Good Practices for Enhancing the Verification Process

Improving model confidence

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Enhancing the Verification Process

- Introduction
- Data Collection
  - Confidence Scores
- Pipe Flow Verification (1D)
  - A Single Measure of Verification Fit
- Overland Flow Verification (2D)
  - The Use of Social Media

INTRODUCTION

Why do we build hydraulic models?

- Simulate drainage networks
  - Fluvial

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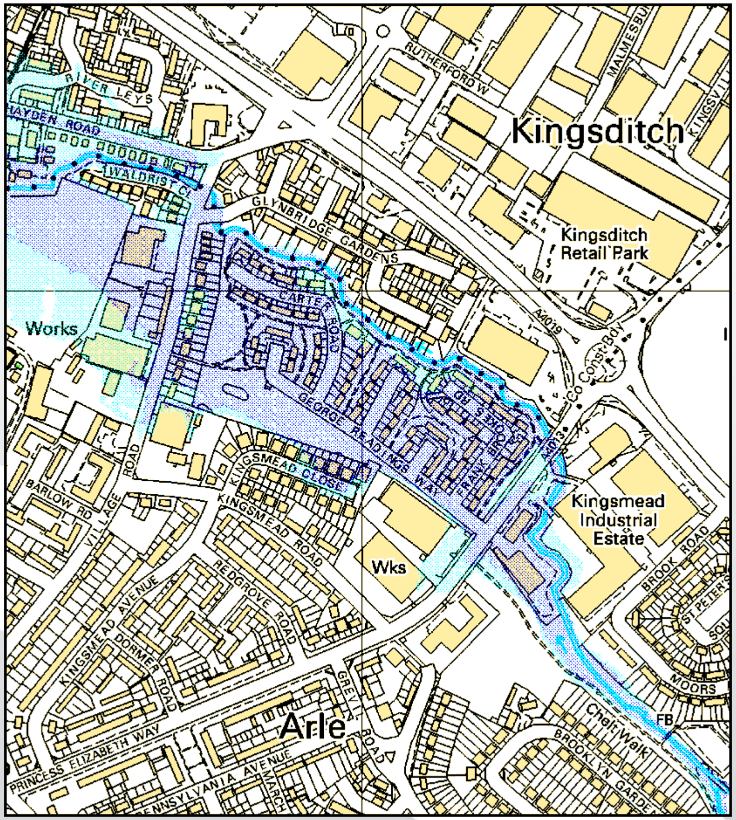
- Assess Flood Risk



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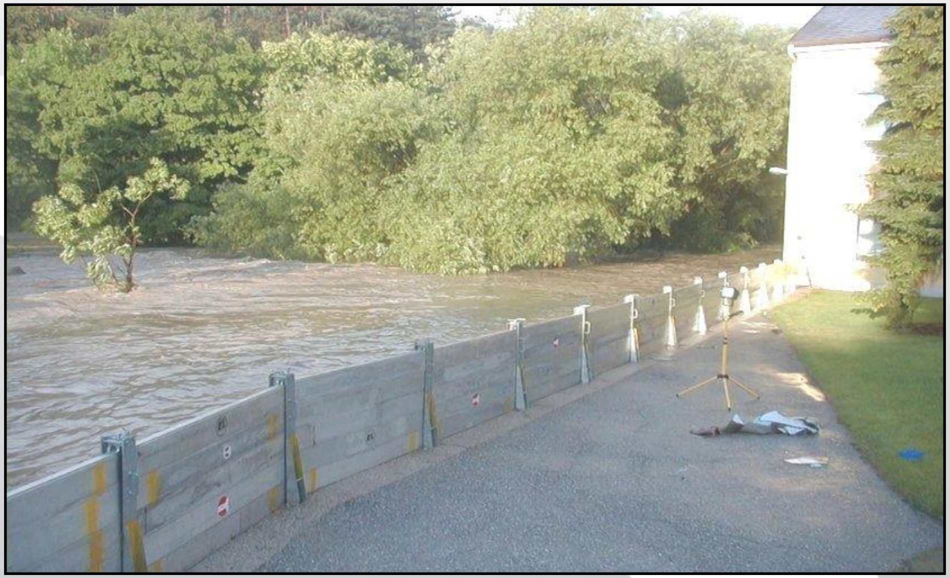

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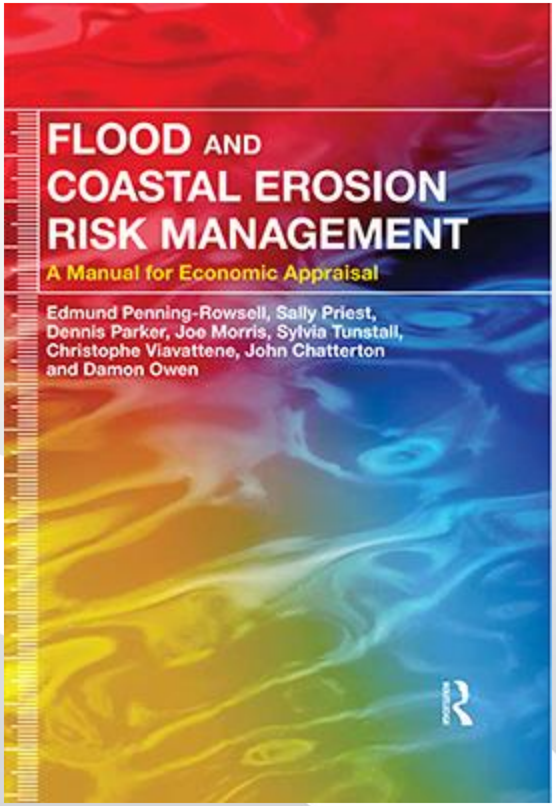

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- Assess Flood Risk
- Test scenarios
- Calculate impacts
- Scheme design

How are modelling outputs used?

- Often the final model outputs will be used for 'strategic financial investment'
  - Upgrading existing assets
  - Flood defences
  - Flood warning systems
- Contribute to the evidence base to build the case for flood relief schemes
- Calculate the benefit provided by schemes
- Provide levels and volumes to inform detailed design

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These outputs demand that a high confidence can be placed in the model

Model build process

Data Collection

Model Build

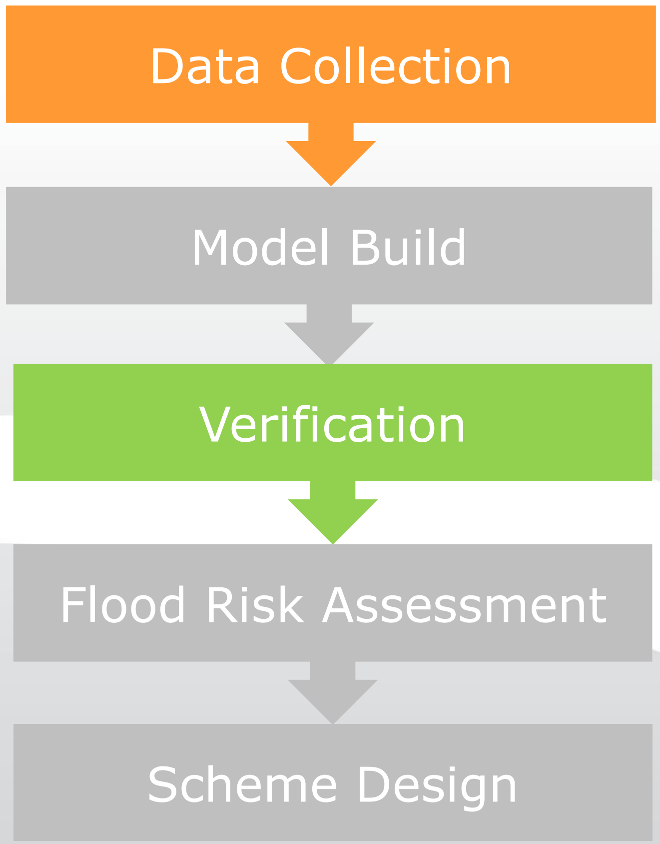
Verification

Flood Risk Assessment

Scheme Design

Building a hydraulic model is a multi-stage process

Enhancing Model Verification



- Improve the quality of input data
- Test the model against accurate recorded data.

Data Collection

Model Build

Verification

Flood Risk Assessment

Scheme Design

Myth busting

- **The source alone is enough to fully understand the confidence that can be placed in the data**

Myth busting

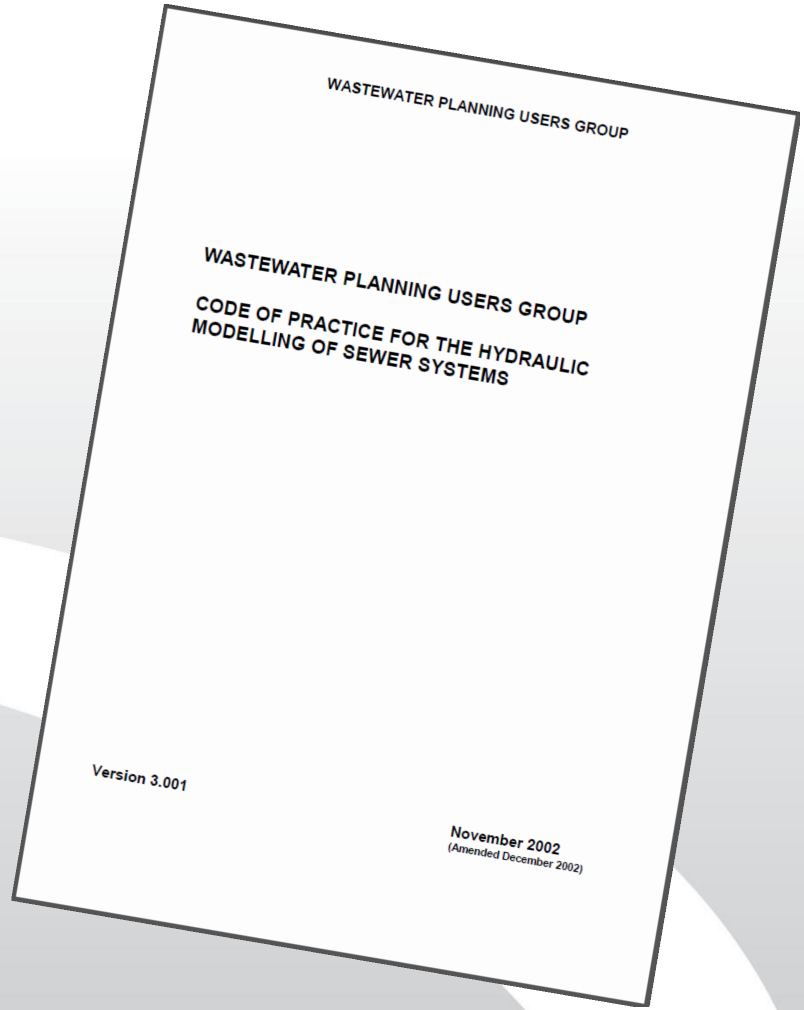
- ~~**The source alone is enough to fully under stand the confidence that can be placed in the data**~~

