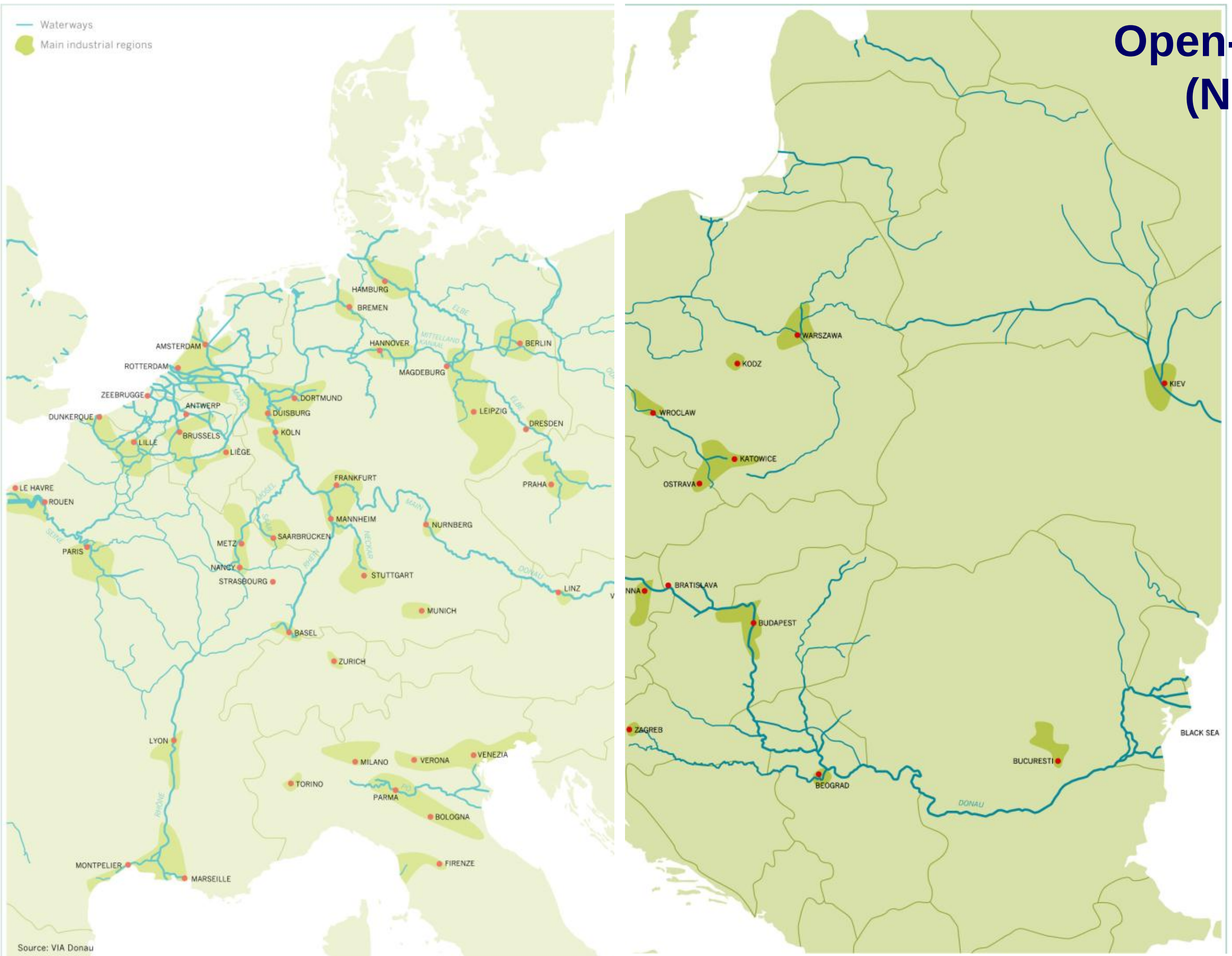
An Overview of Key Features of
WATER WAY INFRASTRUCTURE

EUROPEAN UNION NAVIGABLE WATERWAYS

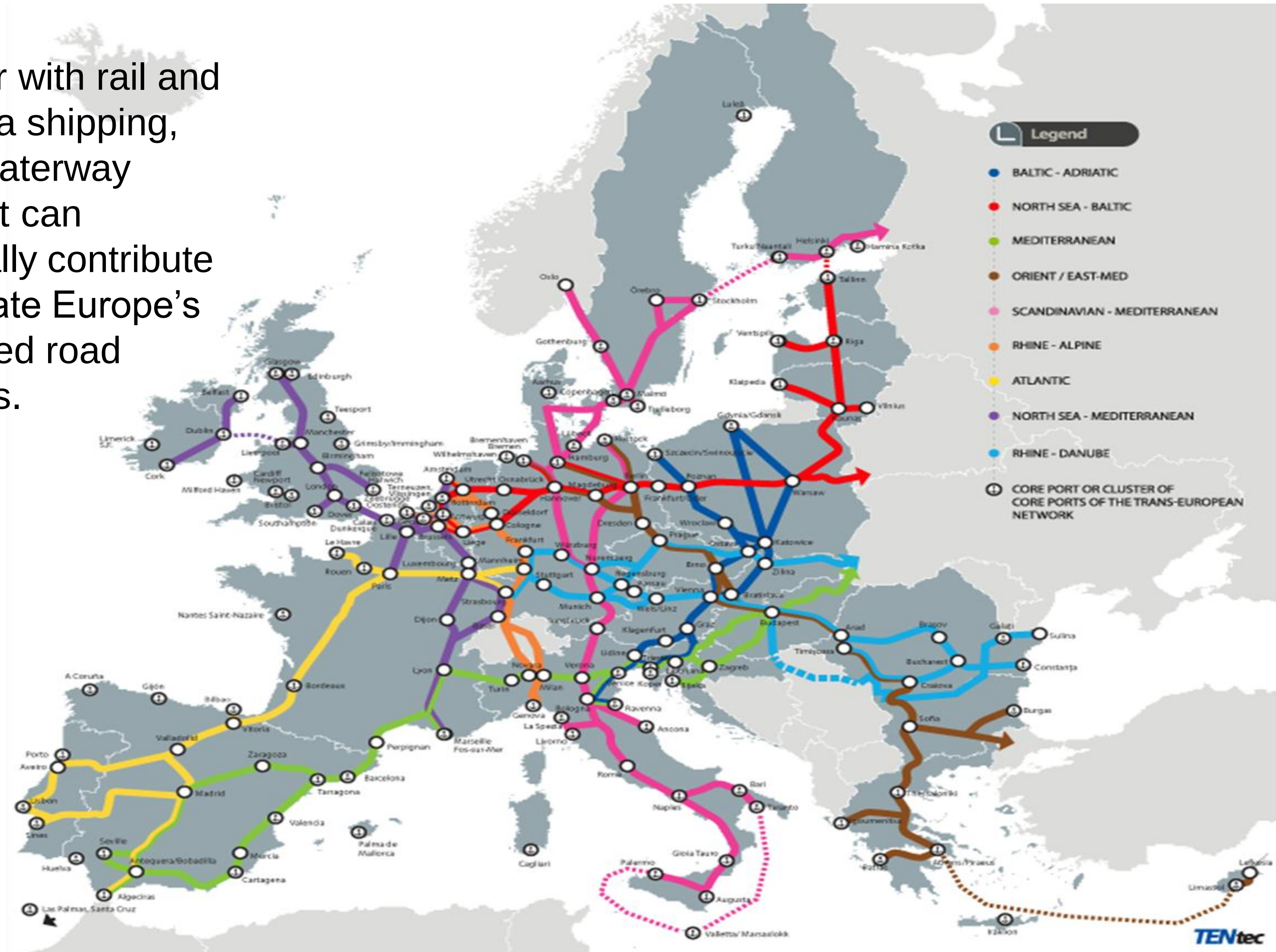


Open-river navigation (Natural channels)

Canalized river

Canals

Together with rail and short sea shipping, inland waterway transport can essentially contribute to alleviate Europe’s congested road networks.



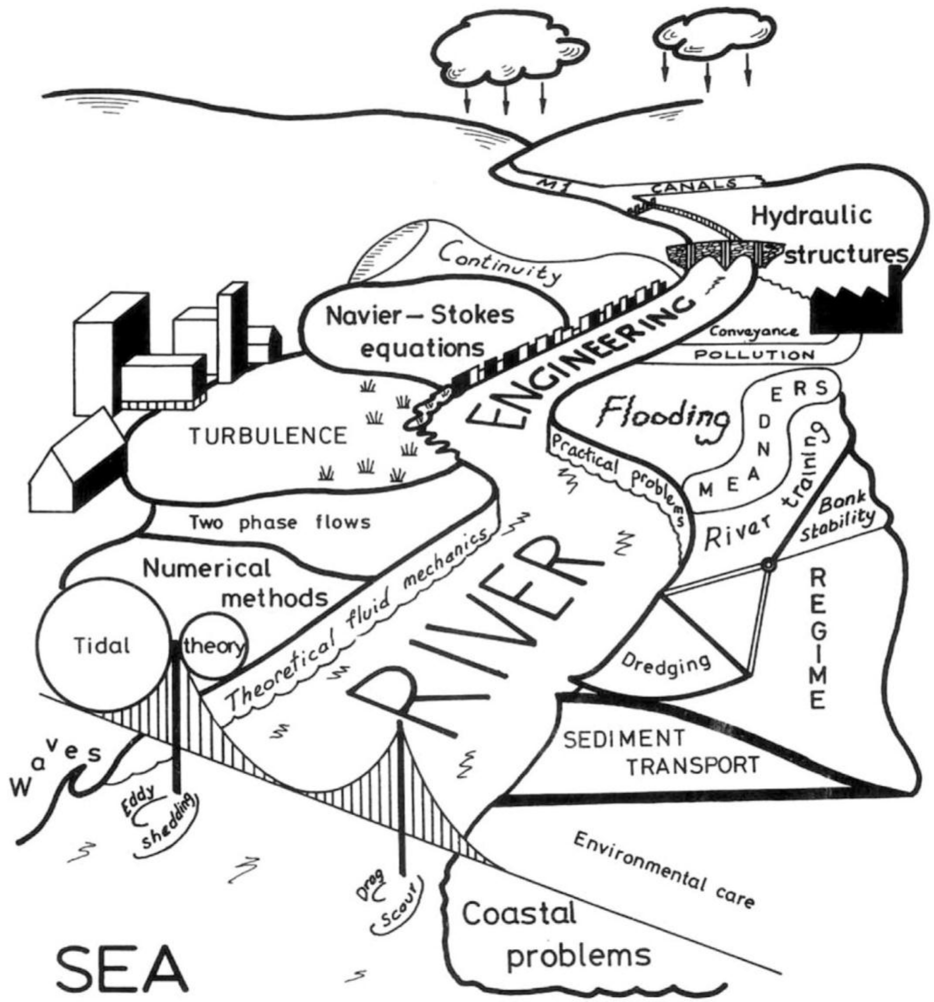
RIVER USES AND MEASURES TO ACHIEVE THEM

RIVER USES AND MEASURES TO ACHIEVE THEM

1 Measure to achieve the required use
2 Measure of secondary importance for the use
3 Measure which might be necessary as result of the operation

Measure	Bed regulation								Discharge and water level regulation		Quality control
	repeated dredging	temporary construction in river bed	fixation of bottom	elimination of obstacles from low-water bed	channel rectification and fixation	channel constriction	revetments and groynes	rectification in the flood plains	reservoirs	weirs	quality control works
Use of river											
Flood control					1		3	1	1		
Navigation	1	1	2	1	1	1	3		1	1	
Hydropower									1	1	
Irrigation and water supply			3				3		1	2	
Waste discharge											1
Bank protection			2		1		1				
Cooling water						3	2				1
Commercial sand dredging	1		3								
River crossings		1					3	2			
Control of sea water intrusions			2						2	2	

