This paleohydrology study is dedicated to the many scientists who have helped citizens to better understand the riddles of Mesa Verde National Park.

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James “Al” Lancaster
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1.0 INTRODUCTION

In 1995, archeology rangers Cynthia Williams and Joe Brisbin of Mesa Verde National Park (MVNP) escorted Kenneth Wright to Morefield Mound, Mummy Lake and a series of check dams. They inferred that water-oriented studies might be made of each in a manner similar to Wright’s ongoing paleohydrological research at Machu Picchu in Peru. As a result, field research was conducted at Morefield Reservoir from 1995 through 1997, culminating in a 16-foot deep trench some 125 feet long. The trench wall exposed the evidence of some 350+ years of reservoir operation and put to rest the long-lived question of the purpose and function of the Morefield Mound.

Fieldwork commenced at Mummy Lake in May 1998 and was completed in June 1999, under the authority of the superintendent’s letter dated March 20, 1998 (Appendix A) and a generous grant from the Colorado Historical Society of which Georgianna Contigualia serves as President.

While the work of Wright Water Engineers, Inc. (WWE) and the Wright Paleohydrological Institute (WPI) at Mesa Verde is a result of the generous encouragement of Ms. Williams and Mr. Brisbin, it was Larry Nordby, Research Archeologist, and Linda Towle, Chief Research Archeologist with Mesa Verde National Park, who paved the way for the water-based studies by expeditiously processing the necessary permits and approvals and making the hydrological engineers and scientists feel at home and welcome. To all four of these dedicated MVNP scientists, we owe a debt of gratitude.

WPI thanks all of the many financial contributors and volunteers who made this research project possible.
1.1 Location

Mummy Lake is centrally located on Chapin Mesa approximately four miles north of MVNP headquarters and slightly more than one mile south of the Fairview Cafeteria and Lodge complex, which includes the Park Visitors’ Center. Mummy Lake lies only 50 feet east of the main paved road. Mummy Lake is in the SE¼ of Section 33, T35N, R15W of the New Mexico Principal Meridian at an elevation of about 7,739 feet, as shown in the following Figure 1. Mummy Lake is one of three dozen archaeological sites open to the public; it enjoys significant public interest because it is adjacent to Far View Village, Coyote Village and Megalithic House.

The Mummy Lake drainage catchment, conveyance and storage system are about one mile long from north to south including the Water Gathering Area at the northern end. The entire system is perched along the ridgeline of Chapin Mesa with 310 feet of elevation difference from 8,020 feet at the north to 7,739 feet at Mummy Lake.

The graphical description, location, topography and special features of the Mummy Lake system are presented in Drawings 1, 2, and 3 at the end of this report.

1.2 Background

While Mummy Lake was first described by Chapin (1892) and Nordenskiold (1893) as a water storage facility, and while many subsequent investigators such as Lancaster (1969), Fewkes (1917), Stewart (1940) and Rohn (1963, 1972 and 1977) also judged it to be a reservoir, doubts were raised during the last several decades.

The doubts about the original function of Mummy Lake were based upon the fact that there was little tributary watershed on top of Chapin Mesa and, therefore, no likely water supply available (Smith 1979). Leeper (1986) seconded this opinion after performing hydrologic modeling. Following Leeper, Collins (1987) listed Mummy Lake as a problematic domestic reservoir and Crown (1987) listed it as a water storage facility. Wilhusen, et. al. (1997) put Mummy Lake into a water management category, giving the dates AD 1100 – 1200.
FIGURE 1
Topographic Map of Mummy Lake (5MV833) on Chapin Mesa

Park Headquarters (1.3 miles)
Finally, the scientist with the most detailed and intimate knowledge of Mummy Lake, Dr. David Breternitz, presented his important 1969 excavation results and findings in a WPI publication (Breternitz 1999). Breternitz concluded that Mummy Lake was a seasonal source of domestic water. His five conclusions are listed below:

1. Without any doubt, the Anasazi attempted to exploit the available sparse surface runoff water on upper Chapin Mesa, and quite probably sub-surface seepage, by constructing Mummy Lake, beginning about AD 950-1000.

2. Mummy Lake was periodically desilted and remodeled in an attempt to make it more effective, and probably in response to changing climatic and cultural factors.

3. Mummy Lake ceased to be utilized in the latter half of the AD 1100s, at the same time that the 16 Anasazi habitation sites in the Far View Group were abandoned.

4. Mummy Lake was never a reliable or more than seasonal source of domestic water for the nearby habitation sites.

5. The Anasazi devoted tremendous effort towards harvesting their most precious commodity, water; but it was probably both inefficient and unreliable.

The WPI publication of the 1969 Breternitz work was part and parcel of the 1998-99 hydrological research effort so that a starting place for this report would be established. The two reports should be considered in tandem. WPI thanks Dr. Breternitz for his cooperation in the publication of the long-overdue 1969 scientific work. Additionally, he graciously participated in the WPI final field trip in June 1999 and contributed significantly to the overall success of the latter research and findings, as did Dr. Arthur Rohn, Dr. Linda Scott-Cummings, Dr. Calvin Cummings and Dr. Jack Smith.

1.3 Purpose

The purpose of the WPI paleohydrological research on Mummy Lake was to define the ancient function and use of Mummy Lake so as to put to rest the ongoing uncertainty over whether or not the structure was an irrigation reservoir, a domestic water reservoir, a dance pavilion or even some other social-oriented facility.
Myths often surround well-known ancient ruins such as Mummy Lake. The myth of Mummy Lake as being part of a virtual ancient “water garden” was exemplified by the *National Geographic Magazine*’s portrayal of Chapin Mesa in February 1964 (Appendix B).

The uncertainty and myth created certain problems for the MVNP staff scientists. As late as June 1999, the MVNP had two interpretative signs at Mummy Lake that gave the park visitor a choice: either a reservoir or a dance pavilion.

It was believed that with scientific hydrological studies, coupled with onsite engineering investigations, the data would help define whether or not a water source existed for Mummy Lake. A project-sponsored symposium held at MVNP in June 1999, as described later, resulted in near unanimity among the 26 participants as to the function and purpose of Mummy Lake, and to whether or not there ever was a Far View Ditch. As a result, the purpose of the WPI research was achieved. It was concluded by WPI that Mummy Lake (Site 5MV833) was a seasonal and unreliable domestic water supply reservoir, and that the Far View Ditch route was an old packtrain trail or early roadway, and that it was not an ancient irrigation ditch.

### 1.4 Field Trips

Subsequent to numerous informal scoping trips to Mummy Lake during the 1995-97 period, three WPI field sessions were conducted at Mummy Lake under the 1998 authorization letter that, in total, included five trips with 27 individuals, as listed in Appendix C.

The field research sessions included multiple engineering and scientific functions and were conducted as follows:

- **May 1988:** Field instrument surveys, auger holes, soils analyses, reconnaissance, reconnaissance surveys of the Far View Ditch route and field search for the Water Gathering Area, Collector Ditches and the Delivery Ditches.

- **June 1998:** Research at the MVNP Research Center to examine archives, printing of 1969 black and white photographs and typing the field notes of Al Lancaster.
October 1998: Field instrument surveys, auger holes, soil and geologic studies, detailed measurements, collection of pollen soil samples, study of the Far View Ditch route and measurement of the “Cowboy Ditch.”

January 1999: Construction of three piezometers for ongoing groundwater level measurements within Mummy Lake and logging of the borings.


2.0 INVESTIGATIONS AND ANALYSES

Many natural resource investigations and analyses were conducted on Chapin Mesa as part of the 1998-99 paleohydrological research. A brief description of the activities follows.

2.1 Field Reconnaissance

The May 1998 trip included reconnaissance surveys on Chapin Mesa from the Far View Restaurant and parking lot south to the old quarry area near the Research Center.

The reconnaissance work focused on the Water Gathering Area, the Gathering Basin, the Delivery Ditch, the Cowboy Ditch, the West Ditch and the Far View Ditch. Trained personnel carefully walked the areas to identify and sort varied field evidence of ditches. Auger holes were drilled in the Water Gathering Area and Gathering Basin to confirm soil types and to record depth-to-bedrock where it was shallow.

The reconnaissance work continued throughout all of the three major field trips to check and reconfirm field evidence. Special observations were made at Coyote Village with Dr. Jack Smith, who conducted the excavation and reconstruction there. Special attention was given to the seasonal water levels in the Coyote Village’s deep kivas.
Photo 1: Chief Surveyor Christopher Crowley used certified bench marks to ensure quality control on all elevations.
2.2 Field Instrument Surveys

Trained hydrographic survey crews headed by Christopher Crowley performed field instrument surveys of all system features during the three major field trips using electronic theodolites, survey rods and measuring tapes. Two-way radios were utilized for efficient crew communication.

One-half foot contour interval data were collected at Mummy Lake for precise mapping purposes. All known archeological sites in the Water Gathering Area were identified and surveyed as part of the topographic surveying. The Cowboy Ditch was mapped and measurements were made for its cross-sectional characteristics and slope.

2.3 Geology

The geology of Chapin Mesa, while well known, was field checked and further defined by John Rold, former Colorado State Geologist, and Eric Bikis, WWE geologist. In particular, attention was paid to bedrock depth north of Mummy Lake and the occurrence of the underlying red clay in the vicinity of Mummy Lake.

2.4 Hydrogeology

Studies were conducted by Eric Bikis and Kenneth Wright to determine the likelihood of either a seasonal or permanent groundwater table in the vicinity of Mummy Lake and to explore the potential of a high water table that might cause seasonal inflow to Mummy Lake.

2.5 Soils

Douglas Ramsey of the Natural Resource Conservation Service (NRCS) located in Cortez, Colorado had earlier mapped the soils of Chapin Mesa. For the 1998-99 study, the soils were checked and confirmed in the field by visual inspection and from the results of numerous auger holes. WPI appreciates the significant support of the NRCS.
2.6 Infiltration Tests

The rate at which rainfall soaks into the ground and runs off was determined using field infiltration tests performed in accordance with NRCS’ procedures. Charles Lawler performed the work under the general supervision of Douglas Ramsey.

Additional observations were made during periods of rainfall when actual runoff was noted in the field, especially from bare ground surfaces and areas of ground surface compaction from foot traffic.

2.7 Precipitation

Kenneth Wright, Ruth Wright and John Rold inspected the United States Weather Bureau station at the MVNP Research Center. The long precipitation period of record was obtained and analyzed by Lynnette Schaper. Fortunately, the weather station is located only four miles south of Mummy Lake.

2.8 Palynology

Soil samples were collected from the Water Gathering Area in October 1998 by geologist Kurt Loptien for pollen analyses. The purpose was to determine if this area had been a prehistoric farming area and, if so, what crops might have been grown there by the Early Americans.

Later, in June 1999 under the direct supervision of Dr. Linda Scott-Cummings and Dr. David Breternitz, auger holes were drilled at Mummy Lake between Walls 2 and 3, which is a sediment deposition area. Soil samples were collected for laboratory study. The Paleo Research Laboratory of Golden, Colorado performed the pollen studies on all of the samples.

2.9 Archeological Sites

Each of the recorded archeological sites marked by pins was inspected by Dr. Linda Scott-Cummings and Dr. Calvin Cummings along with Jeanne and Donald Tucker and other members of the team to determine if they were likely agricultural field houses.
Photo 3: The Archeological Pins in the Water Gathering Area were identified and then surveyed for location and elevation. Ken Wright is shown with a typical pin.
2.10 Artifacts

Dr. David Breternitz, who provided his interpretations in the field as requested, had previously made the evaluation of artifacts in Mummy Lake. Dr. Breternitz provided additional information on the early intake system, the walls and details related to his 1969 excavations along with the work of Al Lancaster, in part based on his artifact analyses.

2.11 Piezometers

Eric Bikis and Charles Lawler constructed three piezometers in January 1999 under the supervision of Larry Nordby and Douglas Ramsey. The piezometers were constructed in accordance with normal standards and in a manner for longer-term groundwater level observations. The locations of the piezometers are given in Drawing 1. In June 1999, one piezometer was found not to have full penetration.

2.12 Far View Ditch

Dr. Jack Smith and Kenneth Wright made the initial Far View Ditch field inspections in May 1998. In October 1998, detailed field inspections continued with John Rold and Lynnette Schaper, who identified the ditch right-of-way from Mummy Lake to Far View Village. Mr. Rold prepared approximate cross-sections. In June 1999, the right-of-way was further inspected by Douglas Ramsey, Dr. Arthur Rohn, Dr. David Breternitz, Ernie Pemberton, Mary Gillam and other team members at which time field evaluations were made and conclusions were drawn.

Field reconnaissance of a potential West Ditch provided no evidence of a former ditch. However, the likely ditch route contains a MVNP road track into the forest to an archeological site.

2.13 Archives

Dr. Jack Smith and Ruth Wright went through the archival records pertaining to Mummy Lake for three days in June 1998. Copies of the original field cross-sections of the Mummy Lake 1969 excavations were made, copies of the 1969 black and white photographs were printed from the Breternitz negatives and Al Lancaster’s field notes were studied and converted to typewritten pages.
2.14 Photographic and Video Records

The three major field trips were documented by photographer Ruth Wright using 35-mm Kodachrome. Kenneth Wright prepared a video record that was used to produce a 20-minute educational video of Mummy Lake for distribution to museums, libraries and scientists. Rita Baysinger produced the video with funding by the Colorado Historical Society.

2.15 Aerial Photography

The MVNP aerial photographs of Chapin Mesa taken in June 20, 1997 were enlarged to 40”-x-40” for detailed study of visible features and to note what was not apparent on the ground. The aerial photographs were also used in the field for correlation purposes and to evaluate modern vegetation.

3.0 TECHNICAL RESULTS AND EVALUATIONS

Pertinent parameters associated with Mummy Lake are summarized below based upon the WPI 1998-99 field instrument surveys, research, descriptions and findings from the 1969 excavations (Breternitz 1999).

3.1 Mummy Lake

<table>
<thead>
<tr>
<th>Original Ground Surface</th>
<th>Approximate Elevation or Dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center of Mummy Lake</td>
<td>7,737 feet</td>
</tr>
<tr>
<td>Northwest edge</td>
<td>7,738 feet</td>
</tr>
<tr>
<td>East edge</td>
<td>7,735 feet</td>
</tr>
<tr>
<td>South edge</td>
<td>7,734 feet</td>
</tr>
<tr>
<td>West edge</td>
<td>7,738 feet</td>
</tr>
<tr>
<td>Top of Walls 2 and 3</td>
<td></td>
</tr>
<tr>
<td>North, west and southwest</td>
<td>7,739.5 feet</td>
</tr>
<tr>
<td>East</td>
<td>7,737.5 feet</td>
</tr>
<tr>
<td>South</td>
<td>7,739.5 feet</td>
</tr>
<tr>
<td>Typical</td>
<td>7,739.0 feet</td>
</tr>
<tr>
<td>Bedrock</td>
<td></td>
</tr>
<tr>
<td>Center of Mummy Lake, Approx.</td>
<td>7,731 feet</td>
</tr>
</tbody>
</table>
Approximate Elevation or Dimension

1999 Elevation
Low point of Mummy Lake bed 7,733.5 feet

Diameter
East-west 93 feet
North-south 90 feet

Top Wall 3 to Bedrock, Typical
At center 8 feet

Bedrock Below Original Ground Surface 6 feet

Depth of Post-Occupational Sediment
Range of depth 3 to 5 feet

Stairway into Mummy Lake
Height 3.75 feet
Width 2.1 feet

General Soil Profile* at Mummy Lake
(Morefield Loam)
Brown loam 0-2 inches
Reddish-brown loam 2-8 inches
Reddish-brown clay loam 8-24 inches
Reddish-brown loam 24-58 inches
Yellowish red clay loam 58 inches to sandstone bedrock

* See Appendix D. The profile is based on general conditions for Morefield Loam. Morefield loam is the most common soil found around Mummy Lake.

3.1.1 Soil Moisture Capacity of Native Soil

The ability of the soil to allow downward migration of moisture in excess of its field capacity may allow formation of a perched water table. Based on the soil depth above the red clay loam of 58 inches, the soil moisture capacity is estimated at 8.7 inches. Assuming the soil moisture reservoir is 60 percent depleted at the beginning of a rainy month, it would take 5.2 inches of rainfall to cause saturation and commencement of the formation of a perched water table. A perched water table would cause seepage into Mummy Lake.

To determine whether or not a perched water table would exist at Mummy Lake that would have caused groundwater inflows to the depression, three piezometers were constructed in January
1999. Logs of the piezometer holes are presented in Appendix E, and their locations are shown on Drawing 1.

Monitoring of the piezometers through the late winter and spring of 1999 resulted in no water being found in the piezometers. For that reason, along with field geologic studies, it was concluded that groundwater seepage was not a regular source of water for Mummy Lake.

![Photo 4: Soil sampling near Early Intake Area by Bastiaan Lammers.](image)

### 3.2 Volume of Mummy Lake

The approximate potential water storage capacity of Mummy Lake based on late Pueblo II conditions is shown in the following table:
Table 1

Approximate Stage-Capacity of Mummy Lake*

<table>
<thead>
<tr>
<th>Stage (ft)</th>
<th>Acre-Feet</th>
<th>Gallons</th>
</tr>
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<tbody>
<tr>
<td>0</td>
<td>Bedrock Base</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0.025</td>
<td>8,000</td>
</tr>
<tr>
<td>2</td>
<td>0.064</td>
<td>21,000</td>
</tr>
<tr>
<td>3</td>
<td>0.114</td>
<td>37,000</td>
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<tr>
<td>4</td>
<td>0.175</td>
<td>57,000</td>
</tr>
<tr>
<td>5</td>
<td>0.245</td>
<td>80,000</td>
</tr>
</tbody>
</table>

* Likely maximum water depth is 4.7 feet.

The above table is portrayed graphically in Appendix F.

3.3 Water Collection Feature

The water gathering feature as defined by Professor Arthur Rohn (Rohn 1963), and shown on the WPI collection area map (Drawing 3) has the following parameters:

Water Gathering Area\(^{(1)}\)
- Elevation: Ranges from 7,900 to 8,020 feet
- Length: 2,000 feet
- Width: 700 feet
- Slope: 7%

Gathering Basin\(^{(1)}\)
- Length: 300 feet
- Width: 130 feet
- Slope: 7%

Delivery Ditch\(^{(1)}\)
- Distance from pin 1075 to Mummy Lake: 2,900 feet
- Slope, average: 4.8%

\(^{(1)}\) Terms used by Professor Rohn.

