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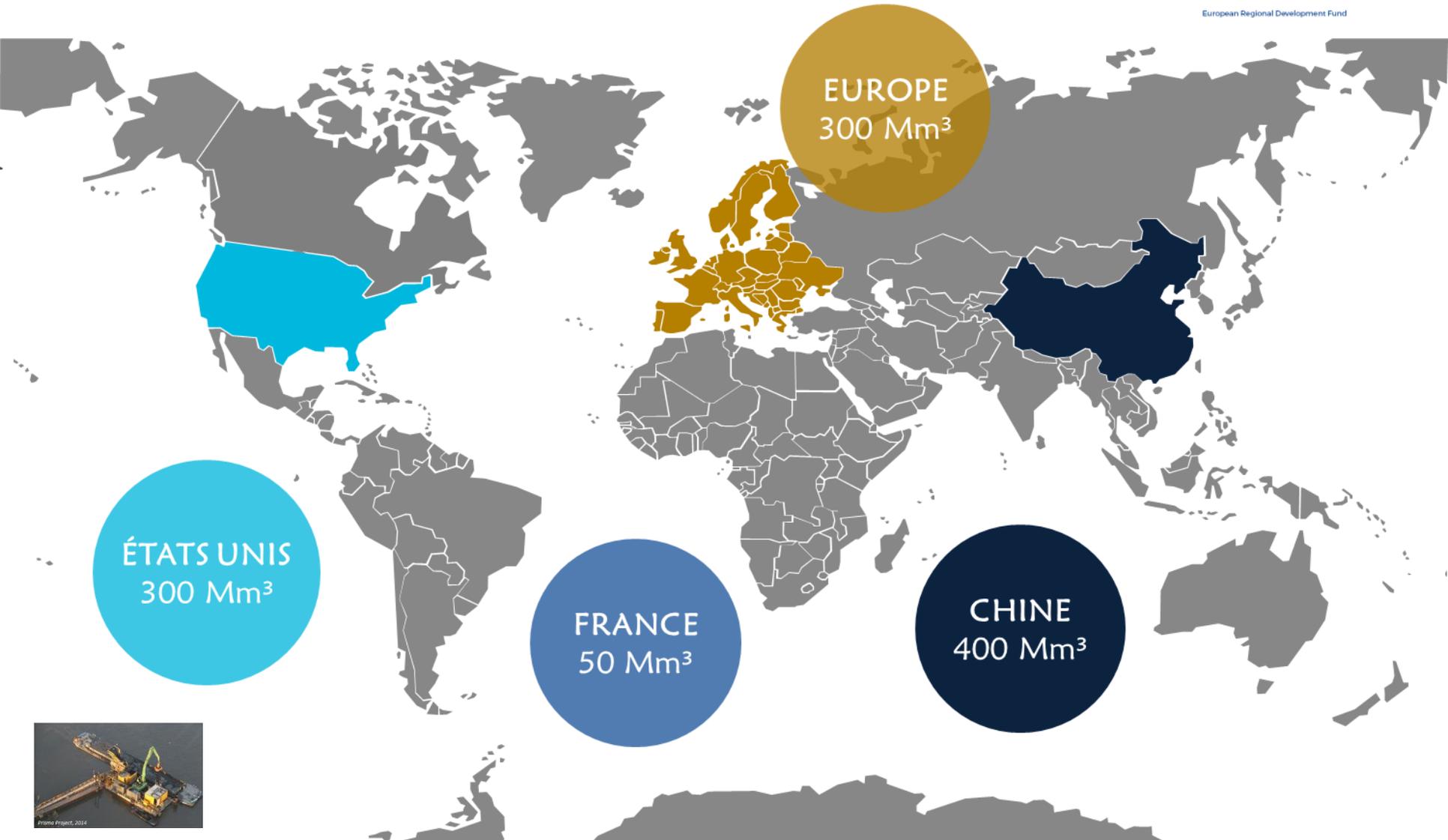
Interreg 
2 Seas Mers Zeeën
USAR
European Regional Development Fund

Using Sediment As a Resource

WikiSed & Operational Sediment Management System “OSMS”

October 13 & 14, 2020

A. ZERAOUI, M. BENZERZOUR, N-E. ABRIAK, W. MAHERZI & R. MANSI



Context

In France, dredging operations generate more than 50 Mm³ of sediment per year.

Dredged sediments



Consequences

- *Siltation of waterways*
- *Flood risk*
- *Environmental issues*
- *Economic issues*

Sediments management



Immersion

Storage

*Saturation of storage centers
Possible treatment before storage*

Need to find alternatives that are part of a sustainable sediment management approach



Valorization

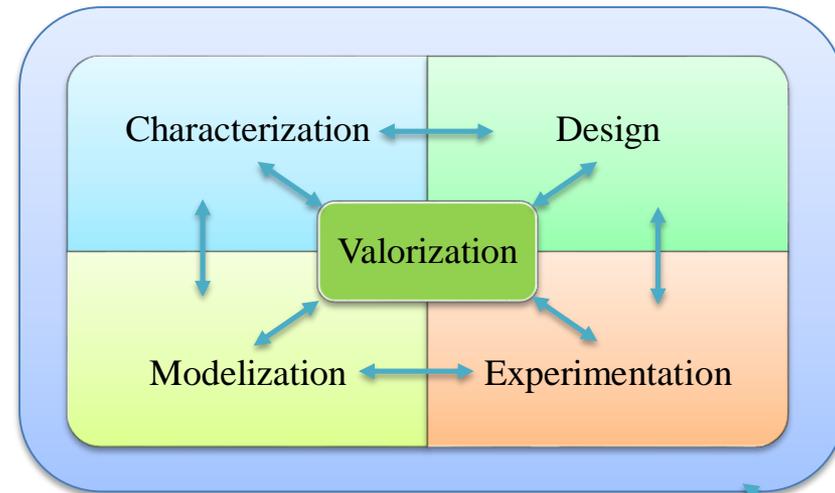
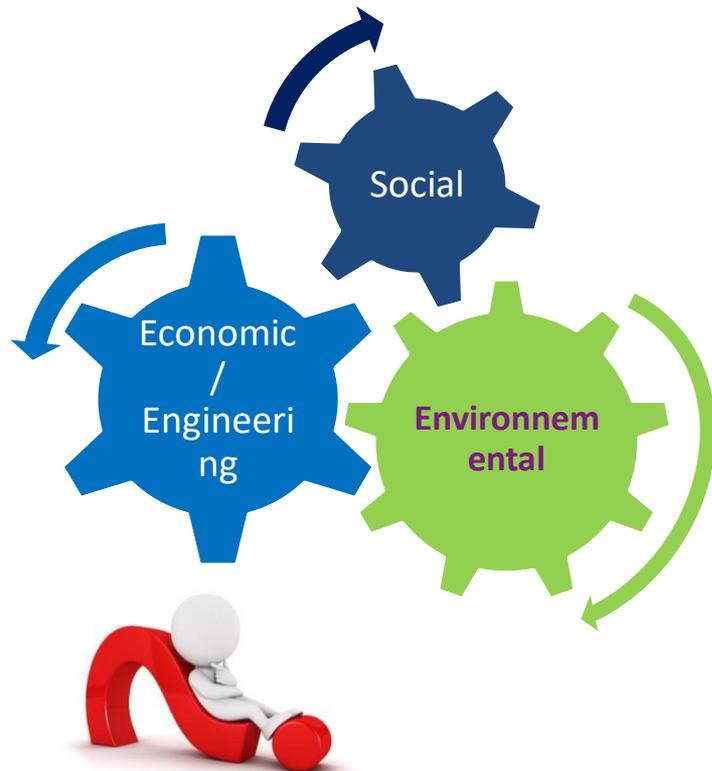
*Which field?
How?
Technical feasibility?
Environmental acceptability?
cost?*



