Appendix C - Upstream Detention Storage Alternative Supporting Technical Information

Regional Detention Storage Costs

Supporting Technical Information

Regional detention basin cost estimates in Chapter 4 were developed based on review of several construction cost estimates for similar storage basins around the Bay Area. Reviewed cost estimates were adjusted to the October 2005 ENR CCI of 8404 for the City and County of San Francisco. Based on the review, a unit cost of $3.00 per gallon was established for the regional detention basin construction cost estimates for the Vista Grande Watershed Study. The sampled Bay Area storage cost estimates included the following projects:

Storage Description	Storage Volume (MG)	Construction Cost Estimate[1]	Unit Cost ($/gal)
Watsonville Clearwell Partially buried, cast-in-place concrete storage tank. Includes groundwater drainage system. 90% design level cost estimate. Non-urban construction. June 2005 ENR CCI of 8282. (RMC Water and Environment, 2005)	0.5	$800,000	$1.60
San Francisco Recycled Water Clearwell Partially buried, concrete storage tank. Planning level cost estimates for urban construction. March 2005 ENR CCI of 8227. (SFPUC, 2005)	5.0	$15,400,000	$3.08
EBMUD Wet Weather Facilities Storage Basin[2] Storage basin with pumping equipment on Alameda Island. 1985 ENR CCI of 5100. (CDM, 1985)	3.0	$11,200,000	$3.73
Presidio Water Recycling Project Underground storage in the Presidio, a part of the Golden Gate National Recreation Area. 2002 ENR CCI of 7660. (The Presidio Trust, 2002)	0.5	$9,100,000	$18.20

Footnotes:

1. Construction cost estimate includes project contingencies but does not include implementation costs such as engineering, permitting, or environmental compliance.
2. The EBMUD cost estimate from 1985 may not account for more restrictive permitting, mitigation, or restoration requirements.

MEMORANDUM

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Date: May 15, 2005
To: Roxanne Stachon, RMC, Inc.
From: Gus Yates, consulting hydrologist
Cc:
Subject: Preliminary Evaluation of Groundwater Recharge Benefits from Proposed Stormwater Detention Basins in Daly City

Additional stormwater detention basins in Daly City offers the dual benefits of decreased peak flood flows and increased groundwater recharg. This memorandum describes the results of simulated operations for seven prospective stormwater detention ponds using a daily time step over a 34-year simulation period. The purpose of the simulations was to estimate the average annual groundwater recharge benefit and the sensitivity of that benefit to selected key parameters such as the permeability of the pond bottom and the rate at which water is actively pumped out of the basin following a storm event.

The average annual groundwater recharge benefit for the seven ponds is on the order of 580 acre-feet per year (or 190 million gallons). This is equivalent to approximately 14% of the annual amount of groundwater pumped by Daly City for municipal supply purposes.

Pond, Rainfall and Soils Data

Seven potential pond locations have been identified within the overall watershed area of Daly City's Vista Grande stormwater drainage system. These are locations where site conditions appear favorable for pond construction or previous stormwater management simulations have identified a need for additional storage capacity. The locations are shown in Figure 1, and some of the basic dimensions of the ponds and their respective watershed areas are listed in Table 1. The proposed pond capacities range from 0.9 to 35.7 million gallons (mgal), and the watershed areas range from 29 to 1,025 acres. Some of the watershed areas overlap, but this analysis treats them all independently. The ratio of watershed area to pond capacity affects pond storage operations significantly and varies by a factor of 8 among the proposed ponds.

Table 2 lists several global parameters needed to simulate pond operations. An empirical rainfall-runoff coefficient was calculated using data from a temporary rainfall and runoff gaging program for Vista Grande Canal implemented between December 1998 and April 1999 (TRS, Inc. 1999). A regression of daily runoff versus daily rainfall for 17 rain days produced a quite linear relationship with a slope of 0.45 and a Y intercept of zero, as shown in Figure 2. The regression coefficient (r-squared) was 0.93.

