A decision-making methodology for the management of dredged sediments on the basis of chemical and toxicological data

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Scope of the work

- This paper presents a methodology of evaluating management options for dredged sediments disposal
- It is based of an array of characterization tests
- An example application for the sediments of Piraeus port is presented.

Dredging driving forces

- (a) dredging in order to meet port and navigation requirements

- (b) environmental cleanup required to reduce contamination levels to a specified level.

Sustainable sediment management

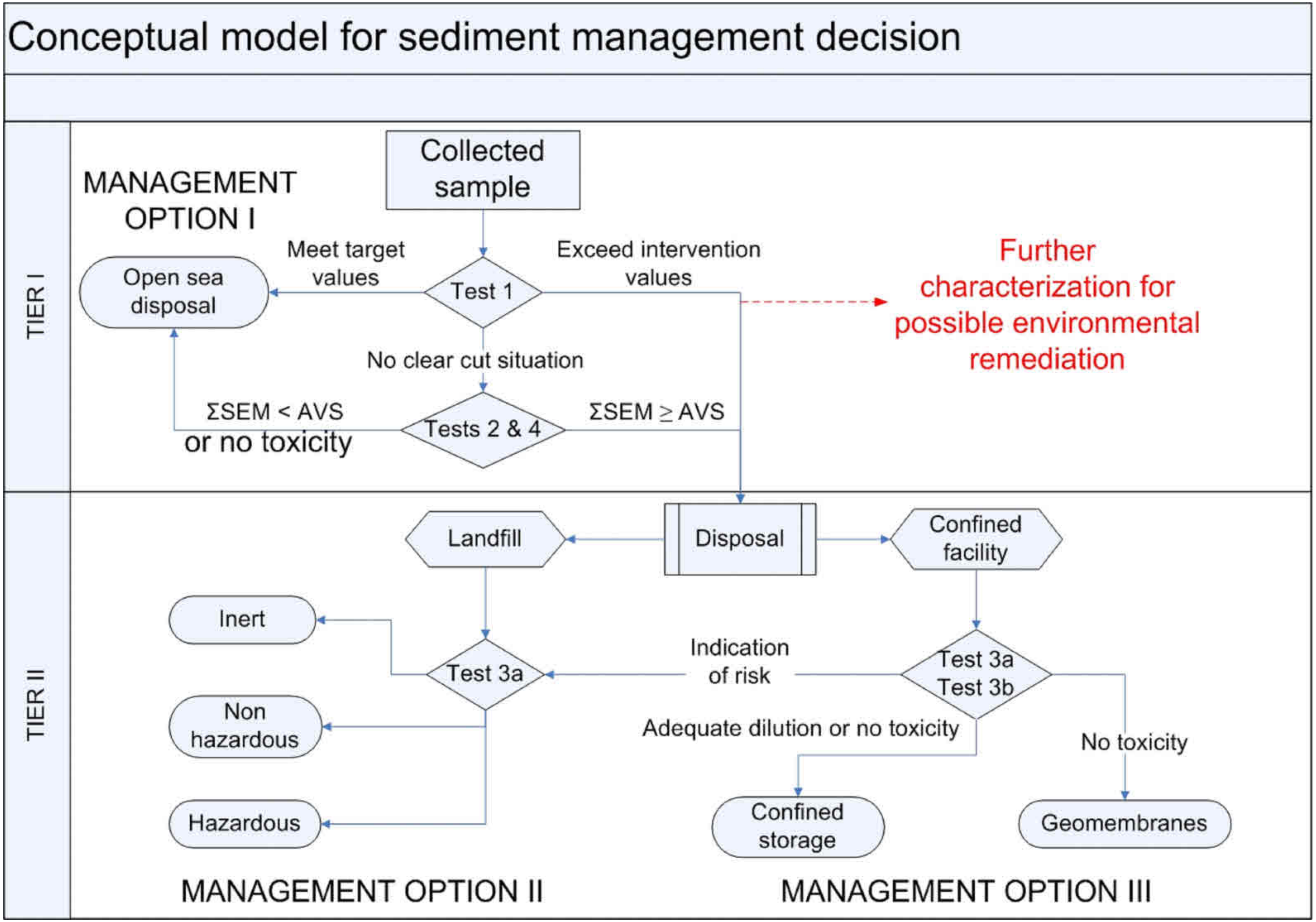
- A very challenging issue.
- Different actors with particular interests are involved in the decision-making process
  - whether, which, and when action has to be taken
  - who has to pay
  - conflicting and some-times confusing legislation framework.
- Management options depend on the chemical characteristics and the toxicity of the sediments
  - the question of risk needs to be addressed.
- The characterization of sediments before final disposal becomes necessary

