Hydromodification Monitoring – Characterization of Bedload Movement for Evaluation of the 2-Year Runoff Event

WB Academy/College of Stormwater
4th Hydromodification Seminar & Workshop – Sediment Management and Modeling

November 21, 2012

David Renfrew, Weston Solutions

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Agenda

- San Diego Hydromodification Monitoring Requirements Overview
- Development of the Monitoring Program
- Monitoring Results & Recommendations
- Flow Prediction Tools (Modeling for Monitoring)

Hydromodification Management

MS4 Permit Order R9-2007-0001 Section D.1.g.

"...manage increases in runoff discharge rates and durations from all Priority Development Projects, where such increased rates and durations are likely to cause increased erosion of channel bed and banks, sediment pollutant generation, or other impacts to beneficial uses and stream habitat due to increased erosive force."

Permit Required the development of a Regional Hydromodification Plan

HMP Assessment Questions

- **Do field observations confirm that the HMP appropriately defines the flow rate (%Q_2) that initiates movement of channel bed or bank materials?**
  - ***"Since most of the sediment transport modeling prepared as part of the HMP development relied on laboratory flume data, it is important to supplement the sediment transport data set with field observations…"***
- **Are BMPs adequately meeting flow duration design criteria outlined in the HMP?**
- **What is the effect of development on downstream cross section incision and widening?**

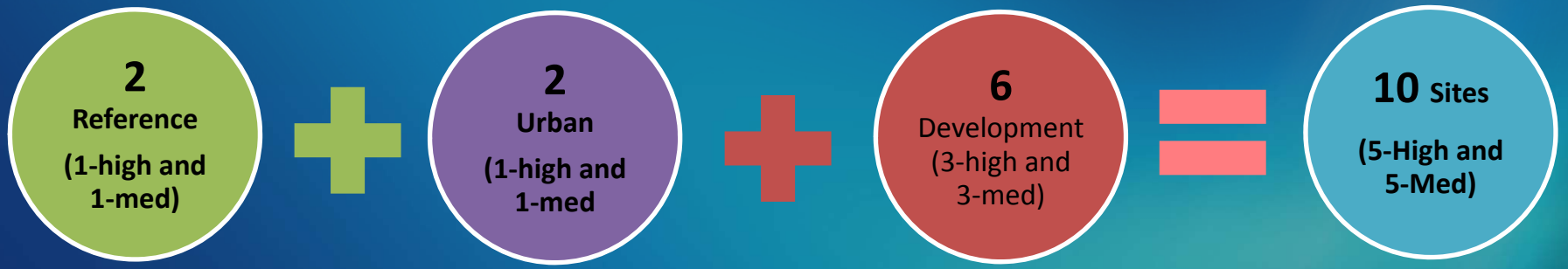
HMP Page 8-1

San Diego HMP Susceptibility Ratings

- **High** Susceptibility to erosion
  - Low Flow Threshold **$0.1Q_2$** (default)
- **Medium** Susceptibility to erosion
  - Low Flow Threshold **$0.3Q_2$**
- **Low** Susceptibility to erosion
  - Low Flow Threshold **$0.5Q_2$**

HMP Monitoring Requirements

- **10 Sites Representing High and Medium Susceptibility Channels**
  - **2 Reference**
  - **2 Urban**
  - **6 Development**
    - **Downstream Pre/Post Construction**



HMP Page 8-5

HMP Monitoring Requirements

- **Administrative**
  - **QAPP**
  - **Rain gage installation**
  - **Gages & BMP station inspections (2012-16)**
  - **Monitoring and Annual data analysis (2012-16)**
  - **Reevaluation of Monitoring Plan (2013)**
  - **Final Report (2016)**

HMP Page 8-5

HMP Monitoring Field Requirements

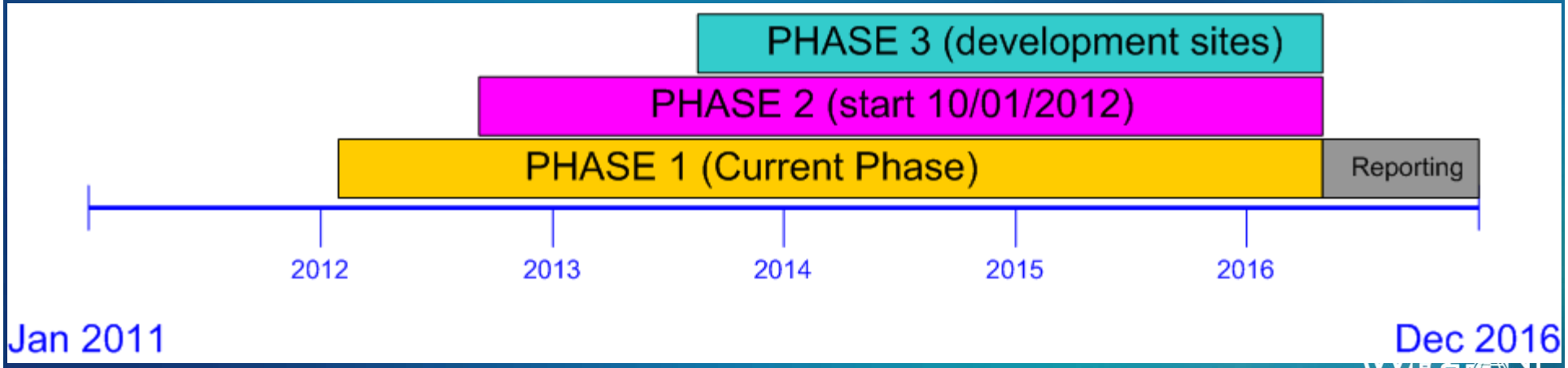
- **Channel Assessments**
  - Initial Geomorphic Assessment
  - Baseline Surveys
  - Annual Geomorphic Assessments
  - Final year Surveys
- **Sediment Transport Analysis**
  - Flow & sediment monitoring installation
  - Continuous flow, SSC, and turbidity data
- **Flow Duration Analysis**
  - BMP outflow monitoring installation
  - Continuous post BMP outflow data

HMP Page 8-6

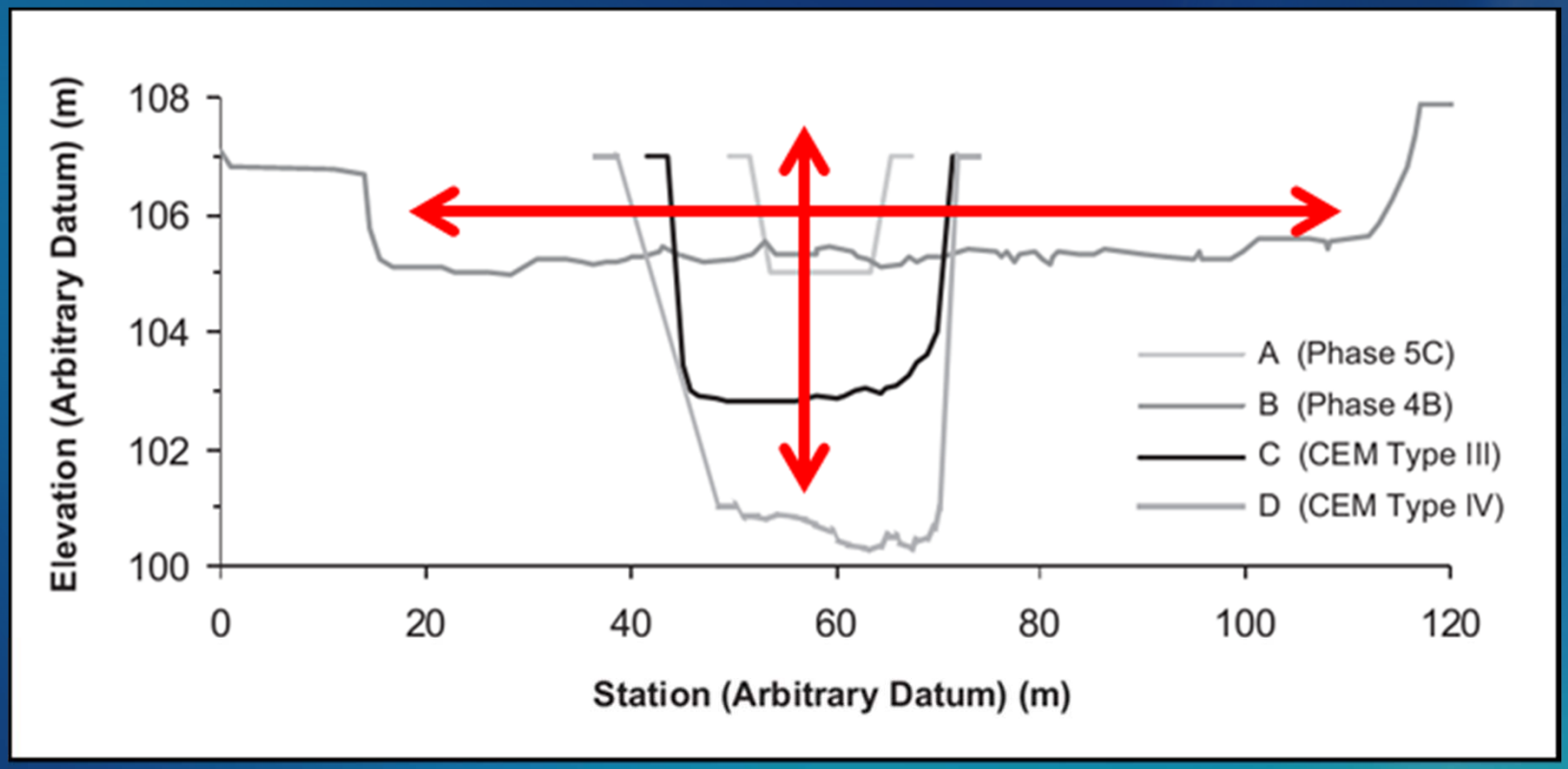
3 Project Phases

Each Phase adds on to the previous phase...

