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UNITED STATES
(DEPARTMENT OF THE INTERIOR)
GEOLOGICAL SURVEY. *[Reports-Open file series]*

COMPREHENSIVE MONITORING OF METEOROLOGY, HYDRAULICS, AND
THERMAL REGIME OF THE SAN DIEGO AQUEDUCT, CALIFORNIA

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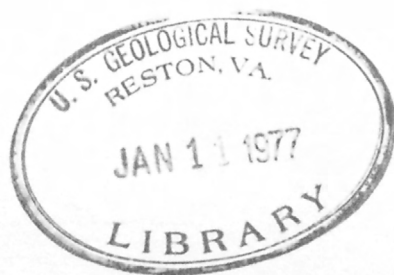
By Harvey E. Jobson, and Alex M. Sturrock, Jr.
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CONVERSION TABLE

Factors for converting metric units to English units are shown to four significant figures.

<u>Multiply metric unit</u>	<u>By</u>	<u>To obtain English unit</u>
metres (m)	3.281	feet (ft)
millimetres (mm)	0.03937	inch (in)
metres per second (m/s)	35.31	feet per second (ft/s)
cubic metres per second (m ³ /s)	0.02832	cubic feet per second (ft ³ /s)
pascal (pa)	10.00	millibars (mb)
watts per square metre (W/m ²)	2.065	calories per square centi- metre per day (cal/cm ² /d)

COMPREHENSIVE MONITORING OF METEOROLOGY, HYDRAULICS, AND THERMAL
REGIME OF THE SAN DIEGO AQUEDUCT, CALIFORNIA

By Harvey E. Jobson, and Alex M. Sturrock, Jr.

ABSTRACT

Water temperature, as well as meteorologic and hydraulic variables which influence the energy budget of the San Diego Aqueduct in southern California, were continuously monitored for a 1-year period beginning July 24, 1973. The incoming solar and atmospheric radiation, windspeed and direction, water temperature, and the wet- and dry-bulb air temperatures were recorded at 10-minute intervals at each end of the 26-km concrete-lined canal, while the flow rates and stages were determined at hourly intervals for five locations. While only daily averaged values are presented in this report, a magnetic tape containing all the data can be obtained from the Automatic Data Processing Unit, U.S. Geological Survey, Water Resources Division, Reston, VA 22092. This report presents all information necessary for the use and interpretation of these data.

Windspeeds were typically low during the early morning hours and a maximum during the late afternoon; however, they were variable spatially. On the other hand, incoming radiation and absolute vapor pressure appeared to vary little from point to point. At a point where only the air temperature is known, the most accurate method to estimate vapor pressure is to compute it from the wet- and dry-bulb temperatures obtained at a remote site.

INTRODUCTION

The ability to predict the effects of man-induced activity on various physical and biological water-quality factors is becoming increasingly important. Water temperature, while being an important water-quality characteristic in itself, affects nearly every physical property of water and influences the rate of nearly all chemical and biological reactions. A major obstacle to accurate temperature prediction in open channels is the estimation of the heat exchange due to evaporation.

In 1973 a comprehensive study of evaporation from open channels was initiated. The San Diego Aqueduct, owned and operated by the Metropolitan Water District of Southern California, was selected as the study site. The San Diego Aqueduct is a concrete-lined, open channel originating near Hemet, Calif. (about 120 km southwest of Los Angeles) and flowing generally south for about 26 km. The canal has a 3.66-m bottom width and side slopes of 1.5 to 1. At full capacity it will deliver about $28 \text{ m}^3/\text{s}$, but it generally flows near half capacity. Since it carries water for municipal purposes, the flow rate is steady for long periods of time. Only three diversion points exist. Two of these are seldom used while the third is insignificant in size.

Water temperature, as well as meteorologic and hydraulic variables, which influenced the energy budget of the canal were continuously recorded for a 1-year period beginning July 24, 1973. The incoming solar and incoming atmospheric radiation, windspeed and direction, water temperature, and wet- and dry-bulb temperatures were recorded at 10-minute intervals for each end of the canal, while the discharge and stage were recorded at hourly intervals for five locations.

The purpose of this report is three-fold: (a) To present a description of the site, instrumentation, and procedures used in the study of the San Diego Aqueduct, (b) To present daily averaged values of the data obtained and provide the information necessary for the use of the complete data set, and (c) To present a general analysis of the temporal and spatial variability of the recorded data.

All data obtained during the study are available on magnetic tape and can be obtained from the Automatic Data Processing Unit, U.S. Geological Survey, Water Resources Division, Reston, VA 22092. The tape contains 10-minute values of all meteorologic and temperature data, hourly values of hydraulic data, and daily values of rainfall, pan evaporation, and supplementary windspeed measurements.

The spatial and temporal variations in windspeed and direction are analyzed in this report. The frequency of occurrence of winds of various speeds and directions is also presented for each end of the canal. In addition to a presentation of the spatial and temporal variations in incoming atmospheric and solar radiation, the measurements are compared to computed clear-sky values and the dependence of the measured diurnal variation in atmospheric radiation on sensor type is illustrated. Because the wet-bulb temperature is such a difficult parameter to measure, an analysis is presented which determines the most accurate method of predicting the vapor pressure using wet- and dry-bulb temperatures from a remote site. The variations in resistance to flow which occurred throughout the year are also presented.

ACKNOWLEDGMENTS

The authors acknowledge the excellent cooperation extended by the Metropolitan Water District of Southern California. They granted the U.S. Geological Survey permission to install instrumentation on their premises, furnished copies of their operating records, and provided valuable assistance in the routine operation of the data-collection program. Especially helpful were Messrs. Paul Singer and Charles Voyles who were instrumental in granting the Survey permission to use the canal and to Mr. Kenneth Gandee who provided for the routine operations of the data collection.

SITE DESCRIPTION

Evaporation was the process of major concern in the study and thus influenced the selection of a study site. Since the energy exchange due to evaporation is often small by comparison to radiation exchange and energy convected into and out of a streamflow system, the most desirable site for study would be one where evaporation would be large and variations in the other elements of the energy budget small. Thackston and Parker (1971) presented monthly averaged meteorologic conditions for 88 locations in the United States. After a thorough study of these conditions, it was decided that the hot, dry climate found in southern California and southern Arizona provided the best general location for the study. Restricting attention to this general region of the country, a canal or other open-channel reach was sought which would have: (a) a travel time of approximately 12 hours; (b) fairly constant and easily defined geometric and hydraulic characteristics; (c) reasonably steady flow rate; (d) very few tributary inflows or diversions; (e) a maximum depth of about 3 m; and (f) a fairly uniform wind exposure along the reach. After considerable reconnaissance,

it was found that the San Diego Aqueduct most nearly met all the requirements. The San Diego Aqueduct carries water from the Casa Loma Canal to Lake Skinner (fig. 1).

Water for the San Diego Aqueduct is diverted from the Colorado River, below Parker Dam, and carried by the Colorado River Aqueduct to a point just west of the San Jacinto Mountains (fig. 1, upper right corner). At this point, the water can be diverted to the Casa Loma Canal or directly to the city of San Diego by underground pipe lines. Water for the San Diego Aqueduct is diverted from the Casa Loma Canal.

The general topography in the region consists of mountain massifs separated by the flat San Jacinto Valley floor. Areas with elevations above 610 m are shaded in figure 1. The elevation of the valley floor is approximately 450 m. The upper 40 percent of the canal traverses the approximate center of the valley while the lower 60 percent of the canal runs along the extreme eastern edge of the San Jacinto valley with the land generally rising sharply to the east of the canal but being fairly flat to the west. A few short reaches in the lower part of the canal pass through cuts as deep as 18 m with steep side slopes. In general, the hilly areas of the region are used only for grazing while the valley is grazed or used for the production of hay or other dryland crops. The National Atlas (U.S. Geological Survey, 1970) describes the natural vegetation as Coastal Sagebrush or Chaparral. Vegetation is of minor importance to the exposure of the water surface to either wind or radiation.

Thorntwaite (1931) described the climate as semi-arid. The National Atlas (U.S. Geological Survey, 1970) shows the mean annual precipitation

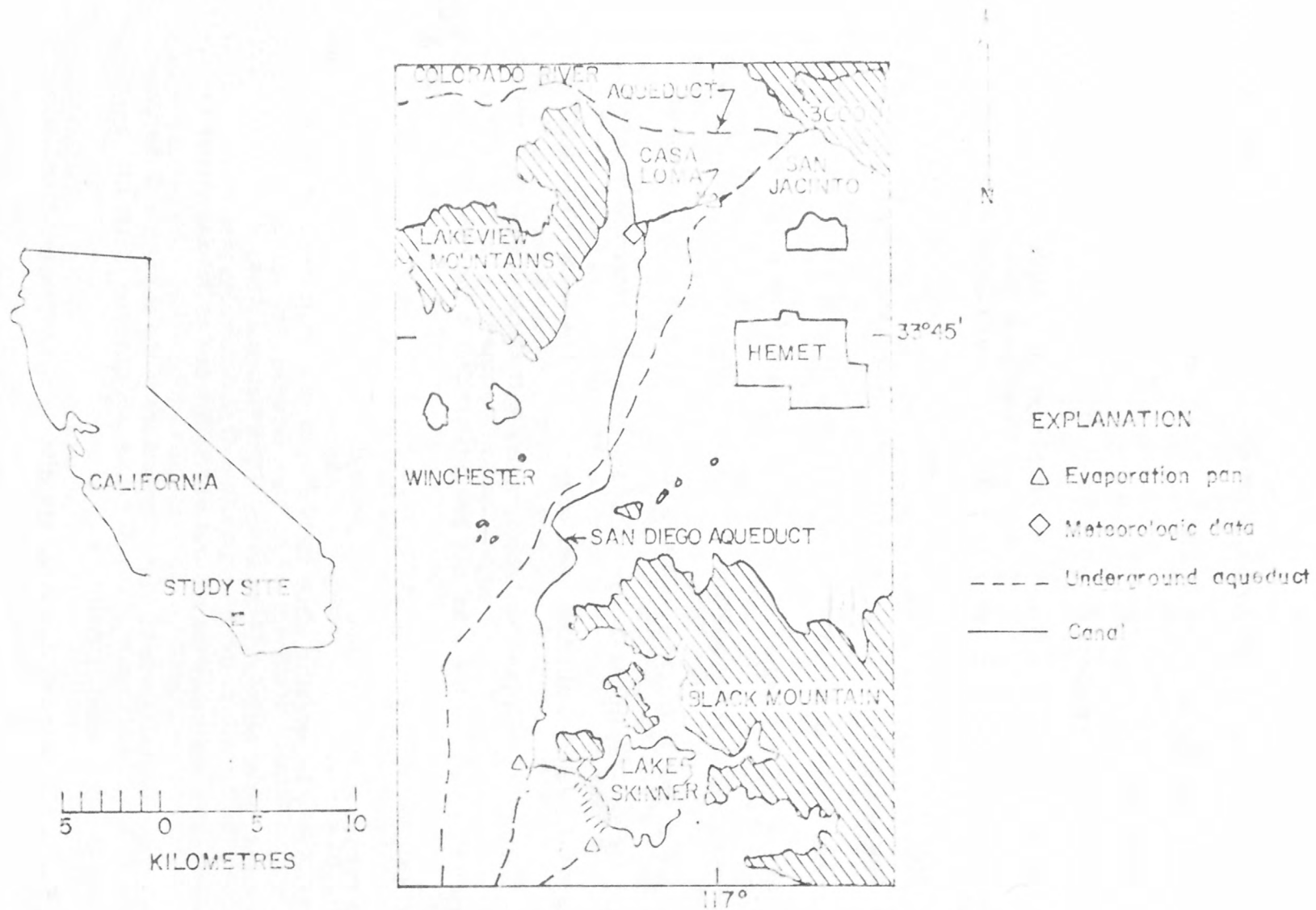


Figure 1.--San Diego Aqueduct showing data-collection points.

as ranging from 200 to 400 mm, with 30 days per year having more than 0.3 mm. The average annual runoff for the region is low, ranging from 10 to 30 mm, however, up to 130 mm of runoff may be expected in the mountains. Almost no precipitation occurs during the months of May - October. The average solar radiation is 121 W/m^2 in January, and is 315 W/m^2 in July, while the mean temperature ranges from a low of 10°C in January to a high of 24°C in July. The mean dew point temperature is 2°C in January, while it is 10°C in July.

The San Diego Aqueduct is concrete-lined with bottom slope of 0.00012. The cross section of the canal is trapezoidal with a 3.66-m bottom width and side slopes of 1.5 to 1. The maximum design depth is 3.05 m with a 0.305-m free board. It has a capacity of about $28 \text{ m}^3/\text{s}$. The spoil dirt from the canal was piled along the sides so that the typical cross section appears as shown in figure 2. The spoil bank height varies along the length of the canal as shown in figure 3. The three very large bank height values represent places where the canal passes through deep cuts, but for the rest of the canal the bank height is more or less representative of the height of the spoil bank.

The 16 siphons which carry water under roads and drainageways for San Diego Aqueduct are shown in figure 4. The longest, just south of Holland Road, is 197 m long, and the shortest, under Cottonwood Avenue, is 13 m long. The length, type, and location of all siphons are summarized in table 1. All siphons here have smooth transitions in the channel cross section upstream and downstream.

Three points are available for diverting water from the canal. The first diversion structure, near Simpson Avenue, allows water to be diverted into

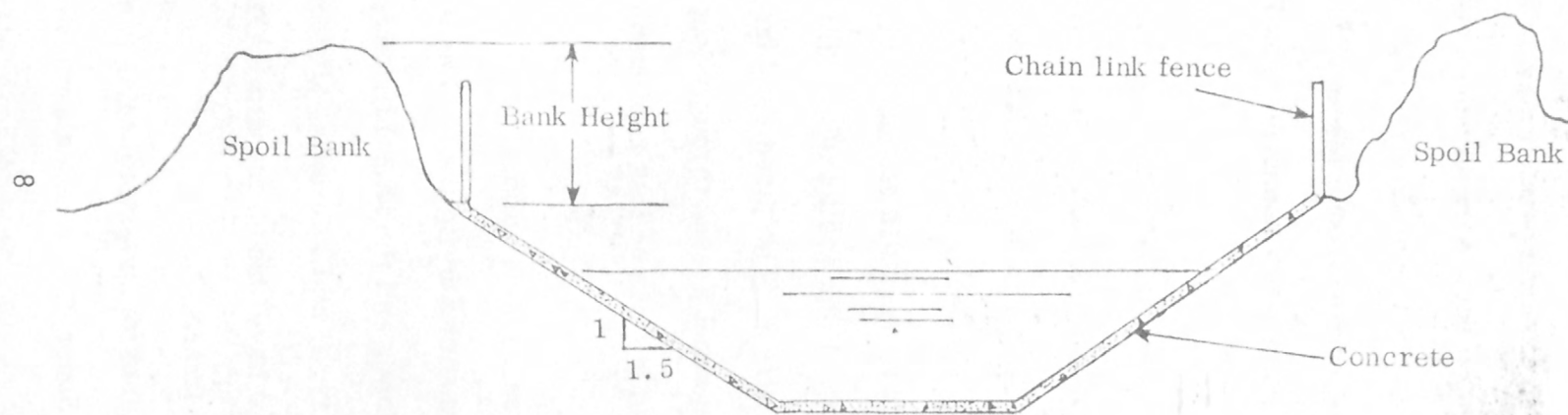


Figure 2.--Typical cross section of the canal.

