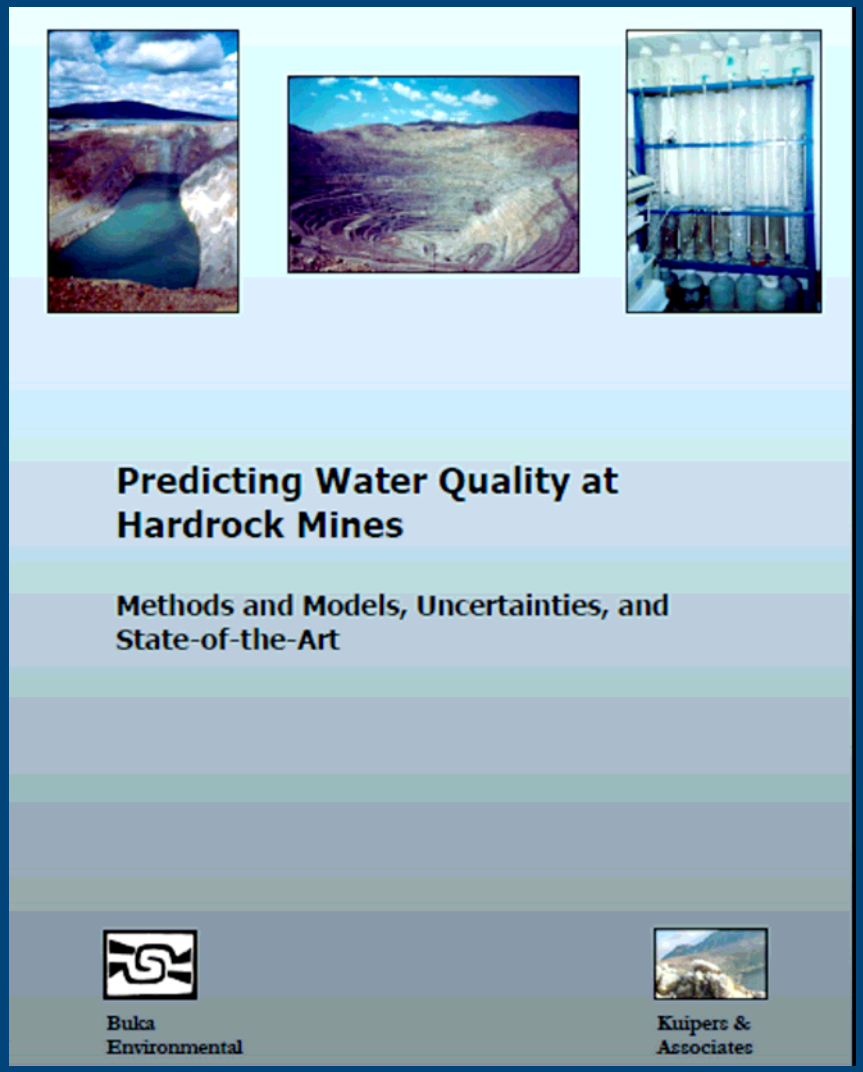
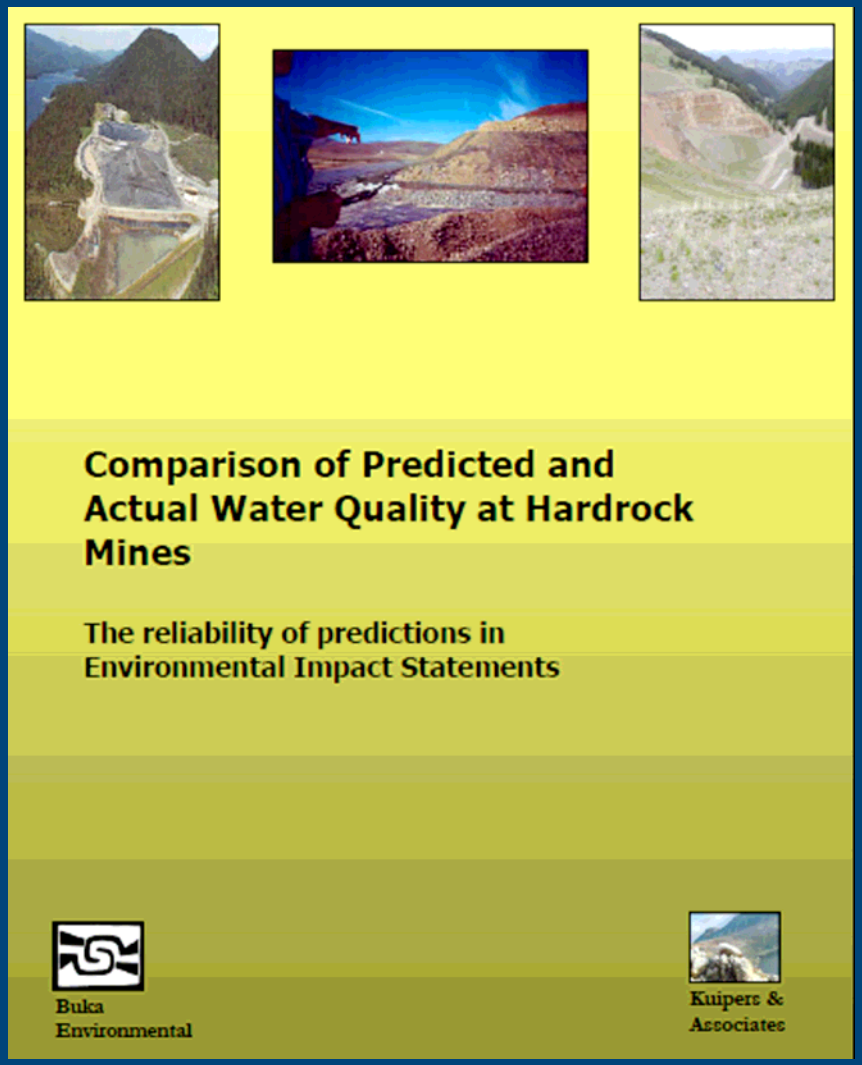
EIS Comparison Study: Inherent Factors