Characterization tests

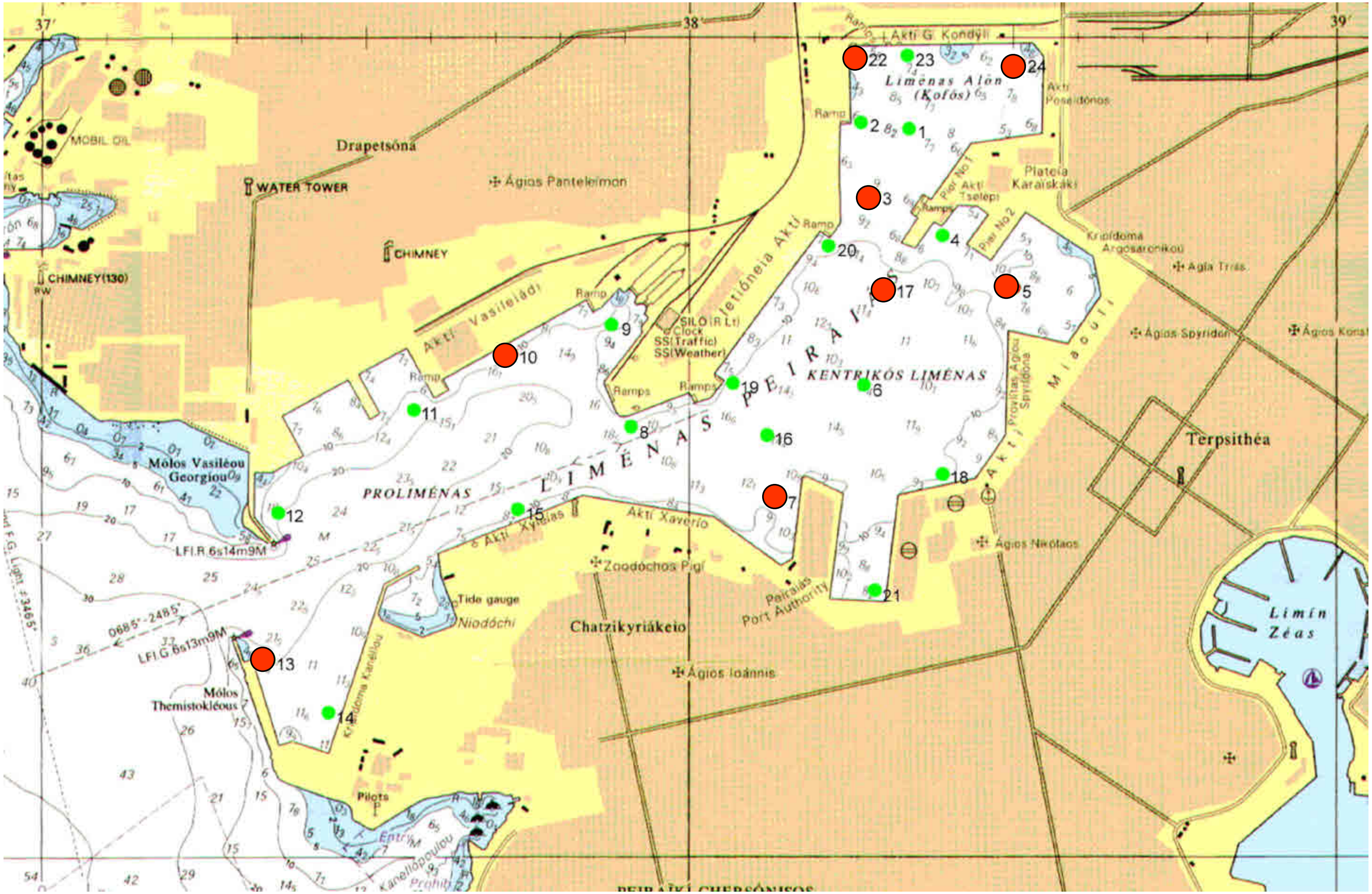
- Test (1): Total metals in sediment
- Test (2a): Metals in pore water
- Test (2b): Toxicity of pore water
- Test (3a): Metals in leachate
- Test (3b): Toxicity of leachate
- Test (4): AVS vs SEM