- Questions:
  - When was the survey undertaken?
  - Was the survey undertaken by a competent contractor?
  - How reliable is the asset data?
  - What are the assumptions based on?

Data Quality Scoring

WaPUG

Data Collection Level	Accuracy	Example
A	Maximum	Survey
B		Records
C		Interpolated
D	Minimum	Estimate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CODE OF PRACTICE FOR THE HYDRAULIC MODELLING OF SEWER SYSTEMS

Version 3.001

November 2002
(Amended December 2002)

Data Quality Scoring

Defra

Score	Description	Example
1	Best possible	LiDAR
2	Data with known deficiencies	Model of a few years old
3	Gross assumptions	‘future risk’ inputs e.g. Climate change
4	Heroic assumptions	Ground roughness

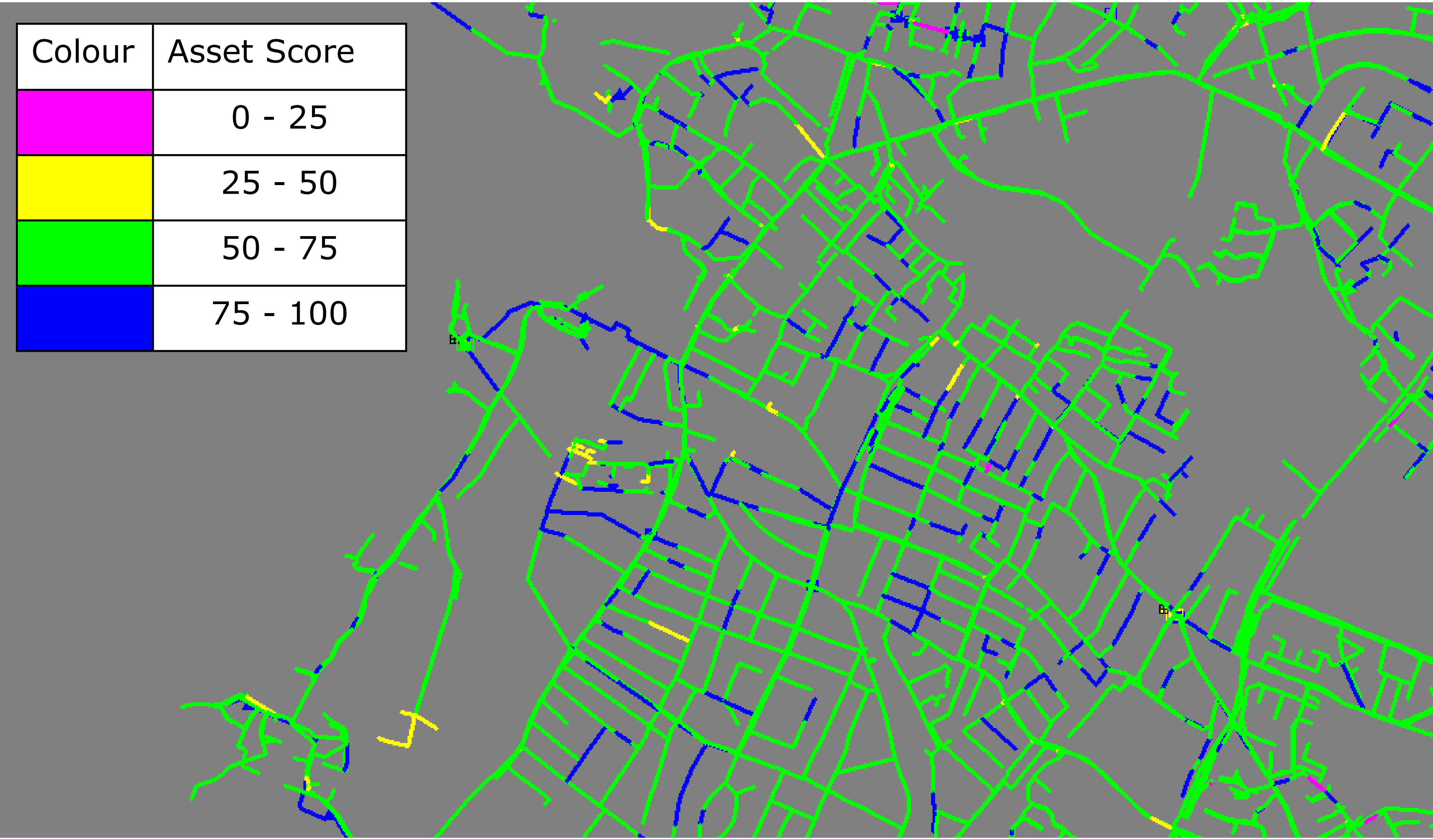
Data Quality Scoring

Colour	ID	Description	Score
	A1	"Data from survey of high quality"	10
	A2	"Data from survey of medium quality"	9
	A3	"Data from survey of low quality"	8
	B1	"Data from records of high quality"	8
	B2	"Data from records of medium quality"	7
	B3	"Datafrom records of low quality"	6
	C1	"Data inferred using built in routines but checked for confidence"	6
	C2	"Data inferred using built in routines with medium confidence"	5
	C3	"Data inferred using built in routines but not checked"	4
	D1	"Data estimated with high confidence"	3
	D2	"Data estimated with medium confience"	2
	D3	"Data estimated with low confidence"	1

Allocate Scores

	US Node ID	Link Suffix	Length (m)	Shape ID	Width (mm)	Bottom Roughness Colebrook-White (mm)	Top Roughness Colebrook-White (mm)	US Invert Level (m AD)	DS Invert Level (m AD)	DS Headloss Type	DS Headloss Coefficient
	SO79128906	1	9.3	CIRC	225	1.500	3.000	15.260	15.210	Normal	1.43
	SO79128907	1	37.1	CIRC	225	1.500	3.000	15.210	15.040	Normal	8.00
	SO79128908	1	101.2	CIRC	225	1.500	3.000	15.040	14.410	Normal	1.33
	SO79129001	1	86.8	CIRC	150	1.500	3.000	14.390	13.290	Normal	6.58
	SO79129101	1	78.1	CIRC	150	1.500	3.000	15.390	14.400	Normal	1.10
	SO79129102	1	66.7	CIRC	150	1.500	3.000	16.610	15.410	Normal	6.06
	SO79129901	1	21.1	CIRC	225	1.500	3.000	15.790	15.540	Normal	4.41
	SO79129902	1	21.1	CIRC	225	1.500	3.000	15.950	15.790	Normal	1.64
	SO79136501	1	8.5	CIRC	150	1.500	3.000	12.100	11.810	Normal	5.86
	SO79136502	1	21.0	CIRC	300	1.500	3.000	11.680	11.360	Normal	2.70
	SO79136503	1	28.2	CIRC	150	1.500	3.000	11.370	11.180	Normal	1.56
	SO79136504	1	24.3	CIRC	300	1.500	3.000	11.810	11.680	Normal	1.74
	SO79136601	1	37.1	CIRC	225	1.500	3.000	11.280	10.860	Normal	1.02
	SO79136602	1	35.3	CIRC	225	1.500	3.000	12.200	11.930	Normal	1.31
	SO79136603	1	22.3	CIRC	300	1.500	3.000	11.930	11.810	Normal	4.66
	SO79136604	1	17.8	CIRC	150	1.500	3.000	11.570	11.500	Normal	6.54
	SO79136605	1	18.7	CIRC	150	1.500	3.000	11.490	11.390	Normal	4.61
	SO79136606	1	35.7	CIRC	150	1.500	3.000	10.950	10.570	Normal	1.01
	SO79136701	1	20.8	CIRC	150	1.500	3.000	9.930	9.660	Normal	1.09
	SO79136702	1	15.6	CIRC	150	1.500	3.000	9.650	9.420	Normal	1.06
	SO79136703	1	61.3	CIRC	150	1.500	3.000	9.410	8.920	Normal	1.19
	SO79136704	1	64.8	CIRC	375	1.500	3.000	10.040	9.360	Normal	1.04
	SO79136705	1	16.3	CIRC	375	1.500	3.000	10.180	10.040	Normal	1.17
	SO79136706	1	35.8	CIRC	300	1.500	3.000	10.860	10.440	Normal	1.02
	SO79136707	1	25.9	CIRC	375	1.500	3.000	10.440	10.180	Normal	1.12
	SO79136708	1	27.0	CIRC	225	1.500	3.000	12.270	10.930	Normal	6.36
	SO79136709	1	41.8	CIRC	150	1.500	3.000	10.560	9.940	Normal	1.00
	SO79136801	1	51.8	CIRC	300	1.500	3.000	9.340	8.940	Normal	6.57
	SO79136802	1	30.6	CIRC	450	1.500	3.000	8.940	8.870	Normal	6.57
	SO79136803	1	55.5	CIRC	450	1.500	3.000	8.870	8.540	Normal	8.00
	SO79136804	1	55.0	CIRC	150	1.500	3.000	8.340	7.510	Normal	8.00

