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Sediment Control at Army Training Areas Case Study:

Hohenfels, Federal Republic of Germany

by
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Sediment control networks are important to Army training lands because they reduce the amount of sediment transported downstream. To evaluate the effectiveness of sediment control networks in training areas, the Army needs to know the water and sediment yield under natural conditions and under conditions produced by training activity.

A study was conducted at the Hohenfels Training Area, Federal Republic of Germany, to evaluate the existing sediment control network and to make recommendations for rehabilitation of damaged check dams. Data gathered during watershed and check dam surveys was used in the Army Multiple Watershed Storm Water and Sediment Runoff (ARMSED) model to simulate the results of various activities and improvements.

Recommendations include using fewer, larger check dams in the drainageways; properly locating and designing check dams; constructing improved crossing points; and prohibiting training vehicles from operating in the drainageways. The procedures used in this study can be used to develop sediment control plans at other Army training areas and installations.

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A study was conducted at the Hohenfels Training Area, Federal Republic of Germany, to evaluate the existing sediment control network and to make recommendations for rehabilitation of damaged check dams. Data gathered during watershed and check dam surveys was used in the Army Multiple Watershed Storm Water and Sediment Runoff (ARMSED) model to simulate the results of various activities and improvements.

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Recommendations include using fewer, larger check dams in the drainageways; properly locating and designing check dams; constructing improved crossing points; and prohibiting training vehicles from operating in the drainageways. The procedures used in this study can be used to develop sediment control plans at other Army training areas and installations.

FOREWORD

This research was performed for the Directorate of Engineering and Housing (DEH), Seventh Army Training Command (7ATC) under Intra-Army Order (IAO) Number 7ATC-52-87. The 7ATC Technical Monitor was Mr. John Brent.

The work was performed by the U.S. Army Construction Engineering Research Laboratory (USACERL), Environmental Division (EN). Dr. Timothy Ward is an Assistant Professor, Department of Civil Engineering, New Mexico State University, Las Cruces, New Mexico.

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1 INTRODUCTION

Background

A sediment control network is a series of low earthen dams (check dams) constructed at intervals along drainageways in watersheds. It is intended to reduce the amount of sediment transported downstream by trapping or slowing runoff after a storm, allowing the sediment to settle out of the flowing water.

Because the vegetation and soil in Army training areas are disturbed during exercises (which increases sediment transport), sediment control networks are constructed in these areas. To evaluate the effectiveness of sediment control networks in training areas, the Army needs to know the water and sediment yield under natural conditions and under conditions produced by training activity.

Training vehicle traffic and recent large storms have combined to damage the sediment control network at Hohenfels Training Area (HTA), Federal Republic of Germany (Figure 1). The network consists of a series of dams, ranging in width from 49 to 115 ft (15 to 35 m) and constructed at intervals from 300 to 900 ft (100 to 300 m) along drainageways in several watersheds. Approximately 188 check dams have been constructed at HTA. Twenty-eight were constructed in the Madental Watershed in 1975. An additional 160 were built in 1978 and 1979.

The U.S. Army Construction Engineering Research Laboratory (USACERL) was requested to survey the sediment control network at HTA and make recommendations for rehabilitation.

Objectives

The objectives of this study were to collect data about climatic and watershed conditions at HTA, evaluate the condition of existing structures, conduct analyses of runoff and sediment yield, and make recommendations for rehabilitation of the sediment control network.

Approach

A watershed survey was conducted in June 1987 to collect data for a computer simulation of water and sediment yield. A survey of check dams was conducted in August 1987 to determine the condition of existing structures.

A series of computer simulations were then made to determine the effectiveness of existing sediment control networks and provide information used to develop recommendations for rehabilitation. Simulations were performed using data from the Madental Watershed. These simulations were adequate to answer the general questions about the effectiveness of the existing structures. Additional simulations will be required for each

