Equity Silver Mine

Over 10 Years Experience with Dry Covers

By: Mike Aziz & Keith Ferguson

PLACER DOME INC.


PAG
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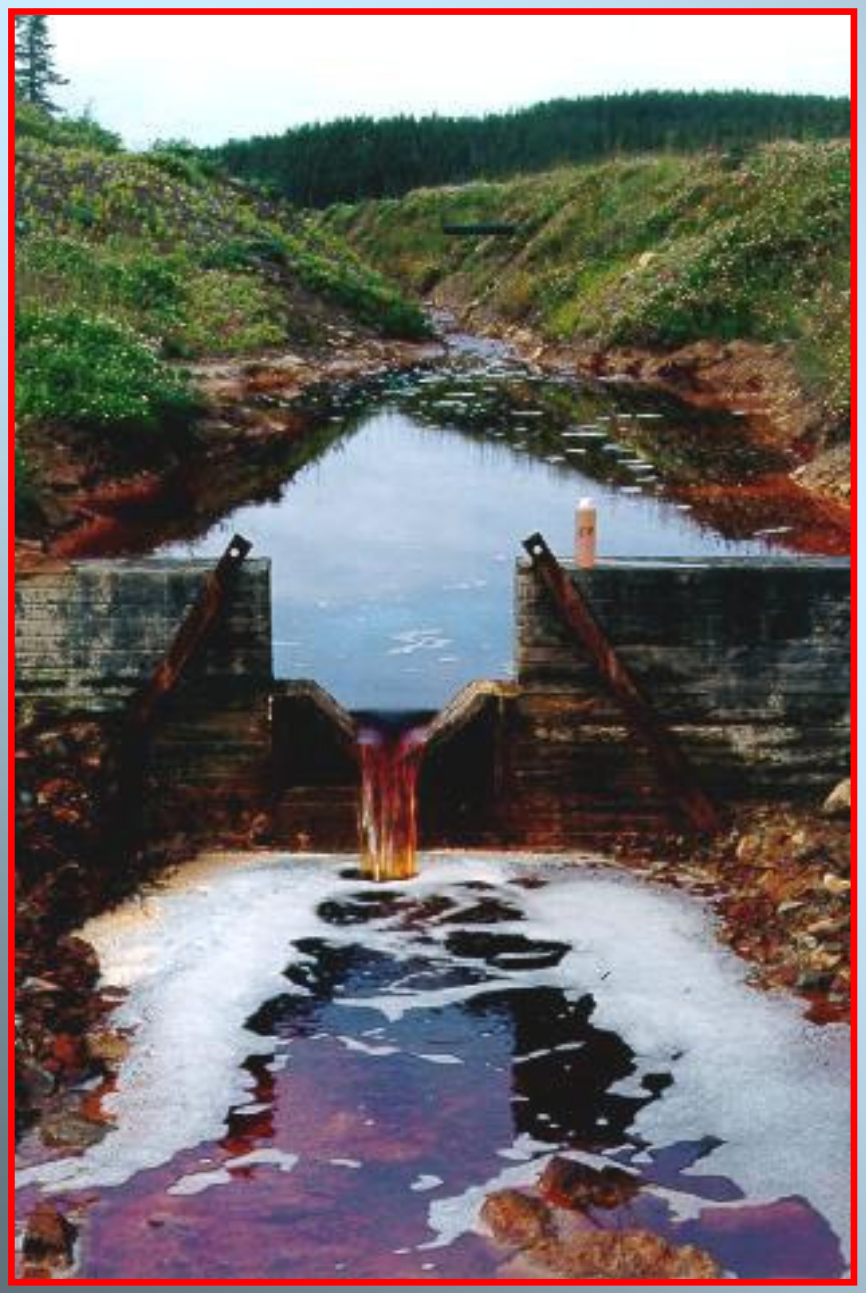
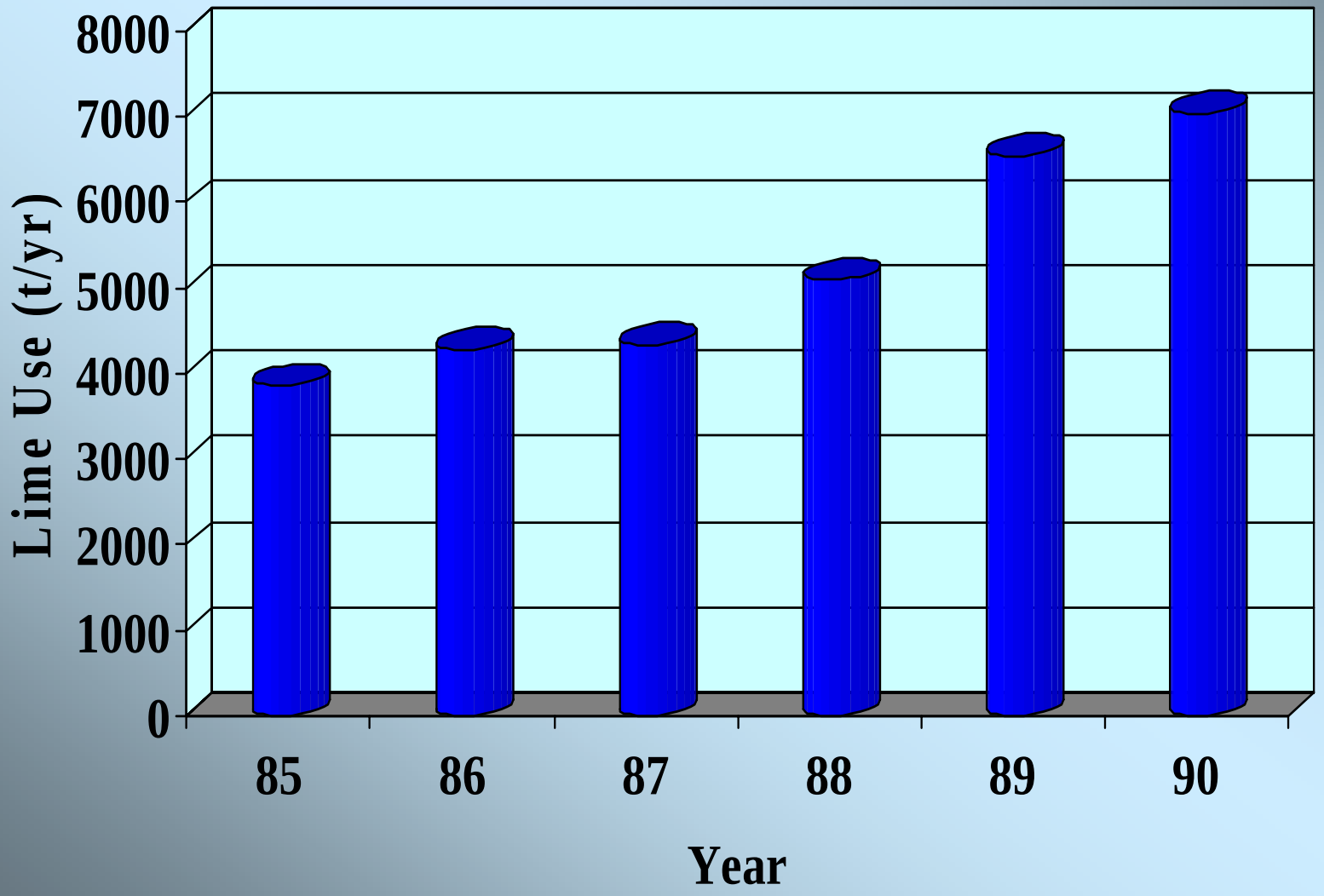


- Annual ARD volumes averaged 852,000 m^3 from 1985 to 2003

	pH	Acidity	Cu	Fe	Zn
Avg	2.6	8080	96	1209	142
Min	2.1	1138	10	84	21
Max	3.2	17200	283	2730	394

All values in mg/L except pH

Lime Use 1985 to 1990



1991 Evaluation of Cover Alternatives

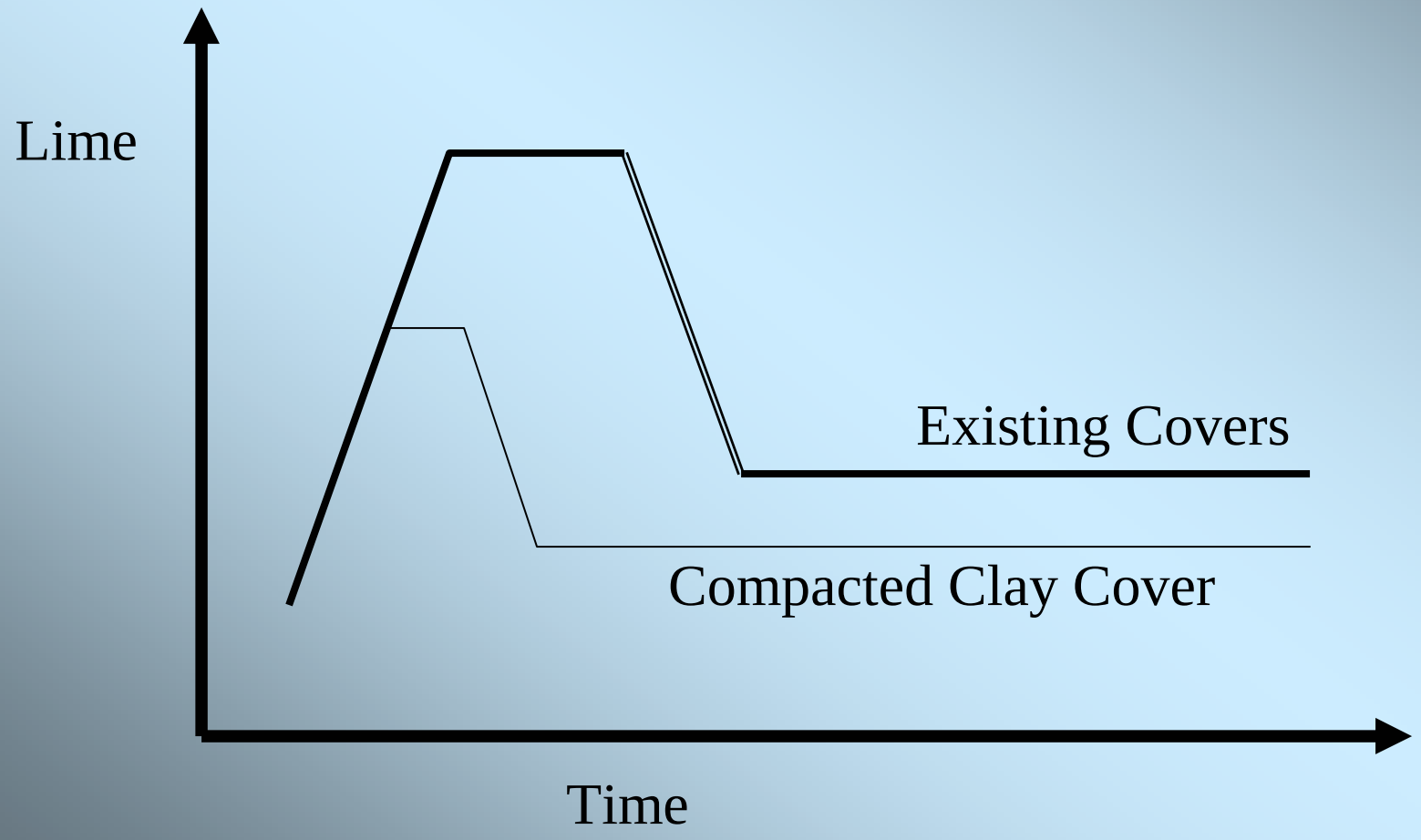
- Closure approaching - ARD getting worse!
  - ARD increasing at 10% per year (lime consumption)
  - lime use correlated with waste rock addition?
  - ARD at No. 1 dam seepage decreasing
  - other sites suggest a reduction after mining
- 1991 bond review
  - expect rather sharp reduction after waste rock dumping stopped, then period of less rapid decline, then levelling off
  - maximum values based on assumed acid conc.
  - significant reduction of ARD expected after installing a compacted till cover