3.3.1 Ancient Character of Water Gathering Area

The character of the water gathering area in ancient times is an important consideration because, under present conditions, the area generates little or no surface runoff due to the natural
vegetative cover and resulting high infiltration rates. The soil type of the gathering area is Beje-Tragmon and its description follows:

### Soil: Beje-Tragmon Complex

<table>
<thead>
<tr>
<th>Beje (60%)</th>
<th>Tragmon (20%)</th>
<th>Contrasting Inclusions (20%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown loam</td>
<td>Brown sandy loam</td>
<td>Rock outcrop</td>
</tr>
<tr>
<td>0-14 inches</td>
<td>0-5 inches</td>
<td></td>
</tr>
<tr>
<td>Sandstone</td>
<td>Brown loam</td>
<td>Granath soils on mesas</td>
</tr>
<tr>
<td>14 inches</td>
<td>5-11 inches</td>
<td></td>
</tr>
<tr>
<td>Brown and yellow-brown loam</td>
<td>11-40 inches</td>
<td></td>
</tr>
<tr>
<td>Light yellow-brown loam</td>
<td>40-60 inches</td>
<td></td>
</tr>
</tbody>
</table>

1 See Appendix D for a complete description of Beje-Tragmon complex.

3.3.2 Bedrock

Sandstone ranges from 0 to 5+ feet below the ground surface.

3.3.3 Infiltration Capability

Charles Lawler conducted field infiltration studies in June 1999 using equipment provided by the NRCS office in Cortez. Douglas Ramsey of the NRCS peer reviewed the findings.

The preliminary soil hydrologic analysis used to calculate runoff from the Water Gathering Area utilized infiltration rates based on permeability rates for the Beje Soil Series. These values were reported in the United States Department of Agriculture’s Soil Survey for the area. Permeability rates are considered to generally reflect infiltration rates at saturation. Field determination of the infiltration rates was intended to confirm the validity of utilizing the Soil Survey’s value.

On June 5, 1999, field activities were conducted in the Mummy Lake area that included performing infiltration testing on soil surfaces in the Water Gathering Area. WPI team members Charles Lawler, hydrologist, and Ryan Unterreiner, field technician, performed the test.
3.3.3.1 Field Methods

Site Selection: The test site was selected to minimize any influence from the shallow, and sometimes exposed, bedrock in the Water Gathering Area. Site selection was intended to reflect a reasonable density of vegetation and to represent the physical properties of the area-wide soil. Vegetative cover at the test site was estimated to 60% and consisted primarily of grasses. No attempt was made to create conditions mimicking the compaction that would have been expected at the time the area was used for agriculture.

Test Method: A double-ring infiltrometer was used to determine the infiltration rate. The apparatus consists of an inner ring of ¼-inch-thick steel that is driven into the ground and, when filled, provides a water column that drops at the rate of infiltration. The inner ring has an inside diameter of 10 inches. The inner ring is surrounded by a ¼-inch thick steel outer ring with an inside diameter of 25 inches.

The rings were driven into the ground using a section of wood plank and a sledgehammer and were leveled prior to initiation of the test. The outer edge of the rings were sealed with bentonite at the point of contact with the ground to minimize the effect of areas of higher permeability that may have been caused by driving the rings into the ground. The outer ring was filled with water before the inner ring, and water was allowed to infiltrate the soil to create a hydraulic boundary for the water that infiltrates within the inner ring. A porous fabric was placed in the inner ring before water was poured into the ring. The fabric served to prevent impacts to the soil surface such as compaction or “puddling” and was removed prior to the start of measurements.

Data collected included a measurement from a reference point on the inner ring to the surface of the water column within the inner ring. The exact time of the measurement was also recorded.

The test performed was a falling head infiltration test because field conditions precluded the use of apparatus allowing for the maintenance of constant head. Consequently, the water column was refilled during the one-hour test.

The test was ended when three consistent infiltration rate values were obtained.
3.3.3.2 Results

The results of the infiltration test are shown in the table below. Infiltration rates were calculated intermittently throughout the test to monitor the stabilization of the rate. The earliest infiltration rate calculated was the highest value. As is normal, infiltration rates became progressively lower as soil saturation increased.

The final three infiltration values in the table (1.9, 2.1 and 2.3 inches/hour) were judged to indicate stable infiltration conditions.

Table 2

Mummy Lake Water Gathering Area—Infiltration Test Field Data Summary

<table>
<thead>
<tr>
<th>Time</th>
<th>Measurement from Reference to Top of Water Column (inches)</th>
<th>Change in Time (minutes)</th>
<th>Change in Water Level (inches)</th>
<th>Infiltration Rate (inches/hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:45:00</td>
<td>4-6/16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10:46:30</td>
<td>4-8/16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10:47:10</td>
<td>4-9/16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10:48:00</td>
<td>4-10/16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10:50:30</td>
<td>5-2/16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10:56:00</td>
<td>5-6/16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10:58:30</td>
<td>5-10/16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11:01:05</td>
<td>5-15/16</td>
<td>2:35</td>
<td>5/16</td>
<td>7.2</td>
</tr>
<tr>
<td>11:03:00</td>
<td>6-3/16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11:05:30</td>
<td>6-4/16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11:09:00</td>
<td>6-7/16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11:12:00</td>
<td>6-8/16</td>
<td>3:00</td>
<td>1/16</td>
<td>1.2</td>
</tr>
<tr>
<td>Water Column Refilled (Test Re-started)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11:14:30</td>
<td>3-9/16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11:21:00</td>
<td>3-15/16</td>
<td>6:30</td>
<td>6/16</td>
<td>3.4</td>
</tr>
<tr>
<td>11:25:30</td>
<td>4-6/16</td>
<td>4:30</td>
<td>7/16</td>
<td>5.9</td>
</tr>
<tr>
<td>11:31:30</td>
<td>4-9/16</td>
<td>6:00</td>
<td>3/16</td>
<td>1.9</td>
</tr>
<tr>
<td>11:37:00</td>
<td>4-12/16</td>
<td>5:30</td>
<td>3/16</td>
<td>2.1</td>
</tr>
<tr>
<td>11:42:00</td>
<td>4-15/16</td>
<td>5:00</td>
<td>3/16</td>
<td>2.3</td>
</tr>
</tbody>
</table>

3.3.3.3 Conclusions

The average of the final three infiltration rates in the test was 2.1 inches per hour. This is consistent with the 0.60-to-2.00-inches-per-hour range reported in the Soil Survey. This correlation confirms the validity of using the Soil Survey’s values for the hydrologic analysis.
It is reasonable to utilize the field results to justify hydrologic evaluation using lower infiltration values since the field test site was not compacted. It could reasonably be assumed that compaction would have been greater at the time Ancestral Puebloans were practicing agriculture at the site. The greater compaction would have resulted in lower infiltration and higher runoff.

The field infiltration test could have been repeated after modestly compacting the soil surface with one’s feet within the inner ring. However, this was considered unnecessary because of the several earlier instances of noting runoff from foot-traffic-compacted areas.

3.3.4 Land Use

Land use consisted of farming for corn and, potentially, wild potatoes.

3.3.5 Delivery Ditch

Field evidence of the Delivery Ditch was not obtained. The ditch was not found at Archeological Pin No. 1074, where it had earlier been located. The following data are based upon potential hydraulic characteristics:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>2,900 feet</td>
</tr>
<tr>
<td>Width</td>
<td>3 feet</td>
</tr>
<tr>
<td>Slope</td>
<td>4.8%</td>
</tr>
<tr>
<td>Manning’s roughness</td>
<td>0.04</td>
</tr>
<tr>
<td>Depth</td>
<td>0.4 feet</td>
</tr>
<tr>
<td>Velocity</td>
<td>3.6 fps</td>
</tr>
</tbody>
</table>
Photo 5: Mummy Lake Early Ditch with overlying Late Wall. Note the bottom of the ditch at 3.4 feet below normal ground surface.
3.4 Climate and Precipitation

The ancient climate on Chapin Mesa has been estimated using a combination of modern weather records from the Chapin Mesa weather station (1925-1997), one year of records from Morefield Canyon near archeological site 5MV1931, and the dendrochronology research performed by Dr. Jeffrey Dean of the University of Arizona.

3.4.1 Modern Climate

Modern precipitation and temperature for Chapin Mesa were recorded by the National Weather Service’s recording station located at the Research Center on Chapin Mesa approximately four miles south of Mummy Lake as described below.

Name: Mesa Verde National Park
Latitude/Longitude: Lat: N 37 12’00”  Long: W 108 29’00”
Elevation: 2168.7 m (7,115.0 ft)
Record: 1925 to present (1999)
Precipitation: Measured and recorded (1923 – 1999, 78 years)
Wind: Not measured
Temperature: Measured and recorded (1925 – 1999, 75 years)

A summary of the weather data as published by the National Weather Center is presented in the following table. In addition to the 78-year record of precipitation, which provides 24-hour rainfall depth values, the station has reported 15-minute precipitation values since 1976.

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Average, Monthly and Yearly Precipitation and Temperature for MVNP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Jan</td>
</tr>
<tr>
<td>Precip.</td>
<td></td>
</tr>
<tr>
<td>1.63</td>
<td>1.40</td>
</tr>
<tr>
<td>Temp (°F)</td>
<td>27.61</td>
</tr>
</tbody>
</table>
The short-term precipitation depths were used to develop intensity-duration frequency relationships for a variety of short-duration precipitation events, as presented in Figure 2. These curves are used for rainfall-runoff analyses because they provide rainfall intensities for a variety of short-storm events for a variety of recurrence frequencies. For example, 2-, 5- and 10-year return frequencies with durations consistent with the time to peak of the Mummy Lake drainage basin are presented.

The Mesa Verde National Park’s weather station, approximately four miles from Mummy Lake, is suitable for defining general weather conditions for the modern period for the Mummy Lake site. Furthermore, the 15-minute precipitation data from the park’s weather station provides a sound basis for determining short-term rainfall intensities suitable for use in rainfall-runoff studies.

The climate of Mesa Verde National Park and that of Chapin Mesa is semi-arid with 18.1 inches of average annual precipitation and temperatures ranging from as low as 0 degrees in the winter to 100 degrees during summer extremes. The frost-free period (temperature \( \geq 32 \) degrees) on Chapin Mesa is approximately 135 days, and the typical growing season is from May through September.
Figure 2
Rainfall Intensity-Duration-Frequency for Chapin Mesa
Mesa Verde National Park, Colorado

[Graph showing rainfall intensity vs. duration for 2-year, 5-year, and 10-year events.]
3.4.2 Paleoclimate

An analysis of dendroclimatic data for Mesa Verde by Dr. Jeffrey Dean of the University of Arizona’s Laboratory of Tree-Ring Research provided the basis for estimating the long-term (AD 481-1988) precipitation patterns. The 1508-year period is estimated to have an average annual precipitation of 18.1 inches, which is the same as that of the modern record. The estimated precipitation for the 230-year period of Mummy Lake operation (AD 950-1180) is presented in Figure 3 showing an average annual precipitation of 17.8 inches. During the 230-year study period there were about 11 years with annual precipitation of 25 or more inches and approximately 14 years having only 11 inches per year or less. During the 12th Century there was a serious and extended drought period of 50 years from approximately 1130 to 1180. This drought would have had a major impact on the hydrological viability of Mummy Lake.

The Chapin Mesa’s climate can be judged to have been harsh with cold winters, hot summer days and a relative paucity of rainfall. The wind experienced on mesa tops such as Chapin Mesa would have added to the discomfort in the winter but would have been generally pleasant in the summer. Snowpack melt within the relatively deep Mummy Lake in spring would have usually provided for some water storage, ranging from a few inches in depth to perhaps 18 inches maximum.
Figure 3
Mesa Verde Dendroclimatic Reconstruction of Annual Precipitation
10 Year Moving Average 950 A.D. - 1180 A.D.
3.4.3 Summary of Estimated Paleoclimate (AD 950-1180)

**Average**

Average annual precipitation AD 481-1988 18.1 inches
Average annual precipitation AD 1948-1997 18.1 inches
Average annual precipitation AD 950-1180 17.8 inches

**AD 950-1180 Precipitation**

Above-average years 47%
Below-average years 53%

**Extremes (AD 950-1180)**

- 25 inches or more 11 years
- 11 inches or less 15 years
- 3 consecutive years above average 7 periods
- 3 consecutive years below average 11 periods

**Major Drought**

Duration of AD 1130-1184 55 years
Average precipitation for this period 16.3± inches

**Monthly Precipitation**

- Frequency of 4.0 inches/month Once every 2.2 years
- Frequency of 5.0 inches/month Once every 7 years
- Frequency of 6.0 inches/month Once every 24 years

**Snowfall (Estimated)**

Average December-March precipitation (Water Equivalent) 6.56 inches
Equivalent snowfall depth (average) 33 inches (approximate)

**Rainfall Intensity**

<table>
<thead>
<tr>
<th>Duration (minutes)</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 Years (in/hr)</td>
</tr>
<tr>
<td>5</td>
<td>2.8</td>
</tr>
<tr>
<td>10</td>
<td>2.2</td>
</tr>
<tr>
<td>15</td>
<td>1.8</td>
</tr>
<tr>
<td>30</td>
<td>1.3</td>
</tr>
<tr>
<td>60</td>
<td>0.8</td>
</tr>
</tbody>
</table>

(See Figure 2.)
3.5 Water Gathering Area Runoff Potential

The rate and volume of runoff from a given area is dependent on both the intensity and amount of precipitation, particularly the intensity. Important to the rate and volume of runoff, however, is the characteristic of the land surface as represented by area, slope, vegetation and relative imperviousness. For instance, while vegetation-covered sandy soil creates very little runoff, a paved parking lot has significant runoff. At Chapin Mesa the shallow soils tend to be sandy but with a substantial percentage of silt and clay. The Chapin Mesa soils, under present conditions, are generally well vegetated and there is little or no natural runoff.

During the 1998-99 WPI field investigations it was noted that:

1. Ground surfaces stripped of vegetation tended to become relatively impermeable after being thoroughly wetted during precipitation events.

2. Where the vegetation was stripped and there was heavy foot traffic, the soil surface became highly impervious.

3. The upper soil zone tends to be erodable at typical slopes of 3 or 4, or more, percent.

3.5.1 Field Observations

During field observations on October 23, 1998 at Mummy Lake, following three days of light precipitation that averaged approximately 1/3 inch per day, runoff was noted from small vegetation-free areas that were subject to heavy foot traffic. For instance, approximately 100 square feet of the Mummy Lake berm area yielded 1 – 2 gpm after a period of approximately 1 hour of rainfall totaling approximately 0.25 inch. The runoff was sufficient to cause a 1-inch-deep gully approximately 4 inches wide with active head cutting located in the inlet structure of Mummy Lake. Furthermore, during the three-day rainfall period, water flowed into Mummy Lake at approximately four locations over Wall No. 2. Overall, it was estimated that during the three-day period, 0.5 cubic yard of sediment washed into Mummy Lake from the heavy foot traffic areas of the 90-foot-diameter berm.
3.5.2 Ancient Land Use

The drainage catchment area for Mummy Lake lies approximately one mile north of Mummy Lake at an elevation 260 feet higher than Mummy Lake. Of three soil samples submitted to PRL of Golden, Colorado for pollen testing, two of the sites showed significant Zia (corn) pollen from the 2-inch to 7-inch depth. The corn pollen analysis would indicate that the drainage basin was at least partially farmed. PRL also identified potential starch from wild potatoes.

After concluding that the catchment basin for Mummy Lake was at least partially farmed, it was surmised that the soil surface would have been at least partially stripped of natural vegetation and that the soil surface would have been worked for cultivation purposes. The field workers walking back and forth from Far View Village would have created a north-south path from the vicinity of Mummy Lake to the catchment area, and field workers would have caused compaction of the top soil with foot traffic as they tended the agricultural field. The slope of the catchment area proper is 6.7 percent. Most trees and brush in the vicinity would likely have been removed for firewood and building materials.

For purposes of computing rates and volumes of runoff from the catchment area, it was assumed that:

1. Approximately five acres of equivalent surface area in the drainage catchment area were stripped of vegetation, subject to foot traffic, and creating runoff.

2. The footpath route between Mummy Lake and the agricultural field would have followed the mesa ridge in a north-south direction. After a period of time, the path would have developed a concave cross-section suitable for use as a ditch.

3. On the basis of soil testing by the NRCS, field observations, analyses using the SCS rainfall/runoff procedure and past professional experience on rainfall/runoff relationships, it was determined that five acres of developed agricultural field would have a typical curve number of 85. A range of curve numbers was analyzed for sensitivity analyses.

4. Using the more widely known rational formula that is a common tool in the engineering profession, a runoff coefficient of 0.3 was selected for the cultivated portion of the
agricultural field. Computations were also performed using the rational method with a C Factor of 0.2 and 0.4 to test sensitivity.

5. Land use on Chapin Mesa was different from that which exists now. Under present conditions, there is little or no runoff.

3.5.3 Ancient Runoff

Using standard engineering hydrological procedures, rainfall/runoff relationships for two, five and ten-year frequencies of occurrence were computed with the various rainfall intensity parameters as represented in Figure 2. The results of the magnitude and frequency of runoff from the Mummy Lake drainage catchment are in the following table:

<table>
<thead>
<tr>
<th></th>
<th>Frequency of Runoff</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 Year</td>
</tr>
<tr>
<td>Discharge (cfs)</td>
<td>1.7</td>
</tr>
<tr>
<td>Volume (af)</td>
<td>0.04</td>
</tr>
<tr>
<td>Volume (gal)</td>
<td>13,000</td>
</tr>
</tbody>
</table>

Area = 5 acres; C = 0.3; curve number = 85; intensity = 1.1 inches per hour; Tc = 40 minutes.

