Comparison of Cell-In-Series and Meso-Scale Physical Habitat Sampling for the Interpretation of Spatiotemporal Variation of Stream Water Quality

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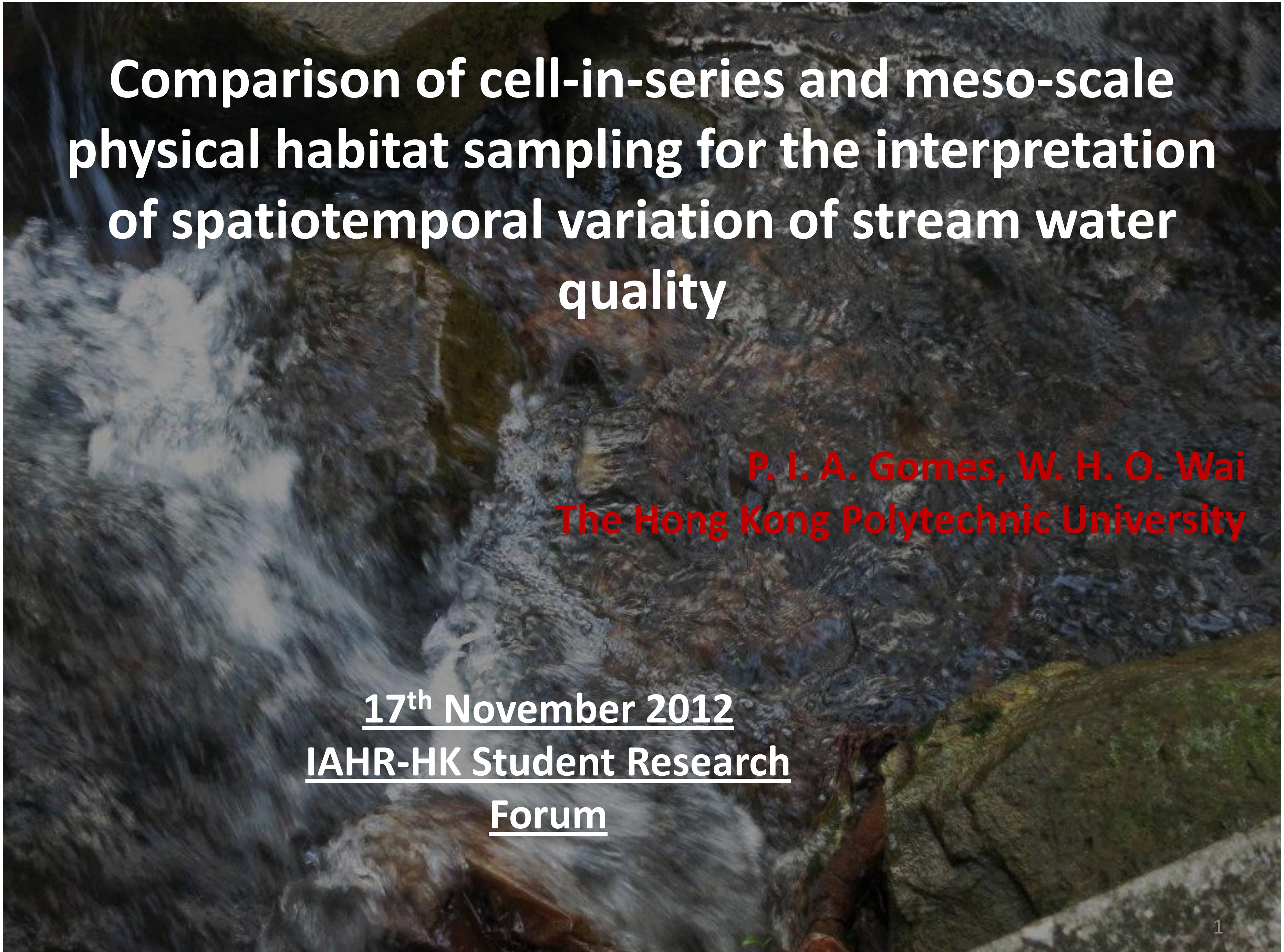
Abstract: Although scale dependence of ecological patterns is conceptually recognised, the studies involving quantitative assessments are rare and rudimentary. Here we evaluate spatiotemporal variation of water quality using two sampling scales (approaches): cell-in-series (CIS) and meso-scale physical habitats (MPH). CIS has its origins in probabilistic sampling and relatively simple. It also reported to be suitable for streams with advective transport. MPH approach is relatively novel for water quality assessments and it considers medium scale morphological units such as pools, riffles, glides, etc. for sampling.

Sampling was carried out in the short and steep Tseng Lan Shue stream, during Spring and Summer of 2012. The stream is subject to regulation and various anthropogenic inputs, but with irregular occurrence. For each season, observations were carried out during periods with no influence of severe weather events (typical state) as well as after a rainfall (flushed state). The response variables including water chlorophyll, turbidity, dissolved oxygen, nitrate, nitrite, ammoniacal nitrogen and soluble reactive phosphorous were checked against a set of hydro-environmental variables. These included: stream velocity, width, depth, and slope, bankfull dimensions, and substrate conditions. Relationships among variables were evidenced using redundancy analysis.

In general, the water quality parameters showed an irregular variation in the longitudinal direction of the stream. Response and hydro-environmental variables based on two best axes showed a 41% of variance in spring response data in the MPH approach. For CIS it was around 44%. But in flashed floods these were observed to be 60% and 35 % for MPH and CIS, respectively. Similar trend was observed in summer where explanatory power based on CIS was higher for typical state but otherwise for the flashed state. Furthermore, significant environmental variable(s) for respective cases changed with the scales being used: substrate conditions for CIS and stream width and slope for MPS.

This study shows that MPH approach is more suitable than CIS as a modelling tool when the stream has less anthropogenic loads. We conclude that the explanatory powers of the MPH and CIS scales (approaches) could be useful in providing a quantitative definition on identifying a "pristine stream".

Key words: *cell-in-series; ecology; meso-scale; variance; water quality*



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17th November 2012
IAHR-HK Student Research Forum

- Lotic waters have suffered a long history of degradation (e.g. channel modification, agriculture, etc.)
- Natural or pristine rivers a rare phenomenon
- Rise in environmental awareness has driven initiatives for river restoration
- Water quality improvement is an essential part
- But the spatial behavior of water quality is not very simple to model or predict due heterogeneity of streams
- First and foremost no agreement on where to sample and also about the scale

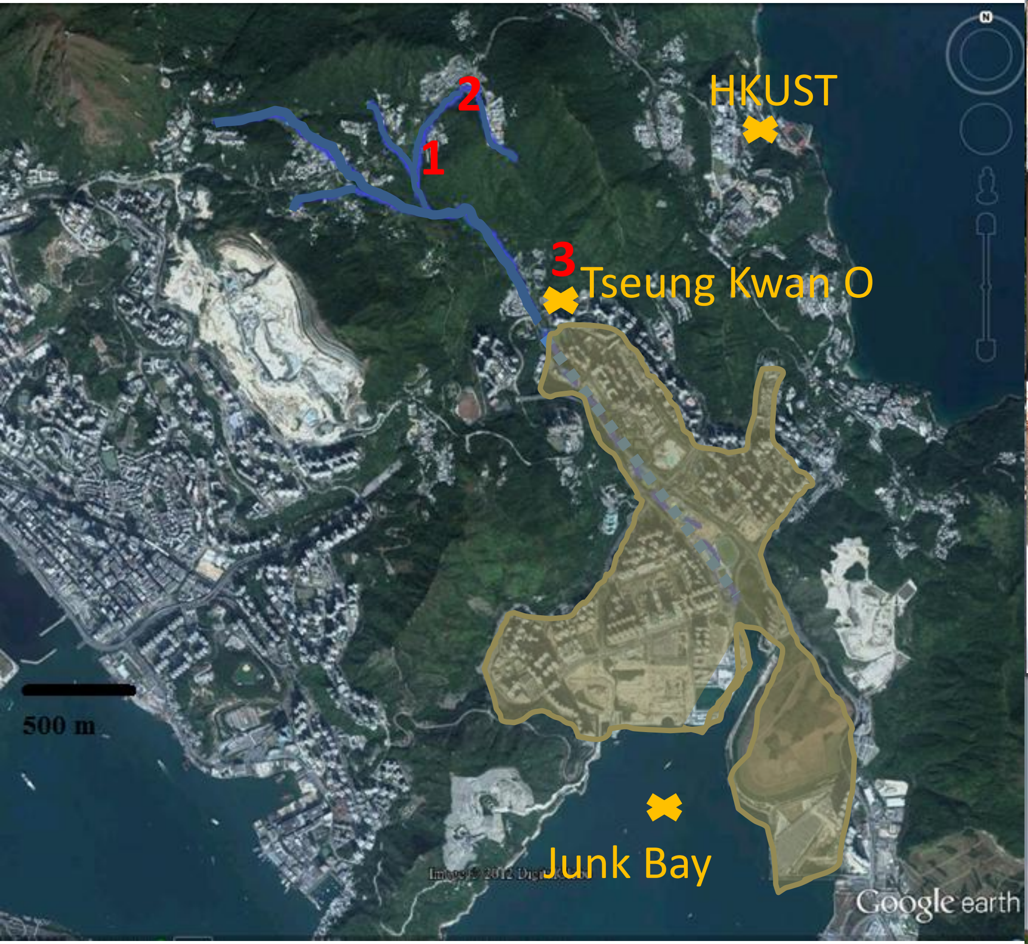
Hong Kong streams

- Short
- Steep
- No distinctive middle course
- Ephemeral
- But streams are densely distributed

