The development of a preliminary approached to sediment site evaluation and associated risk

PROJECT NO. K5/2754

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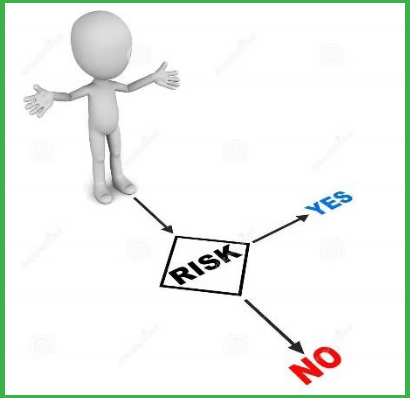
12 September 2019

WATER RESEARCH COMMISSION



PROJECT OVERVIEW

- Contaminated sediments as well as storm-water run-off have been identified as long-term pollutant sources in the aquatic environment
- Contaminated sediment → Source and Sink (known and emerging contaminants of concern)
- Large portions of sediments in industrialised countries have metal and organic contaminants at levels that are hazardous to the aquatic ecosystem and ultimately humans. → The magnitude is unknown.
- Without a correct and standardised approach to sampling, risk evaluations will remain in the "grey" unobtainable abyss.
- The inherent complexity of sediments remains the biggest challenge when assessing the impact of contaminated sediments in the aquatic environment (Burton and Landrum, 2003).

SEDIMENT COMPLEXITIES

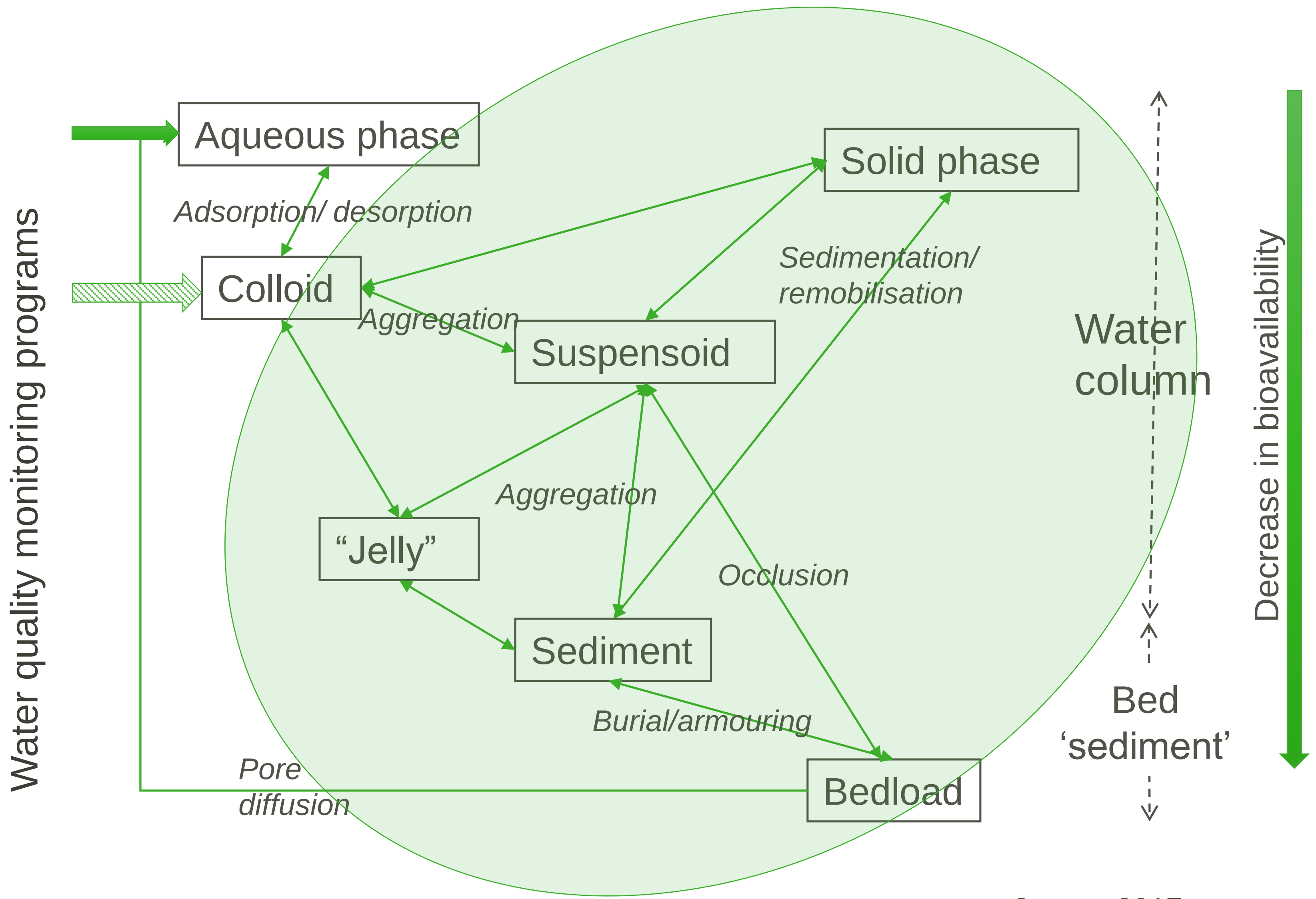
Sediments contain both natural and anthropogenic components

A variety of organic and inorganic contaminants bind to sediment

Sediments get disturbed through natural and anthropogenic means

The bioavailability of contaminants is determined by dynamic processes:

- Chemical availability (adsorption/desorption): determined by hydrophobicity, Redox, solubility, pH, sediment particles <63 µm, organic material content
- Biological availability (Species specific): determined by feeding mechanisms and strategies, habitat preferences
- Toxicological bioavailability (Organism specific): determined by metabolic rates, detoxification abilities and excretion rates

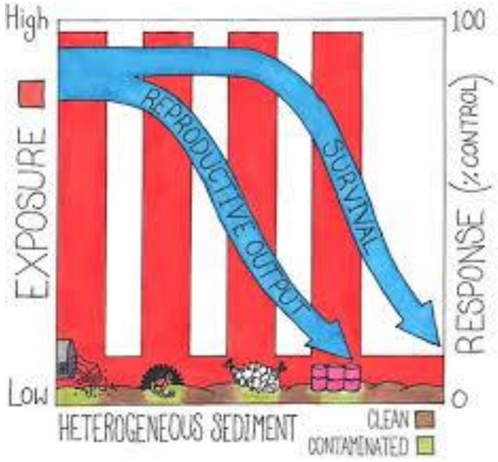


Water quality monitoring programs
Aqueous phase
Adsorption/ desorption
Colloid
Aggregation
Suspensoid
Solid phase
Sedimentation/
remobilisation
Aggregation
"Jelly"
Occlusion
Sediment
Burial/armouring
Pore
diffusion
Bedload
Water
column
Bed
'sediment'
Decrease in bioavailability

Jooste, 2017

SEDIMENT COMPLEXITIES

- Difficult and confusing problems when attempting to evaluate quality, quantity and risk.
- Water quality criteria only protects organisms living in the water column, these criteria fail to provide protection for the sediment dwelling organisms.
- Contaminants can accumulate to high concentrations bound to sediments even when the water concentrations are at or below acceptable water quality guidelines
- Sediments are heterogeneous and disperse based on size, density and porosity



THE APPROACH

TWO CHOICES:

Ignore it → Historical, too complex

Take it one step at a time → Gather information (international, multidisciplinary), get feedback, field data, compile, improve

Project K5/2754: The development of a preliminary approached to sediment site evaluation and associated risk

PREVIOUS ASSOCIATED PROJECTS

- WRC Project No. K8/793 → the development of sediment quality guidelines for South Africa
- WRC Project No. K8/946 → the identification of suitable test organisms to assess sediment contamination
- WRC Project No. K5/2160 → the selection and validation of sediment toxicity test methods

- Shortfalls Identified:
  - RSA does not currently have standard methods to collect and analyse sediment (comparative information which can be used to integrate chemical and biological effects) and guidelines.
  - Need for an approach to differentiate anthropogenic contamination sources versus naturally occurring deposits → limit the overestimation of risk.
  - Need for approach to link chemical concentrations to bioavailable concentrations
  - No approach to identify risk

STUDY APPROACH

- Review international literature on methods, contributing factors, procedures
- Identify potential study areas with anthropogenic influences
- Compile a simplified study design to be applied at study sites
- Conduct selected toxicity bioassays, sediment physical characterisation and contaminant analysis
- Compile a technical brief to function as a guided standard operating procedure
- Use gathered information to identify preliminary linkages to focus on developing an approach for risk assessment.

