

# Environmental design features for large-scale nature-based solutions: Development of a framework that incorporates landscape dynamics into the design of nature-based solutions

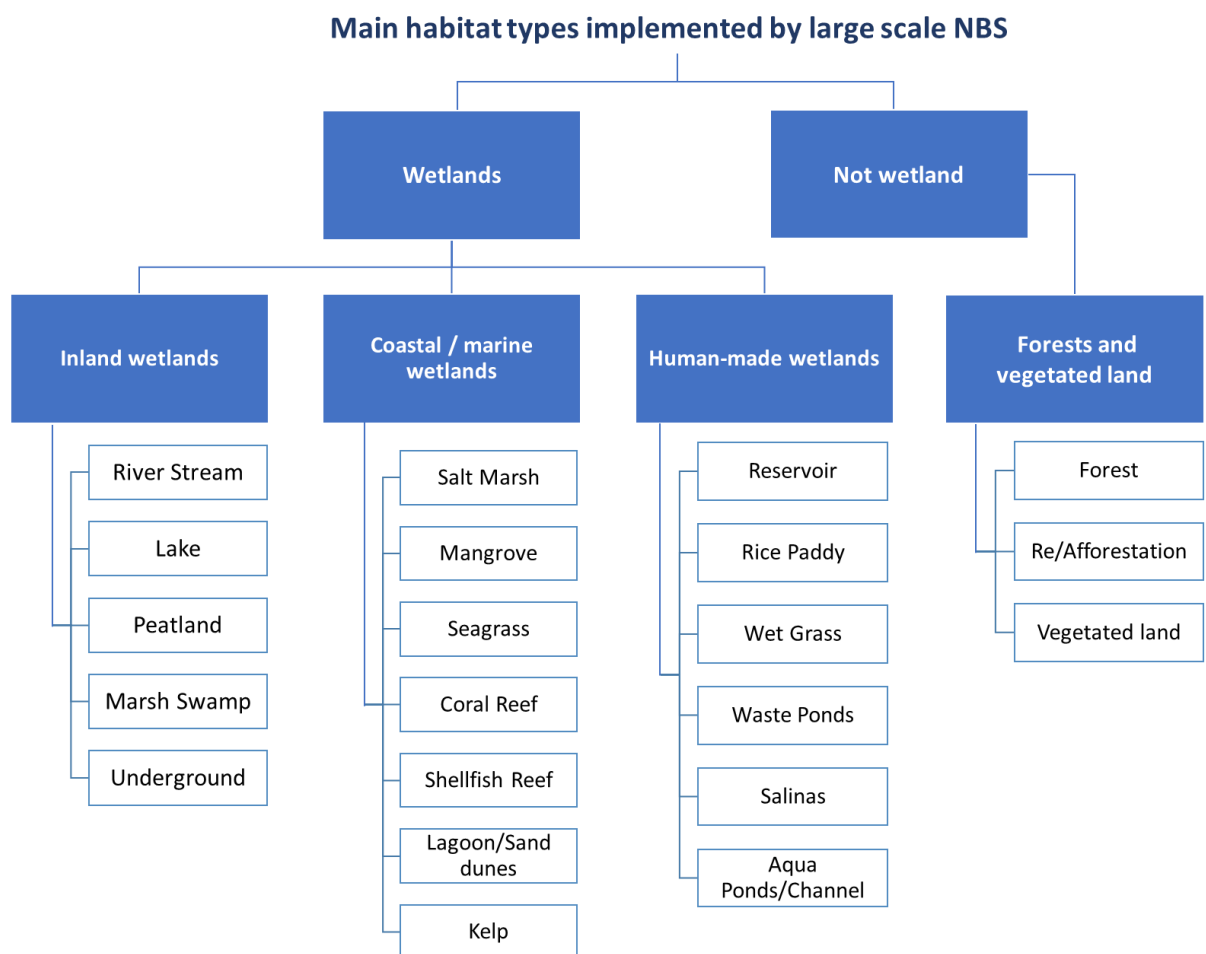
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## Supplementary materials:



