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# Sediment Desiccation, The Unthought About Hazard for Contaminated Sediment Remediation

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SedNet

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# Introductions

**Philip Spadaro**
LG, VP and Principal Scientist

**Jason Dittman**
PhD, Managing Scientist

- 30+ years of experience with large environmental cleanup sites
- Expert in urban and industrial waterfront redevelopment, sediment cleanup, and environmental effects of dredging
- Provides technical support for investigation, cleanup, monitoring, litigation, allocation, construction claims, cost-recovery actions, and other matters related to site remediation
- Expertise in the siting, design, permitting, and construction of confined disposal facilities and in the fate and transport of contaminants in estuarine, riverine, and marine aquatic environments

- 18 years of environmental experience
- Manage and leads TIG's Engineering and Remedial Service practice area
- Leads strategic and technical representation of client interest at large multi-party contaminated sediment sites
- Provides strategic litigation support efforts at multi-party PRP sites
- Provides technical support for source identification and investigation of environmental contamination
- Project and client management

# Disclaimers

- Content represents authors' opinions only
- No company positions are stated
- No specific technologies, vendors, or contractors are endorsed
- No clients are represented
- No animals were harmed

# Agenda

- Contaminated sediment sites in a changing climate
- Drought and higher temperatures
- Desiccation of lakes and rivers
- Changing exposure pathways
- Physical and chemical changes
- Subaqueous sediment caps
- MNR/EMNR
- Conclusions

# Climate Change and Contaminated Sediment Sites

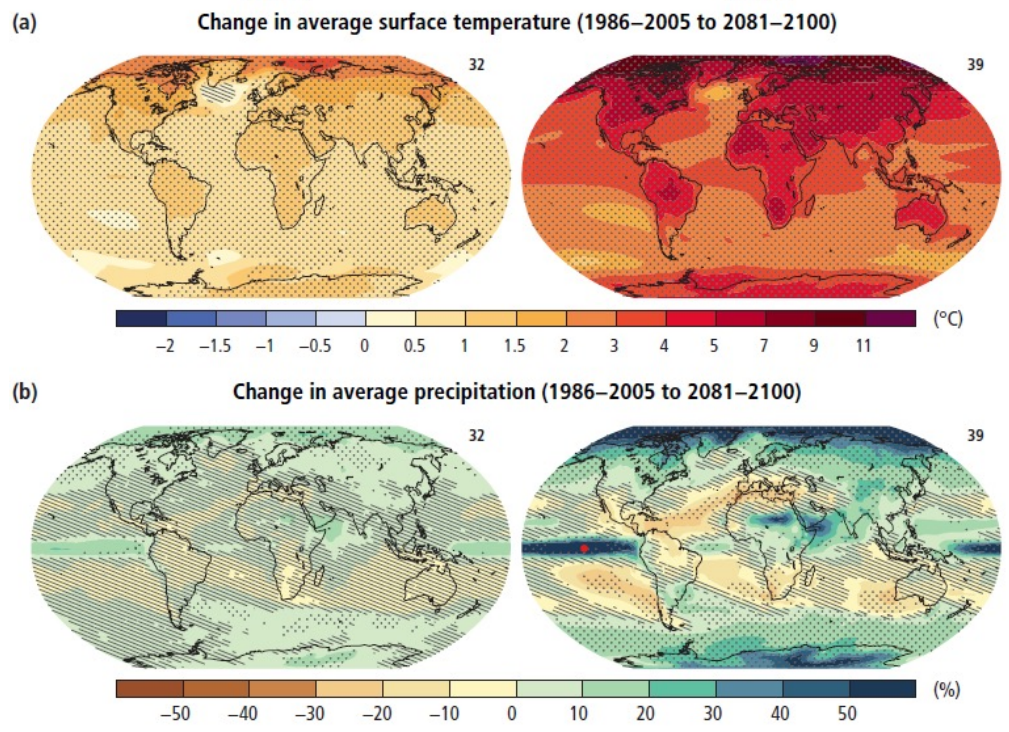
- Sediment sites are uniquely vulnerable to the effects of climate change
  - Sediment acts as a reservoir for contaminants
  - Persistent nature of contamination
  - Bioaccumulation and biomagnification of contaminants from sediments to food chain
  - Contemporary remedies for preventing exposure and transport of contamination
  - Remedies such as capping are expected to last in perpetuity

# Contaminated Sediment Sites

- Post-Remedy Sites (already constructed)
  - Older remedies were designed before (or in the early days) of computer modeling
  - Remedies were designed to operate for decades with proper O&M
  - Climate change may not have been considered in choosing remedies
  - Costs were evaluated without consideration of climate change effects on O&M
  - Remedies may have to be operational indefinitely, during which time the potential effects of climate change may become more extreme
- Sites in Design Phase
  - Move quickly and aggressively to incorporate the projected effects of climate change into its decision processes
  - Design remedies that can withstand future environmental conditions
  - Increased anthropogenic demand for water