Data Confidence Thematic



Colour	Asset Score
	0 - 25
	25 - 50
	50 - 75
	75 - 100

Data Collection

Model Build

Verification

Flood Risk Assessment

Scheme Design

PIPE FLOW VERIFICATION

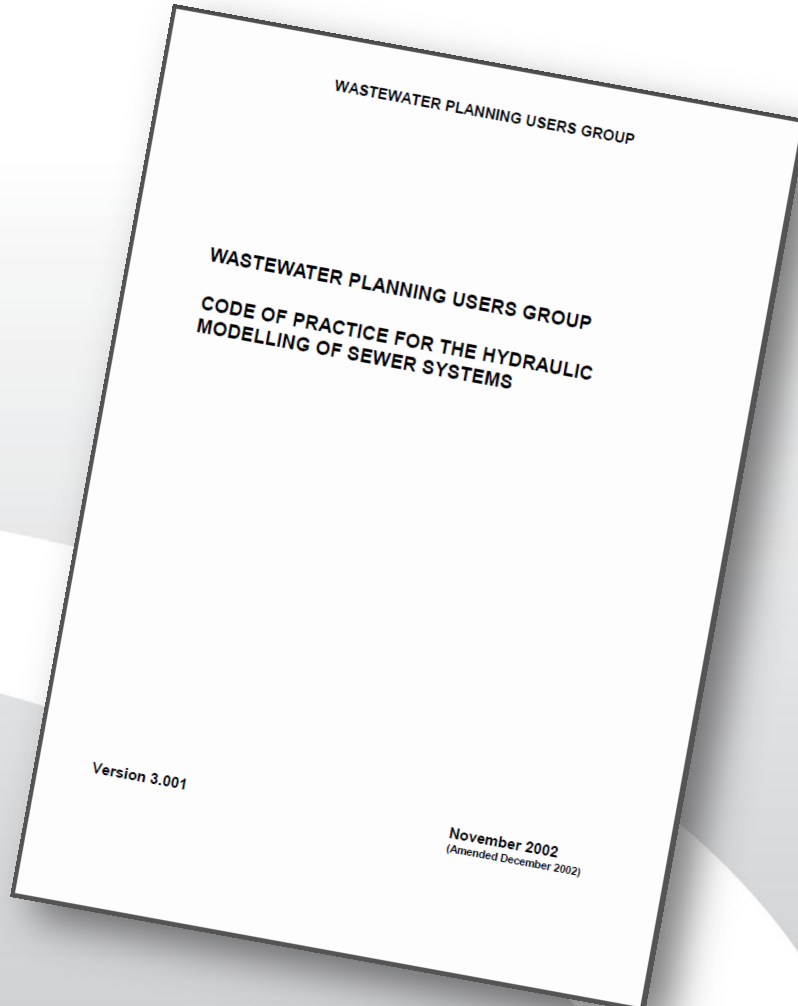
Pipe Flow

- Sewer models
- Usually verified against a short term flow survey
- Use of tipping bucket rain gauges
- Depth, flow and velocities are recorded at the monitor locations

Current Practice

WaPUG Verification

- "The two flow hydrographs should closely follow each other both in shape and in magnitude"
- Similar timing in peaks and troughs
- Peak flow within +25% to -15%
- Volume of flow within +25% to -15%
- Surcharge depth within +0.5m to -0.1m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Proposed Enhancement

- The Nash-Sutcliffe Efficiency Coefficient gives a numerical score for hydrograph shape match
- Can be calculated for each storm event
- Overall verification score is an average of NSEC for each storm
- Removes subjectivity

Nash-Sutcliffe Efficiency Coefficient

- NSEC compares predicted data with observed data using formula:

$$NSEC = 1 - \frac{\Sigma_{t=1}^{T}\left(Q_o^t - Q_p^t\right)^2}{\Sigma_{t=1}^{T}\left(Q_o^t - \overline{Q}_o\right)^2}$$

Where Q_o is observed discharge and Q_p is predicted discharge

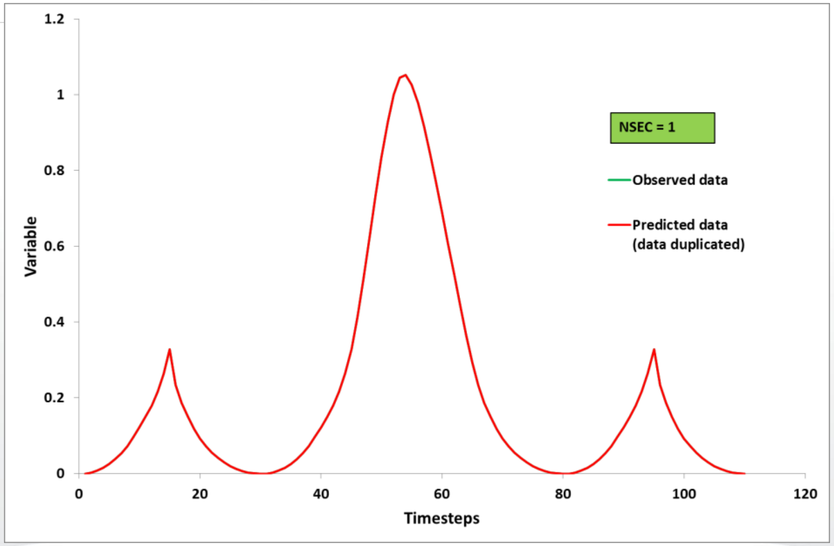
- Value of NSEC ranges between -∞ and 1
- NSEC of 1 = perfect match between observed and predicted data
- Literature states that a NSEC > 0.5 indicates an acceptable replication of observed data

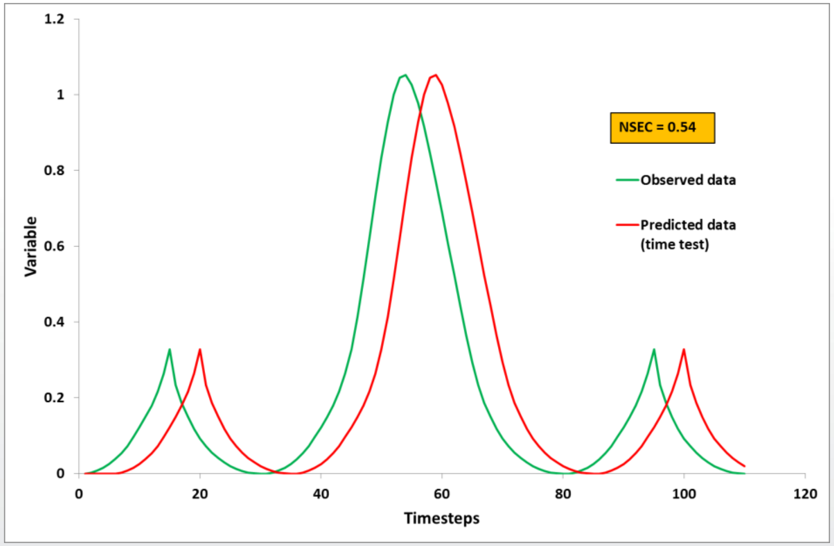
Verification

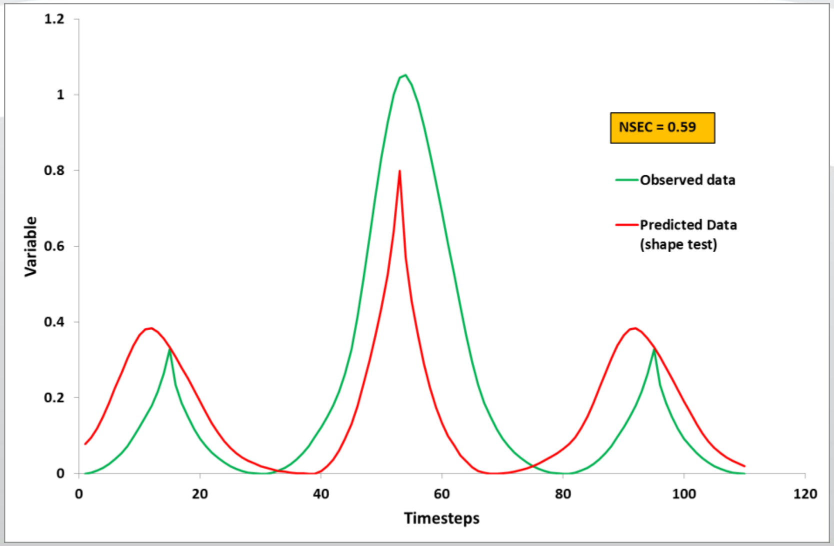
- Nash-Sutcliffe Efficiency Coefficient
  - Value range $-\infty \geq 1$
  - Range of scores to represent verification confidence