- **Phase 1 (FY11-12)**
- **Phase 2 (FY12-13 thru FY16)**
- **Phase 3 (as development occurs)**



Evaluation of Cross Sections a Key Component



(Hawley et al. 2012)

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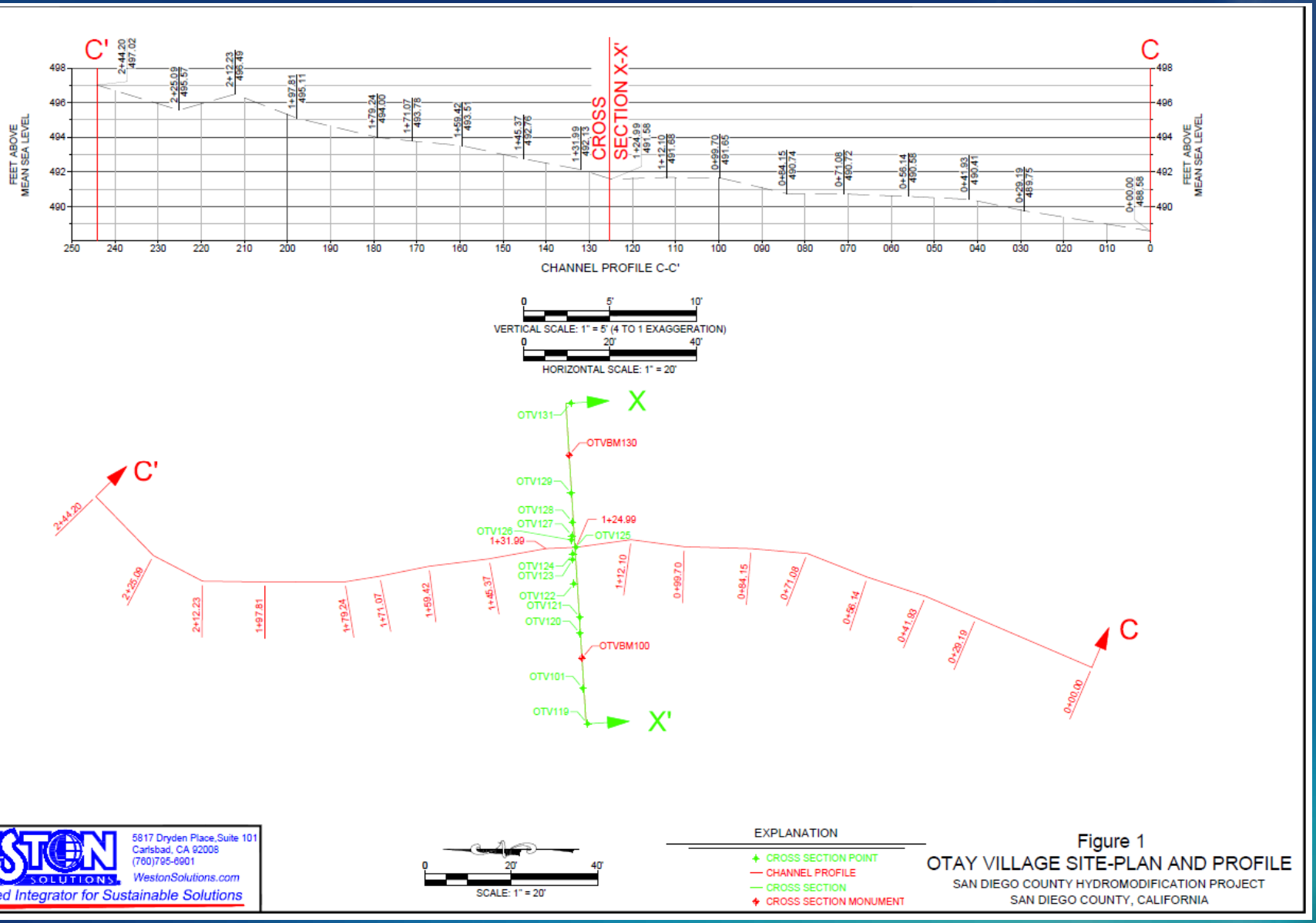

Figure 1
OTAY VILLAGE SITE-PLAN AND PROFILE
SAN DIEGO COUNTY HYDROMODIFICATION PROJECT
SAN DIEGO COUNTY, CALIFORNIA

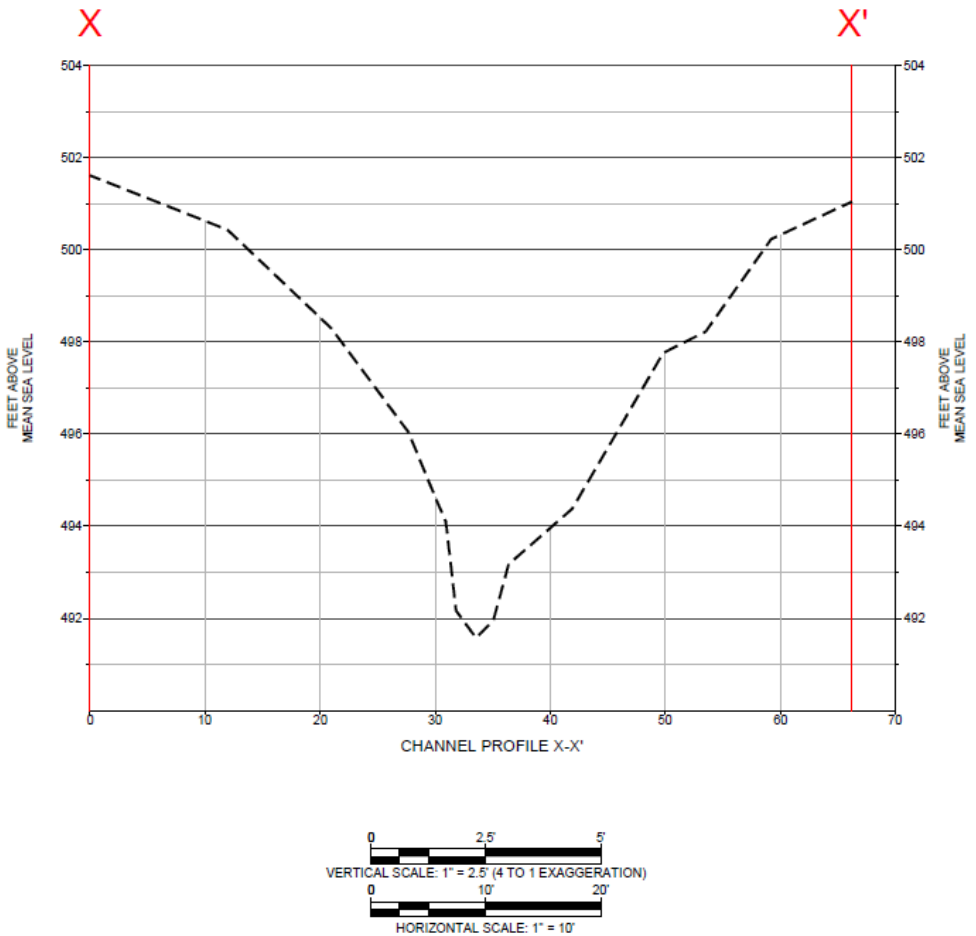

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Figure 2
OTAY VILLAGE SITE-CROSS SECTION
SAN DIEGO COUNTY HYDROMODIFICATION PROJECT
SAN DIEGO COUNTY, CALIFORNIA

Method Development

- **Phase I monitoring was used to develop a standardized methodology for Phase II and Phase III efforts.**
- **Monitoring activities were developed to answer the following question:**

"Do field observations confirm that the HMP appropriately defines the flow rate (expressed as a function of the 2-year runoff event) that initiates movement of channel bed or bank materials?"

Method Goals

Sediment Transport Monitoring

- **Bedload Rating Curves**
  - Develop a relationship between bedload transport rate and stream flow rate
    - Bedload Transport Measurements
    - Continuous Flow Measurements

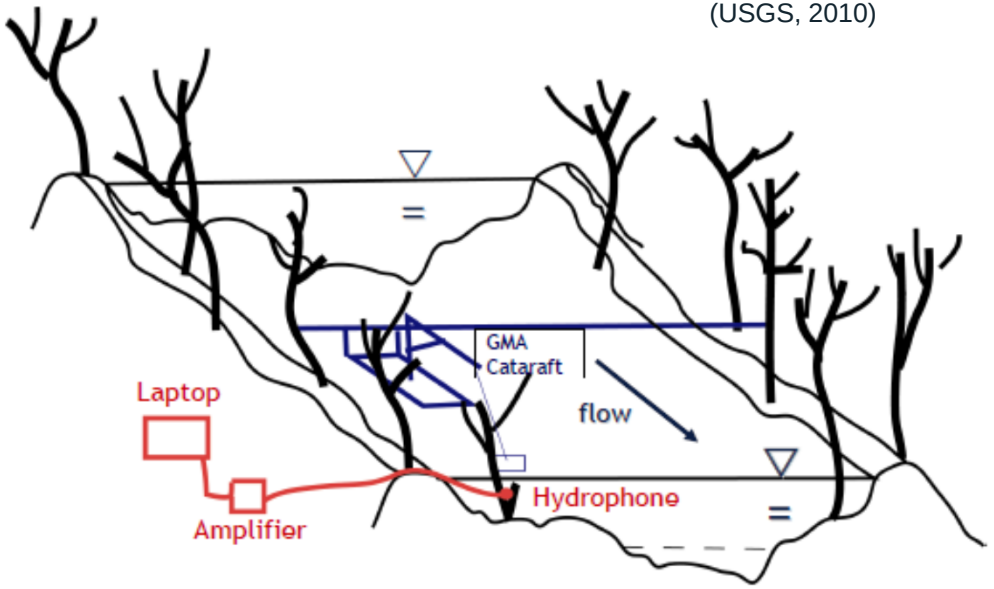
- **Suspended Load Rating Curves**
  - Develop relationship between SSC and turbidity
    - Collect paired Turbidity and SSC grab samples
    - Continuous field measurements of turbidity at high susceptibility sites

