

Stream Mitigation Model

Examples for Mitigation Category 1 and 2 Streams

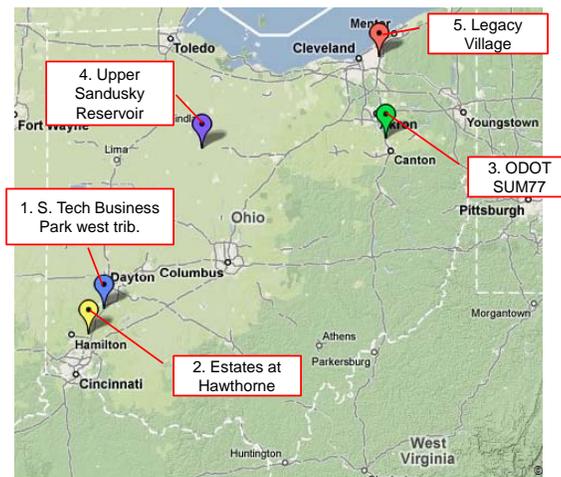
Preface

- Five example sites are presented from Ohio
- Each site is an approved stream mitigation site that served as an on-site stream relocation or replacement project
- All sites fall into Mitigation Category 1 or 2 based upon the draft stream mitigation rules
- Each site has been assessed for channel and flood prone area by Ohio DNR Division of Soil and Water Resources staff
 - Data and site photos used in this analysis were provided courtesy of ODNR
- Comparisons are made regarding outcomes from the proposed standards within the revised Ohio EPA stream mitigation protocol
- Examples of improvements to the original designs with respect to the mitigation model are also provided

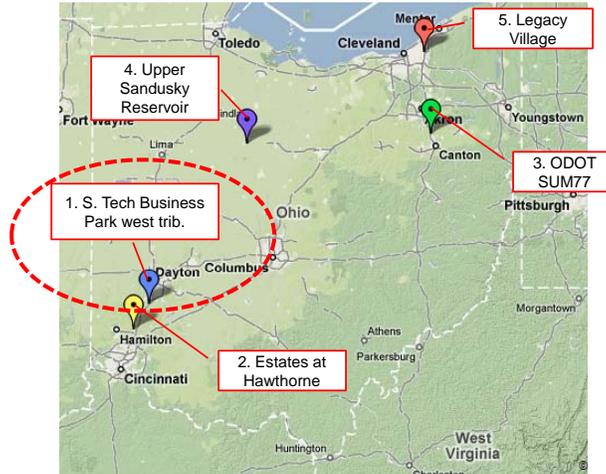
Preface

- Notes regarding stream mitigation protocol evaluation:
 - Habitat criteria do not apply for the stream segments used in these examples
 - Woody riparian buffer criteria also do not apply
 - Mitigation target based upon provision of sufficient flood prone area at or below $2 \times D_{\max}$ to protect downstream water quality
 - D_{\max} = the maximum depth at a riffle at the bankfull stage
 - Minimum acreage required for credit is assumed to be adjusted flood prone acres equal to 30% of the streamway target
 - Data is presented for the flood prone areas inundated or saturated at three elevations: $2.0 \times D_{\max}$, $1.5 \times D_{\max}$, and at the bankfull stage
 - The outcome for the adjusted flood prone area is also provided for the existing condition and an enhanced design for the site

Site Locations



Site 1 South Tech Business Center
Ohio EPA 401 ID: 034301
ACOE ID: (L) 199800240



Site 1 South Tech Business Center

- ❑ “West Tributary” site.
- ❑ Project approved in June 1999.
- ❑ 2,300 foot stream relocation with 25 foot buffer on each side of the stream.
- ❑ Drainage area = 288 acres.
- ❑ HHEI score = 59 (Class II PHWH)
 - falls into Mitigation Category 2

Site 1 South Tech Business Center

Belt width is equal to 74% of the streamway target.

Flood prone width ($2 * D_{max}$) is only 24% of the streamway target.

