



STAMP AS RISK ANALYSIS METHODS FOR DRINKING WATER SUPPLY SYSTEMS

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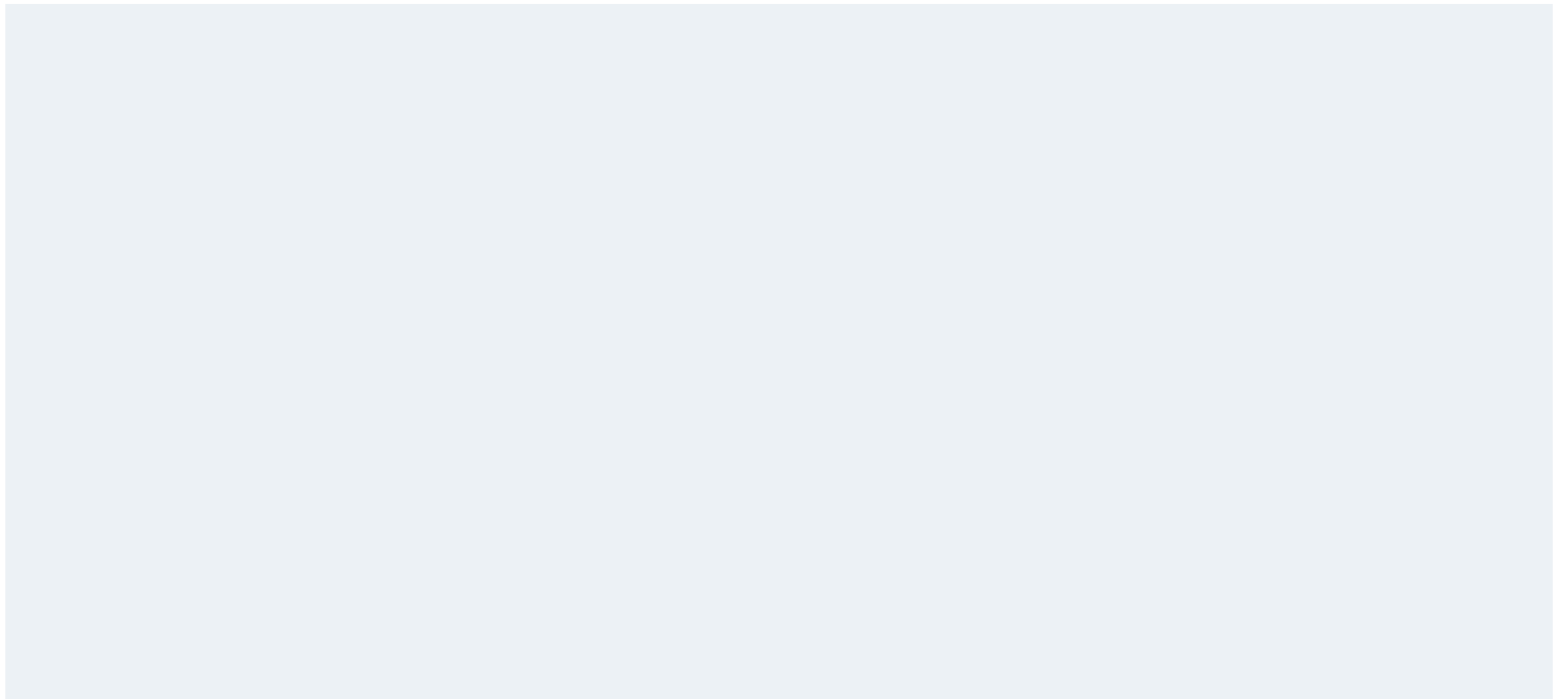
Prof. **Marko V. IVETIC**, PhD, Faculty of Civil Engineering, University of Belgrade, Serbia

CONTENT

- ▶ INTRODUCTION
- ▶ SET UP THE SCENE
- ▶ RISK ANALYSIS IN WATER PRACTICE
- ▶ ISSUES (RISK, SYSTEM, SYNTHESIS)
- ▶ STAMP Concept
- ▶ STPA/CAST Exercise
- ▶ CONCLUDED REMARKS

▶	INTRO	SCENE	RA in WATER	ISSUES	STAMP	STPA	REMARKS
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INTRODUCTION



INTRO

SCENE

RA in WATER

ISSUES

STAMP

STPA

REMARKS

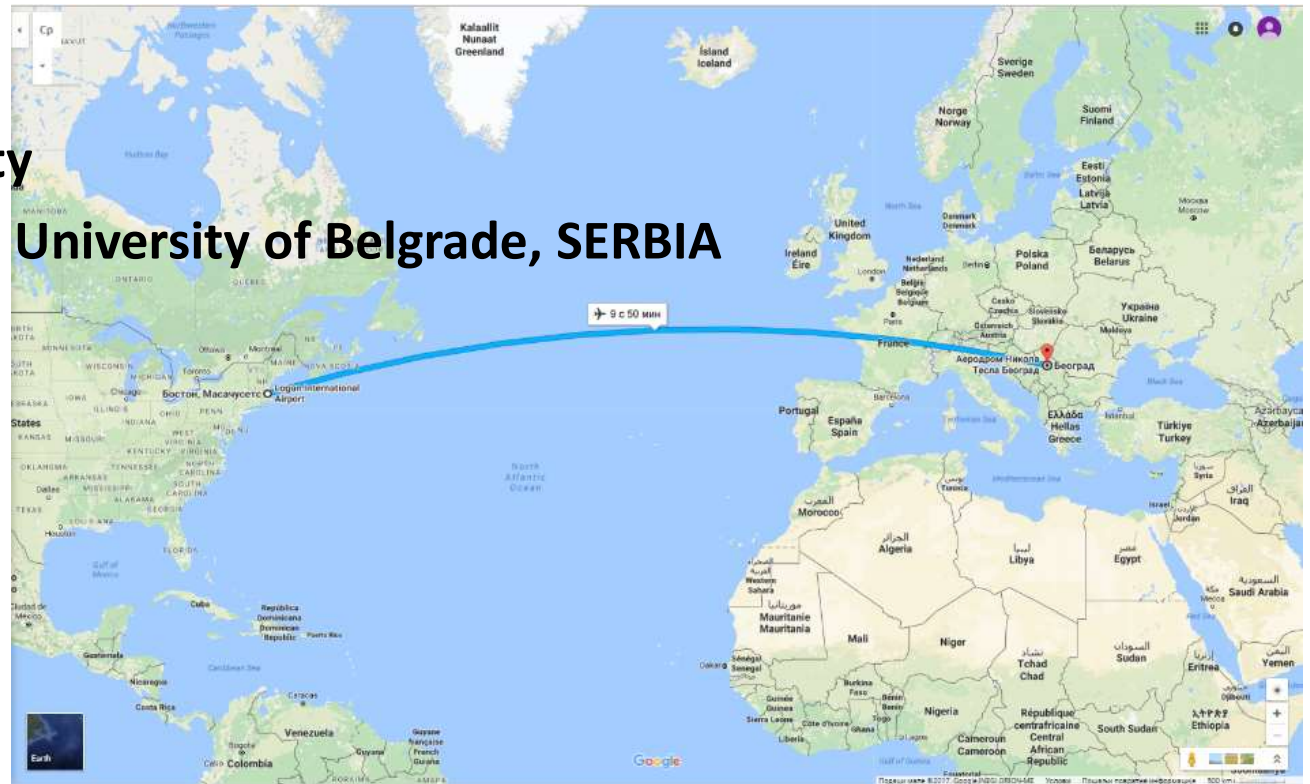
INTRODUCTION

► Belgrade, SERBIA

Few words

→ Belgrade Public Water Utility

→ Faculty of Civil Engineering, University of Belgrade, SERBIA



INTRO

SCENE

RA in WATER

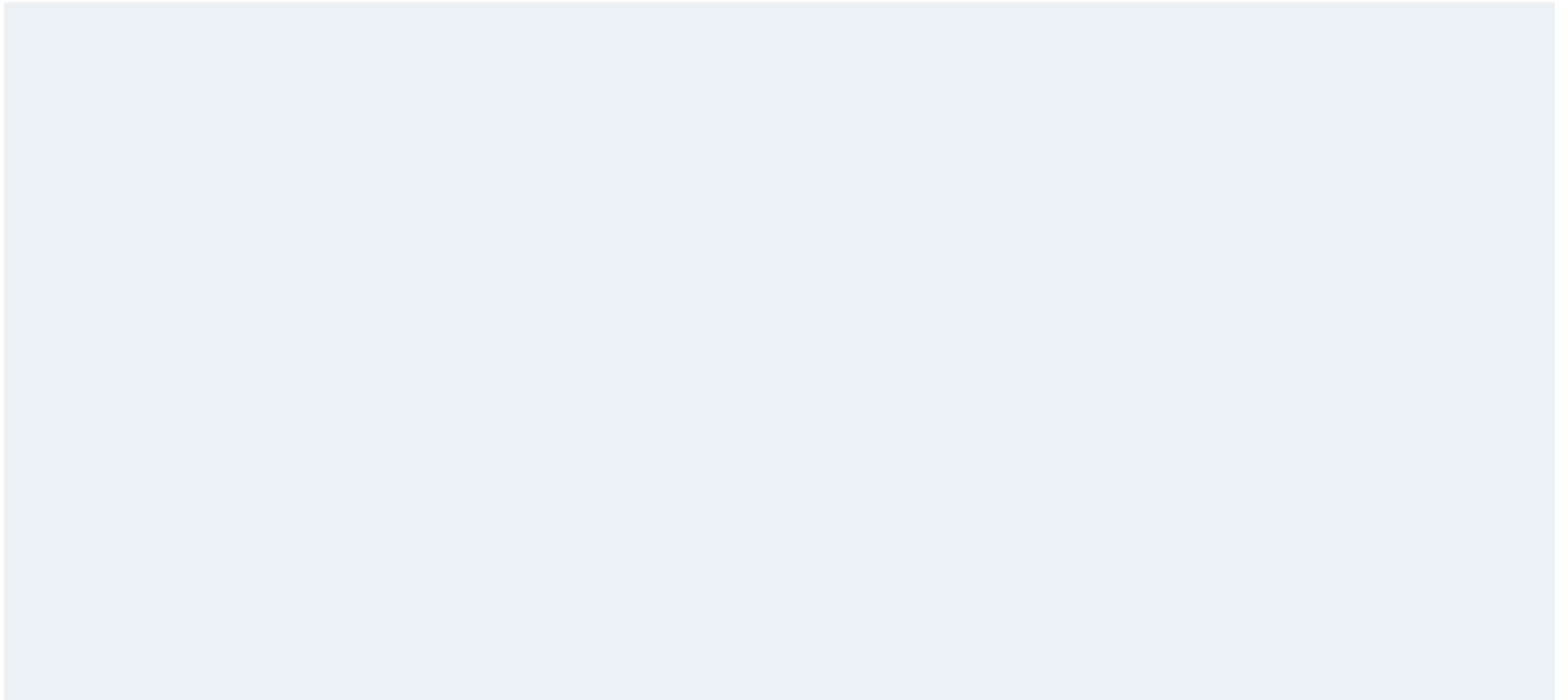
ISSUES

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REMARKS

SET UP THE SCENE



INTRO

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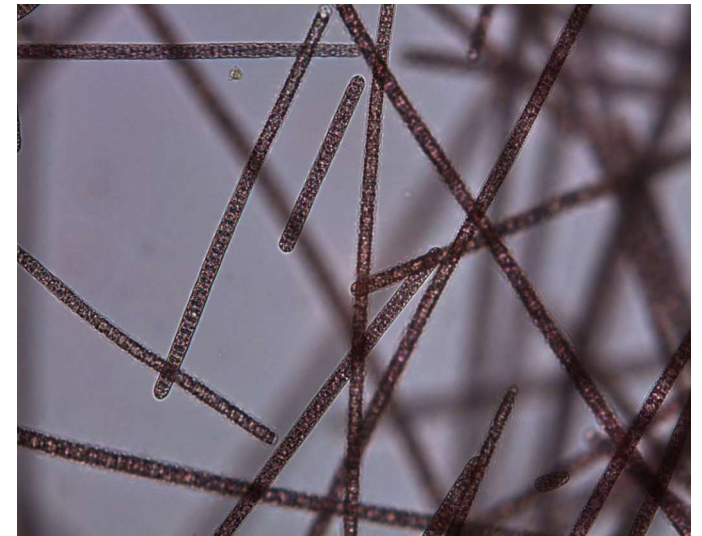
STPA

