C.1. Overview of UBC Waste Rock Hydrology Research Program

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Waste Rock Hydrology Research Program

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Lee Barbour
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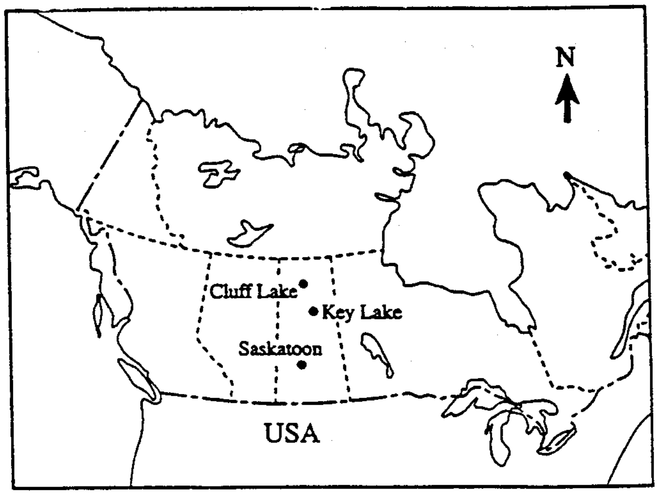
Partners

Cameco Inc.
Cogema Resources
Natural Sciences and Engineering Research Council of Canada (IOR)

Project Schedule: 1998-2003

Research Projects



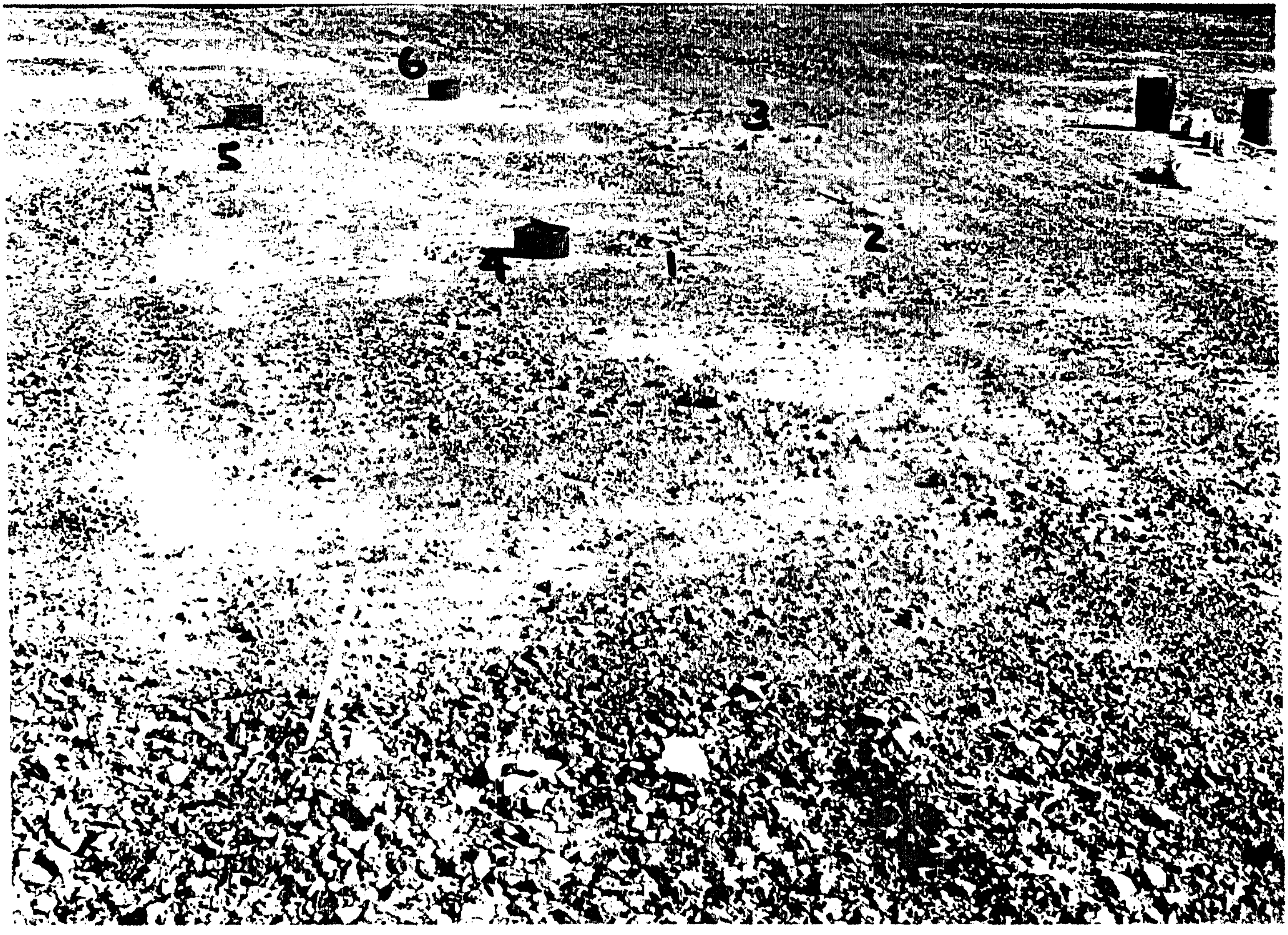
1. Waste Rock Hydrology (Smith / Beckie)
   - surface infiltration mechanisms and fluid flow processes within a waste rock pile

2. Geochemical Weathering Rates (Hendry)
   - CO_2 profiling, rapid kinetic tests

3. Instrumentation / Waste Rock Weathering (Barbour)
   - standpipe lysimeters, gas diffusion tests to monitor moisture content
   - changes in hydraulic properties with time

4. Surface Flux Boundary Evaluation (Wilson)
   - CO_2 and O_2 transport, infiltration, evaporation

5. Environmental Loading (Beckie)
   - metal release, linkage to hydrology, scale effects in prediction



Claude east catchment 2

Claude east catchment 2 34m x 13m

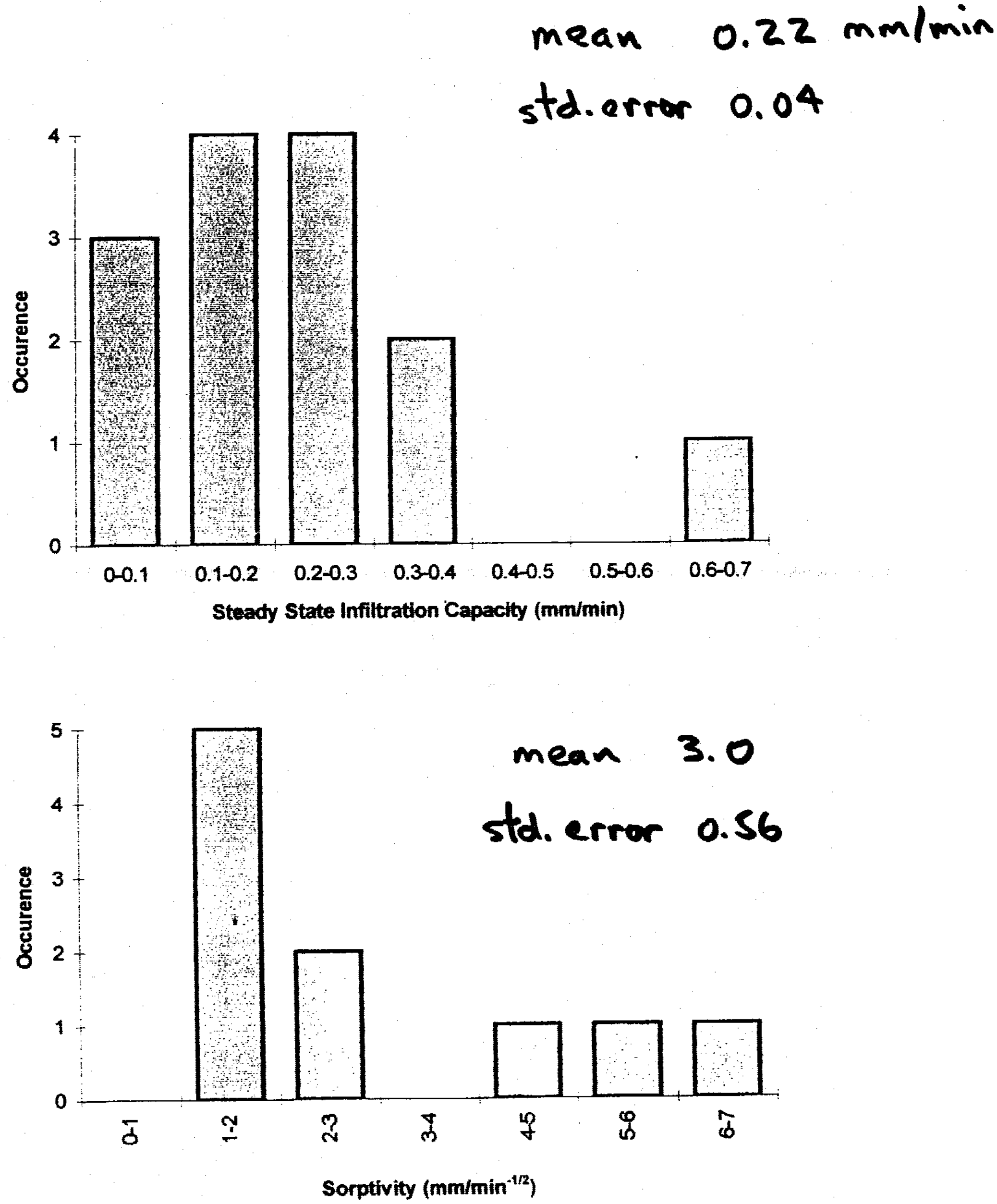


Figure 4-2: Frequency histogram for infiltration parameters measured in Catchment 2. a) Steady state infiltration capacity and b) field sorptivity.

catchment 7

Runoff To Catchment Drains

Observation: Catchment 7 (area 195 m^2)