→ **USAR** Projet (**U**sing **S**ediment **A**s a **R**esource) : Promote the use of sediment, namely in civil engineering

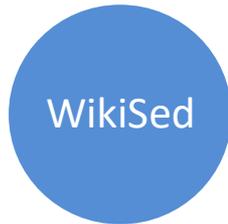
Using sediment as a resource

Complex decision
multi parameters





Inventory catalog



Software



Web Link : <http://wikised.phenixmat.com/>

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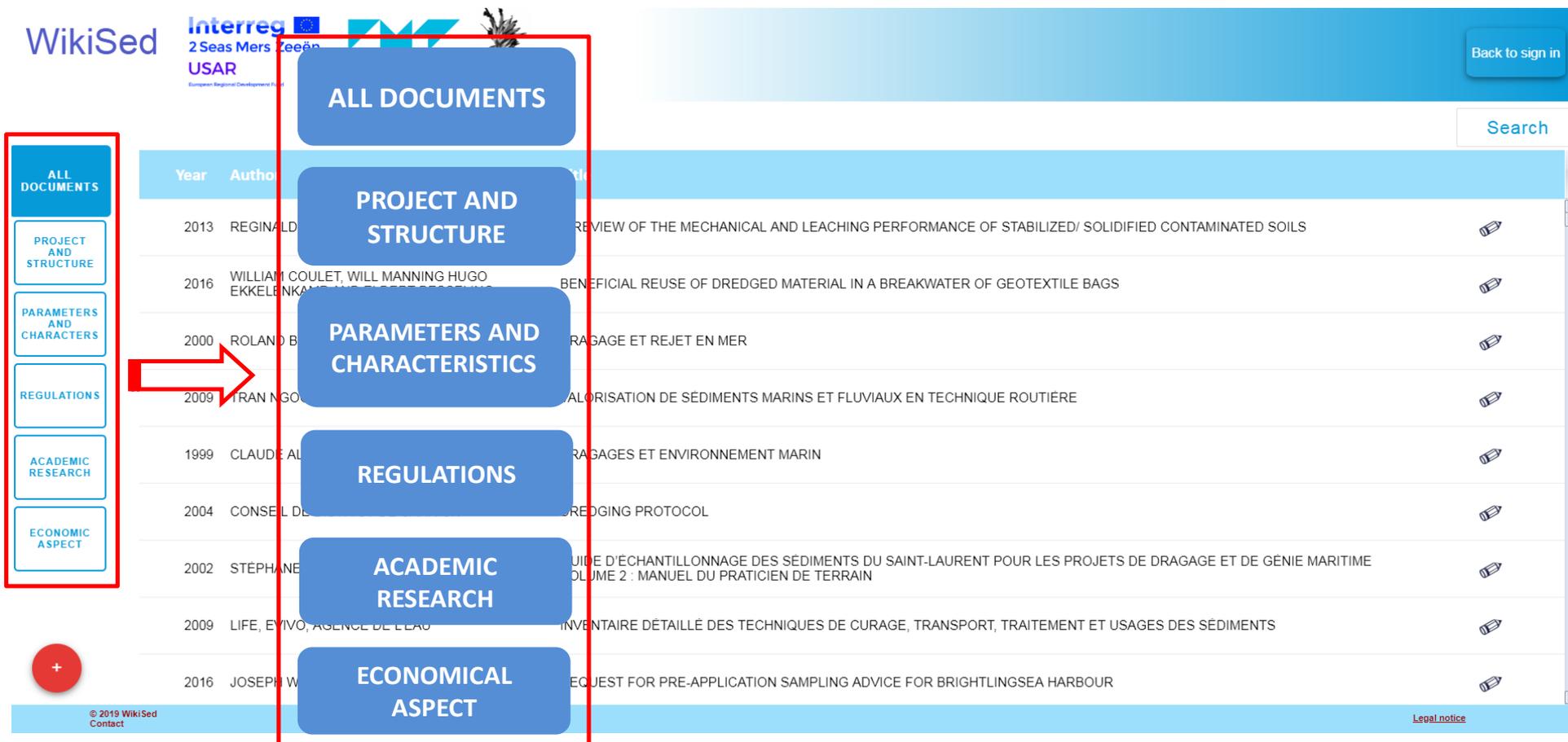
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Year	Author	Title	Category
2013	REGINALD	REVIEW OF THE MECHANICAL AND LEACHING PERFORMANCE OF STABILIZED/ SOLIDIFIED CONTAMINATED SOILS	PROJECT AND STRUCTURE
2016	WILLIAM COULET, WILL MANNING HUGO EKKELENKA	BENEFICIAL REUSE OF DREDGED MATERIAL IN A BREAKWATER OF GEOTEXTILE BAGS	PROJECT AND STRUCTURE
2000	ROLAND B	RAGAGE ET REJET EN MER	PARAMETERS AND CHARACTERISTICS
2009	IRAN NGO	ALORISATION DE SEDIMENTS MARINS ET FLUVIAUX EN TECHNIQUE ROUTIERE	PARAMETERS AND CHARACTERISTICS
1999	CLAUDE AL	RAGAGES ET ENVIRONNEMENT MARIN	REGULATIONS
2004	CONSEIL DE	DREDGING PROTOCOL	REGULATIONS
2002	STÉPHANE	GUIDE D'ÉCHANTILLONNAGE DES SEDIMENTS DU SAINT-LAURENT POUR LES PROJETS DE DRAGAGE ET DE GÉNIE MARITIME VOLUME 2 : MANUEL DU PRATICIEN DE TERRAIN	ACADEMIC RESEARCH
2009	LIFE, EYVO, AGENCE DE L'EAU	INVENTAIRE DÉTAILLÉ DES TECHNIQUES DE CURAGE, TRANSPORT, TRAITEMENT ET USAGES DES SEDIMENTS	ACADEMIC RESEARCH
2016	JOSEPH W	REQUEST FOR PRE-APPLICATION SAMPLING ADVICE FOR BRIGHTLINGSEA HARBOUR	ECONOMICAL ASPECT

