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TECHNICAL MEMORANDUM

TO: Mary Beth Marks – On-Scene Coordinator

FROM: Michael Cormier

DATE: January 7, 2004

RE: McLaren Pit Cover Monitoring System
New World Mining District Response and Restoration Project

This technical memorandum describes the installation of the McLaren Pit Cover Monitoring System (MPCMS) and methods used to determine moisture content in waste before and after the McLaren Pit Cover system was installed, and summarizes moisture content data collected. This work was performed in the period of July through September 2003 by Maxim Technologies, Inc.® (Maxim) for the McLaren Pit Response Action.

During the construction seasons of 2002 and 2003, the waste surface of the McLaren Pit was regraded to a stable configuration and was covered with a geosynthetic and soil cover system. The purpose of the cover system is to eliminate infiltration of water from the surface into mine waste. The MPCMS was installed to monitor relative changes of moisture in mine waste beneath the cover system.

ACCESS TUBE INSTALLATION

Maxim initiated neutron access tube installation during the period of July 25 though July 31, 2003. The purpose of neutron probe access tubes is to allow moisture content monitoring of mine waste beneath the cover system using a neutron probe moisture gauge. Maxim installed nine neutron probe access tubes in the waste prior to placement of the cover system. Due to a conflict with the construction schedule, a tenth access tube could not be installed. Access tubes were installed after mine waste was graded to the finished subgrade elevation.

Access tubes were designated as Daisy Creek Neutron Tube (DCNT) 1 through 9 and are located as shown on **Figure 1, Attachment A**. Due to ongoing construction, several of the access tubes could not be placed at the locations specified in the contract documents (Maxim, 2002). In these instances, the tubes were located as close to the design location as possible. Borings for access tubes were drilled using a CME rubber-tired all-terrain drill rig equipped with 8 ½ inch O.D. hollow stem augers. Field logs of the access tube borings are presented in **Attachment B**. Access tubes were installed to a depth of 20 feet or in underlying bedrock, whichever occurred first. Access tube depths ranged from 3 to 20 feet below the finished waste subgrade elevation. Access tubes consist of 2-inch diameter Schedule 40 PVC pipe with threaded, gasketed connections. Tubes were sealed at both the bottom and top ends with gasketed end caps. After removal of the hollow stem augers, the annular space between the tube and the soil boring wall was filled with drill cuttings.

Following installation of access tubes, the contractor placed the geosynthetic liner over the tube, and constructed a water-proof boot around the tube to bring it through the liner. The tubes were then extended through the geocomposite drainage drainage layer and soil cover as these materials were placed by the contractor.

Troxler recommends that access tube be installed with minimum clearance between the exterior of the access tube and the surrounding undisturbed soil. It is recommended that the soil to be tested be in contact will the exterior of the access tube wall. The equipment most suited to this type of installation is rotosonic drill rig. Because availability of these rigs is limited and given the limited window during which installation had to be completed, the auger method of installation was selected for the project. While this drilling method only allows for sub-optimal installations, Maxim determined that the installations would be acceptable under the circumstances, and would allow for monitoring of at least relative changes in moisture content, if not absolute changes.

Access Tubes DCNT-8 and DCNT-9 were installed but were damaged during construction of the liner and placement of soil cover. The damage caused obstructions within the access tubes, preventing the neutron probe from passing freely through the tube. As a result, the obstructed tubes could not be monitored after cover construction and may be unusable for future monitoring.

METHOD OF DETERMINING MINE WASTE MOISTURE CONTENT

Relative moisture content of mine waste adjacent to access tubes was determined using a Troxler Model 4300 depth moisture gauge. The depth moisture gauge utilizes the principles of neutron thermalization (Troxler, 2001) similar to soil nuclear density/moisture gauges commonly used in the construction industry. The depth moisture gauge sets on top of the access tube and a neutron probe is lowered into the tube to measure soil moisture content of the soils adjacent to the tube. The cord attached to the probe is graduated so the probe can be accurately set at different depths.

To calibrate the depth moisture gauge and to obtain an approximation of actual moisture content, samples of mine waste were collected during drilling from 2.5 foot intervals, and actual moisture content was measured by weight. Because measurements of moisture content are affected by different soil types due to various properties, the probe must be calibrated for each type of material (Troxler, 2001) to correct for these differences. The result of the calibration is the offset, which is a number added or subtracted to the moisture reading to determine actual moisture content. The following method was used to determine the calibration offset for the MPCMS:

1. Samples of in-situ mine waste were recovered at approximately 2.5 foot intervals with 1 ½ inch I.D. split spoons samplers during access tube installation. The samples were stored in zip-lock bags and taken to Maxim's laboratory where the moisture contents were determined using ASTM D2216 (difference by weight after evaporation in an oven).

2. Immediately following access tube installation, moisture readings were taken with the gauge at the same depth where split spoon samples were collected.

3. The laboratory determined moisture content of mine waste samples is the percent water by mass (i.e., mass of water/mass of soil). The depth moisture gauge measures moisture content as percent water by volume (i.e., volume of water/volume of soil). Due to the different units for the two different measurements, the laboratory determined moisture content is converted to

match the units of the depth moisture gauge moisture content. This was done by using the following equation:

$$\text{\% water by mass} = (\text{\% water by volume})/G_{mw}$$
$$= (\text{\% water by volume})/1.92$$

The previous equation was determined as follows:

$$G_{mw} = \text{Specific Gravity of Mine Waste}$$
$$= (W_{mw} / V_{mw})(1 / \gamma_w)$$
$$= 119.8 \text{ pounds per cubic foot (pcf)} / 62.4 \text{ pcf}$$
$$= 1.92$$

Where:

W_{mw} / V_{mw} = Dry unit weight of in-situ mine waste = 119.8 pcf
γ_w = Unit weight of water = 62.4 pcf

The dry unit weight was assumed to be the average of in-place density testing performed on mine waste during construction. These results were provided by URS Construction Services and are presented in **Attachment C**. The average dry unit weight of in-place density was calculated to be 119.8 pcf.