Maest et al., 2005



Kuipers et al., 2006

Note: pdf versions of these reports are available on the course website

Case Study Mines

- Based on Kuipers et al., 2006
- Selection based on
  - ease of access to water quality data
  - variability in geographic location, commodity type, extraction and processing methods
  - variability in EIS elements related to water quality (climate, proximity to water, acid drainage potential (ADP), contaminant leaching potential (CLP))
  - Best professional judgment
- Similar to all NEPA mines, but
  - more from CA and MT
  - fewer Cu mines
  - more with moderate ADP and CLP
  - more with shallower groundwater depths

Case Study Mines: General

- States
  - AK: 1 - MT: 6
  - AZ: 2 - NV: 7
  - CA: 6 - WI: 1
  - ID: 2
- Commodity
  - Au/Ag: 20 - Pb/Zn: 1
  - Cu/Mo: 2 - PGM: 1
  - Mo: 1
- Extraction type
  - open pit: 19
  - underground: 4
  - both: 2
- Processing type
  - Cyanide heap: 12
  - Vat: 4
  - Flotation: 7
  - Dump Leach: 2

Case Study Mines: Water Quality

- Climate
  - Dry/Semi-Arid: 12
  - Marine West Coast: 1
  - Humid subtropical: 3
  - Boreal: 8
  - Continental: 1
- Perennial streams
  - No info: 1
  - >1 mi: 6
  - <1 mi: 7
  - On site: 11
- Groundwater depth
  - No info: 1
  - >200 ft: 3
  - 50-200 ft: 4
  - 0-50 ft/springs: 17
- Acid drainage potential
  - No info: 2
  - Low: 12
  - Moderate: 8
  - High: 3
- Contaminant leaching
  - No info: 3
  - Low: 8
  - Moderate: 10
  - High: 4

Case Study Mines Selected

Mine	State	Mine	State
Greens Creek	AK	Golden Sunlight	MT
Bagdad	AZ	Mineral Hill	MT
Ray	AZ	Stillwater	MT
American Girl	CA	Zortman and Landusky	MT
Castle Mountain	CA	Florida Canyon	NV
Jamestown	CA	Jerritt Canyon	NV
McLaughlin	CA	Lone Tree	NV
Mesquite	CA	Rochester	NV
Royal Mountain King	CA	Round Mountain	NV
Grouse Creek	ID	Ruby Hill	NV
Thompson Creek	ID	Twin Creeks	NV
Beal Mountain	MT	Flambeau	WI
Black Pine	MT		

