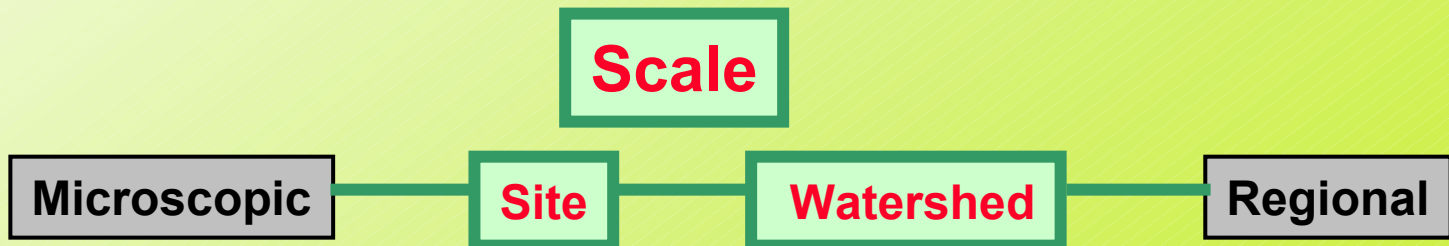
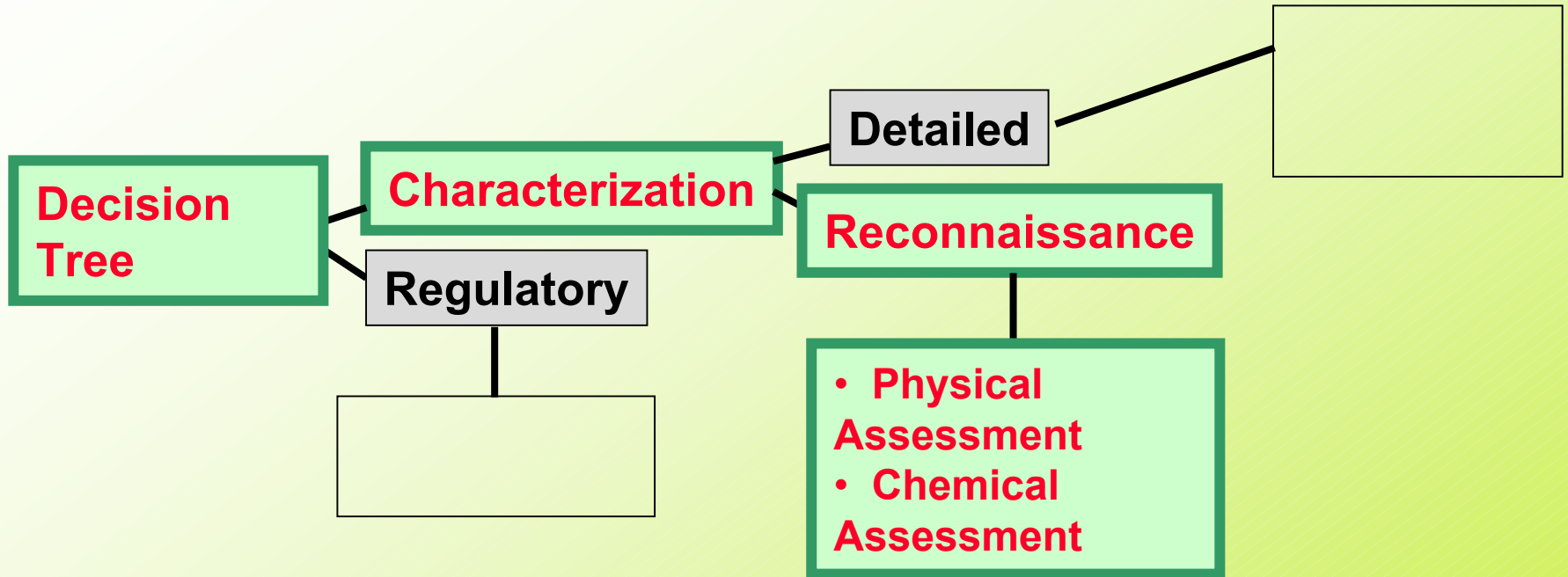


USING THE DECISION TREE

**TOM WILDEMAN
Colorado School of Mines**

Flow Chart for Ranking and Prioritization



OUR GOAL

- **PROVIDE TOXICITY ASSESSMENT & RANKING OF MINE-WASTE PILES**
 - **PHYSICAL & CHEMICAL ASSESSMENT**
 - **SIMPLE ASSESSMENT TESTS**

RECENT APPLICATIONS

- **LAKE CITY, CO – SITE ASSESSMENT**
 - CHICAGO TUNNEL pH ~ 6 – 7
 - GOLDEN WONDER pH ~ 3 – 4
- **RUSSELL GULCH (CENTRAL CITY)**
 - USE OF DECISION TREE
 - WATERSHED ASSESSMENT



