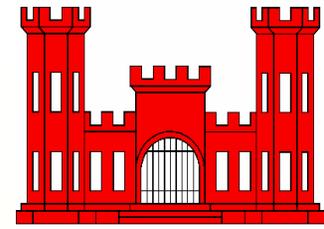




# Bioremediation at Kaiserslautern Army Depot (KAD) US ARMY GARRISON KAISERSLAUTERN



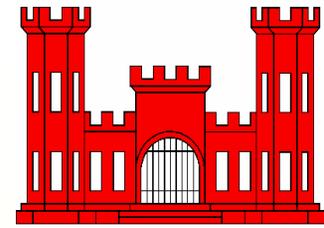
## Bioremediation KAD Summary





# Bioremediation at Kaiserslautern Army Depot (KAD)

## US ARMY GARRISON KAI SERSLAUTERN



### USAG Kaiserslautern

• Kaiserslautern Army Depot	651.5 acres	(263.6 ha)	}	<b>Kaiserslautern East</b>
• Kleber Kaserne	76 acres	(31 ha)		
• Daenner Kaserne	19.3 acres	(7.8 ha)		
• Daenner Post Chapel	1.5 acres	(0.6 ha)		
• KL Equipment Support Center	50.9 acres	(20.6 ha)		
• Panzer Kaserne	18.7 acres	(7.6 ha)		
• Hill 365 Radio Relay Facility	16.7 acres	(6.7 ha)		
• Rhine Ordnance Barracks	3,040.9 acres	(1,230.6 ha)	}	<b>Kaiserslautern West</b>
• Pulaski Barracks	144 acres	(58 ha)		
• Landstuhl Hospital	65 acres	(26 ha)		
• Landstuhl Heliport / SATCOM	113 acres	(45.7 ha)		
• Breitenwald Training Area	135 acres	(55 ha)		
• Sambach AFN Facility	10.1 acres	(4.1 ha)		
• Miesau Ammo Depot	2,326 acres	(941 ha)		
• Husterhöh, Pirmasens	123.5 acres	(50 ha)		

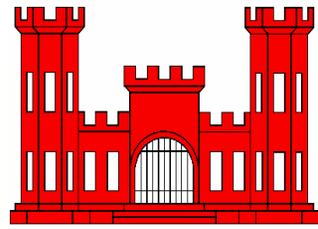
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**Total area USAG KL: 7,257 acres (2,936 ha)**

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# Bioremediation at Kaiserslautern Army Depot (KAD) US ARMY GARRISON KAISERSLAUTERN

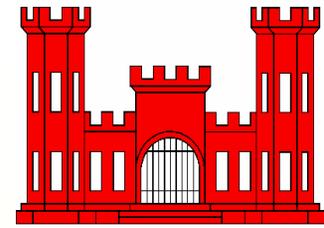


## Background

- **Up to seven different installations constitute the Kaiserslautern East area**
- **The individual installations were constructed at different times and each has its own utilization history; the oldest installation was built between 1912 and 1914**
- **The largest installation (KAD) was and is one of the US Army's principal industrial centers for the maintenance and repair of equipment. Operation is ongoing since the 1950s**
- **Various environmental studies have been conducted for numerous contaminated sites**
- **Before 2002: investigations focused on each "source" rather than getting a sound understanding of the overall picture**



# Bioremediation at Kaiserslautern Army Depot (KAD) US ARMY GARRISON KAI SERSLAUTERN

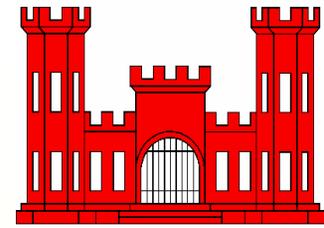


## Problems - 2002

- **CHC impact to groundwater had already been identified on-post; at least one main contaminant plume was migrating off-post**
- **CHC impact to municipal drinking water extraction wells had already been identified; the City of Kaiserslautern was lobbying the Army, very hard, to begin remediation**
- **However, insufficient information about groundwater flow and contaminant distribution, meant that there was no basis for reasonable remediation design**
- **Host Nation (HN) was not accepting CLAIMS process (*Claims Liability, Assessment, Investigation, and Mitigation Surveys*) - Using the CLAIMS process is mandatory for getting off-post investigations funded**