3.5.4 Sensitivity Analyses

The sensitivity analyses included study of a range of curve numbers (CN) from 75 to 90 and a range of runoff coefficients (C) from 0.2 to 0.4. The range of runoff values determined is in the following table:
### Table 5
Sensitivity Analyses of Runoff

<table>
<thead>
<tr>
<th></th>
<th>Frequency of Runoff</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 Year</td>
</tr>
<tr>
<td><strong>Discharge (cfs)</strong></td>
<td></td>
</tr>
<tr>
<td>C = 0.2</td>
<td>1.1</td>
</tr>
<tr>
<td>C = 0.4</td>
<td>2.2</td>
</tr>
<tr>
<td><strong>Runoff Volume (acre-feet)</strong></td>
<td></td>
</tr>
<tr>
<td>CN = 75</td>
<td>0.0</td>
</tr>
<tr>
<td>CN = 90</td>
<td>0.08</td>
</tr>
</tbody>
</table>

### 3.6 Sedimentation Rates

If runoff provided a water supply to Mummy Lake, even if minor, sediment would be deposited. The estimated volume of fill material in the embankment of Mummy Lake has been compared with the excavated volume of cut. The excess of fill material in the embankment over that of the volume of cut would indicate the volume of wind and water sediment deposited during the active life of Mummy Lake. A comparison is made below using estimated parameters.

<table>
<thead>
<tr>
<th>Fill in embankment</th>
<th>1,100 cubic yards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cut volume of Mummy Lake (to bedrock)</td>
<td>550 cubic yards</td>
</tr>
<tr>
<td>Excess fill</td>
<td>550 cubic yards</td>
</tr>
<tr>
<td>Rate of sediment accumulation* (equals excess fill divided by estimated duration of use) over AD 950-1180 period</td>
<td>2.4 cubic yards/year</td>
</tr>
<tr>
<td>Sediment yield for 25 acres and 230-year period</td>
<td>0.013 acre-feet/square mile/year</td>
</tr>
</tbody>
</table>

* Assumes no embankment loss to wind or water erosion and no overbank delivery ditch flows during extremely rare thunderstorm events. Any loss of material since 1180 AD would result in an increased estimate of the annual sediment accumulation.

A comparison was made with the 1995-1998 sediment yield estimates for Morefield Reservoir. A preliminary estimate for total sediment inflow to the Morefield Reservoir Site 5MV1931 is about 700,000 cubic feet or 16.1 acre-feet. This gives, for an area of 4.2 square miles and a period of 350 years, a sediment yield of 0.011 acre-feet per square mile per year. At Morefield Reservoir, any large floods would have continued down Morefield Canyon due to the limited ditch capacity.
3.7 Mummy Lake Bank Deposits

Drawings 1 and 2, coupled with the original field notes and field sketches prepared by the 1969 Breternitz team, were analyzed for evidence of sorted sediments that might be associated with deposition by flowing water. The profile of the east bank contains a sloping sand layer, a pocket of sand along with zones of sands and silts. The south bank profile shows no distinct sand layers, however, there is a large zone of “sandy clay loam mixed with sand particles” and a zone of “sandy loam fill.” There are zones of adobe; consolidated clay and dry clay fill in the banks that can be associated with dredging. It is noted that one large zone of sand in the south bank of Breternitz’s Figure 11 (1999) was described in the field as “black clay.” This was likely a drafting error that was corrected in Drawing 2.

The shape and slope of the sediment deposits in the circular bank of Mummy Lake (outside of Wall 2) is representative of disposal of excavated sediment from a pond and have characteristics similar to the outer deposits of the Morefield Reservoir.

3.8 Pollen Analysis of Mummy Lake’s Interior

The 1973 report on the palynology investigation performed by Dr. Linda Scott-Cummings of PRL is presented in Appendix G. This study was performed in conjunction with Dr. David Breternitz’s work, but was not included in his 1999 publication (Breternitz 1999).

3.9 Pollen Analysis in the Water Gathering Area

Soil samples specially collected by Kurt Loptien in October 1998 for pollen analyses were submitted to Dr. Linda Scott-Cummings of the PRL. Sample locations are shown on Drawing 3. Dr. Linda Scott-Cummings’ report on the pollen analyses is presented below. The pollen diagram for the Water Gathering Area is given in Table 3.9.3.3. For reader convenience, two additional pollen diagrams are provided.

Six pollen samples were collected from three locations within the Water Gathering Area drainage basin to search for evidence of agriculture. Both maize and squash produce pollen grains large enough to find during low-power scans of pollen samples. Therefore, after pollen counts were finished, each slide was scanned in search of evidence of agriculture.
3.9.1 Pollen Methods

A chemical extraction technique based on flotation is the standard preparation technique used in the PRL laboratory for removal of the pollen from the large volume of sand, silt and clay with which they are mixed. This particular process was developed for extraction of pollen from soils where preservation has been less than ideal and pollen density is low.

Hydrochloric acid (10%) was used to remove calcium carbonates present in the soil, after which the samples were screened through 150-micron mesh. The samples were rinsed until neutral by adding water, letting the samples stand for two hours, then pouring off the supernatant. A small quantity of sodium hexametaphosphate was added to each sample once it reached neutrality, then the beaker was again filled with water and allowed to stand for two hours. The samples were again rinsed until neutral, filling the beakers only with water. This step was added to remove clay prior to heavy liquid separation. At this time, the samples are dried then pulverized. Zinc bromide (density 2.1) was used for the flotation process. The samples were mixed with zinc bromide and centrifuged at 1,500 revolutions per minute (rpm) for 10 minutes to separate organic from inorganic remains. The supernatant containing pollen and organic remains is decanted and diluted. Zinc bromide is again added to the inorganic fraction to repeat the separation process. After rinsing the pollen-rich organic fraction obtained by this separation, all samples received a short (20-minute) treatment in hot hydrofluoric acid to remove any remaining inorganic particles. The samples were then acetolated for three minutes to remove any extraneous organic matter.

A light microscope was used to count the pollen to a total of 200 pollen grains at a magnification of 400-600x. Pollen preservation in these samples varied from good to poor. Comparative reference material collected at the Intermountain Herbarium at Utah State University and the University of Colorado’s Herbarium was used to identify the pollen to the family, genus and species level, where possible.

Pollen aggregates were recorded during identification of the pollen. Aggregates are clumps of a single type of pollen and may be interpreted to represent pollen dispersal over short distances or the introduction of portions of the plant represented into an archaeological setting. Aggregates were included in the pollen counts as single grains, as is customary. The presence of aggregates is noted by an "A" next to the pollen frequency on the pollen diagram. A plus (+) on the pollen
diagram indicates that the pollen type was observed outside the regular count while scanning the remainder of the microscope slide.

Indeterminate pollen includes pollen grains that are folded, mutilated and otherwise distorted beyond recognition. These grains are included in the total pollen count, as they are part of the pollen record.

3.9.2 Discussion

Previous pollen analyses at Mummy Lake (Scott 1973 and Wykoff 1977) document the presence of cultural fill near the bottom of Mummy Lake, overlain by post-occupational fill that provides evidence of regrowth of the pinyon/juniper woodland following abandonment of Mesa Verde. Population pressure on local resources is postulated to have resulted in clearing of much of the top of the mesa. Wood was needed for construction and fuel, and land was necessary for agriculture to feed the large population. Current rainfall/runoff characteristics in the pinyon/juniper woodland are not sufficient to account for the accumulation of sediment in Mummy Lake or to supply Mummy Lake with water.

Six pollen samples were collected from three locations within the drainage basin at depths of 0"-2" and 2"-6" in an attempt to recover evidence of agriculture. Pollen samples were collected at 100' North WWE CP-2, 100' East Power Pole H63 and 300' East Power Pole H67, as shown on WWE’s Map 3 and Figure 3. Examining a pollen record from relatively large depths such as these is done to maximize the potential for recovering evidence of agriculture when the depth of the original surface is not known. Should further refinement be necessary, only the layers yielding evidence of agriculture would be resampled at finer intervals. Since some sedimentation was expected since abandonment, the depth of 0"-2" was examined to provide a control, while the depth of 2"-6" was examined in an effort to locate maize and/or squash pollen. Maize pollen is the more likely to be recovered, since the pollen grains are large and carried only minimal distances by the wind. Squash/pumpkin pollen is large, sticky and transported primarily by insects. Even flower drop results in only rare pollen recovery in fields known to have been used to grow squash/pumpkin.

The pollen signatures for these three sets of samples provide averages of pollen that accumulated over the intervals represented. In general, arboreal pollen was less abundant in the lower sample than the upper sample. This is consistent with the hypothesis that during occupation much of the
Mesa Verde National Park
The 1998–1999 Paleohydrology Study of Mummy Lake Site 5MV833

mesa top was deforested. Smaller quantities of both Juniperus and Pinus pollen represent smaller quantities of both juniper and pine than are present today. Quercus pollen is noted in two of the pairs of samples, but not the third, recording the presence of Gambel's oak within the pinyon/juniper woodland. Gambel's oak is most abundant at 100' North WWE CP-2.

Artemisia pollen is more abundant in the lower sample at two locations (100' North WWE CP-2 and 300' East Power Pole H67) than in the upper samples. In samples from the remaining location (100' East Power Pole H63), approximately equal quantities of Artemisia pollen reflect the local sagebrush. Sagebrush appears to have been more abundant on the mesa top in the past than at present, undoubtedly as a result of tree clearing. Cheno-am pollen is present, but not abundant, and probably represents local saltbush. Small quantities of Ephedra pollen reflect local presence of Mormon tea. Poaceae pollen varies widely in these samples and indicates local quantities of grasses. Since these samples represent very long periods of pollen accumulation, trends in pollen frequency should not be used to interpret paleoenvironmental conditions.

Zea mays pollen was recovered in the lower samples at 100' East Power Pole H63 and 300' East Power Pole H67. In the absence of residential sites and/or middens in these areas, recovery of maize pollen suggests agricultural activities. At first glance, this evidence supports the hypothesis that the drainage basin was cleared and used for agriculture, although other potential sources for maize pollen need to be explored.

A single extra large, oval starch granule exhibiting a linear hilum and a strong "X" under cross polar illumination was recovered from the upper sample at 300" East Power Pole H67. This type of starch is consistent with those produced by both wild and domestic potatoes. Kurt Loptien, who collected the samples, washed his hands after eating lunch and wore new, disposable gloves when collecting the samples, so contamination of the sample with modern food is extremely unlikely. In testing numerous brands of disposable gloves, we have never recovered a single potato-type starch, so there is very little possibility that the starch was introduced by use of gloves. Therefore, it is probable that recovery of this potato starch signals the presence of wild potato (Solanum jamesii or S. fendlerii) growing in this area of the mesa. Harrington (1964:485) notes S. jamesii growing in southwestern Colorado at elevations between 6000 and 7500 feet. Recovery of this potato-type starch indicates that wild potatoes grow in this area today and brings up the potential that wild potatoes were available to the Anasazi of Mesa Verde. Evidence for exploitation of wild potatoes
is completely lacking from the archaeological record and would be expected to appear in the charred macrofloral record, provided the remains were recognized, and in the starch record, which often accompanies pollen samples. Starch analysis has only recently been included as part of pollen analysis and, therefore, would not have been attempted on earlier studies of pollen samples from the Mesa Verde area.

*Sporormiella* dung fungal spores were noted at 100' East Power Pole H63. The fungal spore, *Sporormiella*, represents a dung fungus that often becomes more abundant in Historic Period sediments following the historic introduction of grazing animals. Its increasing presence in historic samples has been noted in numerous palynological studies (Davis 1987). *Sporormiella* fungal spores are not confined to the dung of introduced grazers, but also occur in dung from moose, wild sheep, deer, elk, caribou and rabbits. The increase of *Sporormiella* spores in historic sediments may relate to changing land use patterns and increase in the length of time that herds of animals occupy any given area. Since the MVNP does not allow grazing animals, it is likely that the presence of these spores can be traced to native animals or to the cowboy period around the turn on the century.

3.9.3 Conclusions

Pollen analysis undertaken to examine the possible use of the 25-acre drainage basin associated with Mummy Lake has recovered *Zea mays* pollen. This recovery appears to substantiate the potential that this area functioned as an agricultural field. Presence of an agricultural field in this area would change runoff characteristics significantly and be important in the interpretation of the function of Mummy Lake. Should further study of this drainage basin be warranted, samples should be collected at 1 centimeter intervals between 2" and 6". Pollen analysis of these samples would be expected to provide evidence of few trees at the time the area functioned as an agricultural field, the presence of weedy plants often associated with agricultural fields and evidence of plant succession and reestablishment of the pinyon/juniper woodland following abandonment.
### Table 6
Provenience Data for Samples from the Mummy Lake Water Gathering Area

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Depth (inches)</th>
<th>Provenience</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM-G2A</td>
<td>0-2&quot;</td>
<td>100' North WWE CP-2</td>
<td>Pollen</td>
</tr>
<tr>
<td>CM-G2B</td>
<td>2-6&quot;</td>
<td>100' North WWE CP-2</td>
<td>Pollen</td>
</tr>
<tr>
<td>CM-B1A</td>
<td>0-2&quot;</td>
<td>100' East Power Pole H63</td>
<td>Pollen</td>
</tr>
<tr>
<td>CM-B1B</td>
<td>2-6&quot;</td>
<td>100' East Power Pole H63</td>
<td>Pollen</td>
</tr>
<tr>
<td>CM-B6A</td>
<td>0-2&quot;</td>
<td>300' East Power Pole H67</td>
<td>Pollen</td>
</tr>
<tr>
<td>CM-B6B</td>
<td>2-6&quot;</td>
<td>300' East Power Pole H67</td>
<td>Pollen</td>
</tr>
</tbody>
</table>

### Table 7
Pollen Types Observed in Samples from the Mummy Lake Water Gathering Area

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ARBOREAL POLLEN:</strong></td>
<td></td>
</tr>
<tr>
<td>Carva</td>
<td>Hickory, Pecan</td>
</tr>
<tr>
<td>Juniperus</td>
<td>Juniper</td>
</tr>
<tr>
<td>Pinaceae:</td>
<td>Pine family</td>
</tr>
<tr>
<td>Abies</td>
<td>Fir</td>
</tr>
<tr>
<td>Picea</td>
<td>Spruce</td>
</tr>
<tr>
<td>Pinus</td>
<td>Pine</td>
</tr>
<tr>
<td>Pseudotsuga</td>
<td>Douglas fir</td>
</tr>
<tr>
<td>Quercus</td>
<td>Oak</td>
</tr>
<tr>
<td><strong>NON-ARBOREAL POLLEN:</strong></td>
<td></td>
</tr>
<tr>
<td>Asteraceae:</td>
<td>Sunflower family</td>
</tr>
<tr>
<td>Artemisia</td>
<td>Sagebrush</td>
</tr>
<tr>
<td>Cirsium</td>
<td>Thistle</td>
</tr>
<tr>
<td>Low-spine</td>
<td>Includes ragweed, cocklebur, etc.</td>
</tr>
<tr>
<td>High-spine</td>
<td>Includes aster, rabbitbrush, snakeweed, sunflower, etc.</td>
</tr>
<tr>
<td>Liguliflorae</td>
<td>Includes dandelion and chicory</td>
</tr>
<tr>
<td>Cactaceae:</td>
<td>Cactus family</td>
</tr>
<tr>
<td>Cylindropuntia</td>
<td>Cholla</td>
</tr>
<tr>
<td>Opuntia</td>
<td>Prickly pear cactus</td>
</tr>
<tr>
<td>Caryophyllaceae</td>
<td>Pink family</td>
</tr>
<tr>
<td>Scientific Name</td>
<td>Common Name</td>
</tr>
<tr>
<td>-----------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Cheno-am:</td>
<td>Includes amaranth and pigweed family</td>
</tr>
<tr>
<td>Sarcobatus</td>
<td>Greasewood</td>
</tr>
<tr>
<td>Cleome</td>
<td>Beeweed</td>
</tr>
<tr>
<td>Ephedra</td>
<td>Mormon tea</td>
</tr>
<tr>
<td>Ephedra nevadensis-type</td>
<td>Mormon tea</td>
</tr>
<tr>
<td>Ephedra torreyena-type</td>
<td>Mormon tea</td>
</tr>
<tr>
<td>Fabaceae</td>
<td>Bean or Legume family</td>
</tr>
<tr>
<td>Onagraceae</td>
<td>Evening primrose family</td>
</tr>
<tr>
<td>Poaceae:</td>
<td>Grass family</td>
</tr>
<tr>
<td>Polygonaceae:</td>
<td>Knotweed/smartweed family</td>
</tr>
<tr>
<td>Eriogonum</td>
<td>Wild buckwheat</td>
</tr>
<tr>
<td>Polygonum</td>
<td>Knotweed</td>
</tr>
<tr>
<td>Polygonum sawatchense</td>
<td>Sawatch knotweed</td>
</tr>
<tr>
<td>Ranunculaceae</td>
<td>Buttercup family</td>
</tr>
<tr>
<td>Rosaceae</td>
<td>Rose family</td>
</tr>
<tr>
<td>Shepherdia</td>
<td>Buffaloberry</td>
</tr>
<tr>
<td>Zea mays</td>
<td>Maize, corn</td>
</tr>
<tr>
<td>Indeterminate</td>
<td>Too badly deteriorated or corroded to identify</td>
</tr>
</tbody>
</table>

**STARCHES:**
Oval, extra large with linear hilum and an "X" under cross-polar illumination

**SPORES:**
- Monolete: Fern
- Selaginella densa: Little clubmoss
- Trilete: Fern
- Sporormiella: Dung fungus
### Table 8

Pollen Diagram for the Mummy Lake Drainage Basin

<table>
<thead>
<tr>
<th>Sample No</th>
<th>Depth (inches)</th>
<th>Aboreal Pollen</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-6', CM-699</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-2', CM-699</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-2', CM-699</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-6', CM-2A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-2', CM-2A</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Pollen Concentration**

- 300 EAST
- 100 EAST
- WWF CP-2
- 100 NORTH
- POOL

**Types of Pollen**

- Carya
- Quercus
- Populus
- Tilia
- Salix
- Ulmus
- Alnus
- Cornus
- Fraxinus
- Artemisia
- Atriplex
- Chenopodium
- Plantago
- Polygonum
- Polygonaceae
- Convolvulaceae
- Caryophyllaceae
- Poaceae
- Urticaceae
- Asclepiadaceae
- Scrophulariaceae
- Solanaceae
- Liliaceae
- Juncaceae
- Poaceae
- Gramineae
- Cyperaceae
- Equisetum
- Sphenophyllum
- Huperzia
- Lycopodium
- Pseudilium
- Gymnosperms
- Ferns
- Lycophyta
Table 9

