

# THE FlexiGrid: A UNIVERSAL SPATIAL SAMPLING FRAME

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Katznelson, R. (2008). The FlexiGrid: a universal spatial sampling frame. *in*: Proceedings of the sixth National Monitoring Conference of the National Water Quality Monitoring Council, "Monitoring: Key to Understanding our Waters", May 18-22, 2008, Atlantic City, NJ.

## ABSTRACT

Use of monitoring data collected at various spatial dimensions and scales, such as biological data and physical habitat data, requires integration of these monitoring Results and their specific descriptors, often with other Results, into a common data structure. The major challenge of such a structure is to connect each monitoring Result to the exact spatial component it was measured in, so that it is very clear what each Result represents in the environment. For example, each individual depth or velocity measurement has to be connected to the cross-section-point or the vertical-point where it was measured, and the flow discharge (Q), which is calculated from an aggregate of all these spatial components, has to be connected to the cross-section it was measured in. This paper describes a new data structure which enables such connections. It also enables placing every spatial component on a 'virtual map' as an independent entity, while preserving the internal hierarchy (e.g., the relations between reach, transect, and transect-point) and their order in a series. The data structure is a simple data table based on the concept that this author coined as the "FlexiGrid". **A FlexiGrid is a spatial multi-dimensional flexible sampling frame with internal hierarchy** which is laid out on a stream channel by one Team in one Station Visit. It can contain a variable number of dimensions, components, and angles. It refers to permanent locations, but it is not permanent itself (FlexiGrids may be laid out differently at different times). It can be applied to different scales. It can serve different kinds of protocols from any area of inquiry that requires spatial representation of a monitoring Result. And it can be captured in a data structure that allows for reporting of any type of Result and Endpoint, generated for any spatial component (or an aggregate thereof) at any scale, on the 'same page'. This is extremely helpful for data interpretation, e.g., when examining different factors, characteristics, and attributes that may explain the biological results.

## KEYWORDS

FlexiGrid, spatial component, spatial sampling frame, physical habitat, spatial information, stream channel.

## INTRODUCTION

Environmental scientists utilize numerous monitoring and assessment protocols to describe and assess a variety of characteristics related to the physical, chemical, and biological conditions in streams. Whereas most water quality monitoring results can be linked to a single point on the globe (i.e., to the point where a measuring probe was dipped in the water or where a sample was collected), the assessments of attributes related to stream morphology, substrate composition, or

biological communities generate results that must often be linked to a myriad of spatial components. Monitoring programs implement different protocols that apply different types of spatial sampling frames and use different terminology (e.g., Barbour *et al* 1999, Fitzpatrick *et al* 1998, Harrington 1999, Ode 2007, and Peck *et al* 2006; also see Somerville and Pruitt 2004 for a review.) All of these protocols apply spatial sampling frames that have a lot in common: each frame is a flexible grid of one type or another. However, this commonality hasn't always been expressed when different programs developed data management systems to process and store the data generated by their protocols. In some cases data structures were developed in isolation, and in other cases the differences in sampling frames were reflected in the resulting data structures. Consequently, many of the data management systems available for spatial assessments data are incompatible with each other. Often, they are also profoundly different from other systems such as the elaborate data management systems that have been built for storage and retrieval of water quality data. Protocols also differ in the way sampling frames are documented and mapped. Field operators are often instructed to make a drawing of the stream channel and the layout of major spatial components, but this information isn't always incorporated into the data management system.

This paper describes a new way to address three challenges:

- Identify the common elements shared by all spatial sampling frames, and devise 'neutral' terms for referring to them (i.e., terms that have not been used to denote protocol-specific meanings). This will help to increase data comparability by use of the same language. The proposed neutral terms are defined in the Glossary at the end of this paper.
- Create a data structure that connects each monitoring Result (or Endpoint) to the exact spatial component (or aggregate thereof) in which it was measured, make the structure flexible to accommodate any protocol, and make it compatible with existing water quality data management systems. This will facilitate data exchange.
- Capture the information about any spatial sampling frame or any of its components on a virtual map that can be stored in a database and/or easily transferred to a Geographic Information System (GIS). This will enable use of locative media to present and share results.

## THE FLEXIGRID CONCEPT AND ITS EMBODIMENT

Every time a field crew visits a site to conduct spatial assessments, they lay a temporary Sampling Frame on the channel according to the specifications of their protocol. This frame, comprised of all tapes, stakes and ropes, is almost always a combination of a “**Stream Fragment**”, as measured on the stream’s “**Backbone**”, and one or more “**Crosslines**”. A “Stream Fragment” is a stretch of stream defined by its origin, length and direction; it is often called ‘Reach’. The “Backbone” may be the Thalweg, centerline, or centroid. A “Crossline” is a straight line that crosses the wetted channel perpendicular to a given stream-length entity; it is often called Cross-section or Transect. Most sampling frames share the following properties:

- A ‘Grid’ made of a number of components
- Flexible geometry (variable angles)
- Multi-dimensional
- A structure with internal hierarchy

In other words, the conceptual Spatial Sampling Frame is essentially a “universal spatial multi-dimensional flexible sampling frame with internal hierarchy” or USMDFSFWIH. This author called it a “**FlexiGrid**” for brevity. **Figure 1** shows a FlexiGrid that is commonly used for physical habitat assessments; it is the traditional “reach with 11 transects” frame. The figure shows the ‘parent’ Stream Fragment (e.g., the Reach) which is the entire FlexiGrid in this case. Within the FlexiGrid, the figure shows examples of three FlexiGrid Components (Plot, Crossline, and Crossline-point); not shown are other FlexiGrid Components such as the Verticals and the internal Stream Fragments. Examples of internal Stream Fragments include ‘slope section’, ‘Thalweg Profile Section’ (stretches of stream between inter-transects), ‘Trash Assessment Sections’ (a 100-ft linear stretch, bankfull-delimited), etc.