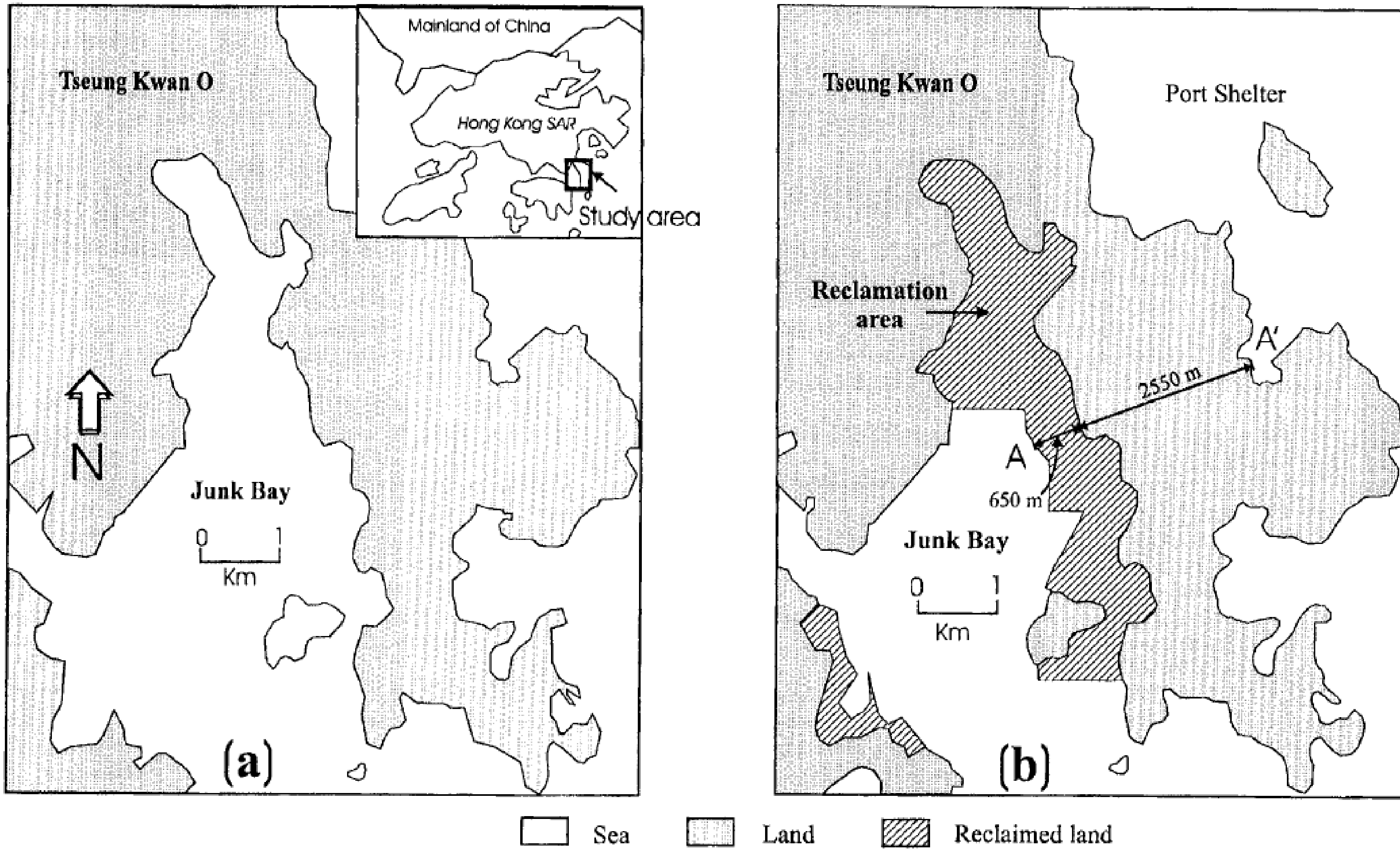
Objectives

- Understand the water quality variation of a short-steep and irregularly disturbed stream against sampling method
- Check the factors affecting the selection of sampling method
- To get the holistic view of water quality variation

Study area :Tseng Lan Shue Stream



- Headwater – mountainous stream
- Steep-short



Coastlines at Tseung Kwan O, Hong Kong, China (a) in 1977 and (b) in 1998.

Jiao et al., 2001

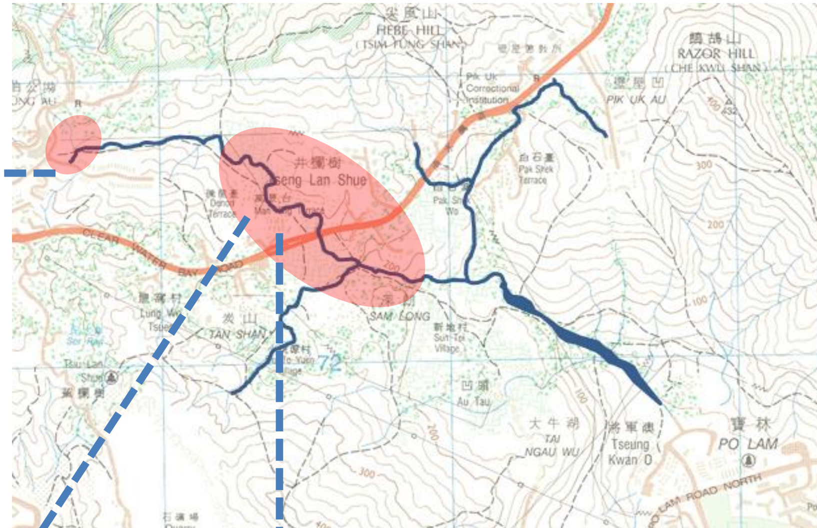
Source of a tributary- a spring


Source of a tributary: a

The stream has many typical headstream pristine features: morphologically as well as in terms of flora and fauna

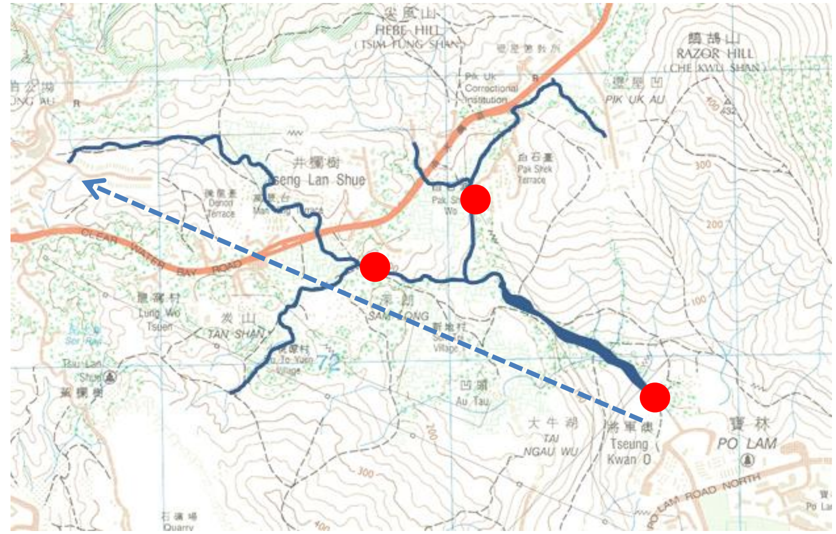

Mayflies, grazers, predators, etc.

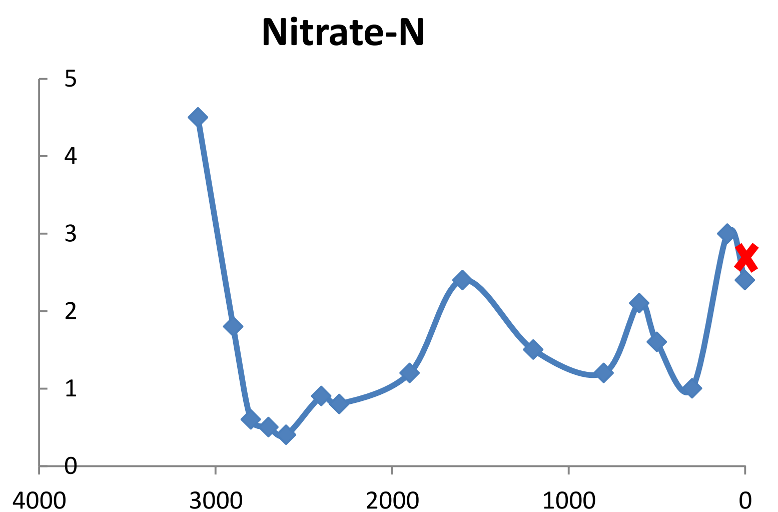
Observations for regulation and pollution



Water quality observations of Tseng Lan Shue stream (by others)

- Monthly water quality observations are carried out by EPD at three monitoring stations (under Junk Bay water quality control)
- End point or junctions does not mean that it will represent preceding locations
- Variation is not simple, it is rapid
- Cant find the hot spots/critical locations
- In case of ecological restoration selected points not enough at all
- Need the holistic view

