CINKARNA Site, Celje Slovenia
Risk Assessment / Summary

18 May 2017

Water

Environment

Infrastructure

Energy

Facilities

Geotechnics

CDM Smith

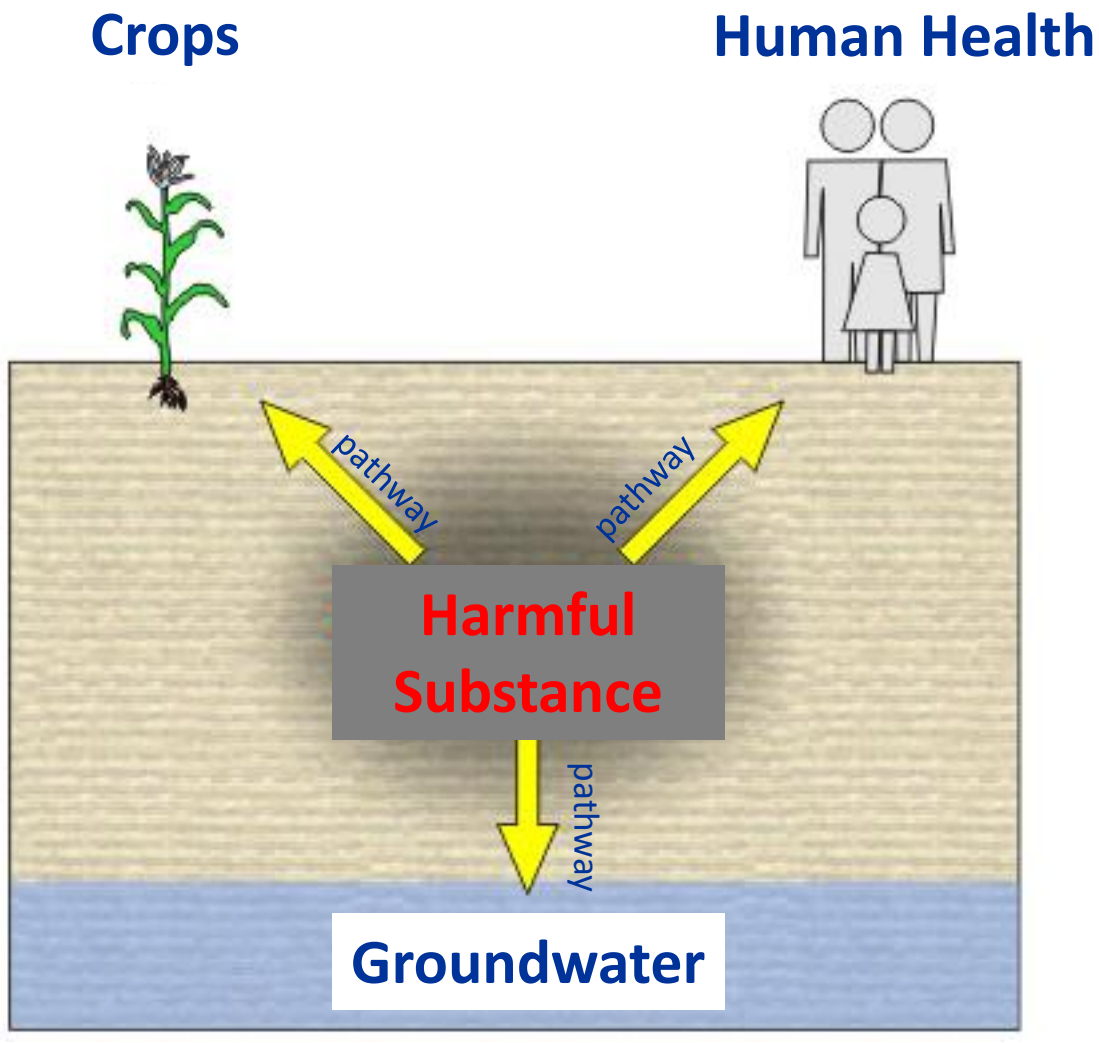
Presentation of Risk Assessment, 18 May 2017

1. Objectives of the Project
2. Methodology of current Risk Assessment
3. Data Basis and Investigations conducted
4. Results Cinkarna Celje Site
5. Results Bukovzlak sites
6. Results Za Travnikom site
7. Summary

1. Objectives of the Project at CINKARNA Celje

1. Risk assessment (human health and ecological)
   -> Collection & review of existing data, definition of relevant contaminant migration pathways, description of risks for sensitive receptors, recommendations for further actions
2. Investigation of possible remediation
   -> Preliminary assumptions on remediation alternatives
3. Evaluation and comparison of alternatives
   -> Technology screening, recommendation for most suitable alternative
4. Remediation plan
   -> Development of detailed remediation design

2. Methodology of Risk Assessment



2. Methodology of Risk Assessment

Rationale of *German Soil Protection Law*

(1) Resources to be protected

- Human Health
- Groundwater
- Plants
- Soil

(2) Exposure

= Contact of sensitive *resources/receptors* with chemical, biological or physical influences (Definition by *German Federal Soil Protection Law*)

(3) Pathway

= migration or transport of harmful substances in the environment and their up-take by resources/receptors

(***4) Risk***

= Interaction of: hazard potential + exposure pathway + affected resource

-> Result: Description of ***identified potential Risks***

2. Methodology of Risk Assessment

Rationale of *German Soil Protection Law*

-> Distinction of Pathways according to Receptors

For investigations regarding the soil - human health pathway, a distinction must be made between the following types of land use:

- playgrounds
- residential areas
- parks and recreational facilities
- plots of land used for industrial and commercial purposes;

for investigations regarding the soil - plant pathway, a distinction must be made between the following types of use:

- agriculture, vegetable garden
- grassland

For investigations regarding the soil - groundwater pathway, no distinction needs to be made based on the type of soil use involved.

2. Methodology of Risk Assessment

Rationale of *German Soil Protection Law*

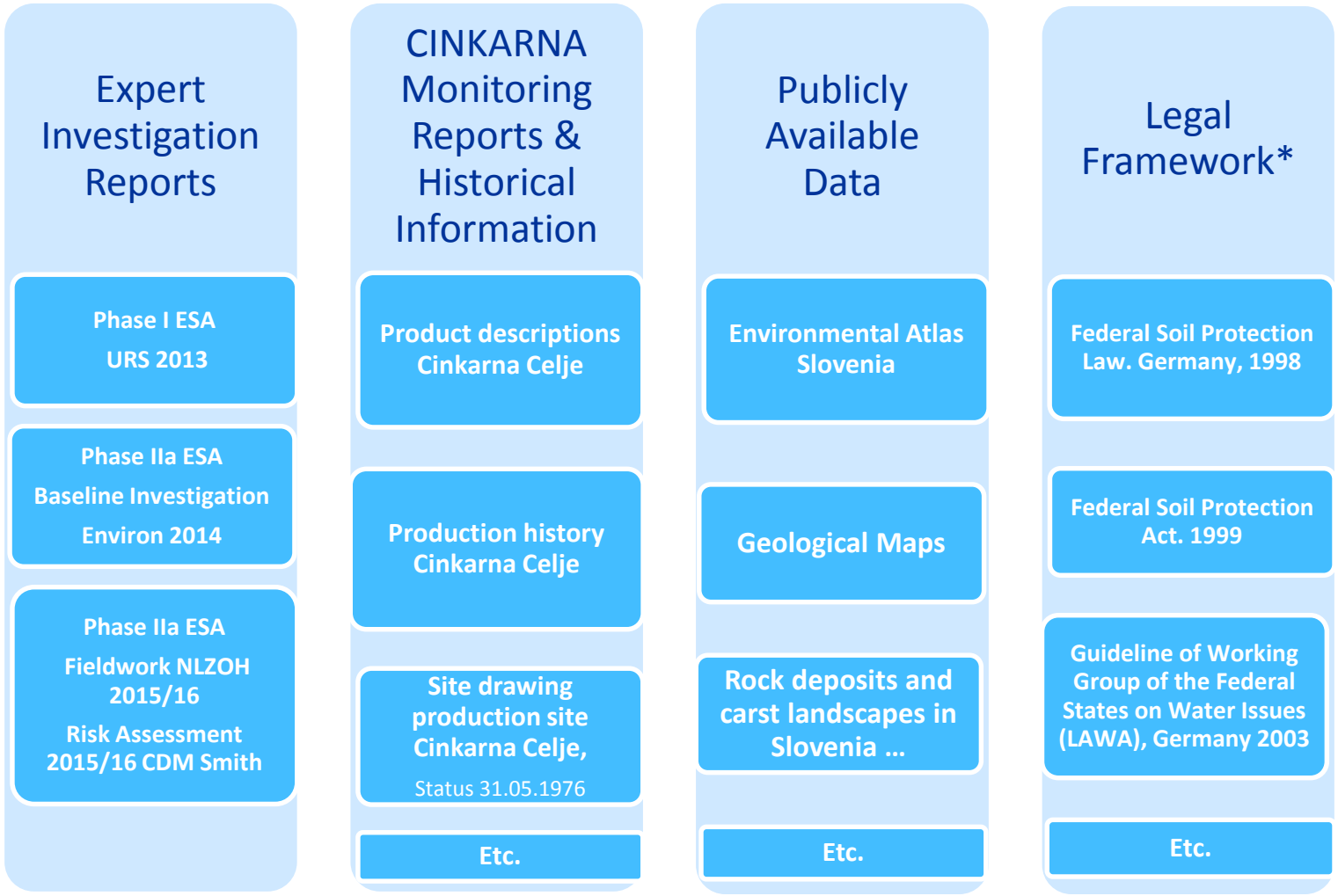
-> Example Pathway Soil – Human Health: Distinction in land use

Parameter	Unit	Threshold Values				Data Base					
						Close to Residential Areas			Distant to Residential Areas		
		(1)	**(2)**	(3)	(4)						
		Play-ground	***Residential Area***	*Park and Recreation Areas*	*Industrial and Commer-cial Area*	CCB-28	CCB-29	CCB-31	CCB-30	CCB-32	CCB-33
Arsenic	mg/kg	*25*	***50***	*125*	*140*	21	9,5	31,8	65	74	32
Cadmium	mg/kg	*10*	***20***	*50*	*60*	2,5	1,7	1,8	4,7	3,2	4,2
Chromium	mg/kg	*200*	***400***	*1.000*	*1.000*	39	32	100	21	41	38
Copper[1)]	mg/kg	*3.000*	***6.000***	*15.000*	-	39	27	54	490	260	100
Lead	mg/kg	*200*	***400***	*1.000*	*2.000*	100	67	47	760	230	180
Mercury	mg/kg	*10*	***20***	*50*	*60*	0,05	0,21	0,21	0,51	0,33	0,23
Nickel	mg/kg	*70*	***140***	*350*	*900*	27	22	38	28	39	43
Zinc[1)]	mg/kg	*10.000*	***20.000***	*50.000*	-	530	380	690	6.500	1.600	1.300