Comparison Results

- Overall, 76% of the mines underpredicted impacts
- Mines with mining-related surface water exceedences: 60%
  - % estimating low impacts pre-mitigation: 27%
  - % estimating low impacts with mitigation: 73%
- Mines with mining-related groundwater exceedences: 52%
  - % estimating low impacts pre-mitigation: 15%
  - % estimating low impacts with mitigation: 77%
- Mines with acid drainage on site: 36%
  - % predicting low acid drainage potential: 89%

Inherent Factors

- Ore type and association
- Climate/proximity to water resources
- Pre-existing water quality
- Constituents of concern
- Acid generation and neutralization potentials
- Contaminant leaching potential

- *How effective are mitigation and mining approaches in preventing or minimizing impacts?*

Mineralization Types (excerpt)

Mineralization Types	Examples	Associated Rock Types
Volcanogenic massive sulfide (VMS) deposits	Iron Mountain CA, Blackbird mine, ID	Volcanic: basaltic (Cyprus type), rhyolitic-andesitic (Kuroko-type); sedimentary rock such as turbidites and black shales (Besshi-type)
High sulfidation epithermal (quartz alunite epithermal) deposits	Summitville, CO, Red Mountain Pass, CO, Goldfield and Paradise Peak, NV, Mt. Macintosh, BC, Julcani, Peru	Silicic volcanic or intrusive rocks (e.g., quartz latite)
Porphyry Cu and Cu-Mo deposits	Globe, AZ, Mt.Washington, BC, Alamosa CO	Altered, intermediate-composition intrusive rocks
Cordilleran lode deposits	Butte, MT; Magma, AZ, Quiruvilca, Peru	Altered, intermediate-composition intrusive rocks
Climax-type porphyry Mo deposits	Climax, Henderson, Mt. Emmons, CO	Silica- and uranium-rich granitic or rhyolitic intrusions
Polymetallic vein deposits and adularia-sericite epithermal vein deposits	Central City, CO (polymetallic vein); Creede and Bonanza, CO; Comstock NV; Sado, Japan (adularia-sericite)	igneous intrusions
Hot-spring Au-Ag and Hg deposits	Leviathan, Sulphur Bank, and McLaughlin, CA; Round Mountain, NV	Epithermal and vein deposits; volcanic rocks
Skarn and polymetallic replacement deposits	Leadville, Gilman, and Rico, CO; New World, MT; Park City and Tintic, UT. Skarn deposits associated with porphyry-Mo, -Cu- Mo and -Cu deposits - Yerington, NV; Chino, NM	Outermost portions of intrusions or in sediments adjacent to the intrusions

Source: Plumlee, 1999

Rock Types and AGP

Rock Type	Subcategory	Rock Name	Relative Neutralizing and Acid-Generating Potential
Sedimentary	Chemical/ Biological	Limestone	High NP
		Dolomite	Mod – high NP
		Chert	Mod NP
	Detrital	Black Shale	Low - mod NP, low - mod AP
		Redbed shales	Mod NP
		Arkose	Low NP
		Calcareous sandstone	Low NP
		Quartzose sandstone	Low NP
Igneous	Intrusive	Carbonatite	High NP, Mod AP
		Ultramafic	Mod – high NP, mod AP
		Granite	Low NP
	Volcanic	Komatiite	Mod – high NP, some AP
		Basalt	Low – mod NP
		Andesite	Low – mod NP
		Poorly welded volcanic tuff	Mod – high NP
		Highly welded volcanic tuff	Low – mod NP
		Rhyolite flows	Low – mod NP
Metamorphic		Marble	High NP
		Gneiss	Low NP
		Quartzite	Very low NP
		Sulfidic schists	Low NP, high AP