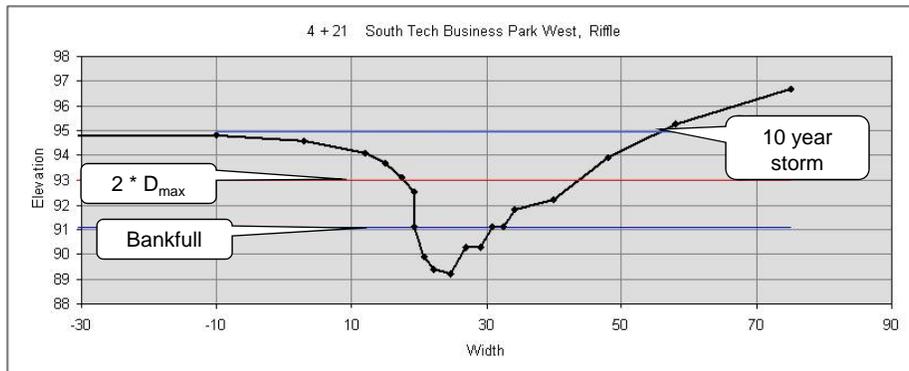
Note the entrenchment of the stream channel.



Photos courtesy ODNR

Site 1 South Tech Business Center

Current Conditions – Site Cross Section



Site 1. South Tech Business Park

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Stream Condition Targets for Replacement as Mitigation

Blue Cells are for Data Input **Red Cells are Auto-Calculated**

Project: Spreadsheet Calibration
 Stream Name: South Tech Business Park West
 Stream Reach ID: Site 1
 River Mile: 0.02

Aquatic Life Use: Class II PHWH
 Margin of Safety: 1.0

HABITAT TARGETS

Site-Specific QHEI Target Applicable?: No Yes Select
See Text. Based on reference reach.
 Values less than default target with Ohio EPA Permission only.

Site-Specific QHEI Target: 94.0
 Site-Specific QHEI Max: 90.0
See Text. Base on Regional Data

FLOODPLAIN COMPARISON WIDTHS

Reference Zones:	Width (ft)	Area (ac)
Full Streamway Width	108	4.09
Intermediate Zone	56	2.03
Core Zone	33	1.24
Vegetated Riparian Buffer Target	NA	NA
Minimum Vegetated Riparian Buffer	NA	NA
Vegetated Riparian Buffer Required:	No	
Minimum Frequently Flooded (%)	30%	
Minimum Frequently Flooded (acres)	1.24	

CALCULATED VALUES:

EXISTING CONDITION		PROPOSED CONDITION	
W_{bank} = Bankfull Width (ft)	10.8	W_{bank} = Bankfull Width (ft)	10.8
L = Channel Length (ft)	2,300	L = Channel Length (ft)	2,300
$A = (W_{bank} * L) / 43,560$ = Channel Area (acres)	0.57	$A = (W_{bank} * L) / 43,560$ = Channel Area (acres)	0.57
Default Target QHEI	NA		
Design Target QHEI	NA		

Site 1. South Tech Business Park

Constructed Design

FLOOD PRONE AREA CONDITION

FLOOD PRONE AREA (includes channel)

Gradient	Area (acres)	Width (ft)
Gradient < 2%		
Low Flood Prone Area	0.80	18
Intermediate Flood Prone Area	0.84	17
High Flood Prone Area	0.95	25
Gradient > 2%		
Total Flood Prone Area	2.59	

Flood Prone Area Soils Quality: Good

Flood Prone Soils Quality Factor: 1.0

A_1 = Adjusted Flood Prone Area: 0.9 (acres)

Alternative Using Same Footprint

FLOOD PRONE AREA (includes channel)

Gradient	Area (acres)	Width (ft)
Gradient < 2%		
Frequently Flooded Area	1.24	33
Intermediate Flooded Area	2.50	67
High Flooded Area	3.00	80
Gradient > 2%		
Total Flood Prone Area	7.74	

Flood Prone Area Soils Quality: Good

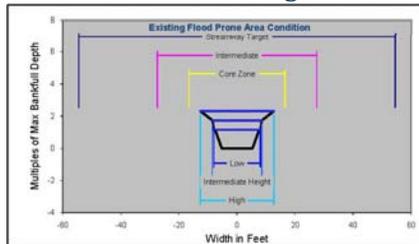
Flood Prone Soils Quality Factor: 1.0

A_2 = Adjusted Flood Prone Area: 2.8 (acres)