Management options

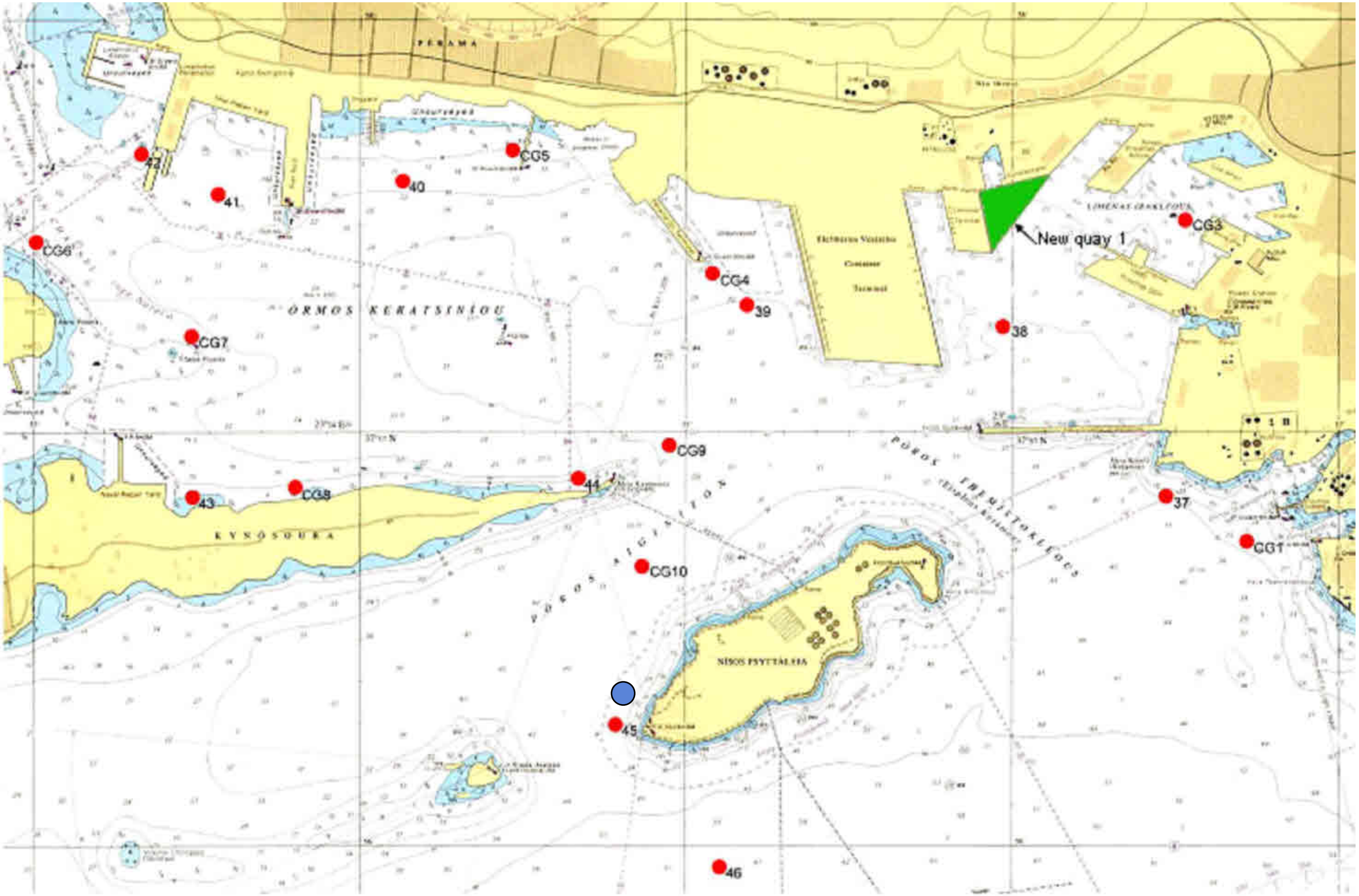
- Option (I): disposal to open sea or other beneficial use (Dutch SQG)
- Option (II): disposal in landfills (2003/33/EC)
- Option (III): disposal in confined facilities (EPA WQC)