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2016	WILLIAM COULET, WILL MANNING HUGO EKKELENKAMP AND ELDERT BESSELING	BENEFICIAL REUSE OF DREDGED MATERIAL IN A BREAKWATER OF GEOTEXTILE BAGS
2000	ROLAND BOUTIN	DRAGAGE ET REJET EN MER
2009	TRAN NGOC THANH	VALORISATION DE SÉDIMENTS MARINS ET FLUVIAUX EN TECHNIQUE ROUTIÈRE
1999	CLAUDE ALZIEU ET AL	DRAGAGES ET ENVIRONNEMENT MARIN
2004	CONSEIL DE DISTRICT DE CARRICK	DREDGING PROTOCOL

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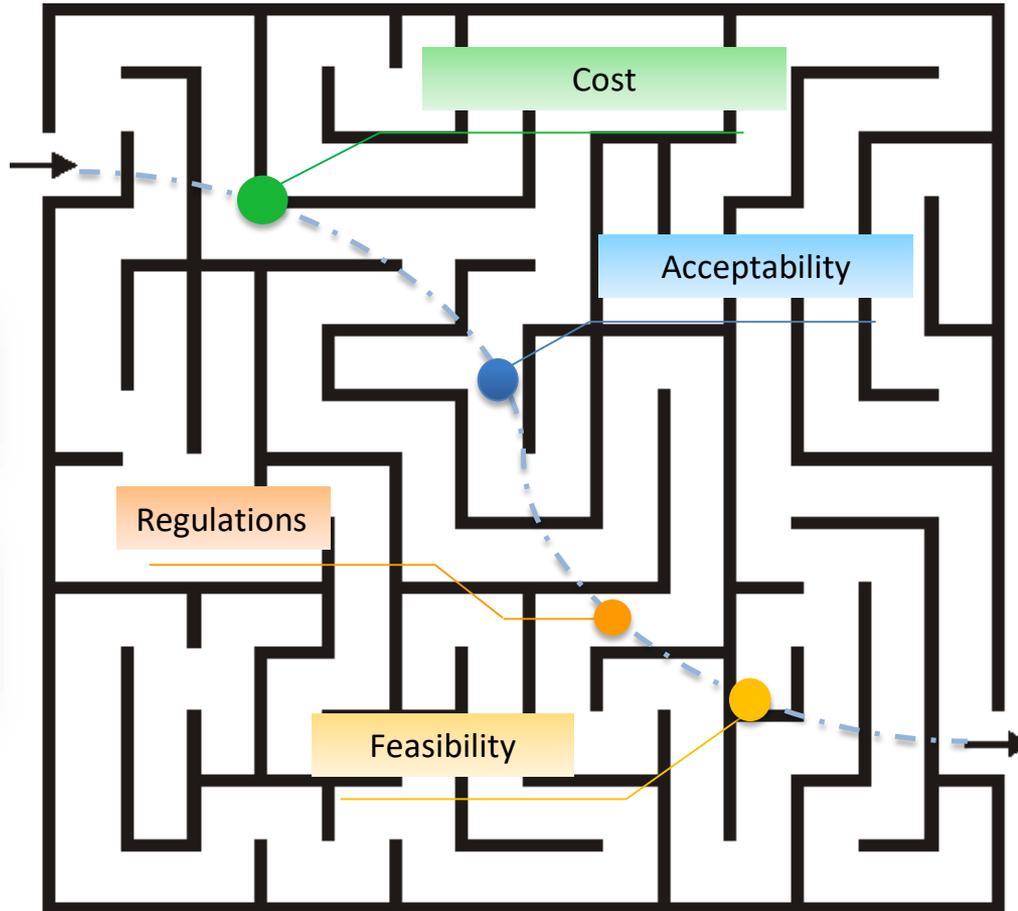
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Operational Sediment Management System (OSMS)

Sediment
« Waste »