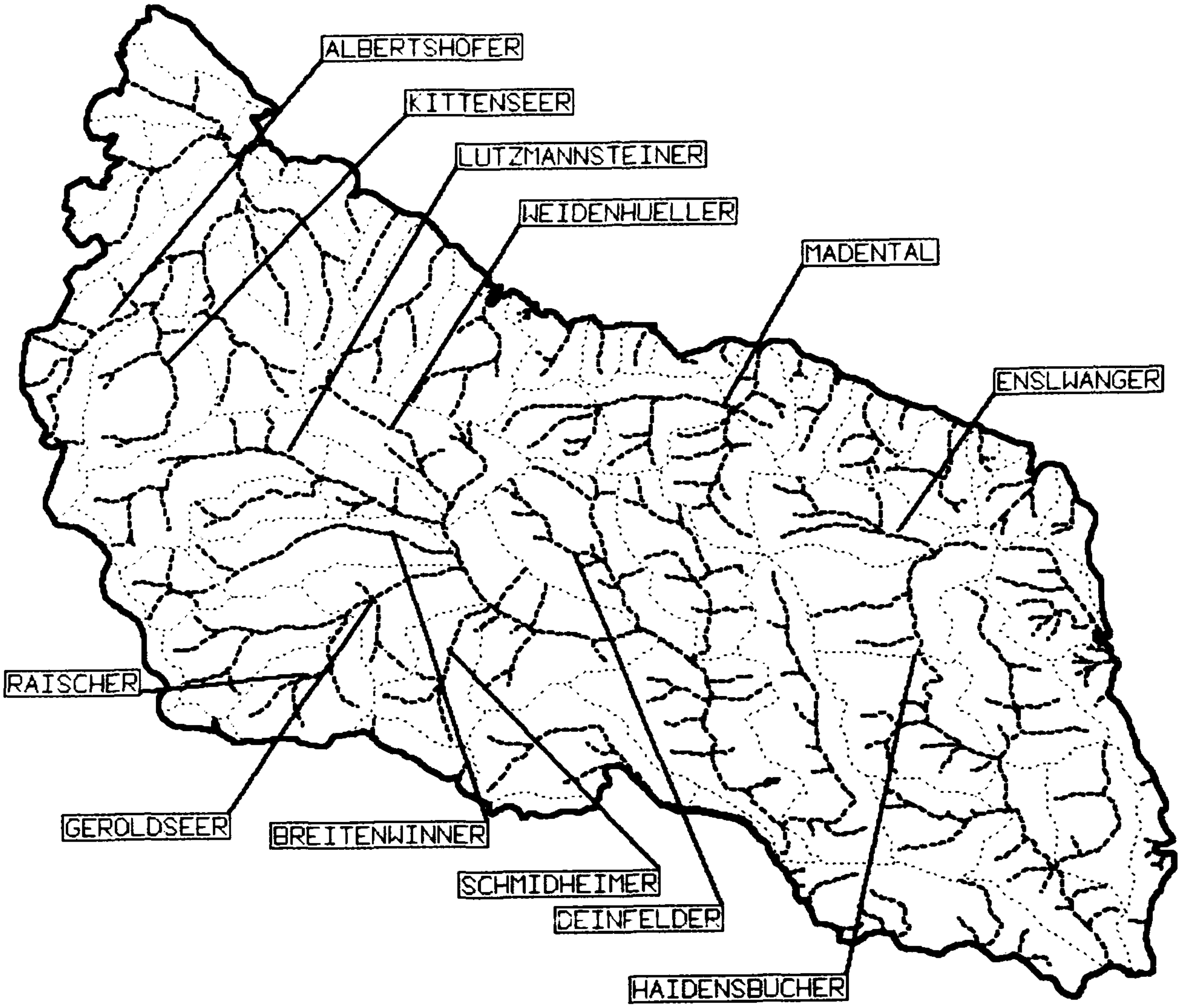

Figure 1. Major drainages in the Hohenfels Training Area, Federal Republic of Germany.

watershed as improvements to the sediment control networks are designed to meet specific watershed management objectives.

Simulations were performed using the Army Multiple Watershed Storm Water and Sediment Runoff Simulation Model, ARMSED. This model is a single event, distributed, deterministic simulation model. It contains two basic components: a hydrologic and hydraulic routing component that computes storm runoff hydrographs, and a sediment component that computes sediment concentration hydrographs and sediment yield. The model includes the capability to simulate impoundments such as sediment basins.

Chapter 2 of this report describes the watershed and check dam surveys and Chapter 3 describes the results of simulations using ARMSED. Chapter 4 contains a summary of the study.

Mode of Technology Transfer

This study contributes to ongoing research related to erosion control and watershed management. The ARMSED model is currently being documented. Watershed analysis procedures are being standardized as part of a work unit in the Environmental Quality Technology Research, Development, Test, and Evaluation (RDT&E) program.

2 DETAILS OF THE WATERSHED SURVEY

Watershed Characteristics

The physiography of the HTA can be characterized as ridge and valley. Elevations range from about 1150 to about 1970 ft (350 to 600 m) above mean sea level. Elevation differences between valley bottoms and ridge tops range from 200 to 500 ft (60 to 150 m), and slope gradients above 10 percent are common.

The bedrock geology is primarily bedded limestones (some containing ammonites) with interbedded sandstones occurring in some areas. Soils in the limestone areas are typically fine-grained plastic clays with a gravel/stone component. Soils derived from the sandstone areas are more coarse-grained.

Because HTA is in a humid climatic zone, vegetation is abundant. Ridges are typically covered with a variety of conifers and some hardwoods. Lower slopes and valley bottoms are mostly grassed with localized patches of trees.

Except where influenced by man's activities, the drainage network is very undefined. This is probably caused by the dense ground cover, healthy riparian/valley bottom growth, low rainfall intensities, and fractured limestone bedrock. These factors also contribute to the lack of perennial streams and well-defined stream channels.

In general, undisturbed or properly maintained channel/riparian systems provide an excellent buffer against sediment inflows from adjacent disturbed training areas. These conditions exist in areas where training vehicles do not operate in drainageways. An important addition to the channel system has been the construction of low earthen dams that form wet areas, encourage plant growth, and trap sediment. The sediment trapping effect can also be seen in areas where the original channel has not been disturbed, but trapping is more pronounced in the channels with earth dams.

The controls on the hydrology and sediment yield for the HTA can be described in terms of general observations of the effect of training on channel function, out-of-channel disturbances, and roadway effects.

Effects of Training on Water and Sediment Yield

Channels have been disturbed by vehicle impacts, increased inflow to the channel, or both. Vehicle impacts are primarily caused by traffic in the channel/valley bottom proper in an along-the-valley direction. This type of traffic creates ruts that lead to more efficient channel flow and higher sediment transport rates. Because cross-channel vehicle traffic tends to create rutting that does not propagate up or down the channel, it is less of a problem. Along-the-valley travel, parallel to the channel bottom is much less destructive in terms of overall sediment source impacts. Water from roadways has created scouring and headcutting in several locations as it enters the channel system.

Out-of-channel disturbances can be classed as along-the-valley, across-the-valley, and in the forest. Although tracked vehicles destroy vegetation, the imprinting of the treads creates a surface roughness that helps retard erosion. Along-the-valley travel tends to act as contour plowing that intercepts and destroys downslope rills before they can develop into gullies. In fact, HTA has very few downslope gullies. The ones that were observed were primarily associated with well-traveled downslope roadways. These disturbed areas must either be reclaimed or disturbed again because the positive effects of the tread imprints will be washed away after a few rainstorms, resulting in a bare, low resistance runoff surface that will contribute both water and sediment to the channel system or will form gullies.

Trails through the forest have created localized erosion zones. However, sediment from these zones is captured in the uplands of the watersheds. A more serious effect is the loss of forest canopy due to vehicle traffic among the trees. Because the forest captures most of the precipitation that falls on it, a decrease in the total forest cover increases water yield and the possibility of downstream flooding.

The road system at HTA is a significant sediment source and contributes to sediment transport in the area by overlaying a highly efficient, disturbed channel (ditch) network on the less efficient and relatively undisturbed natural channel system. Paved tank trails and roads have significantly altered sediment source areas, channel flows, and access to environmentally sensitive areas. The roadways have been constructed in a way that produces very efficient, unvegetated, high gradient channels right next to the road bed. These drainage ditches have become the main watershed channel in many areas while the original grassed waterway has been abandoned.