Phase I
Bedload Method Development

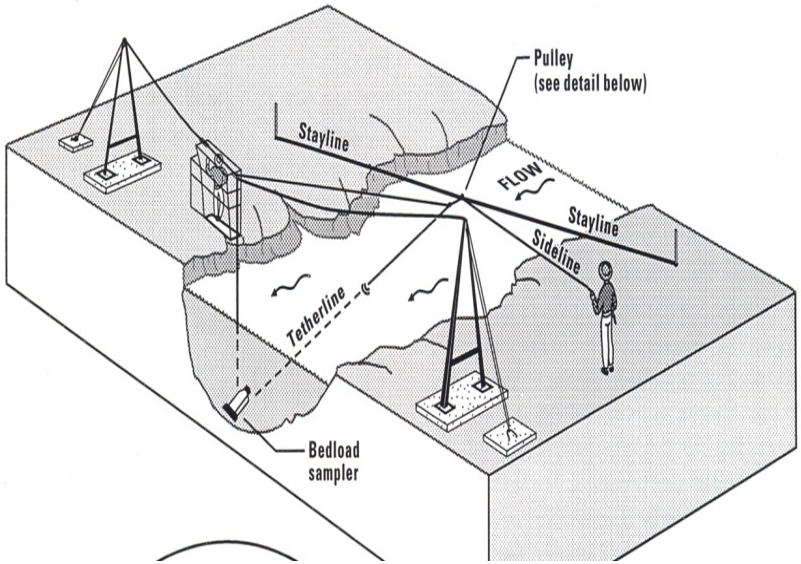
- **Reviewed methods from acoustic monitoring to elaborate trapeze setups.**
- **Through comprehensive literature review and discussions with USGS the handheld bedload sampler was selected.**

(USGS, 2010)

(USGS, 2010)



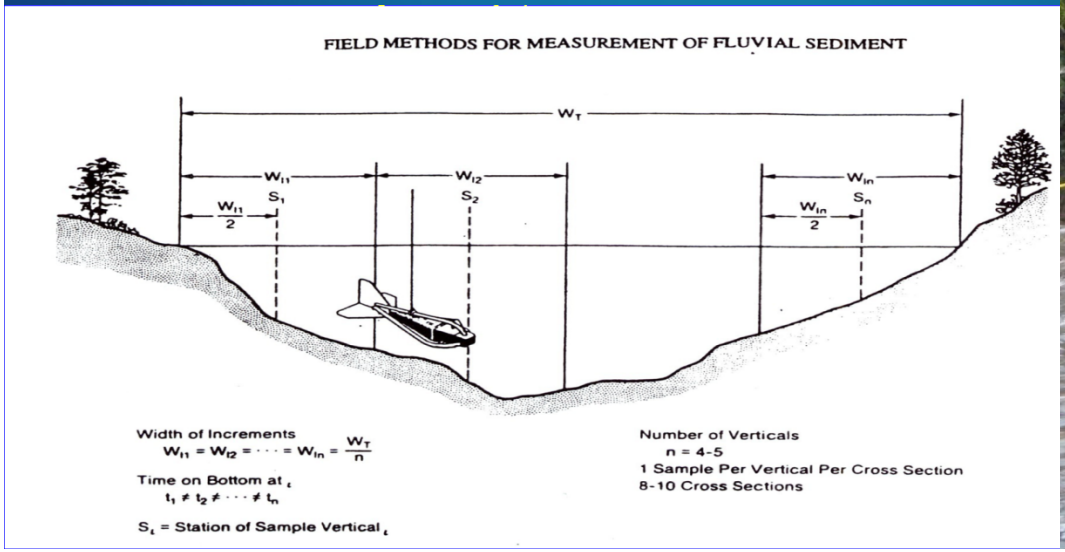
(USGS, 2010)



The Federal Interagency Sedimentation Project (FISP) approved US BLH-84 Handheld Bedload Sampler

Bedload Transport

- Cross-sectional bedload samples collected at different stages over the course of the storm to develop a relationship between flow rate and bedload transport rate.
- Focused at the beginning and end of flow.
- Modified multiple equal-width-increment method similar to a stream flow rating.
- Sampler is placed on the channel bottom for specified time (30 – 60 sec)

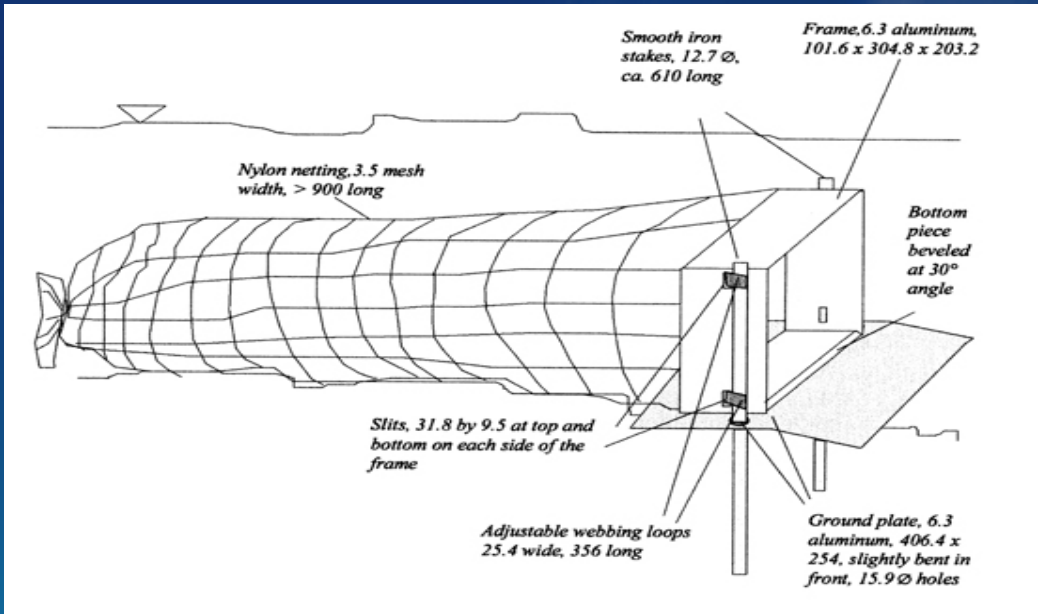


Bedload Samples

- Processing of the sediment samples involves removal of organic debris, drying, and weighing.

USFS PORTABLE BEDLOAD TRAP

Developed for sampling initiation of gravel motion and coarse bedload transport rates in wadable gravel and cobble bed streams.



For sampling, the trap is fastened onto ground plates anchored into the stream bottom and recovered at the end of the event.

USFS Portable Bedload Trap
Qualitative Bedload Movement



- A large amount of organic leaf debris comprised more than 95% of the material captured within the first 15 minutes of sampling.
- The debris influenced the flow dynamics needed to capture bedload movement at higher flow rates.
- The portable bedload trap may be appropriate for perennial streams where organic debris has not accumulated in the channel prior to the storm event

Painted Grid
Qualitative Bedload Movement

- 2.0 ft^2 plots of the bedload material were spray painted with non-toxic orange paint to qualitatively measure bedload movement.

- Following the event, it was observed that bedload material up to 2” in diameter moved downstream during this event up to 4 ft.

