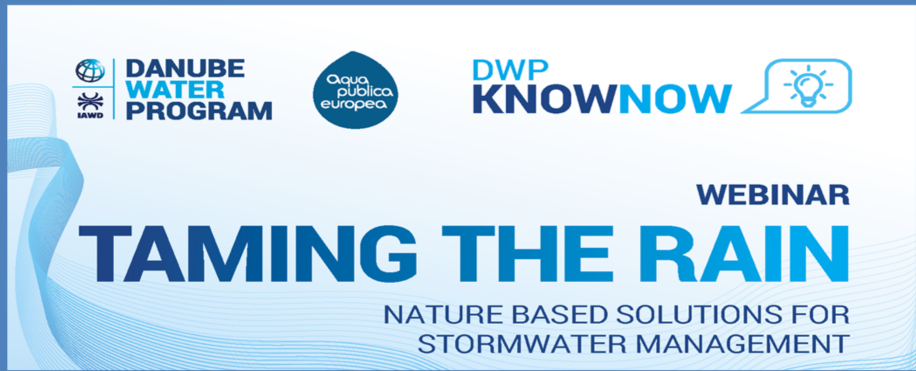
NBS FOR STORMWATER MANAGEMENT

CASE STUDIES FROM TOWN OF PULA, CROATIA

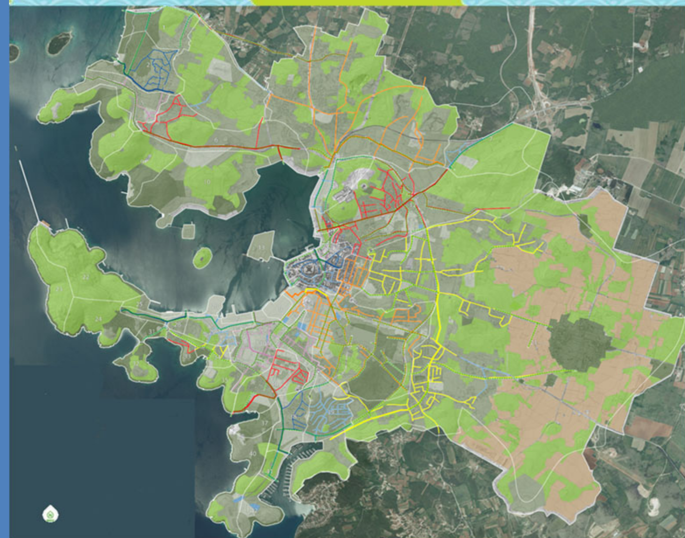


Tatjana Uzelac

Pula, 14.11.2024.

STARUM

CASE STUDIES



Pula had big problems with floods for the following reasons:

- topography (on the lower point of Istria peninsula)
- old sewer channels (mixed sanitary and stormwater)
- sudden urbanization and spatial plans that did not recognize changes in runoff and additionally high-cost stormwater sewer which can not follow the rapid urbanization
- short-term heavy rain (related to climate change)
- underground (impervious clay soil)