**Figure S1.** The main habitat types covered by large-scale NBS [Source: 1,2,3].

**Table S1.** The effect of implementing large-scale NBS on different habitat types: inland wetlands.

No.	Solutions	Inland Wetlands				
		River	Lake	Peatland	Marsh Swamp	Underground
<b>1</b>	<b>Water Transport (room for the water)</b>					
1.1	Depoldering	+	+	+	+	+
1.2	Widening of water channels	+	+	N/A	+	+
1.3	Deepening water channels	+	+	N/A	-	+
1.4	Lowering groynes	+	N/A	N/A	+	N/A
1.5	Removing obstacles	+	N/A	N/A	N/A	N/A
1.6	Bypass/diversion channels	+	N/A	N/A	N/A	N/A
1.7	Re-meandering and reconnection of oxbow lakes and similar features	+	N/A	N/A	N/A	N/A
<b>2</b>	<b>Water Storage</b>					
2.1	Floodplain excavation/enlargement/restoration	+	+	+	+	+
2.2	Dike removal/relocation	+	+	+	+	+
2.3	Retention ponds	+	+	N/A	N/A	+/-
2.4	Rainwater harvesting	+	+	+	+	+
2.5	Wetland restoration/enhancement	+	+	+	+	+
2.6	Detention basins	+	+	+	+	+
2.7	Rain gardens/bio-retention area	+	+	+	+	+
2.8	Artificial wetlands	+	+	+	+	+
2.9	Stormwater detention tank	N/A	N/A	N/A	N/A	+/-
<b>3</b>	<b>Conveyance and Drainage Systems</b>					
3.1	Open water channels and rills	+	+	+	+	+
3.2	Vegetated ditches/dry swale	N/A	N/A	N/A	N/A	+
3.3	Bio swales	N/A	N/A	N/A	N/A	+
3.4	Wetland channel (wet swale)	N/A	N/A	+	+	+
<b>4</b>	<b>Source Control</b>					
4.1	Extensive green roofs	N/A	N/A	N/A	N/A	N/A
4.2	Intensive green roofs	N/A	N/A	N/A	N/A	N/A
4.3	Green streetscape	N/A	N/A	N/A	N/A	N/A
4.4	Green walls	N/A	N/A	N/A	N/A	N/A
4.5	Green deculverting	N/A	N/A	N/A	N/A	N/A
4.6	Greening waterfronts	N/A	N/A	N/A	N/A	N/A
4.7	Permeable pavements	N/A	N/A	N/A	N/A	+
4.8	Urban trees/parks	N/A	N/A	N/A	N/A	N/A
4.9	Forests and naturally vegetated land	+	+	N/A	N/A	+
4.10	Re/Afforestation and forest conservation	+	+	N/A	N/A	+/-
<b>5</b>	<b>Infiltration Techniques</b>					
5.1	Restoration of nature infiltration to groundwater	+	+	+	+	+
5.2	Infiltration trenches	N/A	N/A	N/A	N/A	+
5.3	Infiltration basin/surface	N/A	N/A	N/A	N/A	+
5.4	Filter trenches	N/A	N/A	N/A	N/A	+
5.5	Filter drain	N/A	N/A	N/A	N/A	+
5.6	Filter strips	N/A	N/A	N/A	N/A	+
5.7	Soakways	N/A	N/A	N/A	N/A	+
<b>6</b>	<b>Coastal Protection</b>					
6.1	Sand engine	N/A	N/A	N/A	N/A	+
6.2	Alkborough flats	N/A	N/A	N/A	+	N/A
6.3	Rehabilitation of oyster reefs	N/A	N/A	N/A	N/A	N/A
6.4	Groynes	-	N/A	N/A	N/A	N/A
6.5	Rich revetments	N/A	N/A	N/A	N/A	N/A
6.6	Rehabilitation of seagrass	N/A	N/A	N/A	N/A	N/A
6.7	Rehabilitation of mangroves	N/A	N/A	N/A	N/A	N/A
6.8	Creation of beaches and dunes	N/A	N/A	N/A	N/A	+
6.9	Living breakwaters	N/A	N/A	N/A	N/A	N/A
6.10	Rehabilitation of coral reefs	N/A	N/A	N/A	N/A	N/A
6.11	Rehabilitation of coastal marshes	N/A	N/A	N/A	N/A	N/A

+	Positive impact
-	Negative impact
N/A	Not applicable (neutral)
+/-	Mixed impact