Rainfall typical of a summer thundershower
(8.6 mm in 22 minutes)

92% infiltration to matrix through surface 8% to catchment drain

Predictions: Based on Infiltrometer Measurements

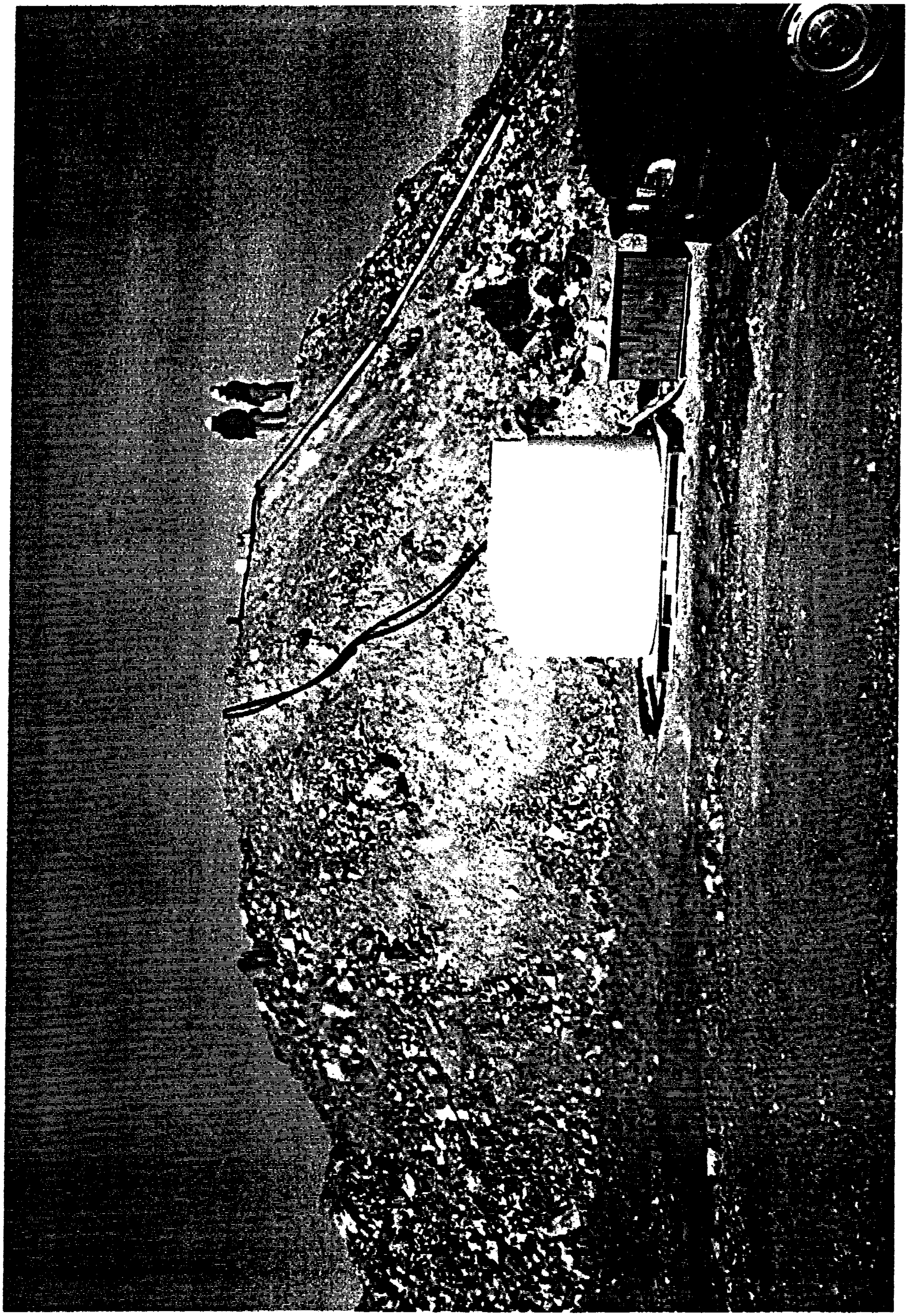
Catchment 2 - 387 m^2
Catchment 8 - 76 m^2

Typical summer thundershower:

water reporting to catchment drains 9 – 12 %

July 1997 storm (18.3 mm in 1 hr - 5 year return)

water reporting to catchment drains 42 – 46 %



Constructed Pile Experiment

Objectives for Phase I

- What physical mechanisms control the flow of water within a waste rock pile, and how does rapid flow relate to matrix water within the pile?

- What precipitation and surface conditions permit the initiation of rapid flow of water?

- What is the degree of spatial variability in unsaturated flow through a waste rock pile?

- What physical measurements of waste rock properties are critical to the characterization of flow in waste rock?

Objectives for Phase II

- What are the relationships between rapid flow, matrix flow, and the time-dependent release of metals from the pile?

- What is the degree of spatial variability in metal loadings?

- What are the relationships between the scale of measurement and prediction of the release of metals from the constructed pile?

Waste Rock in Constructed Pile Experiment

- Peter River Gneiss / Mineralized Zones
- Average total sulphur < 0.6%
- Average neutralization potential - 9.2 kg $CaCO_3$/t
- NP:AP average 2.0 (range 13.2 – 0.1)

Drainage Water Chemistry

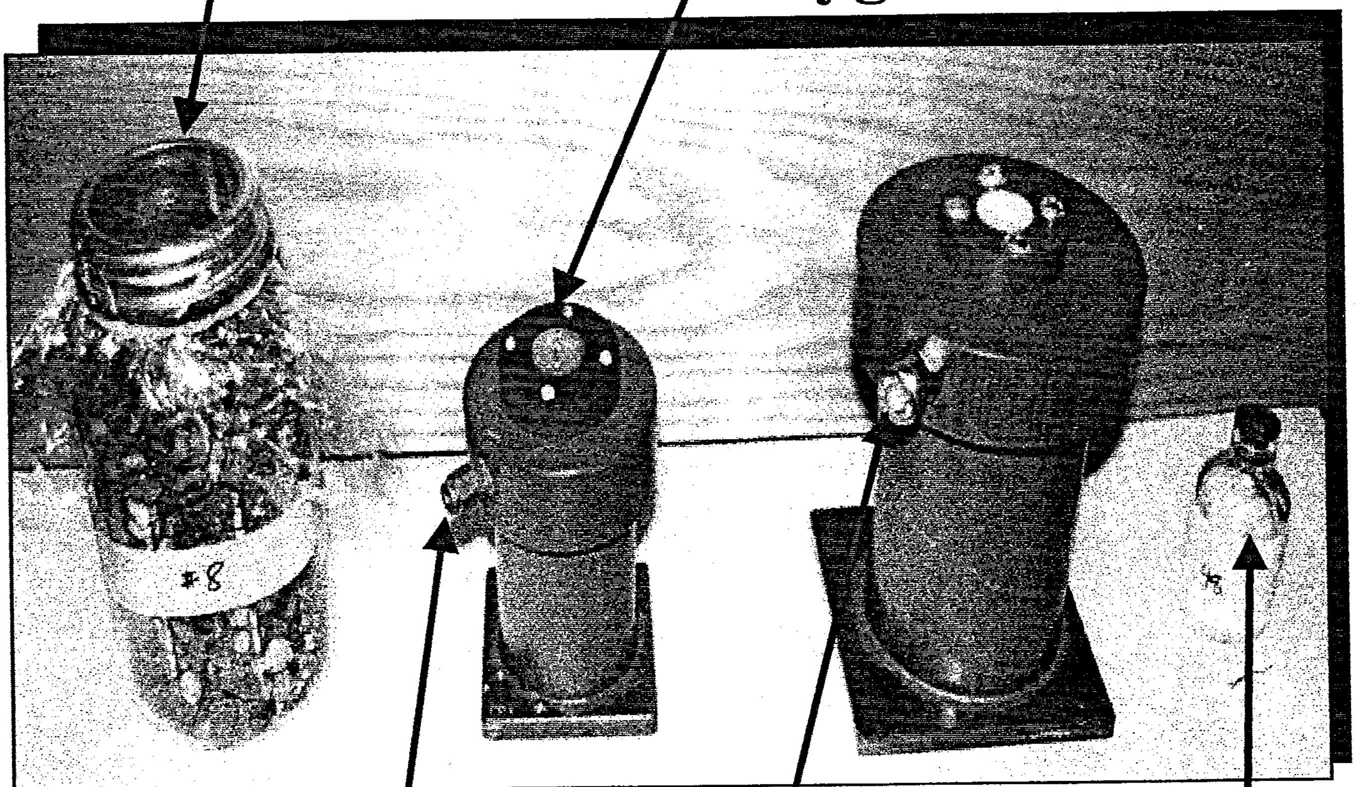
(Outflow Gauge 15 – Sampled June 6/99 – mg/l)

Chloride	28
Sulphate	19300
Aluminum	725
Calcium	488
Magnesium	3130
nickel	190
sodium	831
zinc	5
pH	3.2 – 3.8
uranium	~ 200

Laboratory Program (Kinetic Rates)

Humidity Cell 1000 ml.