It was assumed that inflow to the ponds would be a lateral diversion from a major storm drain by means of a connecting pipe with a limited conveyance capacity. Design work has not advanced to the point of specifying these pipe capacities. A capacity of 100 cubic feet per second (cfs) was selected for this analysis, which was sufficiently large that it did not significantly constrain the recharge benefit.

Groundwater recharge accrues from seepage through the bottom of the pond. However, pond geometry has not yet been specified. For the purposes of this preliminary analysis, ponds were assumed to be 8 feet deep and have vertical side walls. Percolation was assumed to occur only through the bottom of the pond, and the basal area was obtained by dividing pond volume by pond depth. The resulting basal areas are listed in Table 1.

The nearest rain gage with a long historical record of daily rainfall is at San Francisco airport. Daily data were obtained for October 1959 through September 2003 (water years 1960-2003). These daily values were multiplied by 1.06 which is the ratio of average annual rainfall in the Vista Grande watershed to average annual rainfall at the airport, according to an isohyetal map developed by Phillips and others (1993).

Soil permeability data were obtained from the soil survey for San Mateo County (Natural Resource Conservation Service, 19__). Soils in Daly City are loams that are not as permeable as the sandy soils present in San Francisco's Sunset District a few miles to the north. The most common permeability rates for soils in the Vista Grande watershed are 0.2-0.6 inches per hour (in/hr).

Operations Model

A spreadsheet operations model was developed that simulates the operation of a single stormwater detention pond on a daily basis during water years 1960-2003. The model simulates runoff, diversion into the stormwater pond, percolation out the bottom of the pond, pond storage, and active pumping from the pond back into the stormwater main to accelerate draining of the pond. Average annual groundwater recharge was calculated from the daily percolation volumes.

Stormwater runoff in Daly City is rapid, with peaks that develop and pass within the span of an hour or two. Daily data smoothes these peaks and tends to overestimate the amount of water that can be diverted into the stormwater pond (assuming a limited conveyance capacity between the stormwater main and the pond). The model includes an adjustment to estimate the "capturable" fraction of daily runoff. Rainfall recorded at 15-minute intervals for 17 rainy days during water year 1999 were converted to runoff rates in cfs for each pond, given the watershed area and runoff coefficient. The rainfall intensity corresponding to the maximum diversion rate into the pond was identified and the percentage of daily rainfall volume that occurred at rates greater than this maximum was considered not capturable. This percentage varied considerably from storm to storm and pond to pond but was almost always greater than 90 percent for the assumed 100-cfs diversion capacity. Accordingly, a multiplier of 0.9 was applied to the rainfall data to omit the water that would not be capturable.

In the model, diversions from the storm drain into the pond are limited by the available flow in the storm drain, the capacity of the connecting pipe, and the vacant storage capacity in the pond. Percolation out of the pond is limited by the percolation rate (assumed to be constant) and the current storage volume of the pond. Finally, the amount of water pumped out of the pond each day is limited by the current storage volume and the pump capacity. After calculating each of these flows for a given day, the model updates the pond storage volume and proceeds to the next day.

An illustration of simulation results is presented in Figure 3, which shows hydrographs of daily storage in the Franklin School pond during six selected wet seasons. This particular simulation assumed a percolation rate of 0.2 in/hr and a pump-out capacity sufficient to empty the pond in 1 week assuming no further rainfall (898 gpm). Figure 4 is a bar graph showing the annual volume of groundwater recharge from the pond during the simulation period.

Sensitivity of Recharge Benefit to Watershed Area/Pond Capacity Ratio

The size of the detention pond relative to its tributary watershed area affects the percentage of runoff that can be captured, on a daily and average annual basis. For example, the pond with the largest ratio of watershed area to pond capacity is the I-280 cloverleaf pond, which was capable of percolating only 22 percent of runoff on an average annual basis. At the opposite extreme, the middle pond on Lake Merced Golf Club was capable of percolating 59% of runoff.