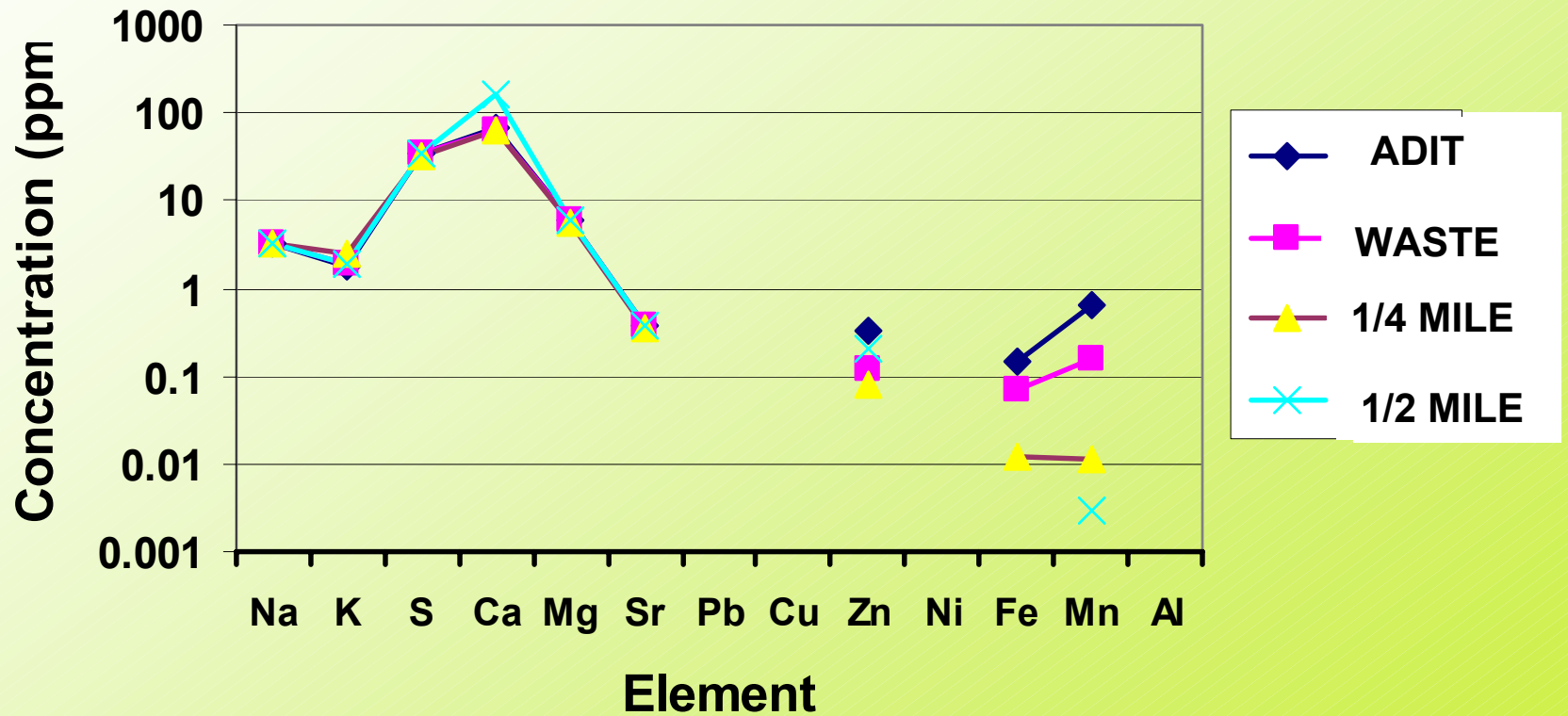
CHICAGO TUNNEL

WATER CHEMISTRY (pH 6.5-7.2)

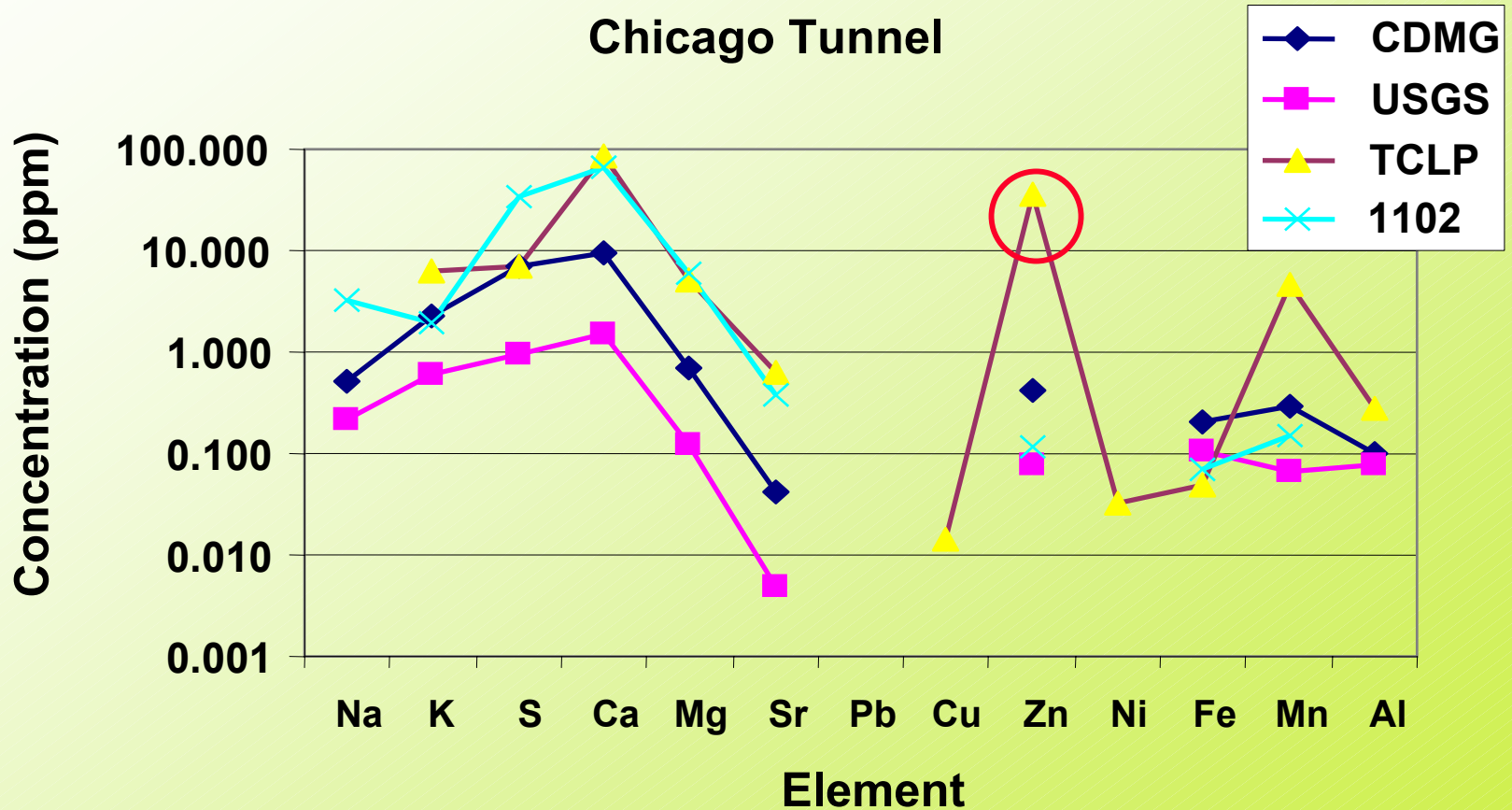
	Det. Lim					WASTE PILE			Stream Stds.	
		ADIT	WASTE	1/4MILE	1/2 MILE	CDMG	USGS	TCLP	Aquatic	Toxic
Al	0.022	BDL	BDL	BDL	BDL	0.102	0.077	0.277	0.1	
As	0.047	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.05	5
Cd	0.0017	BDL	BDL	BDL	BDL	BDL	BDL	0.071	0.005	1
Co	0.0072	BDL	BDL	BDL	BDL	BDL	BDL	BDL		
Cu	0.001	BDL	BDL	BDL	BDL	BDL	BDL	0.014	0.01	
Fe	0.003	0.151	0.071	0.012	BDL	0.205	0.104	0.050	1	
Mn	0.0006	0.634	0.154	0.011	0.003	0.293	0.066	4.613	1	
Ni	0.002	BDL	BDL	BDL	BDL	BDL	BDL	0.033	0.2	
Pb	0.019	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.05	5
Se	0.036	0.069	0.059	0.053	0.050	BDL	BDL	BDL	0.05	1
Zn	0.001	0.319	0.119	0.079	0.203	0.422	0.076	36.130	0.1	

