Wetland Ecosystem Services Workshop

Bauhaus-Universität Weimar

April 25-27, 2024

Establishment, management, and monitoring

Workshop description: Wetlands are rich and diverse landscapes in the water-land interphase. They provide many ecosystem services to people as well as habitats to flora and fauna. Created wetland is a term used for newly built wetlands which are designed to provide both multiple ecosystem services and habitats supporting high biodiversity. We will study the theory behind and learn the design process of created wetlands. To enrich the learning experience, and to support the planet one wetland at a time, we will design and hands-on implement a small new created wetland as a piece of living environmental art.

Outi Wahlroos

outi@palustrine.fi

Urbanization – the challenge

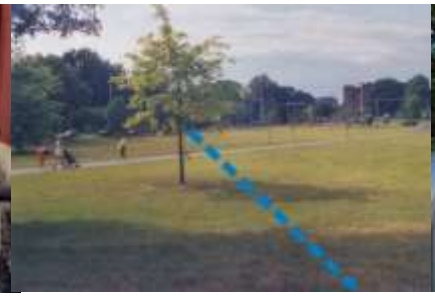
Invisible and altered watershed boundaries

Land-use, land cover

Wetlands

Erosion, draught, low biodiversity, invasive species, flooding, lower groundwater levels, losing connectivity to waterways, water quality

Urban streams



Stormwater reuse or irrigation?

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Ecosystem services created at stormwater wetland parks

Ecosystem services by The Economics of Ecosystems & Biodiversity (TEEB)

1) **Provisioning services** (source of materials or energy)

2) **Regulating services** (state of the environment and natural processes)

3) **Cultural services** (interactive)

4) **Habitat- or supporting services** (maintaining diversity)

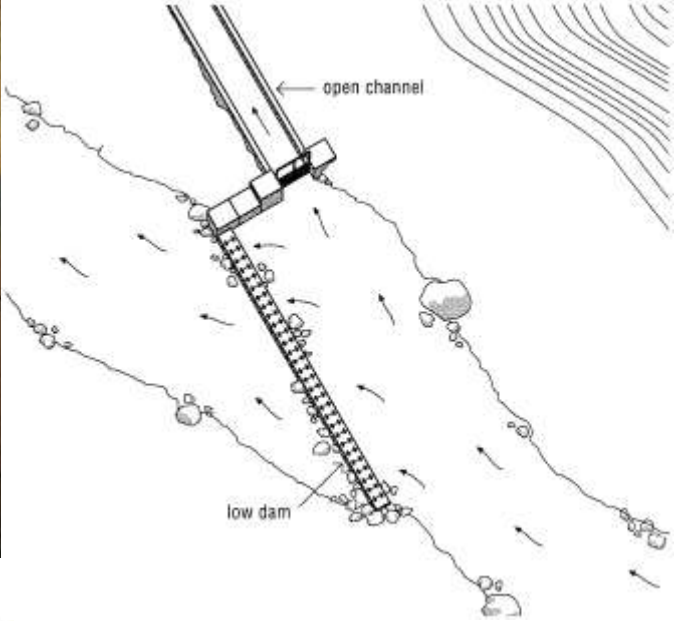
1) Biomass production; hunting, fishing and crayfish catching; berry picking; irrigation water

2) Impacts on microclimate; carbon binding; nutrient uptake; flow&flood control, water quality treatment; erosion control; reducing pathogens

3) Recreation and nature experiences, environmental education, view; source of artistic inspiration and scientific knowledge; builder and enhancer of sense of place

4) Increasing diversity of flora and fauna; increased resilience of environmental change such as flow extremes in urban streams; diverse flora is functional and beautiful every year and season regardless of weather and pest extremes; supporting pollinators

Past and present



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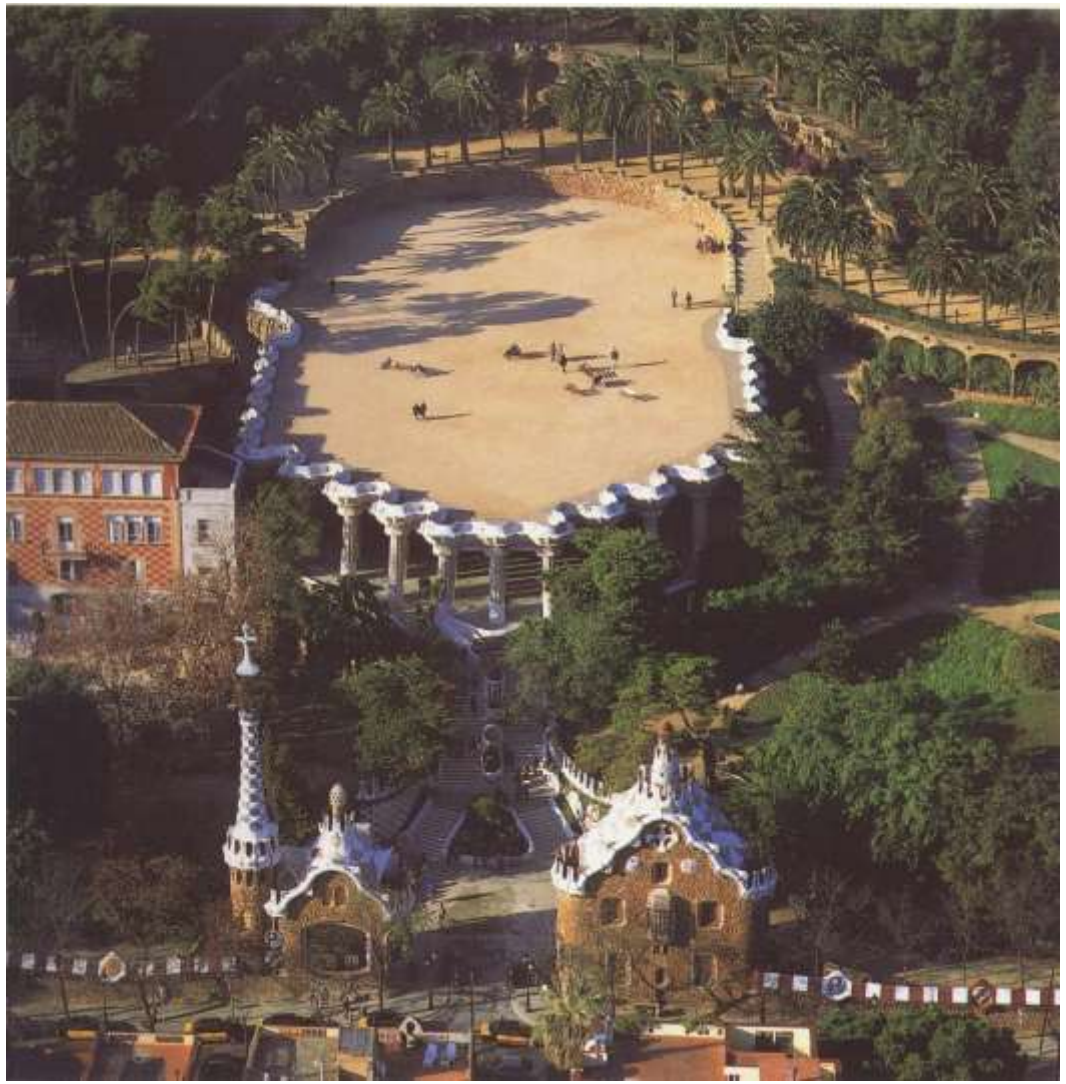
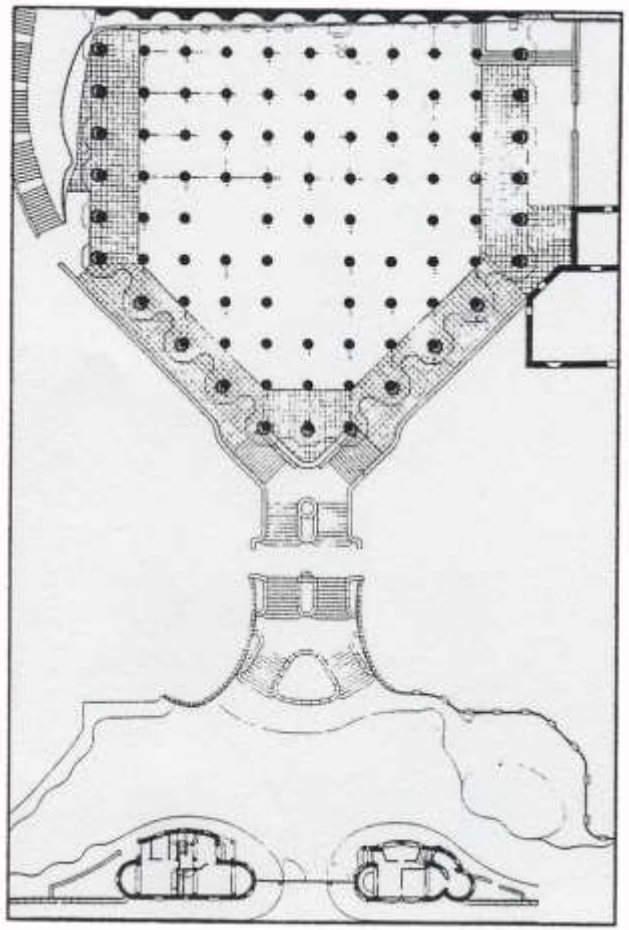
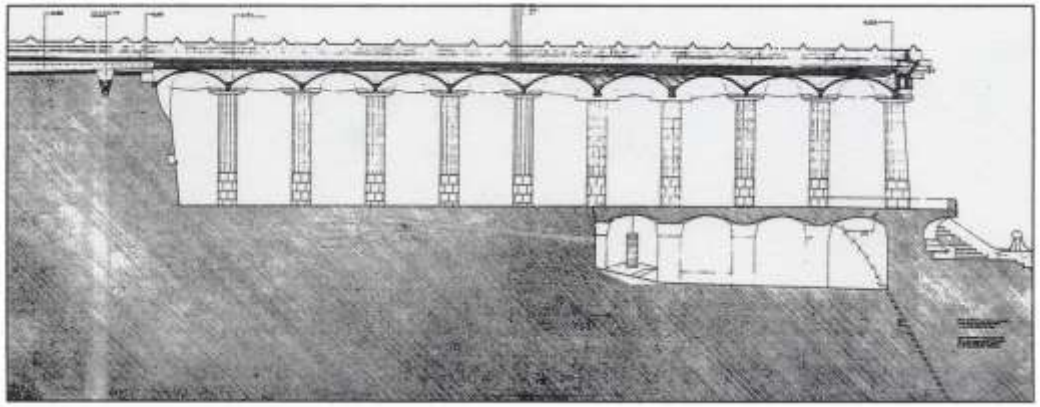
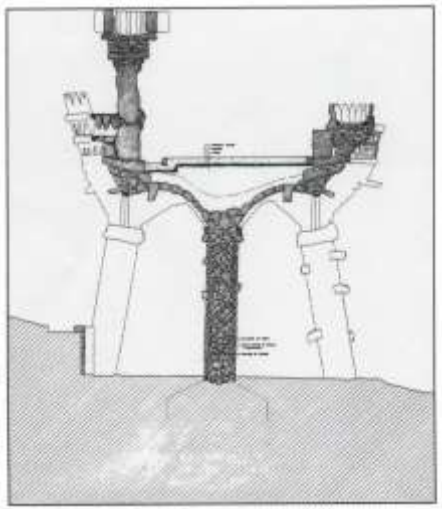
Barcelona 1900-1914, Modernismo, Antoni Gaudi y Cornet, Park Güell



Barcelona 1900-1914, Antoni Gaudi y Cornet, Park Güell
A garden city; stormwater collection – purification – use;
local materials, local shapes







Stormwater management landscaping

- What if? The site (genius loci), the climate

- Watersheds have changed -> hydraulic design, not restoration

- Diverse and healthy plant provides services and tolerates the stress of water level fluctuations -> natives

- ”Soil works 90-100%, planting 0-10%” (self-establishment)

Acceptance of nature

”A wetland? This used to all be wetland, terrible. Now it is all developed.”

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A Peatland – not..

Design scale? Entire watershed the best…

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Creating Urban Oases

Challenge: Urban runoff

Watershed and land-use matter

Employ plants and microbes

Design and implement

Monitor and improve

Share the joy of neighborhood wetlands

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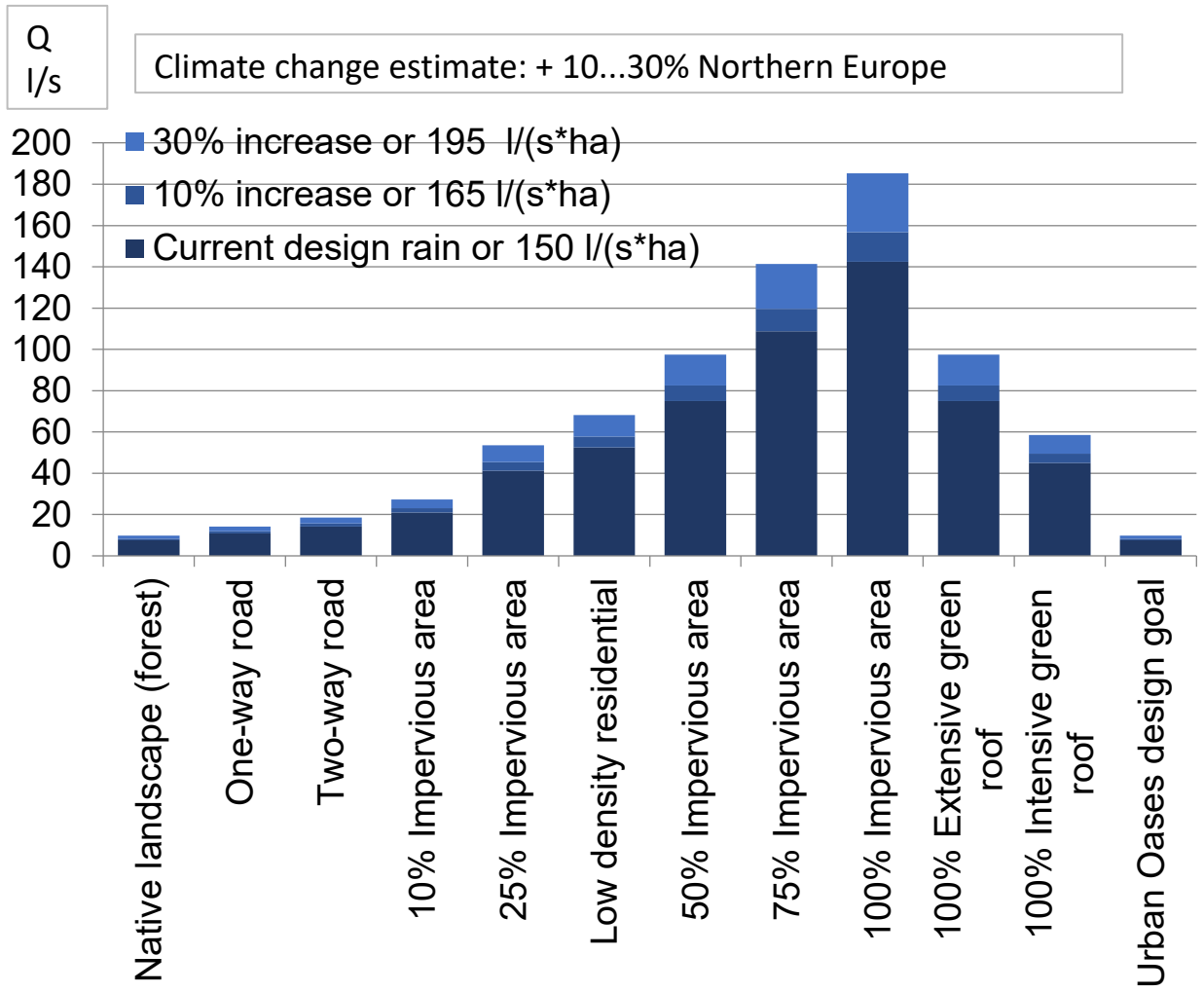
Design process

- **Goals** → Set goals, review after site and watershed analysis
- **Site analysis and watershed analysis** → Land-use, topography, climate, soil type, land cover, water quantity&quality
- **Conceptual plan** → What interventions, how are linked together
- **Design draft** → Review draft with stakeholders
- **Implementation design** → Details ready for construction
- **Implementation** → Meetings with constructor
- **Monitoring** → Monitor for set goals
- **Maintenance** → Maintain goals and ***allow site succession***

Challenge:

Urbanization & climate change: Flow ↑ -> Quality ↓



CLIMATE CHANGE: Global scale

LAND-USE CHANGE: Watershed scale

COMPENSATING STRUCTURES: Local scale

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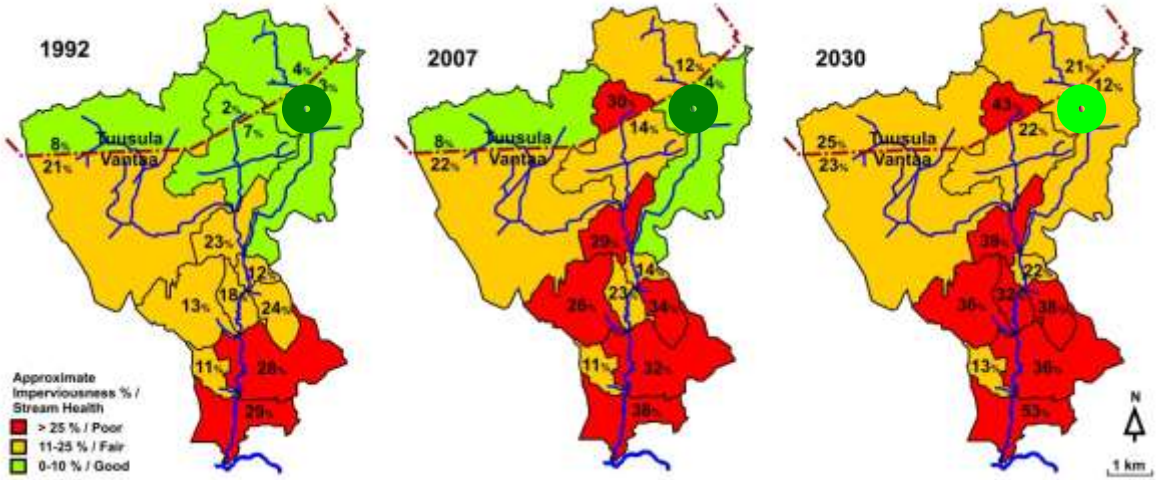
Challenge: imperviousness

Watershed scale and natural processes as a reference for city planning and site design

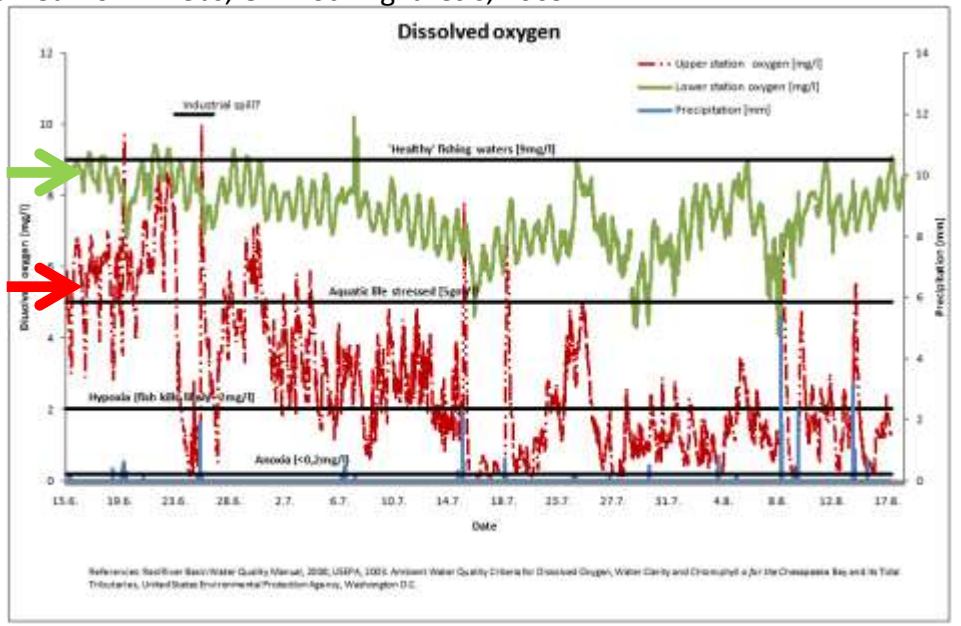
© Map: Vantaan kaupungin mittausosasto 2011



Watershed imperviousness, modified from: Krebs, G. M.Sc.Eng. thesis, 2009.

BIO: Tiensuu, M. M.Sc. thesis, UH, 2008.
Water quality: Taylor, A. M.Sc. thesis, 2012.

Upstream → Municipality border Wetland →



Protect nature types in urban development
- Know what to protect
- Know how to protect

Wetlands are used for many purposes in urban areas

Treated wastewater to re-introduce groundwater, parks

Floating wetlands: water quality and habitat

Habitat and education

Wastewater treatment

Stormwater management

Habitat, stormwater, view

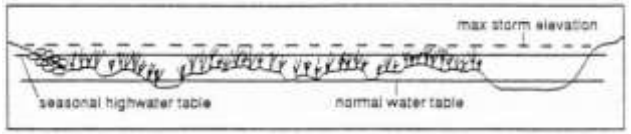
Stormwater wetland or swale

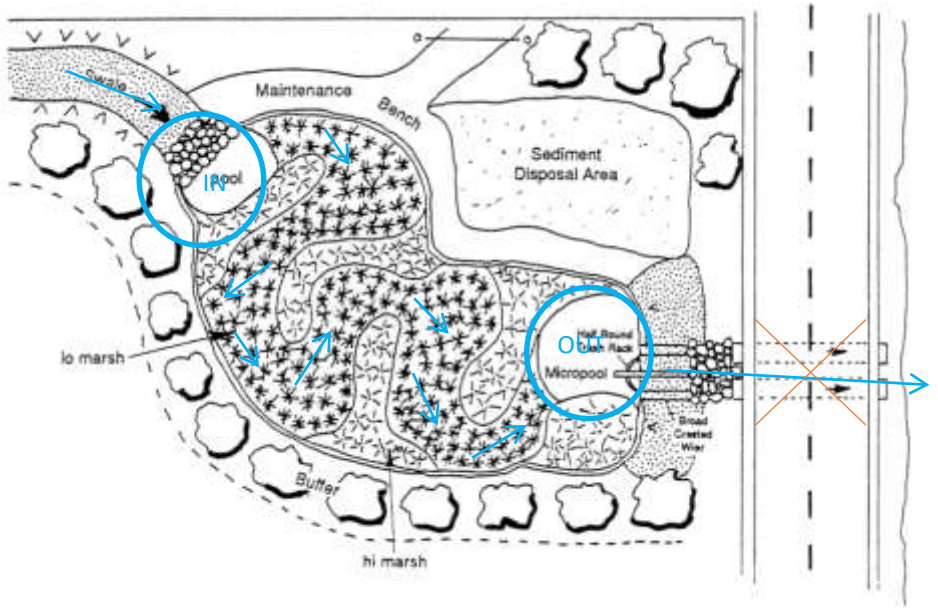
Inflow stilling pond (coarse solids) – shallow treatment train (soluble and fine solids) – outflow pond (withered plants)

Important:

- ➔ increase retention time
- ➔ meandering not necessary, depends on wetland shape
- ➔ outlet dam controls water level and retention: bottom dam usually best, avoid pipes

Varying microtopography
-> biodiversity
-> N x treatment





Graphs: 1980´s Center for Watershed protection, Tom Schueler *at al*.

