



*Hydrology and Water Budget of the
San Dimas Experimental Forest,
San Gabriel Mountains, California,*

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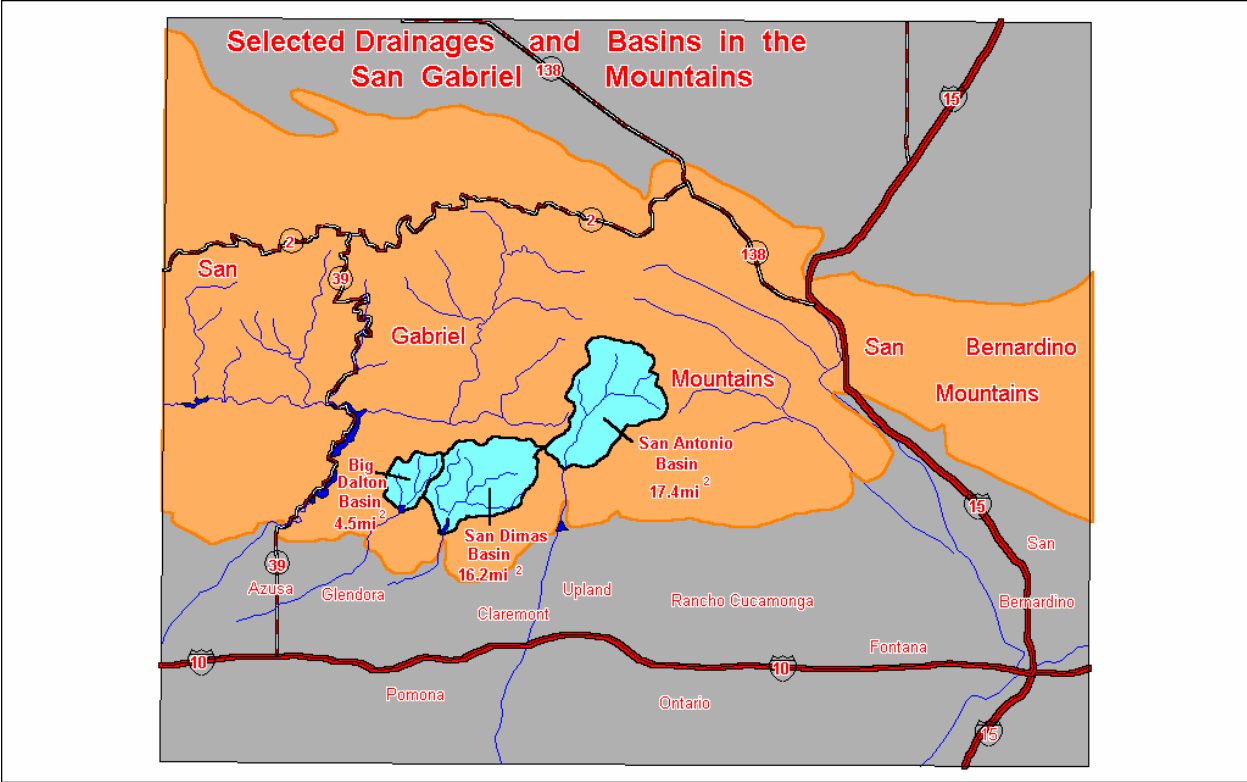


Figure 1. Hydrologic map showing location of Big Dalton and San Dimas drainage basins, the targets of this water budget study.

I. Introduction

Purpose and objectives

This project evaluates historical precipitation, runoff and evaporation data in an attempt to understand the hydrology of a heavily vegetated mountainous area in the southern California. The area of study is located in the San Dimas Experimental Forest (SDEF) (Figure 1). Despite the availability of data, hydrological analyses of this sort have not been performed since its establishment as an experimental forest in 1933. An analysis of historical precipitation, evaporation and runoff data from the two major watersheds will provide the foundation to develop a detailed understanding of the hydrology within the boundaries of the SDEF and the bordering communities of Glendora, La Verne, and San Dimas. The figures and charts produced from a careful analysis of the precipitation, evaporation and runoff data will be used to develop a long-term water budget for both the Big Dalton and San Dimas watersheds.

Acknowledgements

The data used in this study was acquired through several government agencies and professional publications including the United States Department of Agriculture Forest Service and the Los Angeles County Department of Public Works. Previous work used that is integral in this hydrologic study can be found in USGS Professional Paper 417-E, *Natural Water Loss and Recoverable Water in Mountain Basins of Southern California*, by John Crippen (1965).

II. Hydrologic Data

Precipitation

The rain intensity gages currently used have been in operation since the early 1960's (Figure 2). The current models measure the mass of precipitation rather than volume. A cylindrical opening roughly 20 centimeters in diameter collects rainfall into a weighing bucket that is attached to a calibrated scale. The scale is connected to a drum and pen mechanism that resembles a seismometer. A paper chart is attached to the outside of the drum with the writing pen hovering over the paper chart. A battery powered electrical motor rotates the drum continuously once every 24 hours. The accumulation of water in the collection bucket will increase the mass of the

system and cause the pen to rise at a rate corresponding to the rate of precipitation. Evaporation is controlled by the addition of



Figure 2 - Rain gage at Tanbark Flats. All monitoring equipment is housed in an alloy shell. Data recording instruments are located in a chamber at the base of the rain gage. (Baseball cap for scale)

a specially formulated oil that is less dense than water and highly resistant to evaporation. All of the various components of each rain gage, except for the collection bucket, are protected by an alloy shell. Employees of the U.S. Forest Service perform periodic checkups and routine maintenance to each of the individual rain gages to ensure accuracy and dependability. Before any data is entered in the computer database, the contents from each gage is emptied into a large graduated cylinder and the volume from each gage is compared against the volume recorded on the paper chart. Inconsistencies between the mechanical and volumetric measuring devices are corrected using a mathematical correction factor determined by the difference between the total volume measured in the graduated cylinder versus the amount indicated on the paper chart. All data is double-checked for control purposes.