RIVER ENGINEERING



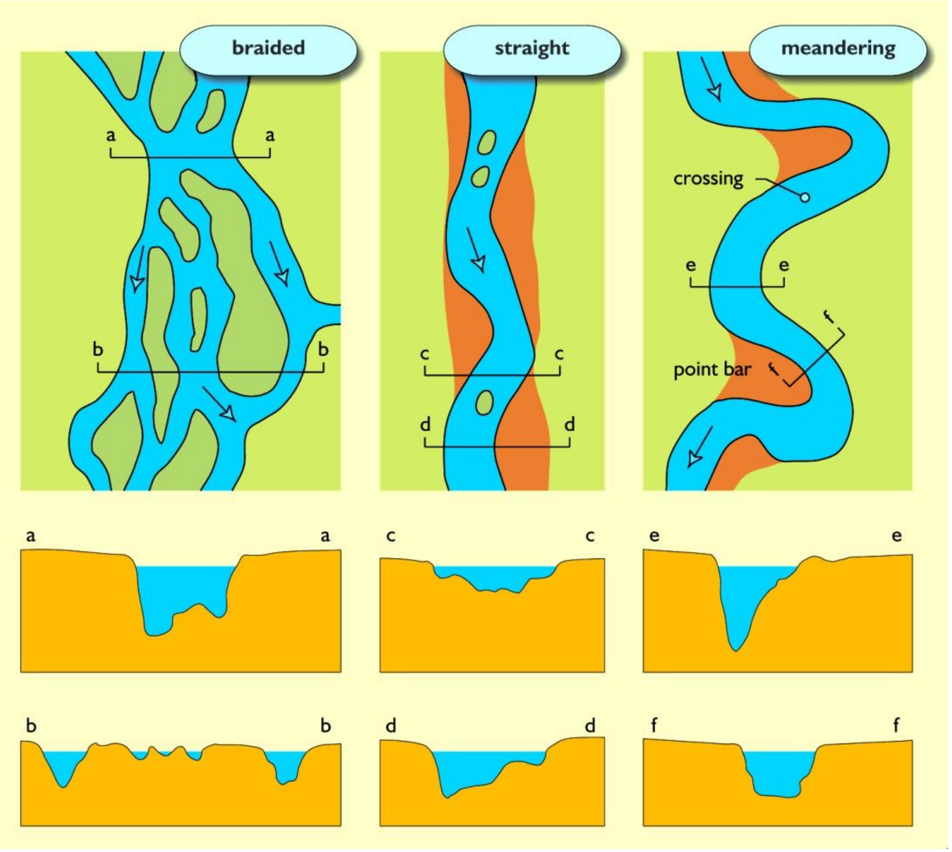
From Nakato and Ettema (1996)

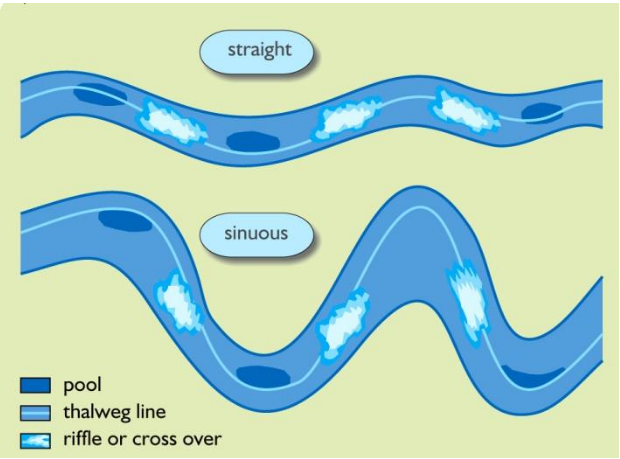
WATERWAY TRAINING STRUCTURES

Use of dikes and revetments on the Mississippi River [1]

GEOMORPHOLOGICAL ASPECTS

Natural processes of river systems like meandering, braiding and the occurrence of avulsions are still only partially understood. Erosion and sedimentation processes at the smaller scales can have large-scale implications that can even determine the course of a river. Bar formation in alluvial channels, bank erosion and accretion as well as interactions between flow and natural vegetation or man-made interventions all play an important role in river morphodynamics

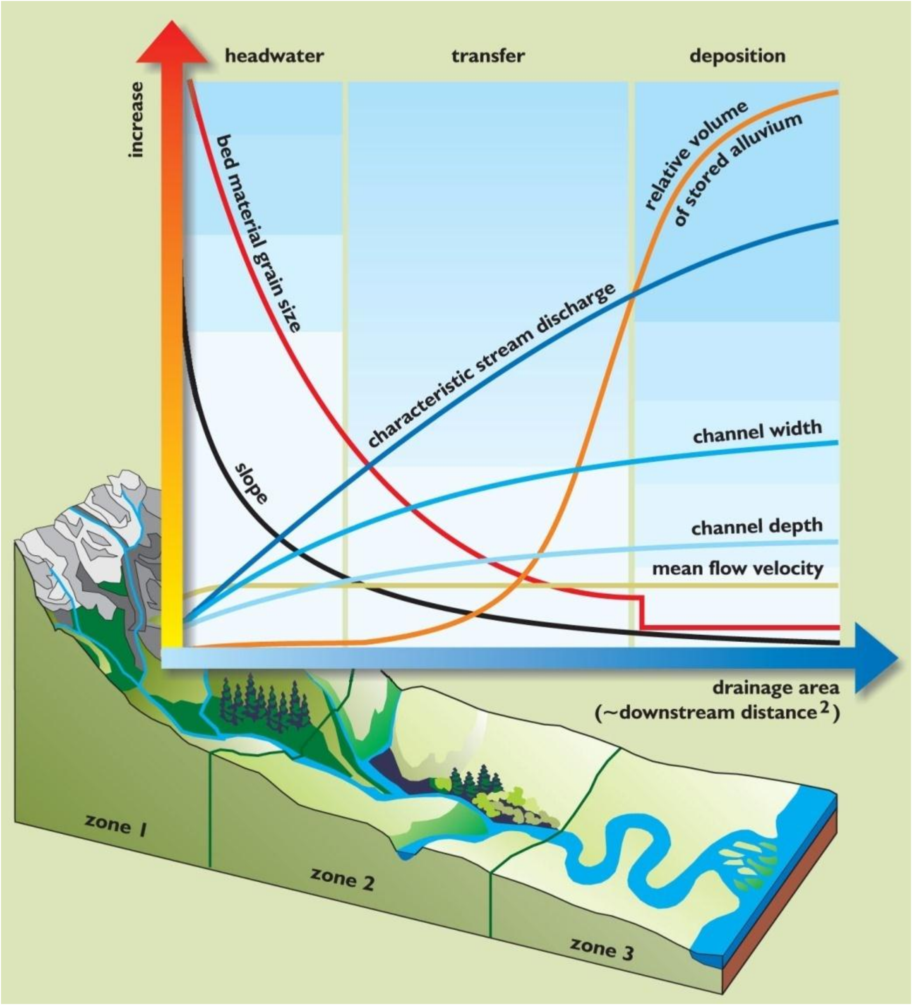


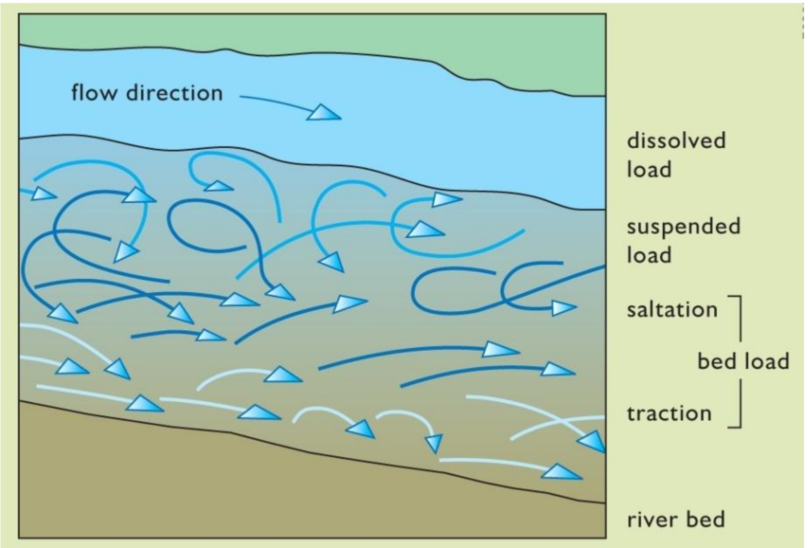


Sequence of pools and riffles in straight and sinuous streams.

Types of channel planforms (after Richardson et al., 1990).

SEDIMENTATION AND SEDIMENT MANAGEMENT IN RIVER CHANNELS

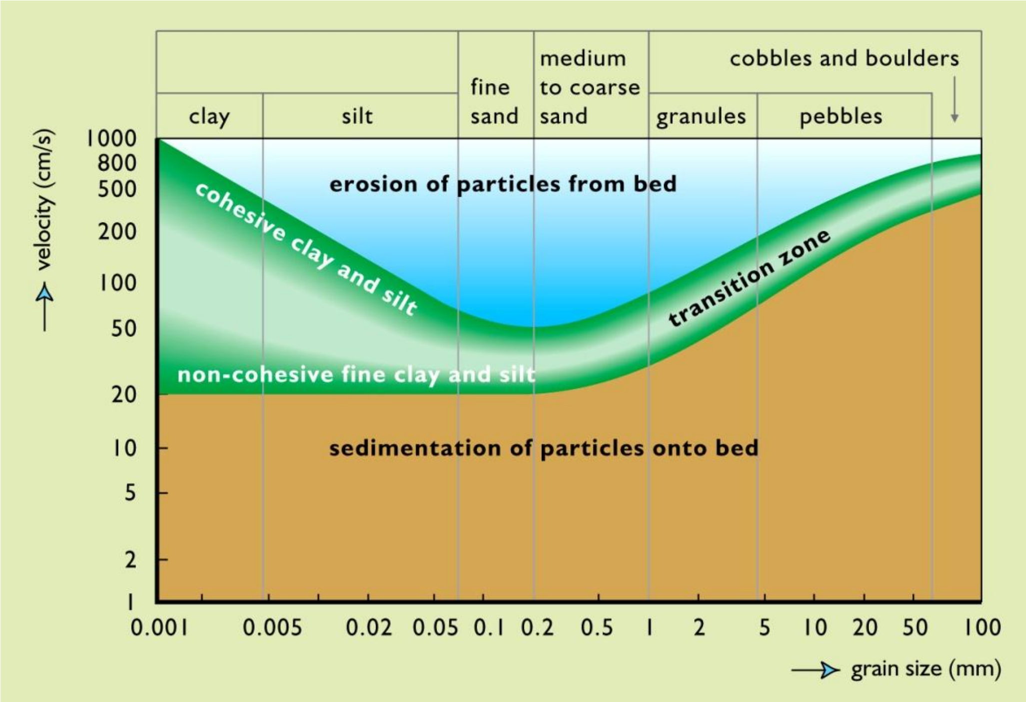




Types of sediment loads in a river channel [2]

Typical changes in the stream channel characteristics along its length [2]

SEDIMENTATION AND SEDIMENT MANAGEMENT IN RIVER CHANNELS



Relation between flow rate and sediment particle size erosion and transport

Channel Sediment Transport and Deposition

Energy is required to erode and transport sediment. The heavier the sediment particles, the more energy required to erode and transport them.