Stormwater swales: open water conveyance structures,

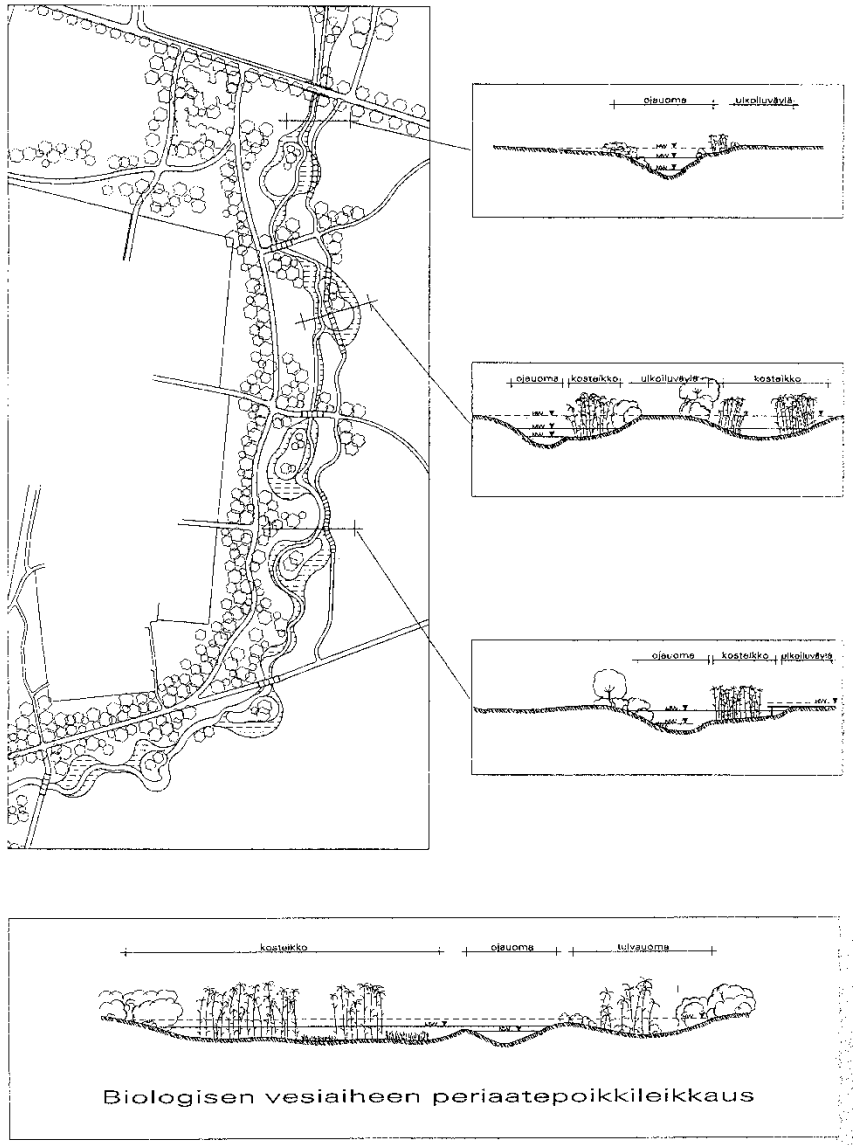
more ecosystem services

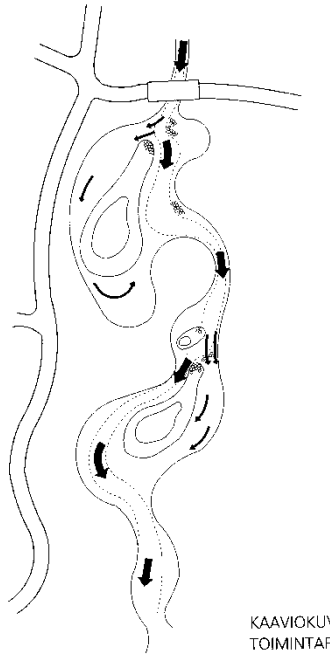
with more vegetation

Case: Viikki ecovillage

Water protection built 1999-2004

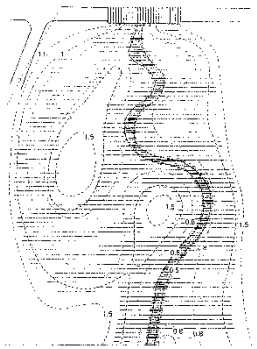
Viikki
Intended Naturnacher stream





KAAVIOKUVA VESIUOMAN
TOIMINTAPERIAATTEESTA

PÄÄVIRTAUS
SIVU- JA TULVAVIRTAUS



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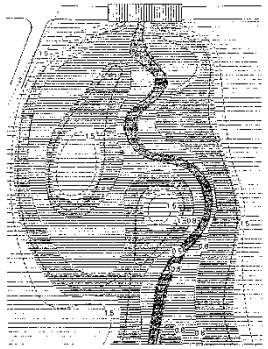
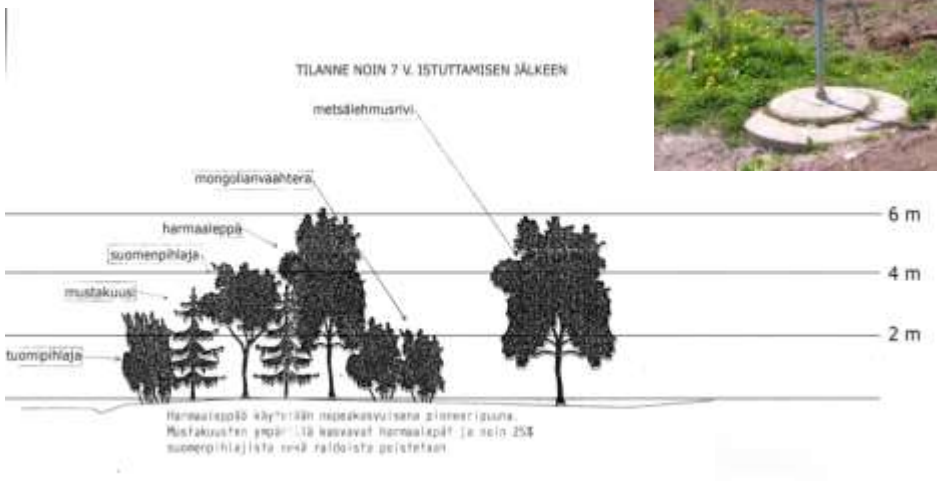


HW

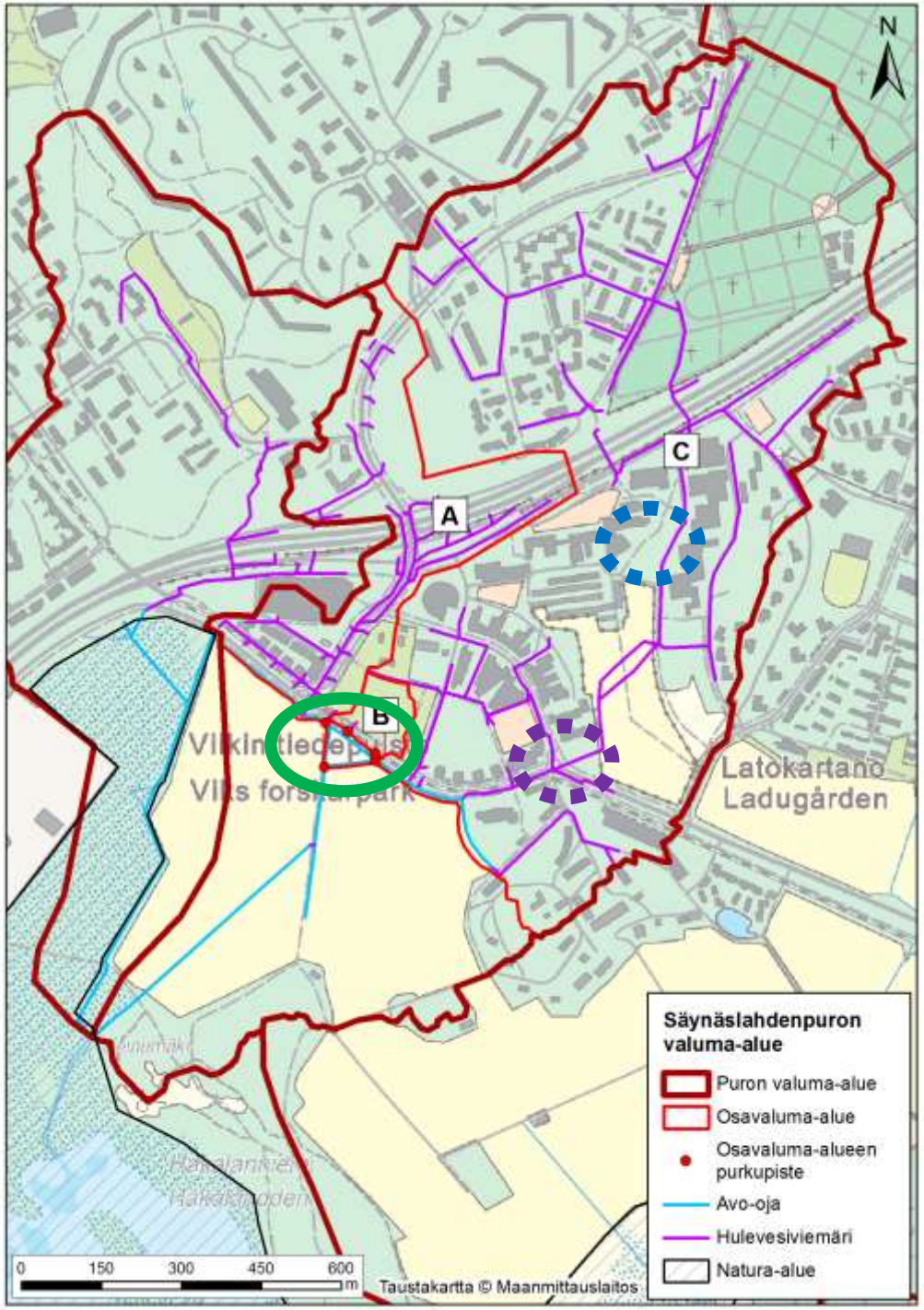
Viikki – riparian zone implementation: engineering only?
However: a much enjoyed landscape
Stormwater involved in community gardening

Anemone ranunculoides	keltavuokko
Butomus umbellatus	sarjarimpi
Caltha palustris	rentukka
Carex acuta	viiltosara
Carex pseudocyperus	varstasara
Claytonia sibirica	alaskankleitonia
Corydalis solida	pystykiurunkannus
Eupatorium cannabinum	punalatva
Filipendula ulmaria	mesiangervo
Iris pseudacorus	keltakurjenmiekka
Juncus effusus	röyhyvihvilä
Lysimachia thyrsiflora	terttualpi
Lysimachia vulgaris	ranta-alpi
Lythrum salicaria	rantakukka
Myosotis scorpioides	luhtalemmikki
Oxalis acetosella	käenkaali
Phalaris arundinacea	ruokohelpi
Phragmites australis	järviruoko
Ranunculus ficaria	mukulalenikki
Scirpus sylvaticus	korpikaisla
Sparganium erectum	haarapalpakko
Veronica longifolia	rantatädyke
Thelypteris palustris	nevaimarre
Typha latifolia	leveäosmankäämi



Research and teaching: campus landscape

Stream
at – 4 m



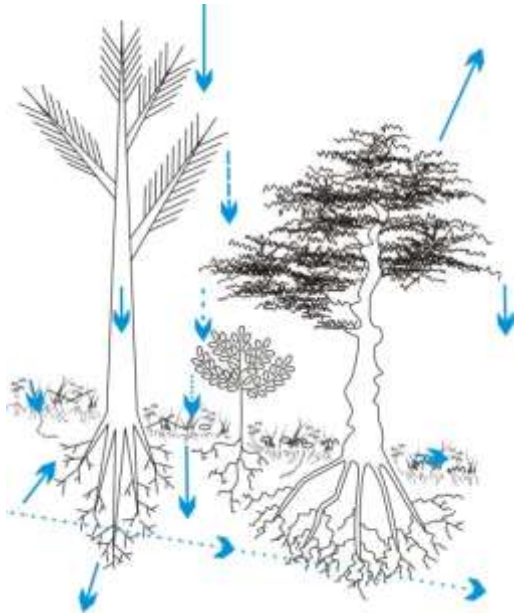
Multiple student projects -> ”Yes BUT”

Viikki campus wetland: It cleans up, it does not, it cleans up?

A plant supporting local fauna is beautiful!

Photo: Antti Nykänen

Design choices
Environmental biotechnology
Climate and hydrology



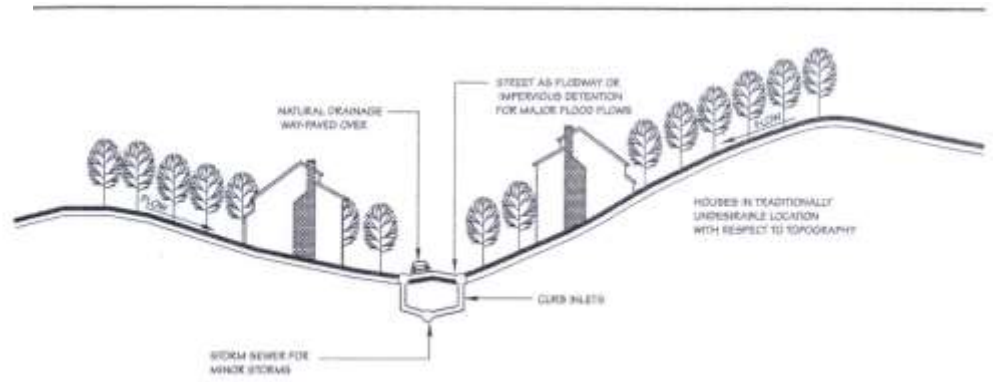


Figure 330-8. Location of imperviousness relative to drainageways in conventional development.

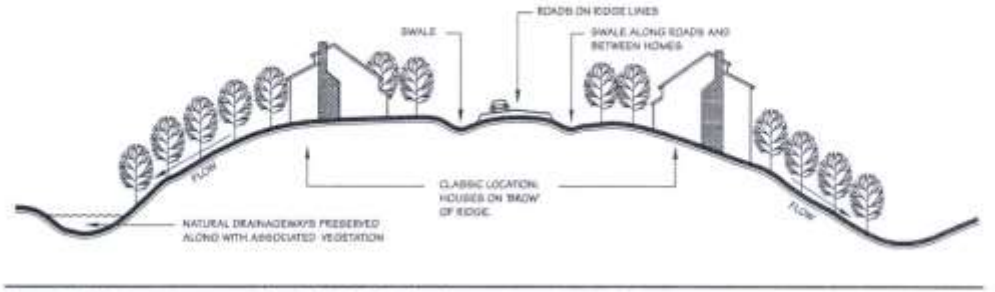
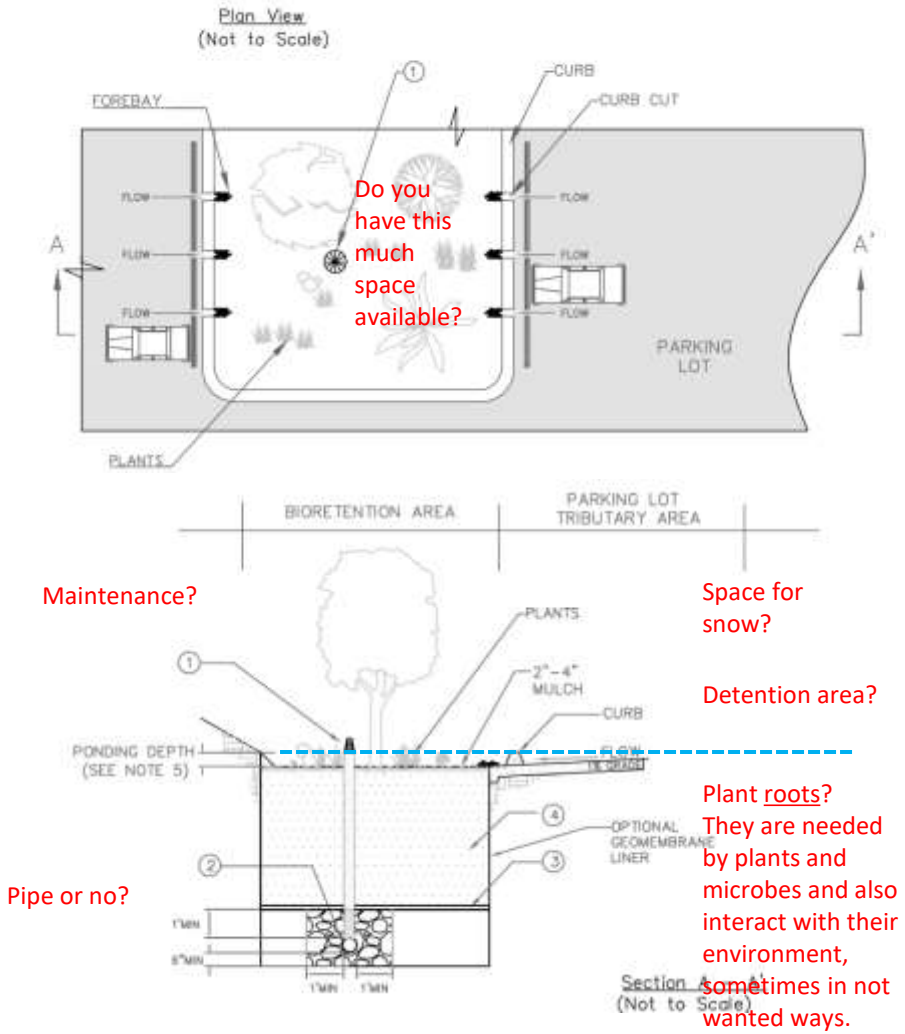


Figure 330-9. Impervousness placed high in the landscape. *Note the lack of storm sewers.*

Critically learn from references

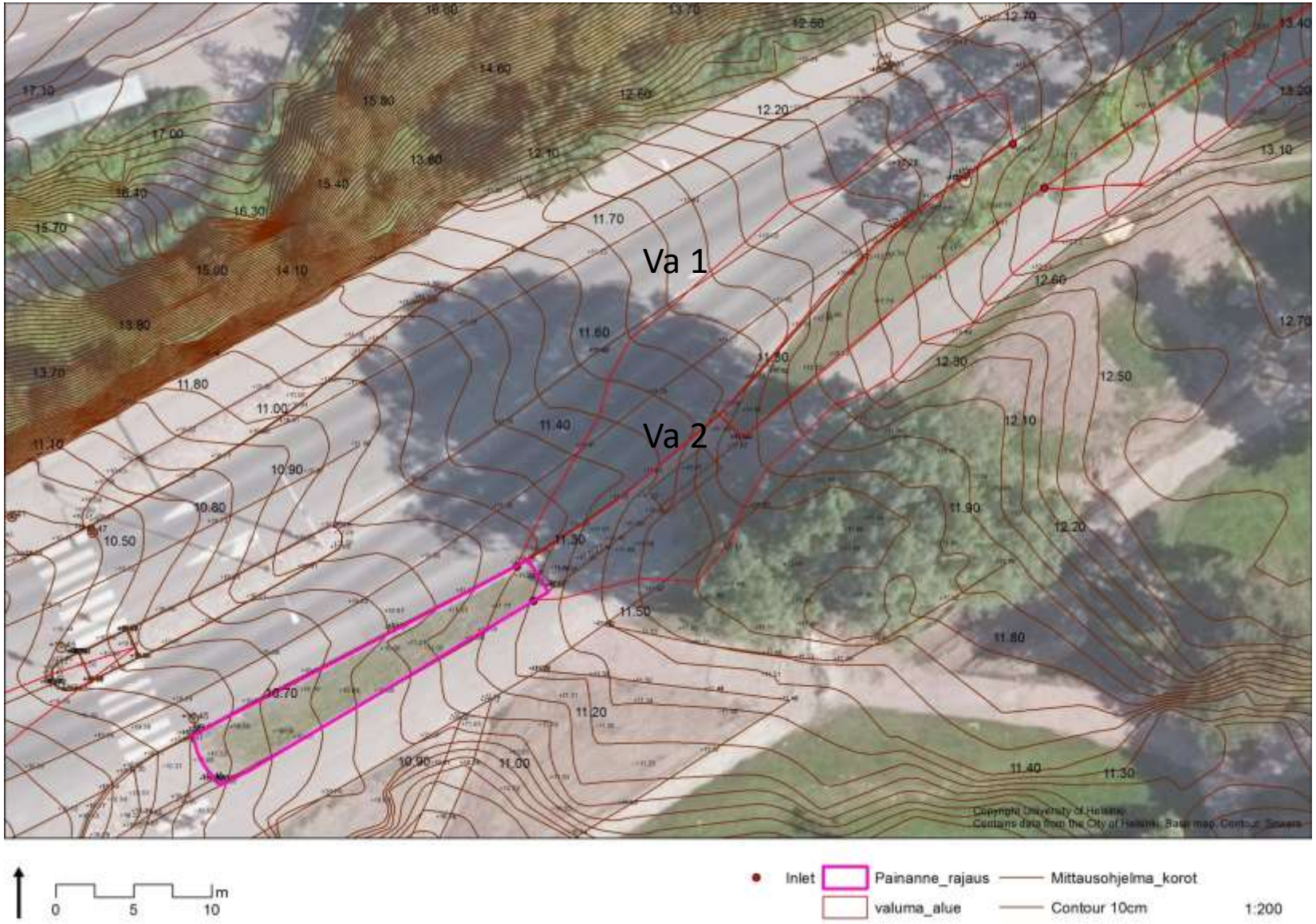


Graphs: Geosyntec consultants (2011)