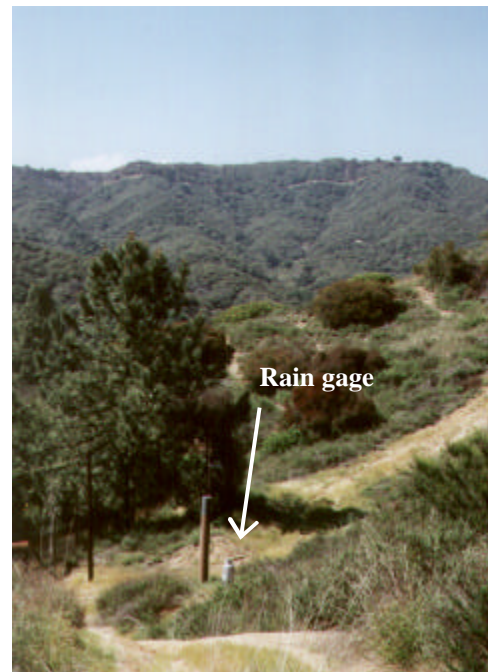
Description of Precipitation Gages

Six standard U.S. Department of Agriculture Forest Service rain gages are located within the San Dimas watershed and two are situated within the Big Dalton watershed monitoring the areas where potential precipitation is greatest. Precipitation data is collected continuously by each of the eight battery powered rain gages. U.S.

Forest Service employees manually check the individual rain gages for accuracy and any problems that may have developed by either natural or man-made sources. Each gage is positioned to insure maximum precipitation capture.

Gage #0599, Tanbark Flats (master gage), elevation 2800' (Figure 3) - Tanbark Flats has the most complete continuous historical precipitation record dating back to 1929. The gage sits in a small valley about 15' below a small, gently sloping northwest trending ridgeline. Its location within a valley may have a small effect on the rainfall totals entering the area. (Glendora Quadrangle, Los Angeles Co. 7.5 minute series, T. 1 N, R. 8 W, sec. 6)

Figure 3 - A view northward from hill just above Tanbark Flats. Glendora Ridge Road winds around the ridge on the horizon. The Tanbark Flats rain gage can be found in the lower third of the photograph in a shallow valley.



Gage #0199, Wolfskill, elevation 3600' - This is the only gage situated along the southeastern border of the SDEF. Data used for the analysis in this project dates from 1938 - 1976 with a gap in the date between 1947 to 1953. Records extending to 1995 can be attained from the U.S. Forest Service SDEF headquarters. (Mt. Baldy Quadrangle, California, 7.5 minute series, T. 1 N, R. 8 W, sec. 16)

Gage #0202, Fern II, elevation 5200' - The highest gage in the SDEF. Its location on a west-facing slope towards the eastern border of the experimental forest provides useful information for the orographic gradient within the

forest boundaries. Precipitation records range from 1946 - 1991, missing 1975. (Mt. Baldy Quadrangle, California, 7.5 minute series, T. 1 N, R. 8 W, sec. 2)

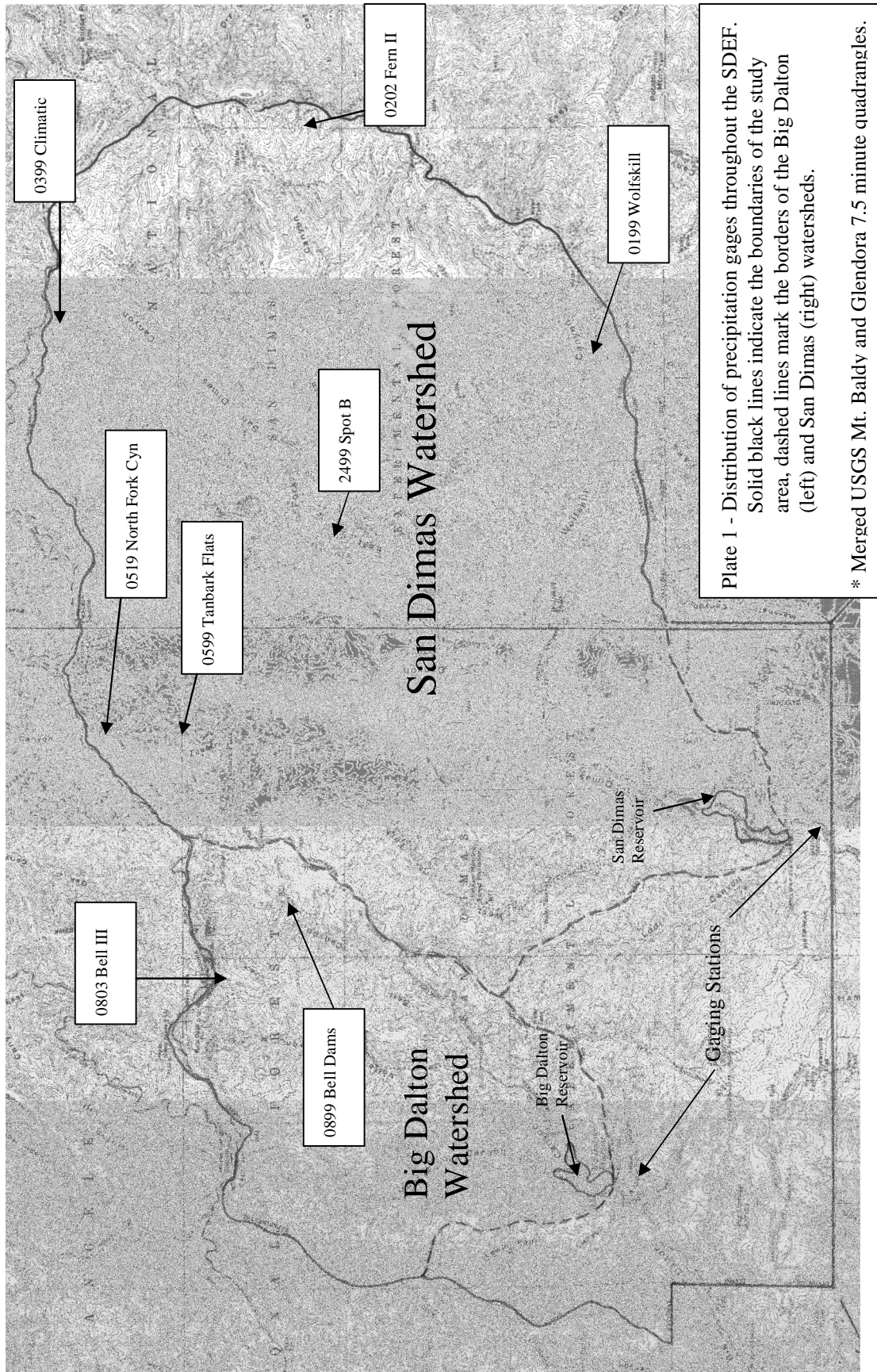


Plate 1 - Distribution of precipitation gages throughout the SDEF. Solid black lines indicate the boundaries of the study area, dashed lines mark the borders of the Big Dalton (left) and San Dimas (right) watersheds.