1991 Comparison of Covers

Parameter	Existing Cover	Compacted Cover
% Increase/yr	10	10
Peak lime (t)	10,000 – 15,000	7,500 – 10,000
Peak period (yrs)	2 – 5	1 – 5
% Decline/yr	4 – 10	10
Low-level lime (t)	2,000 – 3,500	600 – 1,200
Avg. Lime (t)*	2,650 – 5,980	1,080 – 2,270
Potential Bond ($)	$34.2 - $56.6 M	$22.8 - $32.1 M

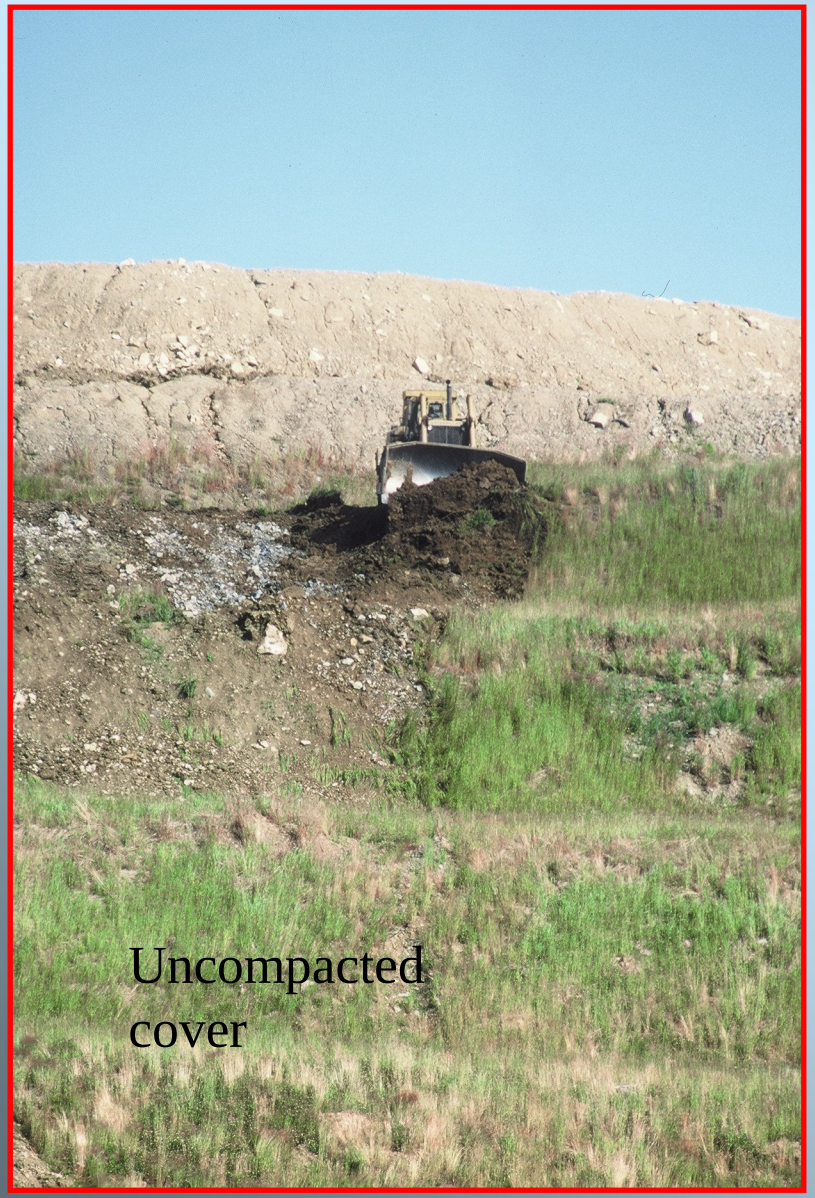
* over 100 years

1991 Technical Committee Lime Scenarios



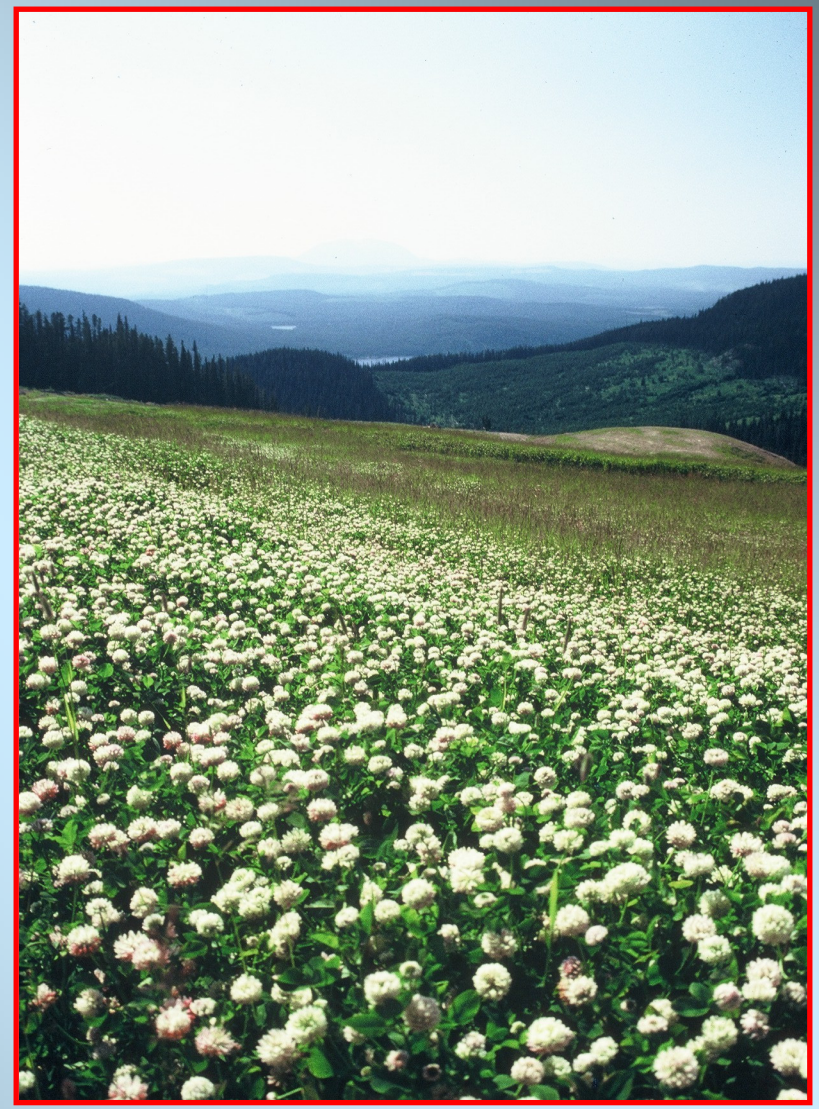
History of the Equity Cover

- Late 1980's placed 1.0 m uncompacted till cover over flat sections of terraced waste rock dump
- 1990 - 1997 – resloped waste dumps and replaced uncompacted till cover with a 0.5 m compacted plus 0.3 m uncompacted till cover
- Progressive revegetation of cover from 1992 to 1998
- Average cost of cover $35,000/ha (includes reslope, cap construction, and seeding)