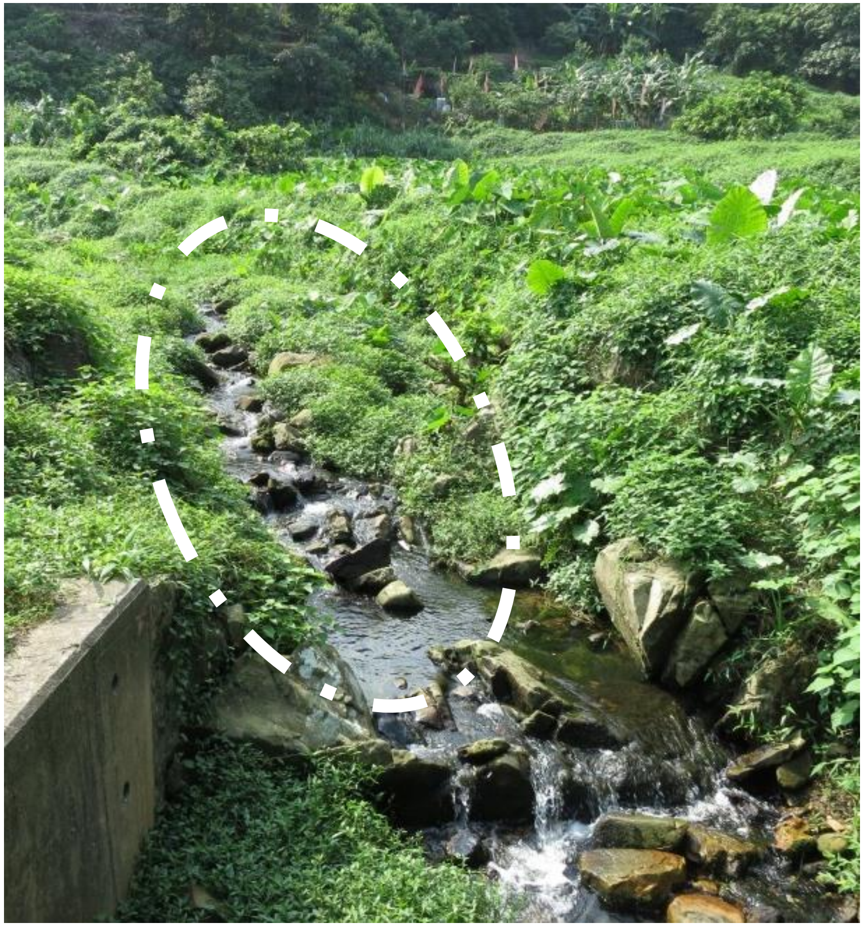


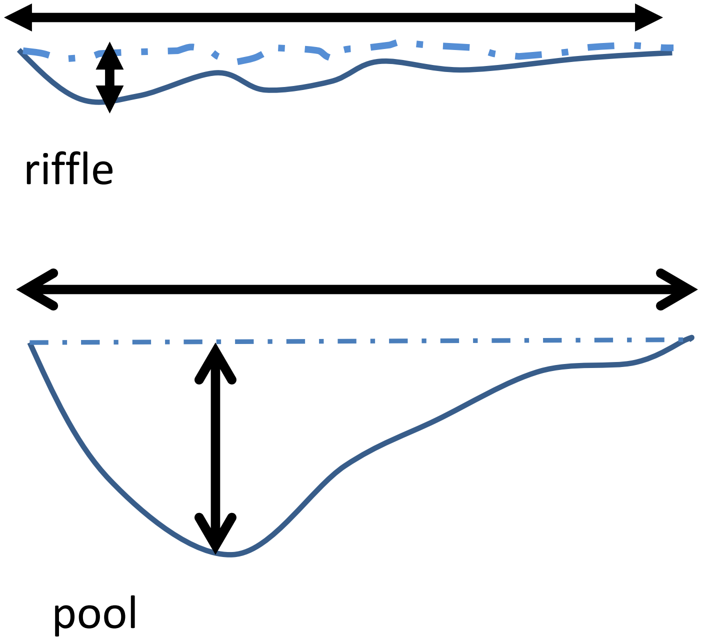


Therefore two types of sampling will be done for the study area to check the variance and explanatory power

Meso-scale physical habitat (MPH)approach

- Medium scale morphological units such as pools, riffles, glides, etc.
- Ecologists/biologists have given special consideration
- Hydraulically these features important due to differential velocities, water depths, etc.



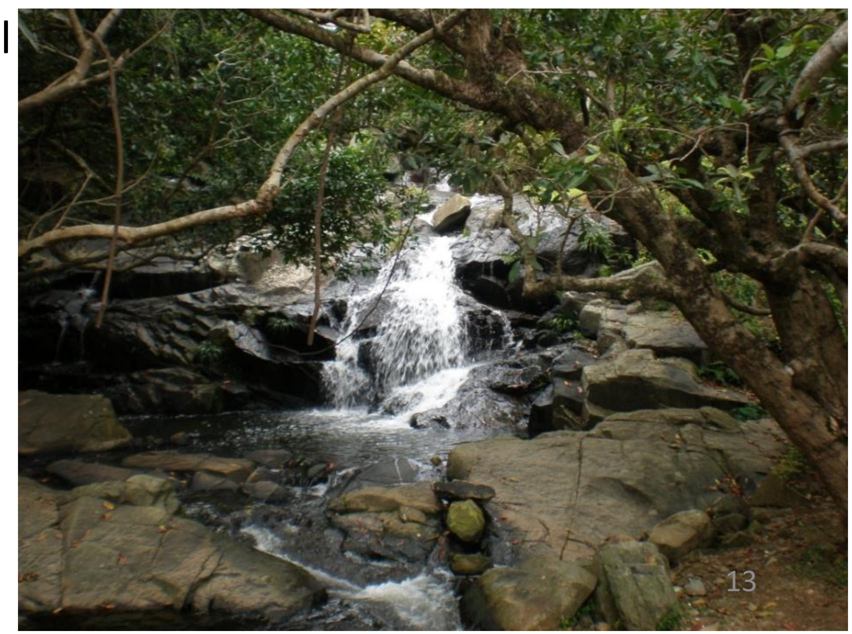


Run-pool

Boulders

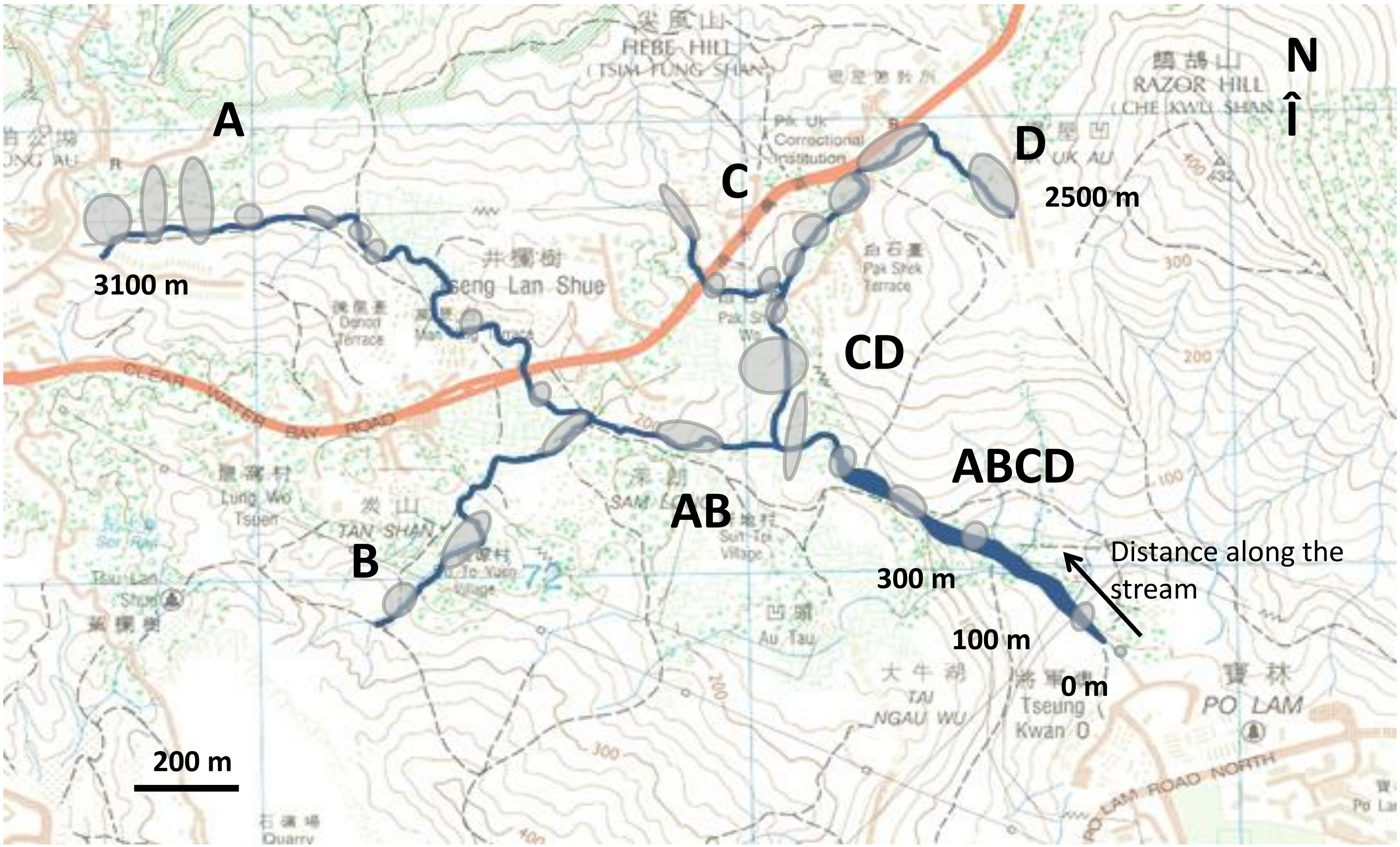
Bed rock outcrop

Fall-pool



Even regulated sections, there are places with morphological variation. E.g. silt traps

