Preliminary Assessment of Environmentally-sound Methods for Treating and /or Diverting Rainwater Run-off from Parking Lots and Roads in the Vicinity of Carlsbad Cavern

Draft Report

Report Date: January 12, 1998

Prepared for:

Resource Management Division
Carlsbad Caverns National Park
3225 National Parks Highway
Carlsbad, NM 88220

Prepared by:

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SUMMARY

Carlsbad Caverns National Park (CAVE), is located in southeastern New Mexico and is the site of numerous spectacular caves. Recent studies indicate there exists contamination of cave waters related to rainwater run-off from surface activities and facilities located above Carlsbad Cavern (van der Heijde et al, 1997; Brooke, 1996). Storm water run-off transports deposited pollutants such as sediment, hydrocarbons, fertilizers, pesticides, and other organic compounds and metals into adjacent stream courses and outfall areas. Due to the rapid capture and infiltration of rainfall indicative of the soils in the Carlsbad Caverns National Park headquarters area as well as most of the reef complex, many of these pollutants washed off of parking areas enter and percolate directly into the subsurface soils, especially where surface slopes are not steep. Through several hydrologic pathways such as fractures and well developed karst, these pollutants have been detected in Carlsbad Cavern. The contamination, linked to surface rainwater run-off, is associated with significant visitor automobile use, park operation and maintenance practices, and resident activities.

Currently there exists few storm water quality devices in any of the park's drainage systems. Existing accident mitigation procedures are inadequate for large spills and management policies related to storm water quality are required to reduce the level of pollutant generation.

This study examined the pollutant sources that potentially contribute to the pollution detected in storm water run-off and examined various measures to mitigate the contamination problems specific to the pollution type encountered. Specific measures from diversion of run-off to adjacent watersheds to treatment methods are investigated. The effectiveness of each of these methods are evaluated with respect to: pollutant removal efficiencies; disturbance to impacted areas; associated benefits; and construction, maintenance, and engineering costs. Recommended accident mitigation procedures and management policies related to storm water quality are integrated with engineering measures for a comprehensive storm water management approach.

The study found many potential pollution threats from many sources from around the headquarters area. The infrastructure at Carlsbad Caverns is extensive and was created to support and manage hundreds of thousands of visitors and over two hundred thousand vehicles per year. Nearly a thousand parking spaces are reserved for visitors. The area most vulnerable to contamination is Bat Cave Draw. The historic parking lot lies directly in the draw. The run-off and infiltration through the cracks in the pavement are sources of contamination for the cave. The maintenance area is the most problematic area for pollution reduction. A large portion of the maintenance yard is directly tributary to Bat Cave Draw. In addition to having nearly one acre of multi-use paved surface, it provides parking for heavy construction vehicles and hazardous materials storage. The main yard

also contains a fueling station which services all of the park's motorized vehicles. One of the main parking lot structures is also tributary to Bat Cave Draw.

Most storm water treatment measures are relatively new. This developing market is possibly in response to the current Storm Water Program implemented under the National Pollutant Discharge Elimination System (NPDES) by the Environmental Protection Agency. EPA uses the NPDES permit process to address storm water discharges associated with industrial and construction activity to reduce pollution from storm water run-off.

Several treatment measures are recommended for all of the affected contamination source areas. These technologies, sharing proven pollutant removal capabilities for the specific application, relatively longer histories and good market acceptance, are proposed at the locations identified in the infiltration study. In both measures which considered redirection of flows to adjacent watersheds, the treatment option was cost competitive in both cases. Recommendations are also provided to integrate current accident mitigation procedures with any storm water quality treatment measures accepted. Suggested management actions are provided to significantly reduce the potential for further contamination and risk of a major spill.

This report demonstrates the need for significant improvements in existing infrastructure, accident mitigation procedures and management policies for the overall improvement of water quality on the surface and in the caves. These methods may permit some reduction of risk to cave resources for the long term, however they do not impact or change the type and control of land use, namely the use of parking areas and access roads for: visitors; operations and maintenance facilities; and residents. The methods presented in this report should be considered as short term mitigation and implemented only in the interim until the contaminating source areas are closed. The treatment measures recommended have the ability to remove a significant percentage of pollutants contained within the storm water run-off. However they are ineffectual at eliminating them. Cost and site constraints as well as the preservation of park esthetics limit the types and extent of measures which are feasible to address the problem.

A certain level of contamination and risk of a major contamination incident, addressed previously as chronic and acute threats, as well as the cave vulnerability examined in the infiltration studies (van der Heidje, 1997, Brooke, 1996), will continue if the current land type and use is to remain above the protected caves.

TABLE OF CONTENTS

FIGURES

TABLES

FOREWARD

This report has been prepared for Carlsbad Caverns National Park, National Park Service, Carlsbad, New Mexico. The purpose of this report is to provide a literature search and consultation on methods for meeting the recommendations as given by van der Heijde et al. (1997) in "Determining Water Infiltration Routes From Structures Located Above Carlsbad Cavern, Carlsbad Caverns National Park, Carlsbad, New Mexico".

The objective of the study by van der Heijde et al. was to provide Park managers with adequate information and data to prevent and abate cave contamination from surface sources. The study concluded that "...Carlsbad Cavern is highly vulnerable for contamination from the surface... primarily related to chronic low-level sewer releases from sewer lines and parking lot run-off. However, it is very conceivable that in the future a major contamination incident may take place if no preventive measures are taken." The authors of this study recommended closure of contamination source areas as the primary measure to protect the cave from pollution.

The primary objective of this report is to address the parking lot run-off, mainly through development of a preliminary assessment of environmentally-sound methods for treating and/or diverting rainwater run-off from parking lots and roads in the vicinity of Carlsbad Cavern. The methods include suggested changes in (1) engineering measures, (2) accident mitigation procedures and (3) management policies.

These measures, procedures and policies, however, do not address the primary recommendation given in the above study -- prevention through closure of the contamination source areas. These methods may reduce the risk to cave resources for the long term, however they do not impact the type and control of land use, namely, the use of parking areas and access roads by visitors, for operations and maintenance facilities; and by residents.

The methods presented in this report should be considered as short term mitigation and implemented only in the interim until the contaminating source areas are eliminated. Interim decisions should be made based on available data to prevent further degradation and promote restoration of natural resources. Only through elimination of these contamination source areas can the reduction of cave susceptibility to further contamination be realized.

This report draws upon the data and recommendations of the infiltration study by van der Heijde et al. as well as the hydrochemistry given by Brooke, 1996 "Infiltration Pathways at Carlsbad Caverns Nation Park Determined by Hydrogeologic and Hydrochemical Characterization and Analysis".

The author appreciates the suggestions and guidance of Don Fitzhugh of Cordero Ward Associates. The author appreciates the assistance of Diane Dobos Bubno and Kelly Bridges in the surveying of the maintenance yard area.

Disclaimers

This report is not intended as a basis for the engineering required to adopt any of the recommendations. The purpose of the recommendations and calculations is to assist the resource staff in determining whether the measures warrant further investment of time and/or resources. Inclusion of vendor information does not constitute endorsement of any one particular vendor or product.

Liability

The author will not be responsible for any direct, incidental, or consequential damages arising out of the materials provided or the concepts discussed in this report and associated calculations.

Warranty

The author provides no warranty of this material, nor the concepts discussed within.

Mark Bremer, P.E.
Carlsbad, New Mexico
January 1998

Preliminary Assessment of Environmentally-sound Methods for Treating and/or Diverting Rainwater Run-off from Parking Lots and Roads in the Vicinity of Carlsbad Cavern

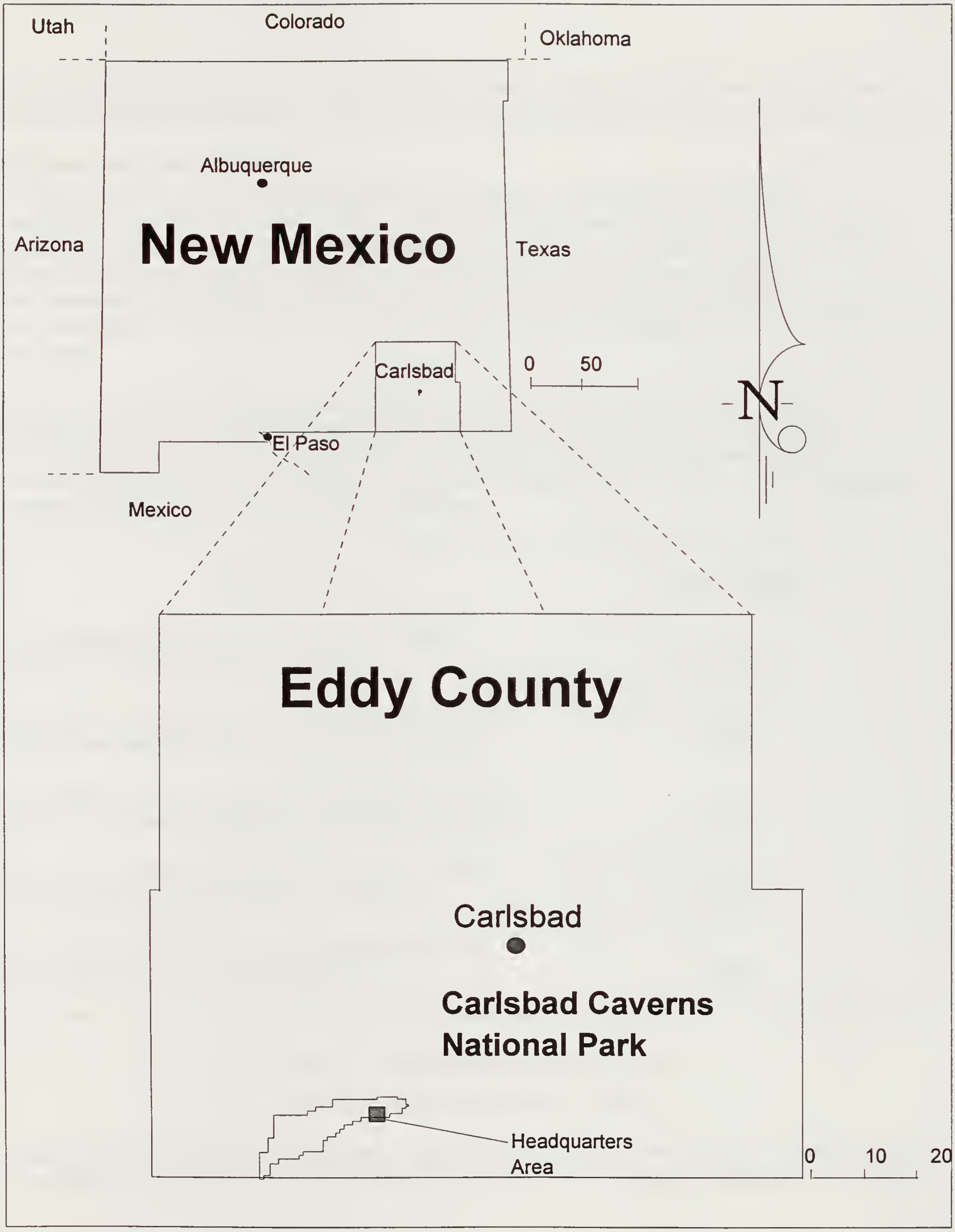
PROBLEM STATEMENT

Carlsbad Caverns National Park (CAVE), established in 1930, is located in southeastern New Mexico (Figure 1) and geographically near the north end of the Chihauhaun Desert.. It is the site of numerous spectacular caves. The purpose of Carlsbad Caverns NP is threefold: 1) to preserve and protect cave resources, portions of the Chihuahuan Desert ecosystem, and a portion of the Capitan Reef, as well as associated natural and cultural resources; 2) to provide a range of opportunities for public use, enjoyment, and understanding while minimizing impacts on park resources and natural processes; and 3) to facilitate research to provide a continuum of information in support of park interpretation and management decisions and the general body of scientific knowledge (NPS, 1996. Final GMP/EIS).

Recent studies indicate that contamination of cave waters related to surface rainwater run-off is from surface activities and facilities located above Carlsbad Cavern (van der Heijde et al, 1997; Brooke, 1996). The contamination, in the form of chemical compounds and metals, is associated with significant visitor automobile use, park operation and maintenance practices, and resident activities. Three large capacity paved parking lots , a visitors center (VC), staff housing, offices and a maintenance yard lie directly above the cave. The main parking lots have a combined capacity for over 900 cars, 63 spaces for recreational vehicles or busses and approximately 500 feet of unmarked parking space for busses and vehicles with trailers . The VC includes a full-service restaurant and has an underground diesel fuel storage tank. The maintenance yard includes: (a) an office; (b) several utility and storage buildings; (c) a paved vehicle storage area for construction and road maintenance vehicles; (d) a fueling station with underground gasoline and diesel fuel storage tanks; (e) two unpaved parking areas, and (f) an unpaved materials storage area. The residents live year-round above the cavern in single family attached or apartment style units and have personal vehicles in the housing area.

All of these drainage areas and their rainwater run-off are tributary to most areas of the main cave, including the most vulnerable drainage area - Bat Cave Draw. In addition a major contamination incident may occur to cave resources if no preventive measures are implemented (van der Heidje, 1997).

Given the stated purposes of Carlsbad Caverns NP and the recognition of ongoing cave contamination and the potential of a major contamination incident, action is needed to protect vulnerable cave resources. Protection must also be given to other known



LOCMAP/stats.xls
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Figure 1. Location Map

resources which include ground water and surface vegetation as well as unknown and undiscovered cave resources, all which exist as receiving bodies for surface water run-off.

Purpose and Need of Report

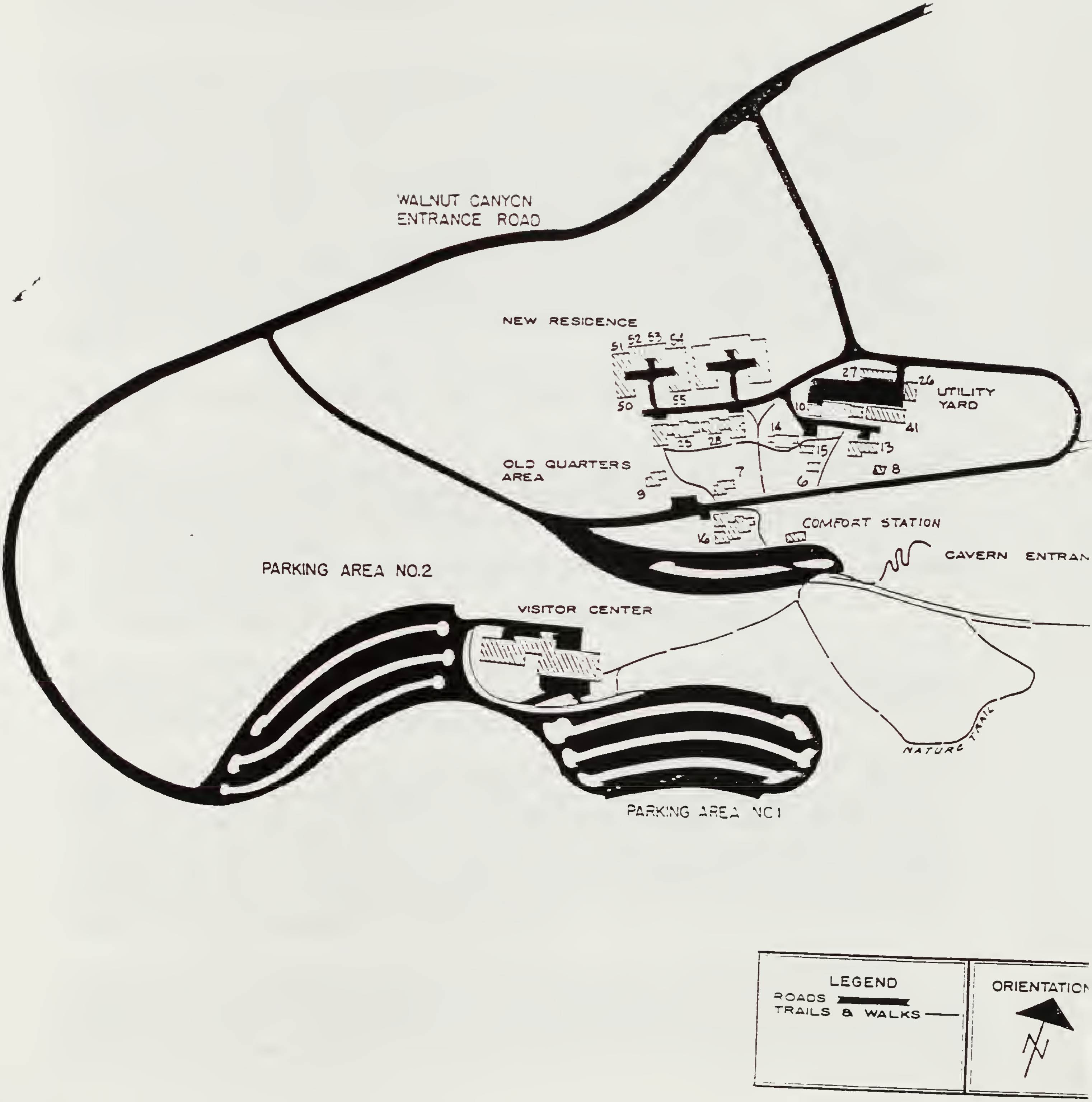
This report evaluates existing engineering measures, accident mitigation, and management policies related to storm water. Visitation and climate are examined for their pronounced effects on pollution generation and transport. The infiltration study identified the areas most vulnerable to contamination. From these conditions, recommended improvements to the engineering measures, accident mitigation procedures and management policies are made in an effort to protect vulnerable cave and water resources.

Infiltration Study Findings - The infiltration study conducted by van der Heijde et al. (1997) has determined the areas most vulnerable to contamination from surface rainwater run-off. Source locations listed in Table 1 indicate by high and extreme vulnerabilities of where contamination is most likely to occur. These source areas listed represent the primary focus of this evaluation.

Source	Vulnerability
1. Infiltration from Bat Cave Draw (lower) parking lot towards Bat Cave Draw	Extreme
2. Surface run-off from the maintenance yard and fluids from leaks/spills towards Bat Cave Draw	High
3. Parking lot run-off towards Bat Cave Draw from the two parking lots east and west of the VC	High
4. Run-off towards Bat Cave Draw from road between main road and lower parking lot	High
5. Water and fluids from leaks/spills infiltrate from service road near Park offices	High

Table 1. Contamination Source Areas
(from van der Heidje et al., 1997)

Other locations within the headquarters area (Figure 2) with lower relative vulnerabilities (moderate, low) related to surface run-off (in/behind VC; employee housing; main road



HQ AREA/Runoff
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Figure 2. Headquarters Area
Scale: 1" = 400'

between (a) service road to maintenance yard and (b) VC; service road near offices) are also examined for their contribution to the contamination problem.

Engineering Measures - Current engineering measures related to the storm water system are only for safe conveyance of rainfall run-off. There are few water quality devices related to storm water run-off installed in the park. Grassed swales provide some pollutant uptake but are too small to provide meaningful reductions. Some minor flooding in the headquarters area noted is related to blockages but the storm water drainage system is generally in good condition (see Appendix). A preliminary assessment of environmentally-sound methods for treating and/or diverting rainwater run-off from parking lots and roads in the vicinity of Carlsbad Cavern is needed. Also included are suggested prevention methods appropriate for comprehensive storm water management. To propose adequate treatment alternatives it is necessary to examine and identify potential surface contamination threats and evaluate specific measures to reduce those threats.

The following engineering measures are proposed to mitigate the potential contamination problems:

1. Tilting the parking lots near the VC so that rainwater runs south off the escarpment
2. Providing drainage of the Maintenance complex to the north vs. other options
3. Treatment of rainwater run-off for the lower "Bat Cave" parking lot as well as all the above mentioned areas.
4. Treatment of rainwater run-off towards Bat Cave Draw from road between main road and lower parking lot
5. Treatment of rainwater run-off from service road near Park offices

This report evaluates the effectiveness of each of these methods with respect to: (a) pollutant removal efficiencies, (b) disturbance to impacted areas, (c) associated benefits; and (d) construction, maintenance, and engineering costs.

Accident Mitigation Procedures - Current accident mitigation procedures related to spills include an array of response methods. A spill kit containing containment barriers is located in the automotive shop to deal with small spills in the immediate shop and yard area. In the event of a spill in a paved area, sand is applied and removed by hand or by mechanical sweeper. In the event of a spill on soil, the contaminated soil is removed by hand or tractor where applicable. Park maintenance staff are actively pursuing training related to hazardous materials and spill response.

Park staff performs daily litter pickup in the parking areas (paving, grassed areas and receptacles). The Park has adequate facilities for recycling or disposal of trash and hazardous materials. The New Mexico Environmental Department regulates the use and disposal of hazardous materials at the park.(National Park Service personnel pers. comm.)

Existing accident mitigation procedures required examination for application and effectiveness as well as integration with any proposed storm water measures.

Management Policies - Other than litter control there are no management policies or guidelines related to storm water run-off or pollution in the park. Most actions related to known sources of pollution are dealt with on an as-needed basis. Comprehensive management policies are needed to reduce the level of pollution contamination in specific areas as well as the current risk of a major pollution incident. Integrated storm water management policies and guidelines are needed to reduce the potential for pollution and increase storm water pollution awareness.

In consideration of these purpose of CAVE as stated in its General Management Plan, it is recommended all methods proposed, short of contamination area closures, achieve to integrate the use of engineering measures, accident mitigation procedures and management policies collectively, to achieve the lowest level of pollutants in parking lot run-off with proven cost-effective solutions while minimizing significant disturbance to the surrounding park environment.

Visitation and Climate

The history of Carlsbad Caverns National Park is one of the visitor experience. It was the notoriety of Carlsbad Cavern which brought National Park status to the area in 1930, after having been first established as a National Monument in 1923. Since then the park has created an extensive infrastructure to support and manage an increasing number of visitors. Carlsbad Caverns National Park currently receives over 500,000 people per year arriving in passenger cars, recreational vehicles, busses and, occasionally, commercial vehicles including tractor trailer rigs. The peak visitation occurs during summer vacation months between June and August with a distinct peak in July. During these three summer months the park receives 47% of its total annual visitation.

The peak visitation months roughly correspond to the peak rainfall months. (Figure 3 and Table 2). This is important since storm water pollution increases with increased visitor and vehicle use. However increased storm activity during this period helps to wash away the pollutants before larger buildup occurs. During the three most abundant rainfall months (July-September), the park receives over 67-percent of its total annual rainfall. Carlsbad Caverns National Park receives 15.84 inches of rain on average annually. The park receives rain or occasional snowfall throughout the year. The minimum rainfall period occurs in March with a monthly average of 0.26 inches. The rainfall peaks have a bi-modal distribution, with the first rainfall peak occurring in July and the second in September. Storms are predominantly of short duration and usually of high intensity. Longer storms are predictably less frequent (Figure 4 and Table 3). Additionally, storms having a precipitation amount greater than 0.5-inches are mostly of shorter duration (Figure 4 and Table 4). The seasonal temperature variation varies between an average summer daily high and low of 90 and 60 °F in July with an average winter daily high and low of 54 and 36 °F in January (Figure 5 and Table 5). Temperature extremes include a

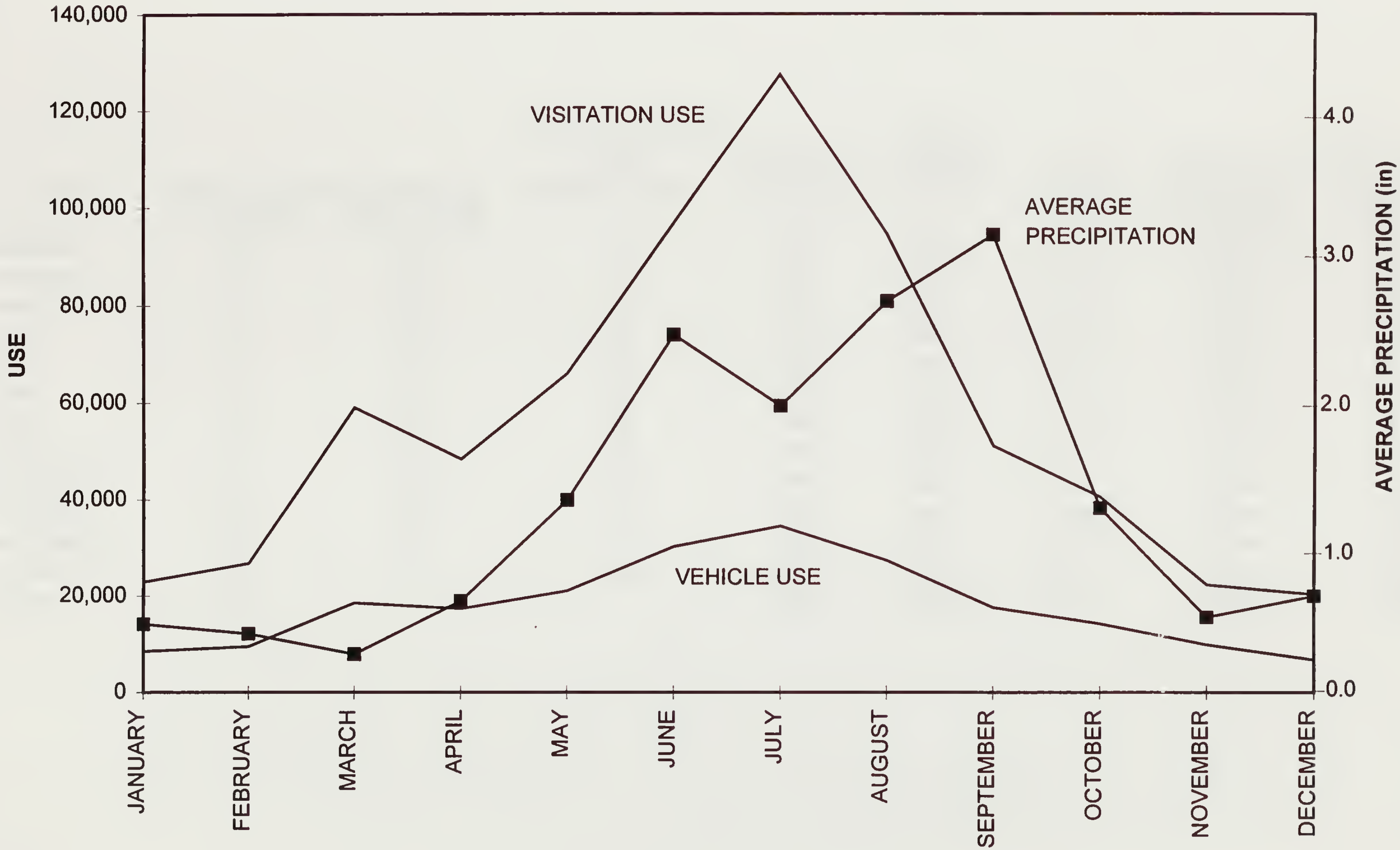

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Figure 3. Visitation and Vehicle Use Compared with Precipitation Amount for 19 year period of record at Carlsbad Caverns National Park (data courtesy of NPS)

MONTH	PRECIPITATION AMOUNT (IN)		DAYS OF RECORD WITH PRECIPITATION	DAYS OF RECORD	TOTAL POSSIBLE DAYS	% OF RECORD	VISITATION (88 90,96-97) AVERAGE	VEHICLE USE (88-90,96-97) AVERAGE
	AVG./MONTH	AVG./STORM						
JANUARY	0.47	0.09	99	532	589	0.90	22,900	8,404
FEBRUARY	0.40	0.10	74	482	537	0.90	26,753	9,435
MARCH	0.26	0.07	69	545	589	0.93	58,983	18,494
APRIL	0.63	0.21	59	514	580	0.89	48,353	17,310
MAY	1.33	0.23	117	559	620	0.90	65,958	21,017
JUNE	2.47	0.34	145	572	600	0.95	96,704	30,243
JULY	1.98	0.30	133	593	620	0.96	127,421	34,533
AUGUST	2.69	0.32	170	565	620	0.91	94,656	27,365
SEPTEMBER	3.15	0.40	156	556	600	0.93	51,090	17,549
OCTOBER	1.28	0.26	97	543	605	0.90	40,590	14,184
NOVEMBER	0.52	0.17	57	492	570	0.86	22,326	9,800
DECEMBER	0.67	0.14	88	517	589	0.88	20,317	6,717
TOTAL	**15.84**			6,470	7,119	**0.91**	**676,050**	**215,052**

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Table 2. Visitation and Vehicle Use Compared with Precipitation Amount for 19 year period of record at Carlsbad Caverns National Park (courtesy of NPS)