Bold: **Applicable thresholds for off-site (close to residential areas) risk assessment**
Italic: *Applicable thresholds for on-site risk assessment*
1): Threshold value according to [D9], non-binding
Note: Per each sampling location, the highest **concentration within the upper 0,30 m bgs.** has been compared to the respective threshold

Example taken from Risk Assessment Report

3. Data Basis and Investigations conducted

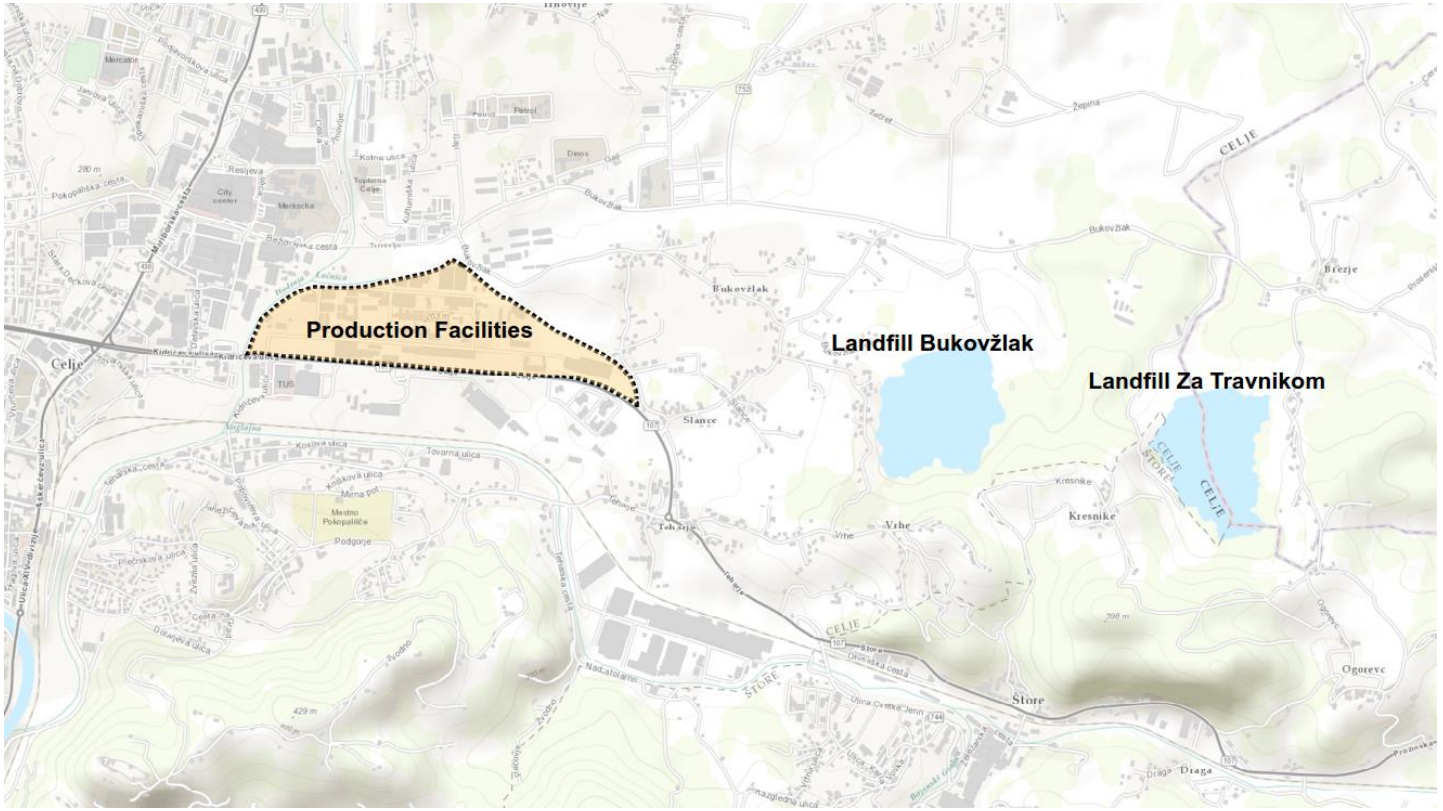


* *German Soil Protection Law* was used as future Slovenian Environmental Laws will likely be oriented to German, Austrian and European Guidelines.

3. Data Basis and Investigations conducted

Phase II Environ Site Assessment, 2014:

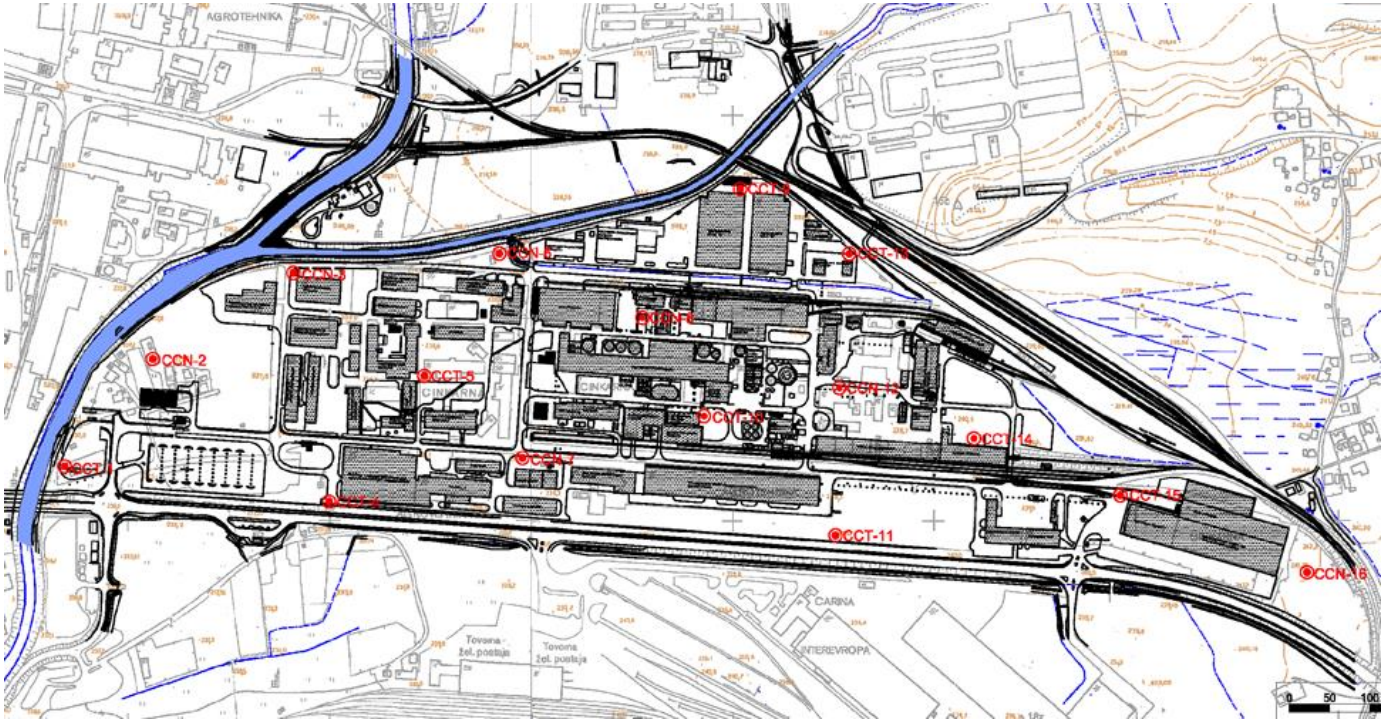
- Soil drillings, soil and shallow groundwater sampling at Celje Production Facility and Bukovzlak and Za Travnikom sites with 70 boreholes and 28 temporary (shallow) wells and existing wells



3. Data Basis and Investigations conducted

Fieldwork Program September to December 2015:

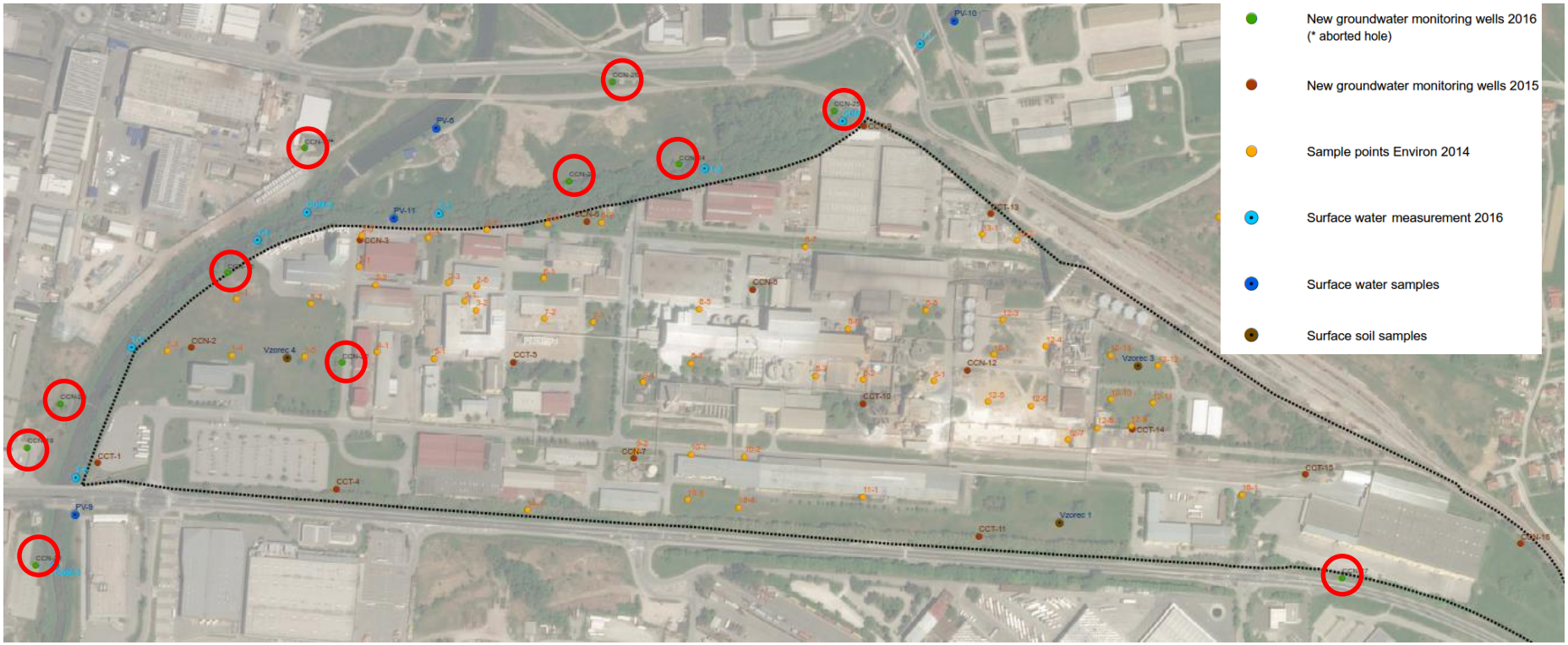
- Installation of 16 groundwater wells (depth 6-10 m, 4”)
- Soil and groundwater sampling
- Pumping tests