Mummy Lake Pollen Diagram, Samples Between Retaining Walls
Table 10

Pollen Diagram from Mummy Lake Sediments

<table>
<thead>
<tr>
<th>SAMPLE NO.</th>
<th>ARBOREAL POLLEN</th>
</tr>
</thead>
<tbody>
<tr>
<td>70A</td>
<td></td>
</tr>
<tr>
<td>70B</td>
<td></td>
</tr>
<tr>
<td>70C</td>
<td></td>
</tr>
<tr>
<td>70E</td>
<td></td>
</tr>
<tr>
<td>70F</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Juniperus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Picea</td>
</tr>
<tr>
<td></td>
<td>Pinus</td>
</tr>
<tr>
<td></td>
<td>Quercus</td>
</tr>
<tr>
<td></td>
<td>APICEAE</td>
</tr>
<tr>
<td></td>
<td>Asteriscia</td>
</tr>
<tr>
<td></td>
<td>Centaurea-Type</td>
</tr>
<tr>
<td></td>
<td>LOW-SPINE ASTERACEAE</td>
</tr>
<tr>
<td></td>
<td>HIGH-SPINE ASTERACEAE</td>
</tr>
<tr>
<td></td>
<td>LIGULIFLORAE</td>
</tr>
<tr>
<td></td>
<td>CHENO-AM</td>
</tr>
<tr>
<td></td>
<td>Sarcobatus</td>
</tr>
<tr>
<td></td>
<td>Cleome</td>
</tr>
<tr>
<td></td>
<td>CYPERACEAE</td>
</tr>
<tr>
<td></td>
<td>Ephedra</td>
</tr>
<tr>
<td></td>
<td>Ephedra nevadensis-type</td>
</tr>
<tr>
<td></td>
<td>Ephedra toreyana-type</td>
</tr>
<tr>
<td></td>
<td>Euphorbia</td>
</tr>
<tr>
<td></td>
<td>LAMIACEAE</td>
</tr>
<tr>
<td></td>
<td>LILIACEAE</td>
</tr>
<tr>
<td></td>
<td>NYCTAGINACEAE</td>
</tr>
<tr>
<td></td>
<td>ONAGRACEAE</td>
</tr>
<tr>
<td></td>
<td>Epilobium paniculatum</td>
</tr>
<tr>
<td></td>
<td>Opuntia</td>
</tr>
<tr>
<td></td>
<td>Plantago</td>
</tr>
<tr>
<td></td>
<td>POACEAE</td>
</tr>
<tr>
<td></td>
<td>Erigonum</td>
</tr>
<tr>
<td></td>
<td>Polygonum sawatchense-type</td>
</tr>
<tr>
<td></td>
<td>ROSACEAE</td>
</tr>
<tr>
<td></td>
<td>Castilleja-type</td>
</tr>
<tr>
<td></td>
<td>SCROPHULARIACEAE</td>
</tr>
<tr>
<td></td>
<td>Calleta-type</td>
</tr>
<tr>
<td></td>
<td>Sphaeralcea</td>
</tr>
<tr>
<td></td>
<td>Yucca</td>
</tr>
<tr>
<td></td>
<td>Zona mays</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>POLLEN SUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>301</td>
<td>302</td>
</tr>
<tr>
<td>63</td>
<td>128</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

TOTAL POLLEN CONCENTRATION
3.10 Pollen Analysis of Mummy Lake Perimeter Depositional Area

The WPI team members collected dozens of soil samples from the zone between Walls 2 and 3 on June 6, 1999 under the supervision of Dr. Linda Scott-Cummings by Dr. Calvin Cummings, Dr. Jack Smith, Dr. David Breternitz, Eric Bikis and Kenneth Wright at multiple test hole locations.

Examination of pollen samples collected between the retaining walls of Mummy Lake provide evidence of Zea mays throughout the deposits, which is consistent with the interpretation that Mummy Lake represents a prehistoric water reservoir. Accumulation of small quantities of Zea mays pollen, probably without aggregates, is a signature consistent with water transport of maize pollen from an agricultural area into a holding basin or reservoir. If this area had been used for ceremonies, maize pollen might well have been used as part of the rituals, resulting in recovery of substantially more maize pollen, probably accompanied by aggregates. Other variabilities and/or inconsistencies also would be expected in the pollen record. In addition, the pollen record from samples collected between the retaining walls exhibits pollen representing plants typically associated with riparian vegetation communities including at least cattail, smartweed and knotweed, Phacelia, sedges, buttercup family, and pink family. Most of these pollen types were not recovered during the pollen study of the drainage basin, suggesting that they represent plants growing either along the end of the drainage ditch feeding Mummy Lake or more probably in the sediments at the edge of the water that accumulated in Mummy Lake. This pollen record presents a picture of plants that included tall cattails and short herbaceous plants growing in the mud at the edges of Mummy Lake while it contained water.

A report by Dr. Scott-Cummings on the pollen analyses of the Mummy Lake Depositional Area is included as Appendix H. In that report, she also discusses the pollen findings of the Water Gathering Area and the Mummy Lake interior.

3.11 Artifact Review

According to David Breternitz (1999), the 1969 excavations and artifact analyses processed 2,651 ceramic pieces, of which 1,543 were from the bank forming the circumference of Mummy Lake. Here, sediments were cast from the lake itself to form the surrounding bank and, for that
reason, the potsherds are chaotic, i.e., they are not in-situ. Sixty-seven percent of the pieces were Mesa Verde White Ware.

The Early Intake System contained 168 potsherds, of which 64 percent were Mesa Verde White Ware. The Late Intake and Late Ditch excavations contained 136 potsherds, with 65 percent also being Mesa Verde White Ware. Inside the lake, the backhoe cuts recovered 80 potsherds, with 81 percent being Mesa Verde White Ware. Of the total 2,651 pieces recovered, 1,767 were Mesa Verde White Ware for 67 percent and 343 pieces were Mancos Black on White for 13 percent.

Ladles, bowls and jars represented by the potsherds totaled 1.1, 12.4 and 86.5 percent, respectively. This is similar to the potsherd distribution found by Smith and Zubrow in 1967 at Morefield Reservoir. The distribution and type of potsherd shapes imply that Mummy Lake was a specialized use structure for harvesting and supplying domestic water.

### 3.12 Photographs

The various black and white and colored photographs taken during the 1969 excavations by the Breternitz team provided verification of the graphic representation of the deposits in the Mummy Lake perimeter bank along with a visual representation of the early and late ditches and the early intake works.

### 3.13 Early Ditch and Circular Intake

The early ditch depth was noted as being some three feet below the normal ground surface and the early circular intake was deep. As described by Breternitz in his report (1999) and in the field, the early intake works continues to be an unsolved question. Ernest Pemberton emphasized the uncertainty of the function of the early intake works.

The old photo of Mummy Lake taken after the turn of the century shows water in the depression; thus providing visual evidence of the water holding capability of Mummy Lake with sufficient capacity as a settling basin for the sizes of sediment transported in suspension.
3.14 Symposium

A Mummy Lake Symposium was conducted in the MVNP Recreation Center on June 5, 1999. The minutes of this symposium are presented in Appendix I.

4.0 OBSERVATIONS

A summary of 1998 to 1999 research includes the following observations:

1. Based on surface examination, there is no compelling field evidence of ancient water collection ditches in the water collection area, but no evidence was found which would exclude such ditches. The long, stone embankment described by Professor Arthur Rohn was identified in the field and located on Drawing 3.

2. Two of the three field soil test profiles submitted to PRL were found to contain *Zia mays* pollen (corn). One shallow sample contained “oval ex lg starch w/-potato type” also known as wild potato. The water gathering area for Mummy Lake would likely have been a farming area.

3. A number of check dams were noted in side gullies as described by Professor Arthur Rohn. The check dams had been used for creation of small flat areas for agriculture.

4. No compelling surface evidence was found for a gathering basin of the collection ditches.

5. No surface evidence was found of a delivery ditch passing through or close to pins 1074 or 1075.

6. No compelling field surface evidence was found of a delivery ditch between pin 1075 and Mummy Lake.

7. Evidence of a Cowboy Ditch was found, as noted on WPI’s Drawing 1.

8. The 1915 MVNP road location, shown on WPI’s Drawing 3, is proximate to surface evidence of an apparent ditch lying 200 to 750 feet north of Mummy Lake for a length of 500 feet.
9. The beginning of the West Ditch described by Rohn was not identified in the field; however, the location of the West Ditch is similar in location to the 1915 MVNP road.

10. The likely Far View Ditch route from Mummy Lake to east of Far View Village was identified but judged to be an old trail or road based on the cross-sectional characteristics.

11. Between Far View Village and MVNP Headquarters, no compelling field evidence was found of the Far View Ditch extension towards the Spruce Tree House area.

12. Small-diameter auger holes were drilled in the Water Gathering Area and in the vicinity of Mummy Lake. Depth to bedrock varied from hole to hole. There would have been no significant groundwater accumulation in Mummy Lake.

13. During the October 1998 field trip, rainfall-runoff relationships were noted on October 23, 1998 during and following three days of low-intensity rainfall totaling about one inch.

   a. Tourist trails near Mummy Lake that exhibited compacted soils had significant runoff. The walking surfaces were nearly impervious.

   b. Measurable runoff occurred from small areas of the Mummy Lake bank surface where there was heavy foot traffic. Water flowed into Mummy Lake from the berm surface at about four locations. Water flowing down the inlet route amounted to 1 to 2 gpm and was erosive.

   c. During the October 21-23, 1998 period, it was estimated that about one-half cubic yard of alluvial sediment was carried into Mummy Lake.

   d. The natural ground surface with vegetation had no runoff; however, non-vegetated areas often had small shallow pools of water representing depression storage.

   e. Significant runoff occurred from the paved MVNP road, which flowed in the roadside ditches and then in distribution ditches that tended to create erosional patterns in the adjacent woodlands.
5.0 PALEOHYDROLOGY FINDINGS

1. Based upon the 1998-99 WPI field work and studies, the Breternitz-Lancaster field data (notes, photographs, and field sketches of maps and trench profiles) and the Breternitz (1999) published report, it can be concluded that:

   a. Mummy Lake was constructed in several phases. The depositional area to the east and south shows evidence of alluvial materials.
   
   b. During prehistoric times, sand was removed from the excavation from time to time. Some of the sand was likely alluvium deposited in the excavation, while a portion may have been decomposed sandstone from the bedrock.
   
   c. The berms and fill at Mummy Lake represent approximately 1,100 cubic yards, roughly 200 percent of the excavation of natural soils. Without considering wind-deposited sediments, the sediment volume at Mummy Lake would indicate an average inflow of sediment of about 2.4 cubic yards per year over 230 years. Wind and water erosion of the banks, if considered, would tend to raise this sedimentation rate. The unit sediment yield in acre-feet/year/square mile was similar to Morefield Reservoir.
   
   d. Due to sandstone bedrock and native clay loam of the Morefield soil, the excavation would have been relatively watertight.
   
   e. Mummy Lake has a high-quality stone stairway leading into it. Based upon study of the Pueblo I-II Morefield Reservoir four miles to the east, the Mummy Lake stairway is inconsistent with an ordinary functioning water storage reservoir.
   
   f. Based on the 1973 pollen testing it can be concluded that existing Mummy Lake sediment deposits include both occupational (pre-1180 AD) and post-occupational (i.e., after 1180 AD) sediments. For instance, Zea pollen, recovered in two samples from FS 66B and 70B near the base of the profile indicate occupational sediments are native to the site low in the profile.

2. Based upon the resource evaluation and surveys of the water gathering area of 25 acres, including pollen testing, it can be concluded that:
a. The water gathering area was capable of producing surface runoff at least about once each year from farmed areas (corn and possibly potato).

b. A footpath from the Mummy Lake area, following the approximate ridgeline upslope to the water gathering area (cornfield) would have been capable of transporting surface runoff to Mummy Lake with only minor losses.

3. Based upon a study of average precipitation patterns during the December to March winter period, it can be concluded that snowpack would usually accumulate in the excavation of Mummy Lake, creating snowmelt water in mid-April amounting to at least a few inches to as much as perhaps 1.5 feet of depth.

4. From analyses of the soil character, geology, and frequency of monthly precipitation amounts, it can be concluded that:

a. There was no permanent water table on Chapin Mesa.

b. A perched water table top at the clay layer or at the soil/sandstone contact would occur infrequently, at the most about once every 5 to 10 years. A perched water table would cause groundwater flow into Mummy Lake along the surface of the red clay layer or on top of the sandstone bedrock. If the depth to the clay layer was less than 58 inches, the frequency of groundwater flow into Mummy Lake would likely be proportionately more frequent.

c. During 1999, the three piezometers in Mummy Lake remained dry, however, the 1998-1999 winter was dry and the April 1999 rains on Chapin Mesa totaled only 2.13 inches for the month. Nevertheless, a perched water table source of water to Mummy Lake is unlikely. The logs of the two piezometer holes are presented in Appendix E.

6.0 CONCLUSIONS

Based upon the technical data collected, derived and studied by the Wright Paleohydrological Institute in 1998 and 1999 and the work of Breternitz (1999) it has been concluded that:
1. Mummy Lake was initiated in about AD 950 as a simple excavation without walls for the purpose of occasionally storing domestic water.

2. Groundwater was not a water source for Mummy Lake. The water source was from the spring melting of snowpack in the excavation and infrequent surface runoff.

3. An old route running from Mummy Lake southward down Chapin Mesa toward the MVNP Headquarters or Cliff Palace was not an irrigation ditch. The route was an old pack-train trail, a cattle trail or an early NPS roadway. There was not an ancient irrigation ditch known as Far View Ditch.

4. The three stone walls of Mummy Lake were for retaining sediment. One wall is buried under the surrounding embankment.

5. The 25-acre area (Water Gathering Basin) lying one mile north of Mummy Lake was an agricultural field likely during the Pueblo II period. As a result, rainfall-runoff characteristics were such as to cause surface runoff, on the average of about once each year. Runoff water could have been carried to Mummy Lake via a foot-packed trail from Far View Village to the agricultural field.

6. The potential ditches in the Water Gathering Basin were likely natural flow paths created by runoff flowing downslope at right angles to the contour lines rather than manmade ditches.

7. The high-class stone stairway leading into Mummy Lake is only one of two known to exist in MVNP. The other is at the nearby Pipe Shrine House. A stairway like that at Mummy Lake is not an essential part of an ancient water storage facility; however, it provided good access from the embankment to the potential water body.

8. The primary purpose and function of Mummy Lake from AD 950 to 1180 was for periodic domestic water storage. Most of the time it would have had no water and, therefore, it provided an infrequent and unreliable source of water for the early inhabitants, as concluded by Dr. David Breternitz (1999).

9. The 1999 Far View informational brochure is included as Appendix G. It needs to be revised to reflect the findings of this report. The considerable occupational activity adjacent
to Mummy Lake is described for Far View Village, Coyote Village, Pipe Shrine House, Far View Tower and Megalithic House.

7.0 **ADDITIONAL RESEARCH NEEDS**

The long history of research and study of Mummy Lake has tended to culminate in this 1999 paleohydrology report that has fully considered previous work. The WPI research team, however, concluded that the stairway and early intake works of the Mummy Lake structure are still not adequately defined as to their function and purpose.

WPI recommends that additional study be performed to better define the purpose of the nine-step stone stairway of Mummy Lake. In addition, WPI recommends that further analysis and research be performed on the early intake works; primarily, the circular settling basin and early ditch.

The symposium held at Mesa Verde on June 5, 1999 left the stairway and early intake works somewhat open in regards to their purpose and function. Dr. Breternitz described the early intake works as primarily being under the investigative direction of Al Lancaster, who is now deceased.

![Photo 6: Early Intake System of Mummy Lake with Early Intake Ditch in Foreground.](image-url)
8.0 REFERENCES


Photo 7: Mummy Lake June 1999 Interpretive Sign. Two theories presented; one for reservoir and one for dance pavilion.
March 20, 1998

Mr. Kenneth R. Wright  
Wright Water Engineers, Inc.  
2490 West 26th Avenue, Suite 100A  
Denver, Colorado 80211

Dear Mr. Wright:

This letter is in response to your proposal to conduct paleohydrological research at Mummy Lake, a potential reservoir in the vicinity of the Far View Group of sites at Mesa Verde National Park. The Research Committee has reviewed the proposal, and members unanimously concur that the project will help address an important research issue regarding the site and its use by the Far View Community.

As telephone conversations between you and Research Committee Chair Larry Nordby have indicated, the two issues raised during the discussion of the proposals involved performance bond insurance, and parking for research team members.

We believe that both the scope of this project, and the previous experience of your research team members in working within Mesa Verde National Park are sufficient grounds for waiving the bond insurance that usually attends the Special Use Permitting process. A Special Use Permit will still be necessary, and will be forwarded to you prior to initiation of the field work.

We have discussed various parking strategies with our staff of rangers, and are working out a strategy by which your team will be able to work in the research area with minimal disruption, both for your team and other members of the visiting public. Larry Nordby will be in touch with potential solutions as the project nears.

We look forward to working again with your team of professionals, and hope to resolve the issue of Mummy Lake use in the same way as was done for the Morefield Reservoir site.

