Effect of Mining on Gravel-bed Rivers
and
Why You Should Care

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“…….look at streams not as purely aquatic phenomena, ……. but rather view them as parts of the valleys that they drain.”


Internationale Vereinigung für Theoretische und Angewandte Limnologie: Verhandlungen Volume 19, 1975
Mining Pollution – there is no known case of mining occurring in a wet environment where toxic waste has not gotten into and polluted the water.

Direct Toxicity to Aquatic Life

Cascading consequences to terrestrial organisms
This map represents inactive metal mining operations across the United States. This map does not include any mines exclusively producing non-metallic minerals (clay, coal, etc.), and does not include any information about the status of reclamation.

The U.S. Geological Survey (USGS) Mineral Resources Data System (MRDS) defines these 64,883 sites as "past producers," that is, "a mine formerly operating that has closed, where the equipment or structures may have been removed or abandoned."

To explore imagery of these sites, go to cdb.io/1huHHzF
<table>
<thead>
<tr>
<th>Basin</th>
<th>Above Mines</th>
<th>Below Mine</th>
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<tbody>
<tr>
<td>Flathead</td>
<td>5</td>
<td>5</td>
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<tr>
<td>Elk</td>
<td>5</td>
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</tbody>
</table>
Elk Basin Nitrate (NO3)

Mean Concentration ug/L

Sites

ERB - 0  ERB - 1  ERB - 2  ERB - 3  ERB - 4  ERB - 5  ERB - 6  ERB - 7  ERB - 8  ERB - 9

ABOVE MINES  BELOW MINES
Aquatic Life

- Algae
- Macroinvertebrates
Algal Diversity, Chlorophyll Content and Biomass
Algal Species Richness

P<0.001

Species Totals
Flathead - 74
Elk - 18
Chlorophyll Content

P<0.001
Biomass

P = 0.092
Macroinvertebrates
Composition of the Order Trichoptera

- Misc. Pupae
- Rhyacophila
- Parapsyche elsis
- Micrasema
- Lepidostomatidae
- Hydroptila
- Dicosmoecus gilvipes
- Brachycentrus americanus
- Arctopsyche grandis

Total Abundance (per m²)

- Flathead
- Elk
Composition of the Order Ephemeroptera

Total Abundance (per m²)

- Serratella
- Rhithrogena
- Heptageniidae
- Ephemereallidae
- Ephemarella
- Epeorus
- Drunella spinifera
- Drunella doddsii
- Drunella coloradensis
- Cinygmula
- Caudatella hystrix
- Baetis tricaudatus
- Baetis bicaudatus
- Baetis
- Ameletus
- Acentrella

Pollution Tolerant - Grazers
Selenium Toxicity
Gravel-Bed River

Tagliamento, Italy

Flathead, BC and Montana

Paloma, Chile

Wamakariri, New Zealand

Photo – Ric Hauer

Photo – Mark Lorang

Photo – Harvey Locke

Photo – Ric Hauer
BioStation Faculty, Staff and Students
Geo-Physical Basis of Gravel-bed River Floodplains
Hydrograph – Discharge as Power to perform Cut and Fill Alluviation
River/Floodplain hydro-geomorphic and vegetative structures of the Shifting Habitat Mosaic
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Whited et al. 2007 *Ecology*
Groundwater / Surface Water Exchange between the Channel and Hyporheic Zone
**RADON-222**

$t_{1/2} = 3.825$ d

$A(t) = A_0 e^{-t/t_{1/2}}$

$A(t) - A_\infty = A_\infty (1 - e^{-t/t_{1/2}})$

$A(t)/A_\infty$ vs. BUILD-UP TIME (days)

**All sites**

Residence Time (days)
- Pure sw
- 0.1 - 0.2
- 0.2 - 0.3
- 0.4 - 1.2
- 1.3 - 2.9
- 3.0 - 5.0
- 5.1 - 8.0
- > 8.0

$bq/l$
- < 0.2
- 0.3 - 0.6
- 0.7 - 1.1
- 1.2 - 3.9
- 4.0 - 7.9
- 8.0 - 11.9
- 12.0 - 15.9
- > 16

Unpublished data: T. Gonser with permission
GW upwelling

Tributary

12°C

Main Channel

16°C

Mixing Zone

Solar Heated shallows

22°C

7°C

Hauer and Hill 2006
MiSE, Chapter 5
The 4-dimensional structure of the gravel-bed river.

The floodplain landscape is created and maintained by biophysical processes that lead to a complex and dynamic habitat mosaic.

A legacy of cut-and-fill alluviation, characterized by highly sorted open-network cobble substrata with interstitial flow pathways are left behind as the river channel moves laterally on the floodplain surface.

The hyporheic alluvial aquifer, is characterized by river-origin water flowing through the gravel subsurface, from floodplain-edge to floodplain-edge (often valley wall to valley wall).

[illustration credit: Emily Harrington].
Gravel-bed River Floodplains are the Ecological Nexus of Glaciated Mountain Landscapes

F. Richard Hauer, Harvey Locke, Victoria J. Dreitz, Mark Hebblewhite, Winsor H. Lowe, Clint C. Muhlfeld, Cara R. Nelson, Michael F. Proctor, Stewart B. Rood

Science Advances: advances.sciencemag.org/content/2/6/e1600026
Why You Should Care

Gravel-bed river floodplains in mountain landscapes disproportionately concentrate diverse habitats, nutrient cycling, productivity of biota, and species interactions.
Base of the Food Web

Trophic Dynamics, Growth and Secondary Production

Glossosoma spp.
Size Comparison

Pteronarcella badia
Size Comparison

Pepin and Hauer. 2002
JNABS
Open – sorted sediments facilitate both high hydraulic conductivity (water flow), but also the movement of hyporheic organisms.
Salmonid spawning habitat selection is directly associated with GW/SW interaction.
Shifting Habitat Mosaic

Vegetation Species Diversity

Highest diversity of vegetation regionally is found on floodplains

Especially old-growth gallery forest stands have significantly higher species diversity in up-welling compared to down-welling regions on floodplains.

Western Montana, Western Alberta and Eastern BC

• 235+ known breeding bird species
  (Montana Bird Distribution Committee 1996)

• 90% (210+ species) use floodplain habitat for significant portions of their life histories (Mosconi and Hutto 1982)

• Of these >200 species about 105 species (45% of all bird species) are restricted to floodplain/riparian habitats during the nesting season (Mosconi and Hutto 1982)
Elk – Wolf Interactions

Mark Hebblewhite and students

Elk – Wolf Interactions

- Elk spatial frequency
- Wolf spatial frequency
Critical Grizzly Bear Habitat
Grizzly Bears – a primary user of floodplains

“Heat Map” of six grizzly bear locations over a month

Alluvial Floodplain – Flathead River
bull trout spawning reach

Locations of alluvial GW upwelling
Alluvial Floodplain – Flathead River
bull trout spawning reach
Grizzly Bear GPS Spatial Frequency Distribution

Unpublished Data: Michael Proctor and Bruce McLellan with permission
In a Nutshell

• Although occupying < 3% of the area within the region, gravel-bed river floodplains account for > 60% of vegetation diversity, > 70% of aquatic food web diversity and productivity, > 80% of bird diversity.

• The primary “arena” where competition, predation, and critical life history events occur for a wide variety of aquatic and terrestrial species, from microbes to grizzly bears.

• Disproportionately concentrate diverse habitats, nutrient cycling, productivity of biota, species interactions, and connectivity corridors between populations.

from: Hauer et al 2016 Science Advances