**Materials,
products**

Using Sediment As A Resource

OSMS Optimization process



Embankments



Road

Optimization of the mixing and
the treatment of dredged
sediments

Technical
feasibility

Environmental
impact

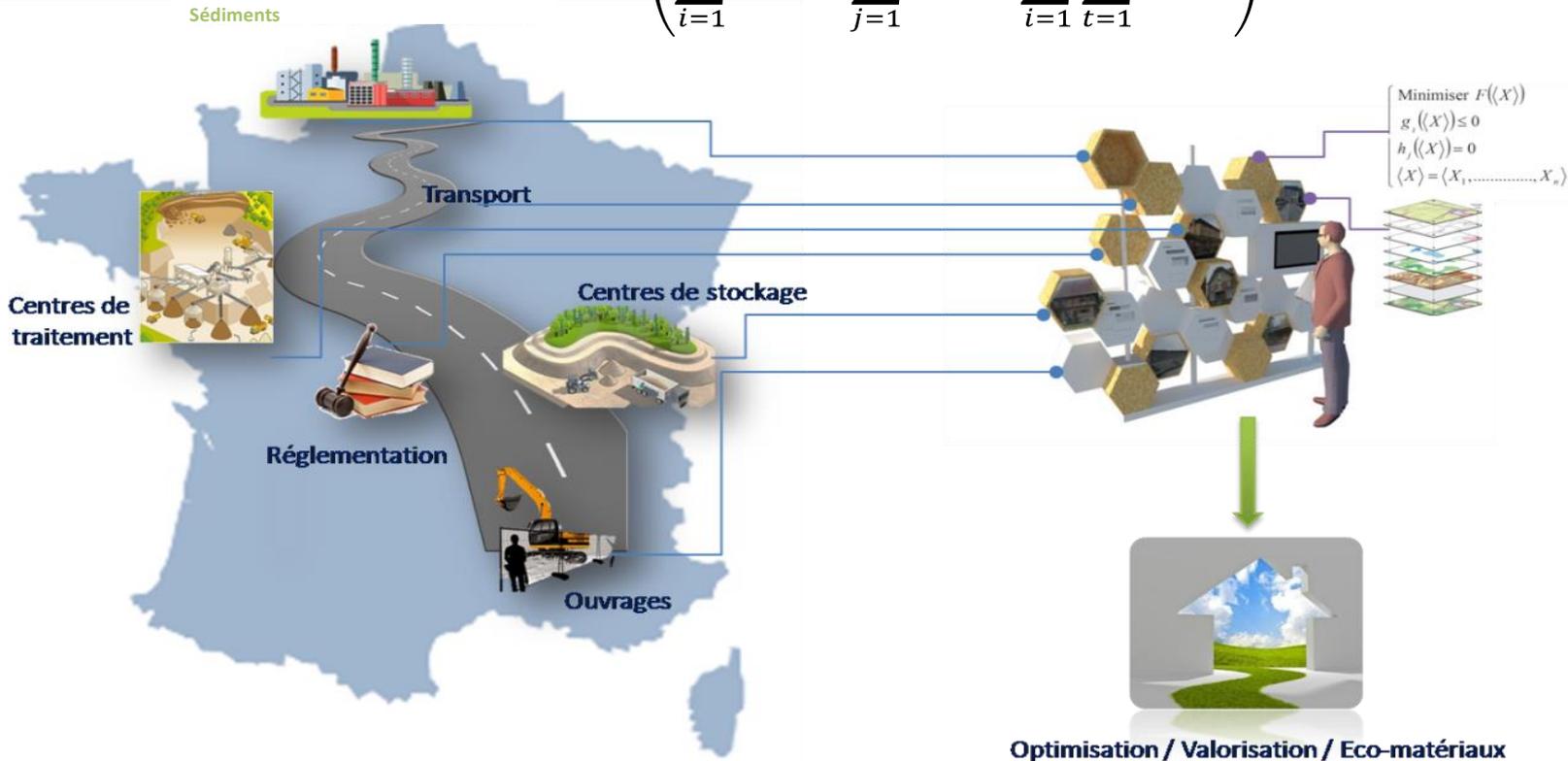
Concrete

Agricultural
spreading



Propose the optimal solution that meets technical and environmental requirements at the lowest cost.

$$\text{Min} \left(\sum_{i=1}^n C_i x_i + \sum_{j=1}^m C_j S_j + \sum_{i=1}^n \sum_{t=1}^{|T|} C_{ti} T_{ti} \right)$$



Objective Function : Lower cost for optimal valuation

Software : Input data

Sediment

- Name
- Type of sample
- *Characteristics*
 - . *Chemical (as, zn, ...)*
 - . *Mechanical (GTR)*
- Centre of studies
- dredging date
- dredging location
- *GPS coordinates*
- *Transport costs* T / km
- Operating costs
- Notes

Treatment center

- Unit name
- Type of treatment
- **For each type:**
 - . *Name of treatment*
 - . *Cost* € / T
 - . *Impact on polluting element%*
- Address of the center
- GPS coordinates
- Notes

Storage areas

- Zone Name
- *Type (Inert, Not dangerous, Dangerous)*
- *GPS coordinates*
- *Storage costs* € / T
- Notes

Materials

- Name
- *GPS coordinates*
- *Transportation cost*
- *Operating cost (or purchase)*
- *Characteristics*
 - . *chemical*
 - . *mechanics*
- Notes



Mathematical model : Constraints

Environmental constraints : Heavy metals

$$e_{si} \left(1 - \sum_{t=1}^{|T|} \hat{e}_{sit} T_{ti} \right) \leq e_s + (1 - x_i)M$$

Environmental constraints : Organic matter

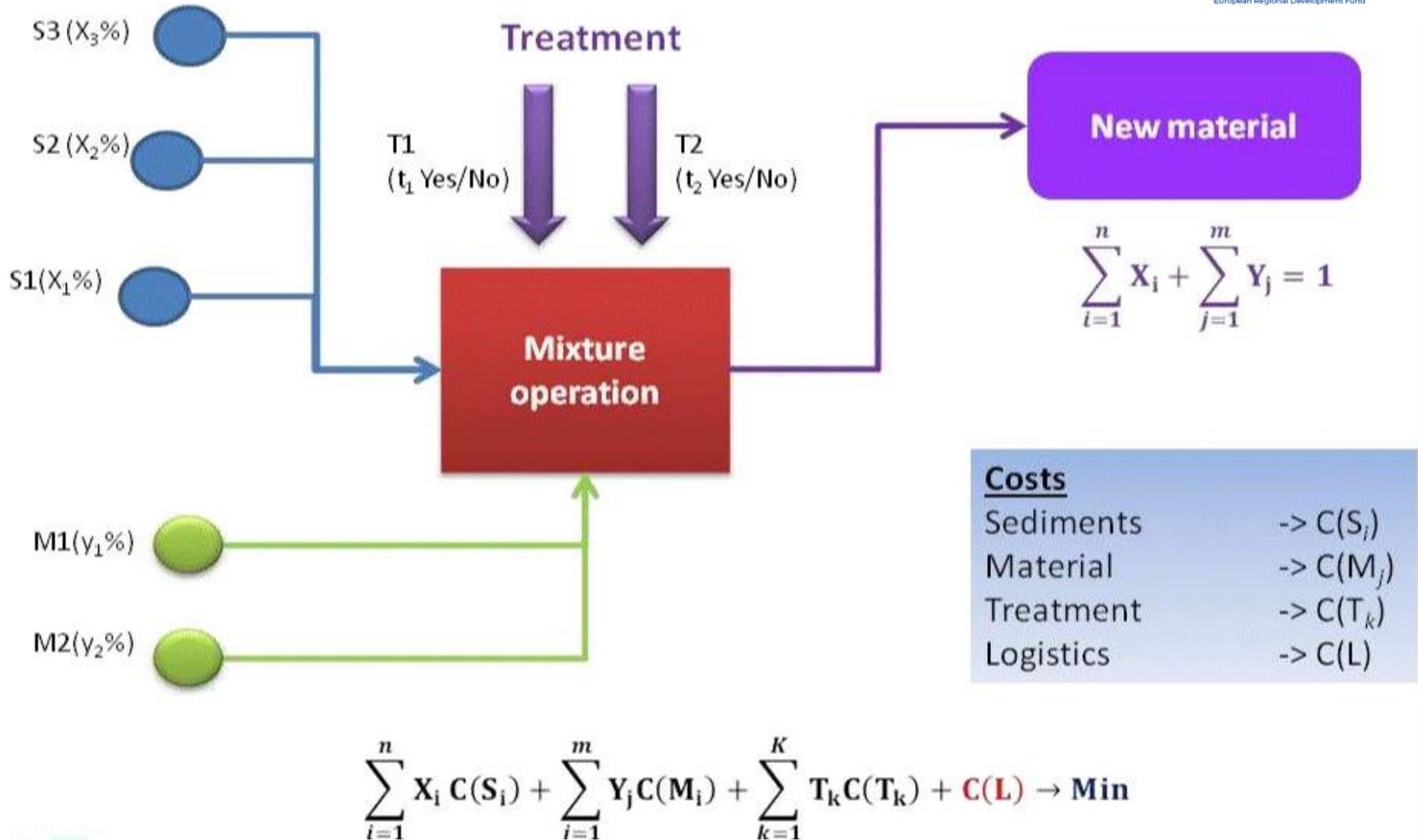
$$e_{Mi} \left(1 - \sum_{t=1}^{|T|} \hat{e}_{Mit} T_{ti} \right) \leq e_M \left(1 + \sum_{j=1}^m S_j \right) + (1 - x_i)M$$