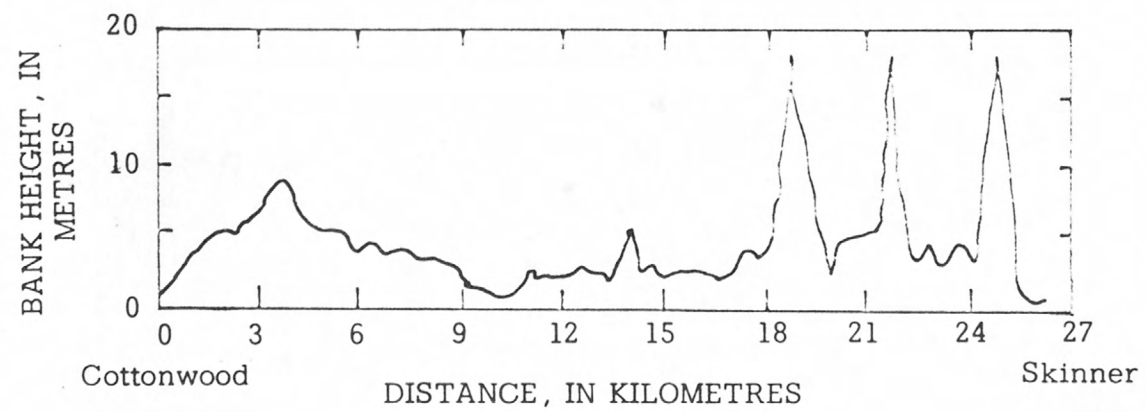


Figure 3.--Variation of bank height with distance along the canal.

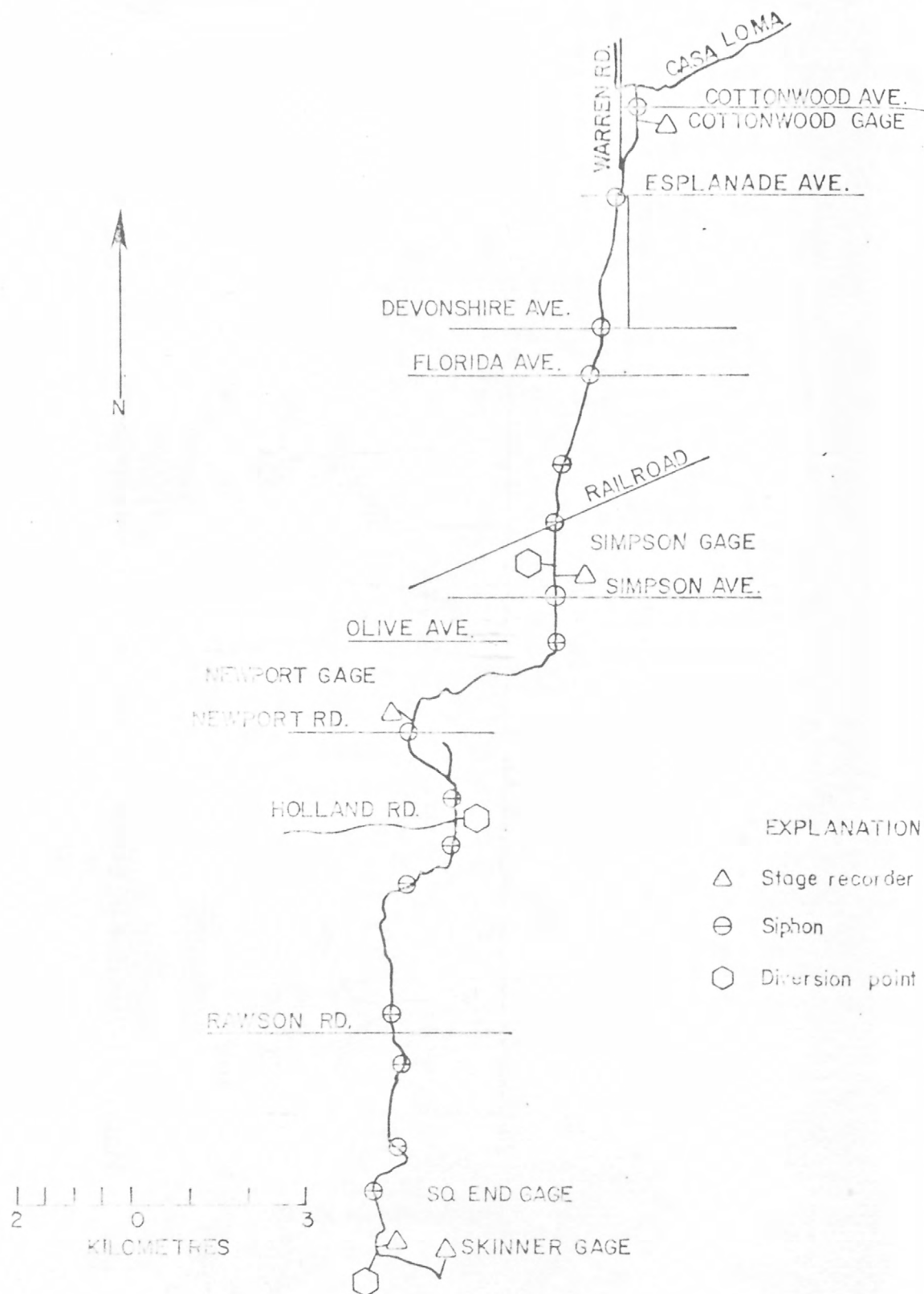


Figure 4.-- San Diego Aqueduct showing the diversion points, and the locations of siphons and stage recorders.

Table 1.--Locations of structures on San Diego Aqueduct

(Information furnished by the Metropolitan Water

District of southern California)

Name of structure	Distance from canal intake (m) ¹	Siphon characteristics	
		Length (m)	Size
Cottonwood	297.5	13.0	pipe, 3.96 m I.D. ²
Cottonwood stage	593.7	-	-
Esplanade	1978.6	75.3	box, 3.81 x 3.35 m
Devonshire	4453.4	40.3	box, 3.81 x 3.35 m
Florida	5275.8	66.3	box, 3.81 x 3.35 m
Stetson	6982.8	65.0	box, 3.81 x 3.35 m
Railroad	8019.6	107.8	box, 3.81 x 3.35 m
Simpson diversion	8793.8	-	-
Simpson stage	9134.2	-	-
Simpson	9410.9	61.1	box, 3.81 x 3.35 m
Olive	10135.8	142.9	pipe, 3.96 m I.D.
Newport stage	13460.3	-	-
Newport	13604.5	55.9	box, 3.81 x 3.35 m
Holland Road	15155.7	197.5	pipe, 3.96 m I.D.
EM-8 diversion	15353.2	-	-
South Domanigoni	15932.6	133.8	pipe, 3.96 m I.D.
Garbani Ranch	17042.0	158.5	pipe, 3.96 m I.D.
French	19571.5	36.4	box, 3.81 x 3.35 m
Rawson Road	20519.8	61.1	box, 3.81 x 3.35 m

Note: Footnotes on last page of table.

Table 1.-- (Continued)

Name of structure	Distance from canal intake (m)	Siphon characteristics	
		Length (m)	Size
Bachelor Mountain	22525.7	158.5	pipe, 3.96 m I.D.
South Bachelor Mountain	23852.1	36.4	box, 3.81 x 3.35 m
So End diversion	24978.4	-	-
So End stage	24978.4	-	-
Skinner stage	25978.1	-	-
Skinner inlet	25982.7	-	-

¹Locations for siphons are determined by location of the siphon intake.

²Inside diameter.

the underground aqueduct shown in figure 1. This structure was in operation during 35 percent of the study and diverted a maximum of $3.02 \text{ m}^3/\text{s}$. The second diversion, known as EM-8, is insignificant in size. The maximum diverted flow was $0.15 \text{ m}^3/\text{s}$, but it generally diverted only about $0.03 \text{ m}^3/\text{s}$ for 1 or 2 hours during the day. This diversion structure is just below Holland Road and supplies water for a chicken farm. The third diversion structure, the So End diversion, allows water to be diverted to San Diego without passing through Lake Skinner (fig. 1). The So End diversion was not used except during the last 71 days (20 percent) of the study when it was in continuous operation.

The diversion of water from the Casa Loma Canal at the entrance to the San Diego Aqueduct is shown in figure 5. This photograph was taken from the east bank of the San Diego Aqueduct while facing north. The Casa Loma flows from east to west just behind the diversion structure. The outlet of the canal into Lake Skinner is shown in figure 6. This photograph was taken while standing on the dam facing west.

INSTRUMENTATION

Recording System

Three types of recording systems were used for the study. Windspēed, wind direction, solar radiation, atmospheric radiation, wet- and dry-bulb temperatures, and water temperatures for each end of the canal were recorded digitally at 10-minute intervals. Analog recorders were used to continuously record the stage at five points along the canal, the discharge of the EM-8 and Simpson road diversions, and after February 28, 1974, the discharge at the lower end of the canal. Analog records were digitized

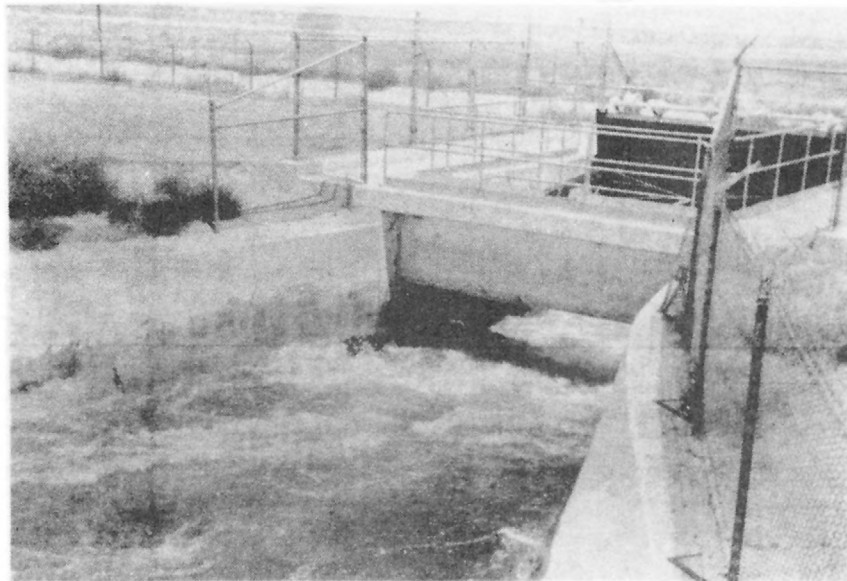


Figure 5.--Diversion of water from the Casa Loma Canal at the entrance to the San Diego Aqueduct. Photo taken from the east bank while facing north.

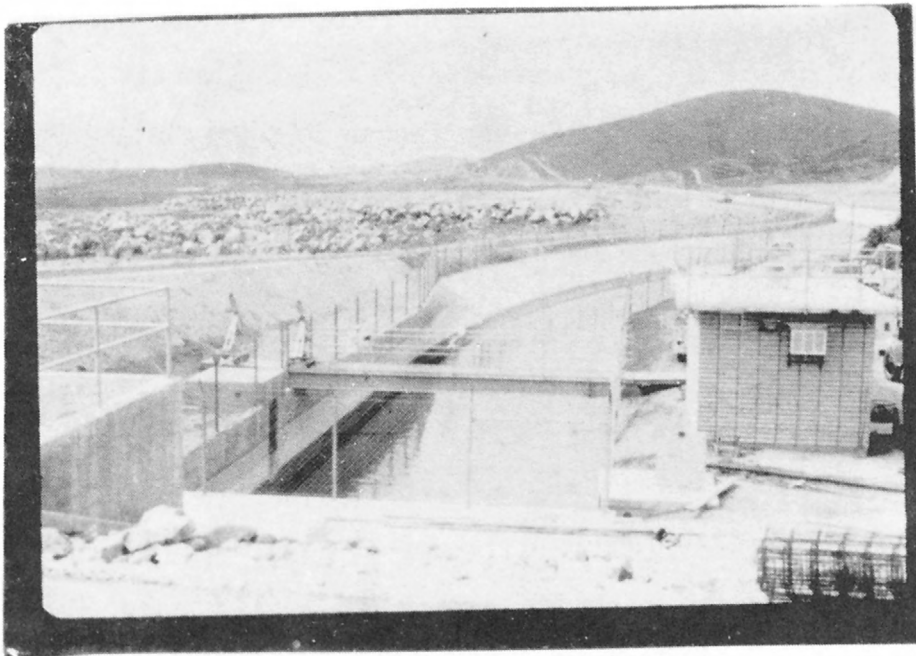


Figure 6.--Skinner end of San Diego Aqueduct. Photo taken from Lake Skinner dam looking west.

manually at hourly intervals. Rainfall, pan evaporation, pan windspeed, prevailing wind direction, and general weather conditions were observed daily.

The primary recording system to monitor radiation, wind, and temperatures consisted of Esterline Angus¹ D2020 recorders coupled with Pertec magnetic tape recorders. At 10-minute intervals the time, as well as the millivolt values of all 10 parameters, were recorded on magnetic tape. No averaging of the readings was possible, so recorded values were the millivolt readings at the instant they were sampled. A sampling of all 10 channels took only about 5 seconds. At approximately 1-hour intervals, the same information was printed in digital form on a paper tape. The paper tape allowed field monitoring of the system and served as a backup record on a few occasions when the magnetic tape system failed. At weekly intervals the magnetic and paper tapes were removed and mailed to Bay St. Louis, Miss. for processing. A total of 12 tapes was sufficient to allow them to be copied, cleaned, and returned to the field for reuse without a shortage occurring. The system at the Cottonwood (north) end was housed in a plywood shelter (fig. 14), and at the Skinner (south) end it was housed in a concrete building (figs. 6 and 7).