# Bioremediation at Kaiserslautern Army Depot (KAD) US ARMY GARRISON KAISERSLAUTERN



## Solution

- **After 20 years of refusing to use the CLAIMS process, the Host Nation agreed to a three-phased investigation approach**

**Phase I:** USACSEUR funded a preliminary groundwater model

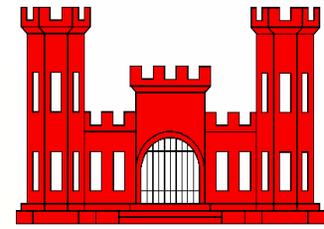
**Phase II:** City of Kaiserslautern agreed to act as Claimant and hired a contractor to close existing data gaps identified in Phase I

**Phase III:** USACSEUR funded a detailed groundwater model and preliminary fate and transport model

- **IMA-E funded additional investigations of previously identified contaminated sites (source areas) within the boundaries of the KAD**



# Bioremediation at Kaiserslautern Army Depot (KAD) US ARMY GARRISON KAISERSLAUTERN



## Solution

### GW-Model Phase I

#### Data inventory

- ⇒ >90 reports
- ⇒ Evaluation

#### Fieldwork

- ⇒ Isotope investigation
- ⇒ Well survey
- ⇒ Borehole geophysics
- ⇒ GW head measurement
- ⇒ Discharge

#### Numerical model

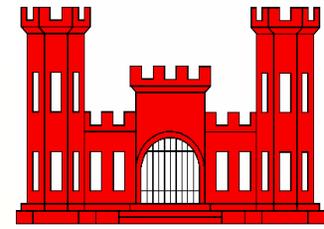
- ⇒ Groundwater flow

- Conceptual site model
- Different aquifers
- Flow model

Apr/2002 - Oct/2002



# Bioremediation at Kaiserslautern Army Depot (KAD) US ARMY GARRISON KAISERSLAUTERN



## Solution

GW-Model Phase I  GW-Model Phase IIa and IIb

### Data inventory

- ⇒ >90 reports
- ⇒ Evaluation

### Fieldwork

- ⇒ Isotope investigation
- ⇒ Well survey
- ⇒ Borehole geophysics
- ⇒ GW head measurement
- ⇒ Discharge

### Numerical model

- ⇒ Groundwater flow

- **Conceptual site model**
- **Different aquifers**
- **Flow model**

### Hydrogeol. investigation & characterization (Phase IIa)

- ⇒ Isotope investigation
- ⇒ Construct 40 new GW wells
- ⇒ Borehole geophysics
- ⇒ Pumping tests
- ⇒ Contaminant investigation

### Investigate main source area Build. 2288 (Phase IIb)

- ⇒ Construct 10 new GW wells
- ⇒ Borehole geophysics
- ⇒ Contaminant investigation

- **Develop a detailed conceptual site model**
- **Understand the complex hydrogeol. contaminant distribution**

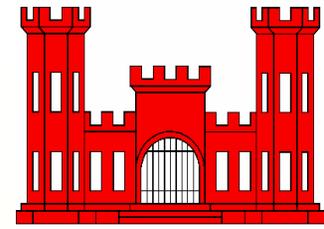
Apr/2002 - Oct/2002

Jun/2003 - May/2004





# Bioremediation at Kaiserslautern Army Depot (KAD) US ARMY GARRISON KAISERSLAUTERN



## Solution



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### Fieldwork

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### Delineation of source areas and contaminant plumes

- ⇒ Construct 24 new GW wells
- ⇒ Borehole geophysics
- ⇒ Pumping tests
- ⇒ Groundwater sampling

- **Min. of 6 different source areas**
- **Delineate & differentiate various contaminant plumes**