FLOODS

NAZOROVA STREET

KING TOMISLAV SQUARE

ŠIJANA WATERSHED

LOŠINJSKA STREET

Nazorova street – Pula

2007-2009

USED NBS SYSTEMS – RAIN GARDENS, INFILTRATION TRENCH

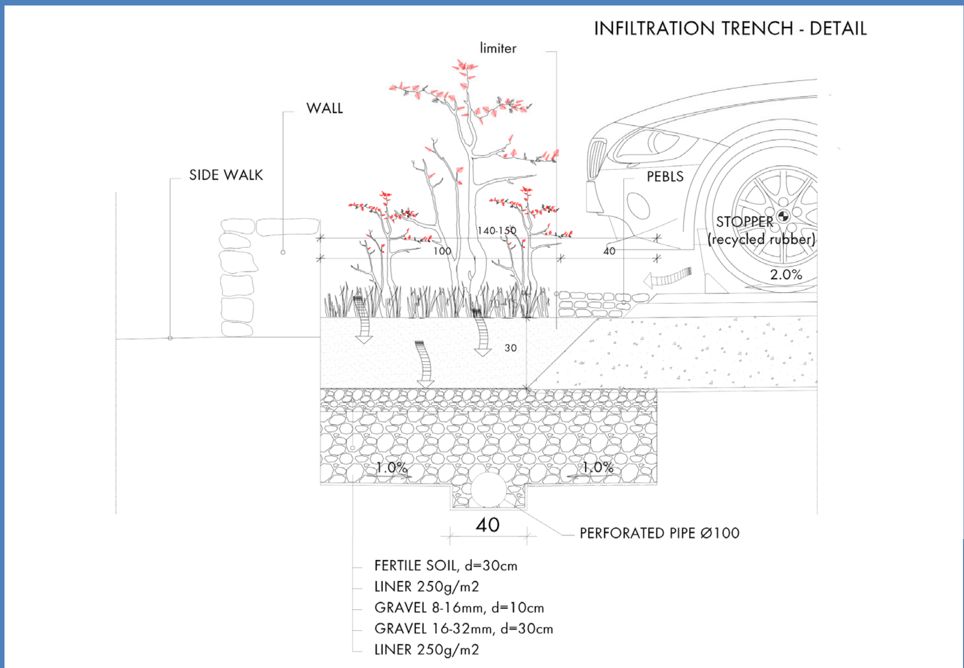
Nazorova street – Pula

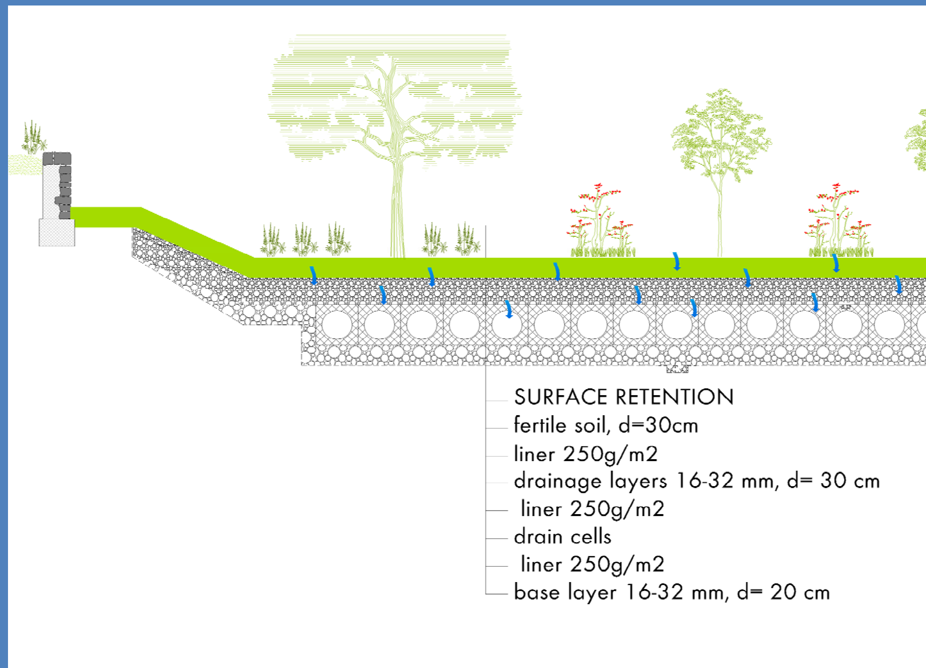
2007-2009

USED NBS SYSTEMS – RAIN GARDENS, INFILTRATION TRENCH

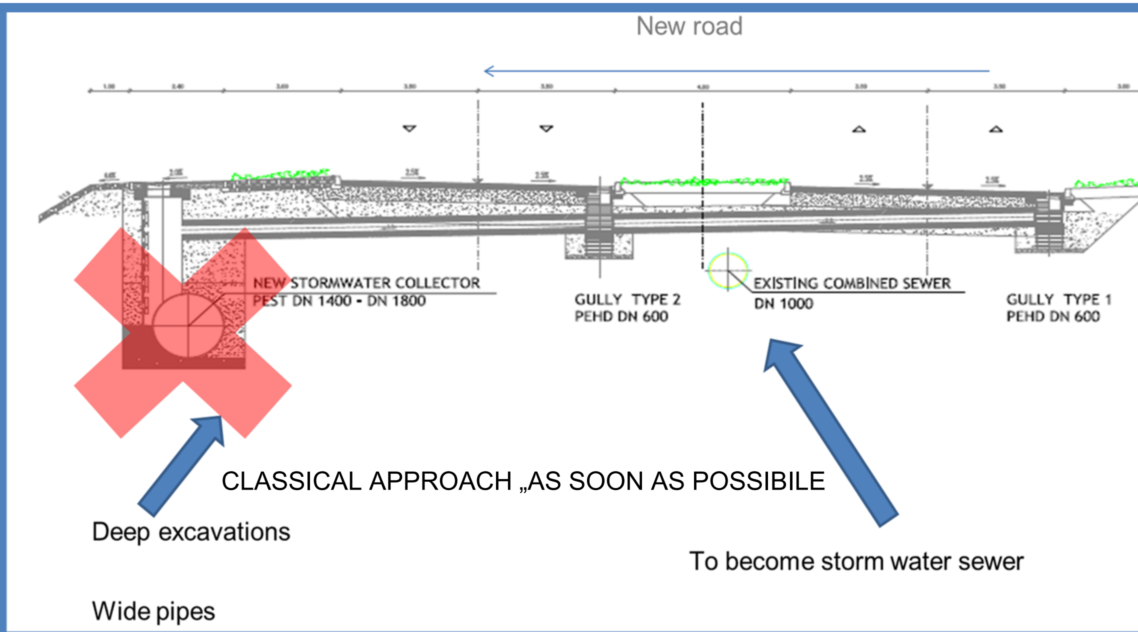
WE HAD USED NBS SOLUTIONS WITH
3 RAIN GARDENS, UNDERGROUND RETENTIONS WITH DRAIN CELLS,
AND INFILTRATION TRENCH FOR THE PARKING LOT

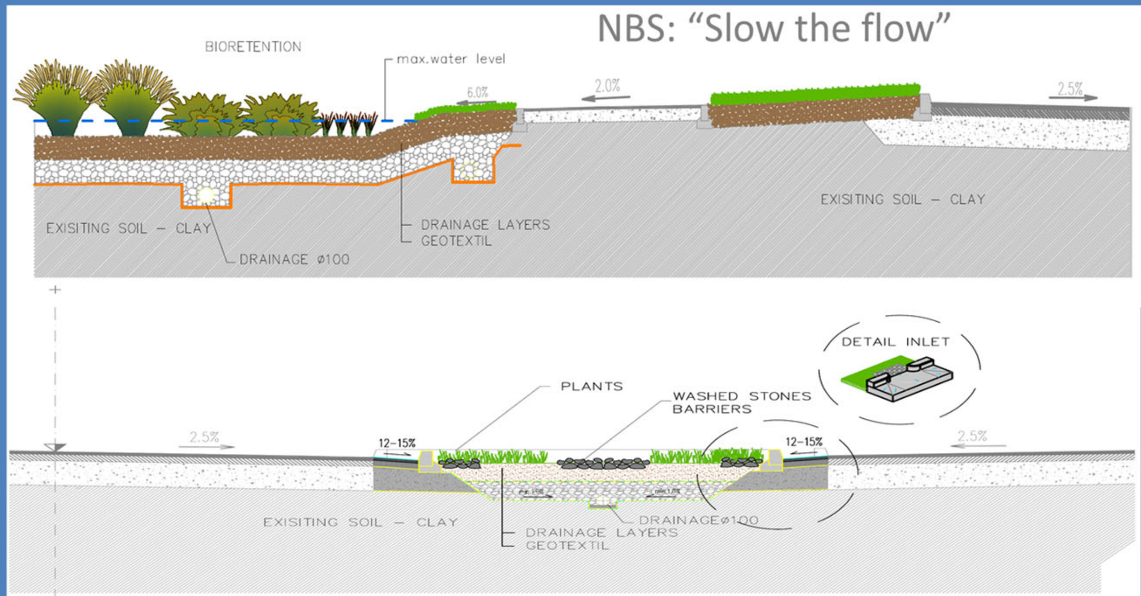
CALCULATION METHOD USED :
Rational Method: Q = c x i x A, RETURN PERIOD 100 YEARS, DURATION: 24 HOURS

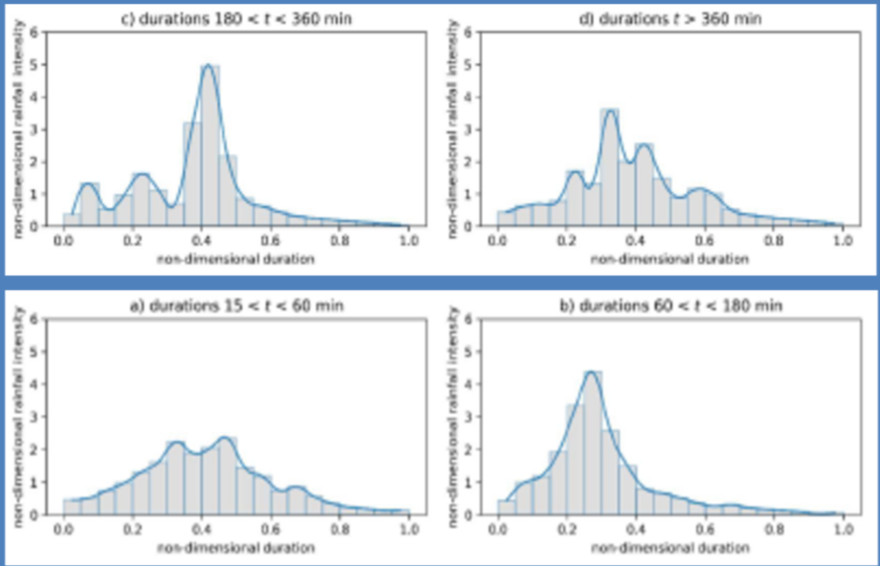




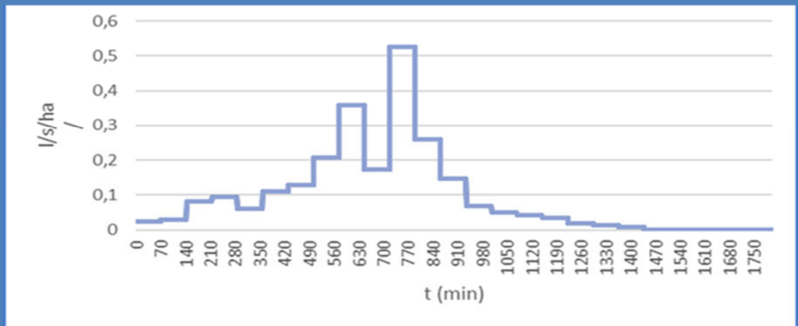
Town Beltway– Pula 2017





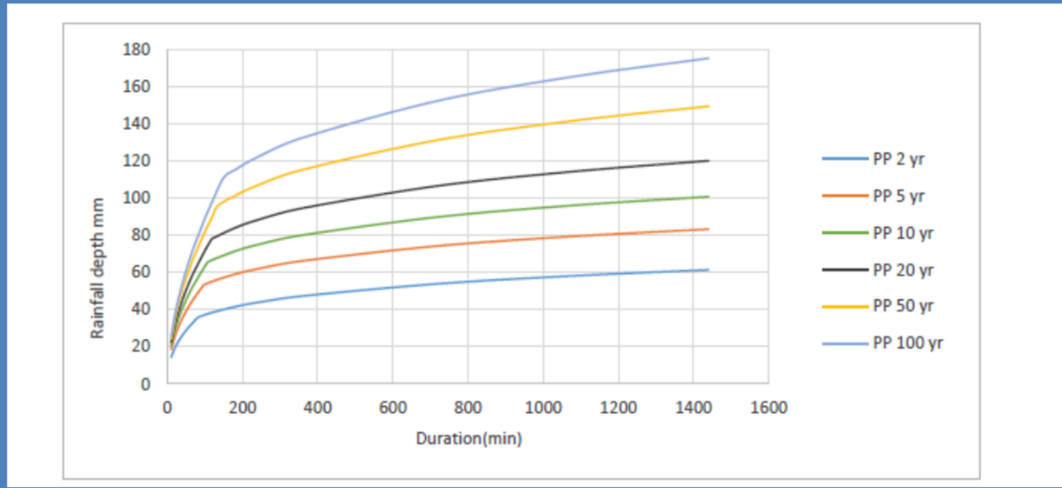


Defined dimensionless hyetograms of DESIGN STORM for different classes of rainfall duration:
a) 15 < t ≤ 60 min, b) 60 < t ≤ 180 min, c) 180 < t ≤ 360 min, d) t > 360 min