Kinetic Cells Oxygen Sensor



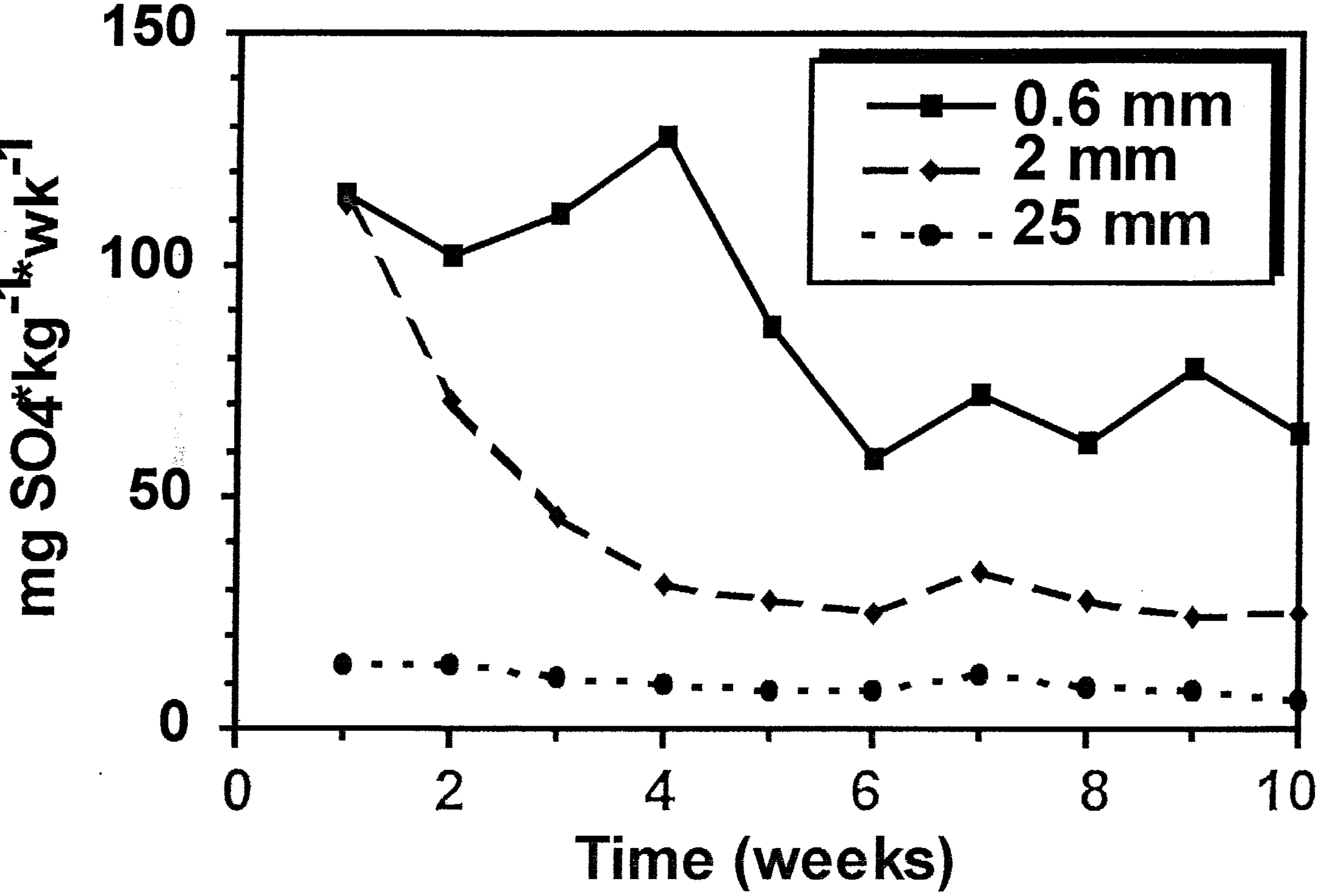
500 ml. with Septum

150 ml. with Air Vent

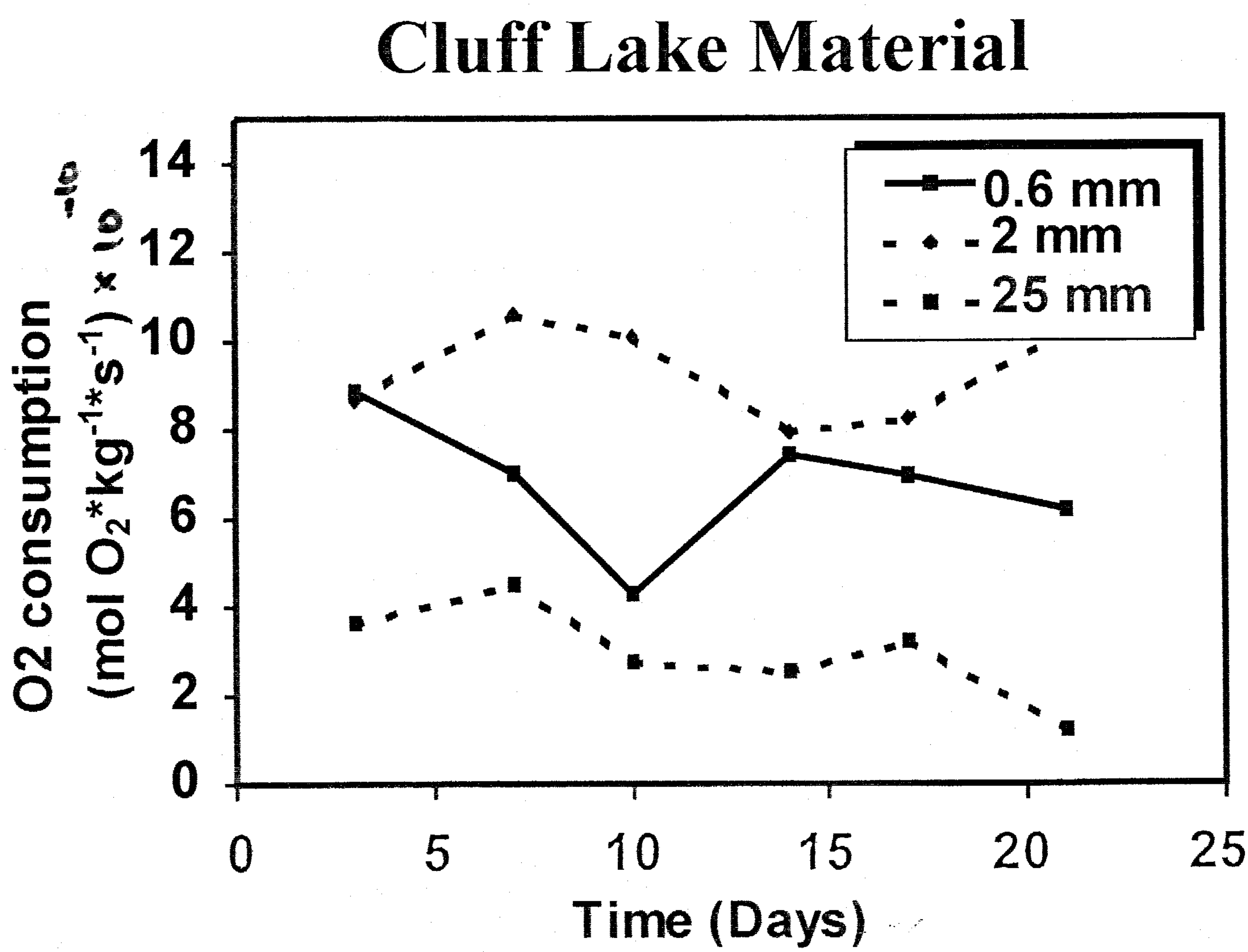
50 ml. Serum Bottle with Septum

Humidity Cell: SO_4 Release Rates

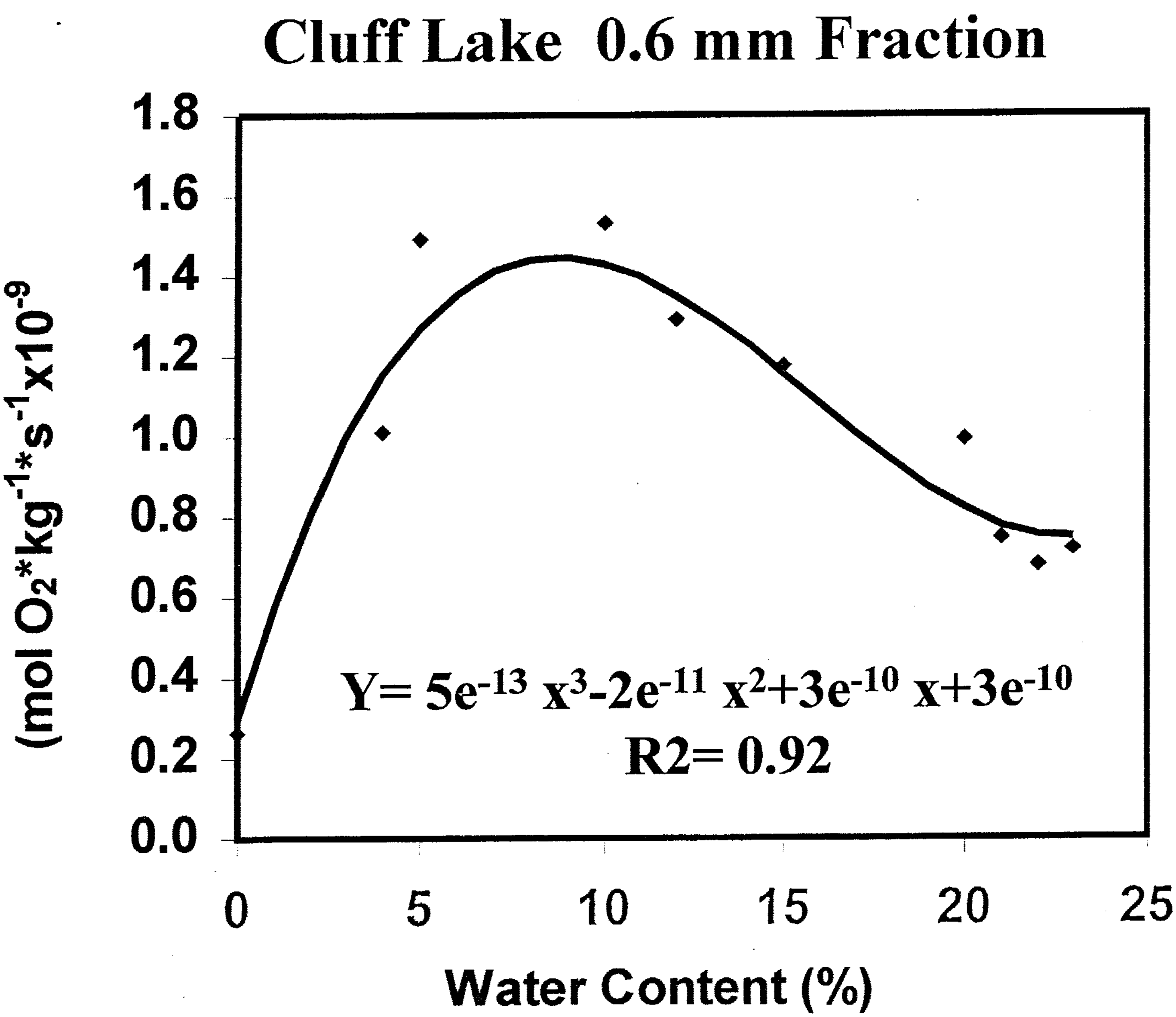
Cluff Lake Material



Kinetic Cell:
O_2 consumption versus Time



Kinetic Rate vs. Water Content