SEDIMENT TRANSPORT

Surface sediment plume from vessel passage [1]

Vessel traffic can suspend sediment from the bed and banks of a waterway through:

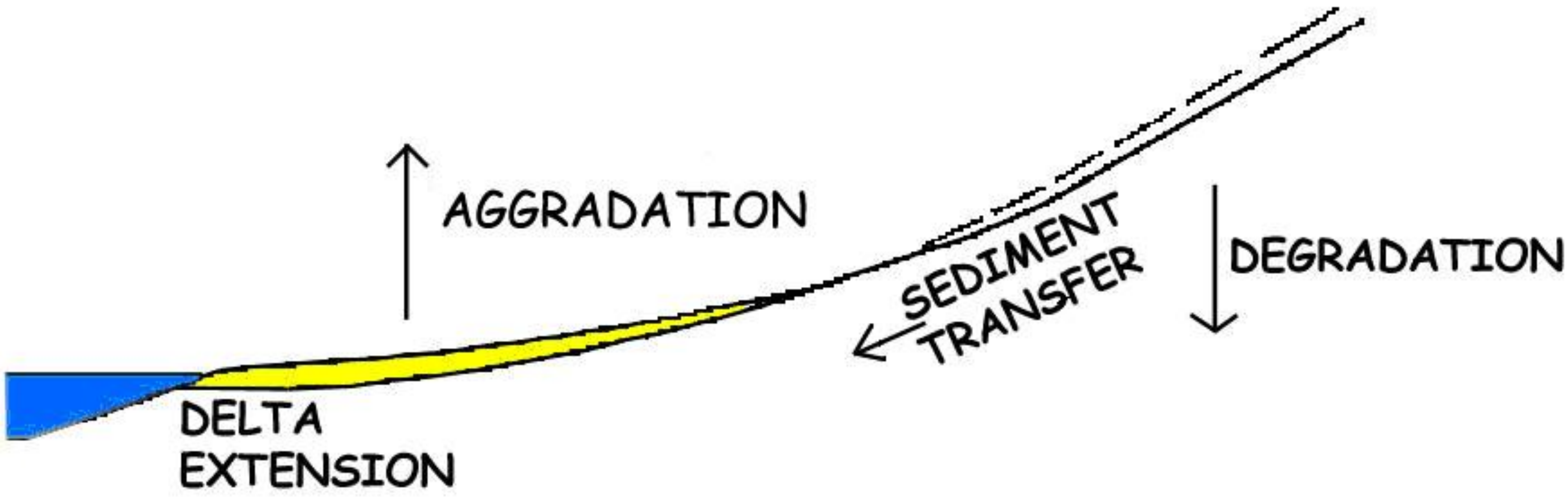
Flow under and around the vessel as water moves from the bow of the vessel to the stern

Pressure fluctuations beneath the vessel

Propwash striking the bed

Bow and stern waves agitating the bed and breaking against the bank

River sediment problems associated with navigation can be grouped into two main categories; local scour and deposition, and general degradation (overall erosion) or aggradation (deposition) problems.



OPEN-RIVER NAVIGATION

Open-river navigation implies the use of natural streams for navigation without locks and dams. The development of open-river navigation usually involves lower first cost but maintenance cost could be high because of the complex nature of these streams, tendency to meander and migrate, need of continuous dredging, and difficulty of designing the training and stabilization structures needed.

The improvement of natural streams for navigation involves channel realignment, stabilization, training structures, and in many cases the modification or replacement of existing bridges.

TRAINING STRUCTURE TYPES AND LAYOUT

There are two types of waterway training structures:

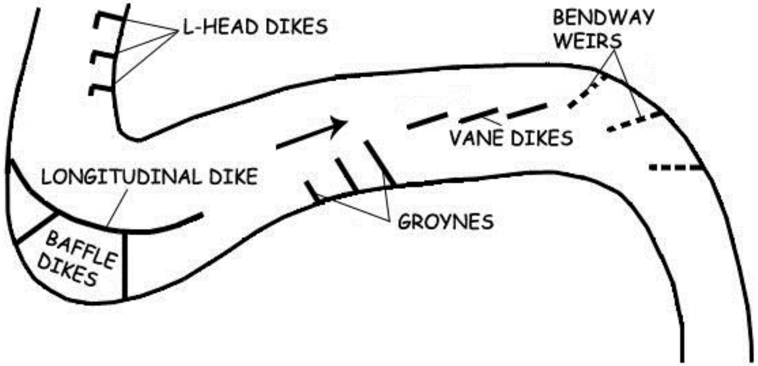
1. **re-directive**
2. **resistive**.

Re-directive, as the name implies, is the use of the river's energy and managing the energy in a way that benefits the system i.e., enhance the navigation channel.

A **resistive** structure acts to maintain the system as status quo i.e., reducing bank erosion.

RE-DIRECTIVE STRUCTURES

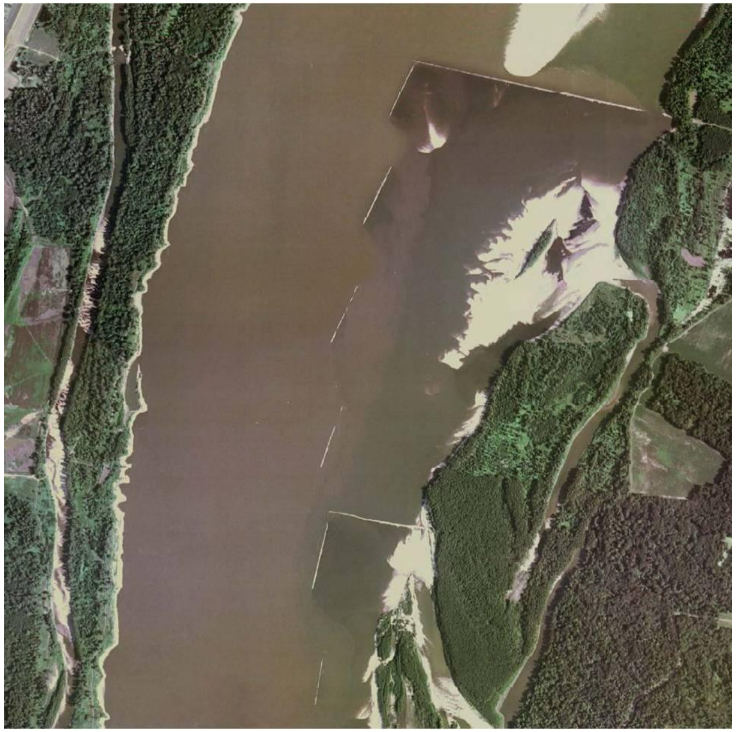
Certain types of control works are essential in the very early phases of development of a navigation channel, while others are used primarily in the final refinement phases of the project.



Dike Bank Paving On The Upper Mississippi River

Dikes placed in the form of a series of vanes have proved effective as a means of controlling channel development and sediment movement under certain conditions

L-head dike on the Mississippi River [1]



Vane dikes between L-head dikes on Mississippi River near Providence, LA [1]

RESISTIVE STRUCTURES

Resistive structures are primarily used to prevent bank erosion and channel migration on the outside of a river bend and to establish or maintain a desired channel alignment. Revetments are usually rock, Articulated Concrete Mats (ACM) or concrete mattress.

CHANNEL ALIGNMENT AND CONTRACTION

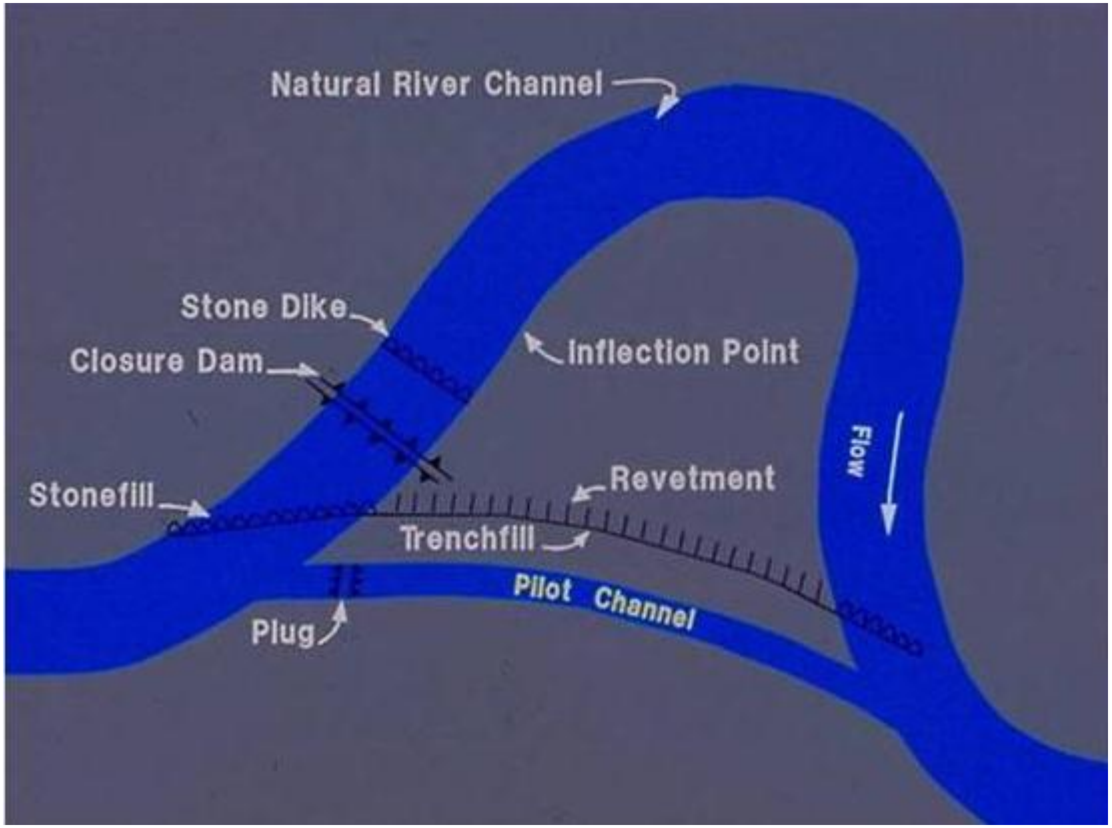
The layout of river training structures normally depends on the limits of contraction required to maintain a self-scouring channel of adequate width and depth through the full range of flows to permit continuous navigation.

CHANNEL ALIGNMENT AND CONTRACTION

Hog Lake additional contraction structures [1]

Even with locks and dams, some channel improvements as training river structures for stream stabilization and channel maintenance will be required.

