SURFACE FLOW ON MEDANO, MOSCA, AND SAND CREEKS IN RELATION TO FAULT ZONES AND WATER TABLES

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INTRODUCTION

This project seeks to determine the relation between surging surface flow and projected groundwater declines at the Great Sand Dunes National Monument. Surging flow in Medano Creek is a unique visitor attraction at the Monument, and is exhibited from April through July at easily accessible sites. Projected water table declines of up to 46 m due to an adjacent groundwater development scheme may increase infiltration rates in Monument creeks, thus leading to diminished or eliminated surge flow. This report covers the third 6-month period of the contract (May 15-Nov. 15, 1992).

♦ OBJECTIVES

Task 1- Establish the relationship of creek flow distance to water table level. Determine the infiltration rate through dry, wet, and saturated sand.

Task 2- Develop a model of Medano Creek flow distance and volume considering variables of ground water height, amount of water in Medano Creek, and precipitation patterns in the watershed. Apply this model to Mosca and Sand Creeks.

Task 3- Determine the water flow needed to develop surge flow phenomena.

FIELD VISITS AND DATA COLLECTION

The following listing summarizes field visits, personnel included, and work accomplished during this report period.

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May 27-29, 1992- COLLECT DATA; J. McCalpin (USU); Collect data from flumes and monitor wells L and C1; measure discharge of Little Medano Creek.

July 19-22, 1992- COLLECT DATA; J. McCalpin, G. Hadlock (USU); Collect data from flumes and monitor well L; do resistivity survey near well M.

Sept. 15, 1992- COLLECT DATA; G. Hadlock (USU); Collect data from flumes and monitor well L.

Nov. 3-5, 7, 1992- COLLECT DATA; J. McCalpin (USU); Collect data from flumes and monitor well L; remove instruments from Boundary flume for winter.

METHODS

Surface flow volumes in Medano Creek were measured from calibrated Parshall flumes (see details in McCalpin 1991, 1992). Depth to groundwater in monitoring wells were measured with pressure transducers coupled to data loggers. 150

RESULTS

SURFACE FLOW VOLUMES

Medano Creek- Boundary Flume

The discharge of Medano Creek is reported herein for the period April 9-Nov. 7, 1992 (8 A complete record for this period is months). available from the Boundary flume. Data were collected at four times during this 8 month-long period, at approximately 2 month intervals. These graphs were generated by the spreadsheet program QUATTRO.PRO, v. 3.0, and suffer from one limitation. Because each graph spans more than one month, the data cannot be plotted as an XY graph, because a large numerical gap would occur on the Xaxis between the last day of one month (e.g., day 4.30) and the first day of the following month (e.g., day 5.01). Therefore, the following four graphs are plotted as LINE graphs, which means that every observation is equally spaced along the X (time) axis. Because the DP 115 in the flume does not record stage measurements at equal time intervals, the X axes of these graphs do not represent linear time. However, the scale distortion is usually small, because (on average) a similar number of measurements is made by the DP 115 each day. Therefore, discharge graphs should be used to gain an overview of the patterns of discharge covering relatively long time periods.

April 9- May 27, 1992

At the beginning of the record, discharge is steadily increasing from 15 cfs to 40 cfs, coupled with pronounced diurnal fluctuations (Figure 1). The peak discharges occur in late afternoon-early evening, after the heat of the day, implying that daily snowmelt is travelling down the channel. On a dayto-day basis, peak temperatures (according to the NPS weather station at GSDNM) correlate with peaks in discharge. In contrast, cool and cloudy weather (sometimes accompanied by light snow) correlates with significant decreases in discharge, such as the decline from 40 cfs (April 15) to 20 cfs (April 23). During these cool periods, diurnal fluctuations are dampened or disappear, which also implies that diurnal fluctuations are the result of solar melting of snowpack.