REMARKS

SET UP THE SCENE

▶ **Cyanobacteria (CB) bloom in Surface Water Reservoir**

- **Surface Water Reservoir 'VRUTCI' on Djetinja river**
- **Main source for Uzice Water Supply System (WSS) (Uzice, SERBIA)**
- **Covers more than 60.000 inhabitants**
- **Had experienced a visible, large, harmful bloom of potentially toxic CB at the end of 2013**
- **Sanitary Authorities issued the ban on using water**

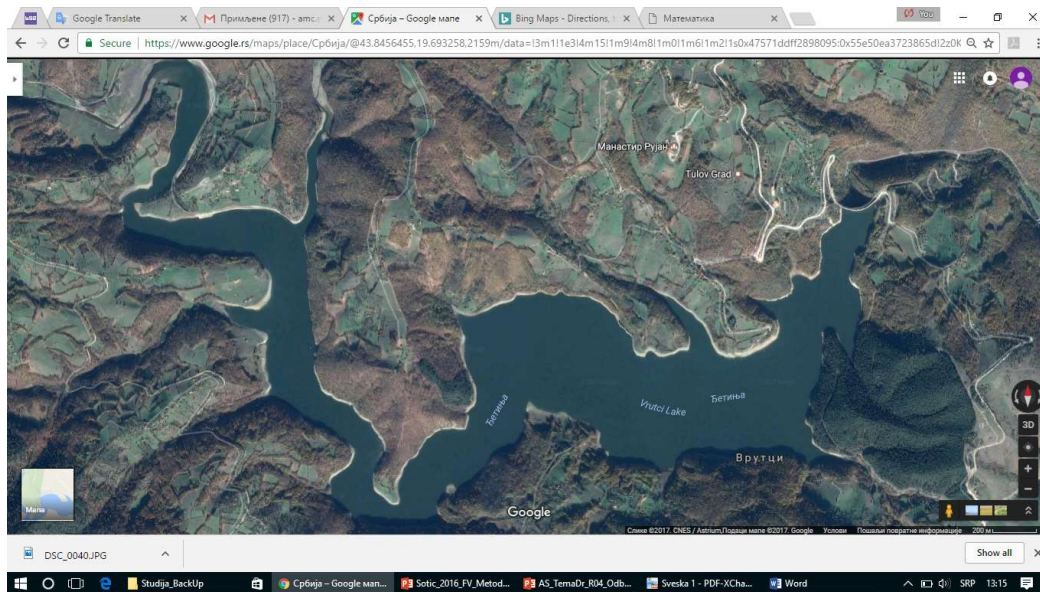


Planktothrix rubescens

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SET UP THE SCENE

→ **Surface water Reservoir 'VRUTCI' on Djetinja river, Uzice water source**



→ **City of Uzice, Serbia - panorama**



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SET UP THE SCENE

► Photos taken during 'VRUTCI' Reservoir CB bloom



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SET UP THE SCENE

► Press Clipping: Who is responsible?



Ужиче – фото Ненад Ковачевић – ДАНАС

Waiting for water...

MINISTARKA PREDSTAVILA IZVEŠTAJ ANTIKORUPCIJSKOG TIMA

Zorana: Vodu u Užicu zagadili Dragin i Zeka!



Draginovo ministarstvo i Republička direkcija za vodu su dozvolu investitoru „Di vi tehnolođzi“, firmi Žarko Zečević, bez saglasnosti pre-

IZ OBLASTI VANJA MARINOVIC
Za odgovornost...
separatni "Vruci"

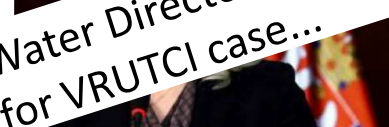
... Sve to analizo je bre ni...
... gungu "Vr. Zekunov"

"Za stanje u Užicu kriva Direkcija"

Za zagađenje vode u Užicu odgovorni su prethodno Ministarstvo poljoprivrede, šumarstva i vodoprivrede i Republička direkcija za vodu, kaže Zorana Mihajlović.

IZVOR: BETA I SIDA, 15.01.2014. | 14:45

Ministarka energetike, razvoja i zaštite životne sredine rekla je da je to utvrdio Antikorupcijski tim.



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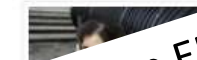
Ministarka energetike, razvoja i zaštite životne sredine rekla je da je to utvrdio Antikorupcijski tim.

Responsibility of Small HPP owners for contamination...

Water Directorate responsible for VRUTCI case...

Fonet | 22. 01. 2014. - 20:09h | 08:38h

Agencija: Nismo odgovorni za zagađenje Vrutci



Serbian EPA: We are not responsible for the contamination...
...edine saopštila je...
...sala kvalitet vode u jezeru...
... odakle se snabdevao grad Užice u skladu...
Sa... »

Tanjug | 05. 01. 2014. - 16:46h | 09:59h

Ministarstvo: Uzrok zagađenja je organska materija



Ministry for EP: Cause of the contamination is organic matter...
...voja i zaštite životne...
... je danas da je obilaskom terena i...
...ama urađenim po hitnom postupku, ... »



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SET UP THE SCENE

► Press Clipping: Who is guilty?

Ko je kriv za ужт
невоље

Who is guilty for water troubles...

maloj HE u Užicu upućen Tužilaštvu



Report for a Small Power Plant (SPP)
sent to the Prosecutor's Office...

Na konferenciji za novinare u Vladi ona je rekla da je Antikorupcijski tim ministarstva završio izveštaj u MHE Vrutci, koja do danas nema vodnu saglasnost.

Mihajlović je ukazala da je Republička direkcija za vode bila obavezna da pošalje inspekciju na taj objekat kao i da traži da se dobije vodna saglasnost, i dodala da pitanje (ne)dobijanja saglasnosti nije samo stvar javašluka već je potrebno iskoreniti i kriminal i korupciju u toj oblasti.
"Ta mala hidroelektrana je koristila više vode nego što je potrebno i spuštala nivo akumulacije", ukazala je ministarka.

Старост акумулације Врутци главни кривац за проблеме

Стручњаци Института „Јарослав Черни“ завршили су извештај о стању Врутци и наложили хитну поправку водозахвата.

Аутор: Бранко Пејовић (/scc/autor/1946/BrancoPejovic)



Водоакumulација Врутци (Фото С. Јовичић)

Reservoir age main cause for water issue...
was sad by Water Institute experts

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SET UP THE SCENE

▶ Press Clipping: GM of Uzice WS detained!!!

Blic online, Tanjug | 22. 07. 2014. - 18:25h ▶ 18:28h

Priveden direktor užičkog Vodovoda



Direktor Vodovoda u Užicu Dragan Simić priveden je danas i određeno mu je zadržavanje... sumnje da je učinio krivično delo...

GM of Uzice Water Supply Arrested
Dragan Simic, GM of Uzice Water Supply, was arrested today and detained, on suspicion of committed the criminal offense for causing general danger...

Vladimir Lojanica | 23. 07. 2014. - 19:07h ▶ 18:28h | [Komentara: 16](#)

KO JE KRIV ZA HAOS U UŽICU Direktor vodovoda prvi osumnjičeni, neka se pripremi...



Osnovni javni tužilac u Užicu Vukašin Vujičić izdao je nalog da se privede, zadrži i saslušaju... Simić, direktor JKP...

WHO IS TO BLAME FOR CHAOS IN UZICE
GM of the Water Supply the first suspect
Public prosecutor in Uzice issued a warrant to arrest, detain and interrogate...

▶	INTRO	SCENE	RA in WATER	ISSUES	STAMP	STPA	REMARKS
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SET UP THE SCENE

▶ Harmful CB Blooms Development

- lead to negative environmental, health and economic impacts
- produce secondary metabolites potentially toxic to secondary consumers
 - zooplankton, fish and mammals
 - humans

which use affected waters:

- as a habitat
- for drinking and recreational purposes



Recommendations for
Public Water Systems to
Manage Cyanotoxins in
Drinking Water

▶	INTRO	SCENE	RA in WATER	ISSUES	STAMP	STPA	REMARKS
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SET UP THE SCENE