3. Data Basis and Investigations conducted

Fieldwork Program Autumn 2016 (Celje site):

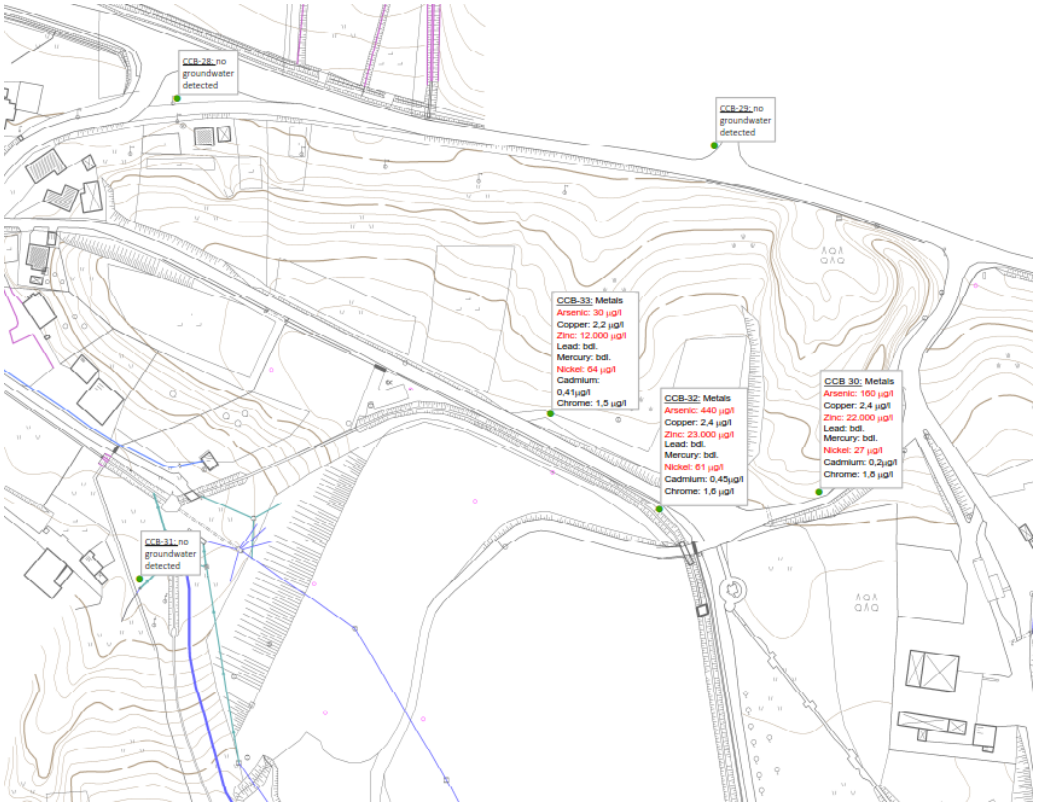
- Based on identified data gaps to describe pathways:
  Installation of 10 additional groundwater wells (depth 6-10 m, 4”)
- Soil and groundwater sampling

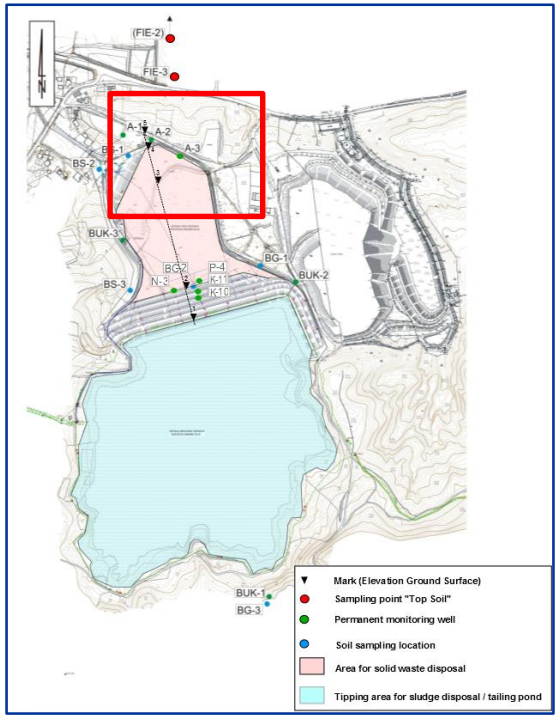


3. Data Basis and Investigations conducted

Fieldwork Program Autumn 2016 (Bukovzlak site):

- Installation of 3 additional groundwater wells and 3 soil borings
- Soil and groundwater sampling

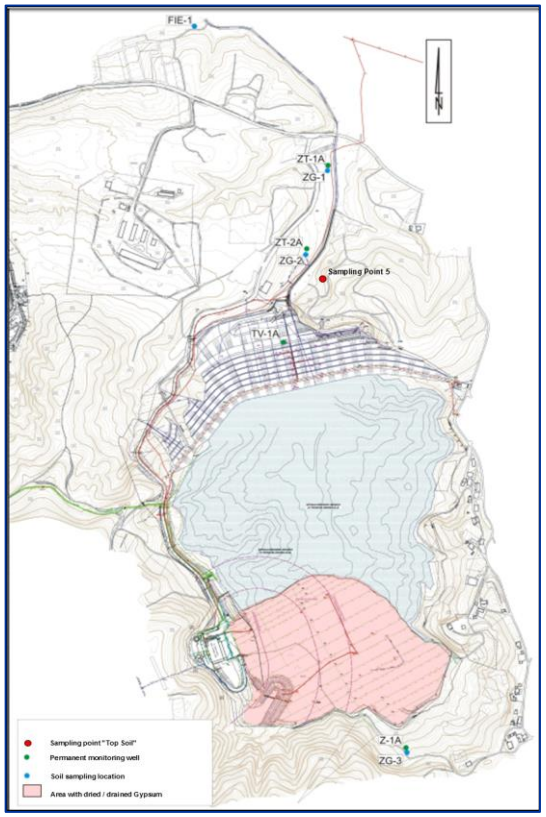




3. Data Basis and Investigations conducted

Fieldwork Program Autumn 2016 (Za Travnikom site):

- Installation of 1 additional groundwater well and 2 soil borings
- Soil and groundwater sampling



4. Results

Celje Production Facility

Soil:

- Significant concentrations above trigger values mainly of **Arsenic** and **Zinc**
- Concentrations in Artificial Fill Layer > Natural Soil
- Decrease of concentrations with depth towards groundwater
- Random distribution in unsaturated soil (predominantly in artificial fill layer)
- Single “hot spots” with deep artificial fill layers (reaching into groundwater, e.g. historic Voglajna riverbed and former landfills)

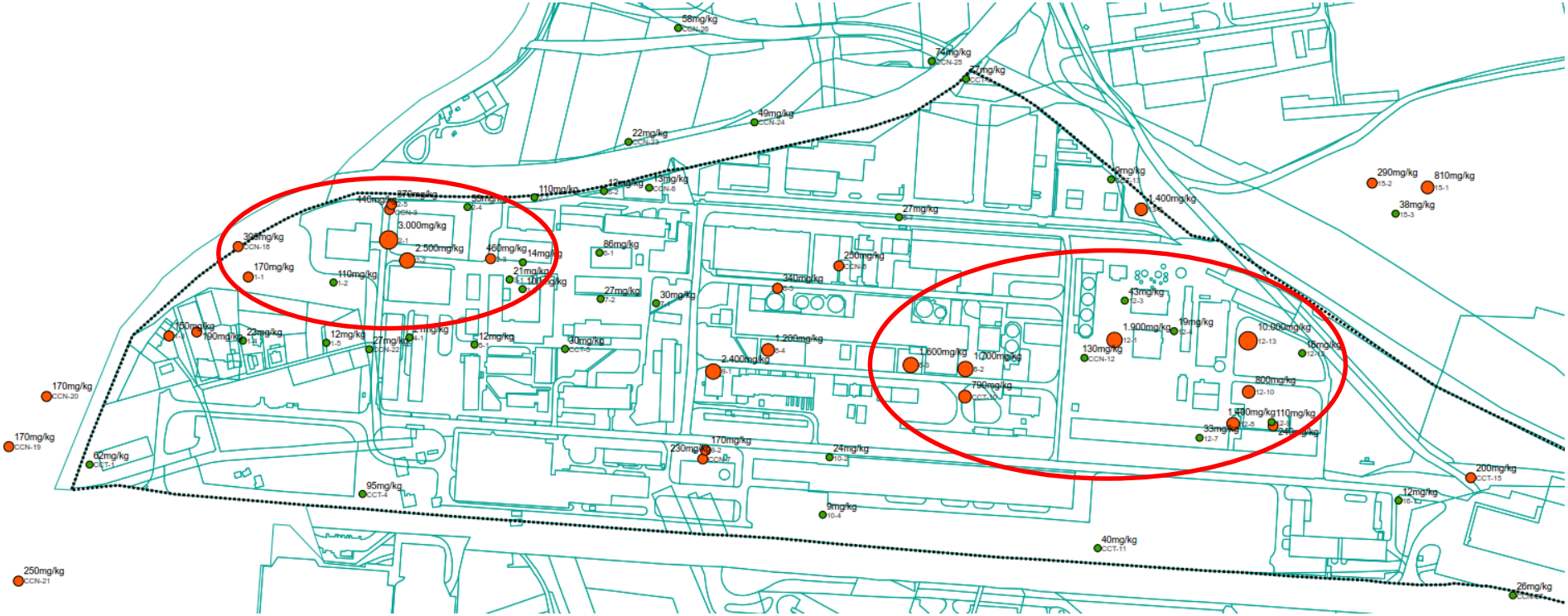
4. Results

Celje Production Facility

Arsenic in Soil (Artificial Fill Layer, results 2014-2016)