CHANNEL REALIGNMENTS (CUTOFFS)

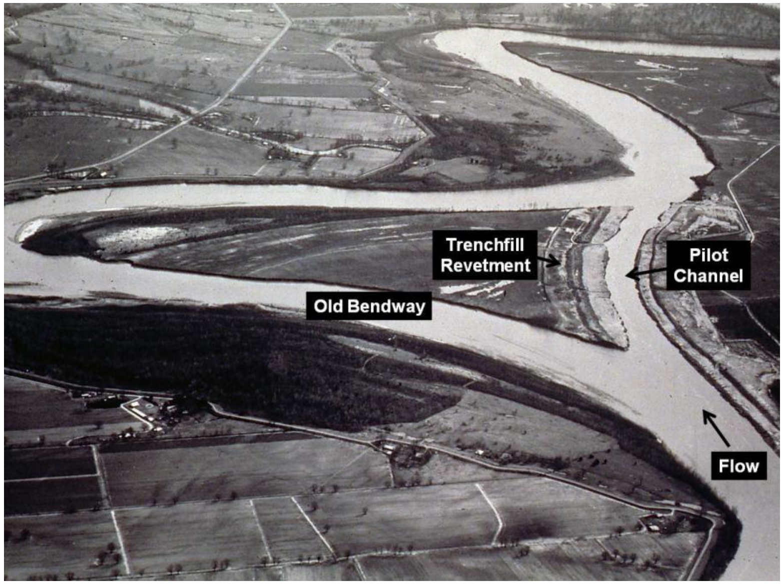


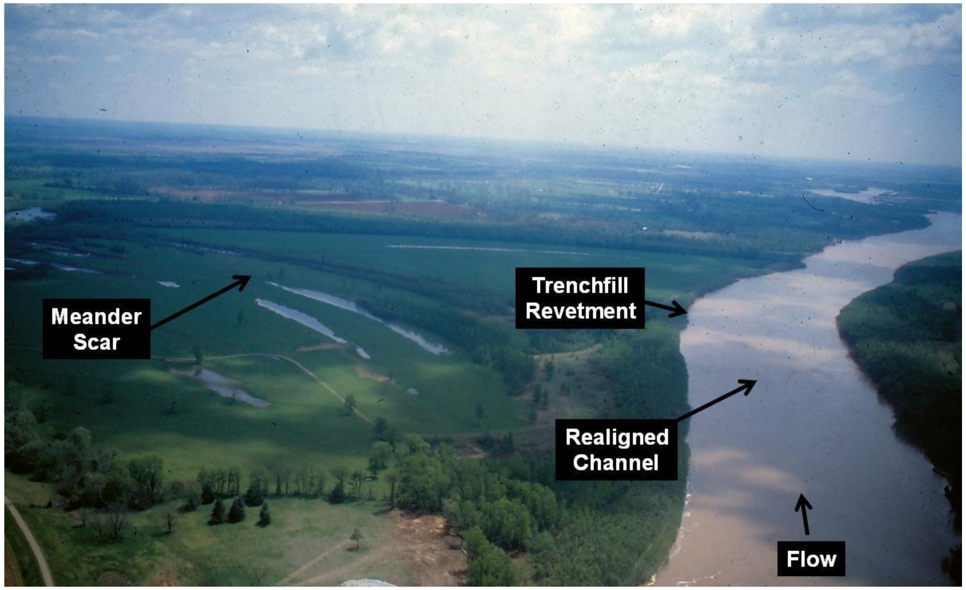
Typical Channel Realignment Plan [1]

Man-made channel realignments are the result of excavating a channel across the neck of a bendway. The primary purposes of these realignments include:

1. Eliminate bends too tight to be safely navigated by commercial tows
2. Reduce flood stages by creating a more efficient channel
3. Provide indirect bank stabilization by realigning the river away from eroding banks

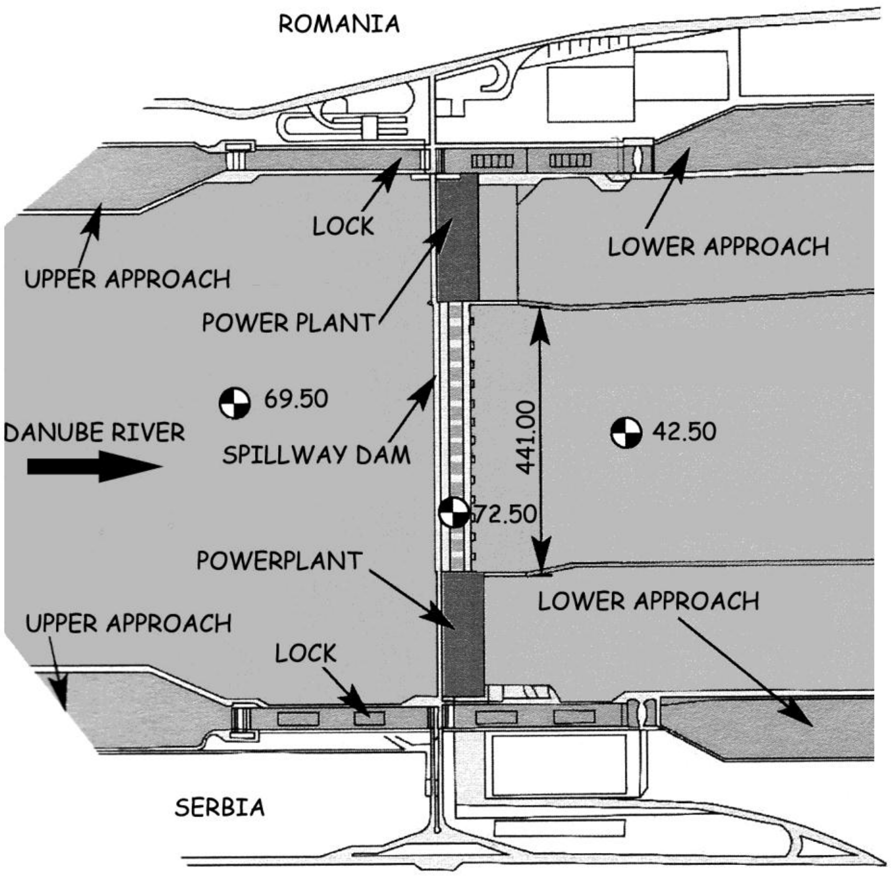
CHANNEL REALIGNMENTS (CUTOFFS)





Kateland Cutoff Fifteen Years After Construction

Canalization becomes necessary from the navigation point of view if the free-flowing river has too shallow depth or too high velocity to permit navigation.



Advantages

the opportunity to develop multipurpose utilization of water resources;
sufficient depth for navigation through the year, even during low river flows period;
reduced flow velocities;
increased width of waterways;
safer and cheaper navigation;
often a reduced need for bank protection and its maintenance (compared with regulated rivers).

CANALIZED RIVERS

Desadvantages

high capital cost;
the lockage costs;
the delay of traffic passing trough locks;
the need for protection of adjacent land;
drainage problems;
the possible deposition of sediments at the upstream end;
possible winter regime complications

WEIRS, BARRAGES AND STORM SURGE BARRIERS

They are meeting points for transportation infrastructure, not only by water but also road or rail. They have to be located in the right places, with sophisticated designs and careful operation.

determining the location on the river, canal or channel
sediment transport & morphological development
boundary conditions
lay-out, orientation
principle design of sill, stilling basins
gates and valves
bed and bank protection
intakes
settling traps
operational aspects

MOVABLES WEIRS, STORM SURGE BARRIER

The **PIANC InCom-WG26 (Working Group)** performed a comprehensive review of the modern technologies, design tools, and recent researches used to design and build structures controlling water level and flow in rivers, waterways, and ports (for navigation and flood protection).

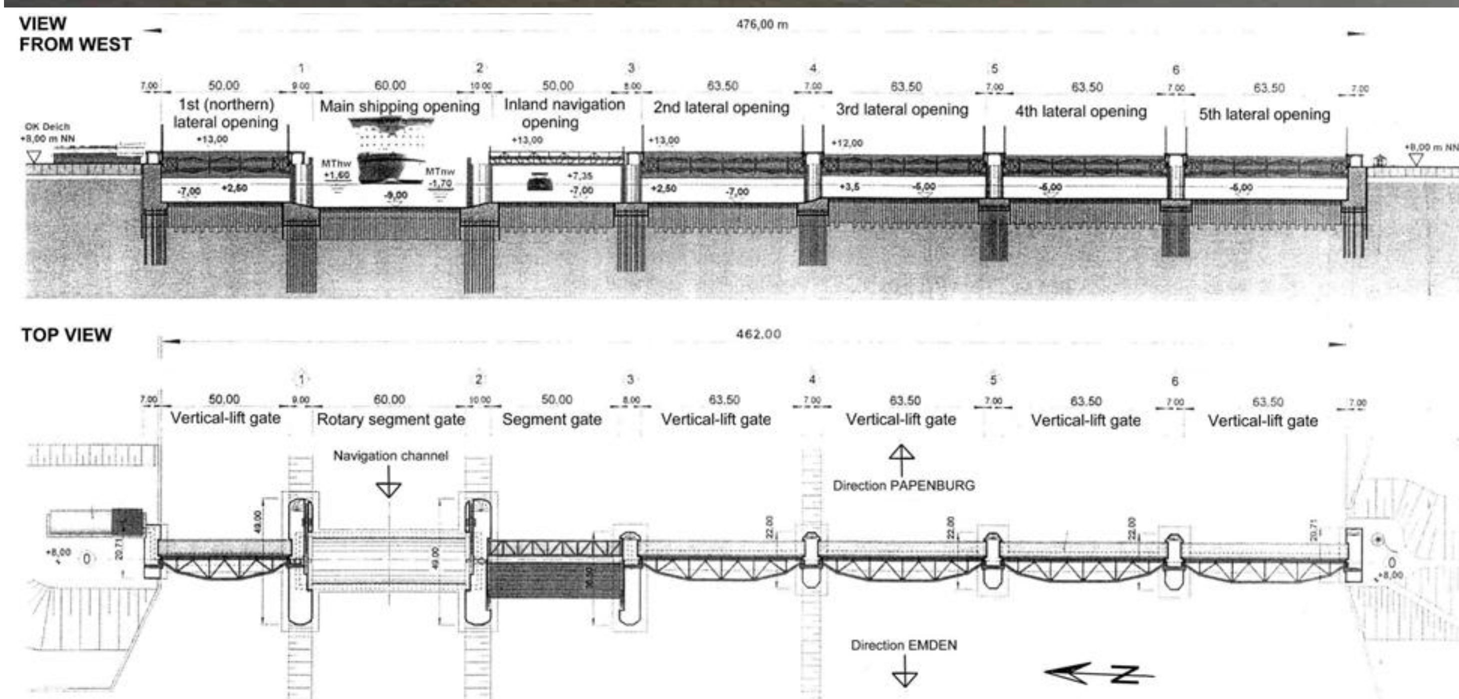
Thames River barrier (UK)

Maeslant Storm Surge Barrier (The Netherlands)

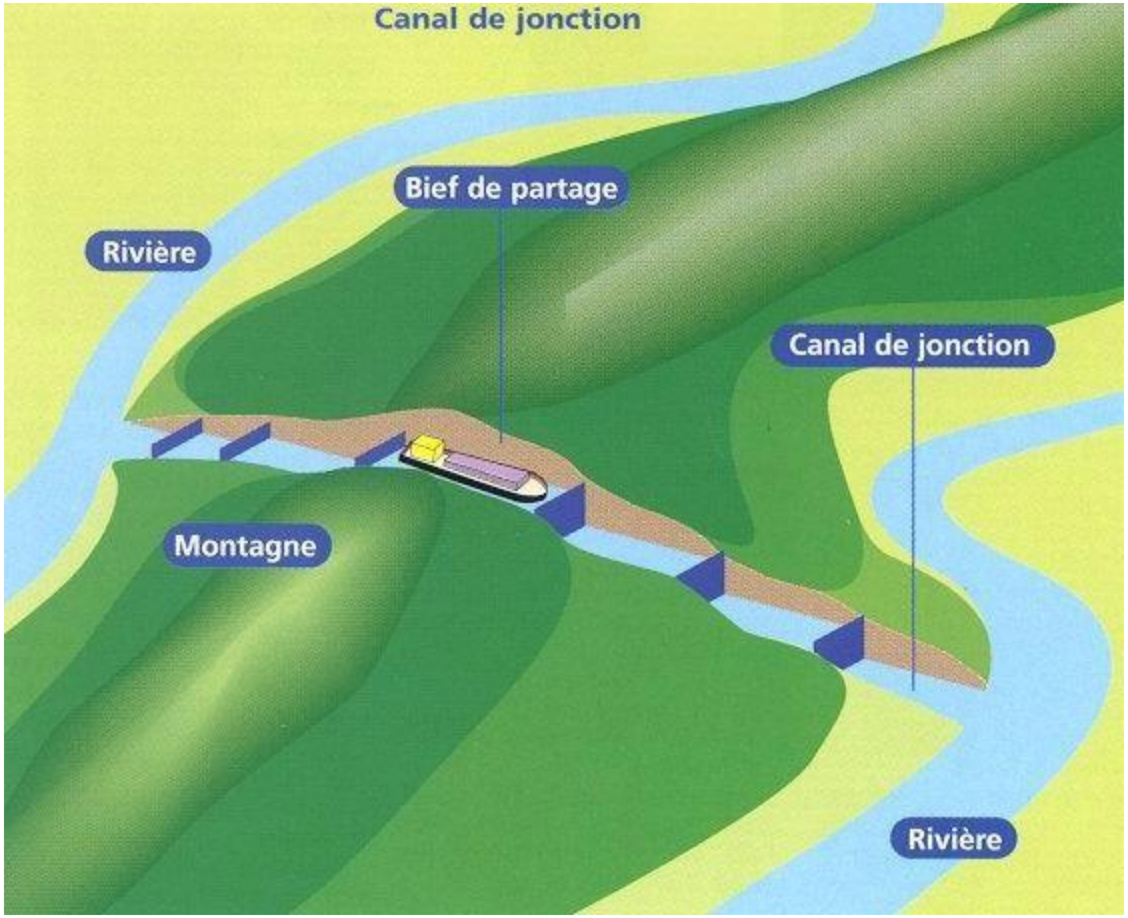
MOVABLES WEIRS, STORM SURGE BARRIER

Eastern Scheldt Storm Surge Barrier

Ems Barrier


VIEW
FROM WEST
476,00 m
1st (northern) lateral opening
Main shipping opening
Inland navigation opening
2nd lateral opening
3rd lateral opening
4th lateral opening
5th lateral opening
OK Deich
+8,00 m NN
TOP VIEW
462.00
Vertical-lift gate
Rotary segment gate
Segment gate
Vertical-lift gate
Vertical-lift gate
Vertical-lift gate
Vertical-lift gate
Navigation channel
Direction PAPENBURG
Direction EMDEN