DCNT MONITORING RESULTS

Mine waste moisture content was monitored using the depth moisture gauge both immediately after the installation of the neutron tubes (7/31/03) and after construction of the cover system was complete (9/29/03). Depth neutron gauge moisture contents are summarized in **Attachment D**. Graphs of moisture content vs. depth for each monitoring event are presented in **Attachment E**.

Several methods were explored in an attempt to correlate gauge moisture content to actual moisture content for the July 31, 2003 event. However, a statistically valid correlation (low correlation coefficients) could not be obtained. The reasons for the difference in gauge moisture readings can be attributed primarily to installation of the access tubes and consist of the following:

- The manufacturer of the moisture gauge (Troxler) recommends that aluminum tubing be used for the access tubes. However, other materials can be substituted providing a correction is used to account for differing material types. Aluminum tubing available from Troxler was not suited to the MPCMS because of the depth of installation required and the need to extend the tubes following cover construction. Schedule 40 PVC pipe was used instead.

- For optimal measurement, the access tube is recommended to be in direct contact with undisturbed material tested. The hollow-stem auger drills a boring 8 ½ inches in diameter with the result being a 6 ½ inch annular space that was filled with drill cuttings.

- Drill cuttings could not be placed in the same interval that they originated, so the actual moisture content was measured in a different material. Backfilled cuttings also could not be compacted to similar densities as the surrounding mine waste.

- An average in-place density that was measured by the contractor during placement and regrading of the waste in the pit was used for calibration. Actual density of the in-place materials could not be measured because the drilling method and material types (gravels) were not conducive to measuring this parameter. Using an average in-place density induces an additional source of error to the calibration.

CONCLUSIONS

Maxim considers the depth moisture gauge to be a tool for measuring the relative change in moisture content of mine waste over time. Neutron probe measurements shown on the graphs in **Attachment E** show relative changes in moisture between monitoring events. As additional measurements are collected over time, particularly in late spring, mid-summer, and late fall in 2004, an assessment of cap performance can be made.