The water stage was recorded on vertical-drum graphic recorders. These recorders had an unlimited range in stage because a stylus-reversing device activated for each 0.3-m change in stage. A distance of 12.7 mm on the chart corresponds to a stage change of 0.305 m, and a distance of 4.6 mm corresponds to a time lapse of 24 hours. The stage records were collected as a part of the Metropolitan Water District's routine operating data. Charts were changed on a weekly basis and copies of the charts

¹The use of brand names in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

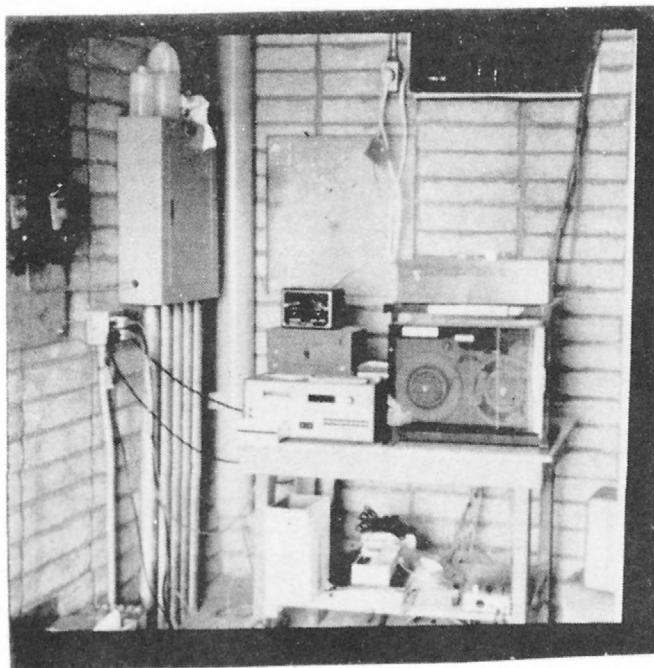


Figure 7.--Recording system at downstream end of the canal.

were furnished to the Survey for analysis. These charts were read manually to determine the stage to the nearest 3 mm each hour. The head on a Venturi meter at the Simpson road diversion was also determined from records of this type. The recorded head was converted to a discharge by use of a rating curve.

The diversion discharge to the chicken farm (EM-8) was recorded on a circular graphic chart which made one revolution per week. The chart was activated by the head on a Venturi meter and was calibrated to read flow rate directly. The discharge could be easily read to the nearest $0.01 \text{ m}^3/\text{s}$. After February 28, 1974, the flow into Lake Skinner was recorded on a circular graphic chart which made one revolution per week. The flow rate could be easily read to the nearest $0.3 \text{ m}^3/\text{s}$. All circular charts were changed weekly, copies were sent to the Survey and digitized on an hourly basis. A supplementary windspeed was recorded on a weekly circular chart which contained a pip mark for the passage of each 16 km of wind. These charts were changed weekly and the mean windspeed for each day estimated.

Wind

Propeller-type anemometers were used as the primary wind-sensing devices. The starting speed of the propeller is about 0.45 m/s with complete tracking at about 1.40 m/s . The wind direction was measured by the movement of a wiper arm on a potentiometer housed in the main body of the anemometer.

The general exposure of the anemometer at Cottonwood is illustrated in figure 8. The sensor head was located approximately 2 m above the

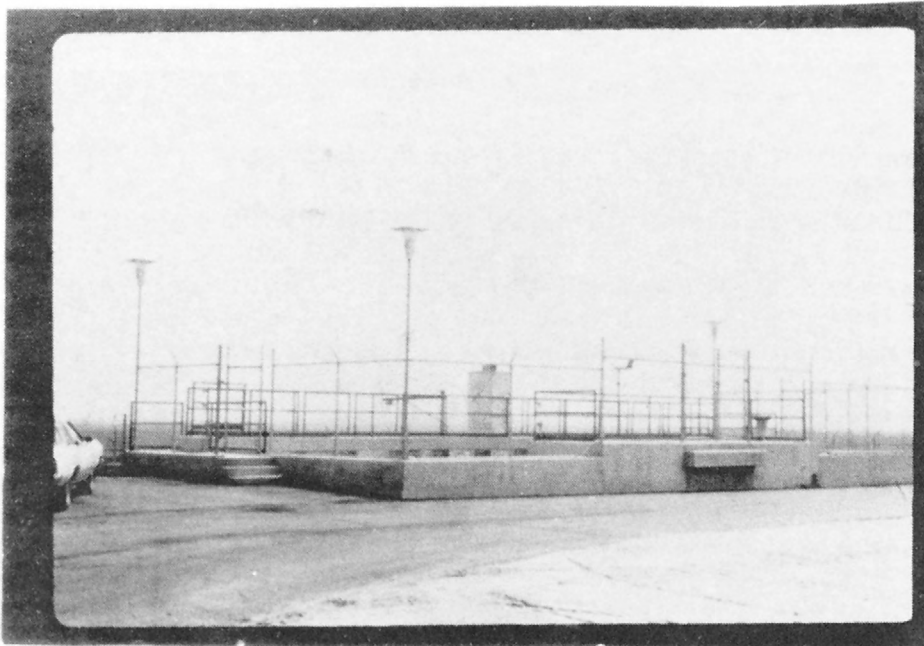


Figure 8.--Wind exposure of Cottonwood meteorologic station.

concrete platform, approximately 2.4 m above the elevation of the asphalt parking lot surrounding the concrete structure, and approximately 3.1 m above the surrounding ground level. The sensor was 3.8 m above the top of the canal. The valley floor is flat in this area and no major obstructions occur within 1 km. The wind exposure at the Skinner station was quite different than the Cottonwood station. The terrain rises steeply to the north as shown in figure 9, whereas it falls off rather rapidly to the south and west (fig. 10). The exposure of the primary anemometer at Skinner was adequate for south or west winds, poor for north winds, and only fair for east winds. The effective height probably varies with wind direction. The sensor was mounted 0.86 m above the roof of the building shown in figure 6. The railing (which was added after the study began) partly hides the sensor in the figure. The building roof is 3.05 m above the level of the parking lot. The parking lot is generally lower than the surrounding terrain but about 0.3 m above the top of the canal.

Supplementary windspeed measurements were obtained over the water. At Cottonwood the supplementary anemometer was mounted on a swing-out arm which projected 3.0 m from the canal edge. The anemometer was 3.3 m above the top of the canal lining. The general location of the anemometer is illustrated in figure 11. Windspeed measurements were obtained by use of vertical axis cup anemometers equipped with totalizing dials. An electrical contact was closed upon the passage of each 16 km of wind and the contact closure times were recorded on a circular chart. A closeup of the anemometer used at Cottonwood is shown in figure 12. At Skinner the supplementary anemometer was mounted on a short arm projecting to

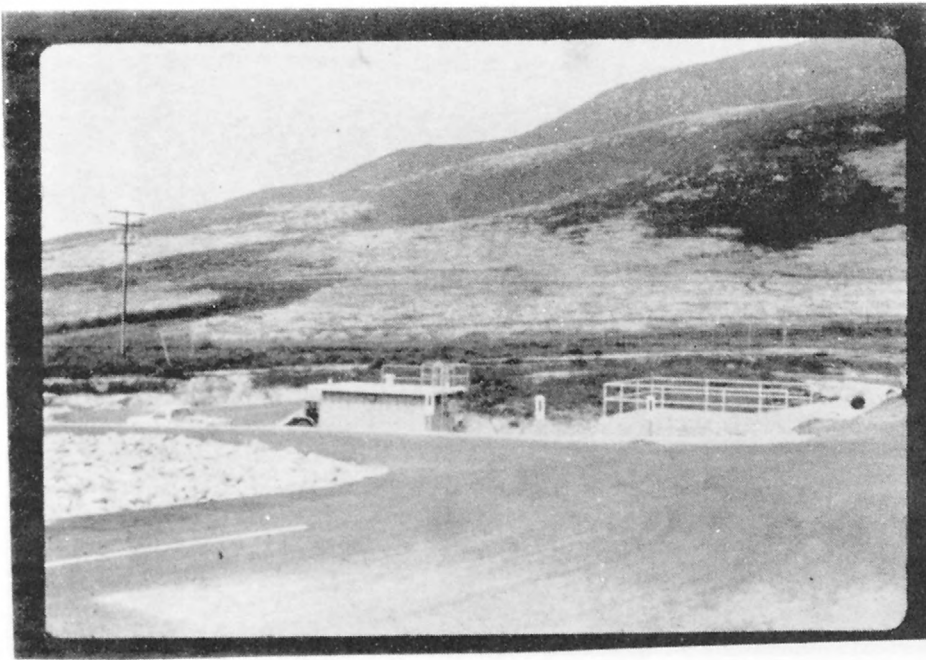


Figure 9.--Wind exposure at Skinner. Photograph taken from dam looking generally north.

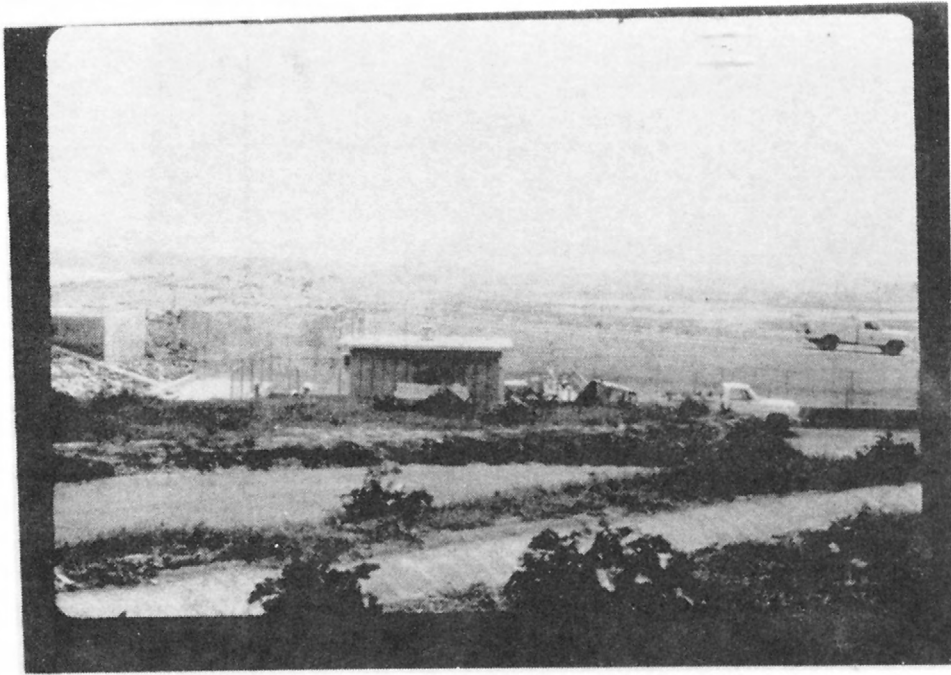


Figure 10.--Wind exposure at Skinner. Photo taken facing south.

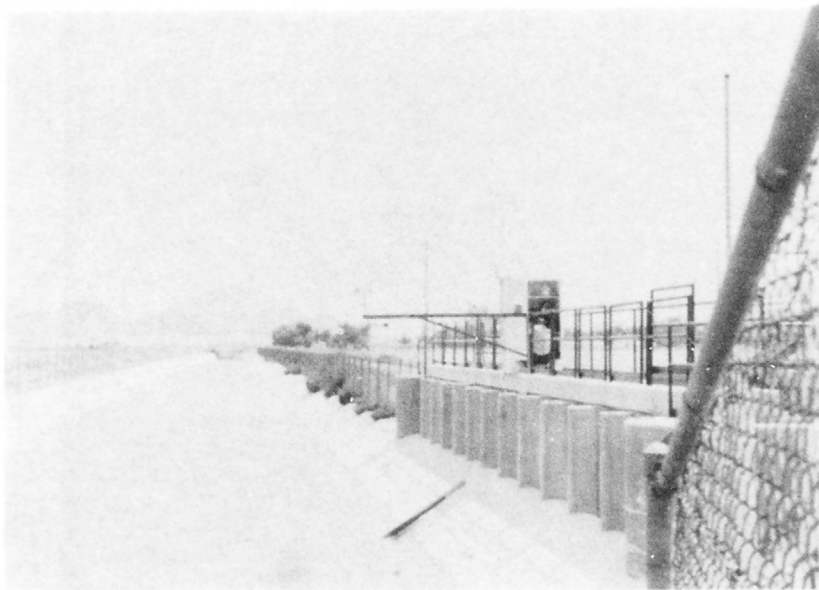


Figure 11.--Psychrometer and supplementary anemometer at Cottonwood.

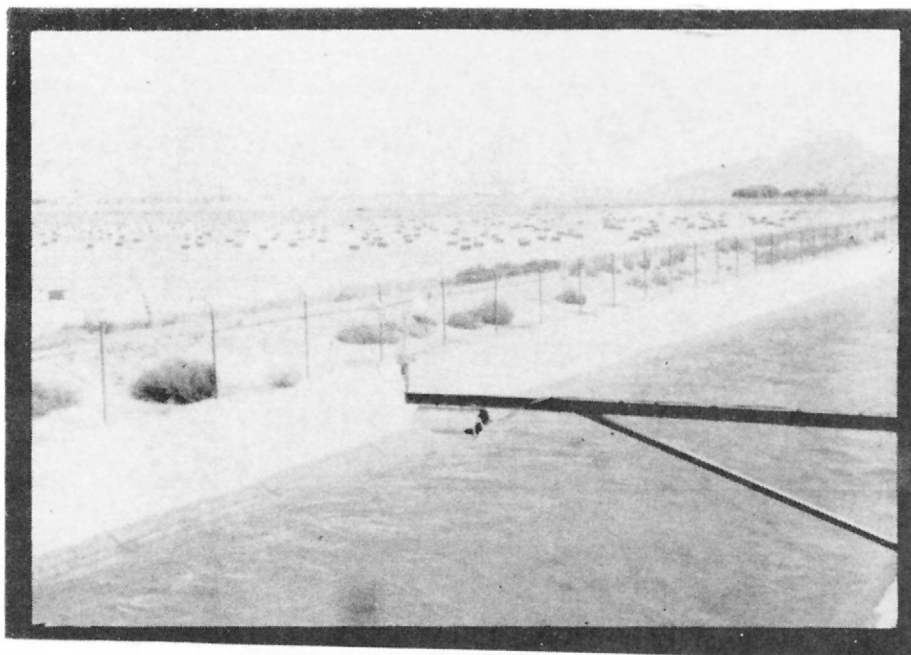


Figure 12.--Closeup of supplementary wind sensor and psychrometer at Cottonwood , looking southeast.

the west of the bridge over the canal shown in figures 6 and 13. The anemometer was 2.0 m above the top of the canal and was located near the center of the bridge.

Average daily windspeeds were obtained at the evaporation pans by reading a totalizing dial on the anemometers at approximately 0900 hours daily. The anemometers were mounted on the northwest corner of the evaporation-pan platform 0.15 to 0.20 m above the lip of the evaporation pan. The location of the evaporation pans is shown in figure 1.

