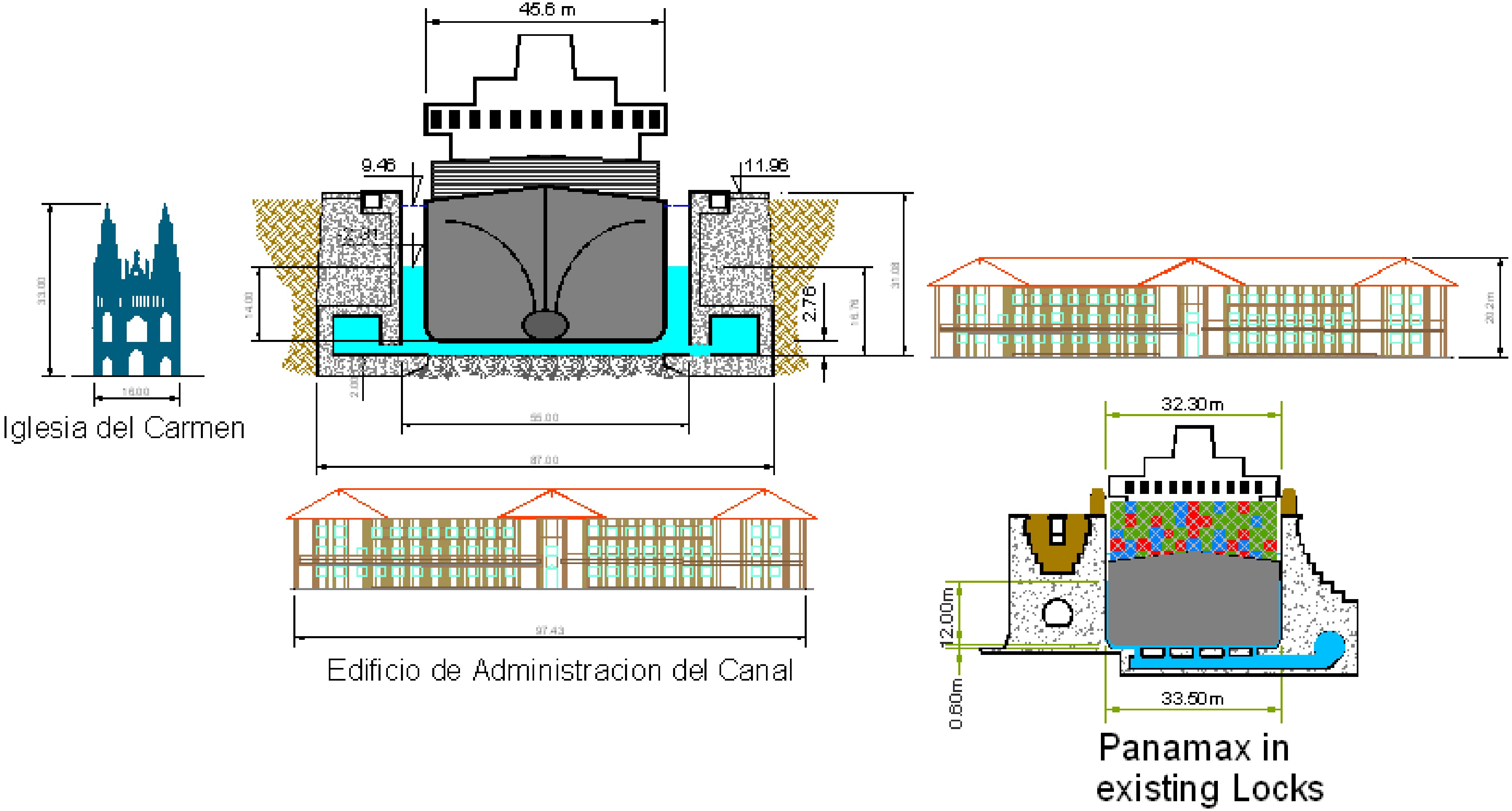


Lock-Lock filling - Non-standard - Maximum Head (20.22 m)

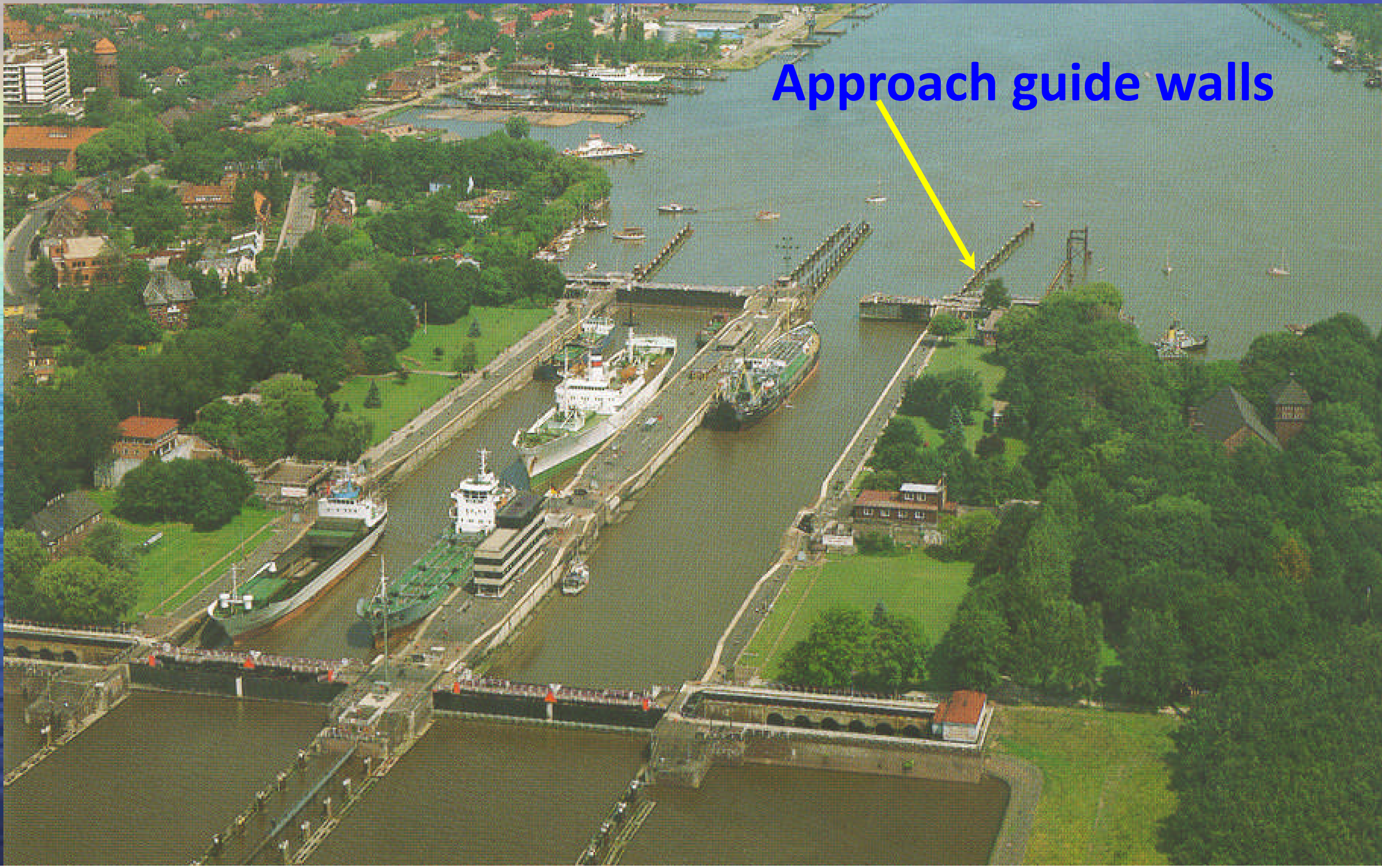
Conclusions from the lock filling/empting model study