Sensitivity of Recharge Benefit to Percolation Rate

The percolation rate through the bottom of the pond strongly affects the average annual recharge benefit and the size of the pump required to empty the pond within a specified number of days. These relationships are shown in Table 3. Part A of the table shows that the pump capacity required to empty a full pond in 1 week (in the absence of rainfall during that period) drops off steeply with increasing percolation rate. In fact, with a percolation rate of 0.6 in/hr, seepage alone will drain an 8-foot-deep pond in 7 days. With percolation rates of 0.2 or 0.4 in/hr, seepage would drain the pond in 20 or 10 days, respectively.

The recharge benefit decreases with decreasing percolation rate because a larger percentage of pond water is removed by pumping rather than percolation. A three-fold decrease in percolation rate decreases average annual percolation by approximately a factor of 3. The graph at the bottom of the table illustrates these tradeoffs using the Franklin School pond as an example.

Sensitivity of Recharge Benefit to Pump-Out Rate

Pumps were assumed to be needed in order to evacuate the storage capacity of the ponds before the arrival of another rain storm. A one-week evacuation time was assumed as the default target for the simulations described above. The adequacy of this rate was explored by checking to see how full the pond was on the day before each of the ten largest rainfall events during the simulation period. Table 4 lists the previous-day simulated storage for each event for a range of assumed pump-out rates. The events are ranked from largest to smallest and the previous-day storage of the pond is expressed as a percentage of pond capacity. The values shown use the Westlake shopping center pond as an example, with pump-out rates ranging from 0.5 to 20 cfs. For comparison, the pumping rate needed to empty this pond in 1 week is 5.1 cfs (2,300 gpm). With a pumping rate of only 0.5 cfs, the pond would have been empty the day before only two of the ten storm events and would have been more than half full the day before five of the events. Increasing the pump-out rate decreases the previous-day storage. With a pump-out rate of 5 cfs, the pond is empty immediately before six of the ten events, but for one event it would still be 86% full.

A closer inspection of the rainfall timeseries for these large events revealed that extremely high daily rainfall amounts sometimes occur in close succession. For example, the second-largest daily rainfall total during the simulation period (4.07 inches on January 21, 1967) was immediately preceded by the 30th largest rainfall total (1.91 inches on January 20, 1967). Similarly, the fifth largest rainfall total (2.62 inches on October 13, 1962) occurred only two days after the ninth largest rainfall total (2.38 inches on October 11, 1962). Obviously, very large pumping plants would be required to vacate the pond capacity between such closely-spaced storm events.

Increasing the pump-out rate inevitably decreases the groundwater recharge benefit. In the example shown in Table 4, average annual recharge with a pump-out rate of 10 cfs is only half the amount of recharge with a pump-out rate of 0.5 cfs.

Conclusions and Recommendations

The following conclusions can be drawn from this analysis:

! The groundwater recharge benefits of percolation from stormwater detention ponds could potentially amount to a modest but significant percentage of Daly City's annual groundwater use. Using reasonable assumptions regarding hydrologic conditions and design parameters, the seven ponds considered in this analysis might contribute 14% of the groundwater use.

! The average annual recharge amount is affected by a number of variables, most notably the ratio of watershed area to pond capacity, the percolation rate and the pond pump-out rate.

! The rate at which pond storage needs to be evacuated following a rainfall event should be considered in the overall context of the storm drain system and the targets for flood management. Simulation of selected major events using a system-wide model and 15-minute time steps would help determine the optimal pump-out rate given the higher costs and lower recharge benefits associated with increased pumping capacity.