ELEMENT PATTERN FOR WATER

Chicago Tunnel Water



ELEMENT PATTERN - MINE WASTE



CHICAGO TUNNEL CONCLUSIONS

- **MINE-WASTE PILE HAS A Zn PHASE THAT IS SOLUBLE IN WEAK ACID OR ACETATE COMPLEX**
- **APPEARS THAT Zn, Fe & Mn ARE BEING REMOVED DOWNSTREAM FROM ADIT**
- **ALKALINITY IS VERY HIGH**
- **LOW LEVEL OF IMPACT; COULD BE EASILY TREATED IF NECESSARY**

GOLDEN WONDER ADIT

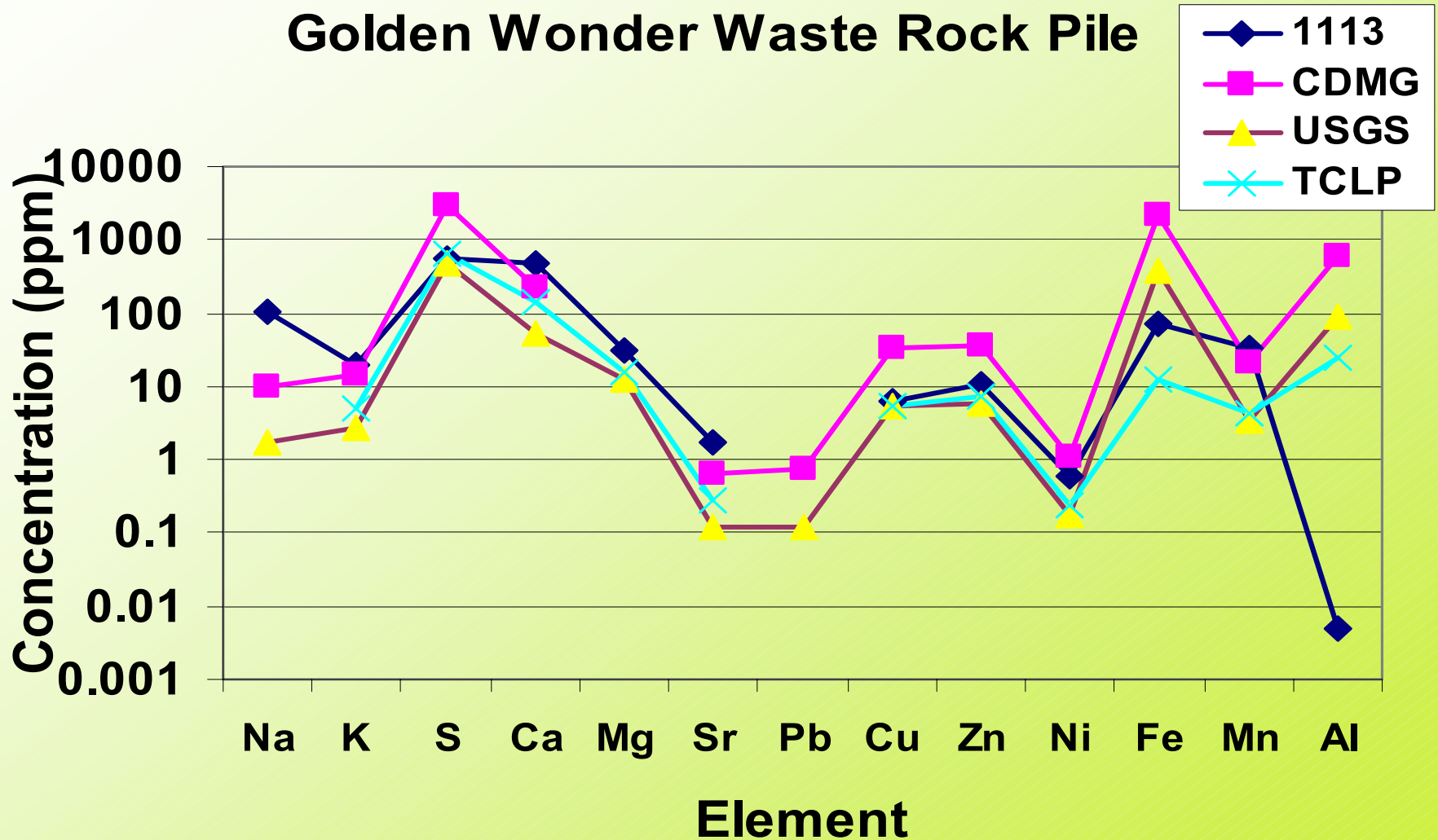


GOLDEN WONDER WASTE PILE



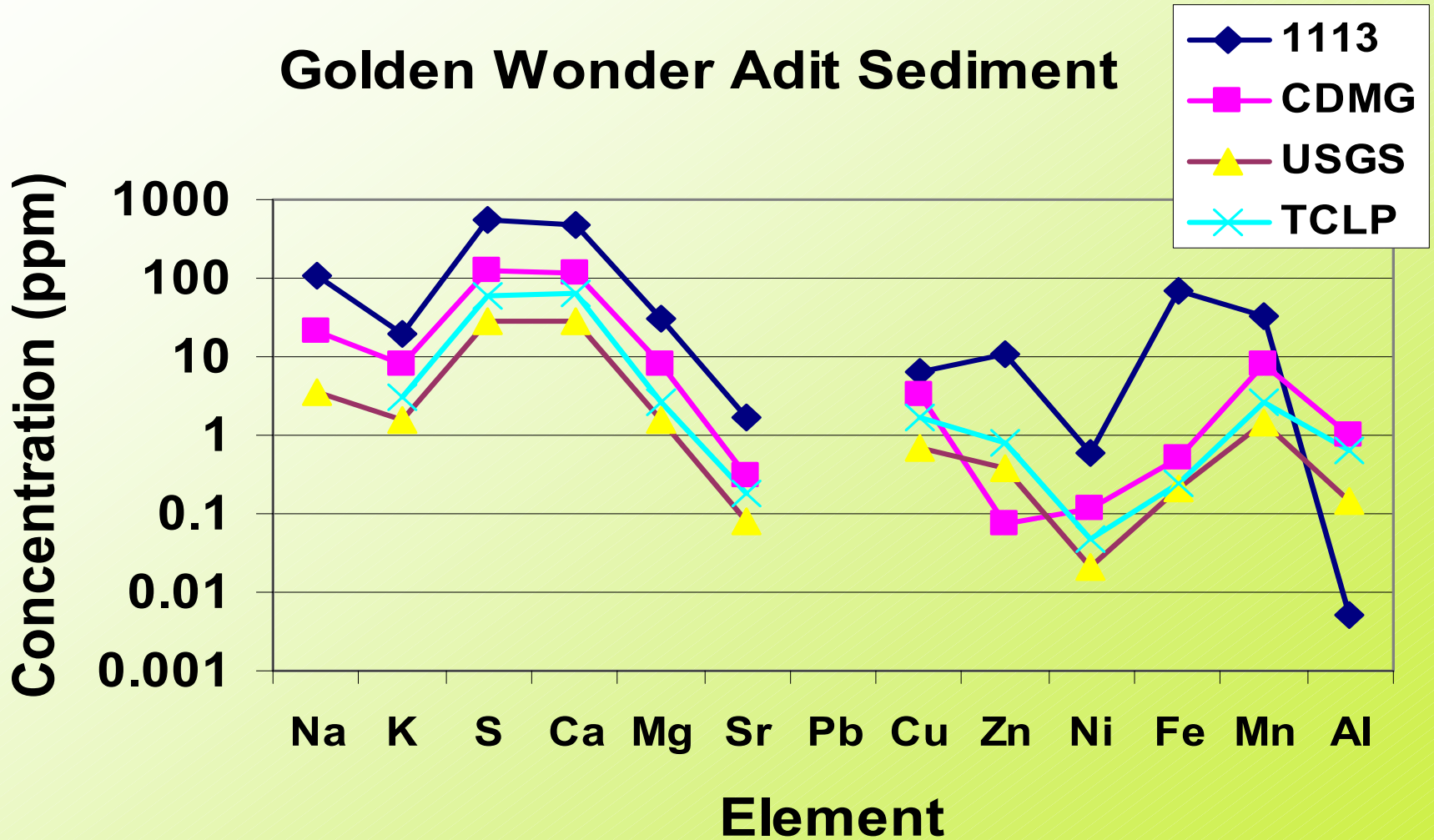
GOLDEN WONDER (pH 4.4)

Golden Wonder Waste Rock Pile



ADIT SEDIMENT

Golden Wonder Adit Sediment



CONCLUSIONS

- **CAN ASSESS TOXICITY EVEN THOUGH LITTLE WATER**
- **FOR WASTE-ROCK PILE LEACHATES, As (mg/L): CDMG 8.3, USGS 0.98, TCLP BDL**
- **EVERYTHING IS ABOVE AQUATIC TOXICITY LEVELS IN SEDIMENT AND WASTE-ROCK PILE LEACHATES**
- **IF WATER EVER REACHES RIVER, A PROBLEM**

RUSSELL GULCH

- **MAJOR ASSESSMENT OF MINE-WASTE PILES IN A WATERSHED LIKE VIRGINIA CANYON**
- **DROUGHT YEAR**
 - **WATER WAS FOUND ON ONLY ONE WASTE PILE**
 - **GULCH WATER FOUND IN ONLY ONE SITE NEAR WASTE PILES**
- **TEST THE DECISION TREE**
- **DO THE LEACHATE TESTS TO CONFIRM TOXICITY**

MINE WASTE DECISION TREE

CHEMICAL CRITERIA

PASTE pH, ALKALINITY

< 5

> 5

Assume Toxicity.
Check with TCLP
& CDMG
extraction tests.

Toxicity Uncertain

TCLP, CDMG, & USGS
extraction tests are
necessary.

Develop a simple
bioavailability test to
confirm toxicity.

PHYSICAL CRITERIA

A. ON-SITE ASSESSMENTS

1. Proximity to year-round or ephemeral stream or gulch.
2. Size of waste-rock pile.
3. Extensiveness of erosion features.
4. Presence of cementation crusts.
5. Presence of a kill zone.
6. Presence of vegetation.