- The filling/emptying time was within an acceptable range,
- the hawser forces were acceptable,
- the ship motion was acceptable,
- the velocities in the culverts were acceptable,
- the pressure in the conduits were acceptable,
- the gate forces were acceptable,
- the balance of flow in the lock chamber was good.

Comparative lock sizes: Present & Expansion Project



Ship lock designs in Europe



Tank Tests of Vessel Entry and Exit for Third Set of Locks

Tractebel Engineering SUEZ

TECHNUM

COYNE ET BELLIER

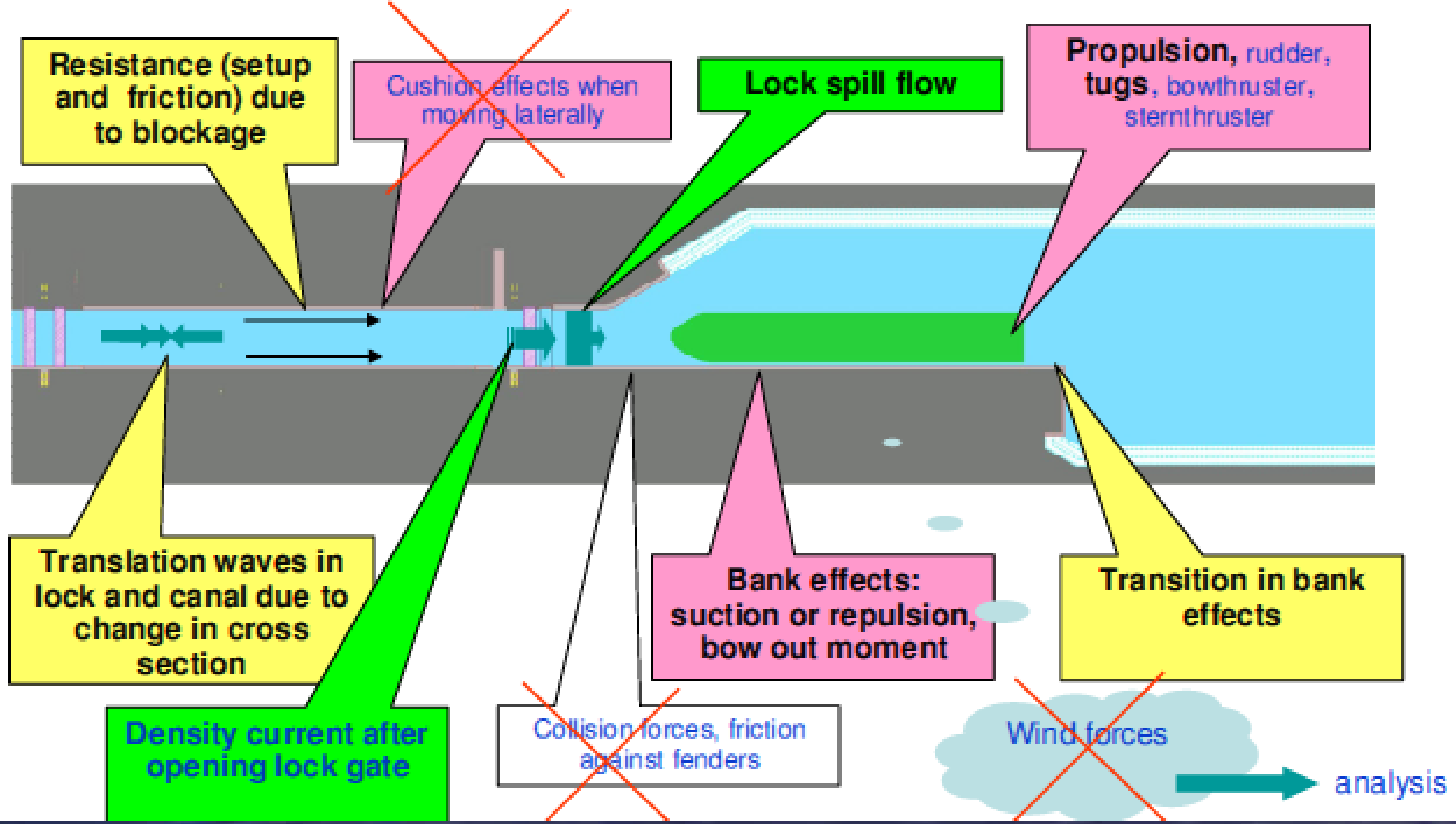
Compagnie Nationale du Rhône

Tank Tests of Vessel Entry and Exit for Third Set of Locks

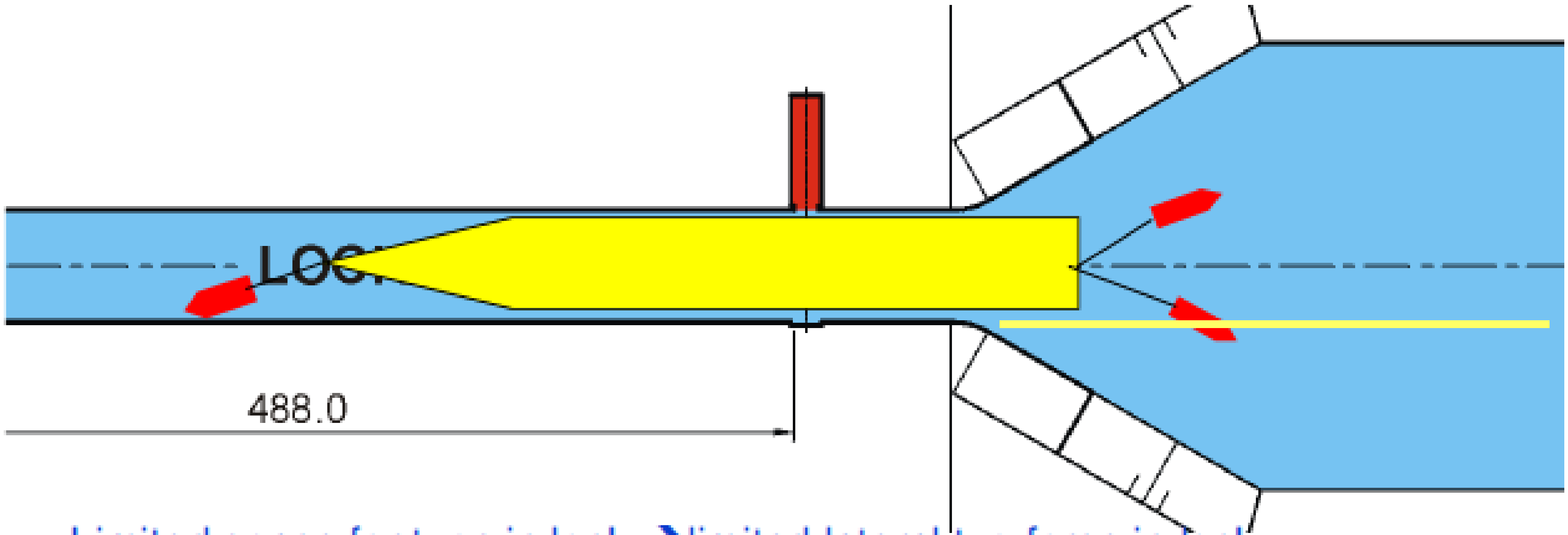
- Perform a literature study
- Perform tank test model studies for vessel maneuvering in future Third Set of Locks in the Pacific, Atlantic, and Lake sides of the Panama Canal to determine design and operational criteria, including:
  - Squat,
  - Need and configuration of approach walls,
  - Fenders inside lock chambers,
  - Tug assistance.