! Groundwater recharge benefits are quite sensitive to the percolation rate through the bottom of the ponds. Geotechnical investigations should be completed at proposed sites to improve the estimate of vertical permeability of near-surface alluvial materials. The rate at which percolation rates would decrease due to clogging of the pond bed should be estimated based on published results for similar areas and measurements of soil texture and the suspended sediment content of Daly City runoff. In the present analysis, the normal decline in permeability was roughly acknowledged by assuming an average permeability toward the low end of the range published in the soil survey.

References

Natural Resource Conservation Service. 19__. Soil survey of San Mateo County. U. S. Department of Agriculture. Washington, D.C.

Phillips, S.P., S.N. Hamlin and E.B. Yates. 1993. Geohydrology, water quality, and estimation of ground-water recharge in San Francisco, California, 1987-92. Water-Resources Investigations Report 93-4019. U.S. Geological Survey. Sacramento, CA.

TRS, Inc. 1999. Vista Grande flow monitoring study. Prepared for the City of Daly City, CA.

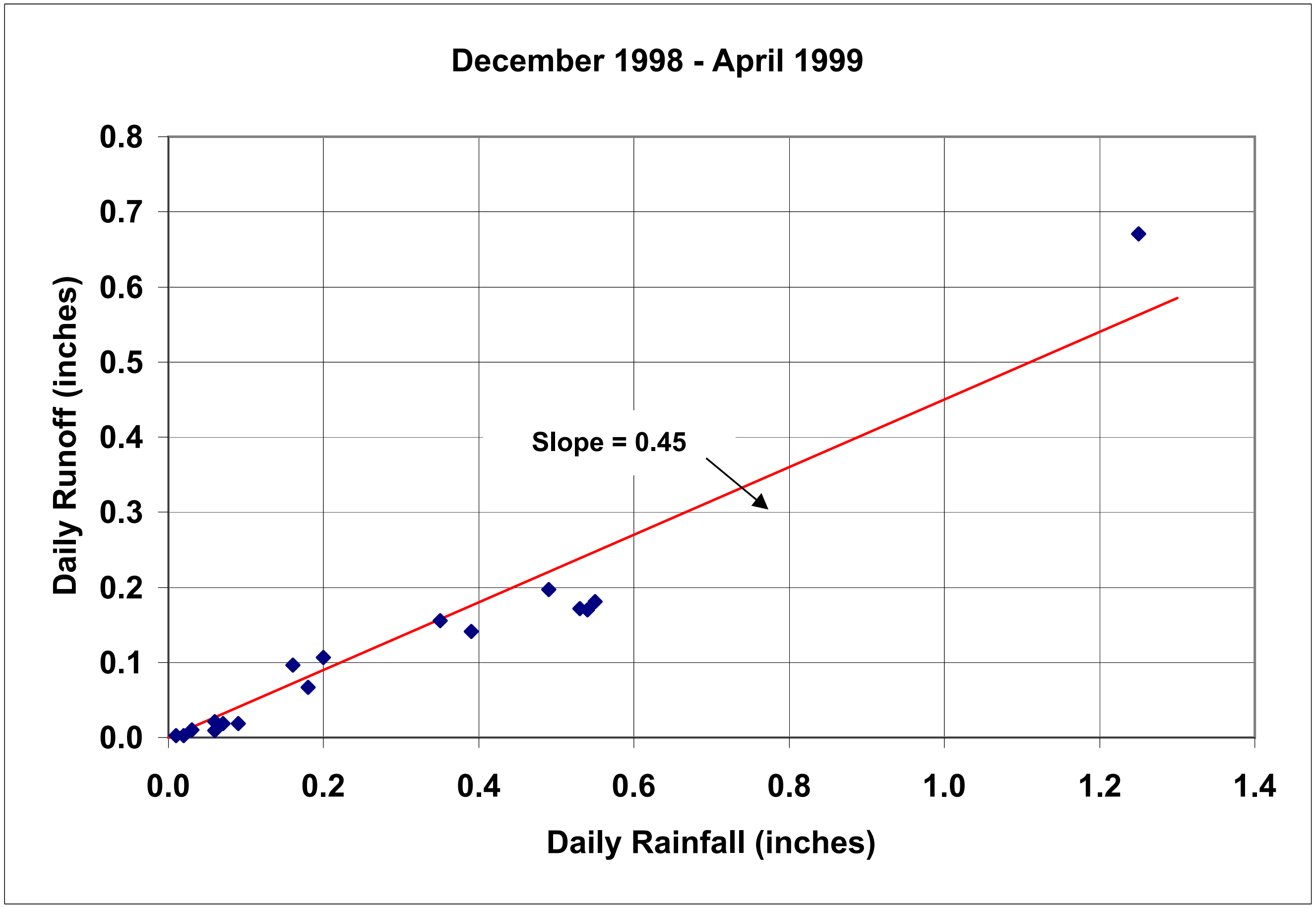

Figure 2. Relationship of Daily Runoff to Daily Rainfall in the Vista Grande Watershed