Figure 1 also shows the main mapping entities used to (a) place the frame on the globe, by mapping the FlexiGrid Origin to the Permanent Station (or to a Permanent Monument, not shown), and (b) to snap each component to the FlexiGrid itself by mapping it to the FlexiGrid Origin on the Backbone (in this case, the Thalweg) and to the Local Reference Point (in this case, Left Bank).

**Figure 2** shows a portion of a FlexiGrid in detail and depicts several kinds of Plots. This figure demonstrates a way to address the problem of different languages: the neutral term for this component type is “Plot” (i.e., a 2-D polygon) and it has a universal single meaning, but the protocol-specific names can also be **added** to any communication about spatial data.

A FlexiGrid is laid out on a stream channel by one Team in one Station Visit. It can contain a variable number of dimensions, components, and angles. It refers to a permanent location, but is not permanent itself: FlexiGrids may be laid out differently in the vicinity of one Permanent Station at different times. It can be applied to different scales. A single FlexiGrid can serve different kinds of protocols from any area of inquiry that requires spatial representation of a monitoring result. In essence, the FlexiGrid can serve as the platform for all the types of monitoring activities performed in a Station Visit. These activities may be of the evaluative activity types (i.e., categorical observation or estimates), the measurement activity types (e.g., survey, or field measurements with any kind of Instrument), or the collection activity type (i.e., generation of a Sample in a container for analysis elsewhere).

To make use of the FlexiGrid concept and connect monitoring results to spatial components, one would need to document the FlexiGrid in some electronic format that can be used to manage data. **Box 1** shows a list of data elements that describe and map the FlexiGrid and its components. Many of these elements are filled out by one value from a pick-list, and those lists are shown in italics in Box 1.