Grading the road bed to remove the soil/mud deposited by vehicles moves the mud into the ditches, providing a continual source of sediment. The road bed is a fairly impervious surface that contributes overland flow to the ditch system. The ditches also act as interceptors for drainage from other, less-used roadways that intersect the primary roadways.

Many trails and roadways intersect at the confluences of watersheds. The heavy traffic caused by the intersection, traffic in and across the channels, and the use of these areas for staging create large areas of bare ground and sediment supply at these critical junctions.

Check Dam Survey

There is a general pattern of continuing damage to sediment control networks at HTA (Table 1). Table 2 lists the physical status of the check dams surveyed for this study. Structures at the lower end of the drainage areas are breached. The valleys are usually narrow at the lower end and the side slopes are steep. Check dams are about 50 to 65 ft (15 to 20 m) long and more than 6 ft (1.8 m) high. Structures are often breached dramatically.

Further up the drainage, the valleys broaden and the structures become wider and lower. Traffic has caused ruts and reduced the height of the structures. Many structures are either headcut or breached, but the size of the cuts are smaller because of the low structure height.

At the upper reaches of the drainage, traffic is not as heavy across the structures. But where check dams are located close together, the structures offer the best sites for crossing because the drainageway is almost always wet and muddy.

In many watersheds, portions of the drainageway upstream from a structure (and often including the impoundment), are planted and posted to restrict traffic. This improves the drainageway but further increases the necessity to use the structures as vehicle crossing points.

Table 1

Comparison of Survey Results

Watershed	1980 Obs/Damaged	1982 Obs/Damaged	1983 Obs/Damaged	1987 Obs/Damaged
Geroldseer	14/3	14/3	14/2	12/11
Breitenwinner	12/7	12/4	12/4	12/10
Kircheneidenfelder	2/2	2/1	2/0	-
Lutzmannsteiner	25/18	25/6	25/5	20/14
Weidenhueller	20/14	20/6	20/9	15/14
Schmidheimer	6/0	6/1	6/1	3/0
Enslwanger	24/14	24/12	24/7	23/20
Kittenseer	11/7	-	11/3	6/4
Albertshofer	11/0	-	11/1	8/0
Deinfelder	19/14	-	20/8	14/8
Madental	32/9	-	32/3	31/28
Dieteldorfer	11/1	-	11/0	-
Totals	187/89	103/33	188/43	149/109

Table 2

Physical Status of Check Dams

Drainage	Observed	Breached*	Headcut	Rutted	No Damage
Geroldseer	12	3	2	6	1
Breitenwinner	12	0	1	9	2
Lutzmannsteiner	19	0	4	10	5
Weidenhueller	15	6	4	4	1
Schmidheimer	3	0	0	0	3
Enslwanger	23	12	6	2	3
Kittenseer	6	2	2	0	2
Albertshofer	8	0	0	0	8
Deinfelder	14	1	5	2	6
Madental	31	12	1	5	3
Total	143	36	25	48	34

*Breached: Structure has been eroded all of the way through and storage volume has been reduced. Headcut: Structure is eroding at one or more locations and will eventually be breached unless the headcut is repaired. Rutted: Vehicle traffic has produced ruts along the top of the structure which provide low points through which flow over the structure is concentrated and headcuts will eventually develop (traffic usually reduces the height of the structure.) No Damage: Structure is intact and at original grade (little or no traffic over the structure).

3 WATERSHED SIMULATION USING THE ARMSED MODEL

Procedure

The June 1987 watershed survey provided information about vegetation cover, disturbance, drainage, condition of drainageways, check dams, erosion and sedimentation. The survey provided information needed to conduct analysis using the ARMSED model for the purposes of quantifying water and sediment yield and evaluating the effectiveness of existing and potential check dam networks.

The analysis was conducted using the Madental Watershed (Figure 2). The watershed is about 2000 acres (810 ha). For simulation, the area was divided into 5 subwatersheds, 10 planes, and 7 channels. A schematic for the computational sequence is shown in Figure 3.

Computer analysis using ARMSED provided information to support the investigation. The model was used to help answer the following questions:

- What effect does Army training have on water and sediment yield?

- How are the sources of water and sediment distributed throughout the watershed?

- Is a single, larger structure better than several smaller structures?

- How well does the current system of check dams and sediment basins capture sediment?

- Where should check dams be located and what should be their size?

Simulations were performed using ARMSED to generate information about water and sediment yield from the Madental Watershed. Additional simulations were performed to determine the effectiveness of alternate check dam systems. Simulations were performed using 2-yr, 10-yr, and 100-yr frequency storms. Rainfall data from Regensburg, FRG was used. A storm pattern was created for a 12-hour storm, distributed at 30-minute intervals. The maximum 12-hour rainfall depth was distributed uniformly over the 12-hour period and a maximum 1-hour rainfall depth was inserted at the middle of the 12-hour period.

Results

- What effect does Army training have on water and sediment yield?

The effect of Army training was simulated by assuming that an undisturbed area had 95 percent ground cover and a disturbed training area had 90 percent ground cover in the forested areas and 50 percent ground cover in the open areas. It was assumed that training does not significantly decrease forest cover. Check dams were not included in the simulation. The results are shown in Table 3.

The results show that as the magnitude of the storm increases, the difference between the yields in an undisturbed watershed and a disturbed watershed decreases. For the 100-yr storm, the disturbed watershed shows a slight reduction in the peak flow rate