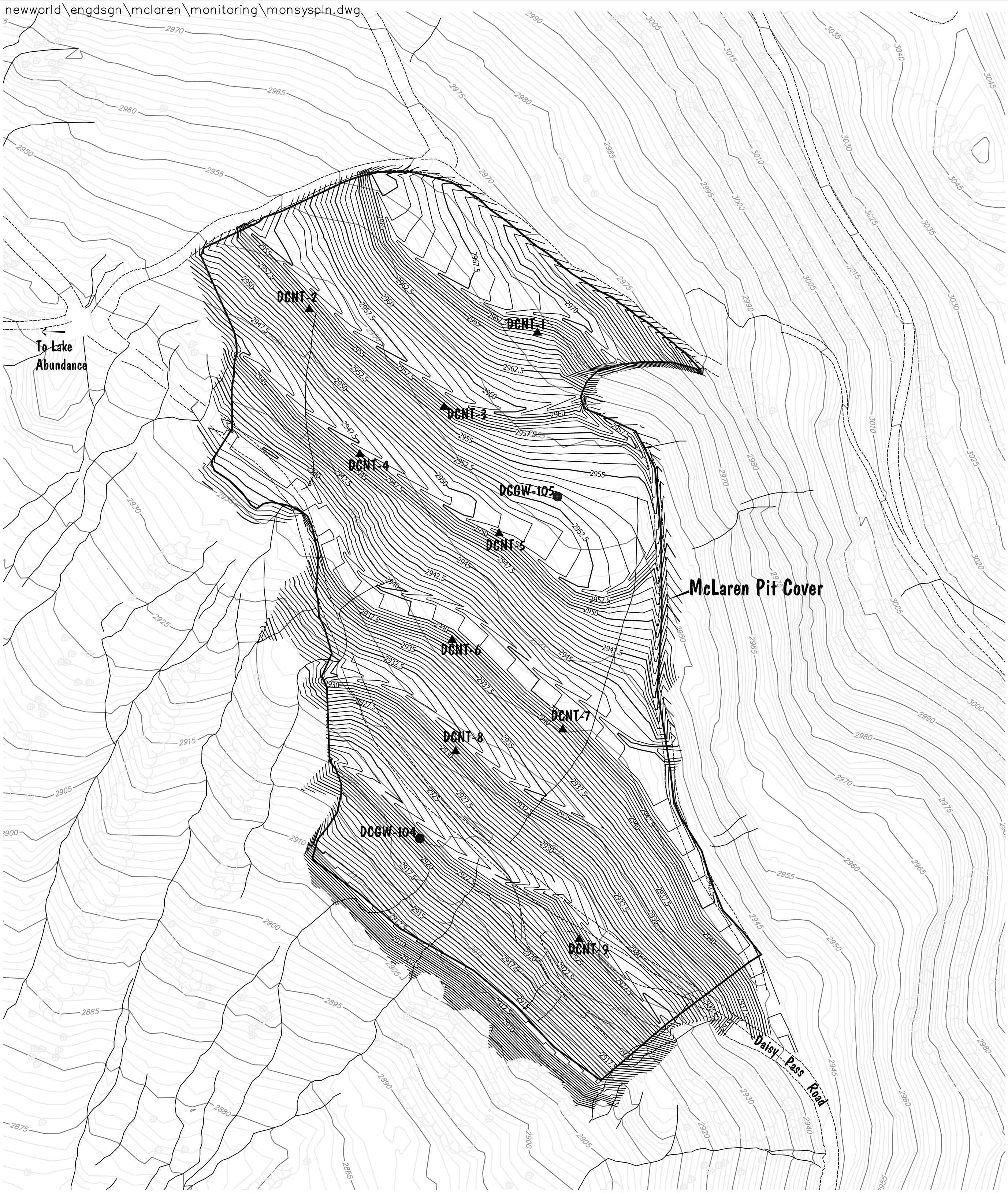
REFEERENCES CITED

Maxim Technologies, Inc. 2002. Amended Contract Specifications, McLaren Pit Response Action, New World Mining District Response and Restoration. Prepared for USDA Forest Service Northern Region Missoula, Montana. March.

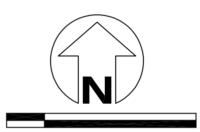
Troxler Electronic Laboratories, Inc. 2001. Model 4300 Depth Moisture gauge Manual of Operation and Instruction. Research Triangle Park, North Carolina.

ATTACHMENT A

McLaren Pit Neutron Access Tube Locations
2003 McLaren Pit Cover Monitoring System Memorandum
New World Mining District Response and Restoration Project



Note: Cover surface topography is from design drawings, not an as-built. As-built topography may be different.



Contour Interval = 1 meter

1:2000

DCNT-1 ▲	Nuetron Tube Location
DCGW-01 ●	Monitoring Well
	Existing Index Contour
	Existing Intermediate Contour
	Index Contour of Cover Surface
	Intermediate Contour of Cover Surface

Neutron Access Tube Locations
McLaren Pit Cover Monitoring System
New World Mining District
Response and Restoration Project
FIGURE 1

ATTACHMENT B

McLaren Pit Neutron Access Tube Boring Logs
2003 McLaren Pit Cover Monitoring System Memorandum
New World Mining District Response and Restoration Project

ATTACHMENT C

URS Construction Group Mine Waste Nuclear Density Results
2003 McLaren Pit Cover Monitoring System Memorandum