* Merged USGS Mt. Baldy and Glendora 7.5 minute quadrangles.

Gage #0399, Climatic, elevation 4350' - Located in the northeastern quadrant of the experimental forest at 4350' and includes a 54 year historical precipitation record from 1936 - 1991 with a gap in the 1947 and 1960 water years. This gage suffers from severe bear and shotgun damage.

Gage #0519, North Fork Canyon, elevation 3500' - Located almost due north of the Tanbark Flats, this gage lies on the top of a small hill and has a complete record from 1961 - 1997.

Gage #0803, Bell III, elevation 3400' - located on a trail leading to southeast facing slope south of Glendora Ridge Road. Historical data extends from 1955 - 1994, minus 1975-75 and 1992. (Glendora Quadrangle, Los Angeles Co. 7.5 minute series, T. 1 N, R. 9 W, sec. 2)

Gage #0899, Bell Dams, elevation 2500' - The Bell Dams are a collection of small dams that trap runoff coming from tributaries that drain into the larger Bell Canyon Creek. A large degree of vegetation overgrowth has sheltered the gage and may have an effect on more recent readings. Historical data ranges from 1950 - 1994, missing 1992. (Glendora Quadrangle, Los Angeles Co. 7.5 minute series, T. 1 N, R. 9 W, sec. 1)

Gage #2499, Spot B, elevation 2580' - Spot B is located on a north-facing slope in the east fork of San Dimas Canyon. Historical data dates from 1935 - 1991 excluding 1947. (Mt. Baldy Quadrangle, California, 7.5 minute series, T. 1 N, R. 8 W, sec. 5)

Potential Sources of Error

The ideal hydrologic analysis demands reliable, complete and readily accessible data. However, the compilation of such data would require the employment of a full time staff devoted to monitoring each of the gages on a day to day basis. The execution of such a task is not logistically or economically feasible and, therefore, errors do exist.

Most of the Experimental Forest consists of heavily vegetated mountainous terrain that can be treacherous in places. This makes for poor access to some of the gages in the more remote areas and more intermittent

checkups and maintenance to these gages. Mechanical failures due to a stop in the internal clock are the most common cause for error. Natural sources for error arise when intense storms enter the region and overcome the capacity of the collection buckets. Snow and ice accumulation during the winter season compromises the accuracy of data collected by preventing precipitation from entering those gages located in higher elevations. Strong prevailing winds can deflect precipitation away from entering rain gages. Less influential but a potential source for error nonetheless, vegetation overgrowth and thick canopy cover can affect rainfall totals by blocking the path of incoming precipitation (Figure 4), however this does not occur overnight. Wildlife and well as wild humans and their kin make a generous contribution to the error factor. Bears have been reported to make their way through anti-wildlife fences devices and knock over rain gages. The effect of human damage is indicated by broken beer bottles and shotgun ridden gages.



Figure 4 - The rain gage at Bell Dams is hidden behind the brush. The initial location was probably not heavily forested. Vegetation overgrowth has engulfed the rain gage and may have an effect on more recent precipitation values.

Graphs Generated from Data

Two types of graphs were generated from the data provided by the SDEF. The first graph is a plot of the mean annual precipitation (Figure 5a). The gross annual precipitation for each water year is determined and a mean annual precipitation rate is calculated by dividing the gross by the total amount of years with complete data for each gage. For example, data from gage #0519 North Fork Canyon covers a period from 1961 - 1997 for a total

of 37 years. In these 37 years, the total amount of rainfall recorded by gage #0519 is approximately 1109.21 inches. The average annual precipitation can be determined by dividing the total amount of rainfall (1109.21 inches) by the number of years the gage has been in activation (37 years); the mean annual precipitation is 29.98 in/yr. Similar calculations have been performed on all eight gages within the San Dimas and Big Dalton watersheds in order to observe trends and variations in precipitation patterns within the region. Comparing values for mean annual precipitation to corresponding runoff rates can consequently lead to a calculation for potential evaporation and plays an important role in proposing a long-term water budget by providing a reasonable estimate as to how water enters and leaves the area of research.

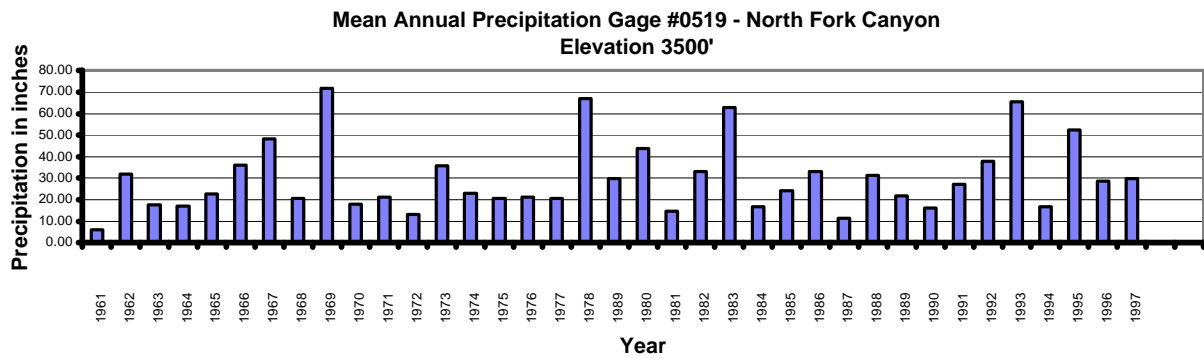


Figure 5a - Graph of mean annual precipitation for North Fork

The second type of graph is a mean monthly precipitation graph (Figure 5b). Monthly mean precipitation graphs are helpful tools in the construction of a water budget. Being able to predict when and where precipitation falls most can aid in planning projects involving the use of water. Comparing the average amounts of precipitation per month versus the month produces mean monthly precipitation graphs.