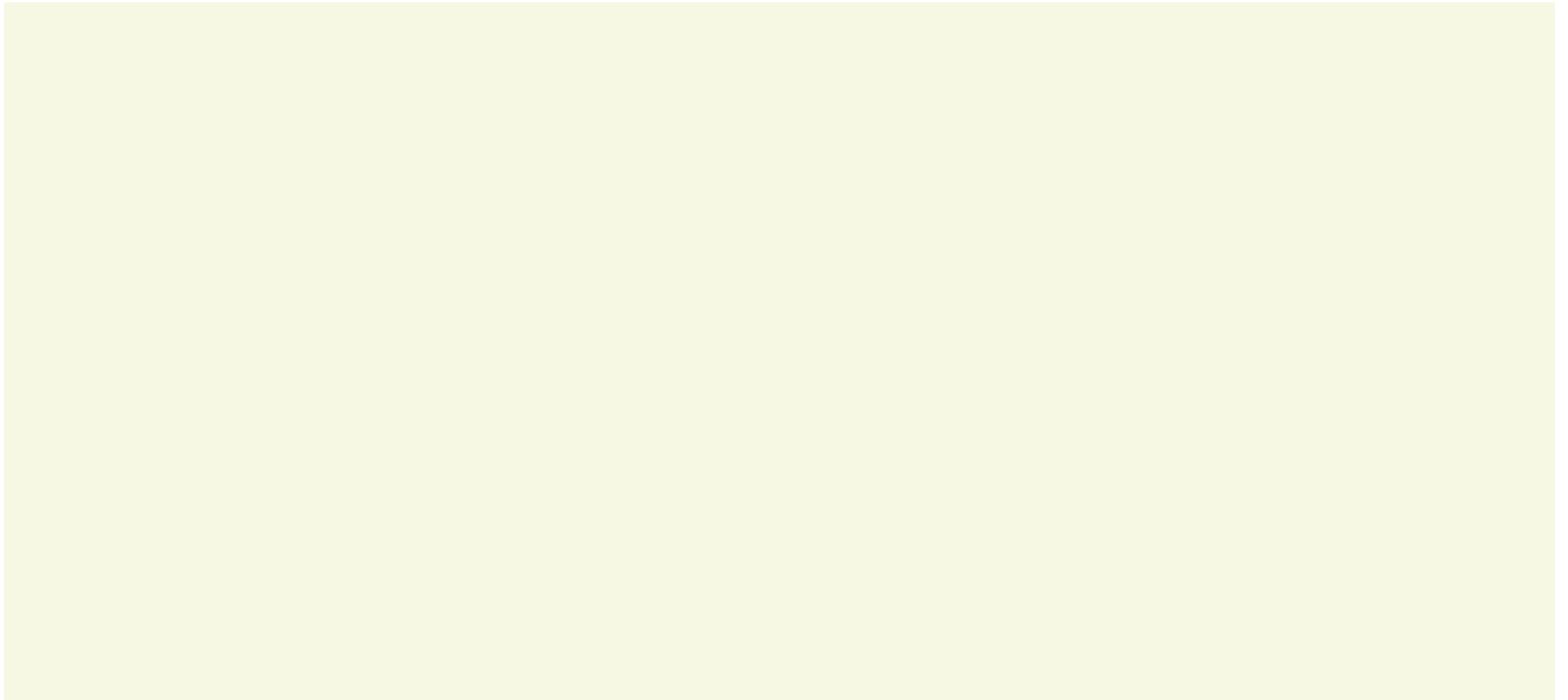
▶ Harmful CB Blooms Consequences

- Depending on the human organ affected, cyanotoxins (CTs) are classified as:
- hepatotoxins (which effect lever)
 - neurotoxins (causes neurodegenerative diseases)
 - cytotoxins (causes necrotic injury)
 - skin and gastrointestinal irritants



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RISK ANALYSIS IN WATER PRACTICE



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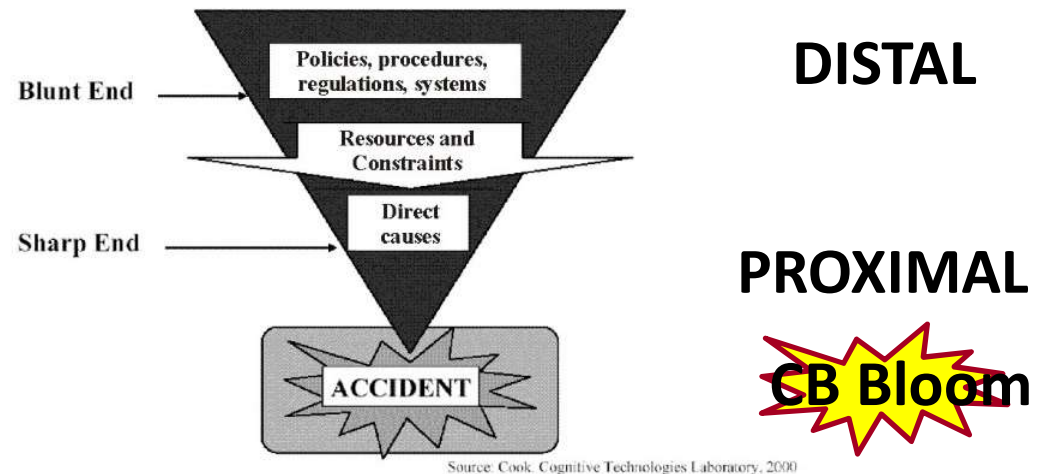
STAMP

STPA

REMARKS

RISK ANALYSIS IN WATER PRACTICE

- ▶ **A Role of Public Health (PH)** (inherently concerned with water supply)
- Handling relationships between causalities of water-related issues:
 - **DISTAL** (associated with social, environmental and engineering status) &



- **PROXIMAL** (associated with microbiological or biological factors)

▶	INTRO	SCENE	RA in WATER	ISSUES	STAMP	STPA	REMARKS
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RISK ANALYSIS IN WATER PRACTICE

- ▶ **A Role of Public Health (PH)** (among others)
- **Current PH RA approach:: based on cause – effect relations**
 - **fails to capture all of the risk factors involved, especially distal ones**
 - **has difficulties to cope with unpredictable harmful events**

RISK ANALYSIS IN WATER PRACTICE

▶ Water Sector Typical RA Methods

→ **TRADITIONALLY:: retrospective approach**

- **previous experience provides main input for analyses**

→ **ENVIRONMENTAL ANALYSIS**

- **primarily concerned with enviro quality issues:: water intake/discharge**

→ **WSP (Water Safety Plans) – adapted form of HACCP with MB approach**

- **primarily concerned with health aspects**

→ **RELIABILITY ANALYSIS**

- **primarily concerned with pipe/pump failures - technical aspect**

▶	INTRO	SCENE	RA in WATER	ISSUES	STAMP	STPA	REMARKS
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RISK ANALYSIS IN WATER PRACTICE

▶ **Water Sector Typical RA Methods**

→ **Increasing request:**

→ **to expand strictly environmental, health or tech domain**

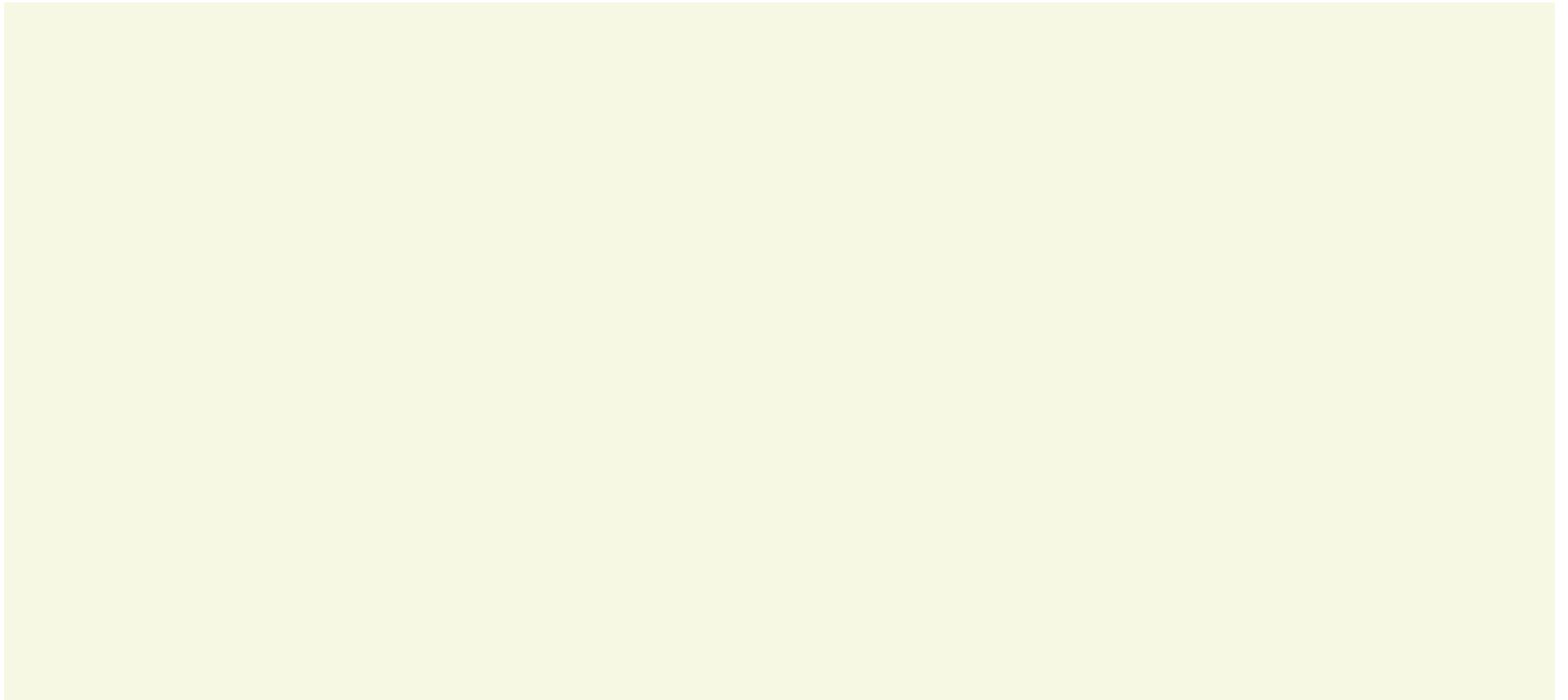
→ **to integrate them (all aspects)**

and also to include:

- **Human and Organizational Factors (HOFs)**
- **all of Assets/System LifeCycle phases**
- **all Players**

▶	INTRO	SCENE	RA in WATER	ISSUES	STAMP	STPA	REMARKS
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ISSUE:: RISK



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ISSUE:: RISK

Risk = Probability \otimes Severity

... hazard occurrence
... exposure to hazard
... unwanted events
... emergence of consequences



Probability of CB Bloom?

Probability of CT Exposure?

What is the reality?

▶	INTRO	SCENE	RA in WATER	ISSUES	STAMP	STPA	REMARKS
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ISSUE:: RISK

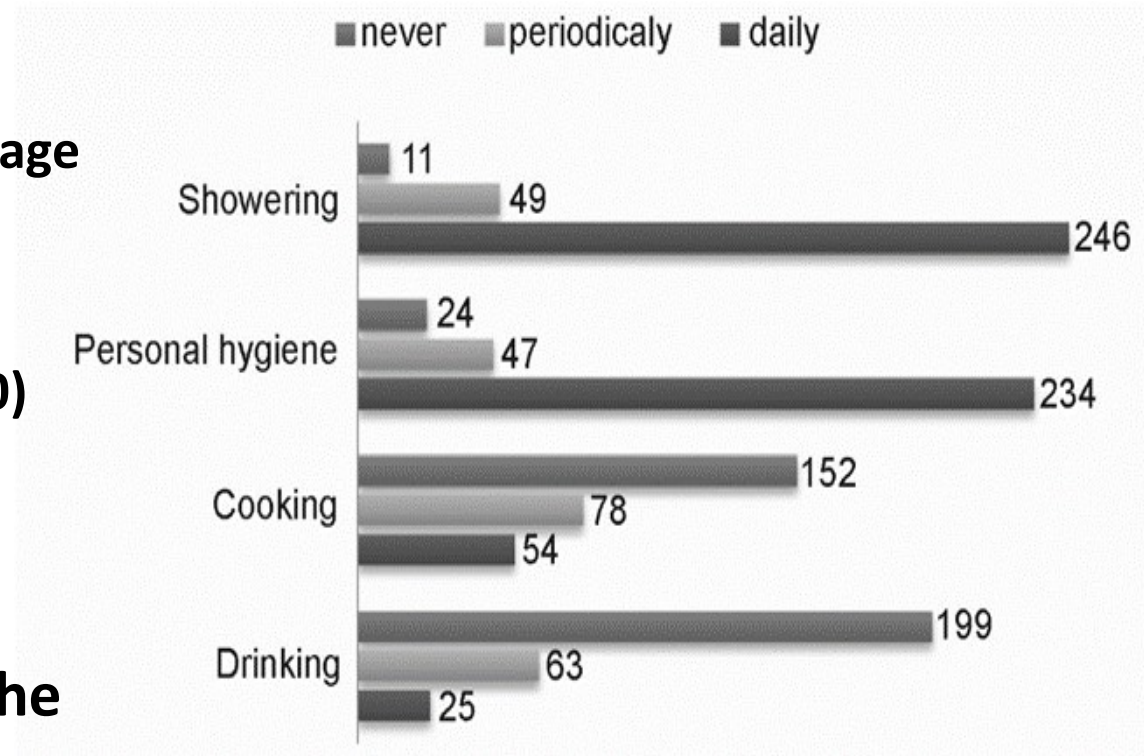
→ Indicative research::