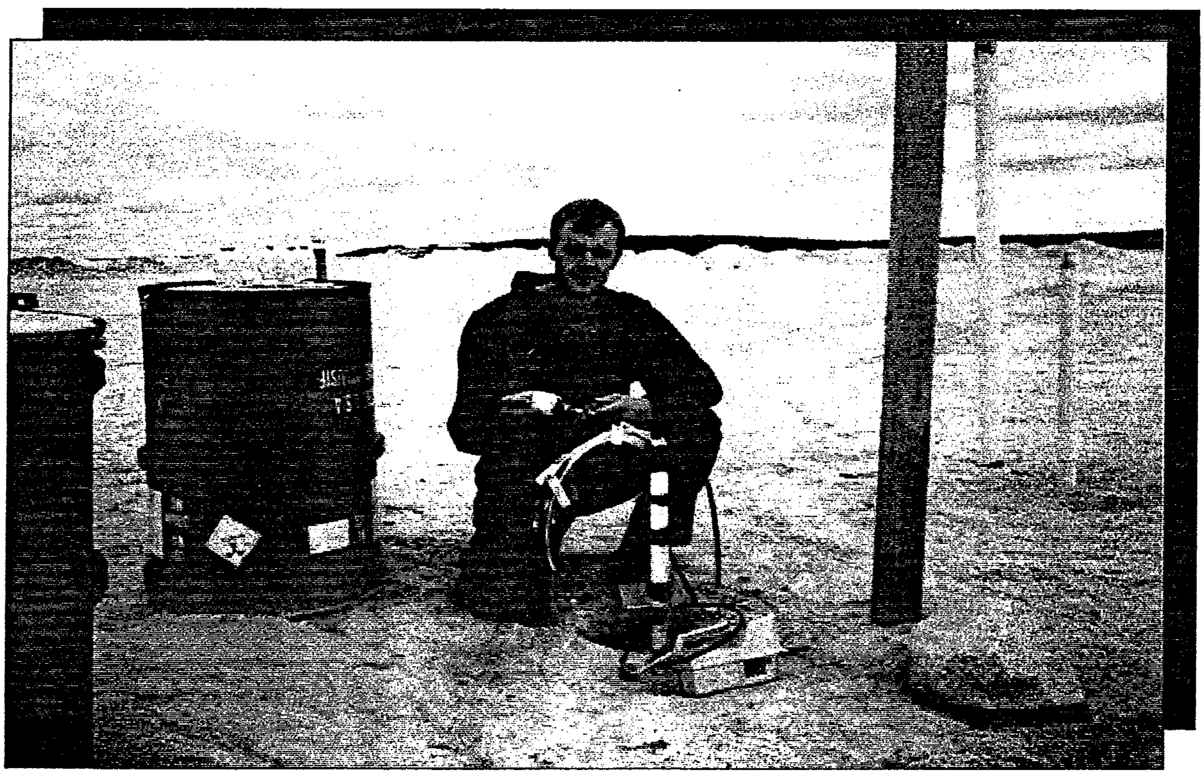


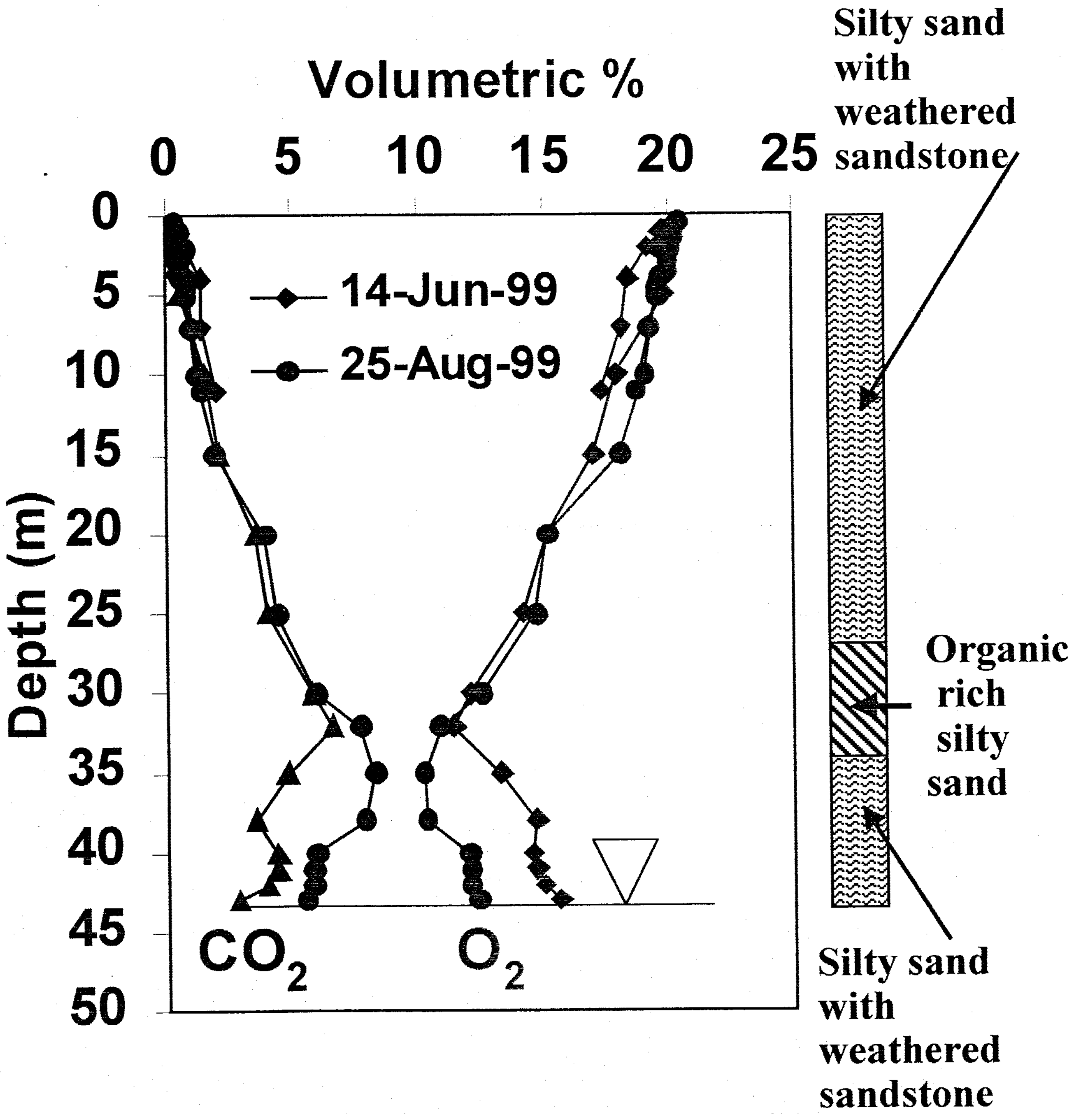
Key Lake Field Program -
Measurement of Gas Transport for Geochemical Weathering Rates

- **Measure O_2 and CO_2** concentrations of pore gas in the waste rock
- **Measure moisture contents** and temperatures in the waste rock
- **Model O_2 consumption and** CO_2 production rates using measured field conditions