**Table S2.** The effect of implementing large-scale NBS on different habitat types: coastal/marine wetlands.

No.	Solutions	Coastal/Marine Wetlands					
		Salt Marsh	Mangrove	Sea-grass	Coral Reef	Shellfish Reef	Lagoon/Sand dunes
<b>1</b>	<b>Water Transport (room for the water)</b>						
1.1	Depoldering	+	+	+	+	+	N/A
1.2	Widening of water channels	N/A	N/A	N/A	N/A	N/A	N/A
1.3	Deepening water channels	N/A	N/A	N/A	N/A	N/A	N/A
1.4	Lowering groynes	N/A	N/A	N/A	N/A	N/A	N/A
1.5	Removing obstacles	N/A	N/A	N/A	N/A	N/A	N/A
1.6	Bypass/diversion channels	N/A	N/A	N/A	N/A	N/A	N/A
1.7	Re-meandering and reconnection of oxbow lakes and similar features	N/A	N/A	N/A	N/A	N/A	N/A
<b>2</b>	<b>Water Storage</b>						
2.1	Floodplain excavation/enlargement/restoration	+	+	+	+	+	N/A
2.2	Dike removal/relocation	+	+	+	+	+	N/A
2.3	Retention ponds	N/A	N/A	N/A	N/A	N/A	N/A
2.4	Rainwater harvesting	N/A	N/A	N/A	N/A	N/A	N/A
2.5	Wetland restoration/enhancement	+	+	+	+	+	+
2.6	Detention basins	+	+	+	+	+	N/A
2.7	Rain gardens/bio-retention area	N/A	N/A	N/A	N/A	N/A	N/A
2.8	Artificial wetlands	+	+	+	+	+	+
2.9	Stormwater detention tank	N/A	N/A	N/A	N/A	N/A	N/A
<b>3</b>	<b>Conveyance and Drainage Systems</b>						
3.1	Open water channels and rills	+	N/A	N/A	N/A	N/A	+
3.2	Vegetated ditches/dry swale	N/A	N/A	N/A	N/A	N/A	N/A
3.3	Bio swales	N/A	N/A	N/A	N/A	N/A	N/A
3.4	Wetland channel (wet swale)	+	N/A	N/A	N/A	N/A	+
<b>4</b>	<b>Source Control</b>						
4.1	Extensive green roofs	N/A	N/A	N/A	N/A	N/A	N/A
4.2	Intensive green roofs	N/A	N/A	N/A	N/A	N/A	N/A
4.3	Green streetscape	N/A	N/A	N/A	N/A	N/A	N/A
4.4	Green walls	N/A	N/A	N/A	N/A	N/A	N/A
4.5	Green deculverting	N/A	N/A	N/A	N/A	N/A	N/A
4.6	Greening waterfronts	N/A	N/A	N/A	N/A	N/A	N/A
4.7	Permeable pavements	N/A	N/A	N/A	N/A	N/A	N/A
4.8	Urban trees/parks	N/A	N/A	N/A	N/A	N/A	N/A
4.9	Forests and naturally vegetated land	N/A	N/A	N/A	N/A	N/A	N/A
4.10	Re/Afforestation and forest conservation	N/A	N/A	N/A	N/A	N/A	N/A
<b>5</b>	<b>Infiltration Techniques</b>						
5.1	Restoration of nature infiltration to groundwater	+	N/A	N/A	N/A	N/A	+
5.2	Infiltration trenches	+	N/A	N/A	N/A	N/A	+
5.3	Infiltration basin/surface	+	N/A	N/A	N/A	N/A	+
5.4	Filter trenches	N/A	N/A	N/A	N/A	N/A	N/A
5.5	Filter drain	N/A	N/A	N/A	N/A	N/A	N/A
5.6	Filter strips	N/A	N/A	N/A	N/A	N/A	N/A
5.7	Soakaways	N/A	N/A	N/A	N/A	N/A	N/A
<b>6</b>	<b>Coastal Protection</b>						
6.1	Sand engine	N/A	N/A	+	N/A	N/A	+
6.2	Alkborough flats	+	N/A	+	N/A	N/A	+
6.3	Rehabilitation of oyster reefs	+	N/A	N/A	N/A	+	+
6.4	Groynes	N/A	-	N/A	-	-	N/A
6.5	Rich revetments	N/A	+	+	+	+	+
6.6	Rehabilitation of seagrass	N/A	N/A	+	N/A	N/A	N/A
6.7	Rehabilitation of mangroves	N/A	+	N/A	N/A	N/A	N/A
6.8	Creation of beaches and dunes	N/A	N/A	N/A	N/A	N/A	+
6.9	Living breakwaters	N/A	N/A	N/A	+	+	+
6.10	Rehabilitation of coral reefs	N/A	N/A	N/A	+	N/A	+
6.11	Rehabilitation of coastal marshes	+	N/A	+	N/A	N/A	N/A