PROJECT STRATEGY AND DESIGN

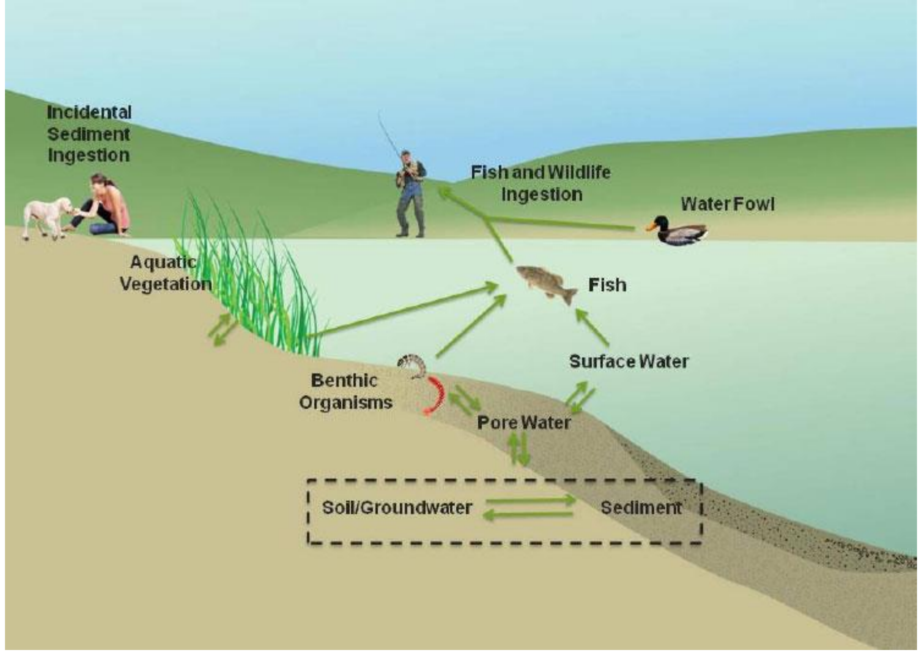
WHY - WHERE – WHEN – WHAT – HOW→

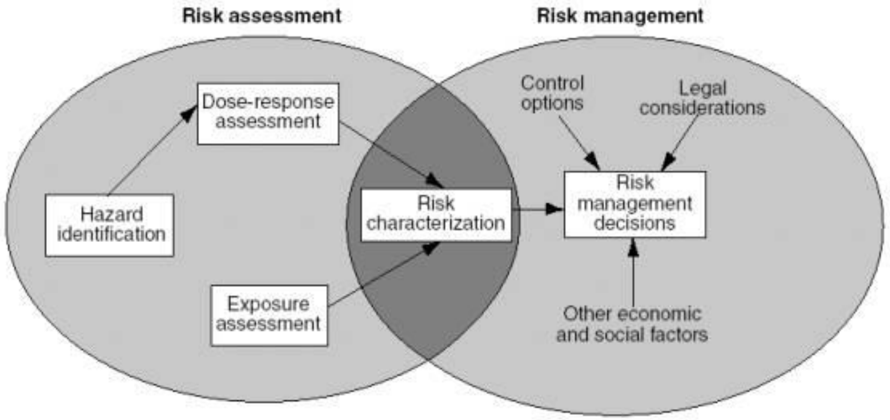
- Sampling program
- Frequency
- Sample types (Grab, composite, core)
- Procedures
- Data interpretation and integration

IDENTIFY THE WHY?

Based on site specific conditions

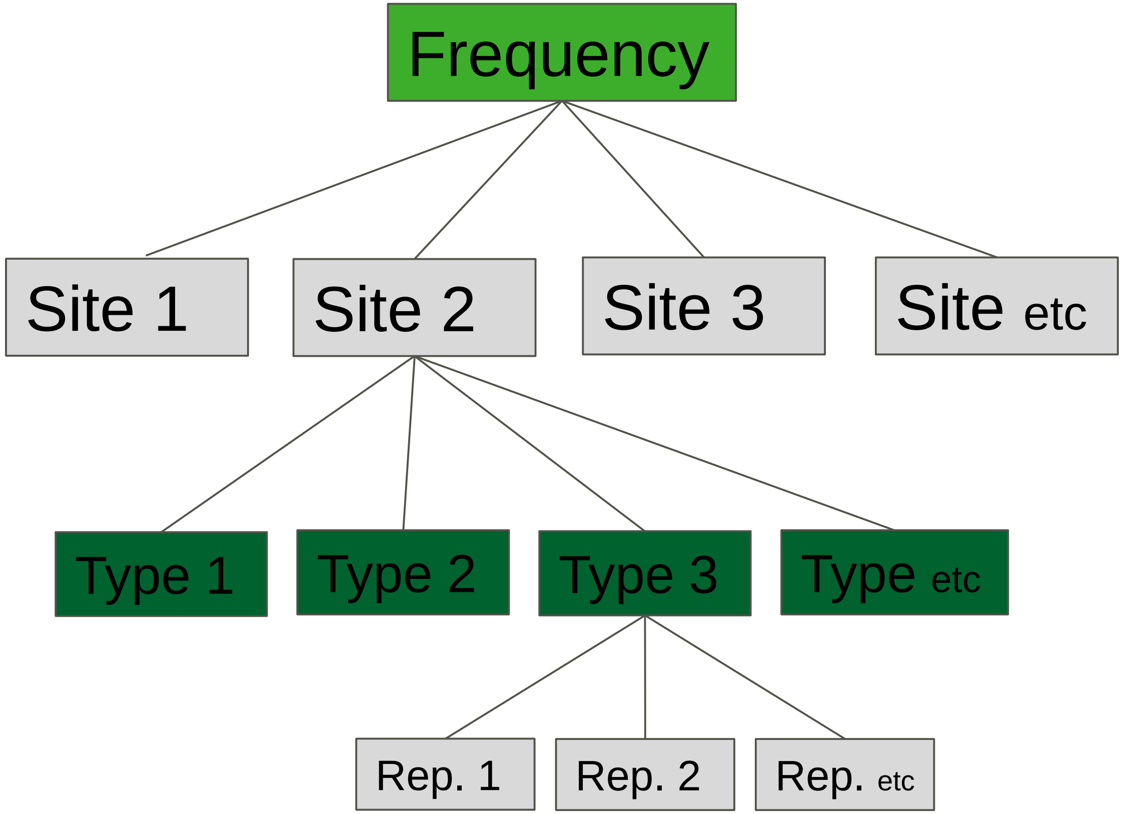
- Area of concern
- Problem statement
- End user and contaminant source
- What end point needs to be quantified





Source: EPA Office of Research and Development.