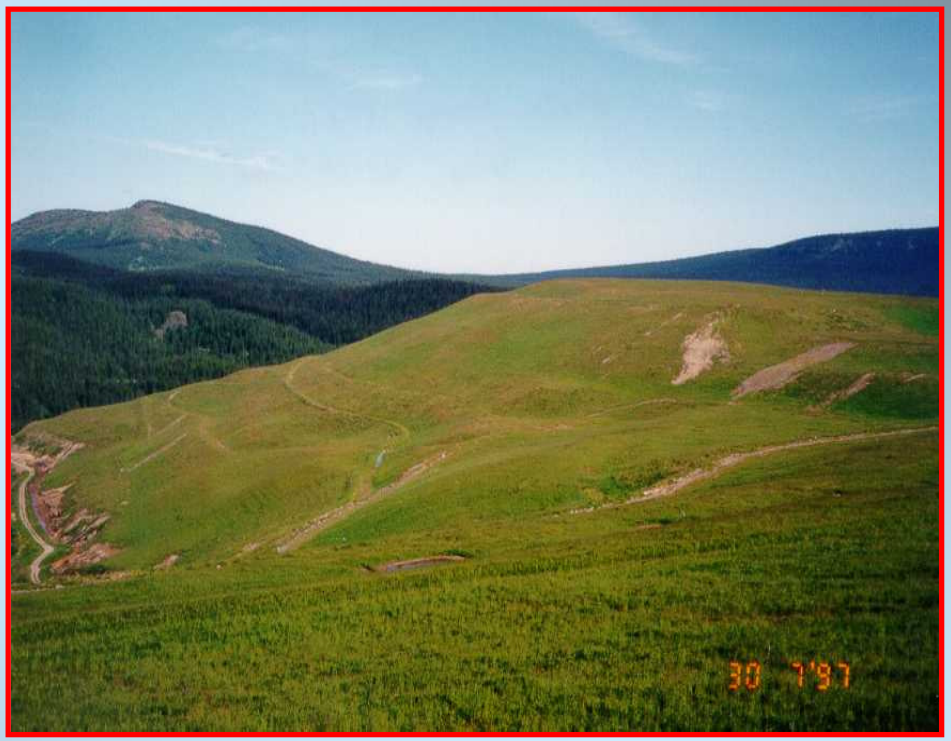


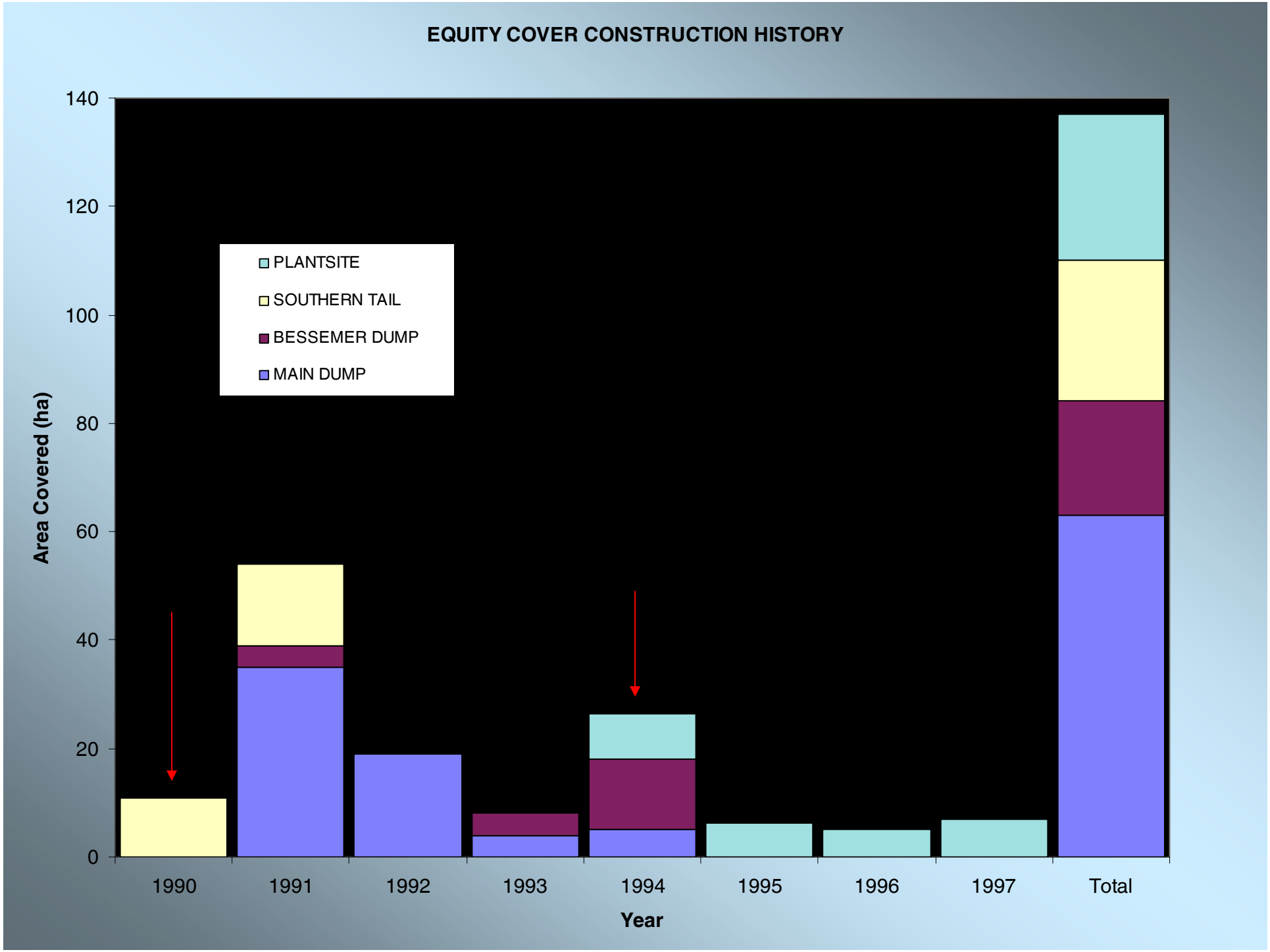
Uncompacted cover

Southern Tail Pit Waste Dump Cover



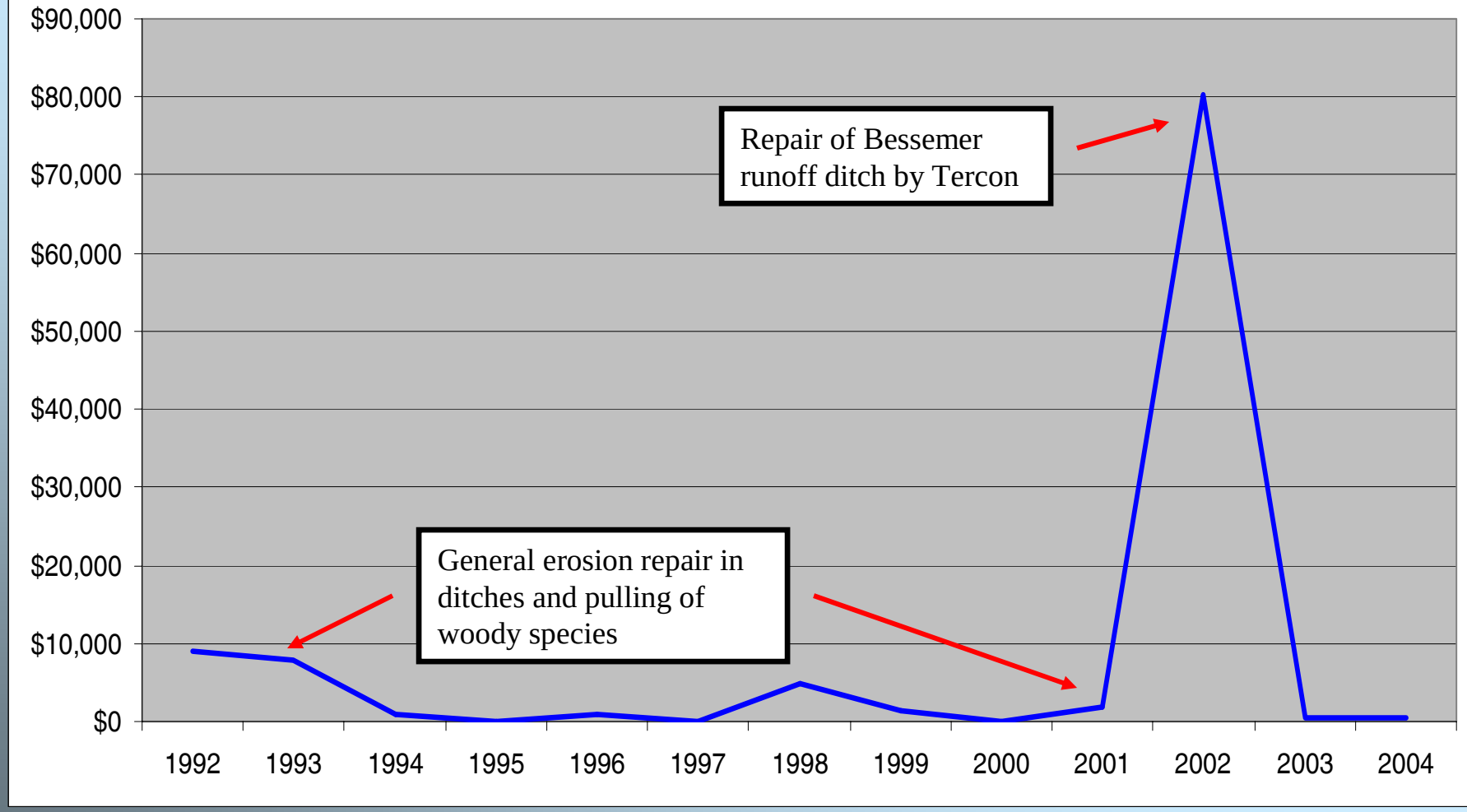
Main Waste Dump Cover




EQUITY COVER CONSTRUCTION HISTORY
Area Covered (ha)
140
120
100
80
60
40
20
0
PLANTSITE
SOUTHERN TAIL
BESSEMER DUMP
MAIN DUMP
1990
1991
1992
1993
1994
1995
1996
1997
Total
Year