**Table S3.** The effect of implementing large-scale NBS on different habitat types: human-made wetlands.

No.	Solutions	Human-made wetlands					Aqua Ponds/ Channel
		Reservoir	Rice Paddy	Wet Grass	Waste Ponds	Salinas	
<b>1</b>	<b>Water Transport (room for the water)</b>						
1.1	Depoldering	N/A	N/A	N/A	N/A	N/A	+
1.2	Widening of water channels	N/A	N/A	N/A	N/A	N/A	+
1.3	Deepening water channels	N/A	N/A	N/A	N/A	N/A	+
1.4	Lowering groynes	N/A	N/A	N/A	N/A	N/A	N/A
1.5	Removing obstacles	N/A	N/A	N/A	N/A	N/A	N/A
1.6	Bypass/diversion channels	N/A	N/A	N/A	N/A	N/A	N/A
1.7	Re-meandering and reconnection of oxbow lakes and similar features	N/A	N/A	+	N/A	N/A	+
<b>2</b>	<b>Water Storage</b>						
2.1	Floodplain excavation/enlargement/restoration	N/A	+	+	N/A	N/A	+
2.2	Dike removal/relocation	N/A	+	+	N/A	N/A	+
2.3	Retention ponds	N/A	+	+	N/A	N/A	+
2.4	Rainwater harvesting	+	+	+	N/A	N/A	+
2.5	Wetland restoration/enhancement	+	+	+	+	+	+
2.6	Detention basins	+	+	+	N/A	N/A	+
2.7	Rain gardens/bio-retention area	N/A	N/A	+	N/A	N/A	+
2.8	Artificial wetlands	+	+	+	+	+	+
2.9	Stormwater detention tank	+	N/A	N/A	N/A	N/A	+
<b>3</b>	<b>Conveyance and Drainage Systems</b>						
3.1	Open water channels and rills	+	+	+	N/A	+	+
3.2	Vegetated ditches/dry swale	N/A	N/A	+	N/A	N/A	N/A
3.3	Bio swales	+	+	+	N/A	+	+
3.4	Wetland channel (wet swale)	+	+	+	+	+	+
<b>4</b>	<b>Source Control</b>						
4.1	Extensive green roofs	N/A	N/A	N/A	N/A	N/A	N/A
4.2	Intensive green roofs	N/A	N/A	N/A	N/A	N/A	N/A
4.3	Green streetscape	N/A	N/A	N/A	N/A	N/A	N/A
4.4	Green walls	N/A	N/A	N/A	N/A	N/A	N/A
4.5	Green deculverting	N/A	N/A	N/A	N/A	N/A	N/A
4.6	Greening waterfronts	N/A	N/A	+	N/A	N/A	+
4.7	Permeable pavements	N/A	N/A	N/A	N/A	N/A	N/A
4.8	Urban trees/parks	N/A	N/A	N/A	N/A	N/A	N/A
4.9	Forests and naturally vegetated land	N/A	N/A	N/A	N/A	N/A	N/A
4.10	Re/Afforestation and forest conservation	N/A	N/A	N/A	N/A	N/A	N/A
<b>5</b>	<b>Infiltration Techniques</b>						
5.1	Restoration of nature infiltration to groundwater	+	+	+	N/A	+	+
5.2	Infiltration trenches	+	+	+	N/A	+	+
5.3	Infiltration basin/surface	+	+	+	N/A	+	+
5.4	Filter trenches	N/A	N/A	N/A	+	N/A	+
5.5	Filter drain	N/A	N/A	N/A	+	N/A	+
5.6	Filter strips	N/A	N/A	N/A	+	N/A	+
5.7	Soakaways	N/A	N/A	N/A	+	N/A	+
<b>6</b>	<b>Coastal Protection</b>						
6.1	Sand Engine	N/A	N/A	N/A	N/A	N/A	+/-
6.2	Alkborough flats	N/A	N/A	N/A	N/A	N/A	N/A
6.3	Rehabilitation of oyster reefs	N/A	N/A	N/A	N/A	N/A	N/A
6.4	Groynes	N/A	N/A	N/A	N/A	N/A	N/A
6.5	Rich revetments	N/A	N/A	N/A	N/A	N/A	+
6.6	Rehabilitation of seagrass	N/A	N/A	N/A	N/A	N/A	N/A
6.7	Rehabilitation of mangroves	N/A	N/A	N/A	N/A	N/A	N/A
6.8	Creation of beaches and dunes	N/A	N/A	N/A	N/A	N/A	N/A
6.9	Living breakwaters	N/A	N/A	N/A	N/A	N/A	N/A
6.10	Rehabilitation of coral reefs	N/A	N/A	N/A	N/A	N/A	N/A
6.11	Rehabilitation of coastal marshes	N/A	N/A	N/A	N/A	N/A	N/A