Radiation

The total incoming solar radiation was determined by use of Eppley precision spectral pyranometers. These instruments are sensitive to radiation with a wavelength between 0.3 and 3 micrometres. At Cottonwood the sensor was mounted on top of the plywood shelter housing the recording system (the instrument to the right in fig. 14). At Skinner it was mounted 1.14 m above the roof of the building (fig. 6)

Incoming atmospheric (longwave) radiation was determined by use of two types of instruments. From July 24, 1973, until November 27, 1973, atmospheric radiation was determined by use of Eppley (longwave) pyrgeometers which are sensitive to radiation in the range of 4 to 50 micrometres. These instruments were mounted beside the pyranometers (figs. 6 and 14). After November 27, 1974, a flat-plate radiometer of the Gier-Dunkle type was used to determine the incoming atmospheric component at Cottonwood. The flat-plate radiometer is sensitive to radiation of all wave lengths. Accordingly, the solar component, determined by use of the pyranometer, was subtracted from the total incoming radiation to

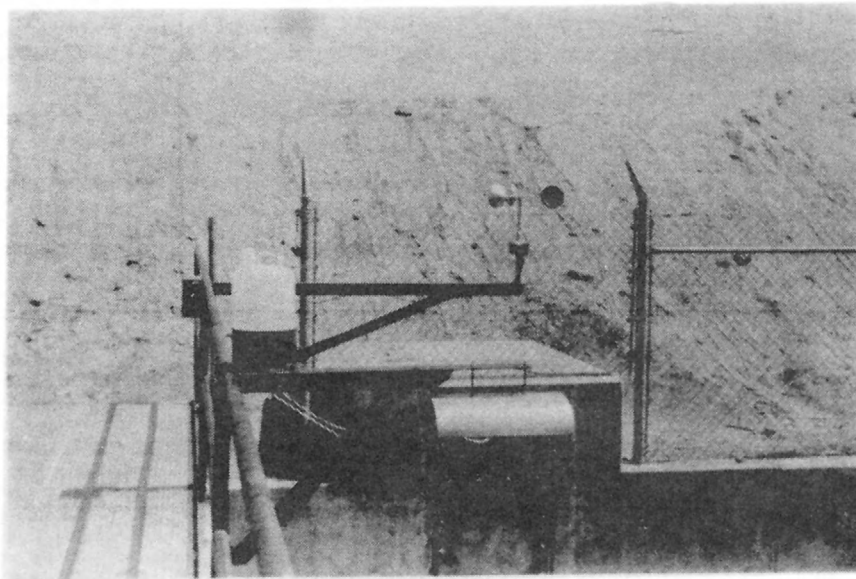


Figure 13.--Closeup of supplementary wind sensor and psychrometer at Skinner, looking south.

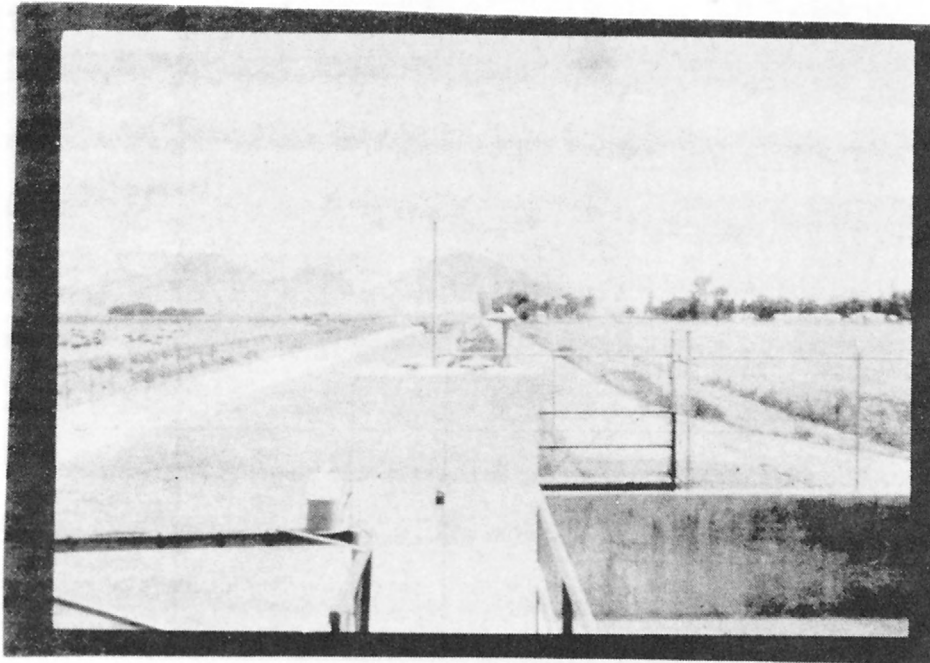


Figure 14.--Radiation instrumentation at Cottonwood, looking south.

give the atmospheric component. The flat-plate radiometer was also mounted on top of the plywood shelter.

Temperature

All temperatures were determined by use of platinum resistance temperature devices (RTD's). A 10-volt regulated d.c. power supply furnished the required voltage to all the sensors. Capsule-style sensors with a sheath length of 63 mm and diameter of 3.2 mm were used for the dry- and wet-bulb temperatures. For measurement of water temperatures, a sensor with a sheath length of 127 mm and diameter of 6.3 mm was used.

Measurements of wet- and dry-bulb temperatures were made with a ventilated psychrometer as shown in figures 12 and 13. To insure proper wet-bulb depression, a vane axial fan with a constant output of 4.5 m/s was used to draw air through the tube. The total length of the tube was 203 mm and the entire assembly was shielded from radiation by a curved aluminum sheet 380 mm long and curved in a semicircle with a 190-mm radius (fig. 15). The wet- and dry-bulb temperatures were measured by probes projecting across the tube mounted 139 mm and 51 mm behind the tube intake, respectively. The wet-bulb probe was covered by a wick which was continuously wetted by distilled water. The wick was a common white cotton shoelace which had been boiled in detergent to remove sizing and rinsed in distilled water. Water was supplied to the wick by gravity flow from a 1-gallon plastic bottle through a capillary tube. The rate of flow in the tube was controlled by a needle valve at the base of the bottle.

At Cottonwood the psychrometer was mounted under the swing-out arm as shown in figure 12. It was 2.7 m above the top of the canal. The

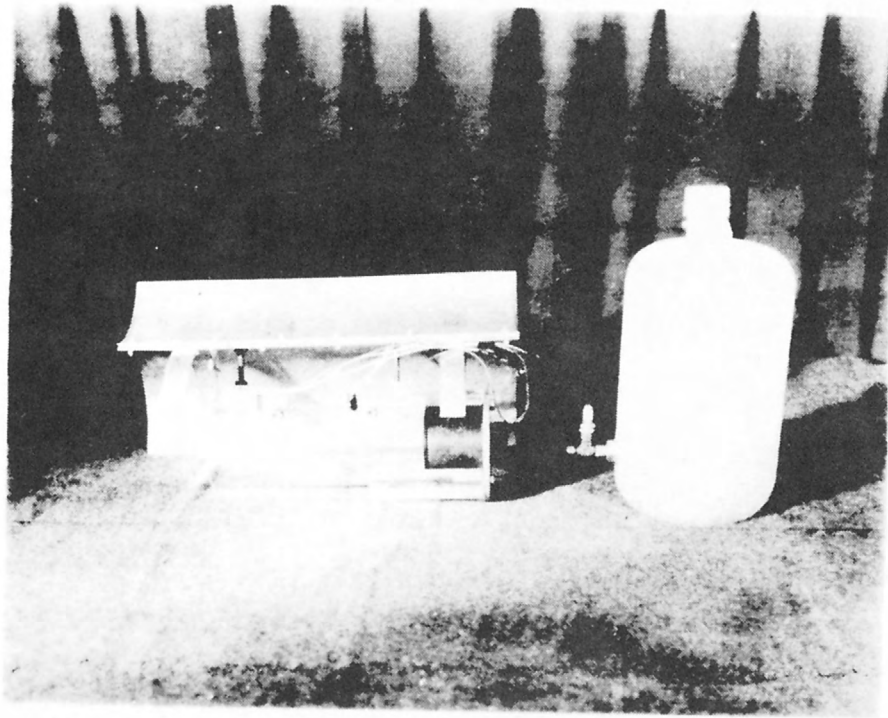


Figure 15.--Closeup of psychrometer.

general location of the psychrometer is illustrated in figure 11. At Skinner the psychrometer was mounted on a short arm which projected to the west of the bridge shown in figures 6 and 13. The psychrometer was 1.4 m above the top of the canal and near the center of the bridge.

Water-temperature probes were fastened to a wooden plank in such a manner that they would be 0.15 , 0.61 , 1.1 , and 1.5 m above the bottom of the canal. At Cottonwood the plank was mounted to the west side of the canal so that it sloped downward with the canal side. The top of the plank can be seen in figure 11. The temperature probes were held about 40 mm away from the concrete wall. Water temperatures were always found to be uniform, so on November 29, 1973, the bottom probe at Cottonwood was removed and not used during the remainder of the study. At Skinner a plank was mounted to the bridge so that it was held vertically near the center of the canal. The vertical locations of the probes at Skinner were the same as those used at Cottonwood.

Stage

The stage in the canal was recorded at the five locations shown in figure 4. In all cases, a float-stilling-well arrangement was used, and zero stage corresponds to zero depth in the canal. The Cottonwood gage was located on the right bank 0.593 km downstream of the canal entrance. The outlet of the Cottonwood Avenue siphon was 0.28 km upstream of the gage, and the entrance to Esplanade Avenue siphon was 1.38 km downstream. A gentle curve to the right begins 0.07 km below the gage. A photograph of the recorder and top of the stilling well is shown in figure 16, and the general canal conditions with a flow of about $2.8 \text{ m}^3/\text{s}$ is shown in figure 17.



Figure 16.--Recorder and stilling well at the Cottonwood gage, looking upstream.

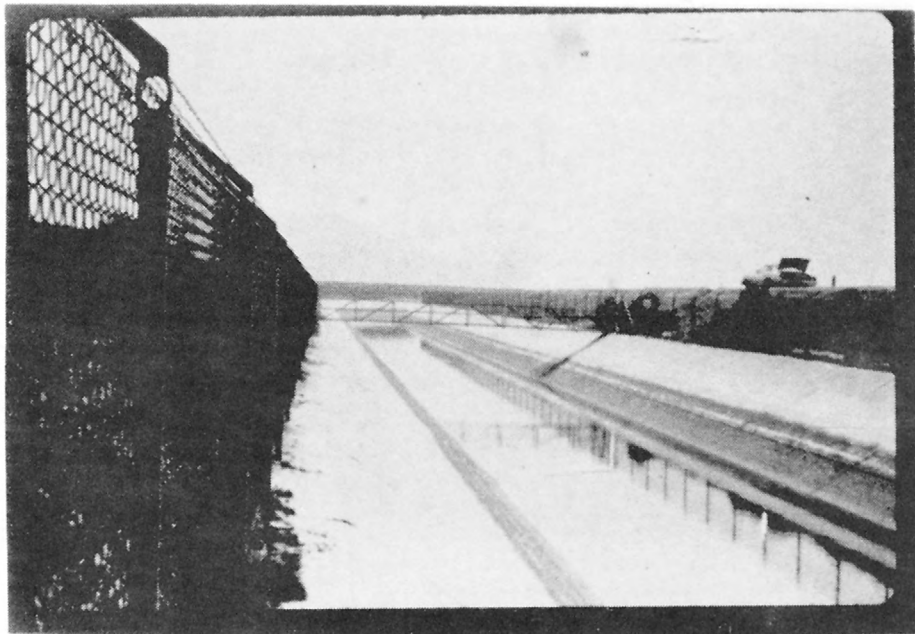


Figure 17.--Canal at the Cottonwood gage, looking downstream.

Current meter measurements, made from the bridge shown in figure 17, were used to determine a stage-discharge relationship. The Cottonwood stage record was used to determine the discharge during times of unsteady flow.

The Simpson gage located 9.13 km downstream from the canal entrance is mounted over the center of the canal as shown in figure 18. It is 1.01 km downstream of the railroad siphon and 0.28 km upstream of the Simpson Road siphon. The Newport gage, located on the right bank 13.46 km downstream of the entrance, is shown in figure 19. The Newport gage is 3.18 km downstream of the Olive Avenue siphon and 0.14 km upstream of the entrance to the Newport Road siphon. The So End gage, shown on the left side in figure 20, is located at the entrance to the So End diversion (fig. 1). Before the construction of Skinner reservoir, the So End diversion was the south end of the open part of the San Diego Aqueduct. The diversion is to the left in figure 20 and the flow into Lake Skinner continues toward the lower right. The Skinner gage was housed in the concrete building shown in figure 6 and is at the downstream end of the canal 25.98 km downstream of the canal entrance. The use of this gage was discontinued on February 20, 1974. The discharge at the time the photographs in figures 17, 18, 19, and 20 were taken was about $2.8 \text{ m}^3/\text{s}$.

Flow Rate

Canal and diversion discharges were furnished by the Metropolitan Water District from their operating records during times of steady flow. The flow rate at Cottonwood was determined by the Metropolitan Water District from an analysis of gate openings which were periodically calibrated by current-meter measurements at the Cottonwood gage. The diver-



Figure 18.--Simpson gage, looking south.

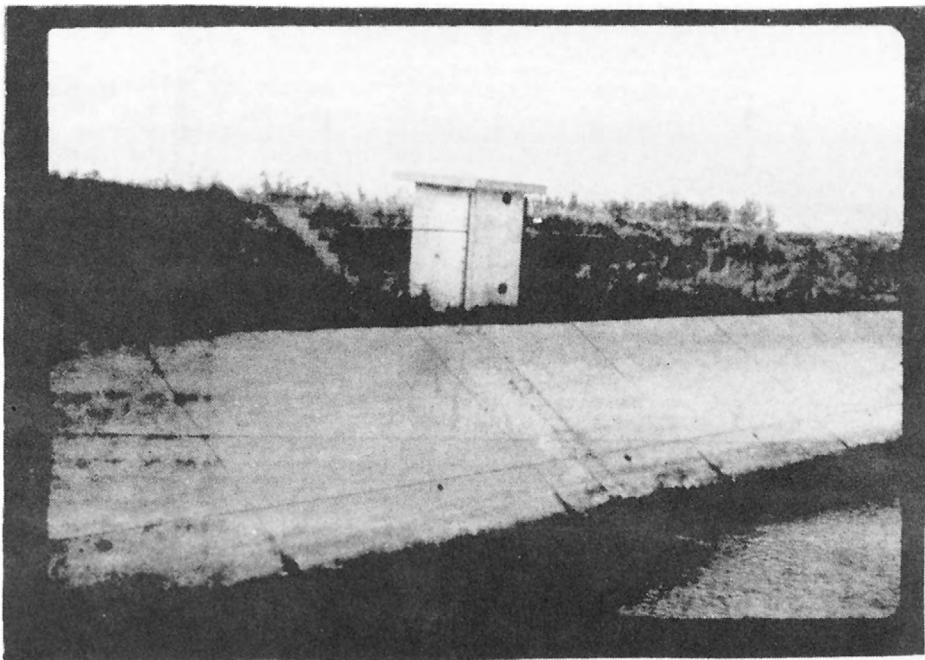


Figure 19.--Newport gage.