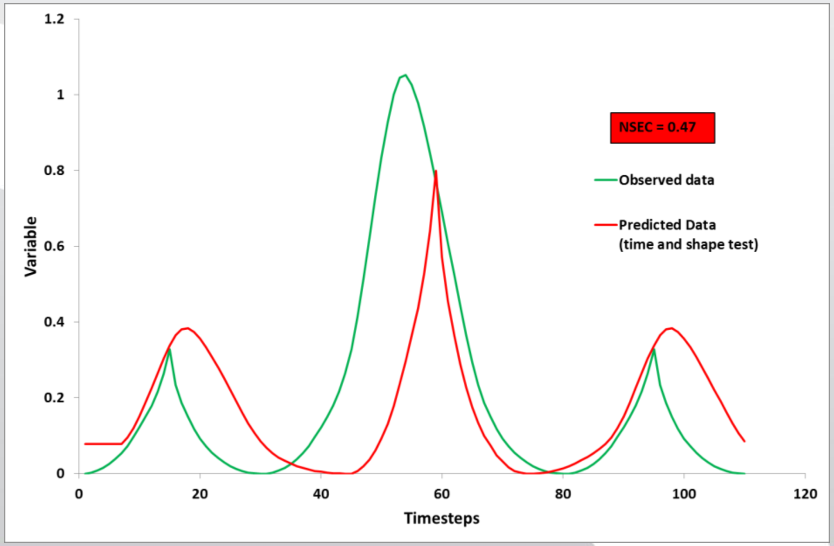
Colour	NSEC Range	Description
	$0.85 \geq 1.00$	Excellent verification
	$0.50 \geq 0.85$	Acceptable verification
	$-\infty \geq 0.50$	Unacceptable verification

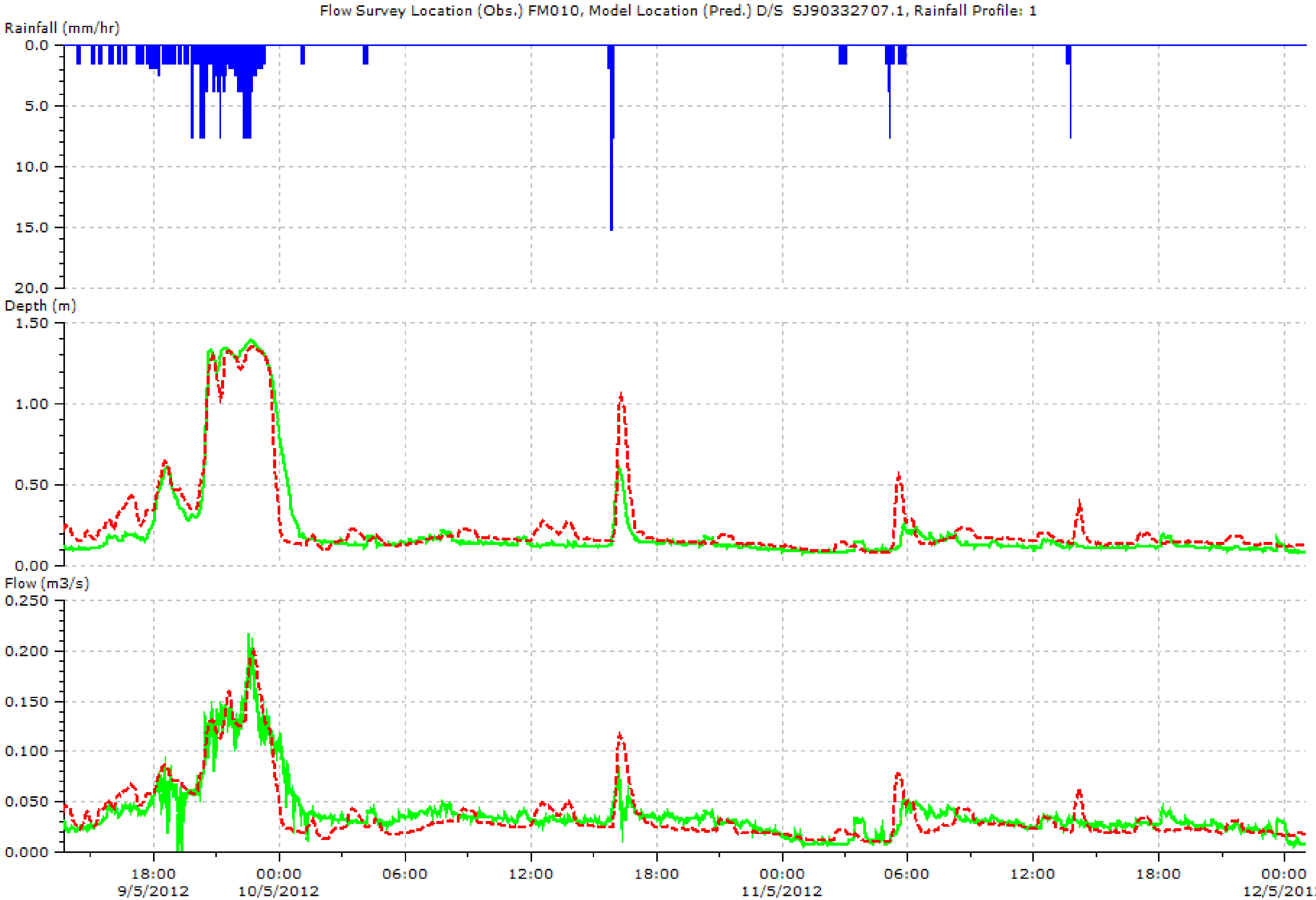
Quantifying Shape and Timing



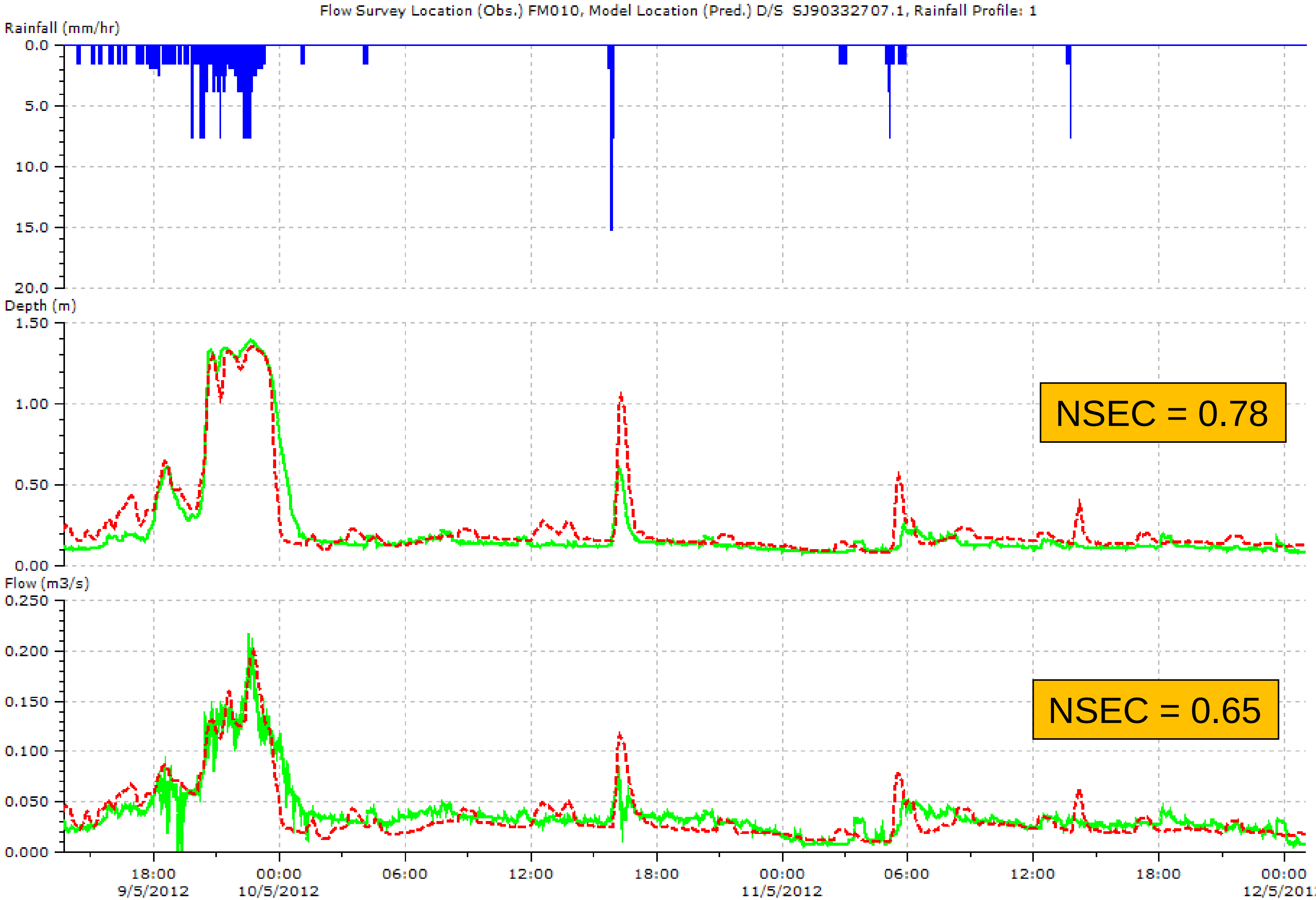








	Rainfall			Depth (m)		Flow (m3/s)		
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min	Max	Min	Max	Volume (m3)
Rain	19.812	15.240	0.334					
Obs.				0.079	1.388	0.000	0.204	8055.713
...ration>Storm C>Storm C				0.079	1.348	0.010	0.199	7761.531