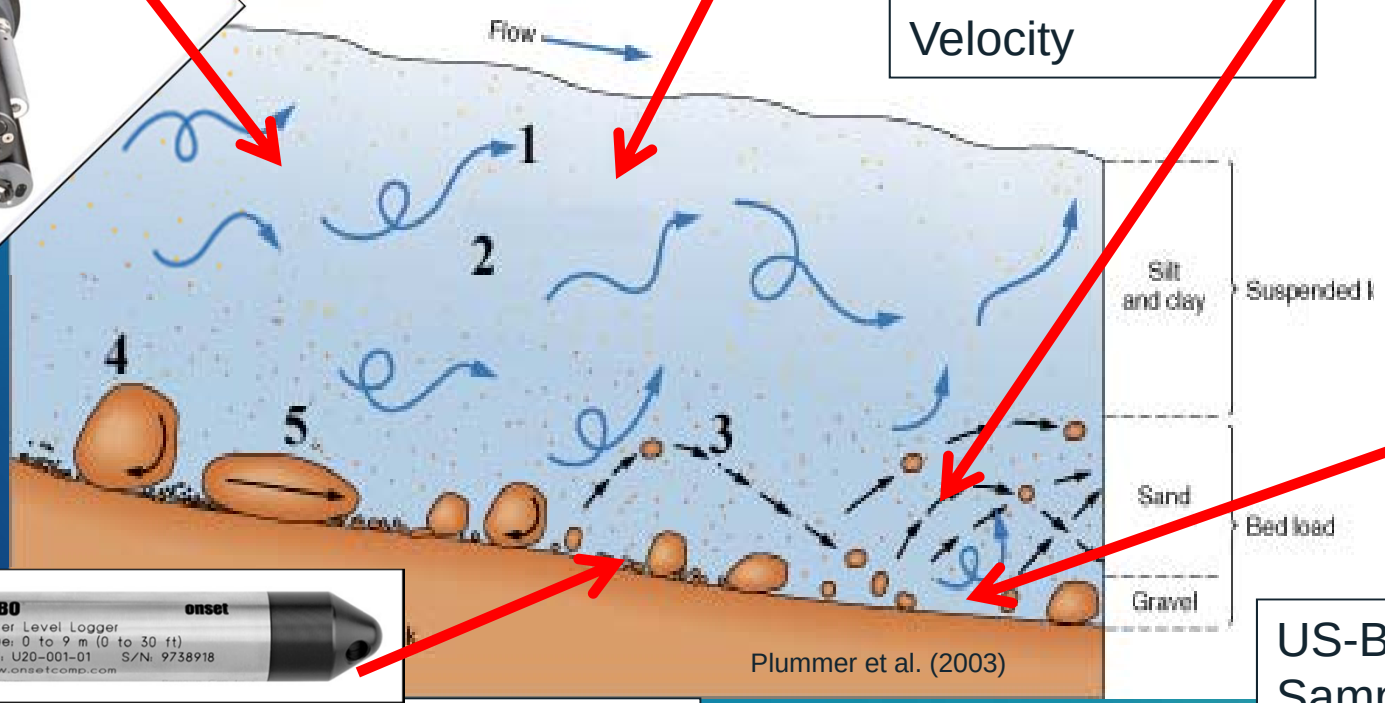
Method Summary

Continuous Turbidity at Sand Sites with YSI Data Sonde

8-12 Samples over the storm hydrograph

SSC and Turbidity Grabs

Sontek FlowTracker for Velocity



Hobo Continuous Level Logger

US-BLH-84 Sampler for Bedload

Method Summary

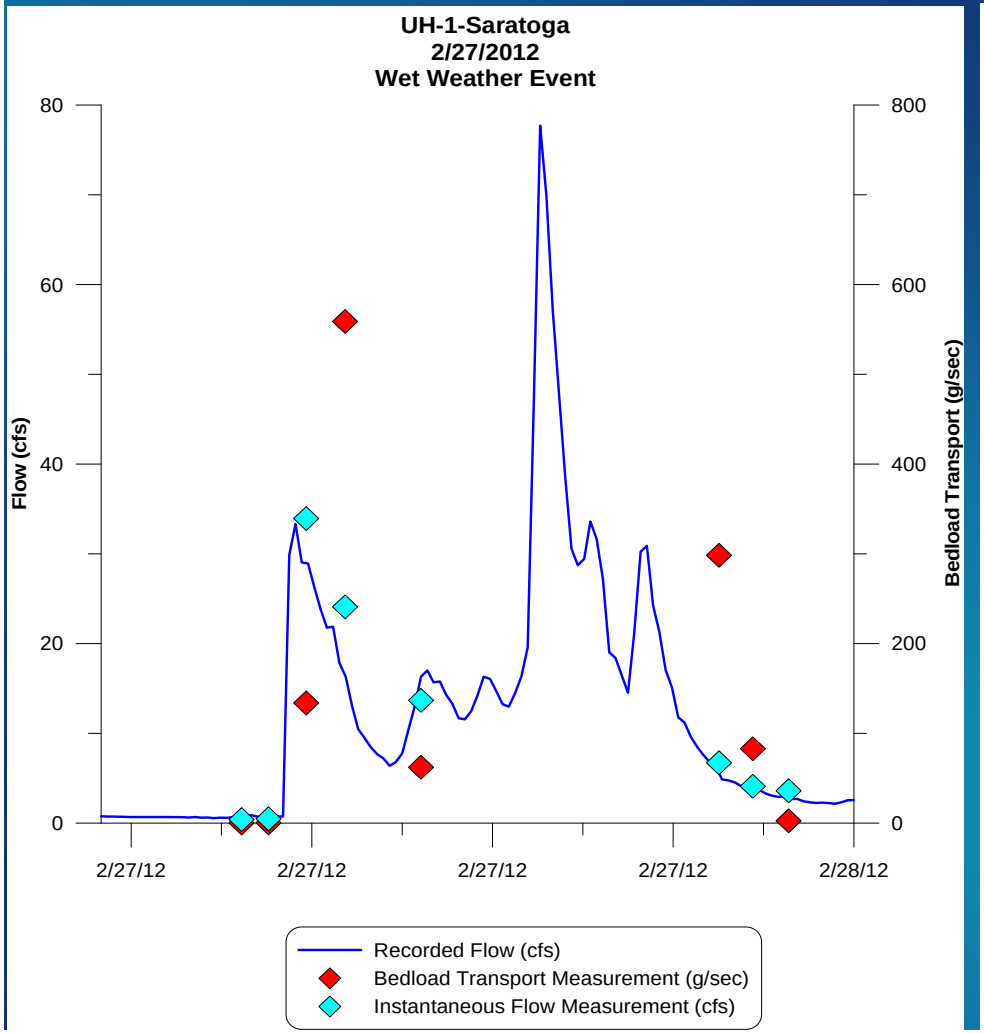
- The US-BLH-84 handheld bedload sampler is a useful tool to conduct bedload transport ratings in wet weather flows
- Safety limitations at urban sites
- Qualitative methods an alternative option
- Standardized sediment transport methods incorporated into draft QAPP
  - Event Based Sampling
    - Turbidity and SSC Grab Samples
    - Stream Ratings with Sontek/Marsh McBirney
    - Bedload Ratings with USGS US-BLH-84 handheld bedload sampler
  - Continuous Monitoring
    - HOBO Level Loggers
    - YSI Data Sondes with Turbidity Probes (Sand Bed Sites)
- Phase I highlighted need for predicting when sites would flow.