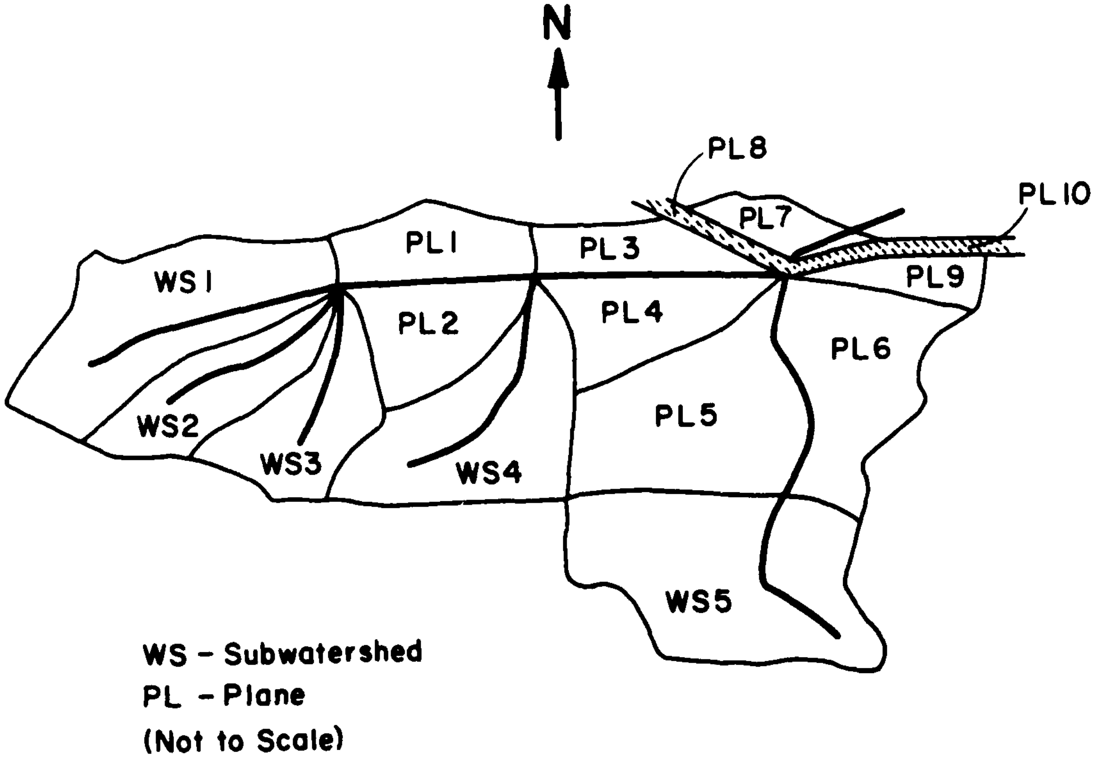

Figure 2. The Madental Watershed.

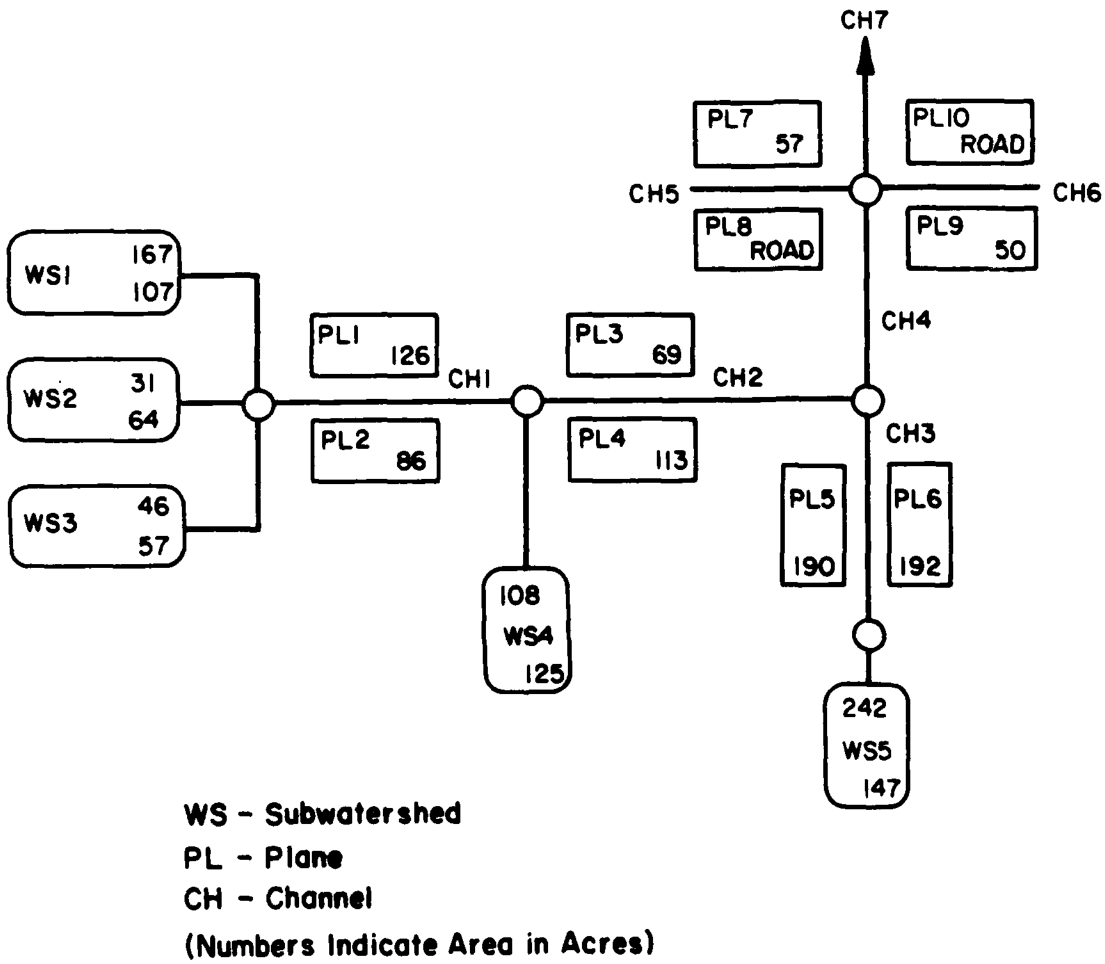

Figure 3. A schematic for the ARMSED computational sequences.

Table 3

The Effect of Training Disturbance on Water and Sediment Yield

Storm Frequency	Total Discharge (acre-ft)			Total Sediment (lb)			Peak Flow (cfs)		
	U*	D	F	U	D	F	U	D	F
2-yr	52.5	59.8	1.14	5921	15,757	2.66	195	285	1.47
10-yr	225.0	237.9	1.06	54,087	82,656	1.53	1543	1801	1.17
100-yr	461.0	458.0	0.99	152,075	186,468	1.23	3776	3669	0.97

*U = undisturbed surface, D = disturbed surface, and F = the factor of increaae.

and total flow. This indicates that the disturbance from training does not increase flooding during very large storms.