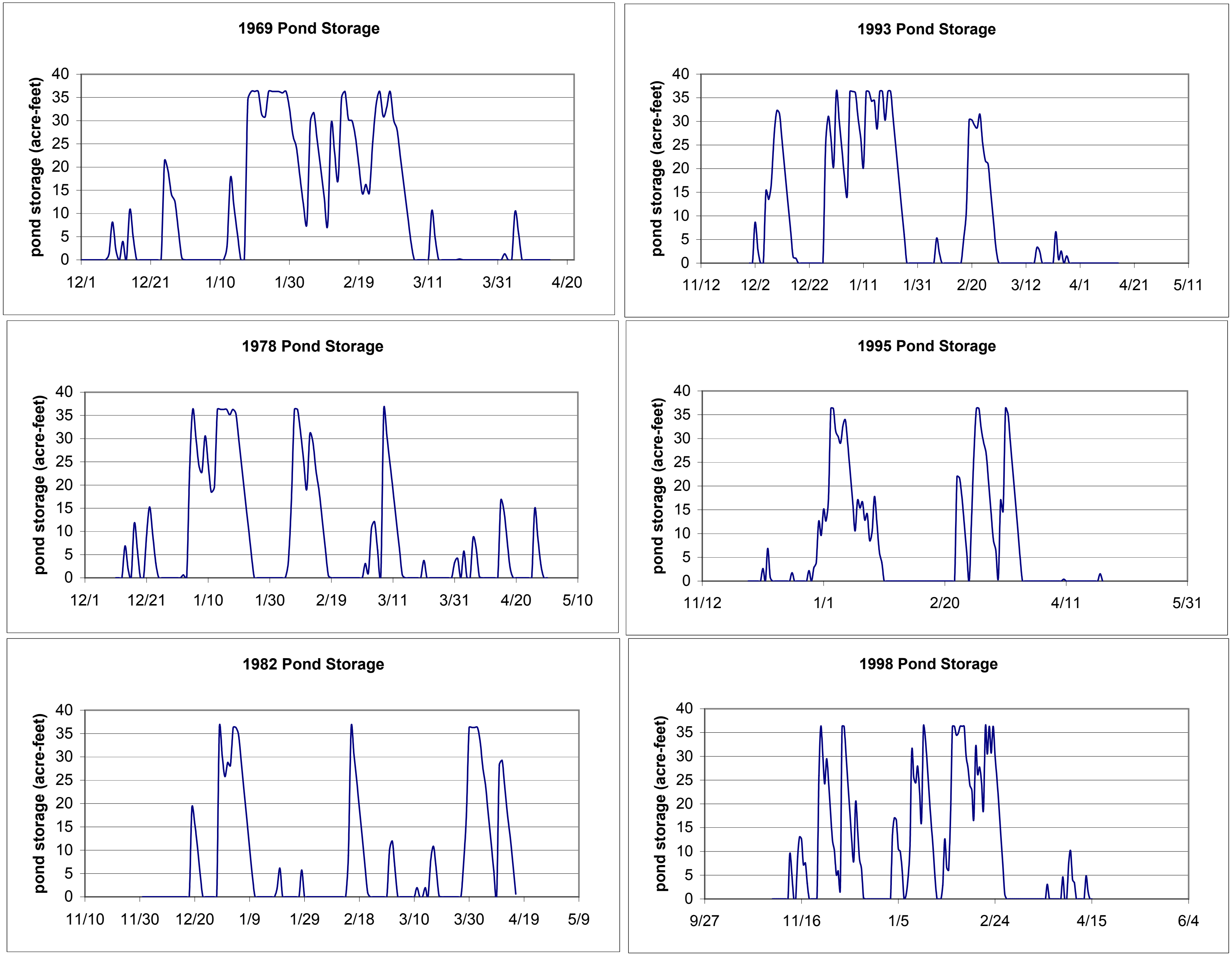

Figure 3. Simulated Daily Storage in the Franklin School Pond during Six Selected Wet Seasons