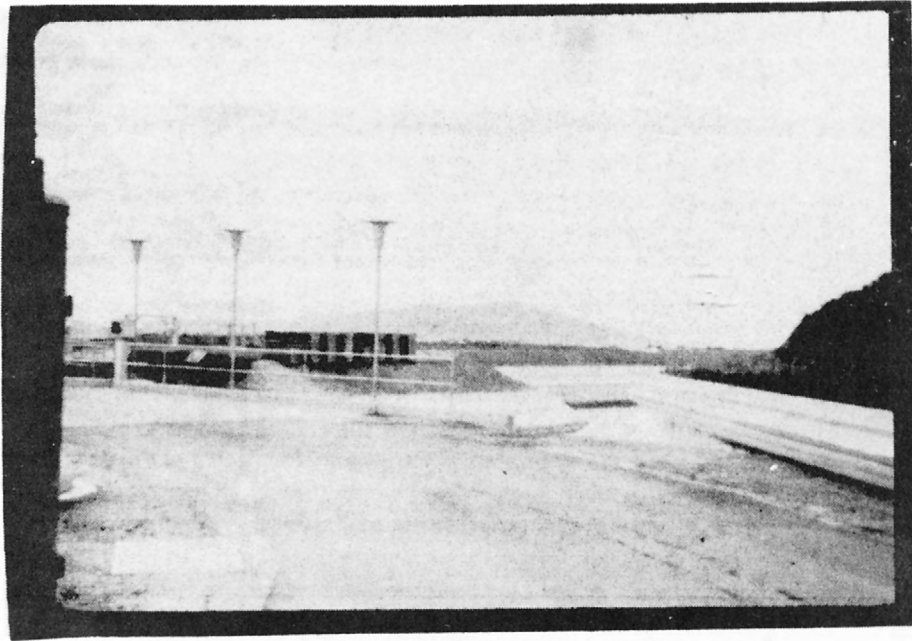


Figure 20.--So end gage and diversion, looking west.

sion discharge at Simpson road is determined by use of a calibrated weir. At the EM-8 diversion a Venturi meter was used. After February 28, 1974, the flow rate into Lake Skinner was continuously monitored by use of a sonic flow meter. The flow rate at the So End diversion was not measured but can be obtained from continuity considerations.

Other Data

The Metropolitan Water District maintains two evaporation pans at the locations indicated in figure 1. The daily rainfall, pan evaporation, pan windspeed, general weather observations, and wind direction are recorded at about 0900 each day. On October 9, 1973, the observation station near the So End diversion was moved to a point near the Lake Skinner outlet. Both locations are shown in figure 1.

PROCEDURE

Data Collection

All meteorologic instrumentation was designed to operate unattended for time periods of up to 1 week. However, on alternate days, the canal patrolman: (1) wiped dust from the radiometer bulbs; (b) checked the wick on the psychrometer (clean or change if necessary); (c) filled bottle with distilled water if necessary; (d) checked the printed output tapes for obvious malfunctions; (e) checked blower motors on the psychrometers; and (f) reported any malfunction to the Survey for correction. On a weekly basis, Water District personnel changed the magnetic and paper tapes as well as all weekly charts. The junior author visited the site on an approximately monthly basis to perform maintenance, check on the overall operation of the data-collection system, and carry out special measurements.

When the field magnetic tapes were received at the office, they were copied in compacted form on an in-house tape. At the same time, a complete listing was produced as well as a time plot of the millivolt level for each channel. The computer listing and plots were compared with the output on the paper tape and instructions for further processing generated. At this point the major concern was to be sure the correct data were associated with each data block, the recorded times were correct, and that each day contained exactly 144 entries for each parameter. Corrections to the recorded times were frequently necessary because of short-term power outages, and so forth. Power outages were easily detected because the recorder clock would automatically start over at 0000 hours (midnight). All data were referenced to Pacific daylight time. Time checks written on the paper tape served as a reference for time corrections.

The hourly stage and discharge values were read from charts and keypunched. Likewise, the daily values of the supplementary windspeed, pan windspeed, pan evaporation, and daily rainfall were computed from recorded parameters and the values added to the dataset. The declination of the sun was determined from a solar ephemeris.

Data Processing

The next step in the processing of the data was to convert the millivolt values to engineering units and to delete all questionable values from the set. Converting to engineering units was simply a matter of applying the appropriate calibration factors to the millivolt readings, but detection of bad data in the set required considerable patience and systematic sorting.

Judgement as to the authenticity of the data was based primarily upon plots of the data as a function of time. Two types of plots were used; the

original plots from the field data tapes where each 10-minute value was plotted as a function of time, and daily averaged plots where the entire year's data for a single parameter at each end of the canal could be displayed on one figure. The recorder at Cottonwood developed a malfunction early in the study which caused the data to drift off the true value rather slowly with time. Comparison of the daily average plots from Cottonwood and Skinner on a channel-by-channel basis enabled the processor to determine the time at which a particular channel started drifting.

Considerable difficulty was experienced in keeping the wick on the psychrometer sufficiently wet. Time periods for which the wick was not sufficiently wet were obvious when a plot of the wet- and dry-bulb air temperature was inspected. In a like manner, times during which one of the water temperature probes was out of the water, due to low stage, were also easily detected from a plot of the four water temperatures. Each channel of data was scanned several times and data which were questionable were deleted. As a final check, after the datasets had been transferred to engineering units and questionable data deleted, a program was written which searched each channel of data for each station and printed the 20 largest values, 20 smallest values, and 20 largest changes to occur in 10 minutes, along with the date and time of occurrence of each event. The data on these listings were then rechecked for consistency and accuracy. As a final step the data were replotted on the 10-minute interval basis and the plots scanned a final time.

Hydraulic data were processed in a similar fashion except that only hourly values and not 10-minute values were involved. The EM-8 diversion

discharge was read directly from the circular chart and no processing was necessary. An analog chart of the head on the weir at the Simpson Road diversion was furnished as well as the diversion discharge during times of steady flow. An analysis of the recorded head and discharge indicated that the flow could be computed from the formula

$$Q_s = 1.62 Y_w^{1.317} \quad (1)$$

in which Y_w is the head on the weir in metres, and Q_s is the Simpson Road diversion discharges in m^3/s . Equation 1 was used to determine the Simpson Road diversion discharge during time periods when the flow was changing.

For each day during which the flow was constant (209 out of 365), the Manning's roughness coefficient applicable to the Cottonwood stage was determined. The coefficients ranged from 0.0135 to 0.0191 and could not be directly correlated with either stage or discharge. The variation appeared to result primarily from algal growth on the canal lining, and therefore, was more related to time of year than anything else.

Variable flow, extending over periods of 1-15 days, occurred on 27 occasions. During these time periods, the upstream flow was computed for each hour using the measured Cottonwood stage and Manning's equation. The roughness coefficients, obtained before and after the period of unsteady flow, were averaged for use in this computation.

Between February 28, 1974, and May 15, 1974, the discharge, as determined from the sonic flow meter at Skinner, was used to determine the flow in the canal. This value was read directly from an analog chart. The So End diversion was in operation after May 15, 1974. Subsequent to that

date the stage at Cottonwood was used to determine the flow into the upstream end of the canal, and the sonic flow meter was used to determine the flow at the downstream end. The flow at the So End diversion could then be determined indirectly.

Calibration

Table 2 contains a summary of the calibration factors for instruments used in the study. All calibration equations were of the form

$$O = a + bE \quad (2)$$

in which O is output in the engineering units shown in table 2, E is recorder output in millivolts, and a and b are constants shown in table 2.

After the study the anemometers were recalibrated and their calibration constants had changed by less than 3 percent. Temperature probes were periodically checked against mercury thermometers and always found to be within $\pm 0.1^{\circ}\text{C}$. The pyranometers were calibrated before and after use and their calibration coefficients were found to have remained constant to within ± 1 percent.

Considerable difficulty was experienced with the measurement of atmospheric radiation. Both pyrgeometers were calibrated before installation on July 25, 1973. By the end of August 1973, the measured atmospheric radiation at Cottonwood appeared to be drifting to the high side. To see if the difference between Cottonwood and Skinner readings was real or due to a drift in the calibration of pyrgeometers, on August 29, 1973, the sensors were interchanged. No shift in the daily average values at either end of the canal was observed after the sensors were interchanged, so it was assumed that the sensor calibrations were still valid. Although the

Table 2.--Calibration factors (for use in equation 3) of
instrumentation used at the San Diego Aqueduct

Parameter	a	b	Units	Applicable dates
Cottonwood windspeed	0.11	0.1984	m/s	07-25-73 - 07-23-74
Skinner windspeed	0.08	0.1997	m/s	07-25-73 - 07-23-74
Cottonwood wind direction	1.2	2.114	degree	07-25-73 - 07-23-74
Skinner wind direction	-0.7	2.089	degree	07-25-73 - 07-23-74
Cottonwood solar	0	110.0	W/m ²	07-25-73 - 07-23-74
Skinner solar	0	103.1	W/m ²	07-25-73 - 07-23-74
All temperatures	-0.03	4.995	C	07-25-73 - 07-23-74
Cottonwood atmospheric	0	145.2	W/m ²	07-25-73 - 08-28-73
Cottonwood atmospheric	0	145.6	W/m ²	08-29-73 - 11-27-73
Cottonwood total incoming	0	562.4	W/m ²	11-28-73 - 01-31-74
Cottonwood total incoming	0	355.0	W/m ²	03-07-74 - 04-24-74
Cottonwood total incoming	0	474.2	W/m ²	06-05-74 - 07-23-74
Skinner atmospheric	0	145.6	W/m ²	07-25-73 - 08-29-73
Skinner atmospheric	0	145.2	W/m ²	08-29-73 - 03-24-74
Skinner atmospheric	0	145.6	W/m ²	04-24-74 - 05-28-74

recorder at Cottonwood malfunctioned three times between September 1, 1973, and November 28, 1973, the atmospheric radiation values measured at each end of the canal and the computed clear-sky values were all in general agreement.

On November 28, 1973, the pyrgeometer at Cottonwood was removed for a calibration check and replaced by a flat-plate radiometer of the Gier-Dunkle type. During December 1973, the measured atmospheric radiation at Skinner was 30 percent higher than that measured at Cottonwood. Unfortunately, it was impossible to determine whether one or both sensors were out of calibration. On January 31, 1974, the flat-plate radiometer failed and it was replaced on March 7, 1974. This second flat-plate radiometer was operated until April 24, 1974, when it also failed. The first flat plate, which had been repaired and recalibrated, was reinstalled at Cottonwood on June 5, 1974. This radiometer operated continuously until the end of the study on July 23, 1974.

Meanwhile, difficulty was also being experienced at the other end of the canal. On March 24, 1974, the output of the pyrgeometer at Skinner started dropping sharply, falling essentially to zero by March 31, 1974. Unfortunately, the instrument could not be calibrated, so only the original calibration factor is available.

On April 24, 1974, the pyrgeometer removed from Cottonwood on November 20, 1973, was installed at Skinner. Although it had been recalibrated locally, the output using the new calibration factor appeared to be too large, so it was assumed that the original manufacturer's calibration factor was still valid. This instrument failed in a manner similar to the

first pyrgeometer on May 28, 1974. After this date, no atmospheric radiation measurements were available at Skinner.

The hydraulic data were furnished by the Metropolitan Water District, and no extensive check on their accuracy was made by the Survey. However, the accuracy of the stage recorders at Cottonwood and Simpson Road were checked by measuring the centerline water depth from the bridge and comparing the results to the recorded stage. The centerline depth and stage always agreed to within ± 6 mm. On January 15-16, 1974, the discharge was measured and the results compared with the value provided by the Metropolitan Water District. The results agreed to within 4 percent which is considered to be about the accuracy of the flow measurements. Personnel of California District of the Geological Survey made current-meter measurements which were used to calibrate the sonic flow meter at Skinner. The sonic flow meter was installed during the latter part of February 1974, and calibrated in early March.

It was realized that the five measured stages may not be representative of depths at all points along the canal. The word "depth" is used to mean the centerline (maximum) depth, which is also the stage (fig. 2) in all cases. An attempt was made to measure a longitudinal depth profile under several flow conditions to determine how to predict mean local depths from the recorded stages. These profiles were determined in the following manner. First an automobile odometer was used to place reference marks on the canal fence. No reference mark was placed closer than 160 m to either the intake or outlet of a siphon. Water depth was measured at each of these reference points for seven conditions which included flows ranging from 2.8 to 23 m³/s.

It was impossible to measure the centerline depth (stage) directly except at a few points along the canal; however, it was fairly easy to measure the slope distance from the top of the canal lining to the water surface. The stage could then be computed from the known geometry of the canal. Comparisons of the stage, as determined from the slope measurements to the stage as measured directly, where possible, indicated that the slope measurements allowed the stage to be estimated within about ± 9 mm.

The results of these measurements and calculations are summarized in table 3 which gives the centerline depth (stage) and the distance from the canal intake for each of seven runs. The flow variations during any run were very small and the measured stages and discharges at the time of the runs will be presented later. Runs 1 and 7 were conducted on March 6 and April 24, 1974, respectively, when the hydraulic conditions were essentially constant. Unfortunately the flow was slightly unsteady during run 2 made on March 24, 1974, as well as during runs 3 and 4 made on March 25, 1974, and runs 5 and 6 made on March 26, 1974. The effect of the slight unsteadiness was accounted for by noting the time at which each measurement was obtained. All measurements were obtained by working in the downstream direction at a very nearly constant rate. The beginning times of runs 2, 3, 4, 5, and 6 were 1354, 0635, 1100, 0632, and 1012 hours, respectively, and the ending times were 1922, 0903, 1325, 0829, and 1705 hours, respectively.

RESULTS

General

All data obtained during this study are available on magnetic tape from the Automatic Data Processing Unit of the U.S. Geological Survey. The

tape contains 10-minute values of all meteorologic and temperature data, hourly values of hydraulic data, and daily values of the supplementary data.

Table 4 contains daily averages of all meteorologic and temperature data. Averages are included in table 4 only if sufficient data were present to adequately define the daily mean. The windspeed, solar radiation (short-wave), atmospheric radiation (longwave), and air temperatures represent averages of individual measurements. The wind azimuth represents the azimuth of the resultant wind vector for the day and the water temperature represents the average obtained at all levels of measurement. A wind azimuth of zero represents a wind blowing from north to south. The vapor pressure was computed from the wet- and dry-bulb air temperatures for each 10-minute period and the results averaged. The conversion from wet- and dry-bulb temperatures to vapor pressures involved a two-step process. First the saturation vapor pressure of air at the wet-bulb temperature was computed using the formula

$$e_s = \exp \{ 52.418 - 6788.6 / (273.16 + TW) - 5.0016 \ln (273.16 + TW) \} \quad (3)$$

in which e_s is saturation vapor pressure in kilopascals, and TW is wet-bulb temperature in degrees Celsius. The vapor pressure was then computed from

$$e_a = e_s - 96.0 (0.00066) (TA - TW) (1 + 0.00115 TW) \dots \quad (4)$$

in which e_a is vapor pressure of the air in kilopascals, TA is dry-bulb temperature in degrees Celsius, the atmospheric pressure is assumed to be 96.0 kilopascals, and 0.00066 is the psychrometric constant.

Table 5 in supplemental data contains daily averages of all hydraulic data as well as daily rainfall values. The diversion discharge at EM-8 is not listed because the mean daily value was always less than $0.1 \text{ m}^3/\text{s}$. The diversion discharge at the So End diversion was not measured but can be determined by continuity considerations, however. This diversion was zero prior to May 15, 1974.

The rain gages were serviced at approximately 0900 hours. The observed rainfall was assigned to the day preceding the date of observation. In some cases, the record had the word "trace" written in the rainfall column. In this case, the rainfall was recorded as 0.25 mm.