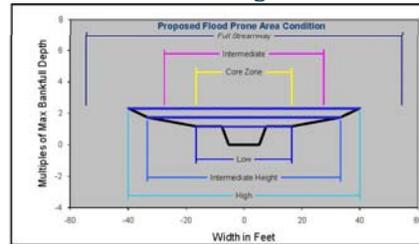
- Constructed design provides 0.9 acres after adjustment for elevation and proximity to the stream.
- Constructed design = 22% of the streamway target (4.1 acres).
 - The minimum for mitigation credit is 1.2 acres (30% of target) for the site.
- An alternative design within the same land area would provide flood prone acreage equivalent to 68% of the target (2.8 acres)

Site 1. South Tech Business Park

Stream Mitigation Model Output: Constructed Design



Alternative Design



Project: Spreadsheet Calibration
Stream Name: South Tech Business Park West
Stream Reach ID: Site 1
River Mile: 0.02

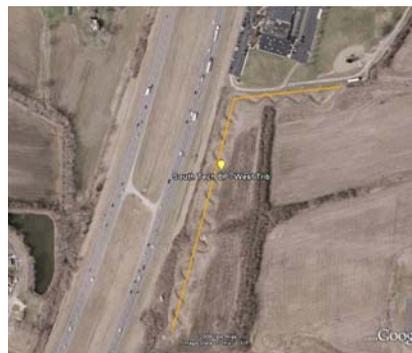
Note:

- ❑ Constructed design would not receive credit under the new stream mitigation protocol

Site 1 South Tech Business Center West Tributary

❑ Summary

- Land set aside as stream "buffer" is not connected with the stream except under very high flow conditions.
- Mitigation model guidelines would not have been met for the project.
- Stream mitigation model informed design could have provided over 3 times the functional flood prone area for the site with no additional buffer acreage.



Site 2 Estates at Hawthorne

Ohio EPA 401 ID: 052228
ACOE ID: (L) 200500113



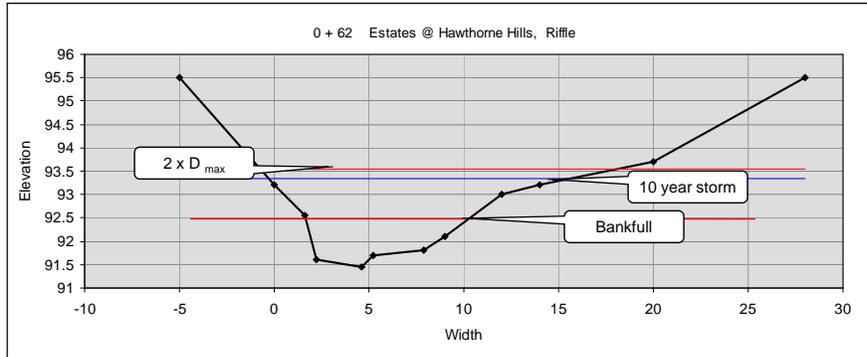
Site 2 Estates at Hawthorne

- ❑ Created channel constructed in 2006
- ❑ 850 foot reach of intermittent stream
- ❑ 2 stage channel design with 60 foot total width
- ❑ Drainage area = 54.4 acres
- ❑ Assumed to be Class II PHWH
 - Mitigation Category 2



Rod is at $2 \times D_{\max}$
and is equal to 30%
Target Width

Site 2 Estates at Hawthorne



Note that the 10 year storm is carried within the flood prone width of the channel

Site 2 Estates at Hawthorne

Stream Condition Targets for Replacement as Mitigation

Blue Cells are for Data Input Red Cells are Auto-Calculated

Project: Spreadsheet Calibration
 Stream Name: Estates at Hawthorne Hills ATF
 Stream Reach ID: Site 1
 River Mile: 0

HABITAT TARGETS

Site-Specific QHEI Target Applicable?: Yes No Select
See Text. Based on reference reach.
 Values less than default target with Ohio EPA Permission only.

Site-Specific QHEI Target: 95.0

Site-Specific QHEI Max: 90.0
See Text. Base on Regional Data

CALCULATED VALUES:

EXISTING CONDITION	
W_{max} = Bankfull Width (ft)	5.8
L = Channel Length (ft)	950
$A = (W_{max} * L) / 43,560$ = Channel Area (acres)	0.11
Default Target QHEI	NA
Design Target QHEI	NA

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Aquatic Life Use: Class I PHWH
 Margin of Safety: 1.0

FLOODPLAIN COMPARISON WIDTHS

Reference Zones	Width (ft)	Area (ac)
Full Streamway Width	58	1.07
Intermediate Zone	29	0.44
Core Zone	18	0.34
Vegetated Riparian Buffer Target	NA	NA
Minimum Vegetated Riparian Buffer	NA	NA