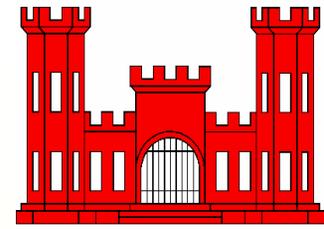
Apr/2002 - Oct/2002

Jun/2003 - May/2004

Sep/2003 - Nov/2004



# Bioremediation at Kaiserslautern Army Depot (KAD) US ARMY GARRISON KAISERSLAUTERN



## Solution



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### GW-Model Phase III

### Prognosis-instrument for:

- **Fate**
- **CHC-transport**
- **Remediation-scenarios**

Apr/2002 - Oct/2002

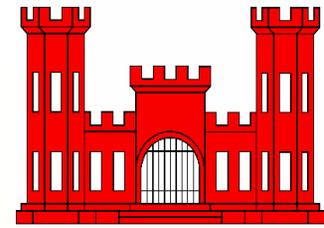
Jun/2003 - May/2004

Sep/2003 - Nov/2004

until -  
Feb/2005



# Bioremediation at Kaiserslautern Army Depot (KAD) US ARMY GARRISON KAISERSLAUTERN



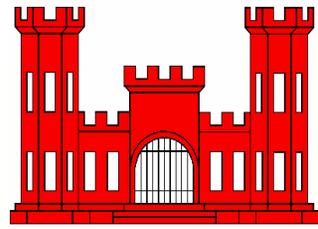
## Groundwater Contours sTo-Aquifer in April 2004

**105 Groundwater Monitoring  
Wells**

 **GW - flow direction**



# Bioremediation at Kaiserslautern Army Depot (KAD) US ARMY GARRISON KAISERSLAUTERN



## Remediation Approach, Water Legislation in Germany

### **Federal Water Act (Wasserhaushaltgesetz, WHG)**

- **Art 1a, 3:** The ownership of land does not entitle anyone to use a body of water which requires a permit or approval either under this Act or under Land water legislation
- **Art 3:** Usages within the meaning of this Act are .... Introducing substances into the groundwater ...

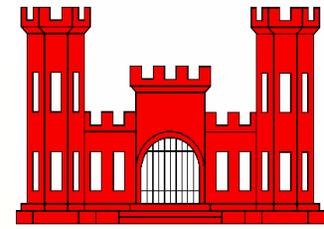
### **Organic elements/provisions are the competency of the States**

**In Rheinland-Pfalz power over water resource protection and management is allocated to three levels of government:**

- **Supreme Water Authority** (Oberste Wasserbehörde)
- **Upper Water Authority** (Obere Wasserbehörde)
- **Lower Water Authority** (Untere Wasserbehörde)



# Bioremediation at Kaiserslautern Army Depot (KAD) US ARMY GARRISON KAISERSLAUTERN



## Remediation Approach

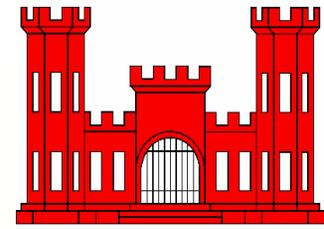
- **Pilot test using molasses in the uppermost aquifer most affected by contaminants**

### **The pilot test will be used to**

- demonstrate the efficiency of the technology
- determine the reagent feed rate, the frequency of injection and the solution strength
- define well spacing, perpendicular and along the groundwater flow direction, based on the extent to which the reactive zone was established during the test



# Bioremediation at Kaiserslautern Army Depot (KAD) US ARMY GARRISON KAISERSLAUTERN



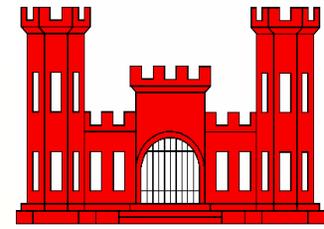
## Remediation Approach: Molasses - What It Is