Source: Plumlee, 1999

Mines with Inherent Factors

- Proximity to water
  - 16 with perennial streams on site or direct SW discharges
  - 18 shallow depth to GW (0-50 ft) or discharge to GW
- Acid drainage/contaminant leaching
  - 18 mod/high ADP or CLP (static or S tests; leachate concentrations 1-10 or >10x standards)
- Close to SW and mod/high ADP/CLP: 13/25
- Shallow GW and mod/high ADP/CLP: 15/25

Surface Water Results

	# Mines	Percent (%) with Impact to Surface Water	Percent (%) with Exceedences of Standards in Surface Water	Percent (%) with Exceedences that Predicted no Exceedences
Mines close to surface water with mod/high ADP or CLP	13	92 (12/13)	85 (11/13)	91 (10/11)
All case study mines	25	64 (16/25)	60 (15/25)	73 (11/15)

Flambeau Mine, WI

- State law – provide three examples of open pit mines operated and closed for 10 years with no water impacts
- Massive sulfide, Cu - Au, open pit flotation
- Over 50% sulfide (pyrite, chalcocite, bornite and chalcopyrite); gossan cap with Au and Cu
- Started in 1991 - only mine permitted, constructed, operated and reclaimed under new mining rule
- Pit backfilling began in early 1997, completed in late 1998
- Stockpiled materials backfilled according to their pre-mining stratigraphic position (high-S waste rock/limestone placed deepest into pit)

Photo source: http://www.wsn.org/flambeau5.JPG

Flambeau Mine, WI

- Proximity to water: perennial stream on site; shallow groundwater
- Tests: wet/dry and leach tests (Cu, Fe, Mn, SO_4), whole rock and S on 5 waste rock samples - if <1-2%S, no acid drainage
- Models: geochemical model pit backfill GW
- Mitigation: lined stockpiles, limed backfilled pit

Photo sources: http://www.dnr.state.wi.us/org/aw/wm/mining/photos/FMaerialrecl-lg.jpg

Flambeau Mine, WI (cont.)

- Predictions:
  - Increase of contaminants not measurable in river due to dilution
  - Geochemical models – pit GW
    - 1990 EIS – backfilled open pit groundwater: Cu = 0.014 mg/l, Fe = 0.32 mg/l, Mn = 0.25 mg/l, SO_4 = 1,360 mg/l. Used short-term leach test results as inputs
    - 1996-97 predictions (backfill plan): Higher Cu, Mn, Fe concentrations (Cu = 0.18 to 0.56 mg/l)
- Actual water quality
  - Exceedences (copper) in small stream on mine site
  - Actual max post-mining backfill GW: Cu = 0.56 mg/l, Mn = 17 mg/l, Fe = 9.6 mg/l; SO4 = 1,700 mg/l
  - GW between pit and Flambeau River - 2.8-7.4 mg/l Fe, 3.1-4.2 mg/l Mn, pH 5.9-6.2, SO_4 250-460 mg/l, and TDS 810-1,100 mg/l

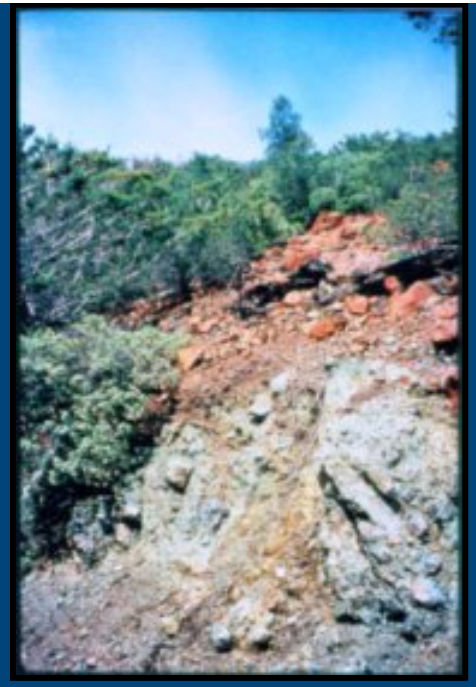
Photo source: http://www.dnr.state.wi.us/org/aw/wm/mining/photos/FMaerialrecl-lg.jpg