SAMPLE DESIGN



- Seasonality, Sedimentation rate, Biannual etc

- Point source / Non-point source
- Impoundment / River
- Assessment / Historical

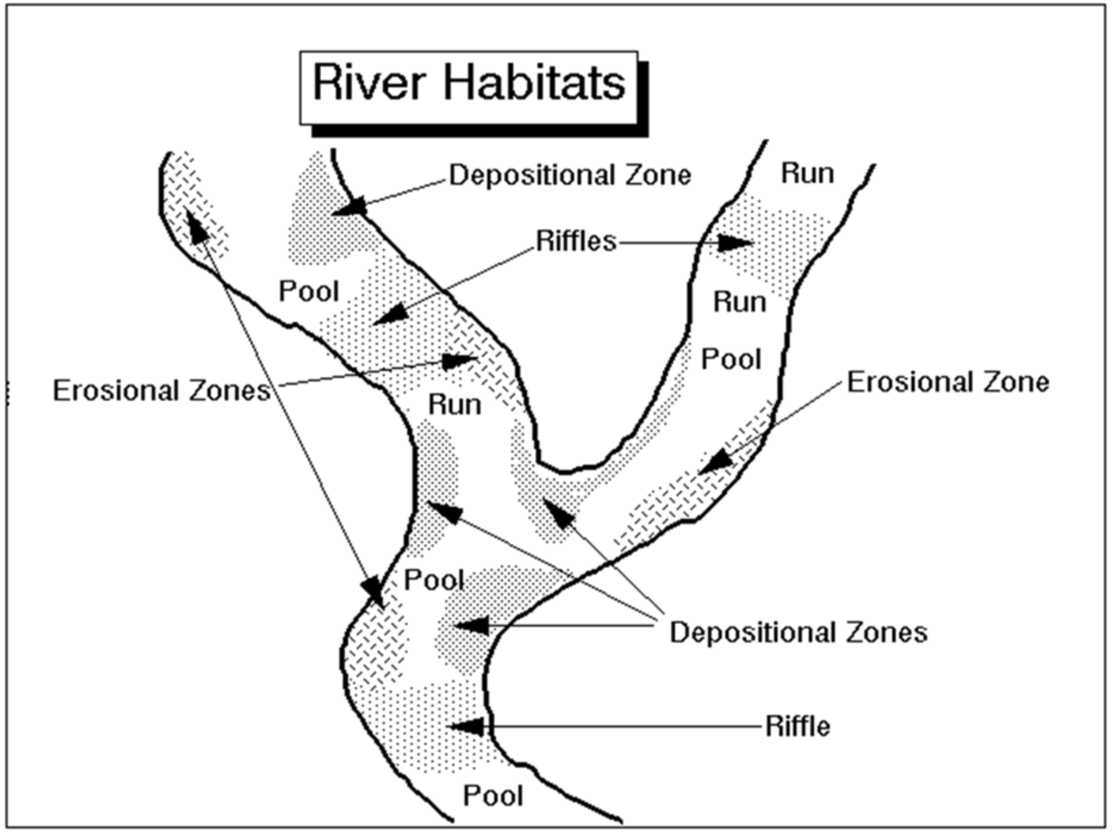
- Chemistry, Physical, Toxicity etc
- Sampler, Container, sample integrity, sample preparation

- Statistics, quantity

SITE SELECTION

Based on site specific conditions as well as purpose of sampling:

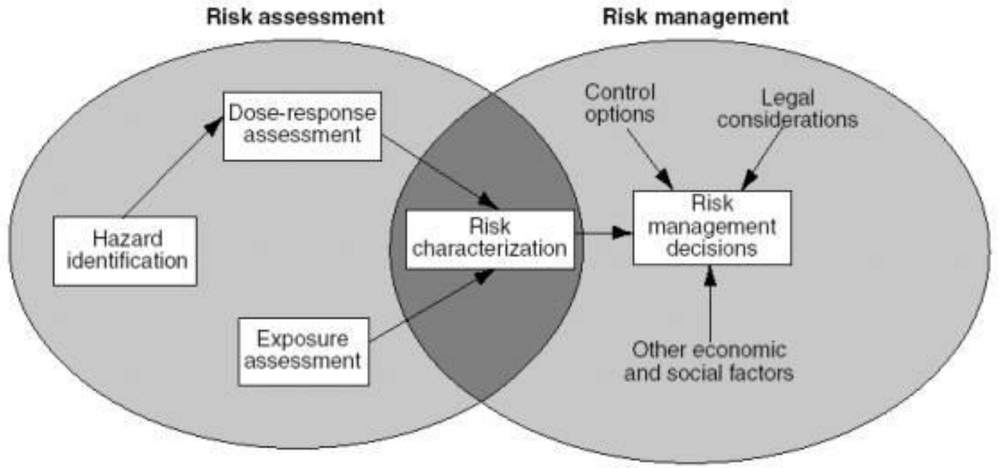
- Area of concern
- Problem statement
- End user and contaminant source
- What end point needs to be quantified
- Prior history
- Visual judgement



SAMPLING METHOD

Based on what needs to quantified:

- Grain size distribution and Total organic content
- Organic and Inorganic components
- Radionuclides
- Microbiology
- Toxicity, Biological availability and potential effects of contaminants
- Benthic biota
- Magnitude and fate of contaminants
- Contaminant source and pathways



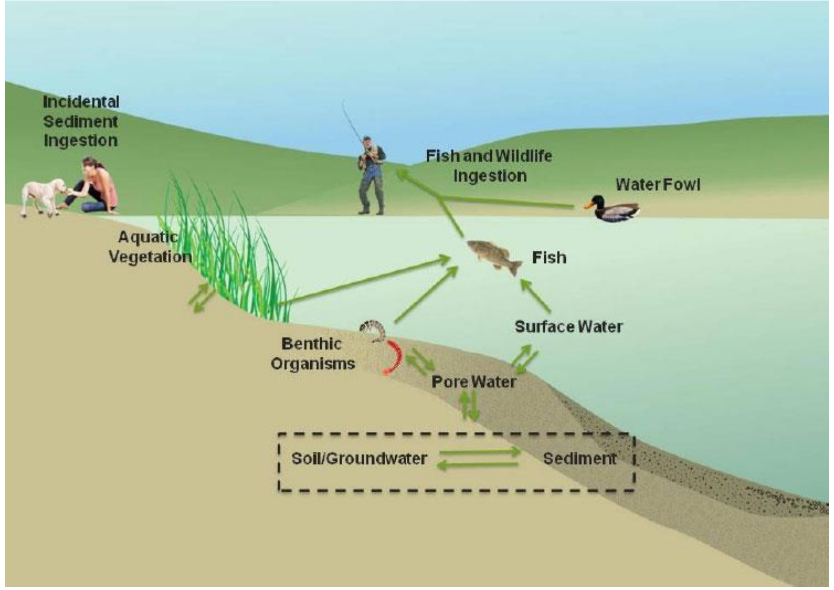
Source: EPA Office of Research and Development.

SAMPLE REQUIREMENTS FOR ANALYSIS

Sampling requirements (e.g. plastic, glass) as well as recommended transport and holding times

- Trace metals
- Organics
- Bioassays
- Microbiology (Sterile containers)
- Radionuclides
- Microplastics

Current standard analysis approaches available.