Sincerely yours,

[Signature]
Larry T. Wiese  
Superintendent

Mesa Verde National Park
Appendix B
Appendix B

National Geographic depiction of historic land use on Chapin Mesa.
Appendix C
# APPENDIX C

## MUMMY LAKE FIELD TRIP PARTICIPANTS

<table>
<thead>
<tr>
<th>June 5 - 6, 1999</th>
<th>October 1998</th>
<th>May 1998</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bikis, Eric – Hydrologist</td>
<td>Anderson, Don – Graphics Specialist</td>
<td>Bikis, Eric – Geologist &amp; Hydrologist</td>
</tr>
<tr>
<td>Breternitz, David – Archeologist</td>
<td>Bikis, Eric – Geologist &amp; Hydrologist</td>
<td>Crowley, Chris – Chief Surveyor &amp; Forest Hydrologist</td>
</tr>
<tr>
<td>Crowley, Chris – Surveyor &amp; Drainage</td>
<td>Crowley, Chris – Chief Surveyor &amp; Forest Hydrologist</td>
<td>Ewy, John – Civil Engineer</td>
</tr>
<tr>
<td>Cummings, Calvin – Archeologist</td>
<td>Gillam, Mary – Geologist</td>
<td>Lammers, Bastiaan – Agriculture</td>
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<td>Gillam, Mary – Geologist</td>
<td>Hagen, Brad – Civil Engineer</td>
<td>Loptien, Kurt – Graphics &amp; Geologist</td>
</tr>
<tr>
<td>Hagen, Brad – Civil Engineer</td>
<td>Loptien, Kurt – Graphics &amp; Geologist</td>
<td>Marshall, Scott – Civil Engineer</td>
</tr>
<tr>
<td>Scott Marshall – Civil Engineer</td>
<td>Marshall, Scott – Civil Engineer</td>
<td>Pemberton, Ernie – Sedimentation Expert</td>
</tr>
<tr>
<td>Lawler, Chuck – Hydrologist</td>
<td>Meissner, Liv – Record Keeping</td>
<td>Ramsey, Doug – Soil Scientist</td>
</tr>
<tr>
<td>Loptien, Kurt – Geologist</td>
<td>Ramsey, Doug – Soil Scientist</td>
<td>Rold, John – Former State Geologist</td>
</tr>
<tr>
<td>Earles, Andrew – Water Resources</td>
<td>Rold, John – Former State Geologist</td>
<td>Schaper, Lynn – Water Resources Engineer</td>
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<tr>
<td>Pemberton, Ernie – Sediment</td>
<td>Schaper, Lynn – Water Resources Engineer</td>
<td>Smith, Jack – Archeologist</td>
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<tr>
<td>Pruess, Jon – Paleohydrologist</td>
<td>Sheftel, Janice – Water Attorney</td>
<td>Wright, Ken – Civil Engineer &amp; Hydrologist</td>
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<td>Ramsey, Doug – Soil Scientist</td>
<td>Smith, Jack – Archeologist</td>
<td>Wright, Ruth – Resources Attorney, Photographer</td>
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<td>Rhodes, Ed – Civil Engineer</td>
<td>Wright, Ken – Civil Engineer &amp; Hydrologist</td>
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<tr>
<td>Rohn, Art – Archeologist</td>
<td>Wright, Ruth – Resources Attorney, Photographer</td>
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<tr>
<td>Scott-Cummings, Linda – Pollen Scientist</td>
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<td></td>
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<td>Smith, Jack – Archeologist</td>
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<td></td>
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<tr>
<td>Unreinere, Ryan – Environmental Scientist</td>
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<tr>
<td>Wright, Ken – Civil Engineer</td>
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<tr>
<td>Wright, Ruth – Resources Attorney, Photographer</td>
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Appendix D
MUMMY LAKE AREA

Soil Classification: IRC
Soil Type: Morefield loam
Morefield soil and similar inclusions: 90%
Contrasting inclusions: 10%

Setting
Slopes: 3% to 6%
Landscape position: Mesas
Parent material: Kind=eolian, source=sandstone
Native plant community: Pinyon and juniper woodland
Elevation: 6,800 to 7,800 feet
Mean annual temperature: 47°F to 50°F
Mean annual precipitation: 16 inches to 19 inches
Frost-free period: 130 days to 150 days

Characteristics of the Morefield Soil
Landscape position: Mesas
Slope range: 3% to 6%
Parent material: Kind=eolian, source=sandstone
SCS curve number hydrogroup: B

Typical Profile
0 to 2 inches: Brown loam
2 to 8 inches: Reddish brown loam
8 to 24 inches: Reddish brown clay loam
24 to 58 inches: Reddish brown loam
58 to 60 inches: Yellowish red clay loam

Soil Properties
Depth class: Very Deep
Drainage class: Well drained
Permeability: Moderately slow
Available water capacity: High
Potential rooting depth: 60 inches or more
Flooding: None
Runoff: Medium
Hazard of water erosion: Moderate
Hazard of wind erosion: Moderate
Shrink-well potential: Moderate

NOTE: The soil classifications are provided by the Natural Resources Conservation Service, United States Department of Agriculture (USDA), Cortez Office by Doug Ramsey.
**Contrasting Inclusions**
Stephouse soils on mesas
Arabrab soils on mesas

**Similar Inclusions**
Robideau soils on mesas
Arabrab soils on mesas

**Major Uses**
Wildlife habitat

**Major Management Factors**

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<th>Rangeland Suitability:</th>
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<tr>
<td>Dominant vegetation in the potential plant community:</td>
<td>Muttongrass, big sagebrush, Indian ricegrass, pinyon, Utah juniper</td>
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<tr>
<td>Dominant vegetation in the present plant community:</td>
<td>Pinyon, Utah juniper, muttongrass, bitterbrush</td>
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<td>Potential annual production of air-dry vegetation:</td>
<td>900 pounds per acre</td>
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**Cropland**

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<th>Suitability:</th>
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<tr>
<td>Soil-related factors:</td>
<td>Slope</td>
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<td>Management considerations:</td>
<td>The steep slopes should be managed to prevent excessive erosion</td>
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**Building Site Development**

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<th>Suitability:</th>
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<tr>
<td>Soil-related factors:</td>
<td>Shrink-swell</td>
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<tr>
<td>Management considerations:</td>
<td>Moderate shrink-well potential should be considered in the design of structures</td>
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</table>
APPENDIX D

CHAPIN MESA SOIL CLASSIFICATION
(Beje-Tragmon Soil)

WATER GATHERING AREA
Soil Classification: 4RC
Soil Type: Beje-Tragmon complex
Beje soil and similar inclusions: 60%
Tragmon soil and similar inclusions: 20%
Contrasting inclusions: 20%

Setting
Slopes: 3% to 9%
Landscape position: Mesas, hills and ridges
Parent material: Kind=residuum, slope allumium and eolinan materials; source=sandstone
Native plant community: Gambel oak woodland
Elevation: 8,000 to 8,500 feet
Mean annual temperature: 43°F to 47°F
Mean annual precipitation: 15 inches to 20 inches
Frost-free period: 80 days to 100 days

Characteristics of the Beje Soil
Landscape position: Mesa, hills and ridges
Slope range: 3% to 9%
Parent material: Kind=residuum and eolian material; source=sandstone
SCS curve number hydrogroup: D

Typical Profile
0 to 27 inches: Brown loam
2 to 14 inches: Brown loam
14 inches: Hard sandstone

Soil Properties
Depth class: Shallow
Drainage class: Well drained
Permeability: Moderate
Available water capacity: Very low
Potential rooting depth: 10 inches to 20 inches
Flooding: None
Runoff: High
Hazard of water erosion: Severe
Hazard of wind erosion: Moderate
Shrink-well potential: Low
Characteristics of the Tragmon Soil

Landscape position: Hills and mesas
Slope range: 3% to 9%
Parent material: Kind=slope, alluvium; source=sandstone
SCS curve number hydrogroup: B

Typical Profile

0 to 5 inches: Brown sandy loam
5 to 11 inches: Brown loam
11 to 40 inches: Pale brown and yellowish brown loam
40 to 60 inches: Light yellowish brown loam

Soil Properties

Depth class: Very Deep
Drainage class: Well drained
Permeability: Moderate
Available water capacity: Moderate
Potential rooting depth: More than 60 inches
Flooding: None
Runoff: Medium
Hazard of water erosion: Moderate
Hazard of wind erosion: Moderate
Shrink-well potential: Low

Contrasting Inclusions

Northrim soils on hills
Sheek soils on hills
Rock outcrop

Similar Inclusions

Granath soils on mesas
Falconry soils on hills

Major Uses

Wildlife habitat

Major Management Factors

Rangeland suitability: Fair
Dominant vegetation in the potential plant community on this unit: Gambel oak, muttongrass, serviceberry, snowberry, mountain brome
Dominant vegetation in the potential plant community on the Tragmon soil: Serviceberry, Gambel oak, snowberry, bluegrass, muttongrass
Potential annual production of air-dry Vegetation on the Beje soil: 1,500 pounds per acre
Potential annual production of air-dry vegetation on the Tragmon soil: 2,000 pounds per acre
Soil-related factors: Depth
Management considerations: Low available water capacity limits forage production

**Cropland**
- Suitability: Unsuitable
- Soil-related factors: Depth

**Building Site Development**
- Suitability: Poor
- Soil-related factors: Depth
- Management considerations: Depth to bedrock may limit excavations. The presence of shallow bedrock may adversely affect septic systems.
TO: Ken Wright  
Dr. Jack Smith

FROM: Wright Water Engineers, Inc.  
Eric Bikis and Chuck Lawler

DATE: January 22, 1999

RE: Mummy Lake Site 5MV833—Perched Groundwater Analysis

BACKGROUND

Consideration of perched groundwater or “interflow” as a contributor of water that might be stored in the Mummy Lake structure is a necessary part of the investigation of Mummy Lake’s possible role as a water storage structure. Evaluation of groundwater conditions at the site required the installation of piezometers.

On January 13, 1999, field activities were conducted at Mummy Lake that included the installation of piezometers for monitoring groundwater conditions. Individuals present for the work included Eric Bikis (Wright Water Engineers), Chuck Lawler (Wright Water Engineers), Larry Nordby (Research Archaeologist, National Park Service), Doug Ramsey (Soil Scientist, N.R.C.S.). Eric directed field activities, Chuck performed augering and piezometer installation, Doug Ramsey performed soil profile description and classification and Larry Nordby took field notes and provided National Park Service oversight and archaeological perspective.

The Park Service allowed the installation of three 1” diameter PVC piezometers within the confines of the Mummy Lake structure. They were installed in order to monitor any changes in groundwater levels reflecting water flowing over the shallow bedrock of the area.

The wells were designed with 1 foot of slotting at the bottom, a granular material well pack, native backfill and a bentonite seal at the surface. At the request of Larry Nordby, the well casing was only allowed to extend 12-18 inches above ground surface.

Well locations were selected based on input from all members of the field team with final locations approved by Larry Nordby. In order to determine the direction of groundwater flow, elevations of the surface of the bedrock were determined utilizing plotted ground surface contours and depths to bedrock determined from boreholes made during previous fieldwork. The general direction of the bedrock slope is downward from northwest to southeast. Well locations included upper, middle, and lower bedrock elevations. The locations were selected to avoid previous excavations and any possible subsurface features of the ruin, particularly the retaining wall in the northwest part of the structure.
FIELD DATA

The soil profile data obtained during the fieldwork is generalized as follows:

PZ #1

This piezometer is located in the northern portion of Mummy Lake at the most upgradient point relative to bedrock slope. This location had the most exposure to the sun of the three piezometer sites. There was no snow on the ground surface at this point, the profile was dry throughout and no frozen soils were encountered during augering.

The profile in general showed more coarse particles than the other two, particularly in the upper 20 inches that were classified as fine sandy loam. One possible explanation was the proximity to the “Cowboy Cut,” which may have been a source of coarse sediment inflow where it came into Mummy Lake. Thin clay lenses were noted in the depths from 20-34 inches and total clay content increased with depth, reaching an approximated 40% in the 36-40 inch depth. Bedrock was encountered at 40 inches.

Redoximorphic features (mottles) were first encountered in the profile at a depth of 23 inches. These features indicate saturation during some period in time. The occurrence of these features, as a percent of the soil, was most pronounced in the 34-36 inch depth range and was described as representing 30% of the profile. Below this depth, redox features decreased to approximately 5% of the profile.

Some small pieces of charcoal were encountered in the 36-39 inch depth range.

PZ #2

This piezometer was located in the middle section of Mummy Lake relative to bedrock gradient. This location appeared to be subject to longer periods of shading from the sun since snow was still present on the ground surface approximately 10 feet to the south. Shading of this site would be due to the walls of the structure and to vegetation south of Mummy Lake. Frozen soil was encountered from the surface down to 11 inches. Below this depth, soils were moist throughout the profile.

The upper depths of this profile had less sand than PZ #1. Surface to 11 inches was described as loam. The zone from 11-21 inches was fine sandy loam. Clay lenses were noted in the 21-28 inch depth range. Bedrock was encountered at a depth of 44 inches.

Redox features were encountered at 21 inches but only represented 1% of the profile at this point. Redox features were 15% in the 28-34 inch range, only 5% in the 34-38 inch range and up again in the 38-44 inch range with 20%.
**PZ #3**

This piezometer was the southernmost of the three and located at the lowest point relative to bedrock gradient. This location appeared to have the least exposure to sun due to the walls of the structure and vegetation to the south of Mummy Lake. Snow was present on the ground surface less than 5 feet from the auger hole. Soils were frozen from the surface to a depth of 14 inches. The profile was moist throughout and appeared to be at field capacity at maximum depth.

The soil at this location was darker in color than the other two suggesting an overall higher organic matter content. In addition, the profile had a higher percentage of fine material with an approximated 35% clay content at 14 inches and a maximum 40% noted in the 26-31” depth range. Soils from the surface to 14 inches were classified as loam. Soils from 14 inches to 32 inches were classified as clay loam.

Redox features were first noted at the 14 inch depth and found throughout the profile. These features were described as 10% in the 14-17 inch range, 25% in the 17-26 inch range and 50% in the 26-32” range.

**MONITORING**

Park Service personnel agreed to monitor water levels in the piezometers on a weekly basis. The general monitoring plan was to collect data for at least the winter and spring runoff period of 1999 but the lack of winter precipitation in 1999 raised concerns over the adequacy of data that might be obtained. The Park Service agreed to allow the piezometers to remain in place for a longer period of time than was initially anticipated.

**JUNE 6, 1999 POSTSCRIPT**

On June 6, 1999, an auger hole was drilled next to P2#3. At 32 inches, refusal was encountered; however, Eric Bikis broke through the apparent stone and continued augering to 57 inches. Therefore, the depth-to-sandstone bedrock is 57 inches rather than the previously determined 32 inches.
### Log of Borehole: PZ-1

**Drill Date:** January 13, 1999  
**Location:** Mesa Verde National Park, CO  
**Position:** Not Surveyed

<table>
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<tr>
<th>Depth (feet)</th>
<th>Description</th>
<th>Remarks</th>
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<td>0</td>
<td>Ground Surface</td>
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<tr>
<td>5</td>
<td>Fine sandy loam; moist; 7.5YR4/2 Brown; Weak red; Clay loam strata interbedded; 10YR3/3 Dark brown</td>
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<tr>
<td>20</td>
<td>Fine sandy loam; moist; 2.5YR4/2 Weak red; Clay loam strata interbedded; 10YR3/3 Dark brown; Redoximorphic features conc. 5%; 2.5YR4/8 Red</td>
<td></td>
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<tr>
<td>25</td>
<td>Fine sandy loam; moist; 2.5YR4/2 Weak red; Clay loam strata interbedded; 10YR3/3 Dark brown; Redoximorphic features conc. 10%; associated with clay loam lenses; 2.5YR4/8 Red</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Fine sandy loam; dry; 10YR3/3 Dark brown; Clay conc. increasing; Redoximorphic features conc. 30%</td>
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<tr>
<td>35</td>
<td>Sandstone bedrock</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>Sandstone bedrock at 40(^\circ) depth</td>
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<tr>
<td>45</td>
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**WELL DESIGN**
- Stick-up 15.5\(^\circ\) Above Ground
- Ground Surface Elevation 7735.83'
- 4\(^\circ\) Bentonite Seal
- Reamer constructed of 1\(^\circ\) Diameter PVC
- 22\(^\circ\) of Sol Backfill
- Top of Gravel Pack at 26\(^\circ\) depth
- Top of Perforations at 29\(^\circ\) depth
- Bottom Cap Bored
- Sandstone Bedrock Encountered at 42\(^\circ\) Depth Below Surface
### Log of Borehole: PZ-2

**Drill Date:** January 13, 1999  
**Surface Elevation:** 7733.6’  
**Position:** Not Surveyed

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<td>0</td>
<td>Ground Surface</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Loam, Frozen; 10YR3/2 to 10YR3/3 Very dark grayish brown to dark brown.</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Fine sandy loam, Moist; 10YR6/4 Brown, Not Frozen.</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Fine sandy loam; Some clay anesas; Approximately 15% redoximorphic features; Moist; 10YR7/4 Very pale brown.</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Fine sandy loam; Single 1/2&quot; gray clay loam band; Approximately 15% redoximorphic features; Moist; 10YR7/4 Very pale brown.</td>
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</tr>
<tr>
<td>25</td>
<td>Sandy loam; 45% redoximorphic features; Moist; 10YR7/4 Very pale brown.</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Sandy loam; 20% redoximorphic features; Moist; 10YR4/3 Brown.</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>Sandstone Bedrock at 44' depth.</td>
<td></td>
</tr>
</tbody>
</table>

**WELL DESIGN**  
- Stick-up 14.5' Above Ground  
- Ground Surface Elevation 7733.6'  
- 3' Bentonite Seal  
- Pacemeter Constructed at 1' Diameter PVC  
- 24" of Soil Backfill  
- Top of Gravel Pack at 37' depth  
- Top of Perforations at 32' depth  
- Bottom Cap Slotted  
- Sandstone Bedrock Encountered at 44' Depth Below Surface

---

**Project:** Mesa Verde-Mummy Lake  
**Project Number:** 991-999.8361  
**Log of Borehole:** PZ-2  
**Drilling Company:** N/A  
**Drill Method:** 3” Manual Bucket Auger  
**Sheet:** 1 of 1
Estimated maximum capacity of approximately 75,000 gallons with high water line defined by David Breternitz in 1969.
Appendix G
Not Included in Electronic Copy
Appendix H
POLLEN ANALYSIS OF MUMMY LAKE AND THE MUMMY LAKE DRAINAGE BASIN, MESA VERDE, COLORADO

By

Linda Scott Cummings

with assistance from
Thomas E. Moutoux

Paleo Research Laboratories
Golden, Colorado


Prepared For

Wright Water Engineers, inc.
Denver, Colorado

December 1999
INTRODUCTION

Mummy Lake has long been the object of debate concerning its function. This feature has been interpreted as a prehistoric reservoir and as a dance pavilion. Additional pollen samples have been examined to address the question of function for Mummy Lake. Samples from the Mummy Lake Drainage Basin were examined to identify any evidence of agriculture. The 25-acre drainage basin feeding Mummy Lake might have been farmed, which would have changed its runoff characteristics, since agricultural surfaces have more runoff than natural vegetated ground surfaces. Six pollen samples were collected from three locations within the drainage basin to search for evidence of agriculture. Both maize and squash produce pollen grains large enough to find during low-power scans of pollen samples. Therefore, after pollen counts were finished, each slide was scanned in search of evidence of agriculture. Sediments between the retaining walls of Mummy Lake also were sampled stratigraphically for pollen. If these samples represent cleaning episodes where sediments that had accumulated in Mummy Lake as a result of its function as a prehistoric reservoir were removed and deposited between the retaining walls, then small quantities of maize pollen are expected as part of this record. If Mummy Lake had been used as a dance pavilion, the pollen record should be more variable, containing large quantities of maize pollen in some samples and none in others, or no maize pollen in any of the samples, depending on whether or not maize pollen was used for ceremonial purposes.