- Vrutci reservoir CB bloom and water usage ban from Uzice WSS (2013)

→ During the water usage ban:

- the majority of respondents (out of 320) did comply with restrictions,
- **while some of them used water occasionally and daily**

→ These data confirm difficulties in the exposure assessment, i.e. in assessment of potential consequences

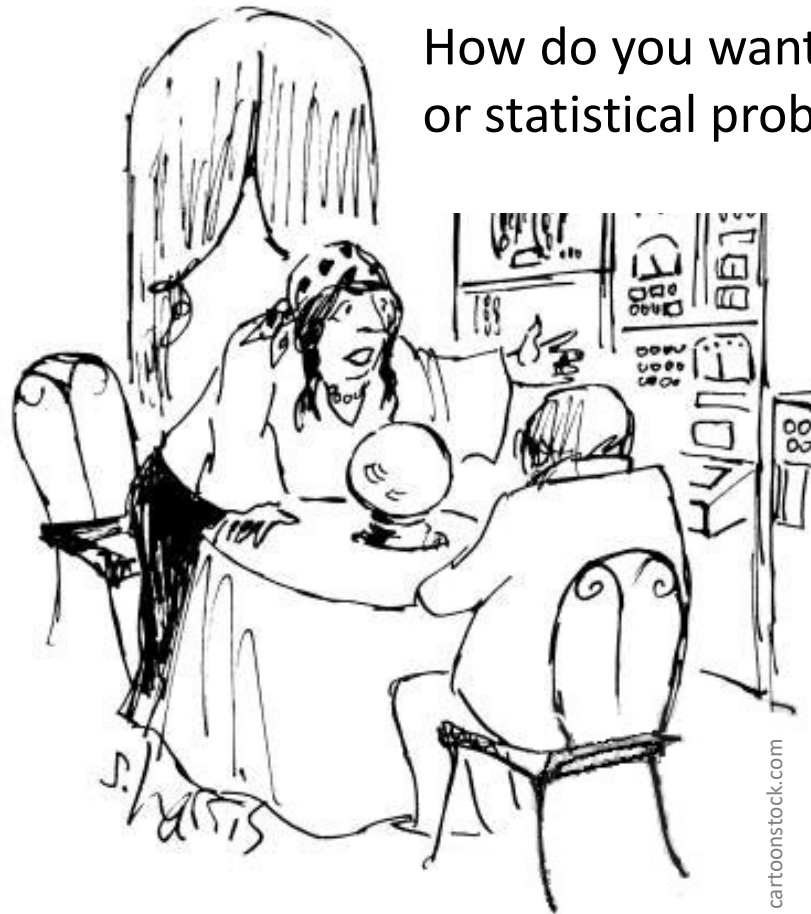


Water usage during Uzice water ban, number of responds (total 320) (Drobac, 2015)

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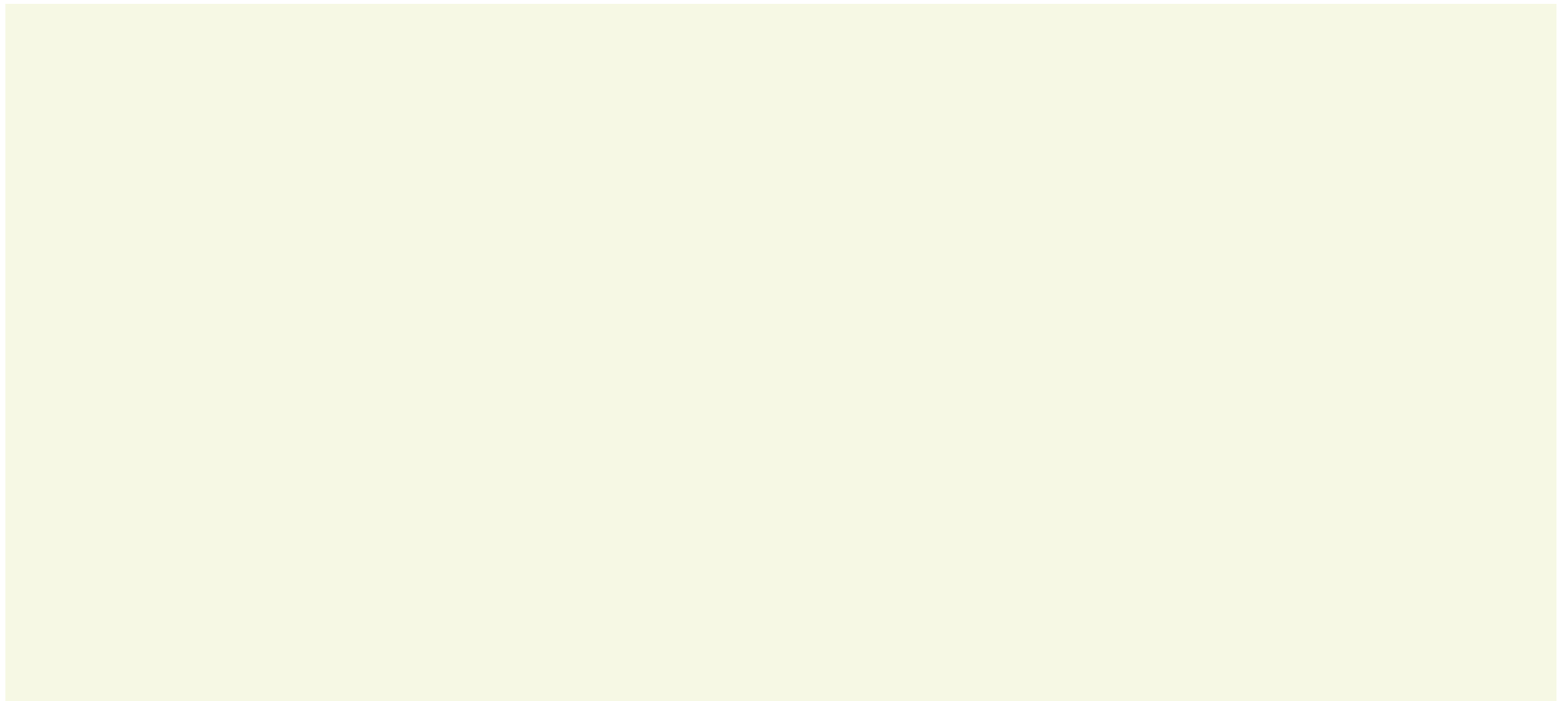
ISSUE:: RISK... AND NOW SERIOUS

How do you want it – the crystal mumbo-jumbo or statistical probability?



▶	INTRO	SCENE	RA in WATER	ISSUES	STAMP	STPA	REMARKS
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ISSUE:: SYSTEM: WSS



INTRO

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ISSUE:: SYSTEM: WSS

▶ WATER SUPPLY SYSTEM (WSS)

System of Systems

interactive with other systems

Elements/Components/Assets of low and high importance

incorporated into the system and environment

Sublimation of past, present and future

both young and old

Stakeholders often opposed

state admin, local gvrnmnt, operators, designers, customers, ...



▶	INTRO	SCENE	RA in WATER	ISSUES	STAMP	STPA	REMARKS
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ISSUE:: SYSTEM: WSS

▶ **WATER SUPPLY SYSTEM (WSS)**

- **RISK** under consideration must be comprehensive and total
- **RISK ANALYSIS** methods:: consistent to the nature of the WSS



▶	INTRO	SCENE	RA in WATER	ISSUES	STAMP	STPA	REMARKS
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ISSUE:: SYSTEM: WSS

**The first step in solving any problem is to understand it.
We often propose solutions to problems that we do not
understand and then are surprised when the solutions
fail to have the anticipated effect**

(Leveson, 1995)

▶	INTRO	SCENE	RA in WATER	ISSUES	STAMP	STPA	REMARKS
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ISSUE:: SYSTEM: WSS

HIERARCHICAL

SYSTEM

COMPLEXITY

DRINKING WATER SUPPLY SYSTEM

SOCIO-TECHNICAL

ADAPTIVE

RESILIENT

▶	INTRO	SCENE	RA in WATER	ISSUES	STAMP	STPA	REMARKS
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ISSUE:: SYSTEM: WSS

Infrastructure Systems: municipality owned (Serbian context)
O&M entrusted to WS Operator

Components/Assets: designed/built by different sides
uninformed in system behaviour
system performances depend on I-G/I-A

DM (components): **FRAGMENTARY PROBLEM SOLVING**

Systemic Approach: systemic events/causality/hazards
system-theoretic principle

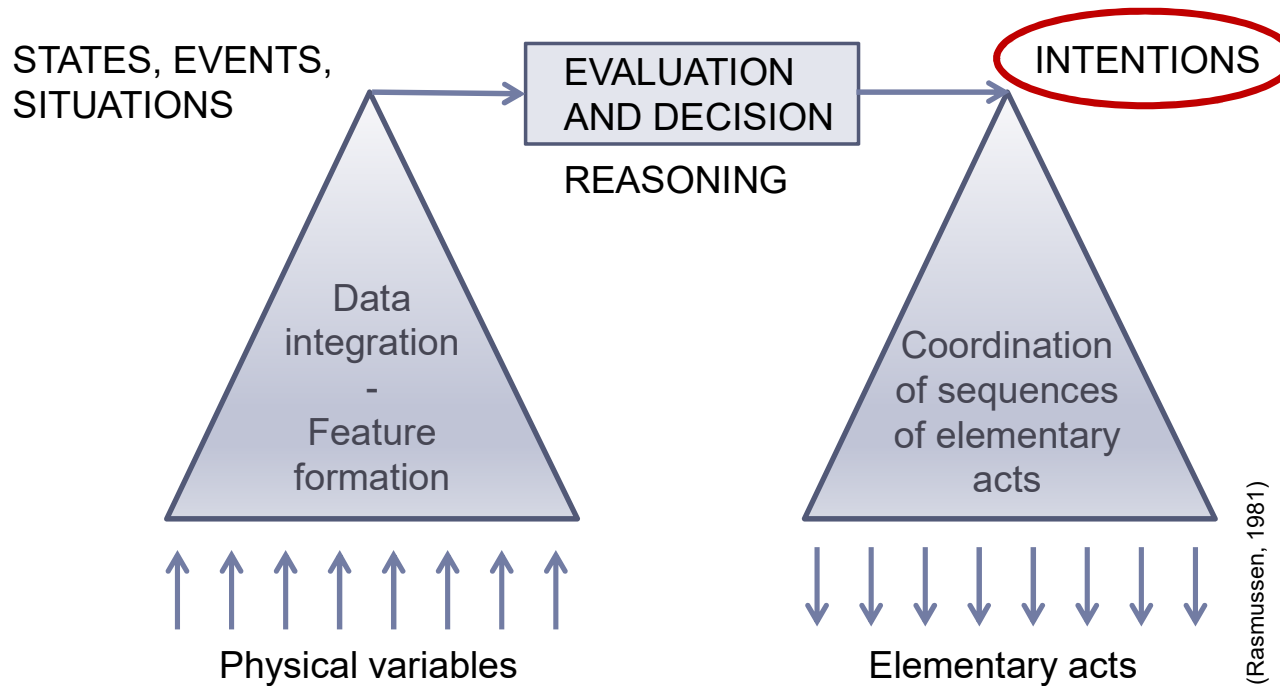
▶	INTRO	SCENE	RA in WATER	ISSUES	STAMP	STPA	REMARKS
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ISSUE:: SYSTEM: WSS COMPLEXITY