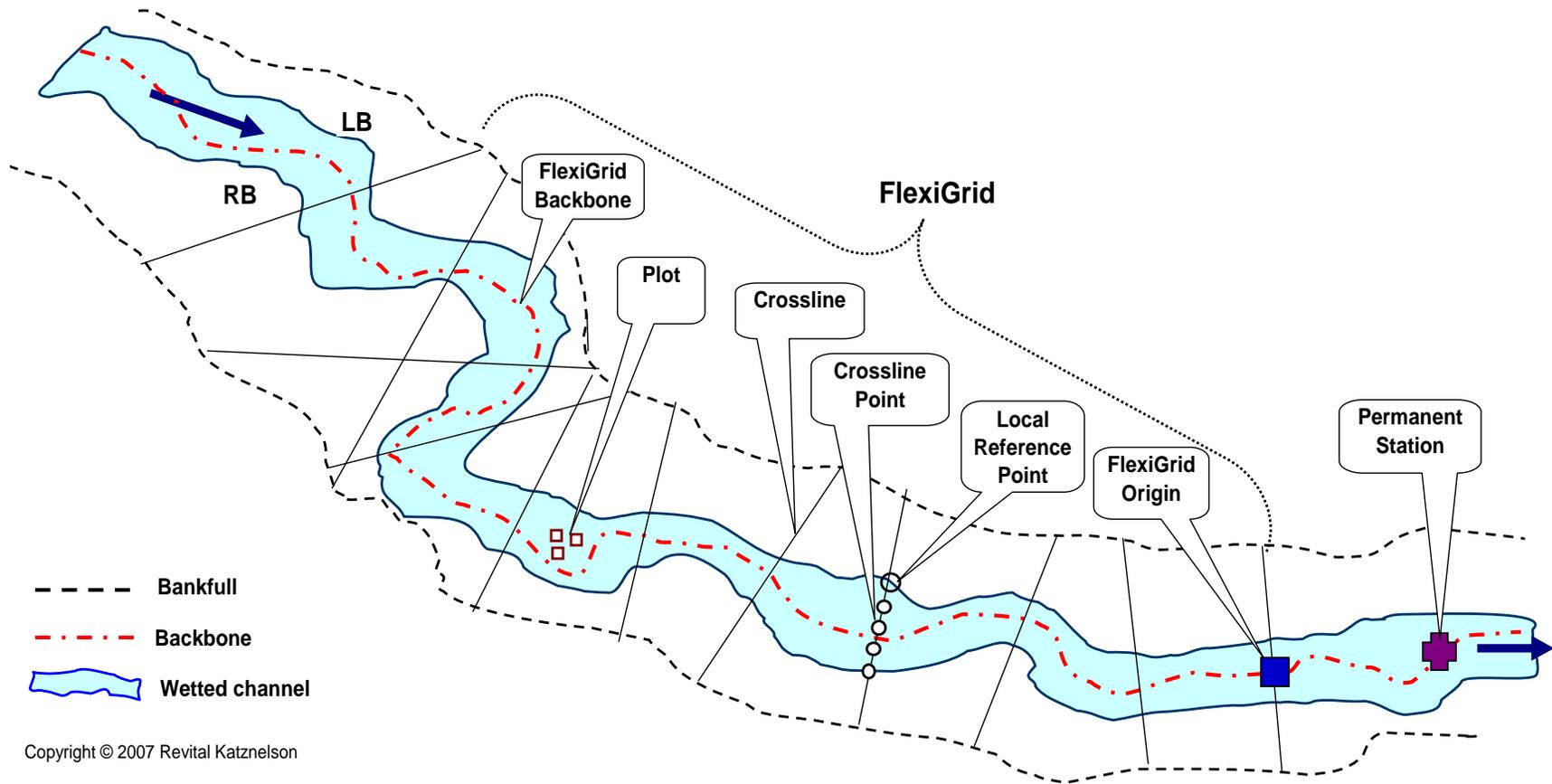
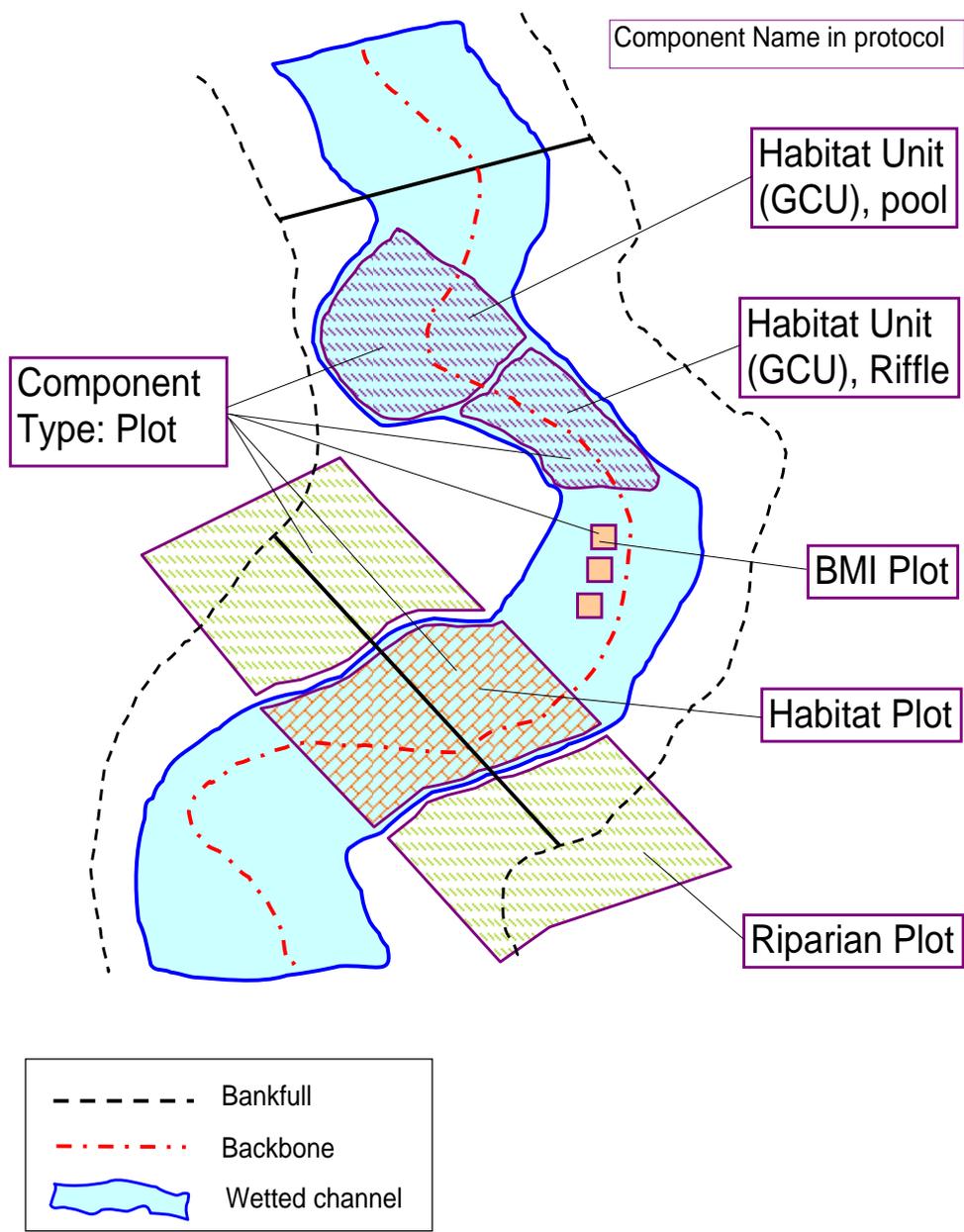


Figure 1: Example of a FlexiGrid with associated mapping handles (Station, Origin, Backbone, and Local reference points) and selected FlexiGrid Components (Plot, Crossline, Crossline-Point).