Mechanical constraints

$$\hat{P}_d^{0.4} \left(\sum_{i=1}^n x_i + \sum_{j=1}^m S_j \right) \leq \sum_{i=1}^n (P_{id} \times x_i) + \sum_{j=1}^m (P_{jd} \times S_j) \leq \hat{P}_d^{0.25} \left(\sum_{i=1}^n x_i + \sum_{j=1}^m S_j \right)$$

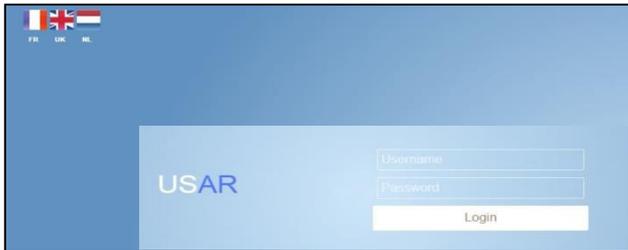
$P_{id} (P_{jd})$: associated percentage to the diameter d in sediment i (material j)

Mathematical model



OSMS softwar

Home page



1. **Admin** import the data, define the constraints, insert the costs, etc.
2. **Data & Analysis** display on the map the position of the different sediments, quarries, treatment centers, etc.
3. **Manual simulation** create a project and start a manual analysis
4. **Automatic simulation** create a project and start automatic analysis



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 SEDIMENT Import & Export
 MATERIALS Import & Export
 PARAMETERS Chemical and Mechanical
 CLASSIFICATION Normes & Legislation
 TREATMENTS Import & Export
 STORAGE AREA Décharges & Ports
 TRANSPORT Terrestrial & marine

- GPS coordinates, characterization and cost
- Sand, gravel, lime, fly ash etc., GPS position, characteristics, costs
- Physical, chemical and geotechnical parameters
- Classification of sediments
- Add a treatment center, GPS coordinates, costs, etc.
- GPS coordinates, acceptability criteria, costs
- Type of transport, costs

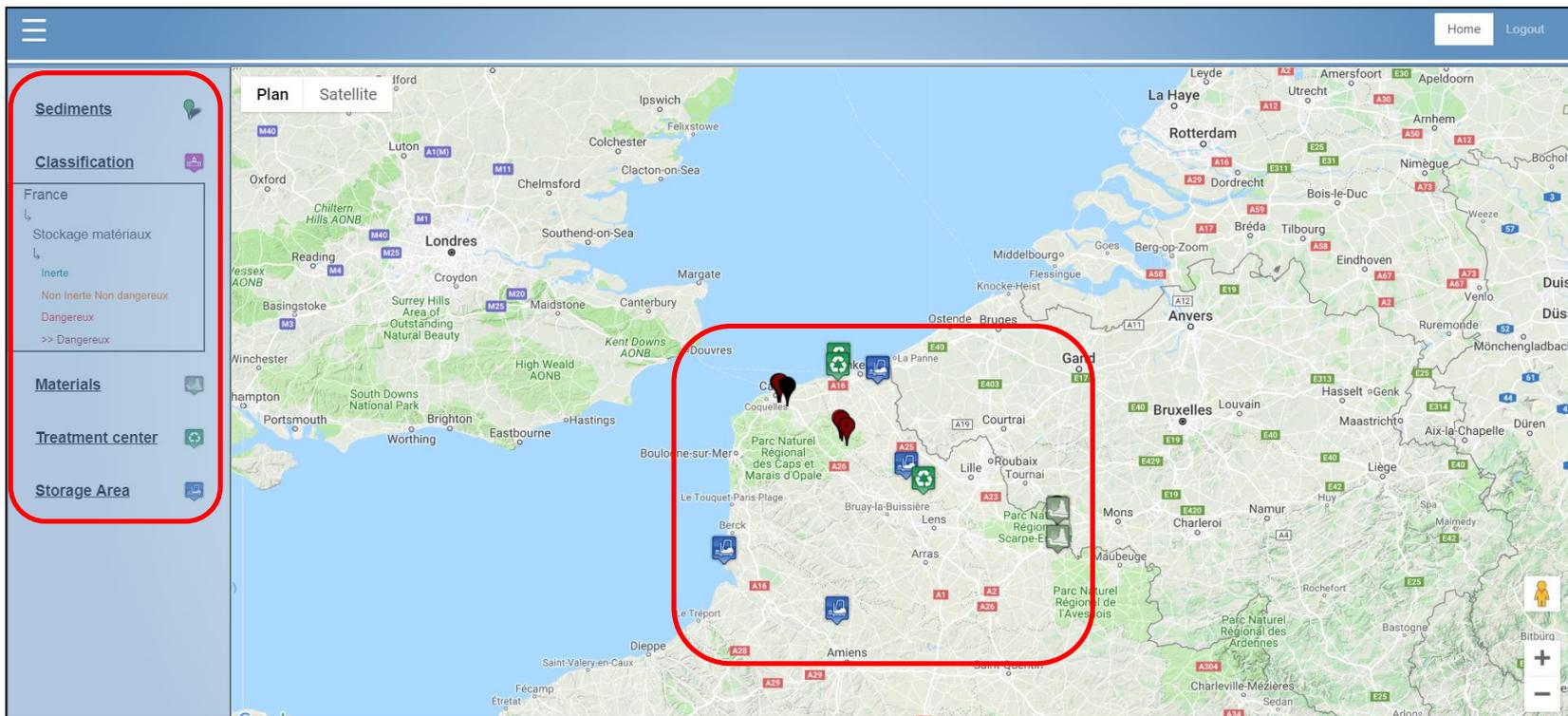
DATA & ANALYSIS

MANUAL SIMULATION

AUTOMATIC SIMULATION

ADMIN

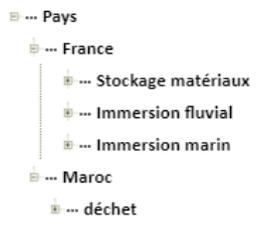
The GPS coordinates of the project, the sediments, the additive, the materials, treatment centers and storage centers are displayed on the map