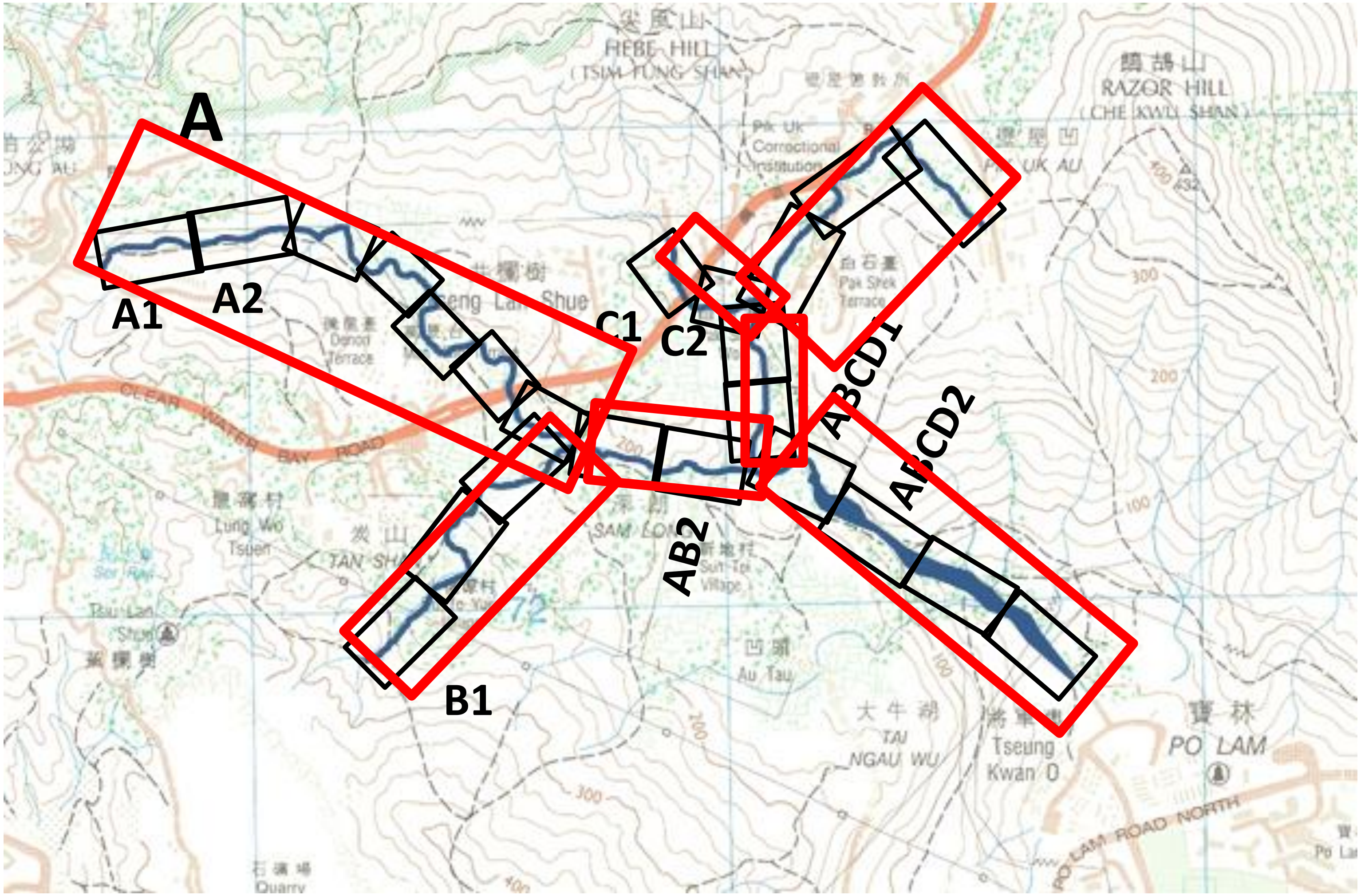
Meso-scale physical habitats of the study area
40% of the stream length covered



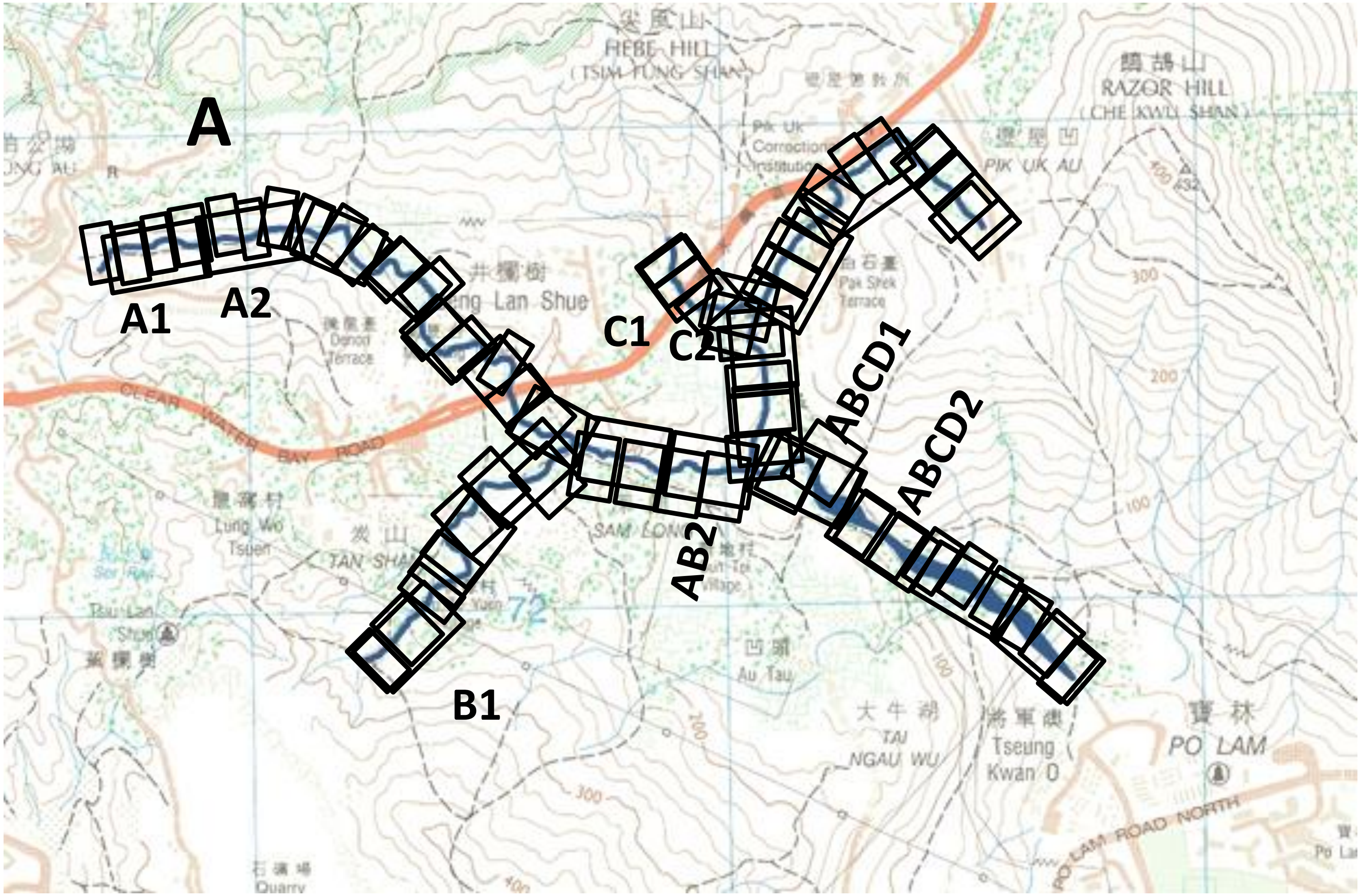
Encircled are sampling reaches, encircled areas approximately corresponds to the actual extent of the relevant reach

Cell-in-series (CIS) approach

- Stream segments (tributaries) are divided into equal lengths (cells)
- Replications are carried out for each cell along the center line
- This type of sampling is commonly used,
  - Due to simplicity
  - Has been recommended for steep and shallow streams where advective transport (in contrast to dispersive)
- Use in water quality models(e.g. Q2E by USEPA, STREAM by Park and Lee, 1996)