  with the following ships:
  - 12,000 TEU containership,
  - 8,000 TEU containership,
  - Bulk carrier.
- Make a plan to use the model data on the ACP simulator
- Make recommendations for further studies

Forces acting on the ship



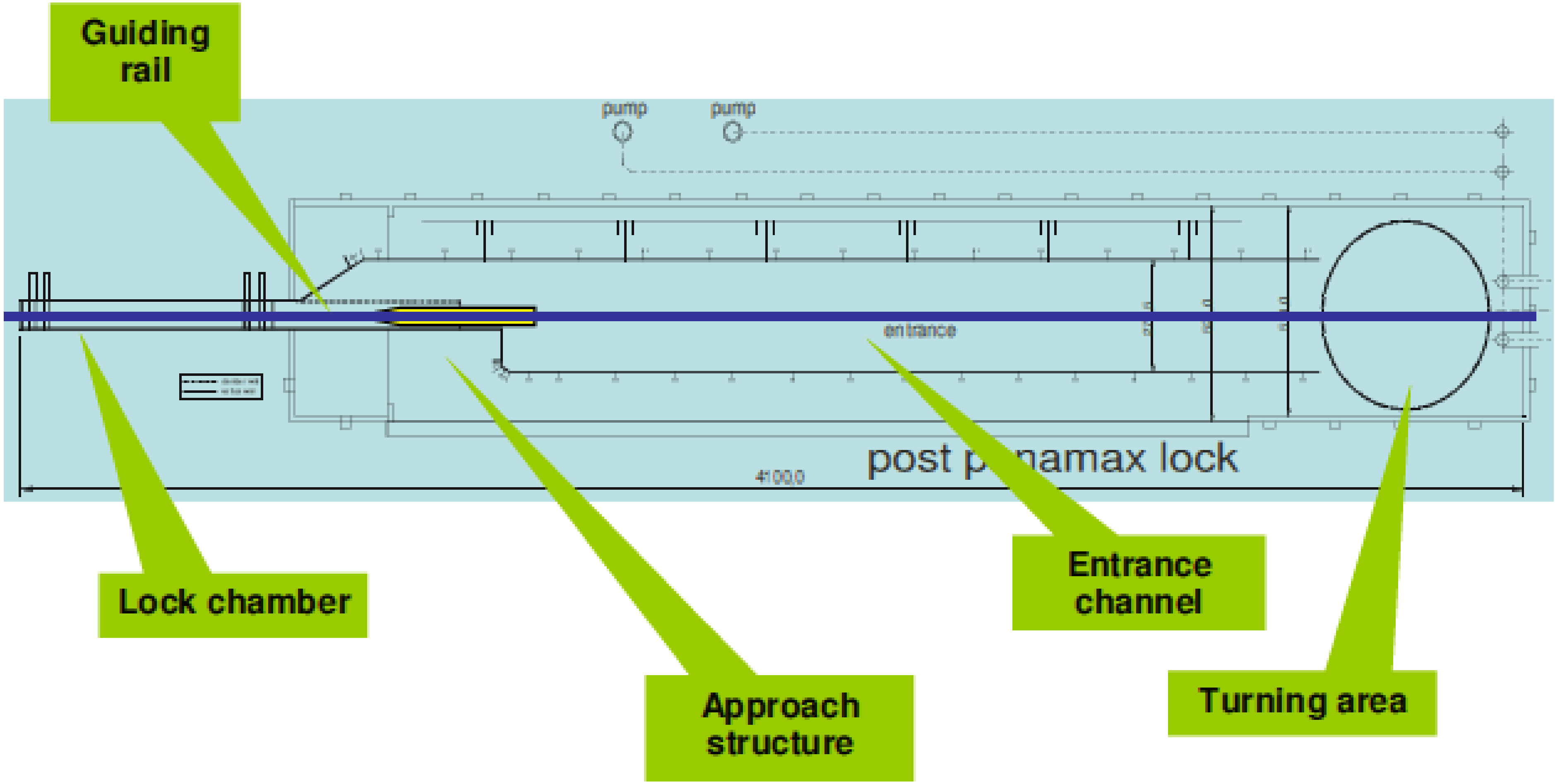
Tug assistance in lock approach and entry



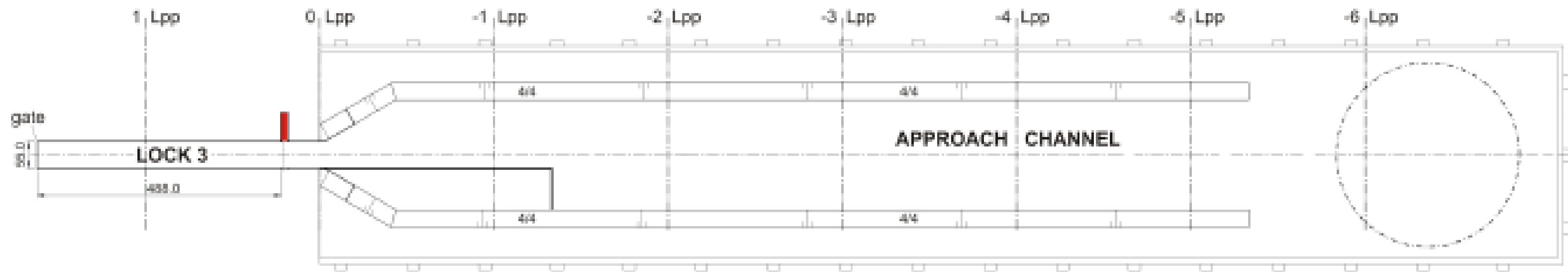
- Limited space for tugs in lock ➔limited lateral tug force in lock
- Construction in approach ➔ limited lateral tug force