Using Sediment As A Resource

Paramètre	Symbole	Unité (MOW)	Unité (MOW)	Min Obs.	Max Obs.	Valeur
Granulométrie						
Fraction 0 à 2 um	Fraction_2	%	%	2.53	5.22	4.98
Fraction 0 à 20 um	Fraction_20	%	%	19.82	45.75	45
Fraction 0 à 50 um	Fraction_50	%	%	39.36	83.21	64.08
Fraction 0 à 60 um	Fraction_60	%	%	41.32	88	67.28
Fraction 2 à 60 um	Fraction_2_60	%	%	38.33	83.82	62.3
Fraction 0 à 200 um	Fraction_200	%	%	59.7	98.65	91.67
Fraction 0 à 2000 um	Fraction_2000	%	%	100	100	100
Fraction 0 à 4000 um	Fraction_4000	%	%	100	100	100
Fraction 0 à 5000 um	Fraction_5000	%	%	100	100	100
Fraction 60 à 2000 um	Fraction_60_2000	%	%	12	58.68	32.72
Fraction 2000 um à DMax	Fraction_2000_DMax	%	um	0	0	0
DMax	DMax	um	um	2000	2000	2000
Limite Atterberg						
WL	WL	%	%	40	65	48.67
WP	WP	%	%	33	48	33.34
Ip	Ip	%	%	7	21	15.33
Ic	Ic	%	%	1.57	3.42	1.57
Naturel						
Wn	Wn	%	%	87.9	169.9	106.13
Hydraulique						
Perméabilité	K	m/s	m/s	0.000001	0.000001	0.000001
Organique						
MO	MO	%	%	4.4	9.4	6.5
Géotechnique						
IPI	IPI	-	-	17	22	22
VBS	VBS	-	-	1	1.99	2.03
Chimique						
Arsenic	As	mg/kg	mg/kg	5.15	14.8	7.06
Cadmium	Cd	mg/kg	mg/kg	0.4	15.6	0.4
Chrome Tot	Cr Tot	mg/kg	mg/kg	13.7	88.4	16
Cuivre	Cu	mg/kg	mg/kg	14.6	439	14.6
Mercuré	Hg	mg/kg	mg/kg	0.1	3.09	0.75
Nickel	Ni	mg/kg	mg/kg	8.49	25.7	9.53
Piomb	Pb	mg/kg	mg/kg	32.2	274	34.4
Zinc	Zn	mg/kg	mg/kg	112	1460	112
Carbone Organique Total	COT	mg/kg	mg/kg	13400	44200	20000
Polychlorobiphényles	PCB	mg/kg	mg/kg	0.07	0.07	0.07
Hydrocarbures Totaux	HCT	mg/kg	mg/kg	0	19166	7661
o-Xylene	o-Xylene	mg/kg	mg/kg	0.05	0.09	0.07
Toluene	Toluene	mg/kg	mg/kg	0.05	1.31	0.07
Ethylbenzene	Ethylbenzene	mg/kg	mg/kg	0.05	0.09	0.07
Benzene	Benzene	mg/kg	mg/kg	0.05	0.05	0.05
Naphthalene	Naphthalene	mg/kg	mg/kg	0.012	0.554	0.041
Acenaphthylene	Acenaphthylene	mg/kg	mg/kg	0.068	0.619	0.194
Acenaphthene	Acenaphthene	mg/kg	mg/kg	0.037	4.08	0.051
Fluorene	Fluorene	mg/kg	mg/kg	0.058	1.77	0.64
Phenanthrene	Phenanthrene	mg/kg	mg/kg	0.216	2	0.354
Anthracene	Anthracene	mg/kg	mg/kg	0.125	1.36	0.242
Fluoranthene	Fluoranthene	mg/kg	mg/kg	0.458	6.61	1.14
Pyrene	Pyrene	mg/kg	mg/kg	0.405	5.33	0.749
Chrysene	Chrysene	mg/kg	mg/kg	0.348	3.48	0.668
Benzo[a]pyrene	Benzo[a]pyrene	mg/kg	mg/kg	0.335	3.34	0.613
Indeno[1,2,3-c,d]pyrene	Indeno[1,2,3-c,d]pyrene	mg/kg	mg/kg	0.311	3.56	0.444
Dibenzo[a,h]anthracene	Dibenzo[a,h]anthracene	mg/kg	mg/kg	0.063	0.739	0.207

Classification environnementale



Inerte Non Iner... Dangere... >>Dange...
 S >>S
 N1 N2 >>N2
 inert dang >>dang



characteristics and classifications



Granularité

Tamiséat 80 um :	Tamiséat 2 mm :	Frac 0/50 mm(%) :
29	5	
Dmax :	D60 :	D30 :
0.2	66	29
D10 :	Cu :	Cc :
5		

Indice de plasticité | Bleu de méthylène

IP : VBS :

19 2

Etat

Wn * : Wopn :

Limites d'Atterberg

Wl * : Wo * : Ic :

55 40 2.5

Comportement mécanique

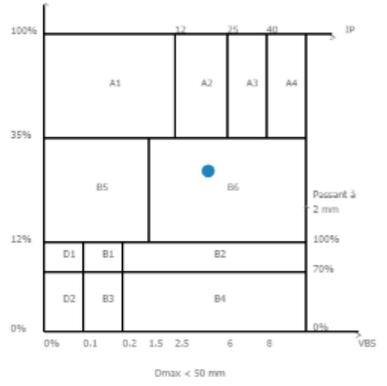
LA : MDE : FS :

Indice portant immédiat | Matière organique

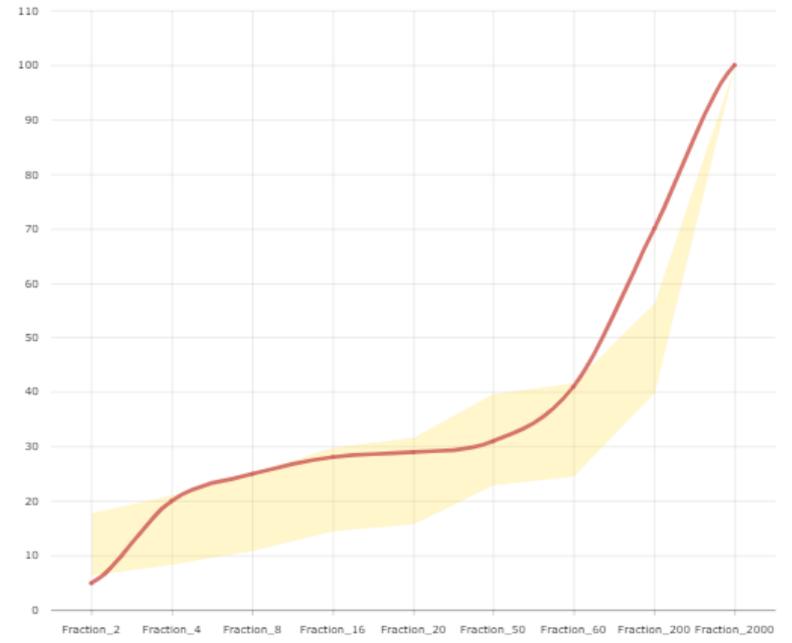
IPI : MO :