POLLEN METHODS

A chemical extraction technique based on flotation is the standard preparation technique used in this laboratory for the removal of the pollen from the large volume of sand, silt, and clay with which they are mixed. This particular process was developed for extraction of pollen from soils where preservation has been less than ideal and pollen density is low.

Hydrochloric acid (10%) was used to remove calcium carbonates present in the soil, after which the samples were screened through 150 micron mesh. The samples were rinsed until neutral by adding water, letting the samples stand for 2 hours, then pouring off the supernatant. A small quantity of sodium hexametaphosphate was added to each sample once it reached neutrality, then the beaker was again filled with water and allowed to stand for 2 hours. The samples were again rinsed until neutral, filling the beakers only with water. This step was added to remove clay prior to heavy liquid separation. At this time the samples are dried then pulverized. Zinc bromide (density 2.1) was used for the flotation process. The samples were mixed with zinc bromide and centrifuged at 1500 rpm for 10 minutes to separate organic from inorganic remains. The supernatant containing pollen and organic remains is decanted and diluted. Zinc bromide is again added to the inorganic fraction to repeat the separation process. After rinsing the pollen-rich organic fraction obtained by this separation, all samples received a short (20 minute) treatment in hot hydrofluoric acid to remove any remaining inorganic particles. The samples were then acetolated for 3 minutes to remove any extraneous organic matter.

A light microscope was used to count the pollen to a total of 200 pollen grains at a magnification of 400-600x. Pollen preservation in these samples varied from good to poor. Comparative reference material collected at the Intermountain Herbarium at Utah State University and the University of Colorado Herbarium was used to identify the pollen to the family, genus, and species level, where possible.

Pollen aggregates were recorded during identification of the pollen. Aggregates are clumps of a single type of pollen, and may be interpreted to represent pollen dispersal over short
distances, or the introduction of portions of the plant represented into an archaeological setting. Aggregates were included in the pollen counts as single grains, as is customary. The presence of aggregates is noted by an "A" next to the pollen frequency on the pollen diagram. A plus (+) on the pollen diagram indicates that the pollen type was observed outside the regular count while scanning the remainder of the microscope slide.

Indeterminate pollen includes pollen grains that are folded, mutilated, and otherwise distorted beyond recognition. These grains are included in the total pollen count, as they are part of the pollen record.

DISCUSSION

Previous pollen analyses at Mummy Lake (Scott 1973; Wyckoff 1977) document the presence of cultural fill near the bottom of Mummy Lake, overlain by post-occupational fill that provides evidence of regrowth of the pinyon/juniper woodland following abandonment of Mesa Verde. This pattern of post-occupational increase in tree pollen also was reported on Wetherill Mesa by Martin and Byers (1965:128), who note "a rise in tree pollen, essentially an increase in pine and juniper, and the disappearance of pollen of economic plants (Zea and Cleome-type) signify postoccupation sediments". Population pressure on local resources is postulated to have resulted in clearing of much of the top of the mesa. Wood was needed for construction and fuel, and land was necessary for agriculture to feed the large population. Current rainfall/runoff character in the pinyon/juniper woodland are not sufficient to account for the accumulation of sediment in Mummy Lake, nor to supply Mummy Lake with water. If the 25-acre drainage basin or a portion of it, had been cleared and used for agriculture, a runoff event would have occurred, on average, at least once per year (Ken Wright, personal communication, April 21, 1999).

Mummy Lake Drainage Basin

Six pollen samples were collected from three locations within the drainage basin at depths of 0"-2" and 2"-6" in an attempt to recover evidence of agriculture. Pollen samples were collected at 100' North WWE CP-2, 100' East ppo63, and 300' East ppo67, as shown on the Wright Water Engineers Map 3 and their Figure 1. Examining a pollen record from a relatively large depth such as these is done to maximize the potential for recovering evidence of agriculture when the depth of the original surface is not known. Should further refinement be necessary, only the layers yielding evidence of agriculture would be resampled at finer intervals. Since some sedimentation was expected since abandonment, the depth of 0"-2" was examined to provide a control, while the depth of 2"-6" was examined in an effort to locate maize and/or squash pollen. Maize pollen is the more likely to be recovered, since the pollen grains are large and carried only minimal distances by the wind. Squash/pumpkin pollen is large and sticky and transported primarily by insects. Even flower drop results in only rare pollen recovery in fields known to have been used to grow squash/pumpkin.

The pollen signatures for these three sets of samples provides averages of pollen that accumulated over the intervals represented. In general, arboreal pollen was less abundant in the lower sample than the upper sample. This is consistent with the hypothesis that during occupation much of the mesa top was deforested. Smaller quantities of both Juniperus and Pinus pollen represent smaller quantities of both juniper and pine than are present today. Quercus pollen is noted in two of the pairs of samples, but not the third, recording the presence of Gambel's oak within the pinyon/juniper woodland. Gambel's oak is most abundant at 100' North WWE CP-2.
Artemisia pollen is more abundant in the lower sample at two locations (100' North WWE CP-2 and 300' East ppo67) than in the upper samples. In samples from the remaining location (100' East ppo63) approximately equal quantities of Artemisia pollen reflect local sagebrush. Sagebrush appears to have been more abundant on the mesa top in the past than at present, undoubtedly as a result of tree clearing. Cheno-am pollen is present, but not abundant, and probably represents local saltbush. Small quantities of Ephedra pollen reflect local presence of Mormon tea. Poaceae pollen varies widely in these samples and indicates local quantities of grasses. Since these samples represent very long periods of pollen accumulation, trends in pollen frequency should not be used to interpret paleoenvironmental conditions.

Zea mays pollen was recovered in the lower samples at 100' East ppo63 and 300' East ppo67. In the absence of residential sites and/or middens in these areas, recovery of maize pollen suggests agricultural activities. At first glance, this evidence supports the hypothesis that the drainage basin was cleared and used for agriculture, although other potential sources for maize pollen need to be explored.

A single extra large, oval starch granule exhibiting an eccentric hilum and a strong "X" under cross polar illumination was recovered from the upper sample at 300' East ppo67. This type of starch is consistent with those produced by both wild and domestic potatoes. Kurt Loptien, who collected the samples, washed his hands after eating lunch and wore new, disposable gloves when collecting the samples, so contamination of the sample with modern food is extremely unlikely. When gloves are powdered corn starch or talcum powder are common. In testing numerous brands of disposable gloves, we have never recovered a single potato-type starch, so there is very little possibility that the starch was introduced by use of gloves. Therefore, it is probable that recovery of this potato starch signals the presence of wild potato (Solanum jamesii or S. fendleri) growing in this area of the mesa. Harrington (1964:485) notes S. jamesii growing in southwestern Colorado at elevations between 6000 and 7500 feet. Recovery of this potato-type starch indicates that wild potatoes grow in this area today and brings up the potential that wild potatoes were available to the Anasazi of Mesa Verde. Evidence for exploitation of wild potatoes is completely lacking from the archaeological record and would be expected to appear in the charred macrofloral record, provided the remains were recognized, and in the starch record, which often accompanies pollen samples. Starch analysis has only recently been included as part of pollen analysis and, therefore, would not have been attempted on earlier studies of pollen samples from the Mesa Verde area.

Sporormiella dung fungal spores were noted at 100' East ppo63. The fungal spore, Sporormiella, represents a dung fungus that often becomes more abundant in Historic Period sediments following the historic introduction of grazing animals. Its increasing presence in historic samples has been noted in numerous palynological studies (Davis 1987). Sporormiella fungal spores are not confined to the dung of introduced grazers, but also occur in dung from moose, wild sheep, deer, elk, caribou, and rabbits. The increase of Sporormiella spores in historic sediments may relate to changing land use patterns and increase in the length of time that herds of animals occupy any given area. Since Mesa Verde National Park does not allow grazing animals, it is likely that the presence of these spores can be traced to native animals or to the cowboy period around the turn of the century.

Mummy Lake

During May of 1999 a crew went into the field to examine Mummy Lake and collect pollen samples as part of that examination. Eight pollen samples were selected (Table 3) for analysis from those collected between retaining walls surrounding Mummy Lake. If these samples
contained *Zea mays* pollen, then the sediments filling the area behind the retaining walls should represent sediments removed from Mummy Lake after accumulating as a result of entering this area as part of runoff through agricultural fields. Alternate possibilities for inclusion of *Zea mays* pollen in these sediments would be use of maize pollen in ceremonies conducted in this area. If ceremonial use of maize pollen was responsible for the presence of maize pollen, it should be found in the lower sediments of Mummy Lake in abundance, and accompanied by aggregates.

Examination of eight samples collected from sediments between the retaining walls yielded a pollen signature consistent with accumulation of the sediments and pollen record during occupation of the mesa. In addition, a small white ware ceramic sherd was recovered from sample 27, confirming the fact that this sample represents a period of prehistoric occupation. In general arboreal pollen frequencies were relatively low and *Juniperus* and *Pinus* pollen were observed in nearly equal frequencies. Since *Pinus* produces larger quantities of pollen than do *Juniperus*, one may assume that juniper were more numerous in this area than were pines. Recovery of small quantities of *Quercus* pollen in all samples indicates the presence of Gambel’s oak as part of the local, sparse pinyon/juniper woodland. Recovery of relatively small quantities of arboreal pollen from these samples substantiates the interpretation that many of the trees from the mesa top had been cut down, perhaps for use in construction of dwellings or other structures or even for use as fuel. Recovery of small quantities of *Abies, Picea, and Pseudotsuga* pollen indicates longer distance transport of fir, spruce, and Douglas fir pollen from either canyons around Mesa Verde or the San Juan Mountains to the north. *Salix* (willow) pollen was present in three of the samples, indicating that willow grew in the general area as part of a riparian plant community.

*Artemisia* pollen was dominant in all samples, representing a relatively large sagebrush population on the mesa top during occupation. Sagebrush often is noted growing in areas with relatively deep soil on the mesa top, taking advantage of winter moisture stored in the soil with their deep root system. Recovery of smaller quantities of Low-spine and High-spine Asteraceae pollen represents local members of the sunflower family that include shrubby and weedy herbaceous plants. The presence of small quantities of *Liguliflorae* pollen represents growth of a member of the chicory tribe of the sunflower family as part of the local vegetation. Some members of this group are weedy and grow in relatively dry areas while others prefer moister disturbed areas. Cheno-am pollen represents between 10 and 20% of the pollen in these samples. Members of the Cheno-am group expected to grow in this area include shrubby saltbush as well as more herbaceous *Chenopodium* and *Amaranthus*, as well as other plants. None of the samples exhibit enough Cheno-am pollen to indicate that these plants were dominant in the vegetation community surrounding Mummy Lake.

*Poaceae* pollen was noted regularly in the pollen record and indicates a healthy population of grasses in the area of Mummy Lake or perhaps along the drainage system bringing water to Mummy Lake. The pollen record also includes evidence of shrubby plants including *Ephedra* (Mormon tea), and various members of the rose family such as service berry, mountain mahogany, and mountain spray or rock spirea. Herbaceous plants recorded include members of the wild buckwheat, spurge, members of the primrose family including fireweed, various smartweeds and knotweeds, and globe mallow. Other pollen types of note represent either edible resources such as members of the umbel, mustard, mint, and lily families, prickly pear cactus, beeweed, purslane, and members of the potato family. Other pollen represent plants of ceremonial importance such as tobacco (*Nicotiana* pollen).

Other plants represent plants commonly found in wet or riparian habitats. These pollen types include Caryophyllaceae, *Sarcobatus*, Cyperaceae, *Phacelia*, *Polygonum*, Ranunculaceae, and
Typha. Recovery of this suite of pollen in these samples supports the interpretation that sediments between the retaining walls represent accumulation of sediments in a wet environment, such as that of a water reservoir, which were then removed or cleaned out and dumped between the retaining walls. It is instructive to note that many of these pollen types representing riparian plants were not recovered from samples examined from the Mummy Lake Drainage basin, which also serve as control samples from the mesa top. Total pollen concentrations for these samples is high, indicating that pollen preservation was excellent, perhaps because the sediments were removed from the reservoir and dumped into the narrower area between the retaining walls where they accumulated rapidly, providing some protection against pollen deterioration.

Previous analysis of Mummy Lake included examining pollen samples from Location 70 (Table 3). The two lowest samples from this location were not examined originally in 1973 and have been examined along with this study. These samples represent sediments immediately overlying sandstone at the base of Mummy Lake. Examination of these samples, coupled with pollen counts done in 1973 by the author, yields the expected record of small quantities of arboreal or tree pollen in the lower sediments assumed to represent occupation of the mesa top and increased quantities of arboreal pollen representing post-occupational sedimentation. Post-occupational samples 70E and 70F exhibit large quantities (over 40%) arboreal pollen, while occupational samples 70A, 70B, and 70C exhibit less than 20% arboreal pollen (Figure 3). Increases in Juniperus, Pinus, and Quercus pollen document reforestation by juniper, pine and Gambel’s oak on the mesa top. During the period of occupation the quantity of High-spine Asteraceae pollen is much higher, suggesting that shrubby plants such as rabbitbrush or herbaceous members of the sunflower family were more abundant than after abandonment. A cluster of Epilobium paniculatum (willowweed) pollen was observed in sample 70B, suggesting that this weedy annual (Harrington 1964:390) might have lived in the disturbed sediments along the edge of Mummy Lake. Cleome and Zea mays pollen were recorded in sample 70B, marking this level as associated with the occupation of the mesa top. Samples 70A, 70B, and 70C all represent consolidated sands and silts overlying sandstone. Samples 70E and 70F represent consolidated clay and laminated modern sands and silts above. Abandonment of Mesa Verde appears to have taken place between samples 70C and 70E. The lower samples (70A, 70B, and 70C) all reflect a period of time when the pinyon/juniper woodland was either extremely sparse on or absent from the mesa top. Wind transport of juniper, pine, and oak pollen from trees growing on the canyon slopes could easily account for the amount of pollen recovered from these samples. After abandonment of the mesa top, the pinyon/juniper woodland re-established, leaving a signature of more arboreal pollen in the upper samples.

**SUMMARY AND CONCLUSIONS**

Pollen analysis undertaken to examine the possible use of the 25-acre drainage basin associated with Mummy Lake has recovered Zea mays pollen. This recovery appears to substantiate the potential that this area functioned as an agricultural field. Presence of an agricultural field in this area would change runoff characteristics significantly and be important in the interpretation of the function of Mummy Lake. Should further study of this drainage basin be warranted, samples should be collected at 1 cm intervals between 2” and 6”. Pollen analysis of these samples would be expected to provide evidence of few trees at the time the area functioned as an agricultural field, the presence of weedy plants often associated with agricultural fields, and evidence of plant succession and re-establishment of the pinyon/juniper woodland following abandonment.
Review of samples from Location 70 and analysis of two new samples representing the lowest deposits of this portion of Mummy Lake display the expected pattern of large quantities of arboreal pollen from samples of post-occupational origin and small quantities of arboreal pollen in samples probably related to sedimentation during occupation of the mesa top. Recovery of *Zea mays* pollen in sample 70B provides confirmation that this sample probably represents sedimentation during prehistoric use of the mesa top. The pollen profile from Location 70 displays a pollen record consistent with removal of or at least severe thinning of the pinyon/juniper woodland from the mesa top during occupation and subsequent re-establishment of that woodland after prehistoric abandonment. Recovery of additional *Zea mays* pollen from lower sediments in Mummy Lake is important in documenting the use of this feature as a prehistoric reservoir and in establishing continuity with the pollen record of samples collected between the retaining walls of Mummy Lake.

Examination of pollen samples collected between the retaining walls of Mummy Lake provide evidence of *Zea mays* throughout the deposits, which is consistent with the interpretation that Mummy Lake represents a prehistoric water reservoir. Accumulation of small quantities of *Zea mays* pollen, probably without aggregates, is a signature consistent with water transport of maize pollen from an agricultural area into a holding basin or reservoir. If this area had been used for ceremonies, maize pollen might well have been used as part of the rituals, resulting in recovery of substantially more maize pollen, probably accompanied by aggregates. Other variability and/or inconsistencies also would be expected in the pollen record. In addition, the pollen record from samples collected between the retaining walls exhibits pollen representing plants typically associated with riparian vegetation communities including at least cattail, smartweed and knotweed, *Phacelia*, sedges, buttercup family, and pink family. Most of these pollen types were not recovered during the pollen study of the drainage basin, suggesting that they represent plants growing either along the end of the drainage ditch feeding Mummy Lake or more probably in the sediments at the edge of the water that accumulated in Mummy Lake. This pollen record presents a picture of plants that included tall cattails and short herbaceous plants growing in the mud at the edges of Mummy Lake while it contained water.