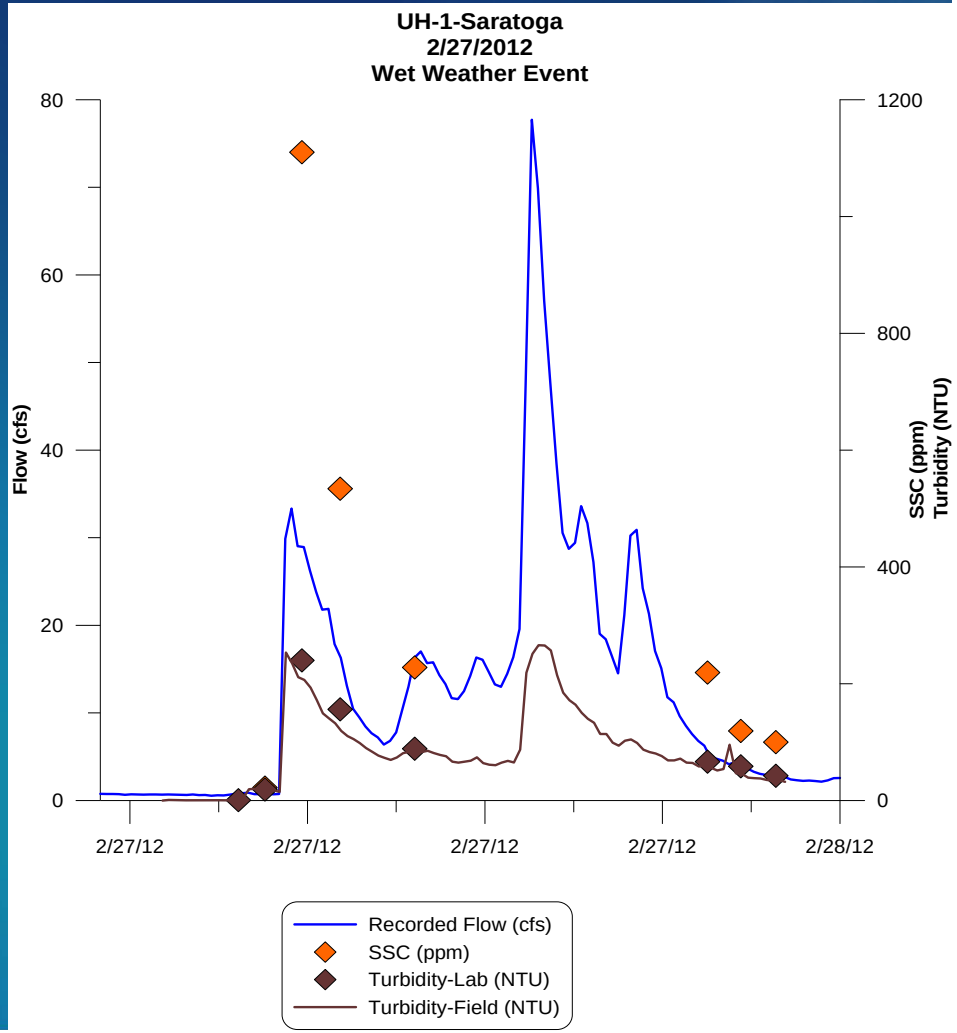
Monitoring and Results

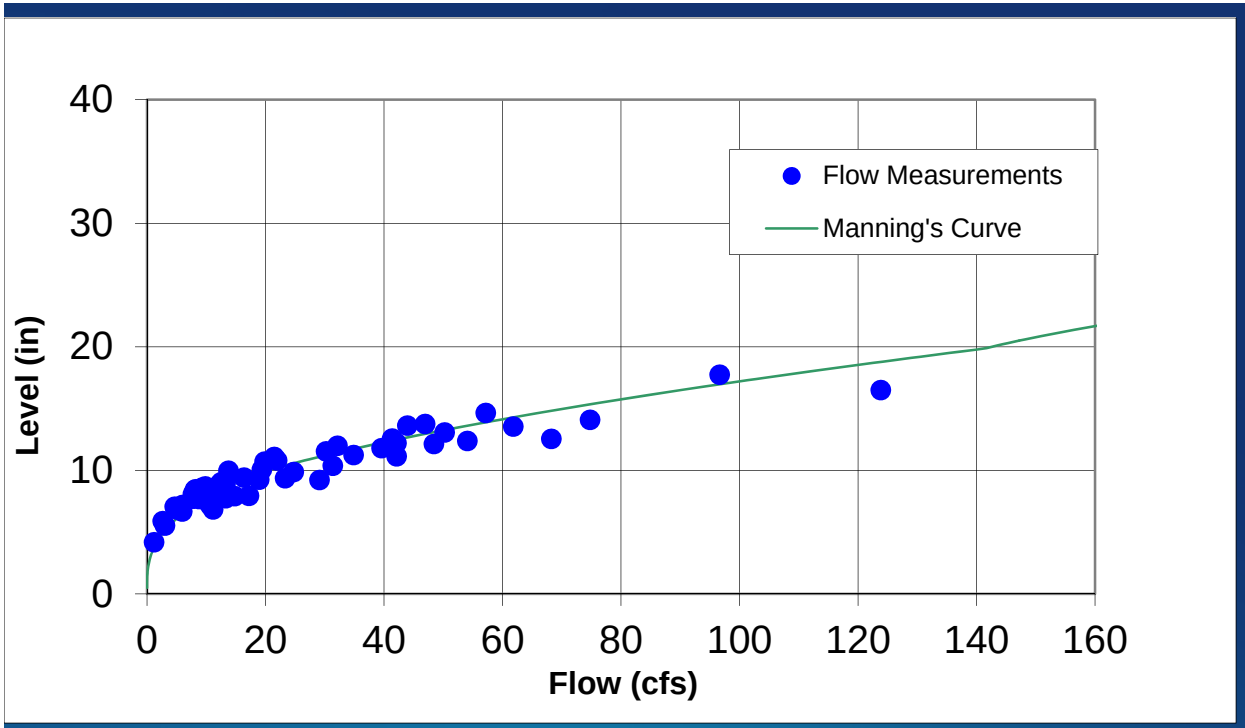
Urban High Susceptibility Site

- Sand Bed Channel

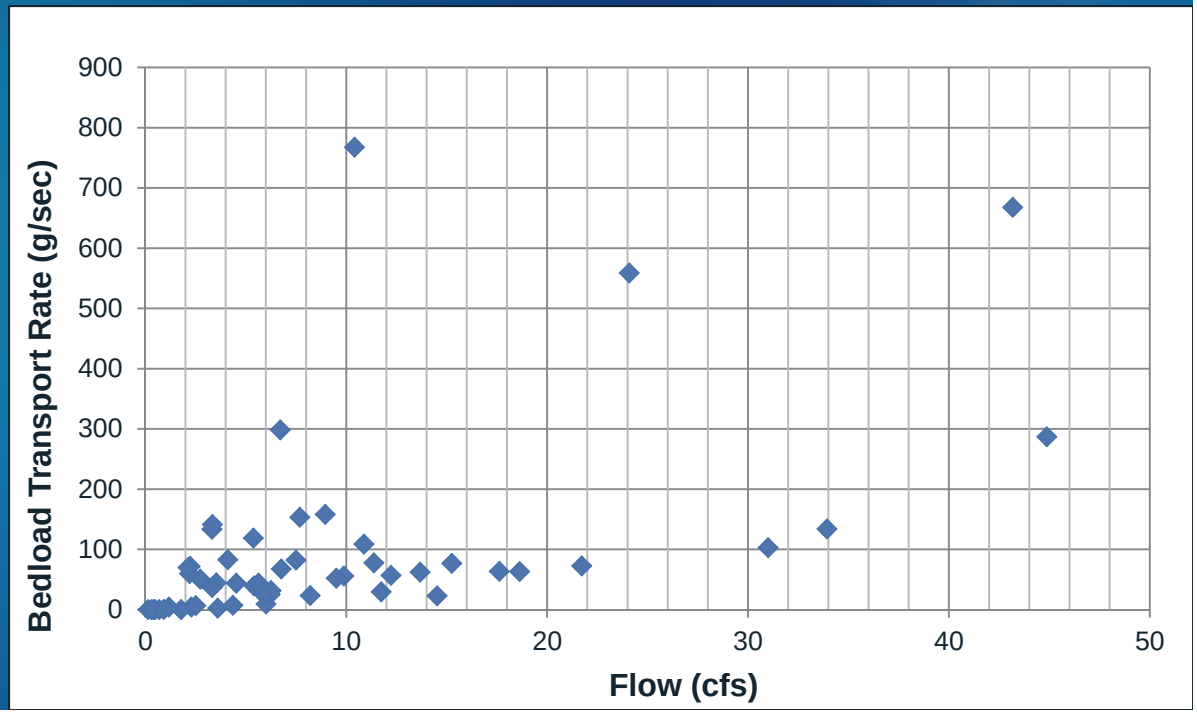
Urban High Susceptibility Site





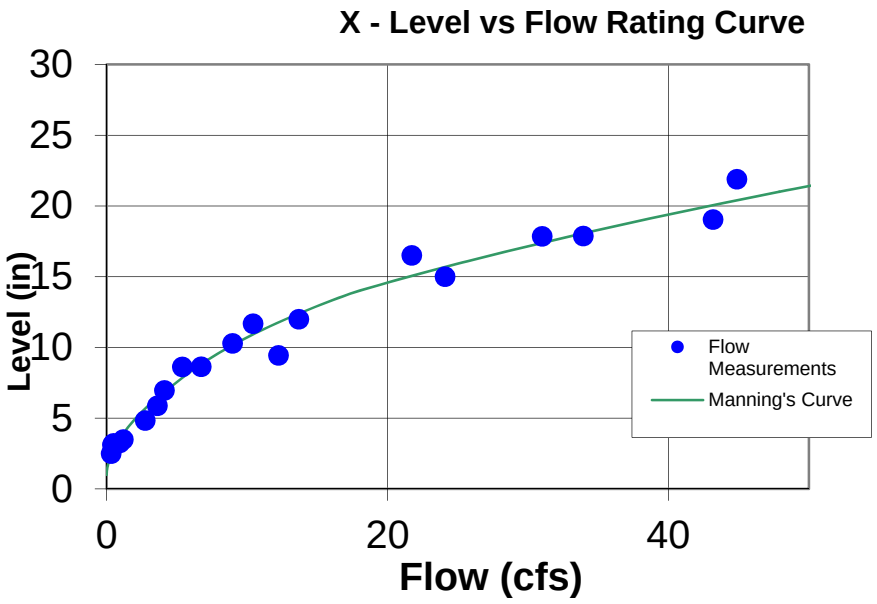


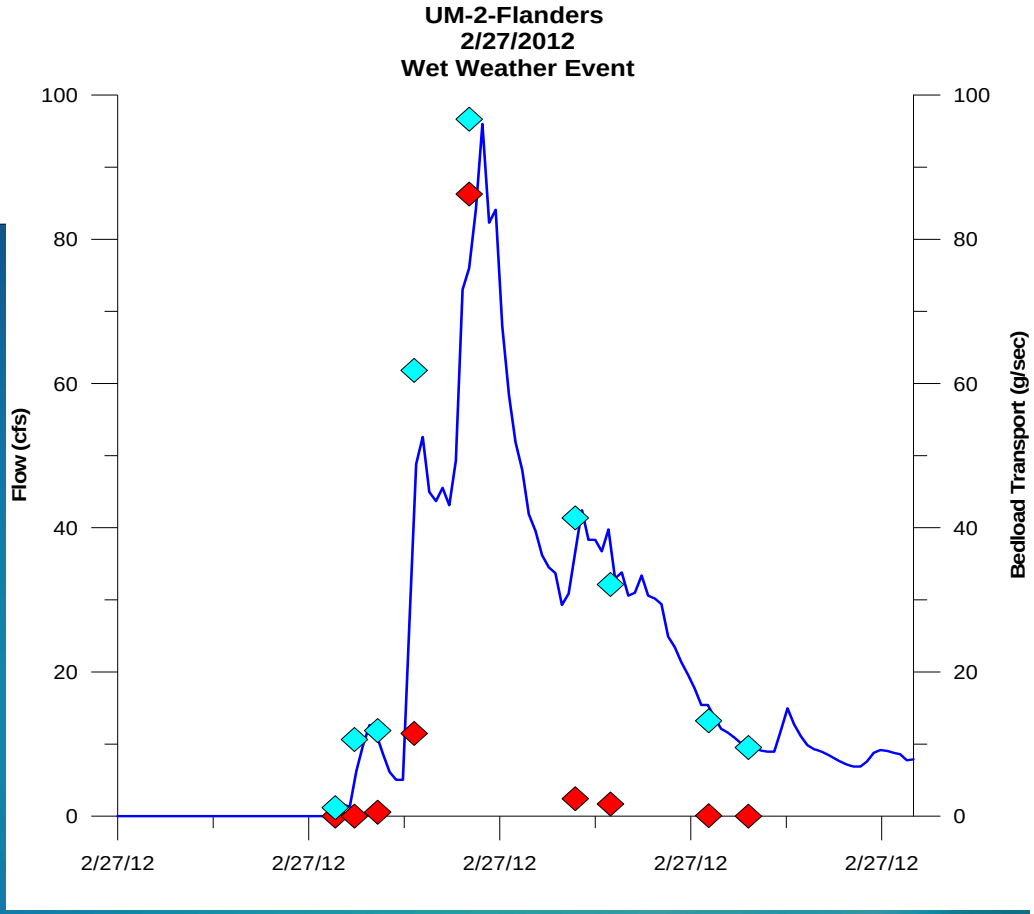
Urban High Susceptibility Site

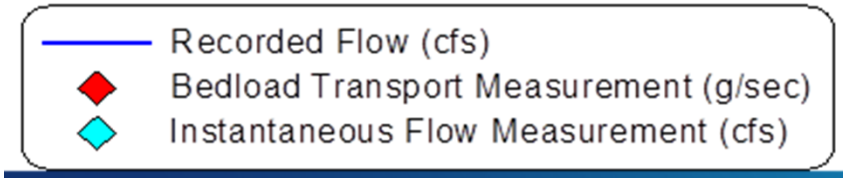