Peak flow increases during the more frequent storms, however the magnitude is not great. Sediment production also increases during the more frequent storms. These results indicate that sediment control systems should be designed to reduce sediment yield in training areas by about one-third for the 10-year storm if sediment transport is to be kept within amounts that would occur naturally. By sizing the sediment control system for the 10-year storm, there should be excellent capture of sediment from the more frequent (e.g., 2-yr) storms.

- How are the sources of water and sediment distributed throughout the watershed?

The results of the previous simulations can be used to estimate the water and sediment yield from each segment of the watershed. Table 4 shows the water and sediment yield for each subwatershed and plane for a 10-year storm and disturbed conditions. The total area of the segment and the percent of the segment with forest cover are also shown.

Subwatersheds seem to generate more water and sediment than planes. For example, subwatershed WS-3 is smaller and has about four times the forest cover as PL-1, but it produces more runoff and about four times the sediment. The shorter overland flow distances in the subwatershed could explain some of the difference in runoff, but sediment must be coming from the watershed channel.

Planes 8 and 10 are roads. They contribute a small percent of the total sediment, but there are no structures between the roads and the off-post watershed outlet now that the sediment basin has failed. The sediment contribution from the roads was not as great as suspected.

Table 4

Results of Simulation for the 10-Year Storm

Segment	Total Discharge (acre-ft)	Total Sediment (tons)	Peak Flow (cfs)	Forest Area (acres)	Forest Cover (%) left/right segments
WS-1	36.9	19.1	458	274	61/39
WS-2	13.3	10.5	136	95	32/70
WS-3	16.0	7.3	184	103	77/73
PL-1	10.5	1.7	.0389*	126	20
PL-2	10.0	1.2	.0340	86	2
WS-4	32.1	16.5	412	233	45/84
PL-3	6.7	0.2	.0248	69	96
PL-4	13.1	1.8	.0400	113	0
WS-5	48.3	18.8	479	389	68/80
PL-5	20.1	0.9	.0736	190	22
PL-6	21.1	1.7	.0806	192	21
PL-7	5.9	0	.0198	57	100
PL-8	0.5	1.1	.0008	2	0
PL-9	5.6	0.3	.0191	50	60
PL-10	0.6	1.2	.0008	2	0

*Peak flow is in cfs per linear foot for planes.

- Is a single larger structure better than several smaller structures?

This question is important because there are several disadvantages to the current system of check dams. The Madental Watershed contains many small check dams. The basins behind the dams range in surface area size from about 0.16 to about 2.0 acres (0.07 to 0.8 ha). A 5-foot (1.5-m) depth is assumed for all dams. The check dams are spaced at varying intervals, the closest being about 150 ft (46 m). For smaller, more frequent storms, the upstream structures capture most of the sediment; the downstream dams are not needed. But for the larger storms, the small size of the structures does not allow sufficient retention time for sediment to settle in any of the basins. These numerous small structures also cause water to be retained at more points along the drainageway. This causes the drainageway and adjacent soils to be wet for longer periods of time and could contribute to a raising of the local water table.

The question of fewer and larger versus more and smaller structures was investigated by performing simulations using subwatershed WS-1. This subwatershed has eight check dams. The lower five are about 2 acre-ft (0.25 ha-m) capacity and are spaced about 150 ft (46 m) apart. The next two are about 400 ft (122 m) apart and are about 6 and 8 acre-ft (0.74 and 0.99 ha-m), respectively. The upper structure is small, about 1 acre-ft (0.12 ha-m), and is located 400 ft (122 m) further upstream.

Three simulations were performed. The first included all eight structures. The second eliminated the upper structure and combined the five lower structures into one 10 acre-ft (1.2 ha-m) structure located at the outlet. The third combined all structures into one 25 acre-ft (3 ha-m) structure at the outlet. Table 5 shows the results. Figure 4 shows the schematic for the three cases.

The results show that several smaller structures will reduce the peak flow. There is no significant difference in sediment yield shown in these simulations. While this does not indicate that a single, larger structure is better in terms of sediment reduction, it does indicate that smaller structures can be combined into a single, larger structure to reduce the work involved in simulation.

One possible reason why the results of these simulations were close for all three cases is that the watershed was divided into smaller contributing areas by check dams evenly distributed along the watershed drainage. Retention time was short for a structure but the peak flow rate into the structure was also lower.

Table 5

Comparison of Alternate Numbers of Structures

Number of Structures	Discharge (acre-ft)	Sediment (tons)	Peak Flow (cfs)
8	8.5	0.7	18.4
3	9.7	0.8	23.6
1	8.8	0.8	26.6

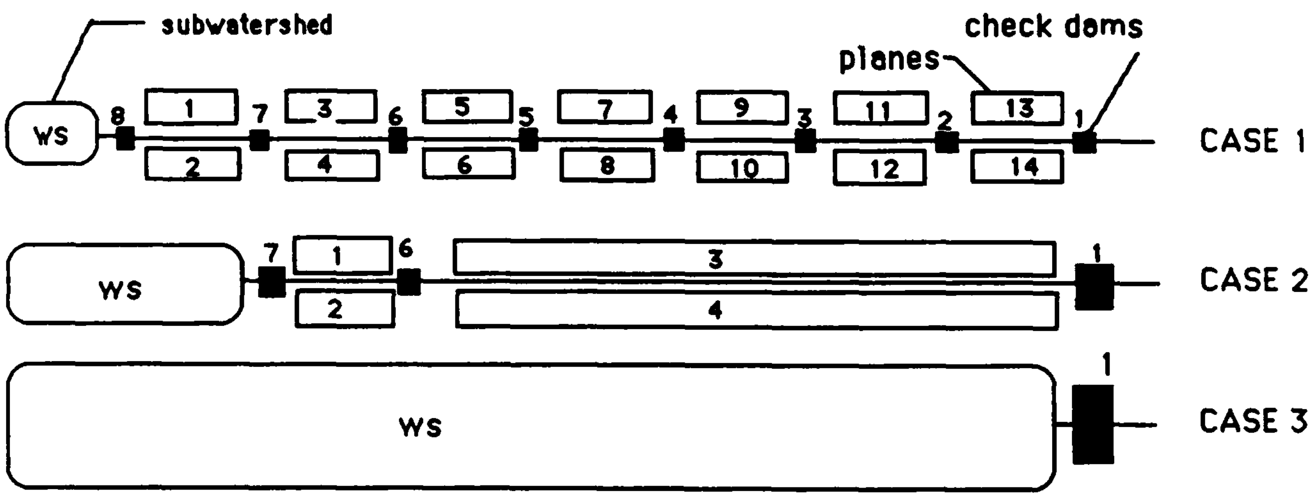

Figure 4. A schematic for comparing various numbers of structures.