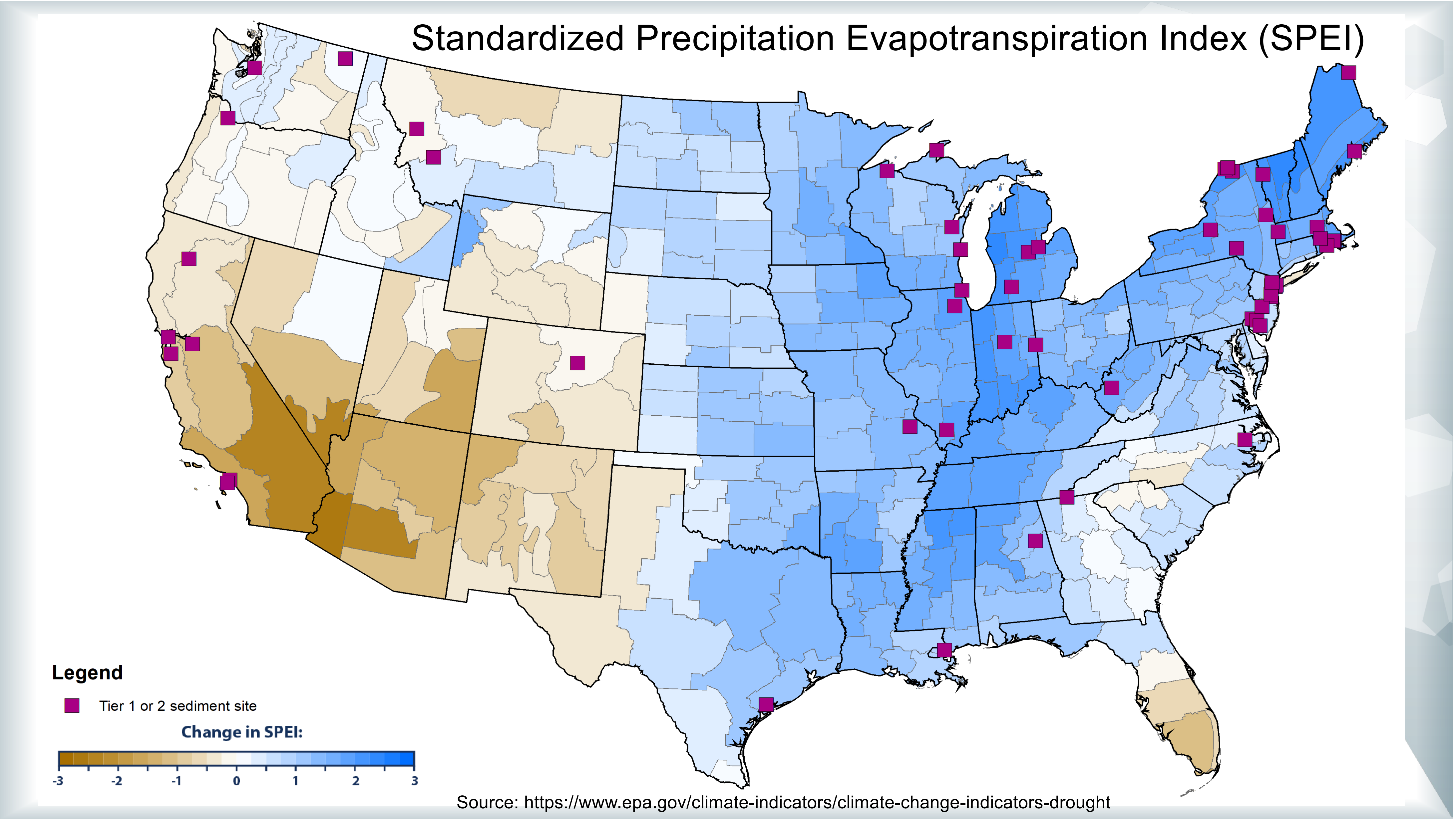
# Projected Changes in the Climate System

- Rising sea levels
- Inundation of low-lying coastal areas
- Acidification of oceans
- Changes in frequency/intensity of storms
- Earlier spring melt and reduced snowpack
- Increased incidence of forest fires
- Increased higher temperatures
- **Long-duration hydrological drought**