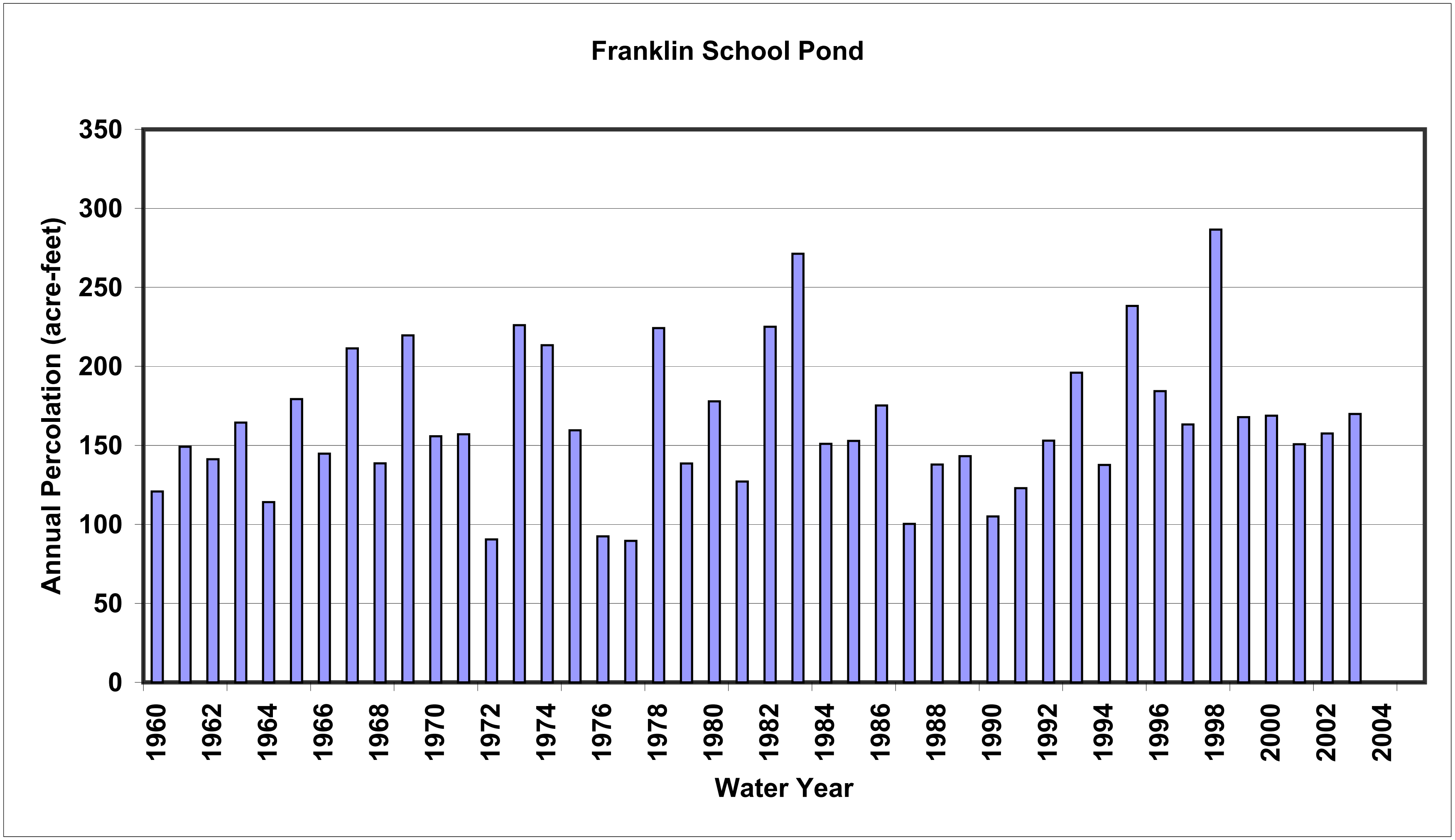

Figure 4. Annual Simulated Percolation from the Franklin School Pond during 1960-2003

Table 1. Dimensions and Recharge Benefits of Seven Potential Stormwater Percolation Ponds in Daly City

Pond Parameter	I-280 cloverleaf	Westlake shopping center	Franklin School	Lake Merced Golf Club			City Hall	Total
				North	Middle	South		
Watershed area (acres)	168	1025	622	59	29	39	108	n.a.
Pond area (square feet)[1]								
Square feet	26,736	596,550	230,599	15,039	36,762	20,052	108,900	1,034,639
Acres	0.61	13.69	5.29	0.35	0.84	0.46	2.50	24
Pond capacity								
Acre-feet	4.9	109.6	42.4	2.8	6.8	3.7	20.0	190
Million gallons	1.6	35.7	13.8	0.9	2.2	1.2	6.5	62
Watershed area/ pond capacity ratio[2]	34.2	9.4	14.7	21.4	4.3	10.6	5.4	n.a.
Approximate average annual recharge benefit[3]								
Acre-feet	26	316	160	12	12	12	41	579
Million gallons	8.5	103.0	52.1	3.9	3.9	3.9	13.4	189
Percent of current groundwater use	0.7%	7.9%	4.0%	0.3%	0.3%	0.3%	1.0%	14.5%

Notes:

[1] Pond basal area assumes 8-foot pond depth and vertical pond walls.

[2] Ratio of watershed area in acres to pond capacity in acre-feet