- How well does the current system of check dams and sediment basins capture sediment?

The results of simulation of the Madental Watershed and existing system of check dams are shown in Table 6. The results show that 63 percent of the sediment generated on the subwatersheds and planes is captured in the channels and check dams. There are two "rules of thumb" for sediment capture efficiency; one is simply to expect 50 percent, the other is that sediment basins should be designed to capture sediment at sizes 0.02 mm (silt 0.0008 in.) and larger. So trap efficiency would be the percent of transported soil that is larger than this size. The particle size distribution used in the simulation was 50 percent greater than 0.02 mm (0.0008 in.).

- Where should check dams be located and what should be their size?

It has been shown that the existing system of check dams is effective for the 10-yr storm. Also, combining the smaller structures into a single, larger structure would not significantly increase sediment capture. So any advantage from changing the check dam system must come from improvements in training operations and maintenance of the system.

Given a choice, fewer, larger check dams would be preferred. They should be drained so that water is not retained for more than a few hours after a storm. Draining not only provides capacity for storage when the next storm occurs, but it will also help decrease soil moisture. A larger dam structure would also provide a dry crossing point for vehicles.

Check dams should be located at points of concentrated runoff such as subwatershed outlets and outlets of channel segments. Another consideration is to locate them where they would provide a useful channel crossing point. Analysis of contributing areas is also important. For example, planes 3 and 4 do not contribute a lot of water and sediment. If adequate structures are located at the outlets of channel 1 and subwatershed 4, structures may not be required along channel 2.

The effectiveness of upstream structures should also be considered when selecting sites for check dams. If the upstream structures capture sediment 0.02 mm (0.0008 in.) and larger, the downstream structures, which must be sized for average flows, will only have to capture sediment from contributing areas between structures. Since upstream structures do not significantly reduce average flow, the downstream structures will have to be very large to capture the small-size sediment.

Since check dams do not reduce average flow rates significantly, they do not reduce the size requirements for downstream structures. If downstream structures are built, they could capture all sediment including what would be captured by upstream structures. So if structures are built to proper size downstream, they could eliminate the need for upstream structures.

To test this idea, a simulation was made with one check dam at the outlet of the watershed. The simulated basin had a surface area of 11.79 acres (4.8 ha) and a total volume of 58.97 acre-ft (7.29 ha-m). The results indicate a decrease in sediment yield of 24 percent. This is less than the 34 percent achieved by the check dam system previously simulated. So a downstream structure does not completely eliminate the need for upstream structures.

Table 6

Simulation Data for Existing Check Dam System

ID	Area/Len	Water Balance (acre-ft): Generated From Watershed	Channel/Structure In	Yield	Dep	Sediment Balance (Tons): Generated From Watershed	Channel/Structure In	Yield	Dep
WS1	274.00	36.90				19.60			
CK1	20.00		36.90	16.90	20.00		19.60	6.00	13.60
WS2	95.00	13.30				10.60			
CK2	2.00		13.30	11.30	2.00		10.60	7.40	3.20
WS3	103.00	16.20				7.40			
CK3	2.00		16.20	14.20	2.00		7.40	5.20	2.20
PL1	126.00	10.50				1.70			
PL2	86.00	10.00				1.30			
CH1	3511.00		62.90	61.60	1.30		21.60	14.30	7.30
CK4	10.00		61.60	51.50	10.10		14.30	12.40	1.90
WS4	233.00	32.10				16.60			
CK5	2.00		32.10	30.10	2.00		16.60	12.80	3.80
PL3	69.00	6.70				0.20			
PL4	113.00	13.00				1.80			
CH2	5267.00		101.40	100.20	1.20		27.20	21.50	5.70
CK6	5.00		100.20	95.00	5.00		21.50	20.90	0.60
WS5	389.00	48.30				18.80			
CK7	7.00		48.30	41.00	7.30		18.80	12.30	6.50
PL5	190.00	20.10				1.00			
PL6	192.00	21.00				1.60			
CH3	2743.00		82.10	81.80	0.30		14.90	12.10	2.80
CK8	1.00		81.80	80.60	1.20		12.10	12.00	0.10
CH4	200.00		175.60	175.60	0.10				
PL7	57.00	5.90				0.00			
PL8	2.30	0.50				1.10			
CH5	3292.00		6.40	6.30	0.10		1.10	0.40	0.70
PL9	50.00	5.60				0.30			
PL10	2.40	0.60				1.10			
CH6	3511.00		6.20	6.10	0.10		1.50	0.50	1.00
CH7	700.00		187.80	187.90	0.10		32.20	30.50	1.70

TOTAL SEDIMENT GENERATED:	83.20
TOTAL DEPOSITION:	52.70
TOTAL TRAP EFFICIENCY:	00.63

The trap efficiency of this check dam was only 25 percent because of channel deposition that removed the larger particles. Fifty percent of the sediment load from the planes and subwatersheds was deposited in the channels before it could reach the structure at the watershed outlet.

- What would be the size of check dams based on the 10-yr storm?

Table 7 shows, for each subwatershed, the average 10-yr storm flow rate and the size of a sediment basin that would be required to capture sediment at sizes 0.02 mm (0.0008 in.) and larger.

The depth of each basin is determined by the volume of sediment expected over the interval between cleanout plus about 2 to 3 ft (0.6 to 0.9 m) for stilling. Assuming that the 2-yr storm produces sediment at about the average annual rate, and assuming a 10-yr interval between cleanouts, the total deposition during this period can be determined by multiplying the 2-yr sediment volume by 10.