Surface Water Examples

- McLaughlin, CA predicted exceedences in surface water and was correct
  - Homestake, 1985-2002, open pit gold, pressure oxidation of sulfide/refractory ore, vat leach CN
  - Testing: NAG testing, short term leach, paste pH
  - Modeling: surface water heavy metals
  - No enforcement actions, despite apparent evidence of chronic degradation of surface water

Photo: www.mii.org/ReclAtoL/homestak/homestak.html

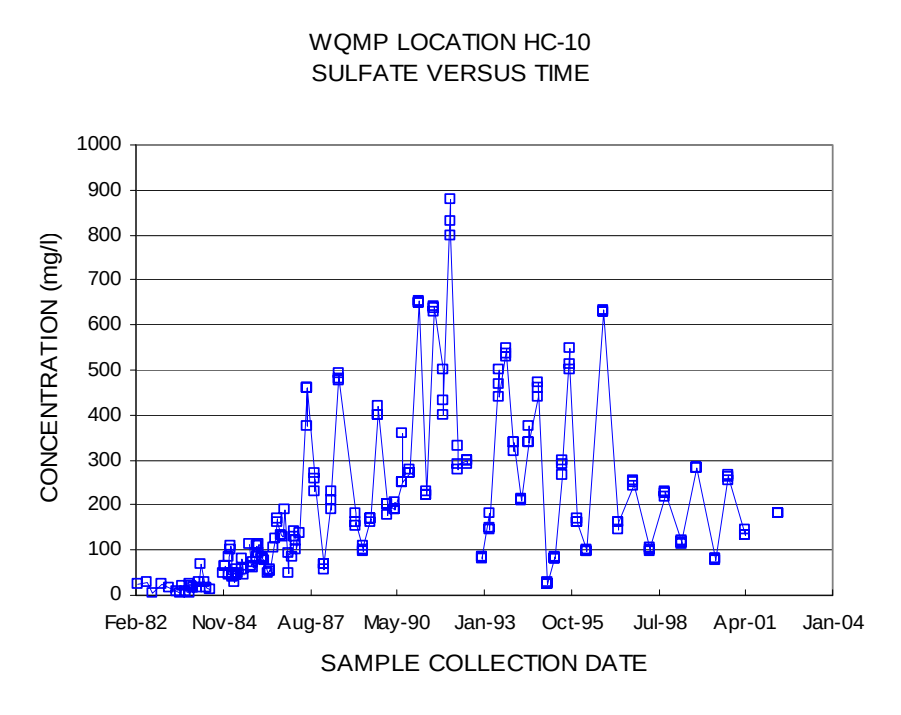
McLaughlin Mine, CA (cont.)