- Several highly contaminated areas **on site**
- Slightly elevated values **off-site** west
- Low values **off-site** north

Trigger value
Arsenic: 140 mg/kg



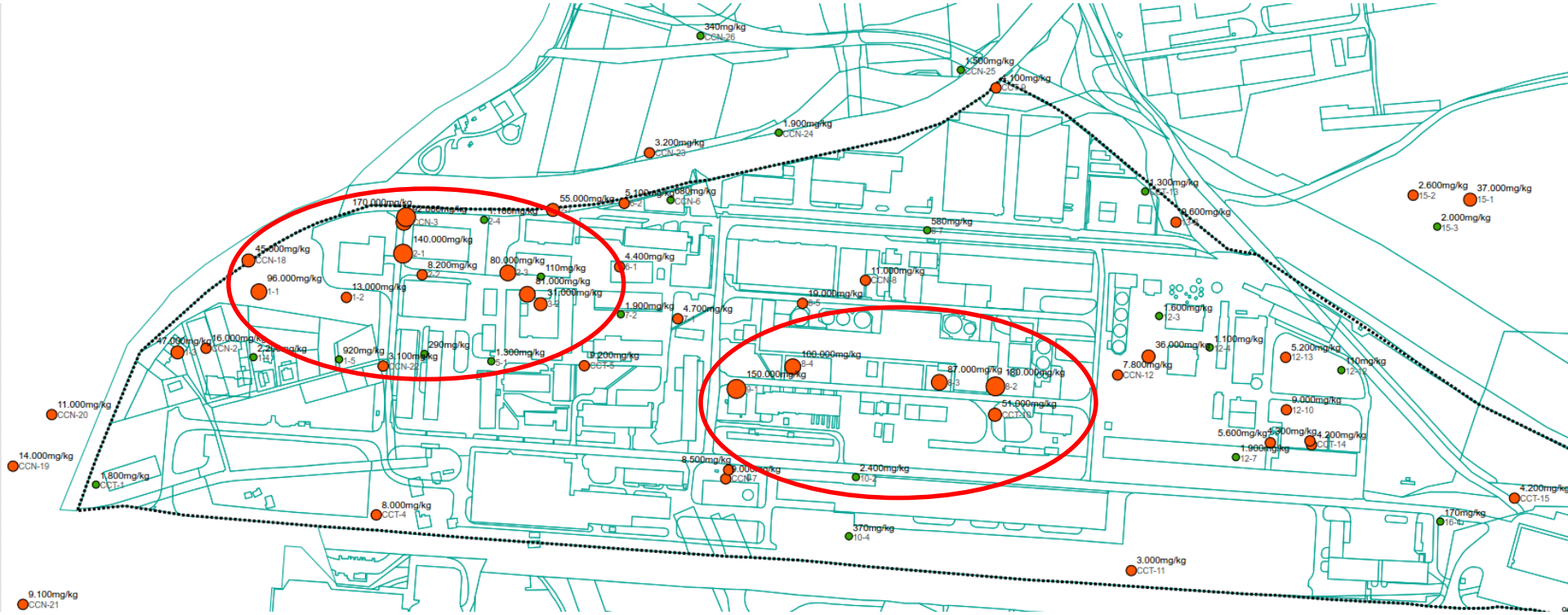
4. Results

Celje Production Facility

Zinc in Soil (Artificial Fill Layer, results 2014-2016)

- Several highly contaminated areas **on site**
- Low values **off-site** north
- Significant concentrations **off-site** west

Trigger value
Zinc: 2500 mg/kg



4. Results

Celje Production Facility

Groundwater evaluation based on Threshold values of German Soil Protection Law:

3. Soil – groundwater pathway

3.1 Trigger values for the assessment of the soil - groundwater pathway pursuant to Article 8 (1) second sentence No. 1 of the Federal Soil Protection Act (in µg/l, analysis according to Annex 1)

Inorganic substances	Trigger value [µg/l]
Antimony	10
Arsenic	10
Lead	25
Cadmium	5
Chromium, total	50
Chromate	8
Cobalt	50
Copper	50
Molybdenum	50
Nickel	
Mercury	
Selenium	
Zinc	
Tin	
Cyanides, total	
Cyanides, volatile	
Fluoride	

Organic substances	Trigger value [µg/l]
Petroleum hydrocarbons [1)]	200
BTEX [2)]	20
Benzene	1
Volatile halogenated hydrocarbons [3)]	10
Aldrin	0.1
DDT	0.1
Phenols	20
PCB, total[4)]	0.05
PAH, total [5)]	0.20
Naphthalene	2

4. Results

Celje Production Facility

Groundwater contour map – flow directions, hydraulic boundary conditions
-> Hudinja and Ložnica: hydraulic barrier – no impact migration to off-site properties

4. Results

Celje Production Facility

Groundwater:

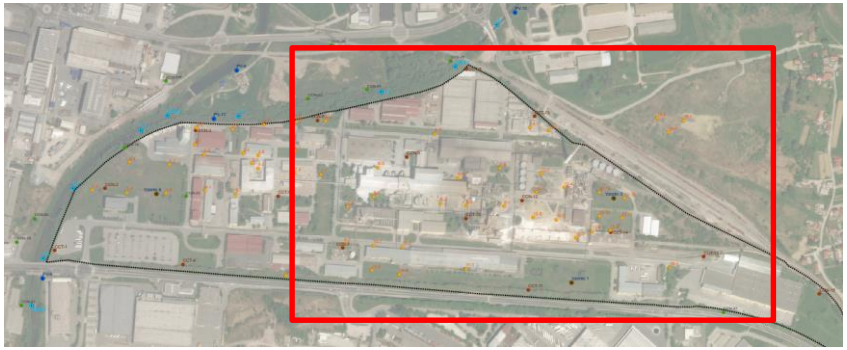
- Significant metal concentrations: **Arsenic, Zinc**
- Local hot spots related to contaminated artificial fill reaching into groundwater

- Elevated organic substances: **Chlorobenzene, chlorinated Hydrocarbons (CHCs)**
- Local source area of chlorobenzene northwest
- Random distribution of CHC in the east and central area

- Low concentrations in groundwater off-site north and west,
  no migration from Cinkarna site (-> pathway to off-site areas not complete)

4. Results

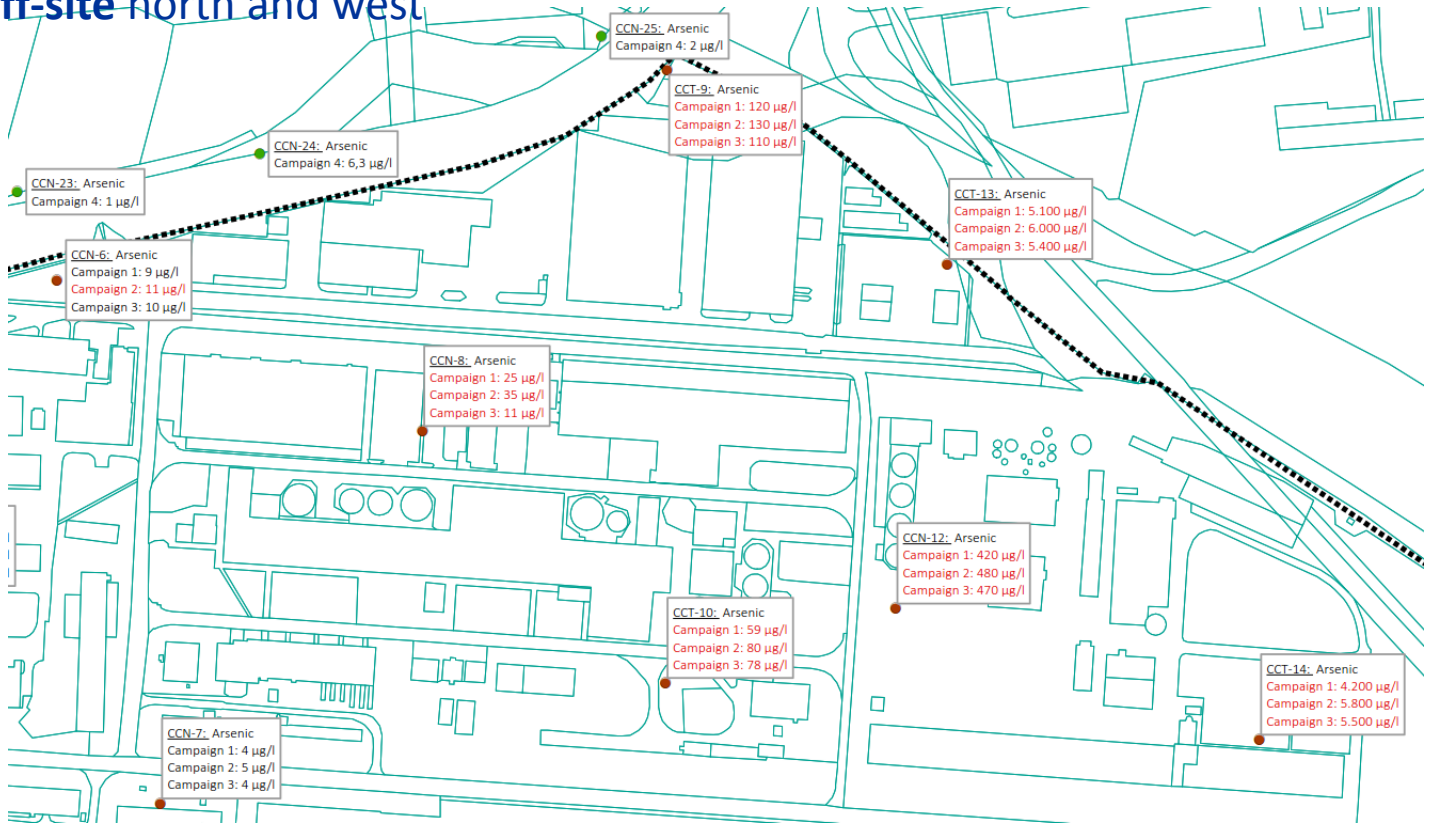
Celje Production Facility



red values above trigger value (=10 µg/l)