For example, WS-1 produced 6,123 lb (2663.5 kg) of sediment for the 2-yr storm. Sediment with specific weight of 2.65 weighs about 165 lb/cu ft (2660.5 kg/m^3). At porosity of 0.4 it weighs about 99 lb/cu ft (1601.6 kg/m^3). So 6,123 lb (2773.7 kg) of sediment would occupy about 62 cu ft (1.74 m^3) of volume. For a basin with surface area of 46,174 sq ft (4294.2 m^2) this means the sediment depth would be a little over 0.001 ft (0.0003 m). Over a 10-yr period, sediment deposition would be about 0.01 ft (0.003 m) an insignificant amount.

Check dam structures can be low. Even allowing 2 to 3 ft (0.6 to 0.9 m) for stilling, the structures need not be higher than 4 to 5 ft (1.2 to 1.5 m).

A simulation was run using check dams sized according to the above dimensions and located at the outlets of subwatersheds 1 through 5 as shown in Figure 5. The simulation results are shown in Table 8.

Much of the sediment transported from HTA is clay with particle sizes smaller than 0.02 mm (0.0008 in.). A few structures at sensitive outflow areas should perhaps be sized to capture some of the clay. To capture sediment down to 0.01-mm (0.0004-in.) size would require basins four times larger than what is required for the 0.02-mm (0.0008-in.) size particles.

Table 7

Basin Surface Size for Subwatersheds

Subwatershed	Average Flow (cfs)	Basin Surface (acres)
1	74	2.12
2	27	0.77
3	33	0.95
4	65	1.86
5	97	2.79

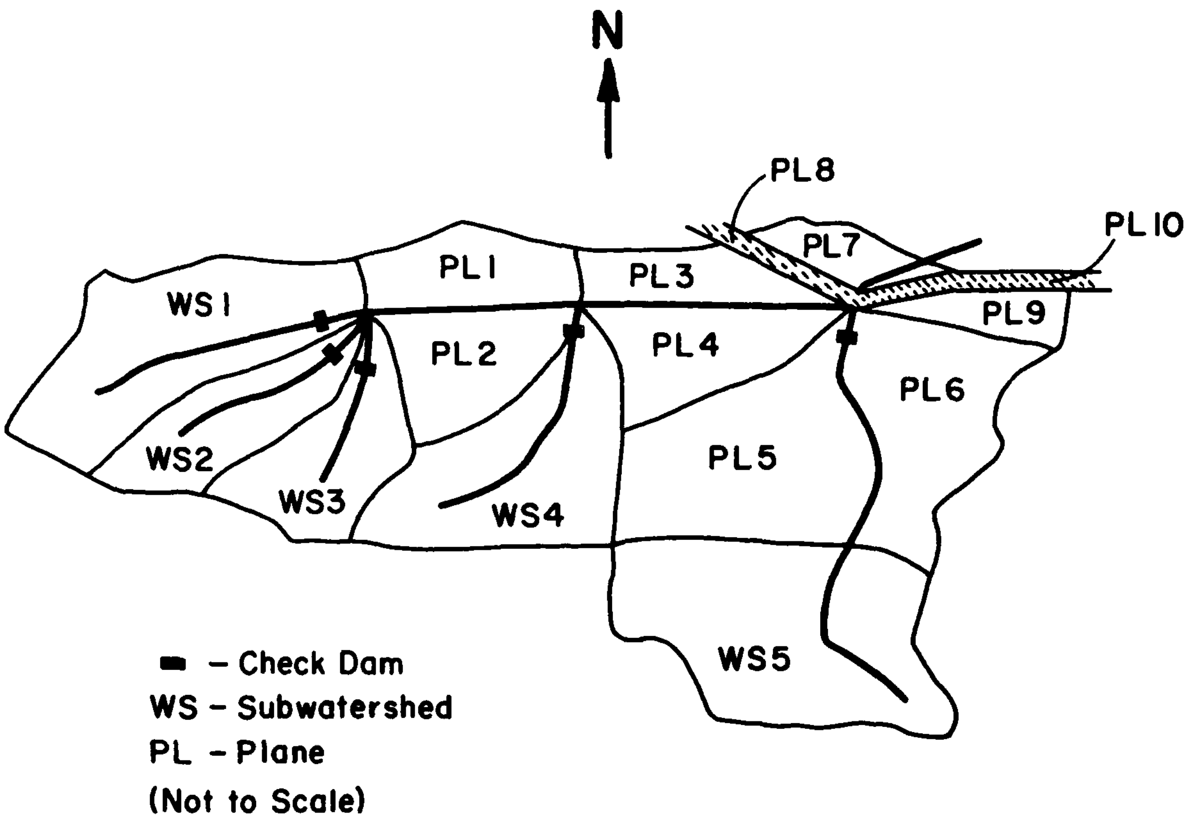

Figure 5. Check dam locations for the simulation.

Table 8

Efficiency of Check Dams at the Outlets of Five Subwatersheds

Check Dam	Sediment In (lb)	Sediment Out (lb)	Efficiency (%)
1	39823	21085	47
2	20992	11369	46
3	14603	7374	50
4	3120	17021	49
5	37631	18379	51

The results of the first simulation were used to size check dams at the outlets of channels 1 and 3. Their areas/volumes were 2.7 acres/13.49 acre-ft (1.1 ha/1.66 ha-m) and 2.61 acres/13.06 acre-ft (1.0 ha/1.6 ha-m), respectively. A simulation with these additional check dams showed that they would capture sediment with efficiencies of 17 percent and 9 percent, respectively. Downstream flows become large in comparison with the additional sediment produced between check dams. So for downstream structures to be worthwhile, they must either be made larger to capture smaller particles or there must be an inflow of sediment from new sources of a magnitude that makes sediment control necessary. Perhaps a big basin at the outlet would be more effective than smaller basins along the downstream portions of the drainage.

Other simulations showed that the original five structures reduced sediment yield by 27 percent and reduced the discharge volume by 18 percent. The addition of check dams at channels 1 and 3 reduced sediment yield by 7 percent more (to 34 percent) and reduced the discharge volume by 12 percent more (to 30 percent).