Wind

The average windspeed at Cottonwood during the 12-month period was 1.70 m/s, whereas that at Skinner averaged 1.24 m/s. The lower value at Skinner undoubtedly reflects the sheltering effect of the hill north of the anemometer. The yearly mean values of the supplementary windspeeds were 1.54 m/s at Cottonwood and 0.90 m/s at Skinner. The monthly mean windspeeds at Cottonwood and Skinner are shown in figure 21. A rather pronounced seasonal variation is seen at Cottonwood, but none is evident at Skinner. The frequency of occurrence of various daily average windspeeds is shown in figure 22. The uniform nature of the Skinner windspeed and the absence of high winds in comparison to Cottonwood is apparent. The highest wind gust observed at Cottonwood was 18.5 m/s and occurred at 1640 hours on July 18, 1974. The highest gust observed at Skinner was 9.9 m/s and occurred at 1420 hours on January 1, 1974.

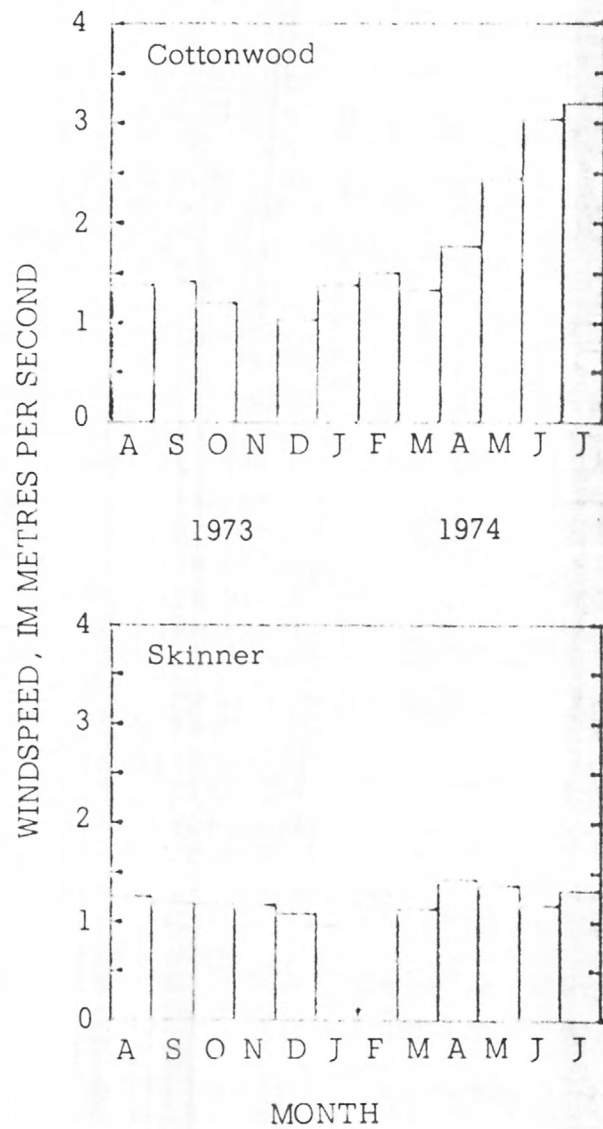


Figure 21.--Monthly mean windspeed. Insufficient data were available for November at Cottonwood and for January and February at Skinner.

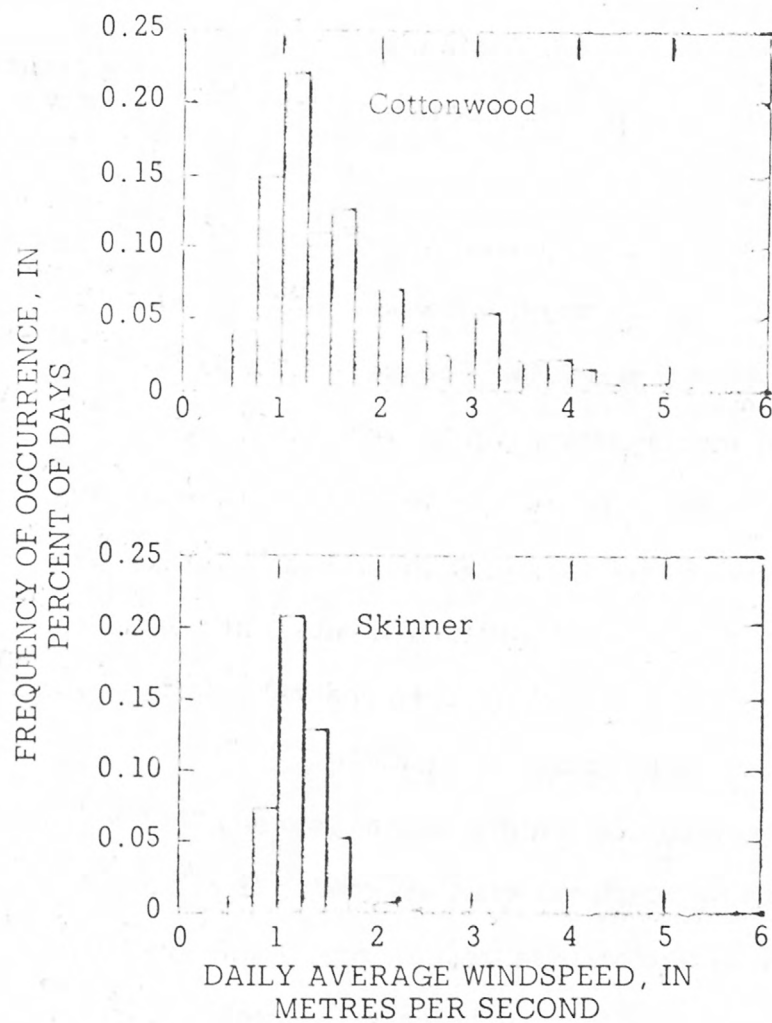


Figure 22.--Frequency of occurrence of daily windspeeds.

A pronounced diurnal variation in windspeed was observed at both stations. In order to illustrate this diurnal effect, the yearly mean windspeed was computed for each 10-minute interval of the day. The results of this averaging process are shown in figure 23. It can be seen that the windspeed is usually low at night and in the early morning hours (2200 - 0800) and usually fairly high in the late afternoon hours (1400 - 1800).

The daily-average windspeeds at Cottonwood and Skinner were poorly correlated. The correlation coefficient for the entire year was only 0.43. For the months of March and April the correlation coefficient was 0.80, but for the months of May through August it was 0.32, and for the months of September through December it was 0.46. The correlation between the daily-average primary and supplementary windspeeds was also poor. Considering the entire year, the correlation between the primary and supplementary windspeeds was 0.64 at Cottonwood and 0.47 at Skinner. These low correlation coefficients highlight the difficulty in attempting to measure a representative windspeed for a reach of any open channel. Surface winds are extremely variable from point to point.

The wind direction was recorded continuously at both ends of the canal. The percent of the time during which the wind was coming from each of eight sectors (numbered counterclockwise from the north) was tabulated by month and year. The results of this tabulation are shown in figure 24. At Cottonwood the wind is from sector 4 (south-southeast) the largest percentage of the time, but the percentage is fairly uniformly distributed among all sectors. The two lowest percentages, for winds from the west, are probably due to a slight sheltering effect of the Lakeview Mountains

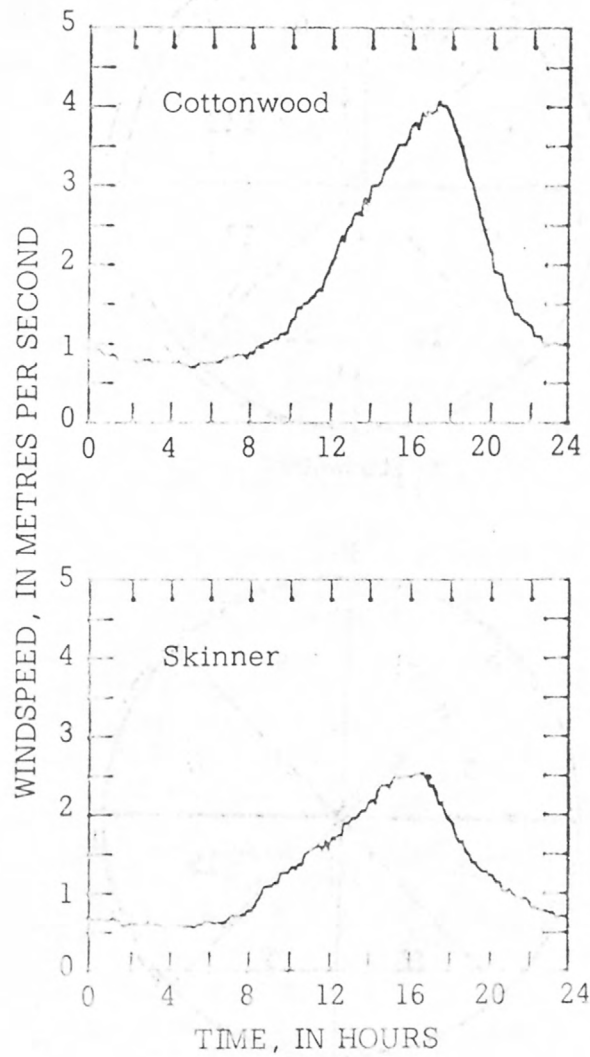


Figure 23.--Mean annual diurnal variation in windspeed, averaged by 10-minute time periods for the period July 24, 1973, to July 23, 1974.

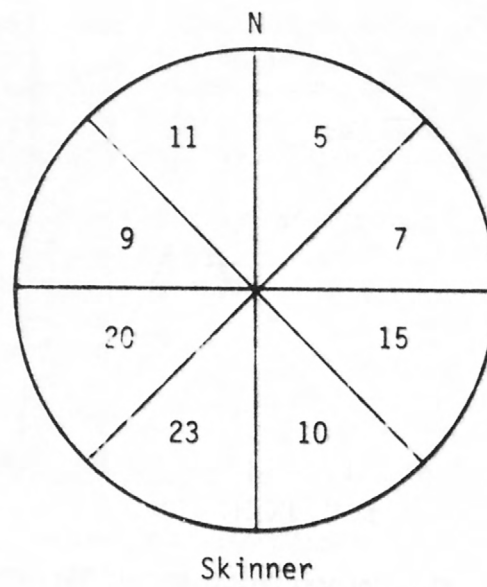
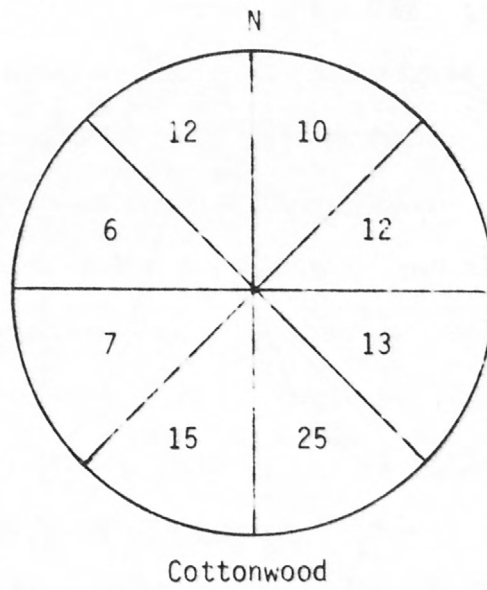


Figure 24.--Frequency of occurrence, in percent of time, of winds from various directions.

(fig. 1) . The distribution of directions did not appear to vary with time of year. The largest percentage fell in sector 4 for every month of the year. Local topography obviously had a great effect on the measured wind directions at Skinner. Notice the sheltering effect of the hill to sectors 1, 2, 7, and 8 and of the dam to sector 4 (figs. 1, 6, 9, and 10) . Sector 5 had the highest percentage for months March through September, and sector 3 had the largest percentage for the months of October through December.

The mean windspeed, average speed irrespective of direction, and the resultant windspeed (vectorial average speed) were computed for each day. The ratio of these two windspeeds is a measure of how consistent the wind direction is and is called the wind consistency. The wind consistency was computed for each day and the monthly average determined by averaging the daily values. At Cottonwood the monthly average consistency varies from a low of 0.12 in February to a high of 0.76 in November, but no annual cycle was apparent. At Skinner the consistency values are probably less meaningful, but they varied from a low of 0.15 in December to a high of 0.71 in May. The months of May through August had values greater than 0.60, and October, November, and December had values less than 0.25. Other months had values between 0.38 and 0.49.

Radiation

The annual pattern of daily solar radiation is shown in figure 25. The yearly mean measured at Cottonwood and Skinner was 238 W/m^2 and 242 W/m^2 , respectively, a difference of less than 2 percent. The daily values at Cottonwood and Skinner were highly correlated. The correlation coefficient between daily average values for the entire year was 0.97. The standard deviation of the difference between the daily means at the two ends of the canal was 21.4 W/m^2 .

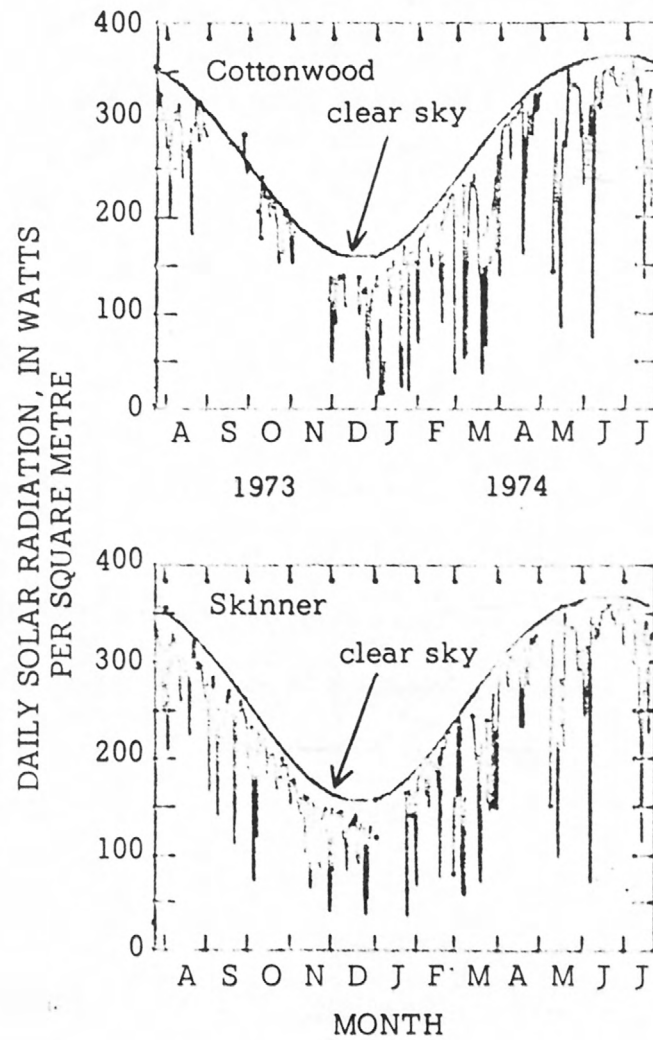


Figure 25.--Daily solar radiation.