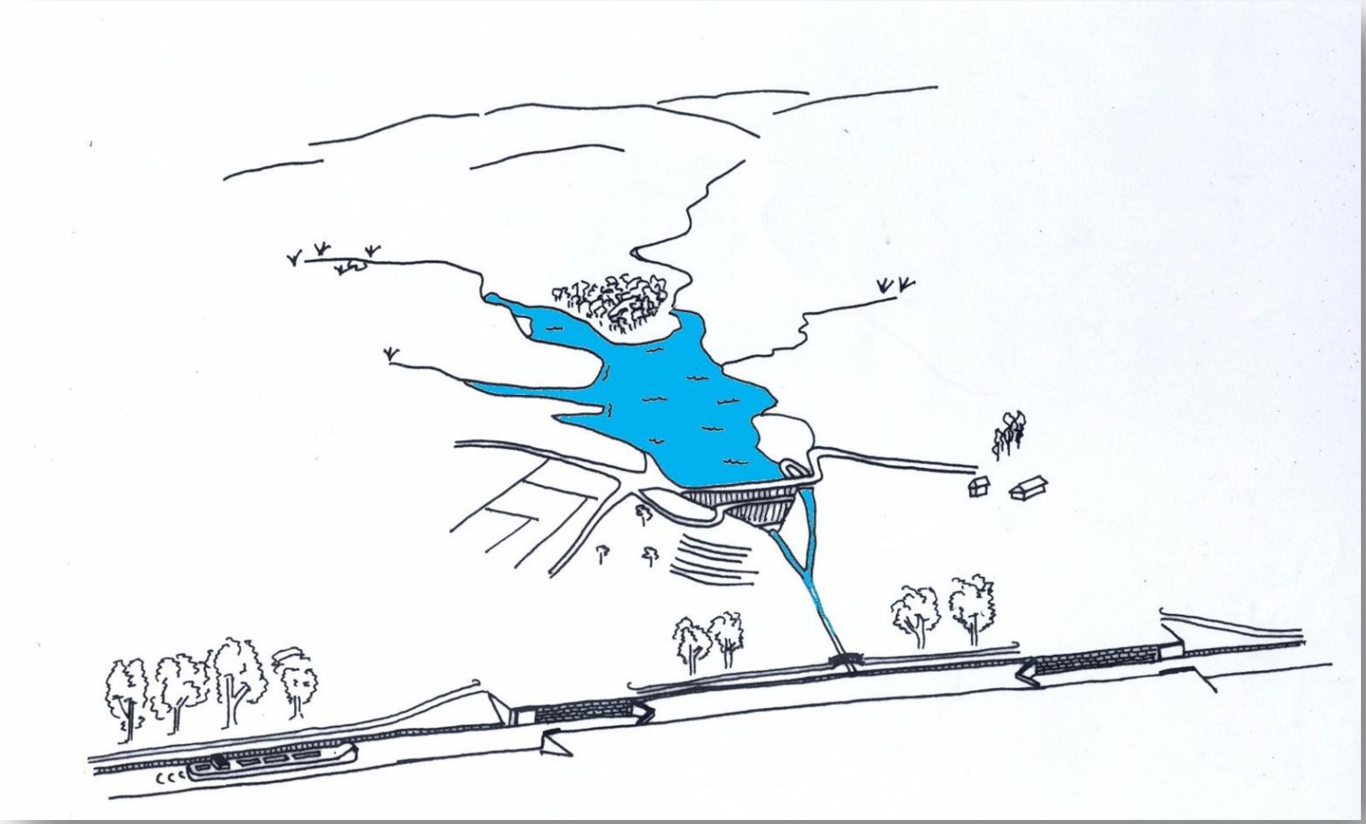
CANALS



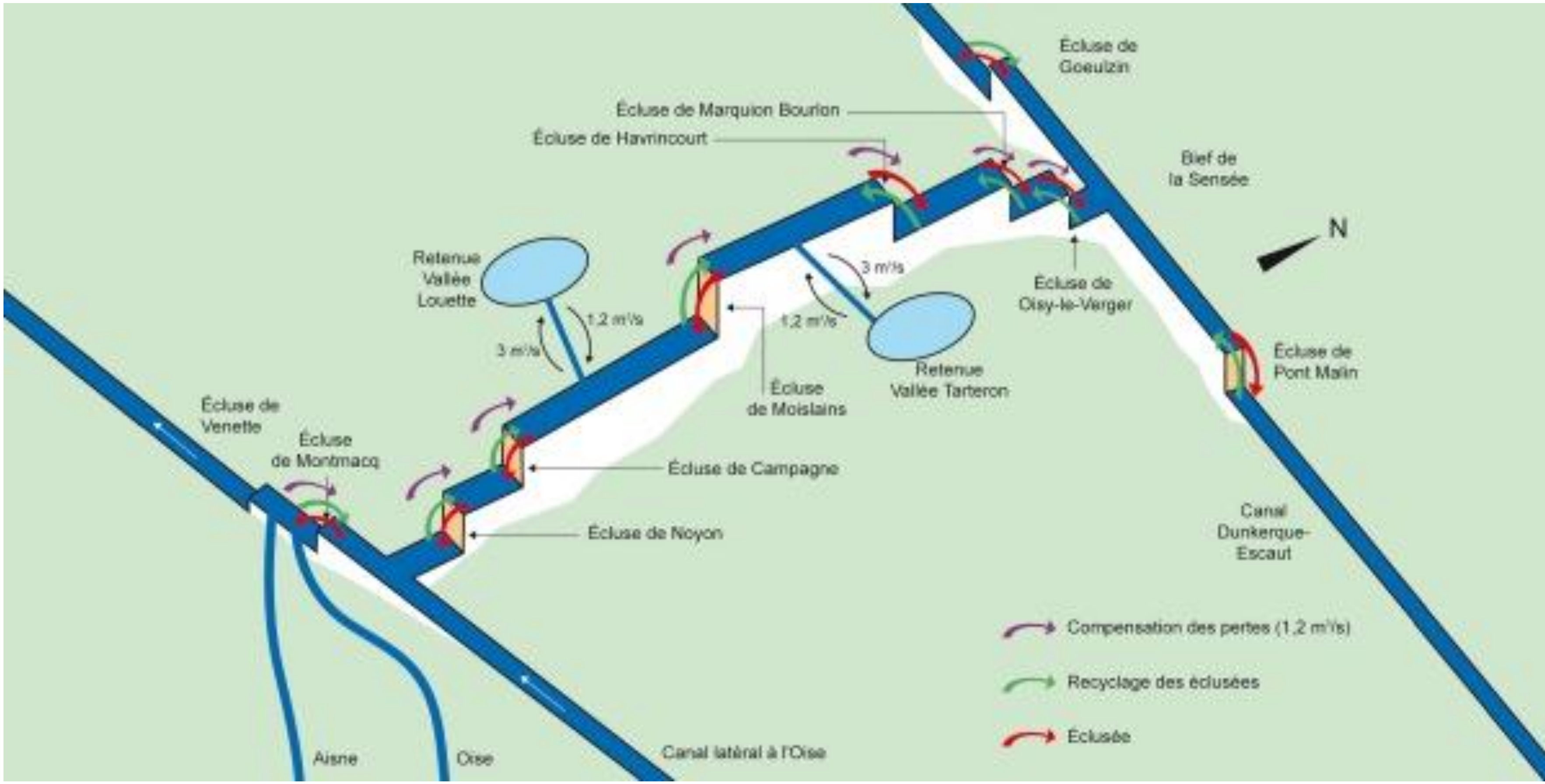
Canals, entirely artificial waterways whose water is obtained by diversion from rivers, by pumping or from reservoirs.

CANALS

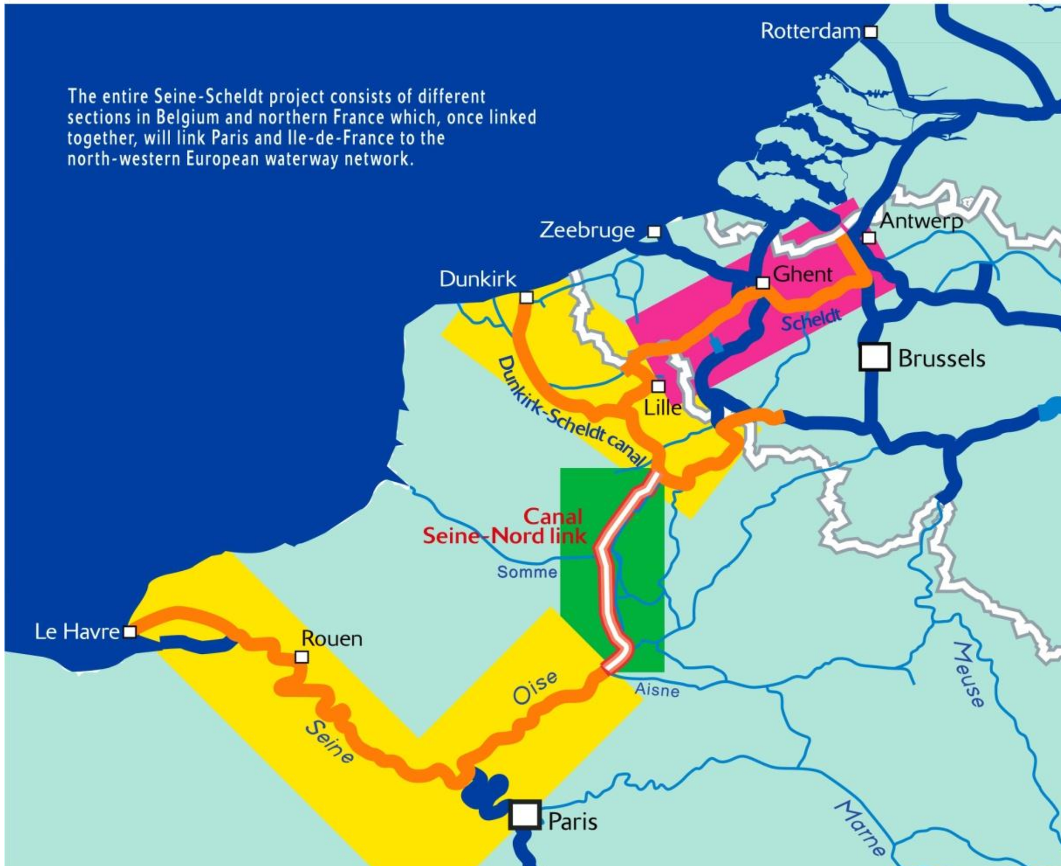
The diagnosis of available resources for the canals is based on the quantitative estimation of natural water supplies, the means of interception in the water cycle and its high storage and shipment to the channel.