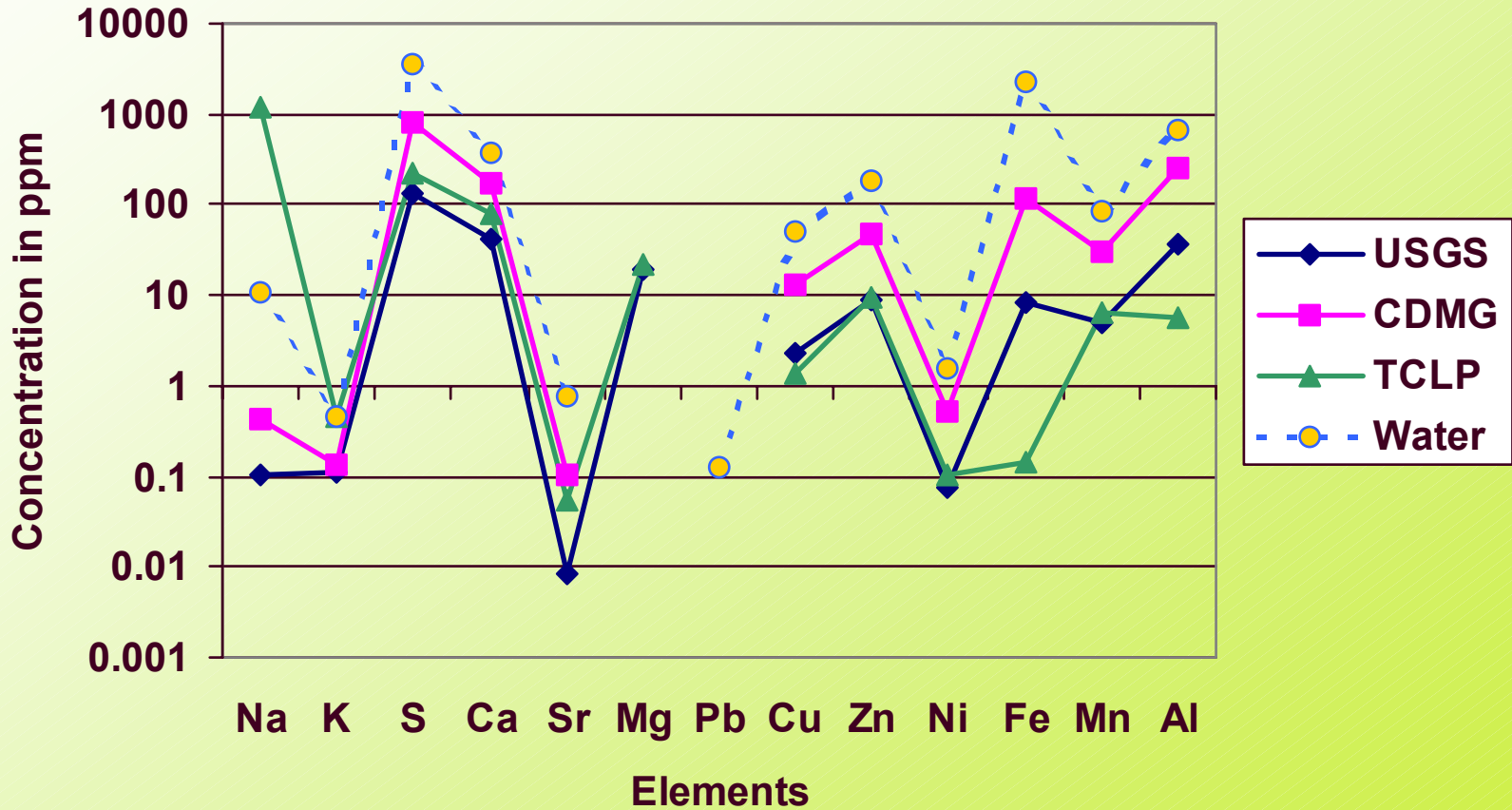
B. ON-SITE TESTS

1. Develop a settling test.

Concerning the tests and observations within the criteria, only the paste pH test can be used as an either/or criterion for determining toxicity. For the other tests, ratings will have to be developed for which the aggregate score will determine the degree of hazard of a waste-rock pile.

ECPG FOR SOLUTION GOLD

Figure 2. Solution Gold ECPG



CHEMICAL CRITERIA

- **ACIDITY, CONDUCTIVITY, AND pH from CDMG tests**
- **TOXICITY from CDMG, TCLP and USGS; each given separate points**

TOXICITY POINT CRITERIA

- **FIVE KEY ELEMENTS CHOSEN**
 - Cd, Pb, Ag, As and Se
- **POINTS BASED ON NUMBER ABOVE AQUATIC STANDARDS**
- **FIVE POINTS GIVEN TO WASTE PILES WITH ANY ELEMENT ABOVE HUMAN TOXIC LEVELS**

EXAMPLE OF TOXICITY SCORE

	DL	Stream Stds.		Old Jordan		
		Aquatic	Toxic	USGS 23	CDMG 23	TCLP 23
Ag 328.068	0.003	0.00015	5	bdl	0.003	bdl
Al 308.215	0.023	0.1		17.415	127.881	7.004
As 193.696	0.047	0.05	5	bdl	0.698	bdl
Be 313.107	0.000	0.6		bdl	bdl	bdl
Cd 214.440	0.002	0.005	1	0.013	0.179	0.027
Cr 205.560	0.003	0.125	10	0.027	0.333	0.005
Cu 324.752	0.001	0.01		0.547	4.004	0.208
Fe 238.204	0.004	1		20.516	228.325	1.127
Mn 257.610	0.001	1		1.239	8.549	1.313
Ni 231.604	0.003	0.2		0.046	0.414	0.053
Pb 220.353	0.020	0.05	5	1.719	1.921	24.591
Se 196.026	0.036	0.05	1	bdl	bdl	bdl
Zn 213.857	0.001	0.1		6.760	45.684	5.913

Toxicity

1 = all of Cd, Pb, Ag, As, and Se below Aquatic

2 = one of Cd, Pb, Ag, As, or Se above Aquatic

3 = three of Cd, Pb, Ag, As, or Se above Aquatic

4 = five of Cd, Pb, Ag, As, or Se above Aquatic

5 = any elements above Toxic levels

Toxicity USGS: 2.5/5, Cd and Pb above aquatic levels

Toxicity CDMG: 4/5, Ag, As, Cd, and Pb above aquatic levels

Toxicity TCLP: 5/5, Pb above toxic levels

PHYSICAL CRITERIA PITTSBURG MILL TAILINGS



PITTSBURG LEACHATE RESULTS

		Stream Stds.		Pittsburg		
	DL	Aquatic	Toxic	USGS	CDMG	TCLP
Ag	0.003	0.0002	5	bdl	bdl	bdl
Al	0.023	0.1		3.069	5.697	3.099
As	0.047	0.05	5	bdl	bdl	bdl
Be	0.000	0.6		bdl	bdl	bdl
Cd	0.002	0.005	1	bdl	bdl	bdl
Cr	0.003	0.125	10	bdl	bdl	bdl
Cu	0.001	0.01		2.581	3.648	3.868
Fe	0.004	1		0.160	0.235	0.073
Mn	0.001	1		1.080	1.667	2.093
Ni	0.003	0.2		0.022	0.005	0.057
Pb	0.020	0.05	5	bdl	bdl	bdl
Se	0.036	0.05	1	bdl	bdl	bdl
Zn	0.001	0.1		0.312	0.553	0.682