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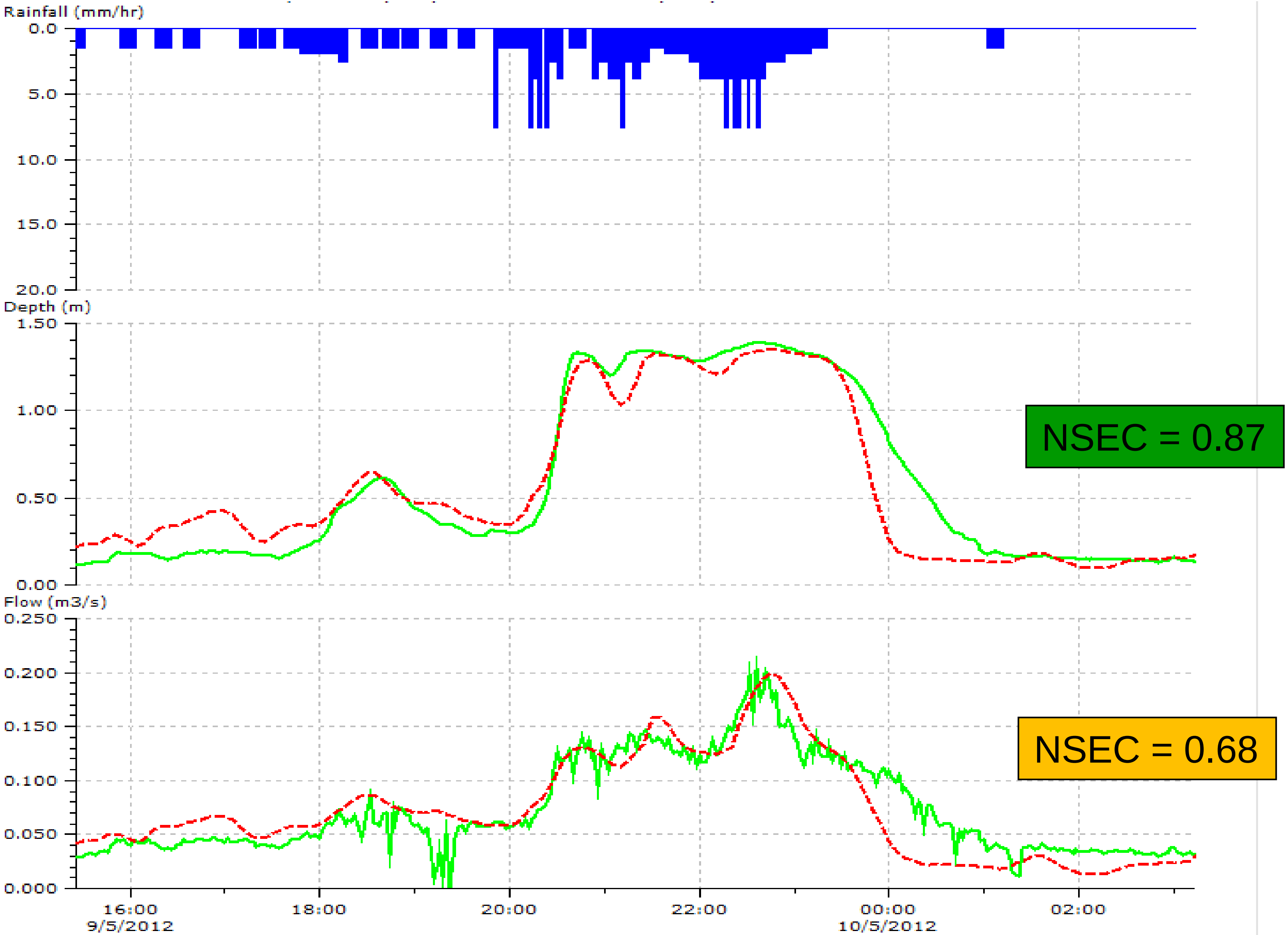
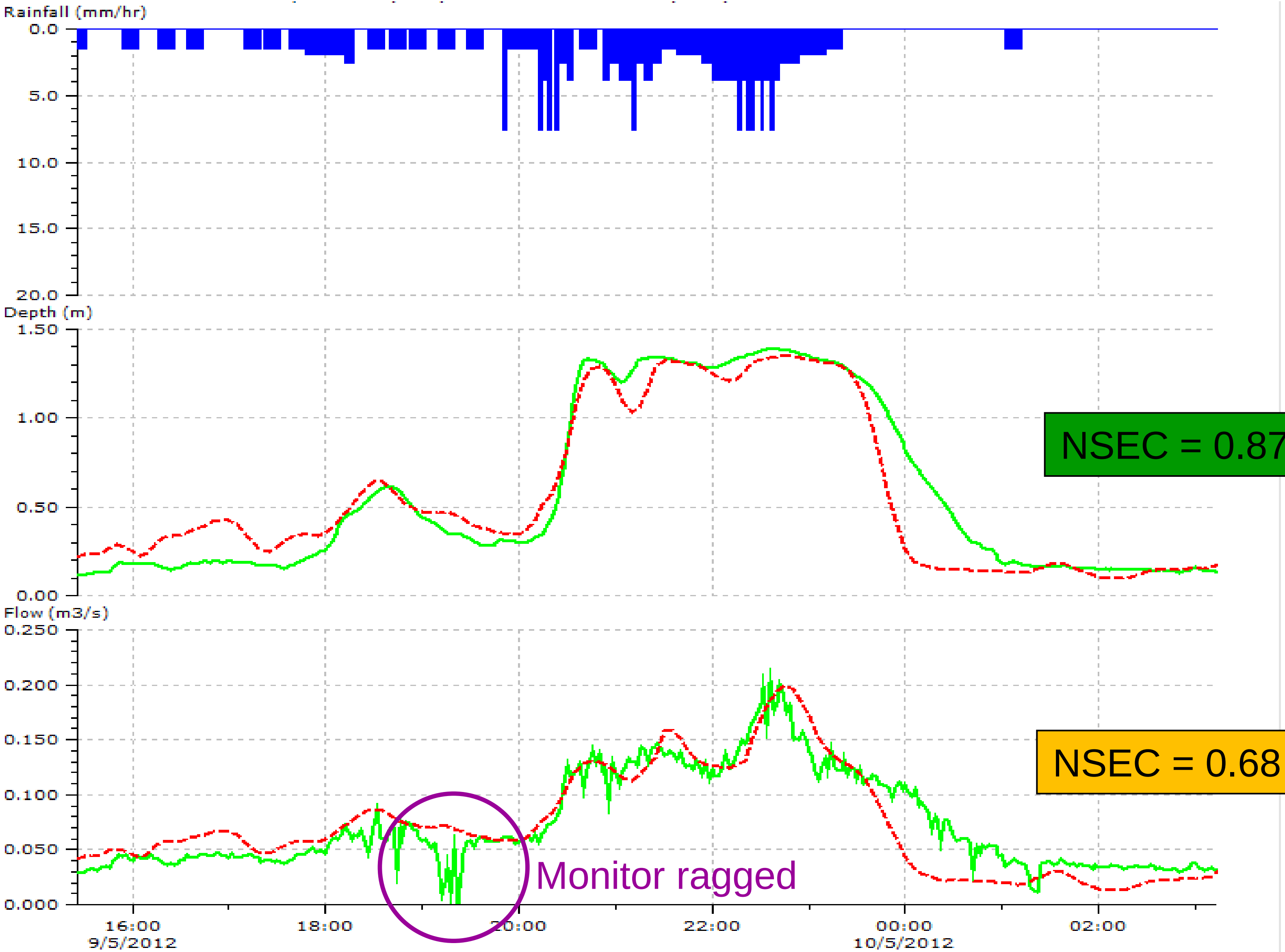


	Rainfall			Depth (m)		Flow (m3/s)		
	Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min	Max	Min	Max	Volume (m3)
Rain	14.376	7.620	1.217					
Obs.				0.112	1.388	0.000	0.204	3114.349
...Storm C>Storm C				0.095	1.348	0.012	0.199	3100.245