Urban Medium Susceptibility Site

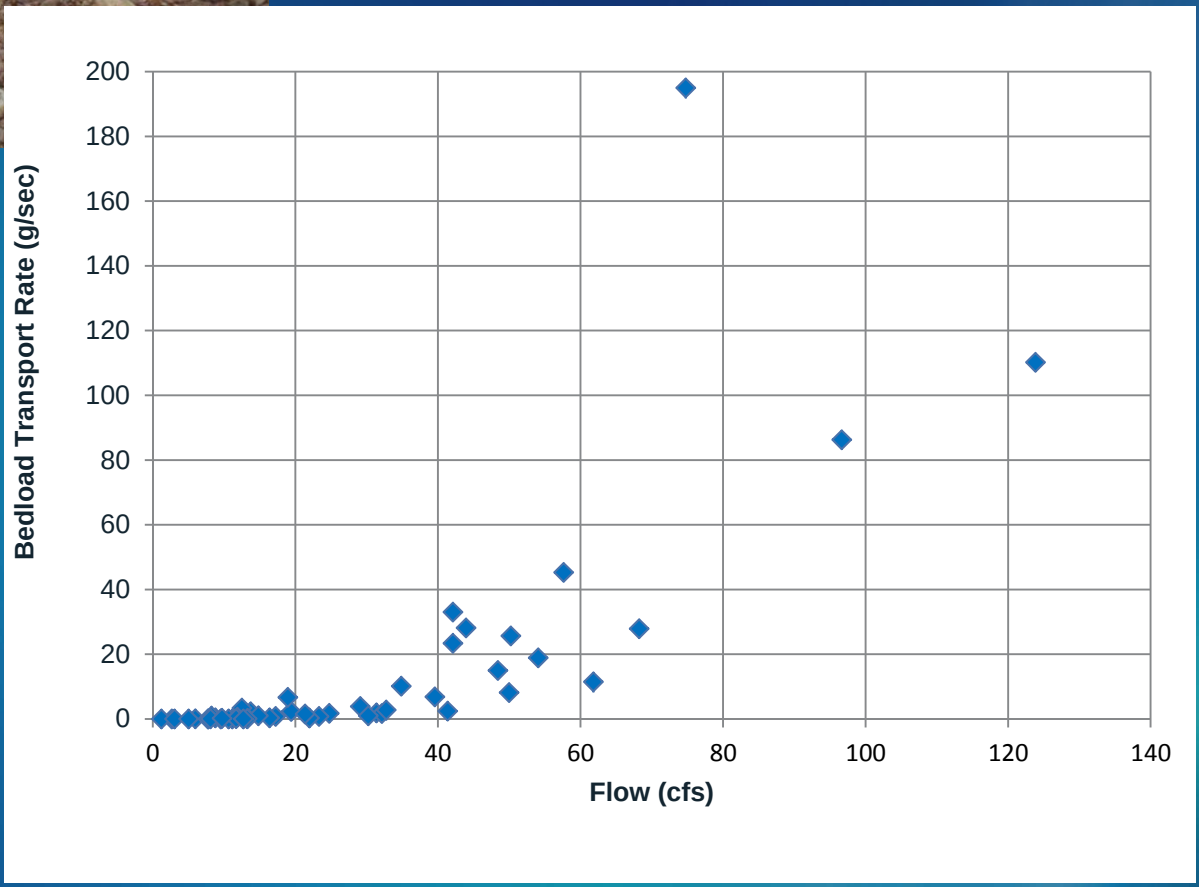
Urban Medium Susceptibility Site



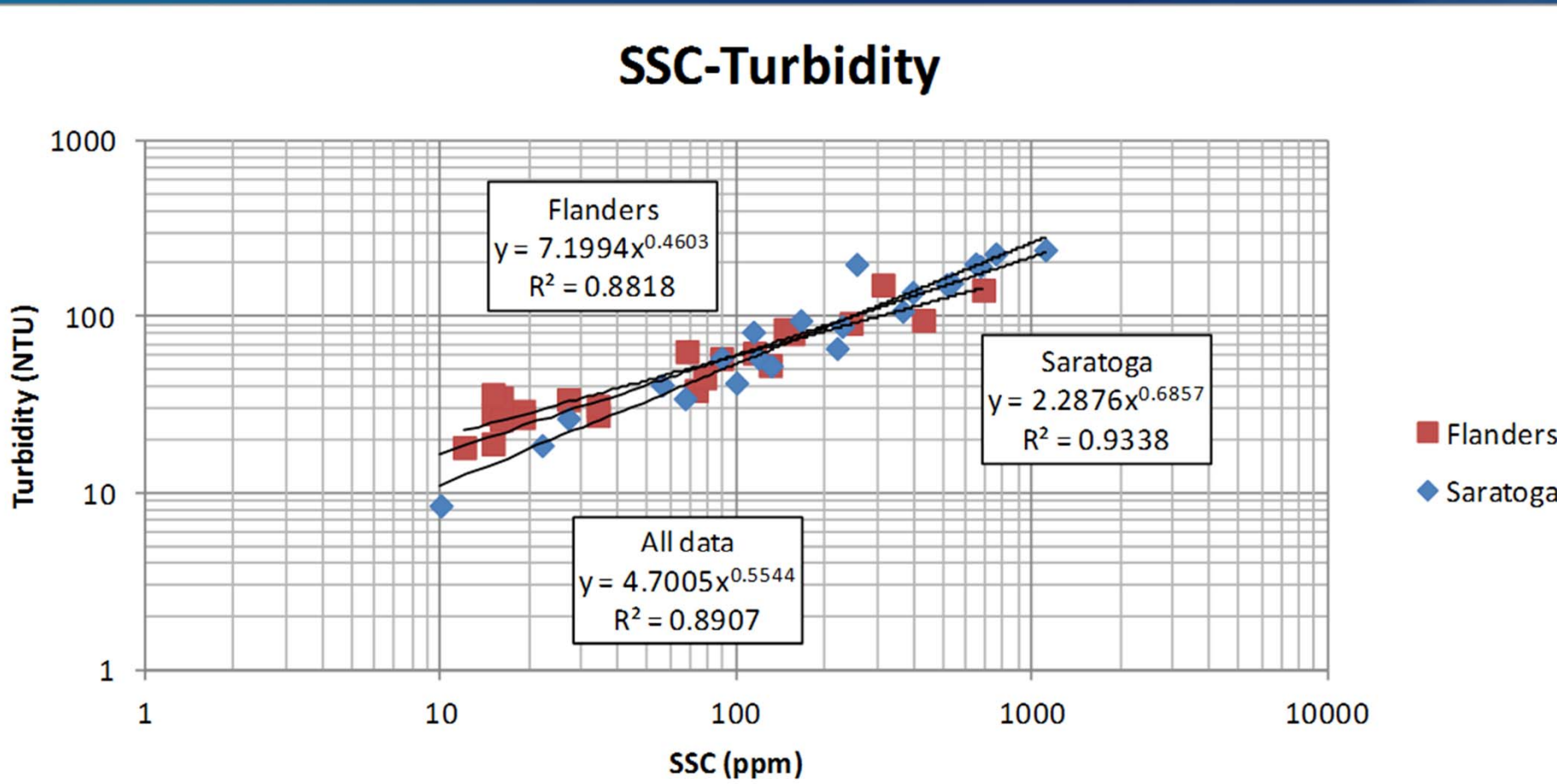




Urban Medium Susceptibility Site



SSC and Turbidity Correlations



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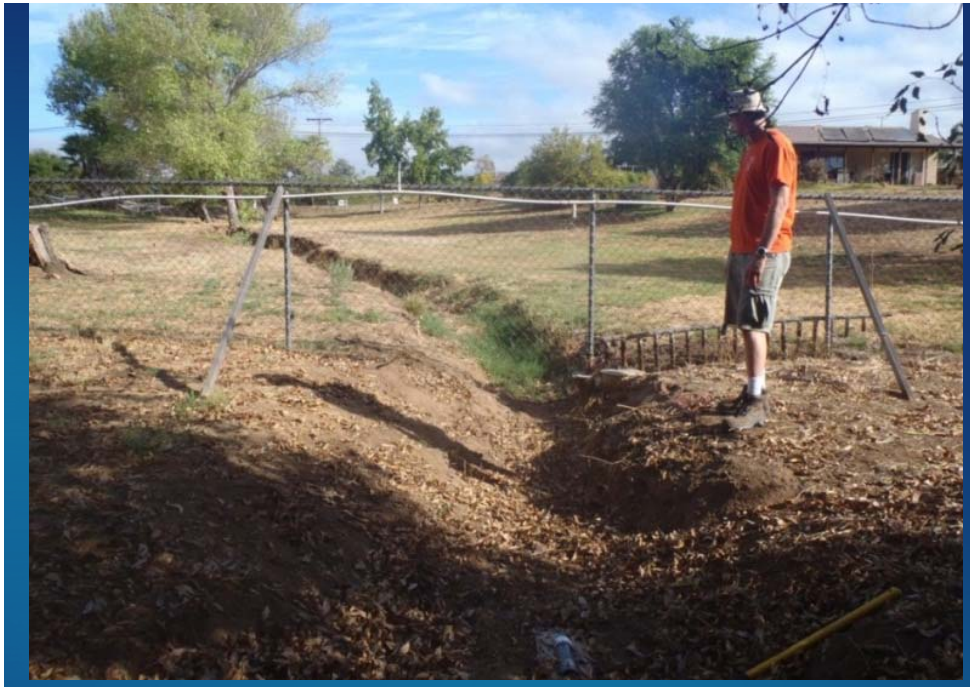
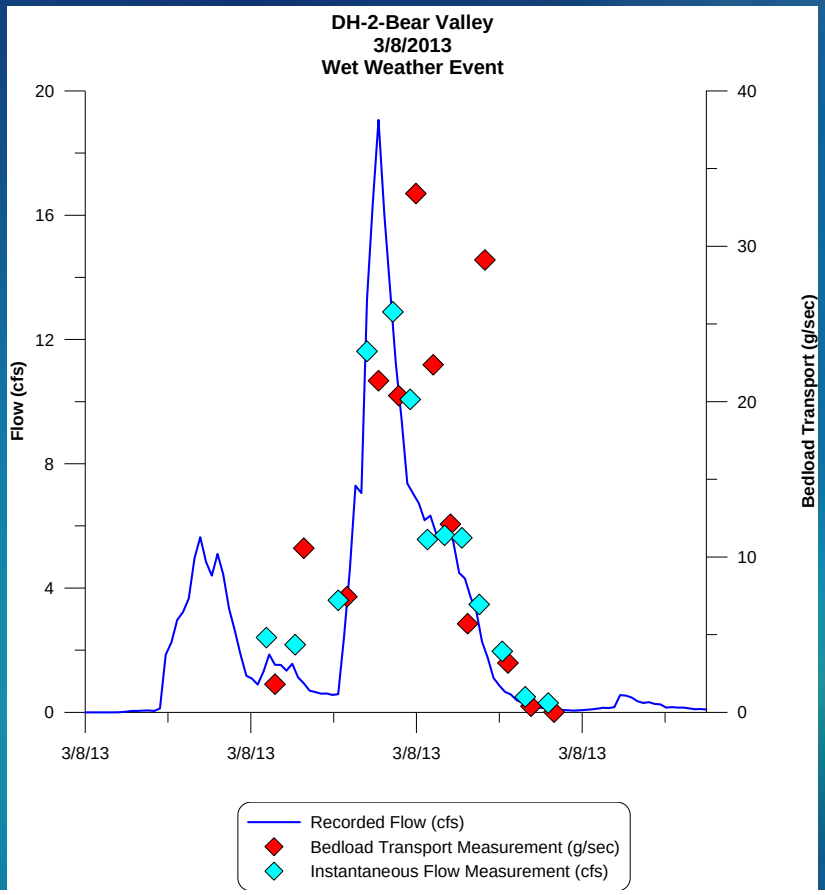