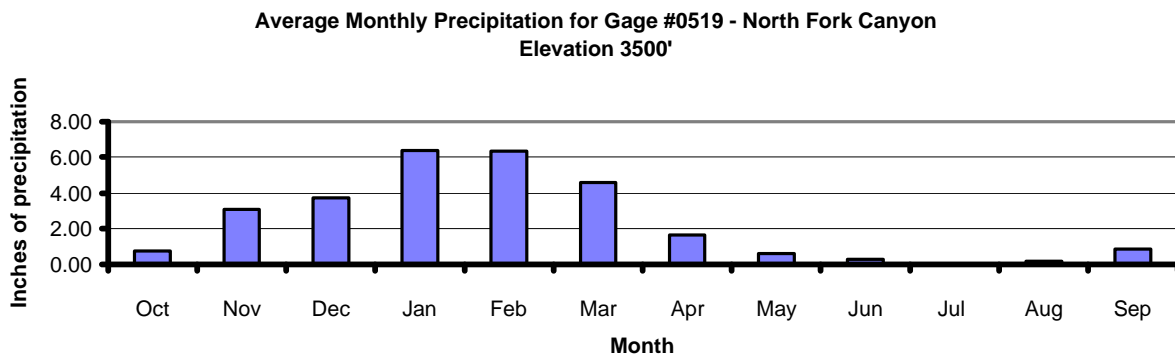


Figure 5b - Graph of mean monthly precipitation for North Fork

Summary of Data Gathered from Graphs

Table 1 - Mean annual precipitation

Mean Annual Precipitation (in/yr)			
Station	Elevation (ft.)	Length of time with complete precipitation data	Mean Annual Precipitation (in/yr)
0199 Wolfskill	3600	32 years, 1938-1976, missing 1947-53	25.39
0202 Fern II	5200	45 years, 1946-1991, missing 1975	29.08
0399 Climatic	4350	54 years, 1936-1991, missing 1947 & 1960	20.88
0519 North Fork	3500	37 years, 1961-1997	29.98
0599 Tanbark Master	2800	70 years, 1929-1998	28.15
0803 Bell III	3400	37 years, 1955-1994, missing 1974, 1975, 1992	28.50
0899 Bell Dams	2500	44 years, 1950-1994, missing 1992	28.08
2499 Spot B	2580	56 years 1935-1991, missing 1947	25.54

Table 2 - Mean monthly precipitation

Mean Monthly Precipitation (in/month)						
Station	October	November	December	January	February	March
0199 Wolfskill	0.68	2.61	4.17	4.34	4.21	3.54
0202 Fern II	0.80	3.26	4.59	5.01	5.27	4.83
0399 Climatic	0.71	1.70	2.93	3.83	4.10	4.00
0519 North Fork	0.74	3.07	3.73	6.38	6.32	4.61
0599 Tanbark Master *	0.94	2.55	4.29	5.88	6.15	4.62
0803 Bell III	0.79	3.17	3.69	6.07	5.48	4.56
0899 Bell Dams	0.75	2.80	3.63	6.08	4.98	2.19
2499 Spot B	0.91	2.48	3.89	4.89	4.66	4.70

Station	April	May	June	July	August	September
0199 Wolfskill	2.66	0.70	0.21	0.05	0.02	0.49
0202 Fern II	2.42	1.53	0.10	0.04	0.20	0.67
0399 Climatic	1.87	0.56	0.07	0.01	0.19	0.51
0519 North Fork	1.65	0.59	0.27	0.04	0.17	0.84
0599 Tanbark Master *	2.19	0.70	0.18	0.03	0.13	0.48
0803 Bell III	2.27	0.80	0.20	0.05	0.19	0.69
0899 Bell Dams	2.19	0.70	0.18	0.03	0.10	0.52
2499 Spot B	2.45	0.65	0.15	0.02	0.15	0.54

* Data taken from SDEF homepage - www.rfl.psw.fs.fed.us/prefire/sdefhtml/sdefprecip.html

Runoff

Outflow data has been provided by the Los Angeles County Department of Public Works (LACDPW) for gaging stations F303-R, San Dimas Creek below San Dimas Dam and F120B-R, Big Dalton Creek below Big Dalton Dam. The LACDPW has been monitoring outflow from both Big Dalton and San Dimas creeks since 1950 and 1952, respectively (Figure 6). Surface runoff from the two major watersheds is measured by stream gages located a small distance downstream from each of the two major dams beyond the Big Dalton and San Dimas reservoirs. The discharge from each of the two dams is measured by a gage that operates similar to a weir. Fetter describes the dynamics behind a weir as the following:

... a small dam with a spillway opening of specified shape. There are a number of standard shapes for sharp-crested weirs, the most common being a 90° V-notch or a rectangular cutout. A small earthen or concrete dam is built and the weir set into it. The dam will impound a small amount of water that should freefall over the weir crest, or the lowest point of the spillway. The elevation of the backwater above the weir crest is measured.

Figure 6 - A photograph of the Big Dalton stream gauge. Electric monitoring equipment is located inside the tower to the right of the photograph. A measuring tape for visual inspection of runoff is secured to the wall below the bridge.



In other words, the stream discharge can be determined simply by reading the height of water flow from a measuring tape permanently fixed into the sides of the weir. The height of the water is then compared to a calibration curve based on the dimensions of the spillway and the amount of discharge can be determined. The shape of the spillway used in the larger San Dimas gaging station resembles that of an irregular rectangle, the one used in Big Dalton Creek has the features of a right triangle (figure 7).

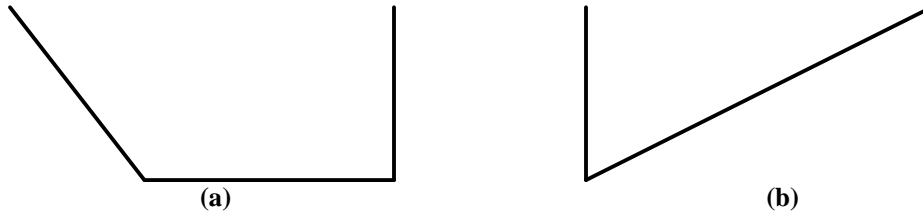


Figure 7 - Schematic representation of the shapes of spillways used in (a) San Dimas gaging station and (b) Big Dalton gaging station.

Potential Sources for Error

The main monitoring equipment used in the measurement of stream outflow consists of an electronic metering device housed inside a tower that is situated alongside the vertical end of each of the two gaging stations. A small slit in the lower portion of the tower allows the infiltration of water (Figure 6). The electronic measuring device then measures the level of water inside the tower. Visual inspection of runoff provides a method to check against potential errors in the electronic measuring equipment. The chance for a large percentage of error is unlikely.

Summary of Data Gathered from Graphs

Using the granted historical data, graphs of annual outflow and mean annual outflow were generated for the two gaging stations. Mean annual discharge and mean daily discharge was then calculated using the information gained from the graphs for each station. This information will be used in the calculation of a water budget for the SDEF.

Table 3 - Mean annual discharge and mean daily discharge of individual gaging stations.