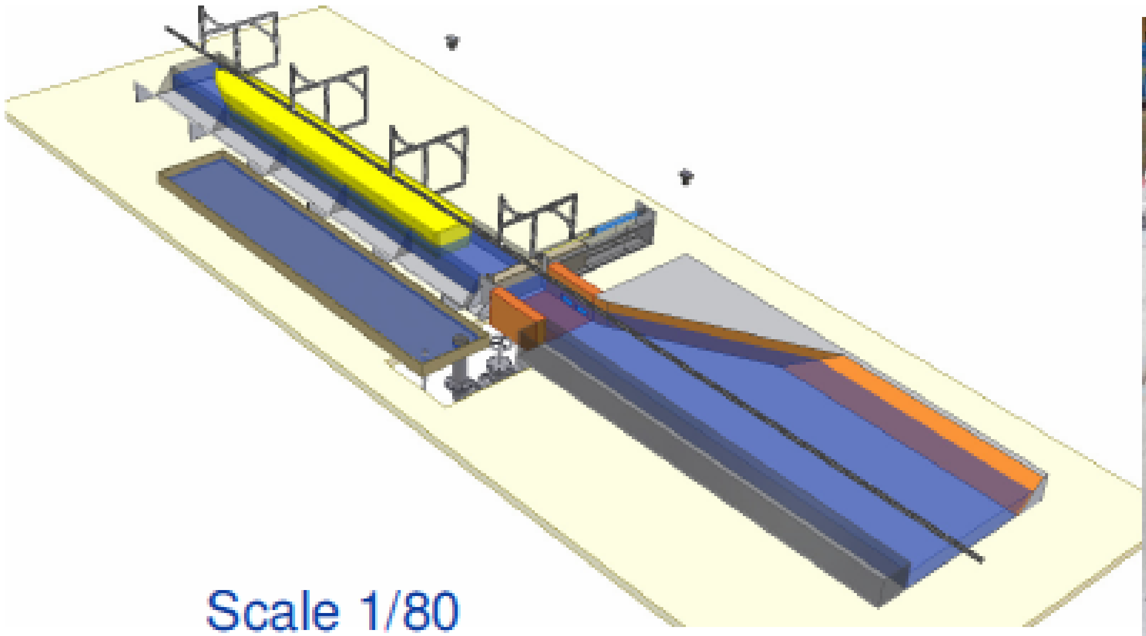
➔ lateral forces have to be measured and evaluated versus available tug assistance (and bow thrusters, rudder force…)