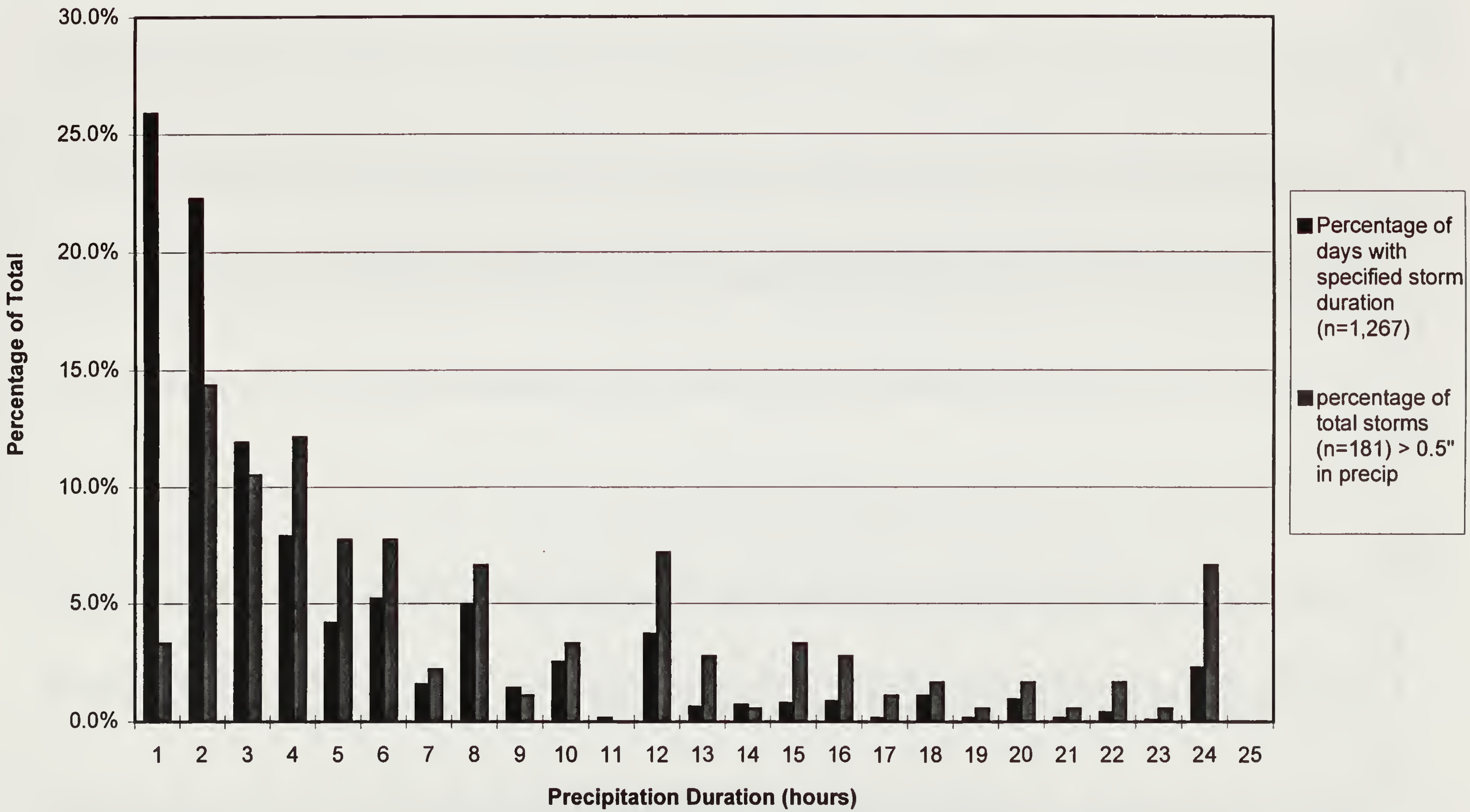

Figure 4. Frequency distribution based upon number of precipitation days (n=1,267) with specified duration for Bat Cave Draw, Carlsbad Caverns National Park, New Mexico (data courtesy of NPS)

Duration-%/stats.xls
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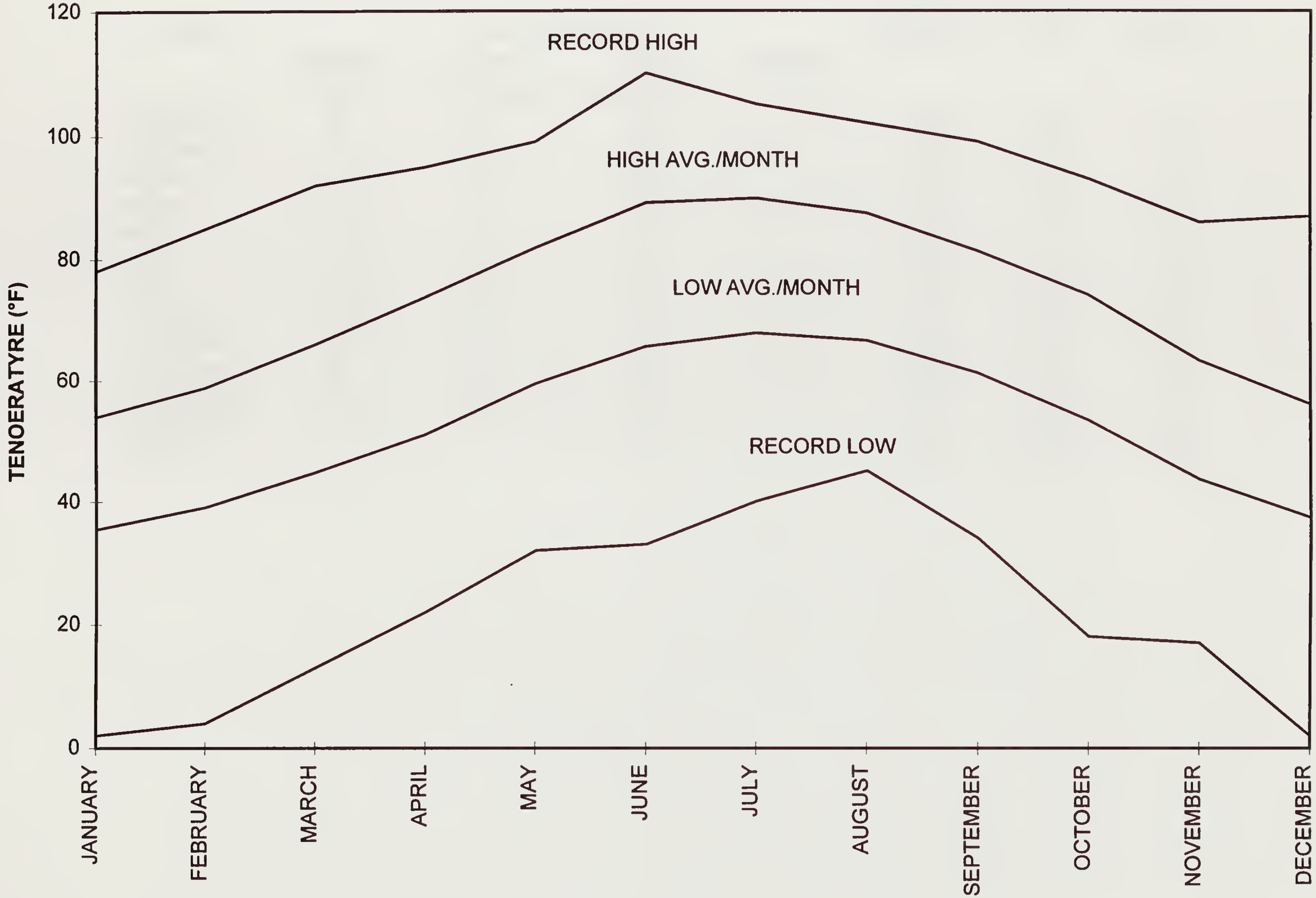
Specified storm precipitation (0.01 in.)	Number of days with specified storm precipitation	Percentage of days with specified storm precipitation	Accumulative percentage	Remaining percentage	Specified storm precipitation (0.01 in.)	Number of days with specified storm precipitation	Percentage of days with specified storm precipitation	Accumulative percentage	Remaining percentage
1	216	0.1685	16.9%	83.1%	73	2	0.00	90.8%	9.2%
2	93	0.0736	24.2%	75.8%	74	4	0.00	91.1%	8.9%
3	64	0.0506	29.3%	70.7%	75	1	0.00	91.2%	8.8%
4	50	0.0396	33.2%	66.8%	76	1	0.00	91.3%	8.7%
5	112	0.0886	42.1%	57.9%	78	1	0.00	91.4%	8.6%
6	40	0.0316	45.3%	54.7%	79	2	0.00	91.5%	8.5%
7	38	0.0301	48.3%	51.7%	80	4	0.00	91.9%	8.1%
8	29	0.0229	50.6%	49.4%	81	2	0.00	92.0%	8.0%
9	20	0.0158	52.1%	47.9%	82	3	0.00	92.2%	7.8%
10	30	0.0237	54.5%	45.5%	83	3	0.00	92.5%	7.5%
11	22	0.0174	56.3%	43.8%	85	6	0.00	93.0%	7.0%
12	23	0.0182	58.1%	41.9%	86	3	0.00	93.2%	6.8%
13	20	0.0158	59.7%	40.3%	87	2	0.00	93.4%	6.6%
14	16	0.0127	60.9%	39.1%	88	1	0.00	93.4%	6.6%
15	32	0.0253	63.4%	36.6%	90	6	0.00	93.9%	6.1%
16	8	0.0063	64.1%	35.9%	92	4	0.00	94.2%	5.8%
17	25	0.0198	66.1%	33.9%	94	4	0.00	94.5%	5.5%
18	11	0.0087	66.9%	33.1%	99	1	0.00	94.6%	5.4%
19	11	0.0087	67.8%	32.2%	100	3	0.00	94.9%	5.1%
20	19	0.0150	69.3%	30.7%	101	4	0.00	95.2%	4.8%
21	10	0.0079	70.1%	29.9%	102	1	0.00	95.3%	4.7%
22	10	0.0079	70.9%	29.1%	104	1	0.00	95.3%	4.7%
23	18	0.0142	72.3%	27.7%	105	1	0.00	95.4%	4.6%
24	9	0.0071	73.0%	27.0%	106	2	0.00	95.6%	4.4%
25	8	0.0063	73.7%	26.3%	107	1	0.00	95.6%	4.4%
26	6	0.0047	74.1%	25.9%	109	2	0.00	95.8%	4.2%
27	13	0.0103	75.2%	24.8%	110	2	0.00	96.0%	4.0%
28	4	0.0032	75.5%	24.5%	111	1	0.00	96.0%	4.0%
29	9	0.0071	76.2%	23.8%	112	1	0.00	96.1%	3.9%
30	9	0.0071	76.9%	23.1%	115	2	0.00	96.3%	3.7%
31	3	0.0024	77.1%	22.9%	117	1	0.00	96.4%	3.6%
32	7	0.0055	77.7%	22.3%	118	1	0.00	96.4%	3.6%
33	6	0.0047	78.2%	21.8%	119	1	0.00	96.5%	3.5%
34	4	0.0032	78.5%	21.5%	120	1	0.00	96.6%	3.4%
35	12	0.0095	79.4%	20.6%	122	2	0.00	96.8%	3.2%
36	6	0.0047	79.9%	20.1%	124	1	0.00	96.8%	3.2%
37	10	0.0079	80.7%	19.3%	125	1	0.00	96.9%	3.1%
38	6	0.0047	81.2%	18.8%	127	1	0.00	97.0%	3.0%
39	5	0.0040	81.6%	18.4%	128	2	0.00	97.2%	2.8%
40	6	0.0047	82.0%	18.0%	130	1	0.00	97.2%	2.8%
41	5	0.0040	82.4%	17.6%	133	1	0.00	97.3%	2.7%
42	6	0.0047	82.9%	17.1%	134	1	0.00	97.4%	2.6%
43	4	0.0032	83.2%	16.8%	135	1	0.00	97.5%	2.5%
44	4	0.0032	83.5%	16.5%	137	1	0.00	97.5%	2.5%
45	6	0.0047	84.0%	16.0%	140	1	0.00	97.6%	2.4%
46	4	0.0032	84.3%	15.7%	150	1	0.00	97.7%	2.3%
47	1	0.0008	84.4%	15.6%	153	1	0.00	97.8%	2.2%
48	2	0.0016	84.6%	15.4%	155	1	0.00	97.9%	2.1%
49	2	0.0016	84.7%	15.3%	159	1	0.00	97.9%	2.1%
50	12	0.0095	85.7%	14.3%	160	2	0.00	98.1%	1.9%
51	6	0.0047	86.2%	13.8%	165	1	0.00	98.2%	1.8%
52	4	0.0032	86.5%	13.5%	166	2	0.00	98.3%	1.7%
53	4	0.0032	86.8%	13.2%	168	1	0.00	98.4%	1.6%
54	4	0.0032	87.1%	12.9%	170	1	0.00	98.5%	1.5%
55	2	0.0016	87.3%	12.7%	171	1	0.00	98.6%	1.4%
56	5	0.0040	87.7%	12.3%	172	2	0.00	98.7%	1.3%
57	3	0.0024	87.9%	12.1%	173	1	0.00	98.8%	1.2%
58	4	0.0032	88.2%	11.8%	175	1	0.00	98.9%	1.1%
59	3	0.0024	88.4%	11.6%	176	1	0.00	99.0%	1.0%
60	6	0.0047	88.9%	11.1%	181	2	0.00	99.1%	0.9%
61	1	0.0008	89.0%	11.0%	182	1	0.00	99.2%	0.8%
63	2	0.0016	89.2%	10.8%	196	1	0.00	99.3%	0.7%
64	1	0.0008	89.2%	10.8%	206	1	0.00	99.4%	0.6%
65	4	0.0032	89.6%	10.4%	210	1	0.00	99.4%	0.6%
66	2	0.0016	89.7%	10.3%	216	1	0.00	99.5%	0.5%
67	2	0.0016	89.9%	10.1%	283	1	0.00	99.6%	0.4%
68	4	0.0032	90.2%	9.8%	285	1	0.00	99.7%	0.3%
69	1	0.0008	90.3%	9.7%	302	1	0.00	99.8%	0.2%
70	3	0.0024	90.5%	9.5%	352	1	0.00	99.8%	0.2%
71	1	0.0008	90.6%	9.4%	525	1	0.00	99.9%	0.1%
72	1	0.0008	90.7%	9.3%	841	1	0.00	100.0%	0.0%

Table 3. Frequency distribution based upon number of precipitation days (n=1,267) with specified precipitation for Bat Cave Draw, Carlsbad Caverns National Park, New Mexico (data courtesy of NPS)

P-%/stats.xls
5/29/98

Specified storm duration (hrs)	Number of days with specified storm duration	Percentage of days with specified storm duration (n=1,267)	Accumulative percentage	Remaining percentage	number of storms greater than 0.5" in total precip.	percentage of total storms (n=181) > 0.5" in precip
1	328	25.9%	25.9%	74.1%	6	3.3%
2	282	22.3%	48.1%	51.9%	26	14.4%
3	151	11.9%	60.1%	39.9%	19	10.5%
4	100	7.9%	68.0%	32.0%	22	12.2%
5	53	4.2%	72.1%	27.9%	14	7.7%
6	66	5.2%	77.3%	22.7%	14	7.7%
7	20	1.6%	78.9%	21.1%	4	2.2%
8	63	5.0%	83.9%	16.1%	12	6.6%
9	18	1.4%	85.3%	14.7%	2	1.1%
10	32	2.5%	87.8%	12.2%	6	3.3%
11	2	0.2%	88.0%	12.0%	0	0.0%
12	47	3.7%	91.7%	8.3%	13	7.2%
13	8	0.6%	92.3%	7.7%	5	2.8%
14	9	0.7%	93.1%	6.9%	1	0.6%
15	10	0.8%	93.8%	6.2%	6	3.3%
16	11	0.9%	94.7%	5.3%	5	2.8%
17	2	0.2%	94.9%	5.1%	2	1.1%
18	14	1.1%	96.0%	4.0%	3	1.7%
19	2	0.2%	96.1%	3.9%	1	0.6%
20	12	0.9%	97.1%	2.9%	3	1.7%
21	2	0.2%	97.2%	2.8%	1	0.6%
22	5	0.4%	97.6%	2.4%	3	1.7%
23	1	0.1%	97.7%	2.3%	1	0.6%
24	29	2.3%	100.0%	0.0%	12	6.6%
TOTAL number of storm days	1,267	100.0%			181	

Table 4. Frequency distribution based upon number of precipitation days (n=181) with specified duration over 0.5 inches precipitation for Bat Cave Draw, Carlsbad Caverns National Park, New Mexico (data courtesy of NPS)



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5/29/98

Figure 5. Temperature for 19 year period of record at Carlsbad Caverns National Park (courtesy of NPS)

MONTH	RECORD HIGH	TEMPERATURE (°F) HIGH AVG./MONTH	LOW AVG./MONTH	RECORD LOW	DAYS OF RECORD	TOTAL POSSIBLE DAYS	% OF RECORD
JANUARY	78	54	36	2	532	589	0.90
FEBRUARY	85	59	39	4	482	537	0.90
MARCH	92	66	45	13	545	589	0.93
APRIL	95	74	51	22	514	580	0.89
MAY	99	82	59	32	559	620	0.90
JUNE	110	89	66	33	572	600	0.95
JULY	105	90	68	40	593	620	0.96
AUGUST	102	87	67	45	565	620	0.91
SEPTEMBER	99	81	61	34	556	600	0.93
OCTOBER	93	74	53	18	543	605	0.90
NOVEMBER	86	63	44	17	492	570	0.86
DECEMBER	87	56	37	2	517	589	0.88
TOTAL					**6470**	**7119**	**0.91**

M-E/stats.xls
5/29/98

Table 5. Temperature for 19 year period of record at Carlsbad Caverns National Park (courtesy of NPS)

high of 110 °F in June and a low of 2°F in both January and December. The region has incurred periods of drought as well as higher than average annual rainfall. The park's climate is infrequently subject to variations in the monthly and annual rainfall amounts sometimes creating unusually wet or dry periods.

Previous Work

Van der Heidje et al. (1997) has provided the most investigative work relating cave resource vulnerability to surface storm water run-off at Carlsbad Cavern. Their study discussed the wide range of potential relationships between surface facility activities and contamination constituents found in cave drips and pools. Brooke (1996) focused on characterizing the hydrochemistry of both surface water sources and cave resource waters. Many contaminants found in surface storm water run-off are found in cave drips and pools. Brooke hypothesized that the source of many of the contaminants (zinc, aluminum, TOC and nitrates) were directly related to surface and subsurface anthropomorphic activities. This study formed much of the basis for inclusion in the work by van der Heidje et al.

The Final General Management Plan/Environmental Impact Statement, Carlsbad Caverns National Park, New Mexico (1996) presents the alternatives to be considered for addressing issues and achieving management objectives over the next 10 to 15 years. Of the three alternatives proposed, both Alternatives 2 and 3 examine some of the potential contamination sources and provide an analysis to include suggested treatment methods, from technological measures to relocating most surface facilities off of the escarpment.

THREATS

"The potential of contaminants to leach into the caves and the underlying water table depends on many factors, including the composition, structure, texture and permeability of soils and rock, the topography of the local terrain (specifically slope), the amount of precipitation available for infiltration in the subsurface and subsequent percolation through the unsaturated zone, and type and control of land use." (van der Heijde et al, 1997). Considering the above list of participating factors for potential cave contamination, the only factor which is modifiable--short of modifying the composition, structure, texture and permeability of rocks and soils--is the *type and control of land use*.

Type of Land Use

Aside from most of the park which is designated as a natural zone, the park development zone is designated in the vicinity of Carlsbad Cavern. This area includes the Caverns Historic District (Figure 2) encompassing: historic parking (190 spaces); park headquarters; law enforcement offices; historic triplexes; storage, plumbing shop, and fire cache; paint and flammable storage; maintenance garage; maintenance office and warehouse; carpenter and automotive shops, fire truck storage; dormitories, residence, non-NPS cave research temporary housing; a public restroom; Cavern entrance, amphitheater; and connecting paved service roads, trails and walkways (NPS, 1996).

Immediately adjacent the Historic District lies the remainder of the development zone to include: two parking lots (315 and 460 spaces, respectively); visitor center (including a full-service restaurant and gift shop); interpretive offices and workspace (temporary building); mid-1960's apartments; paved entrance and service roads; and paved trails and walkways.

Control of Land Use

The control of the land use in the headquarters area is generally restricted to: residents, guests and occasionally maintenance employees in the staff housing areas; and employees in the maintenance yard and staff offices during normal working hours. The visitor center is open to the public from 8:00 am-5:30 pm during winter hours and 7:00 am-7:30 pm during summer hours. The remainder of the park headquarters area is generally unrestricted however most use occurs between the hours of visitor center operation.

The area most vulnerable to contamination is Bat Cave Draw primarily from the historic parking lot. It receives visitor vehicles mainly during the summer bat flight programs running from as early as 5:00 pm to as late as 9:00 pm. As many as 1,000 visitors are present during mid-to late-summer programs. The parking lot also serves to provide overflow parking capacity during busy non-winter holidays (Memorial, Independence and Labor Day holidays).

Since the cave was first made a national monument in 1923, the park has created an extensive above ground infrastructure, unfortunately lying directly over perhaps the most important cave resource in the park. The visitor, operation and maintenance, and resident activities associated with the extensive and varied type and control of land use are identified as the sources of the contamination as well as the increased risk of a major contamination incident to protected cave resources. (van der Heidje. 1997)

Visitor Activities

Since the park started recording visitation statistics in 1924, a total of 35,719,932 visitors carried by an estimated 14,287,973 vehicles have entered the park to date, the vast majority to the parking lots during their visit to the main cave and natural entrance in the headquarters area (Tables 6, 7). In 1997 the park's official year end visitation was 540,797 visitors carried by an estimated 228,540 vehicles (Dec. figures outstanding). Considering the recent historical trend from 1950, the number of visitors tends to rise roughly proportionally to the nation's population (0.30-0.35%). The corresponding number of vehicles also tends to rise with visitation. This trend can be expected to continue.

The chronic threats related to visitor use in the headquarters area exist in the form of visitor vehicle pollution and litter. The contamination threat from vehicles is perhaps the greatest when considering the types of pollution involved.

Brooke (1996) examined three chemical compounds which appeared in anomolous concentrations in the cave waters. He found concentrations of zinc, aluminum and Total Organic Carbon (TOC), all which can be associated with automotive vehicle use. Zinc is a component of automobile tires that leaches from the tires and persists through the breakdown and wear of tires. This aspect of vehicle use is of concern because the storm water from the parking lots contains high concentrations of zinc (Brooke, 1997) and this may be a possible source in the run-off as well as in the caves.

Surface run-off samples were extremely high in aluminum and run-off may be a source for the aluminum in the cavern waters (Brooke, 1996). Evaporators in nearly all automobile air-conditioner systems are made of chromate-plated aluminum (Looby and Kirsch, 1992) and their condensation drains are piped directly to the exterior of the vehicle. Greater use of aluminum in automobiles may also account for some of the elevated levels found. Lightweight materials, such as aluminum, play a large part in the assembly of an automobile. Aluminum flake pigments are popular in some automotive finishes in powder coatings (EPA, 1994). Some other potential sources may be aluminum trim, anodized exhaust parts (coated with aluminum oxide), and aluminum wheels for automobiles.

YEAR	VISITORS OF RECORD	VEHICLE USE OF RECORD	VEHICLE USE MULTIPLIER	VEHICLE USE PROJECTED	U S POPULATION	VISITORS AS % OF POP.	NOTES
1924	1,878		2.50	750			visitors of record compiled yearly 1/1/24
1925	2,453		2.50	981			
1926	11,741		2.50	4,696			
1927	29,034		2.50	11,614			
1928	46,222		2.50	18,489			
1929	78,649		2.50	31,460			
1930	91,462		2.50	36,585	123,202,624	0.07%	
1931	80,144		2.50	32,058			
1932	61,159		2.50	24,464			
1933	56,002		2.50	22,401			
1934	92,397		2.50	36,959			
1935	116,457		2.50	46,583			
1936	155,357		2.50	62,143			
1937	207,038		2.50	82,815			
1938	200,617		2.50	80,247			
1939	218,382		2.50	87,353			
1940	241,590		2.50	96,638	132,164,569	0.18%	
1941	285,418		2.50	114,187			
1942	124,809		2.50	49,924			
1943	89,128		2.50	35,651			
1944	122,466		2.50	48,988			
1945	193,237		2.50	77,295			
1946	380,465		2.50	152,188			
1947	405,266		2.50	162,106			
1948	435,481		2.50	174,192			
1949	431,187		2.50	172,475			visitors of record compiled monthly 1/1/49
1950	467,283		2.50	188,913	151,325,798	0.31%	
1951	493,618		2.50	197,447			
1952	531,831		2.50	212,732			
1953	510,318		2.50	204,127			
1954	444,342		2.50	177,737			
1955	466,184		2.50	186,474			
1956	454,960		2.50	181,984			
1957	451,078		2.50	180,430			
1958	435,194		2.50	174,078			
1959	483,928		2.50	193,571			
1960	537,005		2.50	214,802	179,323,175	0.30%	
1961	590,035		2.50	238,014			
1962	555,960		2.50	222,384			
1963	586,580		2.50	234,632			
1964	587,957		2.50	235,183			
1965	590,979		2.50	236,392			
1966	604,760		2.50	241,904			
1967	630,770		2.50	252,308			
1968	668,401		2.50	267,360			
1969	672,934		2.50	269,174			
1970	712,741		2.50	285,096	203,211,926	0.35%	
1971	791,634		2.50	316,654			
1972	856,086		2.50	342,434			
1973	840,093		2.50	336,037			
1974	672,442		2.50	268,977			vehicle use of record multipliers appear 1/1/74
1975	789,957		2.50	315,983			
1976	876,500		2.50	350,600			
1977	862,784		2.50	345,114			
1978	867,276		2.50	346,910			
1979	721,647		2.50	288,659			
1980	672,960		2.50	269,184	226,545,805	0.30%	
1981	771,766		2.50	308,706			
1982	781,963		2.50	312,785			
1983	712,247		2.50	284,899			
1984	712,989		2.50	285,196			
1985	732,482		2.50	292,993			
1986	752,552		2.50	301,021			
1987	781,300		2.50	312,520			
1988	786,135	211,738	3.71	211,738			
1989	792,378	214,060	3.70	214,060			
1990	747,016	217,746	3.43	217,748	248,709,873	0.30%	
1991	679,450		2.50	271,780			vehicle use of record multipliers changed 1/1/9
1992	688,742		2.50	275,497			
1993	687,161		2.50	274,864			
1994	617,087	180,848	3.41	180,848			vehicle use of record multipliers eliminated 1/1/
1995	792,378	220,969	3.59	220,969			
1996	557,217	223,624	2.49	223,624			
1997	540,797	208,090	2.60	228,540			Dec. records not included
TOTALS	35,719,932			14,287,973			vehicle use multiplier = 2.50

VISITS/stats.xls
5/29/98

Table 6. Historical visitation and vehicle use at Carlsbad Caverns Ntional Park
(courtesy of NPS)

Year	Month	ACTUAL VEHICLE MONTHLY DATA	MPU REPORT VISITS	MPU REPORT BUSSES	NOTES
1988	JAN	6,968	23,401	28	YEARLY VEHICLE USE MULTIPLIER = 3.71
	FEB	8,202	27,399	42	
	MAR	16,349	55,585	84	
	APR	15,334	53,018	67	
	MAY	20,726	74,685	122	
	JUN	28,882	109,480	74	
	JUL	36,055	152,161	55	
	AUG	30,536	120,137	32	
	SEP	17,600	65,078	48	
	OCT	14,119	49,674	37	
	NOV	8,981	29,304	0	
	DEC	7,986	26,215	3	
		211,738	**786,135**	**592**	

Year	Month	ACTUAL VEHICLE MONTHLY DATA	MPU REPORT VISITS	MPU REPORT BUSSES	
1989	JAN	8,330	27,408	16	YEARLY VEHICLE USE MULTIPLIER = 3.70
	FEB	8,548	28,866	38	
	MAR	18,300	63,734	44	
	APR	15,199	50,214	36	
	MAY	20,134	79,294	34	
	JUN	30,105	113,245	37	
	JUL	36,741	147,887	27	
	AUG	25,343	108,612	15	
	SEP	18,376	82,534	56	
	OCT	14,897	49,389	57	
	NOV	9,859	33,012	20	
	DEC	8,228	28,183	19	
		214,060	**792,378**	**399**	

Year	Month	ACTUAL VEHICLE MONTHLY DATA	MPU REPORT VISITS	MPU REPORT BUSSES	
1990	JAN	8,354	28,949	12	YEARLY VEHICLE USE MULTIPLIER = 3.43
	FEB	9,917	33,125	29	
	MAR	17,575	57,764	41	
	APR	17,347	57,079	27	
	MAY	20,187	69,620	50	
	JUN	29,090	112,238	61	
	JUL	36,081	138,906	54	
	AUG	28,969	110,426	52	
	SEP	17,839	57,045	54	
	OCT	14,671	38,123	46	
	NOV	9,567	25,291	15	
	DEC	8,149	20,450	1	
		217,746	**747,016**	**442**	

Year	Month	ACTUAL VEHICLE MONTHLY DATA	MPU REPORT VISITS	MPU REPORT BUSSES	
1996	JAN	8,930	18,131	2	YEARLY VEHICLE USE MULTIPLIER = 2.49
	FEB	10,682	24,697	15	
	MAR	19,715	58,601	15	
	APR	23,867	45,224	32	vehicle monthly data estimated, counter zeroed on 5/22
	MAY	22,219	53,376	74	
	JUN	37,359	75,024	37	
	JUL	28,199	99,269	18	
	AUG	26,070	63,686	5	
	SEP	17,042	38,167	35	
	OCT	12,103	32,281	47	
	NOV	10,215	24,022	11	
	DEC	9,223	26,739	12	
		223,624	**557,217**	**301**	

Year	Month	ACTUAL VEHICLE MONTHLY DATA	MPU REPORT VISITS	MPU REPORT BUSSES	
1997	JAN	9,439	18,612	1	YEARLY VEHICLE USE MULTIPLIER = 2.37
	FEB	9,825	19,677	21	
	MAR	20,529	61,231	14	
	APR	14,804	36,230	24	
	MAY	21,819	52,817	77	
	JUN	25,780	73,534	28	
	JUL	37,588	98,880	27	
	AUG	25,906	70,418	22	
	SEP	16,889	32,626	46	
	OCT	15,131	33,481	49	
	NOV	10,380	23,299	4	
	DEC	20,450	19,992		
		228,540	**540,797**	**313**	

VISITS(88-90,96-97)/stats.xls
5/29/98

Table 7. Visitation and Vehicle Use at Carlsbad Caverns National Park for 1988-90 and 1996-97
(courtesy of NPS)

MPU - Monthly Public Use

Brooke (1997) also found high concentrations of TOC in the surface run-off that may be associated with asphalt, motor oils, solvents and detergents. Petroleum hydrocarbons are derived from oil products, and the source of most such pollutants found in typical urban run-off is vehicles, primarily from auto and truck engines that drip oil.