The peak discharge occurring on April 30

(47.3 cfs) caused an undercutting failure of a 6 ft by 10 ft section of streambank immediately south of the flume. This collapse led to significant leakage of water around the south side of the flume, as shown by the sudden 8 cfs drop in discharge. During the period April 30- May 14, the discharge record is affected both by this leakage, and by cool weather which reduced snowmelt. The leakage was repaired on May 14 by NPS personnel. Discharges remained between 28-40 cfs during late May, punctuated by one small rainstorm on the remaining snowpack.

May 27- July 19, 1992

This period contains the end of snowmelt runoff and the slow decline down to baseflow conditions. Discharge remained near 35 cfs until June 7, but then began a gradual decline to near 7 cfs by July 15. Superimposed on the decline are several individual rainstorm events, which have discharge peaks lasting 2-3 hours, but which also contribute a delayed flow increase for the next 1-2 days. Diurnal fluctuations become more pronounced after June 23, probably indicating that no precipitation events existed to obscure the pattern. The irrigation diversion at Medano Pass was returned to the Creek on July 15, and a sudden increase of about 5 cfs was observed. After the diversion, flow continued to decline with superimposed diurnal fluctuations.

July 19- Sept. 15, 1992

The expected continued decline of discharge in late summer- early fall was interrupted by rainstorms of at least three sizes. Small rainstorms led to increases of 2-3 cfs that lasted several hours. Moderate rainstorms led to increases of 3-5 cfs that lasted for 1-2 days. A major rainstorm occurred on Aug. 24-25 that increased discharge by 12 cfs, and increased baseflow for 10 days. By Sept. 3, the effects of that storm had subsided, and slow decline was again taking place, with pronounced diurnal fluctuations.

Sept. 16- Nov. 7, 1992

A very slow decline in discharge occurred through this period, from about 4 cfs on Sept. 16, to 3 cfs 7 weeks later (Figure 2). The earliest and latest part of the record exhibit the results of small rainshowers (maximum increase = 1.5 cfs). Most of the record shows a slow decline complicated by either

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DISCHARGE AT BOUNDARY FLUME from April 9 - May 27, 1992



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DISCHARGE AT BOUNDARY FLUME from Sept. 16-Nov.7, 1992



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weak diurnal fluctuations or by very small random variations. Beginning Oct. 15, the discharge record is essentially flat, with only random fluctuations; we infer that the water in the stilling well froze at this time, and random variations reflect sensor drift or temperature variations in the stilling well. Increased discharge from Oct. 25-30 probably reflects a rain event, which flooded the stilling well with more water atop the old ice. After Oct. 30 the stilling froze again, but at a higher level than before. This behavior mimics the behavior of stilling well ice in the winter of 1991-92, when ice in the stilling well was frozen at a higher level than the running water in the flume itself. Therefore, after Oct. 30 the discharge record is presumably not accurate.

MEDANO CREEK-CASTLE CREEK FLUME

The peak snowmelt discharge that occurred in April, 1992, undermined the Castle Creek flume, causing partial collapse. In addition, the access tube to the stilling well was frequently clogged with twigs and leaves. Discharge measurements were obtained in the Castle Creek flume from May 28- July 19, 1992, but most of the data are not believed to be accurate. The Castle Creek flume was dismantled by NPS personnel in October, 1992.

DIURNAL FLUCTUATIONS

Diurnal fluctuations in discharge occur throughout the year in Medano Creek, but spring fluctuations are different than summer and fall fluctuations. During the initial spring snowmelt (April 1-9, 1992), the peaks and troughs of discharge appear 2-3 hours later at the Castle Creek flume than at the Boundary flume. Peak flow at the Boundary flume occurs at about 6-7 pm, after the hottest part of the day, and does not appear at the Castle Creek flume until after 10 pm. The timing of peak discharge in the early evening, and the lag time between the flumes, suggests that each day a "slug" of snowmelt water enters the channel from high in the basin during the late morning and afternoon, and this slug travels downstream at about the velocity of water in the stream. To travel the ca. 5 km between the flume sites in 2-3 hours, velocities of 2-3 ft/sec are indicated. Current meter measurements confirm that this is the average water velocity in the channel.