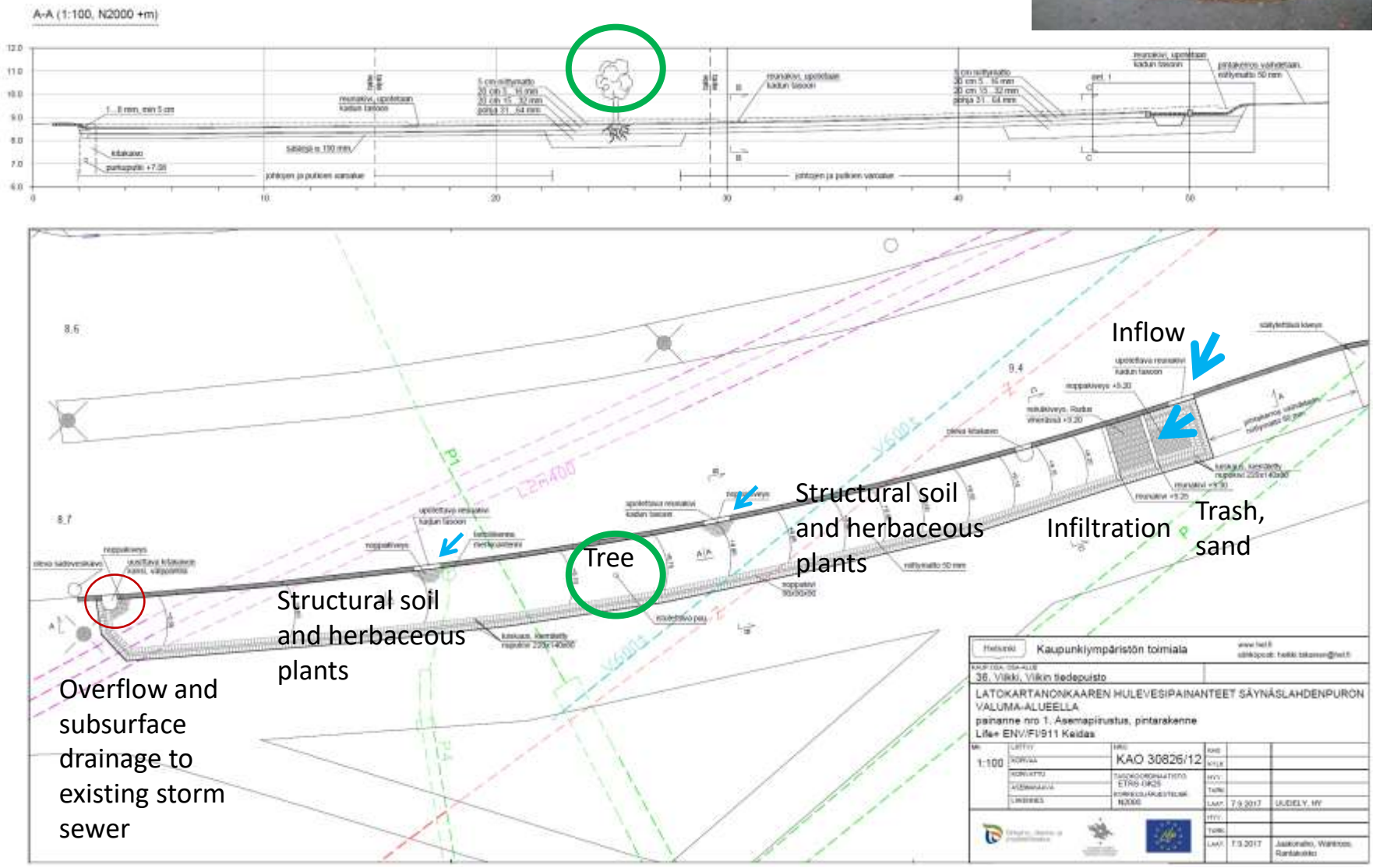
Requirements: existing inflow, no underground structures, pitch towards a possible overflow into a stormwater network, landscaping accepted, easy maintenance

Above ground looks ”good”!

Watershed analysis: curbs not visible..



Stormwater management tree swale retrofit



Graphs w/: Olli Jaakonaho

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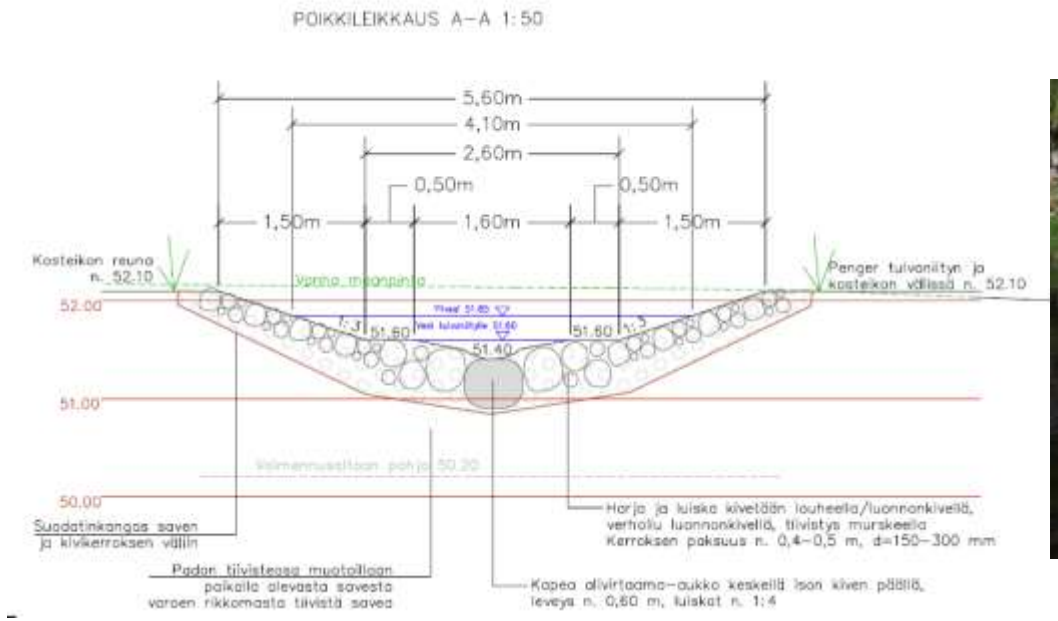
Details!

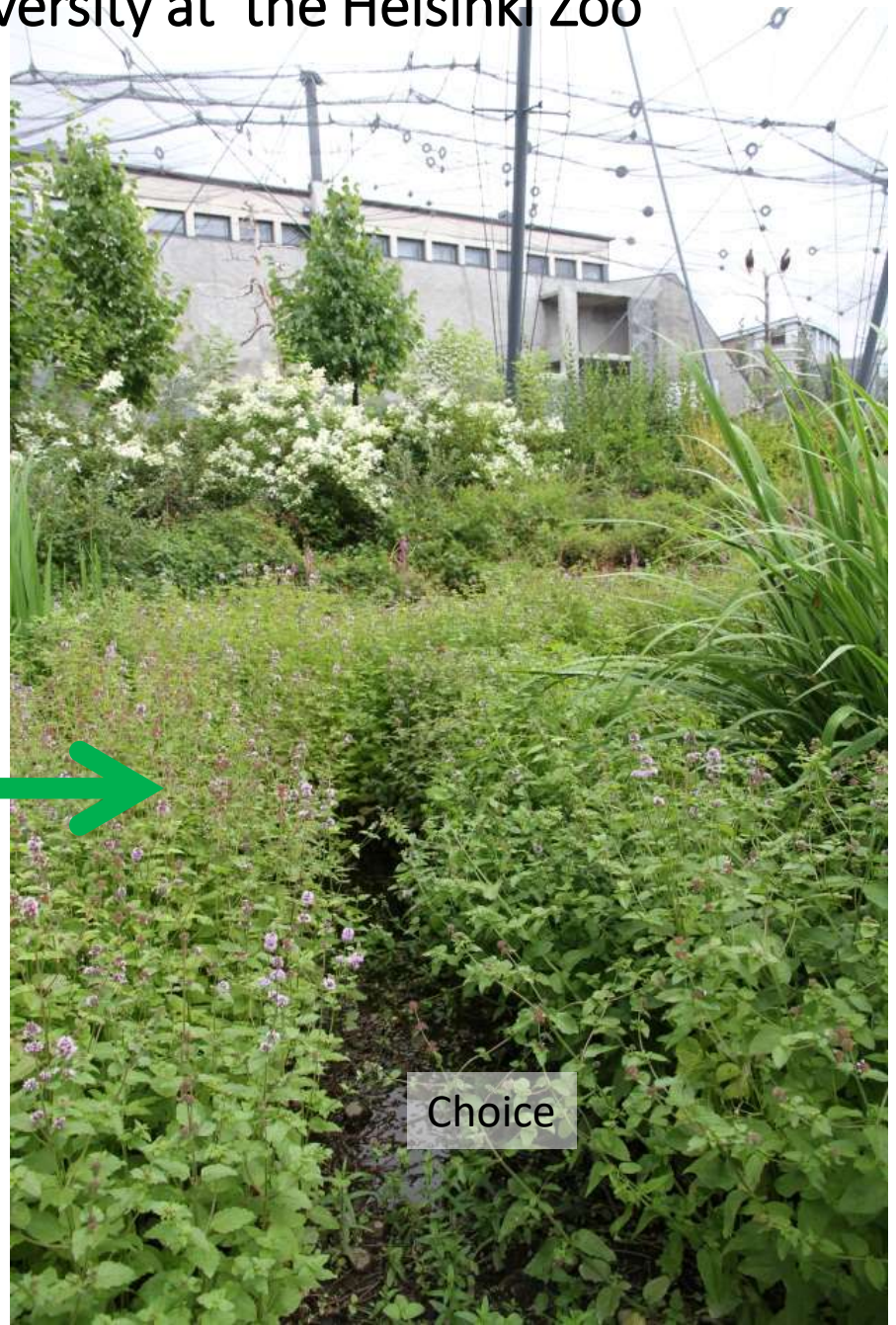
Outflow dam defines mean water depth and water retention

Solutions vary



Kuva: Emmi Mäkinen / UUDELY

Example: Landscaping for Biodiversity at the Helsinki Zoo

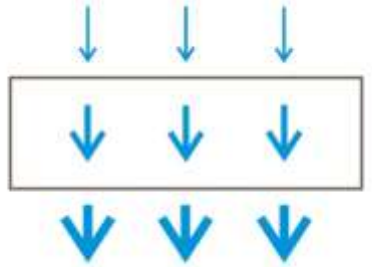


The Helsinki Zoo

An island (25ha) in the City of Helsinki and in the Baltic Sea (60°N, 20°E)

Site conditions

- Intense use: animals, visitors, maintenance
- Steep slopes, runoff, erosion, draught



Landscaping goals

- Healthy environment for the Zoo animals
- Visitor environmental awareness, sense of beauty
- Erosion and draught control
  - diverse vegetation
  - soil amendments
  - stormwater treated on site as a resource
- Support and benefit from local biodiversity

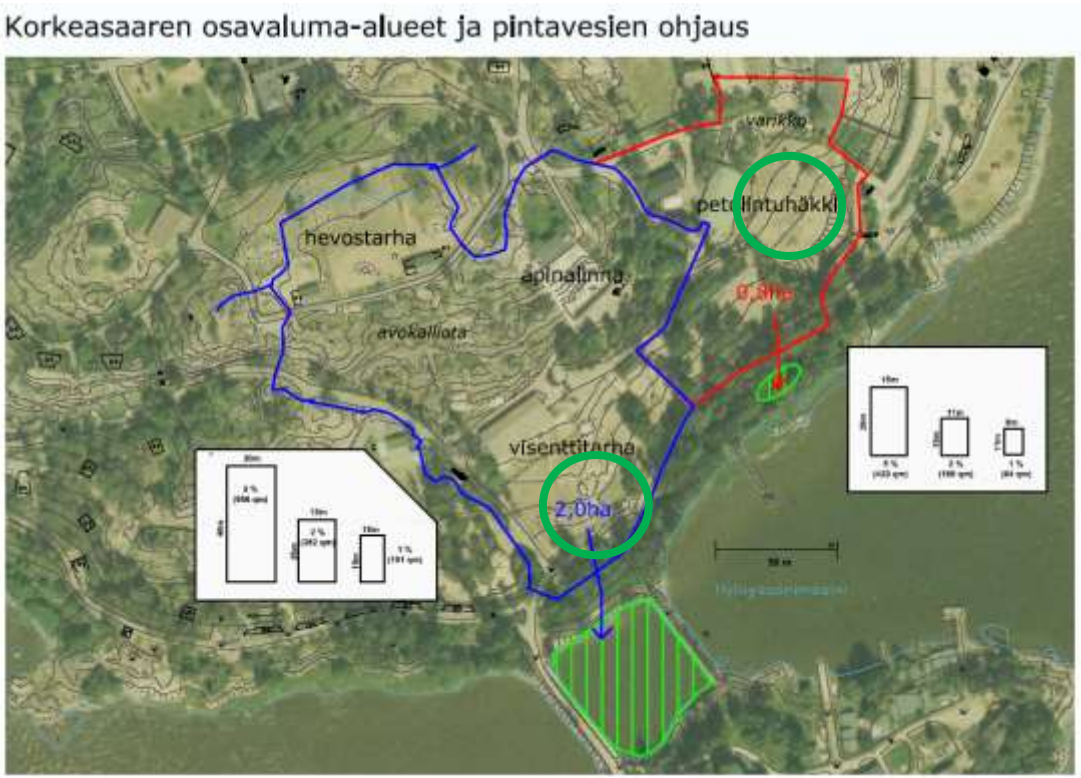
Green landscaping, but…

Green and edible…

Stormwater to support urban oases?

Watershed scale as a starting point

1. Steller's Sea Eagle subwatershed
2. European Bison subwatershed



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The Steller´s Sea Eagle Watershed

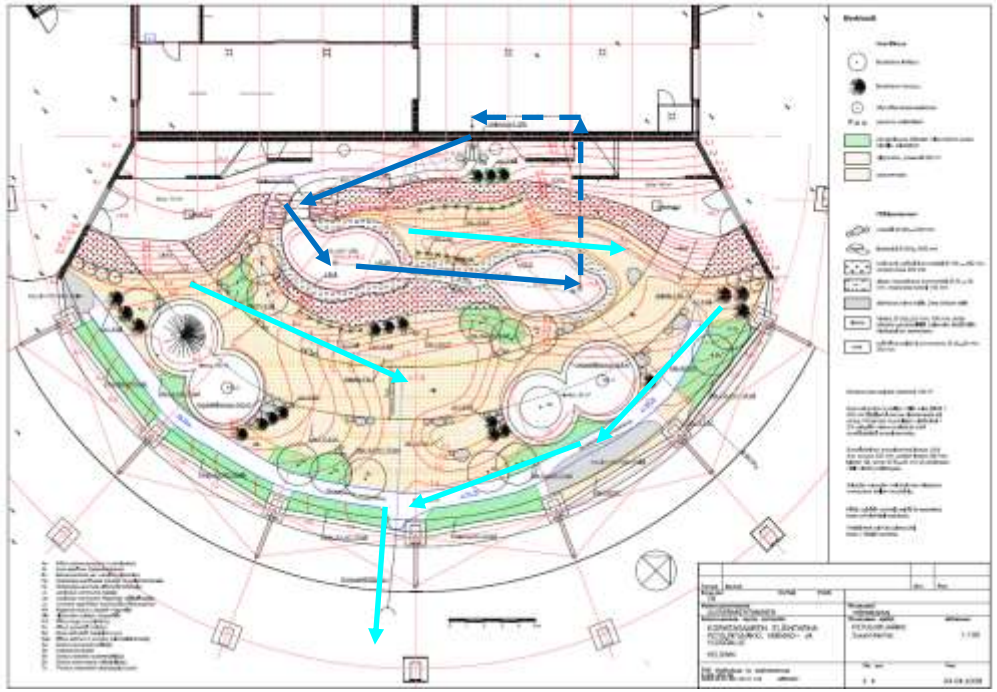
- Site: an existing management area, new Sea Eagle enclosure, adjacent park area
- Condition: steep slope, draught, bare soil

2006

The Steller´s Sea Eagle Enclosure Plan

- Conditions for the eagles: maximal space for flying, wading pools
- Runoff: controlled conveyance, establish shelter vegetation outside the enclosure
- Roof runoff reuse: not for the pools – tap water & biofilter;

  runoff to support vegetation downhill

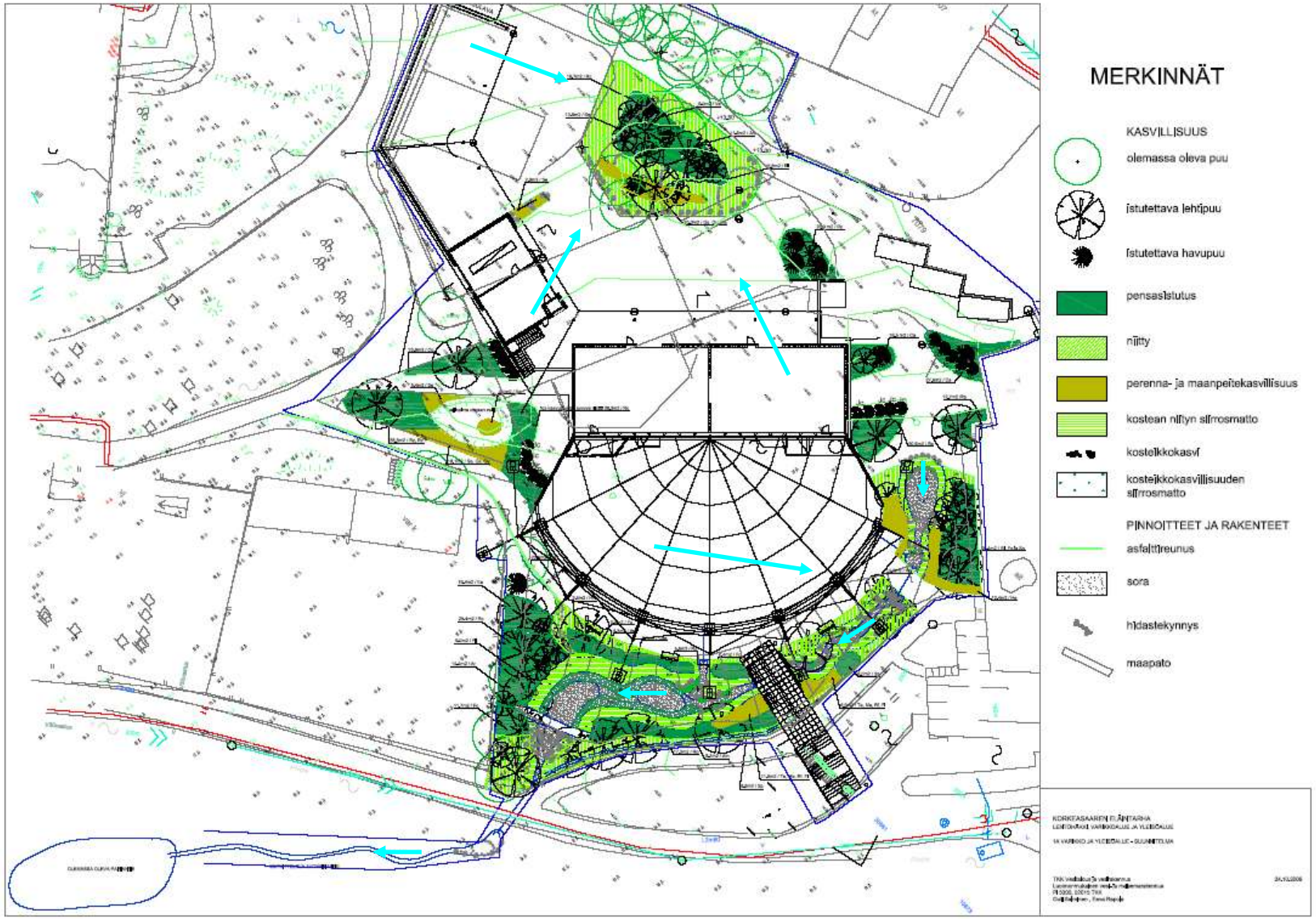


3D Graph: w/ Lassi Warsta

Enclosure: herbageous native vegetation mats

The Sea Eagle Watershed Plan

Controlled conveyance, lush vegetation, constructed wetland, infiltration



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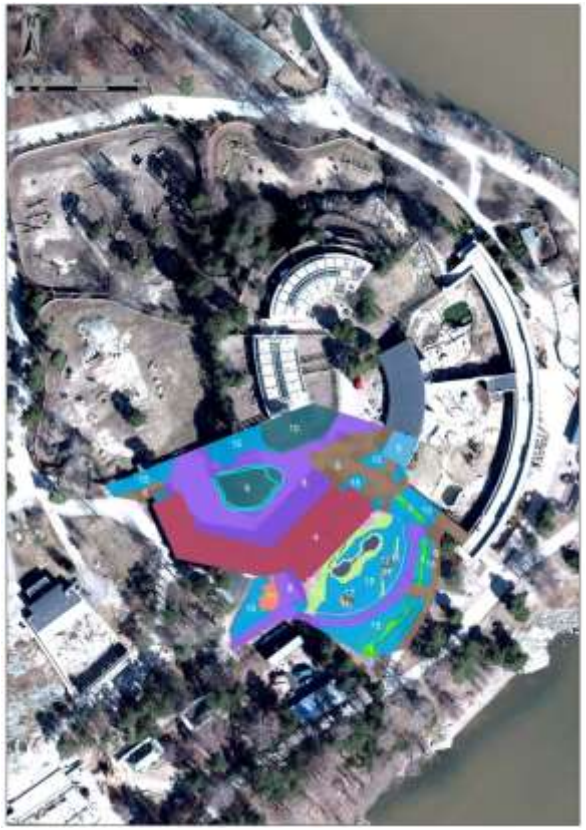
From dry and eroding south slope to a refreshing green oasis



2006

2010

Circa 3% area = wetland/swale
Circa 35% impervious

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Runoff management one watershed at the time

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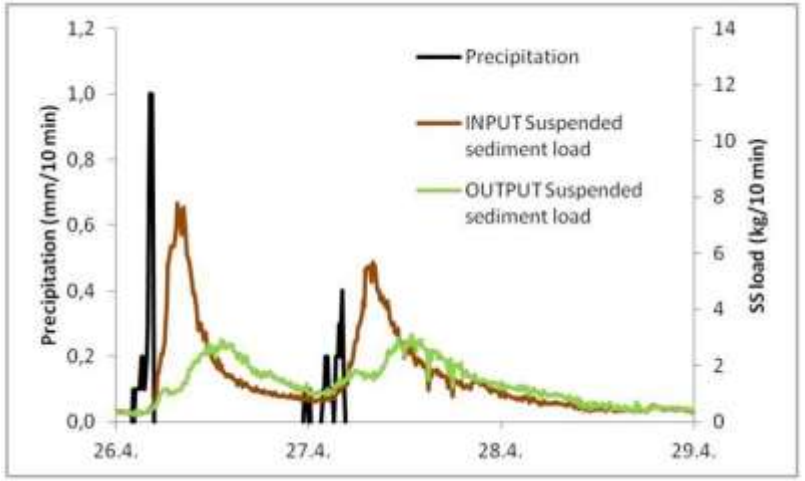
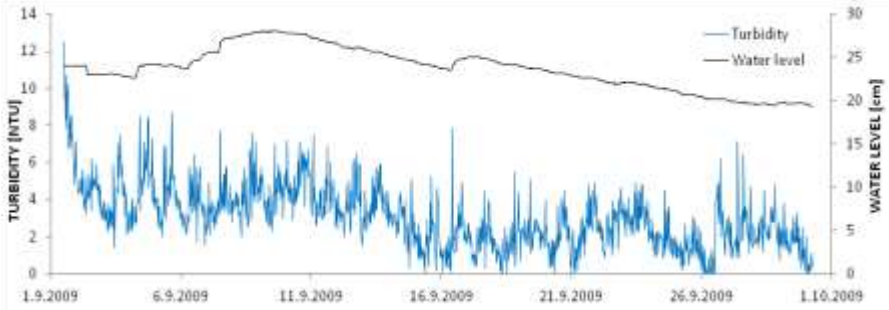
2009 pre-construction and 2009 post-construction

Monitoring for landscaping success: water quality

Example Nummela wetland: reduction of turbidity (inflow - outflow)



Korkeasaari pocket wetland: well, there is inflow when it rains...