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Figure 2: Portion of a FlexiGrid in detail, showing a variety of Plots

### Box 1: Descriptors of a FlexiGrid and its Components

#### The FlexiGrid data elements:

- FlexiGrid Origin ID
- FlexiGrid distance units (*m, ft*)
- FlexiGrid Origin distance from permanent Station [and monument]
- FlexiGrid Type (*transects&points, right-angle grid, string of habitat units, etc.*)
- FlexiGrid Backbone (*Thalweg, midstream, centerline, centroid*)
- FlexiGrid positive distance direction (*Upstream, downstream*)

#### The FlexiGrid Component data elements

- FlexiGrid Component **ID** [note: the naming conventions can reflect hierarchy]
- FlexiGrid Component **Type** (*Stream-fragment, Crossline, Plot, Point, Vertical, River-Parallel, Crossline-point, etc.* )
- FlexiGrid Component **Name in Protocol** (e.g., *Reach, Transect, Transect-point, BMI Plot, etc.*); [these are protocol-specific]
- FlexiGrid Component **Pre-determined size** [and shape, and boundaries]
- FlexiGrid Component **backbone-distance from Origin**
- FlexiGrid Component place in series
- FlexiGrid Component **distance from Local Reference Point**
- Local Reference Point type (e.g., Left-bank)
- FlexiGrid Component **depth from surface**
- FlexiGrid Components **Aggregate** [used to derive a given result Endpoint]

**Figure 3** shows the embodiment of the FlexiGrid concept in the data structure developed by this Author to report Results generated for a variety of spatial components (Note: The examples in this section show fictitious data that are actually very similar to real data.) This data structure is contained in a simple spreadsheet. In the interest of presentation simplicity, only a selected subset of data fields are shown in Figure 3; the full spreadsheet contains all the other relevant information (e.g., date, time, Team ID, Instrument ID, etc.) The Results selected as examples include individual measurements/observations as well as calculated endpoints. Each data record (a spreadsheet row) shows a Result and the spatial component in which it was measured, or a Result Endpoint (e.g., Pct cobble, third row) with the aggregate of spatial components it was calculated from (e.g., Transect Points) as well as the spatial component it now represents (e.g., Reach).

Note that the naming convention used in this embodiment to generate the FlexiGrid Component ID (e.g., FG35-R1-T6-TP2) reflects the internal hierarchy of this FlexiGrid. In other words, a Transect-point's ID reflects each point's order in a series (e.g., the second point is TP2), the Transect it belongs to (T6), the Reach this transect is a part of (R1), and the FlexiGrid (FG35) that holds all these components. In addition (or alternatively), one can always insert more data fields to the spreadsheet, for the "Parent FlexiGrid Component ID" and the "Grandparent FlexiGrid Component ID" if needed.

Also note that the last 5 examples in this spreadsheet are taken from protocols in which the FlexiGrid is not a Reach.

As seen in Figure 3, this data structure is based on a traditional result database table which has been extended to include identifiers and descriptors of the spatial components involved. Thus it is compatible with other water quality data management systems that are based on the 'vertical' table (a.k.a. flat file) format. The same spreadsheet can easily be extended to include mapping information, as shown in **Figure 4** for the examples from Figure 3. Note that the distances are descriptors of the Results, while stream width, depth, slope, and bearing measurements are reported as Results in this structure (not shown). The mapping information can also be organized in a separate data table and linked to other data elements via the unique FlexiGrid Origin ID and/or FlexiGrid Component ID. Mapping information for each component has to be gathered in the field when the tapes are laid out, by recording the distances from each component to the FlexiGrid Origin and to the Local reference point. This level of detail is not always essential, but the FlexiGrid data structure makes it possible to capture the information if it is essential. In other words, the spatial information stored in this basic data structure can be retrieved and be used to reconstruct the spatial sampling frame *in situ* if needed.

It must be emphasized that the FlexiGrid spreadsheet is not a stand-alone data management system. It may be one of several Result tables in a relational database, and it can be linked to other parts, or tables, of the database. For example, the permanent Station and any permanent monument may be described in detail in the Location table, while the Team may be described in the Project Organization table, which also includes all affiliations and contact information.