5

Classification

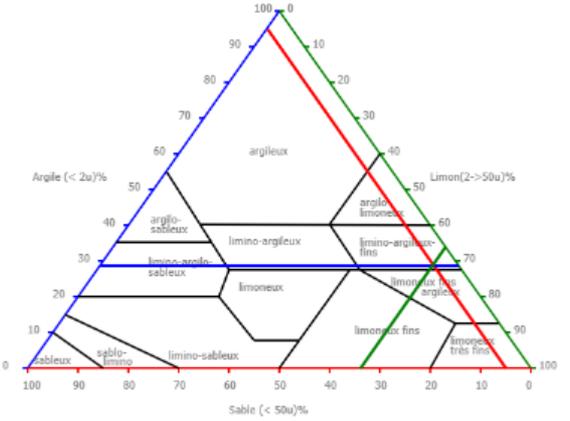
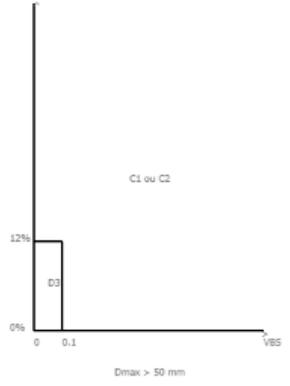


Graphe de granulométrie



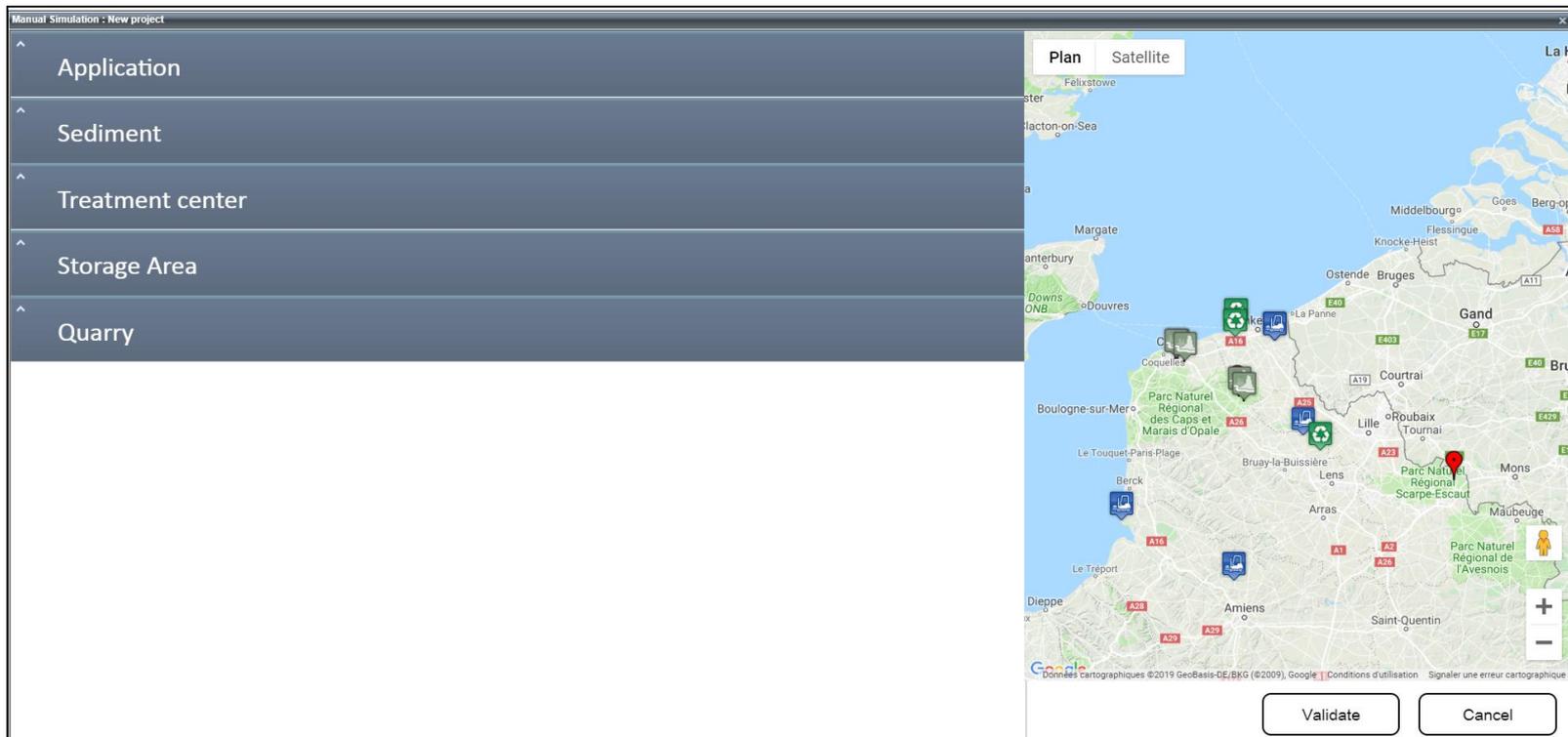
Classement selon la nature - B : Sols sableux et graveleux avec fines. - Sous-classe fonction de la nature - B6 : Sables et graves argileux à très argileux.

F11 : Matériaux faiblement organiques (terres végétales, vases, . . .)





Create a new project and select its characteristics: type of application, sediments, quarries, storage and treatment centers etc.



Using Sediment As A Resource

Example of results, Road application -1-

↑ | **Editor Projet** |

Code	Symbole	Min	Max
Limite Atterberg			
Ic	Ic	0.6	
Organique			
MO	MO		3
Géotechnique			
IPI	IPI		20
Chimique			
Mercuré	Hg	0.2	
Molybdène	Mo	10	
Nickel	Ni	10	
Plomb	Pb	10	
Antimoine	Sb	0.7	
Sélénium	Se	0.5	
Zinc	Zn	50	
Fluorure	F-	150	
Chlorure	Cl-	15000	
Sulfate	SO4-	20000	
Carbone Organique T...	COT	30000	
Hydrocarbures Arom...	HAP	50	
Polychlorobiphényles	PCB	1	
Hydrocarbures Totaux	HCT	500	
Arsenic	As	2	
Barium	Ba	100	
Cadmium	Cd	1	
Chrome Tot	Cr Tot	10	
Cuivre	Cu	50	

Nouveau matériau 11.08(€)

	%	% Max	Coût(€)
Sédiments			
B3	15.14	100.0	1.05
C2	5.37	100.0	0.48
Matériaux			
M2	79.47	100.0	9.53

Graphe de granulométrie



1 → Limit values of acceptability
2 → Mix design
3 → Costs
4 → Characteristics of the new material
5 → New parameters values