New World Mining District Response and Restoration Project

ATTACHMENT D

2003 Mine Waste Moisture Content Data
2003 McLaren Pit Cover Monitoring System Memorandum

New World Mining District Response and Restoration Project

Mine Waste Neutron Moisture Results

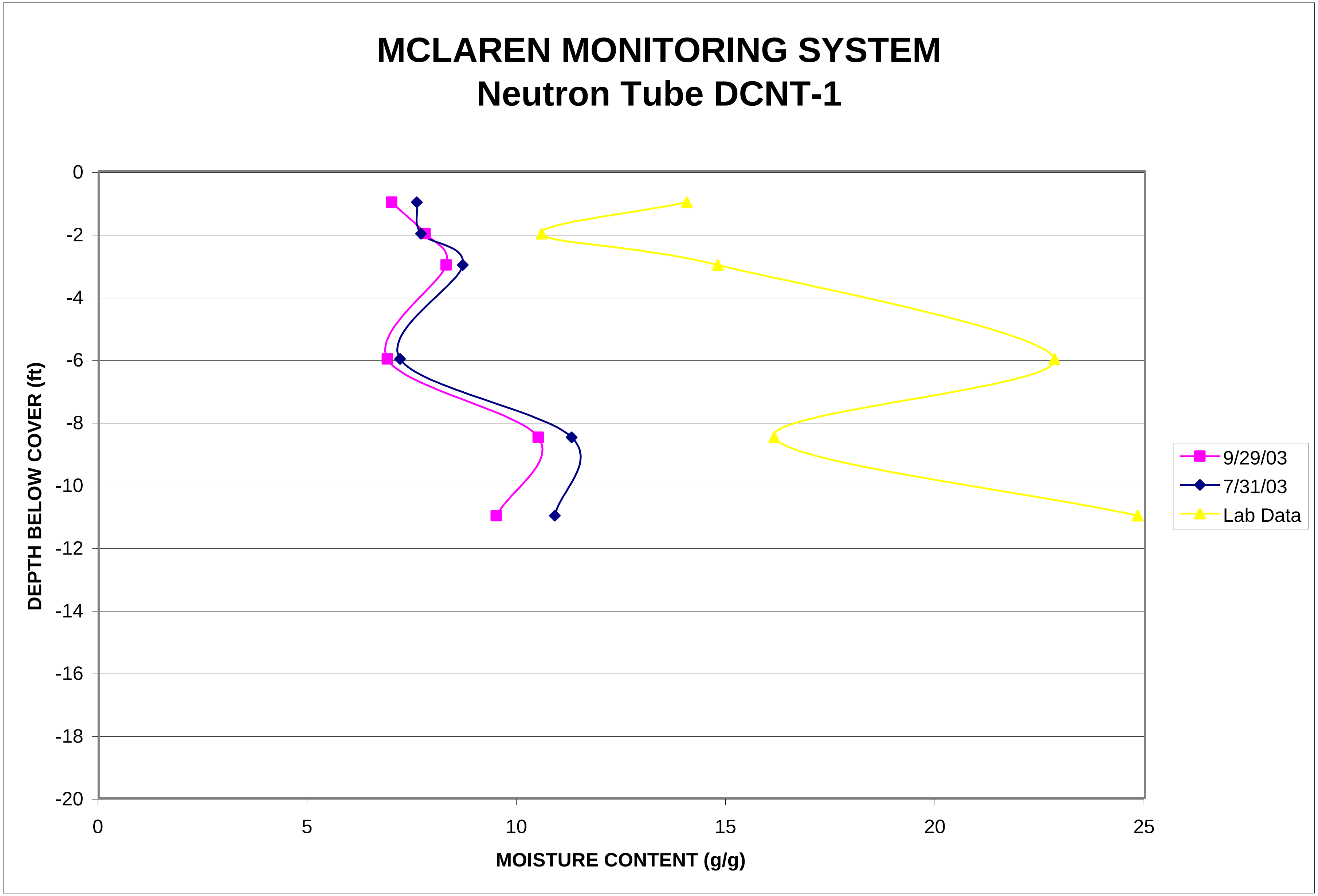
McLaren Pit Cover Monitoring System

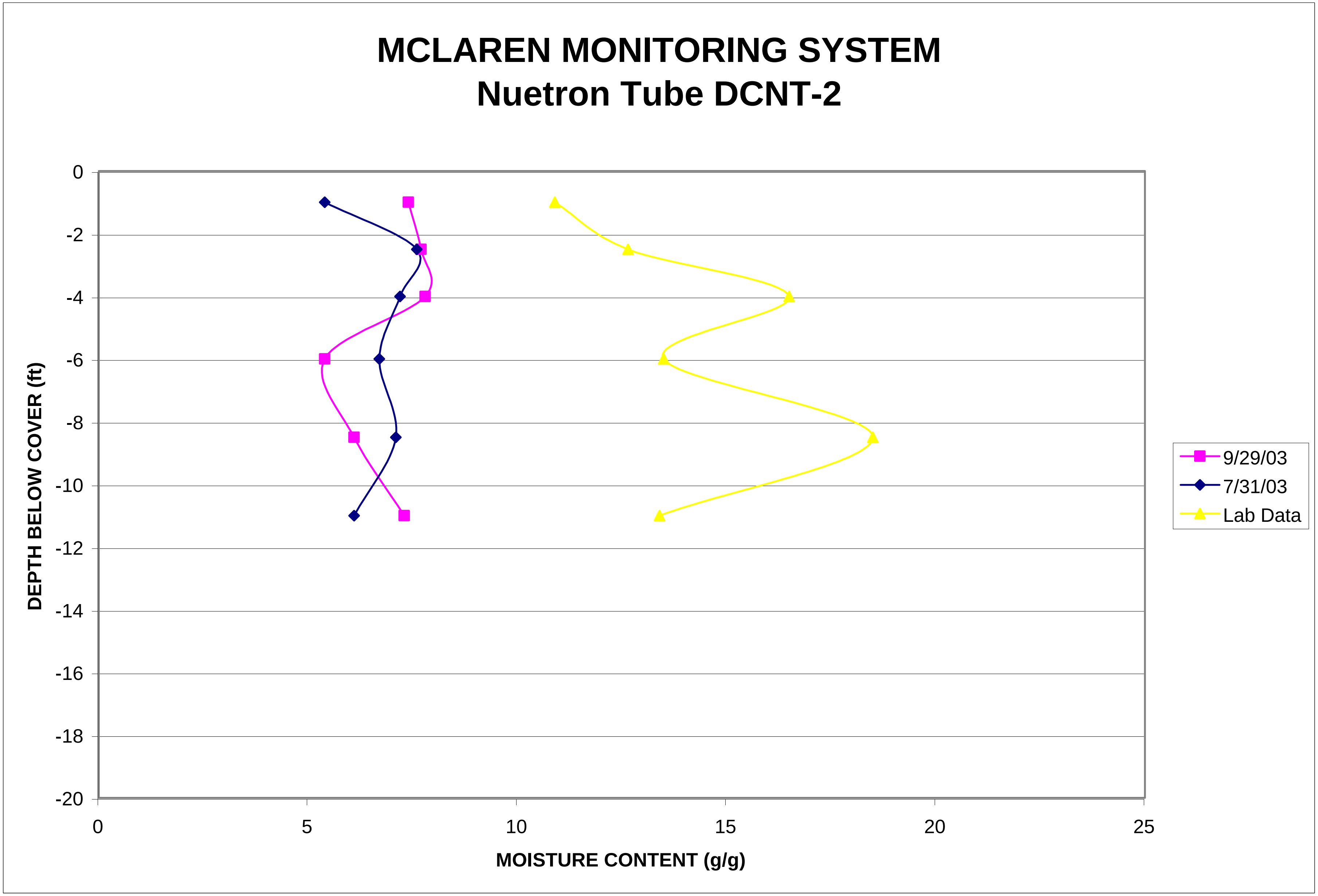
New World Mining District Response and Restoration Project