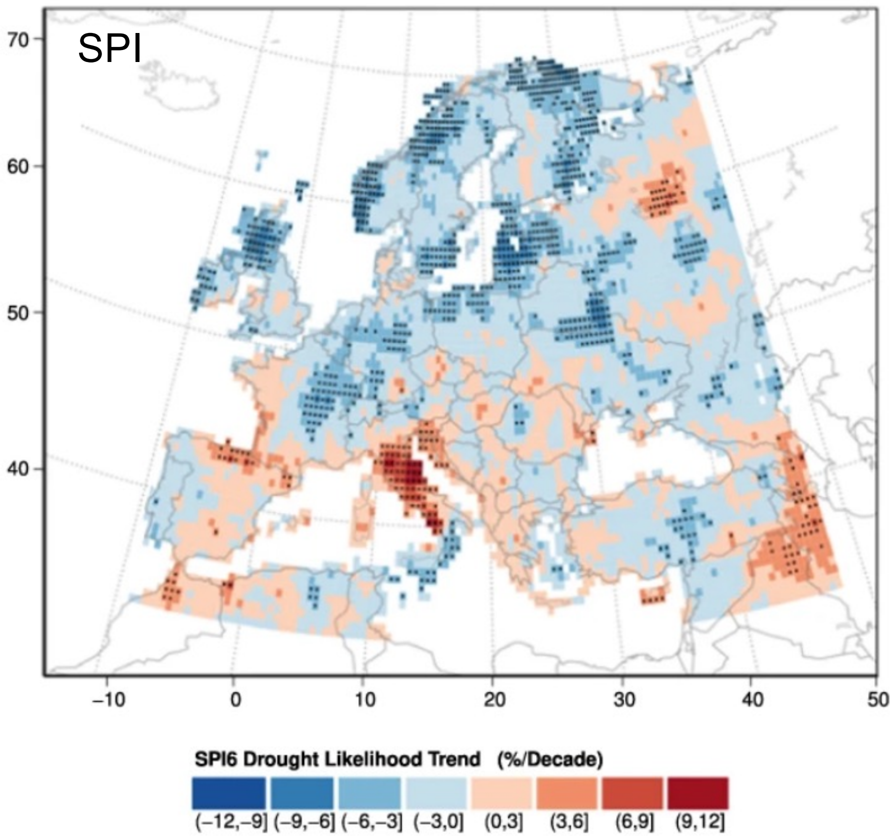


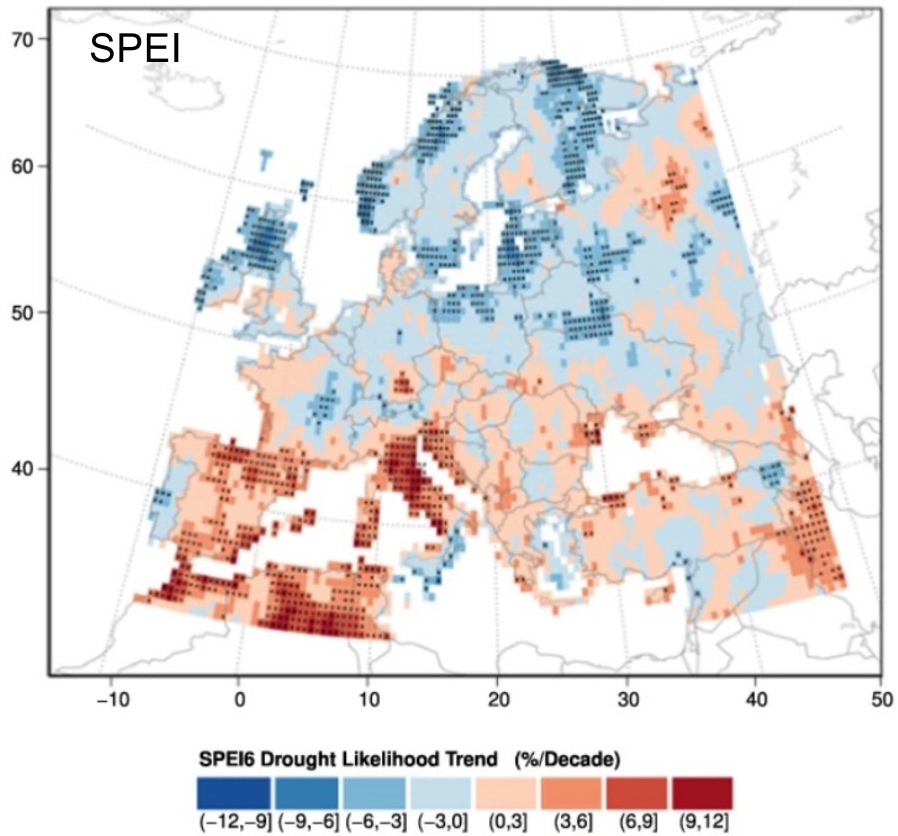

IPCC 2014. Climate Change 2014: Synthesis Report. Geneva Switzerland.

Intergovernmental Panel on Climate Change


Standardized Precipitation Evapotranspiration Index (SPEI)
Legend
Tier 1 or 2 sediment site
Change in SPEI:
-3
-2
-1
0
1
2
3
Source: https://www.epa.gov/climate-indicators/climate-change-indicators-drought

# Drought indices across Europe




Stagge, J.H., et al. 2017. Observed Drought Indices Show Increasing Divergence Across Europe. Nature, Scientific Reports. October.

# Desiccation of Sediment

## Heat, drought and fire: Europe's year of extremes in 2022 will not be a 'one-off,' new report finds

By Laura Paddison, CNN
Updated 4:14 AM EDT, Tue June 20, 2023

Jon Nazca/Reuters

The cracked ground of La Vinuela reservoir during a severe drought in La Vinuela, near Malaga, southern Spain August 8, 2022.

https://www.cnn.com/2023/06/19/europe/europe-state-of-climate-heat-drought-intl/index.html

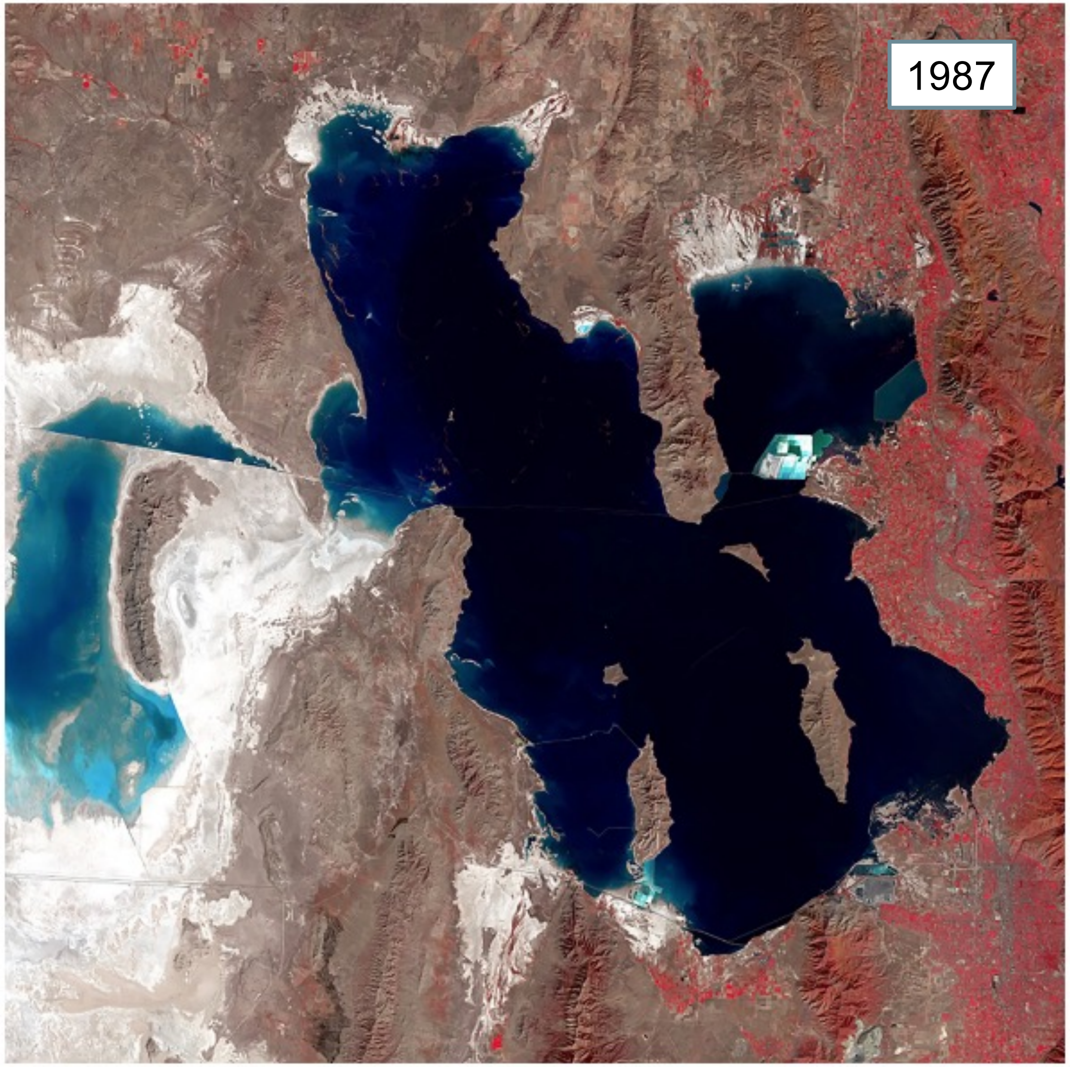
## Europe is struggling with a precarious water situation ahead of another drought-riven summer