SAMPLE INTEGRITY

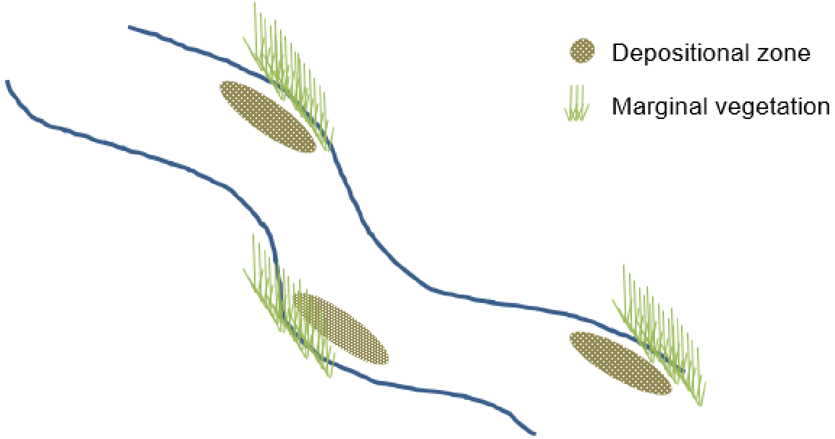
- Labels
- In field manipulations
- Sample container → determined by analysis (Glass versus plastic)
- Transport to the laboratory

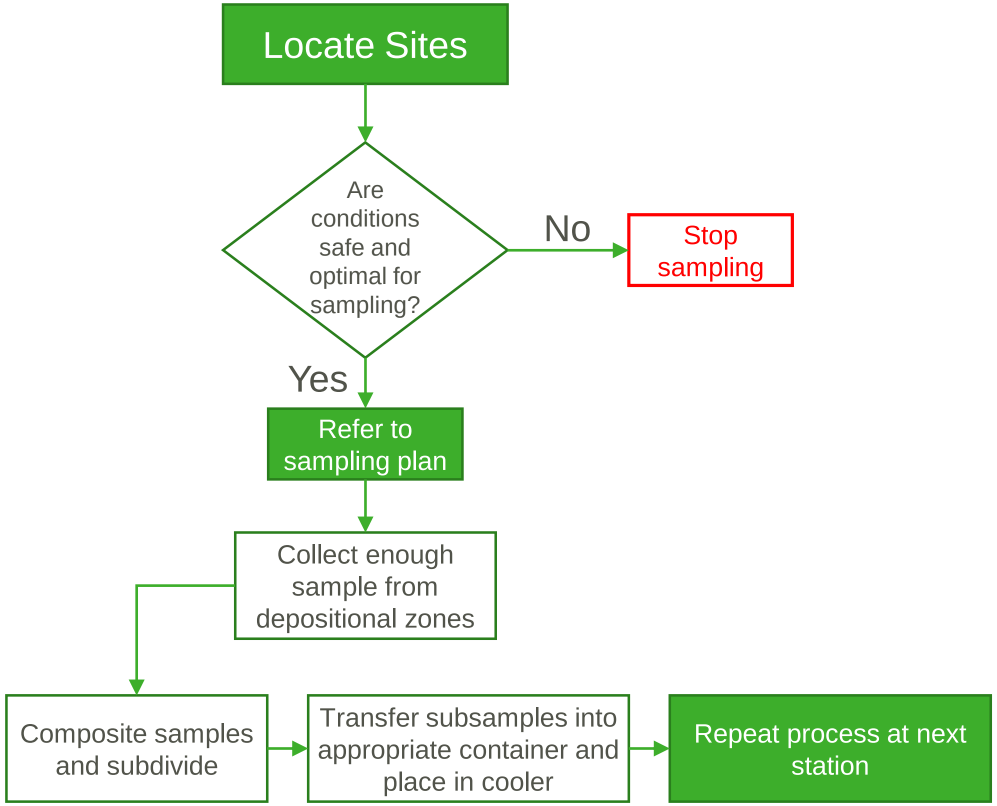
Sample ID:			
Date and Time:			
Collected By:			
Sample Analysis Type:	Inorganic	Organic	Physical
	Toxicity	Other	………………..
Sampling zone			
Sampling Depth			

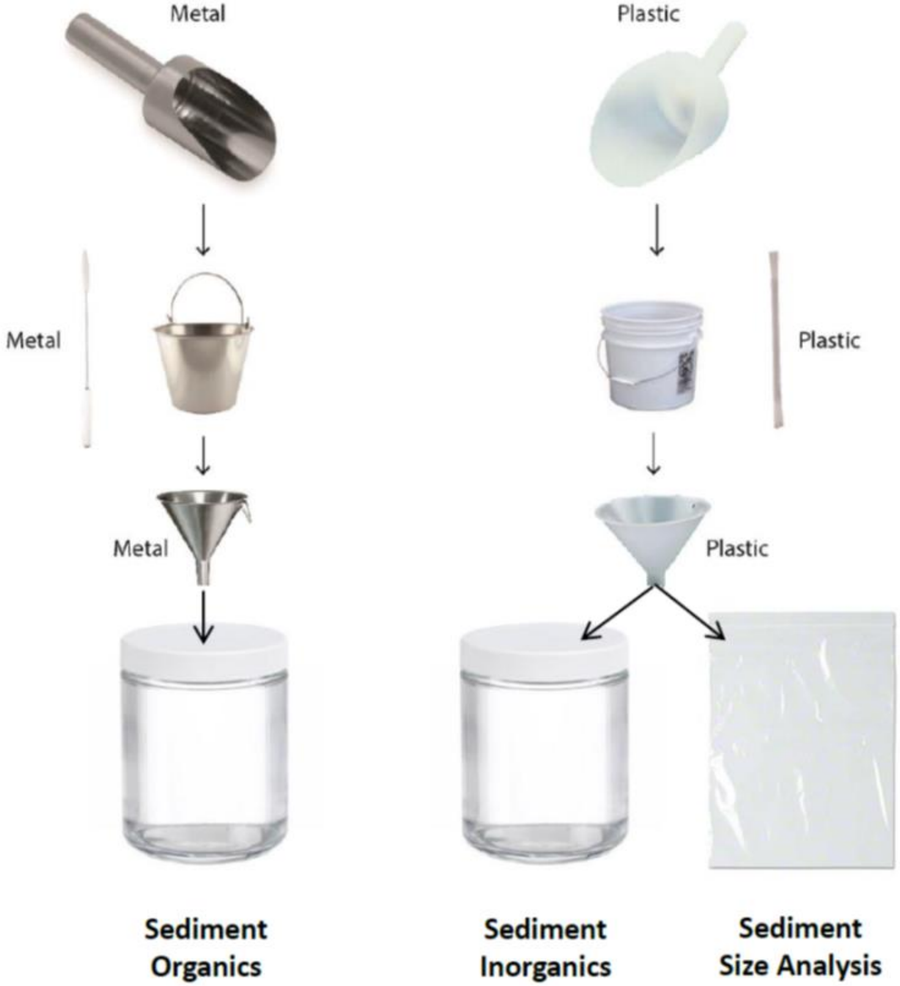
Equipment checklist example

Equipment	✔
Associated documentation: • Permits and approvals • Contact information for person on site • Background information regarding the collection, quantity and preservation of sediment and samples	
Sampling plan and map of area	
GPS	
Single or multi-parameter water quality meter (pH, EC, REDOX)	
Field data sheets, notebook or field computer	
Camera / Cell phone	
Labelling equipment (e.g. stickers, tags and/or permanent markers)	
Personal Protective Equipment (PPE): • Safety boots, high visibility vest, long pants, long-sleeved shirt, hardhat (for industrial sites); • Waders, gumboots, broad-brimmed hat or similar PPE (shore-based sampling). • Life jacket (boat sampling) • Any required safety equipment	
Gloves - non-powdered latex free (e.g. nitrile) which correspond to the potential chemical risk	
Clean collection containers appropriate to the required chemical analysis (e.g. bottles, zip-lock bags, cable ties, buckets for samples/mixing, sterile containers if collecting microbial samples)	
Clean sediment sampling equipment for collection of surficial layers (<10cm depth): • stainless steel (organics or metals) or plastic (ultra-trace metals) trowel/spade if collecting dry sediments or exposed sediments; • stainless steel benthic grab sampling equipment (e.g. Ekman, Ponar or Van Veen) grab sampler for deployment from a boat or jetty.	
Clean hand corer for sediment collection or profiling	
Clean stainless-steel sieve (10mm) if removal of stones, plant material or fauna is required	
Decontamination supplies (e.g. reagent water, solvent)	
Spatula	
Cooler box with ice bricks or portable refrigerator	
Chain of custody forms	

Field equipment check-list may be updated to comply with company or project specific requirements as well as required quantities of consumables to ensure smooth sampling where possible.