Groundwater impact: Arsenic

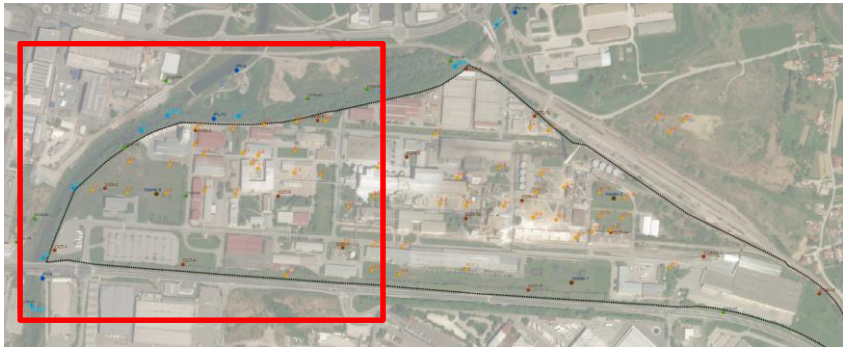
- high values **on site**
- very low values **off-site** north and west



4. Results

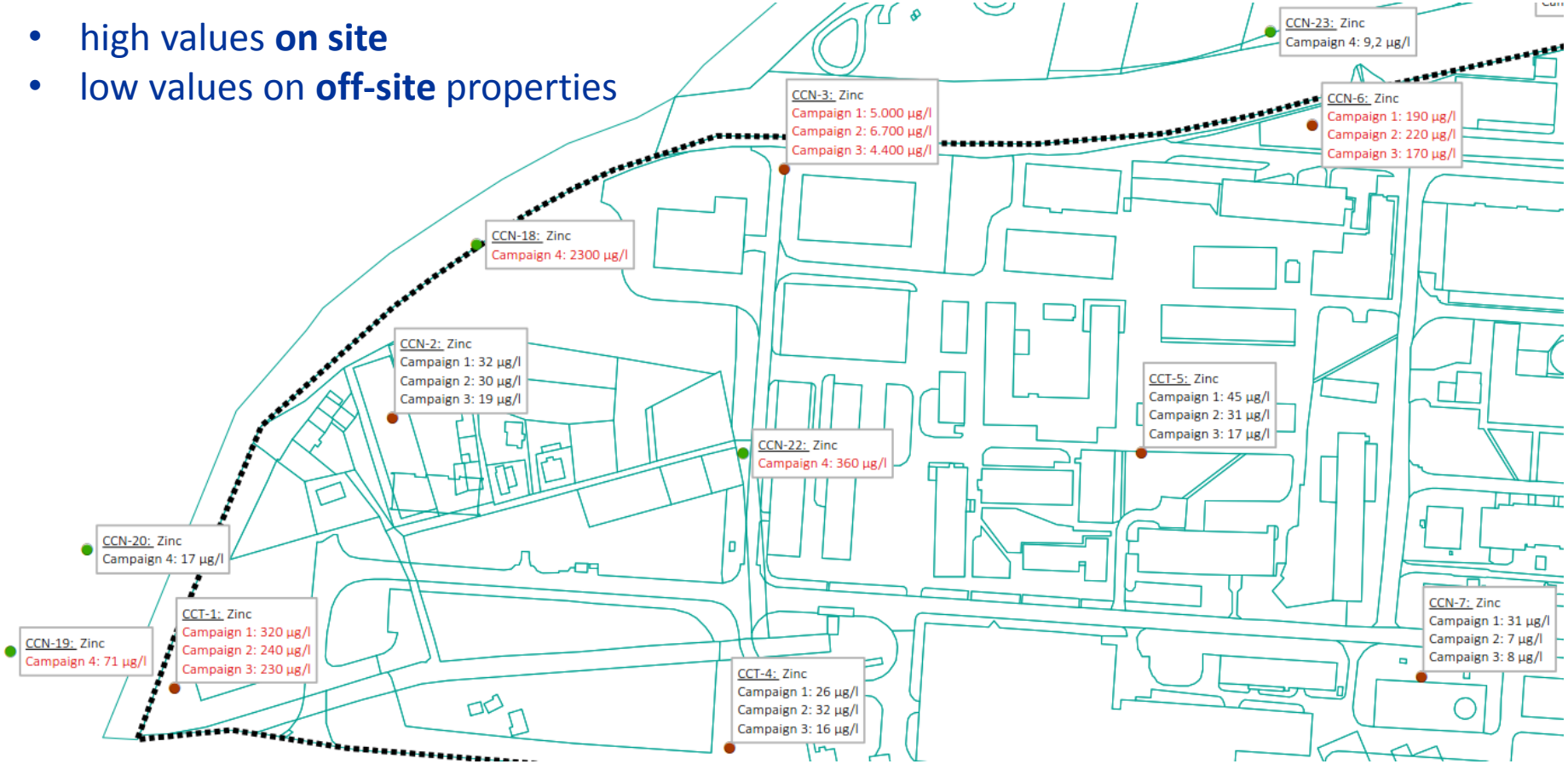
Celje Production Facility

Groundwater impact: Zinc (west)



red values above trigger value (=58 µg/l)

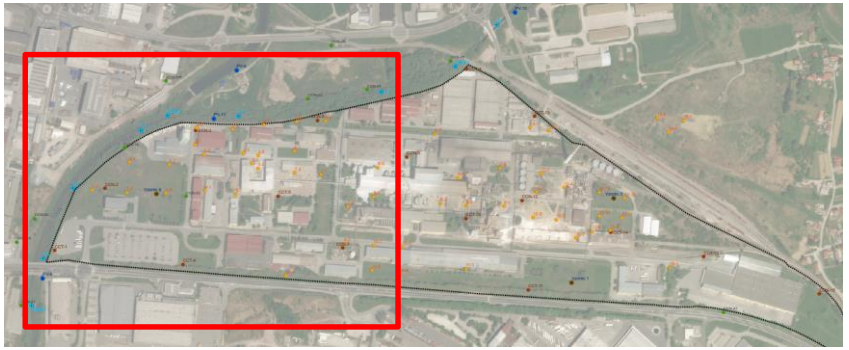
- high values **on site**
- low values on **off-site** properties



4. Results

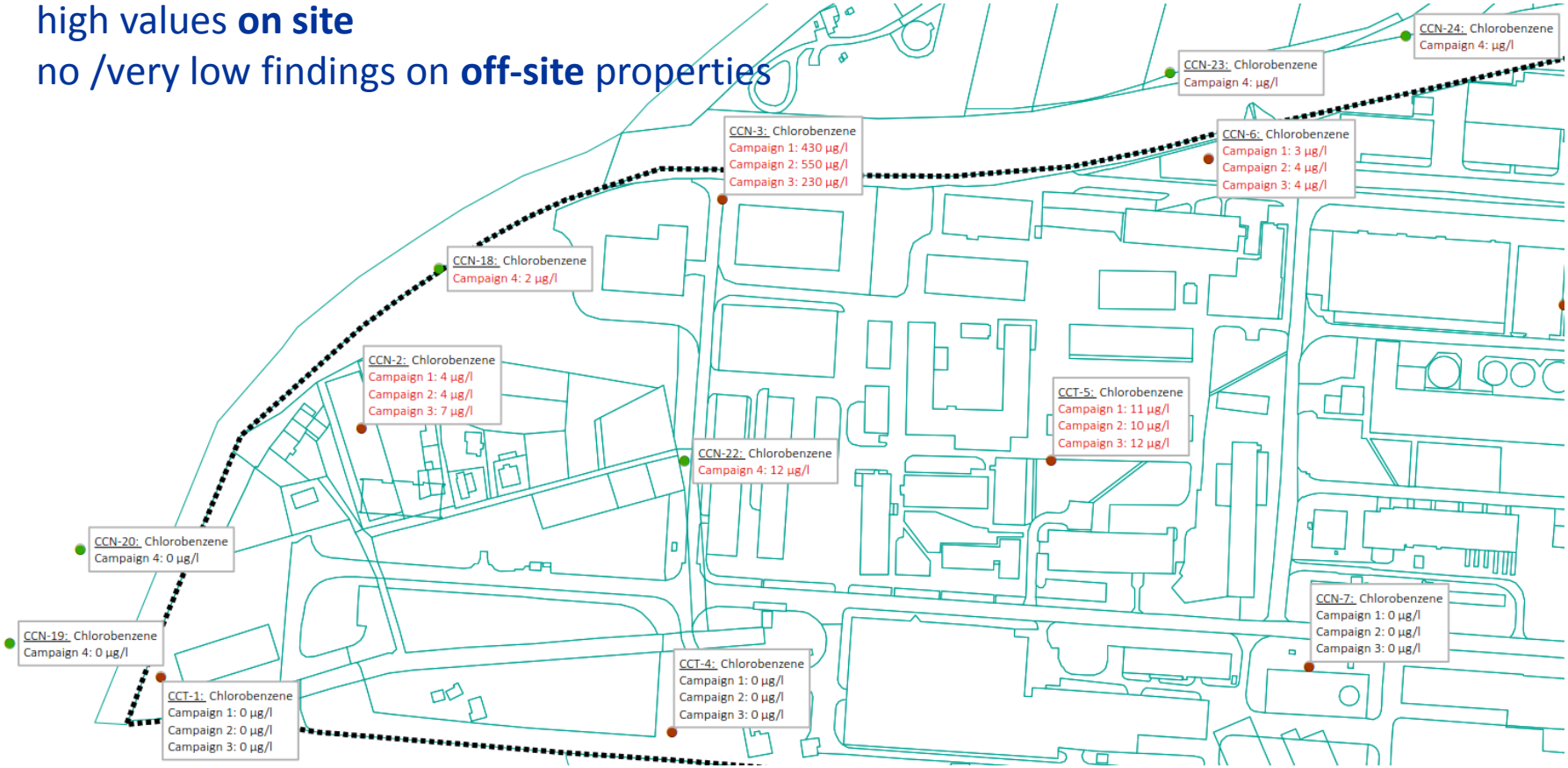
Celje Production Facility

Groundwater impact: Chlorobenzene



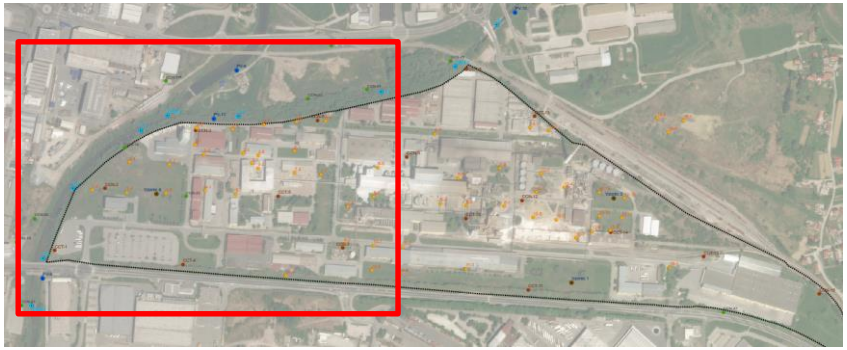
red values above trigger value (=1 µg/l)