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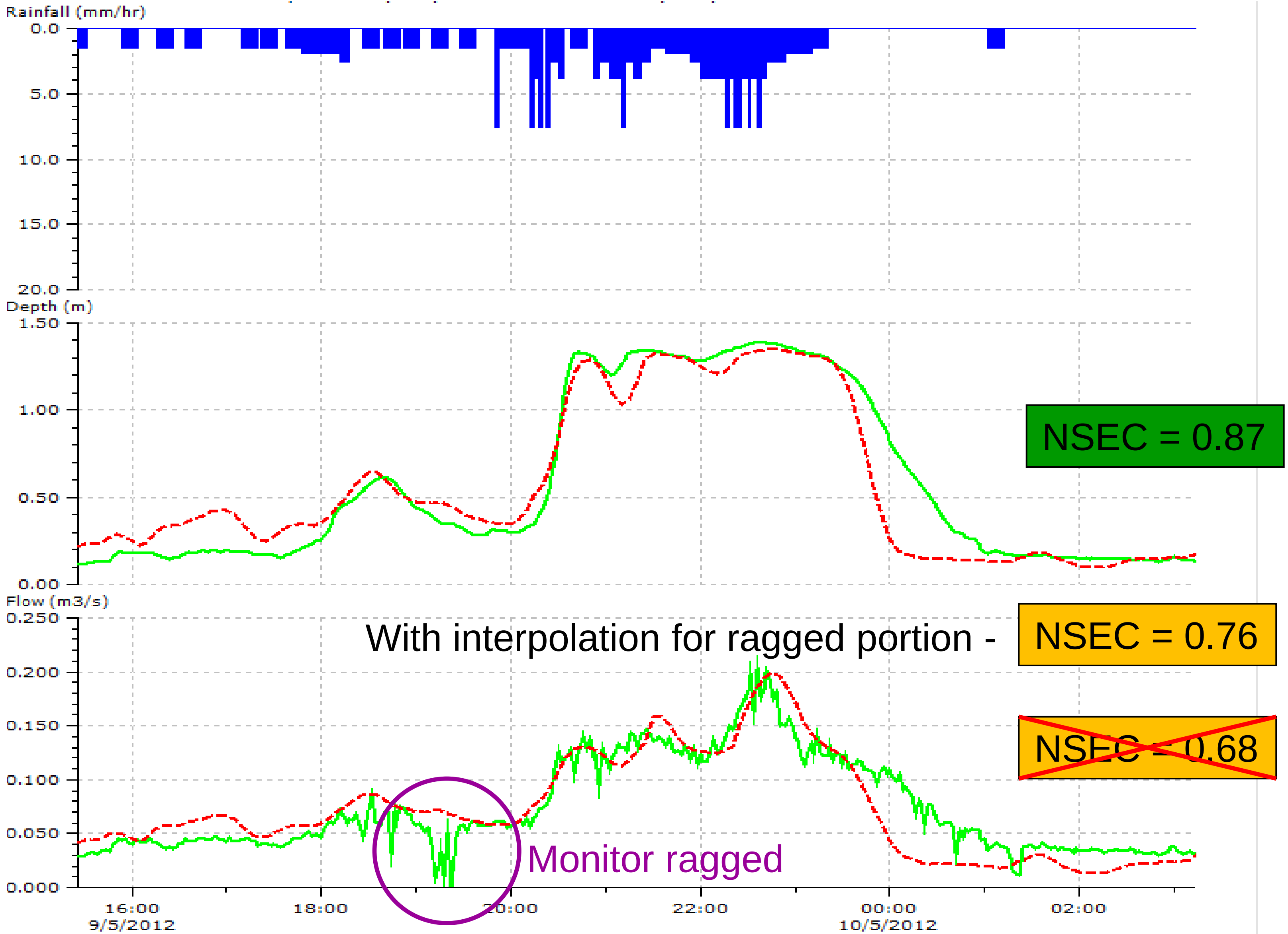
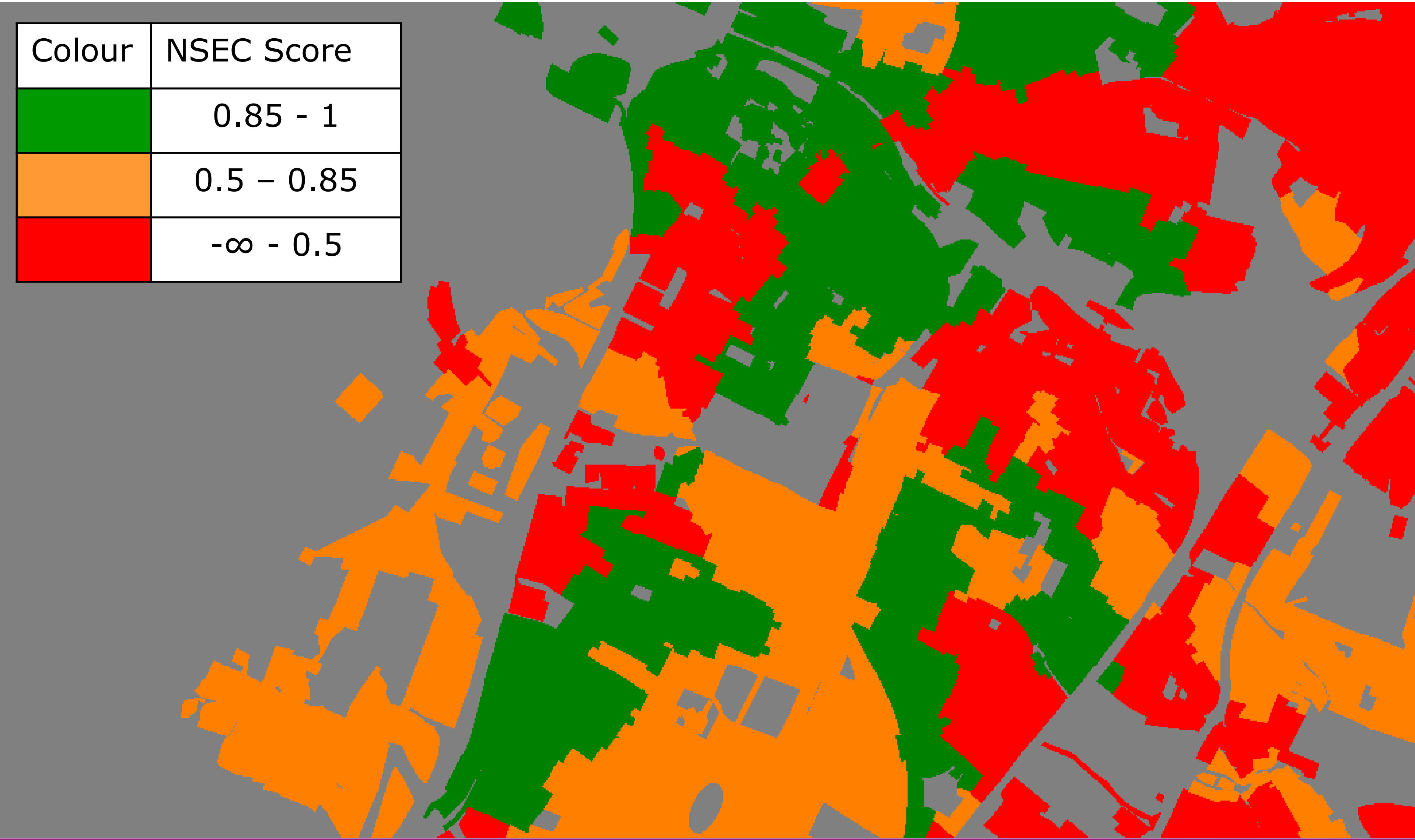


		Rainfall			Depth (m)		Flow (m3/s)		
		Depth (mm)	Peak (mm/hr)	Average (mm/hr)	Min	Max	Min	Max	Volume (m3)
Rain	blue line	14.376	7.620	1.217					
Obs.	green line				0.112	1.388	0.000	0.204	3114.349
...Storm C>Storm C	red dashed line				0.095	1.348	0.012	0.199	3100.245

Flow Verification Thematic

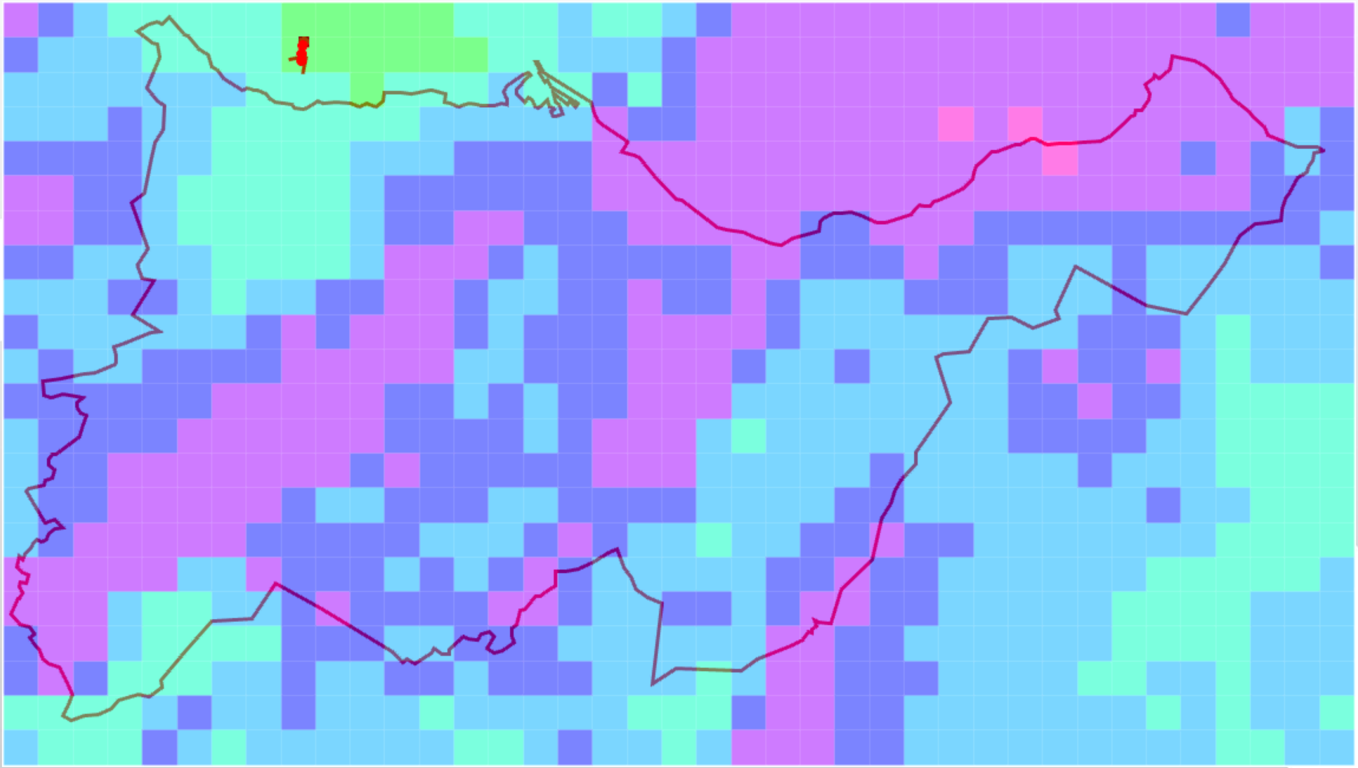


Inherent Problems

- Rain Gauge data suffers from its lack of spatial distribution
- Sewer models are only verified against ‘common’ storm events, usually up to a 1 in 6 month
  - may get a 1 in 5 year event if your lucky!
- Verification against historic flood points has to be used for ‘larger events’ typically using design storms.