Hyetogram of DESIGN STORM RP 100 YEARS, 24 HOURS, PULA

DDF CURVES FOR PULA



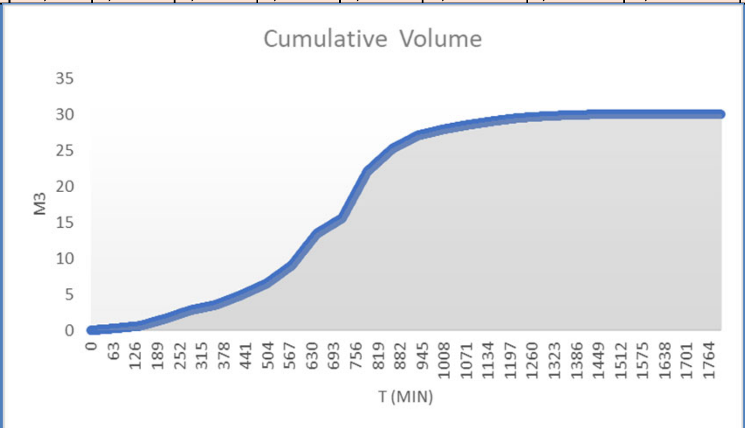
Temporal distribution of rainfall intensity for design (fint correction factors), for all four duration classes at Pula station (1957 - 2017)

f_{int}	Duration class			
Period	15 - 60 min	60 - 180 min	180 - 360 min	360 - 2880 min
P1	0.43	0.53	0.55	0.19
P2	0.53	2.04	0.91	0.24
P3	0.59	4.40	2.35	0.67
P4	0.95	3.38	3.42	0.78
P5	1.27	2.59	4.79	0.49
P6	1.74	1.57	1.82	0.91
P7	3.25	1.24	1.10	1.05
P8	3.11	0.96	0.78	1.70
P9	1.50	0.64	0.66	2.94
P10	2.08	0.77	1.42	1.42
P11	1.05	0.44	0.45	4.32
P12	0.81	0.35	0.39	2.12
P13	0.71	0.28	0.32	1.20
P14	0.45	0.21	0.27	0.57
P15	0.38	0.17	0.22	0.42
P16	0.32	0.13	0.18	0.35
P17	0.27	0.11	0.14	0.29
P18	0.24	0.06	0.11	0.15
P19	0.16	0.04	0.04	0.11
P20	0.15	0.08	0.07	0.06

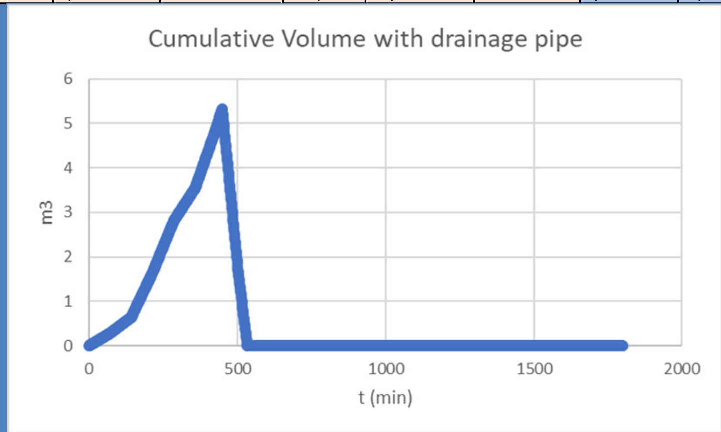
Town Beltway– Pula 2017

CALCULATION METHOD USED :
Modified SANTA BARBARA Method, RETURN PERIOD 100 YEARS, DURATION: 24 HOURS

t	fin	fin	im	im	Isrxfin	Imxfin	Inflow rate	Inflow Volume	Runoff Depth	Inflow rate-RAIN GARDEN	Inflow Volume - RAIN GARDEN	Inflow rate - Inflow rate Rain Garden	Inflow Volume - Inflow Volume RAIN GARDEN	CUMULATIVE INFLOW OF VOLUME TO BE RETAINED	The height of water in the drainage layer	The height of water in the RAIN GARDEN - SURFACE	t	Inflow Volume - Inflow Volume RAIN GARDEN- Inflow Volume Drainage	CUMULATIVE INFLOW OF VOLUME TO BE RETAINED	The height of water in the drainage layer	The height of water in the RAIN GARDEN - SURFACE
(min)	-	-	mm/min	l/s/ha	mm/min	l/s/ha	l/s	m3	m	l/s	m3	l/s	m3	m3	m	m	(hours)	m3	m3	m	m
0	0	0,057903	9,650656	0,011002	1,833625	0,06601049	0	0,000000000	0	0	0	0	0	0	**0**	**0,0000000**	**0**	**0**	**0**	**0**	**0**
1	0,19	0,057903	9,650656	0,011002	1,833625	0,06601049	0,00396063	0,000006601	0	0	0,00396063	0,003960629	8,11604E-05	0	0,016667	0,0000000	0	0,00396063	0,003960629	8,11604E-05	0
2	0,19	0,057903	9,650656	0,011002	1,833625	0,06601049	0,00396063	0,000006601	0	0	0,00396063	0,007921258	0,000162321	0	0,033333	0,0000000	0	0,00396063	0,007921258	0,000162321	0
3	0,19	0,057903	9,650656	0,011002	1,833625	0,06601049	0,00396063	0,000006601	0	0	0,00396063	0,011881888	0,000243481	0	0,05	0,0000000	0	0,00396063	0,011881888	0,000243481	0
4	0,19	0,057903	9,650656	0,011002	1,833625	0,06601049	0,00396063	0,000006601	0	0	0,00396063	0,015842517	0,000324642	0	0,066667	0,0000000	0	0,00396063	0,015842517	0,000324642	0
5	0,19	0,057903	9,650656	0,011002	1,833625	0,06601049	0,00396063	0,000006601	0	0	0,00396063	0,019803146	0,000405802	0	0,083333	0,0000000	0	0,00396063	0,019803146	0,000405802	0
6	0,19	0,057903	9,650656	0,011002	1,833625	0,06601049	0,00396063	0,000006601	0	0	0,00396063	0,023763775	0,000486963	0	0,1	0,0000000	0	0,00396063	0,023763775	0,000486963	0
7	0,19	0,057903	9,650656	0,011002	1,833625	0,06601049	0,00396063	0,000006601	0	0	0,00396063	0,027724404	0,000568123	0	0,116667	0,0000000	0	0,00396063	0,027724404	0,000568123	0
8	0,19	0,057903	9,650656	0,011002	1,833625	0,06601049	0,00396063	0,000006601	0	0	0,00396063	0,031685034	0,000649283	0	0,133333	0,0000000	0	0,00396063	0,031685034	0,000649283	0
9	0,19	0,057903	9,650656	0,011002	1,833625	0,06601049	0,00396063	0,000006601	0	0	0,00396063	0,035645663	0,000730444	0	0,15	0,0000000	0	0,00396063	0,035645663	0,000730444	0
10	0,19	0,057903	9,650656	0,011002	1,833625	0,06601049	0,00396063	0,000006601	0	0	0,00396063	0,039606292	0,000811604	0	0,166667	0,0000000	0	0,00396063	0,039606292	0,000811604	0
11	0,19	0,057903	9,650656	0,011002	1,833625	0,06601049	0,00396063	0,000006601	0	0	0,00396063	0,043566921	0,000892765	0	0,183333	0,0000000	0	0,00396063	0,043566921	0,000892765	0
12	0,19	0,057903	9,650656	0,011002	1,833625	0,06601049	0,00396063	0,000006601	0	0	0,00396063	0,047527551	0,000973925	0	0,2	0,0000000	0	0,00396063	0,047527551	0,000973925	0
13	0,19	0,057903	9,650656	0,011002	1,833625	0,06601049	0,00396063	0,000006601	0	0	0,00396063	0,05148818	0,001055086	0	0,216667	0,0000000	0	0,00396063	0,05148818	0,001055086	0
14	0,19	0,057903	9,650656	0,011002	1,833625	0,06601049	0,00396063	0,000006601	0	0	0,00396063	0,055448809	0,001136246	0	0,233333	0,0000000	0	0,00396063	0,055448809	0,001136246	0
15	0,19	0,057903	9,650656	0,011002	1,833625	0,06601049	0,00396063	0,000006601	0	0	0,00396063	0,059409438	0,001217407	0	0,25	0,0000000	0	0,00396063	0,059409438	0,001217407	0