Post-Panamax locks scale model 1/80



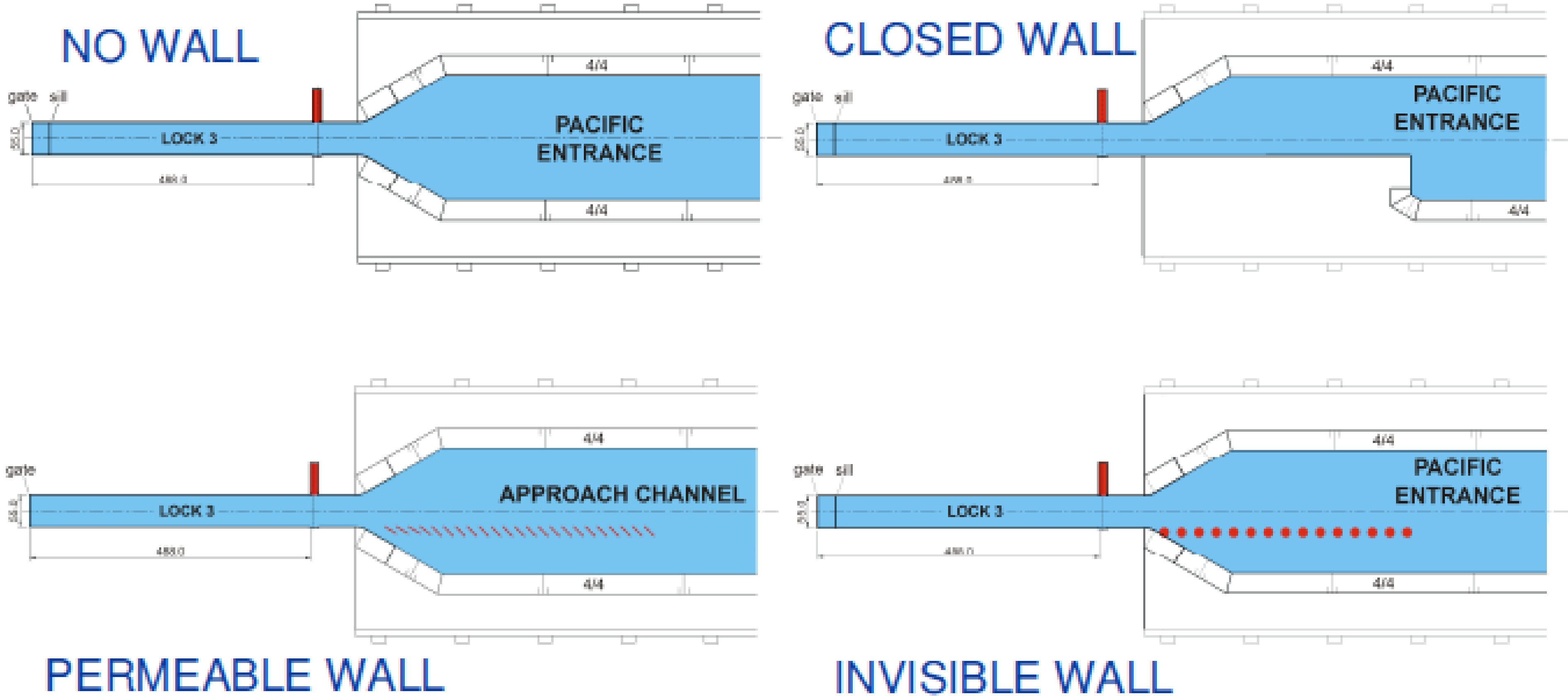
Scale model lock with approach



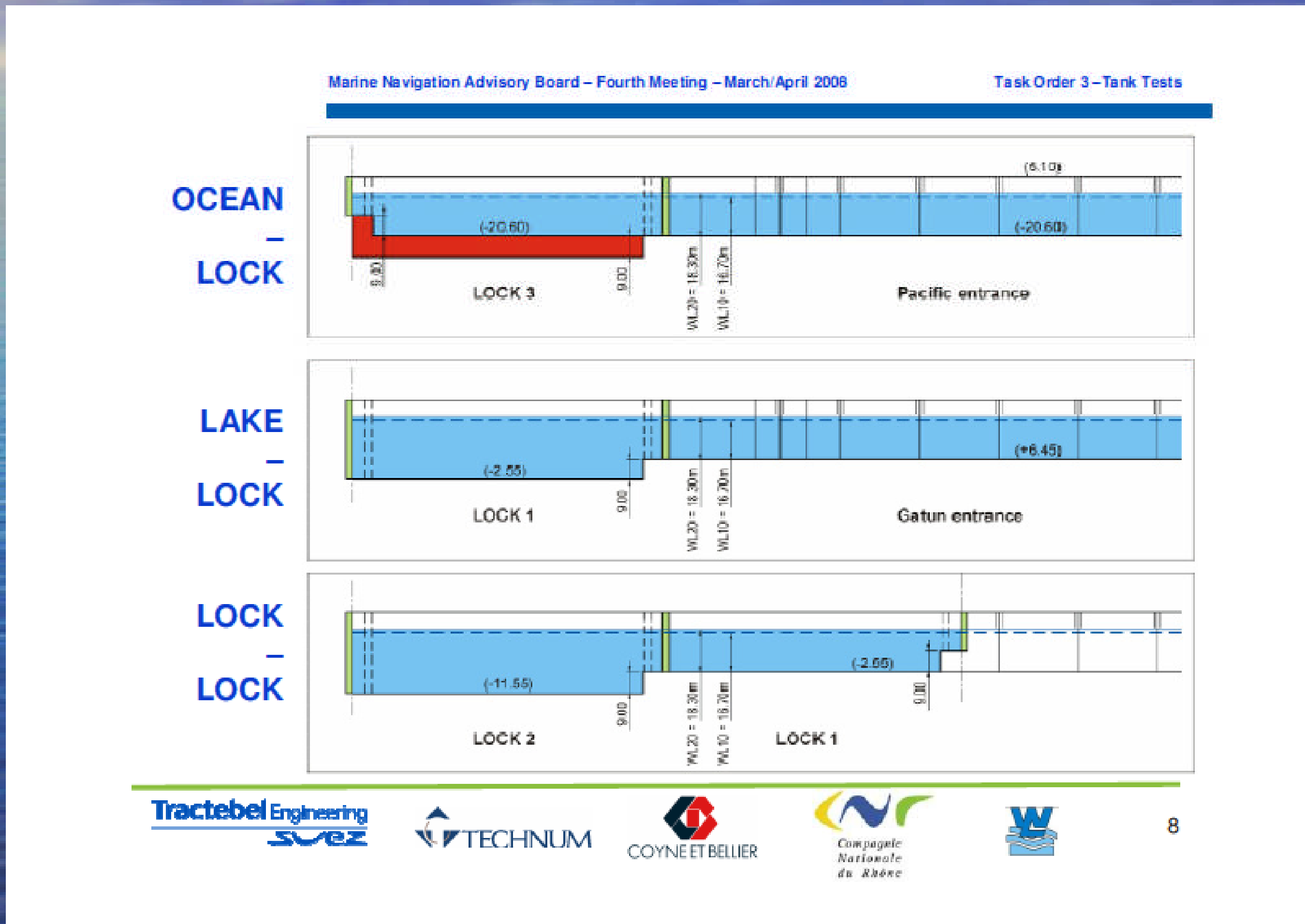


Scale 1/80

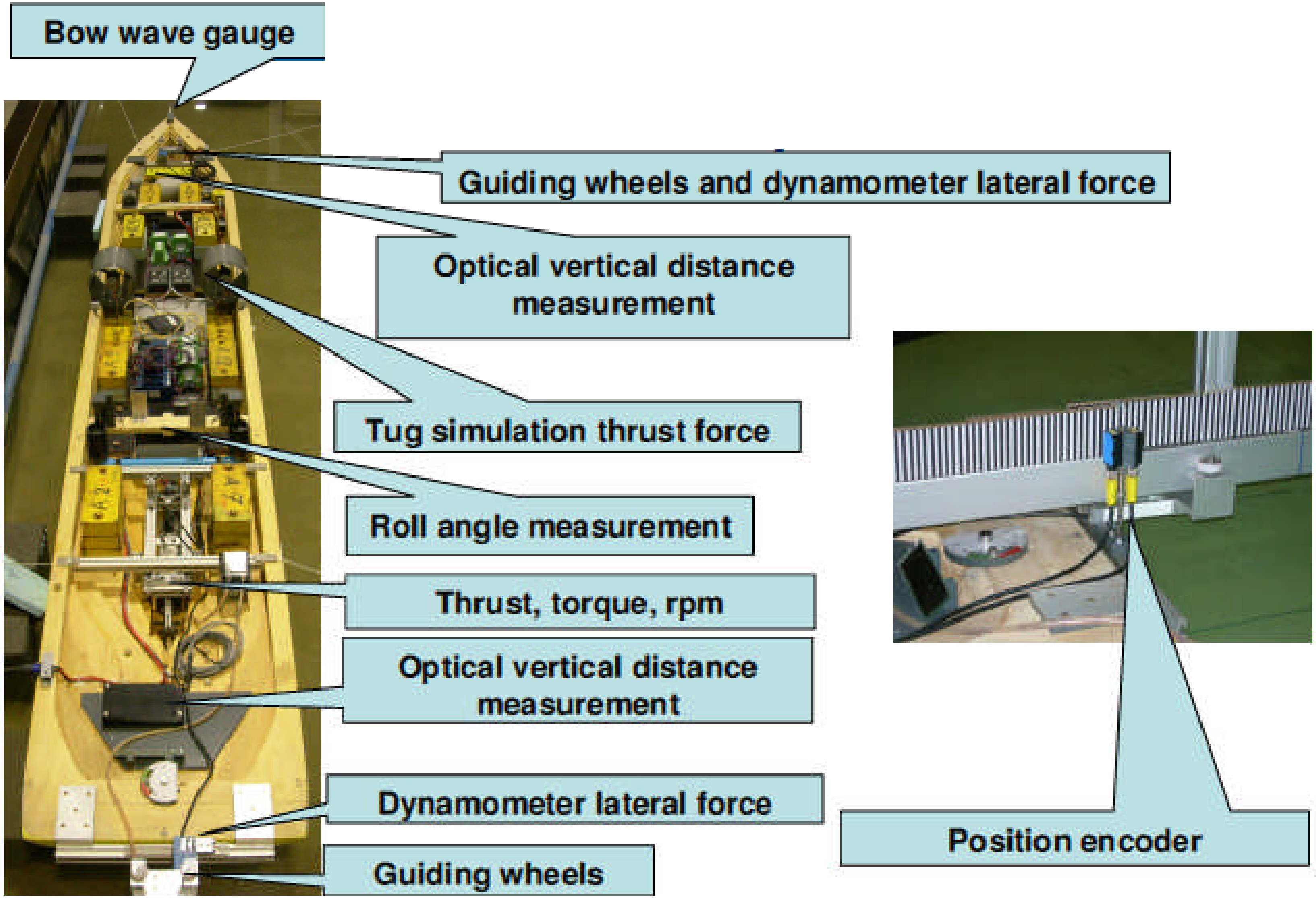
Approach wall configurations



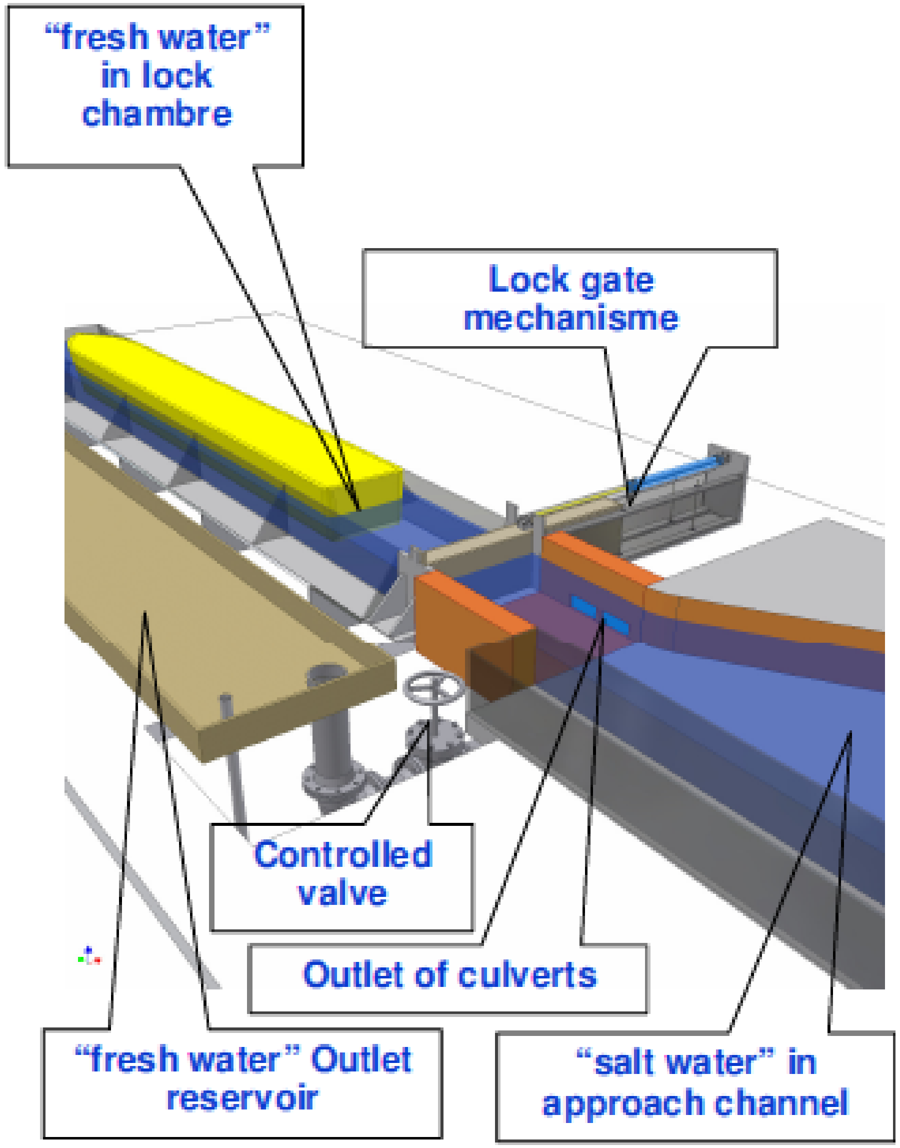
Profiles of lock configurations



Ship's instruments



Density current simulation



- Lock spill: from outlet reservoir to outlet of culverts, discharge controlled by a valve
- Lock gate mechanisme
- Salt water reservoir (1012 kg/m³)
- Measuring density in lock, reservoir and entrance
- Mixing tracer color in the fresh lock water (1000 kg/m³)
- Recording water level in outlet reservoir
- Fixed ship position: measure longitudinal force on ship.

General conclusions: 12,000 TEU Container Carriers

- The open approach wall has always the smallest effort for a given condition.
- The differences decrease with increasing eccentricity.
- If a wall should be fitted the choice is between the invisible wall and the permeable wall, depending on the fact if propeller action will be used (advisable option, if so **invisible wall is better**) or not (**permeable wall is better**).

Conclusions:
Additional 30% UKC