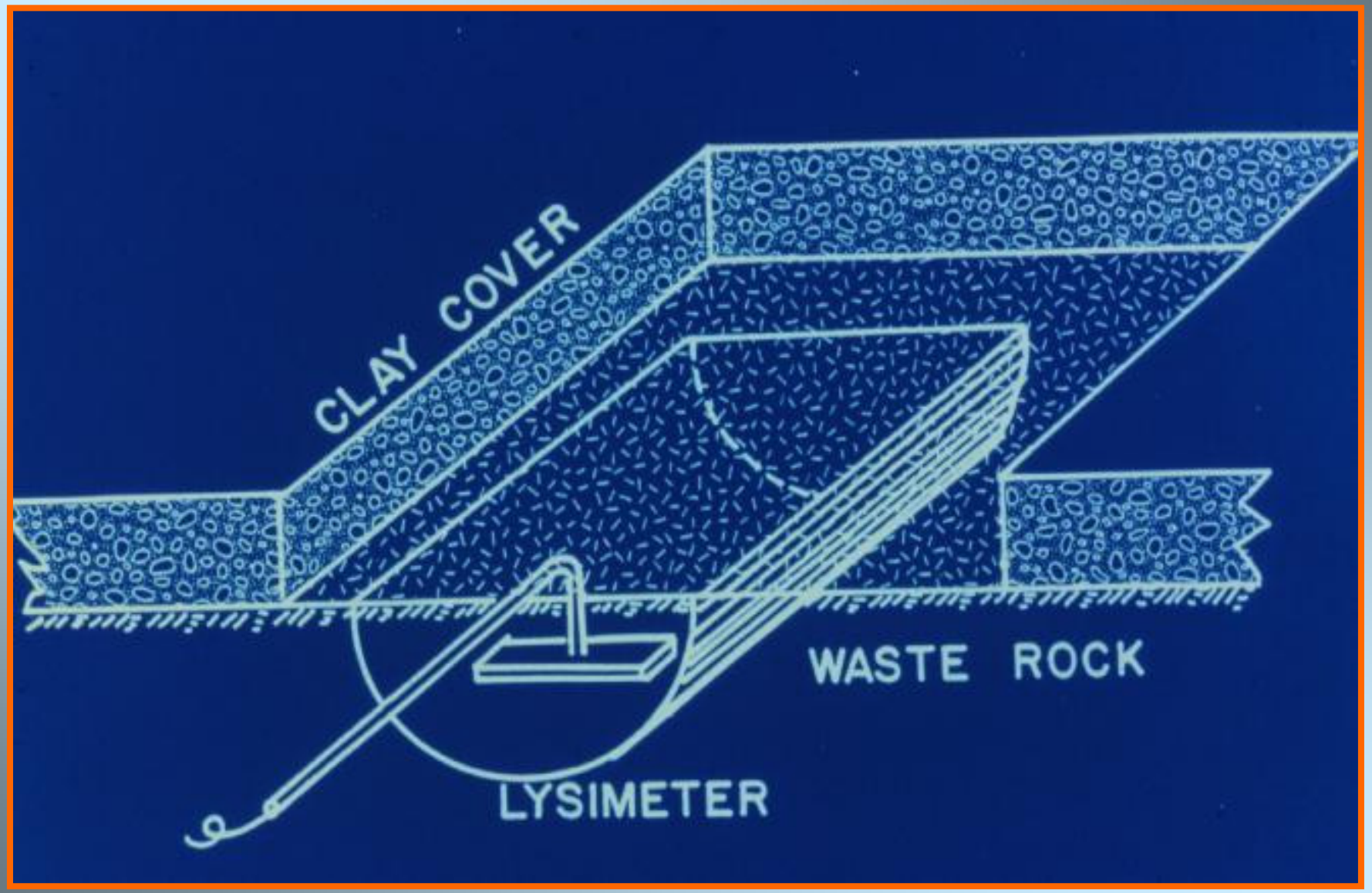
Waste Dump Cover Repairs & Maintenance

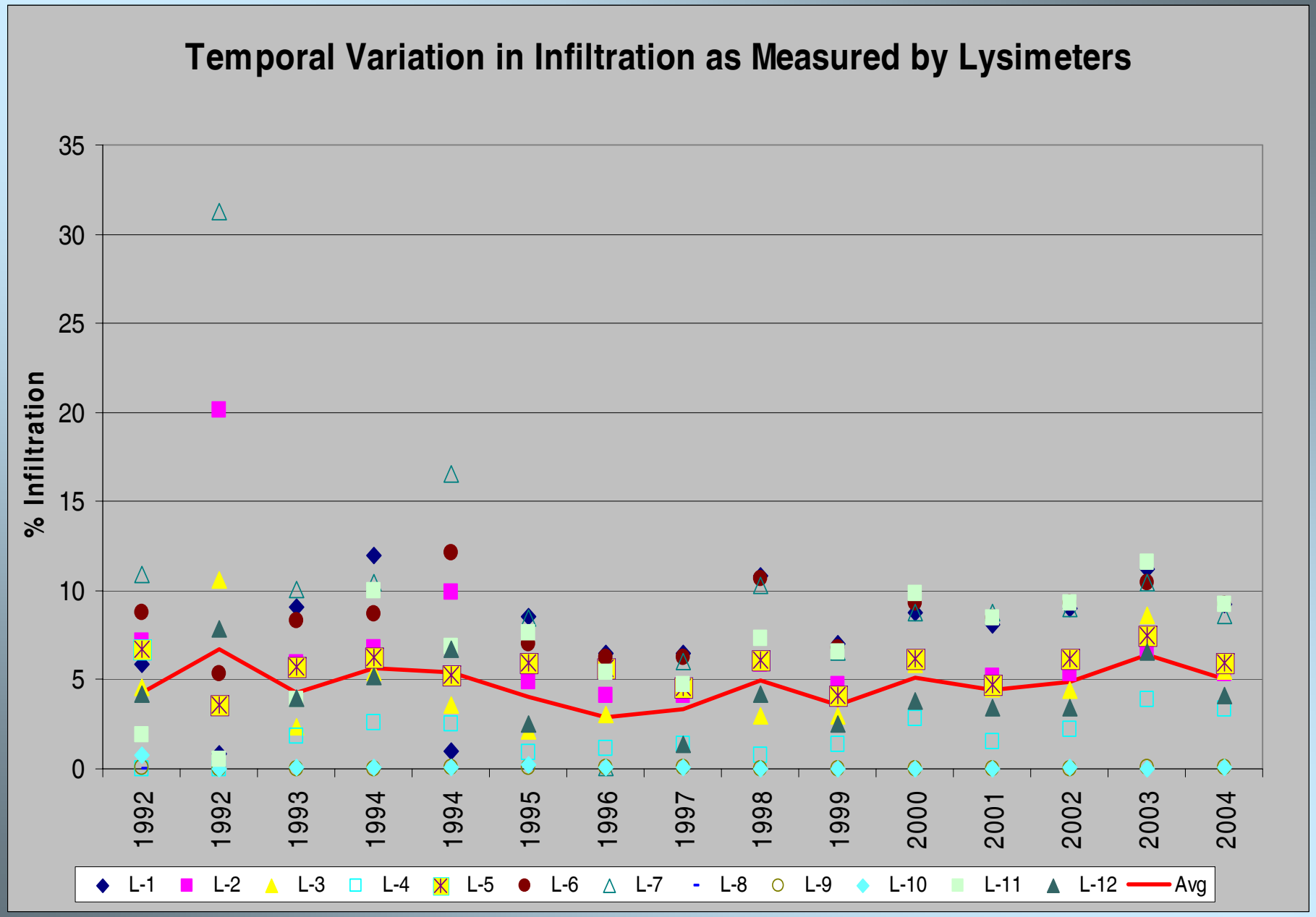
Cover and Ditch R&M Costs



Cover Monitoring

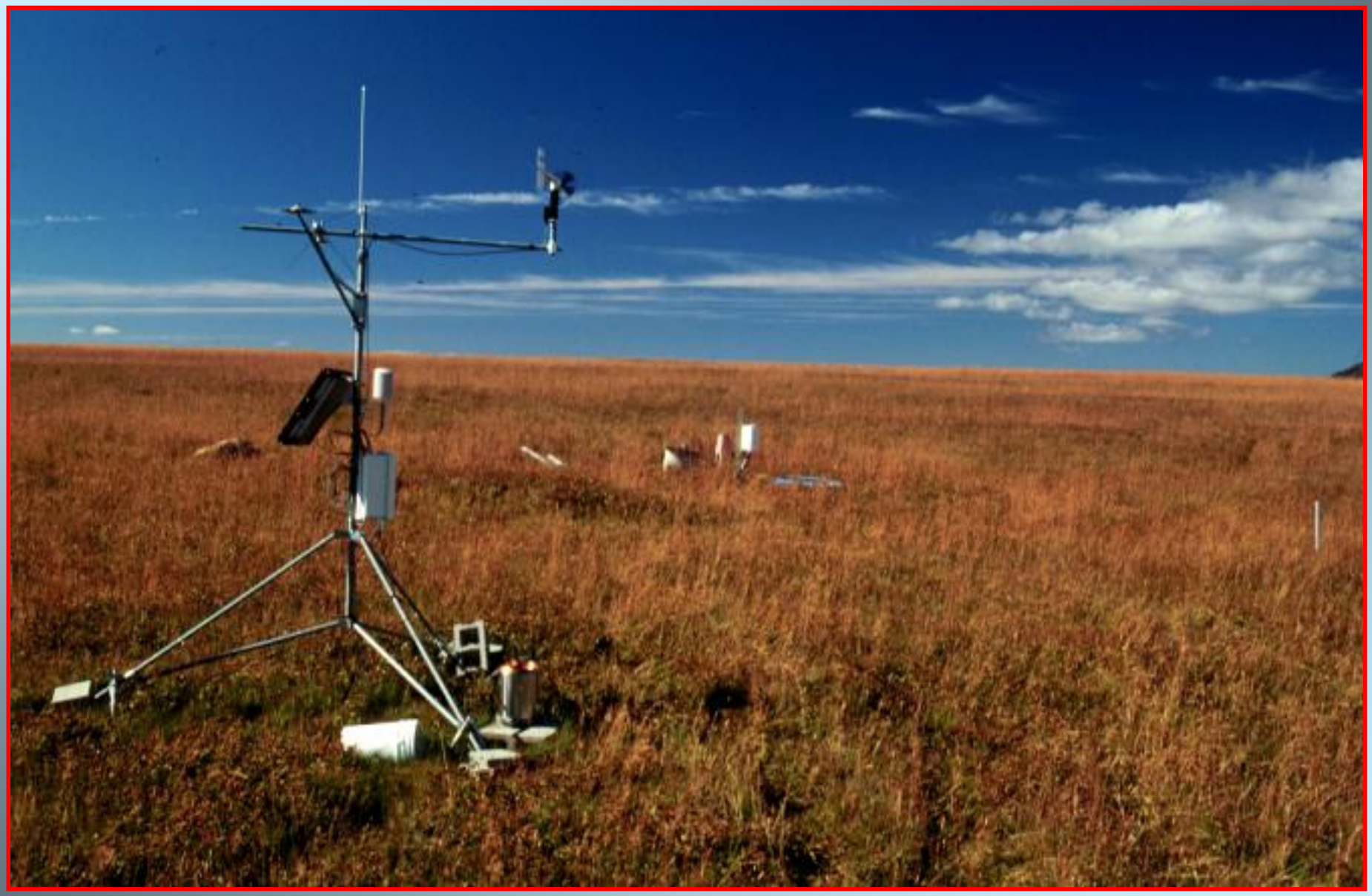
- Infiltration through cover
- Moisture content in cover
- Internal oxygen content
- Internal temperature
- Seepage chemistry and volume
- Overall ARD collection chemistry and volume
- Lime consumption
- Runoff volumes off cover

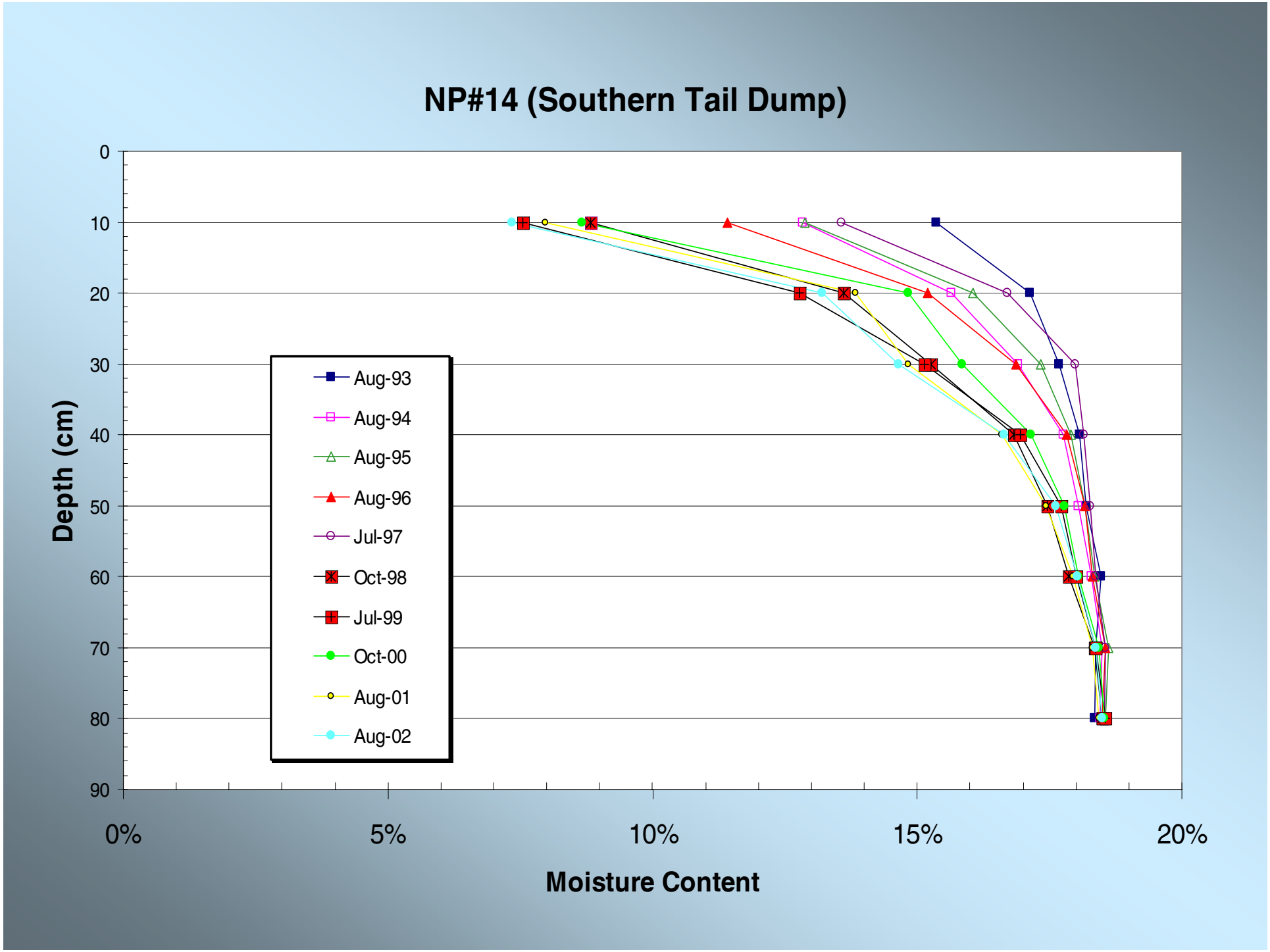

CLAY COVER
WASTE ROCK
LYSIMETER


Temporal Variation in Infiltration as Measured by Lysimeters
% Infiltration
35
30
25
20
15
10
5
0
1992
1992
1993
1994
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
L-1
L-2
L-3
L-4
L-5
L-6
L-7
L-8
L-9
L-10
L-11
L-12
Avg