PUBLISHED MON, JUN 5 2023-1:25 AM EDT

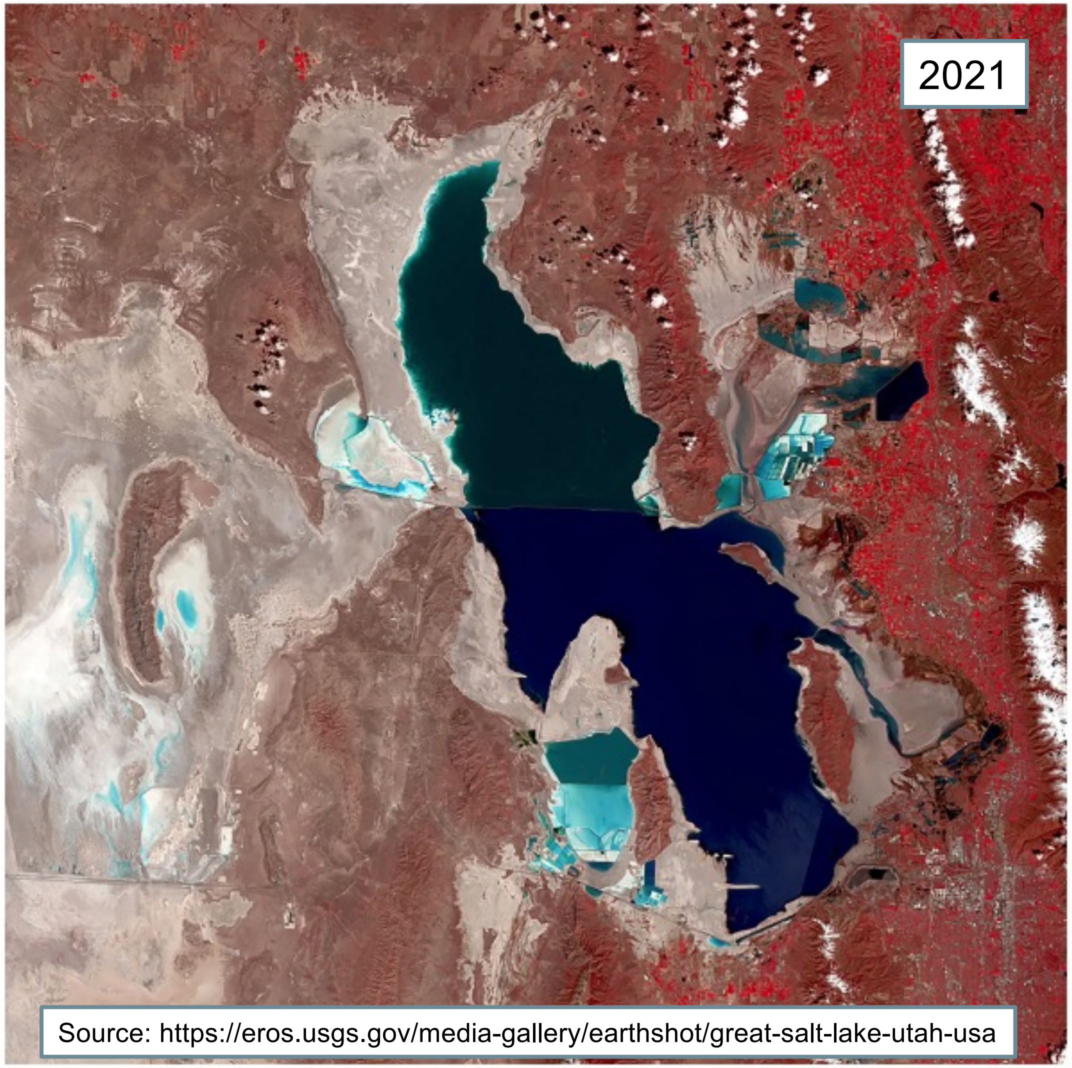
A view of the drought that affected the Los Bermejales reservoir which is at 18% of its capacity in Arenas del Rey in Granada, Spain, May 13, 2023.

https://www.cnbc.com/2023/06/05/expected-european-drought-likely-to-worsen-the-regions-water-crisis-.html

# Shrinking lakes and rivers can expose existing caps or convert sites from aquatic to terrestrial




A satellite view of the Great Salt Lake captured in September 1987. EROS Center, U.S.G.S.




The Great Salt Lake in May 2021. EROS Center, U.S.G.S.