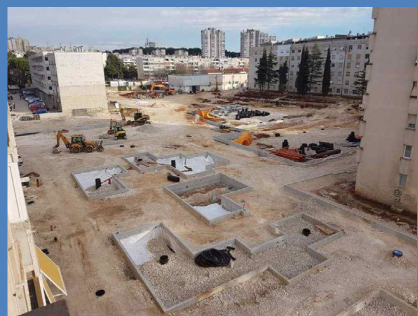


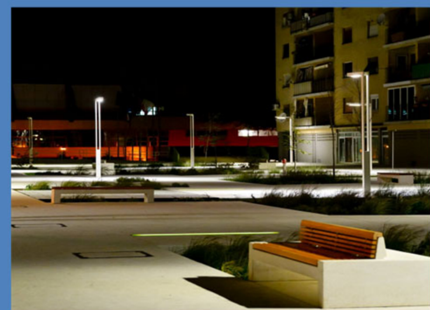
Without drainage pipe
Overflow from rain garden



With drainage pipe
After 550 min, rain garden is empty

King Tomislav square– Pula

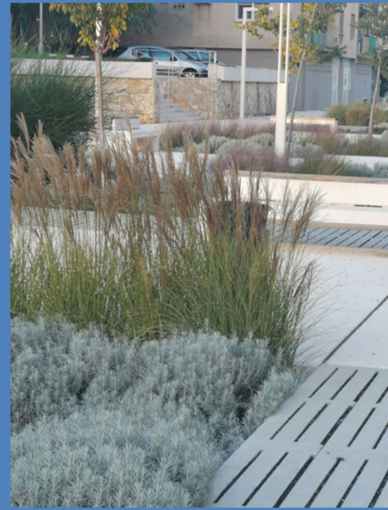




WE HAD USED NBS SOLUTIONS WITH
16 RAIN GARDENS, UNDERGROUND RETENTIONS AND INFILTRATION TRENCHES FOR THE 2 PARKING LOTS

CALCULATION METHOD USED :
Rational Method: $Q = c \times i \times A$, RETURN PERIOD 100 YEARS, DURATION: 24 HOURS

Trg kralja Tomislava– Pula, BUILT



CALCULATION METHOD USED :
Rational Method: Q = c x i x A, RETURN PERIOD 100 YEARS, DURATION: 24 HOURS

V = 6500 m3,

PLANTS:

Cornus alba sibirica
Mahonia aquifolium
Calamagrostis
Panicum virgatum
Miscanthus sinensis
Carex flacca/blue
Carex pendula
Carex grayi
Stipa lessingiana

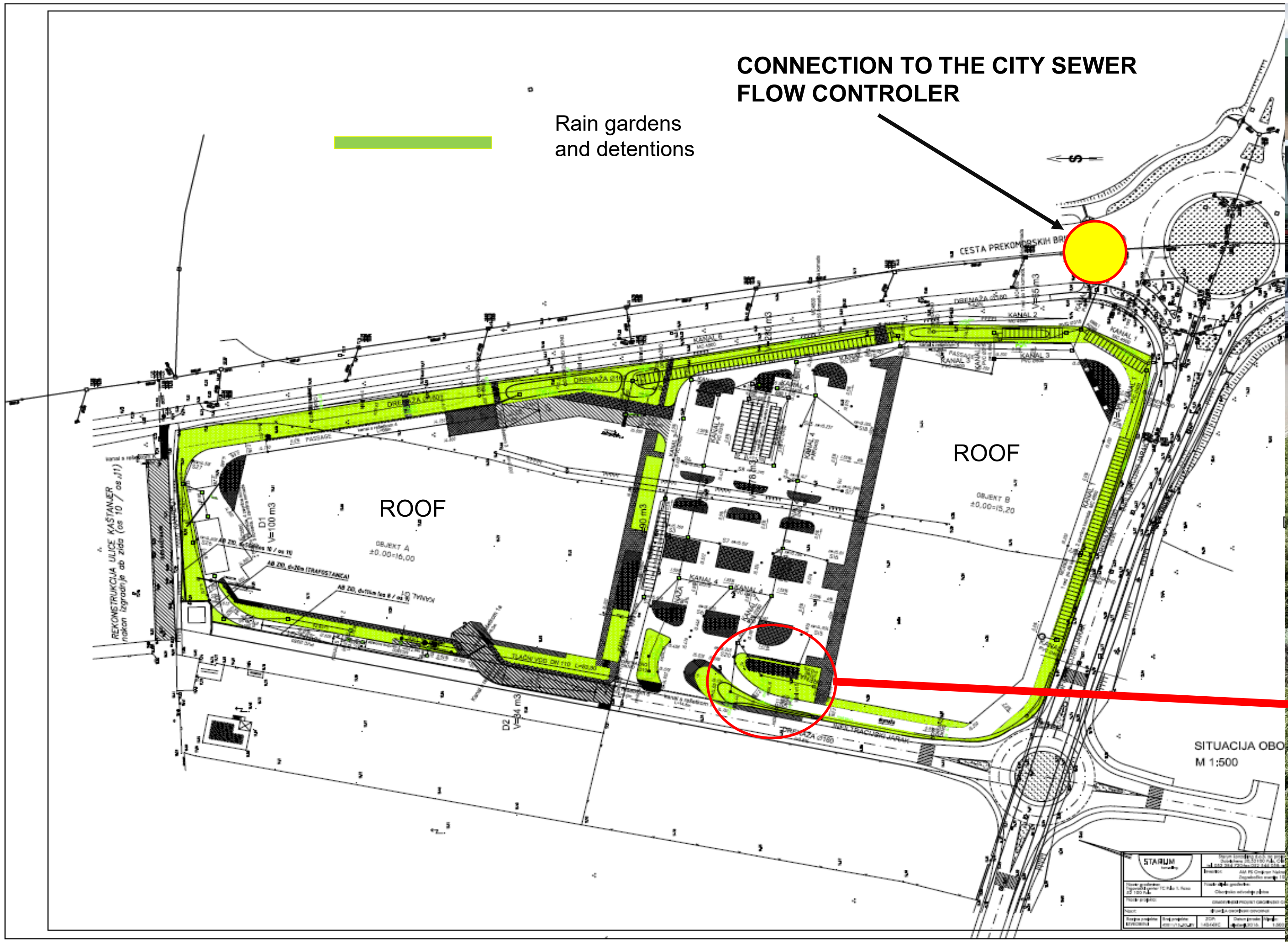
Lavandula sp.
Salvia officinalis
Iris
Allium ursinum
Stipa pennata
Stipa gigantea
Pennisetum hameln
Molinia poul petersen

Celtis australis L.