Project ID	Station Visit (SV) ID	Permanent Station ID	FlexiGrid Origin ID	FlexiGrid Component ID	FlexiGrid Component Type	FlexiGrid Component Name in Protocol	FlexiGrid Components Aggregate	Characteristic	Result	Result unit	Result type	Endpoint type
SYCM09	PW05-v1	SYC050	FG35	FG35-R1	Stream-Fragment	Reach	BMI plots	Index of biological integrity	67	(none)	calculated endpoint	compound endpoint
SYCM09	PW05-v1	SYC050	FG35	FG35-R1	Stream-Fragment	Reach	BMI plots	Estimated Pct Cobble Avg	17	%	calculated endpoint	simple endpoint
SYCM09	PW05-v1	SYC050	FG35	FG35-R1	Stream-Fragment	Reach	transect-points	Pct Cobble	11.2	%	calculated endpoint	aggregated endpoint
SYCM09	PW05-v1	SYC050	FG35	FG35-R1-T6	Crossline	Transect	n/ap	Channel Width	13.5	m	individual measurement	n/ap
SYCM09	PW05-v1	SYC050	FG35	FG35-R1-T6	Crossline	Transect	n/ap	Left Bank Angle	65	degrees	individual measurement	n/ap
SYCM09	PW05-v1	SYC050	FG35	FG35-R1-T6-TP2	Crossline-point	Transect-point	n/ap	Substrate size class	Cobble		verbal category	n/ap
SYCM09	PW05-v1	SYC050	FG35	FG35-R1-T6-TP3-Vr	Vertical Point	Vertical Point	n/ap	Velocity	1.2	ft/sec	individual measurement	n/ap
SYCM09	PW05-v1	SYC050	FG35	FG35-R1-PL06	Plot	BMI Plot	n/ap	Estimated Pct Cobble	10	%	estimated number	n/ap
SUIS06	LM21-v1	SUI085	SF56	SF56-P1	Plot	Pebble Plot	n/ap	d50	34	mm	calculated endpoint	quantile
SUIS06	LM21-v1	SUI085	SF56	SF56-P1	Plot	Pebble Plot	n/ap	% gravel	45	%	calculated endpoint	simple endpoint
SLC95	RD05-v1	SLC116	FG-RD05	FG-RD05-P1	Plot	Bird Plot	n/ap	total # of bird species	15	taxa count	calculated endpoint	simple endpoint
SLC95	RD05-v1	SLC116	FG-RD05	FG-RD05-P1	Point	Point	n/ap	Specific conductance	780	uS	individual measurement	n/ap
SLC95	RD05-v1	SLC116	FG-RD05	FG-RD05-P1-VP02	Vertical Point	Vertical Point	n/ap	Velocity	0.67	ft/sec	individual measurement	n/ap

n/ap = not applicable

Data field names (column headers) are color coded for descriptors of the Station-Visit (pink), FlexiGrid (beige), FlexiGrid Component (yellow), and Results (light blue).

Rows are color coded by Components in the same FlexiGrid, and by Projects.

Figure 3: Selected data fields from the FlexiGrid spreadsheet depicting the monitoring Results' linkage to the spatial components in which they were collected.

FlexiGrid Origin ID	FlexiGrid Origin Latitude	FlexiGrid Origin Longitude	FlexiGrid Origin lat/long datum	FlexiGrid distance units	FlexiGrid Origin distance from permanent Station	FlexiGrid type	FlexiGrid backbone	FlexiGrid positive distance direction	FlexiGrid Component ID	FlexiGrid Component Name in Protocol	FlexiGrid Component backbone-distance from Origin	FlexiGrid Component distance from Local ref point
FG35	37.99688	-118.69953	NAD83	m	23	transects&p oints	Thalweg	Upstream	FG35-R1	Reach	0	n/ap
FG35	37.99688	-118.69953	NAD83	m	23	transects&p oints	Thalweg	Upstream	FG35-R1-T6	Transect	85	n/ap
FG35	37.99688	-118.69953	NAD83	m	23	transects&p oints	Thalweg	Upstream	FG35-R1-T6-TP2	Transect-point	85	3.2
FG35	37.99688	-118.69953	NAD83	m	23	transects&p oints	Thalweg	Upstream	FG35-R1-T6-TP3-Vr	Vertical Point	85	5
FG35	37.99688	-118.69953	NAD83	m	23	transects&p oints	Thalweg	Upstream	FG35-R1-PL06	BMI Plot	67	5.8
SF56	35.21145	-122.6697	WGS84	m	89	right-angle grid	midstream	Upstream	SF56-P1	Pebble Plot	-13	13
FG-RD05	not recorded	not recorded	not recorded	m	0	other	Thalweg	Upstream	FG-RD05-P1	Bird Plot	0	2.5
FG-RD05	not recorded	not recorded	not recorded	m	0	other	Thalweg	Upstream	FG-RD05-P1	Point	5	0.5
FG-RD05	not recorded	not recorded	not recorded	m	0	other	Thalweg	Upstream	FG-RD05-P1-VP02	Vertical Point	5	0.5

n/ap = not applicable

Data field names (column headers) are color coded for descriptors of the FlexiGrid (beige) and FlexiGrid Component (yellow)

Rows are color coded by Components in the same FlexiGrid, and by Projects.

Figure 4: FlexiGrid descriptors and mapping information

## THE APPLICATION

The FlexiGrid concept received its first validation in response to an immediate need to enter and process physical habitat data that were collected in a local community using a temporary protocol (Note: the information and example data provided in this section are real, except that the Station IDs have been altered). This “Interim 2004” protocol was used during a transition phase between the evaluative method (common to the Rapid Bioassessment Protocol, Barbour *et al* 1999) and the more rigorous measurement-based method used by the Environmental Monitoring Assessment Program (Western EMAP for wadeable streams, Peck *et al* 2006). Application of the FlexiGrid concept involved the following steps:

**Step 1- ‘Inventory’:** The protocol was examined thoroughly to identify the spatial components and the characteristics to be measured in each. The result endpoints that will be used to report the data were selected per discussion with Project personnel. The summary list was then organized in the matrix shown in **Figure 5**.