While not a result of climate change, the shrinkage of the Aral Sea has exemplified many of the potential impacts of desiccation

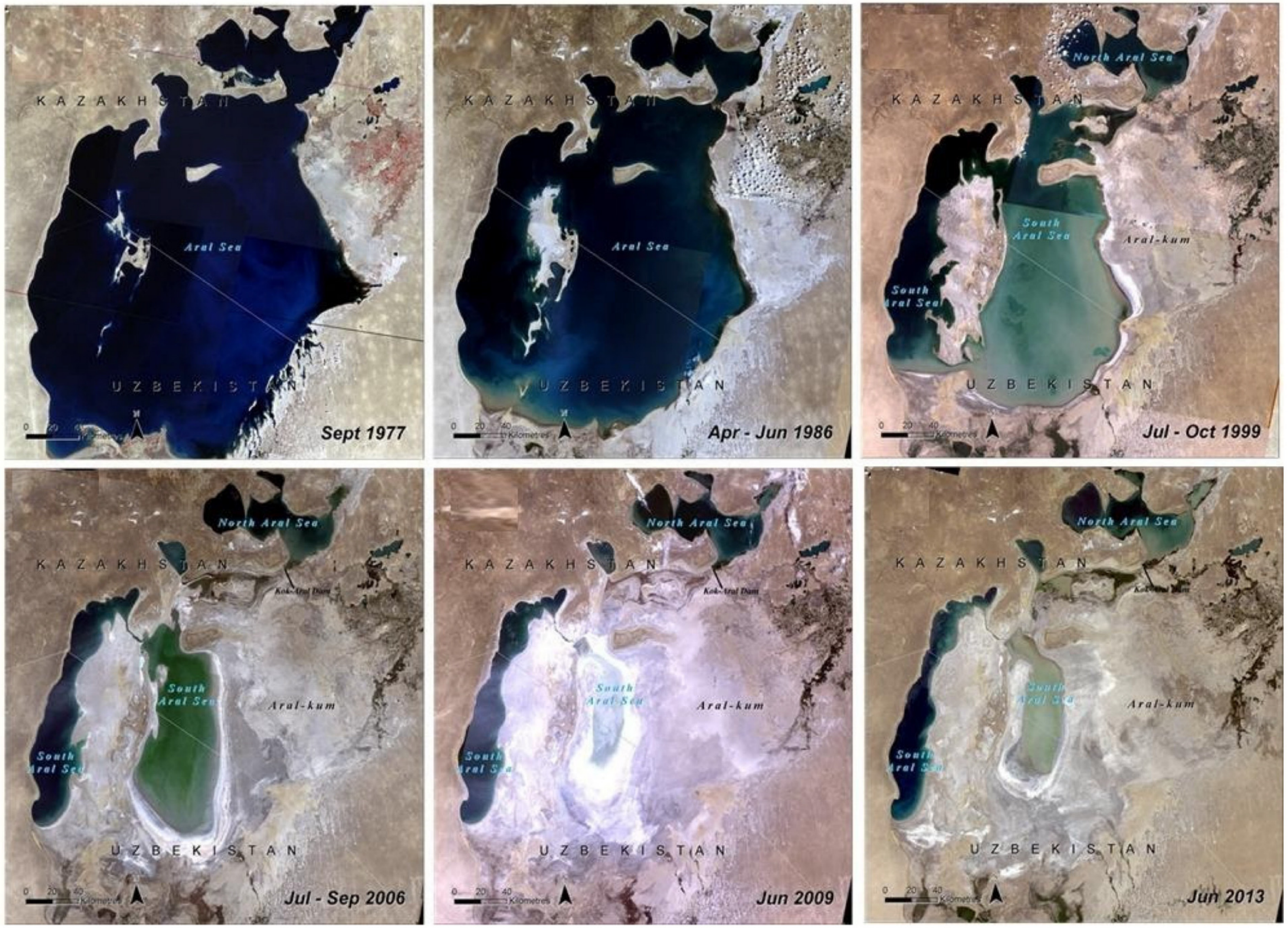
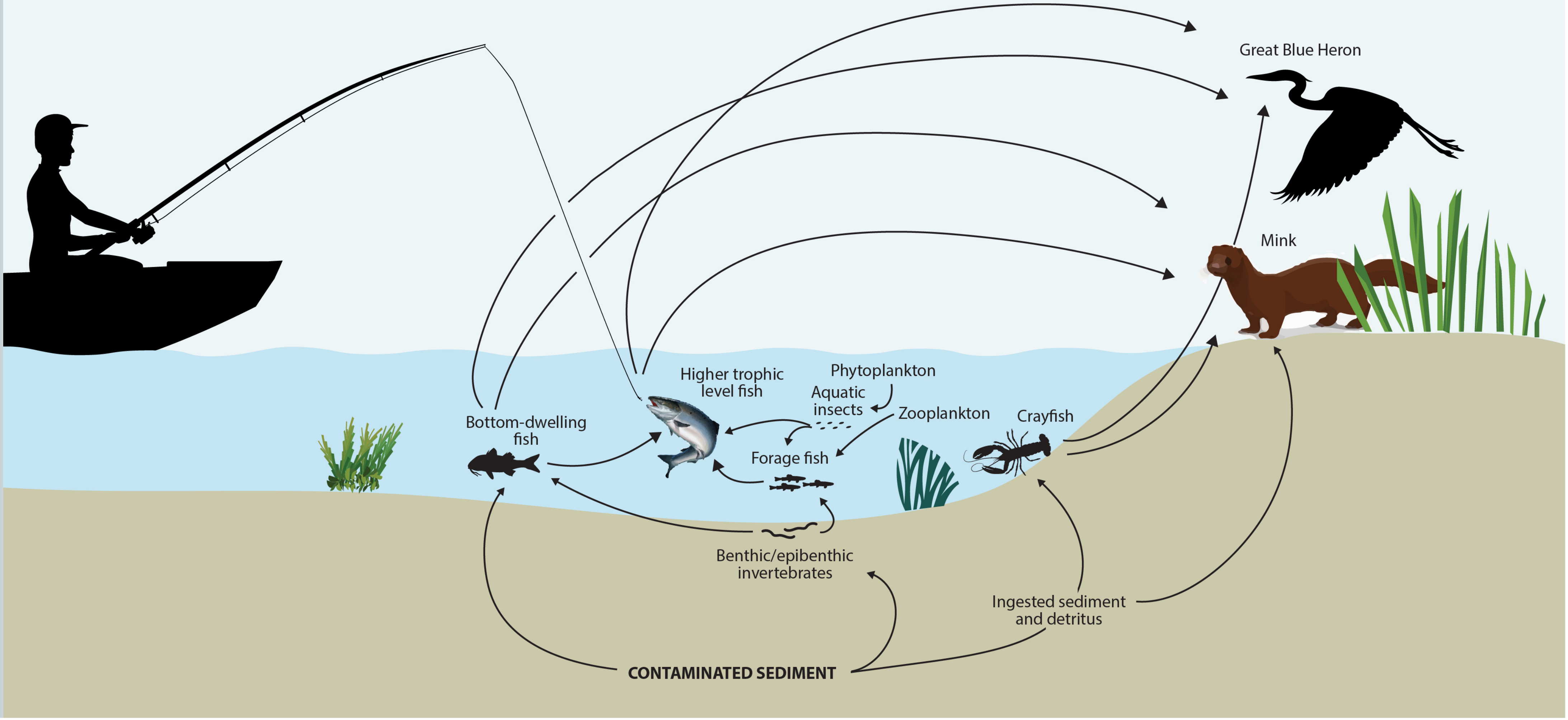