One way to cope with the high number of information

High number of INFO::
Data processing task::

a need to structure the problem
change in abstraction level
on the level with less resolution



▶	INTRO	SCENE	RA in WATER	ISSUES	STAMP	STPA	REMARKS
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ISSUE:: SYSTEM: WSS COMPLEXITY

ABSTRACTION HIERARCHY :: (Rasmussen, 1981, 1986)

- the way for coping with complexity

WSS :: pipes, fittings (bends, branches, connectors), manholes, ...

:: difficult for understanding

- ignoring details, put the attention on high level issues
- representation is event-independent:: system structure
- framework for knowledge representation

Different levels on reasoning about process

while consider technical issues: 5 categories

▶	INTRO	SCENE	RA in WATER	ISSUES	STAMP	STPA	REMARKS
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ISSUE:: SYSTEM: WSS SOCIO-TECHNICAL

Functional purpose

The overall system meaning and its purpose

LOCAL GOVERNMENT

:: supply of water as life foodstuff
e.g. WS objectives

Abstract function

General and symbolic level of the system

WATER OPERATOR

:: system resources (Mass/Energy)
system balance models (M/E)

Generalised function

Generalised processes of the system
reflects behavioural states

Top Management

:: flows of INF flows and feedbacks

Physical function

Specific processes related to
interacting components

Middle Management

:: biological process schemes, technical specifications

Line workers

:: tasks implementation, process development
e.g. assets status and condition, setting up of pumps, valves, reservoirs

Physical term

Specific objects in the system
physical terms

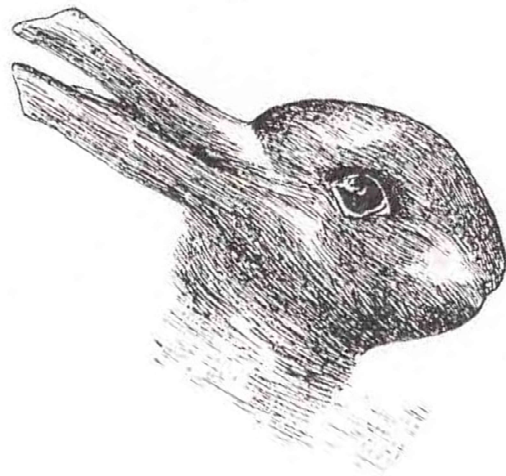
**WATER SUPPLY SYSTEM
(PHYSICAL FORM)**

:: physical materialisation of WS
e.g. pipes, fittings, pumps, reservoirs -
appearance, state, location

▶	INTRO	SCENE	RA in WATER	ISSUES	STAMP	STPA	REMARKS
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ISSUE:: SYSTEM: SYNTHESIS:: PARADIGM SHIFT

CHANGE IN PERSPECTIVES
for looking at the problem



(Kuhn, 1972, 1992)

Duck or Rabbit
Poper vs Kuhn

Not perceive risk just with future events!
RISK THAT IS OCCURED :: ACCIDENT
ACCIDENT :: SYSTEM ACCIDENT
SYSTEM SAFETY

RISK concept have difficulties to cover all factors
SAFETY concept have potential to cover it

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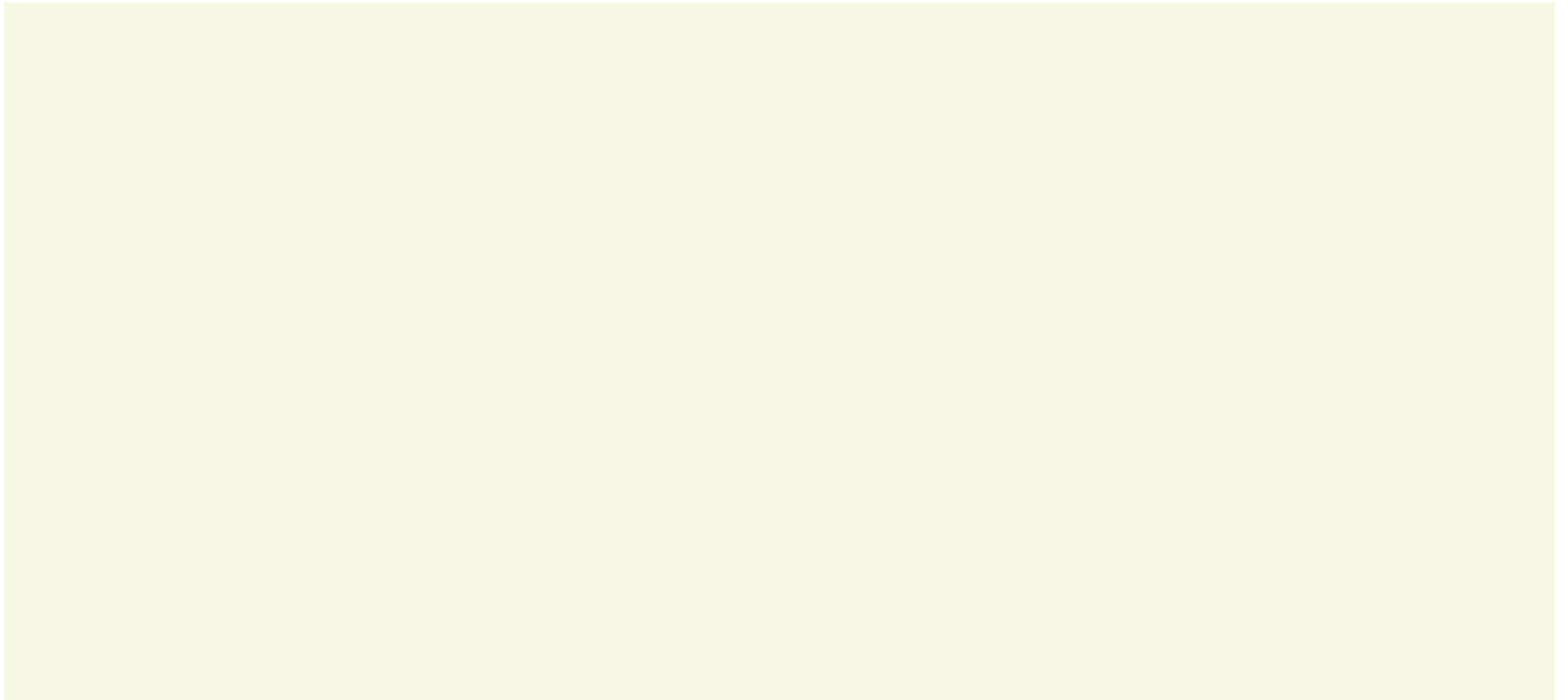
ISSUE:: SYSTEM: SYNTHESIS:: PARADIGM

DON'T PREVENT failures
but
MAKE things go wright

	<i>Defined by</i>	<i>Look into</i>	<i>Focus on</i>	<i>Based on</i>	<i>Management</i>
RISK	NEGATIVE	EVENTS	FAILURES	OVERSIGHTS (FAULTS)	PRESCRIPTIVE
SAFETY (risk antipode)	POSITIVE	PROCESSES	HOW IT SHOULD BE	INSIGHT IN STATES	ADAPTIVE

▶ | INTRO | SCENE | RA in WATER | **ISSUES** | STAMP | STPA | REMARKS |

STAMP CONCEPT

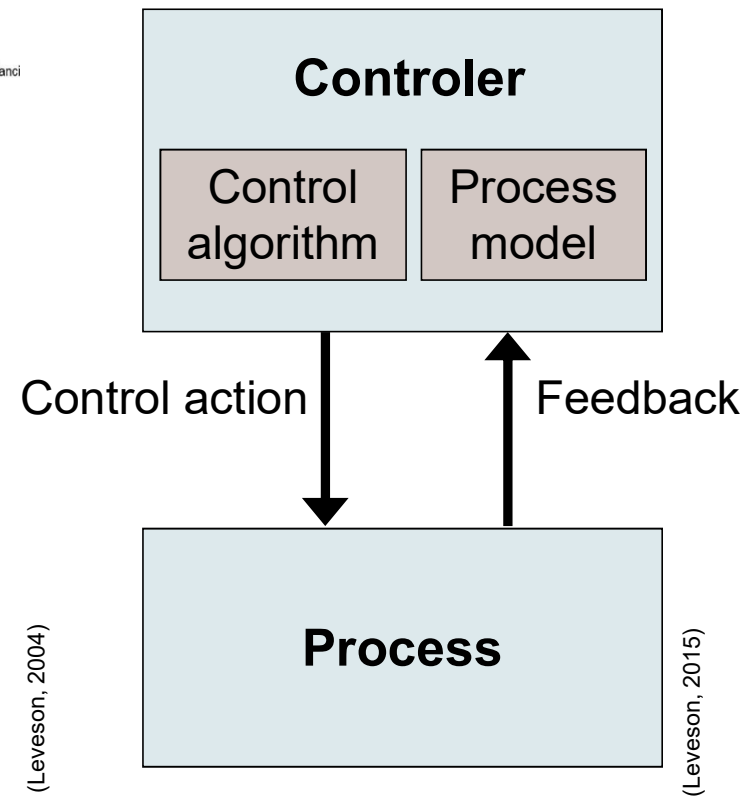
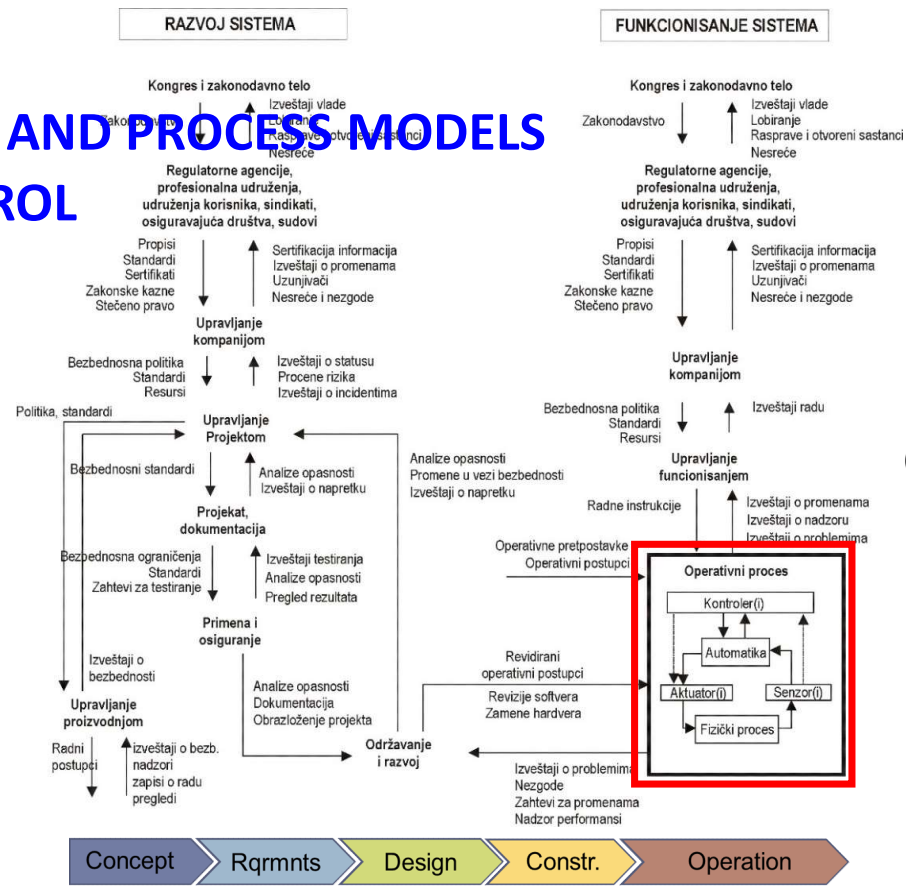