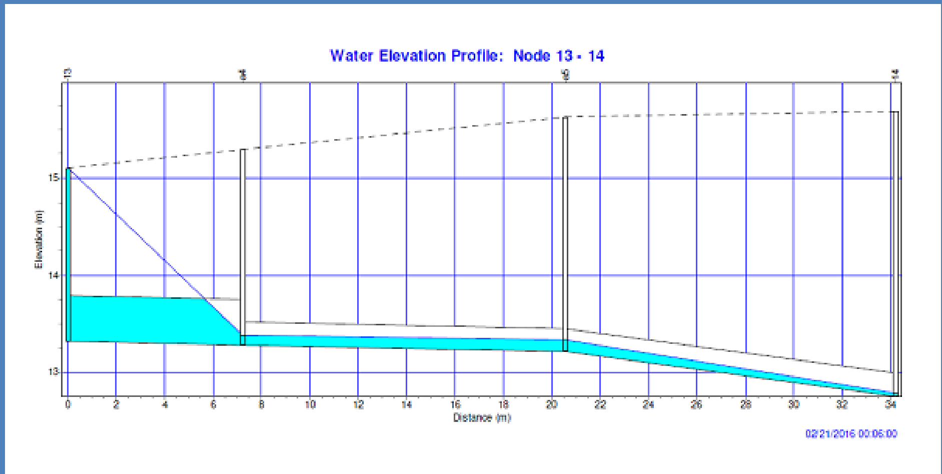
Liquidambar styraciflua

Pula City Mall – rain gardens and underground deteniton with flow controller

CALCULATION METHOD USED :
Rational Method: Q = c x i x A, RETURN PERIOD 100 YEARS, DURATION: 24 HOURS

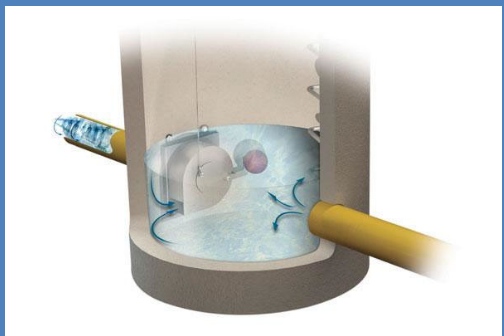


Pula City Mall – rain gardens and underground reteniton with flow controller



Mehanical Flow controller - connection to city sewer in the main manhole.

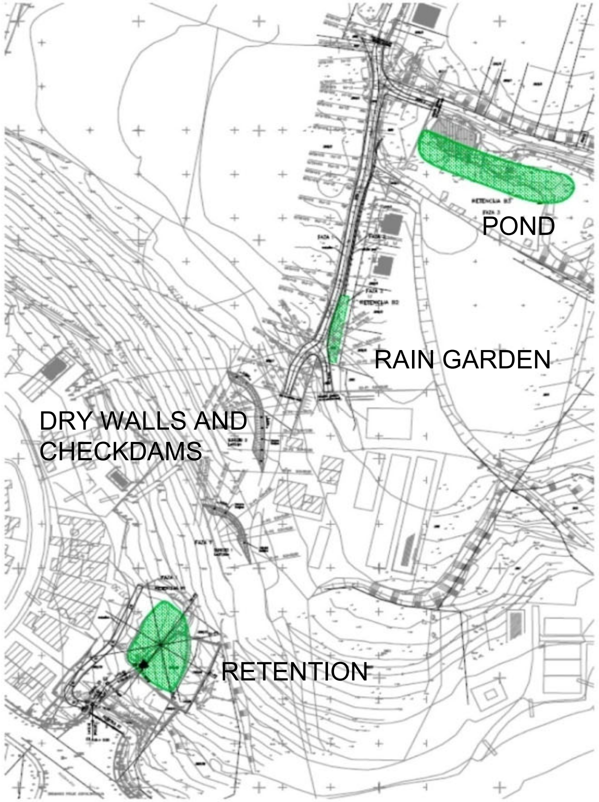
During a heavy rain flow controller will be activated (works on principle in difference pressure between water level in city sewer and water level in manhole) and then the rain gardens and retention will start recharging. After a heavy rain, water from the rain gardens and retention will be slowly discharged in the city sewer.

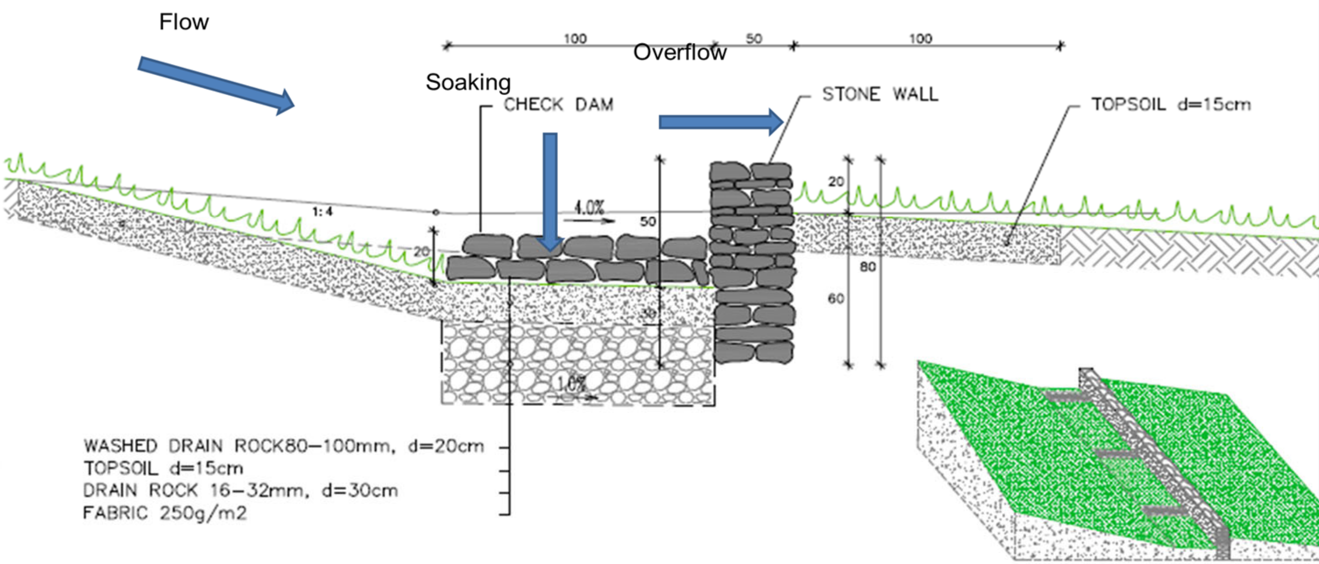


Flow controller

Detentions

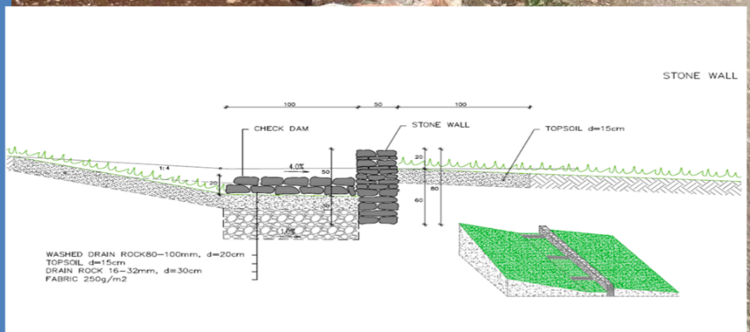
Lošinjska street – Pula, protect lower area of town