Mean Discharge		
Gaging Station	Mean Annual Discharge	Mean Daily Discharge
Big Dalton Creek*	$4.16 \times 10^7 \text{ ft}^3/\text{yr}$	$1.14 \times 10^5 \text{ ft}^3/\text{day}$
San Dimas Creek**	$1.61 \times 10^8 \text{ ft}^3/\text{yr}$	$4.41 \times 10^5 \text{ ft}^3/\text{day}$

* Calculated over a period of 40 years

** Calculated over a period of 37 years.

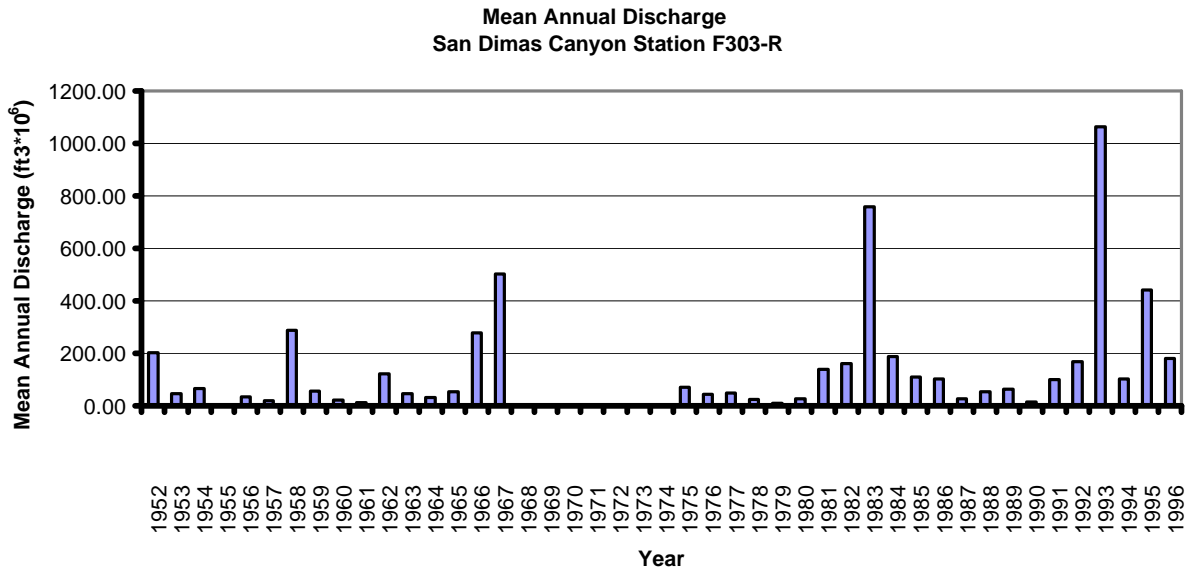
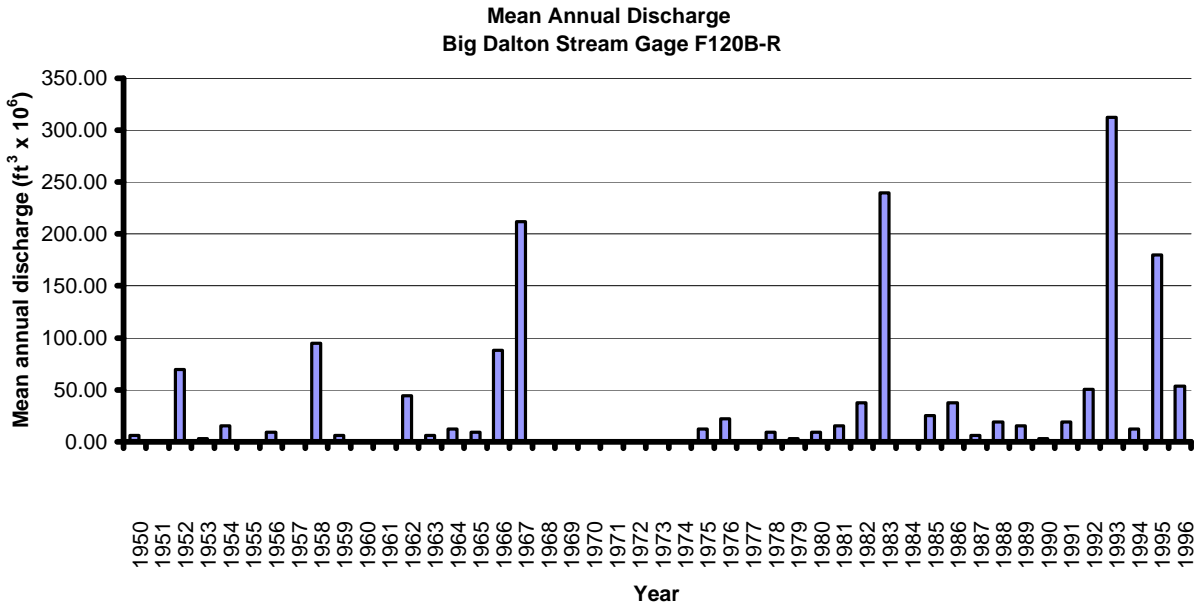


Figure 8a - Graph of mean annual discharge from Big Dalton drainage basin.



Graph 8b - Graph of mean annual discharge from San Dimas Canyon drainage basin.

Lake Evaporation

Table 4 shows the results of lake evaporation from Big Dalton Reservoir and San Dimas Canyon. Pan evaporation data is listed in USGS Professional Paper 417-E, *Natural Water Loss and Recoverable Water in Mountain Basins of Southern California*, by Crippen. Mean evaporation data for Big Dalton Reservoir comes from screened land pans, that for San Dimas Canyon is taken from standard U.S. National Weather Service Class A land pans. They (Class A land pans) are 4 ft (122 cm) in diameter and 10 in. (25.4 cm) deep, made of unpainted galvanized metal and rest on supports so that air can circulate around; water depths of 7 to 8 in (18 - 20 cm) are maintained (Fetter, 1994). Potential errors can occur with heavy rainfall or drinking by wildlife. Wind speed is measured and a correction factor is used when calculating total evaporation rates.

Because land pans are made out of metal and contain a much smaller volume of water than a lake does, evaporation tends to take place at a faster rate in a land pan than is does in a lake. A pan coefficient of 0.75 is used in Class A land pans to calculate evaporation rates. Screened pans have a coefficient that is $1.32 \times$ Class A coefficient.

The area of each of the reservoirs is required to calculate the total amount of lake evaporation over each watershed. This was accomplished using basic tools by tracing the largest outline of each reservoir onto a sheet of gridded paper and counting the number of squares occupied. The number of squares multiplied by the actual area represented by each square results in a reasonable approximation of the total acreage in each reservoir.