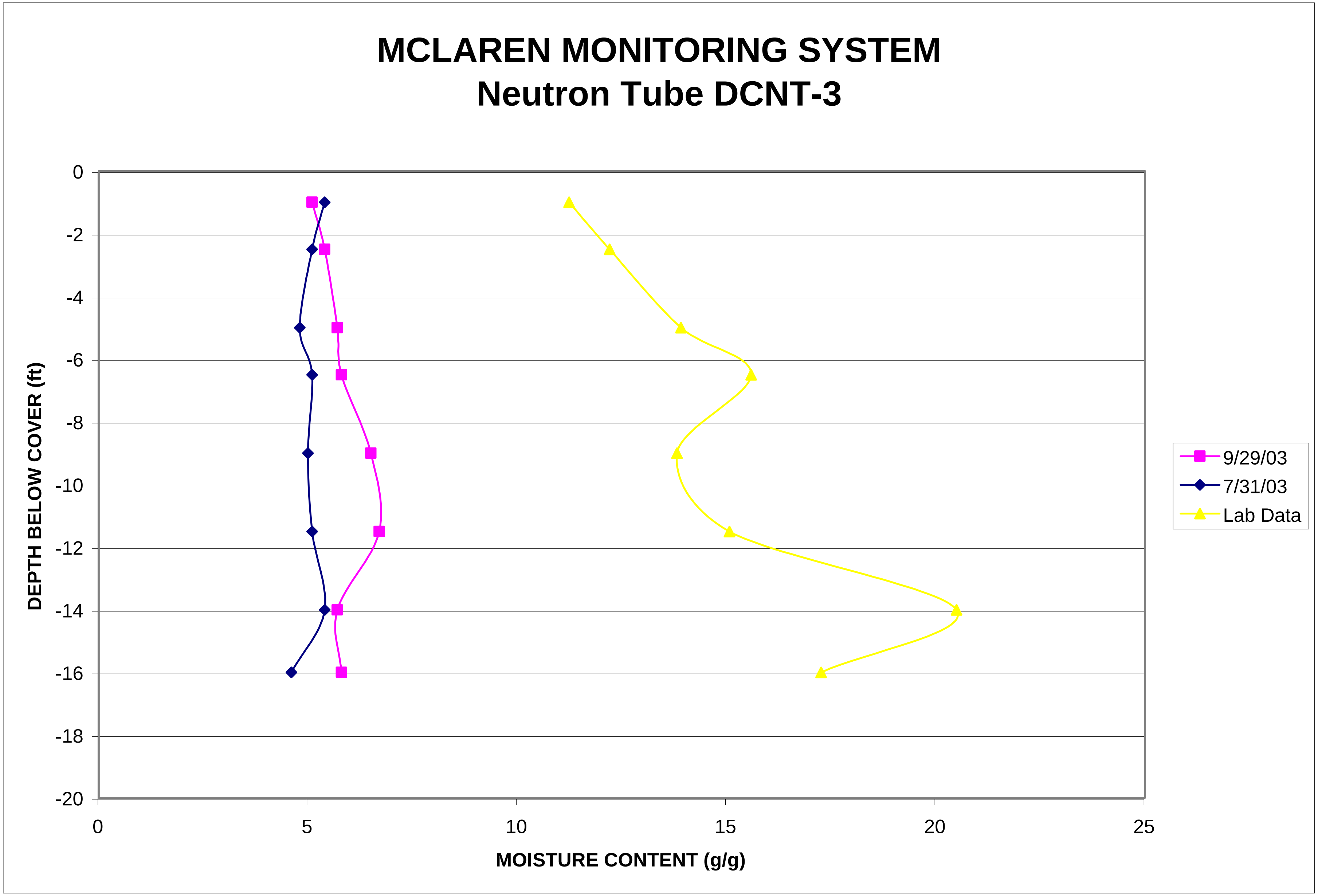
Neutron Tube	Depth of Neutron Probe Moisture Reading (ft)	Actual Moisture Content (% by Mass)	Neutron Probe Moisture Content (% by Mass) (7-31-03)	Neutron Probe Moisture Content (% by Mass) (9-29-03)
DCNT-1	1	14.1	7.6	7.0
	2	10.6	7.7	7.8
	3	14.8	8.7	8.3
	6	22.8	7.2	6.9
	8.5	16.1	11.3	10.5
	11	24.8	10.9	9.5
DCNT-2	1	10.9	5.4	7.4
	2.5	12.7	7.6	7.7
	4	16.5	7.2	7.8
	6	13.5	6.7	5.4
	8.5	18.5	7.1	6.1
	11	13.4	6.1	7.3
DCNT-3	1	24.7	11.5	0.0
	2.5	11.2	5.4	5.1
	5	12.2	5.1	5.4
	6.5	13.9	4.8	5.7
	9	15.6	5.1	5.8
	11.5	13.8	5.0	6.5
	14	15.1	5.1	6.7
	16	20.5	5.4	5.7
DCNT-4	1	17.3	4.6	5.8
	2	11.4	6.2	6.2
	4	12.5	6.2	6.5
	6.5	15.1	5.8	6.7
	9	16.4	5.2	6.0
	11.5	16.3	4.9	5.5
DCNT-5	1	26.5	5.0	5.5
	2	14.7	5.5	6.1
	4	13.5	9.4	8.9
	6	13.9	5.2	4.7
	8.5	15.2	8.8	8.0
	12	17.8	8.1	7.8
	14	18.5	6.9	6.6
	16.5	18.8	6.4	6.1
	18.5	18.1	5.9	6.3
DCNT-6	1	18.4	10.9	7.4
	2	24.4	4.8	4.8
	3	11.2	5.1	4.9
DCNT-7	1	4.3	4.9	5.6
	3	13.1	5.6	3.1
	4	15.0	4.9	4.8
	6.5	16.8	4.9	5.3
	9	20.2	4.9	4.8
	11.5	12.0	4.8	5.4
	13	16.2	4.8	5.7
	16	18.0	4.9	5.6
	19	20.2	6.3	9.6