Locate Sites
Are conditions safe and optimal for sampling?
No
Stop sampling
Yes
Refer to sampling plan
Collect enough sample from depositional zones
Composite samples and subdivide
Transfer subsamples into appropriate container and place in cooler
Repeat process at next station


Metal
Plastic
Metal
Plastic
Metal
Plastic
Sediment Organics
Sediment Inorganics
Sediment Size Analysis

SAMPLING RECORD - AQUATIC SEDIMENTS

Project Name: ____________ Project/Contract. No. ____________
Sampling Date: ____________ Sampling Time: ____________
Weather: ____________
Field conditions and general comments: ____________

Province: ____________ Municipality: ____________
Site name: ____________ Sample Location: ____________
Name of River, Lake, Pond etc: ____________
Latitude: ____________ Longitude: ____________
Altitude: ____________ River Order: ____________
Water Gouge No.: ____________ Water Gouge Measurement: ____________

In Field measurements
Air Temperature: ____________ °C Water Temperature: ____________ °C
Electrical Conductivity: ____________ pH: ____________
Dissolved Oxygen: ____________ % ____________ mg/l
REDOX Potential: Reducing ____ Oxidising ____ In Field Measurement: ____________ mV
Comments: ____________

Sampling Data
Grab sample ____ Composite sample ____ Number of Replicates: ____________
Sample Depth: 0 – 3 cm 0 – 10 cm 0 - >10 cm Specific depth: ____________
Sample Equipment: Shovel ____ Grab ____ Corer ____ Other: ____________
Sediment Characteristics: Gravel ____ Sand ____ Sand-Silt ____ Silt-Clay ____
Smell: Yes ____ No ____ Gas Production: Yes ____ No ____
Colour: Additional Observations: ____________

Sediment samples, preparation and transport
In-field Sample preparation: Yes ____ No ____ Sieving ____ Homogenising ____

Sample container	Quantity	Replicates	Subsampled		Storage			
Glass			Yes	No	Room T°	Fridge	Freezer	Darkness
Plastic Bottle			Yes	No	Room T°	Fridge	Freezer	Darkness
Plastic Ziploc			Yes	No	Room T°	Fridge	Freezer	Darkness
Aluminium			Yes	No	Room T°	Fridge	Freezer	Darkness
Other…………....			Yes	No	Room T°	Fridge	Freezer	Darkness

Analysis Requirements

Chemistry			
Physical Characteristics			
Ecotoxicity			

Table 8: General guide to preservation and holding times for sediment analyses (Abia *et al.* 2015; DES, 2018b)

Analysis	Preservation	Holding Time
Whole sediments: analysis for bioavailable metals or for metal speciation.	Refrigerate <6°C, unless metals associated with acid volatile sulphide (AVS) are the contaminants of interest.	Analyse as soon as practical, but generally within 7 days.
Whole sediments: analysis for mercury	Refrigerate at <6°C and store in the dark.	28 days.
Whole sediments: analysis for extractable organics. **Note**: Always measure Total Organic Carbon when sampling for organics.	Refrigerate at <6°C and store in the dark.	Analyse within 7 days for volatile compounds or those prone to microbial degradation. Analyse within 8 weeks for stable organics such as organochlorine pesticides, dioxins/furans, polychlorinated biphenyls (PCB), polycyclic aromatic hydrocarbons (PAH).
Whole sediments for acid volatile sulphide (AVS), ammonia or other volatile inorganic compounds	Frozen	28 days
Whole sediment: Microbial analysis	Refrigerate at <6°C and store in the dark.	Analyse as soon as possible
Whole sediment: Microplastics	Refrigerate at <6°C and store in the dark. Frozen -20°C.	Analyse as soon as possible, no storage time stipulated
Where sediments are to be used for toxicity assessments, holding times and sample storage conditions should meet the requirements described for the specific compounds present (with appropriate refrigeration; <6°C), but generally no longer than two weeks.		

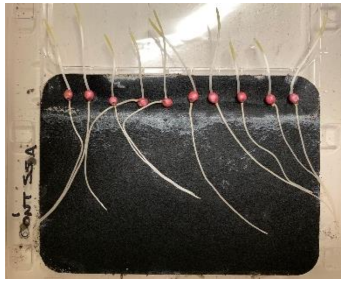
ANALYSIS PROCEDURES

Physical

- Particles Size Determination
- Total Organic Carbon
- Moisture Content

Toxicity

- Whole sediment (Ostracod)
- Soluble fraction (Phytotoxkit)
- Acute vs Chronic effects



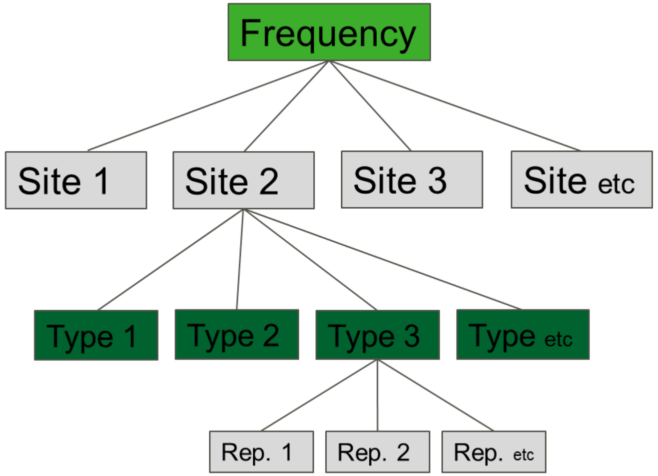
Laboratory Analysis

- Total Concentrations
- Elutriates (1:20, 1:10)
- Acid Extractable Metals
- Pore Waters
- Acid-Volatile Sulphides
- Metals
- Organics
- Redox
- Microbiology

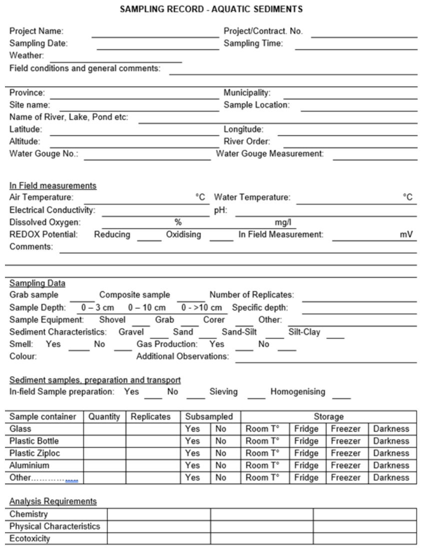
Taking into account appropriate QA/QC through all stages

SO WHAT?