[3] Average annual percolation through the pond bottom during water years 1960-2003 under the global parameter assumptions in Table 2.

Table 2. Global Parameters for Simulation of Pond Operation

Parameter	Value
Mulitplier to convert rainfall at airport to rainfall at Daly City:	1.06
Mulitplier to convert daily rainfall to "capturable" hourly rainfall:	0.9
Runoff coefficient:	0.43
Maximum diversion rate into pond (cfs):	100
Pond depth (feet):	8

Table 3. Effect of Percolation Rate on Required Pump Capacity and Average Annual Recharge Benefit

A. Pumping Rate Needed to Empty Pond in 1 Week (gpm)

Percolation rate (in/hr)	I-280 cloverleaf	Westlake shopping center	Franklin School	Lake Merced Golf Club			City Hall
				North	Middle	South	
0.2	103	2,302	898	58	144	76	422
0.4	48	1,064	413	27	67	36	193
0.6	0	0	0	0	0	0	0

B. Average Annual Groundwater Recharge Corresponding to Above Pumping Rate (acre-feet)

Percolation rate (in/hr)	I-280 cloverleaf	Westlake shopping center	Franklin School	Lake Merced Golf Club			City Hall
				North	Middle	South	
0.2	26	316	160	12	12	12	41
0.4	50	542	291	23	18	20	63
0.6	82	981	499	39	38	36	127