Also shown in figure 25 is the variation of the estimated clear-sky solar radiation. This value was computed using the procedure suggested by the Tennessee Valley Authority (1972). The clear-sky solar radiation was determined from

$$\Phi_{cs} = \frac{I_o}{\pi r^2} (h_{ss} \sin \Phi \sin \delta + \cos \Phi \cos \delta \sin h_{ss}) \quad (5)$$

in which Φ_{cs} is clear-sky solar radiation, I_o is effective solar constant, r is ratio of actual to mean earth to sun distance, h_{ss} is hour angle of sunset in radians, Φ is latitude, and δ is declination of the sun. The effective solar constant was varied by trial and error until the clear-sky curve appeared to form an envelope of the measured data. The value used in figure 25 is 1046 W/m^2 . The value of r was approximated from

$$r = 1 + 0.017 \left(\cos \frac{360}{365} (186 - D) \right) \quad (6)$$

in which D is Julian date (1-365). The value of h_{ss} was determined from

$$h_{ss} = \arccos \left(\frac{\sin \alpha_{ss} - \sin \Phi \sin \delta}{\cos \Phi \cos \delta} \right) \quad (7)$$

in which α_{ss} is solar altitude at sunset, which was assumed to be zero.

The latitude of the Cottonwood and Skinner sensors was $N33^{\circ}47'$ and $N33^{\circ}36'$, respectively. The declination of the sun was approximated by use of the expression

$$\delta = 23.45 \cos \left(\frac{360}{365} (172 - D) \right) \quad (8)$$

From equations 5, 6, 7, and 8 the yearly average clear-sky radiation at Cottonwood and Skinner is computed as 268.8 and 269.3 W/m^2 , respectively, a difference of 0.2 percent.

The annual variation of atmospheric radiation is shown in figure 26. The estimated clear-sky atmospheric radiation is also shown for reference. The clear-sky value was computed from the formula presented by Idso and Jackson (1969)

$$\Phi_{ca} = \sigma (Ta + 273.16)^4 (1 - 0.261 \exp (-0.000777 (Ta)^2)) \quad (9)$$

in which Φ_{ca} is incoming clear-sky atmospheric radiation, σ is Stefan-Boltzman constant ($5.671 \times 10^{-8} \text{ W/m}^2$), and Ta is air temperature in degrees Celsius. The presence of clouds should increase the incoming atmospheric radiation over the clear-sky value by as much as 20 to 25 percent. The measured values would, therefore, be expected to be equal to or greater than the clear-sky values. In general, this appears to be the case as indicated in figure 26. Notable exceptions do occur, particularly at Cottonwood after March 1, 1974. After November 28, 1974, the atmospheric radiation at Cottonwood was determined for each 10-minute interval by subtracting the measured solar radiation from the all-wave radiation measured by a flat-plate radiometer.

The diurnal variation in atmospheric radiation, measured by the pyrgeometer for relatively clear days, is illustrated in figure 27. This mean diurnal variation was determined by averaging, on a time-period-by-time-period basis, the measured atmospheric radiation for 18 days. These days were selected between July 25, 1973, and December 1, 1973, from both Cottonwood and Skinner, such that the ratio of the measured solar to the computed clear-sky solar radiation was greater than 0.97. Also shown in figure 27 is the mean diurnal variation in atmospheric radiation as determined by subtracting the instantaneous value of the measured solar

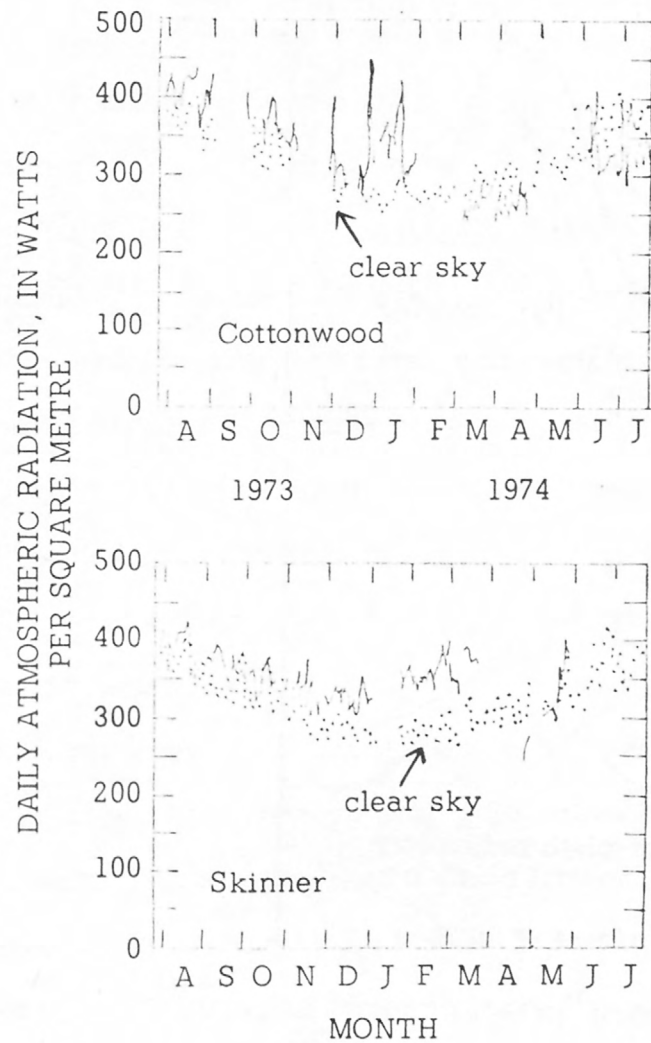


Figure 26.--Daily atmospheric radiation.

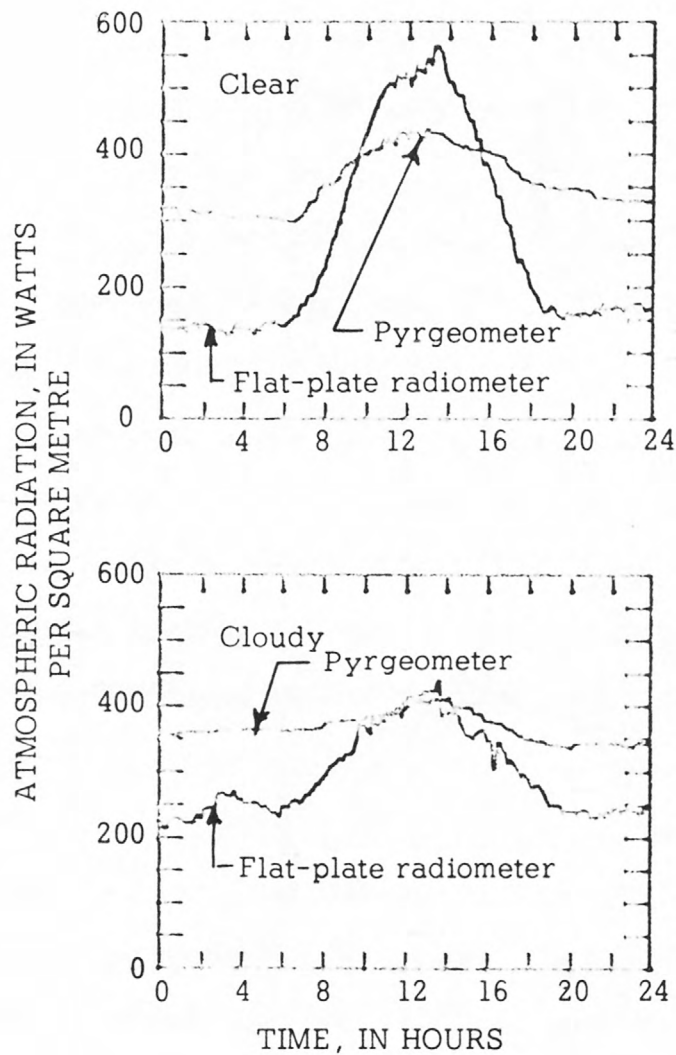


Figure 27.--Typical diurnal variation in atmospheric radiation as measured by the pyrgometer and by subtracting the measured instantaneous solar radiation from the all-wave radiation measured by the flat-plate radiometer.

radiation from the instantaneous value of the all-wave radiation measured by the flat-plate radiometer. This curve represents an average of the 4 days after November 28, 1973, for which the ratio of the measured solar to computed clear-sky solar radiation was greater than 0.97. Unfortunately these 4 days are not included in the set of 18 days represented by the pyrgeometer because it was impossible to select any clear-sky days during which both instruments were operating satisfactorily. The diurnal variation in the atmospheric radiation, as measured by the pyrgeometer, follows very closely the diurnal variation computed by equation 9. On the other hand, the flat-plate, with the solar component deducted, indicates a much greater night-to-day variation. The mean value of these two curves should not be compared because each curve represents the average of several but different days. The diurnal variation in the atmospheric radiation, as determined by deducting the solar radiation from the flat-plate all-wave radiation, appeared to be a function of the cloudiness. A comparison of the atmospheric radiation estimated by use of the pyrgeometer and the flat plate under cloudy to overcast conditions is also illustrated in figure 27. This figure represents the average of all days with a ratio of measured to clear-sky solar radiation of less than 0.60. Thirteen days are included in the pyrgeometer curve and 20 days in the flat-plate curve. From an inspection of figure 27, it would appear that the flat plate is overly sensitive to the solar component of the radiation spectrum. Jackman (personal commun., 1975) found flat plates to be overly sensitive to solar radiation.

Air Temperature

The annual pattern of daily average air temperature is shown in figure 28. The mean daily temperatures at Cottonwood and Skinner had a correlation

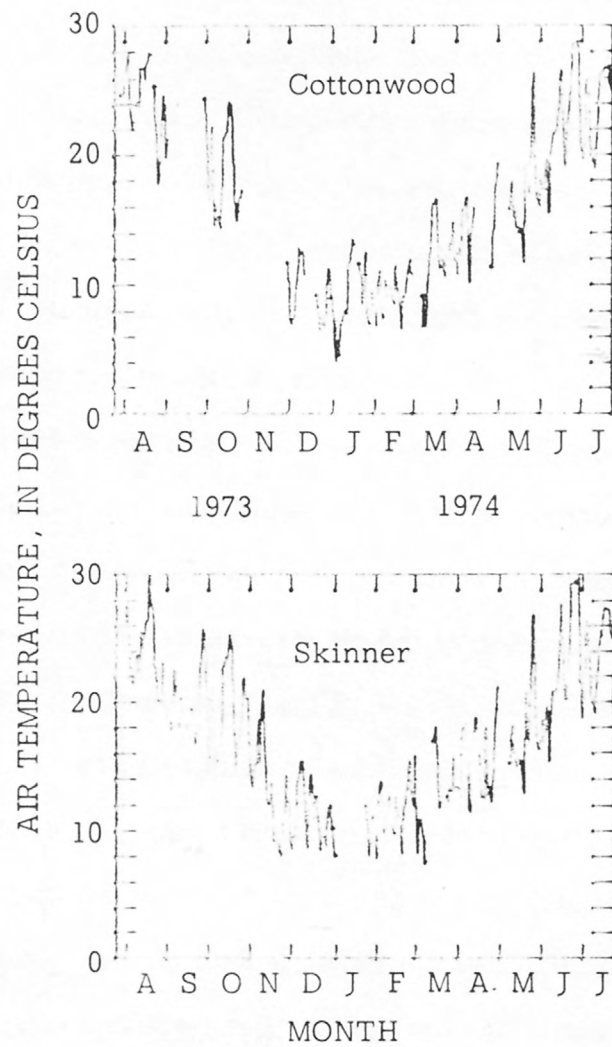


Figure 28.--Daily average air temperature.

coefficient of 0.99 for the period of record. This correlation coefficient remained stable throughout the year. The mean air temperatures at Cottonwood and Skinner were 17.06 and 17.90°C, respectively. The rather sheltered location of the Skinner station, on a south hillside, is undoubtedly reflected in its higher mean temperature. The standard deviation of the difference between the daily average temperatures at the two ends of the canal was 1.45°C.

Vapor Pressure

Other than atmospheric radiation, the vapor pressure of air proved to be the most difficult parameter to measure. More specifically the wet-bulb temperature was very difficult to measure continuously because of the problem of keeping the wick saturated. Overall, wet-bulb data are available for 44 and 56 percent of the 10-minute time periods at Cottonwood and Skinner, respectively.

The annual pattern of daily averaged vapor pressure values is shown in figure 29. Daily averages are shown in figure 29 only if more than 130 of the 144 possible 10-minute periods contained data. On a daily average basis the correlation between the Cottonwood and Skinner vapor pressures was good. The correlation coefficient was 0.96 and the standard deviation of the difference between the daily averaged values was 0.15 kPa. The mean value at Skinner was higher than that at Cottonwood by 0.10 kPa. This higher value at Skinner undoubtedly reflects the nearness of Lake Skinner. The standard deviation among daily values was also higher at Skinner (0.38 kPa) than at Cottonwood (0.30 kPa). The higher variability at Skinner would also be expected because the presence or absence of

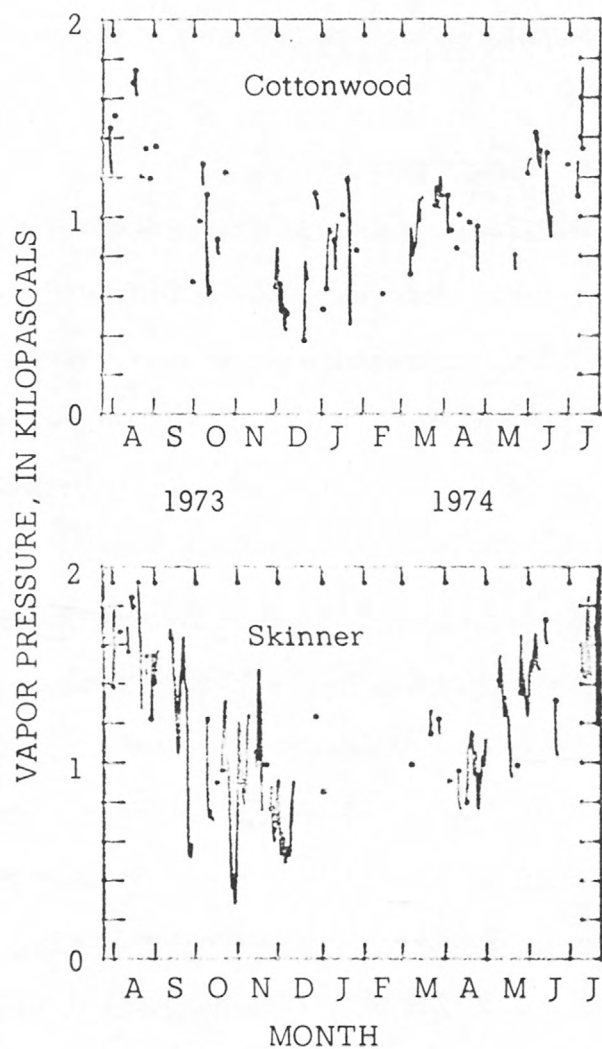


Figure 29.--Daily average vapor pressure.

the vapor blanket from Lake Skinner would depend on wind direction which is of course quite variable.