Vegetated Riparian Buffer Required? No

Minimum Frequently Flooded (%)	30%
Minimum Frequently Flooded (acres)	0.34

PROPOSED CONDITION

W_{max} = Bankfull Width (ft)	5.8
L = Channel Length (ft)	950
$A = (W_{max} * L) / 43,560$ = Channel Area (acres)	0.11

Site 2. Estates at Hawthorne

Constructed Design

FLOOD PRONE AREA (includes channel)

Gradient	Area (acres)	Width (ft)
Low Flooded Area	0.16	9
Intermediate Flooded Area	0.22	12
High Flooded Area	0.36	20
Total Flooded Area	0.74	41

Flood Prone Area Soils Quality: Good

Flood Prone Soils Quality Factor: 1.0

A₁ = Adjusted Flood Prone Area: 0.3 (acres)

Alternative Using Same Footprint

FLOOD PRONE AREA (includes channel)

Gradient	Area (acres)	Width (ft)
Frequently Flooded Area	0.50	27
Intermediate Flooded Area	0.75	41
High Flooded Area	1.00	54
Total Flooded Area	2.25	122

Flood Prone Area Soils Quality: Good

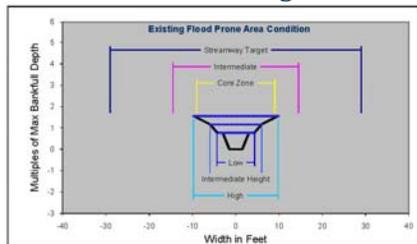
Flood Prone Soils Quality Factor: 1.0

A₂ = Adjusted Flood Prone Area: 0.9 (acres)

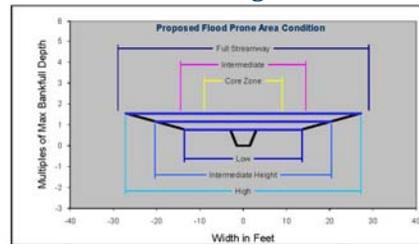
- ❑ Constructed design provides 0.3 acres after adjustment for elevation and proximity to the stream.
- ❑ Constructed design = 30% of the streamway target (1.1 acres)
 - Note : acreages rounded to nearest 0.1 acres
- ❑ An alternative design within the same land area would provide flood prone acreage equivalent to 80% of the target (0.9 acres)

Site 2. Estates at Hawthorne

Stream Mitigation Model Output: Constructed Design



Alternative Design



Project: Spreadsheet Calibration
 Stream Name: Estates at Hawthorne Hills ATF
 Stream Reach ID: Site 1
 River Mile: 0

Note:

- ❑ Constructed design is at the minimum threshold to receive credit under the new stream mitigation protocol

Site 2. Estates at Hawthorne



□ Summary

- The constructed channel meets the minimum design criteria for Mitigation Category 2 replacement (30% of streamway target)
- Note sediment deposition within the bankfull channel and lack of bank erosion.
- Function could have been enhanced by providing a wider flood prone area (0.9 acres vs. 0.3 acres)

Site 3 ODOT SUM-77-20.502 Ohio EPA 401 ID: 033874 ACOE ID: (H)200000142



Site 3 ODOT SUM-77-20.502

- Constructed in 2006
- 1,000 ft constructed 2 stage channel
 - Design includes riffles and sinuosity
- HHEI score = 56
- Class II PHWH, Mitigation Category 2



Site 3 ODOT SUM-77-20.502

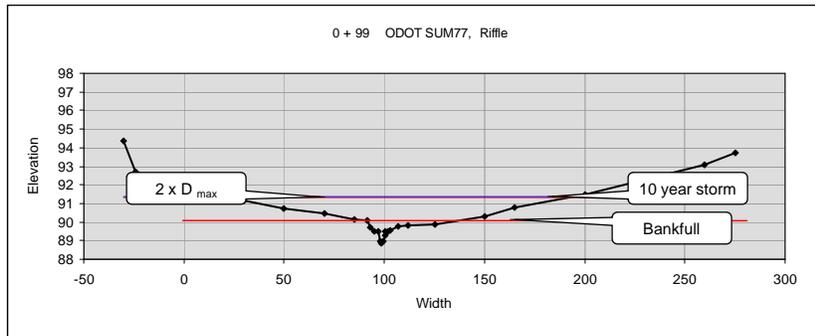
Current condition



Constructed Streamway



Site 3 ODOT SUM-77-20.502



- Notes:
 - The 10 year storm is carried within the flood prone width of the channel
 - The flood prone width is equivalent to 58% of the site