Dielmann South Pile

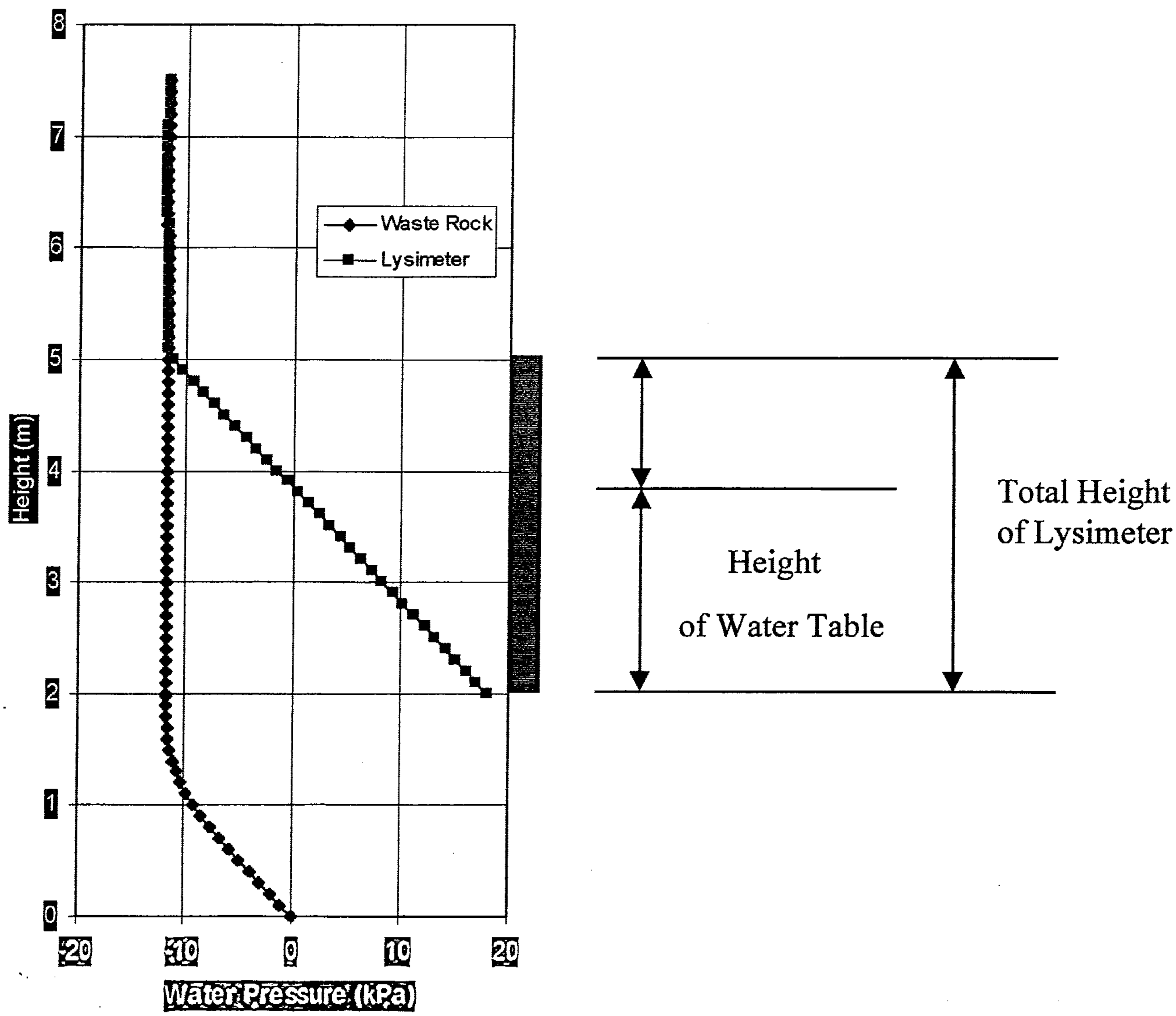
- **Centrally located; no** lateral effects
- **Well-instrumented;**
  - **30 gas probes to water table** (43 m deep)
- **Kinetic cell testing**




Volumetric %
0
5
10
15
20
25
Depth (m)
0
5
10
15
20
25
30
35
40
45
50
14-Jun-99
25-Aug-99
CO_2
O_2
Silty sand with weathered sandstone
Organic rich silty sand
Silty sand with weathered sandstone

Standpipe Lysimeter: Operating Principle

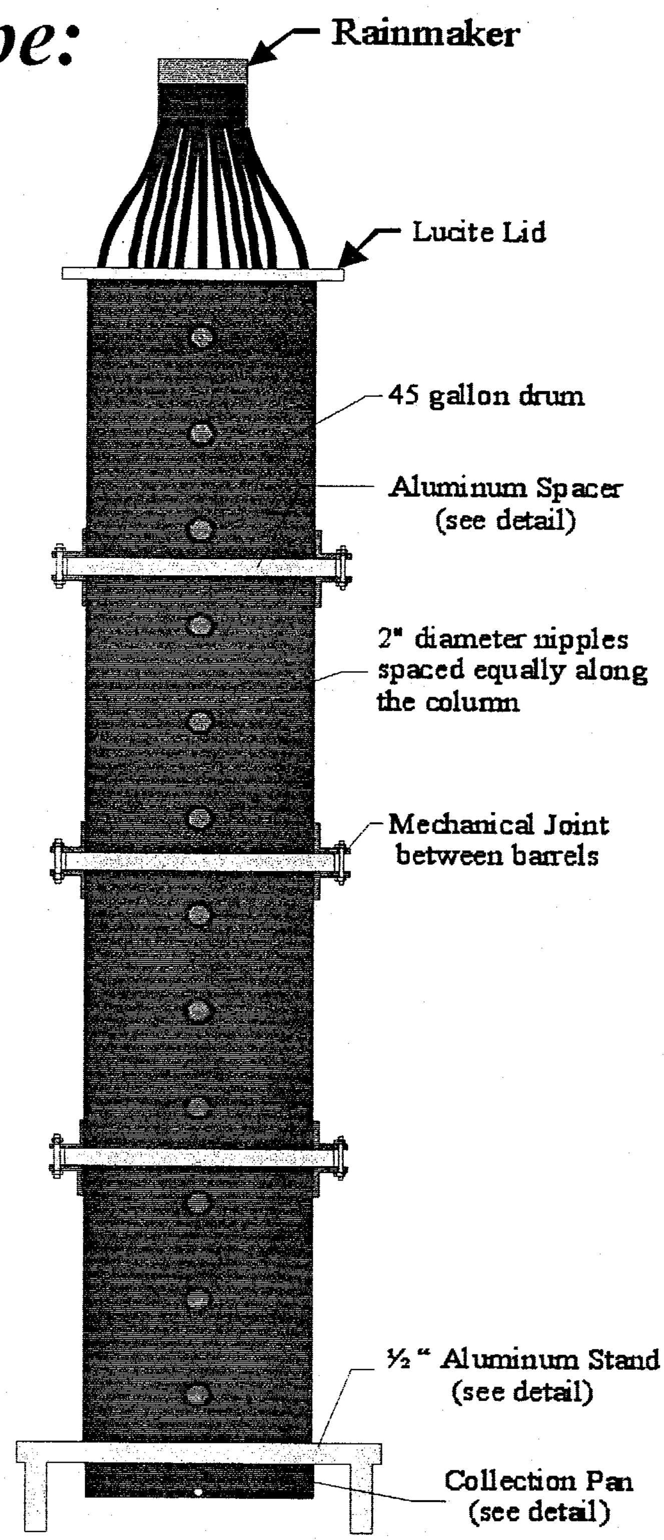
- **Install standpipe of tension saturated silica flour**
  - **closed at base / open at top**
- **Allow inflow/outflow to equilibrate suction with** waste rock
- **Measure the 'water table' elevation within standpipe**
- **Suction at top of standpipe estimated based on** hydrostatic conditions within silica flour



Pressure Head in Waste Rock Pile = Total Height - Height of Water Table

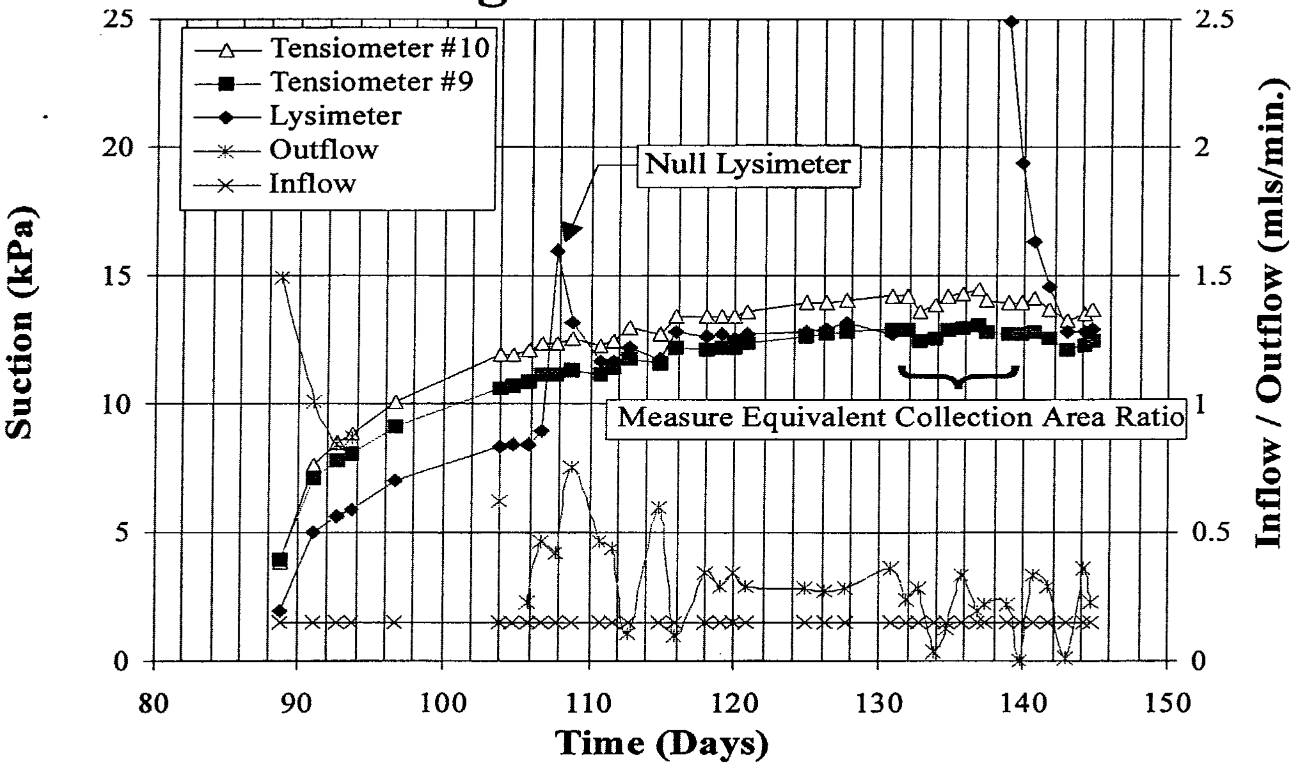
Laboratory Prototype:

- **Applied Flux (% of Precipitation)**
  - **Rainmaker**
- **Measure Suction**
  - **Tensiometers**
- **Lysimeter**
  - **Measure suction (lysimeter closed)**
  - **Sample collection (lysimeter drained)**