→ Standard monitoring for water quality is not useful for pocket wetlands

Vegetation establishment:
Barnacle geese (*Branta leucopsis*) and the Korkeasaari Zoo [1]

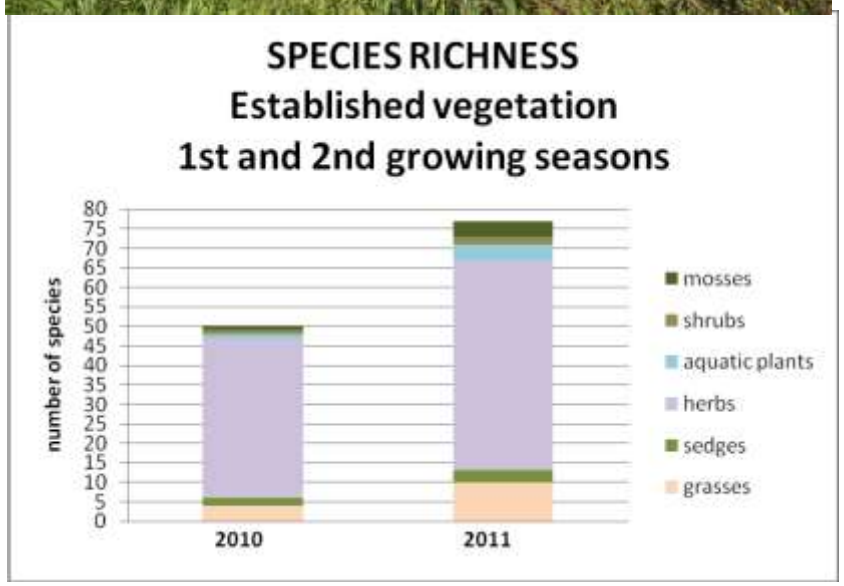
- Helsinki is on the arctic flyway of the wild barnacle geese
- The first wild barnacle goose pair in the Helsinki area settled to breed amongst captive barnacle geese at the Korkeasaari Zoo in 1989
- The Zoo released excess 54 captive barnacle geese in 1987-1990: these birds and the wild individuals attracted by them have formed the Helsinki urban barnacle goose population

[1] Väänänen V-M *et al*., 2011, Habitat complementation in urban barnacle geese: from safe nesting islands to productive foraging lawns, *Boreal Env. Res.* 16(suppl.B):26-34.

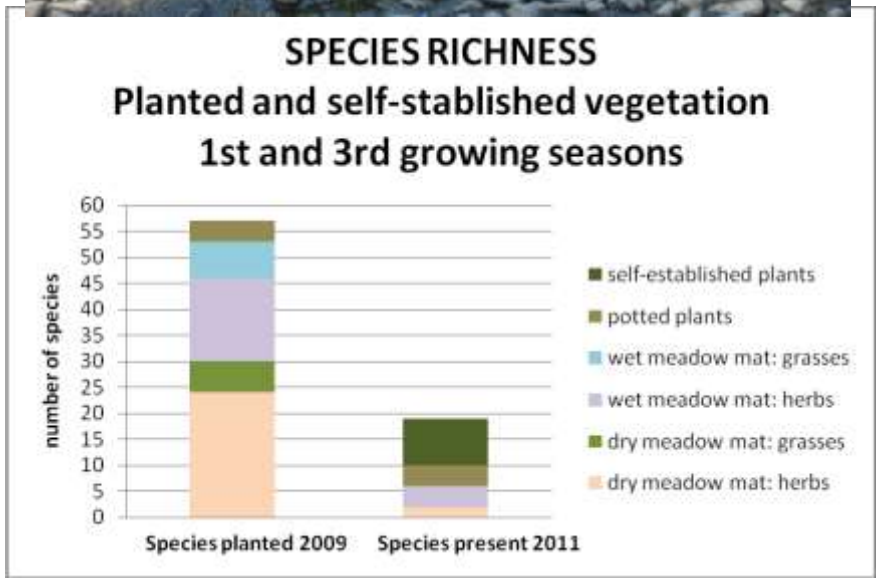
- The barnacle geese in Helsinki utilize habitat complementation
  - islands for nesting, urban irrigated lawns near the shoreline for foraging, and sheltered bays and islets for roosting
- Population growth has been exponential
  - 45% increase per year in 1996-2003
  - After 2003 to 22,5% increase per year
- The number of nesting pairs
  - 1 pair in 1989
  - 1500 pairs in 2010
- The geese feel very much at home in Korkeasaari there predators such as the red fox cannot reach them
- At the Zoo nature-based stormwater landscapes the barnacle geese selectively ate herbaceous vegetation lowering diversity of plant species

Designing and evaluating urban stormwater landscapes is a complex task

The Nummela Gateway Wetland



Zoo Pocket Wetland



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The European Bison enclosure

- Site: steep slope, draught or standing water, erosion, nutrient release
- Goal: Bison bearing, no sharp stones; grasses for landscaping?





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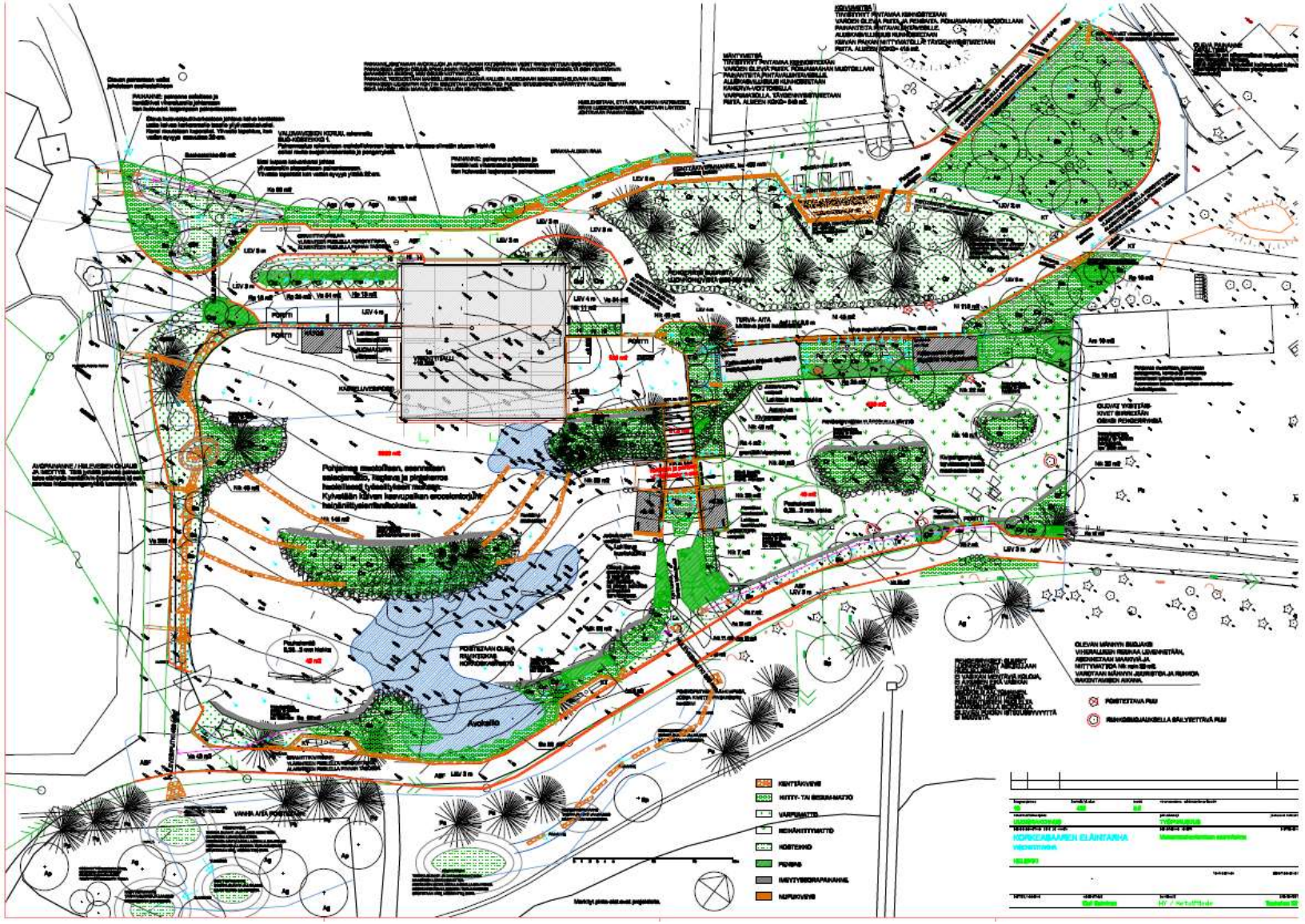
Multiple runoff management structures…



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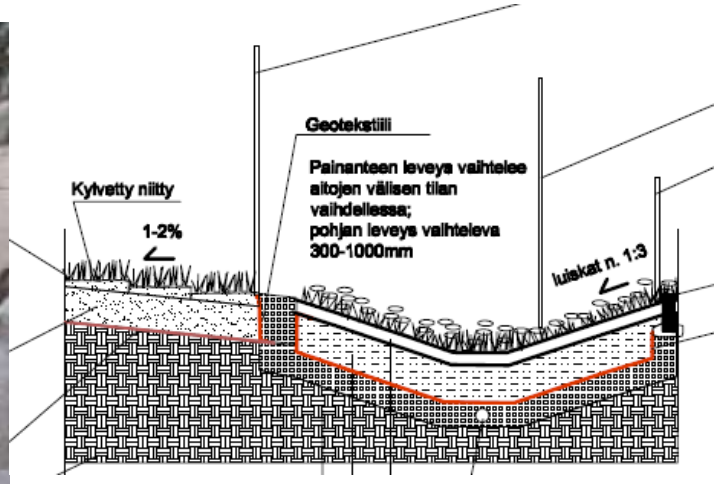
Slope runoff and erosion control

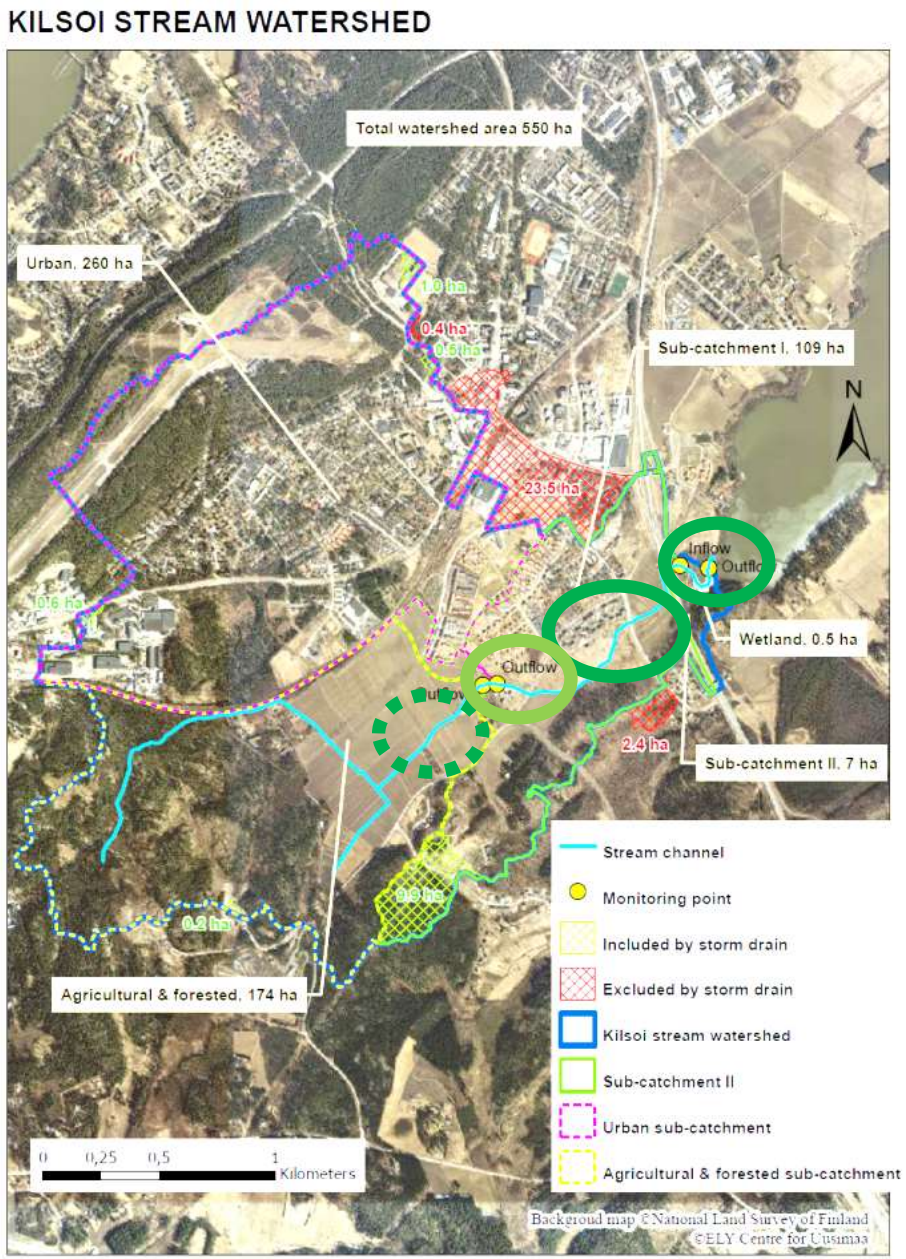


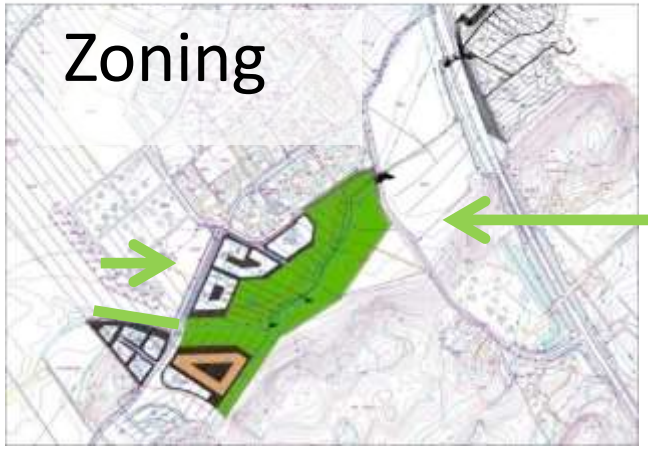
Local diverse vs. imported vegetation

- The built green oases can be supported by runoff even through dry seasons
- The constructed landscaping creates pleasant environments for enclosure animals and visitors alike
- Barnacle geese grazing impacts plant species present and must be considered when planning functional landscaping

• Diverse local vegetation provides functions and tolerates disturbances better than monoculture imported species
• Multiple landscape structures designed at the watershed scale is necessary
• Controlled conveyance, diverse vegetation, and soil mixtures contribute to erosion control success
• No more runoff from enclosures enters the Baltic Sea

Case Nummela: Kilsoi Stream wetlands and critically endangered clay stream habitat









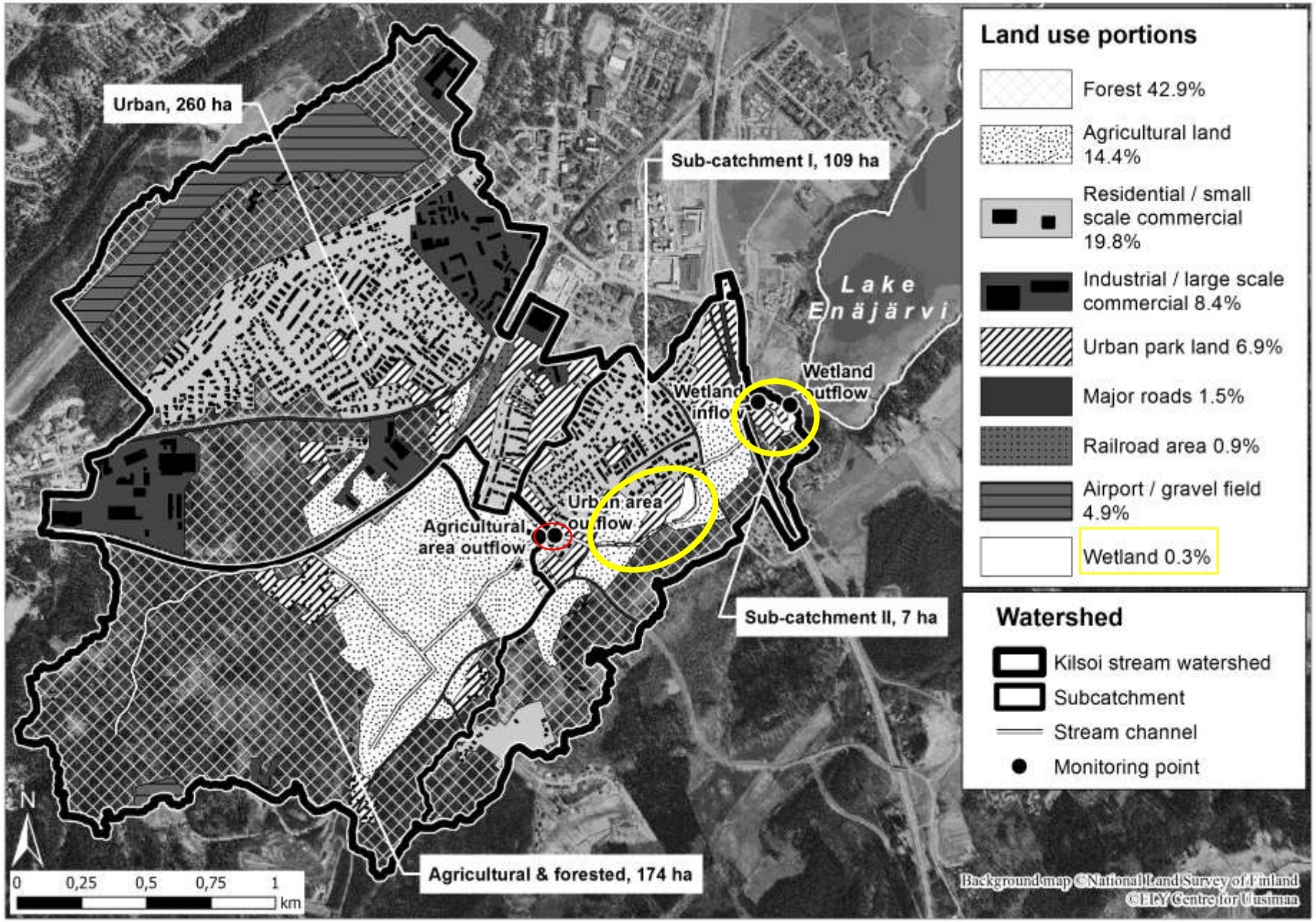








WATERSHED



LAND-USE

Graph: Emmi Mäkinen

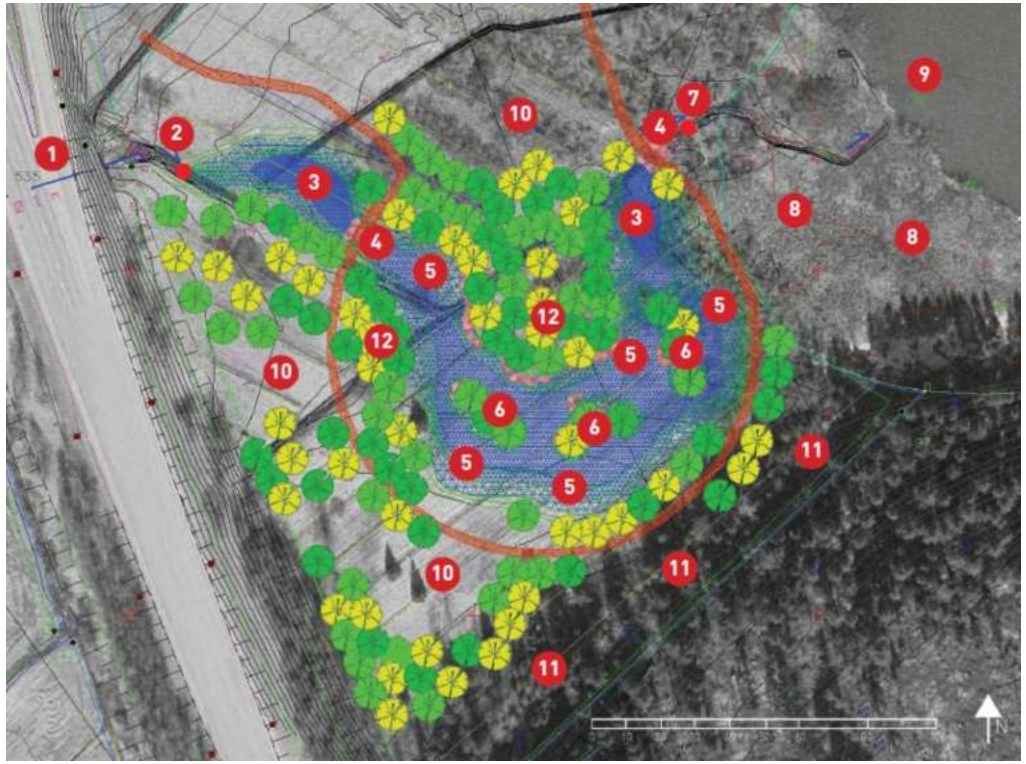
The Nummela Gateway Wetland Park

1. CULVERT from the 500 hectares urban(350)/urbanizing /agricultural/forest watershed. Steam flow 10 l/s (low flow)...1000 l/s (storm/snowmelt peak flow).