Site 3 ODOT SUM-77-20.502

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Blue Cells are for Data Input *Red Cells are Auto-Calculated*

Project: Spreadsheet calibration test
 Stream Name: ODOT SUM-77-20.502
 Stream Reach ID: Site 1
 River Mile: 0

Aquatic Life Use: Class II PHWH
 Margin of Safety: 1.0

HABITAT TARGETS

Site-Specific QHEI Target Applicable?: Yes No
See text. Based on reference reach. Values less than default target with Ohio EPA Permission only.

Site-Specific QHEI Target: 65.0
 Site-Specific QHEI Max: 80.0
See Text. Base on Regional Data

FLOODPLAIN COMPARISON WIDTHS

Reference Zone	Width (ft)	Area (ac)
Target Streamway Width	91	1.8
Intermediate Zone	46	0.9
Core Zone	28	0.6
Vegetated Riparian Buffer Target	NA	NA
Minimum Vegetated Riparian Buffer	NA	NA

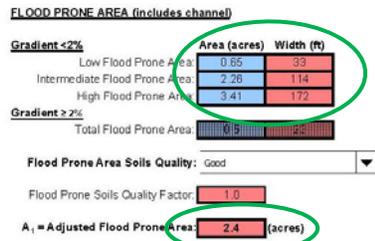
Vegetated Riparian Buffer Required? No
 Minimum Frequently Flooded (%): 30%
 Minimum Frequently Flooded (acres): 0.6

CALCULATED VALUES:

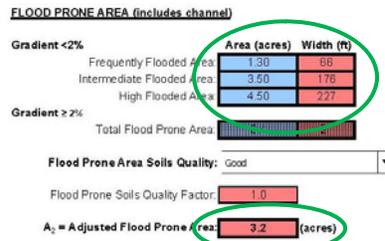
EXISTING CONDITION		PROPOSED CONDITION	
W_{bkf} = Bankfull Width (ft):	9.0	W_{bkf} = Bankfull Width (ft):	9.0
L = Channel Length (ft):	1,000	L = Channel Length (ft):	1,000
$A = (W_{bkf} * L) / 43,560$ = Channel Area (acres):	0.21	$A = (W_{bkf} * L) / 43,560$ = Channel Area (acres):	0.21
Default Target QHEI:	NA		
Design Target QHEI:	NA		

Site 3 ODOT SUM-77-20.502

Constructed Design



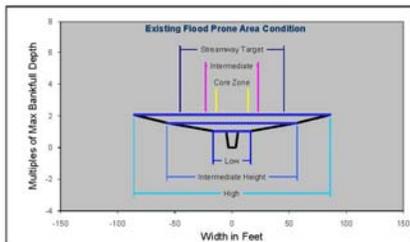
Alternative Using Same Footprint



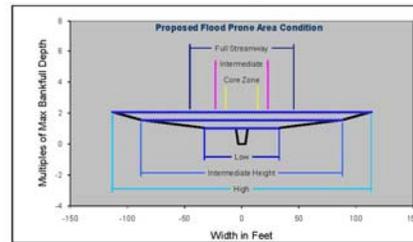
- Constructed design provides 2.4 acres after adjustment for elevation and proximity to the stream. Equivalent to 71% of the actual flood prone area (demonstrates adjustment for lateral distance and elevation)
- Constructed design = 133% of the streamway target (1.8 acres)
 - Note : acreages rounded to nearest 0.1 acres
- An alternative design within the same land area would provide flood prone acreage equivalent to 178% of the target (3.2 acres)

Site 3 ODOT SUM-77-20.502

Stream Mitigation Model Output: Constructed Design



Alternative Design



Project: Spreadsheet Calibration
 Stream Name: ODOT SUM-77-20.502
 Stream Reach ID: Site 1
 River Mile: 0

Notes:

- Constructed design is at 133% of the streamway target.
- Alternate design presented to indicate additional water quality benefit from using more of the available area for flood storage. The flood prone area could be enlarged an additional 33% within the same site footprint (3.2 acres vs. 2.4 acres)