In the summer and fall, as discharge decreases so does the amplitude of diurnal fluctuations. For example, during the spring snowmelt (April 9-14, 1992) discharge fluctuates as much as 5 cfs at discharges of 15-30 cfs. By July fluctuations are down to 1-2 cfs at discharges of 8-15 cfs. In early September fluctuations are less than 1 cfs at 4-7 cfs, and decrease to about 0.25 cfs in October at 3 cfs. The fluctuations during July-September are exactly in phase between the two flumes, suggesting that a simultaneous mechanism is occurring at both sites. This mechanism may be phreatophyte transpiration by streambank cottonwoods, which would withdraw water from Medano Creek.

STREAM LOSSES

Discharge in Medano Creek at any given time decreases downstream due to infiltration into the stream bed (i.e., losing stream conditions). The amount of water lost by infiltration should increase with increasing discharge, due to two factors: 1) at greater discharges, the wetted perimeter of the stream increases, and 2) as discharge increases, water depth increases, and the hydraulic gradient driving stream bed infiltration increases.

In the gravel bed section of Medano Creek, the stream bed has relatively steep, vegetated banks, so increases in discharge are accompanied mainly by increases in channel depth rather than in channel width. Because infiltration rate should be a linear function of water depth, we should expect a linear increase of stream loss with increasing discharge. Stream infiltration loss rate into the gravel bed section of Medano Creek was moderately correlated to discharge at the boundary flume (stream loss cfs/km=0.49 discharge cfs, n=11, r^2 =0.76). In the final 6 months of this contract, many more data points will be plotted to see if stream loss rate is also a function of time of year, in addition to discharge.

Stream losses in the sand bed section of Medano Creek are hard to calculate, because discharge measurements are difficult to make in the wide, braided sections. Preliminary methods and results were described by McCalpin (1992). An alternative method of measuring stream loss would be to measure the distance between the Castle Creek flume and the flow terminus (where flow = 0 cfs)

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over many days. Obviously, the entire discharge measured at Castle Creek has been lost into the stream bed by the time the flow terminus is reached. The resulting averaged stream loss rate may turn out to be variable, i.e., the stream bed may suck up water faster in some reaches (e.g., opposite the Picnic Ground) than in other reaches. Variable loss rates could then be used to target detailed geophysical surveys, particularly ground-penetrating radar, to correlate the loss rate changes with changes in subsurface stratigraphy or surface water- groundwater interactions. For example, loss rates should change as Medano Creek flows onto, and then off of. the underlying hardpan layer that supports the perched aquifer. Unfortunately, tracking the position of the flow terminus during the period that the Castle Creek flume was operative (July, 1991 to April, 1992) would be difficult, since the flow was mainly retreating during that period, and contrast between water and wet sand on aerial photographs or satellite imagery might be low. In addition, no aerial photography was flown during that period, so expensive satellite imagery would have to be used.

GROUNDWATER LEVELS UNDER THE MEDANO CREEK FLOODPLAIN, MONITOR WELL CLUSTER

Period of Constant Water Level (May 28-July 8, 1992)

Water level stood at about -4.2 ft throughout this period, with minor fluctuations. During the period, the active channel was only 25 ft east of Well L. According to the Boundary flume records, discharge during this period declined from 35 cfs to 9 cfs, but no effects of this decline are noticeable in Well L.

Period of Slow Water Decline (July 8- July 16, 1992)

Water level began to rapidly decline in this period (0.5 ft in 1 week), when discharge at the Boundary flume declined slightly from 9 cfs to 7 cfs. The rapid decline probably indicates that the surface flow terminus had retreated to just upstream of the monitoring well cluster during this week.