- Manoeuvres can be carried out faster and easier with a larger under keel clearance, especially when the ship enters centrically;
- Eccentricity has more influence when the under keel clearance increases;
- The disadvantage of a larger under keel clearance is that due to the decreased resistance, the stern tugs have to provide more braking power and also have to counteract (relatively) more lateral force during braking;
- The increased under keel clearance is especially a bonus when waiting along the approach wall during density current exchanges.

Lock to lock transitions: Conclusions

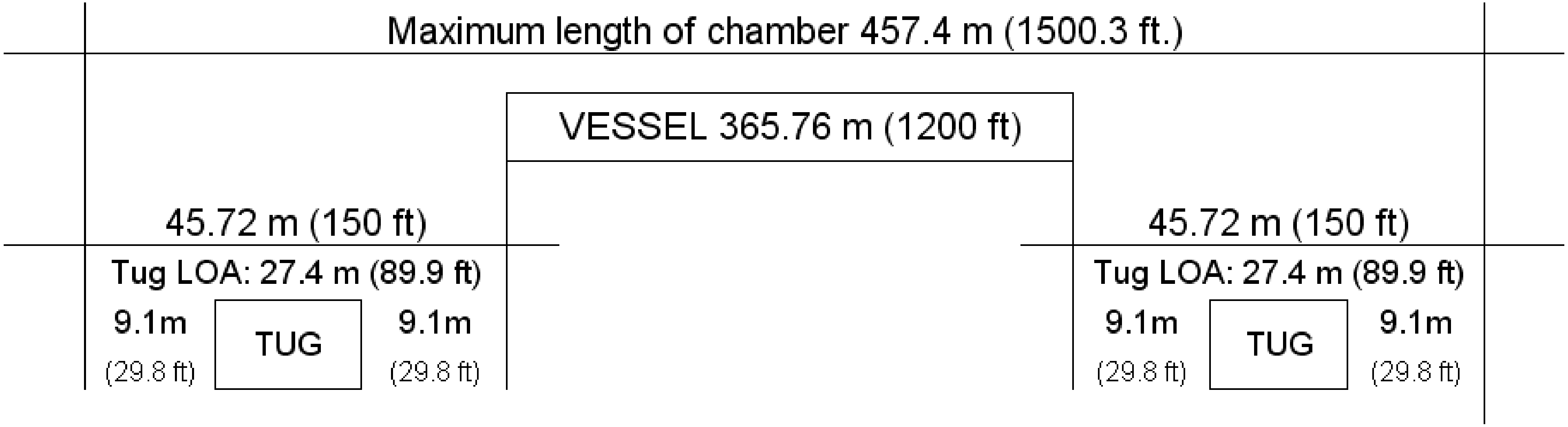
- All tested lock-lock transitions at a minimal under keel clearance of 20% can be carried out. In some cases a bow thruster or even a stern thruster is advisable.
- The manoeuvre can be carried out faster if the propeller rate is increased, however too high propeller rates generate oscillating forces, sinkages and roll angles due to the turbulence.
- Considering effort, time, thruster use, the optimal manoeuvre can be carried out with 2 knots at dead slow in more or less 15 min.
- Going from a deeper chamber to a more shallow chamber is easier and faster:

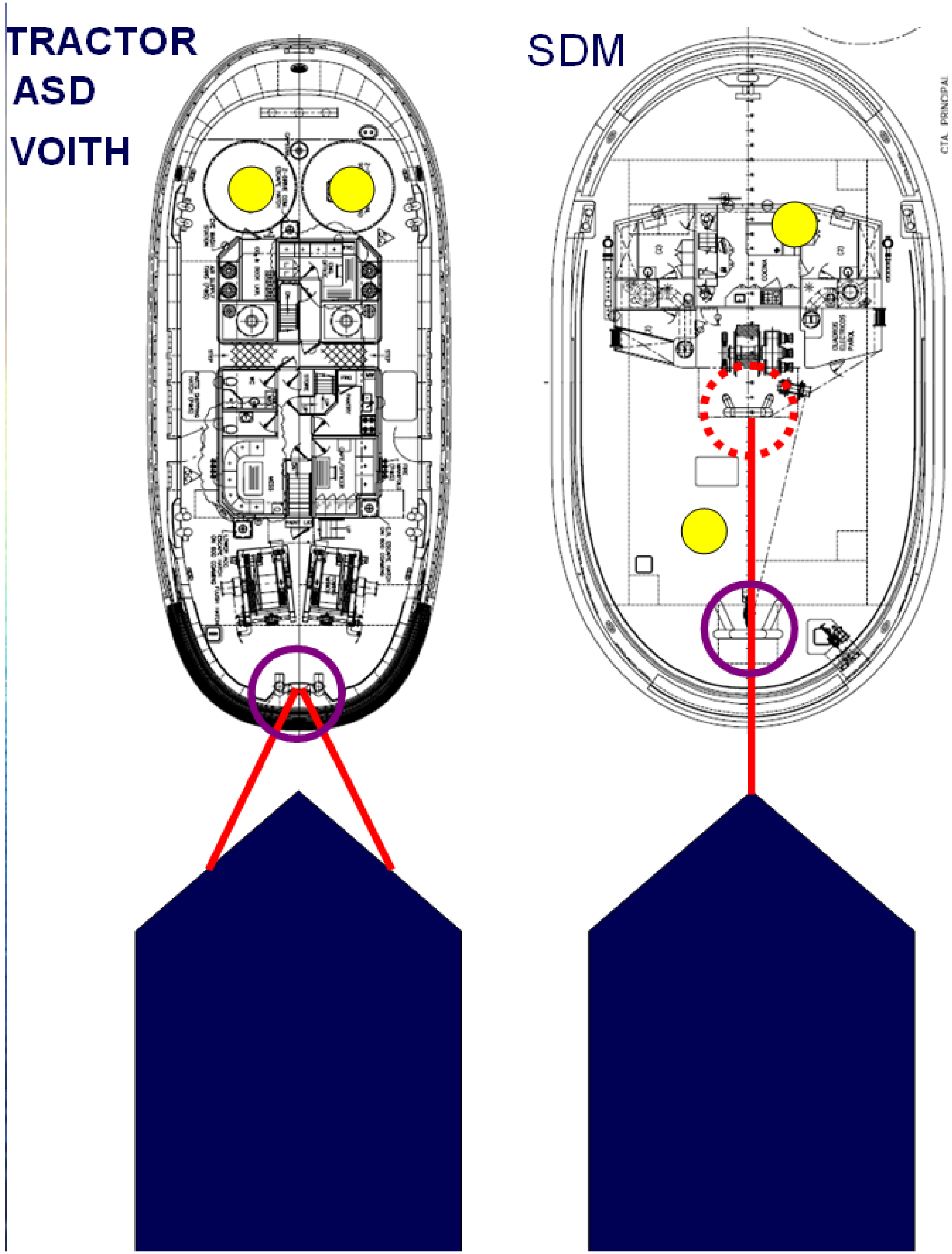
  Ocean → *Lake* will be easier and faster than *Lake* → *Ocean*

Exit maneuvers conclusions

- To leave the lock a speed of 1 knot within the lock seems to be an optimal limit. Increasing the speed will give a small bonus of time, but a huge increase of effort.
- Once outside the lock the speed can be increased to 2 knots if no wall or a permeable approach wall is placed, but the speed still needs to be limited to 1 knot along a closed approach wall, because the large lateral forces cannot be counteracted at a speed of 2 knots.
- After the approach wall a speed of 4 knots can be used.

Operating room for tugs in lock chambers





Tugs maneuverability options

Due to the location of the propulsion units and the existence of an alternate pivot point between the units, the SDM can provide assistance transversely in a more effective way than an ASD, VOITH or TRACTOR tug.

Location of propulsion units

Pivot point

Alternate pivot point on the SDM

Safety factor and length of ropes

Minimum of 3.5:1 is required, meaning that the rope must have a minimum breaking strength of at least 3.5 times the sustained bollard pull of the tug.