Oil and grease contain a wide variety of hydrocarbon compounds. Some polynuclear aromatic hydrocarbons (PAHs) are known to be toxic to aquatic life at low concentrations. Hydrocarbons have a high affinity for sediment; they collect in bottom sediments where they may persist for long periods of time and result in adverse impacts on water communities. Lakes are especially prone to this phenomenon. Other liquids and materials (with their respective pollutants) from automobiles which may be a contaminate in parking lot run-off include: antifreeze (ethylene glycol); transmission fluids (hydrocarbons, mineral oils); brake fluids (glycol esters, heavy metals) and linings (asbestos, metals); fuel (hydrocarbons e.g. benzene, heavy metals); and batteries (sulfuric acid, lead). The fate of these hazardous pollutants, once released on the pavement surface, is unknown.

Visitor Littering - Deliberate and accidental discharge of litter is plainly evident in the storm drain outfall areas. Park maintenance performs thorough daily litter collection yet despite their efforts, litter accumulates at the outfall areas. The most common articles observed were: cigarette butts; candy and food wrappers; and soft drink containers (plastic, paper and aluminum). Although not a source of cave contamination, the problem is chronic and can continue hundreds of yard beyond the outfall. The existence of deliberate or accidental waste dumping by visitors into existing storm inlets is unknown. Recreational vehicles, including large motor homes which have service drains for wastewater, are permitted in both Bat Cave Draw parking lot and Parking Lot No. 2.

Potentially acute threats include a major spill caused by a vehicle fuel tank rupture resulting from an accident, an accidental sewage release from a recreational vehicle, or even illegal hazardous dumping. Some camper trailers and RV's have externally mounted fuel tanks which increase the likelihood of a spill/fire in the event of an accident. One important restriction for visitors with respect to vehicle use in the Park is stated in the Code of Federal Regulations:

> "The use of government roads within park areas by commercial vehicles, when such use is in no way connected with the operation of the park area, is prohibited, except that in emergencies, the Superintendent my grant permission to use park roads" (36 CFR 5.6 (B)).

However no sign prohibiting potentially dangerous commercial vehicles such as semi-tractor rigs and fuel carriers exists at the park entrance (National Park Service personnel pers. comm.). Tractor trailer rigs can carry between 100-250 gallons of diesel fuel on each of two externally mounted side tanks (New Mexico Department of Transportation, pers. comm.). While most drivers prefer to drop their trailers for convenience prior to

entering the park, they bring with them a potentially substantial amount of fuel into identified vulnerable areas.

Operation and Maintenance Activities

Fuel Refilling - Perhaps the most significant acute risk to the caves is a fuel spill into the headquarters most vulnerable area -- Bat Cave Draw. Diesel, gasoline and propane tanker trucks are required to enter the maintenance yard to resupply the vehicle filling station's two 2000-gallon underground fuel storage tanks and the two 1000-gallon propane tanks. Diesel tanker trucks are also required to enter the visitor service parking area to resupply the 6000-gallon underground fuel storage tank for the VC boiler and emergency generator set. Both of these refueling areas are tributary to and situated less than 400 yards from the cave's natural entrance in Bat Cave Draw. An accidental spill from tank refilling operations could close the entrance and perhaps the entire cave in addition to causing permanent damage to the protected cave resource. A third propane fueling operation involves entering directly behind the mid-1960's apartments to resupply the above-ground 3000-gallon propane tank used by the residences and apartments. A fuel spill accident in any area tributary to the known cave could have similar impacts. Unknown cave systems in the headquarters area are at risk as well.

Maintenance Yard - The maintenance yard is a concern to park staff for three reasons: 1) the use and storage of hazardous and non-hazardous materials; 2) a major portion of its run-off is tributary to Bat Cave Draw, a focused infiltration zone; and 3) the yard lies in a diffuse infiltration zone directly above the Guadalupe Room.

Washing of maintenance vehicles, equipment and other staff vehicles is normally performed in an area with a drain to the septic sewer system and does not become a component of the surface run-off. However any vehicles that are washed and all that are stored in the maintenance yard are sources for contamination as a result of a storm event.

The paint shop stores hazardous materials (paints, thinners, solvents, cleaners, etc.) which are mainly used in the yard area. The adjacent maintenance garage, which has no floor drain and is sloped to the open paved yard, stores flammable liquids, an oil recycling center, gas powered lawn equipment (mowers, trimmers, tillers) , 55-gallon drums of used oil and antifreeze, an off-road vehicle, a fire truck, forklift and various metal building materials. Although not open to rainfall, spills and drips associated with these materials and equipment can migrate out to open pavement areas which present a risk to the downstream areas.

Behind the maintenance office is a gravel surface open storage area with the following items stored directly on the ground and open to rainfall: salvage drums; 55-gallon storage drums; electrical transformers (potential PCBs); an air-conditioning unit; a recycling center (glass, paper, cardboard etc.); disposable used flashlight batteries (in both a salvage drum and an open metal trash can); fence posts and fencing mesh; copper steel

pipe, scrap metal, water main fittings and pipe; and miscellaneous metals; all stored directly on the ground and open to rainfall. Corrosion is evident on most of the metal materials. Barrels, drums, dumpsters, and other packaging containing industrial wastes are inherently prone to leak and therefore could be a source of exposure. A leak from any one of the containers or devices could impact cave resources, the realization of which would only occur after the contamination has had time to infiltrate to known cave areas.

Many pathways exist for surface run-off to reach pervious subsurface areas immediately near the maintenance yard area. The absence of paving, curb and gutter in the parking lots surrounding the maintenance yard permits run-off to directly infiltrate to the underlying soil structure and subsequently to protected cave resources.

VC - The operations of the Cavern Supply restaurant and supporting park maintenance contributes to pollution through inadequate trash disposal practices. Food waste deposited in VC trash cans contains liquids consisting of oils, grease, soft drinks, etc. The portable trash compactor is used daily to compact this trash. Previously the decant from the compactor drained onto the pavement surface where it washed directly into Bat Cave Draw with each storm event. Subsequently, a catch bar was installed to reduce the loss of decant and a sand trap was also placed at the end of the compactor to catch any remaining drips from the unit. Although the pollution problem is reduced, storm events wash the sand trap removing soluble pollutants into the storm water run-off. Additionally, the commercial-size trash truck used to service the restaurant leaks a similar decant constantly and is regularly parked in Parking Lot No. 2 when not in use. It has created a noticeable oil/grease stain over the storm water inlet (15) where it is parked. This inlet is directly tributary to Bat Cave Draw.

Salting trails to permit safe travel during sub-freezing temperatures is performed only when safety conditions warrant application, normally in the morning prior to staff and visitor use. Although an environmental de-icer is used, concentrated solutions can negatively impact surface vegetation and present unwanted chlorides into receiving waters. The trails which primarily receive de-icer are those between the VC and the natural entrance, again, tributary to the area identified as most vulnerable--Bat Cave Draw.

Trail washing is normally performed once a year in November and December. This operation introduces potable water into the watershed during the normally dry period in the park. Additionally, waterline hydrant flushing generally occurs when the plumbing staff tests water pipes to remove air after line maintenance and once or twice a year to refresh the dead-end portions and reduce buildup of precipitate in the water mains (National Park Service personnel pers. comm.). This introduces a large surge of water to areas in the headquarters area where hydrants exist. These operations are of concern because the water from the potable water system contains high concentrations of zinc. The areas with high zinc concentrations within the caves are located directly below surface structures (van der Heidje), 1997).

Management-ignited prescribed fires in the headquarters area may require the use of retardant foam for suppression or pre-suppression activities. This foam has properties similar to fertilizer and can impact cave ecology if present in sufficient amounts. As an approved pest management tool, retardant foam has also been sprayed to eradicate worm pests on trees in Bat Cave Draw (National Park Service personnel pers. comm.).

Pesticides (with exception noted above) and chemical fertilizers are not used (officially) in the headquarters area. The only herbicide used is RoundUp™, primarily in the parking lot areas. It is mixed at 2 oz. per gallon and is either hand spray-pump or backpack pump delivered. The herbicide is also used in the mescal pits near the natural entrance at reduced concentrations. While not a significant source of pollution, this residue can become a component of parking lot run-off if used just prior to a storm event.

Activities related to the maintenance and operation of all the buildings in the headquarters area may be a contributing source of pollution. Construction materials which erode due to weathering and corrosion include: metals from flashing and shingles, gutters and downspouts, galvanized pipes and metal plating, paint and wood. Metal platings include cadmium, zinc, chromium, and others.

Utility repair in areas can introduce construction debris and increased sediment loads to outfall and downstream areas. Resurfacing operations (repaving, chip and seal, sealing, repair) bring asphalt tars and oils which can leach into subsurface soils. Pavement curing and initial erosion make these volatile pollutants, as well as sediments, available to the surface of the pavement to be carried off by subsequent storm run-off. Ancillary pavement operations (curb painting, pavement striping) also generate residues which break down and erode to receiving waters.

Resident Activities

Resident Automobile Use and Parking - This aspect of vehicle use in the park is significant for three reasons: (1) the amount of use is relatively constant over a 24 hour period, (2) repair and maintenance of resident vehicles occurs in the residence areas, and (3) all resident areas are entirely tributary to Bat Cave Draw and lie in a diffuse infiltration zone directly above the Guadalupe Room.

Considering a visitor auto is parked in the lot for approximately 4 hours on average per day, a resident vehicle may be assumed to be parked up to 24 hours per day, a multiplier of 6. Assuming a conservative estimate of 2 hours per day per vehicle for off-park resident vehicle use, the multiplier becomes 5.5. Given the average number of 25 resident cars of which a maximum of 12 may be in carports (hence excluded from rainwater run-off), this equates to 13 cars producing an additional effective visitation of nearly 72 visitor cars (13*5.5) per day or 26,026 visitor cars per year! This comprises almost 14% of the park's current yearly vehicle use. While the resident vehicles are not

started or operated daily on the paved parking surface, vehicle fluid drips and corrosion deposition does occur nearly constant.

Resident Vehicle Maintenance - Standard vehicle maintenance procedures require frequent fluid replacement at regular intervals. Engine oil and radiator coolant flushing are recommended at least annually or more frequently with increased mileage. For residents who perform their own maintenance operations in the staff housing area, the pavement surface and downstream receiving bodies (caves) are especially vulnerable to improper disposal or spillage of engine oil, brake, radiator and other hazardous vehicle fluids. Resident vehicle washings remove accumulated dirt and oils as well as paint and corrosion from the exterior contributing additional pollutants. Engine cleaning operations using off-the-shelf spray-on spray-off industrial cleaners can remove a host of engine oils, plating metals and battery residues in concentrated form.

General vehicle repair to include brake lining and hydraulic component replacement, are especially polluting due to the nature of repair (no containment of brake lining residues, difficult component access impedes spill containment). Other repairs commonly performed can introduce numerous types of pollutants onto the pavement surface which are eventually carried by storm water run-off to vulnerable areas during storm events. Additionally the *lack* of proper vehicle repair and maintenance can contribute to significant fluid leaks exacerbating the pollution problem.

Lawn and Garden Care - Pesticide, herbicide and fertilizer use by residents is unknown. However any watering activity for either lawn or garden use in the residential area can potentially carry any excess applied materials along with potable water to infiltrate into the subsurface. The resident areas are in diffuse and focused infiltration zones permitting this potable water (zinc source) and potentially hazardous soluble materials to enter into the subsurface soils.

The potential for a major spill puts the cave at serious risk to permanent and potentially catastrophic damage (van der Heidje, 1997). The activities which potentially contribute to the contamination problem are summarized in Table 8. Any one of these activities produces some level of contamination and some may seem negligible when examined individually, but when considered cumulatively they represent significant and dangerous threats to the protected caves. Table 8 is not all-inclusive. Additional activities not identified within the time permitted need examination for other potential pollutant types and sources. A number of metals detected in both storm water and cave drips and pools (Brooke, 1996) have not had their pollutant sources identified. Many metals on the Environmental Protection Agency's list of toxic metals were not tested for in either the surface or the cave waters. Heavy metals are of concern because of toxic effects on aquatic life and the potential for ground-water contamination. High metal concentrations may impact uses of the affected waterbody, namely the cave lakes and pools as well as the ground water.

ACTIVITY	POLLUTANT TYPE	COMPOSITION
Vehicle use (visitor, O&M and resident)	fuel (gasoline, diesel or propane), engine oil	hydrocarbons e.g. benzene, heavy metals
"	antifreeze	ethylene glycol
"	brake fluid	glycol esters, heavy metals
"	transmission and power steering fluid	hydrocarbons, mineral oils
"	brake linings	asbestos, heavy metals
"	batteries	sulfuric acid, lead
"	a/c condensers, exhaust sys.	aluminum, and its oxides
"	tires	zinc, hydrocarbons
Littering	cigarette filter, candy wrapper, drink container	paper, plastic, metals
Washing of vehicles and equipment	potable water, surfactants, plating metals, paint, wax	zinc, heavy metals, total suspended solids (TSS)
Paint shop	paints, thinners, solvents, cleaners, etc.	aliphatic hydrocarbons, ethylene, resins, esters, etc.
Electrical transformers storage	transformer oil	polybichlorinated bifenals (PCBs)
Air conditioner storage	refrigerant oils	metals
Used hand-held battery storage	metals, acids	nickel, copper, cadmium, lithium
Building materials storage	metals (pipes, valves, fenceposts and mesh, structural steel, etc.)	iron, copper, chrome, tin, zinc, nickel
Park trash and restaurant operations	trash compactor and commercial trash truck	oils, grease, food waste decant, TSS
Salting of trails for safety	environmental de-icer	chlorides
Washing of trails	potable water	zinc, , TSS
Fire suppression, pre-suppression, pest management	potable water, retardant	zinc, 2-1-0/butyl carbitol, ether sulfate, glycol ether
Weed control	RoundUp™ herbicide	glyphosate, N-(phosphono-methyl) glycine
Utility repair	construction debris, sediments	metals, TSS
Pavement repair	asphalt tars/oils, sediments	hydrocarbons, TSS
Lawn and garden care	potable water, pesticides, fertilizers and herbicides	chlorinated hydrocarbons, zinc, organo-phosphate, etc.

Table 8. Pollutant Types and Sources

(source: most from EHMI, 1990)

POTENTIAL METHODS

The number of threats which contribute to the contamination of surface facilities and subsurface water systems above and in Carlsbad Cavern are numerous and widely varied. Few single approaches address the contamination problems comprehensively. Other than contamination area closure by virtually eliminating the sources of pollution, suggested engineering measures, accident mitigation procedures, and management policies can reduce the level of pollution as well as the perceived risk.

The main focus of this study was to provide a preliminary assessment of environmentally-sound methods for treating and/or diverting rainwater run-off from parking lots and roads in the vicinity of Carlsbad Cavern. The following methods are suggested based upon their effectiveness of addressing the reduction of the identified threats that contribute to the contamination problem. Also included are appropriate prevention methods which can help protect the viability of treatment systems and reduce their associated maintenance costs. Management policies are suggested to meet these needs as well as promote an understanding of the processes involved with contamination. Many of the technologies currently used for storm water quality improvement include spill prevention technology inherent in the design. Therefore spill and accident mitigation procedures are evaluated to address the integration of these technologies with any recommended engineering measures.

Engineering Measures

Drainage area maps north and south (Figures 6 and 7) delineate: surface features; storm water inlets and outfalls; existing and proposed pipes and swales; limits of impervious areas; and drainage divides between tributary areas. The corresponding drainage areas are detailed in the drainage area tabulation (Table 9). The following measures are proposed to mitigate the pollution contamination threats in storm water run-off tributary to Bat Cave Draw:

1. Tilting the parking lots near the VC so that rainwater runs south off the escarpment

2. Providing drainage of the Maintenance complex to the north vs. other options

3. Treatment of rainwater run-off for the lower "Bat Cave" parking lot as well as all the above mentioned areas.
4. Treatment of rainwater run-off towards Bat Cave Draw from road between main road and lower parking lot
5. Treatment of rainwater run-off from service road near Park offices

One method to assess various treatment technologies is through comparison of their respecitive pollutant removal efficiencies. Pollutant removal efficiency is the individual percentage of pollutant removed after a specific process. For example, if a pre-treatment

Fig. 6. Drainage Area Map North
Scale: 1"=100'
(courtesy of NPS)

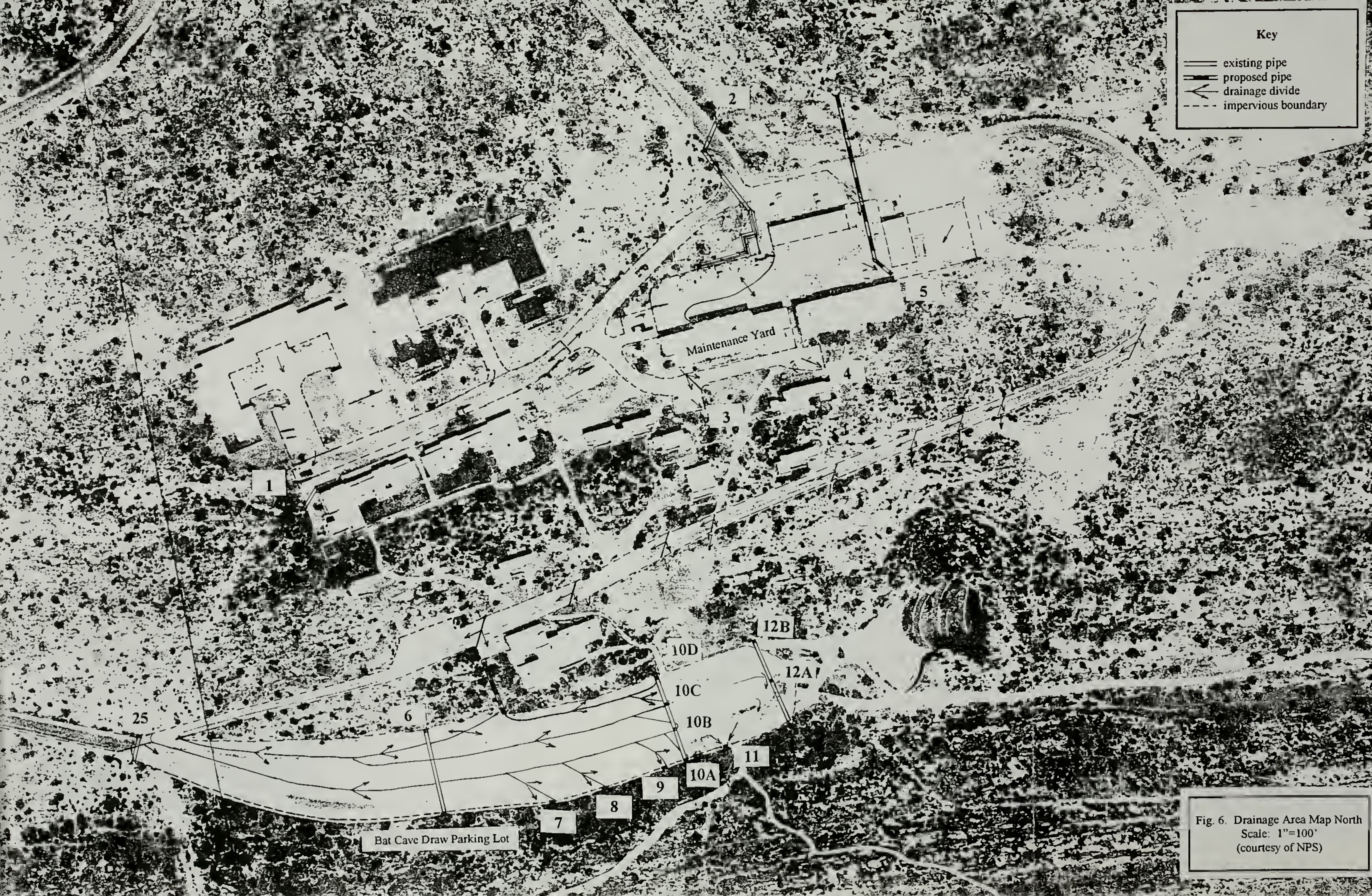

Fig. 6. Drainage Area Map North
Scale: 1"=100'
(courtesy of NPS)

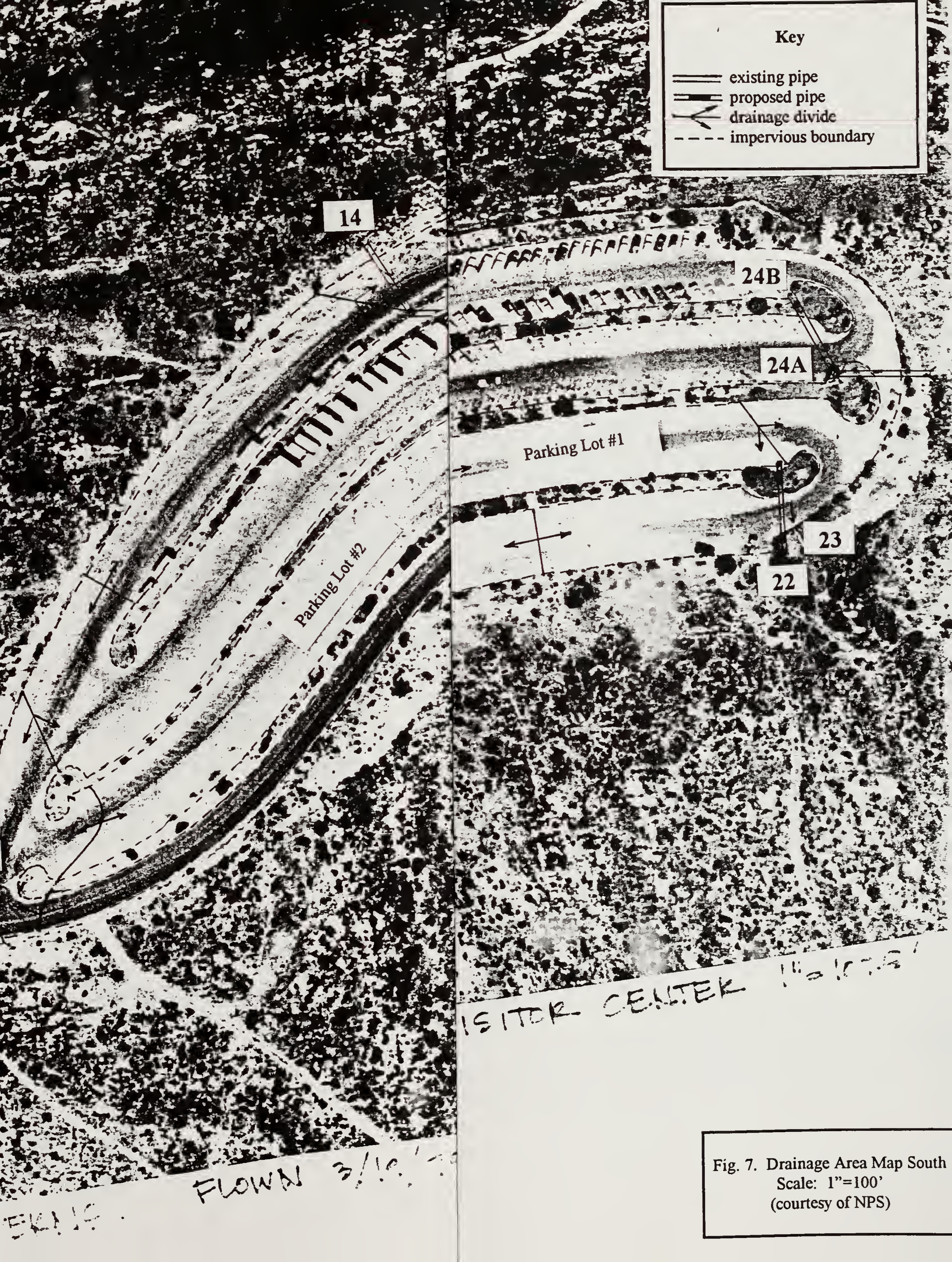

Fig. 7. Drainage Area Map South
Scale: 1"=100'
(courtesy of NPS)

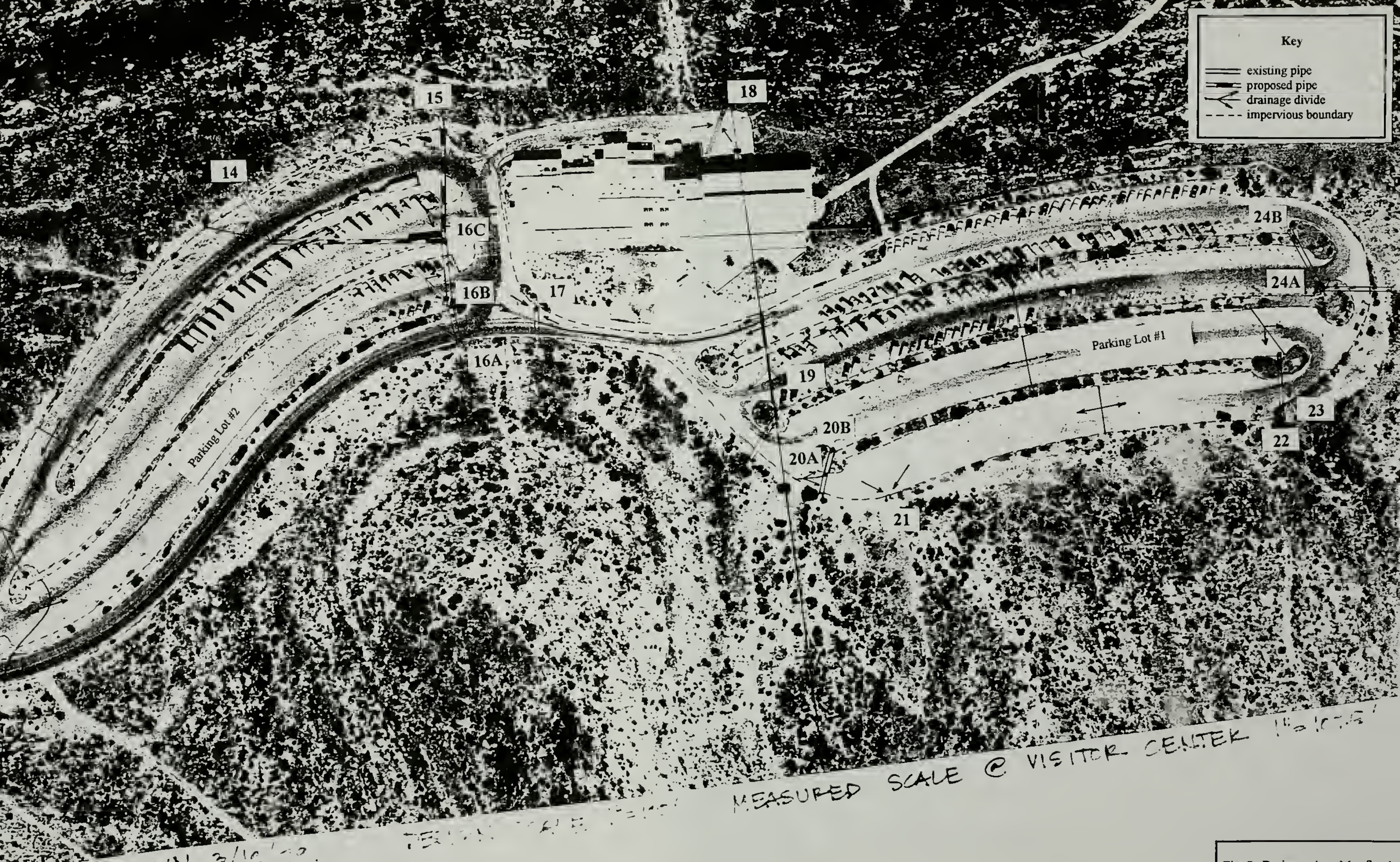

Fig. 7. Drainage Area Map South
Scale: 1"=100'
(courtesy of NPS)

INLET OR OUTFALL STRUCTURE NO.	DESCRIPTION	PAVED IMPERVIOUS DRAINAGE AREA (FT2)	PAVED IMPERVIOUS DRAINAGE AREA (AC)	FIRST FLUSH 1/2 INCH VOLUME (FT3)	FIRST FLUSH 1/2 INCH VOLUME (GAL)	10 YEAR 24-HOUR STORM DISCHARGE Q=CIA (CFS)	100 YEAR 24-HOUR STORM DISCHARGE Q=CIA (CFS)
1	QTRS. 51-60	23,900	0.55	996	7,449	1.60	2.47
2	NW MAINT	14,200	0.33	592	4,426	0.95	1.47
3	W RES. BLDG 1	9,880	0.23	412	3,079	0.66	1.02
4	SE RES. BLDG 1	4,100	0.09	171	1,278	0.28	0.42
5	SE MAINT	25,308	0.58	1,055	7,888	1.70	2.61
6	BAT FLIGHT	7,500	0.17	313	2,338	0.50	0.77
7	BAT FLIGHT	16,400	0.38	683	5,111	1.10	1.69
8	BAT FLIGHT	2,200	0.05	92	686	0.15	0.23
9	BAT FLIGHT	2,430	0.06	101	757	0.16	0.25
10A	BAT FLIGHT	1,040	0.02	43	324	0.07	0.11
10B	BAT FLIGHT	31,200	0.72	1,300	9,724	2.10	3.22
10C	BAT FLIGHT	9,820	0.23	409	3,061	0.66	1.01
10D	BAT FLIGHT	6,700	0.15	279	2,088	0.45	0.69
11	BAT FLIGHT	23,000	0.53	958	7,168	1.54	2.38
12A	BAT FLIGHT	0	0.00	0	0	0.00	0.00
12B	BAT FLIGHT	0	0.00	0	0	0.00	0.00
13	PARKING LOT 2	16,500	0.38	688	5,143	1.11	1.70
14	PARKING LOT 2	21,640	0.50	902	6,744	1.45	2.24
15	PARKING LOT 2	16,400	0.38	683	5,111	1.10	1.69
16A	PARKING LOT 2	17,680	0.41	737	5,510	1.19	1.83
16B	PARKING LOT 2	37,700	0.87	1,571	11,750	2.53	3.89
16C	PARKING LOT 2	40,330	0.93	1,680	12,570	2.71	4.17
17	PARKING LOT 2	18,950	0.44	790	5,906	1.27	1.96
18	VC SERVICE RD.	13,520	0.31	563	4,214	0.91	1.40
19	PARKING LOT 1	20,100	0.46	838	6,265	1.35	2.08
20A	PARKING LOT 1	23,430	0.54	976	7,302	1.57	2.42
20B	PARKING LOT 1	15,370	0.35	640	4,790	1.03	1.59
21	PARKING LOT 1	22,190	0.51	925	6,916	1.49	2.29
22	PARKING LOT 1	19,420	0.45	809	6,053	1.30	2.01
23	PARKING LOT 1	26,060	0.60	1,086	8,122	1.75	2.69
24A	PARKING LOT 1	24,270	0.56	1,011	7,564	1.63	2.51
24B	PARKING LOT 1	37,440	0.86	1,560	11,669	2.51	3.87
25	SERVICE ROAD	4,400	0.10	183	1,371	0.30	0.45
26	SERVICE ROAD	15,600	0.36	650	4,862	1.05	1.61
	TOTAL	**568,678**	**13.06**	**23,695**	**177,238**		

Note: For 10-year 24-hour storm, I = 3.25 in/hr., C = 0.90 (Dingham, 1994)
Note: For 100-year 24-hour storm, I = 5.00 in/hr., C = 0.90 (Dingham, 1994)

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Table 9. Drainage Area Tabulation for Carlsbad Caverns National Park

run-off discharge has a concentration of aluminum of 4300 ppb and the post-treatment discharge is 200 ppb, the pollutant removal efficiency is 95 percent [(4300-200)/4300].