Enregistrer

Exécuter

Arbre de décision

Export

Code	Symbole	Valeur
Limite Atterberg		
Ic	Ic	0.47
Organique		
MO	MO	1.6
Géotechnique		
IPI	IPI	
Chimique		
Arsenic	As	1.41
Barium	Ba	0
Cadmium	Cd	0.2
Chrome Tot	Cr Tot	10

Example of results, Road application -2-

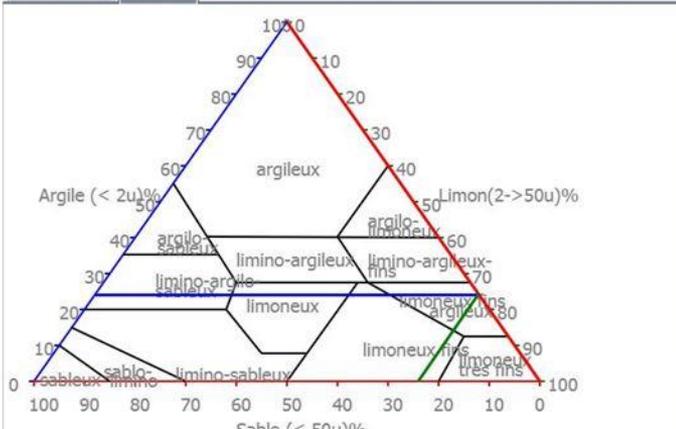
FRANCE | Route | Route

↑ | **Editer Projet** |

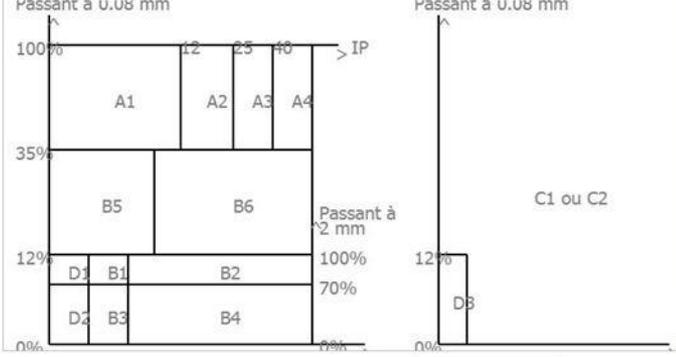
Code	Symbole	Min	Max
Granulometrie			
<input type="checkbox"/> DMax	DMax	5000	✓
<input type="checkbox"/> Fuseau Talbot	TALBOU		⊘
Organique			
<input checked="" type="checkbox"/> MO	MO	3	✓
Géotechnique			
<input checked="" type="checkbox"/> IPI	IPI	20	✓
Chimique			
<input checked="" type="checkbox"/> Molybdène	Mo	10	✓
<input checked="" type="checkbox"/> Nickel	Ni	10	✓
<input checked="" type="checkbox"/> Plomb	Pb	10	✓
<input checked="" type="checkbox"/> Antimoine	Sb	0.7	✓
<input checked="" type="checkbox"/> Sélénium	Se	0.5	✓
<input checked="" type="checkbox"/> Zinc	Zn	50	✓
<input checked="" type="checkbox"/> Fluorure	F-	150	✓
<input checked="" type="checkbox"/> Chlorure	Cl-	15000	✓
<input checked="" type="checkbox"/> Sulfate	SO4-	20000	✓
<input checked="" type="checkbox"/> Carbone Organique T...	COT	30000	✓
<input checked="" type="checkbox"/> Hydrocarbures Arom...	HAP	50	✓
<input checked="" type="checkbox"/> Polychlorobiphényles	PCB	1	✓
<input checked="" type="checkbox"/> Hydrocarbures Totaux	HCT	500	✓
<input checked="" type="checkbox"/> Arsenic	As	2	✓
<input checked="" type="checkbox"/> Barium	Ba	100	✓
<input checked="" type="checkbox"/> Cadmium	Cd	1	✓
<input checked="" type="checkbox"/> Chrome Tot	Cr Tot	10	✓
<input checked="" type="checkbox"/> Cuivre	Cu	50	✓
<input checked="" type="checkbox"/> Mercure	Hg	0.2	✓

Nouveau matériau **11.49(€)**

	%	% Max	Coût(€)
Sédiments			
A3	37.82	100.0	1.89
Transport			
Transport marin	Initial	Cible	0.3
C2	62.17	100.0	5.59
Traitements			
Traitement MO (Biot)			3.1
Paramètres			
Transport	Initial	Cible	
Transport marin	Initial	Traitement MO	0.3
Transport marin	Traitement MO	Cible	0.3
Centre de stockage			
centre de stockage Inerte			0.0



Passant a u.08 mm



Passant a u.08 mm

Export

Enregistrer

Exécuter

Example of results, Embankments

FRANCE | Digue-Couverture | Digue Cou_verture

↑ | **Editer Projet** |

Nouveau matériau 10.94(€)

	Sédiments	%	% Max	Coût(€)
	B2	7.48	100.0	0.52
	B3	13.61	100.0	0.95

Arbre de décision - Digue

```

    Tamit_2 ≥ 18 %
    └─ Tamit_2 ≥ 35 %
       Tamit_60 - Tamit_2 ≤ 45 %
       Tamit_2000 - Tamit_60 ≤ 45 %
       IP ≤ 25
    └─ 18 ≤ Tamit_2 ≤ 35
       15 % ≤ Tamit_60 - Tamit_2 ≤ 50 %
       15 % ≤ Tamit_2000 - Tamit_60 ≤ 50 %
       5 ≤ IP ≤ 25
    └─ 35 ≤ Tamit_2 ≤ 55 %
       Tamit_60 - Tamit_2 ≤ 20 %
       45 % ≤ Tamit_2000 - Tamit_60 ≤ 50 %
       5 ≤ IP ≤ 25
    └─ 35 ≤ Tamit_2 ≤ 55 %
       45 % ≤ Tamit_60 - Tamit_2 ≤ 50 %
       Tamit_2000 - Tamit_60 ≤ 20 %
       5 ≤ IP ≤ 25
    └─ Tamit_60 - Tamit_2 ≥ 50 %
       45 % ≤ Tamit_2000 - Tamit_60 ≤ 50 %
       5 ≤ IP ≤ 15
    └─ Tamit_2 ≥ 18 %
       Tamit_2000 - Tamit_60 ≤ 50 %
       15 ≤ IP ≤ 25
  
```

Graphe de granulométrie



Code	Symbole	Valeur
Granulometrie		
Fraction 60 à 2000 um	Fractio...	46.58 ✓
Limite Atterberg		
WL	WL	9.48 ✓
Ip	Ip	2 ✓
Ic	Ic	0.44 ✓
Hydraulique		
Permeabilité	K	✓
Organique		
MO	MO	1.73 ✓
Géotechnique		

Using Sediment As A Resource

Thank you for your attention

Contact: ahmed.zeraoui@imt-lille-douai.fr