Table 4 - Summary of lake evaporation data*

Lake Evaporation Data*			
Station	Area or reservoir	Equivalent lake evaporation*	Total annual evaporation
Big Dalton	$1.08 \times 10^6 \text{ ft}^2$	41.7 inches	$3.75 \times 10^6 \text{ ft}^3/\text{yr}$
San Dimas	$1.52 \times 10^6 \text{ ft}^2$	39.7 inches	$5.03 \times 10^6 \text{ ft}^3/\text{yr}$

* Taken from Crippen, 1965.

III. Analysis and Discussion

Historical Variations in Precipitation

A complete precipitation record exists from Tanbark Flats ranging from 1934 through 1998. Of these 65 years, 33 can be considered normal (20 - 40 inches of precipitation), 11 wet years (40 - 60 in.), 3 very wet years (60+ in.) and 18 dry years (<< 20 in.) (Figure 9). Notable years include 1961 and 1969 the driest and wettest year with 10.14 and 62.80 inches, respectively, of rainfall. There does not appear to be a "normal" precipitation pattern. Wet years and dry years seem to take place randomly, although episodes of dry years tend to occur more frequently than multiple wet years. Runoff data corresponds to the precipitation data with increased runoff in the wetter years and decreased runoff during dryer years. This is a good indicator of the reliability and accuracy of the monitoring equipment.

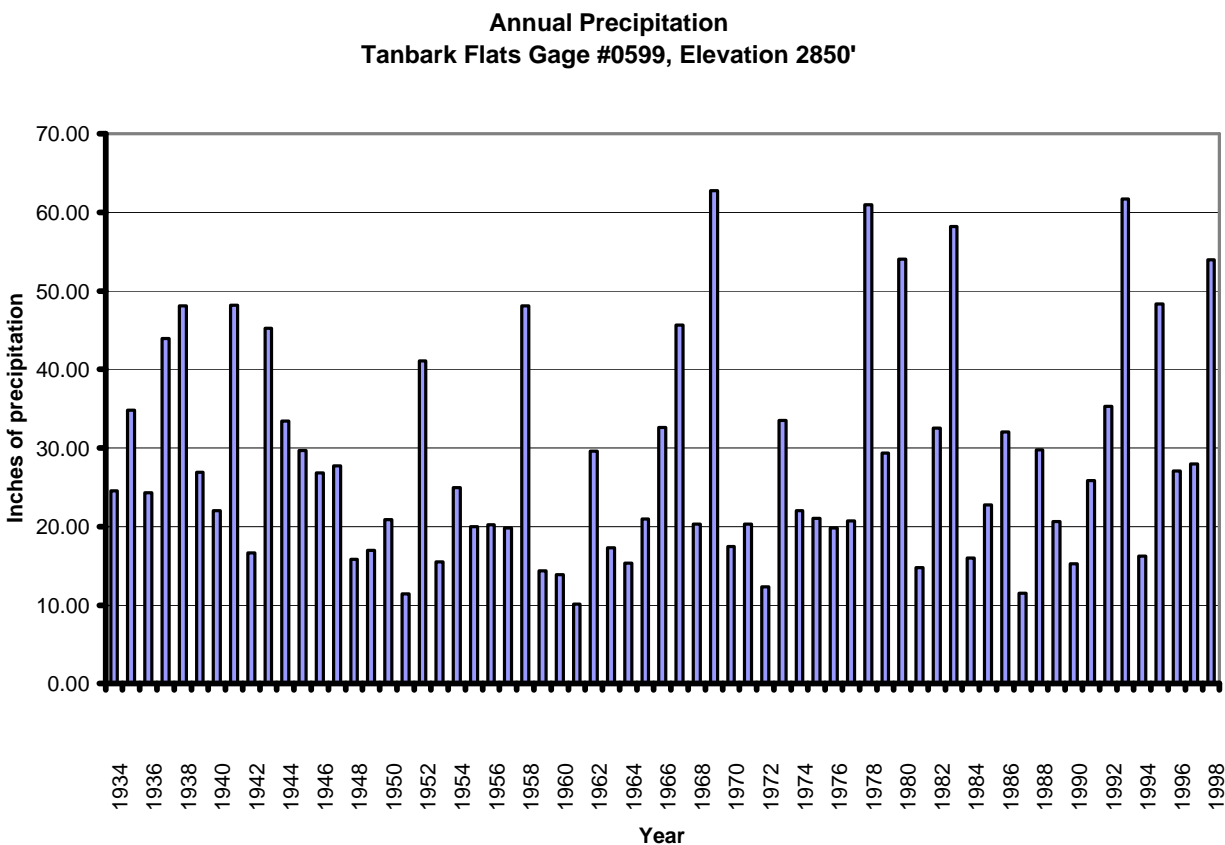


Figure 9 - Graph of average annual precipitation in Tanbark Flats.

Representative long-term precipitation averages are required to gain some insight of how much, when, and how frequently water enters a drainage basin. Detailed information regarding these topics can aid in future construction projects involving water conservation or water distribution. Long-term averages also make it possible to develop a water budget that best characterizes the hydrology within an area of similar geological and geographical essence and is thereby a very valuable tool in this study.

Normalization of Precipitation Data

The sources available for precipitation data present a complete but unequal distribution in the period of record from gage to gage. Therefore, an adjusted mean annual precipitation rate must be devised to compare the periods with the shortest historical record to that with the longest record, Tanbark Flats. *Normalization* is a procedure that can be used to equate adjusted mean precipitation rates by comparing each gage to the one with the longest complete data set. The steps involved in normalizing data are outlined in figure 10.

<p>Sample Calculation for North Fork Canyon</p> <ol style="list-style-type: none"> 1. Determine partial mean by dividing the total precipitation by the number of years covered in each gage: $1115.9 \text{ in} \div 37 \text{ yrs} = 30.16 \text{ in/yr}$ 2. Calculate the % of the 70 year record from Tanbark Flats: $[30.16 \text{ in/yr} \div 28.15 \text{ in/yr}] \times 100\% = 107.14\%$ 3. Determine the adjusted mean precipitation by dividing the % of the 70 year record into the mean precipitation: $29.98 \text{ in/yr} \div 1.0714 = 27.98 \text{ in/yr}$

Figure 10 - Normalization of data from North Fork Canyon, gage #0519

Normalization provides an estimate of the mean precipitation if there were a complete 70 year record from all eight rain gages in the SDEF. Runoff data from the two dams has also been normalized using a similar method to precipitation, however precipitation data is replaced with runoff data.

Table 5 - Summary of normalized data.