The effectiveness of each of these measures are evaluated with respect to pollutant removal efficiencies, disturbance to impacted areas, associated benefits and installation maintenance, and engineering costs. Engineering costs include complete project design and construction administration.

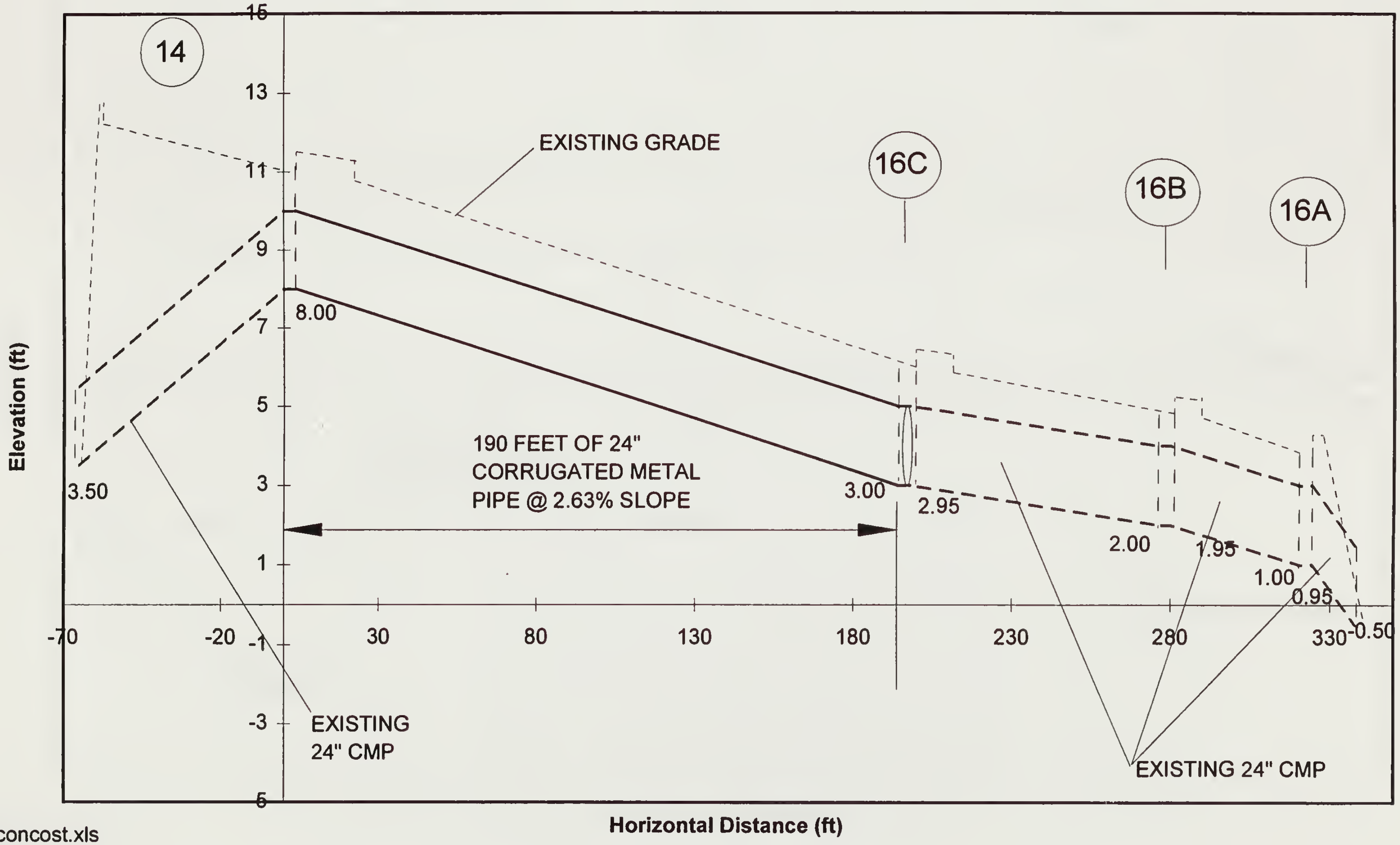
1. Tilting the parking lots near the VC

Tilting the parking lots near the VC so that rainwater runs south off the escarpment redirects pollutants away from Bat Cave Draw to the north. All of the outfalls for Parking Lot No. 1 are tributary to the south escarpment and require no modification. Only Parking Lot No. 2 has drainage areas tributary to Bat Cave Draw, namely outfalls 14 and 15 (Figure 7). In order to direct drainage across any road surface, safe conveyance of a storm of a particular return period is usually required. Safe conveyance in relation to vehicle and pedestrian traffic is normally defined as a specific maximum quantity of water which a road can carry to permit safe travel. When the carrying capacity of curb and gutter is reached, or when the width of the storm flow in the road exceeds a specified distance into the road way from the curb, or begins to cross the intersection with significant flow, a storm water inlet or curb opening is placed to capture and convey the flow using either an underground or surface system. The tilting of the parking lots would achieve redirection of drainage away from Bat Cave Draw, however safe conveyance is not maintained.

In order to retain the original design criteria for safe conveyance, the outfalls require redirection. Installing a piped conveyance from outfalls 14 and 15 to inlet 16A achieves the required redirection. The two proposed pipes are shown in plan view on Figure 7 in the northeast section of Parking Lot No. 2. The downstream piped system has the capacity to convey the additional drainage from the two redirected areas without surcharge for up to a 100-year 24-hour storm. This design event is of such intensity and duration which statistically occurs only once every 100 years. The proposed 24" corrugated metal pipes are sized to convey each drainage area for the slope available for each pipe run and entrance condition. The profiles for the two proposed runs are shown in Figures 8 and 9.

Impacts - This measure has a significant impact to the removal of pollutants to Bat Cave Draw, however it does not change the pollutant removal efficiency of the run-off from Parking Lot No. 2. Run-off and their associated pollutants are permitted to discharge to areas with a steeper slope permitting them to rapidly run-off with limited infiltration until they reach the bottom of the escarpment. The fate of the pollutants and the potential for unknown cave and groundwater contamination is unknown. The disturbance to impacted areas includes a temporary closure of a portion of the lot for pipeline construction.

Associated positive impacts include the elimination of pollutants from Parking Lot No. 2 to Bat Cave Draw and reduced erosion in Bat Cave Draw. Negative impacts include increased erosion to the south facing arroyo and a minor increase in the potential for diffuse infiltration from leaks from the system. A complete pavement sealing of all tributary drainage areas is included in the construction cost. The construction, maintenance and engineering costs are shown in the Appendix. A large portion of the construction cost for this measure is based on the assumption that all of the excavation is rock. Should this not be the case, the total cost would be significantly reduced. Since the maintenance of the existing storm water piping system is not a function of pipe length, and there is no increase in the number of inlets and a net decrease in the number of outfalls, no additional maintenance costs for this measure are applied.



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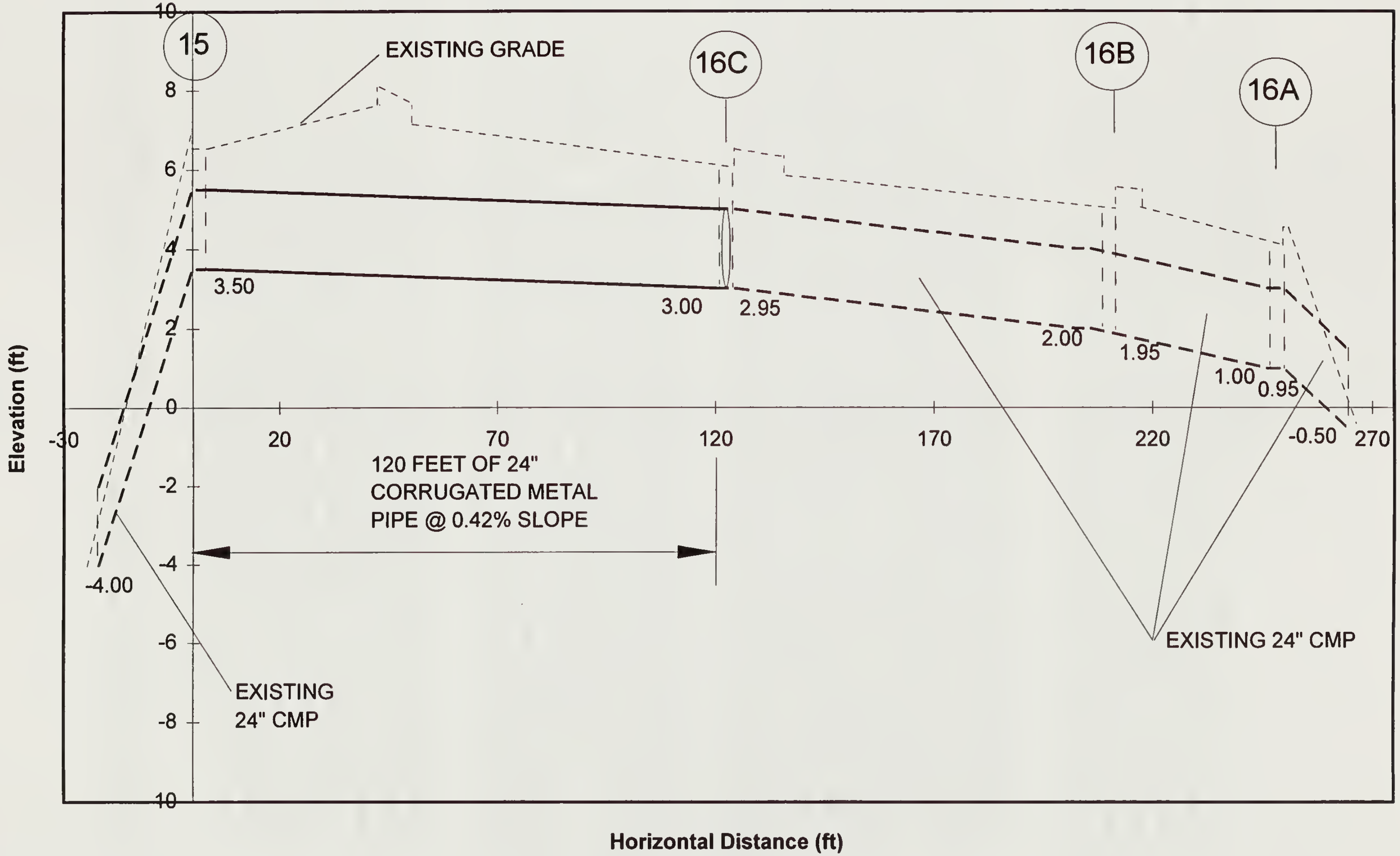
Note: Add 4400 feet to all elevations

Figure 8. Proposed Outfall Pipe for Drainage Area #14



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NOTE: Add 4400 feet
to all shown elevations.

Figure 9. Proposed Outfall Pipe for Drainage Area #15

2. Providing drainage of the maintenance complex

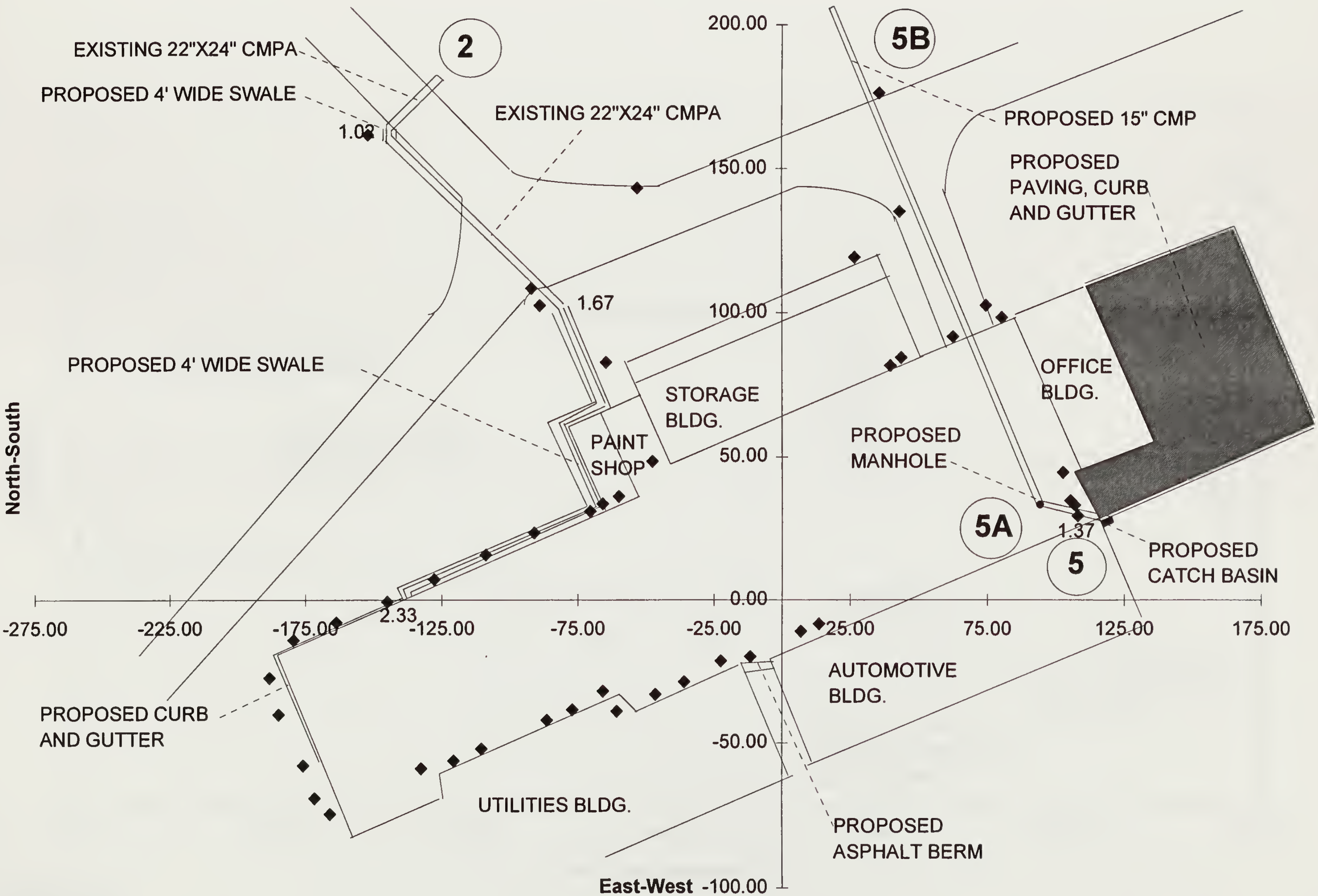
Providing drainage of the maintenance complex to the north vs. other options redirects pollutants away from Bat Cave Draw to the south where rapid surface run-off occurs due to the steep slopes. The maintenance yard drains to three separate areas: the northwest area drains north to outfall 2; the area immediately in front of the utilities building drains south between the utilities and automotive buildings to outfall 4; and the east area drains to the southeast to outfall 5. The storage area behind the maintenance office drains to the south but separately from outfall 5.

The drainage system for outfall 2 requires modification since there exist areas where diffuse infiltration of run-off occurs prior to outfall to an area of rapid surface run-off. Curb and gutter is required in the west portion to contain the run-off prior to exiting the pavement. Immediately next to the pavement where the run-off exits the yard is an undeveloped area approximately 120 feet away from the outfall pipe. The slope is less than 0.5% and provides an area suitable for infiltration. A concrete swale paralleling the pavement area (around the paint shop) would provide the necessary conveyance and constructability required due to the gentle slope available. A much smaller concrete swale is also required between the two pipes to complete the confinement of the system. The two proposed swales are shown in plan view on Figure 10 in the northwest section of the maintenance yard. The profile for the combined proposed run is shown in Figure 11.

The majority of the grade of the maintenance yard drains primarily towards the south. The small paved portion of the maintenance yard that drains to outfall 4 can conveniently be redirected to outfall 5 with the construction of a small asphalt berm between the utility and automotive buildings. The unpaved storage area behind the office has no concentrated outfall and is also tributary to Bat Cave Draw. Construction of a paved area surrounded by curb and gutter and directed to outfall 5 would prevent diffuse infiltration of any pollutants and permit a concentrated discharge. The drainage area map (Figure 6) and tabulation (Table 9) reflect these minor adjustments.

The available slope however is too small to permit re-grading of these pavement areas towards outfall 2. The slope from the most remote part of the drainage area (relative to outfall 2) from the far eastern edge of the automobile building to the first pipe entrance, is approximately 0.08%, much too flat and beyond constructability even for concrete pavement without creating extended periods of significant standing water for even the smallest of storm events. In order to drain the run-off from outfall 5 towards the north, the outfall requires redirection using an alternate piped conveyance. The proposed 15" corrugated metal pipe is sized to convey the drainage area for the slope available and entrance condition. The profile for the proposed run is shown in Figure 12.

Impacts - This measure has a significant impact to the removal of pollutants to Bat Cave Draw, however it does not change the pollutant removal efficiency of the run-off from



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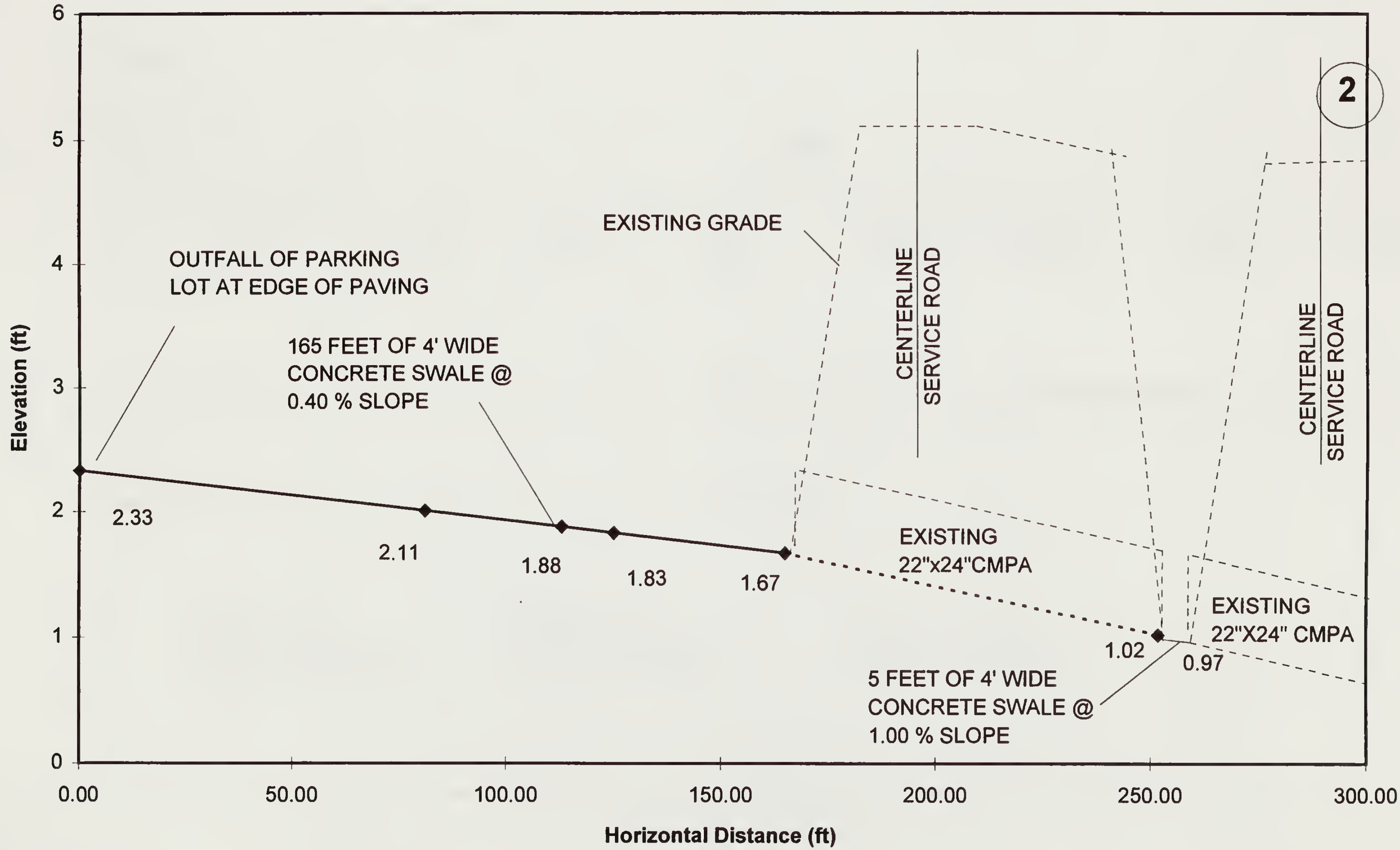
NOTE: Add 4430 feet to all shown elevations.

Figure 10. Maintenance yard site plan
Scale 1"=50'



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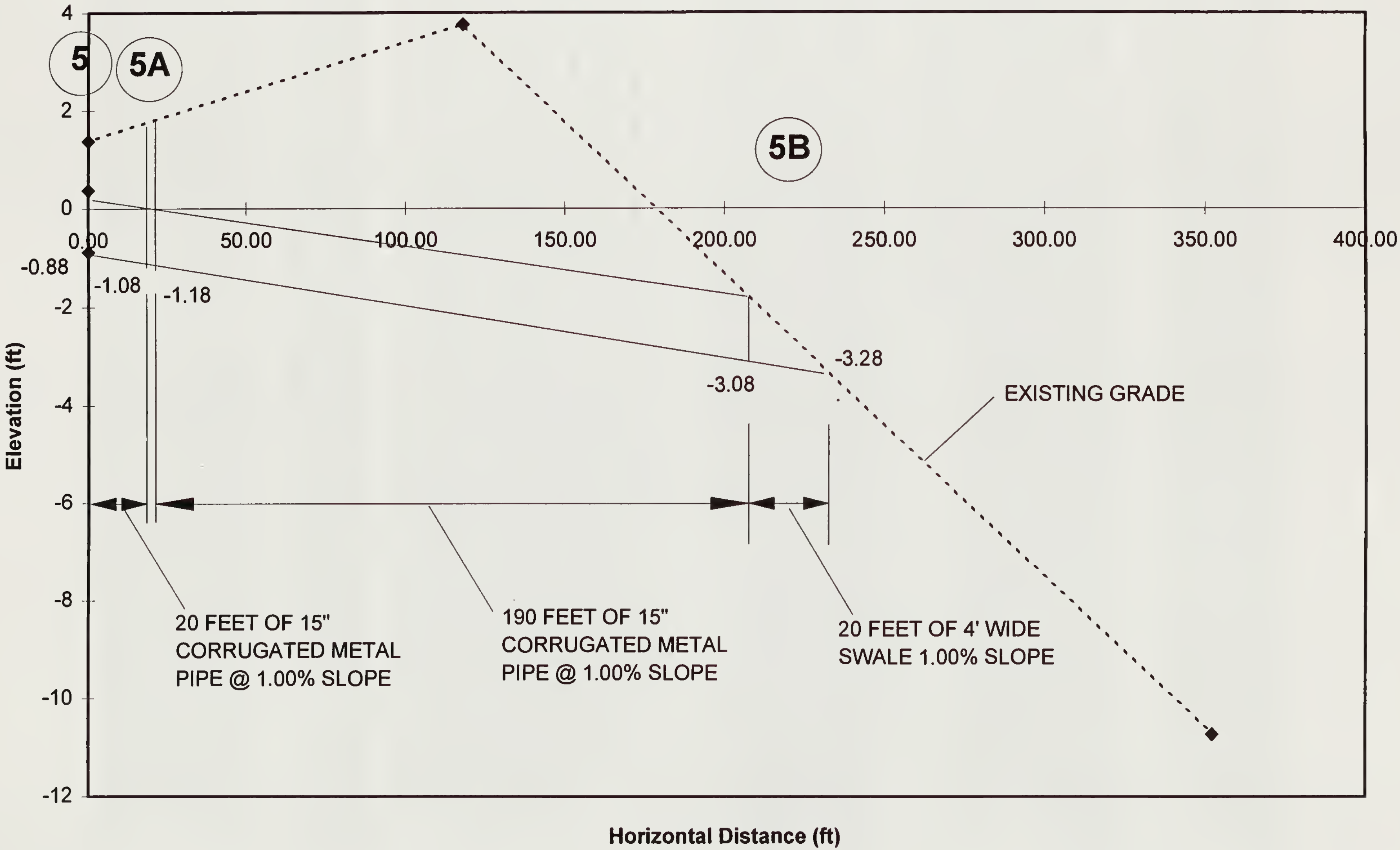
NOTE: Add 4430 feet
to all shown elevations.

Figure 11. Proposed Outfall Swale for Maintenance Yard



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NOTE: Add 4430 feet to all shown elevations.

Figure 12. Proposed outfall pipe for maintenance yard
Scale: as shown

the maintenance yard. Run-off and their associated pollutants are permitted to discharge to areas with a steeper slope permitting them to rapidly run-off with limited infiltration until they reach the bottom of the focused infiltration zone of the downstream arroyo. The fate of the pollutants and the potential for unknown cave and groundwater contamination is unknown.

The disturbance to impacted areas includes a temporary closure of a portions of both the service road and yard for pipeline construction. Associated positive impacts include the elimination of pollutants from the maintenance yard to Bat Cave Draw and reduced erosion in Bat Cave Draw. Additionally the potential for diffused infiltration of pollutants in the run-off is reduced significantly. Negative impacts include increased erosion in the arroyo to the north and a minor increase in the potential for diffuse infiltration from leaks from the system.

A complete pavement sealing of all tributary drainage areas is included in the construction cost. The construction, maintenance and engineering costs are shown in the Appendix. A large portion of the construction cost for this measure is based on the assumption that all of the excavation is rock. Should this not be the case, the total cost would be significantly reduced. Since the maintenance of the existing storm water piping system is not a function of pipe length, and there is no increase in the number of inlets, no additional maintenance costs for this measure are applied.

3. Treatment of rainwater run-off for the lower "Bat Cave" parking lot

Redirection of the drainage run-off in this parking lot by tilting the lot or piped conveyance is not a feasible alternative due to the location of the lot relative to an appropriate outfall. The lot sits in a deep arroyo where the only outfall of the run-off travels over a half-mile before it extends beyond where Carlsbad Cavern is known to exist. Treatment of rainwater run-off for the lower "Bat Cave" parking lot provides an alternate approach to mitigating the contamination problem by using (a) specific treatment process(es) to remove pollutants prior to discharge. This approach can be applied to the previous two measures as well as other areas in the headquarters area.

In Bat Cave Draw, an emphasis has been placed on minimizing the visual impacts of the treatment measures to maintain the character of the historical landscape. Where possible, structural elements have been placed beneath the pavement surface.

The type of treatment process selected is dependent upon the types of pollutants to be removed and the desired pollutant removal efficiency. Where existing development precludes the use of effective nonstructural controls (change of land use and control), treatment practices may be the only suitable option to decrease the pollution loads generated from developed areas such as the headquarters area. For existing developed areas it is necessary to retrofit the existing surface water run-off management systems.

Retrofitting is a process that involves the modification of existing surface water run-off control structures or surface water run-off conveyance systems, which were initially designed to control flooding and not to serve a water quality improvement function.. Where the presence of existing development or financial constraints limits treatment options, targeting may be necessary to identify priority pollutants and select the most appropriate retrofits.