100% of the stream is covered


A
A1
A2
B1
C1
C2
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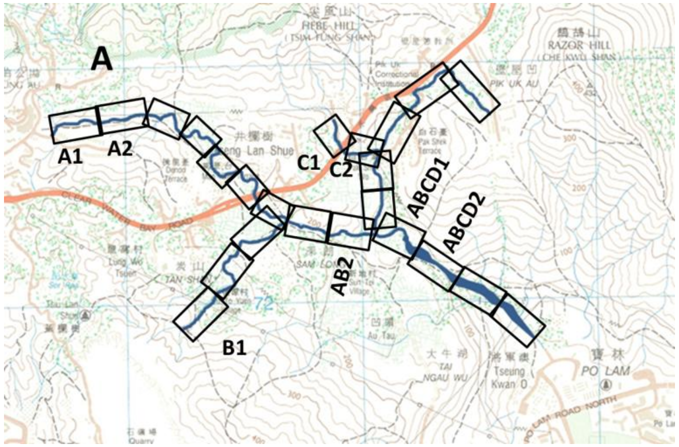
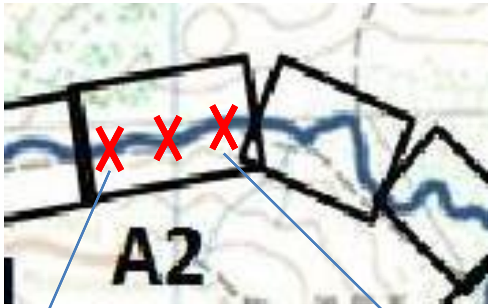
ABCD2
HEBE HILL
(TSIM TUNG SHAN)
RAZOR HILL
(CHE KWU SHAN)
PIK UK AU
Pik Uk Correctional Institution
Pak Shek Terrace
Ling Lan Shue
CLEAR WATER BAY ROAD
Lung Wo Tsuen
TAN SHAN
SAM LONG
Au Tau
TAI NGAU WU
Tseung Kwan O
PO LAM
PO LAM ROAD NORTH
Quarry
72

Is Cell-in-series approach unfair as it may show less variance?

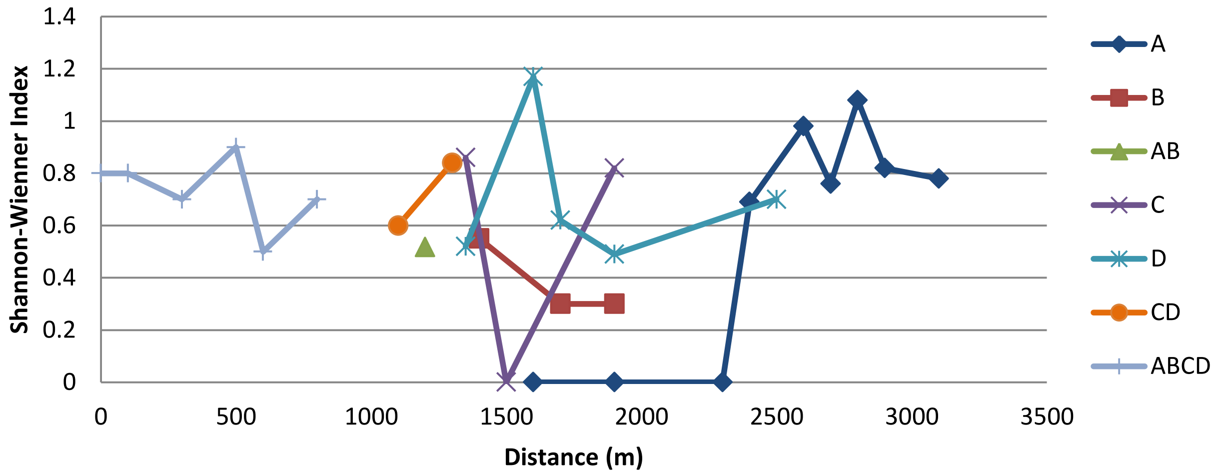




Some cells may cover totally different stream profiles

Selection of Response and Hydro-environmental variables

- The selected variable need to have a possibility to be observed at all sampling locations



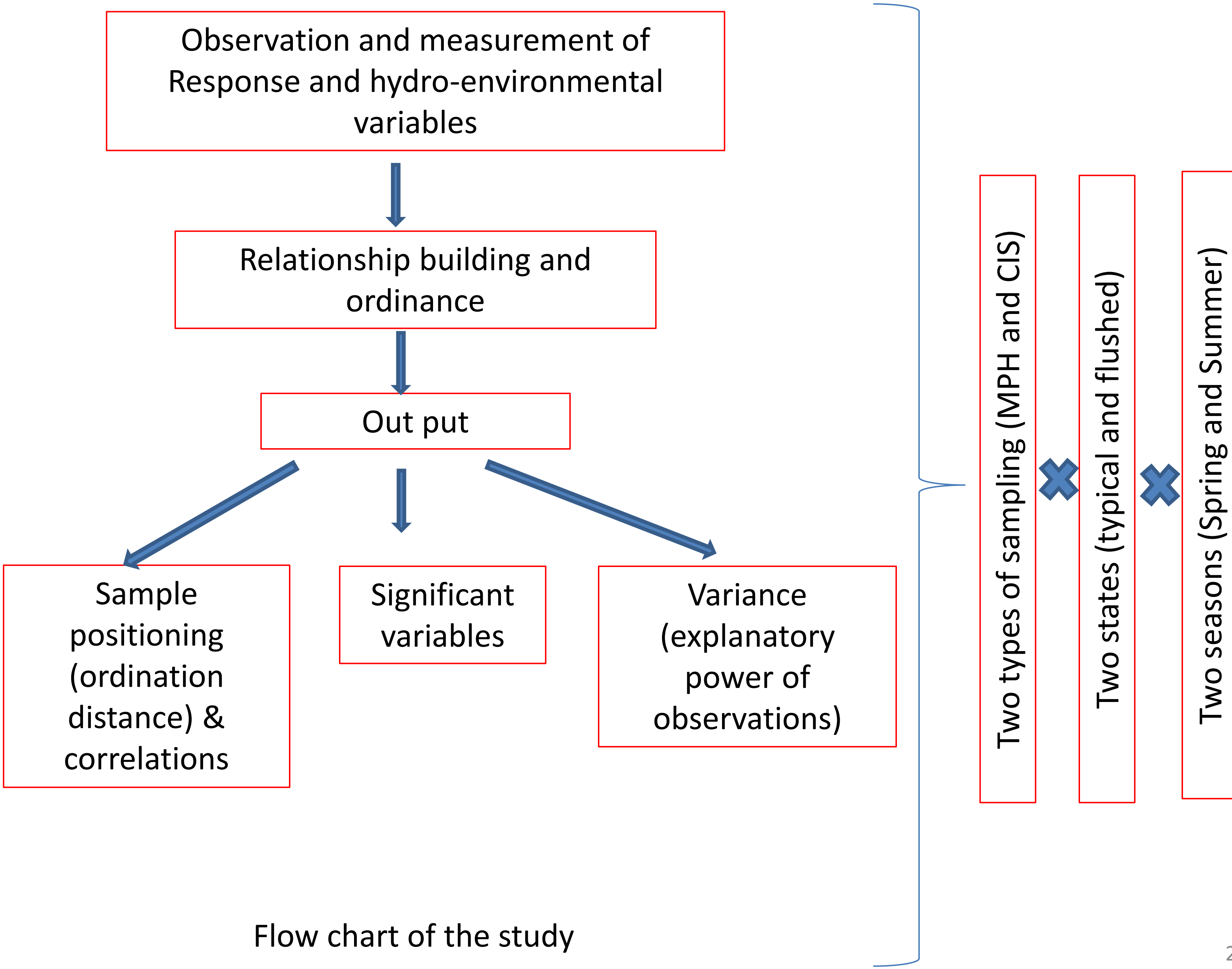
Some samples have plenty of riparian and submerged vegetation

But others not at all, and also no way of having

Response and hydro-environmental variables of the study

Hydro-environmental variables	**Response variables**
Velocity (average)	Chlorophyll
Standard deviation of velocity (SDV)	Nitrate
Standard deviation of velocity/average velocity (dV/V)	Nitrite
Water depth , SD, SD/depth	Ammoniacal nitrogen
Bankfull depth	Phosphorous- soluble reactive
Bankfull width	Dissolved oxygen
Slope	Turbidity
d50	In-stream primary production
Weight of particles less than 1 mm of the top 1cm layer (PSMALL)	Conductivity, total benthic macroinvetebrates, etc.