Site 3 ODOT SUM-77-20.502

□ Summary

- The flood prone width provided in the constructed design exceeds the target streamway width. Project would meet the goals of the draft mitigation rule
- Soil characteristics may limit the success of riparian vegetation establishment
 - Note soil quality information was not available for this analysis
- Additional water quality benefit could have been realized with an enhanced design



Site 4 Upper Sandusky Reservoir Expansion Ohio EPA 401 ID: 010532 ACOE ID: (B)2000-01678(2)

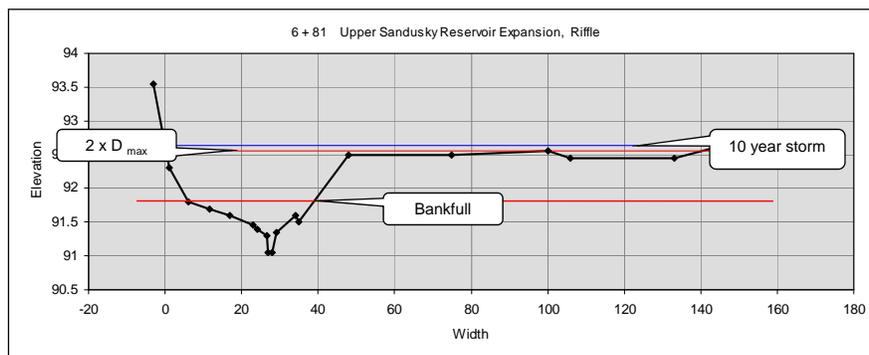


Site 4 Upper Sandusky Reservoir Expansion

- 1,200 feet of constructed channel to mitigate for 300 feet of impact
- Drainage area = 64 acres
- HHEI score = 59
 - Class II PHWH
 - Mitigation Category 2
- Constructed in 2002



Site 4 Upper Sandusky Reservoir Expansion



- Notes:
 - The streamway is 240% of the target and the entire flood prone width is inundated by the 10 year storm
 - 45% of the site is inundated by the 2 year storm

Site 4 Upper Sandusky Reservoir Expansion

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Stream Condition Targets for Replacement as Mitigation

Blue Cells are for Data Input **Red Cells are Auto-Calculated**

Project: Spreadsheet Calibration
 Stream Name: Upper Sandusky Reservoir Expansion
 Stream Reach ID: Site 1
 River Mile: 0

Aquatic Life Use: Class II PHVM
 Margin of Safety: 1.0

HABITAT TARGETS

Site-Specific QHEI Target Applicable?: Yes No Select
See Text. Based on reference reach.
 Values less than default target with Ohio EPA Permission only.

Site-Specific QHEI Target:
 Site-Specific QHEI Max:
See Text. Base on Regional Data

FLOODPLAIN COMPARISON WIDTHS

Reference Zones	Width (ft)	Area (ac)
Full Streamway Width	62	1.43
Intermediate Zone	31	0.72
Core Zone	16	0.44
Vegetated Riparian Buffer Target	NA	NA
Minimum Vegetated Riparian Buffer	NA	NA

Vegetated Riparian Buffer Required	No
Minimum Frequently Flooded (%)	30%
Minimum Frequently Flooded (acres)	0.44

CALCULATED VALUES:

EXISTING CONDITION		PROPOSED CONDITION	
W_{bank} = Bankfull Width (ft)	6.1	W_{bank} = Bankfull Width (ft)	6.1
L = Channel Length (ft)	1,200	L = Channel Length (ft)	1,200
$A = (W_{bank} * L) / 43,560$ = Channel Area (acres)	0.17	$A = (W_{bank} * L) / 43,560$ = Channel Area (acres)	0.17
Default Target QHEI	NA		
Design Target QHEI	NA		

Site 4 Upper Sandusky Reservoir Expansion

Constructed Design

FLOOD PRONE AREA (includes channel)

Gradient	Area (acres)	Width (ft)
Low Flood Prone Area	0.75	33
Intermediate Flood Prone Area	0.93	40
High Flood Prone Area	3.21	139
Total Flood Prone Area	4.89	192

Flood Prone Area Soils Quality: Good

Flood Prone Soils Quality Factor: 1.0

$A_1 = A$ Adjusted Flood Prone Area: 1.7 (acres)