ATTACHMENT E

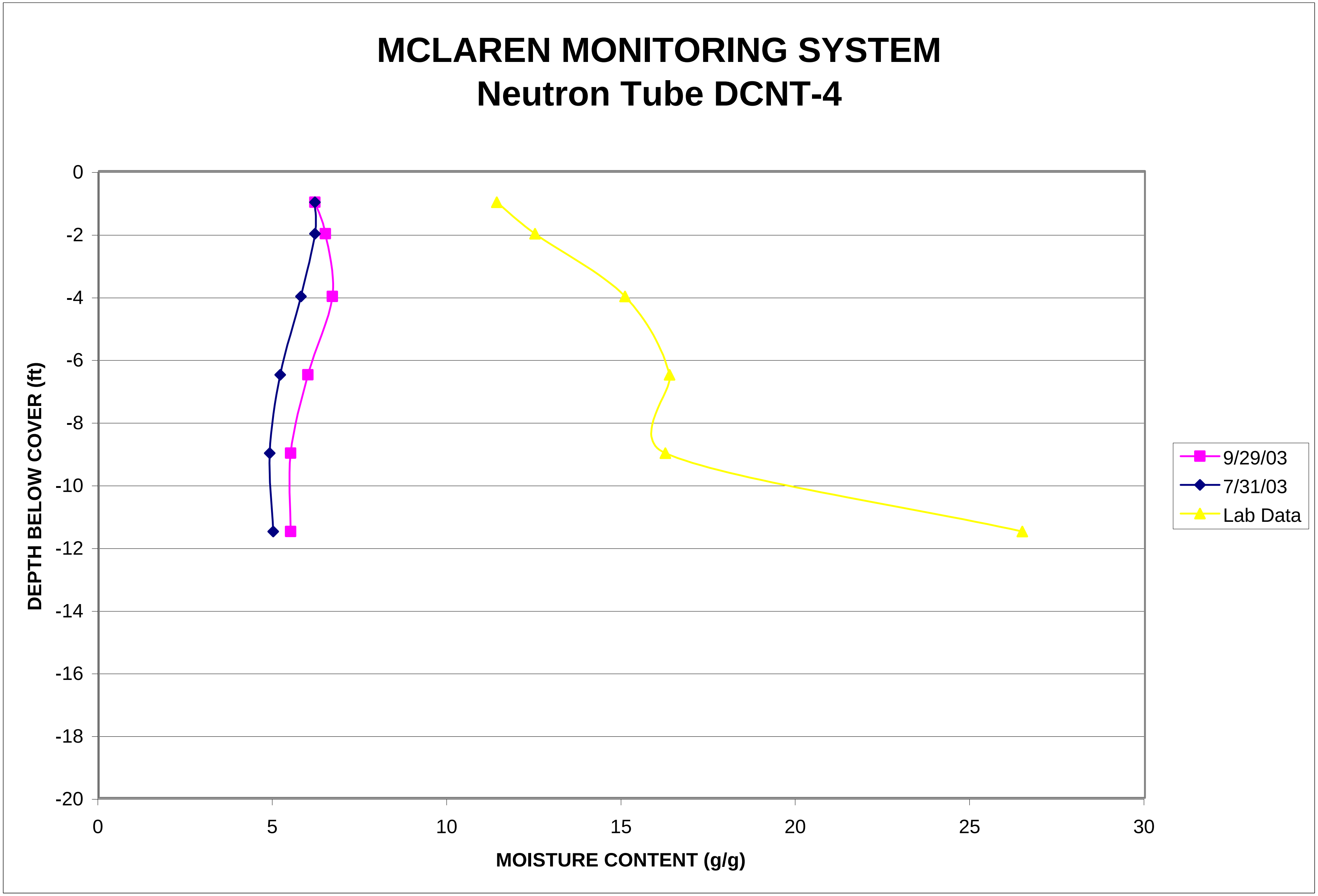
Depth Vs. Moisture Content Graphs
2003 McLaren Pit Cover Monitoring System Memorandum
New World Mining District Response and Restoration Project