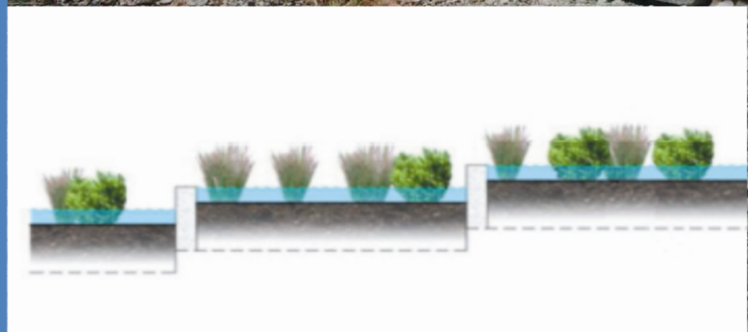




Lošinjska street – Pula

Drywalls– protection of the lower parts of the town from surface water





Šijana watershed, Pula





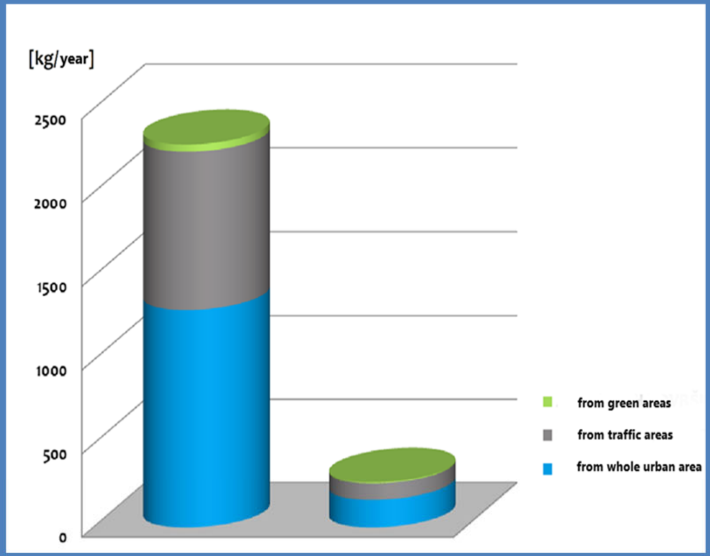
WE HAD USED NBS SOLUTIONS WITH
RAIN GARDENS, 5 LAGOONS (WET AND WITH EXTENDED RETENTION)

SAVINGS

Facilities-road with storm water sewer and landscape design	Savings compared to classical project
Riva Street Pula	550.000,00 EUR
City beltway I phase, 1 km, Pula	7.000.000,00 EUR
Stanga - industrial zone, Town of Rovinj, Istria	660.000,00 EUR
Monsena Tourist village, Town of Rovinj	700.000,00 EUR
Nazorova Street, Pula	100.000,00 EUR
Municipality of Stupnik	200.000,00 EUR
"Viktor Lenac" Shipyard, Municipality of Kostrena	1.700.000,00 EUR

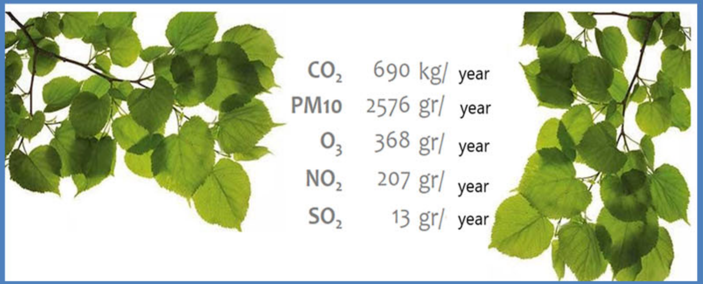
3 TO 10 TIMES CHEAPER

Reducing the burden of pollution on Nazorova Street



Reducing the burden of pollution:
85 % ANNUALY

Tilia cordata: new 23 pieces



SWOT

STRENGTHS

Protects property from water damage and flooding
It provides ecological solutions
Rainwater harvesting

WEAKNESS

Lack of regulation
The connection between concept and construction is often not well-established
Some stakeholders are also yet to be convinced of the extent of effectiveness of NBS methods in practice.

OCCASIONS

The future approach focuses on urban space planning as an interactive, publicly visible, technically simple, and beautiful ecological infrastructure.

THREATS

Lack of knowledge and lack of knowledge transfer
Institutional fragmentation, as well as the gap between knowledge and awareness
Need for significant research to identify underlying barriers and drivers
Additional research and education for the public and institutions

APPLICATION GUIDELINES FOR DESIGNERS:

- The drainage system should take full advantage of existing vegetation and natural drainage
- If possible, build the drainage system before constructing the building
- The design begins with the discharge of collected water. The calculated discharge quantities must not exceed the existing downstream capacity to reduce the possibility of flooding, erosion, habitat degradation, and the burden on the existing drainage system.
- Design so that the drainage system requires minimal maintenance costs
- Drain surface water to permeable and green areas and depression to increase infiltration
- Apply terrain shaping techniques and use depressions for water storage and infiltration
- Design retention spaces with sinusoidal banks to ensure more space for littoral vegetation (thus increasing filtration), a greater number of plant species, and a better aesthetic impression
- Place entrance buildings and water intakes in grassy areas, not asphalted ones
- On traffic areas, use gutter constructions with side openings for even distribution of inflow over nearby grassy areas and ditches
- Locate protective buildings within the road belt, dividing belt or traffic junctions

APPLICATION GUIDELINES FOR PLANNERS:

- All plans must have the possibility of implementing the NBS system
- The management of precipitation inflows at the planning level for each location should be based on and be in accordance with the plan of the entire basin - water knows no administrative boundaries
- Runoff before and after construction should be the same - maintain or reduce runoff coefficients by applying the NBS system
- To the greatest extent possible to maintain the permeability of the soil - reduce concreting
- Increase water retention in the basin and reduce the size of the inflow - by landscaping
- Use the existing relief when building parts of the drainage system - make maximum use of the natural environment
- Increase infiltration and filtration and reduce flow rates and erosion - by landscaping the watershed
- If possible, envisage the use of purified rainwater - especially in agriculture

Where conditions exist, multi-purpose facilities should be planned or in the immediate vicinity.

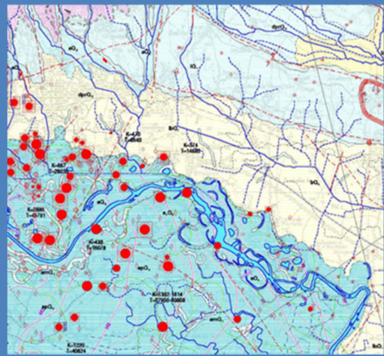
- Prescribe the use of porous materials in the construction of squares, and streets in the old city cores - unbound stone and porous asphalt or concrete or similar in low-lying parts of the settlement (near busy streets or idle parking and pedestrian and bicycle paths)

METHODOLOGY-MICRO SCALE

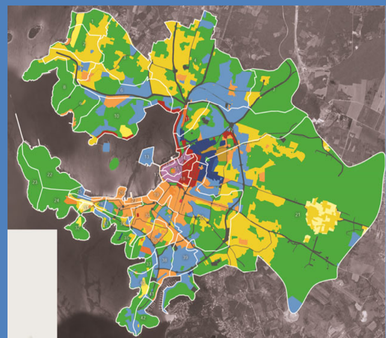
- analysis the possibility of water remaining in the natural basin
- analysis of engineering-geological maps
- hydrological study (IDF and DDF curves)
- Designed storm
- analysis the runoff coeff. due to spatial plan
- analysis of the watershed according to natural and anthropogenic factors
- in situ infiltration measurement
- planning of the main drainage channel
- recipient – determination of the recipient
- determination of one or more landscaping techniques depending on the part of the settlement and the size of the watershed

- calculations are made according to adopted methods (SCS, Rational, Santa Barbara, Modified Santa Barbara with perforated pipes etc. especially for high density urban areas with impervious soil)