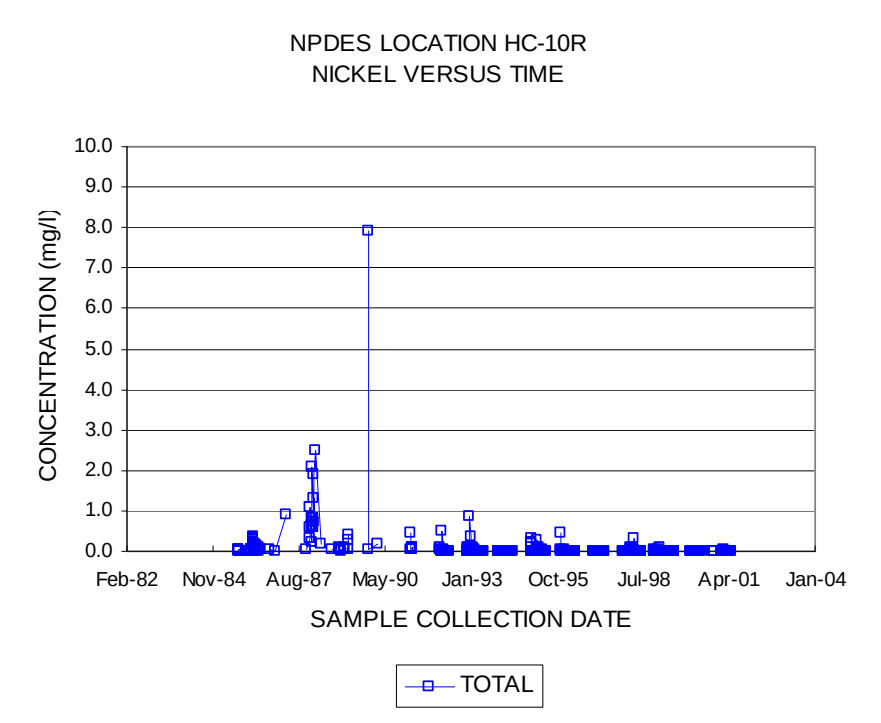


- Potential surface water quality impacts from waste rock (sediment, TDS, heavy metals)
- Predicted post-mitigation (add lime to sediment ponds, segregate/blend PAG waste rock): surface water model predicts As, Ni, Zn, Ag, Fe, Cu will not exceed drinking water standards and Mn will
- Actual: Surface monitoring locations downstream of the mine show exceedences of sulfate and occasionally large exceedences of As, Cr, Cu, Pb, Mn, Hg, Pg, Fe, Zn

Photo: nrs.ucdavis.edu/McL/natural/geology/index.html

McLaughlin Mine – Hunting Creek





Kuipers et al., 2006

Groundwater Results

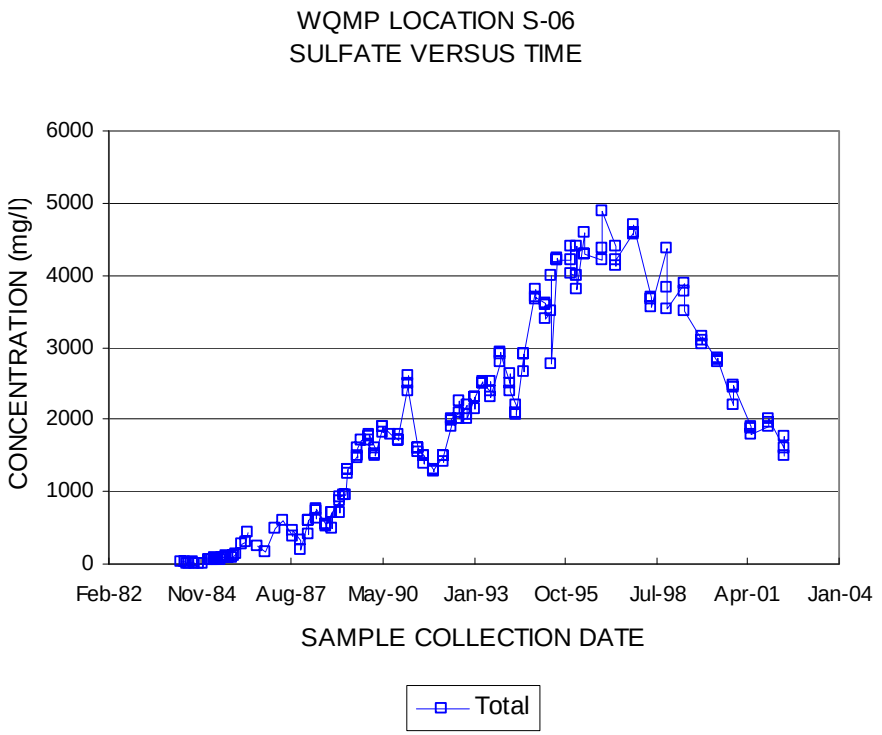
	# Mines	Percent (%) with Impact to Groundwater	Percent (%) with Exceedences of Standards in Ground water	Percent (%) with Exceedences that Predicted no Exceedences
Mines close to groundwater with mod/high ADP or CLP	15	93 (14/15)	93 (14/15)	86 (12/14)
All case study mines	25	68 (17/25)	68 (17/25)	77 (13/17)