2. Wetland **INLET** monitoring point: even stream section.

3. Stilling **POND**.

4. Rocky bottom **DAM**s: keep water level relatively even and above the lake level; add oxygen.



5. Wide and slowly deepening shallow coast line: facilitating a large and diverse **WETLAND**.

6. Three habitat **ISLANDS** slow down flow increasing water contact time. Shoreline embankment of on-site made willow bundles.

7. Wetland **OUTLET** monitoring point: even stream section.

8. Conserved shoreline **WETLAND**.

9. Receiving **LAKE** Enäjärvi.

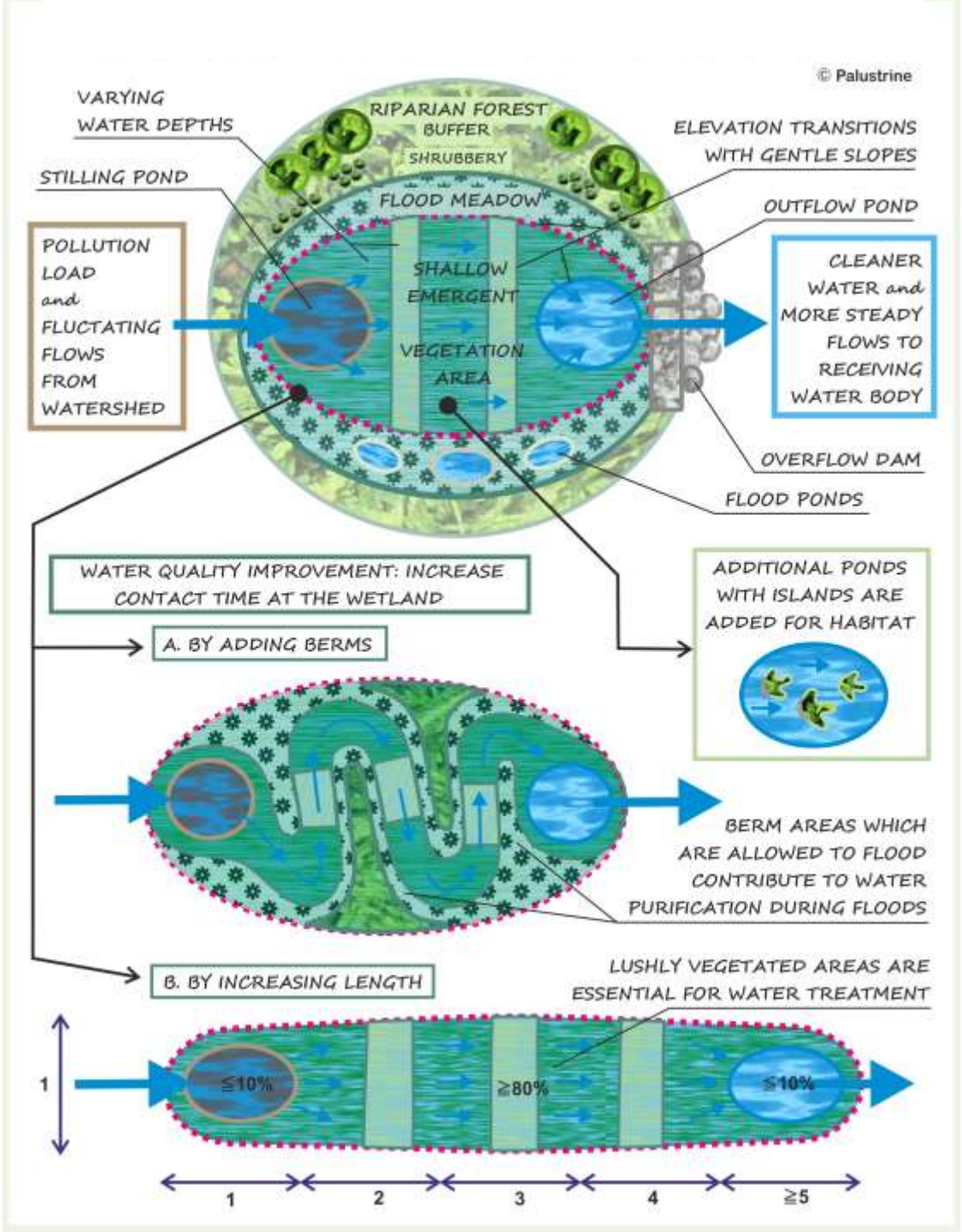
10. Conserved willow **SHRUBBERY**, open **MEADOW** patches supporting songbirds and insects. Drainage **DITCHES** were disconnected and conserved as frog habitats.

11. Conserved **FOREST** on a steep hill: conserved as erosion control and a designated flying squirrel habitat.

12. Planted buffer **TREES** to partially shade pond and wetland: wetland species richness, cool water temperature, habitat, erosion control.

Diffuse pollution treatment wetlands

- Often considered:
  - Permanently inundated area
  - Berms
  - Length
- Floods: heavy rain, snowmelt
- Nature-based:
  - Gentle sloping banks
  - Flood meadows
  - Flood pools
  - Riparian buffer



A TREATMET WETLAND ?

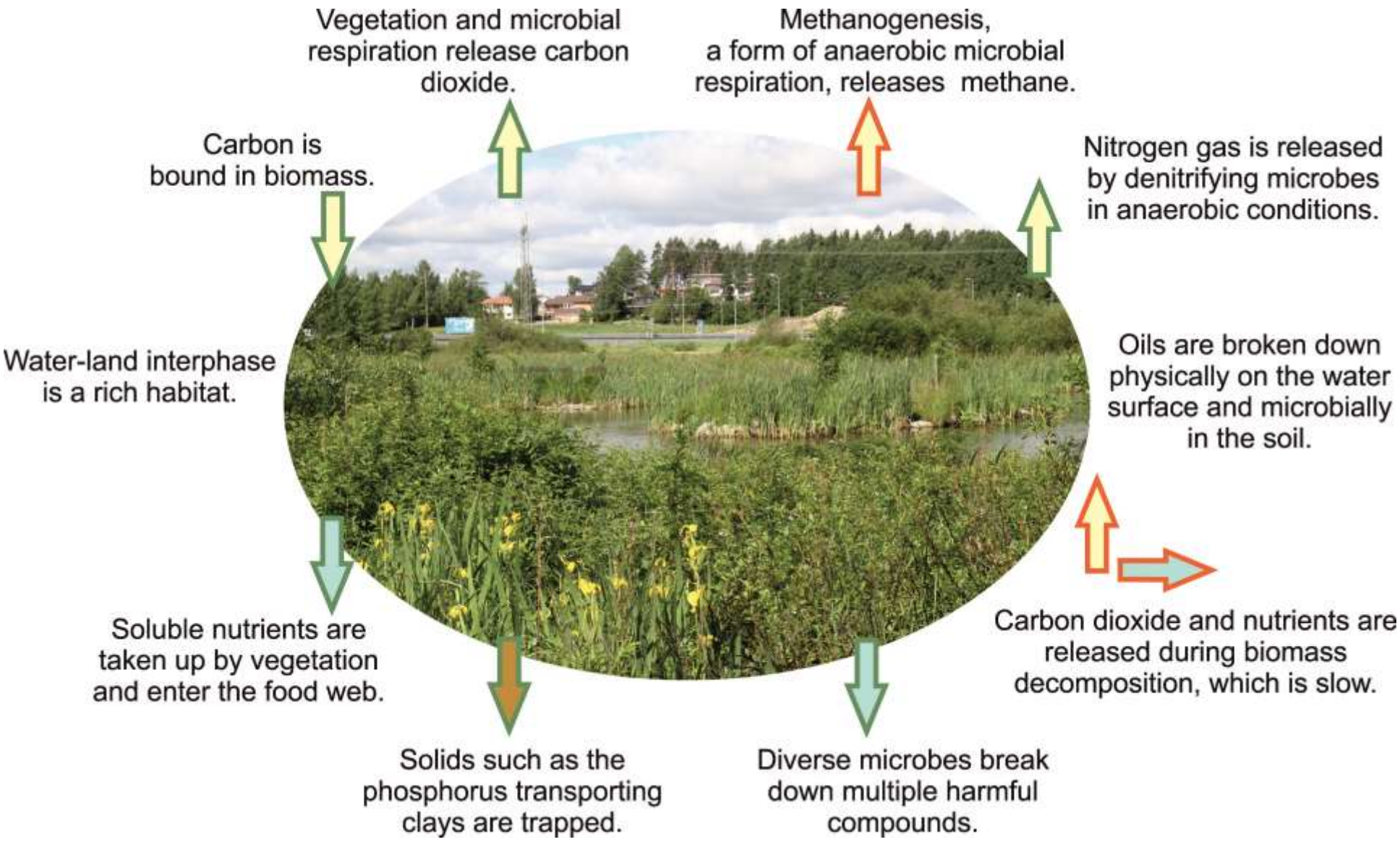
DEEP, STEEP: NO PLANTS - PIPE DAM: ERODE, DISCONNECT



REDO: GENTLE SLOPES, SHALLOW, RECONNECTED CORRIDOR, NO GEOTEXTILE



WETLANDS ARE COMPLEX!



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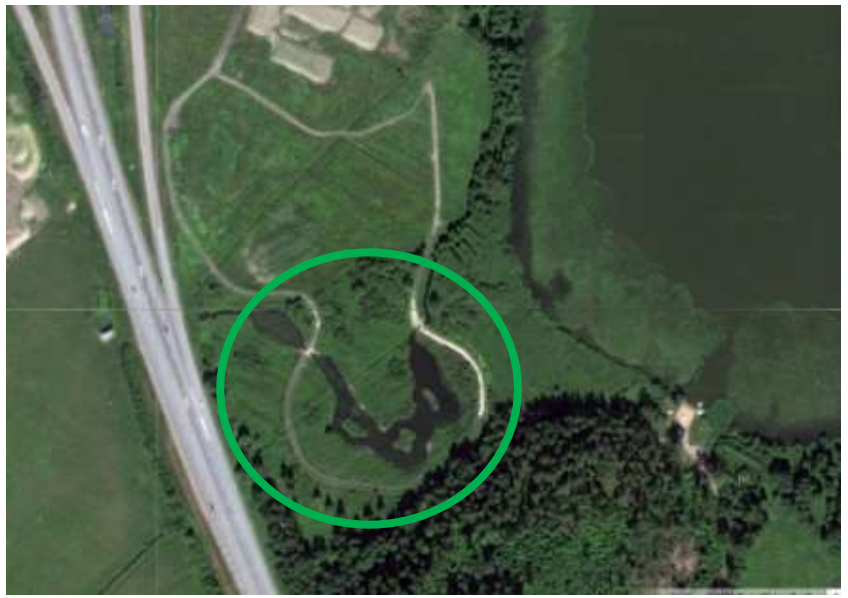
Graph: Emmi Mäkinen

Nummela Gateway Wetland Park -> TEEB Nordic

2005

2010



2011

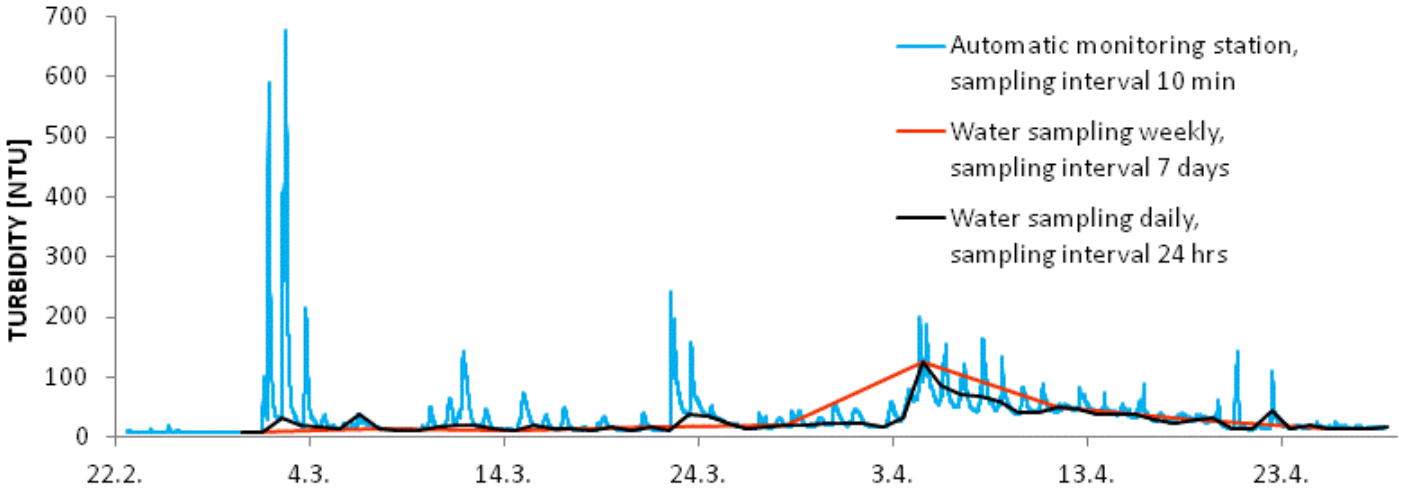
OW






OW

MONITORING BEFORE&AFTER



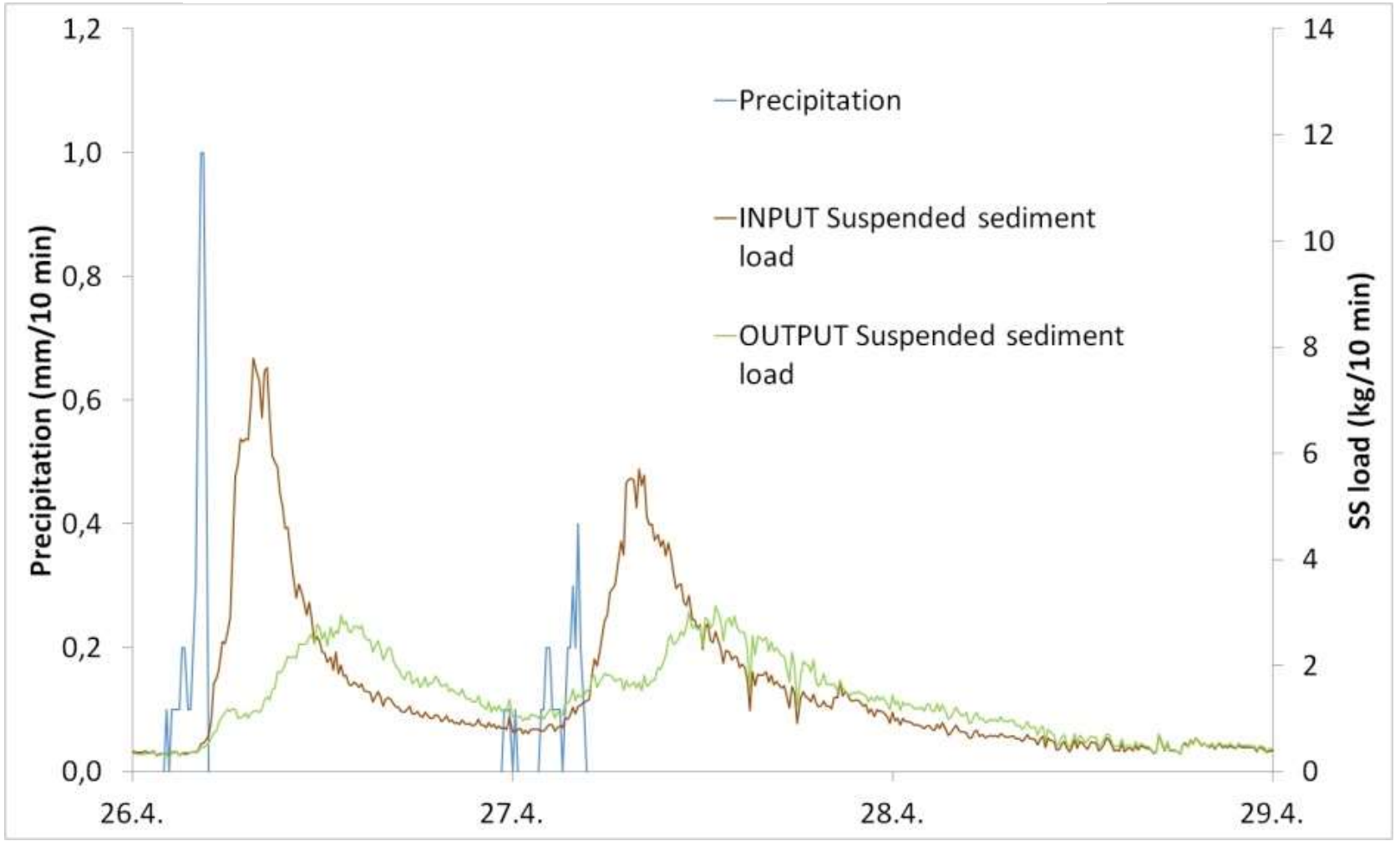
HERBACEOUS VEGETATION SELF-ESTABLISHMENT

Herbaceous species	2010	2017
Total	50	151
Non-native	2	4

July 2010 July 2011 July 2012

Graph: Emmi Mäkinen

Nummela Gateway



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Water quality, example:

Nummela Gateway wetland, 0,1% area of watershed: TP

- Calculated monthly averages from 10 min interval continuous monitoring
- Monthly relative (%, white bars) and absolute (kg/month, grey bars) reduction rates of Total Phosphorus (annual 10% 2013; 13% 2014, 16% 2015, 21% 2016)

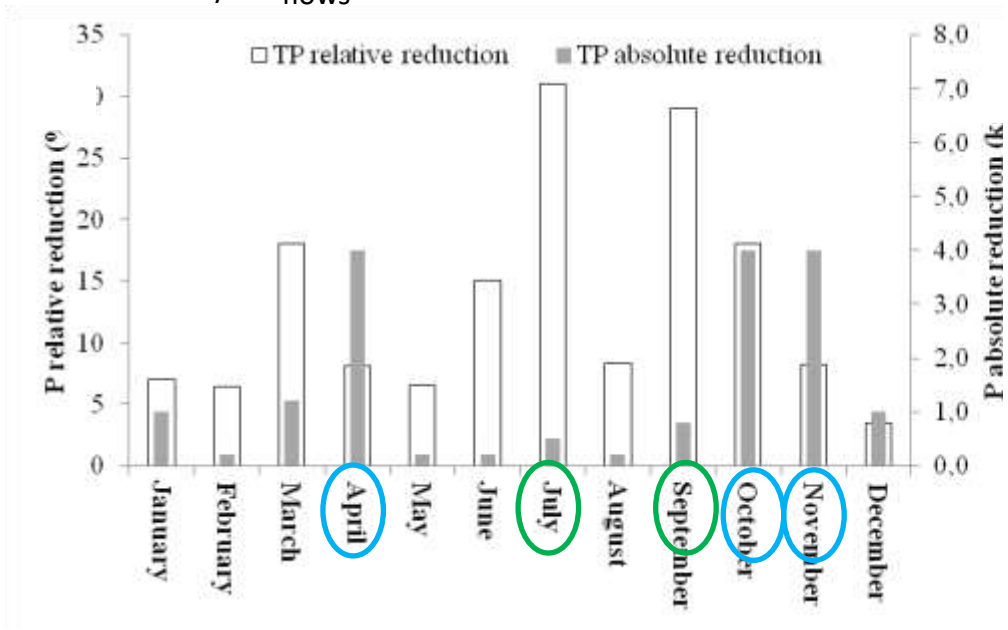
2013, ”Normal weather”

Unusual snow Melting early January

Feb-March snow and ice, high April snowmelt flows

Modest rain in growing season

Rainy October and November

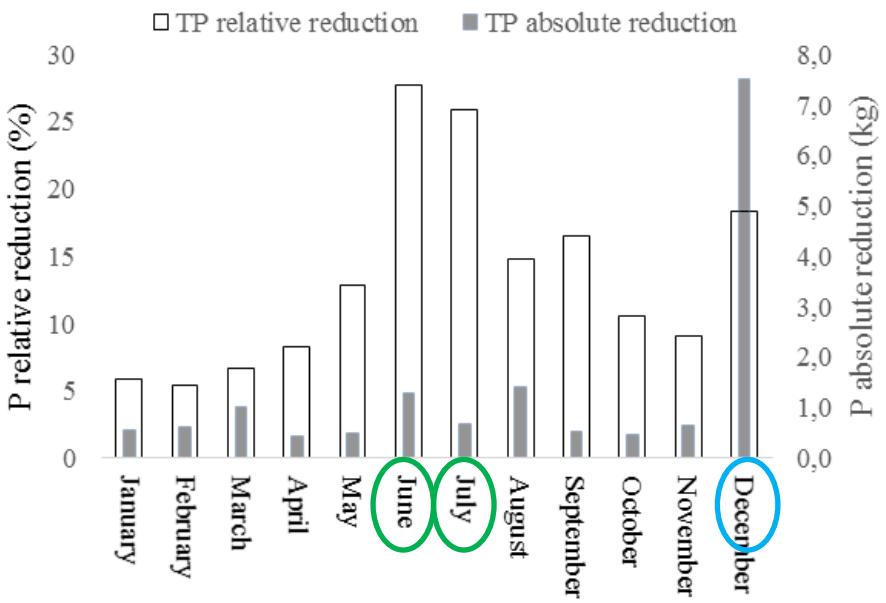


2014, ”Climate change weather”