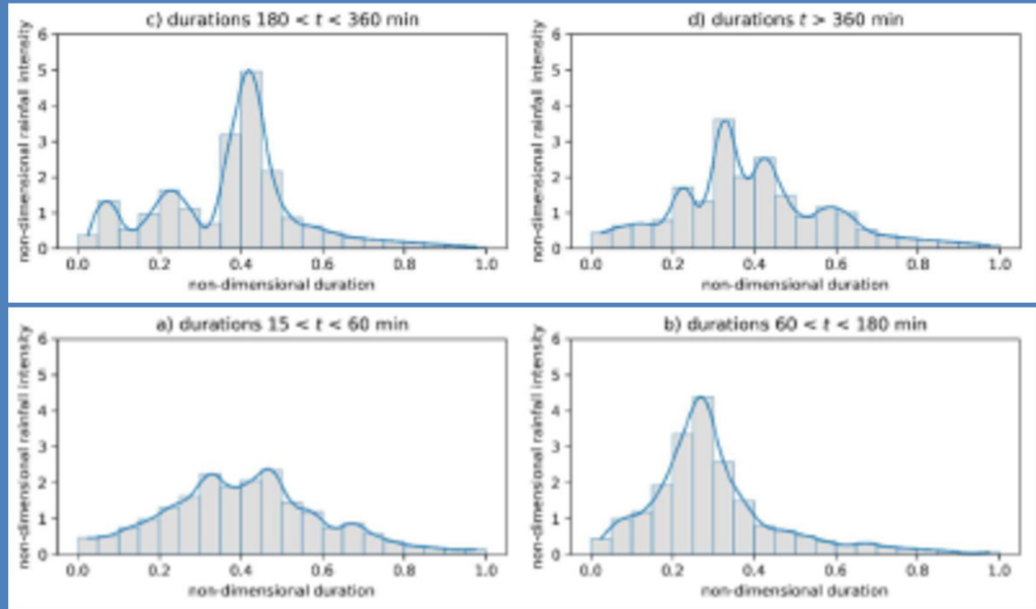
Planning and arrangement of roads, part of the settlement, park or square, as well as drainage channels and landscapes inseparable from each other



Engineering-Geological Map



Runoff coefficient



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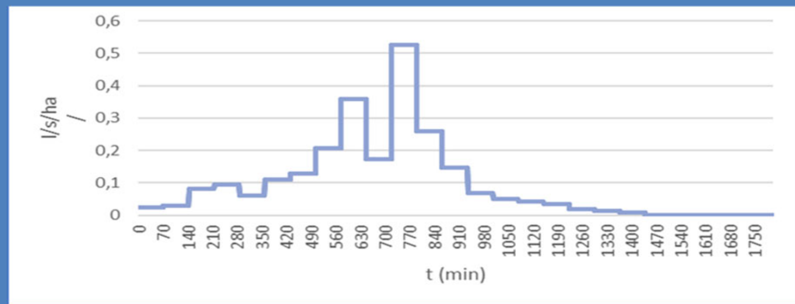
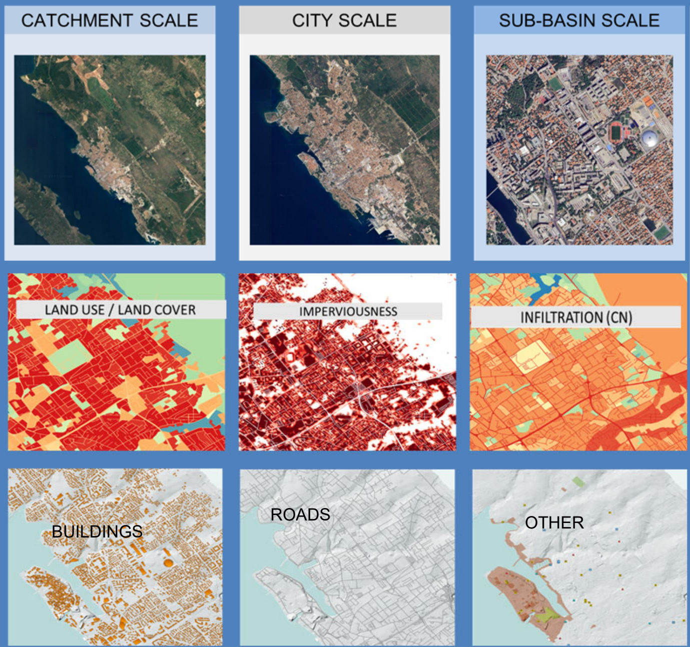
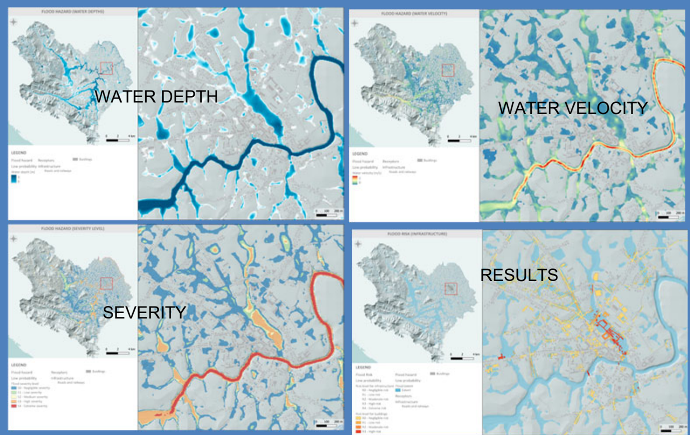


Hyetogram of DESIGN STORM RP 100 YEARS, 24 HOURS, PULA

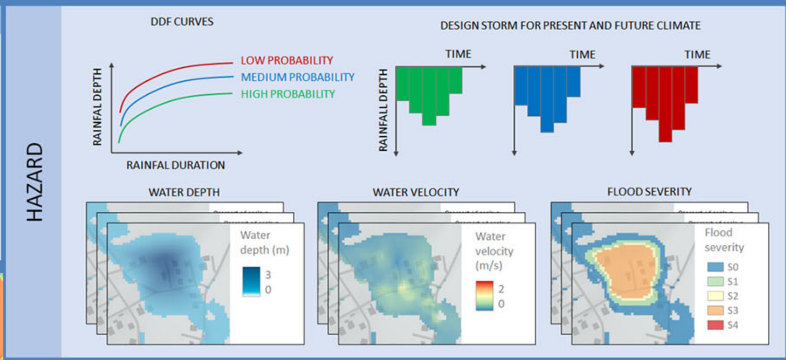
METHODOLOGY- MACRO SCALE – FOR SPATIAL PLANS
THE SIMPLEST SOLUTION: **MULTIPLE SCALE MODELS**

Pilot projects for SPLIT, ZADAR, BIOGRAD NA MORU, POREČ, GOSPIĆ I METKOVIĆ – INTERREG ITALY – CROATIA „STREAM"