Many storm water technologies currently on the market use pollutant separation strategies that include sedimentation and displacement through fluid density differentials. Some technologies employ extensive surface contact with either rock or organic media to remove metals and nutrients, in addition to conventional separation strategies. The systems store the pollutants for periodic extraction and disposal. Considerable research and development has been conducted to maximize the efficiencies of these processes in the removal of pollutants from storm water.

Treatment technologies are referred to as "on-line" measures if the inflow and discharge rates of storm water are identical. When high rates of throughput are encountered, as in larger storm events, the pollutant removal methods that the technologies rely upon are negatively impacted with this increase flow. The throughput velocities increase and inversely impact the rate of sedimentation, oil or grease separation from water or metal and nutrient uptake. All devices have a limit to the amount of storm water that can effectively be treated and are typically sized for the tributary drainage area. When intense storms are encountered, a bypass strategy is used to permit safe conveyance of water. This permits untreated water to bypass the treatment process and continue downstream of the treatment system.

During a storm event the first-flush samples taken from pavement run-off flows indicate a substantial increase in quantity of unattached fine particulates and soluble surface material over samples taken later during the storm event. This represents the accumulation of pollution deposited between storms. Consequently the first moments of a storm contribute the highest concentration of pollutants to the receiving bodies (Bailey, 1993).

A widely used strategy for treating the pavement run-off captures the first 1/2-inch of the total precipitation which falls on the paved area. These technologies are referred to as "off-line" measures. This portion of the run-off, containing a significant amount of the surface pollutants, is diverted from the outfall area to a specific process to meet the desired treatment objective (diversion from surface waters by recharging ground water directly, oil/grit/sediment removal, nutrient removal, heavy metals removal, etc.) This strategy also serves to capture the majority of storm events which are smaller in total rainfall volume than the volume of storage in the design process. Over 85% of the storms occurring in Bat Cave Draw have a total volume less than this run-off amount and therefore would be fully treated with this strategy (Figure 13). In the event of a high

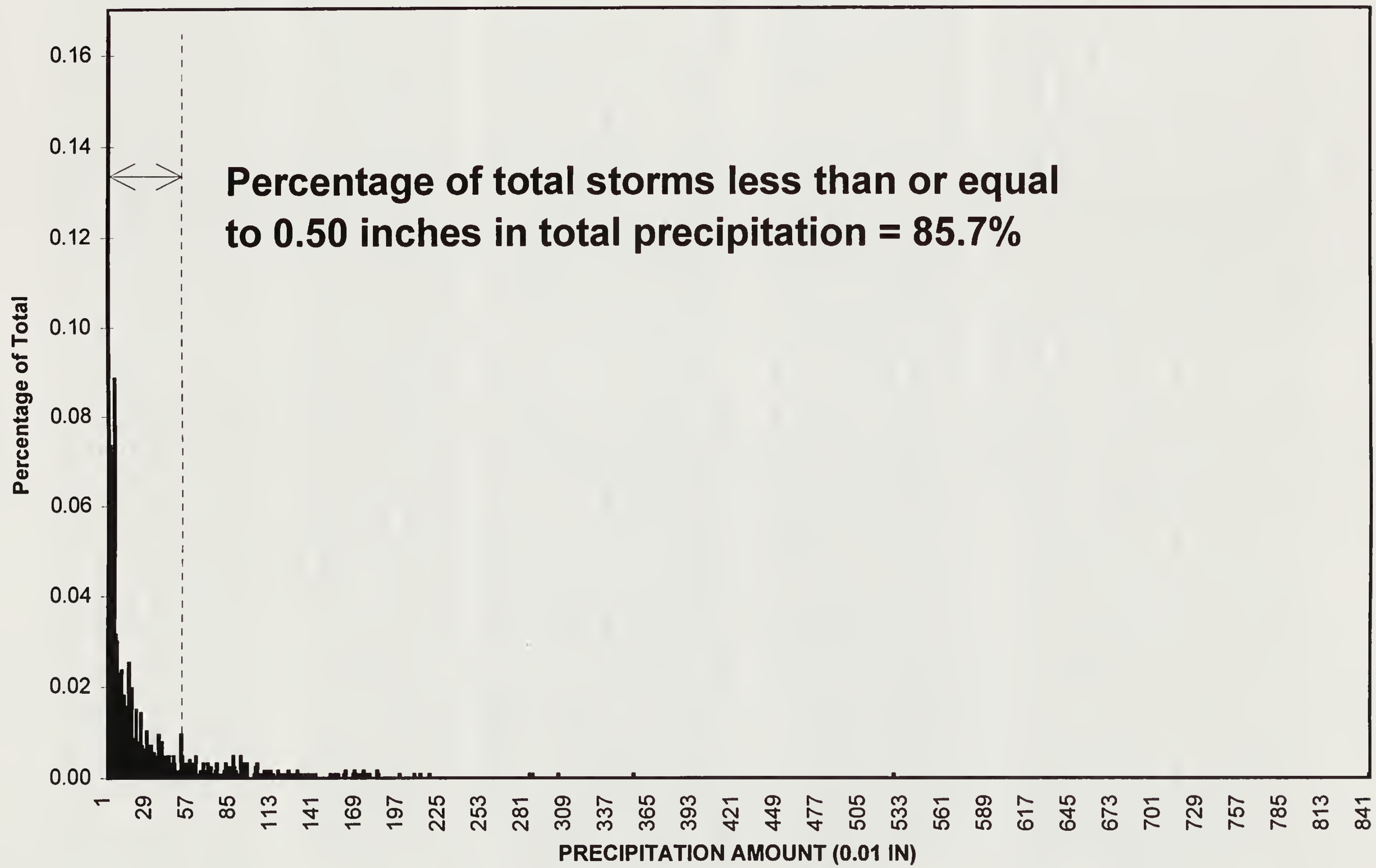

Figure 13. Frequency distribution based upon number of precipitation days (n=1,267) with specified precipitation amount for Bat Cave Draw, Carlsbad Caverns National Park, New Mexico (data courtesy of NPS)

Precipitation-%/stats.xls
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intensity or long duration storm that exceed the volume of storage, provisions are made to bypass the secondary component of the run-off to the outfall directly. However this bypassed portion of the run-off can be greatly diluted with respect to pollutants since the first-flush has retained the majority of pollutants. This evaluation focuses on the latest available water quality devices and technologies, commonly referred to as structural Best Management Practices (BMP's). Nine measures currently in use for treating storm water are presented. Only third-party evaluations for pollutant removal efficiencies are used in this assessment and are summarized in Table 7. Conventional oil/grit separators are excluded from this evaluation due to their inability to retain pollutants and sediments during large storm events. Conventional wet and dry pond systems are excluded from this evaluation due to their large area requirements.

3a. ***BaySaver*** **TM** is an on-line system and uses a plastic oil/grit separator with two manholes that can be used as a storm water management, sediment control, or spill containment device. The two standard precast concrete manholes are connected by a separator unit which provides the diversion of run-off for treatment. One manhole serves as a coarse-grained sedimentation unit and the other collects debris, oils and suspended sediments. Sediments are dewatered and solids are landfilled. Oil and grease are disposed of as a hazardous waste. The device cannot act as an inlet structure.

Redistribution of the drainage areas is necessary to minimize the number of individual systems. Outfalls 7, 8, and 9 shall be closed and abandoned to permit these flows to be picked up by inlet 10A. The additional inflow exceeds the flow capacity of 10A to accept without bypass. An storm inlet is proposed at the bottom of outfall 6 to intercept a large portion of the drainage area tributary to 10A to offset the increase from outfalls 7, 8, and 9. A storm inlet is proposed at outfall 11 to convey the flow to the treatment system. The drainage redistribution creates three treatment systems at outfalls 6, 10A and 11. The units are proposed to be constructed inside the paved area next to the stone wall. Each system requires a separator unit, two manholes, and an appropriate outfall pipe.

No rockwork excavation is included in the cost estimate since the area of excavation is in earth fill. Maintenance consists of removing by vacuum truck the contents of each manhole about once a year. The periodic inspection and removal service is performed through a maintenance contract with local septage haulers. A complete pavement sealing of all tributary drainage areas is included in the construction cost. The construction, maintenance and engineering costs are shown in the Appendix.

3b. *Bioretention* is an off-line method to manage storm water run-off using native plants and soil conditioning. Begun as an experimental process by the Maryland Department of environmental Resources in 1993, it has become a standard practice for improving storm water quality in Maryland and Virginia. Bioretention areas are conceived to capture sheet flow from impervious surfaces and are typically limited to small drainage areas of up to 1 acre (ETA et al., 1993). The BMP type is referred to as an organic filter. Bioretention areas are modeled after terrestrial forest ecosystems-forest, mulch, and deep rich soils.

	Pollutant Removal Efficiencies % for Various BMP's				
Species	Bioretention[1]	CSF®	Fossil Filter™	StormCeptor®	StormTreat™
Turbidity		81.7			
TSS		91.8	0.0	98.7	95.2
COD		70.4			74.3
TVSS		88.8			
SS		94.7			
TDS		+36.5			
TS		48.7			
TKN	68	57.4	-10.1		55.0
TDN					47.5
NH^4	79	59.5			90.7
NO^3	23	+144.8	-15.5		54.0
Total N	43		-11.2		65.0
Alk.					
Hard.					
Cl^-					
$S0_4^{2-}$					
TOC					
Ag				0.0	
Al		84.4			
As		70.9		0.0	
B		61.2			
Ba		66.5		75.0	
Ca		3.4			
Cd				0.0	
Co		85.9			
Cr		65.1		0.0	96.0
Cu	93	65.3			
Fe		84.4			
Hg				0.0	
K		+111.7			
Li					
Mg		+25.4			
Mn		81.3			
Mo					
Na		11.3			
Ni		48.1			
P (total)	81	48.7	-7.5	79.2	88.0
P (soluble)		+197.4			
$o\text{-}PO_4$					67.7
Pb	99	82.5		83.3	75.4
Se				0.0	
Si					
Sr					
Ti					
V		68.3			
Zn	99	83.2			91.3
S					
Oil & Grease		80.9	41.1	99.9	
Total Petroleum Hydrocarbons		84.0		99.9	44.5

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Table 7. Pollutant removal efficiencies for various treatment devices

1. Bed depth is equal to 4 feet.

This community was selected based on its documented ability to effectively assimilate a wide range of pollutants. The primary application is for commercial parking lots (Bitter, Bowers, 1994) and is designed to capture and store the first half-inch of parking lot run-off. The volume fills with storm water run-off up to a maximum water depth of 6 inches above the mulch layer. This water is then slowly released as it passes through the planted soil matrix. An underdrain system collect and conveys the treated water to the existing storm drain system. The soil requires removal and site replanting in 5 to 20 years. Due to the seasonal use of the parking lot, replanting is not foreseen until after the 20 year limit.

Bioretention requires the use of a grass buffer strip which receives sheet flow run-off from the paved surface. The minimum width of a functional bioretention area is 15 feet. Minimum length should be 40 feet. The grassed buffer width around the bioretention area is proposed to be 3 feet. The ponded area should have a maximum depth of 6 inches and the planting soil should have a minimum depth of 4 feet. The size of the bioretention area should be 7% of the drainage area (ETA et al., 1993).

To achieve the minimum planting requirements for design, the planted areas are proposed inside of the lower stone wall. This measure requires a change in land use and control of three portions of the paved area (one for each parking terrace level) and replaces a total of approximately 33 parking spaces (8 - upper, 10 - middle, and 14 - lower) with selected planting areas. Outlets 7, 8, 9, and 11 are to be closed and abandoned to permit the drainage to be redirected to the lower terrace bioretention area. Regrading of the drainage area to two inlets (6 and 10D) and abandonment of the inlets are required to collect the drainage for the upper parking terrace. Storm drain inlets 10C, 10B, and 10A will provide the collection points for all the drainage. An underdrain system of pervious pipe is proposed to collect the bioretention area collected run-off and convey it to the existing storm drain system.

No rockwork excavation is included in the cost estimate since the area of excavation is in earth fill. Maintenance consists of periodic inspection and service (repair erosion, soil testing, remulching, removal of dead and diseased vegetation, vegetation treatment, stake replacement, etc.) performed through a maintenance contract with a local arborist. A complete pavement sealing of all tributary drainage areas is included in the construction cost. The construction, maintenance and engineering costs are shown in the Appendix.

3c. *CSF®* is an on-line storm water treatment system treats run-off from parking lots, roadways, and other impervious surfaces, efficiently removing high levels of sediment (TSS), soluble metals, and oil and grease from storm water run-off. Using an innovative approach, the system utilizes deciduous leaf media among other varieties in replaceable cartridges to remove pollutants. The BMP type is referred to as an organic filter. It has good pollutant removal efficiencies over a broad range of pollutants. The device cannot act as an inlet structure.

Redistribution of the drainage areas is necessary to minimize the number of individual systems. Outfalls 7, 8, and 9 shall be closed and abandoned to permit these flows to be picked up by inlet 10A. The additional inflow exceeds the flow capacity of 10A to accept without bypass to the next downstream inlet. An storm inlet is proposed at the bottom of outfall 6 to intercept a large portion of the drainage area tributary to 10A to offset the increase from outfalls 7, 8, and 9. A storm inlet is proposed at outfall 11 to convey the flow to the treatment system. The drainage redistribution creates three treatment systems at outfalls 6, 10A and 11. The units are proposed to be constructed inside the paved area next to each outfall and next to the stone wall. All flows are to be diverted from the new or existing outfall to the treatment device and out a new outfall pipe.

No rockwork excavation is included in the cost estimate since the area of excavation is in earth fill. Maintenance consists of yearly cartridge replacement. Cartridge contents are designed for beneficial use and cartridges are returned to the manufacturer for reuse. The periodic inspection and removal service is performed through a maintenance contract with a local contractor. There are no disposal costs for the organic media. A complete pavement sealing of all tributary drainage areas is included in the construction cost. The construction, maintenance and engineering costs are shown in the Appendix.

3d. *Downstream Defender* ™ is an on-line treatment device designed to capture settleable solids, floatables, oil and grease from storm water run-off. The device consists of a concrete cylindrical vessel with a 30 degree sloping base. Storm water is introduced tangentially into the side of the cylinder and spirals down the perimeter allowing heavier particles to settle out by gravity and the drag forces on the wall and base of the vessel. The device cannot act as an inlet structure.

Redistribution of the drainage areas is necessary to minimize the number of individual systems. Outfalls 7, 8, and 9 shall be closed and abandoned to permit these flows to be picked up by inlet 10A. The additional inflow exceeds the flow capacity of 10A to accept without bypass. An storm inlet is proposed at the bottom of outfall 6 to intercept a large portion of the drainage area tributary to 10A to offset the increase from outfalls 7, 8, and 9. A storm inlet is proposed at outfall 11 to convey the flow to the treatment device. The drainage redistribution creates three treatment systems at outfalls 6, 10A and 11. The units are proposed to be constructed inside the paved area next to each outfall and next to the stone wall. All flows are to be diverted from the existing outfall to the treatment device and out a new outfall pipe.

No rockwork excavation is included in the cost estimate since the area of excavation is in earth fill. Maintenance consists of removing by vacuum truck the contents of each device. The periodic inspection and removal service is performed through a maintenance contract with local septage haulers. A complete pavement sealing of all tributary drainage areas is included in the construction cost. The construction, maintenance and engineering costs are shown in the Appendix.

3e. *Enviro-Drain®* filters urban run-off through three trays located in each storm drain inlet. The first tray filters out sediments and debris, the second retains oil, the third neutralizes fertilizers and pesticides. The trays are conveniently designed to fit into storm drains and require little maintenance. In large storms, the first flush is treated, and excess run-off overflows between the filter trays and their casings. This is an on-line system.

All of the inlets require modification to accept the trays. None of the existing inlets have removable grates and are smaller than the smallest standard sizes available for this technology. Outfalls 7, 8, and 9 shall be closed and abandoned to permit these flows to be picked up by inlet 10A. The additional inflow exceeds the flow capacity of 10A to accept without bypass. An storm inlet is proposed at the bottom of outfall 6 to intercept a large portion of the drainage area tributary to 10A to offset the increase from outfalls 7, 8, and 9. A storm inlet is proposed at outfall 11 to convey the flow to the treatment device. New inlets are proposed at all existing inlet locations for a total of seven inlets. Four foot square inlets are proposed.

No rockwork excavation is included in the cost estimate since the area of excavation is in earth fill. Maintenance consists of monthly replacement of the trays. A complete pavement sealing of all tributary drainage areas is included in the construction cost. The construction, maintenance and engineering costs are shown in the Appendix.

3f. Fossil Filter™ is a storm drain attachment that captures petroleum-based hydrocarbons and other contaminants in a metal trough containing a filter cartridge. It contains amorphous alumina silicate contained between two screens to absorb hydrocarbons and a filter skirt to capture heavy metals. This is an on-line treatment measure.

All of the inlets require modification to accept the trays. None of the existing inlets have removable grates and are smaller than the smallest standard sizes available for this technology. Outfalls 7, 8, and 9 shall be closed and abandoned to permit these flows to be picked up by inlet 10A. The additional inflow exceeds the flow capacity of 10A to accept without bypass. An storm inlet is proposed at the bottom of outfall 6 to intercept a large portion of the drainage area tributary to 10A to offset the increase from outfalls 7, 8, and 9. A storm inlet is proposed at outfall 11 to convey the flow to the treatment device. New inlets are proposed at all existing inlet locations for a total of seven inlets. Four foot square inlets are proposed.

No rockwork excavation is included in the cost estimate since the area of excavation is in earth fill. Maintenance consists of bi-annual replacement of the filter media. A complete pavement sealing of all tributary drainage areas is included in the construction cost. The construction, maintenance and engineering costs are shown in the Appendix.

3g. *Stormceptor ®* is an on-line treatment measure using a precast water quality structure that can be used as a primary water quality, pretreatment, or as a spill control device

designed to capture and treat the first flush of run-off. Stormceptor® traps petroleum and suspended solids.

Redistribution of the drainage areas is necessary to minimize the number of individual systems. Outfalls 7, 8, and 9 shall be closed and abandoned to permit these flows to be picked up by inlet 10A. The additional inflow exceeds the flow capacity of 10A to accept without bypass to the next downstream inlet. An storm inlet is proposed at the bottom of outfall 6 to intercept a large portion of the drainage area tributary to 10A to offset the increase from outfalls 7, 8, and 9. A storm inlet is proposed at outfall 11 to convey the flow to the treatment system. The drainage redistribution creates five treatment systems, three at outfalls 6, 10A and 11, and two at inlet 10B. Three units are proposed to be constructed inside the paved area next to the lower stone wall and two in the middle terrace adjacent to the middle stone wall.

No rockwork excavation is included in the cost estimate since the area of excavation is in earth fill. Maintenance consists of removing by vacuum truck the contents of each manhole about once a year. Sediments are dewatered and solids are landfilled. Oil and grease are disposed of as a hazardous waste. The periodic inspection and removal service is performed through a maintenance contract with local septage haulers. A complete pavement sealing of all tributary drainage areas is included in the construction cost. The construction, maintenance and engineering costs are shown in the Appendix.

3h. *StormTreat™* Systems is a off-line storm water treatment technology consisting of a series of gravel filled sedimentation chambers and constructed wetlands which are contained within a modular, 2.9 meter (9.5 feet) diameter recycled-polyethylene tank. The treatment systems are designed to capture and store the first half inch of run-off. Influent is piped into the sedimentation chambers where pollutant removal processes such as sedimentation and filtration occur (Graham et al., 1996). The device also serves as a spill containment device. Gravel based storm water wetlands have proved to be very effective in removing particulate pollutants, such as sediment, iron and particulate phosphorus and have performed well in cold, high altitude climates (TRS, 1995).

Redistribution of the drainage areas is necessary to minimize the number of individual systems. Outfalls 7, 8, and 9 shall be closed and abandoned to permit these flows to be picked up by inlet 10A. The additional inflow exceeds the flow capacity of 10A to accept without bypass to the next downstream inlet. An storm inlet is proposed at the bottom of outfall 6 to intercept a large portion of the drainage area tributary to 10A to offset the increase from outfalls 7, 8, and 9. A storm inlet is proposed at outfall 11 to convey the flow to the treatment system. The drainage redistribution creates three treatment systems at outfalls 6, 10A and 11. The wetland units are proposed to be constructed outside the paved area adjacent to the stone wall in the arroyo. Each system requires a set of wetland tanks (2 or 3) which includes all connecting piping, and a precast concrete inlet of sufficient depth at the outfall. The tanks are equipped with an outfall at grade elevation.

No rockwork excavation is included in the cost estimate since the area of excavation is in earth fill. Maintenance consists of removing by vacuum truck the pollutants of each tank once every 4 years. Sediments are dewatered and solids are landfilled. Oil and grease are disposed of as a hazardous waste. The gravel requires renewal and constructed wetlands need replanting once every 10 to 20 years. Due to the seasonal use of the parking lot, replanting is not foreseen until after the 20 year limit. The periodic inspection and removal service is performed through a maintenance contract with local septage haulers. A complete pavement sealing of all tributary drainage areas is included in the construction cost. The construction, maintenance and engineering costs are shown in the Appendix.

3i. *Vortechs* TM storm water treatment system is an advanced oil/grit separator unlike conventional oil/grit separators. The structures may be placed in- or off-line with the storm drain system. The design combines a swirl-concentrator technologies to collect sediments and a flow control technology to collect oil and grease and prevention of resuspension of trapped pollutants. The high efficiency in sediment capture assists in the removal of metals attached to fine particles.

Redistribution of the drainage areas is necessary to minimize the number of individual systems. Outfalls 7, 8, and 9 shall be closed and abandoned to permit these flows to be picked up by inlet 10A. The additional inflow exceeds the flow capacity of 10A to accept without bypass to the next downstream inlet. An storm inlet is proposed at the bottom of outfall 6 to intercept a large portion of the drainage area tributary to 10A to offset the increase from outfalls 7, 8, and 9. A storm inlet is proposed at outfall 11 to convey the flow to the treatment system. The drainage redistribution creates three treatment systems at outfalls 6, 10A and 11. The units are proposed to be constructed inside the paved area next to the stone wall. Each system requires a precast concrete structure, a diversion pipe from each final storm drain inlet, and an appropriate outfall pipe.

No rockwork excavation is included in the cost estimate since the area of excavation is in earth fill. Maintenance consists of removing by vacuum truck the contents of each manhole. The periodic inspection and removal service is performed through a maintenance contract with local septage haulers. A complete pavement sealing of all tributary drainage areas is included in the construction cost. The construction, maintenance and engineering costs are shown in the Appendix.

Impacts - All treatment measures have a significant impact to the removal of pollutants to Bat Cave Draw. Run-off and the majority of pollutants are no longer permitted to discharge to areas with focused infiltration. The degree and type of pollutant removal however varies with each system. The maintenance costs are considerable for some measures and are a significant part of the lifetime costs (Table 10). The return period of 15 years is used to accommodate the time framework presented in the Final General Management Plan/Environmental Impact Statement (GMP) for management action. The associated lifetime costs of the alternatives are graphically presented in Figure 14.

Item No.	Treatment Device	Spill containment system	Store first half inch of run-off	Third-party evaluation of pollutant removal efficiencies	Number of site locations	Number of site installations	Year of first installation	Notes
3a.	BaySaver ™	yes	no	no	3	5	1997	
3b.	Bioretention	no	yes	no	40	100	1993	(a)
3c.	CSF®	no	no	yes	150	300	1992	
3d.	Downstream Defender	yes	no	no	15	20	1995	
3e.	Enviro-Drain ®	no	no	no	n/a	n/a	1994	
3f.	Fossil Filter ™	no	no	no	350	3,500	1993	
3g.	Stormceptor ®	yes	no	yes	259	1,100	1994	
3h.	StormTreat™ Systems	yes	yes	yes	19	70	1995	(b)
3i.	Vortechs™	yes	no	no	100	300	1991	

Item No.	Treatment Device	Installation costs	Yearly maintenance costs manpower	Yearly maintenance costs equipment	Yearly maintenance costs materials	Yearly hazardous waste disposal costs	Total yearly costs	15 year lifetime cost[(c)] in 1998 $
3a.	BaySaver ™	$46,000	$100	$500	$0	$900	$1,500	$61,569
3b.	Bioretention	$72,000	$680	$0	$425	$0	$1,105	$83,470
3c.	CSF®	$69,000	$100	$0	$1,100	$0	$1,200	$81,456
3d.	Downstream Defender	$82,000	$100	$500	$0	$900	$1,500	$97,569
3e.	Enviro-Drain ®	$58,000	$700	$0	$858	$250	$1,808	$76,766
3f.	Fossil Filter ™	$34,000	$700	$0	$330	$250	$1,280	$47,286
3g.	Stormceptor ®	$157,000	$90	$450	$0	$1,200	$1,740	$175,061
3h.	StormTreat™ Systems	$62,000	$672	$240	$0	$400	$1,312	$75,618
3i.	Vortechs™	$67,000	$160	$640	$0	$900	$1,700	$84,645
							AVERAGE	$87,049
							MEDIAN	$81,456

NOTES:
(a) Measure has partial or full spill containment with no storm water run-off.
(b) Measure may have only partial spill containment with storm water run-off.
(c) Lifetime costs use an annual adjusted interest rate equal to 5%
Engineering costs not included.
n/a information not available

treatment/concost.xls
5/29/98

Table 10. Evaluation criteria and costs of treatment measures for Bat Cave Draw parking lot.

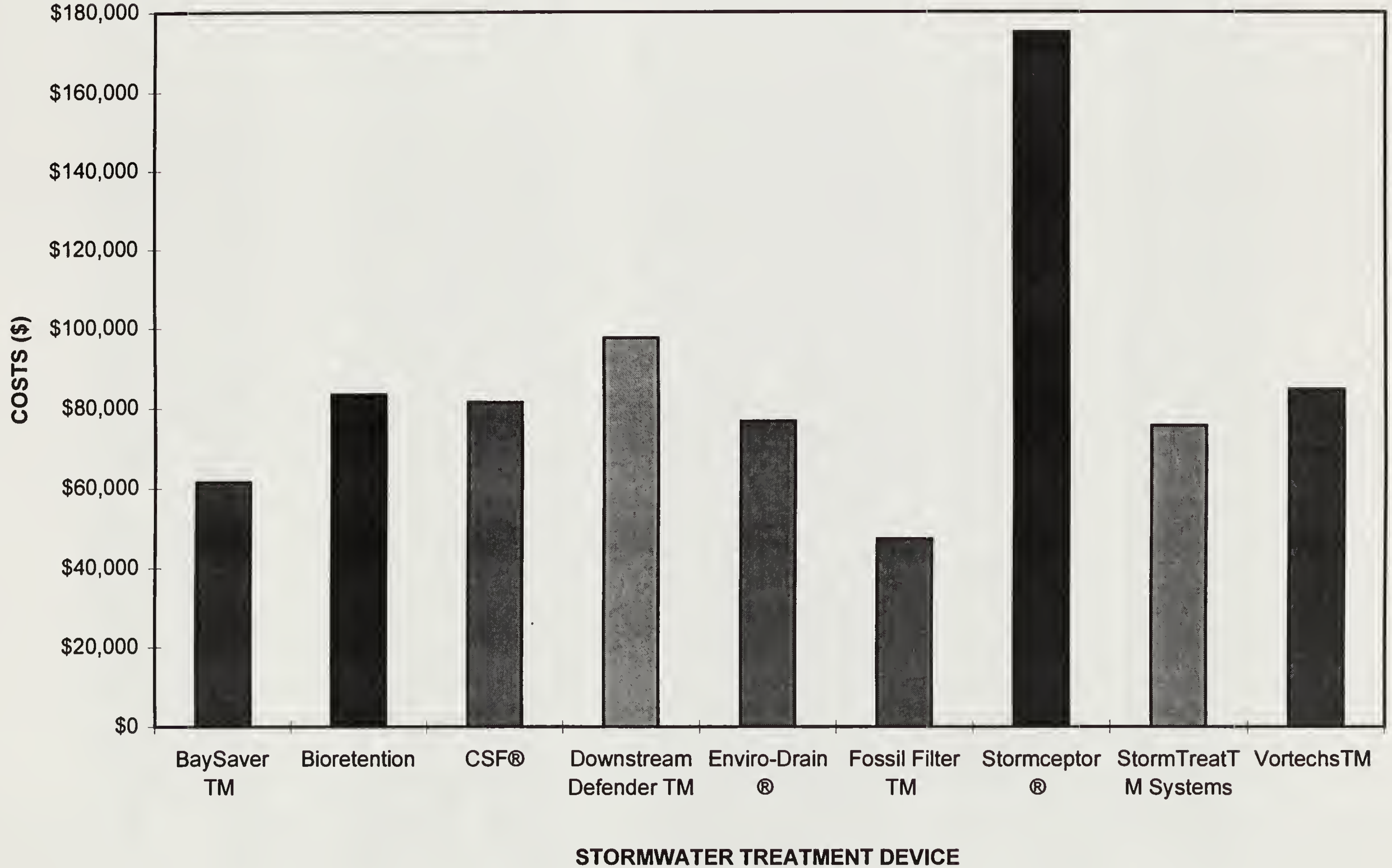


Figure 14. 15 year lifetime cost for
Bat Cave Draw parking lot treatment alternatives
(in 1998 $)

15YRCOST/concost.xls
5/29/98

Associated positive impacts include reduced erosion in Bat Cave Draw for those measures which *store* the first half-inch of rainfall. This results in a reduction of peak storm flows to the receiving streams. Negative impacts include minor increase in the potential for diffuse infiltration from leaks from the system. For some systems an additional negative impact includes the production of hazardous waste for disposal.