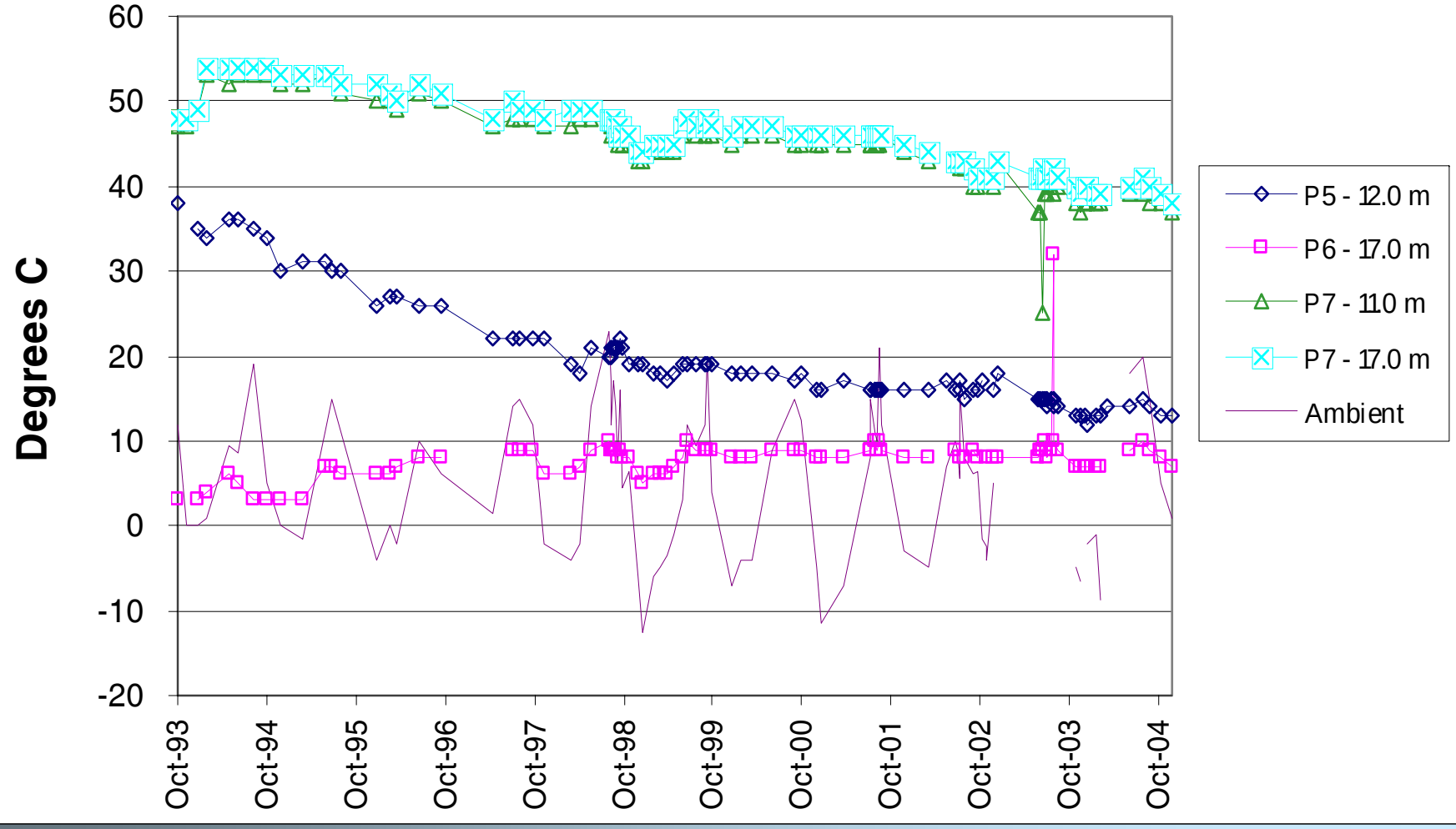
U of Saskatchewan Studies

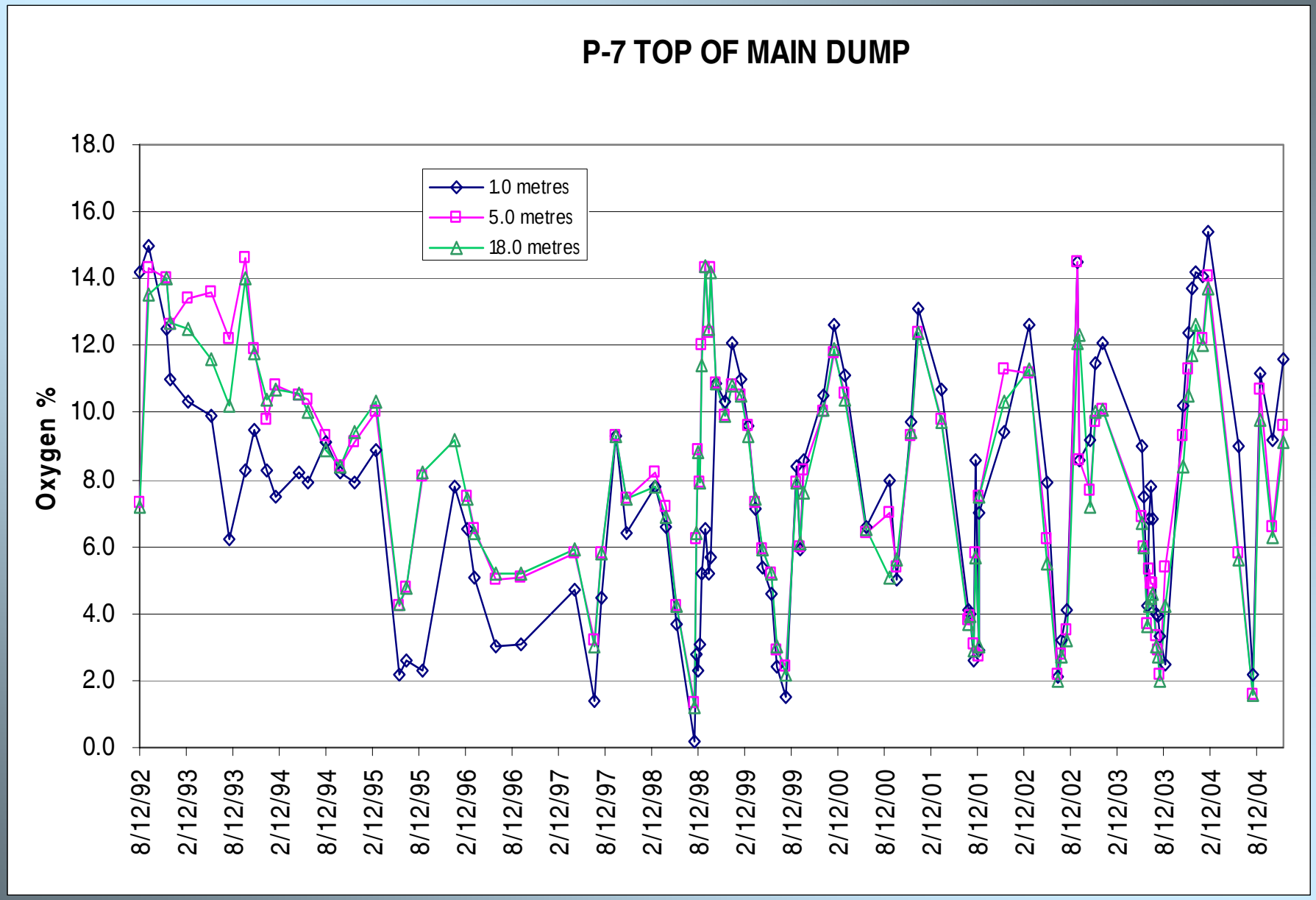
- 5 year study to investigate performance of the cover started in 1993
  - measurements of water content and suction in the cover
  - modelling of cover performance
  - erosion study
- saturated layer that prevents oxygen ingress
- measured 4% infiltration
- modelled 3% infiltration



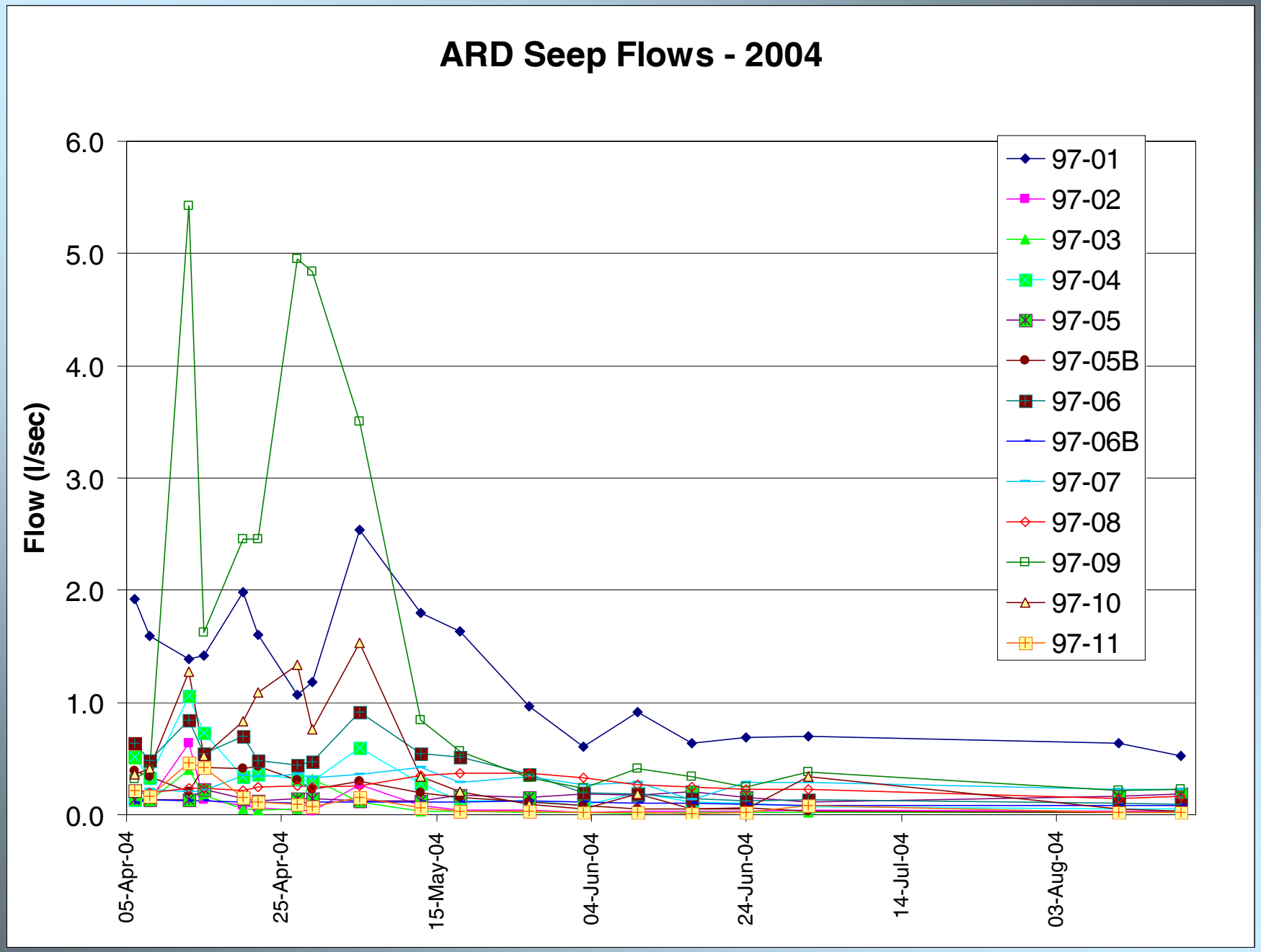

NP#14 (Southern Tail Dump)
Depth (cm)
0
10
20
30
40
50
60
70
80
90
0%
5%
10%
15%
20%
Moisture Content
Aug-93
Aug-94
Aug-95
Aug-96
Jul-97
Oct-98
Jul-99
Oct-00
Aug-01
Aug-02