**Step 2 – Development of a Data Entry Template:** The data fields of the FlexiGrid spreadsheet were tailored to the information bits within the protocol, and the order of data entry was tailored specifically to the field data sheets used for data collection. This adaptation included insertion of formulae, creation of internal worksheets (e.g., to calculate flow discharge), and introduction of color codes and color separators. The resulting Data Entry Template contains over 750 records to accommodate one assessment (i.e., raw data from one set of the 14 data sheets filled out in each Station Visit).

**Step 3 – Data Entry:** The physical habitat data were entered into the FlexiGrid Spreadsheet templates by student interns, each assessment (one Station-Visit) into its own spreadsheet.

**Step 4 – Data preparation:** This step included data Verification and Validation, removal of data entry formulae, and sorting of the data in each spreadsheet by Characteristics.

**Step 5 – Development of an Endpoint Calculation Template:** A variety of formulae were then added to the right of the raw data columns. Each of these formulae refers to a specific range of raw data and calculates the desired endpoint (per Kaufmann *et al* 1999 whenever possible.) Additional formulae organize the endpoints in two formats simultaneously; one is a database table (in a ‘vertical’, a.k.a. flat file format) and the other is a reader-friendly summary table (in the ‘horizontal’, a.k.a ‘cross-tab’ format.)

**Step 6 – Data Processing:** The Endpoint Calculation Template was then copied and pasted onto each of the spreadsheets prepared in Step 4, to the right of the raw data columns. Endpoints from different spreadsheets (i.e, different assessments) were then compiled by simple copy and paste operations. An example of the resulting database table, showing a variety of aggregated endpoints, is presented in **Figure 6**.

FlexiGrid Component Type	FlexiGrid Component Name in Protocol	FlexiGrid Component Pre-determined size	FlexiGrid Component pre-determined Shape	FlexiGrid Component pre-determined boundaries	total # of same FlexiGrid Components in a series	Characteristics measured or evaluated at FlexiGrid component	FlexiGrid Components Aggregate	Endpoint (characteristic name) calculated for aggregate and reported for the Reach
Point	WQ point	n/ap	n/ap	n/ap	n/ap	Water Temperature; pH; Salinity; Dissolved Oxygen; Specific Conductance; Alkalinity;	n/ap	
Stream-Fragment	Reach	150	n/ap	n/ap	n/ap	Epifaunal Substrate/Available Cover; Sediment Deposition; Channel Alterations;	n/ap	
Plot	BMI plot	1x1 ft	square	wetted channel	8	Estimated Percent of Fines&Sand; Gravel; Cobble; Boulder; Bedrock	BMI plots	Avg Fines&Sand ; Avg. Gravel ; Avg. Cobble ; Avg. Boulder; Avg. Bedrock;
Stream-Fragment	Slope-section	n/ap	straight line	n/ap	variable	% slope	Slope section	Average slope;
Plot	Habitat Unit	n/ap	n/ap	wetted channel	variable	hab unit type; hab unit length	habitat units	Total length of Pools; Glides; Runs ; Riffles; Cascades/falls; Dry
Crossline	Flow Cross-section	n/ap	straight line	wetted channel	n/ap		Flow verticals	Flow Discharge (Q);
Vertical	Flow Vertical	n/ap	straight line	water column	n/ap	water depth; current velocity;	Flow verticals	
Crossline-point	Transect-point & Inter-Transect point	n/ap	point	n/ap	5	Water Depth; Particle size class; Pcnt Cobble Embeddedness	Transect-point & Inter-Transect-point	Avg depth (of wettted points), particle size distribution, avg % embeddedness
Crossline	Transect & Inter-Transect	n/ap	straight line	wetted channel	11+10	Stream width	Transect & Inter-Transect	Avg stream width
Plot	Habitat Plot	10 stream m	n/ap	wetted channel	11	(cover catagories for a list of habitat elements)	Habitat Plot	(Avg % cover for the list of habitat elements)
Plot	Riparian Plots	10 stream m	n/ap	10m out from each bank	11	(cover categories for a list of riparian and other bank covers)	Riparian Plots	avg % cover for the list of riparian and other bank covers)
Crossline	Human Influence transect	n/ap	straight line	not defined?	11	(relative location for a list of human influence elements)	n/ap	
Point	Mid-wet-channel points	n/ap	point	n/ap	4	Number of shaded squares	canopy point	Pct Shade&Canopy cover (4 dir);

n/ap = not applicable

Data field names (column headers) are color coded for descriptors of the FlexiGrid Component (yellow) and the Results (light blue).

Figure 5: FlexiGrid components and associated characteristics, component aggregates, and result endpoints per the Interim 2004 Protocol.