Mild winter, little snow, little snowmelt

Rainy August

Snow melting and rain in December



Graph: Pasi Valkama

Stormwater treatment wetland

- Discrete source pollution
  - Stilling pond: coarse solids
  - Shallow emergent vegetation area: fine solids, dissolved compounds
  - Outlet pool: organic debris from the wetland
  - Outlet = bottom dam
- Wetland area of contributing watershed: recomendation 1-5 %
  - Already 0,1 % meaningful

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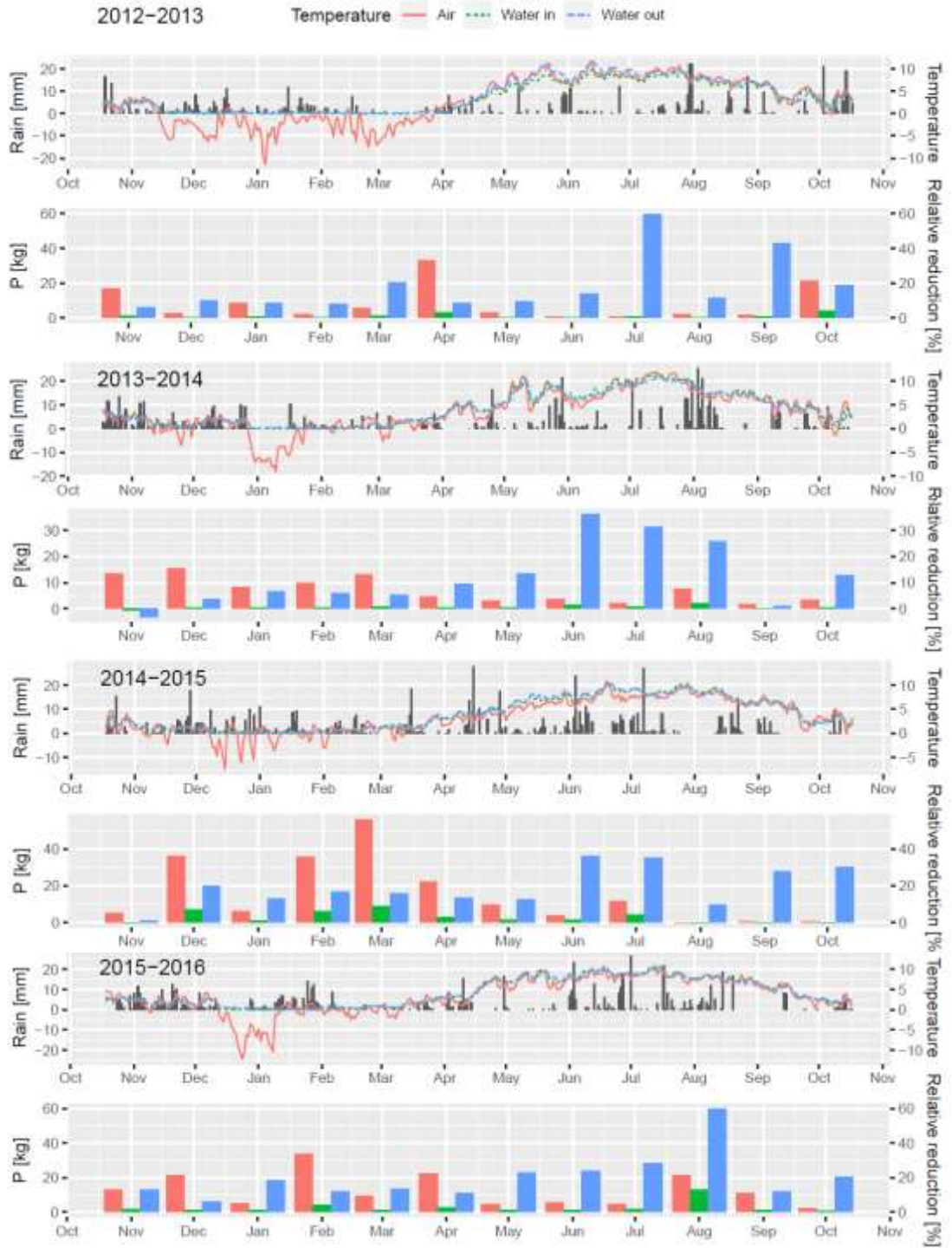
WATER QUALITY
e.g. Gateway, TP

- Hydrological year: Nov 1st –Oct 31st
- Years are different
- Construction etc. at the watershed

- Heavy rain or snowmelt:
  - Flow ↑
  - Turbidity ↑
- At the wetland
  - **Flood meadow** becomes inundated, flow ↓ HRT ↑
  - Relative reduction, % ↓
  - **Absolute reduction**, kg ↑

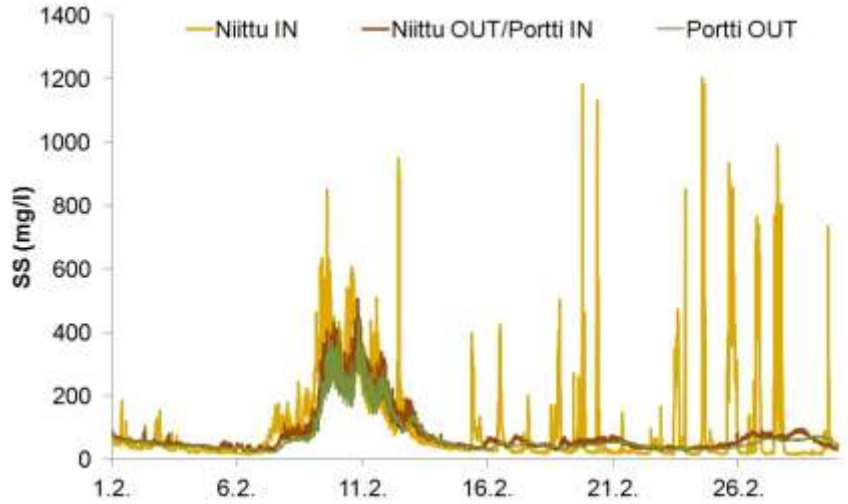


P in Absolute reduction Relative reduction

Water quality after Niittu and Portti

Wetland, construction year, size of watershed

Niittu, 2013-2015, 0,3% and Portti, 2010, 0,1%



Suspended solids reduction in spring 2016

•*Snowmelt period*

- Niittu 4% + Portti 13% = 17%

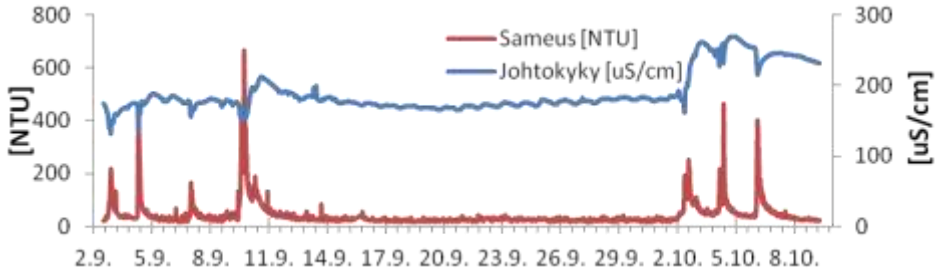
•*Construction of urban development after snowmelt period*

- Niittu 22% + Portti 9% = 31%

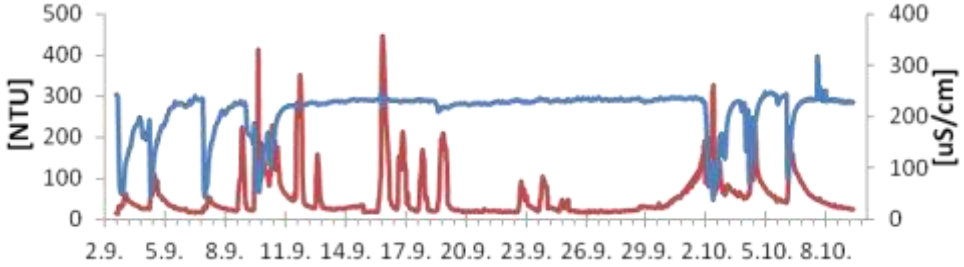
Landuse and landscape management impact

Construction

Upstream (conductivity, turbidity)



Downstream (conductivity, turbidity)

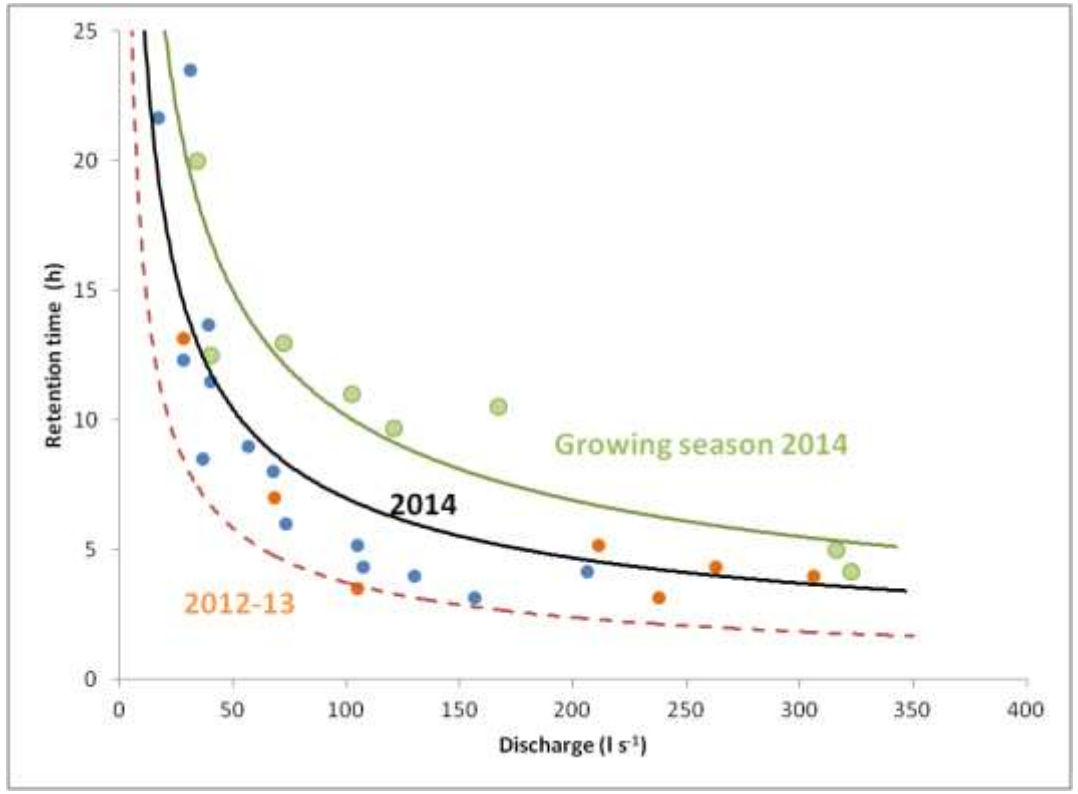


LUODE Consulting

Graph: Joose Mykkänen

- Hydraulic retention time

- - Wetland maturation
- - Growing season



Graph and lower photo: Pasi Valkama

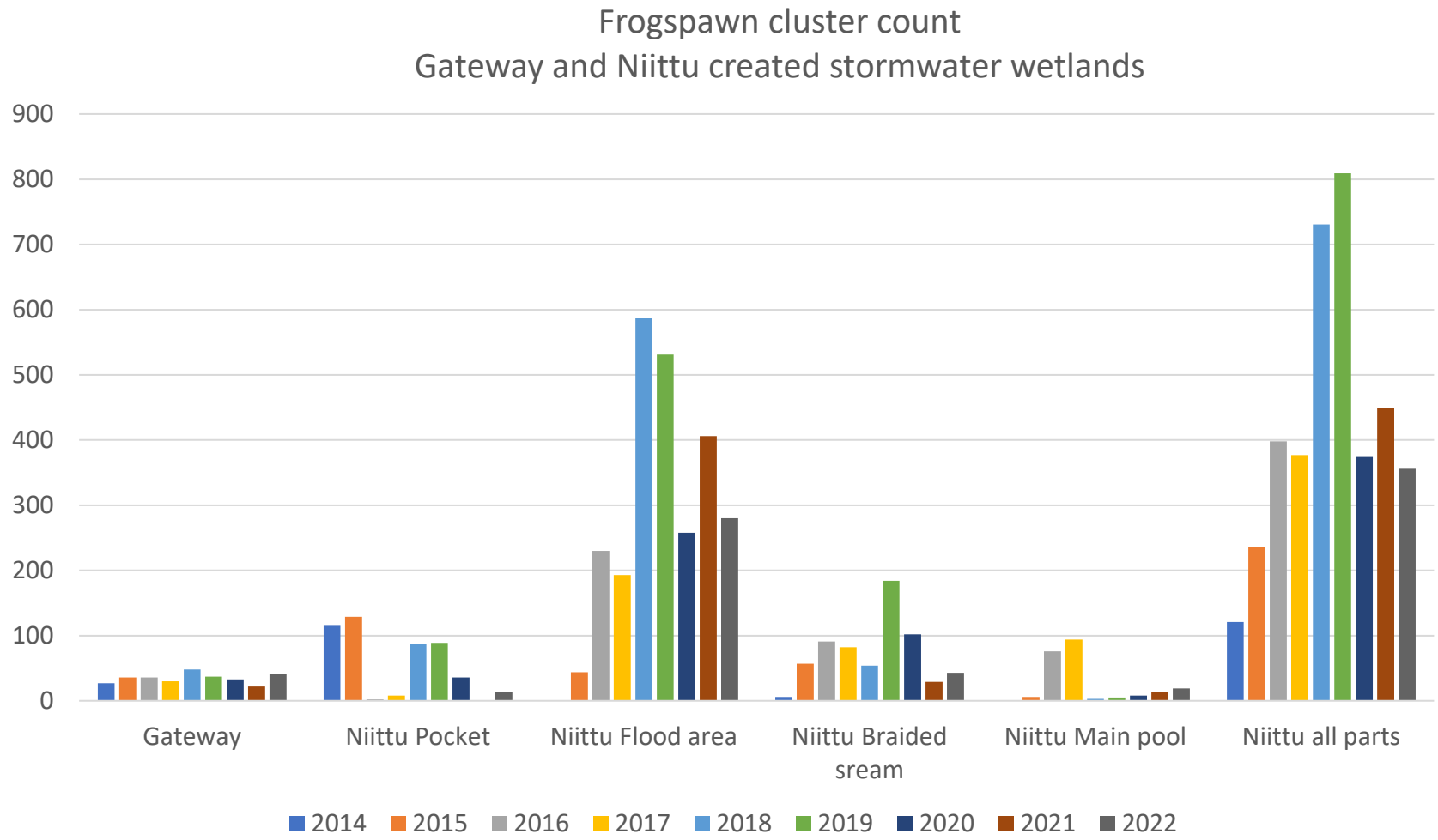
Frogs: most *Rana temporaria*, hibernating in water, some *R. arvalis*, soil

Wetland site	Construction year	Inundated area ha	Fish access	Frogspawn cluster count									
				2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Gateway	2010	≥ 0.5 *	yes	27	36	36	30	48	37	33	22	41	42
Niittu (four distinctive parts)													
Pocket wetland	2011	0.1	low	> 115	129	2	8	87	89	36	0	14	8
Intermittent flood area	2013	max 0.4 **	no	0	44	230	193	> 587	> 531	> 258	> 406	> 280	181
Braided clay stream	2013 - 2014	0.1	very low	6	57	91	82	54	184	102	29	43	37
Main pool	2013 - 2014	0.9	yes	0	6	75	94	3	5	8	14	19	7
Niittu total	2011 - 2014	1.5	varies	> 121	236	398	377	> 731	> 809	> 374	> 449	> 356	233

***Up to > 1 ha flooded during high floods ca. 5 x yr. **Max ha inundated during spring amphibian spawning season. May dry completely in late summer.**

Habitat capacity: frogs (common+moor)

- Gateway wetland ca. 30-40 female frogs
- Niittu wetland ca. 300-400 female frogs



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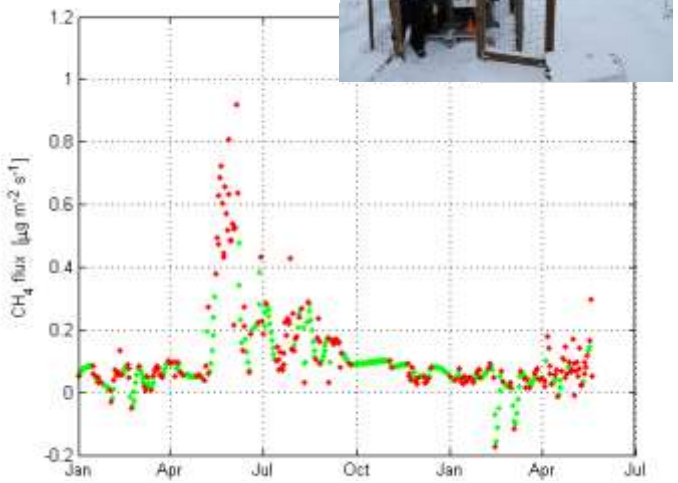
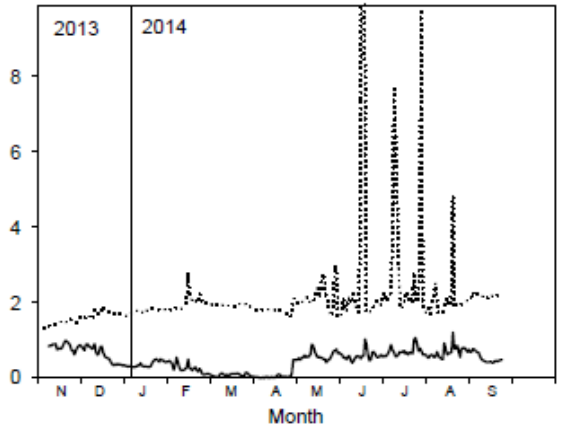
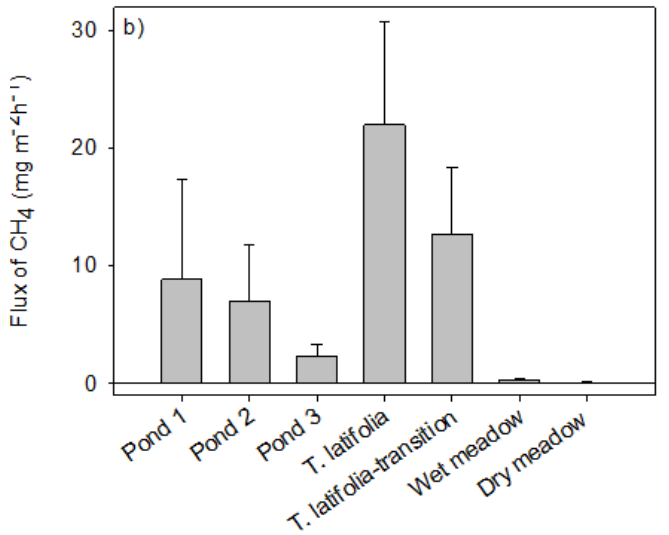
Greenhouse gases, e.g. methane



Eddy covariance

Concentration in water

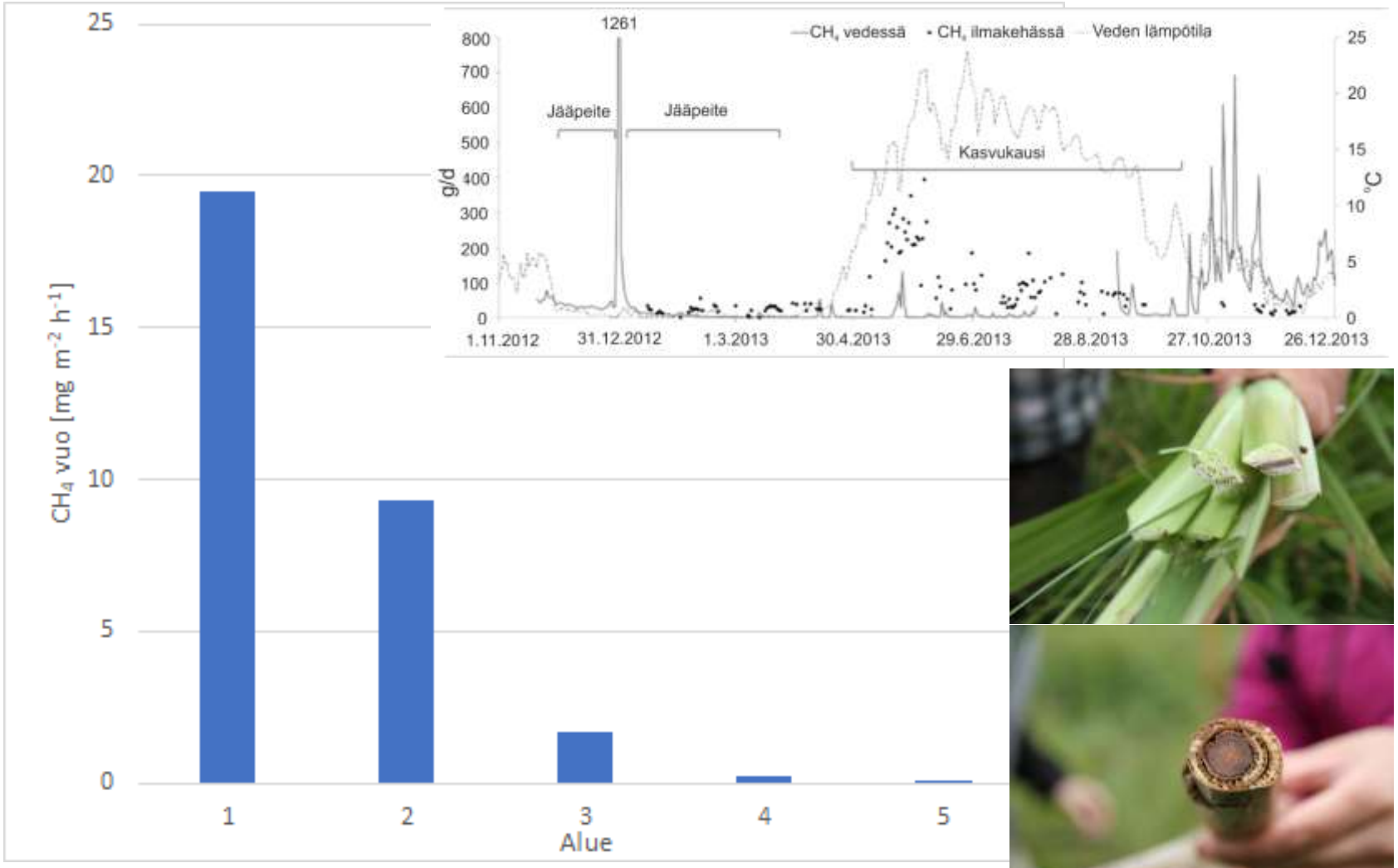




Chambers

Graphs: Maria Tolppanen, Anne Ojala, Sami Haapanala, Pasi Valkama, Outi Wahlroos and Emmi Mäkinen

METHANE EMISSIONS



FLOOD MEADOWS:

- WATER QUALITY
- BIODIVERSITY AND HABITAT
- REDUCE METHANE EMISSIONS
- IMPORTANT AT S-RICH AREAS

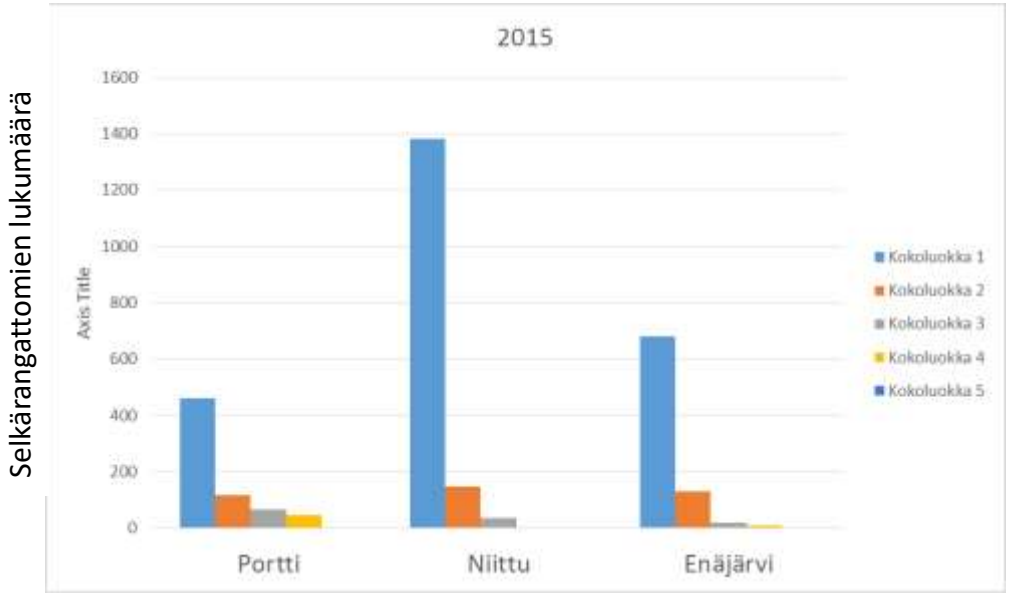
KEEP THE WETLADS COMPLEX!