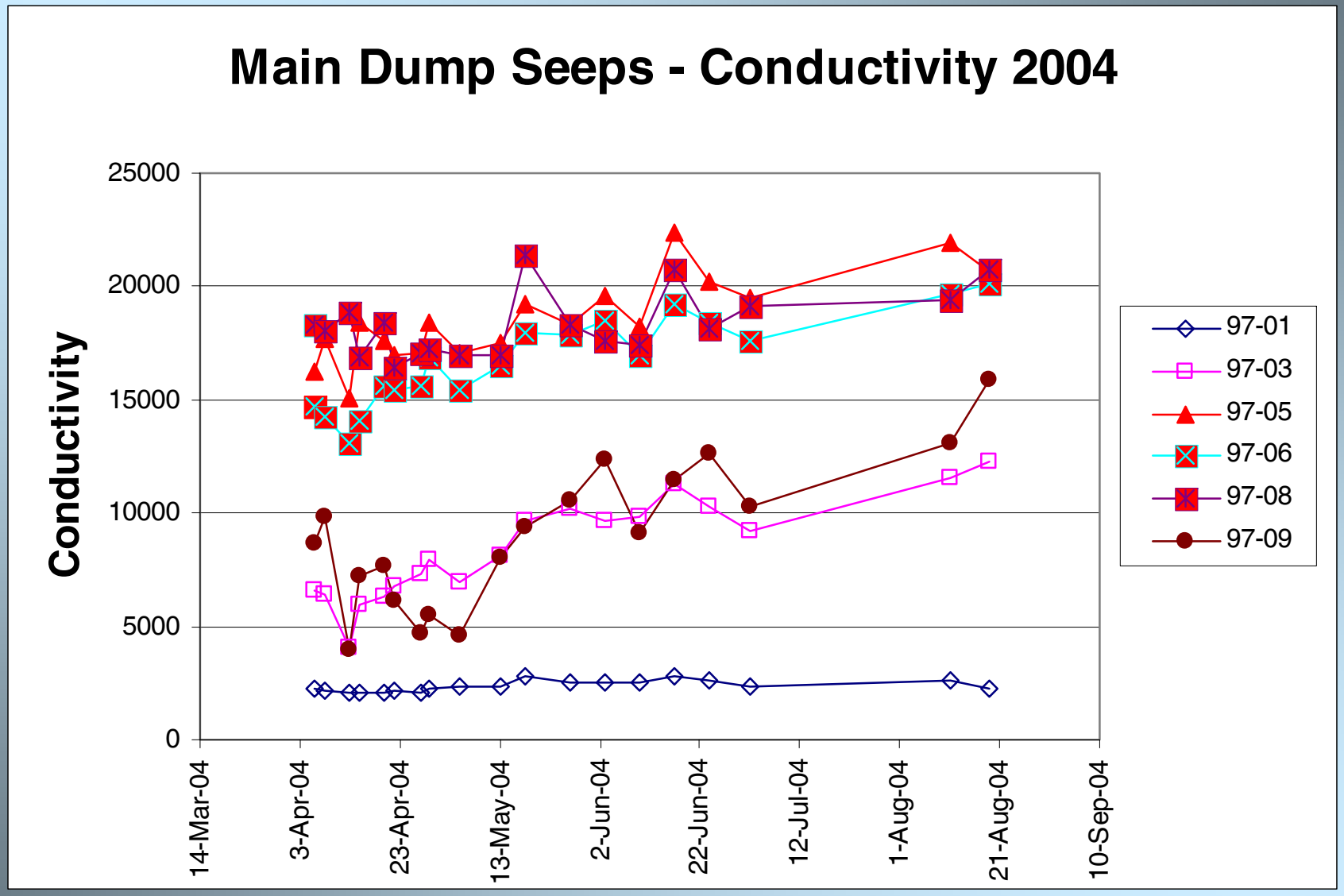
Waste Dump Internal Temperatures
Deep Ports




P-7 TOP OF MAIN DUMP
Oxygen %
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1.0 metres
5.0 metres
18.0 metres
8/12/92
2/12/93
8/12/93
2/12/94
8/12/94
2/12/95
8/12/95
2/12/96
8/12/96
2/12/97
8/12/97
2/12/98
8/12/98
2/12/99
8/12/99
2/12/00
8/12/00
2/12/01
8/12/01
2/12/02
8/12/02
2/12/03
8/12/03
2/12/04
8/12/04

ARD Seeps


ARD Seep Flows - 2004
Flow (l/sec)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
05-Apr-04
25-Apr-04
15-May-04
04-Jun-04
24-Jun-04
14-Jul-04
03-Aug-04
97-01
97-02
97-03
97-04
97-05
97-05B
97-06
97-06B
97-07
97-08
97-09
97-10
97-11


Main Dump Seeps - Conductivity 2004
Conductivity
25000
20000
15000
10000
5000
0
14-Mar-04
3-Apr-04
23-Apr-04
13-May-04
2-Jun-04
22-Jun-04
12-Jul-04
1-Aug-04
21-Aug-04
10-Sep-04
97-01
97-03
97-05
97-06
97-08
97-09

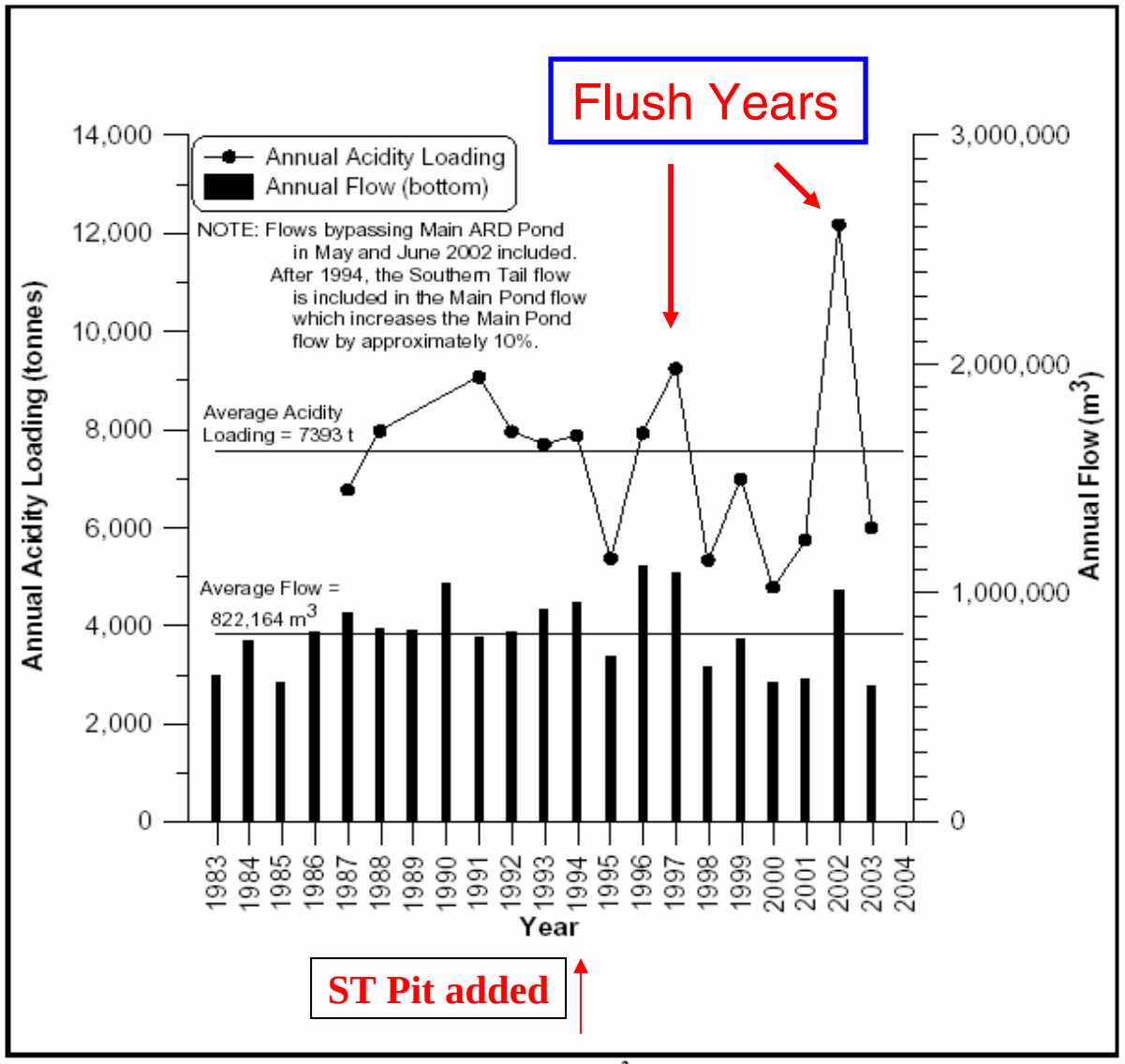
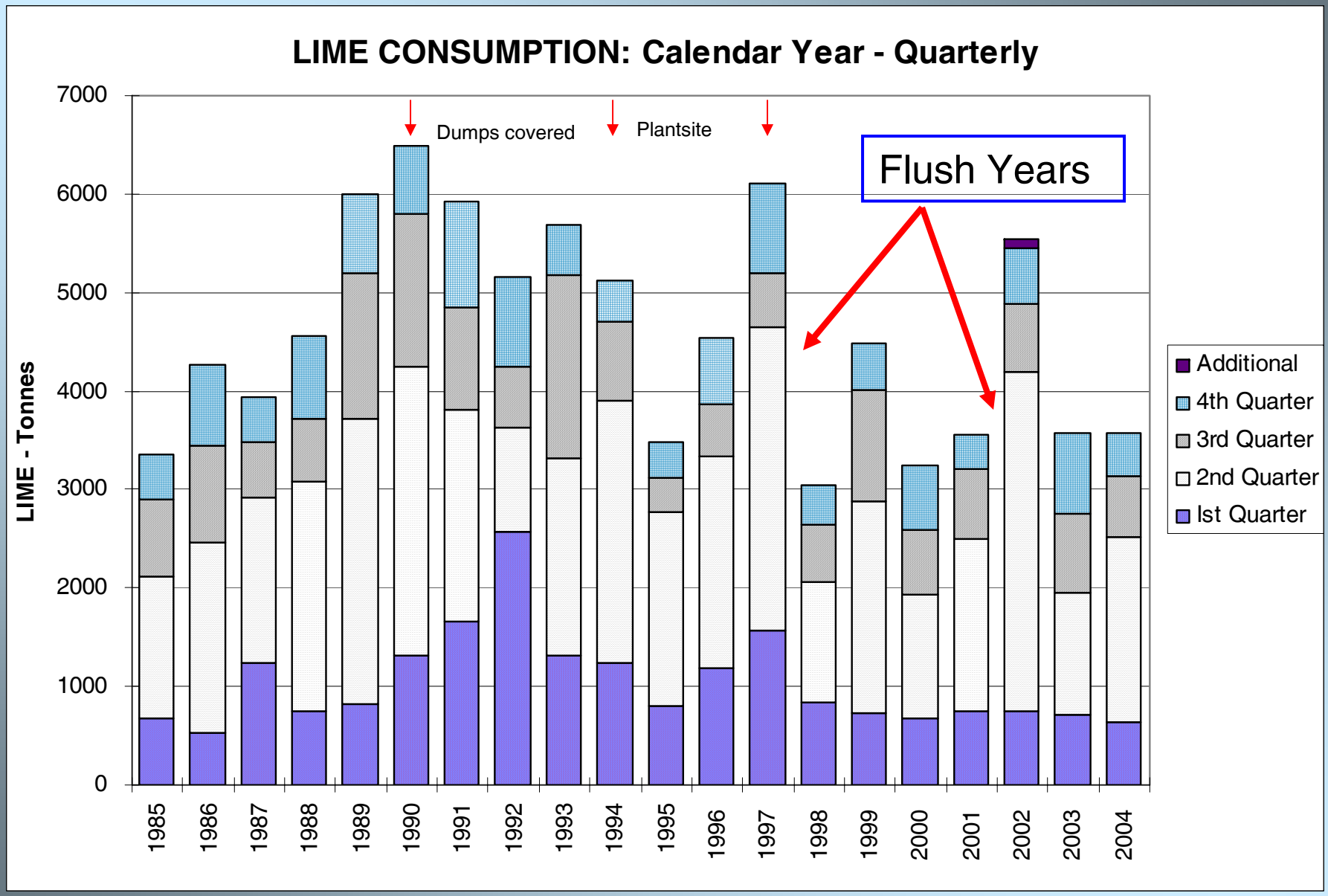
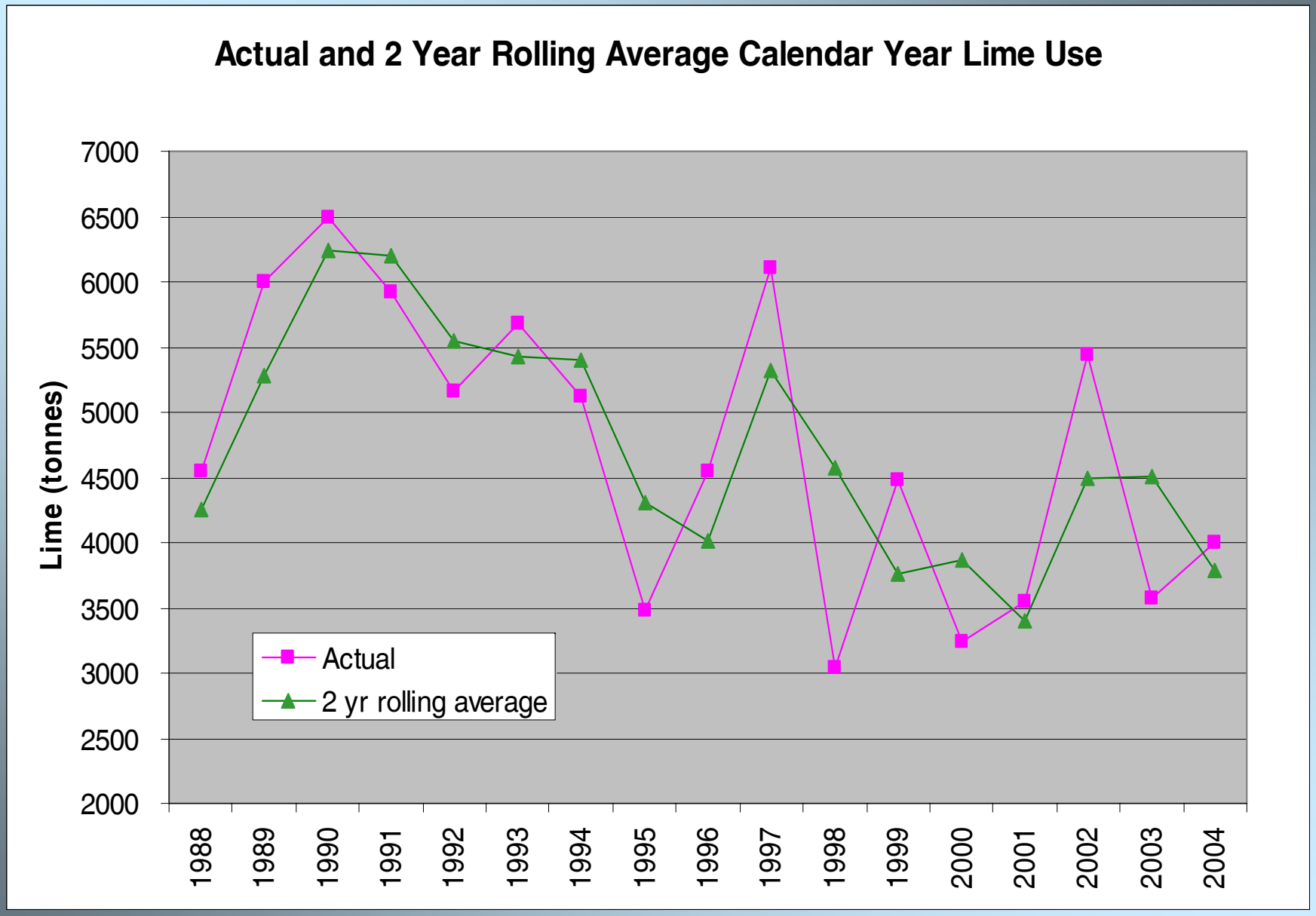