Sampling design



Sample collection and analysis



SAMPLING RECORD - AQUATIC SEDIMENTS

Project Name: Project/Contract. No.
Sampling Date: Sampling Time:
Weather:
Field conditions and general comments:

Province: Municipality:
Site name: Sample Location:
Name of River, Lake, Pond etc:
Latitude: Longitude:
Altitude: River Order:
Water Gouge No.: Water Gouge Measurement:

In Field measurements
Air Temperature: °C Water Temperature: °C
Electrical Conductivity: pH:
Dissolved Oxygen: % mg/l
REDOX Potential: Reducing Oxidising In Field Measurement: mV
Comments:

Sampling Data
Grab sample Composite sample Number of Replicates:
Sample Depth: 0 – 3 cm 0 – 10 cm 0 - >10 cm Specific depth:
Sample Equipment: Shovel Grab Corer Other:
Sediment Characteristics: Gravel Sand Sand-Silt Silt-Clay
Smell: Yes No Gas Production: Yes No
Colour: Additional Observations:

Sediment samples, preparation and transport
In-field Sample preparation: Yes No Sieving Homogenising

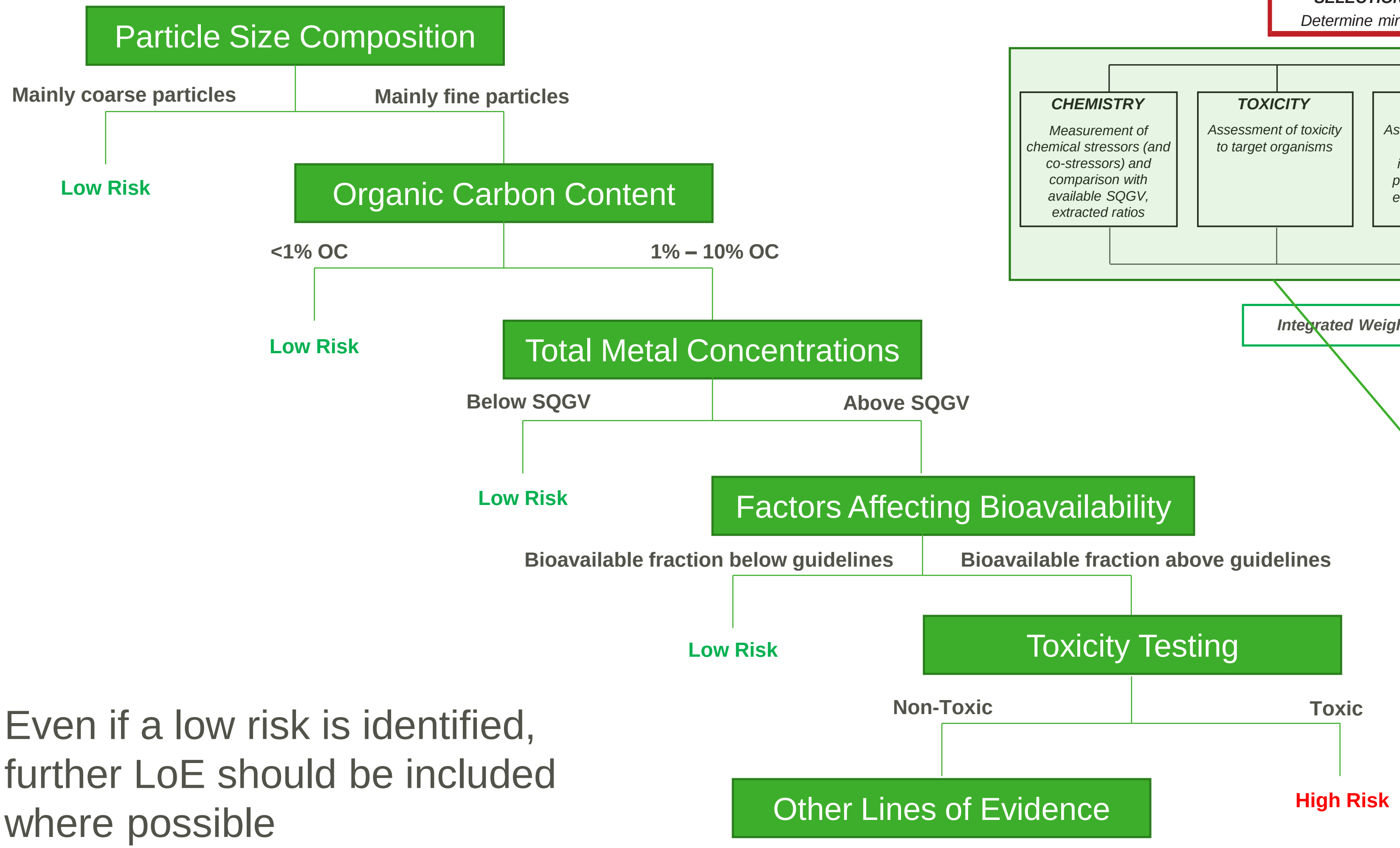
Sample container	Quantity	Replicates	Subsampled		Storage			
Glass			Yes	No	Room T°	Fridge	Freezer	Darkness
Plastic Bottle			Yes	No	Room T°	Fridge	Freezer	Darkness
Plastic Ziploc			Yes	No	Room T°	Fridge	Freezer	Darkness
Aluminium			Yes	No	Room T°	Fridge	Freezer	Darkness
Other.................			Yes	No	Room T°	Fridge	Freezer	Darkness

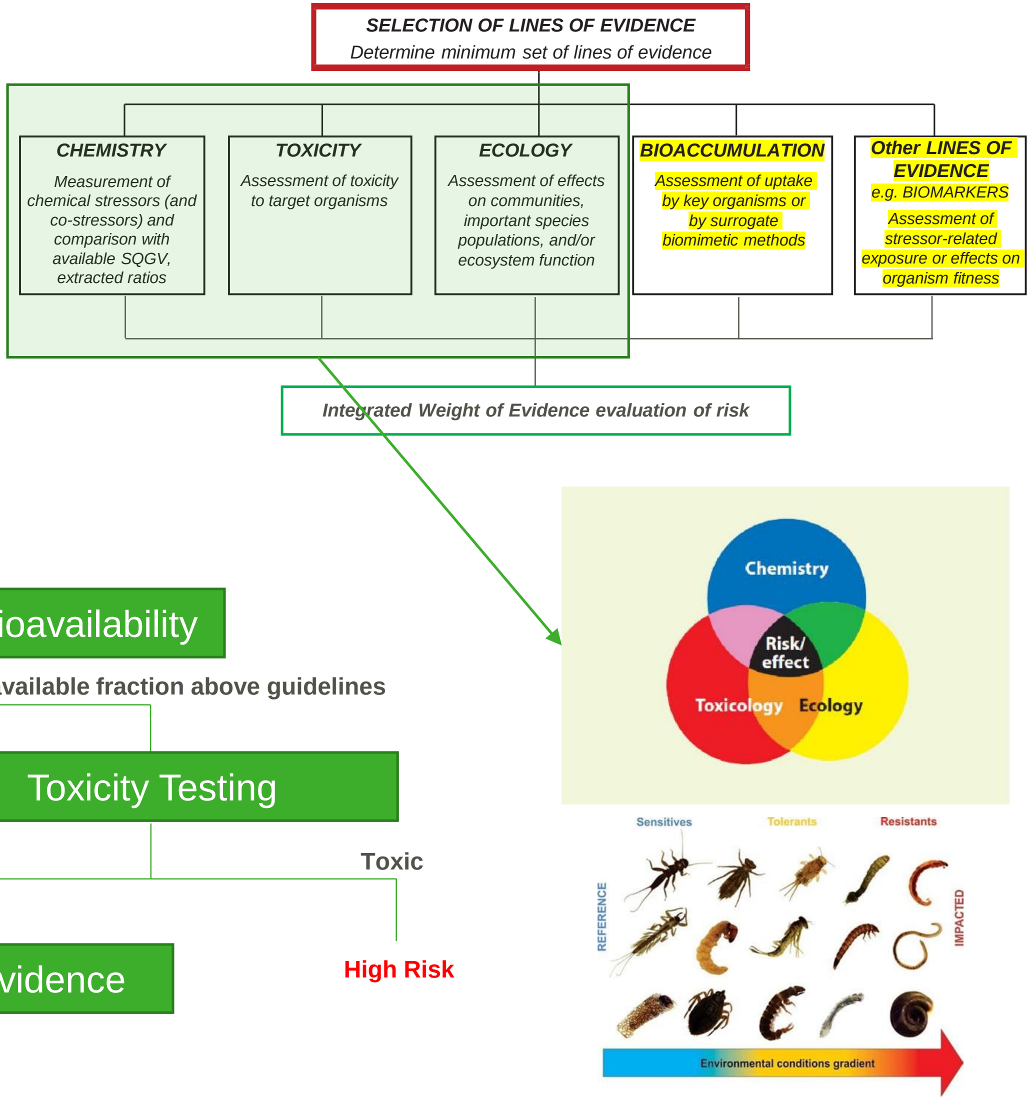
Analysis Requirements

Chemistry			
Physical Characteristics			
Ecotoxicity			

Way forward

RISK→ ULTIMATE GOAL





Even if a low risk is identified, further LoE should be included where possible

DATA INTERPRETATION AND INTEGRATION → RISK

Risk	1	2	3	4	5
Particle size		Substrate composed mainly of gravel, coarse and medium sand	Substrate composed mainly of fine sand, silt and clay		
Organic Carbon		<1% or >10%	>1 - <10%		
SQGV	<SQGV	>SQGV<High G	>High G		
Bioavailability	<1%	>1%-<10%	>10%-<30%	>30%<50%	>50%-100%
Pesticides	<SQGV	>SQGV<High G	>High G		
Toxicity Testing	<SPE	>SPE<50%	>50%<100%	100%	