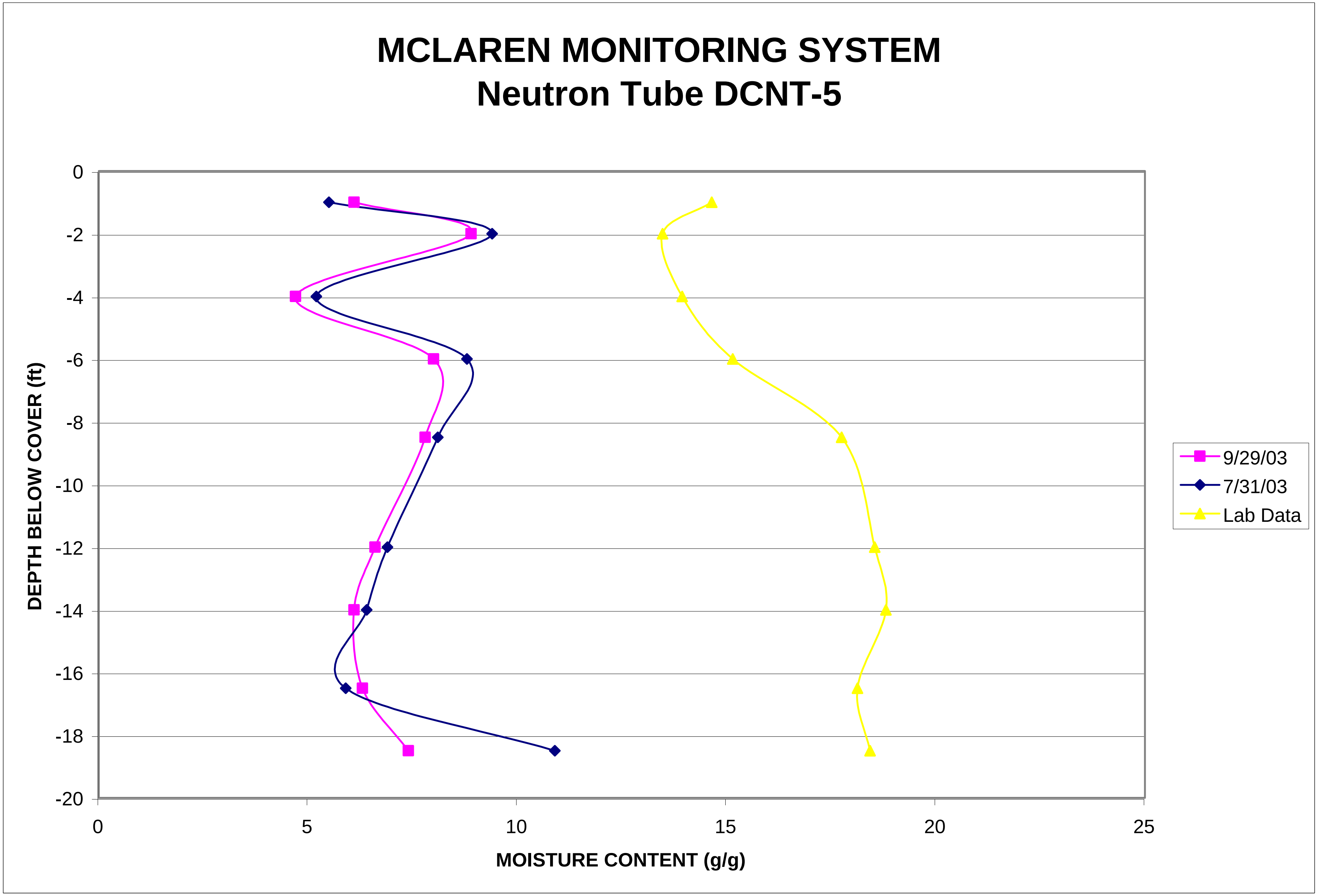

MCLAREN MONITORING SYSTEM
Neutron Tube DCNT-1
DEPTH BELOW COVER (ft)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
0
5
10
15
20
25
MOISTURE CONTENT (g/g)
9/29/03
7/31/03
Lab Data


MCLAREN MONITORING SYSTEM
Nuetron Tube DCNT-2
DEPTH BELOW COVER (ft)
MOISTURE CONTENT (g/g)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
0
5
10
15
20
25
9/29/03
7/31/03
Lab Data