### Molasses

- A syrup-like waste product of sugar production processes
- Contains up to 50% sugar
- A high content of vitamins (B<sub>1</sub>, B<sub>2</sub>) and minerals (K, Ca, P, Mg, Cu and Fe)
- Can be injected into the subsoil
- Can serve as extra food (carbon source) for CHC degrading soil bacteria



# Bioremediation at Kaiserslautern Army Depot (KAD) US ARMY GARRISON KAISERSLAUTERN



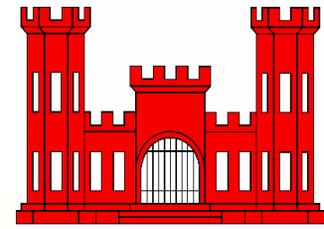
## Remediation Approach: Molasses - What It Does

### Enhanced Reductive Dechlorination by Molasses Injection

- CHCs can be degraded by soil bacteria into other (non-toxic) compounds (metabolism)
- Complicated chemical reactions (redox reactions) that need a reductive (anaerobic) hydrogeochemical environment.
- Redox conditions can be manipulated to become favorable for CHC degrading bacteria by adding molasses into the aquifer.
- In each CHC-Degradation step a chlorine atom is removed from the CHC molecule (reductive dechlorination).



# Bioremediation at Kaiserslautern Army Depot (KAD) US ARMY GARRISON KAISERSLAUTERN



## Remediation Approach: Permit

### Permit for Pilot Test using molasses

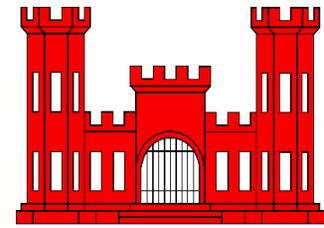
- Application/approval took long time
- Limited to a very small test area (first hydro-stratigraphic unit, only)
- Was limited to best possible hydraulic controlled aquifer, only