For some response variables sub-sampling has been carried out



Flow chart of the study

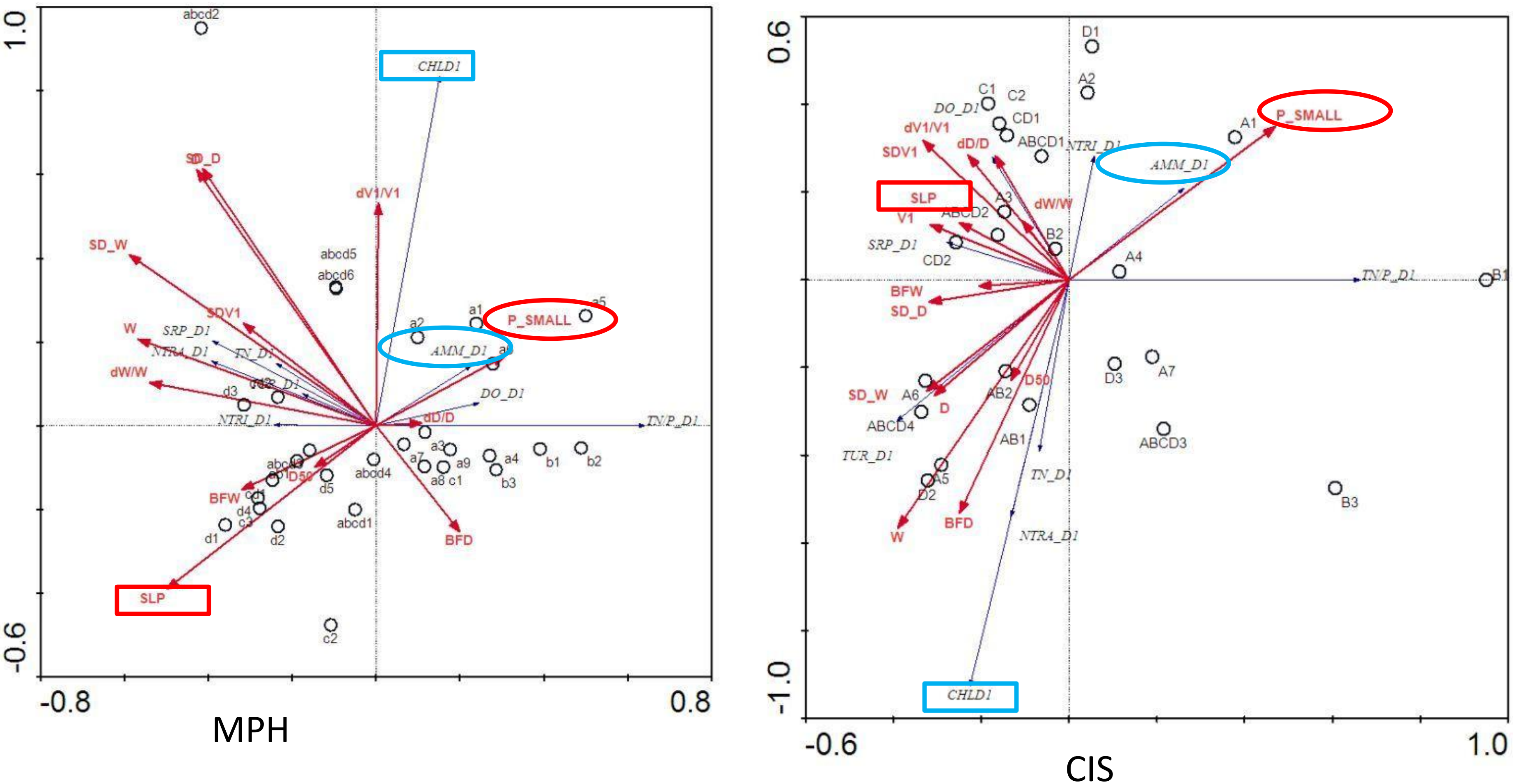
Methods of analysis of water quality

- Nitrogen measurements
  - Nitrate (Cadmium Reduction method)
  - Nitrite (Ferrous Sulfate method)
  - Ammoniacal nitrogen (Ammonia Salicylate and Ammonia Cyanurate Reagents)
- Soluble reactive phosphorous (Murphy and Riley, 1962)
- Chemical oxygen demand (Closed reflux method)
- Dissolved oxygen (DO meter)
- Turbidity (Turbidity meter)
- Conductivity (Conductivity meter)
- Chlorophyll (APHA, 1998)

Results

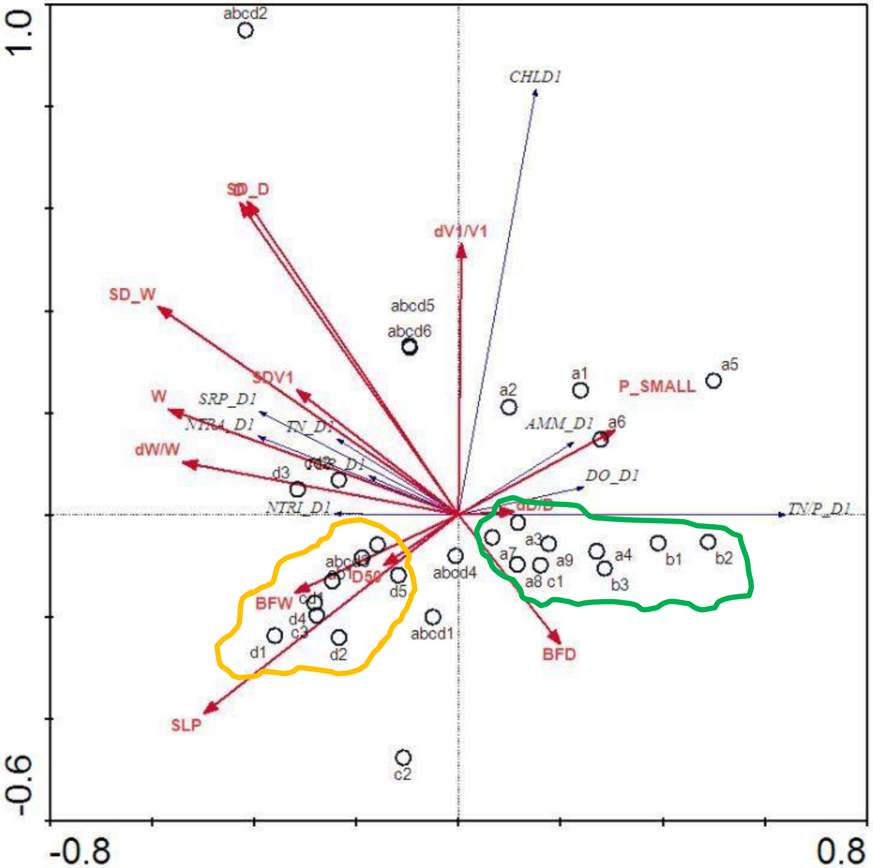
General relationships and polarisation of samples

Typical state- Spring

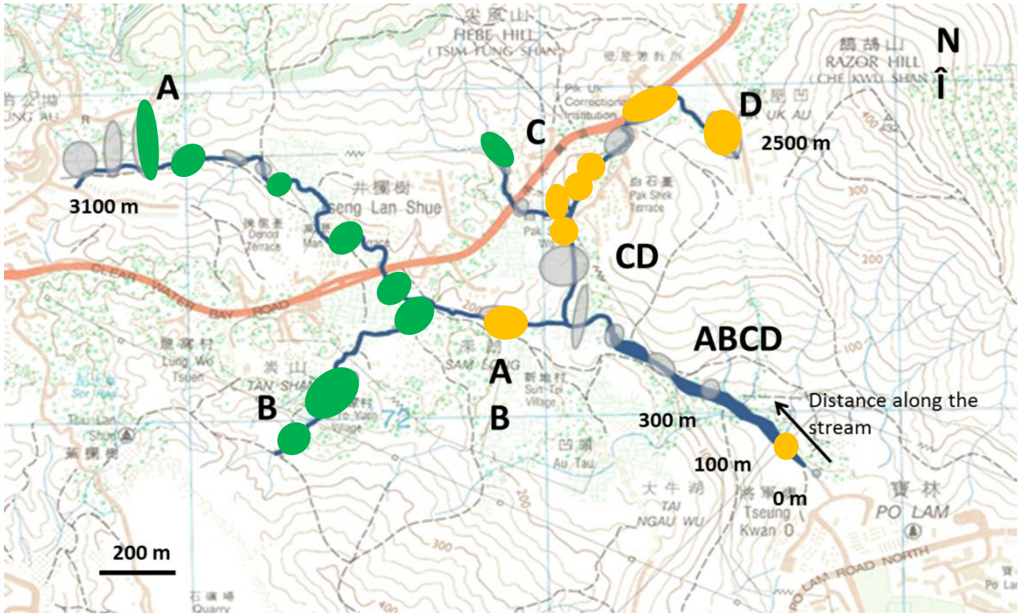


- Several Response and Environmental variables show similar correlation in both methods, e.g. Ammoniacal-N & PSMALL; Chlorophyll & Slope
- Few but some also showed less than similar relationships, e.g. DO & dV1/V1