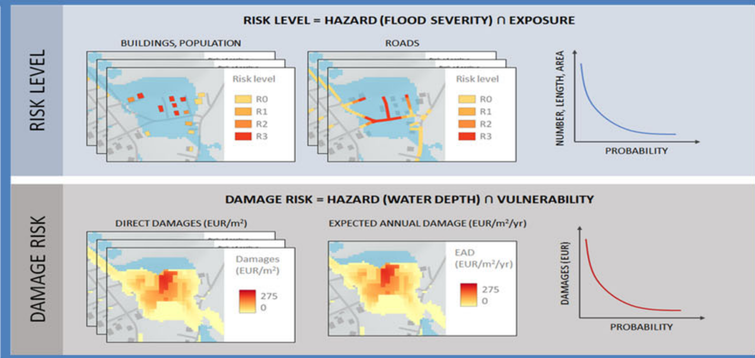




HAZARDS

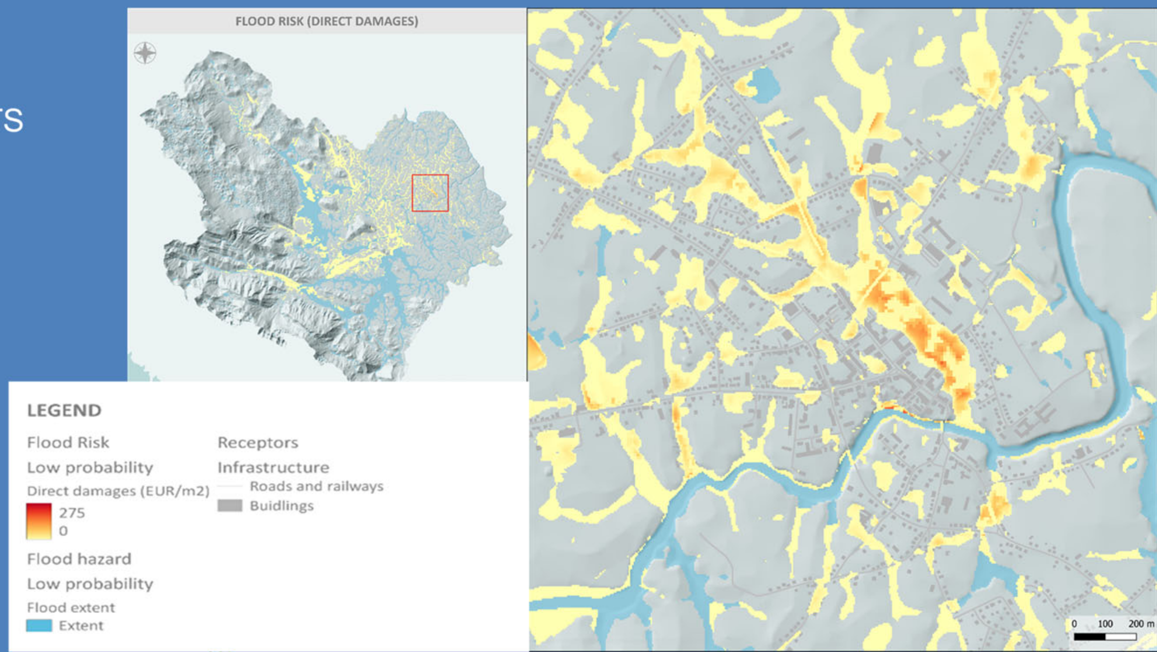


RISK

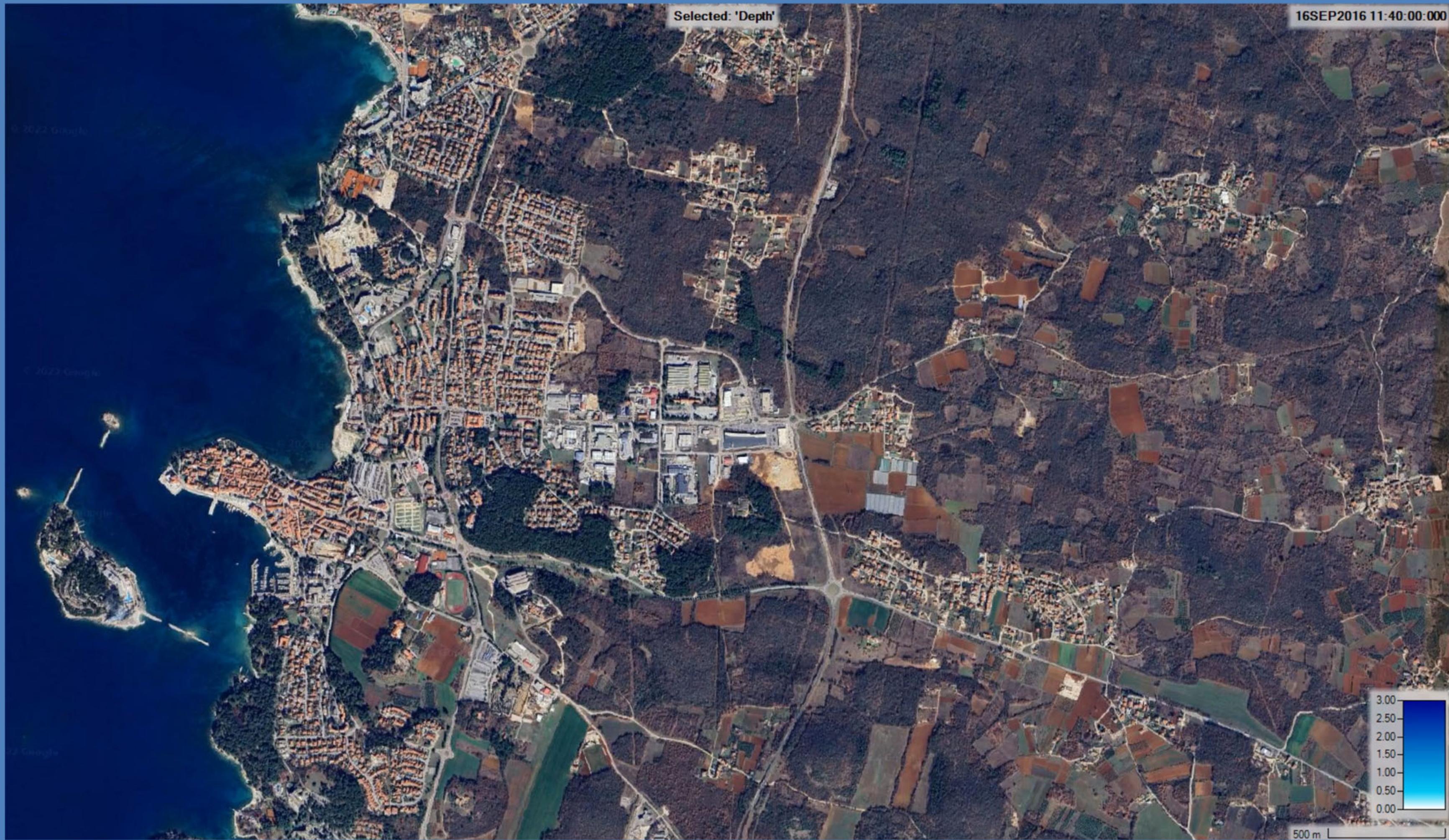


FLOOD RISK – DIRECT DAMAGE

RESULTS



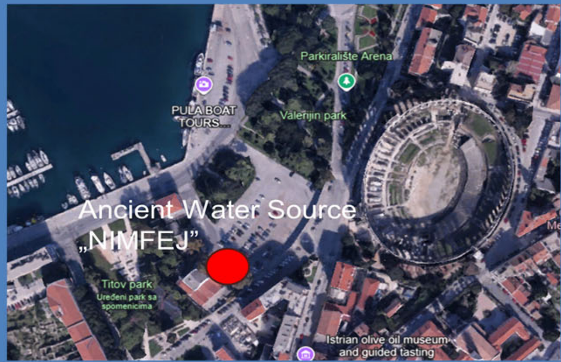
A HISTORIC FLOOD - TOWN OF POREČ– WATER DEPTH OR PREDICITON FLOOD FOR DESIGN STORM



Why we cannot tame the rain ?

The basics of spatial and environmental planning are the principles of a broader socio-ecological approach to the entire ecosystem and the hydro-technical techniques presented.

Emphasized components are the aesthetic, ecological, and economic sustainability of built and natural spaces, especially in adaptation to climate change.



The abandoned water source in the very center of the town of Pula is also an example of how Nature comes to its own but without human activity, specifically without using that source.

People are part of Nature.

But, imitating nature as a whole excludes human activity and thus the very existence of people in a certain area.

Our opinion is that the **HOLISTIC APPROACH** to the problem is the only correct solution.

Nature itself, without human activities, will adapt perfectly to climate changes, but people must survive too.

That's why we have to find semi-natural solutions and what we have shown from the above examples.

THANK YOU FOR YOUR ATTENTION !

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