Canal Seine-Nord Europe



SEINE-SCHELDT CANAL



IN FRANCE, the launch for a new 105 km canal Seine-Nord linking the Dunkirk-Scheldt canal to the Oise river (close to Janville) has been officially decided by the French government on 18 December 2003.

At the north and south end of the new canal, the rivers Seine and Oise and the Dunkirk-Scheldt canal are currently being upgraded to make the navigation infrastructure more reliable and to facilitate, in the long term, the passage of larger vessels, for instance by raising bridges.

IN THE WALLOON REGION, investments have already been carried out on the canal du Centre, in particular the boat-lift of Strépy-Thieu.

IN THE FLEMISH REGION, expanding the Lys and the maritime Scheldt will allow larger vessels to connect to the Rhine via the Scheldt-Rhine canal.

Seine-Scheldt – the only large-scale European transport project enhancing sustainable development, improving accessibility of regions and raising economic efficiency is supported at local, national and European level

3 major benefits

1 Linking large economic centres of north-western and central Europe will provide a solution for logistics players

2 A solution for the traffic gridlock on the north-south road corridor

3 An example of sustainable development

Canal Seine-Nord Europe

4 multimodal platforms, 7 loading/unloading quays serving transhipment with other transport modes (road and rail)

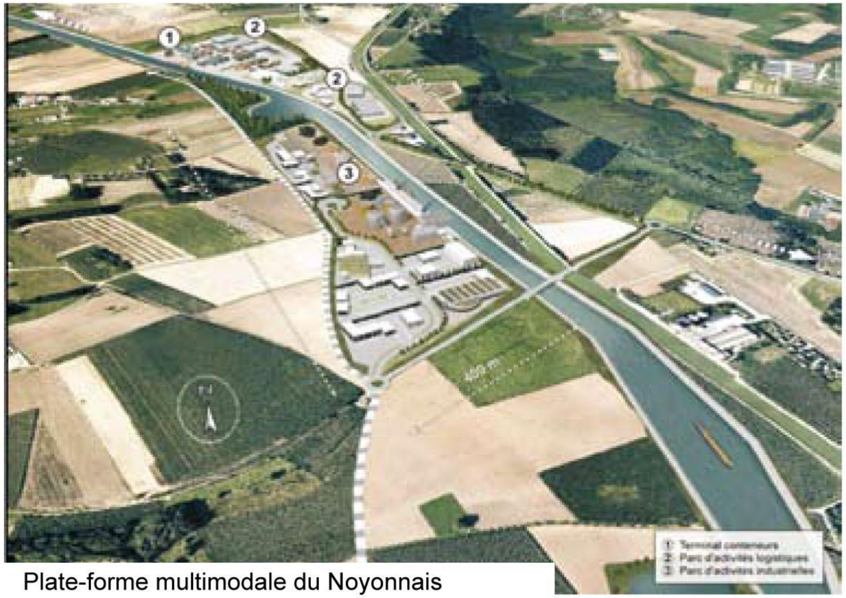


Plate-forme multimodale du Noyonnais

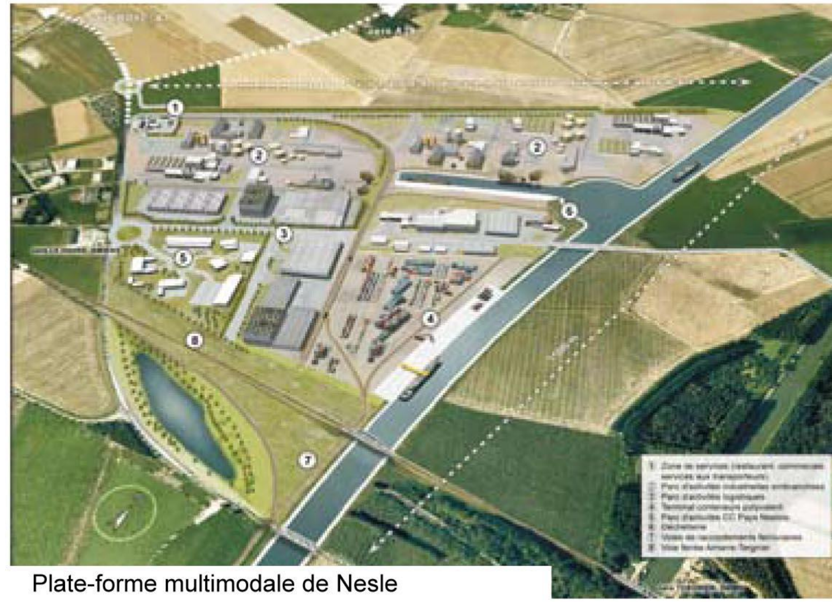


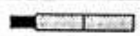
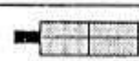
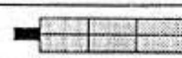
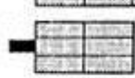
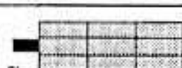
Plate-forme multimodale de Nesle

Plate-forme multimodale de Péronne Haute-Picardie

Plate-forme multimodale de Cambrai-Marquion

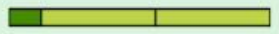
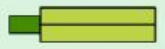
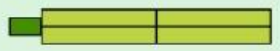
CLASSIFICATION OF INLAND WATERWAY

Table 4.1

Type of inland waterways	Classes of navigable waterways	Motor vessels and barges – Type of vessel: General characteristics: Designation	Maximum length	Maximum beam	Draught 7/	Tonnage	Pushed convoys – Type of convoy: General characteristics	Length	Beam	Draught 7/	Tonnage	Minimum height under bridges 2/	Graphical symbols on maps
			L(m)	B(m)	d(m)	T(t)		L(m)	B(m)	d(m)	T(t)	H(m)	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
OF REGIONAL IMPORTANCE – To West of Elbe	I	Barge	38.5	5.05	1.80-2.20	250-400						4.0	
	II	Kampine-Barge	50-55	6.6	2.50	400-650						4.0-5.0	
	III	Gustav Koenigs	67-80	8.2	2.50	650-1,000						4.0-5.0	
OF REGIONAL IMPORTANCE – To East of Elbe	I	Gross Finow	41	4.7	1.40	180						3.0	
	II	BM-500	57	7.5-9.0	1.60	500-630						3.0	
	III	6/	67-70	8.2-9.0	1.60-2.00	470-700		118-132	8.2-9.0	1.60-2.00	1,000-1,200	4.0	
OF INTERNATIONAL IMPORTANCE	IV	Johann Welker	80-85	9.5	2.50	1,000-1,500		85	9.5 5/	2.50-2.80	1,250-1,450	5.25 or 7.00 4/	
	Va	Large Rhine vessels	95-110	11.4	2.50-2.80	1,500-3,000		95-110 1/	11.4	2.50-4.50	1,600-3,000	5.25 or 7.00 or 9.10 4/	
	Vb							172-185 1/	11.4	2.50-4.50	3,200-6,000		
	VIa							95-110 1/	22.8	2.50-4.50	3,200-6,000	7.00 or 9.10 4/	
	VIb	3/	140	15.0	3.90			185-195 1/	22.8	2.50-4.50	6,400-12,000	7.00 or 9.10 4/	
	VIc						 	270-280 1/ 195-200 1/	22.8 33.0-34.2 1/	2.50-4.50 2.50-4.50	9,600-18,000 9,600-18,000	9.10 4/	
	VII						 8/	285	33.0-34.2 1/	2.50-4.50	14,500-27,000	9.10 4/	

CLASSIFICATION OF INLAND WATERWAY

Categories of European waterways (ECMT)*

Class	Type of motorized vessel	Tonnage (ton)	Formation push convoy	Tonnage (ton)	Length (m)	Width (m)	Draught (m)	Height (m)
0	Leisure	< 250	-	-	-	-	-	-
I	Spits	250 - 400	-	-	38.5	5.05	1.8 - 2.2	4
II	Campine vessel	400 - 650	-	-	50 - 55	6.6	2.5	4.0 - 5.0
III	Dortmund-Eems canal vessel	650 - 1,000	-	1,250 - 1,450	67 - 80	8.2	2.5	4.0 - 5.0
IV	Rhine Herne canal vessel	1,000 - 1,500		1,600 - 3,000	80 - 85	9.5	2.5 - 2.8	5.25 / 7
Va	Large Rhine vessel	1,500 - 3,000		3,200 - 6,000	95 - 110	11.4	2.5 - 2.8	5.25 / 7
Vb	Push convoy (2 barges)	-		3,200 - 6,000	172 - 185	11.4	2.5 - 4.5	9.1
VIa	Push convoy (2 barges)	-		3,200 - 6,000	95 - 110	22.8	2.5 - 4.5	7.1 - 9.1
VIb	Push convoy (4 barges)	-		6,400 - 12,000	185 - 195	22.8	2.5 - 4.5	7.1 - 9.1
VIc	Push convoy (6 barges)	-		9,600 - 18,000	270 - 280	22.8	2.5 - 4.5	9.1
VIc	Push convoy (6 barges)	-		9,600 - 18,000	193 - 200	33 - 34.2	2.5 - 4.5	9.1

Standard dimensions

Push barge: 76.5 m x 11.40 m

NAVIGATION LOCKS

Shipping locks allow vessels to move freely while keeping water use to a minimum. Vessels and their owners want to move along as quickly *and* as safely as possible

selecting the location
the lay-out
boundary conditions
forces on vessels and gates
hydraulic design of filling and emptying system
saltwater/freshwater separation systems
water management systems
hydraulic design of gates and valves
bed and bank protection
operational management

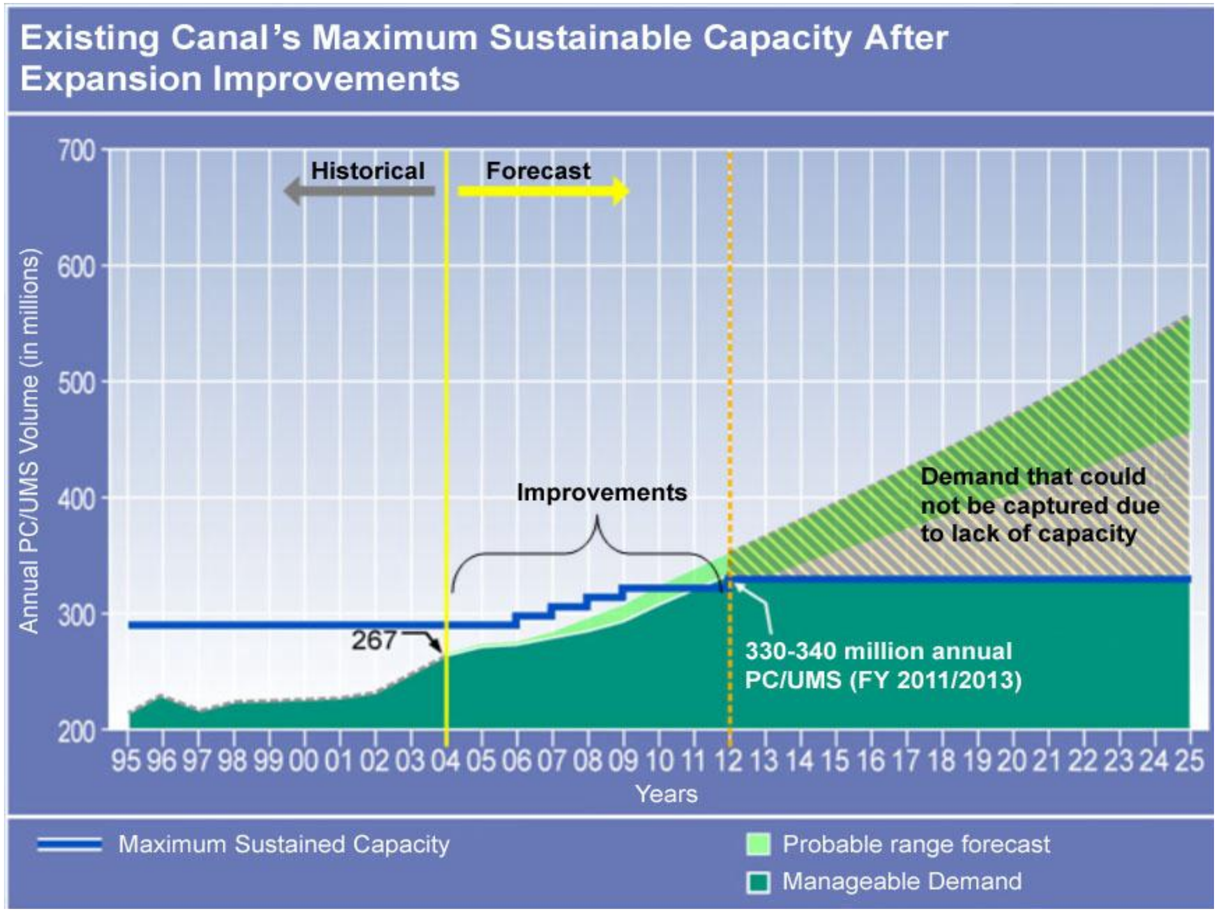
The following main design objectives and optimization goals are governing the design of a lock:

Reliability of the system, structures and the operations,
Reduced duration of a lock navigation cycle times,
Reduced water motions inducing ship displacement and mooring forces
Avoid water resource problems (minimise water use)
Saltwater intrusion
Reduced life cycle cost
Minimizing energy use
Avoid negative environmental impact
Minimize impacts to navigation traffic and surrounding community
Safety and Security

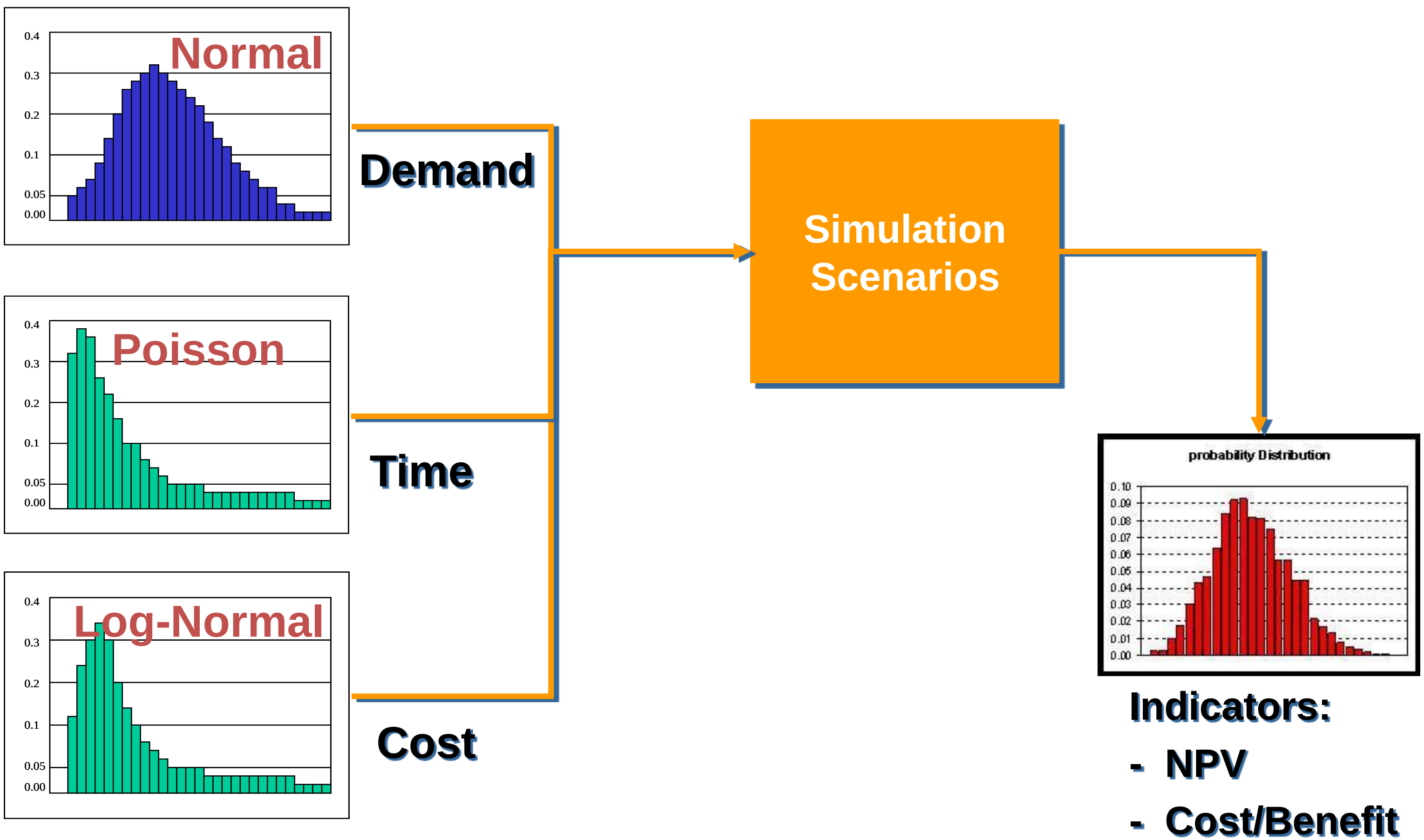
(a) Simulation of the traffic on the waterway

Validation of the choices for the dimensions

Capacity vs. forecast



(b) Risk analysis & costs estimate



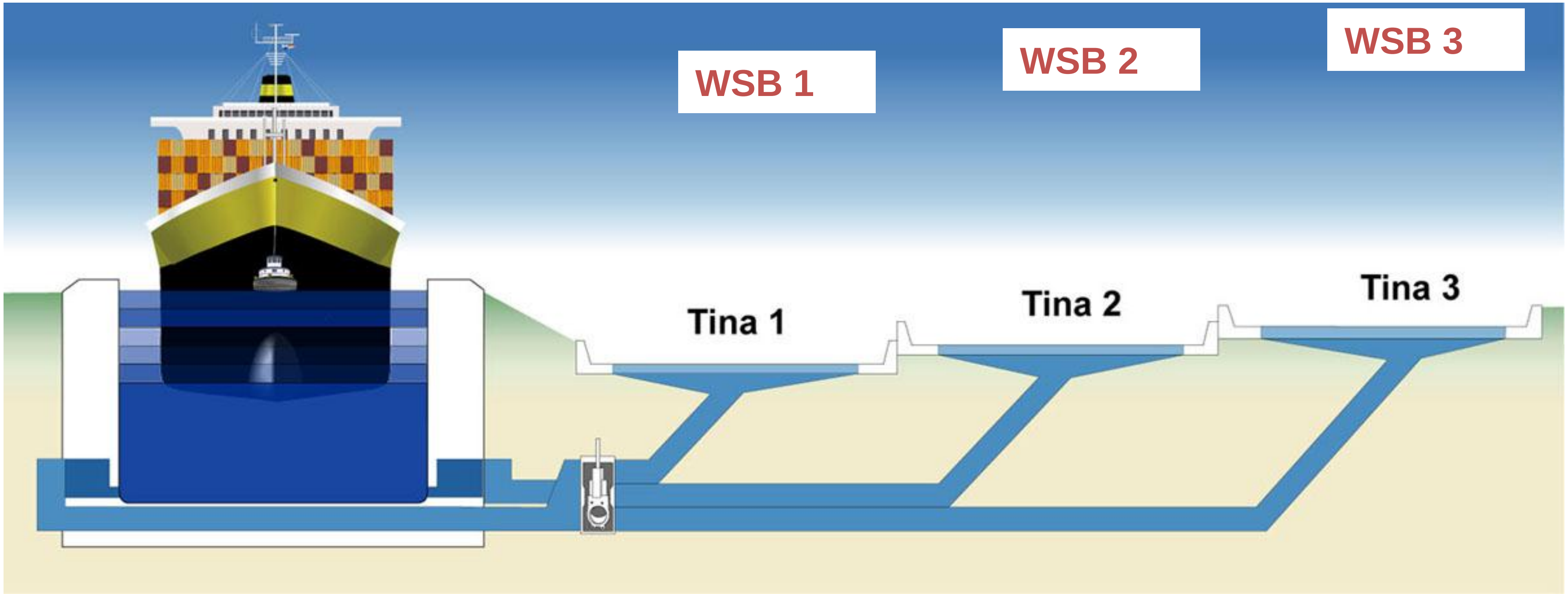
2) Choice of the ***type of the lock***, characterized by :

A. Hydraulic system

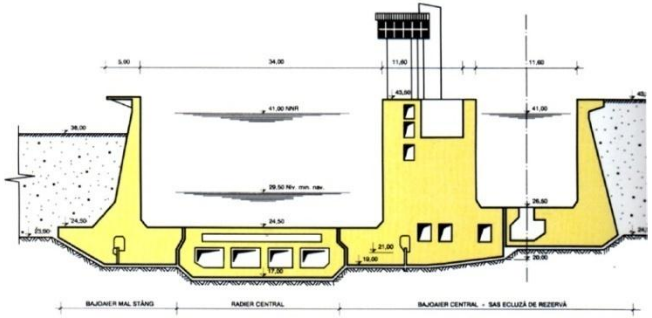
B. Type of structure (lock floor, lock walls, etc.)