All of the BMP technologies are relatively new with the oldest applied technology being only seven years old. For each measure the number of installations and the year of its first installation are also provided. The disturbance to impacted areas includes a temporary closure of a portions of the parking lot for treatment system construction. However most construction times are projected to be less than 1 month in duration.

4. Treatment of rainwater run-off towards Bat Cave Draw from road between
main road and lower parking lot - The run-off towards Bat Cave Draw from the road between the main road and Bat Cave Draw parking lot including outfalls 25 and 26 (drainage area of 0.46 acres) can be collected using curb and gutter on the north side of the road. Curb and gutter are not required on the south side since the road has no crown and pitches the entire road surface to the north. An appropriate treatment measure with spill containment technology can provide measurable pollutant removal and reduce the risk of a visitor caused accidental spill of hazardous material in a sensitive and vulnerable area. Since the existing drainage system is in place and simple in design, an end-of-pipe treatment solution is appropriate with little modification to pavement and drainage structures.

5. Treatment of rainwater run-off from service road near Park offices
Water and fluids from leaks/spills infiltrate from the service road near Park offices (VC area) at the service road (outlet 18). The area is particularly attractive for storm water treatment due to its lack of an appropriate outfall. This outfall is under the same constraints as Bat Cave Draw parking lot and cannot be diverted. Refueling operations also occur in this drainage area. A treatment measure with spill containment can be implemented with little modification to the parking and drainage structures with minimal construction impact. Its small drainage area (0.31 acres) and single outfall would limit treatment costs.

Other Areas
Some of the measures for treating storm water run-off in areas of high risk to the caves, also offer spill containment technology and have applications in other areas of the headquarters area. Site constraints, such as rock excavation and system space requirements limit the application of certain treatment methods. The following descriptions of these other areas are given below, however the selection of the best appropriate treatment system(s) is provided in the recommendations section.

6a. The drainage from the portion of the parking lot west of the VC (Parking Lot No. 2) tributary to Bat Cave Draw (outfalls 14 and 15), examined for diversion to the south face of the escarpment, are excellent candidates for storm water treatment. The drainage areas to these outfalls are much smaller (0.87 vs. 2.3 acres) and less complex than those encountered in Bat Cave Draw parking lot. Treatment for this area can be assumed to be implemented at a much reduced cost than Bat Cave Draw parking lot. Treatment of the storm water run-off in these areas can be assumed to be more cost effective than diversion.

6b. The maintenance area tributary to the southeast (outfall 5), where refueling operations occur, is an appropriate area for a storm water treatment device with both spill containment and high metal pollutant removal efficiency. Since no one treatment measure can achieve both treatment goals, a combined approach to removing the targeted pollutants is necessary.

6c. Water and fluids from leaks/spills infiltrating from service road near Park offices (superintendent/resource management building) are conveyed by the road in the existing drainage flows (upper portion of outfall 10B) associated with Bat Cave Draw with the exception of the small parking lot adjacent to the building. A small storm water inlet, underground pipe and energy dissipation structure at the outfall can provide proper conveyance to eliminate the possibility of any storm water run-off infiltration prior to reaching the parking lot below. Since treatment is provided by the downstream system, no additional measures are required here.

6d. Parking Lot No. 2, outfalls 13, 16 and 17 - would require three separate systems. On-line systems require no disturbance to pavement or existing storm drain structures. These systems would also connect directly to the outfall pipes since there are few siting constraints as existed in Bat Cave Draw.

6e. Parking Lot No. 1, outfalls 19 through 24 - Installing storm water treatment would require five separate systems. On-line systems require no disturbance to pavement or existing storm drain structures. These systems would also connect directly to the outfall pipes since there are few siting constraints as existed in Bat Cave Draw.

6f. Residential housing areas, outfall 1 - Other vulnerable areas identified in the infiltration study can benefit from storm water treatment. A single treatment system could adequately treat all of the storm water run-off from this area. Metals and nutrients are targeted pollutants. Since only minor spills are anticipated, a spill protection system is not a primary concern.

6g. Residential area, outfalls 3 and 4 - Combining the drainage areas by re-grading the small 3 space parking lot, and providing approximately 300 feet of curb and gutter would permit collection and treatment by a single treatment system. For a fraction of the cost to

treat other areas previously identified in the park, the treatment of storm water drainage from these areas (0.55 and 0.32 acres), would complete the list of paved areas tributary to Bat Cave Draw.

The detailed construction, maintenance, engineering and 15-year lifetime costs for all of the above areas with the recommended treatment measures are shown in the Appendix.

Other issues - Some United States post offices are experimenting with bioremediation using organisms that degrade oil and grease sludge in their oil-grease separators. This practice reduces the frequency of expensive clean-outs, saving each site about $1,000 per year (NPS News-Notes, 1997). This strategy should be further investigated for any implemented measures requiring oil and grease disposal and could potentially change the measure's cost effectiveness in comparison to those measures without disposal costs.

Permits - Since storm water discharges from many sources are largely uncontrolled, the Storm Water Program has been implemented under the National Pollutant Discharge Elimination System (NPDES) permitting program to achieve measurable results. Amendments to the Clean Water Act established a two-phased approach to addressing storm water discharges. Phase I, currently being implemented, requires permits for separate storm water systems serving large- and medium-sized communities (those with over 100,000 inhabitants), and for storm water discharges associated with industrial and construction activity involving at least five acres. Since the combined construction activity for all of the measures total less than 5 acres, no national permits are required. Phase II, which is currently under development, will address remaining storm water discharges. Ultimately, millions of potential permittees will be covered, including urban areas with populations under 100,000, smaller construction sites, and retail, commercial, and residential activities.

Accident Mitigation Procedures

Many of the treatment technologies incorporate a valuable spill containment feature which can provide significant benefit to the existing accident mitigation procedures currently available to park staff. With the increased use of conventional containment devices such as curb and gutter, pavement, and pavement sealcoats, a spill containment device can dramatically reduce the level of risk to sensitive areas. The current spill response procedures are adequate for low volume spills but are ill equipped to react effectively to large spills which enter the existing storm drain system or bare ground. A spill containment device is appropriate for areas where fuel handling occurs or where the risk of accidents are high where limited amounts of fuel are present. Some efforts such as increased spill response and hazardous materials training are currently pursued. Park staff could benefit from training on storm water quality protection and use of storm water quality treatment devices.

Management Policies

There are several immediate actions resource managers can initiate to address the current risk to specific locations in the headquarters area. To assist in reducing the threat of a large scale vehicle accident and major accidental fuel spill, prohibiting commercial vehicles would serve to reduce or eliminate the number of tractor trailer rigs and other large commercial trucks currently entering the park.

Reducing the effect of contamination sources impacting the caves could be achieved through implementation of storm water management policies and guidelines for residents. Voluntary restrictions for types of vehicle maintenance and repair, as well as lawn and garden care practices, are helpful to the cause of storm water quality improvement. Also by notifying residents and employees of general spill response action and notification procedures, an informed, appropriate and timely response to accidental spills is permitted.

A passive strategy to potential dumping in the VC and Bat Cave Draw parking lots includes implementation of storm water pollution awareness for visitors through a storm drain stenciling program. The stenciled message next to the storm water inlet informs potential dumpers that the drain leads to sensitive areas (Hunter, 1997). Some stenciling suggestions include:

1. "Dump No Waste! Drains to CAVE!"
2. "Don't Pollute! Water Drains to Ground water!"

The stenciling program also provides education to visitors which may otherwise be unaware of the potential damage that may occur as a result of dumping.

RECOMMENDATIONS

In order to make informed recommendations on storm water treatment measures for an area with a particular land use, it is necessary to identify the pollutant threats associated with that land use and select the most appropriate retrofits to meet those threats.

Treatment systems that have the same inflow and discharge rates are referred to as *on-line* systems. On-line systems which use sedimentation and oil/grease separation technologies are inherently less efficient at higher flows since water turbulence and velocity are higher. Higher velocities can lead to re-suspension of pollutants and poor sedimentation leading to poor pollutant removal efficiencies. This works against the strategies that on-line systems depend on to remove pollutants. Conversely off-line systems capture and store storm water inflow for a delayed period at a reduced discharge. Water retention times can exceed many days before the storage capacity has completely discharged. Off-line systems can provide a higher level of pollutant removal for all storms due to the extended time permitted these devices to remove pollutants.

Pollutant loadings are concentrated in the "first flush" of run-off from impervious areas. The off-line configuration is superior to an on-line system since it captures the full first flush and stores it for time released treatment. The devices which provide extended treatment of storm water run-off through storage of the first half inch of run-off offer the best treatment for nutrient and metal removal. Additionally due to the coincidence of high visitor and vehicle use and high rainfall, the pollutants concentrations present in storm water run-off are not expected to shock natural systems as abruptly as if the pollutants were permitted to build up over extended periods of time. The existence of continual rainfall throughout the year in the park is a benefit to any of the natural systems proposed.

The recommendations are provided below for each of the measures presented.

1. **Tilting the parking lots** is not recommended considering the treatment alternatives available. Pollutant targets for this area include metals, oil and grease. Spill protection is a secondary concern. The storm water diversion strategy for this area does not remove pollutants and is less cost effective than treatment. The initial total costs, including engineering and pavement sealing, for implementation of this diversion measure is $68,200. A treatment alternative is provided in 6a. The initial total costs, including pavement sealing and engineering, for implementation of the CSF® treatment measure is $46,200.

2. **Providing drainage of the maintenance complex** to the north exclusive of any treatment is also not recommended considering the potential for continued contamination. Pollutant loadings from the three maintenance drainage areas are very high and the potential for a hazardous spill is greatest in the headquarters area. The storm water diversion strategy for this area does not remove pollutants or protect underground water

resources from spills. The cost for the diversion measure including engineering with pavement sealing is $88,000. A treatment alternative is provided in 6b. The initial total costs, including pavement sealing and engineering, for implementation of the Stormcepter® and StormTreat SystemsTM treatment measures is $107,800. This represents a 23-percent increase for treatment over the cost diversion. (If the first two diversion alternatives listed above are compared to the recommended treatment measures given in 6a. and 6b., the total cost differential is $2,200 in favor of treatment.)

Some of the technologies evaluated for Bat Cave Draw are not recommended for use in the park. *BaySaver* TM, the newest entry in the field, is a very cost competitive oil/grit separator with spill protection compared to the well established and widely accepted *Stormceptor®*. *Downstream Defender* TM is also a new entry in the storm water treatment market. However without third party evaluation of pollutant removal performance, it is doubtful support could be generated for these new treatment measures with so little market penetration. Both inlet filter treatment measures, *Enviro-Drain® Filters* and *Fossil Filter* TM, although among the least expensive measures evaluated, appear to be ineffectual at removing any pollutants other than oil and grease. *Vortechs* TM also has no third party evaluation of pollutant removal performance and although becoming accepted in the marketplace, is less cost competitive than the *CSF®* system.

The recommendation of treatment measures are based primarily upon pollutant targeting and spill containment and secondarily upon the existing site constraints. Criteria used to determine the application of the accepted treatment measures in any area is given in Table 11.

Recommended BMP	**Application criteria**
1. Bioretention	all areas except 1. areas exposed to extreme wind and temperature 2. areas with rock excavation required 3. areas where parking capacity cannot be reduced. 4. areas requiring a primary need for spill protection 5. areas too small to permit minimum design criteria
2. StormTreat Systems™	all areas except 1. areas exposed to extreme wind and temperature 2. areas requiring a primary need for spill protection
3. CSF®	all areas except 1. areas requiring a primary need for spill protection
4. Stormcepter®	all areas except 1. areas requiring a primary need for high metal pollutant removal

Table 11. Treatment measure application criteria.

These technologies, sharing proven pollutant removal capabilities for the specific application, relatively longer histories and good market acceptance, are proposed at the following locations.

3. Treating the run-off in Bat Cave Draw parking lot towards Bat Cave Draw is the only reasonable alternative for this area due to lack of an appropriate outfall. Since spill containment is a secondary concern for Bat Cave Draw Parking Lot, the selection of an off-line over on-line system satisfies the primary requirement of high pollutant removal efficiencies and added downstream erosion protection. The ability of the off-line measures to remove heavy metals from run-off is proven. Additionally over 85% of the storms occurring in Bat Cave Draw have a total volume less than this run-off amount and therefore the *total volume* is treated with a first-half inch capture strategy (Figure 13) without bypass. Independent of cost considerations, Bioretention or StormTreat Systems™ is recommended as a treatment measure. Either is superior to the others evaluated for Bat Cave Draw parking lot since they are the only off-line measures considered. Although spill protection is a secondary concern in this parking lot, during dry periods these technologies also provide an adequate level of spill protection. They represent the third and fourth least expensive alternatives of the nine measures evaluated for the Bat Cave Draw parking lot (Table 10). Bat Cave Draw also offers a wind protected area for natural systems in the sometimes hot and dry Chihauhaun Desert environment.

Bioretention has the greatest change to the visual impact to the historical landscape compared to the StormTreat™ Systems and is an important consideration. Bioretention creates a green area that may add to the site's visual amenities. By adding a forest community, summer and winter temperatures extremes in this area would be moderated. For bioretention to receive support for selection, expertise in planning and design are critical to the success of this measure. The StormTreat Systems™ consisting of eight wetland tanks (9-foot diamter and 4-foot high) are located next to the rock wall in the arroyo. If the tanks are not deemed attractive to the riparian area, additional screening using native trees could mitigate the visual impact of these treatment devices. However the devices could be a visual amenity since wetland habitats are perceived as beneficial. The initial total costs, including pavement sealing and engineering, for implementation of bioretention is $79,200. For the alternate system, StormTreat Systems™, the cost is $68,200.

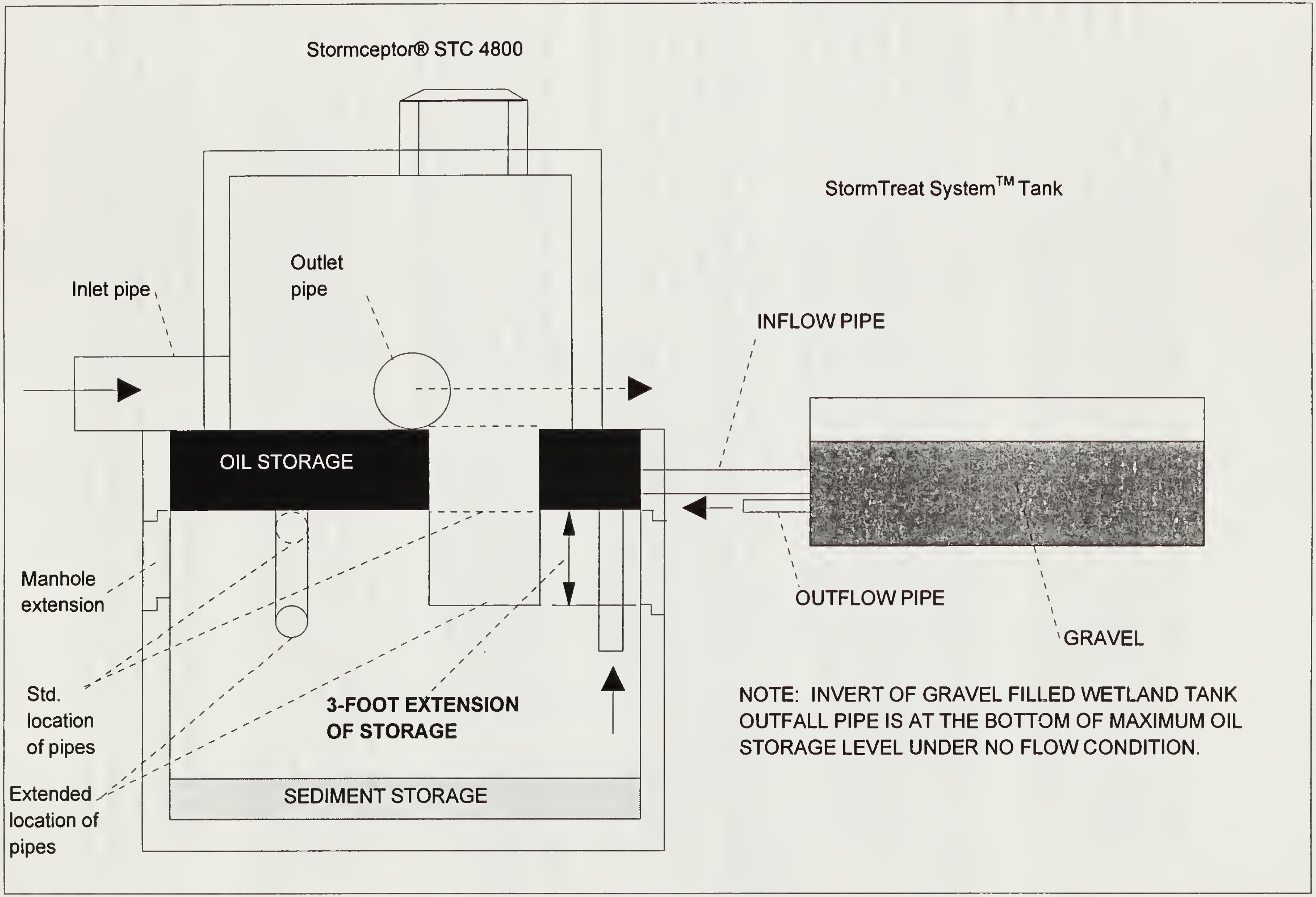
4. Treatment of rainwater run-off towards Bat Cave Draw from road between main road and lower parking lot - Tributary to Bat Cave Draw, this area requires pollutant targeting of metals, oil and grease with a primary emphasis on spill control. Bioretention is infeasable due to extensive rock excavation required on the north side of the road. Stormceptor offers the spill protection in an end-of-pipe solution. The cost for this measure is $48,400.

5. Treatment of rainwater run-off from service road near Park offices - Water and fluids from leaks/spills infiltrate from the service road near Park offices (VC area) at the service road (outlet 18). The area is particularly attractive for storm water treatment due to its lack of an appropriate outfall. This outfall is under the same constraints as Bat Cave Draw parking lot and cannot be diverted. Refueling operations also occur in this drainage area. A treatment measure with spill containment can be implemented with little modification to the parking and drainage structures with minimal construction impact. Its small drainage area (0.31 acres) and single outfall would limit treatment costs. The cost for this measure is $29,700.

Recommended treatment alternatives for other areas identified as contamination sources are presented below.

6a. Treating the run-off for Parking Lot No. 2 tributary to Bat Cave Draw requires pollutant targeting of metals, oil and grease. The CSF® treatment system is recommended for this as well as the remainder of the lot and Parking Lot No. 1. This system has proven high pollutant removal efficiencies for metal, oil, grease and total petroleum hydrocarbons required for the pollutant sources in this area. A natural treatment system (bioretention or StormTreat Systems™) is not recommended for this location due to the increased wind exposure prevalent at the very top of the escarpment. There are no structures or adjacent screening vegetation to provide a protection from prevailing high winds. The use of bioretention would also require the elimination of additional parking spaces in this heavily used lot. Rock excavation would be cost prohibitive for bioretention compared to any of the other accepted measures. Since spill containment is secondary to pollutant removal, no spill containment for this area is proposed. The initial total costs, including pavement sealing and engineering, for implementation of CSF® is $46,200.

6b. Treating the run-off in the Maintenance complex is recommended over diversion of the run-off. Spill protection is a primary concern due to refueling operations conducted in the immediate area. Pollutant targets for this area include high concentrations of metals, oil and grease as well as hazardous substances. No spill protection measure evaluated has any significant metal pollutant removal capability, so a combined strategy using an additional treatment measure is proposed. For outfall 5, the combined use of a Stormcepter® and StormTreat™ Systems is proposed. The Stormcepter® is oversized to permit partial draining of the volume of storage by the StormTreat™ Systems without compromising oil and or sediment storage. The entrance and exit pipes to the oil storage area are extended the three-foot drop required by the StormTreat Systems for treatment. Essentially the Stormcepter® acts as a pretreatment device for the required two StormTreat™ Systems. A cross-section drawing showing the relationship of the two treatment systems is shown in Figure 15. Since spill containment is not a primary concern for outfall 2, it requires only two StormTreat™ Systems and a precast manhole for pretreatment. The initial total costs, including pavement sealing and engineering, for implementation of the combined treatment measures is $107,800.



TreatCeptor/RUNOFF.xls
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Figure 15. Proposed combined treatment system for maintenance area

6c. Water and fluids from leaks/spills infiltrating from service road near Park offices (superintendent/resource management building) Spill protection is a primary concern. Pollutant targets for this area include high concentrations of metals, oil and grease. Pavement sealing and storm water quality treatment are not included in this measure since it is installed under measure 3 and this portion is tributary to those systems. The initial total costs, including engineering, for implementation of the combined treatment measures is $5,500.

6d. Parking Lot No. 2, outfalls 13, 16 and 17 - Spill protection is not a primary concern since refueling operations are not conducted in the immediate area. Pollutant targets for this area include high concentrations of metals, oil and grease. Due to extreme temperature and wind, a natural system is not proposed for these outfalls. The CSF® treatment system has good metal removal efficiencies and excellent oil and grease removal. The initial total costs, excluding pavement sealing and engineering, for implementation of the combined treatment measures is $89,100.

6e. Parking Lot No. 1, outfalls 19 through 24 - Spill protection is not a primary concern since refueling operations are not conducted in the immediate area. Pollutant targets for this area include high concentrations of metals, oil and grease. Due to extreme temperature and wind, a natural system is not proposed for these outfalls. The CSF® treatment system has good metal removal efficiencies and excellent oil and grease removal. The initial total costs, excluding pavement sealing and engineering, for implementation of the combined treatment measures is $121,000.

6f. Residential housing areas, outfall 1 - spill protection is a not primary concern since the area is not a traffic area for hazardous cargo. Pollutant targets for this area include high concentrations of metals, oil and grease. The StormTreat™ System is recommended for this area primarily for the high removal efficiencies of metals and oils. The initial total costs, excluding pavement sealing and engineering, for implementation of the combined treatment measures is $24,200.

6g. Residential housing area, outfalls 3 and 4 - spill protection is also not primary concern since the area is not a traffic area for hazardous cargo. Pollutant targets for this area include high concentrations of metals, oil and grease. The StormTreat™ System is recommended for this area primarily for the high removal efficiencies of metals and oils. The initial total costs, excluding pavement sealing and engineering, for implementation of the combined treatment measures is $18,700.

Based on the performance characteristics of the treatment measures evaluated, their length of performance history, and current level of acceptance in the marketplace, the recommended treatment measures for all areas identified in infiltration study (with an extreme, high, moderate or low vulnerability related to surface run-off) and their total costs are presented in Table 12. The total estimated initial first year implementation cost

Item No.	Treatment Device	Installation costs	Yearly maintenance costs manpower	Yearly maintenance costs equipment	Yearly maintenance costs materials	Yearly hazardous waste disposal costs	Total yearly costs	15 year lifetime cost[c] in 1998 $	Initial construction and engineering costs
1	diversion n/a, see 6a	$0	$0	$0	$0	$0	$0	$0	$0
2	diversion n/a, see 6b	$0	$0	$0	$0	$0	$0	$0	$0
3	Bioretention	$72,000	$680	$0	$425	$0	$1,105	$83,470	$79,200
4	Stormceptor ®	$44,000	$50	$250	$0	$300	$600	$50,228	$48,400
5	Stormceptor ®	$27,000	$50	$250	$0	$300	$600	$33,228	$29,700
6a	CSF®	$42,000	$50	$0	$400	$0	$450	$46,671	$46,200
6b	Stormceptor ® +ST	$98,000	$218	$370	$0	$400	$988	$108,255	$107,800
6c	n/a	$5,000	$0	$0	$0	$0	$0	$5,000	$5,500
6d	CSF®	$81,000	$200	$0	$1,500	$0	$1,700	$98,645	$89,100
6e	CSF®	$110,000	$250	$0	$2,100	$0	$2,350	$134,392	$121,000
6f	StormTreat™ Systems	$22,000	$168	$120	$0	$100	$388	$26,027	$24,200
6g	StormTreat™ Systems	$17,000	$168	$120	$1	$100	$389	$21,038	$18,700
	TOTALS	$518,000	$1,834	$1,110	$4,426	$1,200	$8,570	$606,954	$569,800

NOTES:

(a) Lifetime costs use an annual adjusted interest rate equal to 5%
Engineering costs not included.

n/a not applicable

all costs/concost.xls
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Table 12. Construction, maintenance and engineering costs for all recommended measures.

for the treatment of all paved surfaces in the headquarters area, excluding engineering costs, is $518,000. Including engineering costs the total cost is $569,000.

Accident Mitigation Procedures - With the implementation of any of these or any other measures for storm water quality improvement, additional studies to integrate them with accident mitigation procedures are critical to any spill response developed for the park. Actions should be tailored to the specific device where an accidental spill of hazardous material may occur. Park staff are encouraged to consider the following efforts to maintain an effective response to any hazardous spill occurring within the park.

1. evaluate existing spill response procedures and include use of latest available spill containment and recovery technologies
2. integrate spill response procedures with implementation of any new storm water technology or measures
3. keep response team current through training for spill response and readiness

Management policies and guidelines - Several management actions could significantly reduce the potential for further contamination and risk of a major spill. They may include any of the following:

1. Require all residents to park entirely on asphalt paved surfaces if tributary to a storm water quality structure.
2. Mandatory use of an park provided absorption blanket for oil and radiator fluid changes.
3. Require vehicle maintenance and repair operations to be performed in an area designated area which has wastewater sewer access (this may require such an area to be created specifically for this use).
4. Require all vehicle washing to be performed off park boundaries or in wastewater sewered areas.
5. Require all non-emergency vehicle maintenance and repair to be performed off park boundaries (White City may entertain the lease of appropriate heated space).
6. Request voluntary restricted use of water for outside applications (vehicle washing, lawn and garden use).
7. Request voluntary pesticide/herbicide/fertilizer prohibition for all lawn and garden areas.
8. Install a sign at the park entrance prohibiting commercial vehicles.
9. Implement a storm water stenciling program in visitor parking areas to call visitors attention to a significant source of water quality degradation
10. provide training to park staff about storm water quality technologies and storm water quality protection.

Proper operation and maintenance of the storm sewer system and the storm water pollution control structures is essential to the success of the management program overall.

The effective performance of these program measures hinges on the proper maintenance of the BMPs utilized. Without proper maintenance, BMP performance declines significantly over time, with rates of decline varying by BMP type and site conditions. Maintenance contracts with qualified professionals are the best method to insure consistent and measurable performance.

Water quality testing to monitor the performance of the any BMP installed in the park is recommended to ensure protection of vulnerable resources. Periodic grab samples of inflow and outflow waters tested for a range of pollutant types can help monitor pollutant removal efficiencies. This can provide a valuable source of information to park managers in addressing the contamination problem in Carlsbad Caverns.

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APPENDIX

Existing Storm Water System Assessment

Listed below is a partial list of engineering plans which document the construction of the storm drainage systems currently at the headquarters area. The following storm water system assessment identifies the condition of the entire storm water conveyance system at Carlsbad Caverns N.P. main headquarters area. The analysis was prepared using engineering plans located in the resource management map room and field verification by visual inspection of the system.

Engineering Plans Documentation

General Development Plan, Cavern Entrance Area, Carlsbad Caverns National Monument (drawing no. C81, plans dated April 1928) detailed plans for the 3 terrace 190-space parking lot, and paved service road connecting the parking area to the support buildings, quarters and utility group (maintenance area). Storm drain inlets and pipes are not indicated but appear on a subsequent conceptualized proposed reconstruction of the parking area but not built titled Proposed Parking Area Enlargement (Public Works Project, 1934 F.Y., drawing no. F.P. 119.8, plans dated October 1935).

Proposed Parking Area - Vicinity of Elevator Building, Carlsbad Caverns National Park (drawing no. NP-CC 5317, plans dated October 1939) details the construction of a 4 terrace, 460-space paved parking lot (Parking Area No. 1) and storm water drainage structures, located to the southeast of the elevator building.

Completion Parking Area No. 1, Headquarters Area, Carlsbad Caverns National Park (drawing no. NP-CC 2042, plans dated June 1949) details the construction of concrete walkways, full curb and gutter, and three spillways for Parking Area No. 1 constructed 10 years previous.

Project 1-A, Parking Area No. 2, Walnut Canyon, Carlsbad Caverns National Park, Highways System (proposed plans dated August 1954, as constructed plans date completed 1955) detailed the construction of the upper (western) 3 terrace 315-space paved parking lot, storm drainage structures and wide radius approach road to the visitor center area.

Landscape Development Visitor Center, Headquarters Area, Carlsbad Caverns National Park (drawing no. NP:CC:3103A, plans dated February 1956) details the construction of paved walkways and the visitor center paved service parking area.

Reconstruction Residential Access Road - E (drawing no. NP:CC:3127, plans dated May 1962) details the relocation of the residential access road near the maintenance area and installation of a 30 foot 22"x13" outfall pipe to convey drainage beneath the relocated road.

Residence Area Roads, Headquarters, Carlsbad Caverns National Park (drawing no. NP:CC:3137, plans dated May 1962) details the construction of the paved parking lots for the headquarters building and existing lower residential quarters, service road relocation to the north of the maintenance yard, drainage grate and concrete channel; and paved service and parking for the existing upper and proposed residential quarters.

Current Condition

As a whole the existing storm drain piping is in good condition with limited surface corrosion and minor damage to the metal end sections at the outfalls in the form of slight deformation. No video was taken to determine the condition of the interior of the piping system which remains unknown.

The increased velocity and volume of storm water generated from impervious paved areas has created erosion in the outfall areas and is most visible at the outfalls from both VC parking lots (No. 1 and No. 2).

Nearly all of the piping outfalls are partially blocked with sediment in the form of sand and rocks. Storm drain blockages have previously occurred in the housing areas (specifically the stair drains for quarters 25) causing flooding to apartment spaces warranting removal of debris. The outfall from the dormitory parking area (Bldg. 13) is nearly totally blocked with sediment and requires removal of debris.