**TABLE 1**

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Depth (inches)</th>
<th>Provenience</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM-G2A</td>
<td>0-2&quot;</td>
<td>100' North WWE CP-2</td>
<td>Pollen</td>
</tr>
<tr>
<td>CM-G2B</td>
<td>2-6&quot;</td>
<td>100' North WWE CP-2</td>
<td>Pollen</td>
</tr>
<tr>
<td>CM-B1A</td>
<td>0-2&quot;</td>
<td>100' East ppo63</td>
<td>Pollen</td>
</tr>
<tr>
<td>CM-B1B</td>
<td>2-6&quot;</td>
<td>100' East ppo63</td>
<td>Pollen</td>
</tr>
<tr>
<td>CM-B6A</td>
<td>0-2&quot;</td>
<td>300' East ppo67</td>
<td>Pollen</td>
</tr>
<tr>
<td>CM-B6B</td>
<td>2-6&quot;</td>
<td>300' East ppo67</td>
<td>Pollen</td>
</tr>
</tbody>
</table>
## TABLE 2
**POLLEN TYPES OBSERVED IN SAMPLES FROM THE MUMMY LAKE DRAINAGE BASIN AND AT MUMMY LAKE**

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ARBOREAL POLLEN:</strong></td>
<td></td>
</tr>
<tr>
<td>Juniperus</td>
<td>Juniper</td>
</tr>
<tr>
<td>Pinaceae:</td>
<td>Pine family</td>
</tr>
<tr>
<td>Abies</td>
<td>Fir</td>
</tr>
<tr>
<td>Picea</td>
<td>Spruce</td>
</tr>
<tr>
<td>Pinus</td>
<td>Pine</td>
</tr>
<tr>
<td>Pseudotsuga</td>
<td>Douglas fir</td>
</tr>
<tr>
<td>Quercus</td>
<td>Oak</td>
</tr>
<tr>
<td>Salix</td>
<td>Willow</td>
</tr>
<tr>
<td><strong>NON-ARBOREAL POLLEN:</strong></td>
<td></td>
</tr>
<tr>
<td>Apiaceae</td>
<td>Umbel family</td>
</tr>
<tr>
<td>Asteraceae:</td>
<td>Sunflower family</td>
</tr>
<tr>
<td>Artemisia</td>
<td>Sagebrush</td>
</tr>
<tr>
<td>Centaurea-type</td>
<td>Star thistle</td>
</tr>
<tr>
<td>Cirsium</td>
<td>Thistle</td>
</tr>
<tr>
<td>Low-spine</td>
<td>Includes ragweed, cocklebur, etc.</td>
</tr>
<tr>
<td>High-spine</td>
<td>Includes aster, rabbitbrush, snakeweed, sunflower, etc.</td>
</tr>
<tr>
<td>Liguliflorae</td>
<td>Includes dandelion and chicory</td>
</tr>
<tr>
<td>Brassicaceae</td>
<td>Mustard family</td>
</tr>
<tr>
<td>Cactaceae:</td>
<td>Cactus family</td>
</tr>
<tr>
<td>Cylindropuntia</td>
<td>Cholla</td>
</tr>
<tr>
<td>Opuntia</td>
<td>Prickly pear cactus</td>
</tr>
<tr>
<td>Caryophyllaceae</td>
<td>Pink family</td>
</tr>
<tr>
<td>Cheno-am</td>
<td>Includes amaranth and pigweed family</td>
</tr>
<tr>
<td>Sarcobatus</td>
<td>Greasewood</td>
</tr>
<tr>
<td>Cleome</td>
<td>Beeweed</td>
</tr>
<tr>
<td>Cyperaceae</td>
<td>Sedge family</td>
</tr>
<tr>
<td>Ephedra</td>
<td>Mormon tea</td>
</tr>
<tr>
<td>Family Name</td>
<td>Common Name</td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>Ephedra nevadensis-type</td>
<td>Mormon tea</td>
</tr>
<tr>
<td>Ephedra torreyena-type</td>
<td>Mormon tea</td>
</tr>
<tr>
<td>Eriogonum</td>
<td>Wild buckwheat</td>
</tr>
<tr>
<td>Euphorbia</td>
<td>Spurge</td>
</tr>
<tr>
<td>Fabaceae</td>
<td>Bean or Legume family</td>
</tr>
<tr>
<td>Lamiaceae</td>
<td>Mint family</td>
</tr>
<tr>
<td>Liliaceae</td>
<td>Lily family</td>
</tr>
<tr>
<td>Nyctaginaceae</td>
<td>Four o'clock family</td>
</tr>
<tr>
<td>Onagraceae</td>
<td>Evening primrose family</td>
</tr>
<tr>
<td>Epilobium paniculatum</td>
<td>Willowweed, willow herb</td>
</tr>
<tr>
<td>Gaura</td>
<td>Butterfly weed</td>
</tr>
<tr>
<td>Plantago</td>
<td>Plantain</td>
</tr>
<tr>
<td>Poaceae</td>
<td>Grass family</td>
</tr>
<tr>
<td>Polygonaceae</td>
<td>Knotweed/Smartweed family</td>
</tr>
<tr>
<td>Eriogonum</td>
<td>Wild buckwheat</td>
</tr>
<tr>
<td>Polygonum</td>
<td>Knotweed</td>
</tr>
<tr>
<td>Polygonum sawatchense</td>
<td>Sawatch knotweed</td>
</tr>
<tr>
<td>Ranunculaceae</td>
<td>Buttercup family</td>
</tr>
<tr>
<td>Rosaceae</td>
<td>Rose family</td>
</tr>
<tr>
<td>Rosaceae striate</td>
<td>Rose family including Prunus, Cowania, Potentilla, Rosa and others</td>
</tr>
<tr>
<td>Amelanchier</td>
<td>Serviceberry</td>
</tr>
<tr>
<td>Cercocarpus</td>
<td>Mountain mahogany</td>
</tr>
<tr>
<td>Holodiscus</td>
<td>Mountain spray, rock spirea</td>
</tr>
<tr>
<td>Solanaceae</td>
<td>Potato family</td>
</tr>
<tr>
<td>Nicotiana</td>
<td>Wild tobacco</td>
</tr>
<tr>
<td>Shepherdia</td>
<td>Buffaloberry</td>
</tr>
<tr>
<td>Sphaeralcea</td>
<td>Globemallow</td>
</tr>
<tr>
<td>Typha angustofolia-type</td>
<td>Cattail</td>
</tr>
<tr>
<td>Plant</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>Zea mays</td>
<td>Maize, corn</td>
</tr>
<tr>
<td>Indeterminate</td>
<td>Too badly deteriorated or corroded to identify</td>
</tr>
</tbody>
</table>

**STARCHES:**

<table>
<thead>
<tr>
<th>Description</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oval, extra large with linear hilum and an &quot;X&quot; under cross-polar illumination</td>
<td>Potato-type</td>
</tr>
</tbody>
</table>

**SPORES:**

<table>
<thead>
<tr>
<th>Description</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monolete</td>
<td>Fern</td>
</tr>
<tr>
<td>Selaginella densa</td>
<td>Little clubmoss</td>
</tr>
<tr>
<td>Trilete</td>
<td>Fern</td>
</tr>
<tr>
<td>Sporormiella</td>
<td>Dung fungus</td>
</tr>
</tbody>
</table>

**REDEPOSITED (PRE-PLEISTOCENE) POLLEN FROM BEDROCK:**

<table>
<thead>
<tr>
<th>Description</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carya</td>
<td>Hickory, Pecan</td>
</tr>
</tbody>
</table>
### TABLE 3
PROVENIENCE DATA FOR SAMPLES COLLECTED AT MUMMY LAKE

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Depth (inches)</th>
<th>Location</th>
<th>Provenience</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>20-22</td>
<td>Between retaining walls</td>
<td>Clay loam</td>
<td>Pollen</td>
</tr>
<tr>
<td>26</td>
<td>22-24</td>
<td>Between retaining walls</td>
<td>Clay loam</td>
<td>Pollen</td>
</tr>
<tr>
<td>27</td>
<td>24-26.5</td>
<td>Between retaining walls</td>
<td>Clay loam containing a white ware sherd</td>
<td>Pollen</td>
</tr>
<tr>
<td>28</td>
<td>26.5-29</td>
<td>Between retaining walls</td>
<td>Clay loam</td>
<td>Pollen</td>
</tr>
<tr>
<td>29</td>
<td>29-32.5</td>
<td>Between retaining walls</td>
<td>Sand</td>
<td>Pollen</td>
</tr>
<tr>
<td>30</td>
<td>32.5-34</td>
<td>Between retaining walls</td>
<td>Sand</td>
<td>Pollen</td>
</tr>
<tr>
<td>31</td>
<td>34-36</td>
<td>Between retaining walls</td>
<td>Sand with caliche</td>
<td>Pollen</td>
</tr>
<tr>
<td>32</td>
<td>36-38</td>
<td>Between retaining walls</td>
<td>Redder sand with caliche</td>
<td>Pollen</td>
</tr>
<tr>
<td>70F</td>
<td>Location 70</td>
<td>Laminated modern sands and silts (collected in 1969)</td>
<td>Pollen</td>
<td></td>
</tr>
<tr>
<td>70E</td>
<td>Location 70</td>
<td>Consolidated clay (collected in 1969)</td>
<td>Pollen</td>
<td></td>
</tr>
<tr>
<td>70C</td>
<td>Location 70</td>
<td>Consolidated sands and silts (collected in 1969)</td>
<td>Pollen</td>
<td></td>
</tr>
<tr>
<td>70B</td>
<td>Location 70</td>
<td>Consolidated sands and silts (collected in 1969)</td>
<td>Pollen</td>
<td></td>
</tr>
<tr>
<td>70A</td>
<td>Location 70</td>
<td>Consolidated sands and silts (collected in 1969)</td>
<td>Pollen</td>
<td></td>
</tr>
</tbody>
</table>
REFERENCES CITED


FIGURE 1. POLLEN DIAGRAM FOR THE MUMMY LAKE DRAINAGE BASIN
FIGURE 2. MUMMY LAKE POLLEN DIAGRAM, SAMPLES BETWEEN RETAINING WALLS
FIGURE 3. POLLEN DIAGRAM FROM MUMMY LAKE SEDIMENTS

SAMPLE NO.

ARBOREAL POLLEN

Juniperus
Picea
Pinus
Quercus
APIACEAE
Artemisia

Centaurea-Type
LOW-SPINE ASTERACEAE
HIGH-SPINE ASTERACEAE

LILIIFLORAE
CHENO-AM
Sarcobatus
Chenome
HYPEREA
Ephedra
Ephedra nevadensis-type
Ephedra torreyana-type
Euphorbia
LAMIACEAE
LILIACEAE
NYCTAGINACEAE
ONAGRACEAE

Epilobium paniculatum
Oenothera
Plantago
POACEAE
Polygonum
Polygonum sawatchense-type
ROSACEAE
Cercocarpus
SCROPHULARIACEAE
Castilleja-type
Sphaeralcea
Yucca
Eve mays

POLLEN SUM

TOTAL POLLEN CONCENTRATION
APPENDIX I

MUMMY LAKE SYMPOSIUM
MESA VERDE NATIONAL PARK RECREATION CENTER
JUNE 5, 1999

LIST OF ATTENDEES

See Attachment A to this memorandum.

INTRODUCTION TO SYMPOSIUM

Ken Wright initiated the meeting with an introduction of the fieldtrip’s participants and an explanation of their association with Mesa Verde and Mummy Lake. He expressed gratitude to the Colorado Historical Society, Mesa Verde National Park (MVNP) Superintendent Larry Wiese, and the Natural Resources Conservation Service (USDA). Among the participants in attendance who were involved in the 1960 – 1975 excavations and research on Far View were:

**Dr. David Breternitz, Archeologist**: Dr. Breternitz was the leader of the 1969 excavation of Mummy Lake. He is the author of the recently published report entitled “The 1969 Mummy Lake Excavations, Site 5MV833”. The Wright Paleohydrological Institute published this report.

**Professor Art Rohn, Archeologist**: Professor Rohn was formerly with the Wichita State University Division of Anthropology. He has studied and published extensively on Chapin Mesa.

**Dr. Jack Smith, Archeologist**: Dr. Smith is a Director and Secretary of the Wright Paleohydrological Institute, a non-profit organization formed by Dr. Smith and Ken and Ruth Wright, to perform paleohydrology studies in the public interest. He is the former Chief Archeologist of the Mesa Verde National Park. Dr. Smith and Dr. Ezra Zubrow conducted the 1967 excavation of Morefield Reservoir, and their report entitled “The 1967 Excavations at Morefield Canyon, Site 5MV1931” was published by the Wright Paleohydrological Institute in 1999.

**Larry Nordby, Research Archeologist**: Larry Nordby is Research Archeologist at MVNP. He worked on the 1969 excavation at Mummy Lake and is an expert on the archeology of Chapin Mesa.

**Dr. Linda Scott Cummings**: Dr. Scott Cummings is a noted palynologist and Head of the Paleo Research Laboratories located in Golden, Colorado. She worked on Mummy Lake with Dr. Breternitz in 1969 and prepared a pollen report on the site in 1974.

The remainder of the experts listed in Attachment A was similarly introduced so that there would be special knowledge of each person’s discipline and expertise. Four of them are:

**Dr. Mary Gillam, Geologist**: Dr. Gillam is a specialist in Quaternary sediment that has particular relevance to the Mummy Lake study.
Dr. Calvin Cummings, Archeologist: Dr. Cummings is the former Chief Archeologist for the National Park Service and is presently retired.

Ernest Pemberton, River/Sedimentation Engineer: Mr. Pemberton is the former Head of the Sedimentation Section for the U.S. Bureau of Reclamations, Denver, Colorado. He has extensive reservoir sedimentation experience.

Doug Ramsey, Soil Scientist, U.S. Department of Agriculture: Mr. Ramsey is on the staff of the Cortez Soil Survey Office in Cortez, Colorado, and is a local farmer in the area. He performed the government soil survey for Mesa Verde National Park, which should be published in the near future.

Mr. Wright noted that Jeanne Tucker of Cortez, who is associated with the State Historical Society, was not able to attend.

MUMMY LAKE FIELDTRIPS

- Previous fieldtrips to Mummy Lake were noted, along with a description of field events summarized as follows:
  - May 1998: Surveying, soil tests, mapping, field studies
  - October 1999: Surveying, soil tests, mapping, field studies and pollen testing
  - June of 1999: Collect and review field technical data, inspect site system once again, collect pollen samples and resolve uncertainty

- Reference reports were described:
  - See Attachment B.

HYDROLOGIC FINDINGS (SUMMARY)

Our goal was to resolve uncertainties surrounding Mummy Lake based on facts from data collected and resulting analyses.

Technical Data: (used large maps, diagrams and photographs)

1. Original Mummy Lake ground surface: 7,738 (NW) to 7,735 (E) to 7,734 (S)
2. Top of walls: 7,739 typical (as reconstructed)
3. Bedrock: 7,731 at center of lake
4. Current topo: 7,733.5 at low point
5. Lake diameter: 90 feet ± typical
6. Typical depth from original ground surface to bedrock was approximately 6 feet.

7. General area soil profile in inches
   - 0 – 2 Brown loam
   - 2 – 8 Reddish brown loam
   - 8 – 24 Reddish brown clay loam
   - 24– Reddish

   ➢ Last major episode of soil deposition occurred approximately 15,000 years ago
   ➢ Other soil layers could be dated from fossils found within if desirable

8. Field water bearing/conveyance capacity:
   ➢ Need to reach field capacity before build-up of perched water table
   ➢ 5.2 inches per month to create perched groundwater table. Would occur approximately once per 5 to 10 years

9. Likely Mummy Lake maximum storage: Approximately 75,000 gallons (4.7 feet deep) above bedrock.

10. Water collection features:
    
    Gathering Area: Elev: 7,900 to 8,020 feet
                 L = 2,000 feet
                 S = 7 percent
                 A = 25 acres

    Gathering Basin: 300 feet x 130 feet wide at 7 percent slope (±)
                        Pin 1075 to Mummy Lake distance
                        2,700 linear feet at approximately 4.8 percent

   (Different soil than at Mummy Lake.)

11. Runoff is very infrequent under current conditions; however, if basin was agricultural then runoff would be more likely.
    
    Today’s infiltration tests in Gathering Area: Fifteen inches per hour during initial saturation approximately 2 inches per hour thereafter. Observed approximately 60 percent vegetative cover (natural conditions).

12. Delivery Ditch (2,900 linear feet): For purpose of analysis use 4.8 percent slope, 3 foot wide channel, n=0.04 or assume critical flow.

13. Precipitation:
    ➢ 18.1 inches for 1,500 year record (from tree ring)
    ➢ 18.1 inches (average) 1948 – 1997
17.8 inches (average) for period of interest 950 – 1180 A.D.

- 11 years heavy precipitation
- 15 years dry (less than 11 inches)
- 1130 – 1184 A.D. drought (16.3 inches average annual)

Modern period monthly precipitation:

- 1 per 2 years  4 inches of precipitation in 1 month
- 1 per 7 years  5 inches of precipitation in 1 month
- 1 per 25 years  6 inches of precipitation in 1 month

Snowfall:

October-March period

14. Sediment: If water flows in, then sediment would be excavated periodically.

- Excavated - approximately 550 cubic yards
- Berm fill – approximately 1,100 cubic yards
- 550/230 years – approximately 2.4 cubic yards per year

15. Field observations:

a. Ditches were not obvious.

b. Two of three soil samples from Gathering Area contained corn pollen; one sample contained potato (tuber) pollen.

c. Gathering Basin was not a distinct feature.

d. Did not observe a delivery ditch near pins 1074 or 1075.

e. Found Cowboy Ditch and mapped it.

f. Located old 1915 Park Service road. Location parallels Delivery Ditch and overlies the West Ditch.

g. No compelling evidence of ditch from Mummy Lake to Far View Village. Field evidence indicated it was a packtrain trail or early road.

h. Depression storage was observed to be significant.
16. Findings:

- Mummy Lake was constructed in phases.
- The stairway is inconsistent with domestic water supply.
- 1973 pollen testing in the Mummy Lake sediments indicated that upper sediments were deposited in the post-occupational period.
- Water Gathering Area capable of producing runoff approximately once per year. Footpath could transport water with little loss.
- No groundwater table on Chapin Mesa.
- 1999 Piezometers were dry, however, dry year.
- Logs from borings described.

**GENERAL DISCUSSION**

**Breternitz:** Site shows no evidence of occupation (no hard-packed floor anywhere, at any stratigraphic level; no fire pits, stone vaults, or ceremonial features, although some could have been destroyed in the parts of the site that were excavated by trenching). Western ramp of present reconstruction gives incorrect impression of an entrance for dancers. “Cowboy ditch” should be excavated, since cowboys may have modified a prehistoric water-delivery ditch, though no prehistoric inlet was found there during excavations.