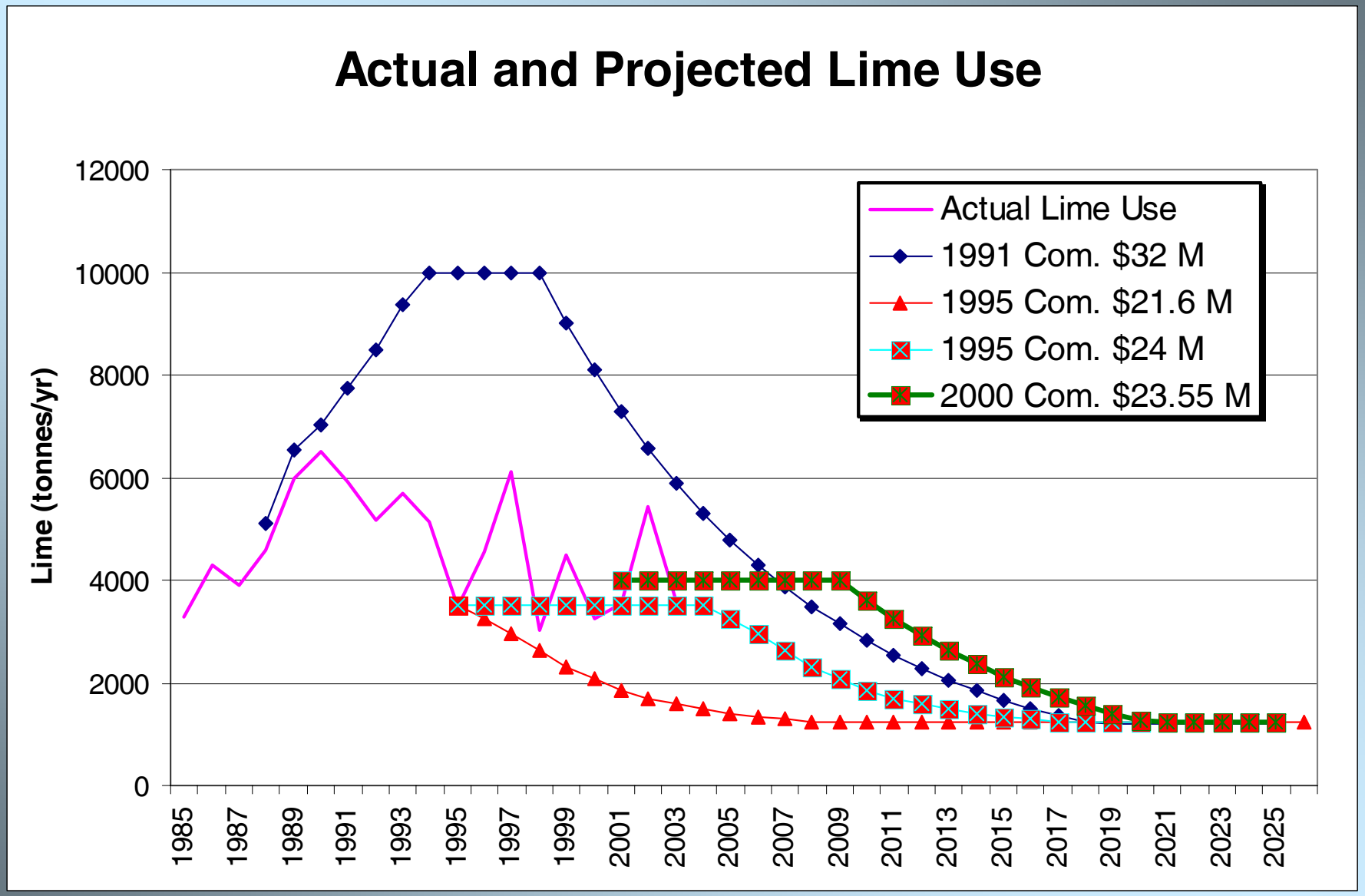
FIGURE 3-6. Time-Series Plot of Annual Flow (m^3) and Annual Acidity Loading (t) for the Main ARD Pond (see also Figures 3-7 and 3-8). NOTE: these and other diagrams with annual flows to the Main ARD Pond include water from the Southern Tail Pit starting in 1994, leading to an approximately 10% increase in annual flow from 1994 onward and thus masking the effect of the cover.

Reproduced from MDAG Report to Equity 2004 (Morin & Hutt)


LIME CONSUMPTION: Calendar Year - Quarterly
LIME - Tonnes
7000
6000
5000
4000
3000
2000
1000
0
Dumps covered
Plantsite
Flush Years
Additional
4th Quarter
3rd Quarter
2nd Quarter
Ist Quarter
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004

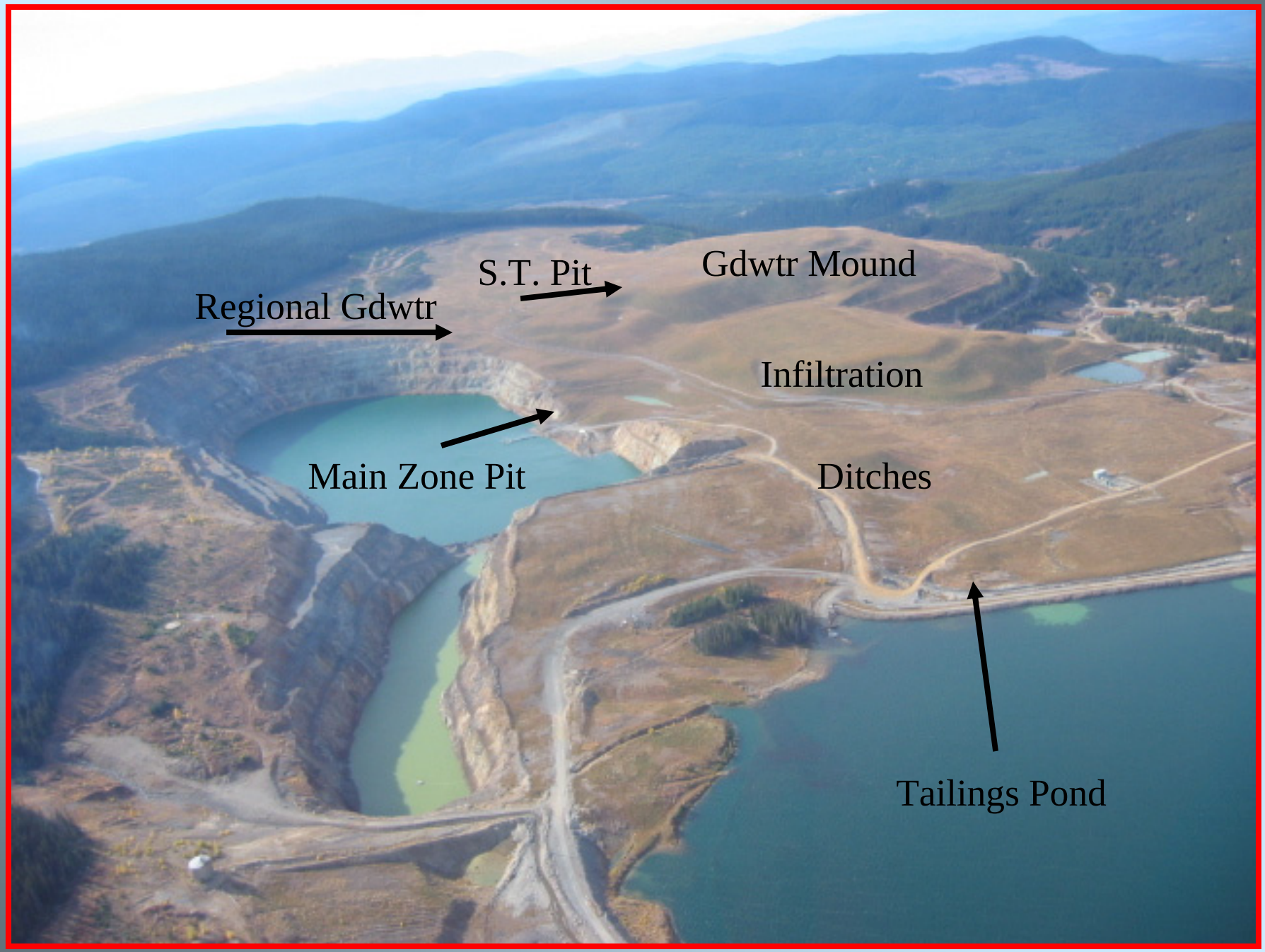

Actual and 2 Year Rolling Average Calendar Year Lime Use
Lime (tonnes)
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
Actual
2 yr rolling average
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004

Actual and Projected Lime Use



What do we know?

- Lime use has dropped from peak and has a general decreasing trend, but predicted decrease much greater
- Lime use is significantly higher than some early projections based on predicted cover performance
  - much higher ARD volumes than expected even with added flows accounted for
- Acidity loading corresponds to precipitation/runoff events
  - no significant change in concentration year to year only seasonal variations based on dilution and flushing
- About 3 day delay from maximum precipitation/runoff to seep flow increase (quick response)
- Increase in some ARD flows seems to be related to groundwater increases (slower response)


S.T. Pit
Gdwtr Mound
Regional Gdwtr
Infiltration
Main Zone Pit
Ditches
Tailings Pond

Where Does all the ARD Come From?