Normalized Data

Station	Total Precipitation (in)	# years of complete record	Mean annual precipitation (in)	Partial mean annual precipitation (in)	Adjusted mean annual precipitation (in)
0199 Wolfskill	843.95	32	25.39	26.37	27.10
0202 Fern II	1146.21	45	29.08	25.47	32.14
0399 Climatic	1464.15	54	20.88	27.11	21.68
0519 North Fork	1115.90	37	29.98	30.16	27.98
0599 Tanbark Master *	-	-	28.15	28.15	28.15
0803 Bell III	1016.40	37	27.81	27.47	28.50
0899 Bell Dams	1157.83	44	26.25	26.31	28.08
2499 Spot B	1512.85	56	25.54	27.01	26.62

* Tanbark Master gage is used as a reference gage; all adjusted values are computed with respect to Tanbark totals.

Orographic Precipitation

The orographic gradient within the SDEF is 1.5 in/1000 ft. This is shown in figure 11. The gage lowest in elevation is Bell Dams at 2500' in the Big Dalton drainage basin; to the east rests the highest gage, Fern II, at 5200' towards the eastern boundary of the SDEF in the San Dimas drainage basin. Differences in topography as well as the positioning of each individual gage within each basin has an overall effect on the calculated value for orographic lifting.

Orographic Precipitation Relationship in San Dimas Experimental Forest 1929-1998

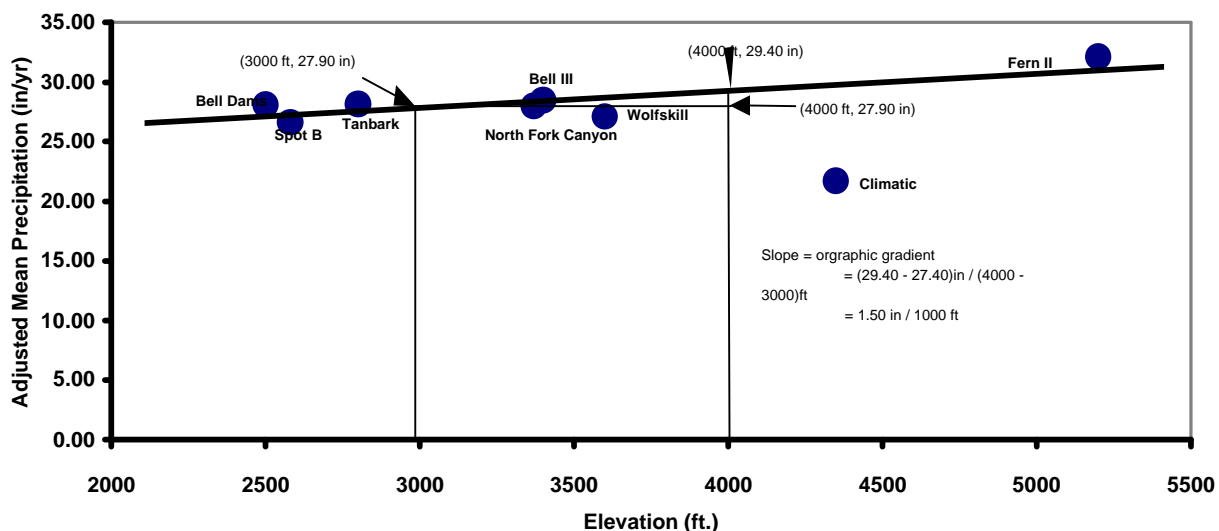


Figure 11 - Graph showing the orographic gradient in the SDEF. Gage #0519, Climatic, is neglected because of extensive damage and inaccurate readings.

NNE making it more likely for gages located on south facing slopes, where orographic lifting is most prominent, to receive more rain than those located on north facing slopes. This potential source for error is evident in the adjusted mean annual precipitation rates for gages #0199 - Wolfskill, elevation 3600' and gage #0803 - Bell III, elevation 3400'. Although their elevation is nearly identical, a difference of only 200', the adjusted mean annual precipitation is nearly 1.5 inches greater in Bell III than it is in Wolfskill. Its position on a north dipping slope makes it a less than ideal place for a rain gage. On the other hand, Bell III is located on a steeply dipping south facing slope making it a prime candidate for maximum precipitation accumulation. In addition to its location, Bell III, as well as other gages located on similar terrain, is designed so that the opening leading to the measuring equipment is slanted at an angle parallel to the slope of the hill to decrease the amount of precipitation lost due to strong winds.

Vegetation overgrowth and canopy cover and also have negative effects on orographic lifting (figure 12). The effects are similar to those described in section II, *potential sources of error*.



Figure 12 - Both watersheds in the SDEF are heavily vegetated. This photo, taken alongside West Fork Road in the San Dimas watershed, shows how rapid overgrowth can shield gages from

The data from gage #0399 Climatic is disregarded in the estimation of the orographic gradient. This gage can be easily accessed by passersby on Glendora Ridge Road and has been heavily vandalized. There have been reports of USFS employees visiting this locale only to find the gage knocked over with fresh bullet holes in its sides.

Volume Calculations for Average Annual Precipitation

The mean annual precipitation amassed in each watershed is found by multiplying the area of the watershed by the average amount of precipitation over a given time period. Naturally, larger drainage basins will collect more precipitation than smaller ones. The San Dimas watershed is roughly 3.5 times larger and receives \approx 3.5 times more rainfall than the smaller Big Dalton watershed receives. To assure accuracy and consistency, the precipitation averages used to calculate the mean annual precipitation rates are computed over a time range identical to corresponding runoff timelines. Outflow data from Big Dalton Creek ranges from 1950 - 1996, with a gap in the sequence from 1968 - 74 (7 years) for a total of 40 complete years of data. San Dimas creek ranges from 1952 - 1996 minus 1955 and 1968 - 74 for a total of 37 years of complete of data. The figures used to calculate average annual precipitation come from gage #0599 Tanbark Flats for several reasons: (1) Tanbark Flats is situated at a median elevation of 2800'. With approximately 50% of the forest above and 50% below this elevation, Tanbark Flats has the most representative mean precipitation values. (2) More importantly, Tanbark Flats has the most complete record of all the rain gages and has been in continuous operation throughout the periods of outflow

information provided by the LACDPW. For these reasons, precipitation averages are completed using totals from Tanbark Flats. Table 6 summarizes the total annual inflow data.