Future Improvements

- Implementation of rain gauge and radar merging to capture both the accuracy of rainfall measurement and spatial variation of the storm event



OVERLAND FLOW VERIFICATION

Overland Flow

- Integrated models
- Usually verified against a previous extreme flood event
- Information on location, depths and time of flooding
- Use of social-media such as BBC, YouTube, Twitter and Google Maps
  - Locate photos of flooding using Google Street view
  - Compare locations in flood photos to dry conditions

Current Practice

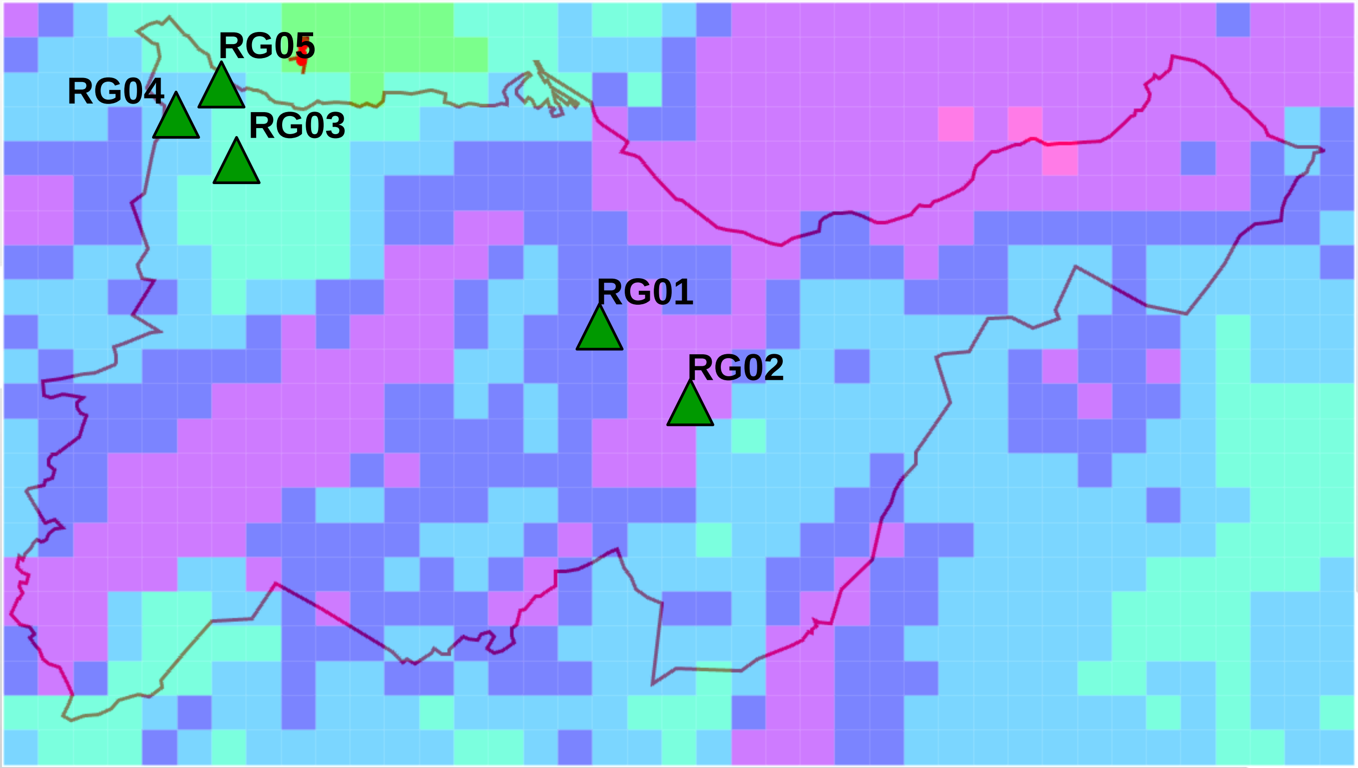
- No definitive guidance
- Direction is given to some 'good practice' examples
- Generally the framework is laid out, but the acceptability of verification is very Client specific

Inherent Problems

- Data collection for Storm verification faces a number of obstacles due to the reliance on the public for this information
- If the residents are unfortunate enough then there will be a large event to verify against. However as we move towards a proactive approach this is not necessarily the case.
- Accuracy of the rainfall data can lead to a model that is either under or over predicting flows
- At what point is a model acceptably verified?