Alternative Using Same Footprint

FLOOD PRONE AREA (includes channel)

Gradient	Area (acres)	Width (ft)
Frequently Flooded Area	1.20	62
Intermediate Flooded Area	2.00	87
High Flooded Area	3.21	139
Total Flood Prone Area	6.41	288

Flood Prone Area Soils Quality: Good

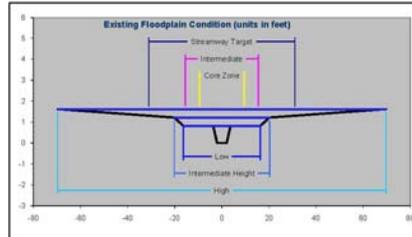
Flood Prone Soils Quality Factor: 1.0

$A_2 = A$ Adjusted Flood Prone Area: 2.2 (acres)

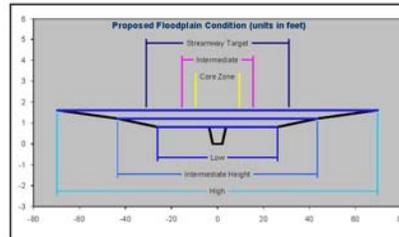
- Constructed design provides 1.7 acres after adjustment for elevation and proximity to the stream. Equivalent to 53% of the actual flood prone area (demonstrates adjustment for lateral distance and elevation)
- Constructed design = 121% of the streamway target (1.4 acres)
 - Note : acreages rounded to nearest 0.1 acres
- An alternative design within the same land area would provide flood prone acreage equivalent to 157% of the target (2.2 acres)

Site 4 Upper Sandusky Reservoir Expansion

Stream Mitigation Model Output: Constructed Design



Alternative Design



Project: Spreadsheet calibration test
Stream Name: Upper Sandusky Reservoir Expansion
Stream Reach ID: Site 1
River Mile: 0

Notes:

- Constructed design is at 121% of the streamway target.
- Alternate design presented to indicate additional water quality benefit from using more of the available area for flood storage. The flood prone area could be enlarged an additional 29% within the same site footprint (2.2 acres vs. 1.7 acres)

Site 4 Upper Sandusky Reservoir Expansion



- Summary
 - Constructed design meets the criteria for credit under the draft mitigation rule
 - Flood prone benefit could be significantly improved by increasing the effective flood prone area
 - This example: could increase the adjusted flood prone area at least 30% within the same footprint (2.2 acres vs. 1.7 acres)

Site 5 Legacy Village Development

Ohio EPA 401 ID: 010231

ACOE ID: (B) 2000-01699(3)

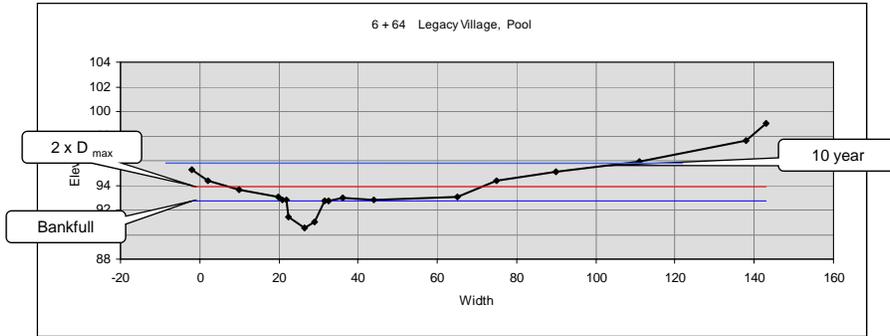


Site 5 Legacy Village Development



- ❑ Constructed in 2005
- ❑ Created 1,625 ft of new stream channel with an expanded floodplain
- ❑ Replaced existing man-made, partially culverted concrete flume
- ❑ Drainage area = 175 acres
- ❑ HHEI score = 56
 - Class II PHWH
 - Mitigation Category 2

Site 5 Legacy Village Development



- Notes:
 - The area inundated at bankfull stage is 50% of the streamway target
 - The flood prone area is 70% of the streamway target
 - However, the area of the protected site is 150% of the target streamway

Site 5 Legacy Village Development

Stream Condition Targets for Replacement as Mitigation Page 2

Blue Cells are for Data Input **Red Cells are Auto-Calculated**

Project: Spreadsheet Calibration
 Stream Name: Legacy Village
 Stream Reach ID: Site 1
 River Mile: 0

Aquatic Life Use: Class II PFWH
 Margin of Safety: 1.0

HABITAT TARGETS

Site-Specific QHEI Target Applicable?: Yes No Select
See text. Based on reference reach.
 Values less than default target with Ohio EPA Permission only.