Typical state- Spring

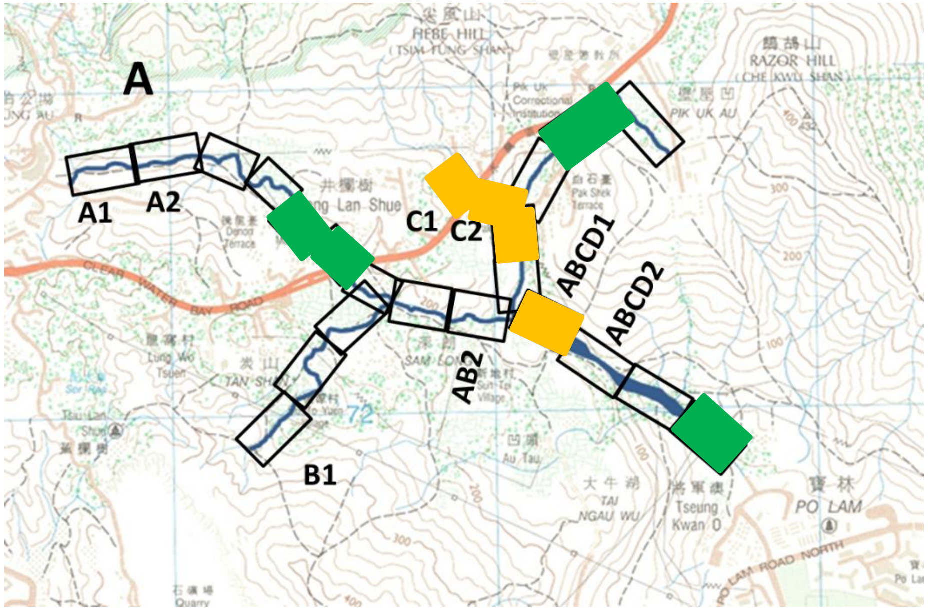


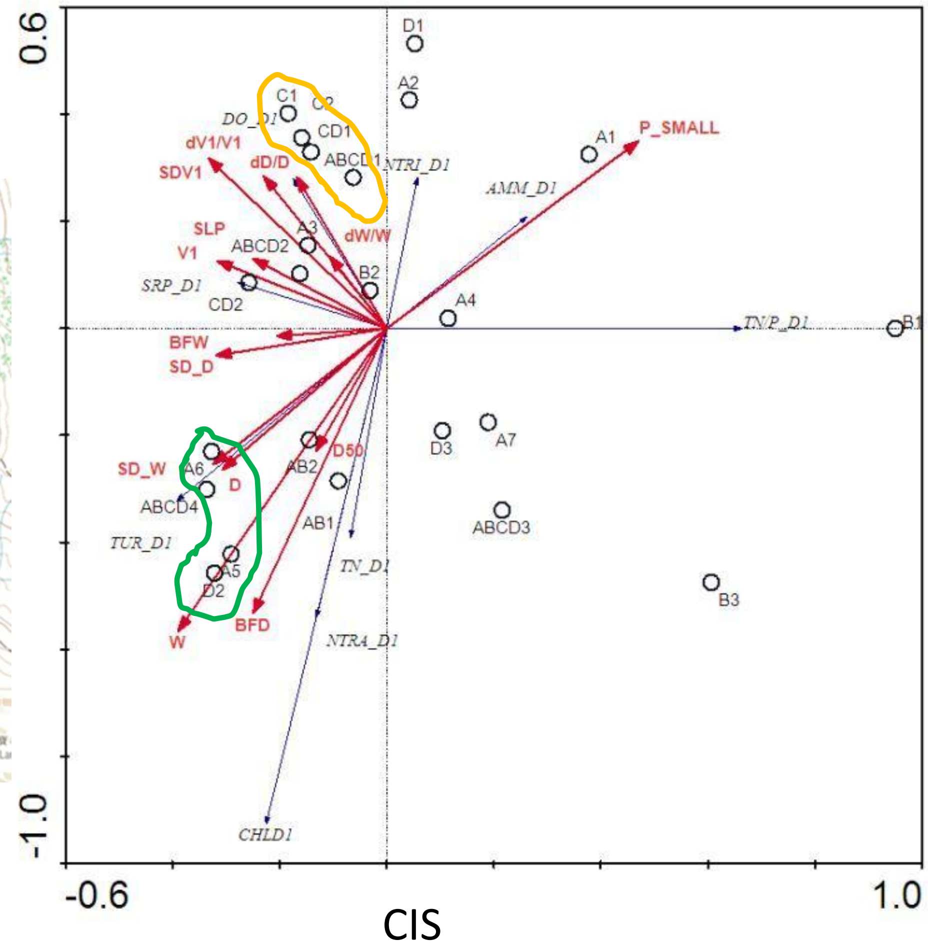
MPH



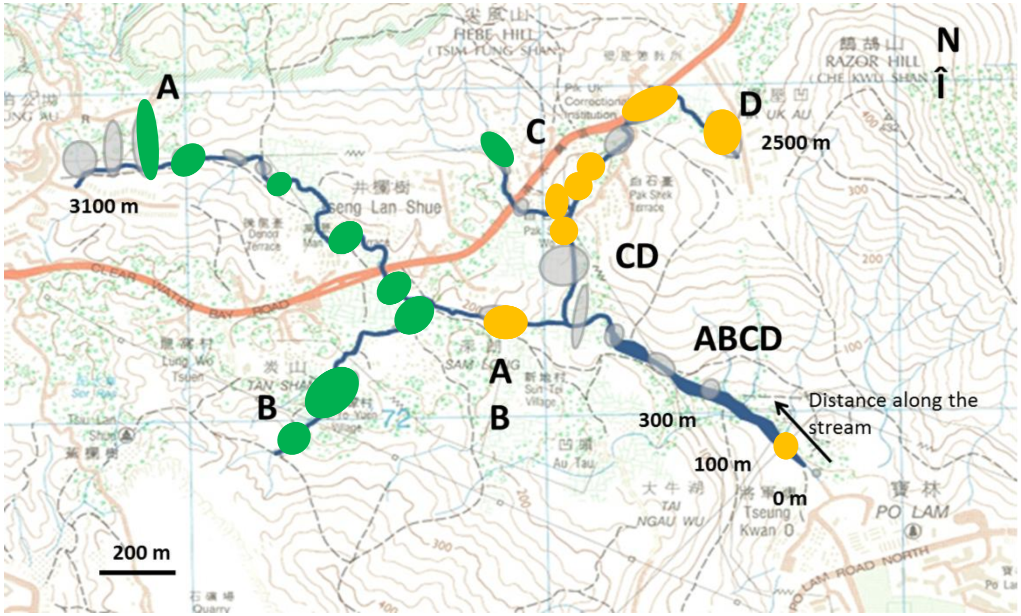
- Grouping of samples is different for CIS and MPH, with very rough and distant similarities
- Some samples showed a totally different ordination positions, e.g. b1, b2 & b3 vs. B1, B2, B3