- high values **on site**
- no /very low findings on **off-site** properties



4. Results

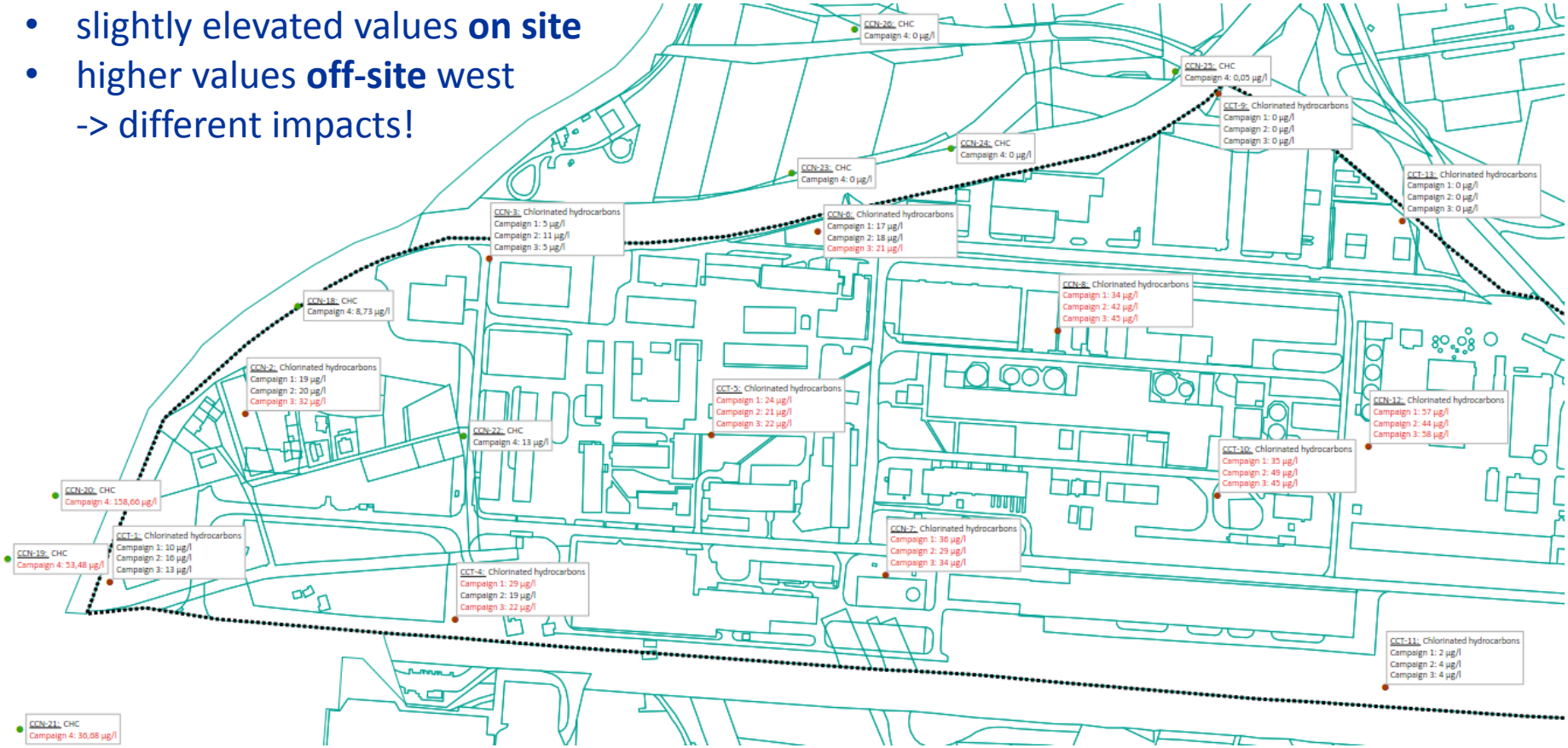
Celje Production Facility



Groundwater impact: Chlorinated Hydrocarbons

red values above trigger value (=20 µg/l)

- slightly elevated values **on site**
- higher values **off-site** west
  -> different impacts!



4. Results

Celje Production Facility

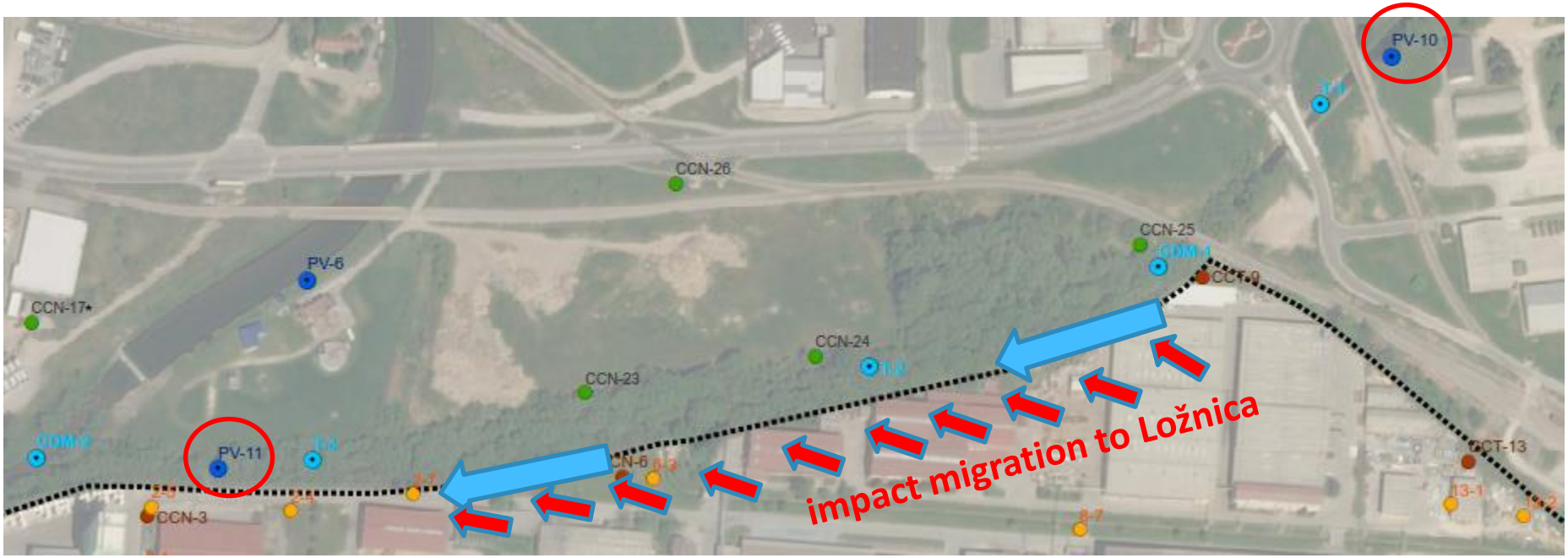
Surface water impact (Ložnica):

Between PV-10 and PV-11 indicate **increase** of impact by migration from Cinkarna site

- Arsenic (1,3 µg/l -> 12 µg/l)
- Zinc (21 µg/l -> 43 µg/l)

-> Slovenian thresholds for surface water not exceeded *(Arsenic: 21 µg/l, Zinc 78 µg/l)*

-> Thresholds in on-site groundwater exceeded -> potential to contaminate river in future



4. Results

Celje Production Facility - Summary

- Pathway ***soil-human health***: low relevance based on site use
- Pathway ***soil-plants***: not applicable or pathway incomplete -> no risk
- Pathway ***soil-groundwater***: major impact -> contaminant migration from soil to groundwater

Massive on-site groundwater contamination has a potential to migrate further towards the rivers which may lead to significantly increased concentrations in surface water.
-> Required: Evaluation of transport mechanisms by modelling, delineation of hot-spots

4. Results

Technology Screening – *How to handle the impact?*

Criteria for technology selection:

- Can ***technical goals*** be achieved? (*-> Type of impact, geology, geochemistry*)
- Can technology be ***implemented*** on site? *(-> site use, disposal pathways*)
- ***How long*** will it take? *(-> construction, duration of clean-up, thresholds*)
- Is it ***sustainable***? *(-> rebound effects, energy consumption, maintenance*)
- Is it ***effective***? (*-> clean-up versus safeguarding*)
- Can it be ***permitted***? (*-> legal basis, compliance with national & EU regulations*)
- What will it ***cost***? (*-> cost/benefit ratio*)

-> Comparison of remediation techniques such as:

- Containment (e.g.: capping, sheet pile, slurry wall)
- In-situ treatment (e.g.: mobilization, fixation, stabilization, reactive barrier)
- Ex-situ treatment (e.g.: adsorption, precipitation etc.)
- Excavation of soil and off-site disposal

4. Results

Technology Screening – *Decision Process*

- Size of site and type of impact:
  Entire clean-up impossible -> safeguarding + mass reduction

- Missing disposal pathways:
  No excavation -> no treatment facilities, no landfill capacities

- Active site operations (buildings, infrastructure):
  No excavation -> contamination below buildings

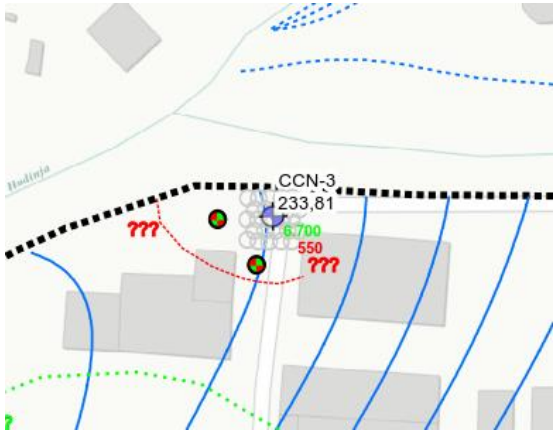
- Random spreading of impact:
  Delineation and characterization for target-oriented local measures required
  (e.g. local containment, in-situ measures such as mass reduction or immobilization)

Most reasonable approach based on current site knowledge:
-> Containment (hydraulic barrier or barrier wall) + reduction of mass at known hot-spots