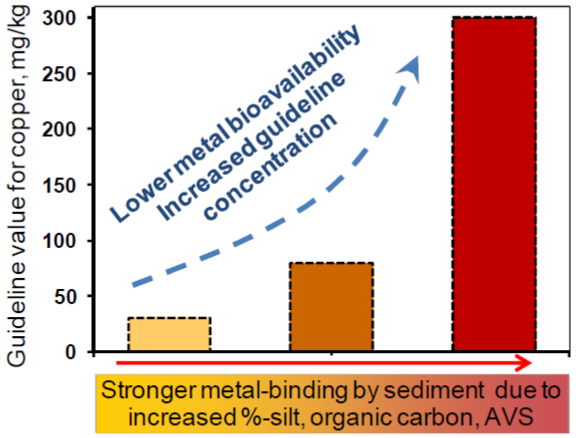
mg/l	G-value	SQG-High
Antimony	2	25
Arsenic	20	70
Cadmium	1.5	10
Chromium	80	370
Copper	65	270
Lead	50	220
Mercury	0.15	1
Nickel	21	52
Silver	1	4
Zinc	200	410

ANZECC/ARMCANZ, 2013

Risk Assessment Code	%	
I	<1	No Biological risk
II	>1<10	Low biological risk
III	>10<30	Moderate biological risk
IV	>30<50	High biological risk
V	>50<100	Very high biological risk

Li *et al.*, 2018

Bioassay	Statistical percentage effect	Acute effect
Phytotox germination	30%	50%
Phytotox root inhibition	20%	
Heterocypris incongruens mortality	20%	
Heterocypris incongruensgrowth inhibition	20%	



CHEMISTRY

- Total (10 SQGV's available from ANZECC for comparison to Total concentrations)
- 1:20 (ASLP, distilled water) - Compare to aquatic guidelines for LoE Criteria
- 1:10 (EPA, INERIS, distilled water) - Compare to aquatic guidelines for LoE Criteria
- Acid Extractible Metals (Acetic acid : HCl)
- The comparison of results will look for correlations and similarities in order to identify associations with identified risk.

WEIGHT OF EVIDENCE DATA EVALUATION

Total	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Sb	Zn
1	0.20	2.64	0.20	302.60	40.66	0.20	46.93	9.19	0.20	37.95
2	0.20	4.35	0.20	274.53	45.98	0.20	39.91	18.74	0.20	37.55
3	0.20	7.77	0.20	620.01	25.55	0.20	26.82	13.86	0.20	36.19
4	0.20	2.77	0.20	458.67	22.98	0.20	37.78	8.57	0.20	37.32
5	0.20	2.54	0.20	341.25	14.70	0.20	24.95	7.49	0.20	23.78
6	0.20	2.56	0.20	401.40	23.44	0.20	43.27	11.12	0.20	29.66
7	0.20	1.88	0.20	468.31	8.13	0.20	14.94	7.27	0.20	14.44
8	0.78	6.65	0.20	516.01	18.72	0.20	22.65	7.82	1.15	30.25
9	2.39	4.79	0.20	628.82	17.44	0.20	21.48	9.97	0.43	22.61
10	1.79	12.91	0.20	314.71	45.73	0.20	42.94	28.55	0.77	43.16
11	0.97	6.73	0.20	383.57	22.87	0.20	30.70	13.63	0.82	28.70
12	0.85	2.23	0.20	394.56	40.85	0.20	21.73	10.74	0.40	18.10
13	0.70	14.79	0.20	538.70	49.84	0.20	48.67	36.80	0.61	51.51

Total	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Sb	Zn	Ave
1	-	1	-	2	1	-	2	1	-	1	1.3
2	-	1	-	2	1	-	2	1	-	1	1.3
3	-	1	-	3	1	-	2	1	-	1	1.5
4	-	1	-	3	1	-	2	1	-	1	1.5
5	-	1	-	2	1	-	2	1	-	1	1.3
6	-	1	-	3	1	-	2	1	-	1	1.5
7	-	1	-	3	1	-	1	1	-	1	1
8	1	1	-	3	1	-	2	1	1	1	1.4
9	2	1	-	3	1	-	2	1	1	1	1.5
10	2	1	-	2	1	-	2	1	1	1	1.4
11	1	1	-	3	1	-	2	1	1	1	1.4
12	1	1	-	3	1	-	2	1	1	1	1.4
13	1	1	-	3	1	-	2	1	1	1	1.4

Total vs AEM	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Sb	Zn
1	12.50	3.93	12.50	9.55	18.38	12.50	10.70	9.92	12.50	14.86
2	12.50	1.84	12.50	8.19	21.43	12.50	14.54	10.53	12.50	14.24
3	44.93	1.67	12.50	8.27	19.41	12.50	20.35	6.87	12.50	12.55
4	151.70	0.90	12.50	6.82	4.45	12.50	24.02	5.99	12.50	14.01
5	66.93	0.98	12.50	12.57	22.03	12.50	18.04	19.19	12.50	10.93
6	45.61	0.98	12.50	10.03	15.30	12.50	13.26	12.75	12.50	5.22
7	26.67	1.33	12.50	9.51	27.13	12.50	26.36	16.57	12.50	2.12
8	3.19	0.38	12.50	12.16	16.12	12.50	29.05	7.23	2.17	38.88
9	1.05	0.52	12.50	10.10	21.24	12.50	26.69	14.62	5.81	18.27
10	1.39	0.19	12.50	8.34	17.78	12.50	9.92	35.16	3.26	11.16
11	2.57	0.37	12.50	11.26	20.00	12.50	14.24	17.04	3.04	4.59
12	2.95	1.12	12.50	5.84	1.21	12.50	26.23	3.13	6.25	3.74
13	11.64	0.83	12.50	1.62	2.73	12.50	10.58	4.03	4.08	8.64

Total vs AEM	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Sb	Zn	Ave
1	3	2	-	2	3	-	3	2	-	3	2.6
2	3	2	-	2	3	-	3	3	-	3	2.7
3	4	2	-	2	3	-	3	2	-	3	2.7
4	-	1	-	2	2	-	3	2	-	3	2.2
5	5	1	-	3	3	-	3	3	-	3	3.0
6	4	1	-	3	3	-	3	3	-	2	2.7
7	3	2	-	2	3	-	3	3	-	2	2.6
8	2	1	-	3	3	-	3	2	2	4	2.5
9	2	1	-	3	3	-	3	3	2	3	2.5
10	2	1	-	2	3	-	2	4	2	3	2.4
11	2	1	-	3	3	-	3	3	2	2	2.4
12	2	2	-	2	2	-	3	2	2	2	2.1
13	3	1	-	2	2	-	3	2	2	2	2.1