Typical state- Spring



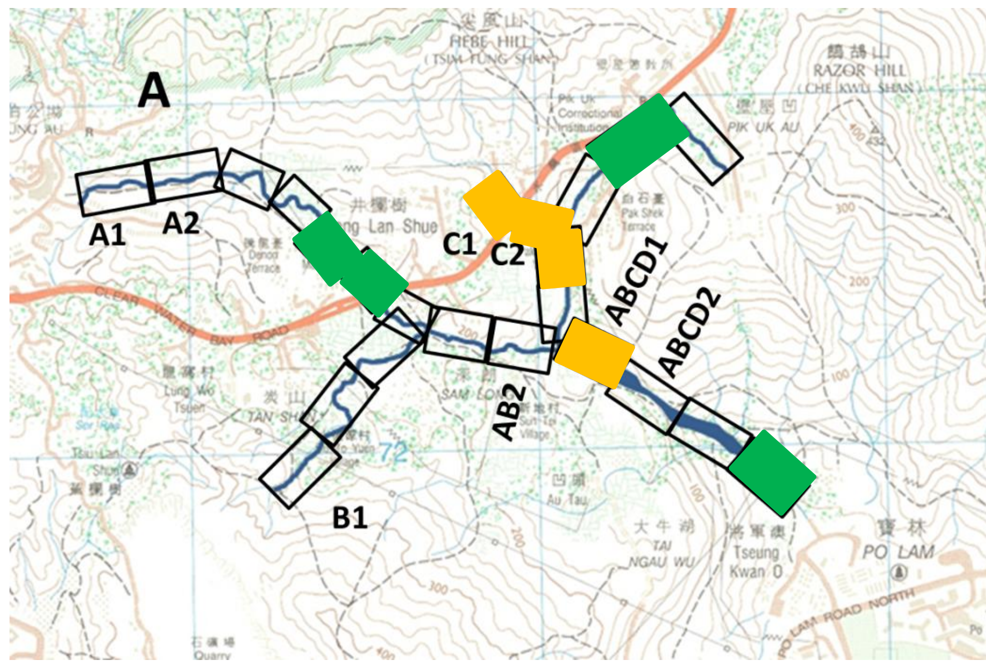


- b1, b2 & b3 vs. B1, B2, B3 total different



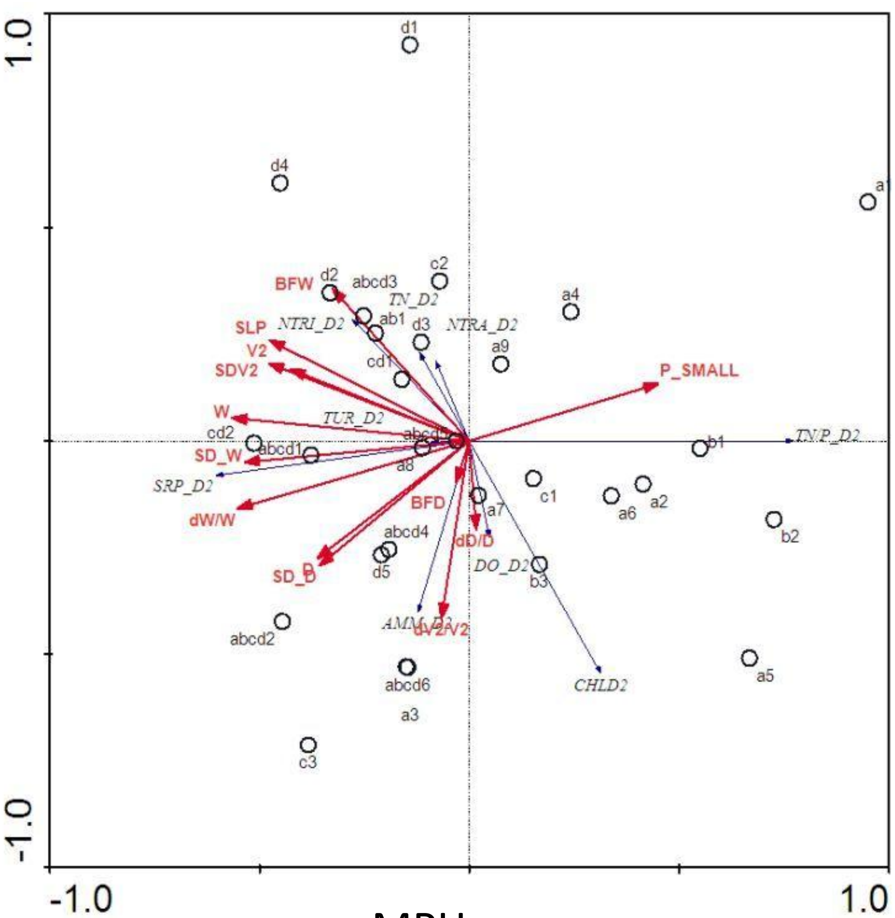
Sample polarisation (grouping) is not similar

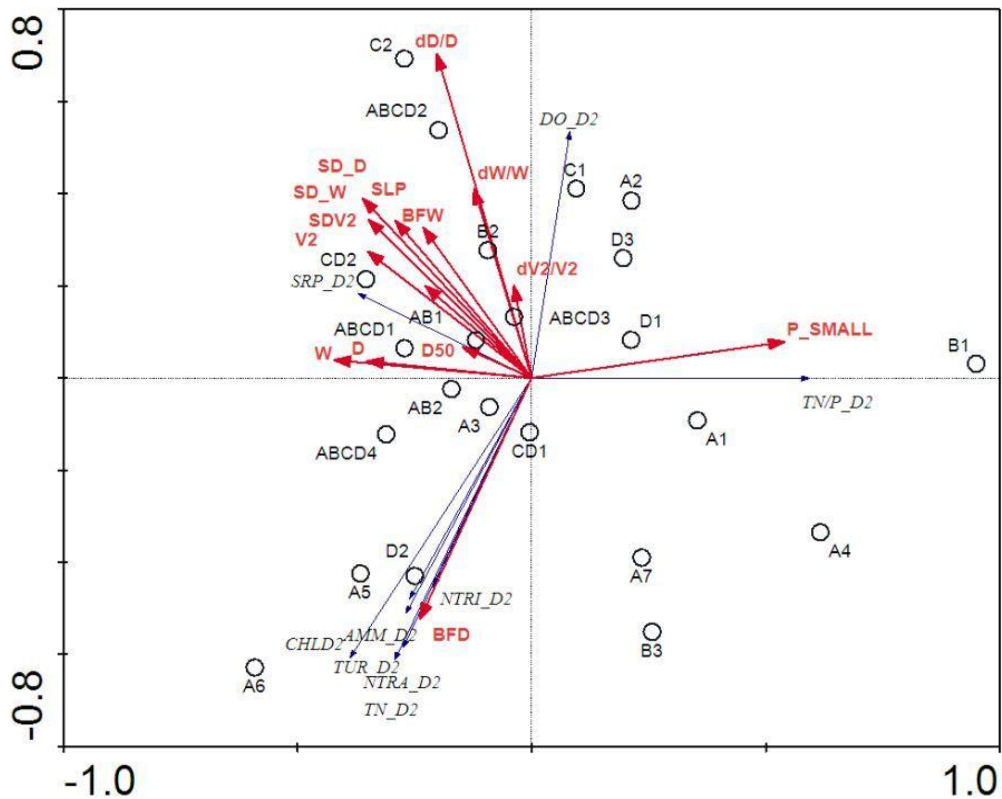
MPH



CIS

Flushed state- Spring





Less polarisation, probably the stream showing more heterogeneity after the rainfall induced flushing

- Correlations more or less same, but there are few differences too
- In general grouping of samples (polarisation) is different, with very remote similarities
- This means each approach may have its own way of attending the explanation of the streams water quality behavior
- Check the variance- which approach maximise the variance?

Variance and significant hydro-environmental variable(s)

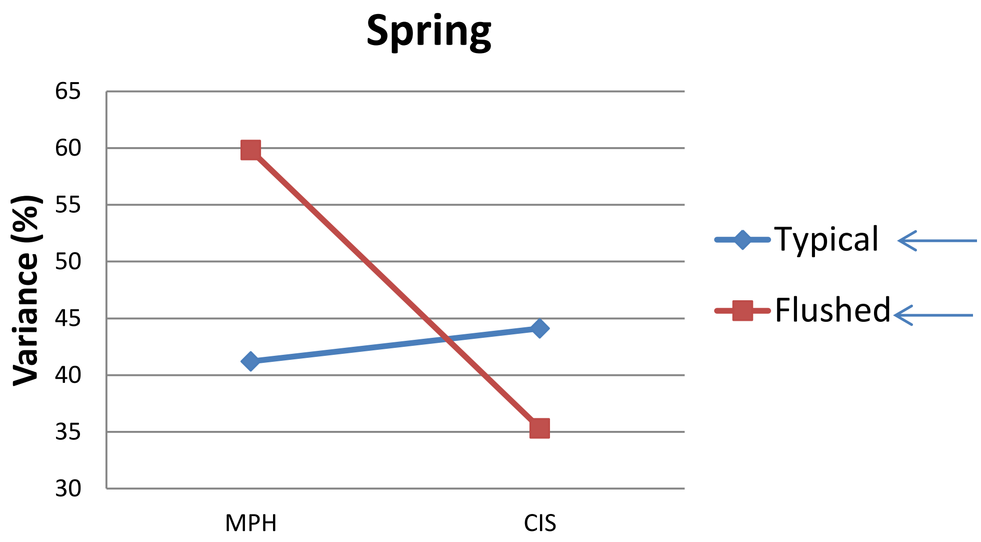
Spring

	MPH		CIS	
Typical state				
Significant variable(s)	SDW	P < 0.05	PSMALL	P < 0.1
Variance		41.2%		44.1%
Flushed state				
Significant variable(s)	W, dW/W	P < 0.05	PSMALL	P < 0.1
Variance		59.8%		35.3%

Summer

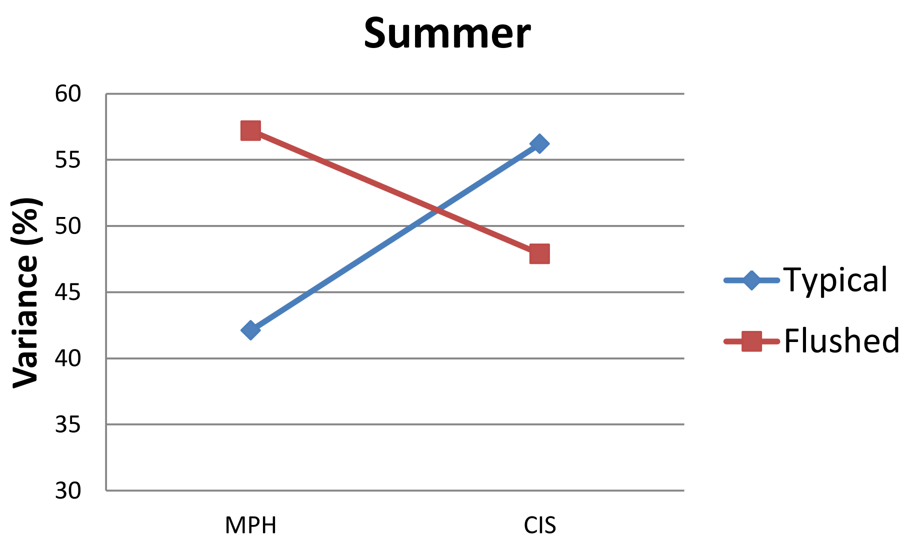
	MPH		CIS	
Typical state				
Significant variable(s)	SDW	P < 0.05	PSMALL	P < 0.1
Variance		42.1%		56.2%
Flushed state				
Significant variable(s)	W, dW/W	P < 0.05	PSMALL	P < 0.1
Variance		57.2%		51.7%

Maximum variance that can be explained by each approach



Polluted scenario

Best unpolluted scenario for this stream



Summary

- Correlations between response and environmental variables are independent of the approach
- But differences were noted with respect to
  - polarisation of samples
  - significant hydro-environmental variable(s)
  - explanatory power (i.e. variance)
- Based on explanatory power or variance it was obvious the state of the stream is a key factor of deciding type of sampling
- When the stream is subject to anthropogenic loads (or when the influence is high) CIS seemed to be better
- But when the pollution is less significant such as in the flushed case MPS seemed to be better
- Conceptually we can use explanatory powers of MPH and CIS to differentiate polluted vs. unpolluted OR pristine vs. disturbed
- We have tested the whole study with few more variables, and the results are more or less the same
- Further studies recommended

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Thank you