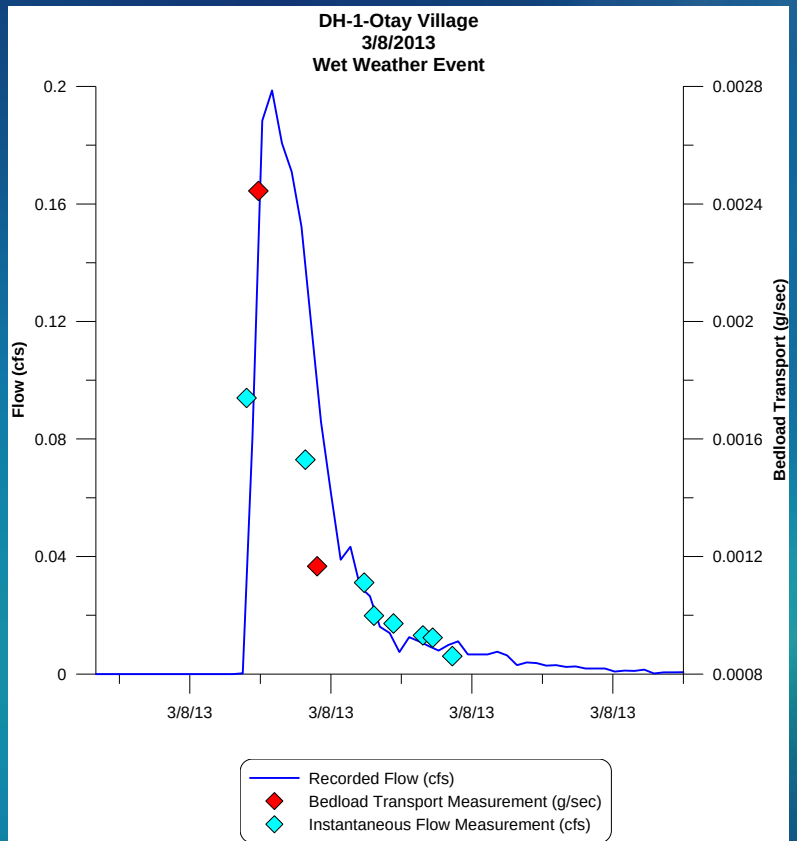
Pre-Development Site
(high susceptibility site)

Site	Date	24 hr. Rainfall Total (in.)	Number of Samples
DH-2	12/13/2012	1.63	10
DH-2	3/8/2013	1.32	13

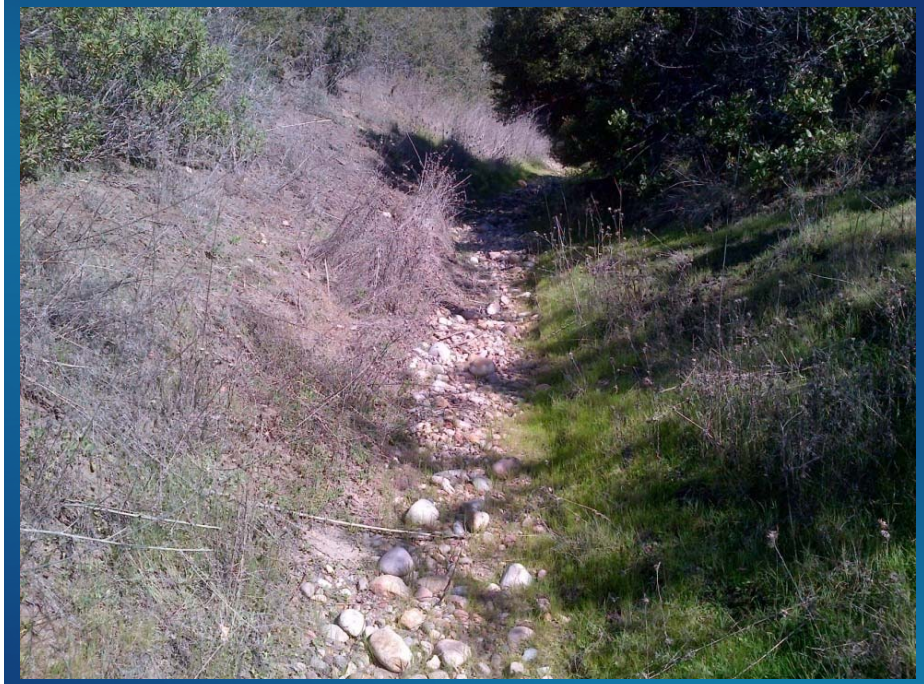


Pre-Development Site
(high susceptibility site)

Site	Date	24 hr. Rainfall Total (in.)	Number of Samples
DH-1	3/8/2013	0.96	8



Reference Sites



RM-1 Deer Valley

Max 24 hr. rainfall total with no recorded flow: 1.84”

RH-1 Ramona

Max 24 hr. rainfall total with no recorded flow: 1.83”

Reference Sites

RM-2 Sycamore Canyon

Max 24 hr. rainfall total with no recorded flow: 1.84”

RH-2 Schoolhouse Canyon

Max 24 hr. rainfall total with no recorded flow: 1.34”

Storm Size Predictions for Mobilization

- **Problem: Which storm size would be provide sufficient flow for sampling and to avoid false starts?**

- **Solution: Used ACOE HEC-HMS 3.5 Model to estimate site specific storm size needed to initiate flows sufficient for successful monitoring.**