**Table S4.** The effect of implementing large-scale NBS on different habitat types: forests and vegetated land.

No.	Solutions	Forests and Vegetated Land		
		Forest	Re/Afforestation	Vegetated Land
<b>1</b>	<b>Water Transport (room for the water)</b>			
1.1	Depoldering	N/A	N/A	+/-
1.2	Widening of water channels	N/A	N/A	N/A
1.3	Deepening water channels	N/A	N/A	N/A
1.4	Lowering groynes	N/A	N/A	N/A
1.5	Removing obstacles	N/A	N/A	N/A
1.6	Bypass/diversion channels	N/A	N/A	N/A
1.7	Re-meandering and reconnection of oxbow lakes and similar features	N/A	N/A	N/A
<b>2</b>	<b>Water Storage</b>			
2.1	Floodplain excavation/enlargement/restoration	N/A	N/A	N/A
2.2	Dike removal/relocation	N/A	N/A	+/-
2.3	Retention ponds	N/A	N/A	N/A
2.4	Rainwater harvesting	N/A	N/A	N/A
2.5	Wetland restoration/enhancement	N/A	N/A	N/A
2.6	Detention basins	N/A	N/A	N/A
2.7	Rain gardens/bio-retention area	N/A	N/A	N/A
2.8	Artificial wetlands	N/A	N/A	N/A
2.9	Stormwater detention tank	N/A	N/A	N/A
<b>3</b>	<b>Conveyance and Drainage Systems</b>			
3.1	Open water channels and rills	N/A	N/A	N/A
3.2	Vegetated ditches/dry swale	+	+	+
3.3	Bio swales	+	+	+
3.4	Wetland channel (wet swale)	N/A	N/A	N/A
<b>4</b>	<b>Source Control</b>			
4.1	Extensive green roofs	N/A	N/A	+
4.2	Intensive green roofs	N/A	N/A	+
4.3	Green streetscape	N/A	N/A	+
4.4	Green walls	N/A	N/A	+
4.5	Green deculverting	N/A	N/A	+
4.6	Greening waterfronts	N/A	N/A	+
4.7	Permeable pavements	+	+	+
4.8	Urban trees/parks	N/A	+	+
4.9	Forests and naturally vegetated land	+	N/A	+
4.10	Re/Afforestation and forest conservation	N/A	+	+
<b>5</b>	<b>Infiltration Techniques</b>			
5.1	Restoration of nature infiltration to groundwater	+	+	+
5.2	Infiltration trenches	+	+	+
5.3	Infiltration basin/surface	+	+	+
5.4	Filter trenches	N/A	N/A	N/A
5.5	Filter drain	N/A	N/A	N/A
5.6	Filter strips	N/A	N/A	N/A
5.7	Soakaways	N/A	N/A	N/A
<b>6</b>	<b>Coastal Protection</b>			
6.1	Sand engine	N/A	N/A	N/A
6.2	Alkborough flats	N/A	N/A	N/A
6.3	Rehabilitation of oyster reefs	N/A	N/A	N/A
6.4	Groynes	N/A	N/A	N/A
6.5	Rich revetments	N/A	N/A	N/A
6.6	Rehabilitation of seagrass	N/A	N/A	N/A
6.7	Rehabilitation of mangroves	N/A	N/A	N/A
6.8	Creation of beaches and dunes	N/A	N/A	N/A
6.9	Living breakwaters	N/A	N/A	N/A
6.10	Rehabilitation of coral reefs	N/A	N/A	N/A
6.11	Rehabilitation of coastal marshes	N/A	N/A	N/A

**Table S5.** Sum of scores and next steps of action.

<b>Feedback</b>	<b>Sum of scores</b>	<b>Next step of action</b>
Strongly disagree	I: General comment: 2 (scores) II. Comment for Step 1: 4 II. Comment for Step 2: 5	To analyze the main reason, take corrective action, and revise the framework based on the comments received from the stakeholders.
Disagree	I: General comment: 3–5 II. Comment for Step 1: 5–11 II. Comment for Step 2: 6–14	To analyze the main reason and revise the framework based on the comments received from the stakeholders.
Neutral	I: General comment: 6 II. Comment for Step 1: 12 II. Comment for Step 2: 15	To analyze the possible reasons. One reason could be that the explanation or introduction was not clear. Another reason could be that the interviewees are unable to give valuable answers because they do not have the required knowledge about the study area.
Agree	I: General comment: 7–9 II. Comment for Step 1: 13–19 II. Comment for Step 2: 16–24	To analyze the main reason and improve the framework based on the comments received from the stakeholders.
Strongly agree	I: General comment: 10 II. Comment for Step 1: 20 II. Comment for Step 2: 25	No need for any corrective action.

## References

1. World Bank. *World Bank Implementing Nature-Based Flood Protection: Principles and Implementation Guidance*; World Bank: Washington, DC, USA, 2017.
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