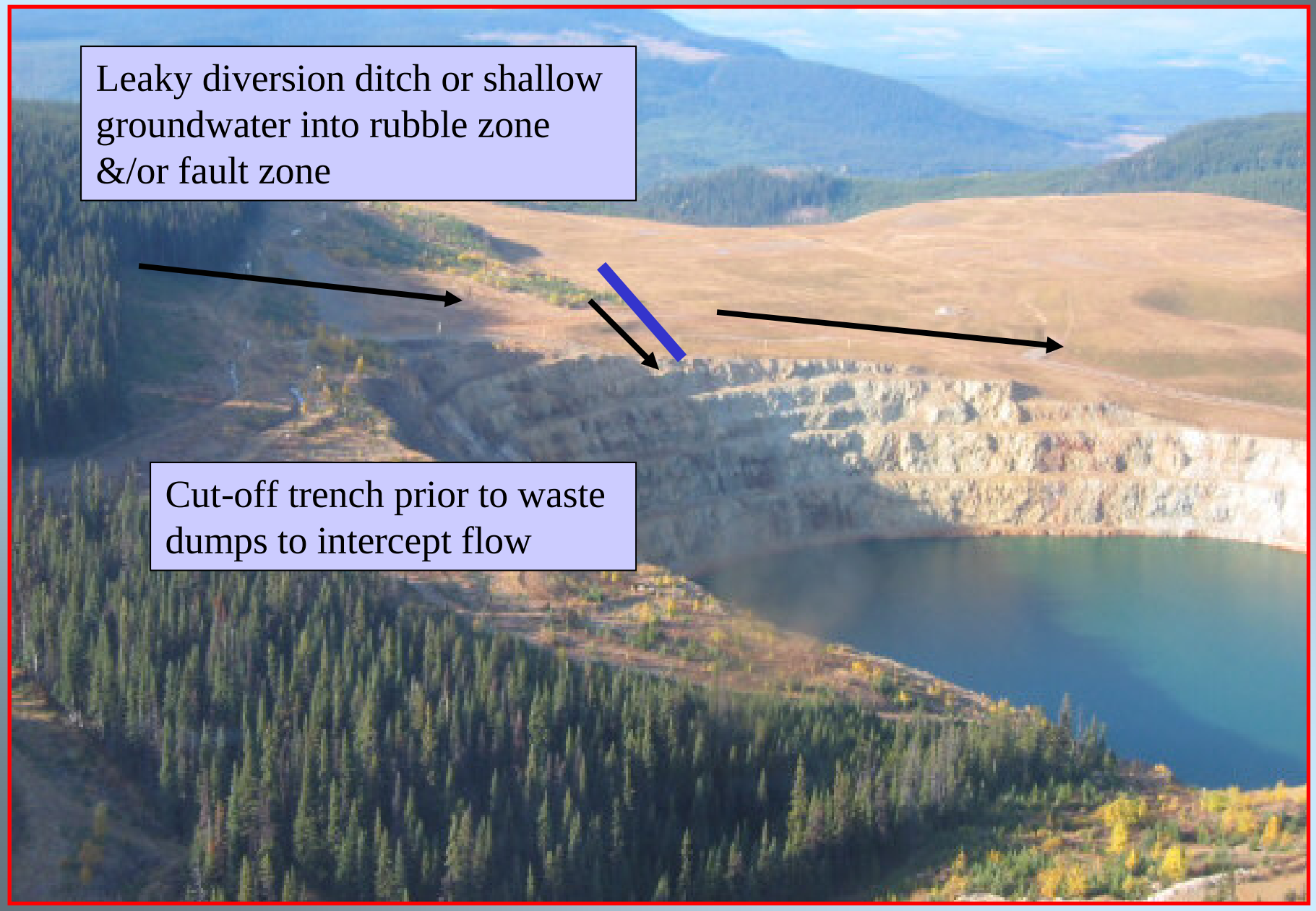
- Main Zone pit groundwater
- Tailing pond groundwater
- Southern Tail pit groundwater
- Groundwater mound in dump
- Regional groundwater (inc. leaking upslope diversion ditches)
- Infiltrating runoff around cover
- Leaking dump runoff ditches
- Infiltration through cover

URS Hydrology Study 1999 - 2001

- Piezometers installed in 1999 (15) and 2000 (13) in and around the waste rock dumps, plantsite, and pits to evaluate theory of groundwater coming in from other sources
- Identified a potential area between Southern Tail and Main Zone pits that might convey shallow groundwater or diversion ditch runoff to waste dump and form ARD
- The study also found that the Southern Tail pit adds some water other than the outflow, the Main Zone pit should be kept below the fractured bedrock elevation, and the tailings pond is adding a low volume to the collection system

Where Does all the ARD Come From?

- ~~Main Zone pit groundwater~~
- ~~Tailing pond groundwater~~
- ~~Southern Tail pit groundwater~~
- ~~Groundwater mound in dump~~
- Regional groundwater (inc. leaking upslope diversion ditches)
- Infiltrating runoff around cap
- Leaking dump runoff ditches
- Infiltration through cap


Leaky diversion ditch or shallow groundwater into rubble zone &/or fault zone
Cut-off trench prior to waste dumps to intercept flow

Consequences of getting the hydrology wrong

- 1997 – Diverted low strength ARD to environment
  - Insufficient ARD pumping capacity at Main Pond
  - Decreased ARD collection catchment, but only minor pumping improvements – see if ARD could be decreased
- 2002 – Diverted low strength ARD, under-treated ARD
  - Insufficient ARD pumping capacity at Main Pond
  - Insufficient treatment capacity
  - Insufficient ARD storage capacity
- Extensive upgrades to the ARD collection and treatment system
  - New pumphouse and pipelines for Main Pond (2002)
  - Increased ARD storage and treated water capacity (2002)
  - New HDS treatment plant (2003)
  - Working on significantly increasing ARD storage (2003 - ?)

Water Management Consultants
Waste dump water Balance (2002)

- Produced a groundwater/surface water model based on flows and groundwater levels
- Conclusions:
  - Majority of ARD collected derived from local rainfall and snowmelt (60 to 80%)
    - Direct runoff from waste dump ~ 30%
    - Infiltration through cover ~ 30 to 50%
    - Discharge of groundwater below diversion ditches
  - Groundwater from outside the collection system (grdwtr, MZ pit, tailings) ~ 10 to 15% or 35 to 40% of ARD collected
  - Infiltration through or around cover ~ 20 to 35%
    - Infiltration not through compacted cover material but through cover discontinuities (cracks or construction flaws)

Cover Studies Since Closure

When	Who	What	Main Conclusions
1995	Swanson (U of Sask)	modelling of soil cover (SoilCover)	3% net infiltration, hydraulic cond 2.0 x 10^{-10} m/s
1996	O'Kane (U of Sask)	original monitoring of soil cover	compacted layer well saturated, infiltration limited, oxygen reduced
1998	Saretzky (U of Sask)	first water balance of waste dump	ARD = 9% runoff, 11% infiltration, 1% storage, 79% groundwater
1998	Merz (Golder)	site hydrology study (snowmelt)	review of pumping and storage capacities for ARD
2000	Wilber (URS)	evaluation of groundwater contribution to ARD	groundwater above pits may be influencing ARD, keep MZ low
2001	Reinson (UBC)	field permeability testing on cover	hydraulic conductivities between 7.2 x 10^{-8} to 3.7 x 10^{-6} m/s
2001	Wilbur (URS)	evaluation of groundwater contribution to ARD	identified area between pits as potential groundwater conduit
2002	Parkinson (Klohn)	geophysical investigation into groundwater	diversion ditches or fault zone could be adding to ARD collection
2002	Smith (WMC)	water balance of waste dump	infiltration through or around cover 20 to 35%, discontinuities
2003	Nichol (UBC)	cover infiltration monitoring in field	hydraulic conductivities between 1.0 x 10^{-8} to 5.0 x 10^{-7} m/s
2003	Johnston (UBC)	cover infiltration modelling	infiltration ranges between 4 to 14% through cover
2003	O'Kane (for INAP)	long term performance of dry covers	upper 10 cm of compacted layer evolving through wet/dry cycles
2004	Morin & Hutt (MDAG)	evaluation of ARD mechanisms	geochemical mass balance mechanism most likely for ARD loadings
2004	Weeks (UBC)	3 D energy model of cover	slope aspect and angle will influence evaporation and infiltration

Uncertainties and Challenges

- Identify source of additional ARD & evaluate cover performance
  - tracer study on dump cover and beyond
  - testing of diversion ditches
  - regional groundwater cut-off trench
  - problems with measuring direct runoff
- Maintenance requirements
  - erosion and woody species over long term
- Long-term evolution of cover
  - testing of cover integrity with time
  - root penetration
- New technologies
  - cover improvements

Conclusions

- Cover construction was straight forward and maintenance has been simpler and less costly than expected
- The Equity cover has reduced ARD production, but not to the degree that was predicted by various models
- Waste rock dump water balances are complicated
  - best to ensure the collection & treatment systems are designed for more volume/acidity than expected
- Other sources of water have been identified to be contributing to ARD production, but have not been able to quantify yet
- Further studies of water sources and long-term performance of the cover are required.
- The construction and monitoring of the Equity cover has progressed the knowledge base on covers for Equity and other sites and will continue to do so into the future

Post Closure Studies Related to Cover

Jan-95	**Predictive Modelling** of Moisture Movements in Engineered Soil Covers for Acid Generating Mine Wastes	Darren Swanson, University of Saskatchewan	Master's Thesis
Aug-95	A Report on the **Performance** of the Engineered Soil Cover System at Equity Mines Ltd.	M. O'Kane & GW Wilson, University of Saskatchewan	
Oct-95	An **Erosion Study** on the Engineered Soil Cover System at Equity Silver Mines Ltd. Final Report	Lawrence Owuputi, University of Saskatchewan	
Nov-95	**Thermal Analysis** of Equity Mine Waste Rock Dump	Greg Newman, University of Saskatchewan	
Feb-96	Report of the 1995 **Security Review**	Peter Adams, Semmens & Adams	First scheduled review of original security
Oct-96	**Instrumentation and Monitoring** of an Engineered Soil Cover System for Acid Generating Mine Waste	Mike O'Kane, University of Saskatchewan	Master's Thesis
Jul-97	**ARD Pumping System Capacity Assessment** and Improvements	Placer Dome Project Development Division	
Aug-98	Equity Silver Mine **Hydrology** Study	Russell Merz, Golder Associates	
Oct-98	**Hydrological Characterization** of a Sulphide Waste Rock Dump	Greg Saretzky, University of Saskatchewan	Master's Thesis
Sep-00	Evaluation of **Groundwater Contribution** to ARD Seeps	Steve Wilbur, URS-Norecol Dames & Moore	
Apr-01	Summary of 2000 **Groundwater Investigation** and Recommended Remedial Action, Equity Silver Mine	Steve Wilbur, Dave Harpley, URS Corp.	
Jun-01	Report of the 2000 **Security Review**	Bill Price et al.	Second scheduled review of original security
Nov-01	Equity Division: Waste Dump and Tailings Dam Areas DC Resistivity and IP **Geophysical Surveys**	Graham Parkinson, Klohn Crippen	
Dec-02	Equity Silver - Waste Dump **Water Balance**	Rod Smith, Water Management Consultants	
Mar-03	Evaluation of the **Long Term Performance** of Dry Covers for INAP	M. O'Kane, O'Kane Consultants Inc.	INAP Report
Dec-03	Case Study and Sensitivity Analysis of the **Performance** of the Waste Rock Cover System at Equity	K. Johnston, UBC	Master's Thesis
Dec-03	Equity Division - 2002 Review and Prediction of Acid Rock Drainage	Morin & Hutt, MDAG	
Oct-04	Equity Division - Review of 2003 ARD and Assessment of **ARD Mechanisms**	Morin & Hutt, MDAG	