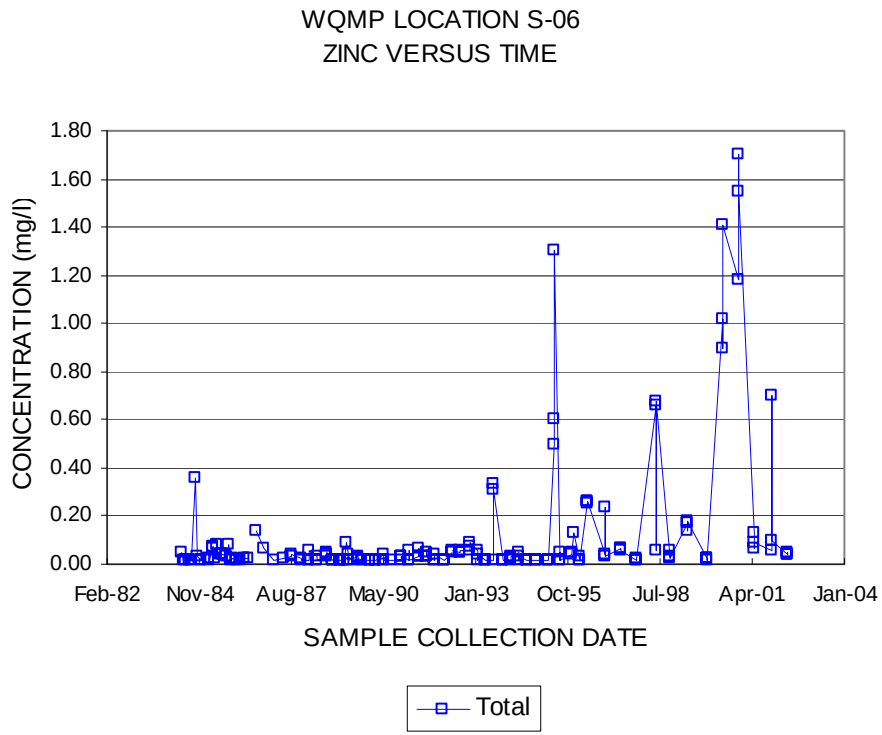
Groundwater Examples

- McLaughlin, CA had inherent factors and did have exceedences
  - 92% of rocks not acid generating
  - Tailings leachate flunked STLC – hazardous aquifer
  - Permanent degradation of groundwater expected from tailings seepage
  - regulatory exclusion for groundwater (poor quality, low K), so no violations
  - Exceedences of TDS, Cl, NO_3, SO_4, and increases in Cu, B, Zn in groundwater downgradient of tailings and waste rock

Photo: www.mii.org/ReclAtoL/homestak/homestak.html

McLaughlin Mine, CA: Waste Rock Monitoring Well





Kuipers et al., 2006

Mines without Inherent Factors

- If there are inherently worse mines, there must be inherently better mines
- California desert mines
  - American Girl, Castle Mountain, Mesquite
  - No groundwater or surface water impacts or exceedences
  - Delayed impacts? Climate change (but less precipitation predicted)
- Stillwater, Montana
  - Close to water, low ADP, moderate/high CLP
  - Unused surface water discharge permit
  - Inherently lucky – ultramafic mineralogy