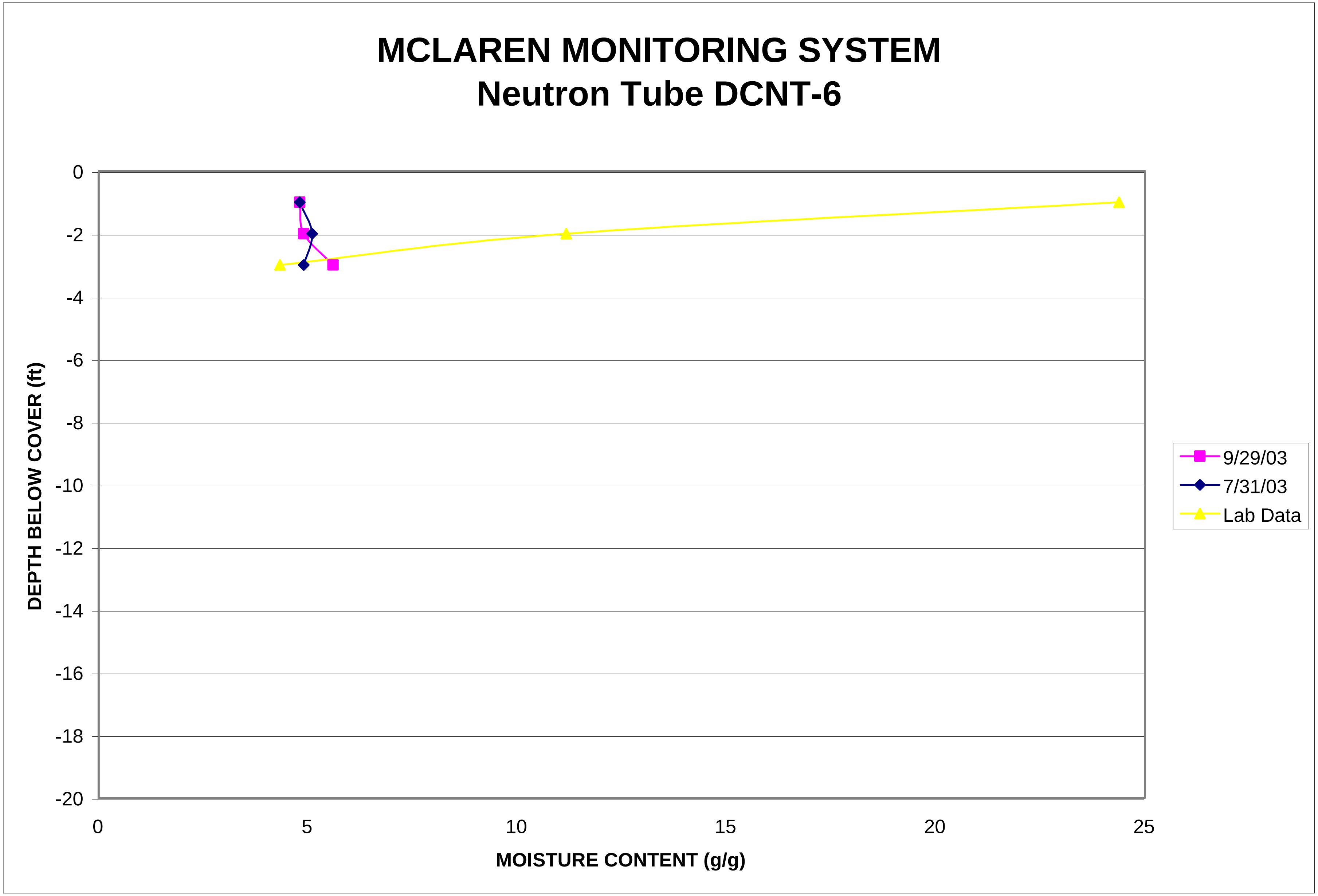


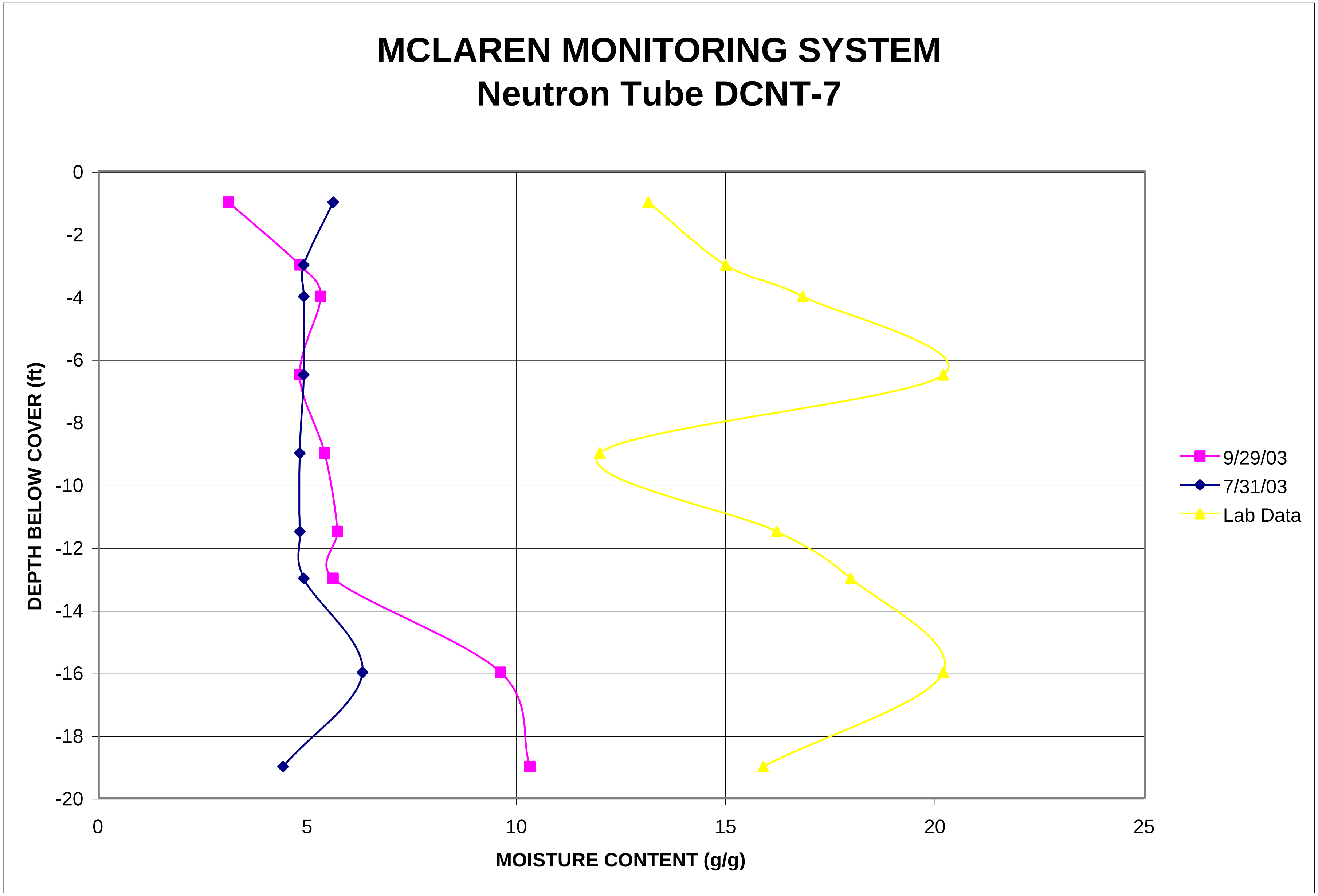
MCLAREN MONITORING SYSTEM
Neutron Tube DCNT-3
DEPTH BELOW COVER (ft)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
0
5
10
15
20
25
MOISTURE CONTENT (g/g)
9/29/03
7/31/03
Lab Data


MCLAREN MONITORING SYSTEM
Neutron Tube DCNT-4
DEPTH BELOW COVER (ft)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
0
5
10
15
20
25
30
MOISTURE CONTENT (g/g)
9/29/03
7/31/03
Lab Data



MCLAREN MONITORING SYSTEM
Neutron Tube DCNT-5
DEPTH BELOW COVER (ft)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
0
5
10
15
20
25
MOISTURE CONTENT (g/g)
9/29/03
7/31/03
Lab Data


MCLAREN MONITORING SYSTEM
Neutron Tube DCNT-6
DEPTH BELOW COVER (ft)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
0
5
10
15
20
25
MOISTURE CONTENT (g/g)
9/29/03
7/31/03
Lab Data


MCLAREN MONITORING SYSTEM
Neutron Tube DCNT-7
DEPTH BELOW COVER (ft)
MOISTURE CONTENT (g/g)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
0
5
10
15
20
25
9/29/03
7/31/03
Lab Data