Concern: sink habitats -> Safe passages for fauna

Picture: Anna Halonen

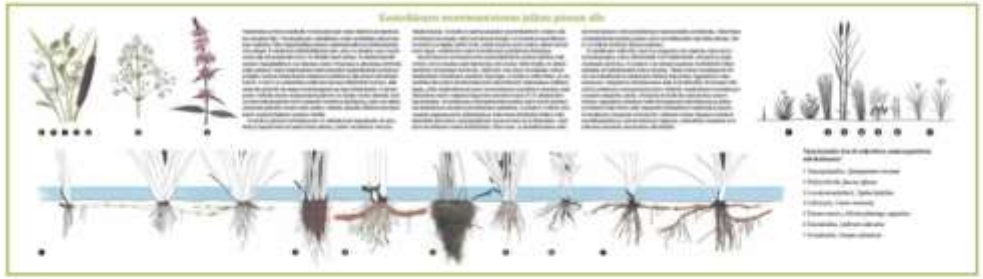
Water invertebrates

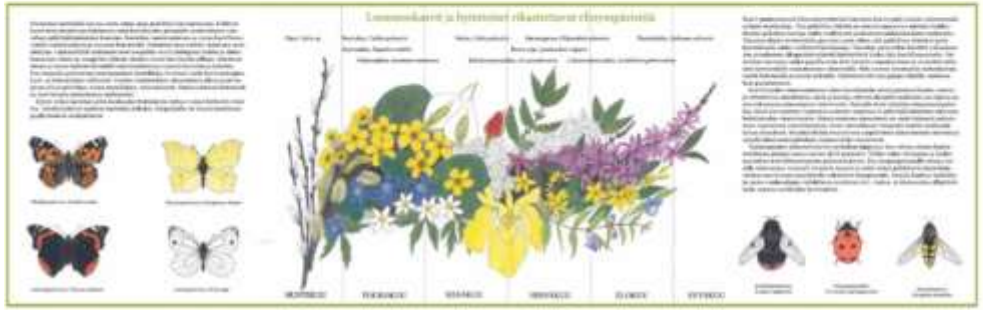
- Species diversity development
  - Succession and environmental conditions



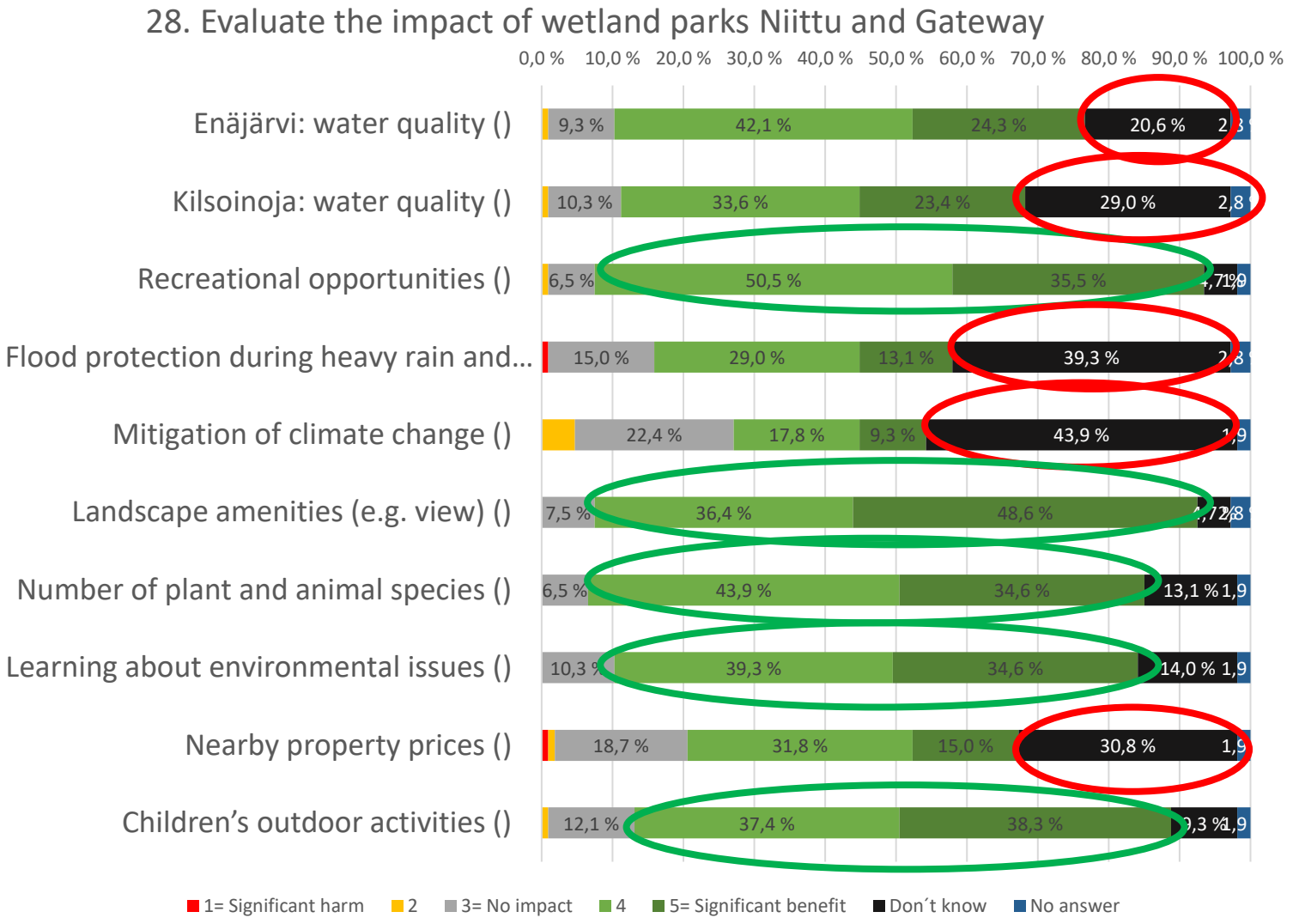
Graph: Sari Holopainen

Environmental education

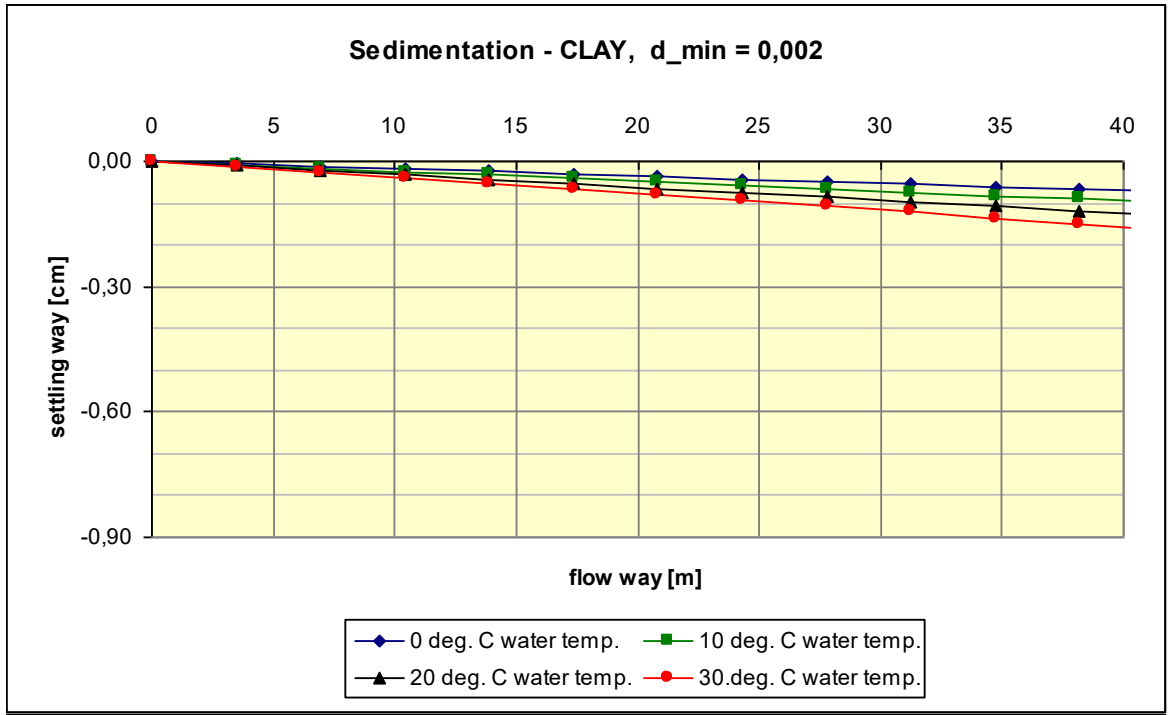


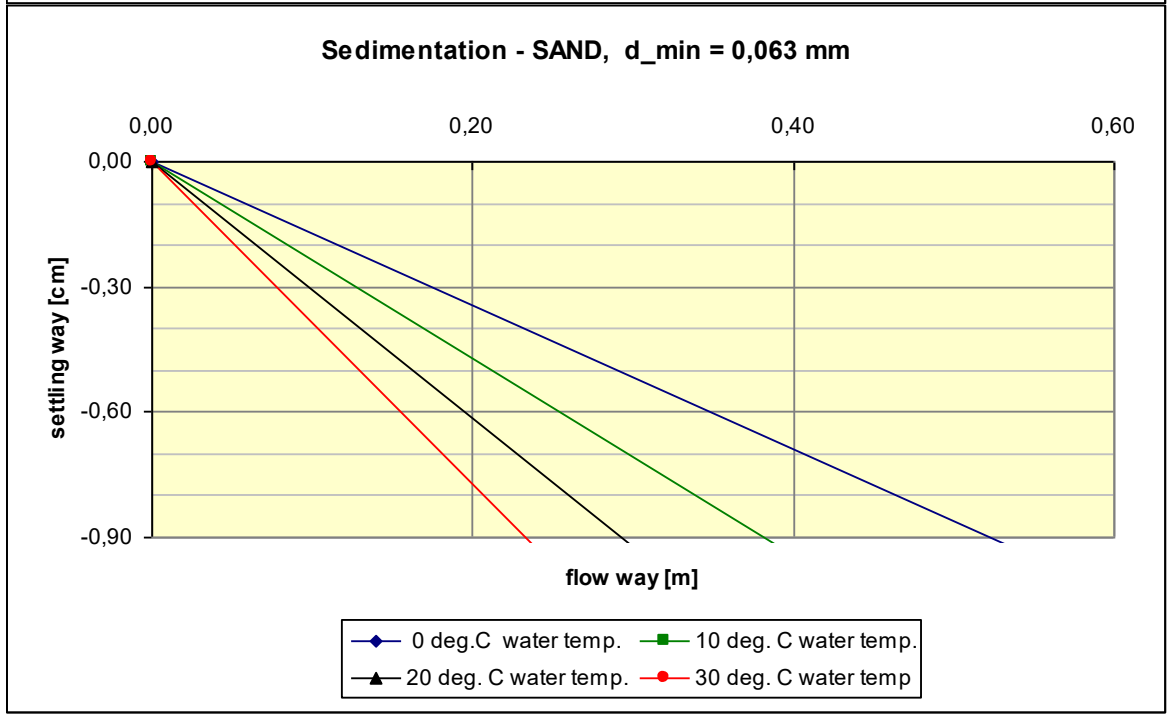


Evaluating ecosystem services of wetlands



Graph: Janne Antikainen





Understanding water treatment

Aerial: Google Maps 2021

Ecosystem services valuation?

Waterworks park, Renton, WA

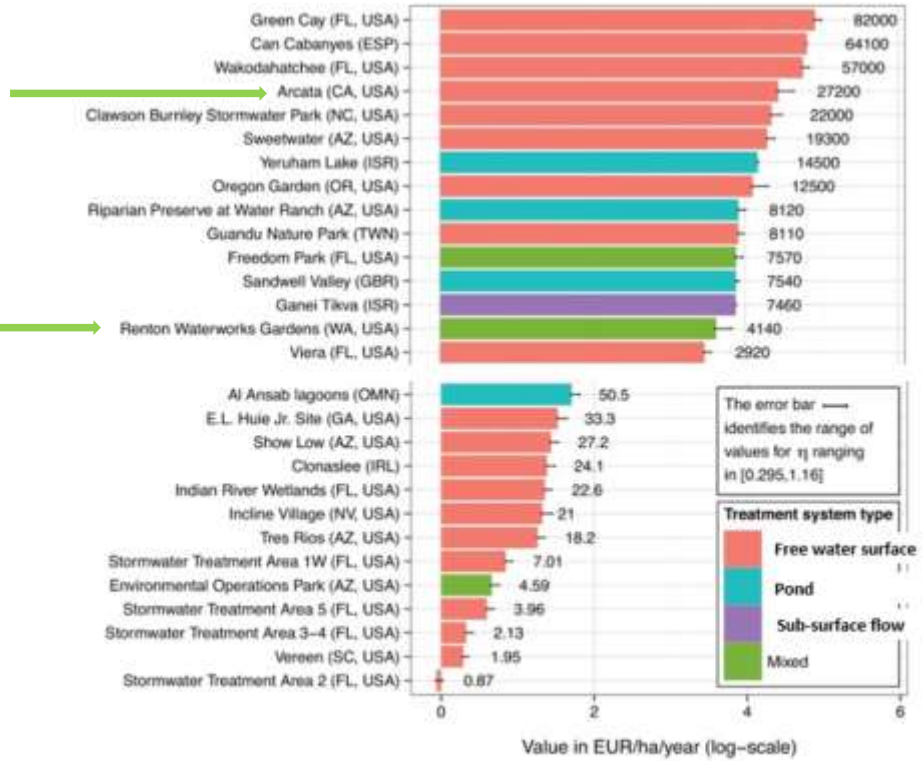
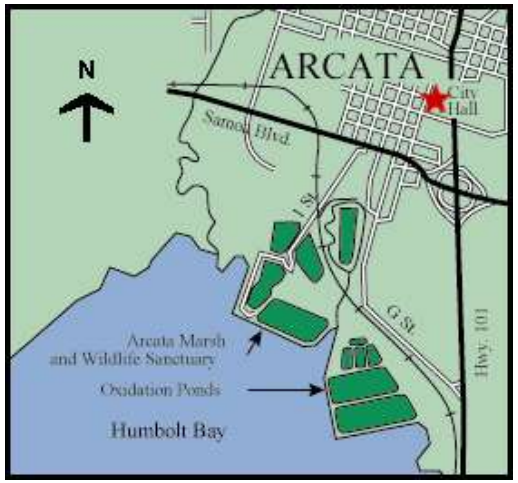


Fig. 3. Estimated per-hectare flow of recreational values in 2013 €/ha/year for 42 constructed treatment wetlands and waste stabilization ponds. From Ghermandi & Fichtman 2015 Ecological Engineering.

Wastewater Treatment Wetland Park, Arcata, CA



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Educational surveys

SURVEY ON THE USAGE OF URBAN WETLANDS IN VIIKKI

CONSTRUCTED WETLANDS AND THEIR USAGE

Stream Viikinoja and stream **Säynäslahdenpuro** watersheds are located in Viikki. Wetland areas are located within these stream networks.

Wetland is part of a landscape, small waters (river, stream or pond) or coastal areas that is saturated with water at least part of the year, and that has a characteristic vegetation of aquatic plants. Wetlands can be either natural or constructed.

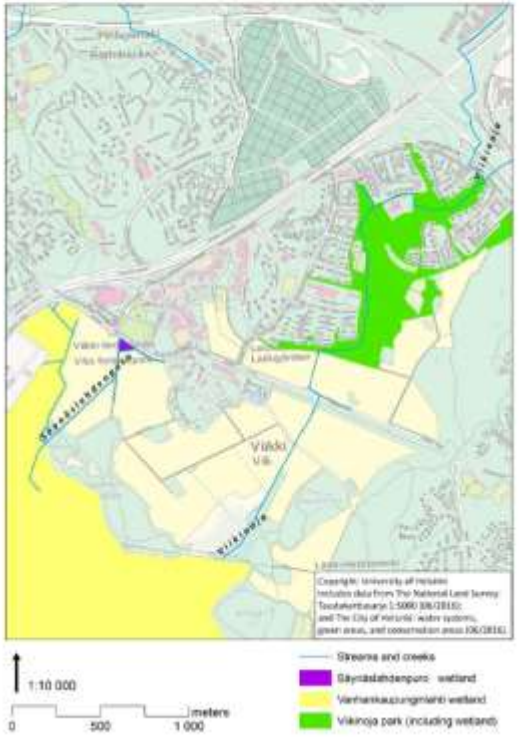
Urban wetlands address various values simultaneously - such as recreation, biodiversity, and water and flood protection. The stream Viikinoja has been augmented with a winding shape, aquatic plant life and tiny islands. Natural wetlands are located in Southern part of Viikki, within the Vanhankaupunginlahti Bay area, which is nature conservation zone.