Conceptual model for sediment management decision
TIER I
MANAGEMENT OPTION I
Collected sample
Meet target values
Exceed intervention values
Open sea disposal
Test 1
Further characterization for possible environmental remediation
No clear cut situation
ΣSEM < AVS or no toxicity
Tests 2 & 4
ΣSEM ≥ AVS
TIER II
Landfill
Disposal
Confined facility
Inert
Indication of risk
Test 3a
Test 3a Test 3b
Non hazardous
Adequate dilution or no toxicity
No toxicity
Hazardous
Confined storage
Geomembranes
MANAGEMENT OPTION II
MANAGEMENT OPTION III

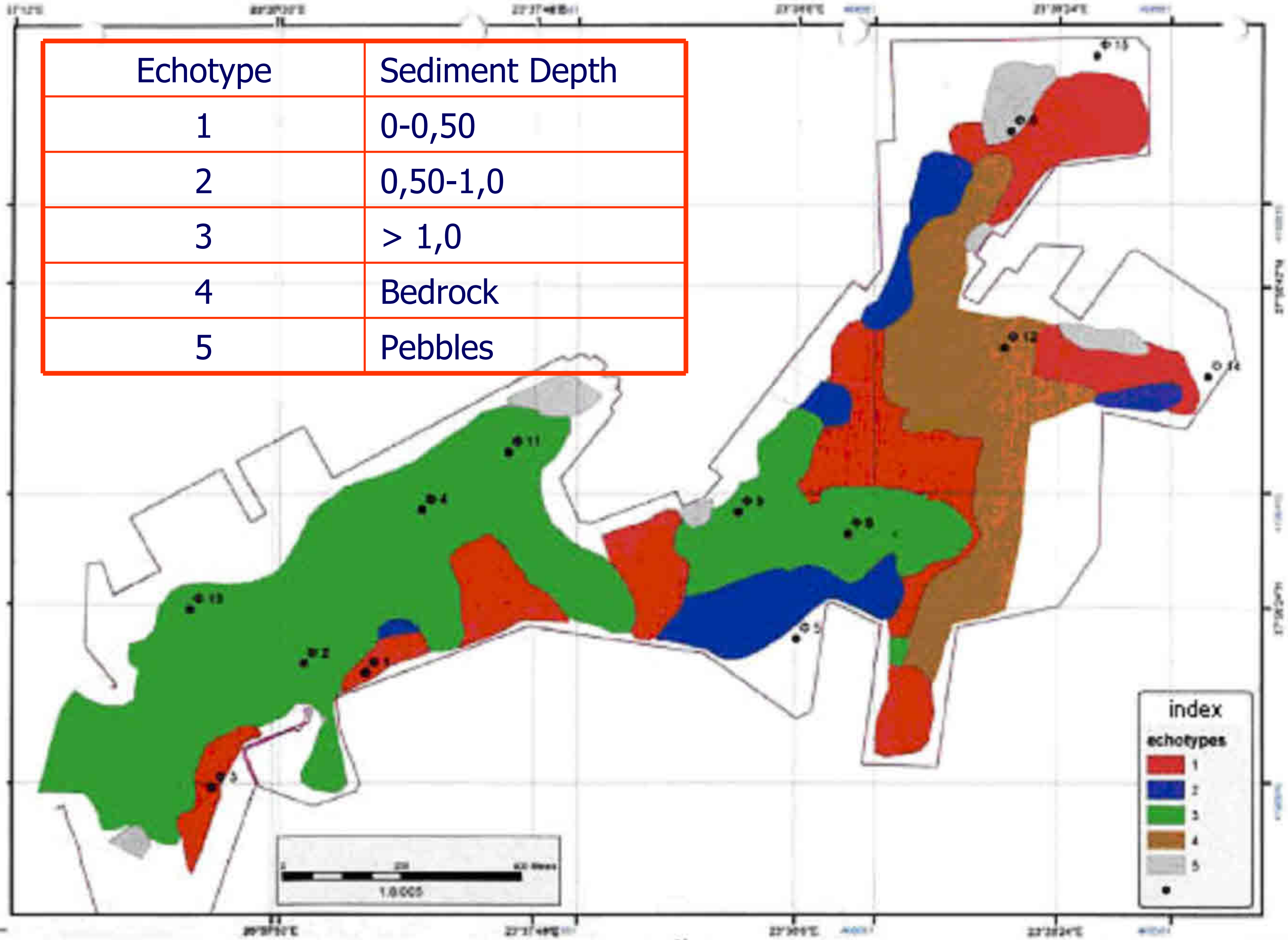
Inner port sampling stations



Outer port sampling stations



Echotype	Sediment Depth
1	0-0,50
2	0,50-1,0
3	> 1,0
4	Bedrock
5	Pebbles



Physical characteristics

Parameter	Unit	Range
Moisture content	%	42 - 49
Volatile content	% DS	7,0 – 16,6
Fine material <74 μm	% DS	38 - 81
Total hydrocarbons	mg/g	79 - 897
Dissolved organic carbon (DOC)	mg/L	350 - 490
pH		8,0

Chemical analyses and AVS/SEM

Station	Cu	Pb	Zn	Ni	Cr	Cd	Hg	AVS	ΣSEM
1	359,8	264,3	504,3	84,0	92,4	<20	0,5	8,3	14,8
2	199,6	147,2	387,7	52,0	67,4	<20	0,48	6,6	7,8
4	196,4	206,5	273,8	46,1	57,4	<20	0,5	7,0	5,7
5	161,1	362,2	730,2	64,5	71,4	<20	0,75	7,6	4,7
7	257,5	1628,8	768,8	46,1	59,0	<20	10,2	5,8	8,4
10	291,7	724,8	827,9	61,1	74,7	<20	1,40	7,5	10,2
13	129,8	377,6	922,8	44,0	67,7	<20	0,30	5,2	5,3
45	127.1	261.6	824.0	42.6	52.1	<20	0.07	8.9	4.6
Target values	36	85	140	35	100	0,8	0,3		
Intervention values	190	530	720	210	380	12	10		

Tier I Decision matrix

Station	1	2	4	5	7	13	10	50
Organic matter and fine material	high	medium	medium	medium	high	low	mediu m	low
Metal Toxicity index	22	14	13,5	19	68	18	30	14.5
Pore water toxicity and bioavailability	-	-	-	-	-	-	-	-
Potential toxicity, $\Sigma SEM - AVS \geq 0$	+	+/-	-	-	+	+/-	+	-