Repaving operations in the Bat Flight parking area have changed the pavement cross slope redirecting storm flows away from one storm drain inlet (12.) bypassing its usefulness. Regrading of the pavement surface to redirect a nearby concentrated surface flow into the storm drain inlet would permit relief of excess flows to the next downstream inlet. However leaving this drainage condition would permit the collection of this area at the next downstream inlet (11) and since no paved area is tributary to inlet 12, it would require no storm water quality device.

The concrete swale which conveys the majority of the maintenance yard run-off towards Bat Cave Draw has heavy deposits of soil, dead organic matter and appears to contain oil residues. Since the swale is open and relatively steep, cleaning and disposal of this material is not recommended since it appears to trap some pollutants providing some level of pollution abatement prior to infiltration.

The concrete swale that conveys the drainage between the grate inlets receiving drainage from the Qtrs. 51-60 areas is damaged and incomplete permitting direct infiltration into underlying soils prior to the outfall.

List of Technology Manufacturers

BaySaver TM	BaySaver, Inc. 1010 Deer Hollow Drive, Suite 111 Mt. Airy, MD 21771	Mark Hausner (301) 829-6119
Bioretention	Prince George's County, Maryland Department of Environmental Resources Division of Environmental Management Watershed Protection Branch 9400 Peppercorn Place, Suite 600 Landover, MD 20785	Maura McMullen (301) 883-7158
	Biohabitats Incorporated 15 West Aylesbury Road Timonium, MD 21093	J. Keith Bowers (301) 337-3659
CSF®	Storm water Management 2035 N.E. Columbia Blvd. Portland, OR 97211	Felon Wilson, P.E. 1-800-548-4667
Downstream Defender TM	H.I.L. Technologies 94 Hutchins Drive Portland, ME 04102	John Bolata 1-800-848-2706
Enviro-Drain® Filters	Enviro-Drain 13226 97th Avenue, NE, C208 Kirkland, WA 98034.	Jim Hutter 206-820-1953
Fossil Filter TM	KriStar Enterprises, Inc. 422 Larkfield Center, Suite 271 Santa Rosa, CA 95403	Doug Allard 1-800 579-8819
Stormceptor®	Stormceptor Corporation 600 Jefferson Plaza Suite 304 Rockville, MD 20852	Vincent Berg, P.E. 1-800-762-4703

StormTreat Systems TM	StormTreat Systems, Inc. 90 Route 6A, Sextant hill Unit 1 Sandwich, MA 02563	Mark Nelson (508) 833-1033
Vortechs TM	Vortechnics, Inc. 41 Evergreen Dr. Portland, ME 04103	Francis Tighe (207) 878-3662

Cost Estimates

Measure 1. Tilting the parking lots, outfalls 14 and 15

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT COST	COST	NOTES
1	pavement sealcoat	4,227	S.Y.	$1	$4,227	petroleum resistant, non-skid
2	pavement demolition	104	S.Y.	$7	$731	incl. hauling & disposal
3	curb/gutter demolition	30	L.F.	$7	$210	incl. hauling & disposal
4	rockwork excavation	103	C.Y.	$310	$32,033	
5	24" CMP	310	L.F.	$34	$10,540	excl. bedding, backfill
6	pipe bedding, backfill	67	C.Y.	$15	$1,009	incl. compaction
7	connections	4	EA.	$200	$800	
8	asphalt pavement repair	940	S.F.	$2	$1,880	6" base, 2" binder, 1" topping
9	curb and gutter	30	L.F.	$13	$390	6" high, t" gutter, 24" wide
10	rehab/reseeding	35	S.Y.	$3	$105	
11	pavement painting	20	TAL	$5	$100	
12	contingencies (10%)				$1,999	items 1-3, 5-11 only
13	overhead and profit (15%)				$7,804	items 1-11 only
	total project cost				$61,828	items 1-13
	total (rounded to nearest $1,000)				**$62,000**	
	additional maintenance				**$0**	per year
	engineering (10%)				**$6,200**	
					$68,200	total cost w/o maintenance

Measure 2. Providing drainage of the maintenance complex, outfalls 2 and 5

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT COST	COST	NOTES
1	pavement sealcoat	4,390	S.Y.	$1	$4,390	petroleum resistant, non-skid
2	curb and gutter	305	L.F.	$13	$3,965	6" high, 6" gutter, 24" wide
3	4' wide concrete swale	170	L.F.	$26	$4,420	6" depth, 2' wide channel
4	2' wide asphalt berm	10	L.F.	$5	$50	3" height
5	asphalt pavement	6,285	S.F.	$2	$12,570	6" base, 2" binder, 1" topping
6	pavement demolition	45	S.Y.	$7	$315	incl. hauling & disposal
7	rockwork excavation	112	C.Y.	$310	$34,843	
8	15" CMP	210	L.F.	$14	$2,940	excl. bedding, backfill
9	pipe bedding, backfill	103	C.Y.	$15	$1,543	incl. compaction
10	4' deep concrete manhole	1	EA.	$534	$534	precast, 4' deep, 4' I.D.
11	manhole frame & cover	1	EA.	$285	$285	24" dia., heavy traffic
12	4' deep catch basin	1	EA.	$534	$534	precast, 4' deep, 4' I.D.
13	curb inlet frame, grate	1	EA.	$650	$650	heavy duty, incl. curb box
14	contingencies (10%)				$3,220	items 1-5, 7-12 only
15	overhead and profit (15%)				$10,056	items 1-12 only
	total project cost				$80,314	items 1-14
	total (rounded to nearest $1,000)				**$80,000**	
	additional maintenance				**$0**	per year
	engineering (10%)				**$8,000**	
					$88,000	total cost w/o maintenance

Construction, maintenance, and engineering
costs for measures 1 and 2
(Means, 1997)

costs1,2/concost.xls
5/29/98

Measure 3b. Treating the run-off in Bat Cave Draw parking lot using BaySaver®, outfalls 6 - 12

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT COST	COST	NOTES
1	pavement sealcoat	11,144	S.Y.	1	$11,144	petroleum resistant, non-skid
2	"1K" separator unit	2	EA.	$3,990	$7,980	
3	"3K" separator unit	1	EA.	$5,990	$5,990	
4	pavement demolition	34	S.Y.	$7	$238	incl. hauling & disposal
5	excavation	38	C.Y.	$5	$189	incl. hauling & disposal
6	8' deep concrete manhole	4	EA.	$860	$3,440	precast, 8' deep, 4' ID, f&c incl.
7	8' deep concrete manhole	2	EA.	$1,796	$3,592	precast, 8' deep, 5' ID, f&c incl.
8	outfall pipe	3	EA.	$500	$1,500	
9	4' deep catch basin	1	EA.	$534	$534	precast, 4' deep, 4' I.D.
10	curb inlet frame, grate	1	EA.	$650	$650	heavy duty, incl. curb box
11	close curb inlets	3	EA.	$50	$150	
12	connections	7	EA.	$200	$1,400	
13	asphalt pavement repair	34	S.F.	$3	$102	6" base, 2" binder, 1" topping
14	contingencies (10%)				$3,691	items 1-13
15	overhead and profit (15%)				$5,536	items 1-13
	total project cost				$46,135	items 1-15
	total (rounded to nearest $1,000)				**$46,000**	
	additional maintenance				**$1,500**	per year
	engineering (10%)				**$4,600**	
					$50,600	total cost w/o maintenance

Measure 3b. Treating the run-off in Bat Cave Draw parking lot using Bioretention, outfalls 6 - 12

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT COST	COST	NOTES
1	pavement sealcoat	10,182	S.Y.	$1	$10,182	petroleum resistant, non-skid
2	pavement demolition	1,295	S.Y.	$7	$9,067	incl. hauling & disposal
3	asphalt pavement	3,000	S.F.	$2	$6,000	6" base, 2" binder, 1" topping
4	excavation	1,040	C.Y.	$4	$4,160	compacted fill
5	4" PVC underdrain	936	L.F.	$5	$4,680	schedule 40, perforated
6	pipe connections	6	EA.	$50	$300	
7	planting soil	1,040	C.Y.	2	$2,080	
8	sodding	1.728	.S.F	$529	$914	
9	trees	46	EA.	$175	$8,058	36" diameter rootball
10	shrubs	115	EA.	$50	$5,756	24" diameter rootball
11	tree installation	46	EA.	$45	$2,072	36" diameter rootball
12	shrubs installation	115	EA.	$28	$3,223	24" diameter rootball
13	mulch, aged barks	260	S.Y.	$5	$1,300	3" depth, hand spread
14	contingencies (10%)				$5,779	items 1-13
15	overhead and profit (15%)				$8,669	items 1-13
	total project cost				$72,240	items 1-15
	total (rounded to nearest $1,000)				**$72,000**	
	additional maintenance				**$1,105**	per year
	engineering (10%)				**$7,200**	
					$79,200	total cost w/o maintenance

Construction, maintenance, and engineering costs for measures 3a. and 3b. (Means, 1997)

Measure 3c. Treating the run-off in Bat Cave Draw parking lot using CSF®, outfalls 6 - 12

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT COST	COST	NOTES
1	pavement sealcoat	11,144	S.Y.	1	$11,144	petroleum resistant, non-skid
2	8x14 w 7 RFC's	1	EA.	$24,000	$24,000	CSF® organic filter media
3	8x6 w 4 RFC's	1	EA.	$13,000	$13,000	CSF® organic filter media
4	crane rental, 33 ton	1	DAY	$835	$835	
5	pavement demolition	30	S.Y.	$7	$212	incl. hauling & disposal
6	excavation	65	C.Y.	$5	$326	incl. hauling & disposal
7	18" CMP, 16 gauge	40	L.F.	$20	$800	excl. bedding, backfill
8	pipe bedding, backfill	12	C.Y.	$15	$183	incl. compaction
9	outfall pipe	2	EA.	$500	$1,000	
10	4' deep catch basin	2	EA.	$534	$1,068	precast, 4' deep, 4' I.D.
11	curb inlet frame, grate	2	EA.	$650	$1,300	heavy duty, incl. curb box
12	close curb inlets	2	EA.	$50	$100	
13	connections	3	EA.	$200	$600	
14	asphalt pavement repair	308	S.F.	$3	$924	6" base, 2" binder, 1" topping
15	contingencies (10%)				$5,549	items 1-14
16	overhead and profit (15%)				$8,324	items 1-14
	total project cost				$69,364	items 1-16
	total (rounded to nearest $1,000)				**$69,000**	
	additional maintenance				**$1,200**	per year
	engineering (10%)				**$6,900**	
					$75,900	total cost w/o maintenance

Measure 3d. Treating the run-off in Bat Cave Draw parking lot using Downstream Defender TM, outfalls 6 - 12

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT COST	COST	NOTES
1	pavement sealcoat	11,144	S.Y.	1	$11,144	petroleum resistant, non-skid
2	Downstream Defender™	1	EA.	$19,000	$19,000	6-foot diameter, polypropelene
3	Downstream Defender™	2	EA.	$15,000	$30,000	4-foot diameter, polypropelene
4	crane rental, 12 ton	1	DAY	$435	$435	
5	pavement demolition	15	S.Y.	$7	$105	incl. hauling & disposal
6	excavation	22	C.Y.	$5	$110	incl. hauling & disposal
7	outfall pipe	3	EA.	$500	$1,500	
8	4' deep catch basin	2	EA.	$534	$1,068	precast, 4' deep, 4' I.D.
9	curb inlet frame, grate	2	EA.	$650	$1,300	heavy duty, incl. curb box
10	close curb inlets	2	EA.	$50	$100	
11	connections	3	EA.	$200	$600	
12	asphalt pavement repair	33	S.F.	$3	$100	6" base, 2" binder, 1" topping
13	contingencies (10%)				$6,546	items 1-12
14	overhead and profit (15%)				$9,819	items 1-12
	total project cost				$81,827	items 1-14
	total (rounded to nearest $1,000)				**$82,000**	
	additional maintenance				**$1,500**	per year
	engineering (10%)				**$8,200**	

Construction, maintenance, and engineering costs for measures 3c. and 3d. (Means, 1997)

costs3c,d/concost.xls
5/29/98

Measure 3e. Treating the run-off in Bat Cave Draw parking lot using Enviro-Drain ®, outfalls 6 - 12

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT COST	COST	NOTES
1	pavement sealcoat	11,144	S.Y.	1	$11,144	petroleum resistant, non-skid
2	pavement demolition	20	S.Y.	$7	$140	incl. hauling & disposal
3	filter installation, 3 tray	14	EA.	$1,800	$25,200	18"x36", 2 required per inlet
4	excavation	20	C.Y.	$5	$100	incl. hauling & disposal
5	4' deep catch basin	7	EA.	$534	$3,738	precast, 4' deep, 4' I.D.
6	curb inlet frame, grate	7	EA.	$650	$4,550	heavy duty, incl. curb box
7	connections	7	EA.	$200	$1,400	
8	asphalt pavement repair	40	S.F.	$3	$120	6" base, 2" binder, 1" topping
9	contingencies (10%)				$4,639	items 1-8
10	overhead and profit (15%)				$6,959	items 1-8
	total project cost				$57,990	items 1-10
	total (rounded to nearest $1,000)				**$58,000**	
	additional maintenance				**$1,808**	per year
	engineering (10%)				**$5,800**	
					$63,800	total cost w/o maintenance

Measure 3f. Treating the run-off in Bat Cave Draw parking lot using Fossil Filter TM, outfalls 6 - 12

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT COST	COST	NOTES
1	pavement sealcoat	11,144	S.Y.	1	$11,144	petroleum resistant, non-skid
2	pavement demolition	20	S.Y.	$7	$140	incl. hauling & disposal
3	filter installation	7	EA.	$850	$5,950	30"x30" round w/ silt basin
4	excavation	20	C.Y.	$5	$100	incl. hauling & disposal
5	4' deep catch basin	7	EA.	$534	$3,738	precast, 4' deep, 4' I.D.
6	curb inlet frame, grate	7	EA.	$650	$4,550	heavy duty, incl. curb box
7	connections	7	EA.	$200	$1,400	
8	asphalt pavement repair	40	S.F.	$3	$120	6" base, 2" binder, 1" topping
9	contingencies (10%)				$2,714	items 1-8
10	overhead and profit (15%)				$4,071	items 1-8
	total project cost				$33,928	items 1-10
	total (rounded to nearest $1,000)				**$34,000**	
	additional maintenance				**$1,280**	per year
	engineering (10%)				**$3,400**	
					$37,400	total cost w/o maintenance

Construction, maintenance, and engineering
costs for measures 3e. and 3f.
(Means, 1997)

Measure 3g. Treating the run-off in Bat Cave Draw parking lot using Stormceptor ®, outfalls 6 - 12

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT COST	COST	NOTES
1	pavement sealcoat	11,144	S.Y.	1	$11,144	petroleum resistant, non-skid
2	STC 900, precast	1	EA.	$8,500	$8,500	7.6' deep, 6' I.D., f&c incl.
3	STC 3600, precast	1	EA.	$17,500	$17,500	11.6' deep, 8' I.D., f&c incl.
4	STC 4800, precast	2	EA.	$23,000	$46,000	13.5' deep, 10' I.D., f&c incl.
5	STC 7200, precast	1	EA.	$34,500	$34,500	14.2' deep, 12' I.D., f&c incl.
6	pavement demolition	52	S.Y.	$7	$364	incl. hauling & disposal
7	excavation	194	C.Y.	$5	$972	incl. hauling & disposal
8	outfall pipe	1	EA.	$500	$500	
9	4' deep catch basin	3	EA.	$534	$1,602	precast, 4' deep, 4' I.D.
10	curb inlet frame, grate	3	EA.	$650	$1,950	heavy duty, incl. curb box
11	close curb inlets	3	EA.	$50	$150	
12	connections	6	EA.	$200	$1,200	
13	asphalt pavement repair	392	S.F.	$3	$1,176	6" base, 2" binder, 1" topping
14	contingencies (10%)				$12,556	items 1-13
15	overhead and profit (15%)				$18,834	items 1-13
	total project cost				$156,947	items 1-15
	total (rounded to nearest $1,000)				**$157,000**	
	additional maintenance				**$1,740**	per year
	engineering (10%)				**$15,700**	
					$172,700	total cost w/o maintenance

Measure 3h. Treating the run-off in Bat Cave Draw parking lot using StormTreat Systems™, outfalls 6 - 12

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT COST	COST	NOTES
1	pavement sealcoat	11,144	S.Y.	1	$11,144	petroleum resistant, non-skid
2	treatment tank	8	EA.	3,510	$28,080	
3	installation cost	8	EA.	$750	$6,000	
4	pavement demolition	7	S.Y.	$7	$46	incl. hauling & disposal
5	excavation	14	C.Y.	$5	$71	incl. hauling & disposal
6	8' deep concrete manhole	3	EA.	$860	$2,580	precast, 8' deep, 4' ID, f&c incl.
7	manhole inlet frame/grate	3	EA.	$650	$1,950	heavy duty
8	asphalt pavement repair	7	S.F.	$3	$21	6" base, 2" binder, 1" topping
9	contingencies (10%)				$4,989	items 1-8
10	overhead and profit (15%)				$7,484	items 1-8
	total project cost				$62,365	items 1-10
	total (rounded to nearest $1,000)				**$62,000**	
	additional maintenance				**$1,312**	per year
	engineering (10%)				**$6,200**	
					$68,200	total cost w/o maintenance

Construction, maintenance, and engineering costs for measures 3g. and 3h. (Means, 1997)

Measure 3i. Treating the run-off in Bat Cave Draw parking lot using VortechsTM, outfalls 6 - 12

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT COST	COST	NOTES
1	pavement sealcoat	11,144	S.Y.	1	$11,144	petroleum resistant, non-skid
2	model 1000	2	EA.	$10,500	$21,000	
3	model 3000	1	EA.	$14,500	$14,500	
4	crane rental, 33 ton	1	DAY	$835	$835	
5	pavement demolition	29	S.Y.	$7	$201	incl. hauling & disposal
6	excavation	63	C.Y.	$5	$314	incl. hauling & disposal
7	outfall pipe	3	EA.	$500	$1,500	
8	4' deep catch basin	2	EA.	$534	$1,068	precast, 4' deep, 4' I.D.
9	curb inlet frame, grate	2	EA.	$650	$1,300	heavy duty, incl. curb box
10	close curb inlets	2	EA.	$50	$100	
11	connections	3	EA.	$200	$600	
12	asphalt pavement repair	231	S.F.	$3	$692	6" base, 2" binder, 1" topping
13	contingencies (10%)				$5,325	items 1-12
14	overhead and profit (15%)				$7,988	items 1-12
	total project cost				$66,569	items 1-14
	total (rounded to nearest $1,000)				**$67,000**	
	additional maintenance				**$1,700**	per year
	engineering (10%)				**$6,700**	
					$73,700	total cost w/o maintenance

Measure 4. Treatment of rainwater run-off towards Bat Cave Draw from road between main road and lower parking lot, outfalls 25 and 26

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT COST	COST	NOTES
1	pavement sealcoat	2,222	S.Y.	1	$2,222	petroleum resistant, non-skid
2	curb and gutter	250	L.F.	$13	$3,250	6" high, t" gutter, 24" wide
3	STC 4800, precast	1	EA.	$23,000	$23,000	13.5' deep, 10' I.D., f&c incl.
4	crane rental, 33 ton	1	DAY	$835	$835	
5	outfall pipe	1	EA.	$500	$500	
6	rockwork excavation	18	C.Y.	$310	$5,728	
7	contingencies (10%)				$3,554	items 1-5
8	overhead and profit (15%)				$5,330	items 1-6
	total project cost				$44,420	items 1-7
	total (rounded to nearest $1,000)				**$44,000**	
	additional maintenance				**$600**	per year
	engineering (10%)				**$4,400**	
					$48,400	total cost w/o maintenance

costs3i4/concost.xls
5/29/98

Construction, maintenance, and engineering
costs for measures 3i and 4a
(Means, 1997)

Measure 5. Treatment of rainwater run-off from service road near Park offices (VC), outfall 18

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT COST	COST	NOTES
1	pavement sealcoat	1,502	S.Y.	1	$1,502	petroleum resistant, non-skid
2	STC 2400, precast	1	EA.	$13,500	$13,500	13.5' deep, 10' I.D., f&c incl.
3	crane rental, 33 ton	1	DAY	$835	$835	
4	excavation	17	C.Y.	$310	$5,212	incl. hauling & disposal
5	outfall pipe	1	EA.	$500	$500	
6	connections	1	EA.	$200	$200	
7	contingencies (10%)				$2,175	items 1-3, 5-6
8	overhead and profit (15%)				$3,262	items 1-6
	total project cost				$27,187	items 1-8
	total (rounded to nearest $1,000)				**$27,000**	
	additional maintenance				**$600**	per year
	engineering (10%)				**$2,700**	
					$29,700	total cost w/o maintenance

Measure 6a. Treating the run-off for Parking Lot No. 2 tributary to Bat Cave Draw using CSF®, outfalls 14

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT COST	COST	NOTES
1	pavement sealcoat	4,227	S.Y.	1	$4,227	petroleum resistant, non-skid
2	8x6 w 4 RFC's	2	EA.	$13,000	$26,000	CSF® organic filter media
3	crane rental, 33 ton	1	DAY	$835	$835	
4	outfall pipe	2	EA.	$500	$1,000	
5	rockwork excavation	4	C.Y.	$310	$1,240	
6	contingencies (10%)				$3,330	items 1-5
7	overhead and profit (15%)				$4,995	items 1-5
	total project cost				$41,627	items 1-7
	total (rounded to nearest $1,000)				**$42,000**	
	additional maintenance				**$450**	per year
	engineering (10%)				**$4,200**	
					$46,200	total cost w/o maintenance

Measure 6b. Treating the run-off in Maintenance area using Stormceptor ®/StormTreat™, outfalls 2 and 5

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT COST	COST	NOTES
1	pavement sealcoat	4,390	S.Y.	$1	$4,390	petroleum resistant, non-skid
2	curb and gutter	305	L.F.	$13	$3,965	6" high, 6" gutter, 24" wide
3	4' wide concrete swale	170	L.F.	$26	$4,420	6" depth, 2' wide channel
4	2' wide asphalt berm	10	L.F.	$5	$50	3" height
5	asphalt pavement	6,285	S.F.	$2	$12,570	6" base, 2" binder, 1" topping
6	STC 4800, precast	1	EA.	$23,000	$23,000	16' deep, 10' I.D., f&c incl.
7	treatment tank	4	EA.	3,510	$14,040	
8	installation cost	4	EA.	$750	$3,000	
9	4' deep concrete manhole	1	EA.	$534	$534	precast, 4' deep, 4' I.D.
10	24" outlet extension pipe	3	FT	15	$45	plastic
11	10" drop tee extension	3	FT	8	$24	plastic
12	manhole extension	3	L.F.	300	$900	10' diameter
13	rockwork excavation	26	C.Y.	$310	$8,095	incl. hauling & disposal
14	connections	4	EA.	$200	$800	
15	4' deep catch basin	1	EA.	$534	$534	precast, 4' deep, 4' I.D.
16	curb inlet frame, grate	1	EA.	$650	$650	heavy duty, incl. curb box
17	close curb inlets	1	EA.	$50	$50	
18	outfall pipe	2	EA.	$500	$1,000	
19	contingencies (10%)				$7,807	items 1-12, 14-18
20	overhead and profit (15%)				$11,710	items 1-18
	total project cost				$97,584	items 1-20
	total (rounded to nearest $1,000)				**$98,000**	
	additional maintenance				**$988**	per year
	engineering (10%)				**$9,800**	
					$107,800	total cost w/o maintenance

Measure 6c. Treating the run-off for from service road near Park offices (RM Bldg.)

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT COST	COST	NOTES
1	outfall pipe	1	EA.	$500	$500	
2	4' deep catch basin	1	EA.	$534	$534	precast, 4' deep, 4' I.D.
3	curb inlet frame, grate	1	EA.	$650	$650	heavy duty, incl. curb box
4	close curb inlets	1	EA.	$50	$50	
5	outfall pipe	1	EA.	$200	$200	
6	15" CMP	70	L.F.	$14	$980	excl. bedding, backfill
7	pipe anchors	8	EA.	$100	$800	
8	connections	1	EA.	$200	$200	
9	contingencies (10%)				$391	items 1-5
10	overhead and profit (15%)				$587	items 1-5
	total project cost				$4,893	items 1-7
	total (rounded to nearest $1,000)				**$5,000**	
	additional maintenance				**$0**	per year
	engineering (10%)				**$500**	
					$5,500	total cost w/o maintenance

Measure 6d. Treating the run-off in Parking Lot No. 2, outfalls 13, 16 and 17

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT COST	COST	NOTES
1	pavement sealcoat	11,144	S.Y.	1	$11,144	petroleum resistant, non-skid
2	8x14 w 7 RFC's	1	EA.	$24,000	$24,000	CSF® organic filter media
3	8x6 w 4 RFC's	2	EA.	$13,000	$26,000	CSF® organic filter media
4	crane rental, 33 ton	1	DAY	$835	$835	
5	pipe connections	3	EA.	$200	$600	
6	rock excavation	6	CY	$310	$1,860	
7	contingencies (10%)				$6,444	items 1-6
8	overhead and profit (15%)				$9,666	items 1-6
	total project cost				$80,549	items 1-8
	total (rounded to nearest $1,000)				**$81,000**	
	additional maintenance				**$1,700**	per year
	engineering (10%)				**$8,100**	
					$89,100	total cost w/o maintenance

Measure 6e. Treating the run-off for Parking Lot No. 1, outfalls 19 through 24

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT COST	COST	NOTES
1	pavement sealcoat	11,144	S.Y.	1	$11,144	petroleum resistant, non-skid
2	8x14 w 8 RFC's	2	EA.	$24,000	$48,000	CSF® organic filter media
3	8x6 w 5 RFC's	1	EA.	$13,000	$13,000	CSF® organic filter media
4	crane rental, 33 ton	1	DAY	$835	$835	
5	pipe connections	3	EA.	$200	$600	
6	rock excavation	8	CY	$310	$2,595	
7	24" CMP	150	L.F.	$34	$5,100	excl. bedding, backfill
8	pipe bedding, backfill	14	C.Y.	$310	$4,318	incl. compaction
9	pipe connections	4	EA.	$200	$800	
10	4' deep catch basin	1	EA.	$534	$534	precast, 4' deep, 4' I.D.
11	curb inlet frame, grate	1	EA.	$650	$650	heavy duty, incl. curb box
12	close curb inlets	1	EA.	$50	$50	
13	contingencies (10%)				$8,763	items 1-12
14	overhead and profit (15%)				$13,136	items 1-12
	total project cost				$109,525	items 1-14
	total (rounded to nearest $1,000)				**$110,000**	
	additional maintenance				**$2,350**	per year
	engineering (10%)				**$11,000**	
					$121,000	total cost w/o maintenance

Measure 6f. Treating the run-off for Residential housing areas, outfall 1

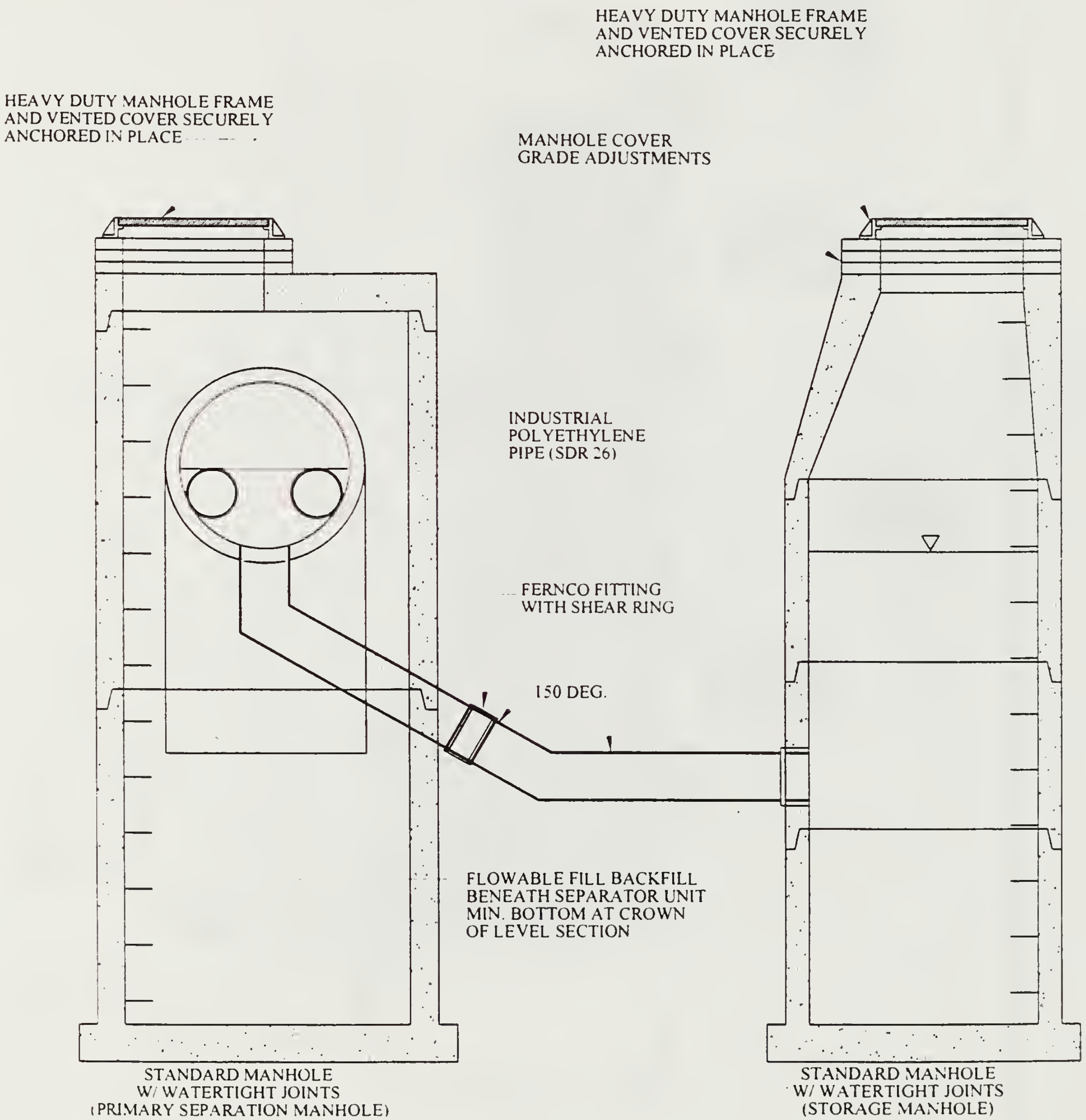
ITEM NO.	ITEM	QUANTITY	UNIT	UNIT COST	COST	NOTES
1	pavement sealcoat	2,656	S.Y.	1	$2,656	petroleum resistant, non-skid
2	treatment tank	2	EA.	3,510	$7,020	
3	installation cost	2	EA.	$750	$1,500	
4	pavement demolition	7	S.Y.	$7	$46	incl. hauling & disposal
5	rock excavation	5	C.Y.	$310	$1,470	incl. hauling & disposal
6	8' deep concrete manhole	1	EA.	$860	$860	precast, 8' deep, 4' ID, f&c incl.
7	manhole inlet frame/grate	1	EA.	$650	$650	heavy duty
	2' wide concrete swale	150	FT	$23	$3,450	1' bottom width, trapezoid
8	asphalt pavement repair	40	S.F.	$3	$120	6" base, 2" binder, 1" topping
9	contingencies (10%)				$1,777	items 1-8
10	overhead and profit (15%)				$2,666	items 1-8
	total project cost				$22,214	items 1-10
	total (rounded to nearest $1,000)				**$22,000**	
	additional maintenance				**$388**	per year
	engineering (10%)				**$2,200**	
					$24,200	total cost w/o maintenance