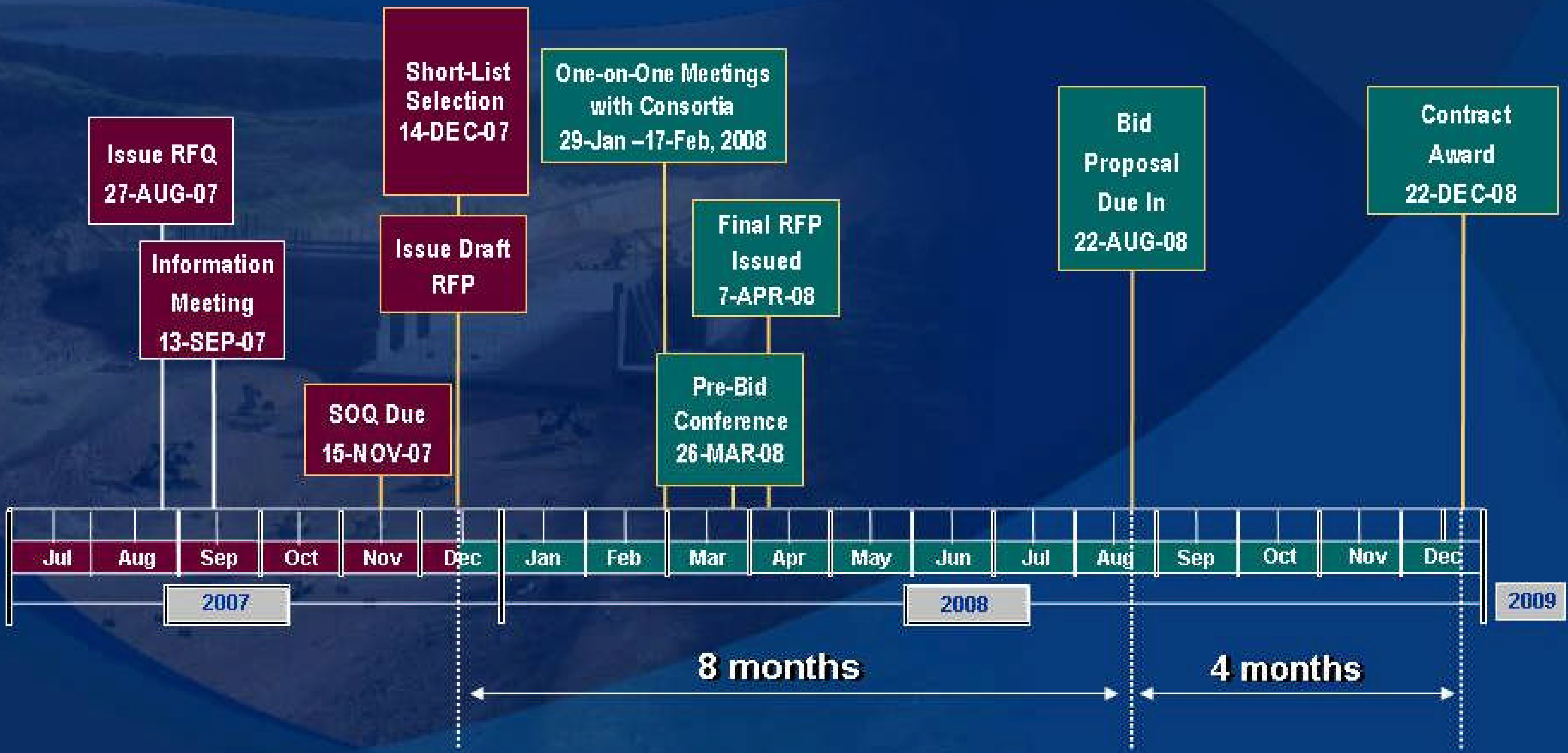
Disadvantage of the close in maneuvers

In Canal Operations, tugs assist vessels very close the stern, for this reason, propulsion units are required to perform in a negative water flow condition which may stall one of the main engines or both.

Topics for selection of tugs

- Maximum LOA for tugs.
- Optimum tug design,
- Number of tugs,
- Arrangement of tugs (2 on stern & 1 on bow),
- Optimum Bollard pull,
- Optimum hawser arrangement.

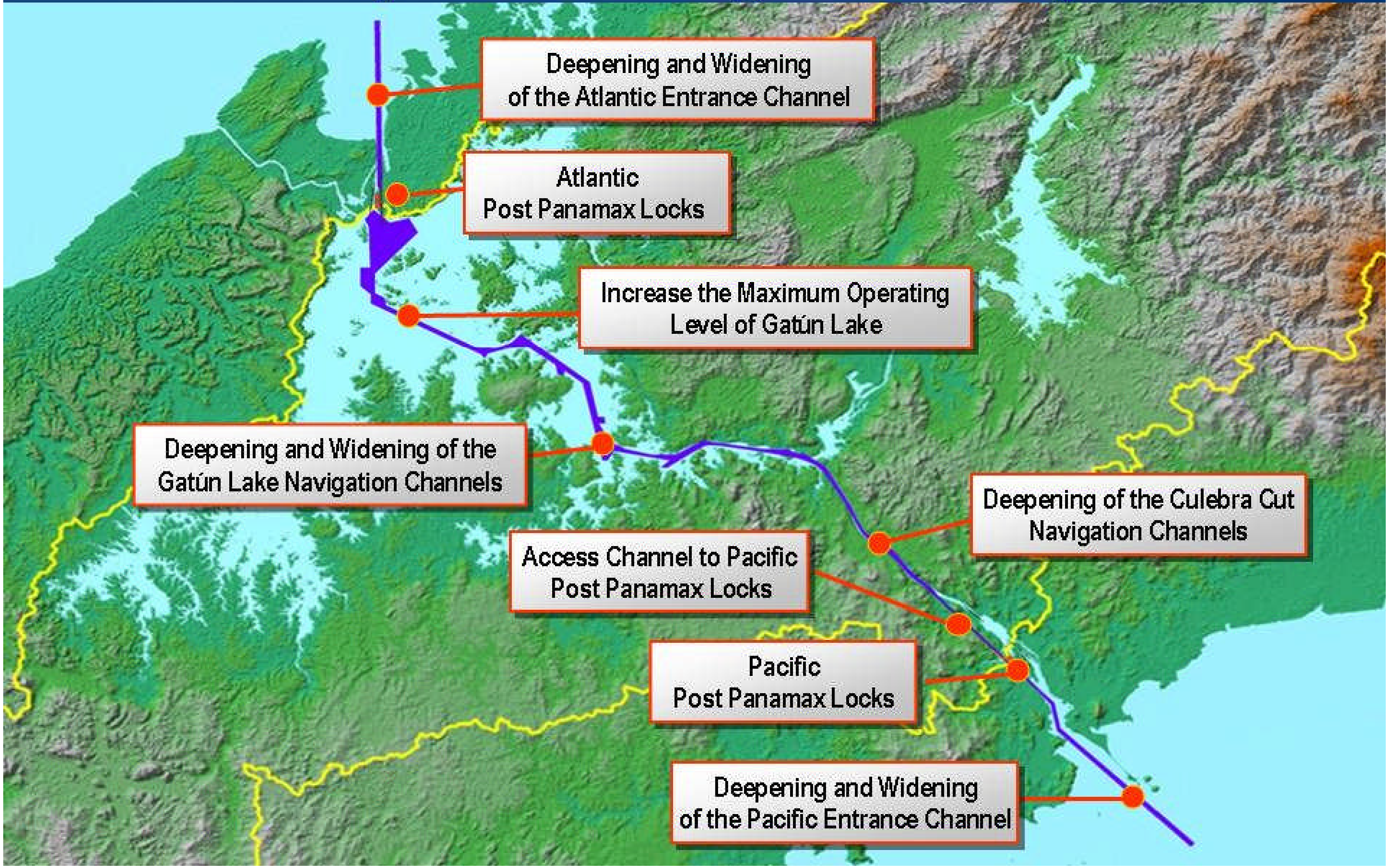
Locks Design-Build Project
Procurement Schedule



Prequalified Consortia

Consortio	Members	Designers	Gate Frabricators
C.A.N.A.L.	ACS Servicios, Comunicaciones y Energía, S.L. – Líder	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.		
Atlántico-Pacífico de Panamá	Bouygues Travaux Publics – Líder	AECOM – Líder	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		
Bechtel, Taisei, Mitsubishi Corporation	Bechtel Internacional, Inc. – Líder	Bechtel Internacional, Inc. – Líder	Wuchang Shipyard
	Taisei Corporation		
	Mitsubishi Corporation		
Grupo Unidos por el Canal	Sacyr Vallehermoso S.A. – Líder	Montgomery Watson Harza (MWH) – Líder	Heerema Fabrication Group
	Impregilo S.p.A.	IV-Groep	
	Jan de Nul n.v.	Tetra Tech	
	Constructora Urbana, S.A.		

Canal Expansion Program Components



The Panama Canal Expansion Program

Contact Information:

Larry Daggett
Chairman, Maritime Navigation Advisory Committee, ACP
Waterway Simulation Technology (WST)
601-638-4226
lldaggett@wst.ms

Thanks

Tercer Juego de Esclusas

ACP