WEIGHT OF EVIDENCE DATA EVALUATION

	Lepidium sativum		*Sinapus alba*		*Sorghum saccharatum*		*Heterocypris incongruens*	
	% effect	% Germination	% effect	% Germination	% effect	% Germination	%Mortality	% effect
1	-34.4	90	-46.93	90	8.8	95	96.67	-121.16
2	19.17	100	10.09	100	7.45	95	26.67	-25.93
3	-12.56	90	33.72	100	8.85	95	36.67	-45.1
4	-23.04	95	-41	95	-17.02	85	80	-90.77
5	-6.58	85	11.49	95	9.03	95	70	-46.49
6	9.18	100	45.95	95	-6.58	90	100	-150.44
7	-1.38	95	34.78	100	8.98	100	20	-37.81
8	-7.92	100	34.24	95	-2.96	100	26.67	-27.97
9	-33.99	100	6.65	100	27.37	90	46.67	-56.31
10	22.21	100	49.2	95	-7.23	100	6.67	-9.99
11	24.12	100	32.19	85	23.61	95	3.33	-20.37
12	-20.39	95	-38.09	85	20.95	100	80	-46.54
13	17.07	100	55.15	100	-2.52	80	3.33	-2.29

	Lepidium sativum		*Sinapus alba*		*Sorghum saccharatum*		*Heterocypris incongruens*		
	% effect	% Germination	% effect	% Germination	% effect	% Germination	%Mortality	% effect	AVE
1	2	1	2	1	1	1	3	4	1.9
2	1	1	1	1	1	1	2	2	1.3
3	1	1	2	1	1	1	2	2	1.4
4	2	1	2	1	1	1	3	3	1.8
5	1	1	1	1	1	1	3	2	1.4
6	1	1	2	1	1	1	4	4	1.9
7	1	1	2	1	1	1	2	2	1.3
8	1	1	2	1	1	1	2	2	1.3
9	2	1	1	1	2	1	2	3	1.6
10	2	1	2	1	1	1	1	1	1.0
11	2	1	2	1	2	1	1	2	1.2
12	2	1	2	1	2	1	3	2	1.7
13	1	1	2	1	1	1	1	1	1.0

RISK POTENTIAL

Equal weighting of components

Site	Particle size	Organic Carbon	SQGV	Bioavailability	Pesticides	Toxicity Testing	Risk Potential evaluation
1	2	3	1.3	2.6	1	1.9	Moderate potential for contaminant binding, Moderate risk of sediment contamination, Moderate biological risk from Ag, Cu, Ni, Zn, Low potential risk from pesticides, Moderate impacts on higher plant germination and growth, High risk potential for benthic invertebrates
2	3	3	1.3	2.7	1	1.3	High potential for contaminant binding, Moderate risk of sediment contamination, Moderate biological risk from Ag, Cu, Ni, Zn, Low potential risk from pesticides, Low impacts on higher plant germination and growth, Moderate risk potential for benthic invertebrates
3	2	3	1.5	2.7	1	1.4	Moderate potential for contaminant binding, Moderate risk of sediment contamination, Moderate biological risk from Cu, Ni, Zn, High biological risk from Ag, Low potential risk from pesticides, Low impacts on higher plant germination and growth, Moderate risk potential for benthic invertebrates
4	3	2	1.5	2.2	1	1.8	Moderate potential for contaminant binding, Moderate risk of sediment contamination, Moderate biological risk from Ni, Zn, Low potential risk from pesticides, Moderate impacts on higher plant germination and growth, High risk potential for benthic invertebrates
5	2	3	1.3	3	1	1.4	Moderate potential for contaminant binding, Moderate risk of sediment contamination, Moderate biological risk from Cr, Cu, Pb, Ni, Zn, High biological risk from Ag, Low potential risk from pesticides, Low impacts on higher plant germination and growth, High risk potential for benthic invertebrates
6	3	3	1.5	2.7	1	1.9	High potential for contaminant binding, Moderate risk of sediment contamination, Moderate biological risk from Cr, Cu, Pb, Ni, High biological risk from Ag, Low potential risk from pesticides, Low impacts on higher plant germination and growth, High risk potential for benthic invertebrates
7	2	3	1	2.6	1	1.3	Moderate potential for contaminant binding, Moderate risk of sediment contamination, Moderate biological risk from Ag, Cu, Ni, Pb, Low potential risk from pesticides, Low potential risk from pesticides, Low impacts on higher plant germination and growth, Moderate risk potential for benthic invertebrates
8	2	3	1.4	2.5	1	1.3	Moderate potential for contaminant binding, Moderate risk of sediment contamination, Moderate biological risk from Cr, Cu, Ni, High biological risk from Zn, Low potential risk from pesticides, Low impacts on higher plant germination and growth, Moderate risk potential for benthic invertebrates
9	3	3	1.5	2.5	1	1.6	High potential for contaminant binding, Moderate risk of sediment contamination, Moderate biological risk from Cr, Cu, Ni, Zn, Low potential risk from pesticides, Low impacts on higher plant germination and growth, Moderate risk potential for benthic invertebrates
10	3	3	1.4	2.4	1	1.0	High potential for contaminant binding, Moderate risk of sediment contamination, Moderate biological risk from Cu, Zn, High biological risk from Pb, Low potential risk from pesticides, Low impacts on higher plant germination and growth, Low risk potential for benthic invertebrates
11	2	3	1.4	2.4	1	1.2	Moderate potential for contaminant binding, Moderate risk of sediment contamination, Moderate biological risk from Cr, Cu, Pb, Ni, Low potential risk from pesticides, Low potential risk from pesticides, Low impacts on higher plant germination and growth, Low risk potential for benthic invertebrates
12	3	2	1.4	2.1	1	1.7	Moderate potential for contaminant binding, Moderate risk of sediment contamination, Moderate biological risk from Ni, Low potential risk from pesticides, Low impacts on higher plant germination and growth, High risk potential for benthic invertebrates
13	2	2	1.4	2.1	1	1.0	Moderate potential for contaminant binding, Moderate risk of sediment contamination, Moderate biological risk from Ni, High biological risk from Ag, Low potential risk from pesticides, Low impacts on higher plant germination and growth, Moderate risk potential for benthic invertebrates

RISK POTENTIAL

Equal weighting of components

Site	Particle size	Organic Carbon	SQGV	Bioavailability	Pesticides	Toxicity Testing	Risk Potential evaluation
1	2	3	1.3	2.6	1	1.9	Moderate potential for contaminant binding, Moderate risk of sediment contamination, Moderate biological risk from Ag, Cu, Ni, Zn, Low potential risk from pesticides, Moderate impacts on higher plant germination and growth, High risk potential for benthic invertebrates
6	3	3	1.5	2.7	1	1.9	High potential for contaminant binding, Moderate risk of sediment contamination, Moderate biological risk from Cr, Cu, Pb, Ni, High biological risk from Ag, Low potential risk from pesticides, Low impacts on higher plant germination and growth, High risk potential for benthic invertebrates

Site	Particle size	Organic Carbon	SQGV	Bioavailability	Pesticides	Toxicity Testing	Risk Potential evaluation
10	3	3	1.4	2.4	1	1.0	High potential for contaminant binding, Moderate risk of sediment contamination, Moderate biological risk from Cu, Zn, High biological risk from Pb, Low potential risk from pesticides, Low impacts on higher plant germination and growth, Low risk potential for benthic invertebrates
11	2	3	1.4	2.4	1	1.2	Moderate potential for contaminant binding, Moderate risk of sediment contamination, Moderate biological risk from Cr, Cu, Pb, Ni, Low potential risk from pesticides, Low potential risk from pesticides, Low impacts on higher plant germination and growth, Low risk potential for benthic invertebrates

A lack of data or knowledge increases uncertainty which translates to increased risk

Acknowledgements

Water Research Commission
Golder Associates
Khume Mtshweni (MSc Student UJ)
Golder Associates Research Laboratory staff (Mahadi Motsumi, Claire Volschenk, Yolandi Cloete)

Thank You

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