Mesquite Mine, CA

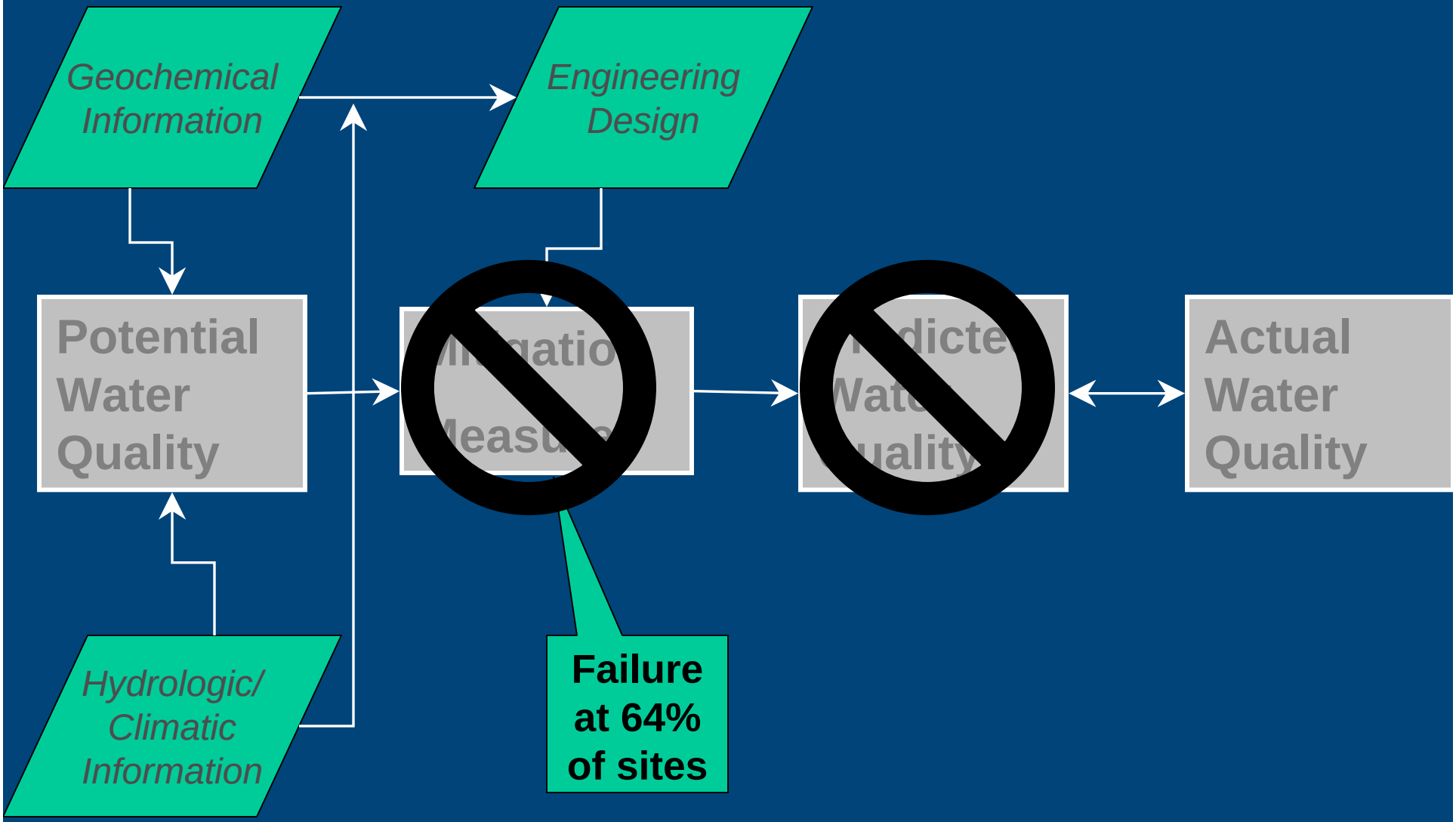
- Open pit heap leach Au + Ag, 1985-present, Newmont
- Background groundwater exceedences of F, Cl, SO_4, Fe, Mn, As, Hg
- Annual precip = 3”/yr; evap = ~80”/yr
- Proximity to water: average depth to groundwater ~200 ft; intermittent/ ephemeral streams on site – perennial streams >1 mile away
- Tests: static ABA on overburden and leached ore, whole rock, 20-wk kinetic (*T. ferrooxidans*)

Photo: www.nafinance.com/.../western_goldfields_e.htm

Mesquite Mine, CA (cont.)

- Potential: low AGP, low leachable metals (whole rock metals = As, Se, Ag, Bi, Tl); leaks of processing fluids, fuel
- Mitigation: leach pad liner/leak detection, reagent containment. Stormwater run-on/off controls
- Models: HEC-1 runoff; proprietary pit lake model
- Predicted: no impacts to groundwater or surface water, long-term pit water quality same as present
- Actual
  - Pit water quality: pH ~8.5, alkalinity ~300 mg/L, TDS up to 3,600 mg/l, low metals
  - Groundwater – no impacts after 15 yrs of operation
  - Small unreported spill in 2002/3 – RWQCB violation, cleaned up

Predicted vs. Actual Water Quality



Implications

- Mines close to water with mod/high ADP/CLP need special attention from regulators
- Water quality impact predictions before mitigation in place more reliable
- These can be in error too – geochemical and hydrologic characterization need improvement
- Why do mitigations fail so often and what can be done about it?