Period of Rapid Water Rise (July 16) and Slow Rise (July 16-July 23, 1992)

Water level abruptly rose 0.5 ft on July 16,

and continued to rise another 0.2-0.3 ft during the next week. This abrupt rise coincides with a sudden discharge increase of 5 cfs at the Boundary flume, due to return of water from the Medano Pass irrigation diversion. Had this diversion not occurred, water levels would probably have continued the downward trend that began on July 8. Instead, added surface flow in the Creek must have readvanced the flow terminus to downstream of the monitoring wells.

Period of Constant Water Level (July 23- Aug. 25, 1992)

Water level remained constant at about -4 ft during this period, despite the fact that discharge at the Boundary flume declined from 10 cfs to 5 cfs in the same period. The relatively high, constant water level implies that the surface flow terminus in the Creek was downstream of the wells during this entire period. The major rainstorm on Aug. 24-25, which tripled the discharge at the Boundary flume (from 5-16 cfs) does not appear to have affected Well L. This observation implies that the water level in the well was already at essentially the same elevation as the floodplain of Medano Creek, and that it could not rise any higher, regardless of discharge in the channel. This is reasonable, because increases in discharge in the broad floodplain at the monitoring wells would be accompanied mainly by increases in channel width, rather than in flow depth.

Period of Rapid Water Decline (Aug. 25- Sept. 15, 1992)

During this period water level declined 2.0 ft in only 2 weeks. This decline is very rapid, and must represent the final seasonal retreat of the surface flow terminus to upstream of the monitoring wells.

Period of Slow Water Decline (Sept. 15- Nov. 7, 1992)

During this 7-week period, water levels declined from -6 ft to -7.5 ft, or about 0.2 ft/week. This rate is only 20% of the rapid rate of the previous period, and is similar to rates of long-term decline observed during the winter of 1991-92.

MONITOR WELL C1

This well, which is located in the center of

the Medano Creek floodplain opposite Coring Hole C, was drilled and instrumented on April 11, 1992. Water level remained at the very bottom of the hole (-14.9 ft) from April 11 to April 18. On April 18, water level began to rise rapidly, gaining all 14.9 ft in about 24 hours. From April 19 to April 18 (end of record) water table was at the ground surface.

This well was monitored to observe how fast the shallow aquifer underneath Medano Creek would "fill up" upon approach of the surface flow terminus. The surface flow terminus reached the monitoring well cluster, 3 km upstream of Well C1, on April 8, 1992. The rapid rise in Well C1 on April 18 implies the flow front arrived on that day; if so, then it took 10 days for the front to advance 3 km. The water level data show that, within 24 hours of the arrival of surface flow, the entire 15 ft unsaturated thickness of the aquifer filled up with water. This extremely rapid rate implies that water infiltrating downward from the streambed cannot continue downward as saturated flow, but is being prevented from downward movement by the "hardpan" layer at the bottom of Well C1. This numerical data complements water level rise data from Wells J and L, where the unsaturated aquifer thickness before filling was only 3.5 ft, or about 1/3 the thickness at Well C1. Surprisingly, it took a very similar amount of time to raise the water table 3.5 ft at Well J as it did to raise the water table nearly 15 ft at Well C1. The implications of this statement are not currently understood, but seem to say that the water table rises in a vertical sense much faster than it spreads laterally.

GEOPHYSICAL EXPLORATION

Electrical resistivity soundings were made by G. Hadlock during August and September, 1992. These data are currently being analyzed. However, in at least one case resistivity soundings were unable to detect a known groundwater table at -17 ft (at Monitor Well M). The resistivity and seismic data collected by the Colorado School of Mines field camp in summer of 1991 is also contradictory (Mike Powers, pers. comm.). At this point, we speculate that ground-penetrating radar may be the most useful geophysical technique to locate the water table and subsurface geologic contacts.

♦ LITERATURE CITED

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