Table 6 - Annual inflow rates

Total inflow into individual watersheds		
Name of drainage basin	Area (approximate)	Total precipitation*
Big Dalton	$1.27 \times 10^8 \text{ ft}^2$	$2.89 \times 10^8 \text{ ft}^3$
San Dimas	$4.53 \times 10^8 \text{ ft}^2$	$1.06 \times 10^9 \text{ ft}^3$

*Based on average precipitation rate = 27.38 in/yr for Big Dalton Creek, 28.19 for San Dimas Creek (gage #0599 Tanbark Master).

Water Budget Calculation

A water budget for the recharge area of a drainage basin is a useful way to determine the total inflow and outflow of water resources. Many of the parameters used for a hydrologic budget are measured directly: precipitation, streamflow (runoff), transported water and reservoir evaporation (Fetter, 1994). Using information acquired from the historical data, a water budget can be proposed for the SDEF to evaluate how hydrologic resources are utilized in the area of study.

The major components of a water budget include inflow and outflow. Inflow calculations rely solely on historical precipitation data. The experimental forest is underlain almost entirely by well consolidated quartz diorite which does not permit the infiltration of groundwater. Therefore most, if not all, of the inflow is surface flow with the majority of it in the form of precipitation.

$$\text{Inflow} = \text{Precipitation (P)} \times \text{area}$$

Annual outflow rates are listed on tables 3 & 4 under mean annual discharge and total annual evaporation. The amount of groundwater leaving the watersheds can be neglected for the reasons mentioned above.

$$\text{Outflow} = \text{Runoff (RO)} + \text{Lake Evaporation (L}_{\text{evap}}) + \text{Potential Evapotranspiration (PET)}$$

Potential evapotranspiration is described by Thornthwaite (in Fetter, 1994) as "the water loss which will occur if at no time there is a deficiency of water in the soil for the use of vegetation." Lysimeter data was not available to calculate actual evapotranspiration for the project area. Therefore, no measured data was used to

calculate evapotranspiration rates for the two drainage basins. The basic hydrologic equation was used to generalize the amount of potential evapotranspiration. It is expressed as

$$\text{Inflow} = \text{Outflow} \pm \Delta\text{Storage}^* \text{ (Fetter, 1994)}$$

$$\Delta\text{Storage} = "0" \text{ over long term}$$

$$\text{PEt} = \text{P} - \text{RO} - \text{L}_{\text{evap}}$$

The change in storage ($\Delta\text{Storage}$) must equal zero for a long-term water budget calculation to agree with the *law of conservation of mass*, which states that the total mass remains constant during a chemical change/reaction. Any differences between rates of inflow and outflow in a hydrologic system will result in a change in the volume of water stored in the system (Fetter, 1994). The assumption that total inflow will equal total outflow over a long period of time has to be made to satisfy the requirements of the law of conservation of mass.

Additional information required to complete the calculation of PEt includes the area of the each watershed. Area calculations were conducted by counting squares as described in section II, lake evaporation. Table 7 shows the results after plugging in the variables into the hydrologic expression for potential evapotranspiration.

Table 7 - Summary of potential evaporation data.

Potential Evapotranspiration Data			
Name of drainage basin	Area (approximate)	Potential evaporation	% of precipitation
Big Dalton	$1.27 \times 10^8 \text{ ft}^2$	$2.44 \times 10^8 \text{ ft}^3$	84%
San Dimas	$4.53 \times 10^8 \text{ ft}^2$	$8.94 \times 10^8 \text{ ft}^3$	84%

* Data used to calculate potential evapotranspiration can be found in tables 3, 4 and 6; average precipitation data used from Tanbark Master gage #0599 = 27.38 in/yr for Big Dalton Creek, 28.19 in/yr for San Dimas Creek.

Because the SDEF is closed off the general public, additional calculations are not needed to compensate for industrial, municipal, domestic or agricultural uses. The only moderately developed area is Tanbark Flats where researchers and employees of the USFS reside.

Comparison of inflow vs. outflow

A majority of the inflow leaves the two watersheds as evapotranspiration. An average of 84% of incoming precipitation is transpired by plants, runoff and evaporation comprise the remaining 16%. Dense vegetation combined with a semi-arid Mediterranean climate leads to evaporation (evapotranspiration) rates as high as 90 inches; however, at most stations it ranges between 40 and 80 inches (Crippen, 1965). Therefore, potential evapotranspiration rates that are 80+% the precipitation rates are not at all unusual.

Figure 12 is a picture taken alongside the West Fork fire road showing the density of vegetation. Chaparral and poison oak are but a few of the many representative species of flora that inhabit the experimental forest utilizing water resources 24 hours a day. The amount of evapotranspiration changes according to fluctuations in the amount of incoming precipitation. Again, no groundwater is readily available to plants. The soil cover can vary in thickness from place to place within the park boundaries. Field observations suggest that areas with thick soil cover are far more common than bordering drainage basins outside park boundaries where there is more exposed basement rock. This reduces the amount of surface runoff and contributes to higher evapotranspiration rates. Short rainy seasons and long, dry southern California summers are other factors that create an intensive demand for water in both drainage basins.

Potential evapotranspiration calculations for the neighboring San Antonio Creek watershed indicate that only 55% of the mean annual precipitation is used by plants. Mean lake evaporation rates were not available and have been neglected from the equation. However, previous computations of lake evaporation did not result in a significant change in total outflow. Considering this and its higher average elevation at 6700' (milder temperatures), water loss through lake evaporation can be assumed to be similar to those in the San Dimas and Big Dalton watersheds. The lower potential evapotranspiration values can be attributed to a smaller percentage of soil cover and a larger degree of exposed basement rock. Plutonic igneous rock is less permeable than sedimentary rock or topsoil and has very poor pore interconnection thus making it an inferior groundwater conductor. A lack of topsoil decreases the odds for water retention and thereby increases surface runoff.

IV. Conclusion

This project reveals the distribution of water resources in heavily vegetated mountain basin in southern California. The historical data provided by the U.S. Forest Service, Los Angeles County Department of Public

Works and Crippen (1965) supply the means to understand how water communicates between the physical and biological domains occupying the SDEF. Although slight, variations in precipitation exist because of differences in topography and climate among basins. Rainfall patterns in southern California are highly unpredictable. Short term records would not be sufficient to develop a representative water budget. In general, increased inflow results in increased outflow. Runoff water and lake evaporation constitute only a small portion of the total outflow. Approximately 80+% of incoming precipitation is lost through evapotranspiration. Almost all of the incoming precipitation is used by vegetation for respiration. This is theory is supported by the dense canopy and massive overgrowth in the lower elevations in each watershed. A future study with detailed lysimeter readings during wet and dry years would allow for a more definitive hydrologic analysis of the Big Dalton and San Dimas watersheds.

V. Bibliography

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