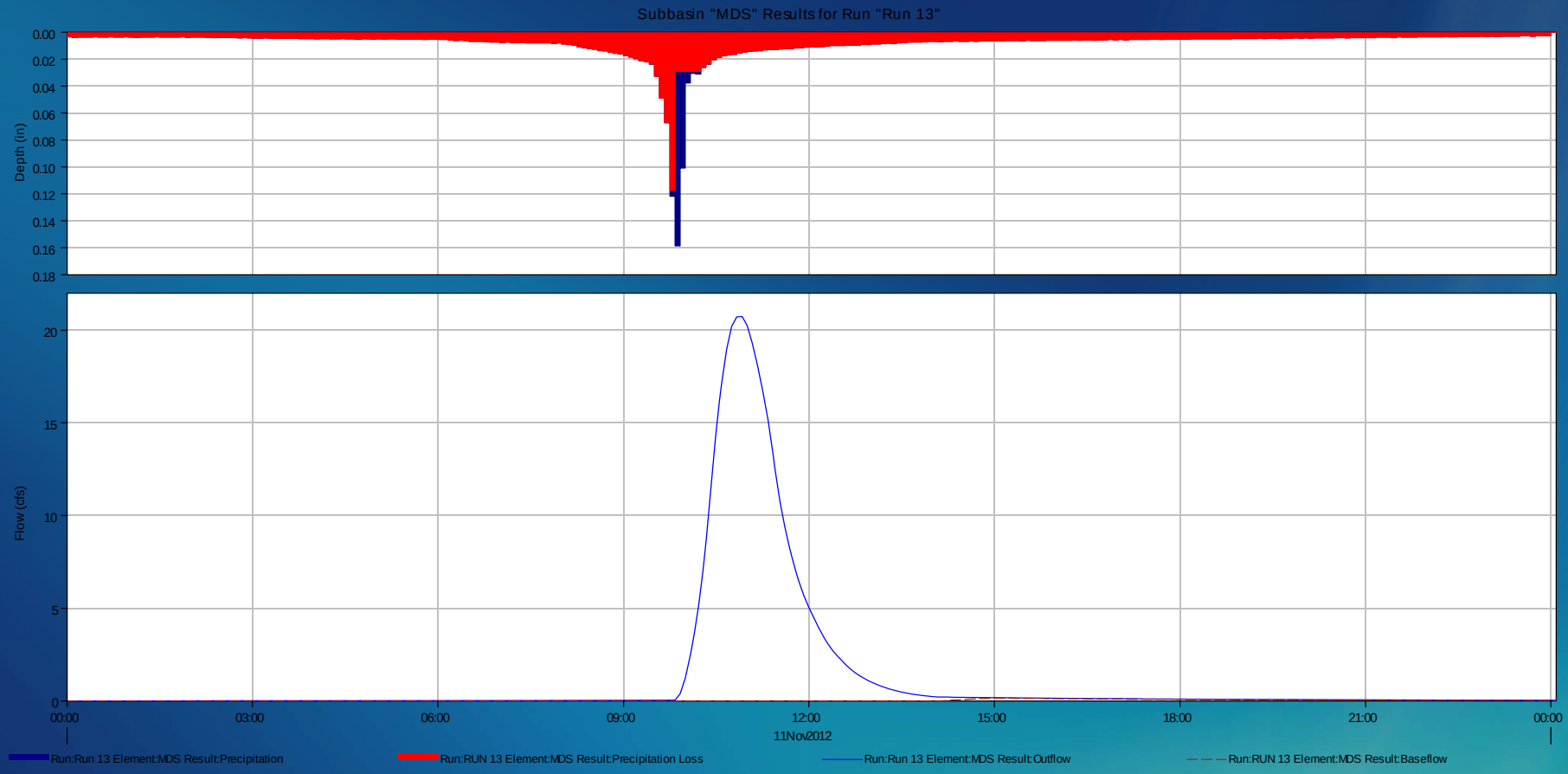
Method

- **Compared different size storms to determine when precipitation overcomes Initial Abstraction**
  - **0.25”, 0.5”, 0.75” precipitation for urban sites (>20% impervious)**
  - **1.5”, 2.0”, 2.5” precipitation for predevelopment and reference sites**
- **Inputs**

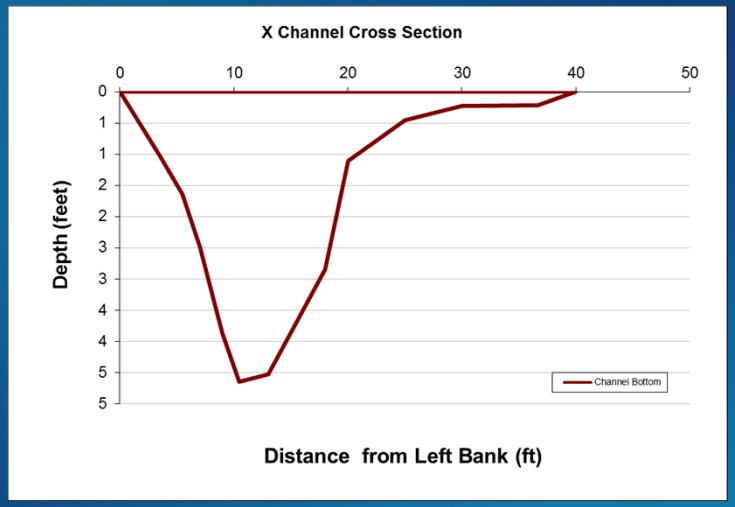
• Drainage Area (Miles2)	• Length (centroid) (miles)
• Length of longest flow path (m)	• Slope (feet per mile)
• Valley Slope (m/m)	• Mannings n (average for stream course)
• Estimated Channel n	• m (constant for SD County)
• % Impervious	• Corps Lag Time (min)
• % Forest Cover	
• Watercourse Length (miles)	

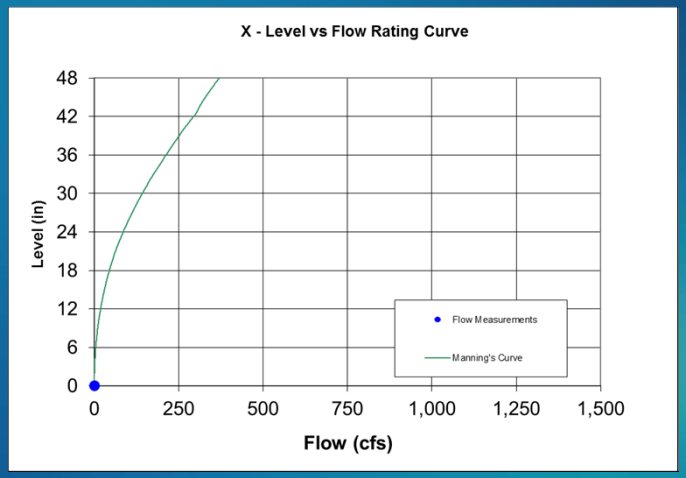
- **Used flow results to back calculate the level and duration of flow > 1” within the stream based on the Chanel Cross Sections and rating curve.**
- **Results compared to USGS Stream Stats flow predictions for 1, 2, and 5 year 24-hour precipitation events using the County Hydrology Manual Isopluvial Maps for each site.**

HEC HMS - Model Outputs



Flow/Level Evaluation





Rating Table

Level (in)	Flow (cfs)	Level (in)	Flow (cfs)
0.0	0.0	**23.0**	76.5
0.1	0.0	**23.5**	80.5
0.2	0.0	**24.0**	84.6
0.3	0.0	**24.5**	88.8
0.4	0.0	**25.0**	93.1
0.5	0.0	**25.5**	97.5
1.0	0.1	**26.0**	102.0
1.5	0.1	**26.5**	106.5
2.0	0.3	**27.0**	111.1
2.5	0.6	**27.5**	115.8
3.0	0.9	**28.0**	120.6
3.5	1.3	**28.5**	125.5
4.0	1.7	**29.0**	130.5
4.5	2.3	**29.5**	135.6
5.0	2.9	**30.0**	140.8
5.5	3.6	**30.5**	146.1
6.0	4.3	**31.0**	151.5
6.5	5.0	**31.5**	157.0
7.0	5.9	**32.0**	162.6
7.5	6.8	**32.5**	168.4
8.0	7.8	**33.0**	174.2
8.5	8.8	**33.5**	180.1
9.0	10.0	**34.0**	186.1
9.5	11.2	**34.5**	192.3
10.0	12.5	**35.0**	198.5
10.5	13.9	**35.5**	204.8
11.0	15.3	**36.0**	211.3
11.5	16.8	**36.5**	217.5
12.0	18.5	**37.0**	223.7
12.5	20.2	**37.5**	230.0
13.0	21.9	**38.0**	236.4
13.5	23.8	**38.5**	242.9
14.0	25.7	**39.0**	249.5
14.5	27.8	**39.5**	256.3
15.0	29.9	**40.0**	263.2
15.5	32.1	**40.5**	270.3
16.0	34.4	**41.0**	277.5
16.5	36.8	**41.5**	284.8
17.0	39.3	**42.0**	292.2
17.5	41.8	**42.5**	299.8
18.0	44.5	**43.0**	305.2
18.5	47.3	**43.5**	310.3
19.0	50.1	**44.0**	315.8
19.5	52.5	**44.5**	321.5
20.0	55.5	**45.0**	327.4
20.5	58.7	**45.5**	333.7
21.0	61.9	**46.0**	340.3
21.5	65.3	**46.5**	347.1
22.0	68.8	**47.0**	354.2
22.5	72.6		

Results

- **Mobilization Criteria**
  - **3 Urban/Development Sites required a range from 0.25” to >0.75”**
  - **Remaining sites required >1.5”**
  - **Original reference sites required > 2.5” (equivalent to a 5-yr 24-hr storm)**

		HEC-HMS 3.5 Model Runs									
		Modeled Storm Size Peak Flow (CFS)			Storm Size Peak Flow Level (Inches (from channel survery and Mannings est.)			Storm Flow Duration >1" of Level (hrs)			Recommended Forecasted Storm Size for Mobilization (Inches Precip in 24 hr period)
Site	Site ID	0.25"* /1.5"	0.5"* /2"	0.75* /2.5"	0.25"* /1.5"	0.5"* /2"	0.75* /2.5"	0.25"* /1.5"	0.5"* /2"	0.75* /2.5"	
Saratoga	UH-1	12.54	25	37.52	12	16	19	>12	>12	>12	0.25"-1.0"
Deer Valley	RM-1	0.15	1.68	6.9	1.75	4	7.6	1.25	3.5	4	≥2.5"**
Flanders	UM-2	43	87	130	18	24	29	>12	>12	>12	≥0.75"
Ramona	RH-1	0.03	1.07	4.63	0	3.25	7.25	0	4	5.5	≥2.5"**
Sycamore	RM-2	0.27	13.58	42	2.7	11	17	3.5	7	10	≥1.5"
Schoolhouse Canyon	RH-2	0.6	7.75	31.9	3.7	9	15	>12	>12	>12	≥1.5"
Otay	DH-1	0.01	7.2	32	0.8	9	19	0	6	12	≥2"
Bear Valley Pkwy	DH-2	2.1	4.22	6.32	4	5.5	7	>12	>12	>12	≥0.5"

*0.25", 0.5",0.75" are used for Saratoga, Flanders, and Bear Valley only. All others use the higher rainfall estimates

**Recommend discontinuing this site, mainly due to small drainage area.

Lessons Learned

- The US-BLH-84 handheld bedload sampler is a useful tool to conduct bedload transport ratings in small creeks.
- The portable bedload trap and painted rocks in a defined area may provide useful qualitative data (in the right setting).
- Using a phased approach allows for a feasible implementation of the program.
- Need predictable and sizable storms to conduct successful monitoring.
- Modeling flows to estimate storm size needed is recommended to prevent false starts.

Next Steps

- Continue with Phase II monitoring and data analysis.
- Update Monitoring Workplan and QAPP in 2013 as needed.
- Validate HMP assumptions.
- Final Report in 2016

HMP Project Collaboration

- San Diego Copermittees (County of San Diego and City of San Diego leads)
- Southern California Coastal Water Research Project (SCCWRP – Dr. Eric Stein)
- San Diego Regional Board staff
- Consultants (Weston Solutions, Inc. and ESA/PWA)
- University Research (Dr. Trent Biggs, SDSU)
- Regional HMP TAC

QUESTIONS?

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