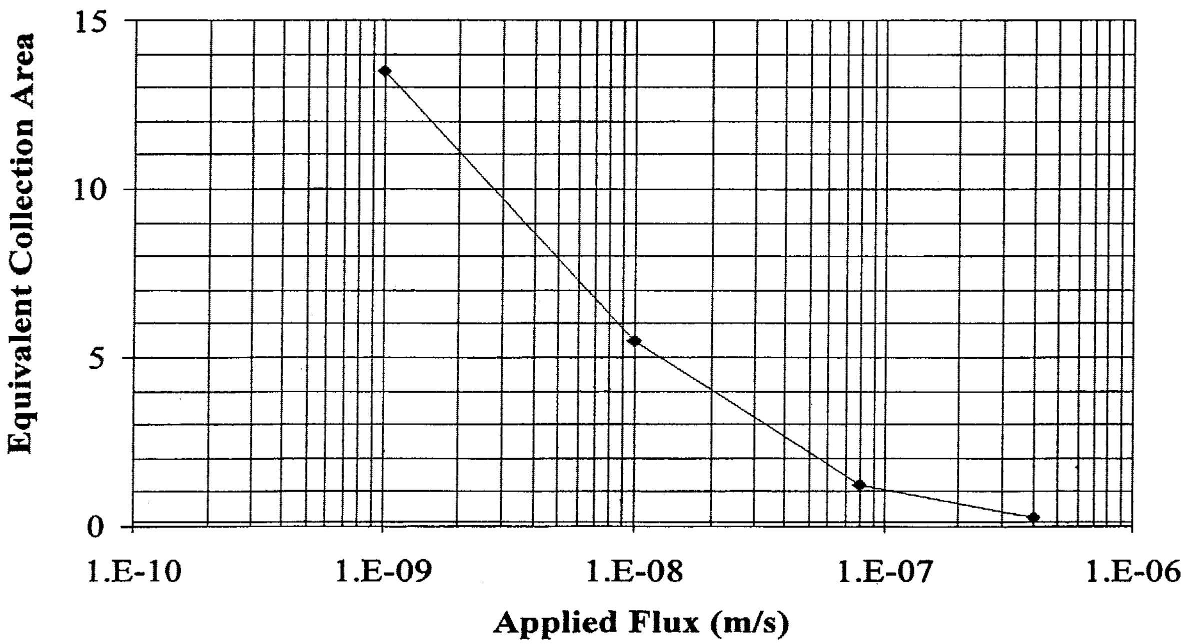


Example of Test Results:

- **Monitoring of Suction:**

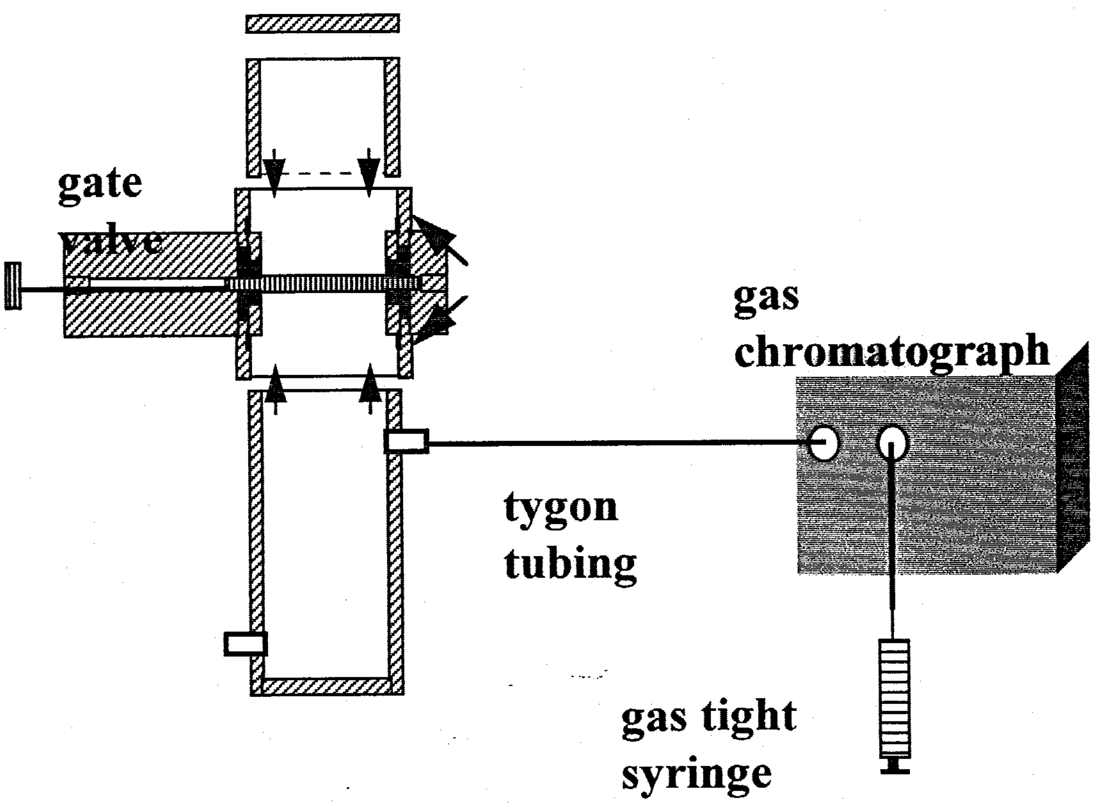


- **Equivalent Collection Area:**
  - **Qlysimeter/Qapplied**

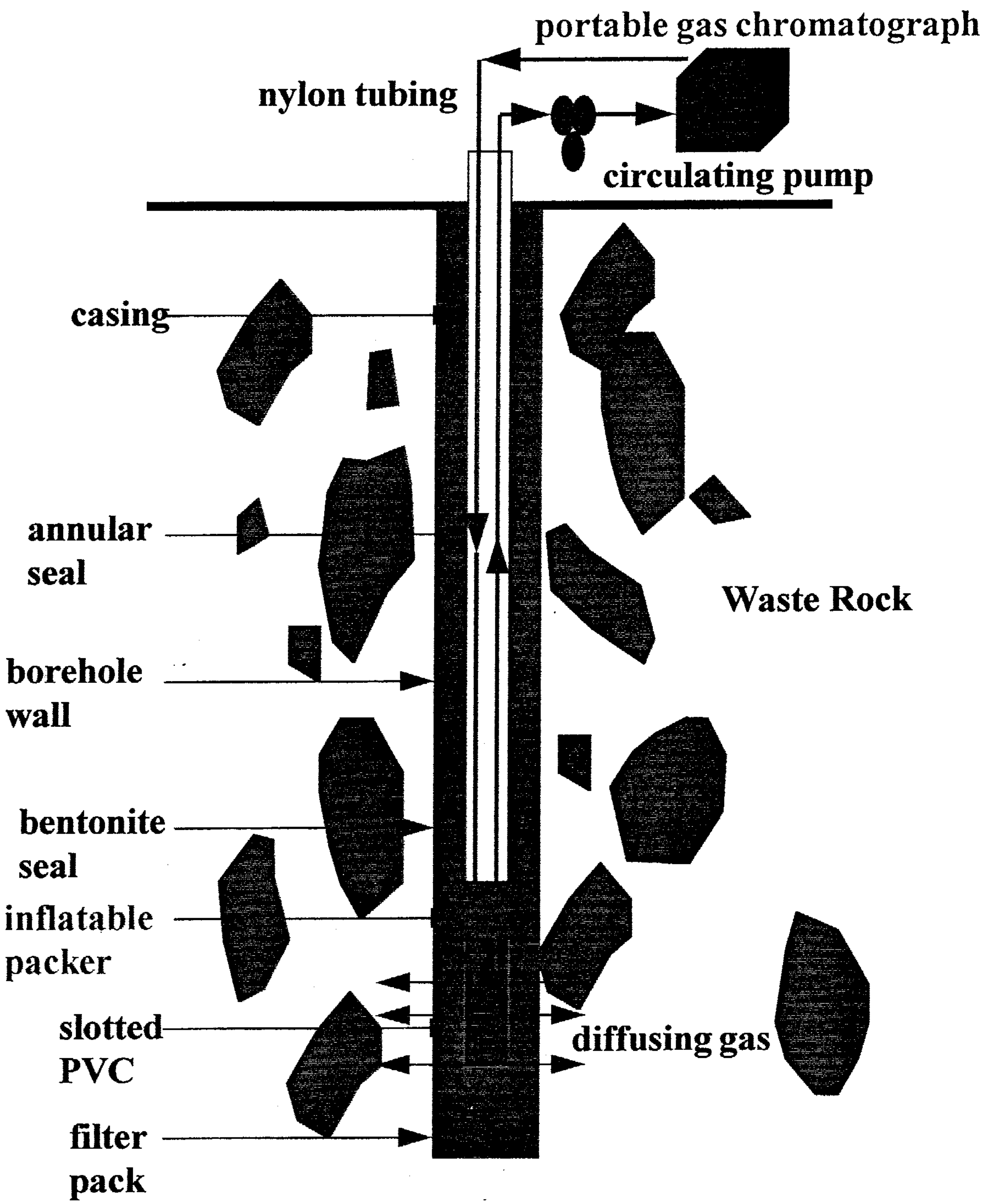


Insitu Gas-Diffusion Test:

- Principle of Operation:
  - Diffusion Coefficient fnc of water content
  - Measure diffusion coefficient
    - Insoluble gas .... Diffusion coefficient
    - Soluble gas ... Diffusion coefficient and water content
- Laboratory Verification:
  - Vary water content of waste rock at known air and water content
  - Measure rate of diffusion of soluble and insoluble gas



Prototype Field Installation Design:



Evaluation of Surface Flux Boundary Conditions

Objectives:

- **Characterization of surface fluxes (temporal and spatial)**
  - **Infiltration (Liquid)**
  - **Evaporation (Vapour)**
  - **Gases (CO_2/O_2)**
  - **Heat**
- **Describe the influence of climate on internal fluid and gas transfer processes**
- **Predict long term fluxes for waste rock dumps with various closure options**