Project ID	Team Name	Station Visit ID	Permanent Station ID	FlexiGrid Origin ID	FlexiGrid Component ID	FlexiGrid Components Aggregate	Characteristic [Endpoint]	Unit	Result
SFyr4	JY crew	JY14.2	<b>PG50</b>	FG14.2	FG14.2-R1	Riparian Plots	Average Big tree Canopy LB+RB	%	34
SFyr4	JY crew	JY14.2	<b>PG50</b>	FG14.2	FG14.2-R1	Riparian Plots	Average Small tree Canopy LB+RB	%	32
SFyr4	SM crew	SM11.5	<b>AM10</b>	FG11.5	FG11.5-R1	Habitat Plots	Average Overhanging vegetation cover	%	8
SFyr4	JY crew	JY15.2	<b>ES50</b>	FG15.2	FG15.2-R1	Mid-wet-channel points	Average Shade&Canopy cover (4 dir)	%	90
SFyr4	JY crew	JY15.2	<b>ES50</b>	FG15.2	FG15.2-R1	Slope sections	Average slope	%	6
SFyr4	SM crew	SM11.5	<b>AM10</b>	FG11.5	FG11.5-R1	Transect-Points	Average water depth	<b>cm</b>	21.7
SFyr4	SM crew	SM11.5	<b>AM10</b>	FG11.5	FG11.5-R1	Verticals	Flow Discharge (Q)	<b>cfs</b>	4.6
SFyr4	SM crew	SM11.5	<b>AM10</b>	FG11.5	FG11.5-R1	BMI Plots	Avg. Gravel	%	<b>51</b>
SFyr4	SM crew	SM11.5	<b>AM10</b>	FG11.5	FG11.5-R1	Transect-Points	Average Percent Gravel	%	<b>37</b>
SFyr4	JY crew	JY14.2	<b>PG50</b>	FG14.2	FG14.2-R1		percent Riffles	%	39
SFyr4	SM crew	SM11.5	<b>AM10</b>	FG11.5	FG11.5-R1		Epifaunal Substrate/Available Cover	score of 20	13
SFyr4	JY crew	JY14.2	<b>PG50</b>	FG14.2	FG14.2-R1		Sediment Deposition	score of 20	10

Data field names are color coded for descriptors of the Station-Visit (pink), FlexiGrid (beige), FlexiGrid Component (yellow), and Results (light blue).

Common attributes of these FlexiGrids (not shown) are: FG type = "transect&points", FG Backbone = "thalweg", FG direction = "upstream", FG distance units = "m", FG Component Type = "Stream Fragment", FG Component Name in Protocol = "Reach", Protocol Name = "Interim 2004"

Figure 6: Selected Result Endpoints for the physical habitat assessments conducted per the Interim 2004 protocol.

Once the time spent on development of the templates has been invested, data entry took 15-20 minutes per assessment. Data preparation took about 2 minutes per assessment (unless an entry error was found). Data processing using the Endpoint template, including compilation of the database table and the Report table, took another 2 minutes per assessment. Future application of the FlexiGrid spreadsheet will benefit from the existing Data Entry template and Endpoint Calculation template. For example, it is estimated that tailoring the existing Templates to a new EMAP-style protocol would require no more than 6-8 hours

## **LESSONS LEARNED**

The experience with the FlexiGrid concept and its embodiment in the FlexiGrid spreadsheet is still rather limited, although it is building up rapidly. Based on this experience, the perceived advantages and disadvantages include the following:

### **Advantages**

- The FlexiGrid spreadsheet can provide the ultimate level of detail in terms of the exact location of each spatial element within the sampling frame – or any combination of details as needed.
- Data entry and processing (i.e., data verification, validation and calculation of Result Endpoints) can be performed using minimal Excel skills (cell entry, find&replace, copy, paste, and data sort.) Specific instructions for this streamlined procedure can be prepared easily.
- The system does not require IT support
- The streamlined processing facilitates rapid turnaround
- The FlexiGrid Data Entry template can be used in the field using a small-screen personal digital assistant (PDA)
- This is a low-tech, transparent system
- The file structure makes it extremely easy to create a batch upload file
- Excel supports easy XML interface

### **Disadvantages**

- Template development and tailoring require focused thinking and advanced Excel skills (formulae, cell references, drop-down menus, etc.)
- The Excel Data Entry Template cannot support as many ‘fool-proof’ safeguards against erroneous entries as some other database systems
- The data management platform is harder to protect (than other database platforms), therefore it is more vulnerable to loss of referential integrity and to file corruption

In balance, derivatives of the FlexiGrid spreadsheet seem to be ideal for groups and organizations that have limited infrastructure and no funding for IT support. The system facilitates streamlined generation of Result Endpoints for the group’s physical habitat assessments, while maintaining the option of easily sharing their data with others.

## **SUMMARY**

The FlexiGrid concept supports a data structure that can achieve the following:

- Connect each monitoring Result to the exact spatial component it was measured in (or to an aggregate thereof);
- Place every spatial component on a 'virtual map' as an independent entity while preserving the internal hierarchy and its order in a series; enable reconstruction of the Frame from the virtual map that is stored in database cells; and allow information transfer into a GIS system;
- Integrate physical habitat (PHAB) results and descriptors with results and descriptors from any other area of inquiry (e.g., chemistry, toxicity, bioassessment, etc.);
- Enable reporting of any type of Result and Endpoint, generated for any Characteristic in any spatial component and at any scale, on the 'same page'; and
- Accommodate data generated by PHAB protocols used by different Agencies and Programs (e.g., NAWQA, EMAP, EPA RBP, DFG Fisheries habitat, etc.).