**Figure 2.** Landsat satellite imagery mosaics showing visible changes of the Aral Sea.Source: USGS/NASA; visualisation by UNEP/GRID-Sioux Falls.

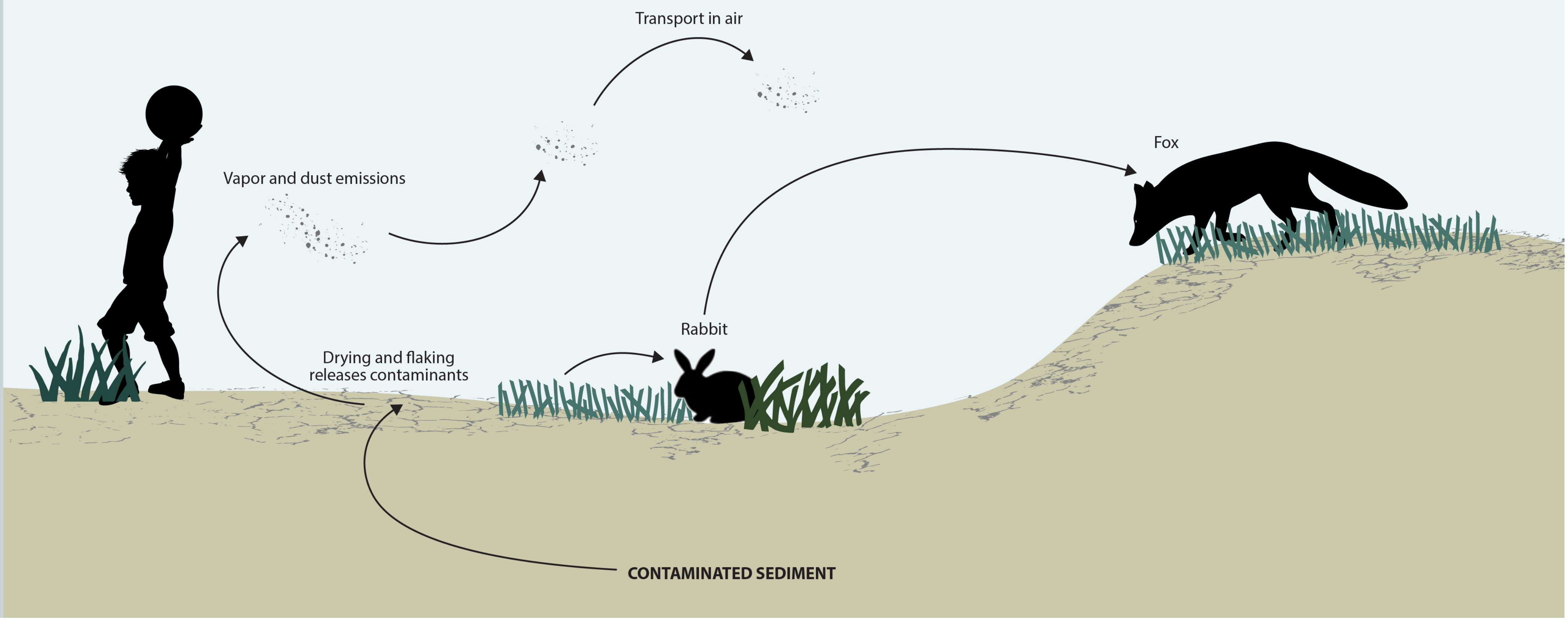
# Changing Exposure Pathways

## Underwater Exposure



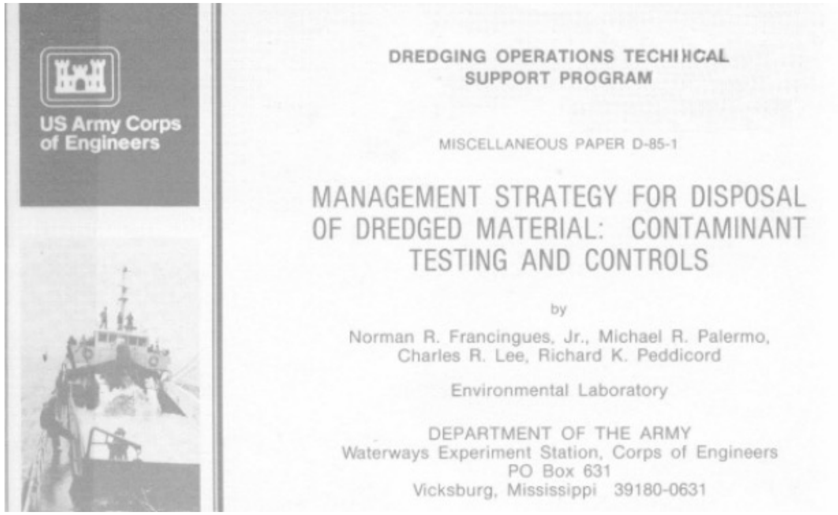
# Changing Exposure Pathways

## Dry Exposure



# Physical and Chemical Changes in Sediment

- Physiochemical changes in contaminated sediment has been studied by the US Army Corps of Engineers and others dating back to the 1970s/80s
  - Important historically and present day to understand in the context of management strategies for the disposal of dredged material
  - Same considerations are applicable to contaminated sediment sites where sediment is desiccated for portions of the year



US Army Corps of Engineers

DREDGING OPERATIONS TECHNICAL SUPPORT PROGRAM

MISCELLANEOUS PAPER D-85-1

MANAGEMENT STRATEGY FOR DISPOSAL OF DREDGED MATERIAL: CONTAMINANT TESTING AND CONTROLS

by

Norman R. Francingues, Jr., Michael R. Palermo, Charles R. Lee, Richard K. Peddicord

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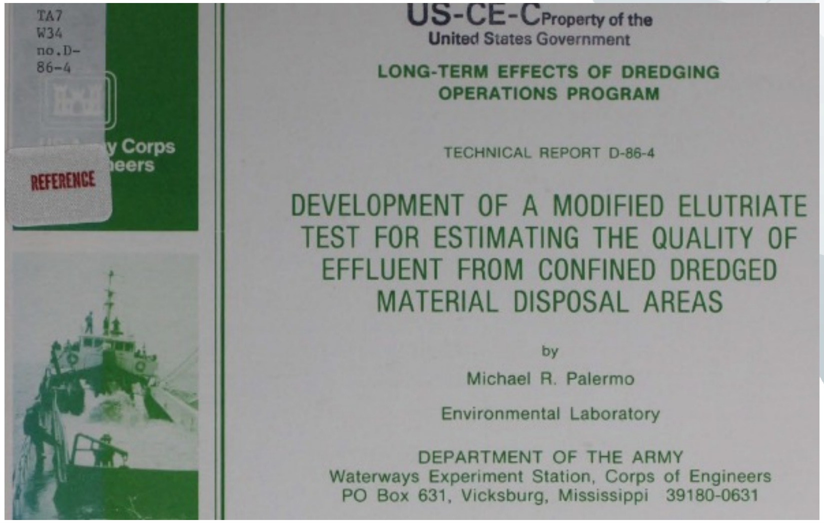

TA7