Measure 6g. Treating the run-off for Residential housing area, outfalls 3 and 4

ITEM NO.	ITEM	QUANTITY	UNIT	UNIT COST	COST	NOTES
1	pavement sealcoat	1,553	S.Y.	1	$1,553	petroleum resistant, non-skid
2	treatment tank	2	EA.	3,510	$7,020	
3	installation cost	2	EA.	$750	$1,500	
4	pavement demolition	7	S.Y.	$7	$46	incl. hauling & disposal
5	rock excavation	5	C.Y.	$310	$1,550	incl. hauling & disposal
6	8' deep concrete manhole	1	EA.	$860	$860	precast, 8' deep, 4' ID, f&c incl.
7	manhole inlet frame/grate	1	EA.	$650	$650	heavy duty
8	asphalt pavement repair	7	S.F.	$3	$21	6" base, 2" binder, 1" topping
9	contingencies (10%)				$1,320	items 1-8
10	overhead and profit (15%)				$1,980	items 1-8
	total project cost				$16,500	items 1-10
	total (rounded to nearest $1,000)				**$17,000**	
	additional maintenance				**$389**	per year
	engineering (10%)				**$1,700**	
					$18,700	total cost w/o maintenance

Standard Drawings

Section B B



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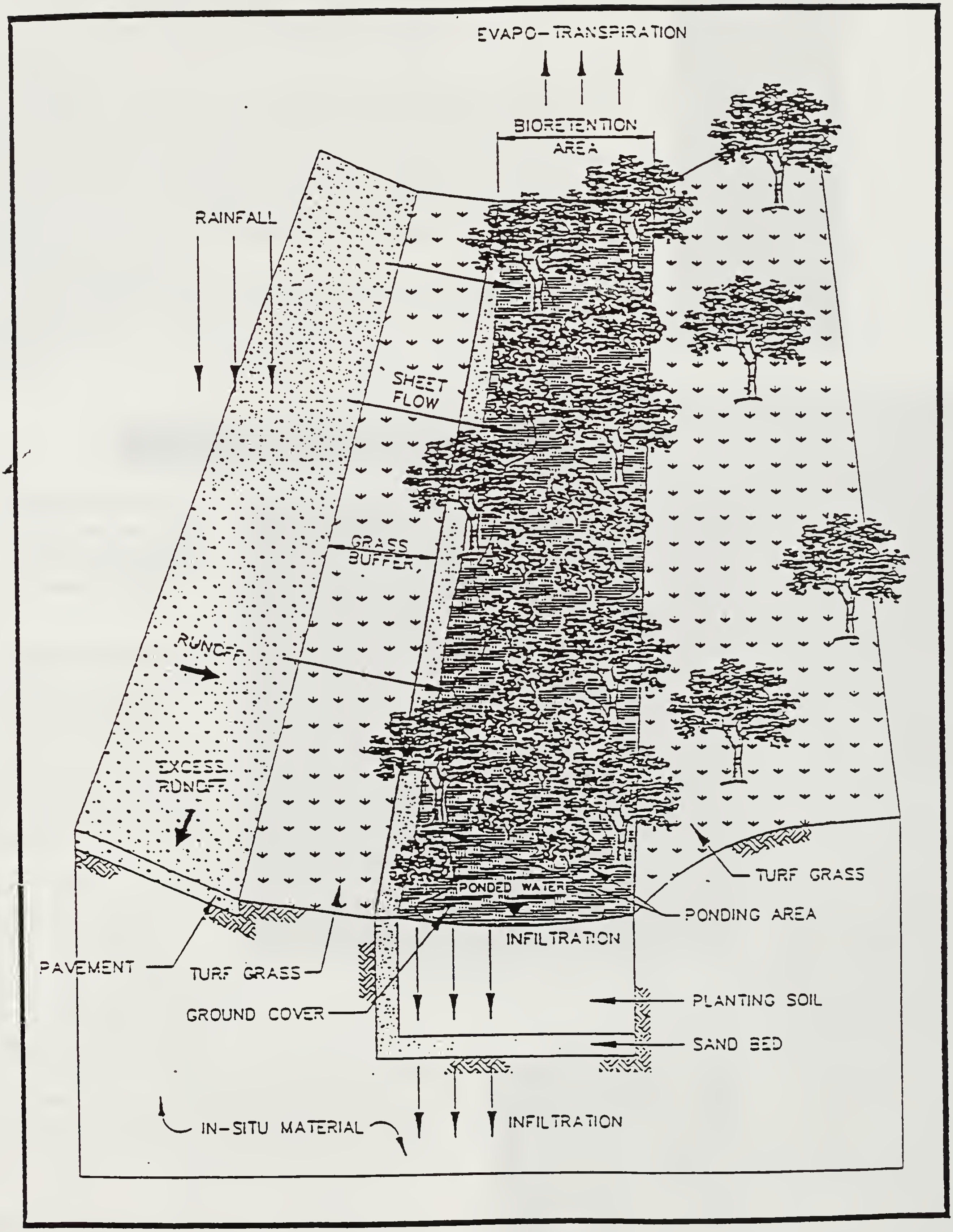


Figure II.1 Bioretention Area Conceptual Layout

H.I.L. Technology, Inc. offers a cost-effective alternative for treating stormwater runoff.

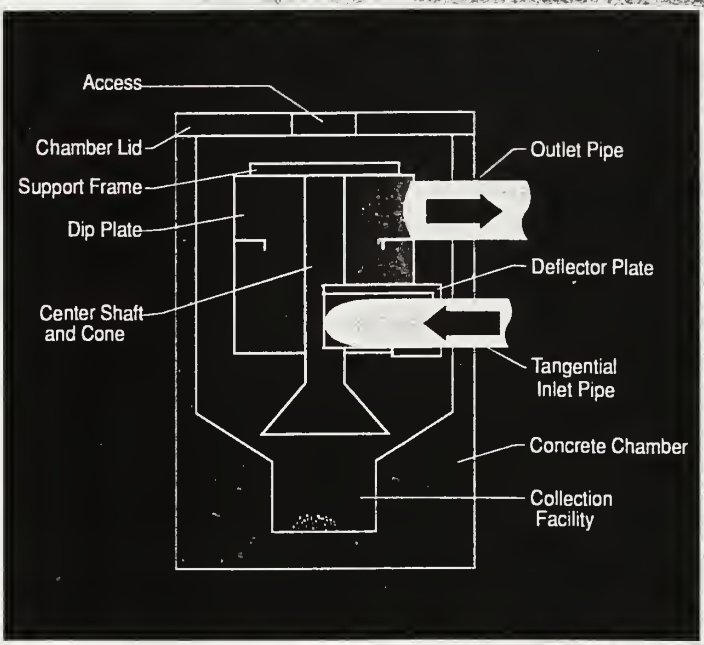
The Downstream Defender™ is a treatment device designed to capture settleable solids, floatables, oils and grease from stormwater runoff. More versatile than conventional stormwater treatment systems, Downstream Defenders require a fraction of the land area of storage tanks and detention ponds. Standard sizes are available, each designed to treat a predetermined design flow to a predetermined solids removal efficiency based on particular solids grading curves.

The Downstream Defender is simple, effective, and economical.

SIMPLE

How it Works

The Downstream Defender consists of a concrete cylindrical vessel with a sloping base and internal components.



Diagrammatic Cutaway

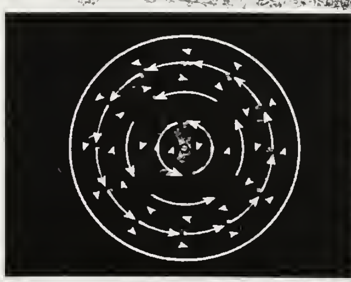
Raw liquid is introduced tangentially into the side of the cylinder and spirals down the perimeter allowing heavier particles to settle out by gravity and the drag forces on the wall and base of the vessel.

The base of the Downstream Defender is formed at a 30 degree angle. As the flow rotates about the vertical axis, solids are directed towards the base of the vessel where they are stored in the collection facility. The internal components direct the main flow away from the perimeter and back up the middle of the vessel as a narrower spiraling column rotating at a slower velocity than the outer downward flow.

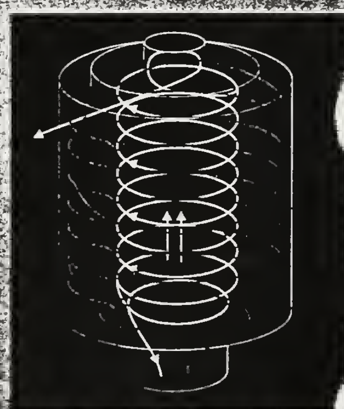
A dip plate is suspended from the underside of a component support frame. This dip plate serves two purposes: 1.) It locates the shear zone, the interface between the outer downward circulation and the inner upward circulation where a marked difference in velocity encourages solids separation and 2.) It establishes a zone between it and the outer wall for floatables, oil and grease capture.

By the time the flow reaches the top of the vessel, it is virtually free of solids and is discharged through the outlet pipe.

A simple sump vac procedure is used to periodically remove the floatables and solids from the collection facility.



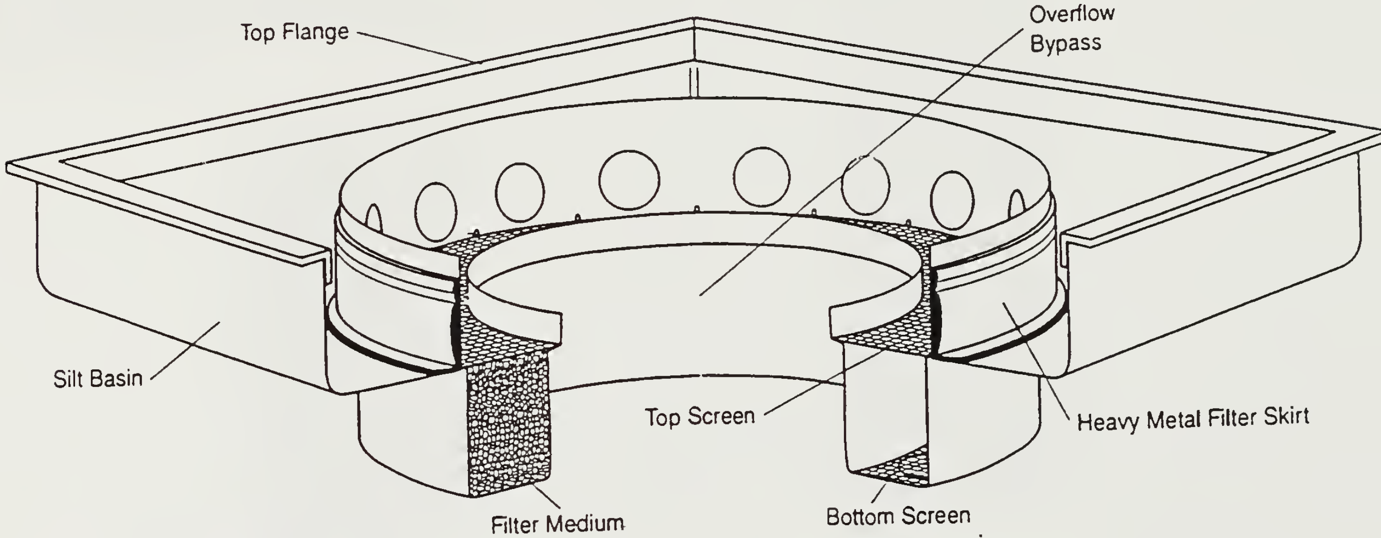
Flow Pattern Plan View



Flow Pattern Profile

FOSSIL FILTER™
WITH SILT BASIN

PATENT PENDING



FEATURES:

★ Provides the same high removal rate of harmful petroleum hydrocarbons as original Fossil Filter™ design PLUS it removes dangerous heavy metals and bothersome silt and debris

★ Silt basin decreases maintenance requirements by collecting silt and debris

★ Heavy Metal Filter Skirt material is treated to remove heavy metals

★ Fiberglass construction provides long life

★ Easy, one-piece, drop-in installation

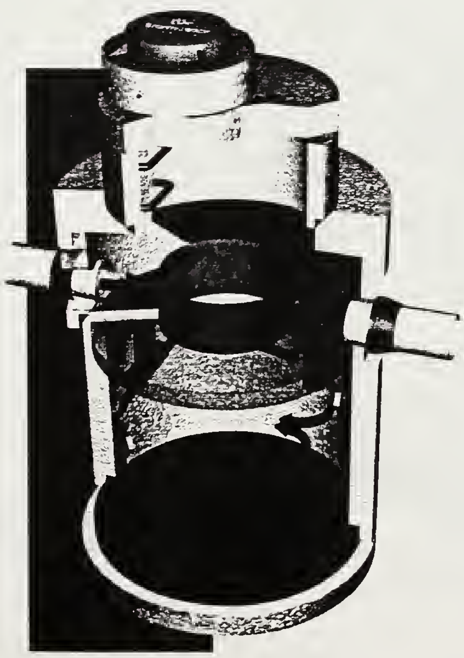
★ Will not impede hydraulic flows

For more information on this dynamic product and to locate a Fossil Filter™ Representative near you please call:

DESIGN AND OPERATION

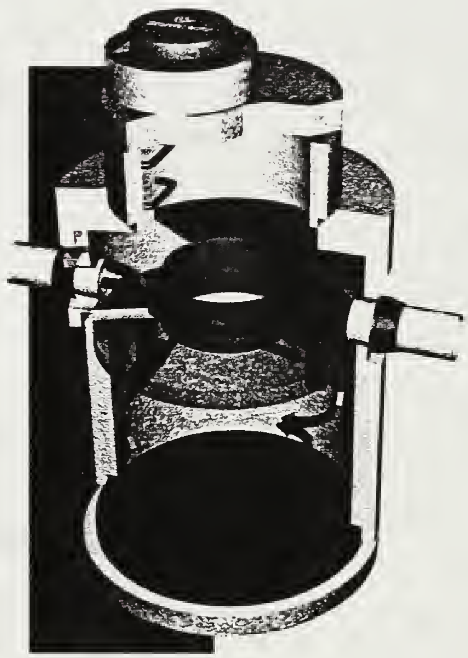
The utility-patented Stormceptor consists of three sections: a "separation/storage" chamber at the bottom, a "bypass" chamber above, and a central maintenance shaft that rises through both to street level.

Under normal, or "design flow" operating conditions, stormwater flows into the upper bypass chamber, is diverted by a v-shaped weir down a pipe, and into the "separation/holding" chamber. This downward flow is directed, by right-angled outlets, around the circular walls of the chamber, and flows horizontally to the outlet pipe. Above and below this throughflow, oil and sediment accumulate in relative quiescence. Up to 80% of the inflowing fines and coarse sediment load settles down to the floor of the chamber, while the petroleum products and volatile vapours rise and become trapped.



DOES NOT SCOUR

During high flow periods –which represent approximately 15% of all events –storm water surges flood over the diverting weir and continue through the bypass chamber into the downstream sewer. This rapid activity creates pressure equalization across the bypass chamber, thus decreasing flow through the separation chamber which will prevent scouring. A proportion of incoming sediment continues to hit the weir and collect in the lower chamber where it remains, with any residual petroleum products, for scheduled removal.



StormTreat™ System InfoCard | Stormwater Treatment Solution

Complies With Water Quality Standards

The StormTreat System meets EPA's recommended 80% removal of Total Suspended Solids (TSS) it can be easily sized to meet more stringent state standards in critical water resource areas. The StormTreat System removes a broad range of pollutants including bacteria, petroleum hydrocarbons, metals, and nutrients.

Saves Space

The StormTreat System significantly reduces the need for unsightly and land-intensive detention facilities. It captures and treats all of the smaller (routine) storms and treats the first flush of the large (less common) storms. Therefore, flood control can be accomplished by using landscape buffers and or smaller detention facilities.

Cost Effective

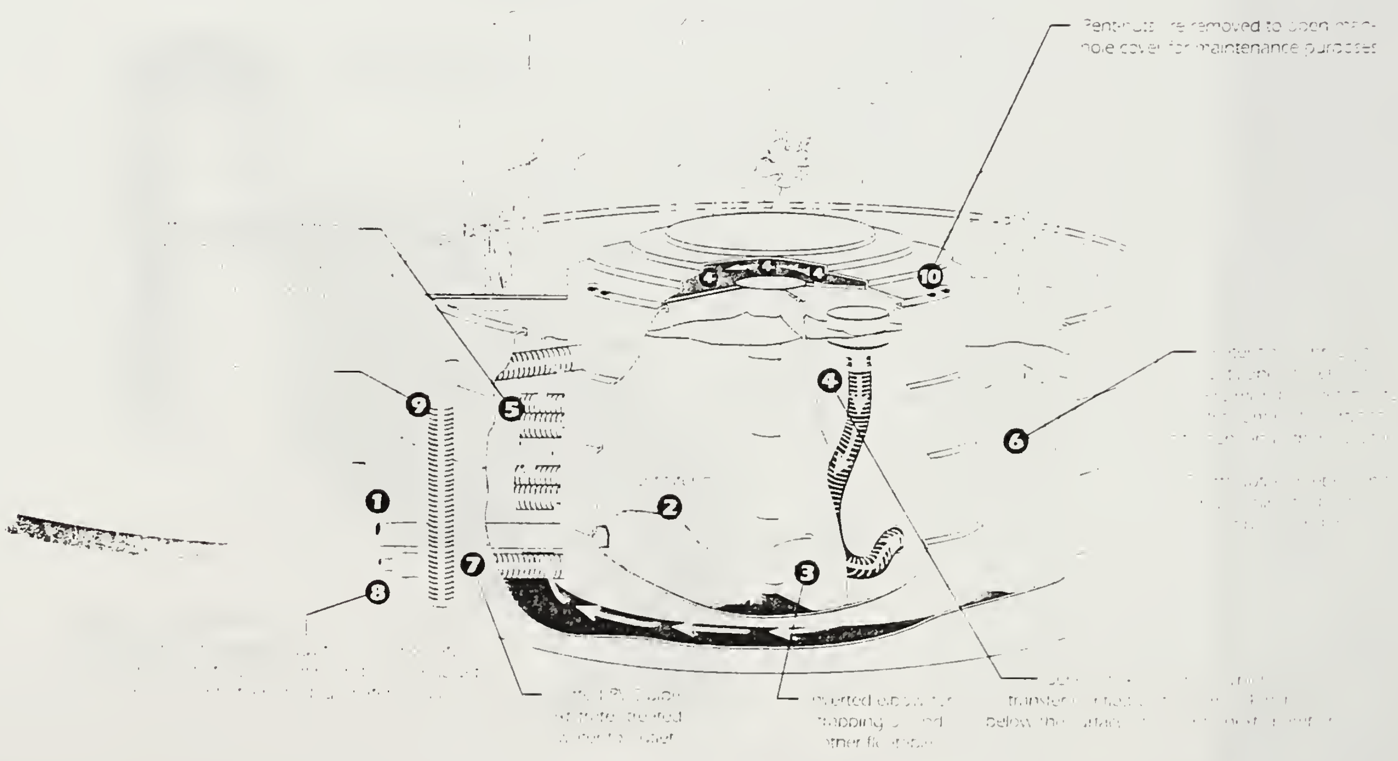
By providing highly efficient treatment of the first flush, the StormTreat System compares favorably with other stormwater BMPs on a per-acre treated basis.

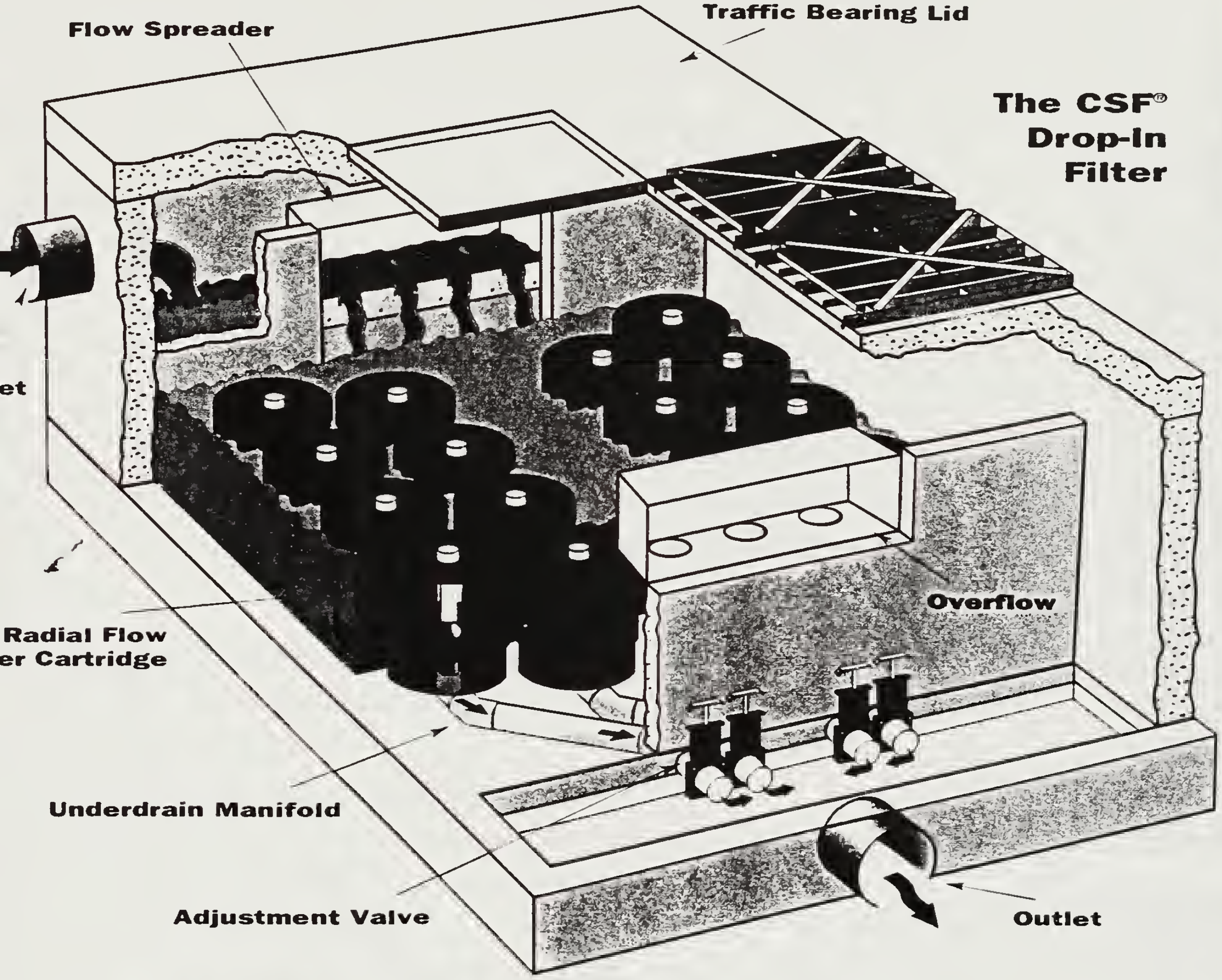
Low Maintenance

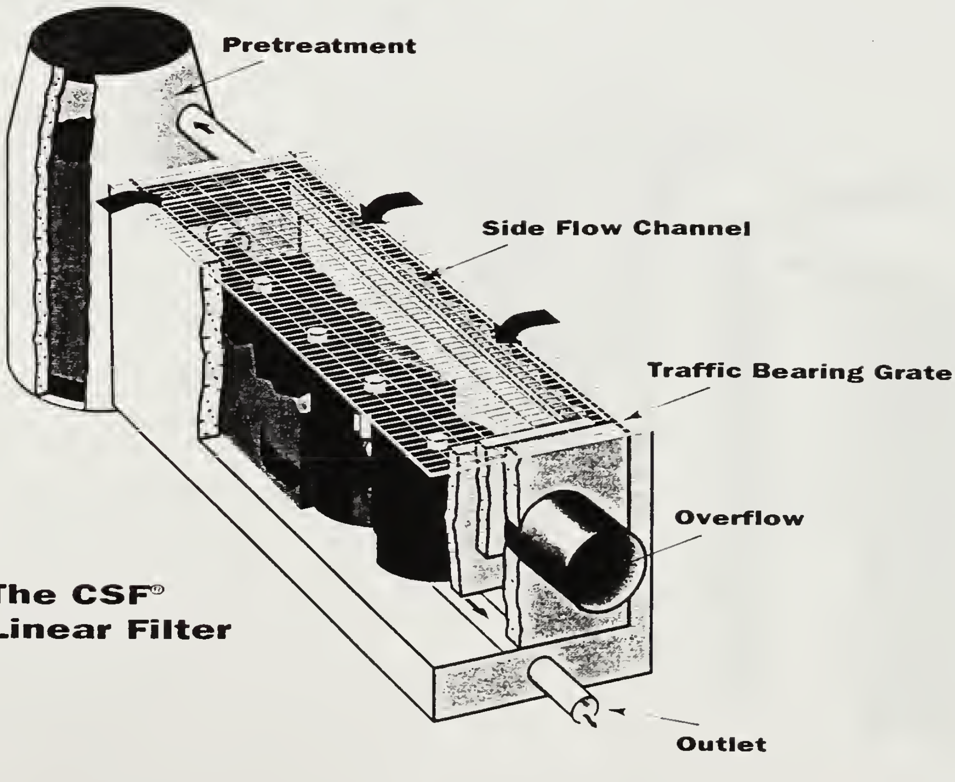
Maintenance is simplified by standardized procedures and is limited to:

a) Annual inspections (and replacement of grit filter bag)
b) Sediment pumping once every three to five years using standard septic system pumper.

Maintenance contracts are available.




Flow Spreader
Traffic Bearing Lid
The CSF® Drop-In Filter
et
Radial Flow
er Cartridge
Overflow
Underdrain Manifold
Adjustment Valve
Outlet


Pretreatment
Side Flow Channel
Traffic Bearing Grate
Overflow
The CSF® Linear Filter
Outlet


Who would
have thought
that using
Autumn leaves
could clean up
pollution in
our rivers and
streams?

Stormwater Treatment System

What are your site's stormwater treatment criteria? If the list includes high pollutant removal efficiencies, minimal land consumption, and easy access for monitoring and maintenance, your options have just been significantly narrowed. The Vortechs Stormwater Treatment System, a major advancement in oil and grit separator technology, efficiently removes grit, contaminated sediments, metals, hydrocarbons and floating contaminants from surface runoff.

The Vortechs System's innovative design combines swirl-concentrator and flow-control technologies to eliminate turbulence within the system. These features ensure proper physical separation and capture of sediment and oils – even at flow rates of up to 25 cfs – and preventing resuspension and release of trapped pollutants.

- Large capacity system provides an 80% net TSS removal rate for the design storm – not just during the "first flush"
- Installs below grade, minimizing land use
- Custom-built of precast concrete near the job site
- Low pump-out volume and one-point access reduce maintenance costs
- Unique baffle design prevents oils and other floatables from escaping the system during cleanout

"We have worked with Vortechnics on at least a dozen stormwater management plans for some of our largest corporate clients. Their efficient turnaround on our requests for technical support and CADD drawings has expedited the permitting process for our clients. We turn to Vortechnics when we need innovative stormwater solutions."

– Lawrence Marsiglio, P.E.
Senior Civil Engineer,
Barakos-Landino, Inc.

Vortechs Systems may be used in a wide range of water-quality improvement applications, including:

Wetlands/Waterfront Protection

Retail Development

Industrial Sites

Municipal Improvements

Commercial Development

CSO Abatement

Transportation Facilities

Existing Site Retrofits