Methods of Measurement

I. Traditional Methods:

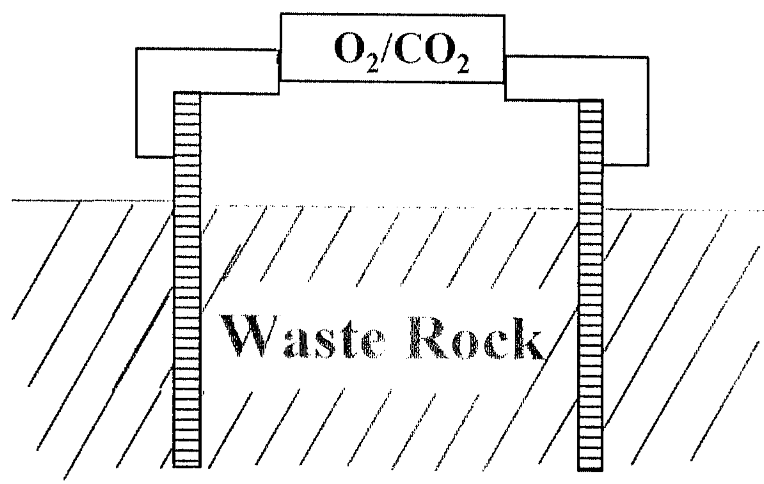
- **Flux Gradient**

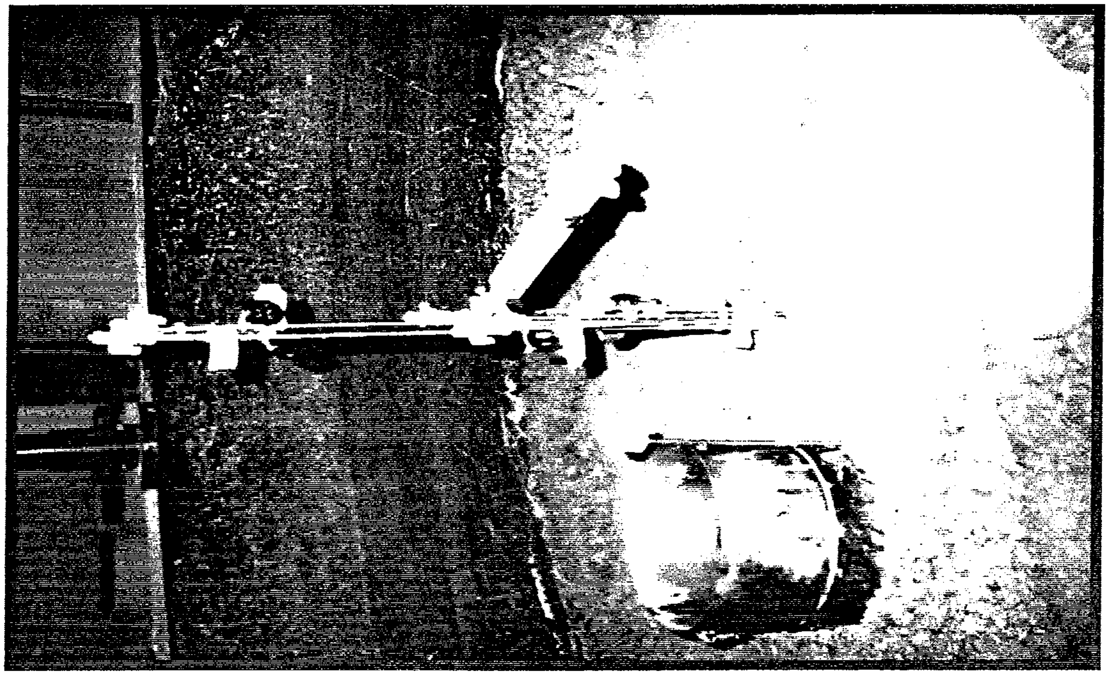
$$F = -D_e \frac{dC}{dz}$$

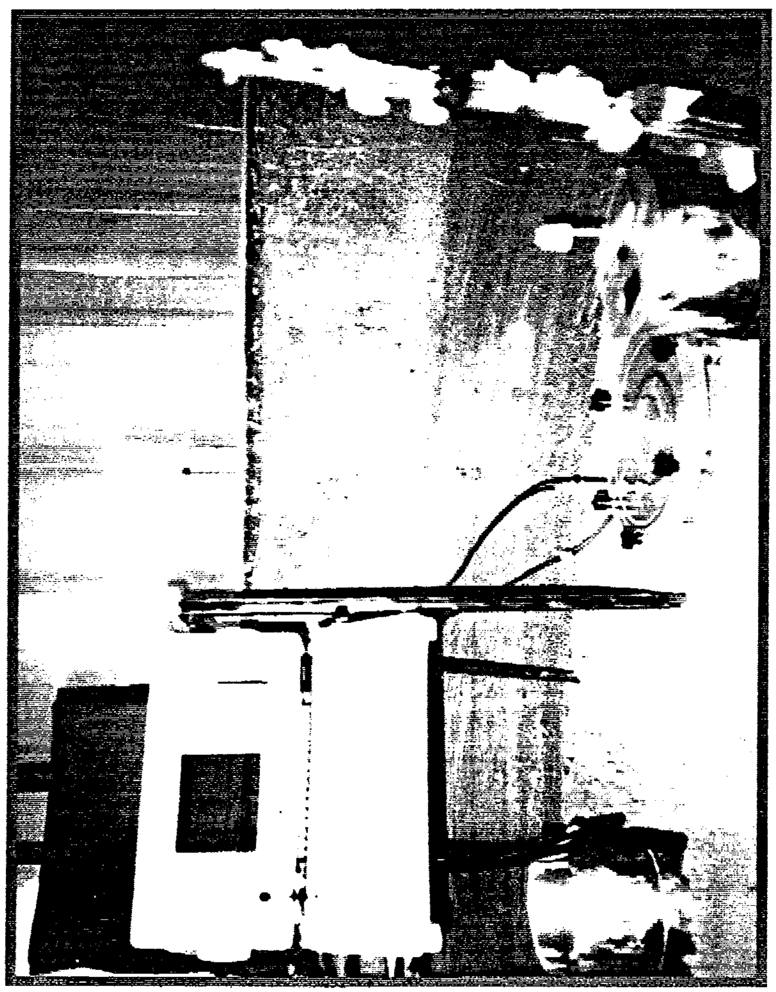
- **Mass Balance of Products**
- **Gas Trapping (alkaline)**

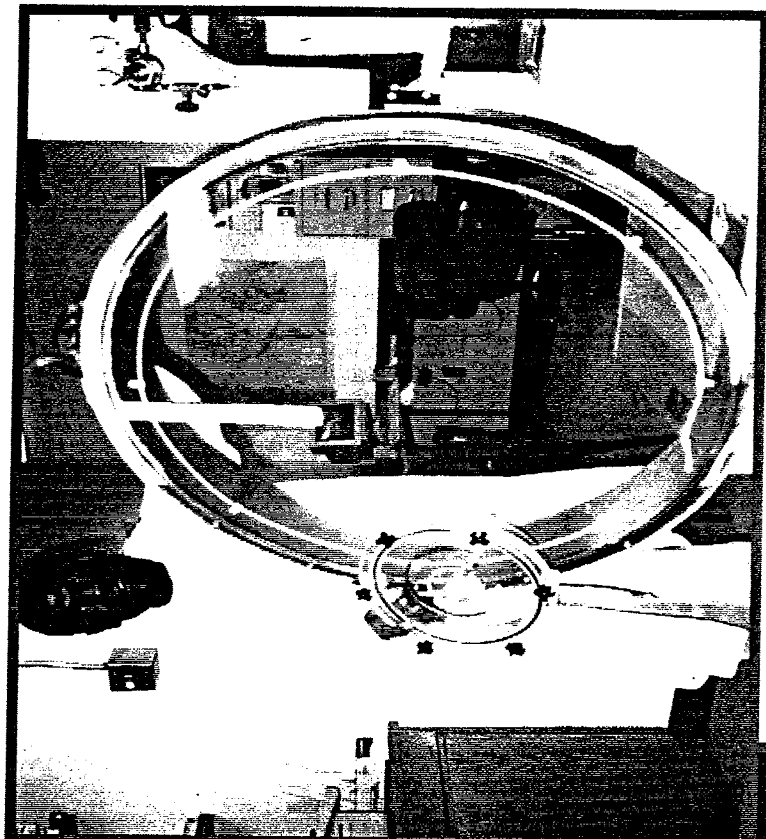
II. Alternative Method:

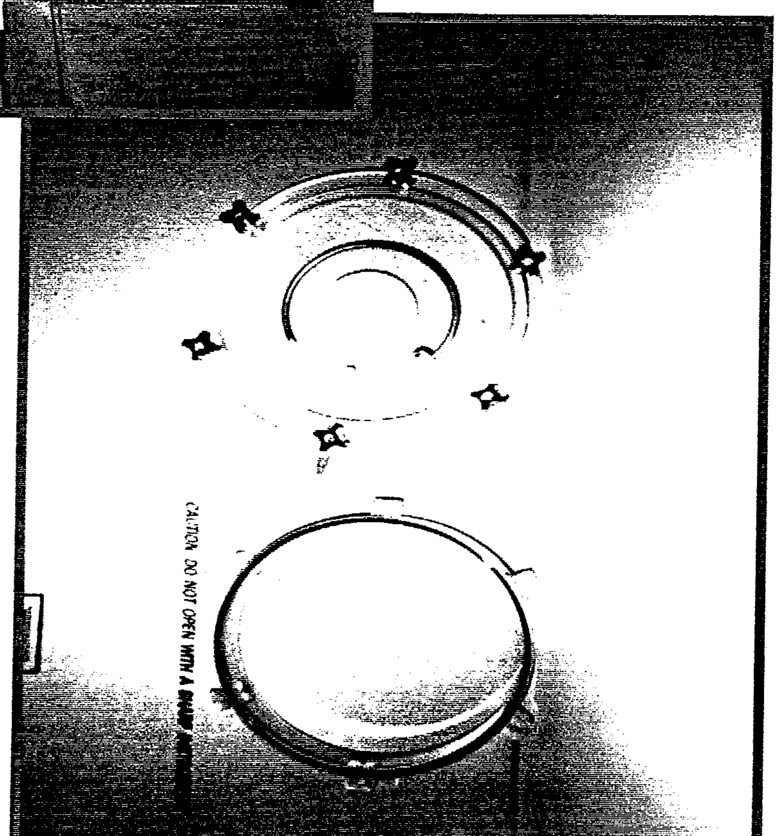
- **Flux Gradient**





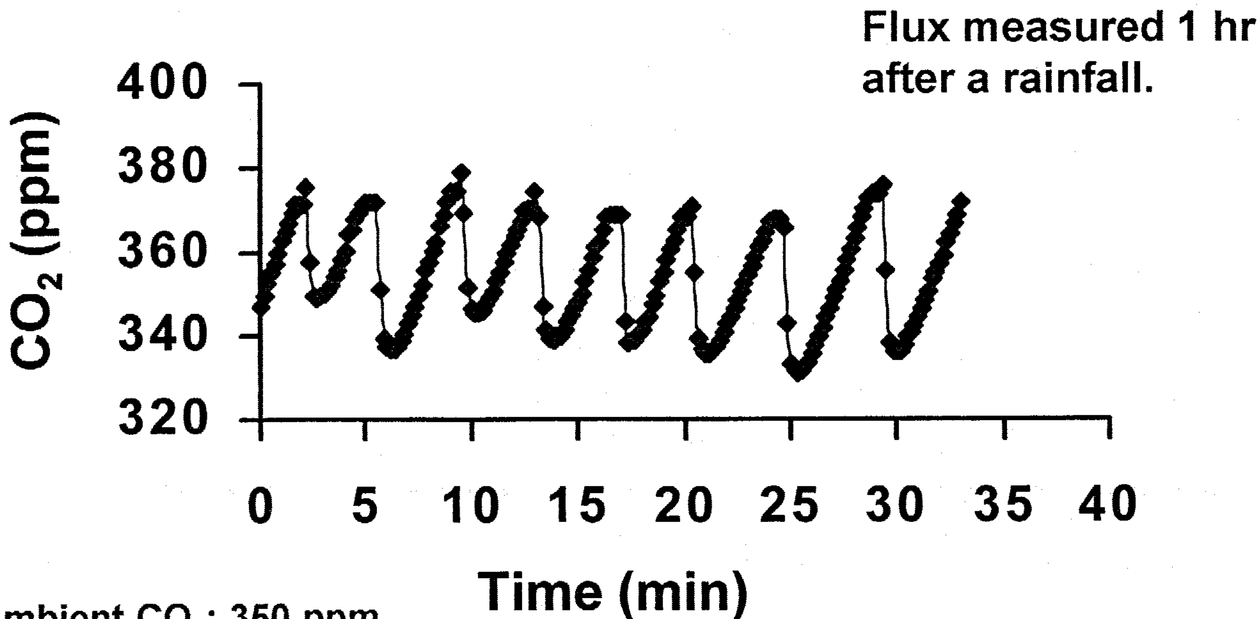




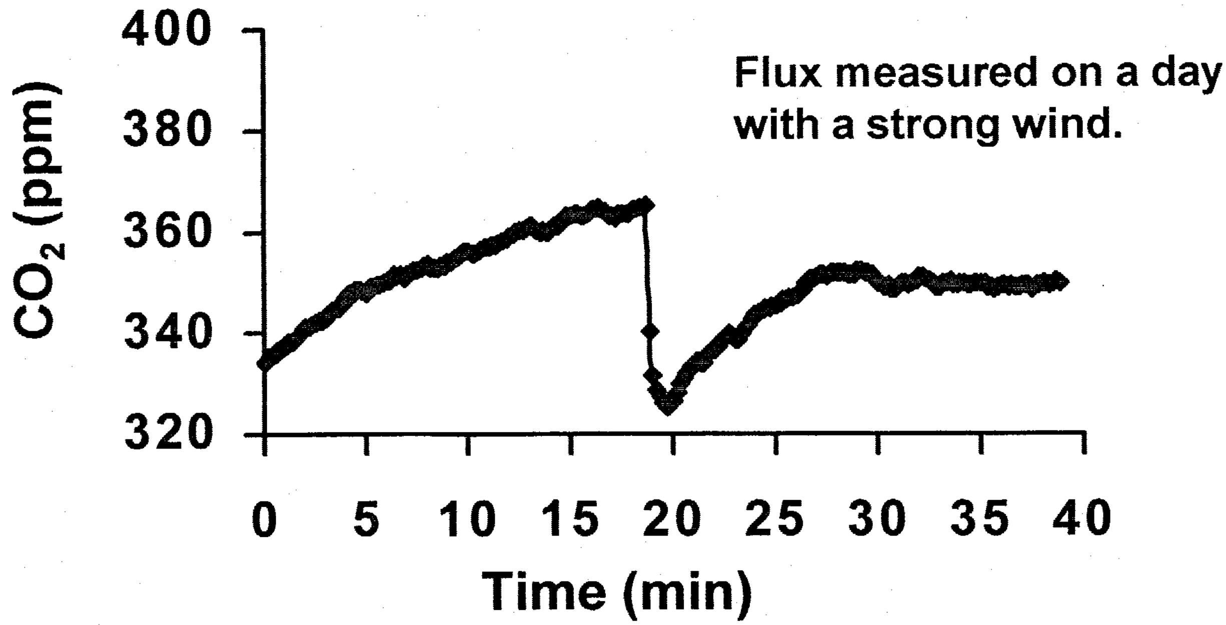

CAUTION DO NOT OPEN WITH A

Effect of Atmospheric Conditions on CO_2 Flux Measurements

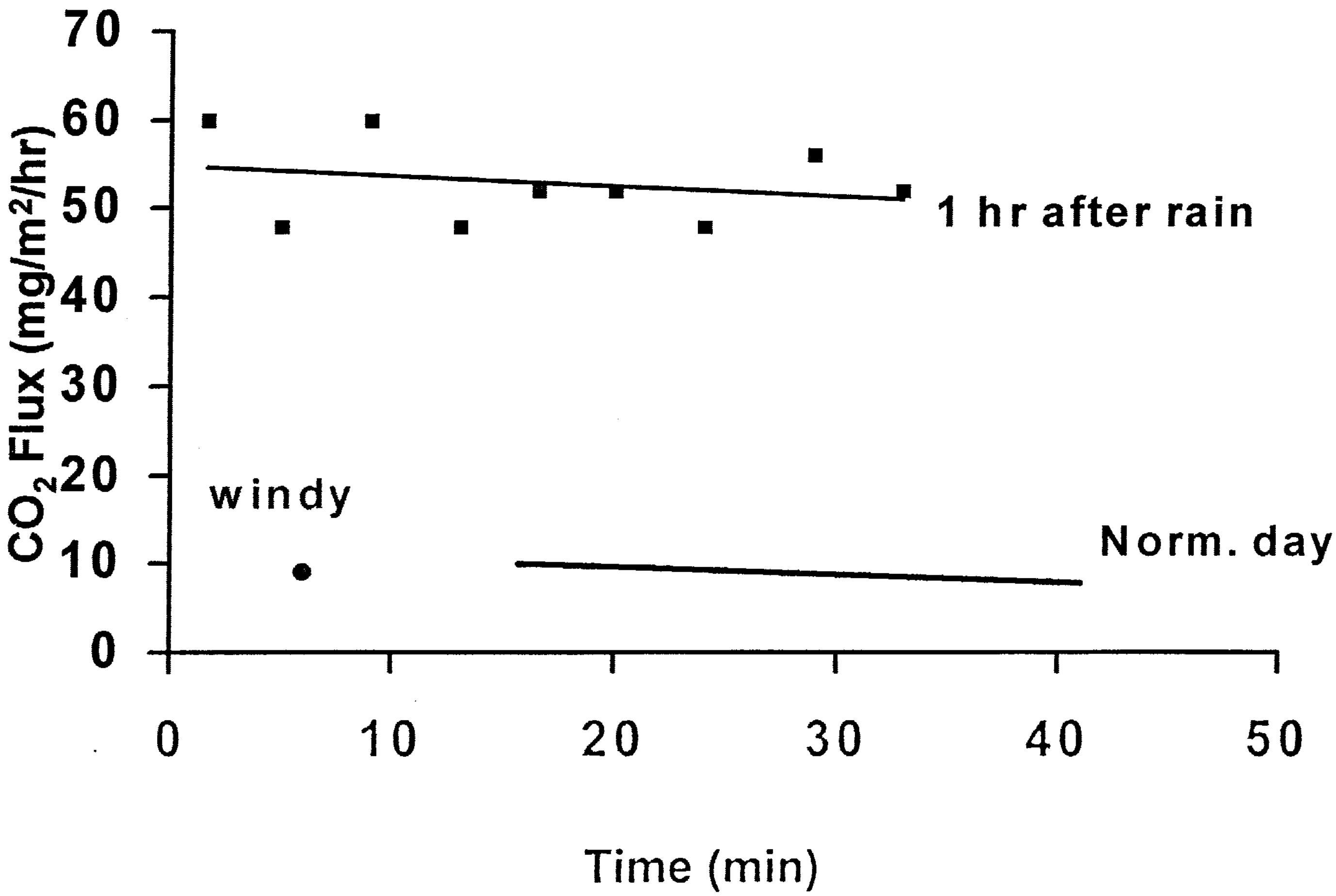
(Constructed Waste Rock Pile - Cluff Lake)



Ambient CO_2: 350 ppm



Effects of Atmospheric Conditions on Flux Measurements - Cluff Lake



Activities to be Emphasized in 2000

- Interpretation of infiltration and tracer experiments carried out on the constructed pile
- Ongoing monitoring of flow and drainage water chemistry at the constructed pile
- Characterization of the linkage between flow, geochemistry, and the scale of measurement
- Deconstruction of 10 m high lysimeters at Key Lake
- Identify sources/sinks of gas (abiotic/biotic) at the Key Lake piles
- Field prototypes of standpipe lysimeter, and in situ gas diffusion test
- Implement gas flux meter in field (Key, Cluff), install up to 12 meters to examine spatial / temporal variability