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STAMP CONCEPT (Leveson, 2004)

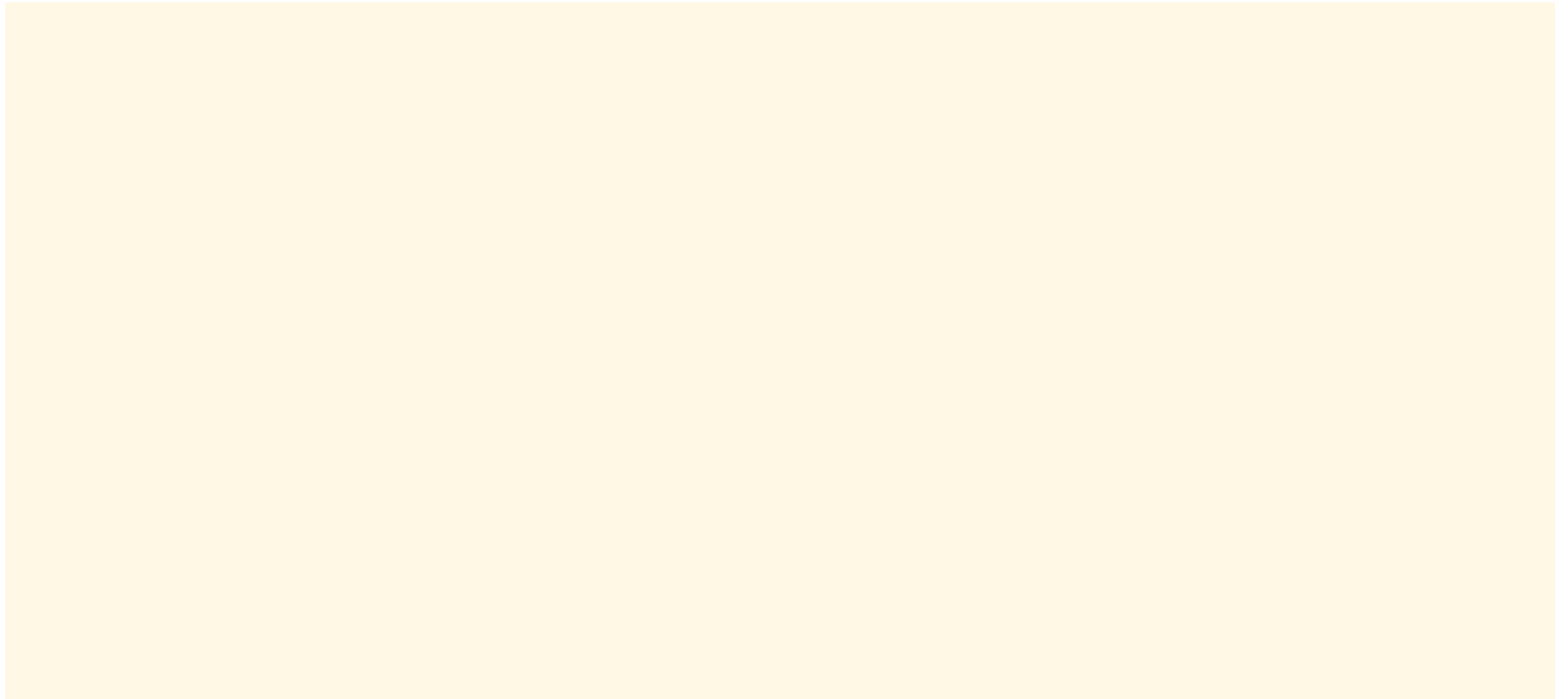
BASIC CONCEPTS::

1. CONSTRAINTS
2. CONTROL LOOPS AND PROCESS MODELS
3. LEVELS OF CONTROL



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STPA/CAST Exercise

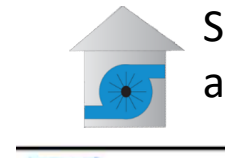
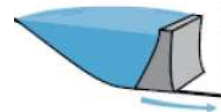


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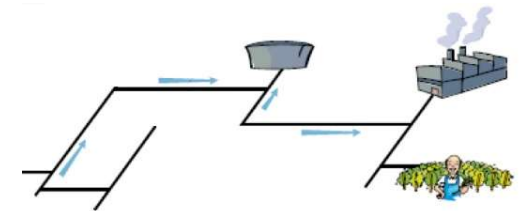
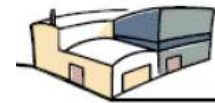
STPA/CAST Exercise

WATER SUPPLY SYSTEM 'UŽICE'

- VRUTCI Reservoir,
- Gravity Main,
- Water Treatment Plant (WTP),
- Water Distribution Network.



SHPP added in a meanwhile



EVENTS

- 14/12/2013 Red stain on the lake surface:: reported by citizens
- 26/12/2013 **Drinking water ban** - **after 12 days** from reported issue
- 07/02/2014 **Ban lifted** - **after 40 days** from water ban

DEMONSTRATION OF APPLICATION of STAMP

- ideas from Systems Theory:: sum of components: The Whole & SC
- elements of Cognitive Engineering:: Man-Machine I-A

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STPA/CAST Exercise:: METHODOLOGY STEPS

- **Defining SA-SH-HLSR** (System Accident, S_Hazards, H-L Safety Rqmts)
- **Defining HLCS** (High-Level Control Structure)
- **Adding details/levels** (expanding/extending CS)
- **Controler & Controled process analysis** (defining USCA & SC)
- **Defining casual factors** (Control Flaws)



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STPA/CAST Exercise:: SA

SYSTEM ACCIDENT for **WSS** is defined in regard with::

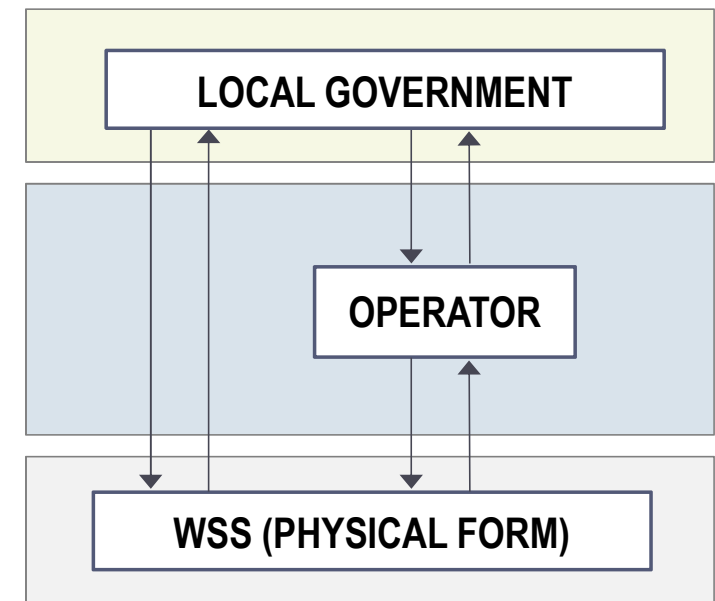
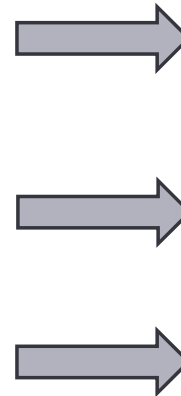
1. Delivering of water quantity
 2. Delivering of water quality
 3. Economic sustainability
 4. Social affordability
 5. Envrmntl issues (water intake/discharge, energy consumption)
 6. Customer relations
 7. Person and property safety/security
- }] Sustainable operation and development
-] OHS

▶	INTRO	SCENE	RA in WATER	ISSUES	STAMP	STPA	REMARKS
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STPA/CAST Exercise:: FUNCTIONAL CONTROL STRUCTURE

FUNCTIONAL SYSTEM BEHAVIOUR::