PRIORITY RATING

- **BASED ON OVERALL RANK, WHICH IS AN AVERAGE OF PHYSICAL AND CHEMICAL RANK**
- **RATED LOW, MEDIUM, AND HIGH PRIORITY (25-50-25 PERCENT BREAKDOWN)**
- **CLIENT HAS OPTIONS WITH USE OF RANK AND RATE INFORMATION**

OBSERVATIONS

- **THERE IS LITTLE CORRELATION BETWEEN CHEMICAL AND PHYSICAL RATINGS**
- **VEGETATION AND KILL ZONES ARE NOT NECESSARILY CONNECTED TO CHEMICALLY BAD SITES**
- **CHEMICALLY BAD SITES DO NOT CONCLUSIVELY HAVE THE WORST IMPACT ON AREA WATER**
- **PHYSICALLY BAD SITES DO NOT CONCLUSIVELY HAVE THE WORST IMPACT ON AREA WATER**

BOTH CRITERIA ARE IMPORTANT

CHEMICAL

- Ranks availability of contaminants

- **PHYSICAL**

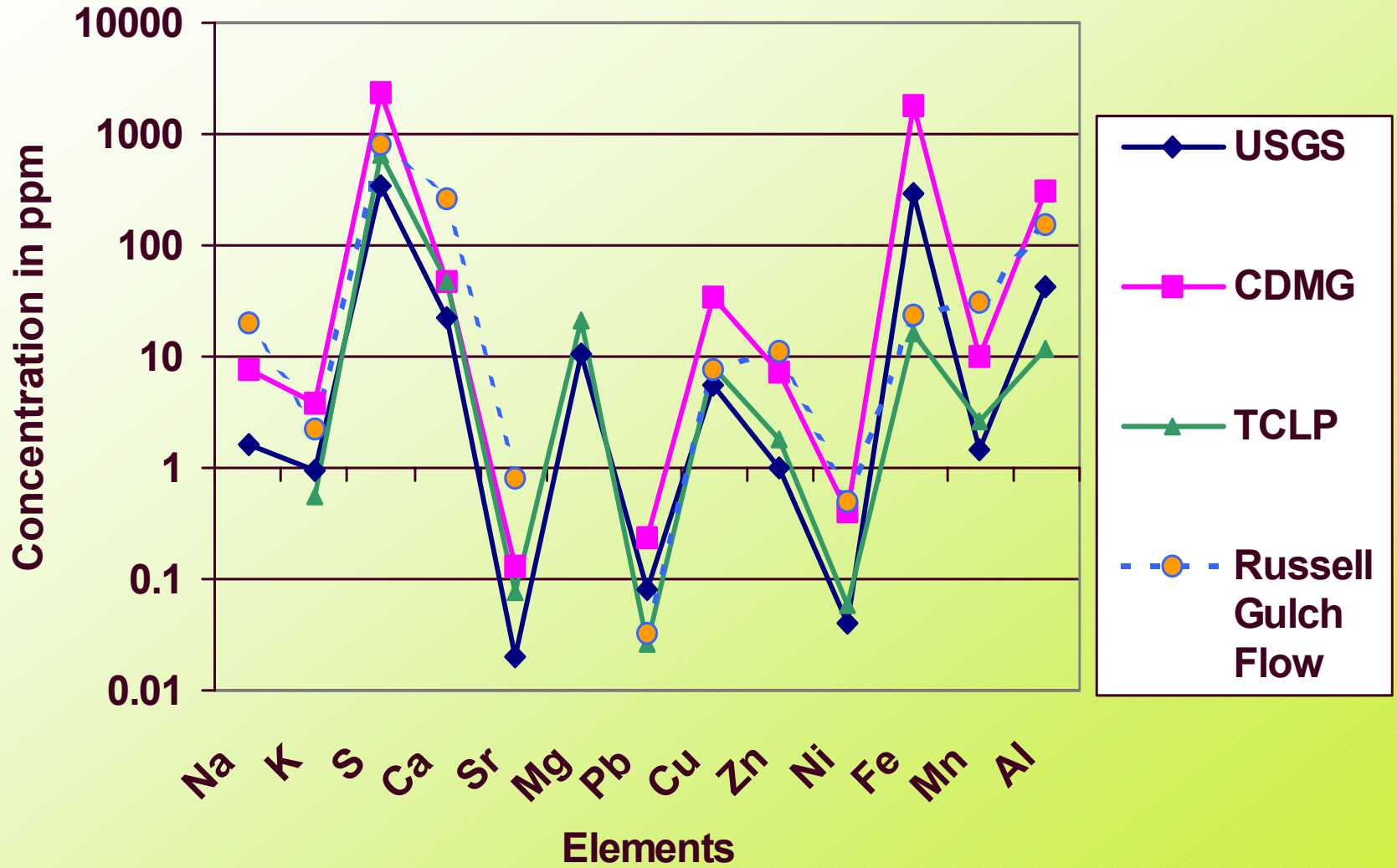
- Ranks ability to deliver contaminants



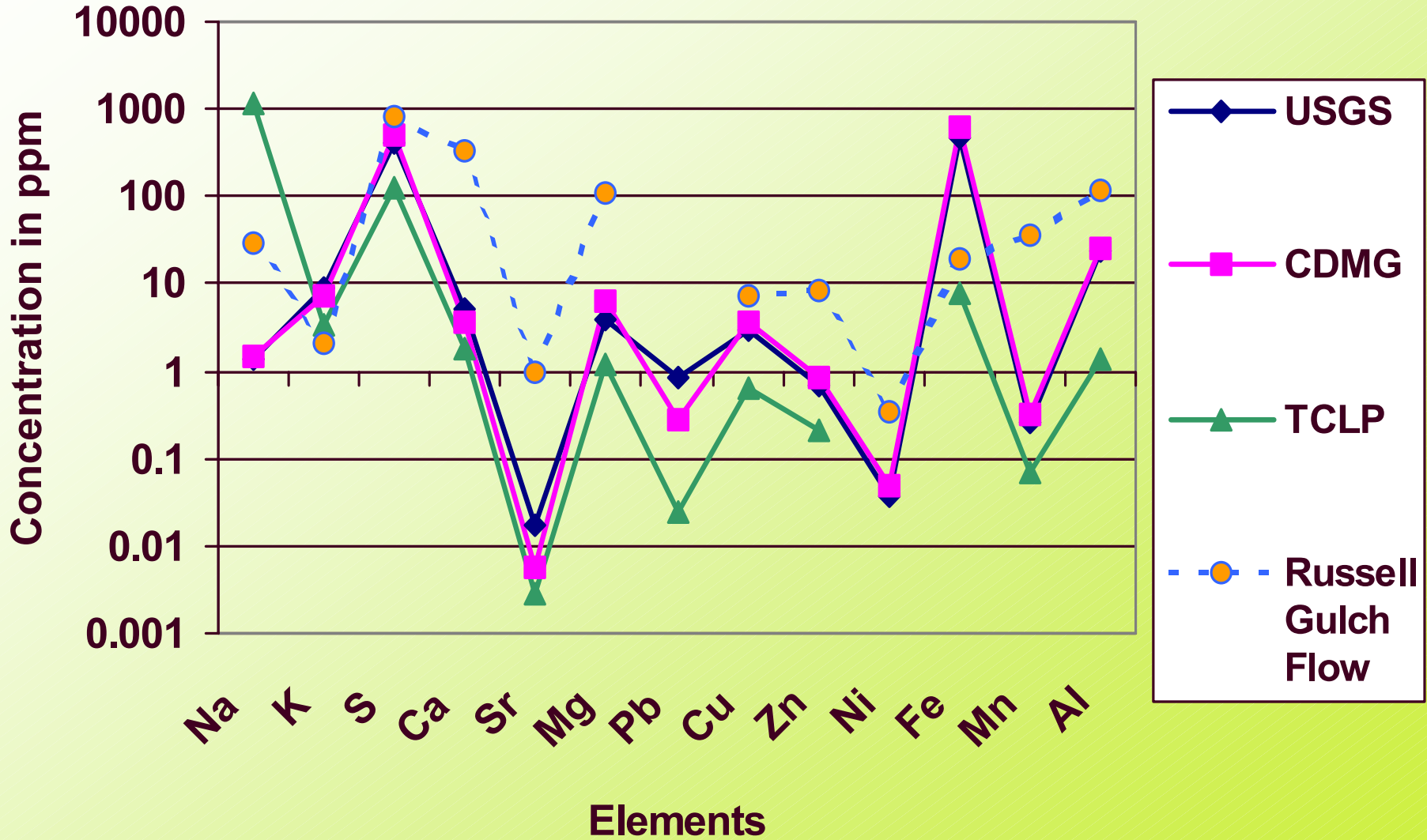
RUSSELL GULCH WATER vs WASTE PILE LEACHATES