C. Construction method (dry works, prefabrication, etc.)

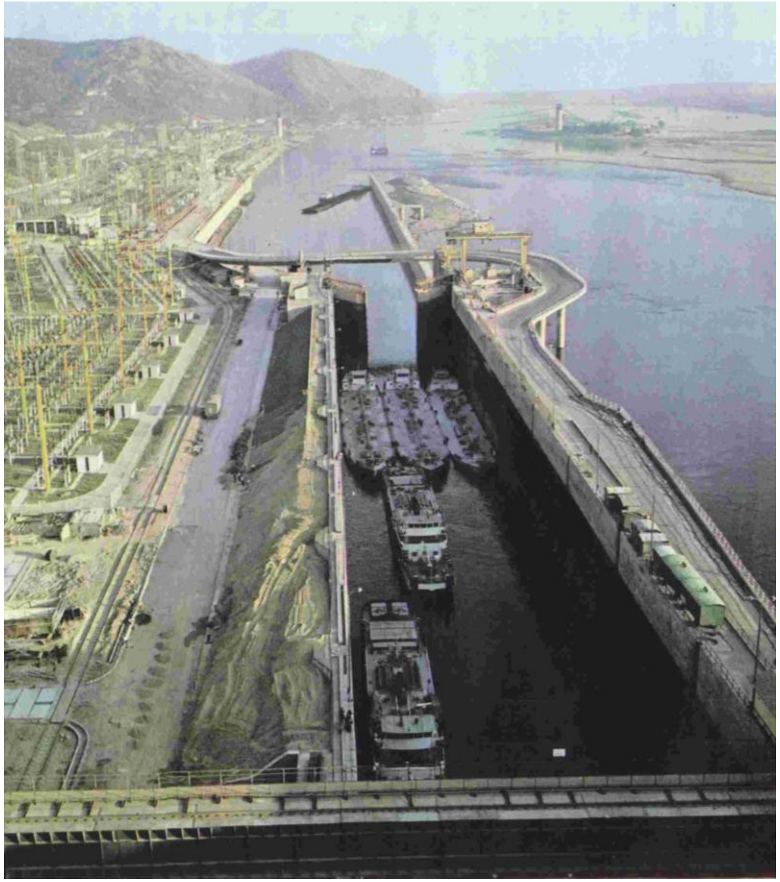
WATER RESOURCES
Water Saving Basins

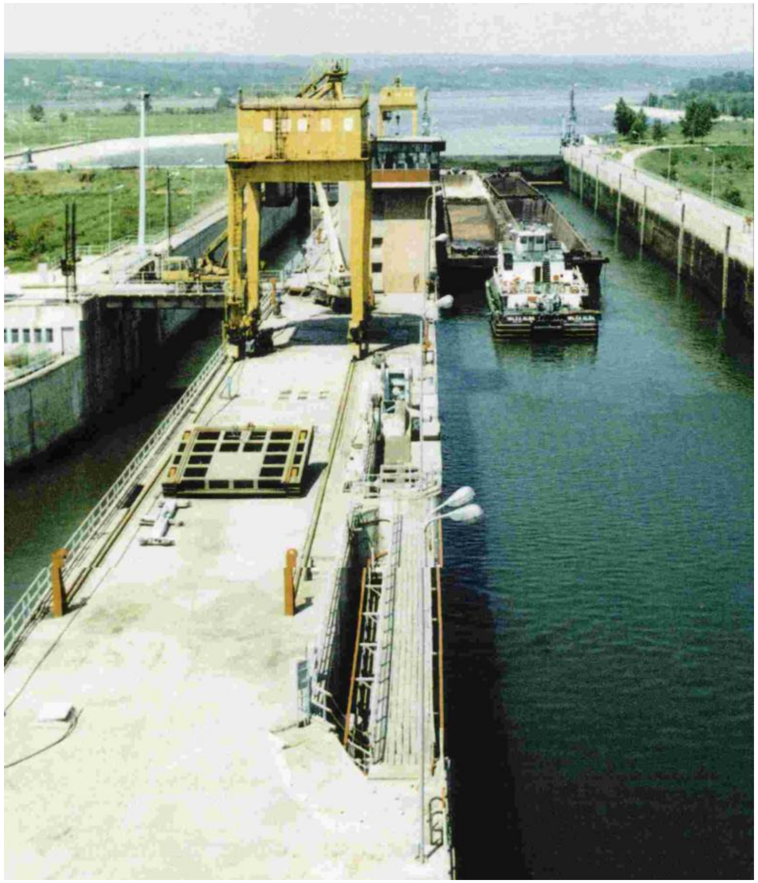


APPROACH WALLS & ACCESS CHANNEL



IRON GATES II (Romania)





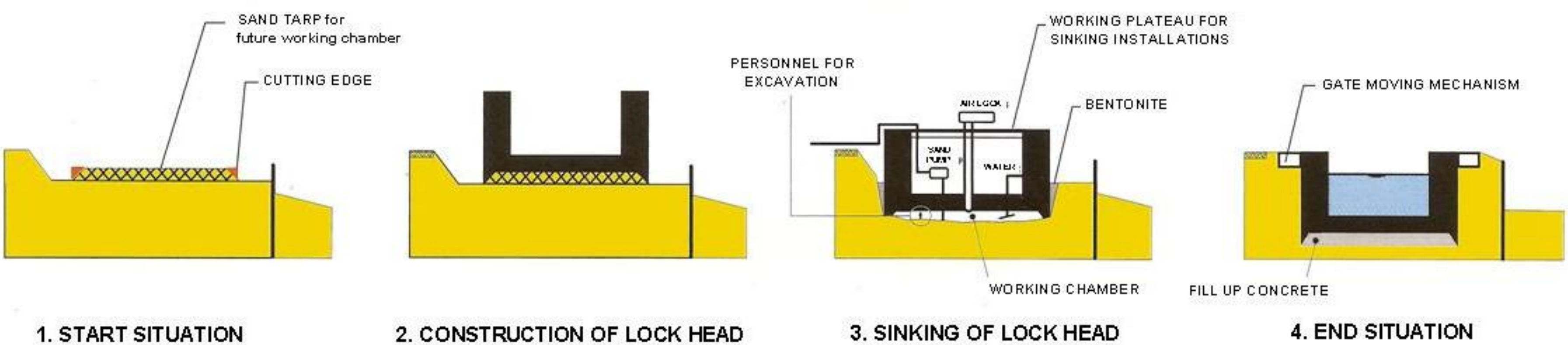
CONSTRUCTION MODES

The problems raised in this section are:
How to minimize impacts to navigation traffic and the surrounding community during construction?
Which are the best construction modes to reduce the impact during construction?
New innovative construction methods including prefabrication techniques like float-in, in-the-wet construction (lift-in precast concrete components, etc.)...

A very unique construction method. 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.

LITH (NL)

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.



NAVIDUCT KRABBERSGAT (NL)

The 'Naviduct' is a combination of a double navigation lock that includes an underpass for road traffic.

MARITIME LOCKS

ZEEBRUGGE

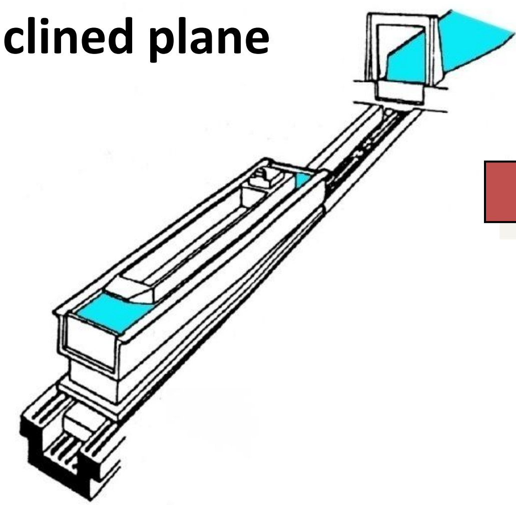
Locks are also strategic infrastructures for port development. In low-lying countries, such as the Netherlands and Belgium, locks are structures in dikes and have an important function in flood defence.

MARITIME LOCKS

LOCKS COMPLEX – ANTWERP (68m x 500m)

CROSSING STRUCTURES
LONGITUDINAL INCLINED PLANE

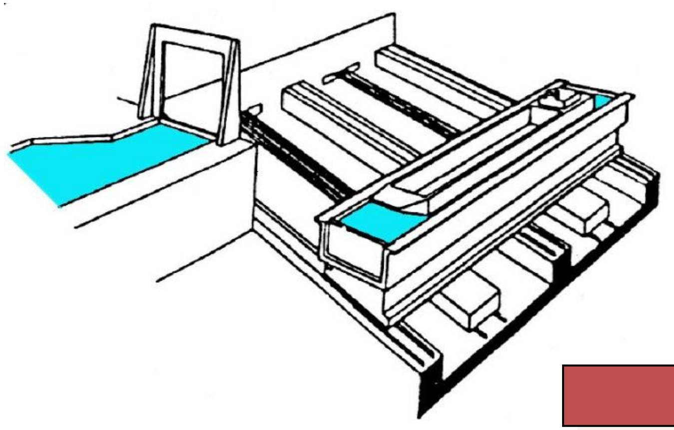
Inclined plane



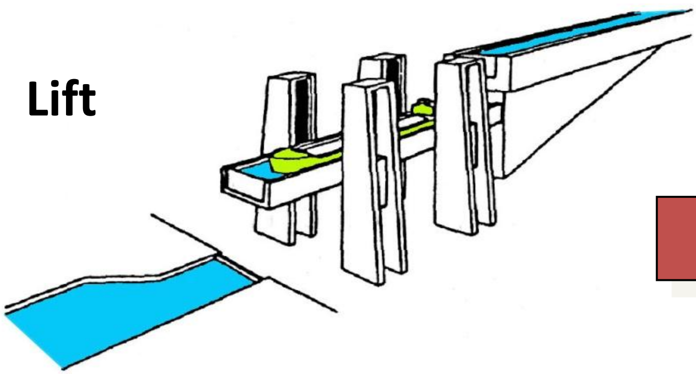
Ronquière (Belgium)

CROSSING STRUCTURES
TRANSVERSE INCLINED PLANE

Inclined plane



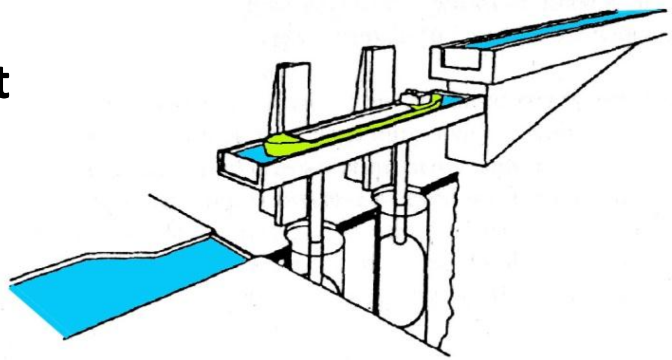
Inclined plane on Marne-Rhine Canal



Hydraulic lift in Strépy-Thieu (Belgium)

CROSSING STRUCTURES
HYDRAULIC LIFTS

Hydraulic lift



Peterborough lift lock

Rothensee boat lift

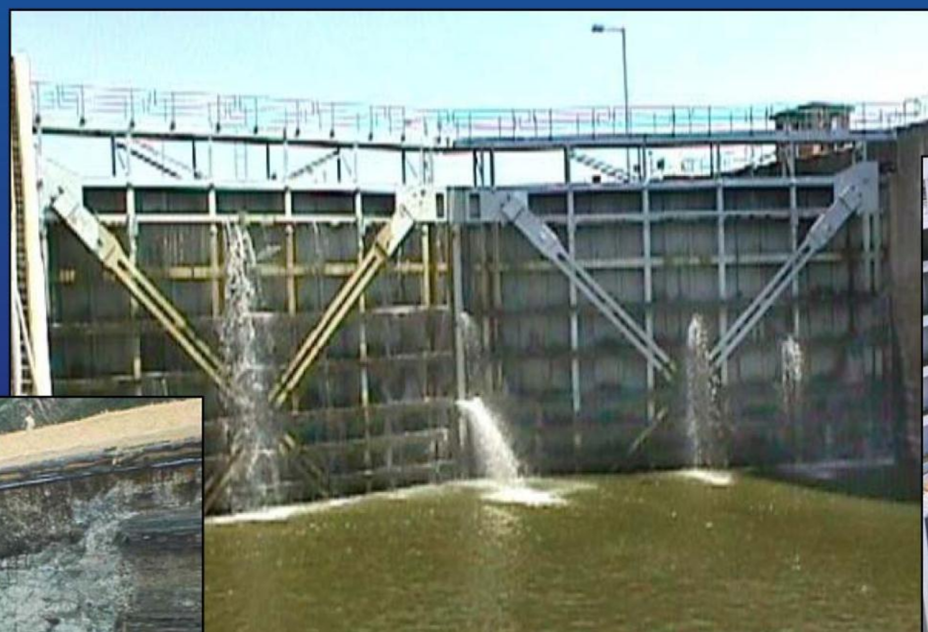
CROSSING STRUCTURES
FALKIRK WHEEL (Scotland)

CROSSING STRUCTURES
FALKIRK WHEEL (Scotland)

Aging Infrastructure

Two issues are vital in looking at aging infrastructure: what is the present condition and how urgent is it to expend significant public funds to achieve its repair, replacement, and management improvement; what are the priorities across the range of infrastructure types.

Crumbling lock wall, Lower Mon 3, opened in 1907



Leaking miter gates, Upper Miss Lock 19

Concrete deterioration at Chickamauga

CONCLUSION

Development of a river system for navigation may involve the construction of several major components such as locks and dams, bank stabilization, river training structures, reservoirs, and channel realignments. The impacts of each of these components of work can be assessed individually.

Because of this complexity it is difficult to develop definite rules or trends that apply to all navigation projects or all rivers. Design criteria and techniques that have been successful on one river system may not be feasible on another system which has different hydrologic, sediment, or geomorphic characteristics.