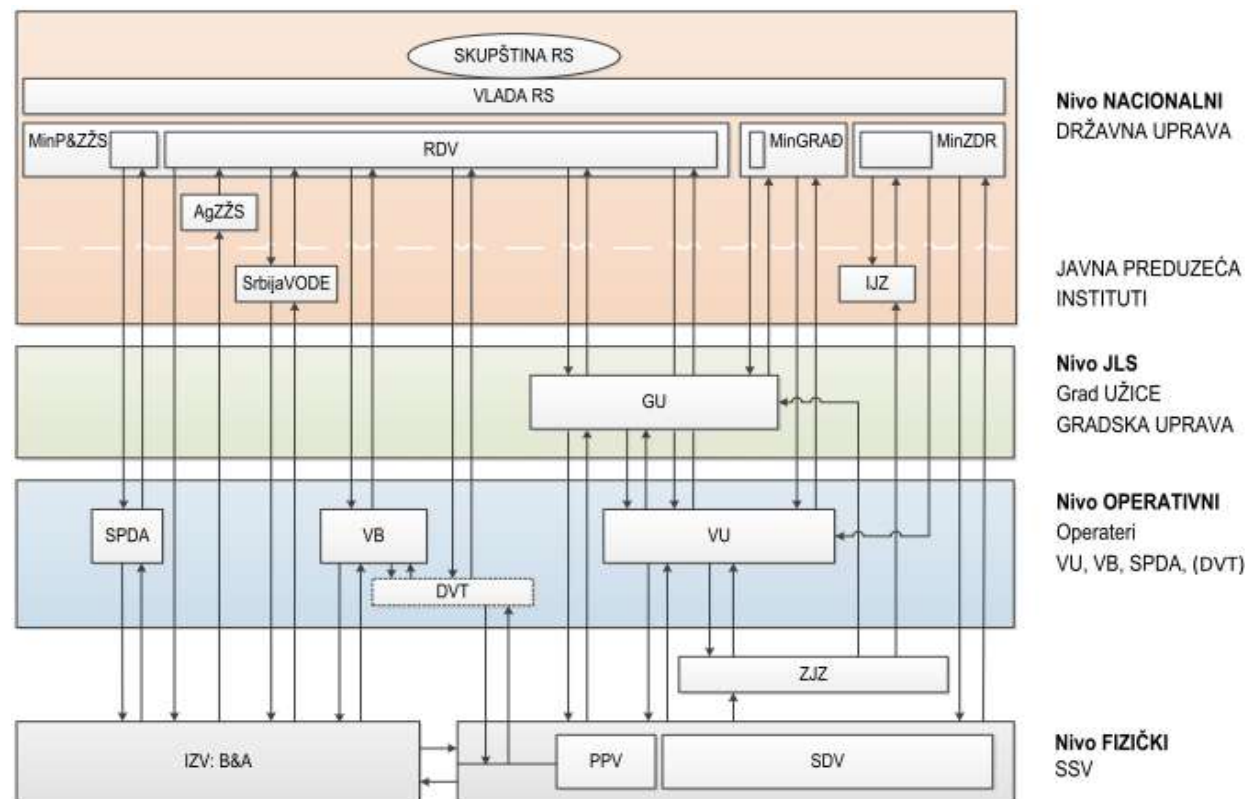
- FUNCTIONAL PURPOSE
- ABSTRACT FUNCTION
- GENERALISED FUNCTIONS
- PHYSICAL FUNCTIONS
- PHYSICAL FORM



▶	INTRO	SCENE	RA in WATER	ISSUES	STAMP	STPA	REMARKS
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STPA/CAST Exercise:: FUNCTIONAL CONTROL STRUCTURE

ADDING DETAILS/LEVELS::

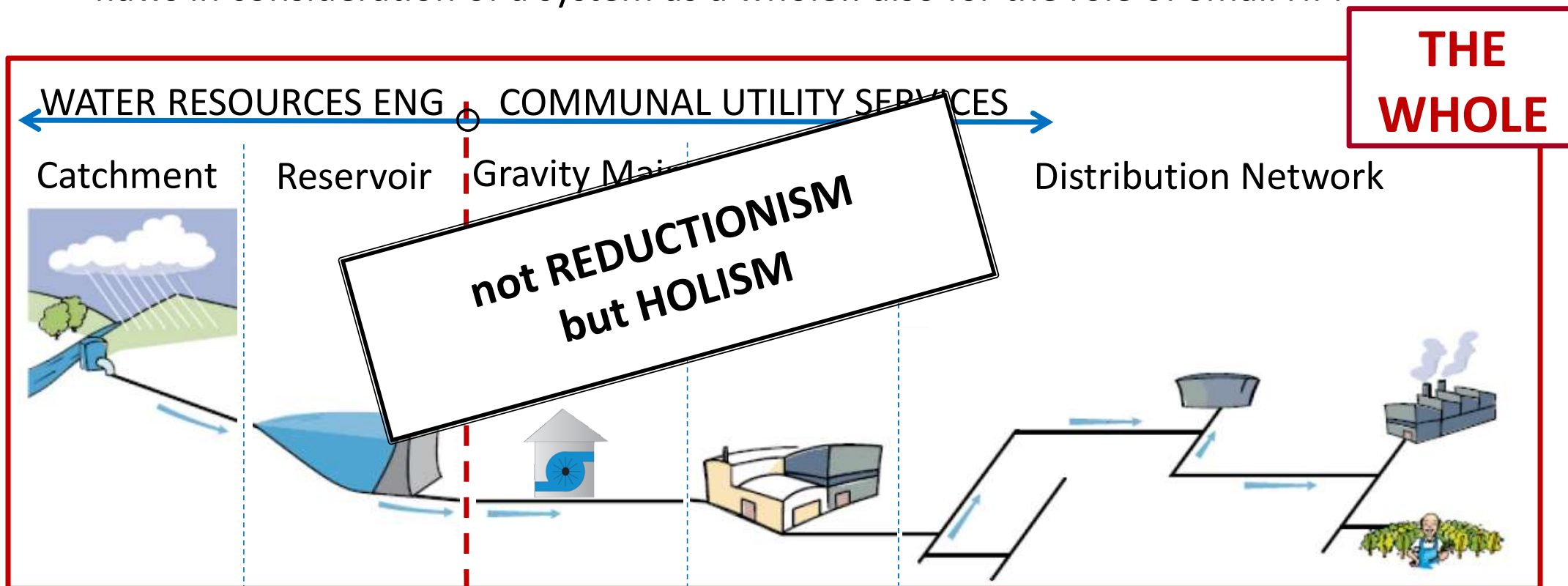


▶	INTRO	SCENE	RA in WATER	ISSUES	STAMP	STPA	REMARKS
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STPA/CAST Exercise:: VIOLATED SAFETY CONSTRAINTS

INCORRECT PROCESS MODELS:

- flaws in consideration of a system as a whole:: also for the role of Small HPP

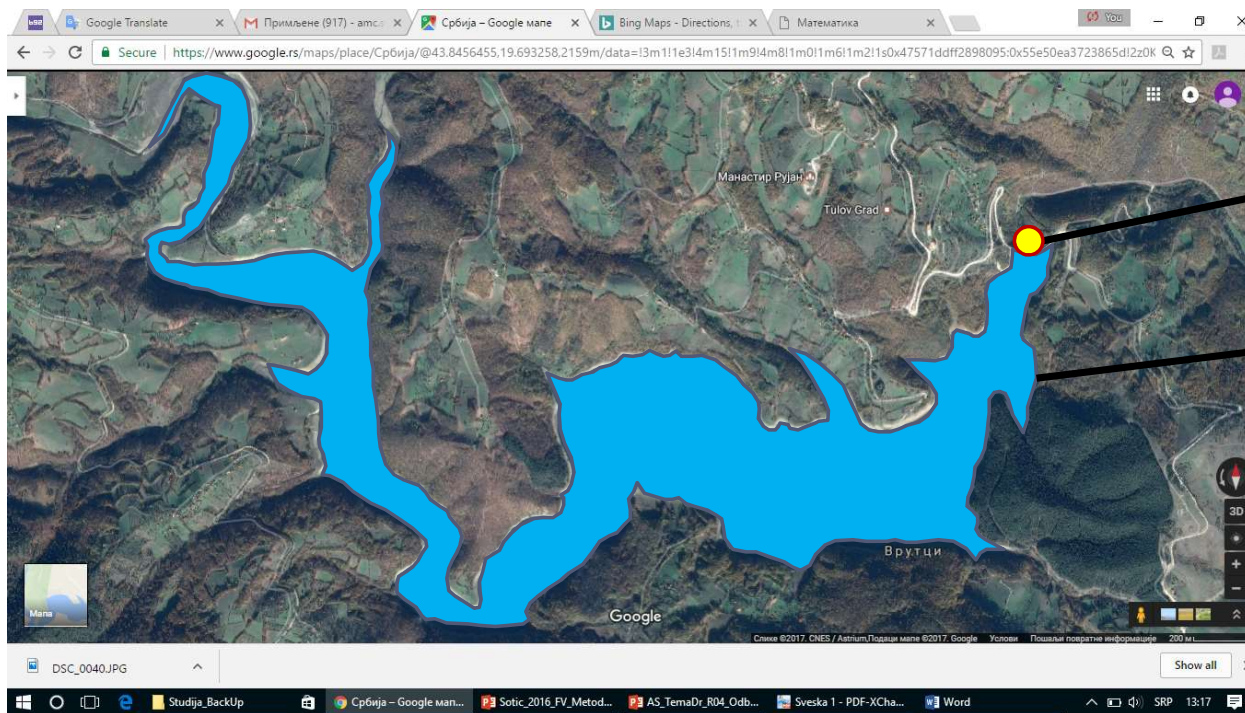


INTRO	SCENE	RA in WATER	ISSUES	STAMP	STPA	REMARKS
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STPA/CAST Exercise:: VIOLATED SAFETY CONSTRAINTS

INCORRECT PROCESS MODELS:

- flaws in definition of the terms ‘water intake’ (different in several regulations), which entails substantial consequences



**One Point
or**

Whole Reservoir (Lake)

(e.g. later consequence is numerous sample points distributed both in space & depth)

INTRO

SCENE

RA in WATER

ISSUES

STAMP

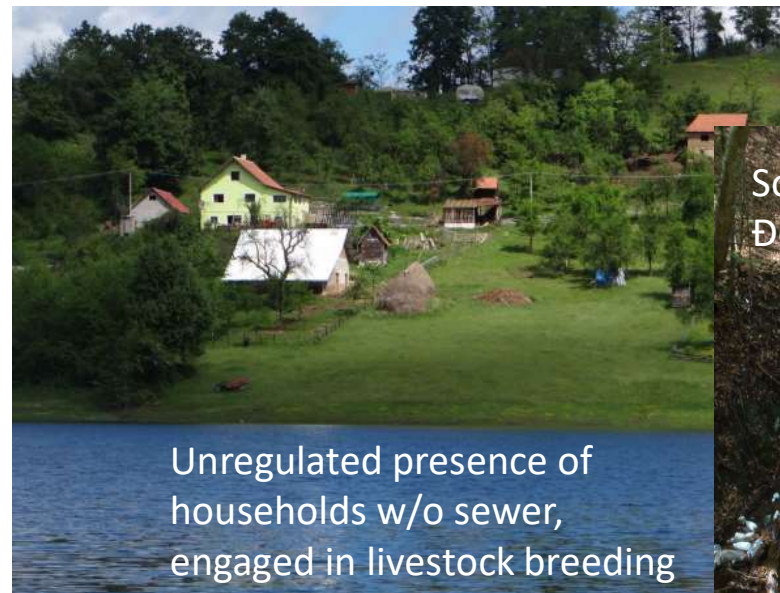
STPA

REMARKS

STPA/CAST Exercise:: IN VIOLATED SAFETY CONSTRAINTS

INCORRECT CONTROL ALGORITHM:

- lack of responsibilities for preservation of Sanitary Protected water source Area (SPA),
- flaws in regulations for testing drinking water quality (e.g. CT limits),
- flaws in water quality monitoring and reporting methodology (e.g. reporting to DM).