Säynäslahdenpuro wetland in summer 2016.
Photo: Janne Ankkainen

Duckboards at a wetland in the Vanhankaupunginlahti Bay area.
Photo: Elina Inkiläinen

4. **How often do you visit the following wetland areas?** (Please select one from each area)

	Viikinoja park	Säynäslahdenpuro	Vanhankaupunginlahti Bay
I have never visited	[ ]	[ ]	[ ]
Daily	[ ]	[ ]	[ ]
Weekly	[ ]	[ ]	[ ]
A few times a month	[ ]	[ ]	[ ]
Once a month	[ ]	[ ]	[ ]
A few times a year	[ ]	[ ]	[ ]
Once a year or less	[ ]	[ ]	[ ]



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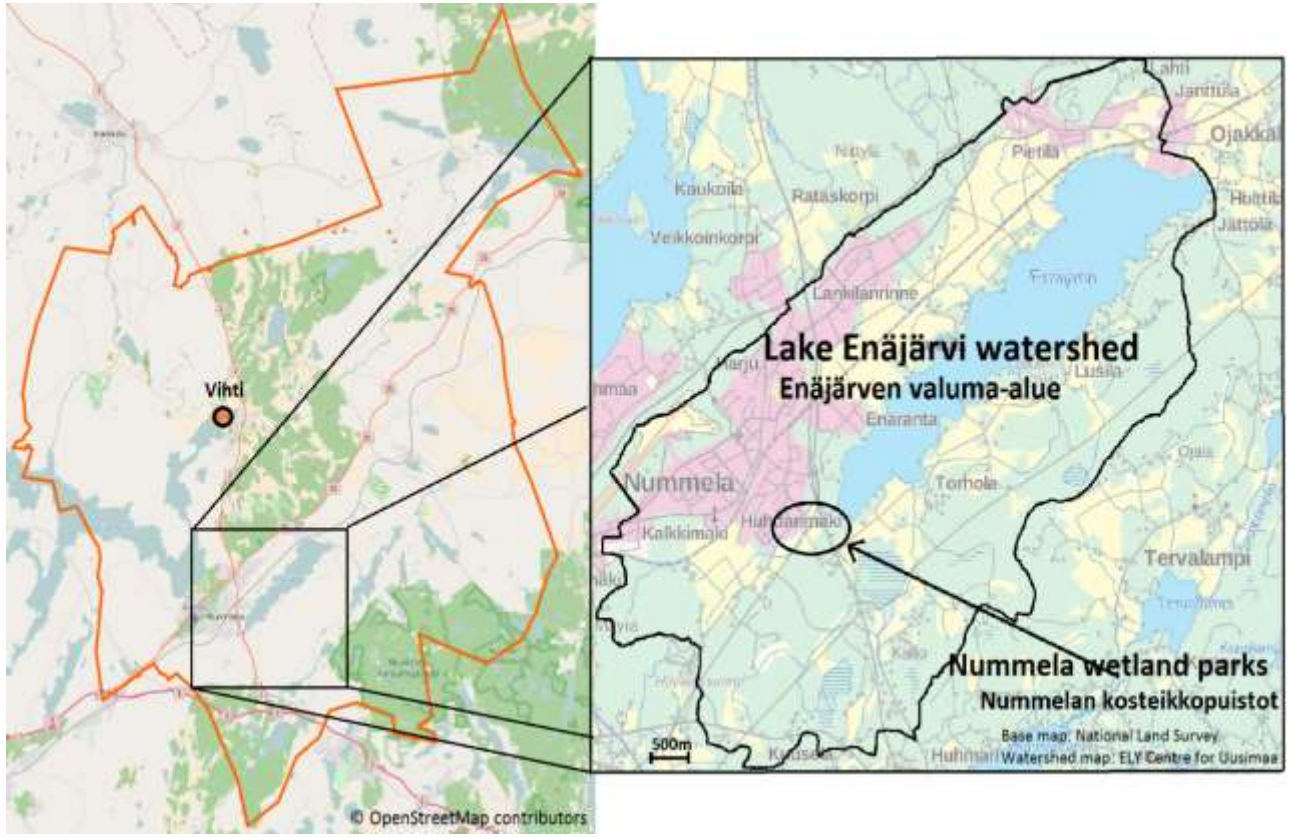
Evaluating ecosystem services

Survey to Vihti residents on
wetland parks
Niittu and Gateway as examples



Graph:Elina Inkiläinen

Interests

- Pathways with trash collectors, information boards, nature observation, nature schools
- Meadows, trees & shrubs
- Views and biodiversity

Willingness to pay by stormwater fee

- Lake water quality improvement & recreation, not for species diversity
- Increased if had previously visited a constructed wetland
- Sum more than twice the current management cost

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Respond to requests

Participatory design

Allowing and observing succession, engaging locals to environmental protection and citizen science





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Volunteer events

- Making, knowing and caring for your backyard
- Learning solutions and outreach






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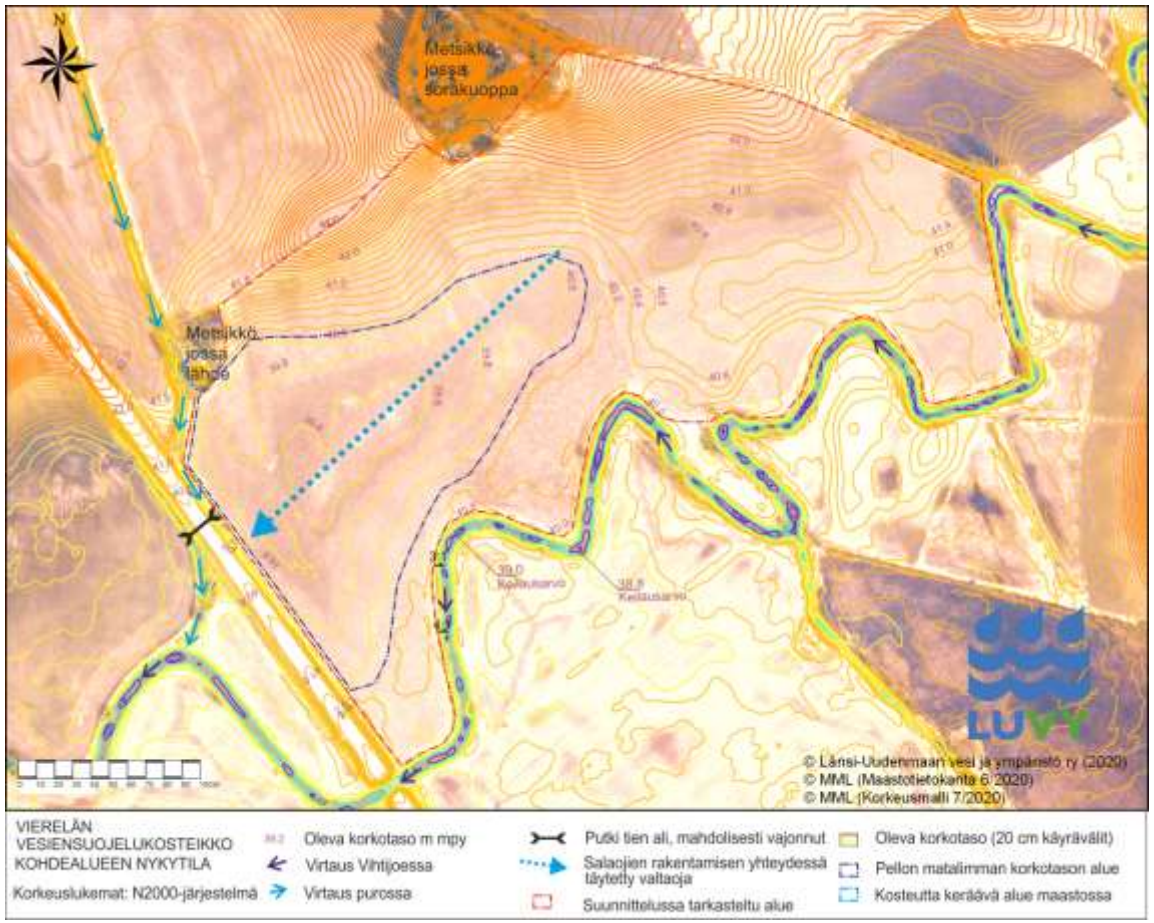
Challenge

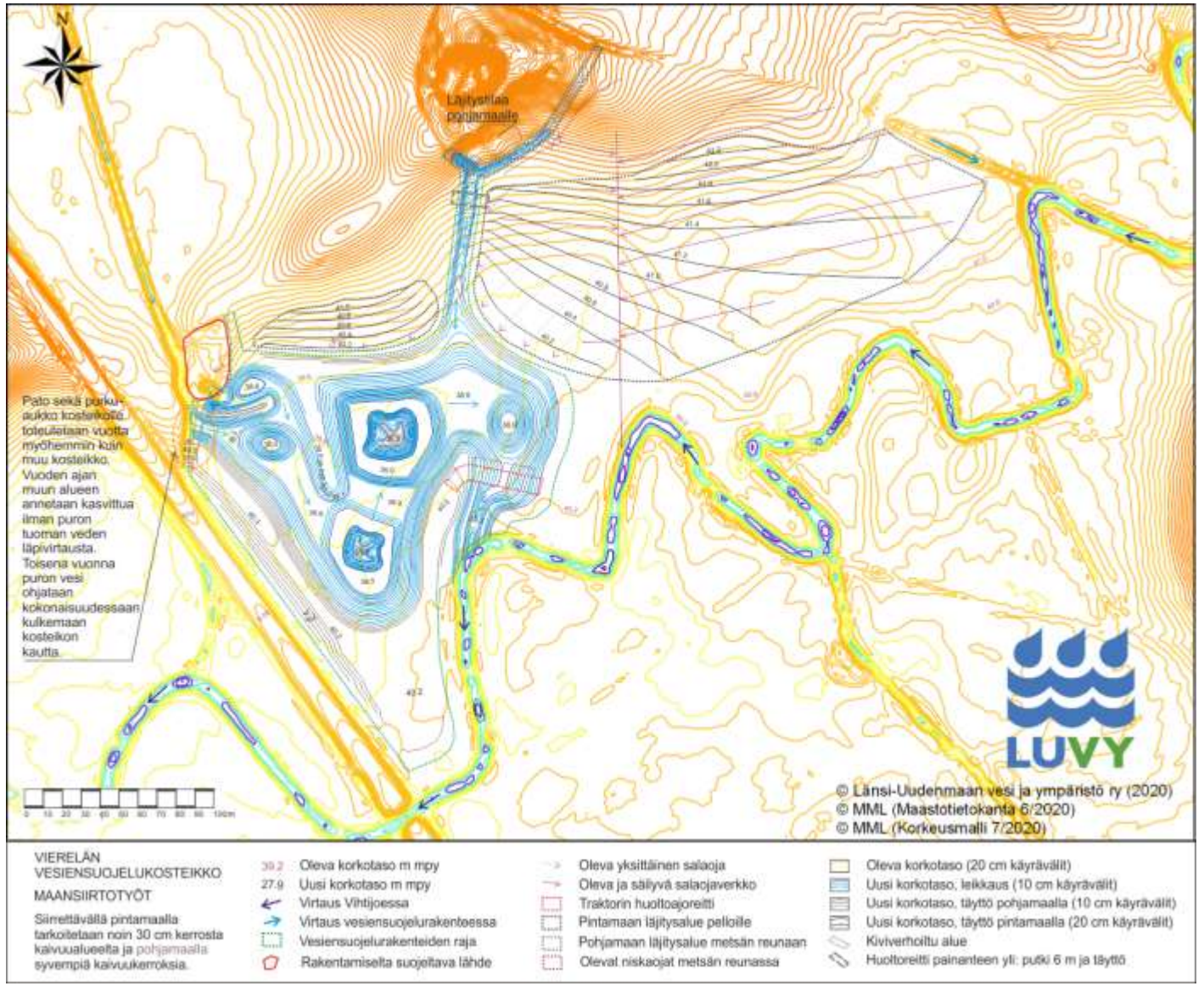

Choice

One must start somewhere

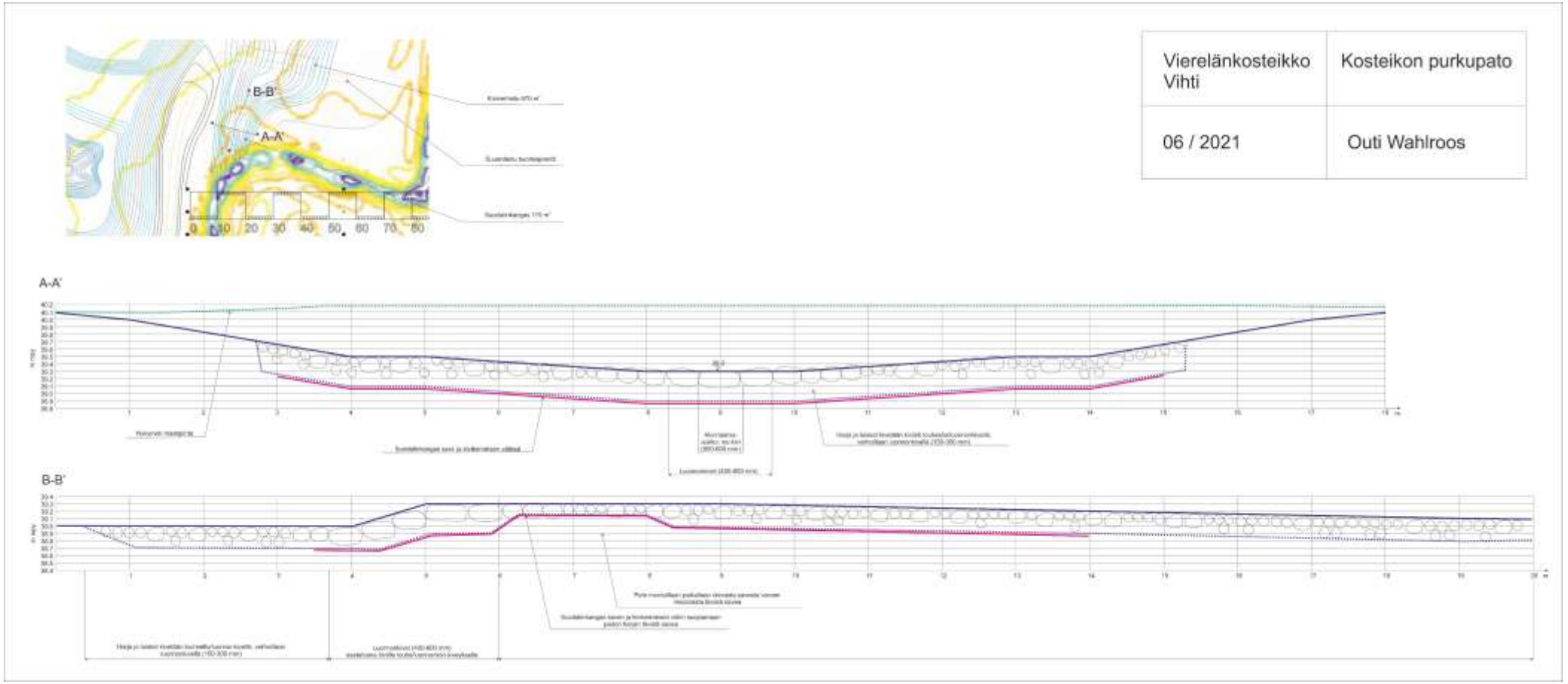
Further example, an agricultural wetland Existing site conditions



Implementation design

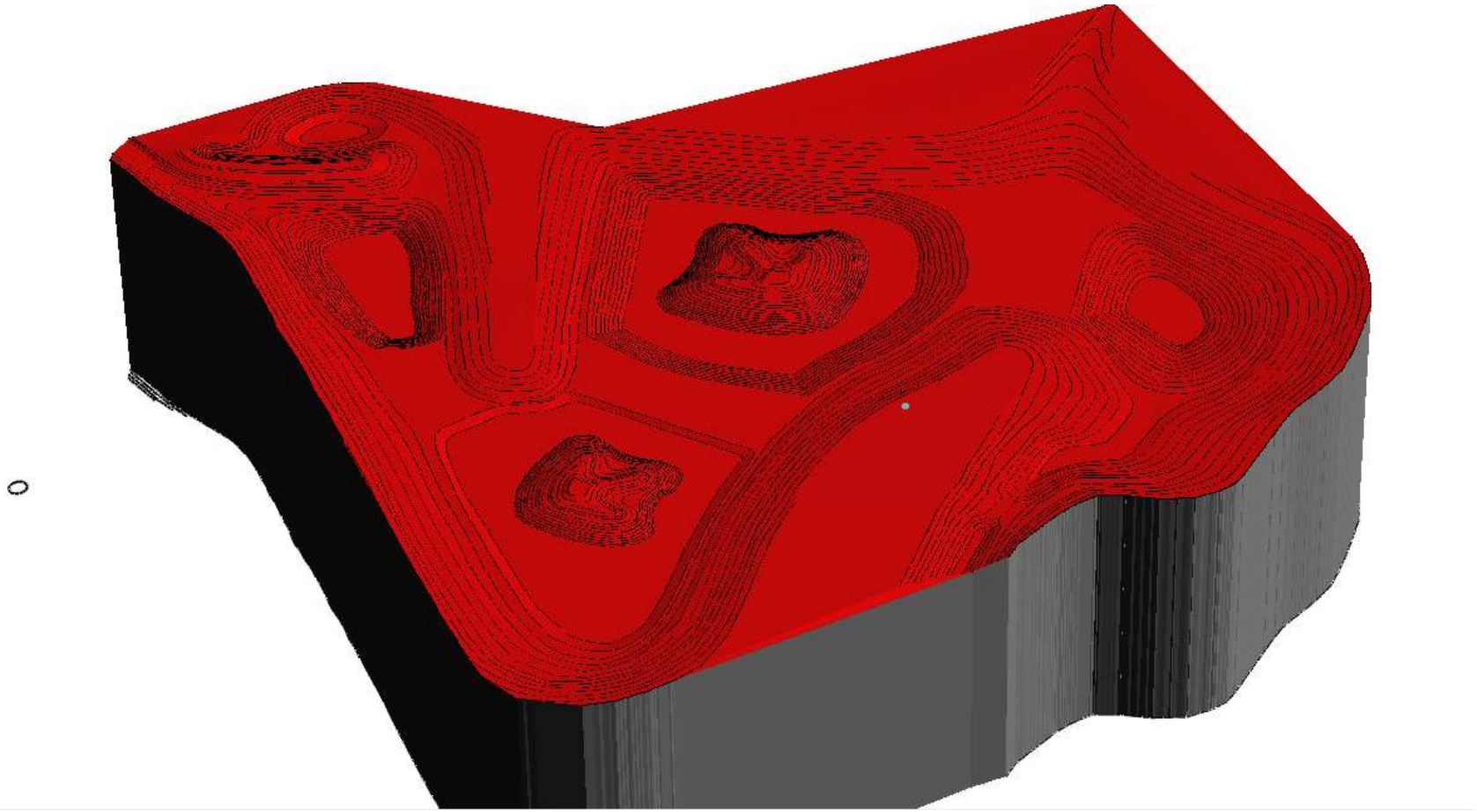


Implementation design detail

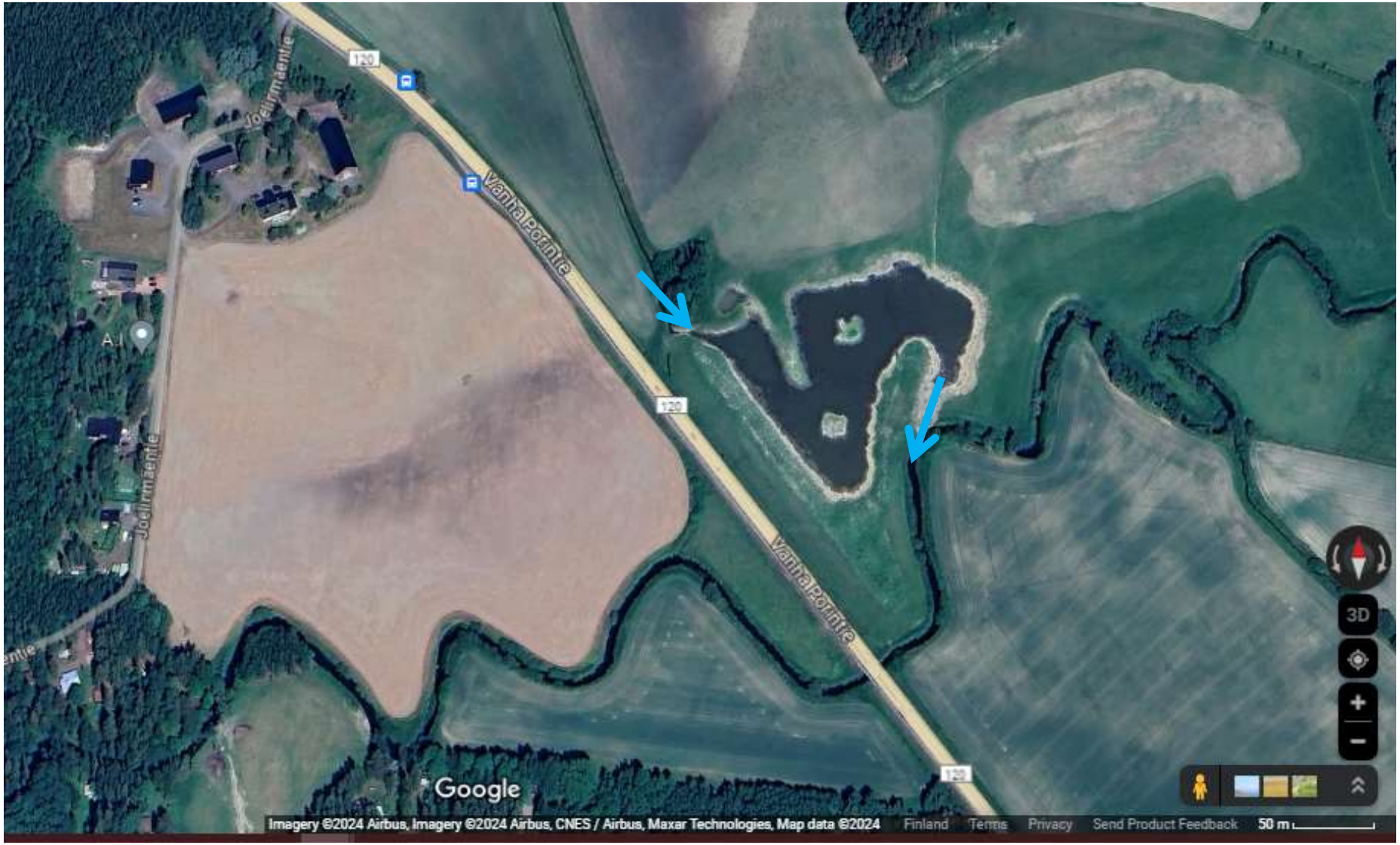


Vierelänkosteikko Vihti	Kosteikon purkupato
06 / 2021	Outi Wahlroos

3D plan for constructor



First year after construction



Second spring after construction, migrating geese and other water fowl

How much water comes to the puddle?

(This runoff estimation method is called the ”rational method”)

Q=CIA

Q = [l/s], I = [l/(s*ha)], A= [ha]

Or:

Q = 0,0028*C*I*A

Q = peak inflowing stormwater runoff rate [m3/s]

C = runoff coefficient: the proportion of rain that turns to runoff (0=none, 1=all)

I = intensity of the design storm [mm/h]

A = area of watershed from which water is collected [ha]

(0,0028=(mm/h)*(1m/1000mm)*(1h/3600s)*(ha)*(10.000 m2/ha))

(1 m3/s = 1000 l/s)

design storm = intensity for a rain event with known duration and return period (such as a 15 min rain event occurring once in 3 years)

Table 330-10. RECOMMENDED RATIONAL FORMULA RUNOFF COEFFICIENTS "C"

Surface		C values Min.	Max.
Street, asphalt		0.70	0.95
Street, concrete		0.80	0.95
Drives and walks		0.75	0.85
Roofs		0.75	0.95
Pervious areas, A soils*	0-1% slopes	0.04	0.09
	2-6% slopes	0.09	0.13
	steep slopes	0.13	0.18
Pervious areas, B soils*	0-1% slopes	0.07	0.12
	2-6% slopes	0.12	0.17
	steep slopes	0.18	0.24
Pervious areas, C soils*	0-1% slopes	0.11	0.16
	2-6% slopes	0.16	0.21
	steep slopes	0.23	0.31
Pervious areas, D soils*	0-1% slopes	0.15	0.20
	2-6% slopes	0.20	0.25
	steep slopes	0.28	0.38
Composite values			
Residential	single-family detached	0.30	0.50
	multi-units, detached	0.40	0.60
	multi-units, attached	0.60	0.75
	suburban lots, < .2 ha (0.5 acre)	0.25	0.40
	suburban lots, ≥ .2 ha (0.5 acre)	0.30	0.45
Apartment dwelling areas		0.50	0.70
Industrial	light areas	0.50	0.80
	heavy areas	0.60	0.90
Parks and cemeteries		0.10	0.25
Playgrounds		0.20	0.40
Railroad yard areas		0.20	0.40
Unimproved areas	pasture (flat-steep)	0.10	0.42
	cultivated (flat-steep)	0.31	0.44