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no.D-86-4

REFERENCE

US-CE-C Property of the United States Government

LONG-TERM EFFECTS OF DREDGING OPERATIONS PROGRAM

TECHNICAL REPORT D-86-4

DEVELOPMENT OF A MODIFIED ELUTRIATE TEST FOR ESTIMATING THE QUALITY OF EFFLUENT FROM CONFINED DREDGED MATERIAL DISPOSAL AREAS

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# Physical and Chemical Changes in Sediment

- Physiochemical (oxidation-reduction, pH, and salinity) conditions of sediment influence the mobility and bioavailability of most contaminants
  - Typically, sediments are anoxic (reducing)
  - Changes in the physiochemical conditions of the sediment may result in mobilization of certain contaminants
- Sulfate reducing bacteria oxidize organic matter reducing sulfate to sulfide in anaerobic environments resulting in metal sulfide precipitation (Cu, Zn, Fe, Ni, As, Co, etc.)
  - Sulfide produced by bacterial metabolic activity reacts with metals to form water insoluble metal sulfides
  - Potential for release of metals back into solution if sulfide is oxidized back to sulfate

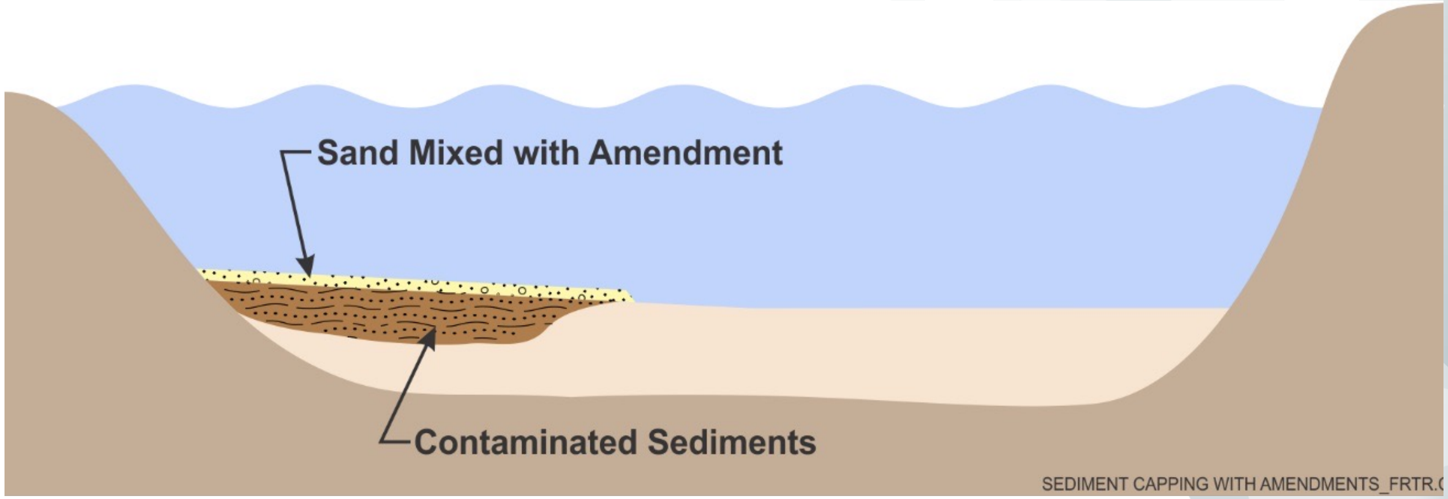
# Physical and Chemical Changes in Sediment