STPA/CAST Exercise:: VIOLATED SAFETY CONSTRAINTS

REFERENCE CHANNEL FLAWS:

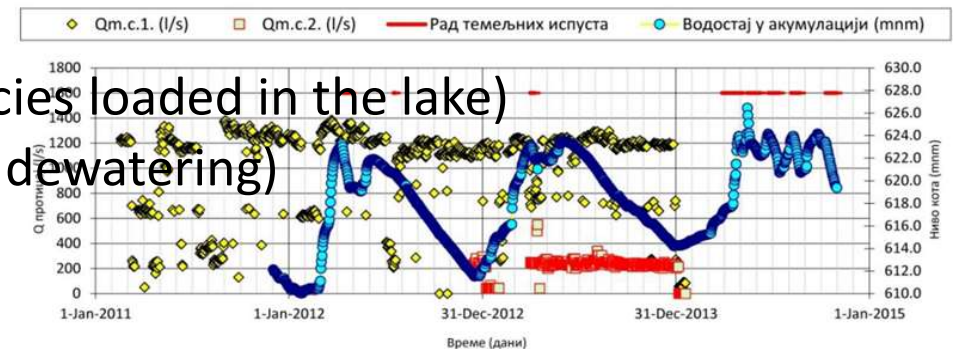
- other than drinking water purpose are not allowed for reservoir by regulation – small HPP was introduced, however
- flaws in fish management (e.g. wrong fish species loaded in the lake)
- flaws in reservoir management (e.g. excessive dewatering)

MEASURING CHANNEL FLAWS:

- flaws of state audit over SPA,
- flaws of audit over the extent of water quality testing,
- Annual Reports on environment and drinking water quality lack the adverse event: 'nothing happened' – nothing to decide about

COMMUNICATION AND COORDINATION FLAWS:

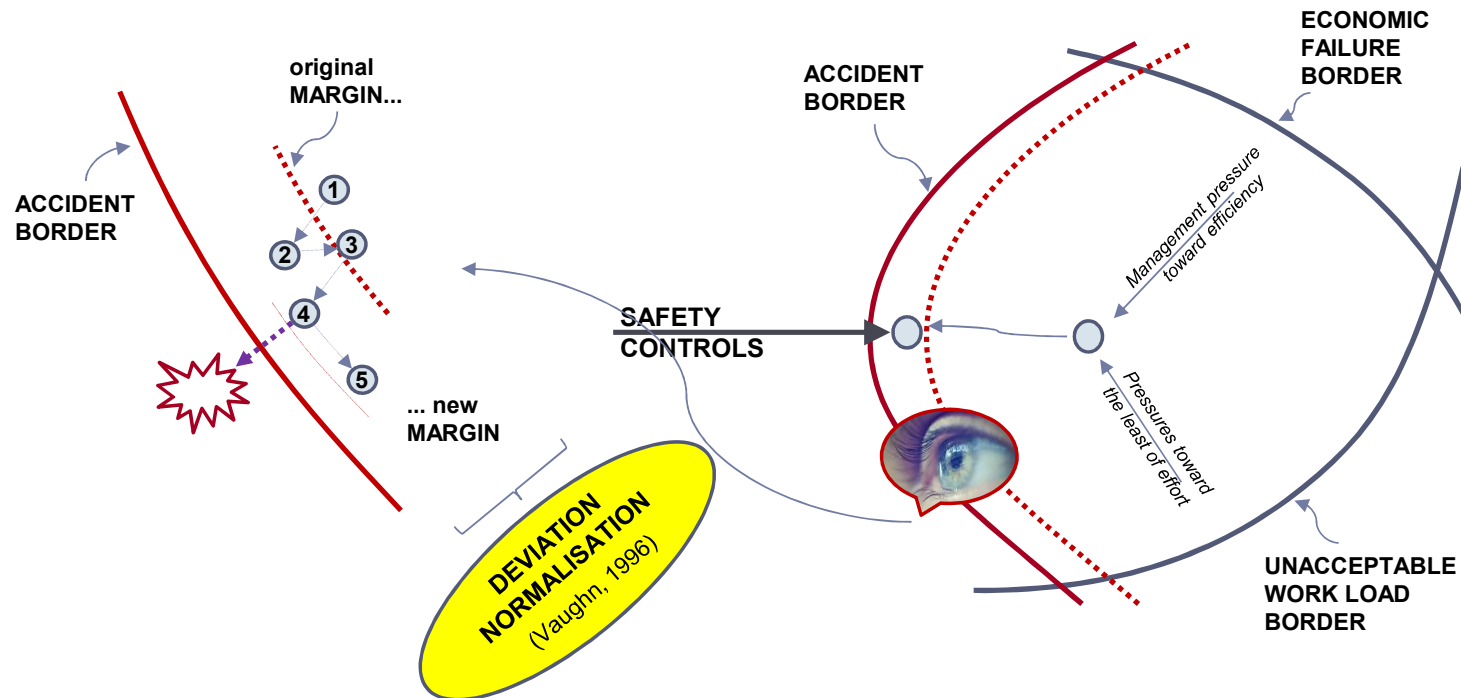
- relationships between governmental departments, local authorities, operators



▶	INTRO	SCENE	RA in WATER	ISSUES	STAMP	STPA	REMARKS
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STPA/CAST Exercise:: MIGRATION MODEL

- Uzice WSS controls degraded with time, if existed at all
- Deviations have become normal in daily operations – no one to see them



(Rasmussen, 1986) (R.I.Cook, 2006)

▶	INTRO	SCENE	RA in WATER	ISSUES	STAMP	STPA	REMARKS
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CONCLUDED REMARKS

Empty area for concluding remarks.



INTRO

SCENE

RA in WATER

ISSUES

STAMP

STPA

REMARKS

CONCLUDED REMARKS

- **Whole environmental and engineering socio-technical structure** has contributed to the discussed adverse event
- **Partitioned responsibilities** in managing different aspects of water among the institutions/actors at different governance levels (local, national) or at the same level (different departments or Ministries) or different professions (environmentalists, engineers, medical workers) had resulted in failure of making effective/timely decisions, either to prevent or to mitigate the issues
- **Initial public blame revealed as wrong**, along with water experts which found themselves lost with detailed CB investigations - they pointed out that event was caused by reservoir maturity, flushing of manure from agricultural areas and high phosphorus content in reservoir

▶	INTRO	SCENE	RA in WATER	ISSUES	STAMP	STPA	REMARKS
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CONCLUDED REMARKS

Therefore, STAMP (Leveson, 2004) is quite appropriate Risk Analysis Method for WSS which are Systemic, Hierarchical, Complex, S-T, Adaptive, Resilient

PARADIGM SHIFT from Traditional to Systems approach of RA is offered (through SAFETY as a kind of antipode):

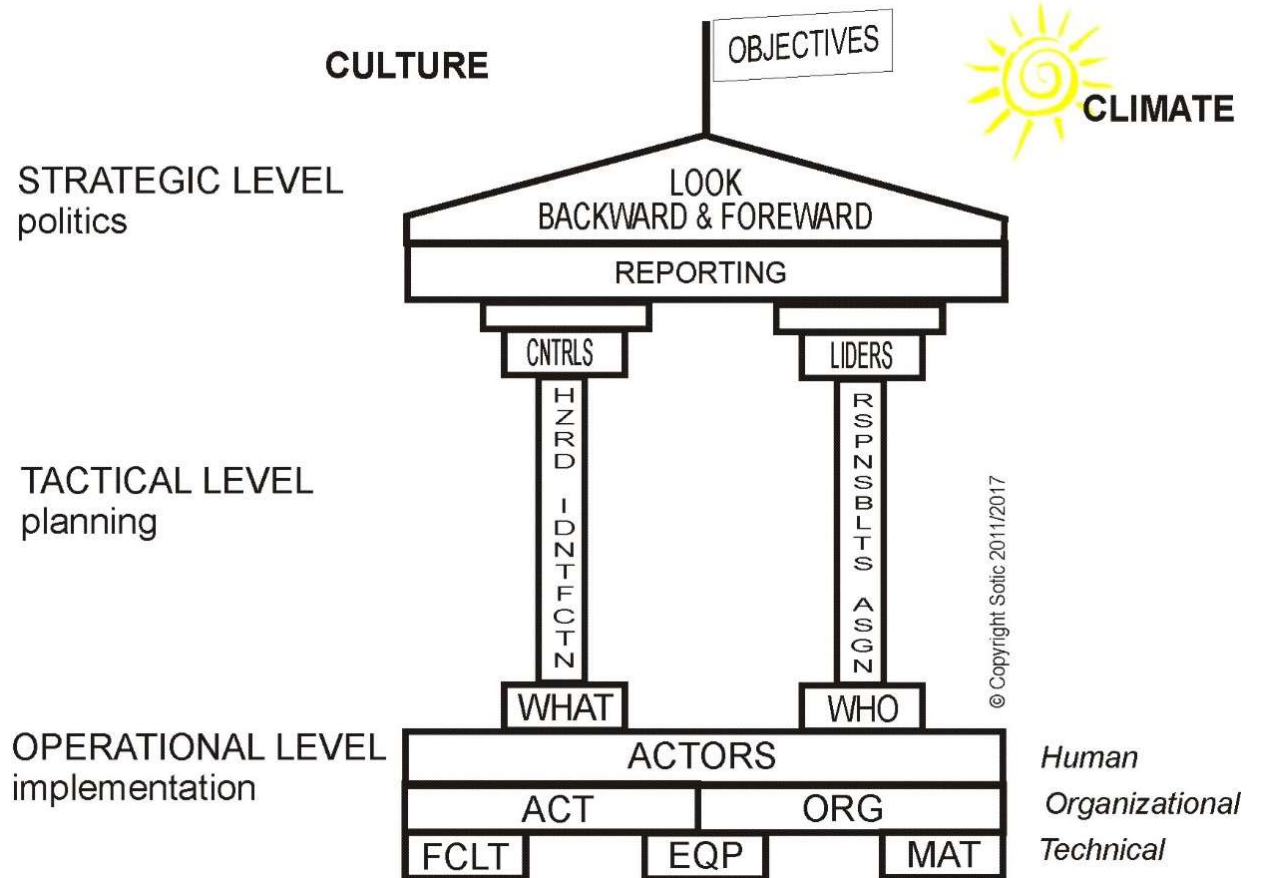
- **system thinking about the whole**, with lowering towards components through AH cognitive techniques
- **based on processes (on system insight)**, not on events (on oversights), i.e. model independence from events
- **covering integrated socio-technical system**, with existence of complex relationships between technical, organisational and social aspects

▶	INTRO	SCENE	RA in WATER	ISSUES	STAMP	STPA	REMARKS
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BONUS TRACK:: SAFETY TEMPLE

SAFETY TEMPLE

as answer on
 prof. Leveson challenge
 (from 'An STPA Primer')
 for visualisation (illustration)
 of Safety
 :: not systemic but
 solid & transitional one
 from traditional perspective



▶	INTRO	SCENE	RA in WATER	ISSUES	STAMP	STPA	REMARKS
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BONUS TRACK:: GREETINGS FROM Belgrade



▶	INTRO	SCENE	RA in WATER	ISSUES	STAMP	STPA	REMARKS
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THANK YOU
FOR
YOUR ATTENTION