### Challenge:

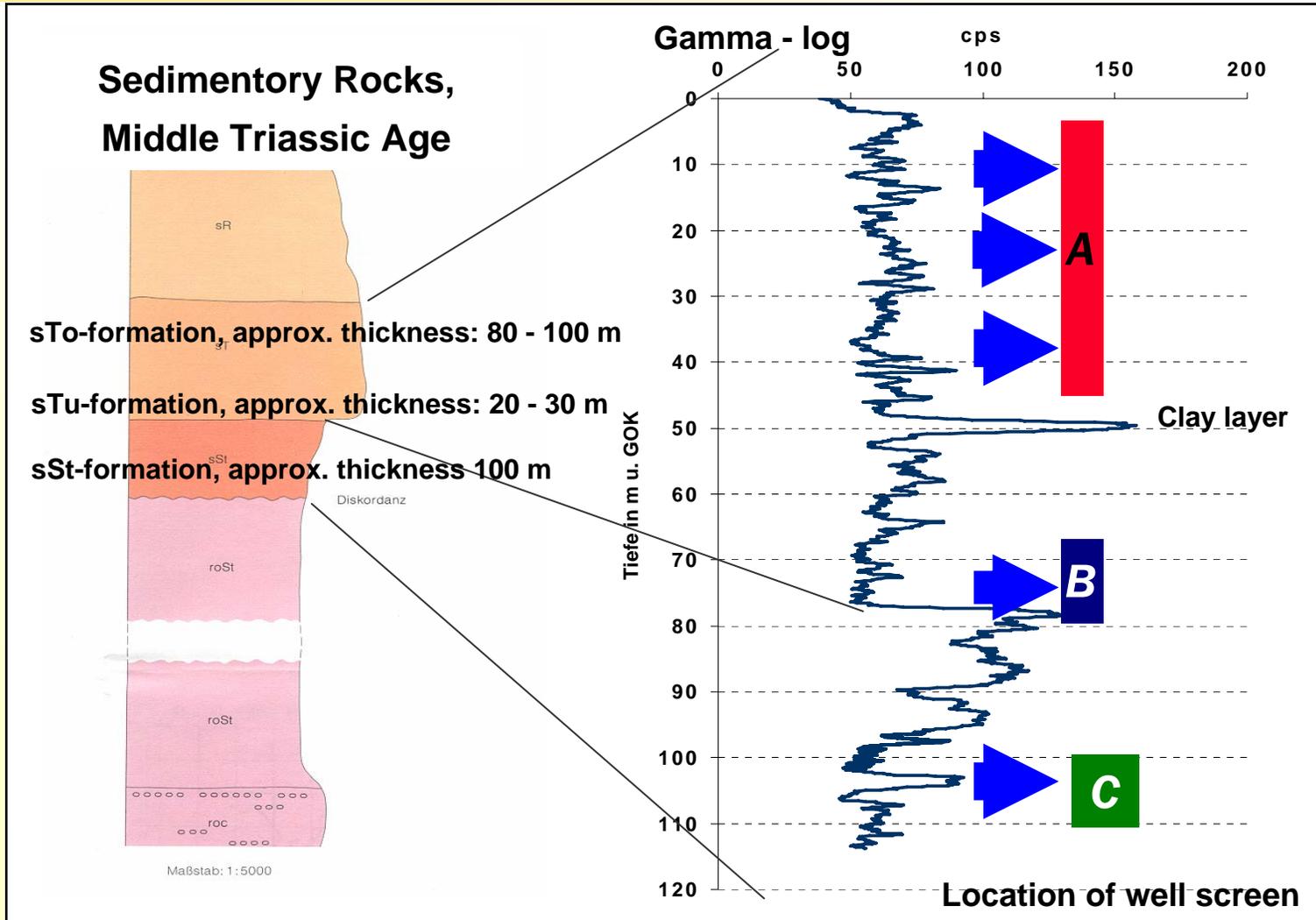
- fractured rock aquifer
- tectonic faults
- three different hydro-stratigraphic units (sTo, sTu, sSt)
- pilot test considers the shallow aquifer (23 to 42m bgs), only
- intersecting clay lenses locally lead to the occurrence of hydraulic sub-horizons with different potentiometric heads in the uppermost hydro-stratigraphic unit
- difficult to define gw-flow direction / adjust test field
- test field consists of one injection well and three monitoring wells, only



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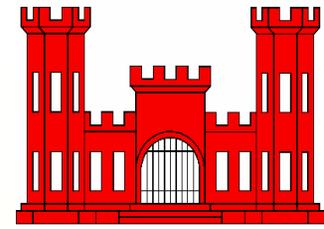


## Remediation Approach: Hydro-stratigraphy





# Bioremediation at Kaiserslautern Army Depot (KAD) US ARMY GARRISON KAISERSLAUTERN



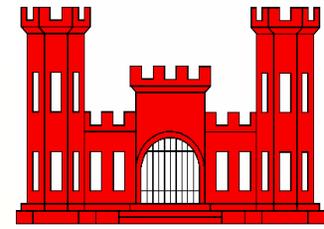
## Remediation Approach: Milestones

### Project Milestones (Pilot Test)

- Host Nation approval phase
- Construction of test field (1 injection well, 3 monitoring wells)
- Baseline monitoring
- Molasses injections / monitoring
- Final sampling round
- Evaluation and reporting
- Using the groundwater model for prognosis of the most efficient source area treatment approach
- If pilot test results and groundwater fate and transport model indicate success, prepare design documents in 2007
- Expected approximately 5 years performance period for full scale operation at various source zones



# Bioremediation at Kaiserslautern Army Depot (KAD) US ARMY GARRISON KAISERSLAUTERN



## Remediation Approach: Evaluation

### **Enhanced Biodegradation Methods are**

#### **Faster:**

**Anticipated clean-up schedule of 5 years vs.  
30 + years for conventional pump & treat techniques**

#### **Cheaper:**

**Expected cost savings of up to 50 % vs. conventional  
methods**

#### **Better:**

**More complete contaminant removal and improved ability  
to complete eliminate the source zones**