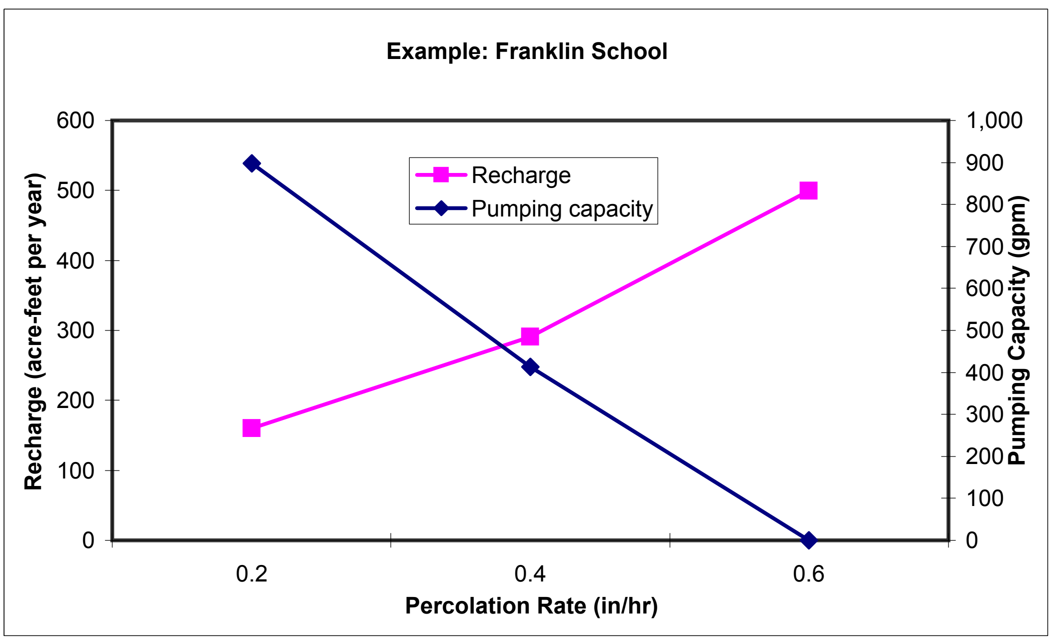

Table 4. Effect of Pond Pump-Out Capacity on Westlake Pond Storage Volume the Day Before a Major Rainfall Event
(Units are percent of pond storage capacity)

Ranked Daily Rainfall at SF Airport			Pump-Out Rate (cfs)							
Rank	Date	Rain (in)	0.5	1	2	3	4	5	10	20
1	01/04/82	5.59	74%	68%	58%	47%	36%	25%	0%	0%
2	01/21/67	4.07	55%	54%	52%	51%	49%	47%	38%	20%
3	12/11/95	3.16	0%	0%	0%	0%	0%	0%	0%	0%
4	02/02/98	2.92	91%	77%	27%	18%	14%	12%	3%	0%
5	10/13/62	2.62	94%	93%	91%	90%	88%	86%	77%	56%
6	01/20/64	2.49	7%	5%	2%	0%	0%	0%	0%	0%
7	12/13/02	2.47	0%	0%	0%	0%	0%	0%	0%	0%
8	11/30/73	2.39	30%	7%	0%	0%	0%	0%	0%	0%
9	10/11/62	2.38	5%	4%	3%	1%	0%	0%	0%	0%
10	01/06/93	2.34	56%	48%	32%	15%	0%	0%	0%	0%
Average annual recharge (ac-ft):			550	499	426	376	343	319	263	241

Notes:

The rainfall events shown are the ten largest daily rainfall totals at San Francisco Airport during water years 1960-2003.

The assumed percolation rate was 0.2 in/hr; other parameters are as shown in Tables 1 and 2.