Summary

1. The current system of check dams in the Madental Watershed, when in good condition, could be as effective for sediment control as that required by a network designed for a 10-yr storm to capture sediment 0.02 mm (0.0008 in.) and larger.

2. The benefits of replacing existing check dams with fewer, larger structures must come from Operation and Maintenance (O&M) concerns (e.g., improved training environment, ease of structure maintenance, etc.) rather than a need to improve sediment control.

3. Downstream structures in a check dam system are not very efficient unless they are sized large enough to capture smaller particles that get past upstream structures, or are needed to capture inflow of sediment that originates from areas between structures.

4. To some extent, if downstream structures are required, they will reduce the requirement for upstream structures.

4 STUDY SUMMARY

Results of the Watershed and Check Dam Surveys

The objective of the watershed and check dam surveys was to determine the condition of the sediment control network at HTA as it affects water and sediment yield.

1. The sediment control network would be effective if it were in good condition. Check dams in the upper areas of watershed drainages are not extensively damaged and are still effective. However, the present capacity of impoundments is very small because the dam height has been lowered by traffic and the sediment basins are beginning to fill up.

2. Roadways and areas at the confluences of watersheds where vehicle traffic occurs in the channels, and areas used for staging are significant sediment sources that are outside the sediment control network.

3. Forest cover absorbs rainfall and protects the soil. It should be preserved to the extent possible and a program of replacement should be initiated to plant new trees to make up for trees destroyed during training. Plantings in and along the drainageways are encouraged in order to protect the drainageway and capture sediment.

4. Gullies have formed in upland areas where vehicle traffic is primarily up and down slope. The problem is not widespread at this time, but plans should be made to control gully formation.

5. Structural methods of channel protection and erosion control need to be used at the confluences of watersheds where vehicle traffic is very heavy. Consideration should also be given to improving the drainage at locations where soils are often wet and traffic creates muddy conditions.

6. The design of the check dams should be reevaluated in terms of the intended function and ability to withstand vehicle traffic. If the intent is to capture sediment and slow the flow of water, the structures should not impound water. They would work better and provide a better training environment if they were drained. However, draining certain check dam impoundments may be criticized by those who consider these areas as aquatic habitat.

7. About 75 percent of the structures are damaged or destroyed. The primary cause of damage is vehicle traffic. The structures were not designed to be used as channel crossing points. Traffic created low points on the structures and subsequent runoff from large storms has headcut or breached many structures.

8. Original height of the structures ranged from 5 to 10 ft (1.5 to 3.0 m). Vehicle traffic has reduced the height of many structures. Selected measurements indicate that even the undamaged structures have little remaining capacity to impound water and capture sediment. Typically only 0.3 to 0.6 ft (0.1 to 0.2 m) of space between the level of the sediment and the top of the check dam (freeboard) exists.

Results of the ARMSED Simulations

The results of the simulations were presented in detail in Chapter 3. Two items are of particular interest: the effect of Army training on water and sediment yield, and the most effective configuration sediment control network.

Simulations showed that Army training increases sediment yield above natural levels about 166 percent for smaller, more frequent storms and about 23 percent for larger, more rare storms. Peak flow rate was increased about 53 percent for smaller storms but was about the same for larger storms. This means that for very large storms, where flood damages are likely, Army training does not contribute significantly to sediment load and does not contribute at all to flood flows. The simulations also indicate that the sediment control network should be designed to reduce sediment yield by about one-third for a storm of 10-year recurrence interval.

The simulations indicate no significant difference between the effectiveness of sediment control for a series of smaller structures evenly distributed along the drainage and fewer, larger structures. However, structures become less effective downstream because larger sediment particles are captured upstream. Downstream structures would have to be very large to capture smaller sediment particles because of the length of time required for settling.

Although the effectiveness of sediment control is similar between a series of smaller structures and fewer, larger structures, the latter are preferred because many smaller structures keep the drainageways wet and muddy. Constantly wet soils have an adverse effect on trafficability during training, and muddy areas are a source of sediment. Larger structures could be strategically placed at the confluences of drainages to obtain maximum sediment control.

Recommendations

Rehabilitation of the sediment control network is going to require a major investment of time, money, and labor. Before any design is undertaken, decisions must be made about watershed management objectives. Should structures be designed to carry traffic? Should impoundments be maintained? Should improved channel crossings be provided and should traffic be restricted from drainageways? Such questions can be better answered if watershed condition and training programs are considered together. Design should be undertaken on a watershed basis. For a given watershed, analysis should be conducted to determine water and sediment yield. This information can then be used to determine the size and location of structures in a network that will provide effective sediment control at the least cost and will enhance training, or at least cause minimum disadvantage to training. Recommendations for watershed management include the following:

- Size structures to capture 0.02 mm (0.0008 in.) and larger-sized sediment particles for a storm of 10-year recurrence interval and use fewer, larger structures.

- Drain water from all basins except where the impoundment is necessary for maintenance of aquatic habitat.

- Provide structures resistant to traffic where channel crossings are needed.

• Limit traffic in and across channels where possible. Build crossings where appropriate.

• Improve drainage along waterways and revegetate to reduce problems associated with wet soils, help control channel erosion, and increase sediment capture along the drainageways.

• Vegetate the structures. Those structures observed to have trees and shrubs growing on or adjacent to them seemed to be in better condition and subjected to less vehicle traffic.

Because so many existing structures are damaged, there are many potential rehabilitation projects. A rational approach would be to prioritize the projects according to returns from protection of existing structures, sediment control, and improvements in the training environment.

Priority rehabilitation activities are:

1. Repair critical structures that are damaged and in danger of failure.

2. Repair or replace selected structures in the most heavily damaged watersheds to reestablish sediment control.

3. Install water and sediment gaging stations to obtain data essential to installation and maintenance of an effective sediment control network.

4. Repair or replace structures and improve drainage along portions of drainageways to improve sediment control and trafficability. Control cross- and along-channel traffic by revegetating drainageways and providing improved crossing points.

5. Improve the general sediment control network in the Deinfelder, Weidenhueller, Lutzmannsteiner, Madental, Breitenwinner, Enslwanger, and Geroldseer drainages, in that order.

6. Certain watersheds that do not currently have water and sediment control should be considered for projects.

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