Sea disposal (Option I)	no	unclear	yes	unclear	no	unclear	no	yes

Metal concentrations in leachate (mg/kg)

Station	**1**	**2**	**5**	**7**	Inert	Non hazardous
Cd	<0.2	<0.2	<0.2	<0.2	0.03	0.6
Cr	<0.1	<0.1	<0.1	<0.1	0.20	4.0
Cu	0.09	0.13	0.29	0.13	0.90	25
Hg (μg)	<0.2	<0.2	<0.2	<0.2	3	50
Ni	0.46	0.38	0.35	0.39	0.20	5.0
Pb	1.0	<0.4	0.90	0.5	0.20	5.0
Sb	0.02	0.052	0.04	0.026	0.02	0.20
Zn	0.30	0.10	0.10	0.20	2	25

Metal concentrations in leachate (μg/L)

Station	1	2	5	7	Limit	Dilution
Cd	<100	< 100	< 100	< 100	40	0
Cr	<50	<50	<50	<50	1100	0
Cu	45	65	66	146	4.8	31
Hg (μg)	0.1	0.1	0.1	0.1	1.8	0
Ni	229	188	193	175	74	3
Pb	501	200	263	440	210	2.4
Sb	10	26	2	130	1500	0
Zn	141	51	70	88	90	1.6
Toxicity %	34.2	14.4	5.0	15.1		

Tier II assessment

- Management option II (land disposal) feasible for all stations
- Management option III (confined disposal)
  - Not feasible for stations 1 and 7 (high dilution required or increased toxicity)
  - Feasible for all other stations

Conclusions

- Sediments contain significant quantities of heavy metals (mainly zinc, copper and lead) that exceed target values and for some elements intervention values.
- Less than 0.6% of the total metal concentration was found in pore water and less than 0.8% in leachates.
- The proposed methodology provides a structured system for sediment characterization for decision making.
- Disposal to open sea proved to be infeasible for the more contaminated sediments found in areas with increased shipping activities in the port of Piraeus.
- Disposal to confined facilities is a good option for sediments with intermediate degrees of contamination.
- Disposal to non-hazardous landfill sites was shown to be a viable alternative method of disposal, even for the most contaminated sediments from the port of Piraeus.

Thank you for your attention!