- Drying and oxidation of sediment will promote microbiological activity breaking down organic material in sediment, oxidizing sulfide compounds to more soluble sulfate compounds
  - Concurrently, reduced iron compounds will become oxidized and iron oxides will form, acting as metal scavengers absorbing soluble metals and rendering them less soluble
- Leachate studies from CDFs have found changes in contaminate concentrations due to desiccation:
  - Volatilization of volatile and semi-volatile organic compounds reducing concentrations in leachate
  - Increase concentration of metals in leachate when dried out oxidized surface is rewetted
- Oxidation of organic matter and consequent desorption of hydrophobic organic species (PCBs, DDT, etc.)

# Subaqueous Sediment Caps

Future drought scenarios

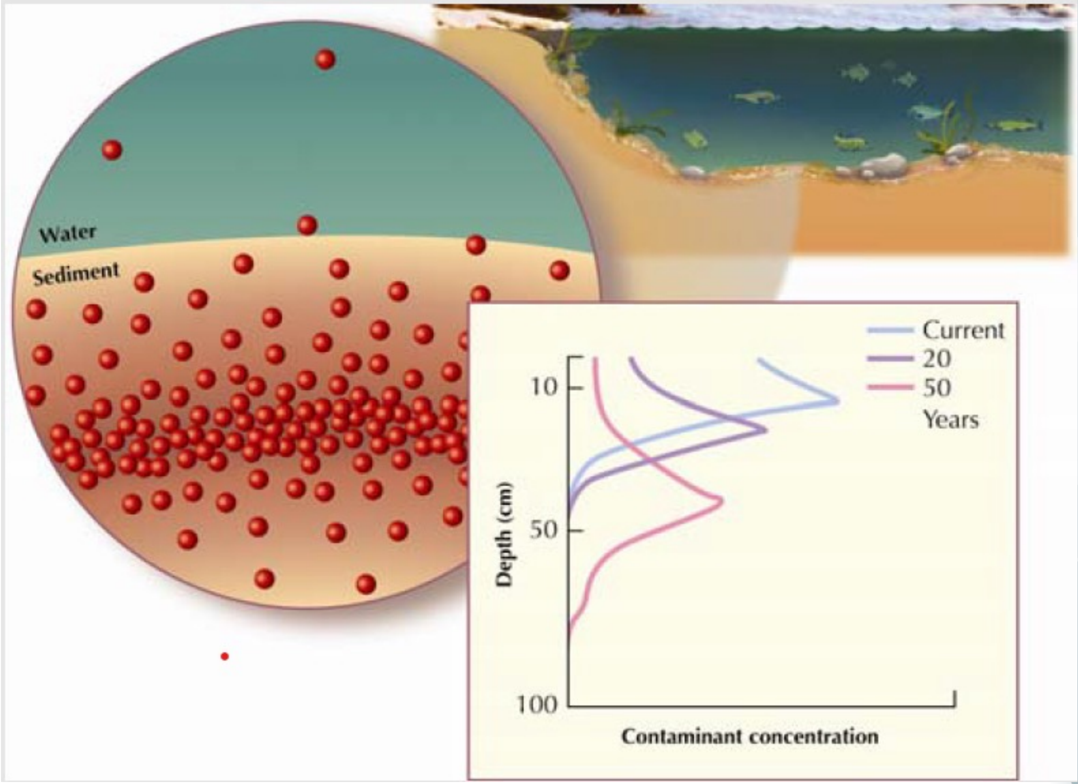
- Lower water depth
- Prop scour
- Desiccation
- Wind erosion
- Channelized erosion
- Terrestrial access
- Terrestrial vegetation
- Remedy failure




Desiccation can lead to changes in food web models for contaminated sediment sites

# Monitored Natural Recovery (MNR)

- Increased drought conditions and associated sediment desiccation will likely influence success of MNR (and EMNR) as a remedy
  - Greater ecological and human health risk
  - Possibly longer recovery time




ESTCP. 2009. Technical Guide. Monitored Natural Recovery at Contaminated Sediment Sites.

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# Accounting for the Past and Planning for the Future

- Managing sites that have been constructed/remediated (historical sites)
  - Risk from climate change at some sites may be significant
  - Identify cleanup sites in specific locations are most vulnerable to climate change
  - Types of impacts from climate change that have the highest potential to compromise cleanup sites
  - Which aspects of cleanup remedies are most vulnerable to climate change
  - Need to closely monitor, especially after weather events
  - Review implemented and in-process MNR and capping remedies to confirm they will adequately address risk

# Accounting for the Past and Planning for the Future

- Planning for sites in design phase (future construction)
  - Incorporate risk from climate change into remedy selection
  - Evaluate if proposed remedies can withstand future environmental conditions
  - Identify both the vulnerable and the resilient aspects of cleanup remedies
  - Include remedies which are less vulnerable and can be adapted in the future
  - Modeling sediment mobility and bounding potential outcomes
  - Provide recommendations/solutions for increasing a site's resilience at each cleanup stage
  - Develop adaptive management and monitoring options
  - Long-term monitoring: review resiliency of the remedy and possible adaptations
  - Include flexibility in the design (and budget) to account for changing climate

# Thank You


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