## **GLOSSARY FOR THIS DOCUMENT**

**Backbone** - A neutral term for the channel property used to measure curvilinear distances within a FlexiGrid.

**Crossline** - A neutral term to describe a line that crosses the stream channel, usually at a right angle to a specific linear entity (e.g., left bank, Thalweg, etc.).

**FlexiGrid** - A neutral term for a spatial multi-dimensional sampling frame with variable angles which contains a variable number of components and is laid out by one Team in one Station Visit.

**FlexiGrid Components** - Building blocks of a FlexiGrid (points, lines, polygons, 3D shapes), or other entities included in the FlexiGrid 'map', where monitoring activities occur.

**FlexiGrid Origin** - The most downstream point on the backbone of a FlexiGrid; the 'anchor' point for all FlexiGrid Components

**Monitoring Activity (STORET)** - A noun that defines the product of an [evaluative, measured, or collected] monitoring action. The product can be a categorical observation, an estimate, a measurement, a count, or a sample in a container.

**Monument (fixture)** - A man-made object created to mark a specific spot permanently and has been constructed, installed, or painted at a permanent location, usually outside the wetted channel.

**Parallel** - A neutral term for a line that is laid out in the water parallel to the bank and at a known distance from it

Plot - A two-dimensional polygon in which certain monitoring activities occur, e.g., sediment or biota samples are collected, or evaluations are done.

Reach (stream) - [A generic definition] A protocol-specific term that describes a length of stream at the 'sampling site' scale, where all monitoring activities of one Station Visit occur. A Reach may have a fixed length, or its length can be determined as a certain multiplier of average width, or determined as an aggregate of certain flow habitat units.

Result - The outcome of a measurement or an observation. Results can usually be expressed in numbers, alphanumeric codes, words (“verbal categories”), or ranges of numbers (“numeric range categories”).

Sampling Frame (spatial) - A spatial entity in which various monitoring activities occur. The Frame can be virtual or clearly delineated, it can have more than one dimension, and it can have any number of components.

Segment (stream) - [A generic definition] A protocol-specific term that describes a length of stream. Example from one protocol: a length of stream at the stream-network scale, defined as the piece between two confluences of major tributaries.

Station Visit - A station occupation event in which one Team (field crew) performs one or several Monitoring Activities, usually within one FlexiGrid.

Stream Fragment - A neutral term to describe a length of stream channel as defined by its point of origin, curvilinear length, and direction (e.g., upstream).

Vertical - A neutral term for a line that is laid out vertically from the water surface to the bottom of the channel. Verticals are often laid along a crossline, but a Vertical can be laid anywhere in the channel.

## **ACKNOWLEDGEMENTS**

The Author would like to thank Faith Fitzpatrick, Peter Ruhl, and Dan Sullivan for the engaging discussions which led to the development and honing of the FlexiGrid concept. Thanks are also extended to Matt Cover for his faith in, and support of, the FlexiGrid Data Entry template and the Endpoint Calculation template.

## **REFERENCES**

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Strubling. (1999) *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish*, Second Edition: EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

- Fitzpatrick, F.A., Waite, I.R., D'Arconte P.J., Meador, M.R., Maupin, M.A., and M.E. Gurtz (1998) *Revised Methods for Characterizing Stream Habitat in the National Water-Quality Assessment Program*. U.S. GEOLOGICAL SURVEY, Water-Resources Investigations Report 98-4052, Raleigh, North Carolina
- Harrington, J.M. (1999) *California stream bioassessment procedures (CSBP)*. California Department of Fish and Game, Water Pollution Control Laboratory. Rancho Cordova, CA.
- Kaufmann, P.R., P. Levine, E.G. Robison, C. Seeliger, and D.V. Peck. (1999). *Quantifying Physical Habitat in Wadeable Streams*. EPA/620/R-99/003. U.S. Environmental Protection Agency, Washington, D.C.
- Ode, P.R. (2007). *Standard operating procedures for collecting macroinvertebrate samples and associated physical and chemical data for ambient bioassessments in California*. California State Water Resources Control Board Surface Water Ambient Monitoring Program (SWAMP) Bioassessment SOP 001.
- Peck, D.V., A.T. Herlihy, B.H. Hill, R.M. Hughes, P.R. Kaufmann, D.J. Klemm, J.M. Lazorchak, F.H. McCormick, S.A. Peterson, P.L. Ringold, T. Magee, and M. Cappaert. (2006) *Environmental Monitoring and Assessment Program-Surface Waters Western Pilot Study: Field Operations Manual for Wadeable Streams*. EPA/620/R-06/003. U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C.
- Plafkin J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. (1989) *Rapid bioassessment protocols for use in streams and rivers: Benthic macroinvertebrates and fish*. U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Washington, D.C. EPA 440-4-89-001.
- Somerville, D.E. and B.A. Pruitt. (2004) *Physical Stream Assessment: A Review of Selected Protocols for Use in the Clean Water Act Section 404 Program*. September 2004, Prepared for the U.S. Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Wetlands Division (Order No. 3W-0503-NATX). Washington, D.C. 213 pp.