**Nordby:** Several issues pertaining to the site’s interpretation still need to be considered. 1) Is the wall configuration odd for a reservoir? 2) Is the low permeability of the “native red clay” circumstantial or unrelated to a reservoir function?

**Pemberton:** Could the unit that Breternitz recorded as “consolidated sand and clay” be a floor?

**Breternitz:** No.

**Rohn:** Archeologists are trained to recognize occupation floors. If Breternitz and Lancaster didn’t see one, he is confident that none is there.

**Nordby:** A dance plaza and a reservoir are endpoints of a range of possible interpretations. Is there an intermediate interpretation that involves some social use, possibly at a particular stage in the evolution of the structure?

**Breternitz:** [Defending reservoir interpretation.] The stratigraphic relationship of the excavated material to the walls (dipping outward in layers from the walls) shows that the walls were built to keep those materials out of the excavation. Thus, the walls are appropriate for this reservoir.
Hagen: [Continuing the floor issue.] If the depression was excavated to bedrock, there wouldn’t be a floor underlain by compacted sediment, even if the site had social use. Therefore, the absence of a floor may not indicate the lack of social uses.

Breternitz: The depression was excavated to “native red clay” in some places and to sandstone in other places. [And there is no floor on the “native red clay,” so an occupation is unlikely.]

Smith: [Responding and adding new issues.] The possibility of a dance floor is remote because the base of the excavation is too irregular for dancing. Also, Mummy Lake should be interpreted in comparison with at least three similar sites in the park. Information about those sites is limited. The only one that was partly excavated (5MV1936), has a tiny opening on one side, but there is not evidence of a ditch or that the opening was a water inlet. Could the “cowboy cut” have been the original inlet to the lake?

Breternitz: During the excavation, he found evidence that the cowboys had removed four or five courses of stone to make their cut, so this was not an original opening.

Pruess: [Continuing discussion of staircase and similar sites.] The location of the staircase at the south side of the lake resembles the preferred orientation of kivas. Could this orientation indicate that the staircase had some cultural significance? Do similar sites in the park also have staircases?

Smith: We don’t know if similar sites have staircases, because only one site has been partly excavated.

Loptien: Do typical floors underlain by compacted sediment show evidence of modification by standing water?

Calvin Cummings: Standing water doesn’t necessarily modify floors. [He gave an example of a site at Wupatki.]

Pemberton: The proposed “stilling basin” is too small for most clay and silt to settle out, because water would fill and flow through it too rapidly. Could “stilling basin” have any other use?

Breternitz: The “stilling basin” might have had one use initially and another use later. Due to later remodeling of the main depression, the “stilling basin” is older than most other features now seen. Therefore, it is hard to tell how the “stilling basin” was related to other features that existed at the same time, or whether it could have had other uses. However, the presence of lenses of sand and gravel in the “stilling basin” supports its interpretation as part of an inlet structure. Concerning early features, he is not confident of his original interpretation that the early inlet ditch approached the “stilling basin” from the northwest.

Earles: The fact that the walls form a complete circle supports the reservoir interpretation.

Breternitz: [He recapped stages of wall construction as outlined in his report and how various features support a reservoir interpretation.] Walls were built to keep silt out of the main depression. The earliest pond was excavated into native materials and had no walls. The first wall was built on sediment that accumulated in that pond and was built only along the south or
topographically lowest side, where the need to block the natural drainage direction was greatest. Thus, the setting and function of the wall suggest a reservoir. It would have been possible to get more information about the site if more of it has been excavated, but complete excavation would have destroyed all of the original structures and sediments. Pottery assemblages [see his report] also supports the reservoir interpretation. Most pottery from the site consists of white ware jars that were used to carry and store water. Ladles and small bowls for dipping were also found. The proportions of various pottery types are very similar to those at Morefield Reservoir. Both assemblages indicate special-use sites and are unlike assemblages at social-use sites.

Wright (Ken): [Made mention of potential water sources, including runoff, snowmelt, and perched water tables.]

Gillam: Since early people removed most vegetation from the mesa top, wind-blown snow could have been trapped in the depression, adding greatly to the depth of snow that fell in the depression.

Ramsey: In modern times, we worry more about water supply in summer than in winter. In summer, evapotranspiration reduces runoff. It is important to store winter moisture because evapotranspiration is lower then and also because the early summer can be relatively dry before monsoonal storms begin in July and August. Winter moisture is more likely to form a perched water table than summer moisture, but a perched water table probably wouldn’t form very often.

Wright (Ken): Perched water tables were inconsequential as a source of water for the reservoir.

Rohn: [Responding to several issues that had been raised so far.] 1) Floor surfaces are very distinctive and would have been found during the excavation if they existed. Therefore, he is confident the site was not a social area. 2) The need for water supports the reservoir interpretation. There are no good, natural water sources nearby. Because the springs issuing from the cliffs are alkaline, the best water would have been in streams far below the mesa top. Actually, Mummy Lake is now the best water source in the area. 3) Clusters of sites often occur near springs, so it is reasonable to expect a cluster of sites near a reservoir. 4) [Responding to comments about the porosity of sandstone and its possible unsuitability as the floor of a reservoir.] In some cases, recharge of perched water tables in sandstone beds may have been deliberate. Dams were often located above pour-offs at the tops of cliffs, for example at Long House. Because sandstone is relatively porous, these dams may have been built partly to increase recharge and thereby to increase the flow rates of springs in alcoves below the pour-offs. 5) Formation of perched water tables most likely resulted from individual summer storms. 6) He agrees with Breternitz that the walls at Mummy Lake were built to retain the earthen embankment. 7) He thinks that the presence of the “stilling basin” could account for a slower rate of sedimentation in Mummy Lake than in Morefield Reservoir (implying that the “stilling basin” was at least partly functional). 8) The stairway at Mummy Lake isn’t necessarily inconsistent with the reservoir hypothesis, since it would have made it easier to descend toward the pool from the direction in which most nearby living areas were located. For example, at a natural sandstone tank, Indians pecked toeholds in steep sandstone slickrock to reach the water more easily.
Smith [to Gillam]: He thinks that dams were built above pour-offs not to increase spring discharge, but for other reasons.

Gillam: Other ancient reservoirs described in the article by Wilshusen had sandstone floors.

Ramsey: One reservoir described by Wilshusen, Moqui Lake, was located on the Dakota Sandstone, which is silica-cemented and more impermeable that the Cliff House Sandstone at Mummy Lake. He doesn’t think that dams above pour-offs would greatly increase recharge to springs in nearby alcoves, as Rohn proposed.

Nordby: If Mummy Lake was a reservoir, could excavation to the top of the sandstone in some places have been an accidental error that decreased the effectiveness of the reservoir?

Breternitz and Wright (Ken): Wilshusen’s published water volume for Mummy Lake is much too large, since it assumes a higher water level than indicated by the site’s stratigraphy and structures.

Pemberton: He has designed many settling basins for irrigation canals. The capacity of the “stilling basin” is not large enough to hold incoming water for long enough to allow suspended silt and clay to settle out. Much silt and clay would have been carried through the basin into the main depression.

Nordby: The reservoir morphology of the Mummy Lake site is relatively well defined. We have a much poorer picture of use issues, such as the size of the local population versus the water volume available. Any amount of water collected in the reservoir would have been very useful, even if it was less than the amount needed. Assuming seasonal filling, how many months would typical volumes have lasted?

Wright (Ken): If the water volume was small, it would not have lasted very long because evaporation could have removed as much as 6 inches of water per month during the summer. To understand how the reservoir functioned, it will be necessary to model water inflows, evaporation, and seepage loss.

Rohn: He estimates a maximum population of 400 people in the Far View area, based on numbers of rooms.

Nordby: To provide input to a model, it should be possible to estimate the cultivated area from the assumed population, and to evaluate the ability of that specific area to generate runoff.

Smith and Breternitz: A complex study of the local community is needed to estimate populations accurately.

Rohn: During the 12th century, the maximum population would have been approximately 400 if all rooms were occupied at once, but the number was probably smaller. Populations during the 10th and 11th centuries are harder to estimate because earlier rooms may have been concealed or destroyed by later ones. Also, soils south of the site are better for agriculture than those north of the site. Therefore, only part of the cultivated area needed to support the population would have been located in the upper basin north of Mummy Lake.
Nordby: It is difficult to get accurate estimates of population from room numbers because many rooms may have been used only for storage, not as living areas.

Earles: Given the problems of estimating parameters for models, it might be best to run models using both maximum and minimum values.

Crowley: Based on his professional experience, it would have been possible to collect most runoff from the area immediately upslope from Mummy Lake by placing an east-west collection ditch across the mesa top (nearly parallel to contour) just above the lake. This would have been a relatively simple and workable design. A system for collecting runoff from the more distant part of the basin, above the “gathering area,” would be more difficult to implement. Since much of the upper basin slopes southeast, toward the eastern mesa edge, a collection system could have followed the eastern mesa edge, obliquely intercepting natural flow. Perhaps there was a second reservoir near the lower end of the upper basin [in the “gathering area”?]. The fill sediment excavated from Mummy Lake would have flowed under its own weight when wet, so walls would have been needed to shape the embankment. He is surprised that the walls didn’t buckle inward or outward because of plastic flow in the saturated materials on which they were built. Finally, the “stilling basin” may have held all the inflow from small runoff events and may have been the only pool when the main depression was dry.

Williams: Does the proposed “Far View Ditch,” leading south from Mummy Lake, actually exist?

Ramsey: The ditch concept is impractical because it has two major problems. 1) Based on his experience as an irrigator, Mummy Lake wouldn’t have contained enough water for it to flow very far down a ditch. 2) Flows in the proposed ditch, with roughly a 5 percent slope and existing soil types, would rapidly have cut gullies “six feet deep and one foot wide” in some areas and built localized alluvial fans composed of the eroded soil in other areas. We don’t see such features. Most ditches now are built with slopes of 0.2 to 1.0 percent.

Pemberton: It is possible to follow a broad, shallow, ditch-like feature most of the way from south of Mummy Lake to east of the nearby Far View visitor area. Rough calculations suggest that this feature could carry about 400 cfs if bankfull and 100 cfs at 1 foot depth. He agrees with Ramsey that such flows would scour the floor of the “ditch,” even though sandstone is exposed in its floor at some places. Could the “ditch” be something else?

Smith: [Giving an alternative interpretation.] Some trees along the “ditch” have been trimmed with steel axes. There are historic references to a trail that leads toward Spruce Tree House (the proposed end of the “ditch”). Fewkes wrote that horsemen and stock used this trail. A Mancos newspaper article from 1906 mentions the need to cut branches that protruded into the trail.

Rohn: He interprets the broad, shallow feature as a ditch, following Stewart and Lancaster. Does the feature bypass Far View visitor area because that area was inhabited when the feature was created? In some places farther south, the feature passes through sites, which might be more likely if it was a historic trail.
Gillam: Site 5MV4242 was identified recently within this broad “ditch” feature between Mummy Lake and the Far View visitor area. This could suggest that the feature is prehistoric. What kind of site is this, and how is it related to the feature?

Ramsey: If the feature is a trail, it may have been easier, when it was created, to take a route around the Far View visitor complex. The reasons for selecting such a route may no longer be clear, but vegetation patterns have probably changed during the last century.

Smith: [Responding to questions about when such a trail might have been used and abandoned.] The first road along the mesa crest began to be used in 1910.

INTERPRETATION OF FINDINGS AND FEATURES

At this point, Ken Wright led the group in a series of consensus hand showings intended to show agreement or disagreement with various interpretive statements. Ken formulated the statements and would then ask for a yes, no, or abstention.

1. Was there potential for surface flows into Mummy Lake to occur? 
   Yes: 24
   No: 0
   Abstain: 0

2. Was Mummy Lake a water storage facility in 950 A.D.? 
   Yes: 22
   No: 1
   Abstain: 1

3. Did an irrigation ditch extend from Mummy Lake to Far View Village? 
   Yes: 1
   No: 23
   Abstain: 0

4. Did a ditch extend from the Far View area to Spruce Tree House or at least farther down the mesa? 
   Yes: 1
   No: 15
   Abstain: 8

5. Was “Far View Ditch” a ditch? 
   Yes: 0
   No: 24
   Abstain: 0

6. When wall 3 and the stairway existed in about 1100 A.D., was the major function of Mummy Lake for water storage? 
   Yes: 18
   No: ---
   Abstain: 6

7. Were walls 2 and 3 built mainly to control excavated sediment? 
   Yes: 24
   No: 0
   Abstain: 0

8. Was the stairway ceremonial? 
   Yes: 0
   No: 20
   Abstain: 4

9. Was groundwater a negligible inflow component of the water supply? 
   Yes: 24
   No: 0
   Abstain: 0

10. Were the ditches in the Water Gathering Area mainly natural, caused by runoff? 
    Yes: 18
    No: 0
    Abstain: 6
ADDITIONAL DISCUSSION

Crowley: The fact that the walls 2 and 3 never shifted inward or outward, because of saturation and plastic deformation of the sediments on which they were built, suggests that the water level was never very high. [This corroborates other evidence of a low water level.]

Williams: The circularity of the walls may have cultural significance even if the feature was used mainly for water storage.

Towle: It may not be possible to answer all questions about the functions of the site. However, she may be able to get ideas about the use of the site and the staircase from tribes that periodically advise the park. The next meeting with these tribes will be in September.

Nordby: [Summarizing his reaction to the discussion.] It appears that Mummy Lake was built mainly as a water storage feature but it is still unclear how they got water to it.

Ramsey: The whole design may have been opportunistic (unplanned, never had an overall design). People noticed water flowing down trails (where the soil was compacted and relatively impervious) after storms. They decided to trap that water in a depression.

Breternitz: Mummy Lake was started when the local population was relatively low [and an opportunistic approach was reasonable]. It was probably built in this general area because precipitation was greater at higher elevations in the upper drainage basin, but also because people also wanted it to be close to villages. The Far View villages were built where they are because the land there is flatter than in the upper basin and because better sources of building stone are available in the adjacent cliff.

Smith and Ramsey: It would be easier to build a reservoir on a flatter slope because less closure would need to be constructed on the downslope side.

Breternitz: Also, soils are deeper in the Far View area than in the upper drainage basin, so it would be easier to dig an initial depression in the Far View area.

Scott-Cummings: Pollen from the base of Mummy Lake fill sediments shows that the mesa top was denuded when the reservoir was abandoned. This supports the interpretation that more runoff would have been available at that time than now.

Wright (Ruth): The idea that the reservoir and its water supply system were developed opportunistically seems good.

Rohn: Too bad the early people didn’t leave us written records of their activities.

SUMMARY

Ken Wright stated that this group represents the best knowledge available concerning Mummy Lake, and that the group would never again assemble. For that reason he would: Summarize the discussions, provide it to Mesa Verde National Park along with the partial video, prepare a
technical summary to the State Historical Society, and prepare a final report to Mesa Verde National Park after analyzing all data.

He thanked Linda Towle, Larry Nordby and Cynthia Williams of the National Park Service for their participation and assistance.

The symposium adjourned at 5:30 p.m. following a four-hour session.
ATTACHMENT A: LIST OF ATTENDEES

Mesa Verde—Mummy Lake Meeting Attendees—June 5, 1999

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Affiliation</th>
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<tbody>
<tr>
<td>Scott Marshall</td>
<td>Civil Engineer</td>
<td>Wright Water Engineers</td>
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<tr>
<td>Brad Hagen</td>
<td>Civil Engineer</td>
<td>Wright Water Engineers</td>
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<tr>
<td>Kurt Loptien</td>
<td>Geologist</td>
<td>Wright Water Engineers</td>
</tr>
<tr>
<td>Jon Pruess</td>
<td>Paleohydrologist</td>
<td>Teacher—Loveland High School</td>
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<tr>
<td>Ryan Unterreiner</td>
<td>Environmental Scientist</td>
<td>Wright Water Engineers</td>
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<tr>
<td>Chris Crowley</td>
<td>Surveyor/Forester</td>
<td>Wright Water Engineers</td>
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<tr>
<td>Cynthia Williams</td>
<td>Archaeologist</td>
<td>Mesa Verde National Park</td>
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<td>Doug Ramsey</td>
<td>Soil Scientist</td>
<td>USDA-NRCS</td>
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<td>Ed Rhodes</td>
<td>Eng./Finance</td>
<td>Arabian American Oil Co.—Retired</td>
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<td>Chuck Lawler</td>
<td>Hydrologist</td>
<td>Wright Water Engineers</td>
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<td>Jack Smith</td>
<td>Archaeologist</td>
<td>Wright Paleohydrological Institute</td>
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<tr>
<td>Mary Gillam</td>
<td>Quat. Geologist</td>
<td>Independent</td>
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<tr>
<td>Ernie Pemberton</td>
<td>Sedimentation</td>
<td>Wright Water Engineers</td>
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<td>Andrew Earles</td>
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<td>Eric Bikis</td>
<td>Hydrogeologist</td>
<td>Wright Water Engineers</td>
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<tr>
<td>Gregory Munson</td>
<td>Arch. Tech</td>
<td>Mesa Verde National Park</td>
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<tr>
<td>Linda Towle</td>
<td>Chief, Research, &amp; Resource Management</td>
<td>Mesa Verde National Park</td>
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<tr>
<td>Larry Nordby</td>
<td>Research Archaeologist</td>
<td>Mesa Verde National Park</td>
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<tr>
<td>David Breternitz</td>
<td>Archaeologist</td>
<td>Independent—Formerly CU</td>
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<tr>
<td>Linda Scott Cummings</td>
<td>Palynologist</td>
<td>Paleo Research</td>
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<tr>
<td>Cal Cummings</td>
<td>Retired Archaeologist</td>
<td>NPS—Retired</td>
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<tr>
<td>Art Rohn</td>
<td>Archaeologist</td>
<td>Wichita State University</td>
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<td>Ruth Wright</td>
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<td>Wright Paleohydrological Institute</td>
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<tr>
<td>Ken Wright</td>
<td>Paleohydrologist</td>
<td>Wright Paleohydrological Institute</td>
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- 24 Participants from 1:30 PM to 5:00 PM
- All people participated in discussion
- All people participated in presentation of their views via raised hands to judge consensus
Appendix J
Not Included in Electronic Copy
Drawing 1
Drawing 2
Drawing 3