Site-Specific QHEI Target:
 Site-Specific QHEI Max:
See Text. Base on Regional Data

FLOODPLAIN COMPARISON WIDTHS

Reference Zones:	Width (ft):	Area (ac)
Full Streamway Width:	90	2.52
Intermediate Zone:	45	1.26
Core Zone:	22.5	0.63
Vegetated Riparian Buffer Target:	NA	NA
Minimum Vegetated Riparian Buffer:	NA	NA

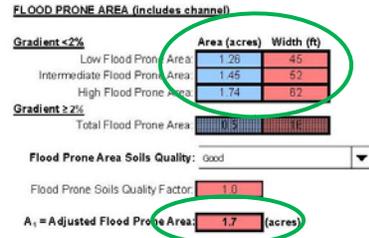
Vegetated Riparian Buffer Required: No Yes
 Minimum Frequently Flooded (%): 30%
 Minimum Frequently Flooded (acres): 0.76

CALCULATED VALUES:

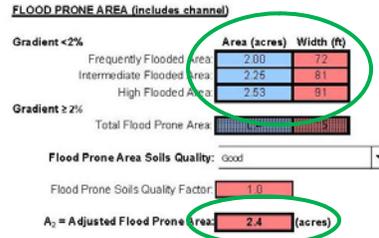
EXISTING CONDITION		PROPOSED CONDITION	
W_{max} = Bankfull Width (ft):	9.0	W_{max} = Bankfull Width (ft):	9.0
L = Channel Length (ft):	1,626	L = Channel Length (ft):	1,626
$A = (W_{max} * L) / 43,560$ = Channel Area (acres):	0.33	$A = (W_{max} * L) / 43,560$ = Channel Area (acres):	0.33
Default Target QHEI:	NA		
Design Target QHEI:	NA		

Site 5 Legacy Village Development

Constructed Design



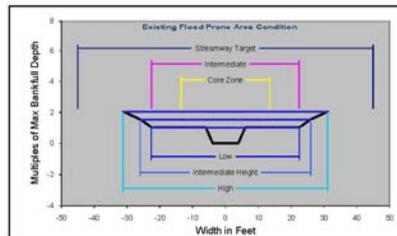
Alternative Using Same Footprint



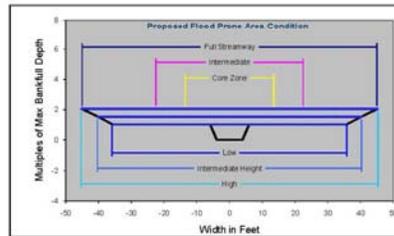
- ❑ Constructed design provides 1.7 acres after adjustment for elevation and proximity to the stream.
- ❑ Constructed design = 68% of the streamway target (2.5 acres) and would meet the criteria for mitigation credit
 - Note : acreages rounded to nearest 0.1 acres
- ❑ An alternative design within the same land area would provide flood prone acreage equivalent to 96% of the target (2.4 acres)

Site 5 Legacy Village Development

Stream Mitigation Model Output: Constructed Design



Alternative Design



Project: Spreadsheet Calibration
 Stream Name: Legacy Village
 Stream Reach ID: Site 1
 River Mile: 0

Notes:

- ❑ Constructed design is at 68% of the streamway target.
- ❑ Alternate design presented to indicate additional water quality benefit from using more of the available area for flood storage. The flood prone area could be enlarged an additional 41% within the same site footprint (2.4 acres vs. 1.7 acres)

Site 5 Legacy Village Development

□ Summary

- Constructed design meets the criteria for credit under the draft mitigation rule
- Note well adjusted, vegetated riparian area
- Flood prone benefit could be significantly improved by increasing the effective flood prone area
 - This example: could increase the adjusted flood prone area at least 41% within the same footprint (24 acres vs. 1.7 acres)



Conclusions

- The flood prone area model used in the proposed protocol can accurately predict and measure outcomes with respect to project design
- The approach utilized in the model has been used successfully at numerous sites throughout the state
- The model can be used to inform design alternatives that can provide additional water quality benefit during the antidegradation review process.