4. Results

Result of Screening - Proposed Corrective Actions – Celje Site

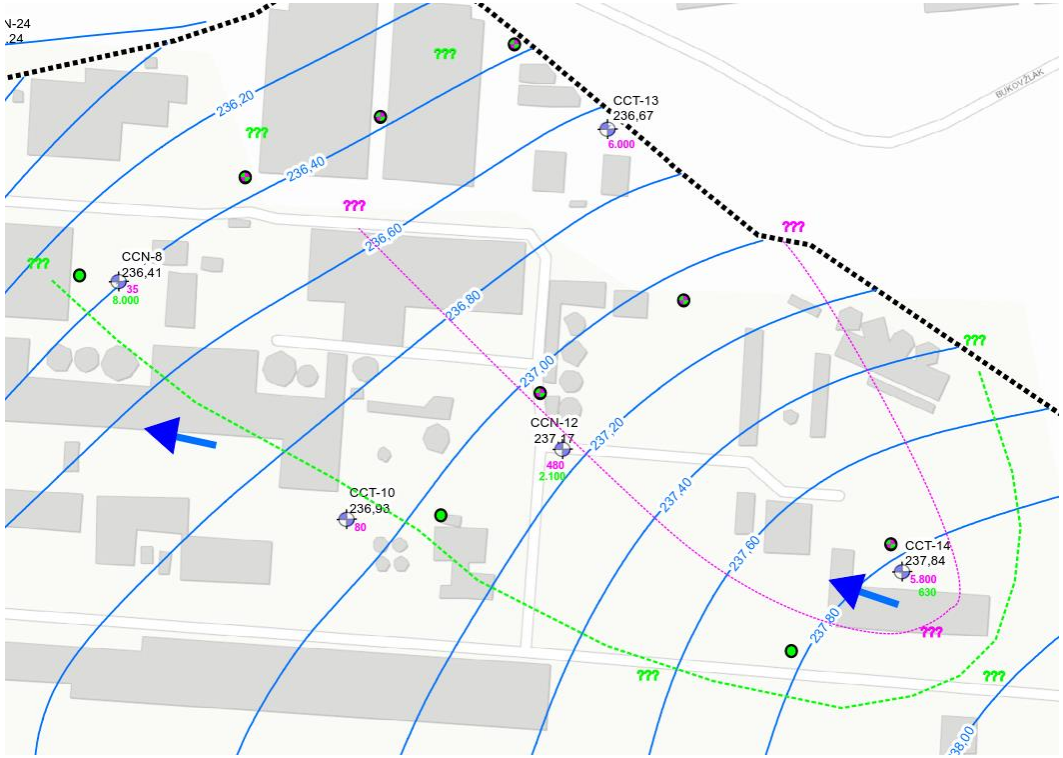
1. **Pump & Treat** (hydraulic barrier + mass reduction)
   -> Groundwater will be pumped from several well curtains to reduce mass in hot spots and to avoid contaminant migration towards the river



Extraction wells for mass reduction, arsenic

Extraction wells for mass reduction, zinc

Extraction wells for mass reduction, chlorobenzene



4. Results

Result of Screening - Proposed Corrective Actions – Celje Site

1. **Pump & Treat** (hydraulic barrier + mass reduction)

- Time frame: 20+ years (estimated based on current site knowledge)

- Costs: 3,30-4,95 M€
  - Investment (investigations, design, construction, equipment): 1,5-2,4 M€
  - Annual costs (monitoring, maintenance, consulting): 85 k€ - 127 k€

- Advantages: mass reduction, adaptability to changing conditions, easy installation
- Disadvantages: High energy and material consumption, maintenance, efficiency

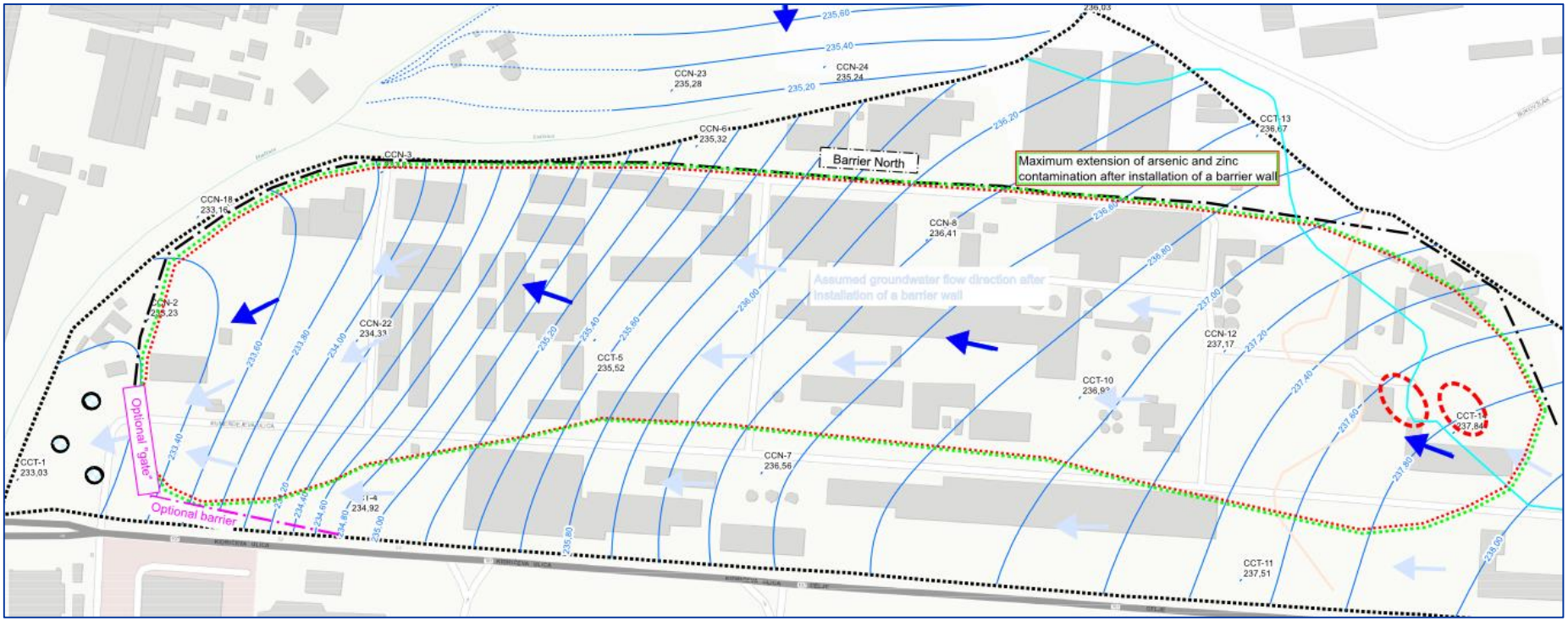
- Potential for optimization after remedial delineation:
  - target-oriented pump & treat measures
  - local in-situ immobilization of contaminants
  - local containment of hot spots

4. Results

Result of Screening - Proposed Corrective Actions – Celje Site

2. Containment ("funnel + gate")

-> barrier to stop migration towards rivers, increased length of onsite flow path, passive gate



4. Results

Result of Screening - Proposed Corrective Actions – Celje Site

2. Containment (“funnel + gate”)

- Time frame: 20+ years (safeguarding measure)

- Costs: 3,0-5,8 M€
  - Investment: investigations, design, construction, equipment: 2,4-4,4 M€
  - Annual costs (monitoring, maintenance, consulting): 30 k€ - 70 k€

- Advantages: lower costs, less energy consumption, less maintenance, higher reliability
- Disadvantages: Safeguarding measure, only minor clean-up function

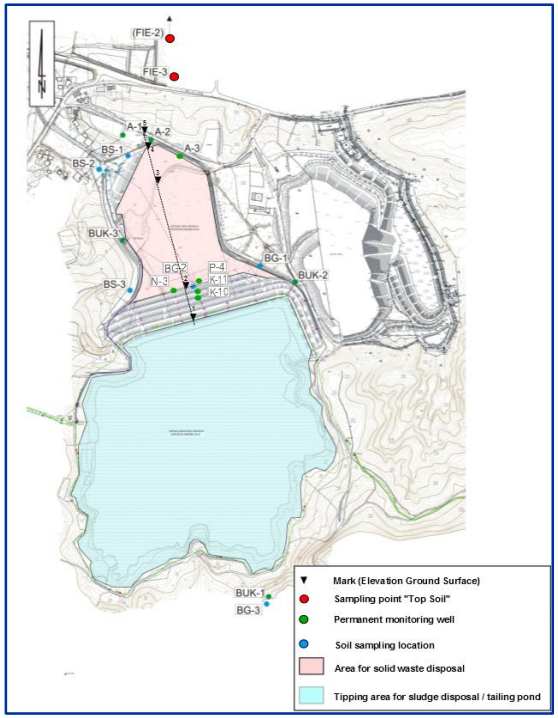
- Potential for optimization after remedial delineation:
  - local containment
  - local in-situ immobilization of hot spots
  - no gate and southern wall required if plume will stabilize on site after installation of northern wall (-> *natural attenuation*)