- **NIAGARA LEACHATES ARE QUITE CLOSE TO RUSSELL GULCH WATER**
- **IPA VA LEACHATES DON'T SHOW AS GOOD A CORRELATION**

Niagara



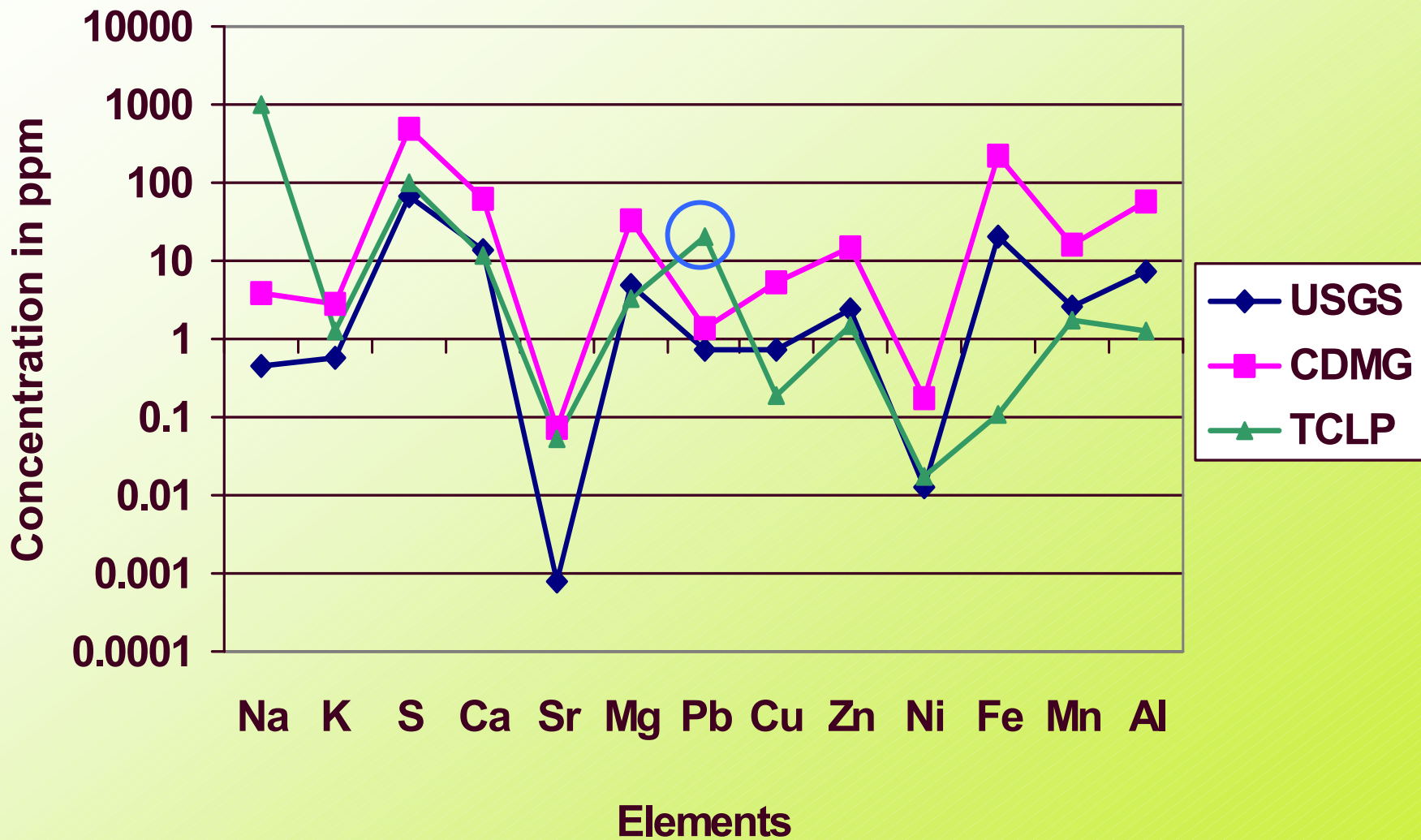
Ipava



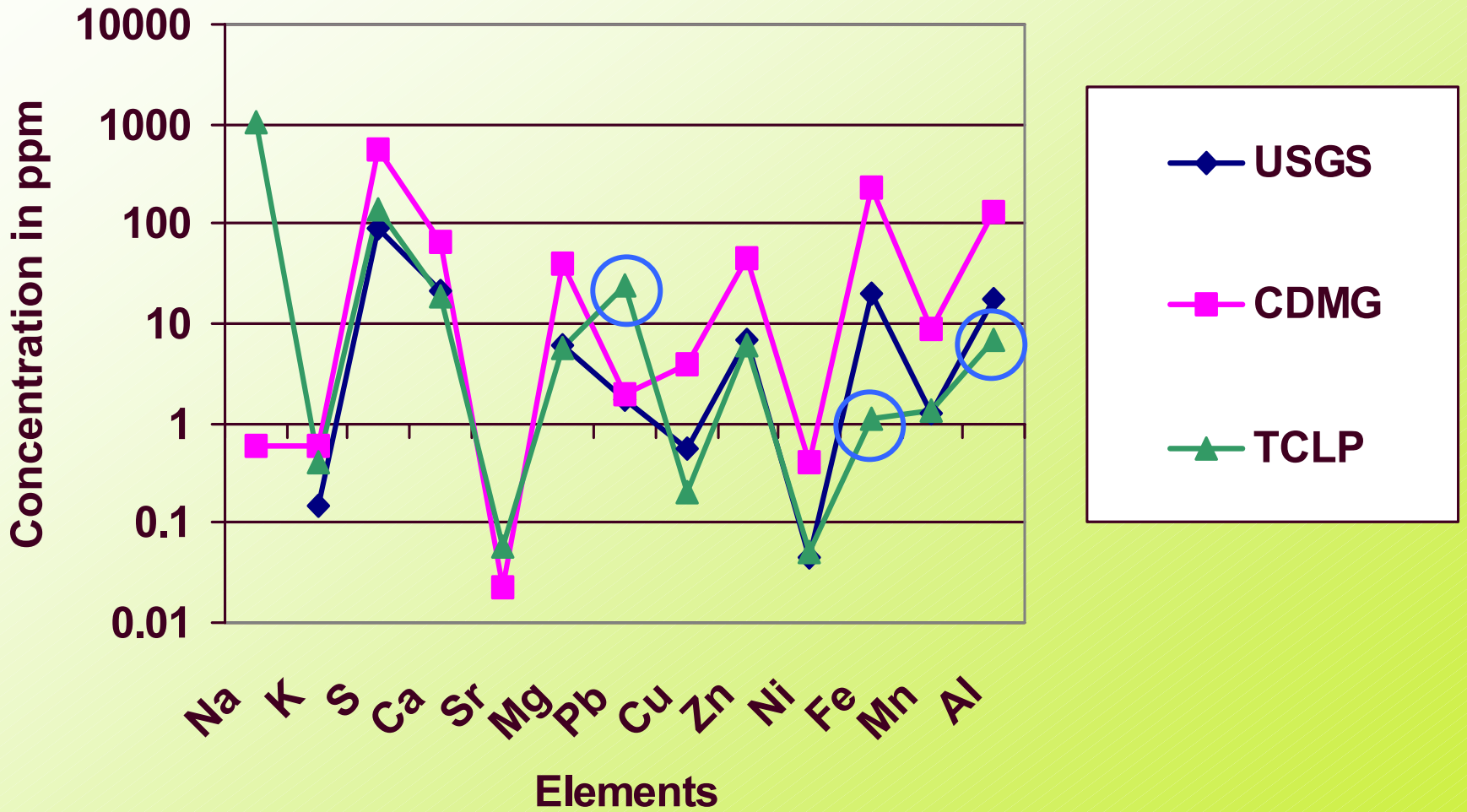
DIFFERENCES IN LEACHATE CHEMISTRY

- **FOR SOME TCLP LEACHATES, THE ACETATE SOLUTION EXTRACTS Pb, Zn, & Cu**
- **BECAUSE IN TCLP LEACHATES THE pH RANGE IS 4 – 5, SMALLER AMOUNTS OF Fe (III) & Al ARE SOMETIMES DISSOLVED**

Arizona



Old Jordan



EXAMPLE OF TOXICITY SCORE

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Toxicity TCLP: 5/5, Pb above toxic levels

RUSSELL GULCH CONCLUSIONS

- **THE DECISION TREE WORKS**
- **THE LEACHATE TESTS ARE A GOOD ESTIMATE OF WATER FLOWING FROM WASTE PILE**
- **IT IS MOST USEFUL TO HAVE A PHYSICAL AND CHEMICAL RATING**
- **NANCY DID A GREAT JOB**