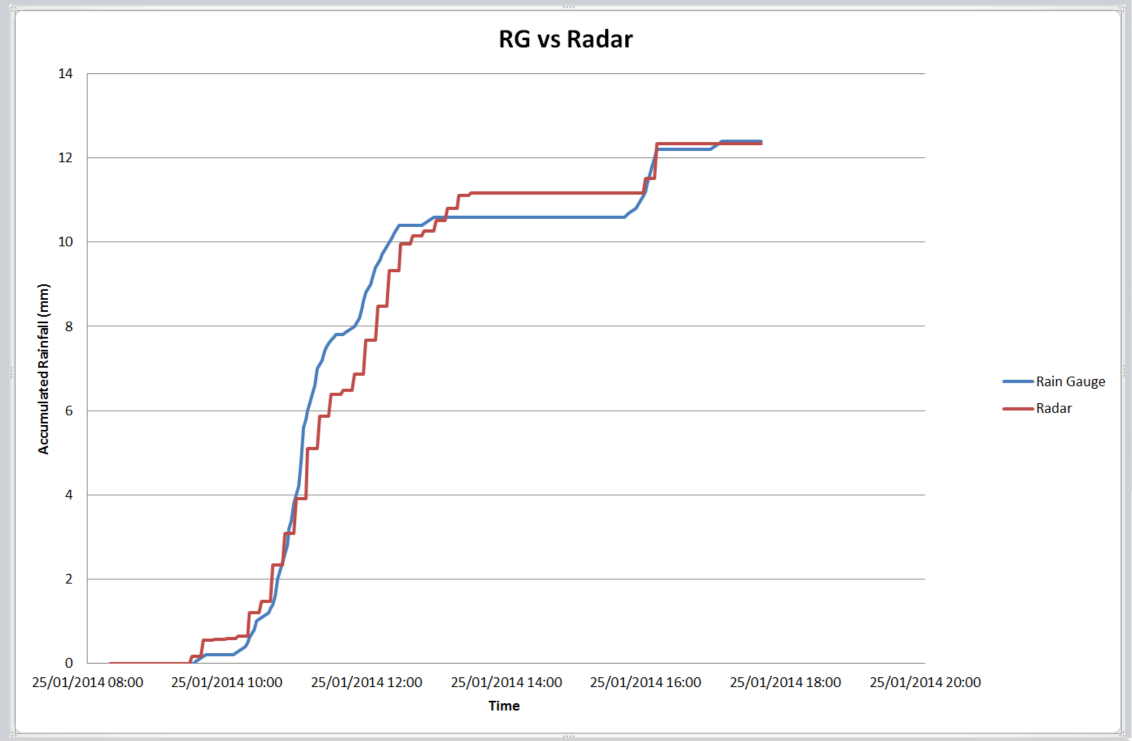
Weather Radar

- Rain gauge locations map



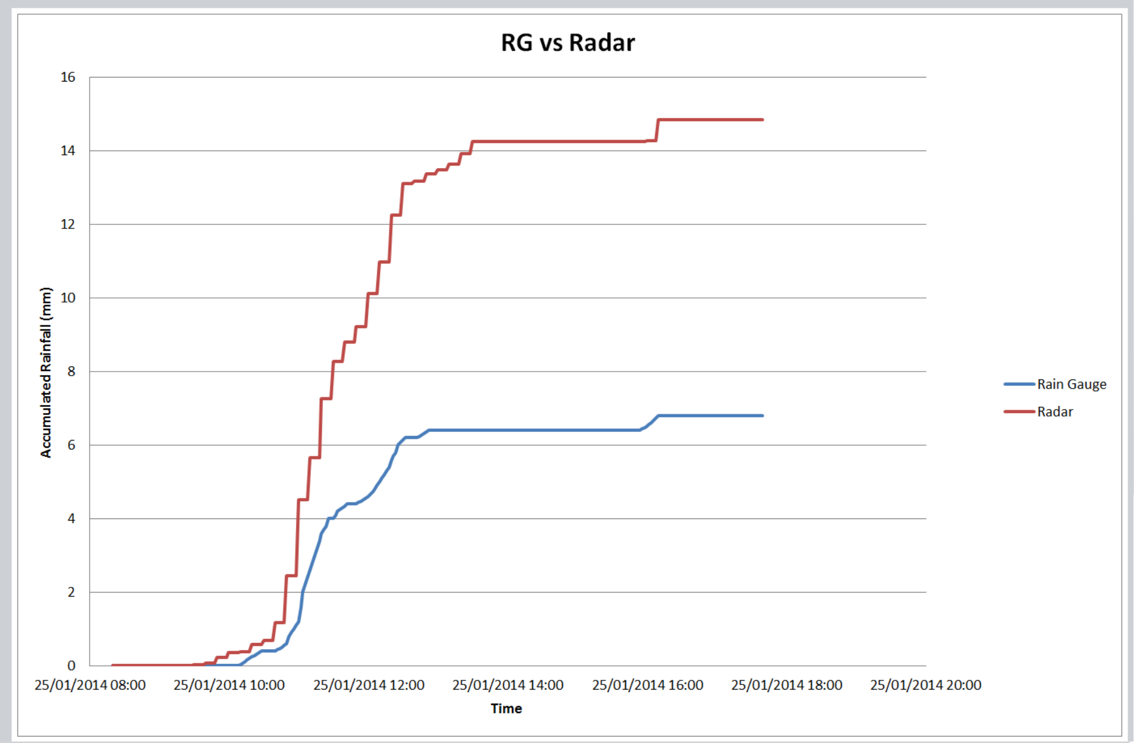
Weather Radar

- RG01 - Excellent match, should provide a ‘good’ verification



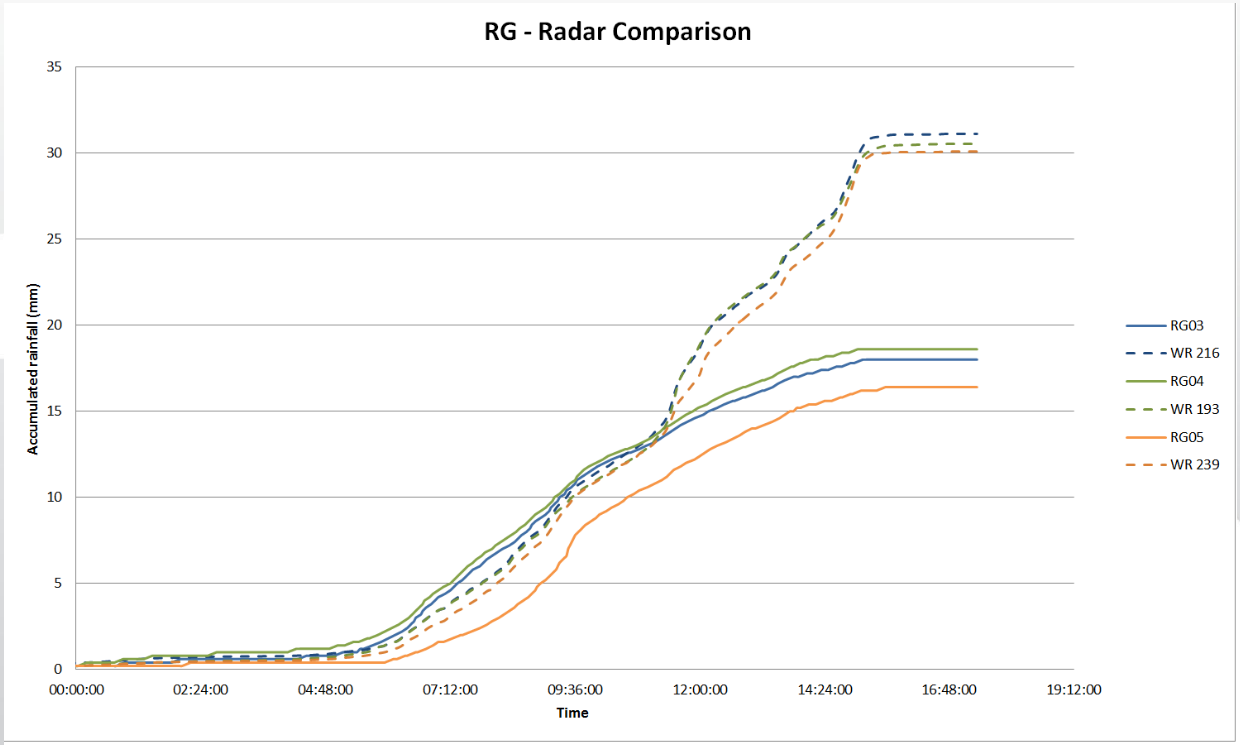
Weather Radar

- RG02 - Poor match, this would lead to a 'poor' verification and likely under-predicting model



Weather Radar

- RG03–05 - ‘Phantom Storm’ this would make verification very problematic



Rainfall Input

There are two alternative options:

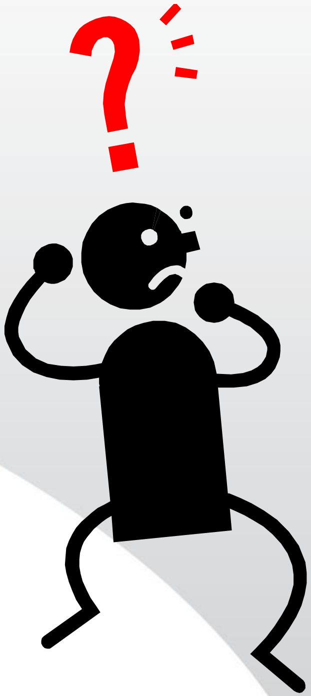
1. Use a ‘nearby’ rain gauge if available; but likely to be for only 1 single point

2. Use a range of design storms of the ‘same’ magnitude; will capture the mechanism but not necessarily the volume

Data Collation

- Data for Overland Flow verification can come from a number of sources but what confidence can be placed in them?

1. Anecdotal evidence (within 5 years)
   - Mechanism – assume a high confidence
   - Depth - assume a reasonable confidence
2. Anecdotal evidence (greater 5 years)
   - Mechanism – assume a reasonable confidence
   - Depth - assumed a low confidence
3. Pictures
   - With timestamp – assume a high confidence
   - Without timestamp – assume a reasonable confidence
4. Videos
   - With timestamp – assume a high confidence
   - Without timestamp – assume a reasonable confidence



Overland Flow

- Identify street furniture and other objects with known dimensions
- Issue of whether photo was taken at peak of flood event

Overland Flow

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Overland Flow

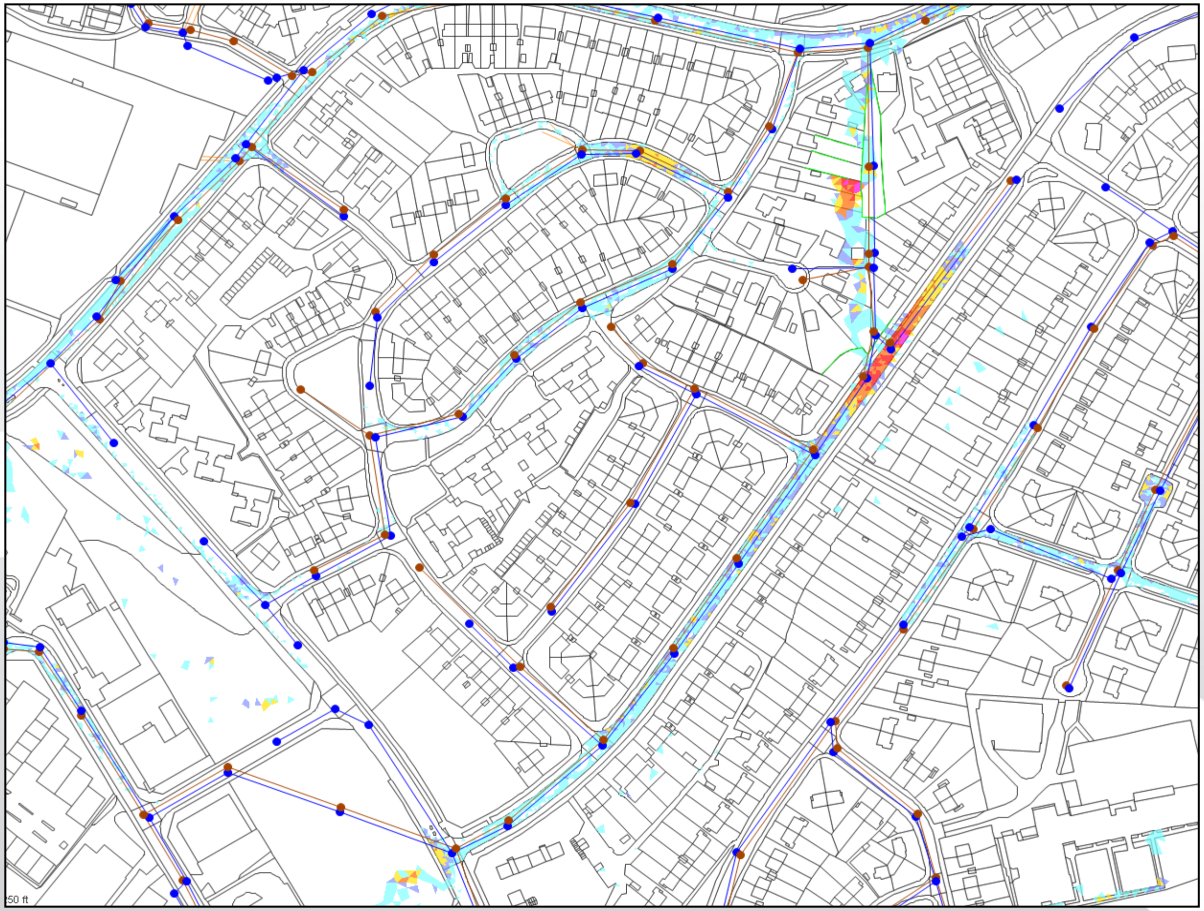
- Identify street furniture and other objects with known dimensions
- Issue of when the photo was taken (at peak of flood event?)

Overland Flow

- Don’t just rely on the provided information – social media now carries a wealth of information regarding a flood event.
- Most people have a camera in their pocket
- Most notably this information (Twitter) will be time stamped although it may have been taken sometime earlier

Overland Flow

Overland Flow



Overland Flow

Photo 2-4

Overland Flow

Photo 2-4

Photo 2-3

Overland Flow

Photo 2-4

Photo 2-3

Photo 2-2

Overland Flow

Suggested Enhancement

- Publish a code of practice
- Improvements in the accuracy of weather radar so that a ‘reasonable confidence’ can be placed in its use for hydraulic modelling
- A move towards fully integrated catchment models will allow a high level of confidence to be placed in the study ‘outcomes’
- Use of Social Media to collate flood data in ‘real time’ for use in verification
- Use of UAVs to quickly and effectively assess and monitor flooding depths and extents as they develop


LUMIX
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Key Messages

- Money spent to improve verification is an investment in security of schemes and services
- Don’t rely on the ‘maximum’ flood depth for verification as this can give a skewed picture. Ensure that the full length of flooding is verified
- Ensure that the flooding mechanism is properly represented by the model - Include the verified sewer network in your 2D model, don’t just use assumptions!

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