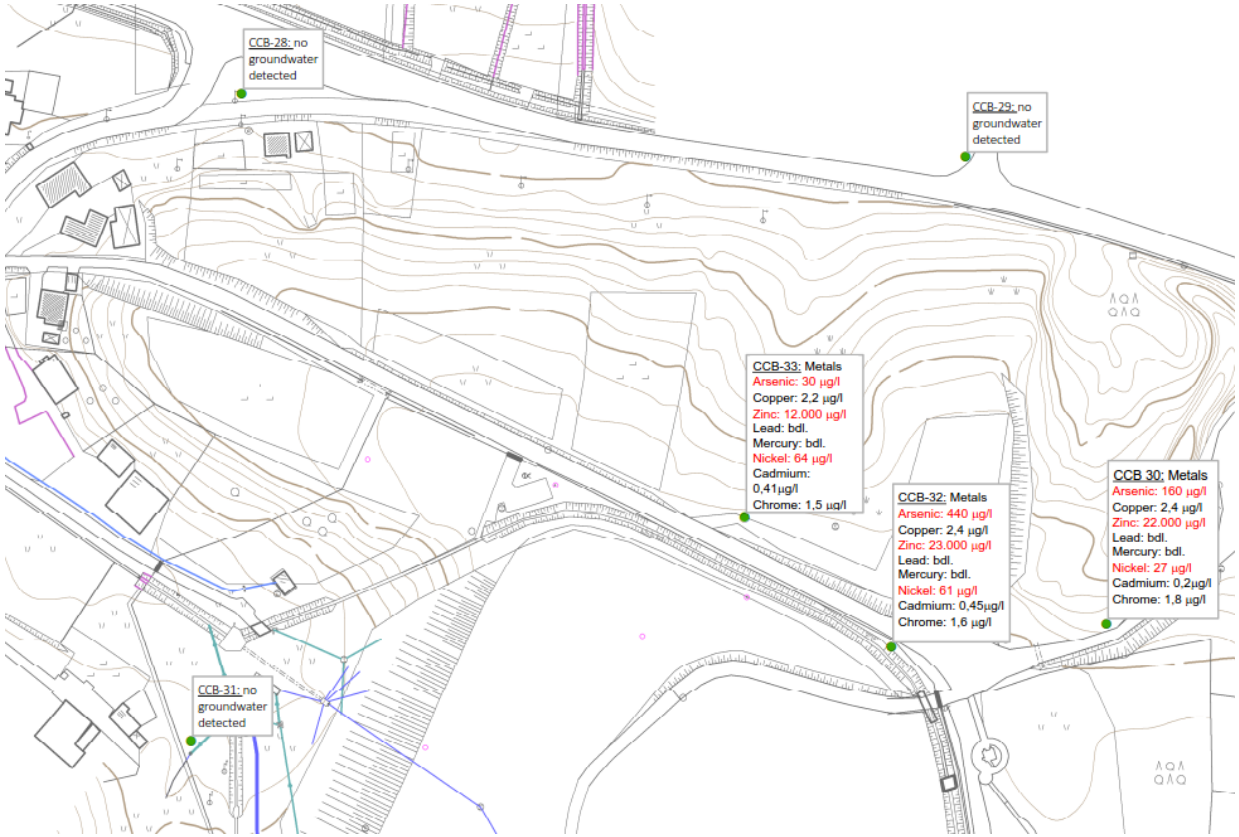
-> **<u>Recommended option</u>**

5. Results

Bukovzlak sites

- Installation of 3 additional groundwater wells and 3 soil borings
- Elevated **Arsenic, Zinc, Nickel** concentrations in groundwater in eastern off-site area
- Off-site, north of road to Prosenisko: no contamination detected deriving from Bukovzlak





5. Results

Bukovzlak sites

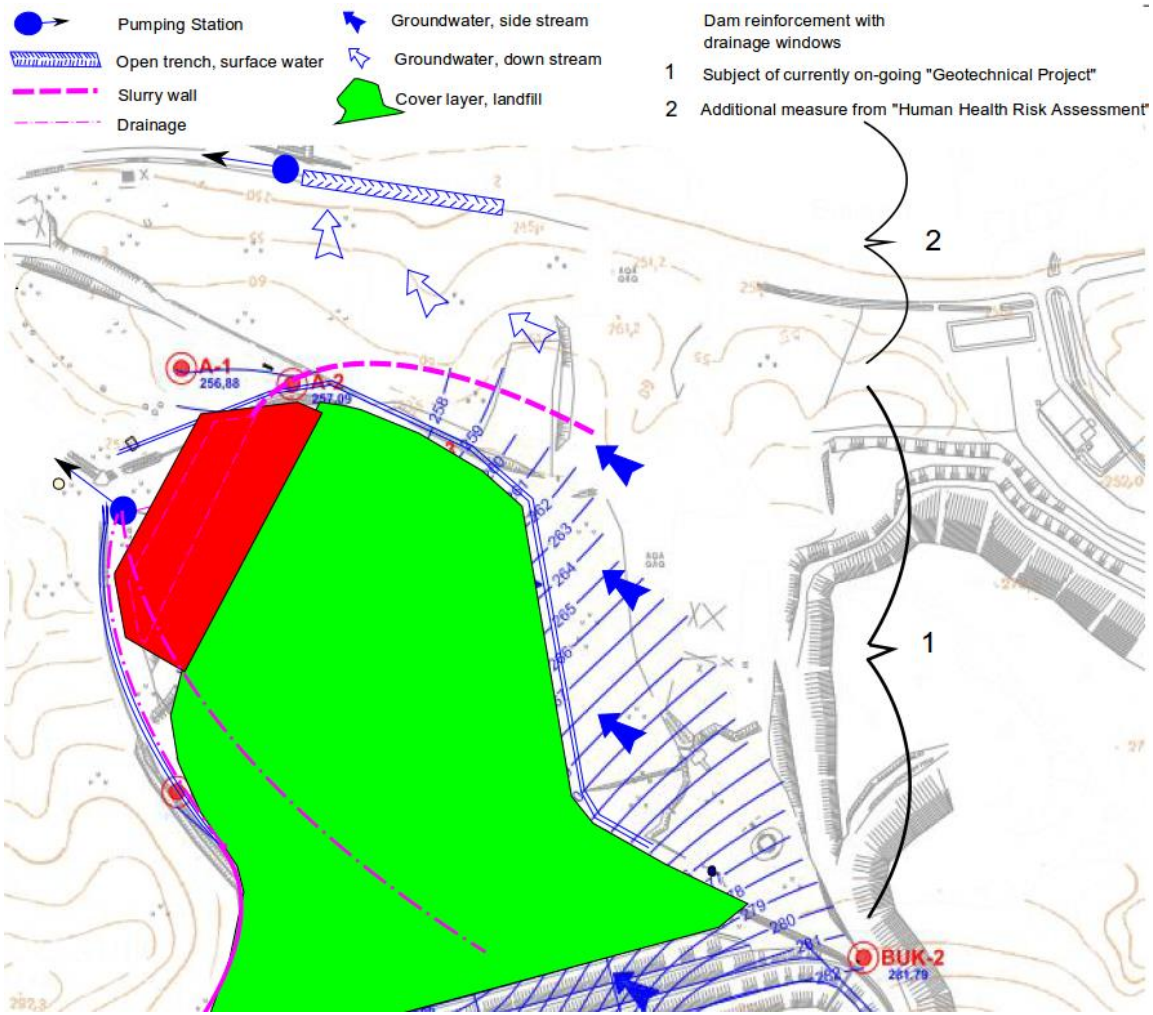
- Since 2016: ongoing construction works at Bukovzlak
  - Geotechnical safeguarding measures, new drainage systems at western and central areas, drainage water treatment at Cinkarna site

- Eastern area and downgradient slope not included drainage system yet
  -> **Required action**: installation of barrier and drainage pipes, connection to existing piping system, treatment at Cinkarna (estimated additional costs 270-525 k€)

- -> Result: potential contaminant migration stopped
  -> Risk of pathway soil-groundwater-plants (off-site) eliminated
  -> recommended: examination of soil and plants on private areas south of road to Prosenisko

5. Results

Bukovzlak sites – required additional drainage systems



6. Results

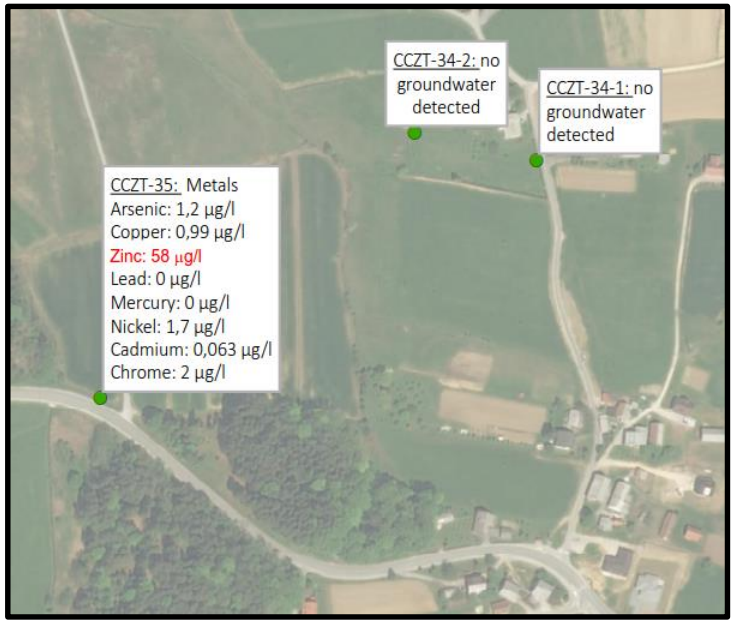
Za Travnikom site

Area between dam and road to Prosenisko:

- Low metal concentrations in soil and groundwater between dam and road

-> no residential or agricultural use

-> no risk to sensitive receptors identified deriving from Za Travnikom site

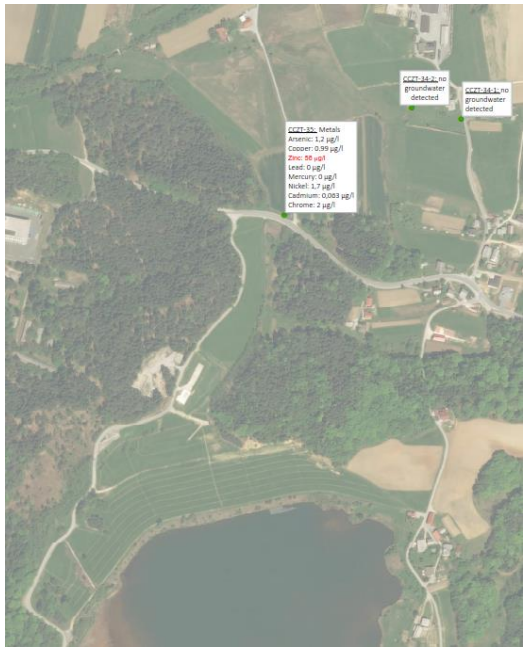


Area north of road to Prosenisko:

- Three drilling locations north of road (CCZT 34-1, 34-2 and 35):
  - Groundwater at well CCZT 35 not polluted
  - No groundwater found at CCZT 34-1, 34-2 (private property Family Slakan)

-> pathway soil-groundwater-plants does not exist

-> no risk to sensitive receptors identified deriving from Za Travnikom site



7. Summary

- ## Cinkarna Celje site

  Major soil & groundwater impact: Risk to groundwater and rivers identified

  -> safeguarding + mass reduction recommended (20+ yrs, 3,0-5,8 M €)

- ## Bukovzlak sites

  Soil & groundwater impact : Risks to groundwater identified

  -> ongoing construction works, risks will be eliminated

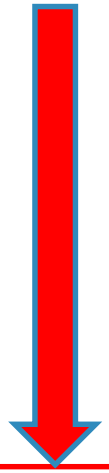
  (construction period +/-1 yr, additional costs to ongoing construction 0,27-0,525 M €)

- ## Za Travnikom site

  Soil & groundwater impact : only minor on-site pollution

  -> pathway does not exist, risks can be excluded, no actions required

7. Summary



1. Risks assessment (human health and ecological)
   -> Collection & review of existing data, definition of relevant pathways, description of risks for receptors, recommendations for further actions
2. Investigation of possible remediation
   -> Preliminary assumptions on remediation alternatives
3. Evaluation and comparison of alternatives
   -> Technology screening, recommendation for most suitable alternative

we are here

4. Remediation plan
   -> Detailed delineation, modeling, Development of remediation design

Thank you
for your Attention!