Because of the large number of missing wet-bulb data and because most of the time complete data were available at either Cottonwood or Skinner, the transferability between Cottonwood and Skinner on a time-period-by-time-period basis was investigated. An obvious question arises: How can one best estimate the vapor pressure at one point given the dry- and wet-bulb temperatures at a remote site and the dry-bulb air temperature locally? There are four possible ways of estimating the vapor pressure under these conditions: (a) Assume it is the same as at the remote station (This method makes no use of the information known about the local dry-bulb temperature.); (b) assume the wet-bulb temperature is the same at both stations (This method makes no use of the dry-bulb temperature at the remote station.); (c) assume wet-bulb depression (dry-bulb temperature minus the wet-bulb temperature) is the same at both stations; or (d) assume the relative humidity is the same at both stations.

Using the 11,688, 10-minute periods for which complete data were available at both ends of the canal, the accuracy of these four transfer methods was checked by assuming one or the other of the wet-bulb temperatures was missing, estimating the vapor pressure by all four methods, and comparing the estimated value to the known local value. Morning, afternoon, and nighttime data were grouped separately to determine if time of day had any influence. The results are tabulated in table 6. In every case, transferring the vapor pressure directly resulted in the smallest root-mean-square error in the estimated vapor pressure. In two cases, the correlation

Table 6.--Comparisons of vapor pressures estimated by
four data transfer methods

Transferred quantity	Estimating Skinner vapor pressures		Estimating Cottonwood vapor pressures	
	Correlation coefficient	Root-mean square error	Correlation coefficient	Root-mean square error
All data				
Vapor pressure	0.837	0.271	0.837	0.271
Wet-bulb temperature	0.825	0.327	0.774	0.326
Wet-bulb depression	0.528	0.700	0.780	0.348
Relative humidity	0.775	0.302	0.806	0.312
Morning (0600 - 1200 hours)				
Vapor pressure	0.875	0.225	0.875	0.225
Wet-bulb temperature	0.860	0.304	0.801	0.302
Wet-bulb depression	0.631	0.509	0.833	0.283
Relative humidity	0.830	0.256	0.851	0.252
Afternoon (1200 - 1800 hours)				
Vapor pressure	0.874	0.227	0.874	0.227
Wet-bulb temperature	0.834	0.313	0.781	0.312
Wet-bulb depression	0.581	0.606	0.823	0.289
Relative humidity	0.819	0.257	0.845	0.261
Night (1800 - 0600 hours)				
Vapor pressure	0.767	0.383	0.767	0.383
Wet-bulb temperature	0.777	0.386	0.751	0.386
Wet-bulb depression	0.500	1.061	0.705	0.499
Relative humidity	0.723	0.415	0.734	0.447

coefficient resulting from the use of this method was slightly less than that resulting from the transfer of the wet-bulb temperature, but no particular significance is attached to this. While transferring the vapor pressure directly was clearly the most accurate procedure, the least accurate procedure is not as well defined. It appears that transfer of the wet-bulb depression is probably the least accurate. Even on a minute-by-minute basis, the vapor pressures are fairly well correlated between sites. Very little diurnal variation in vapor pressure was observed. It is also interesting that the correlation is poorer between Cottonwood and Skinner and the errors larger at night than during the day. This is probably due to the fact that the lake influenced Skinner to a larger degree at night, when winds were light, than during the day. During the day, the average Skinner vapor pressures were 7.0 percent greater than Cottonwood values, whereas at night they were 7.7 percent greater.

Water Temperature

The annual pattern of the average water temperature in the canal is shown in figure 30. Daily average water temperatures at Cottonwood and Skinner were highly correlated with a correlation coefficient of 0.999 and a standard deviation of 0.28°C . There was always a slight warming trend as the water passed through the canal. The average increase in temperature was 0.02°C during January through April, 0.11°C during May through August, and 0.42°C during December. Water temperatures at Cottonwood are not available for September through November. The water temperature was always observed to be uniform in the vertical.

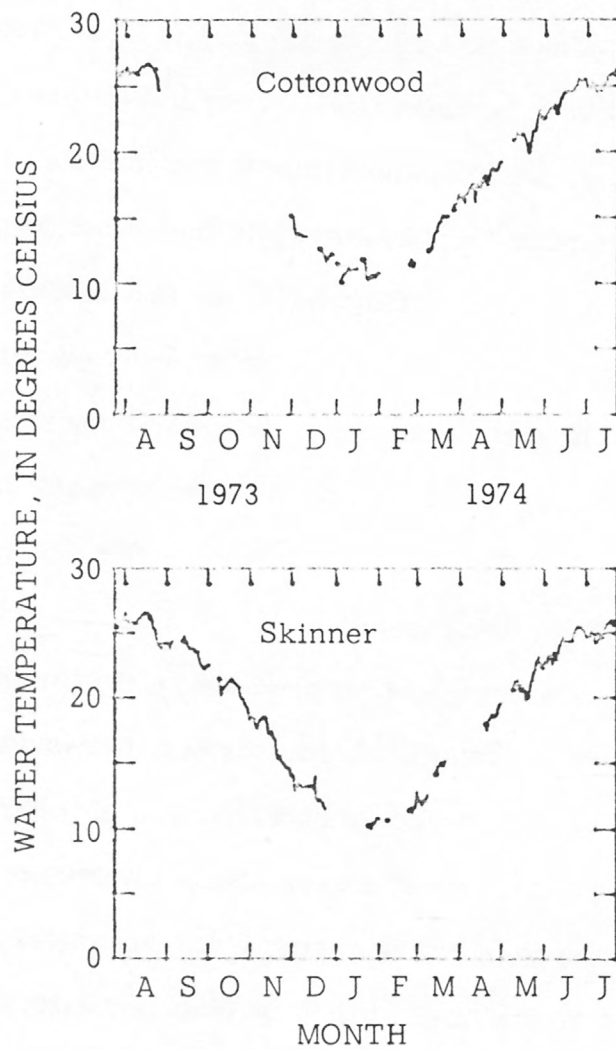


Figure 30.--Daily mean water temperature, averaged over depth.

The diurnal variation in water temperature is illustrated in figure 31 which shows the annual mean obtained for each 10-minute period of the day. These curves were obtained by averaging all available temperature measurements at each individual time period. The mean annual diurnal variation at Cottonwood is very slight. The "average" diurnal range in temperature at Cottonwood is only 0.83°C as opposed to a range of 2.68°C at Skinner. The small diurnal variation in water temperature at Cottonwood results from the fact that the water entering the canal is diverted from the Colorado River Aqueduct which passes under the San Jacinto Mountains just upstream of the entrance to the San Diego Aqueduct (fig. 1). The phase difference in the two distributions is also interesting. The Cottonwood temperature reached its low about midnight and its high at about 1100 hours, while the Skinner distributions reached a low at about 0730 hours and a high about 1700 hours.

Discharge

Discharge values were provided by the Metropolitan Water District during days of constant flow. For each of these 209 days the average stage at Cottonwood was determined and Manning's n computed. During the summer and early fall, July 24, 1973, to October 9, 1973, and May 1, 1974, to July 23, 1974, the n value remained fairly constant. The mean of 114 computed n values during these times was 0.0175 and the standard deviation was 0.0004. Even the extreme values of 0.0182 obtained on May 8 and 0.0165 obtained on May 22 would result in a variation of less than ± 5 percent. Starting about the first of October, the n values started steadily decreasing with time until October 18 when the n value was 0.0151. From October

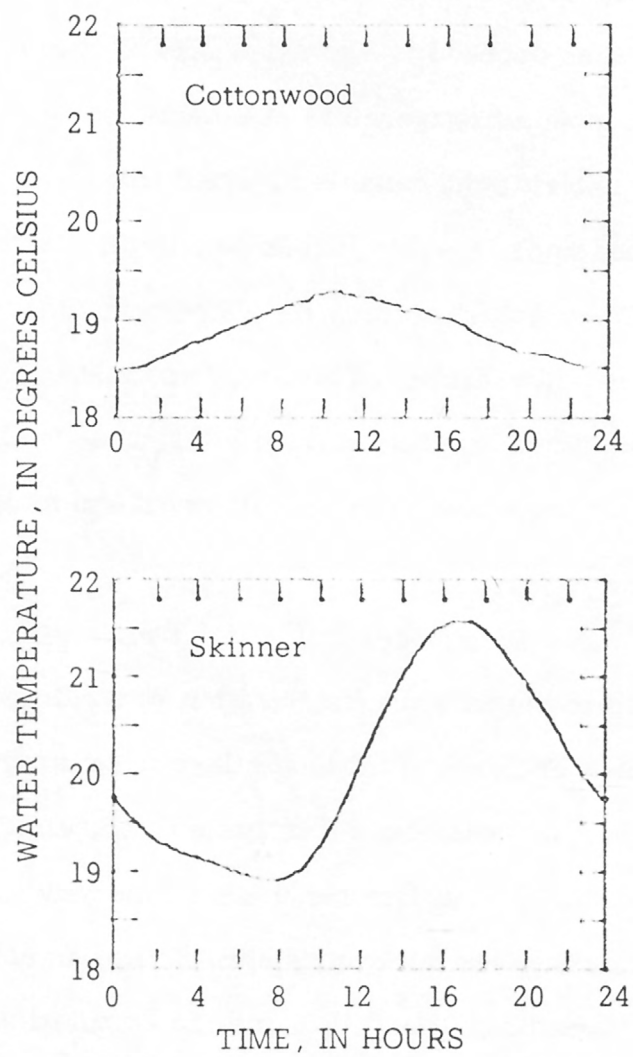


Figure 31.--Mean diurnal variation in water temperature.

18, 1973, to December 26, 1973, the values again remained fairly steady. The 53 values available during the latter period averaged 0.0152 with a standard deviation of 0.0004. During the winter and spring months the n values varied widely in what appeared to be a random pattern, but a moving average seemed to increase more or less uniformly with time to about 0.0175. The 38 values available for the period of January 16 to May 1, 1973, averaged 0.0170 with a standard deviation of 0.0015. Extreme values of 0.0139 occurred on January 19, 1974, and 0.0191 on April 27, 1974. Local operators attribute these shifts in the n values to biological activity of the water. Apparently algae and scum have some tendency to form at certain times of the year varying the roughness of the concrete.

SUMMARY AND CONCLUSIONS

Meteorologic and hydraulic variables which influence the energy budget of the San Diego Aqueduct in southern California were continuously monitored for a 1-year period beginning July 24, 1973. The incoming solar and atmospheric radiation, windspeed and direction, water temperature, and wet- and dry-bulb air temperature were recorded on 10-minute intervals at each end of the 26-km canal, while flow rates and stages were determined on hourly intervals at five locations. These data are available on magnetic tape and can be obtained by contacting Automatic Data Processing Unit, U.S. Geological Survey, Water Resources Division, Reston, VA 22092. A detailed description of the study site, the instrumentation, and the procedures used has been given, as well as all other information necessary for the use of these data by interested persons. A general analysis of the spatial and temporal variability of the recorded data, as well as the daily

mean values of all data, have been presented. From an analysis of these data, the following conclusions are drawn:

1. A pronounced diurnal variation in windspeed was observed at each end of the canal. Windspeeds were typically quite low during the early morning hours and maximum during the late afternoon.

2. Daily average windspeeds are quite variable from point to point, apparently depending on the local topography.

3. Solar radiation measured at Cottonwood was highly correlated to that measured at Skinner. The standard deviation between daily average values, obtained 26 km apart, was 21.4 W/m^2 , while the mean difference was 4 W/m^2 . This parameter is relatively easy to measure by use of pyranometers, and an accuracy of ± 2 percent can be expected.

4. Atmospheric radiation values are difficult to monitor accurately, and results obtained by use of different instrument types are not always comparable.

5. Vapor pressure is another parameter which is difficult to accurately monitor on a continuous basis but it is fairly uniform spatially. Instantaneous measurements taken simultaneously but 26 km apart had a correlation coefficient of 0.837 and a standard deviation of 0.27 kPa. The mean difference was 0.10 kPa.

6. At a point where only the dry-bulb temperature is known, the most accurate method to estimate the vapor pressure is to compute it from the wet- and dry-bulb temperatures obtained at a remote site.

7. Flow resistance, as defined by Manning's n , in the concrete-lined San Diego Aqueduct varied significantly with time of year. Local operators attribute this variation to biological growths.

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NOTES

SUPPLEMENTAL DATA

Table 3.--Profiles of centerline depth for the San Diego Aqueduct under nearly steady flow conditions. All values are in metres.

Distance from intake	Stage run 1	Distance from intake	Stage					
			Run 2	Run 3	Run 4	Run 5	Run 6	Run 7
593	2.98	148	1.02		1.01		1.81	2.47
1398	2.86	477	1.17		1.17		1.98	2.65
2444	2.84	811	1.12		1.10		1.89	2.58
3249	2.80	1145	1.03		1.03		1.82	2.48
4054	2.79	1477	1.03		1.02		1.81	2.45
4897	2.77	1811	1.03		1.03		1.82	2.46
6147	2.77	2294	1.06		1.05		1.84	2.46
7450	2.76	2614	1.04		1.02		1.81	2.44
8529	2.78	2935	1.03		1.02		1.80	2.43
9135	2.79	3254	1.01		.99		1.77	2.40
9794	2.78	3574	1.03		1.01		1.80	2.42
11083	2.77	3893	1.02		.99		1.77	2.40
11388	2.70	4214	1.01		.98		1.75	2.36
12692	2.65	4835	1.02		.98		1.75	2.36
13497	2.60	5030	.98		.96		1.71	2.33
14143	2.64	5611	.99		.96		1.73	2.33
15594	2.62	5927	1.01		.98		1.74	2.33
16371	2.70	6266	.98		.95		1.70	2.30
17602	2.76	6580			.91		1.75	2.25
18407	2.75	6715	.95		.92		1.68	2.25
19212	2.72	7223	.96		.94		1.70	2.26
20011	2.72	7541	.95		.92		1.69	2.26
20333	2.71	7780	.93		.94		1.71	2.27

Table 3.-- (Continued)

Distance from intake	Stage run 1	Distance from intake	Stage					
			Run 2	Run 3	Run 4	Run 5	Run 6	Run 7
21385	2.56	8355	1.01		.96		1.73	2.23
22190	2.61	8679	.98		.95		1.71	2.16
23489	2.51	9004	1.01		.96		1.74	2.16
24532	2.45	9654	.95		.92		1.69	2.17
25015	2.39	9955	.91		.89		1.67	2.15
		10439	1.06		1.05		1.81	2.25
		10778	1.06		1.03		1.78	2.23
		11078	1.03		1.02		1.77	2.23
		11399	1.02		1.01		1.75	2.18
		11718	1.01		.98		1.74	2.19
		12038	.98		.94		1.68	2.05
		12357	.96		.94		1.68	2.13
		12705	.92		.91		1.64	2.13
		12996	.87		.85		1.58	2.11
		13317	.84		.80		1.54	2.11
		13944	.92	.91		1.66	1.61	2.17
		14258	.88	.87		1.60	1.55	2.13
		14574	.84	.82		1.57	1.53	2.13
		14888	.77	.75		1.53	1.46	2.13
		15540	.84	.82		1.68	1.57	2.16
		15775	.80	.77		1.67	1.55	2.16
		16314	.92	.89		1.84	1.68	2.25
		16644	.92	.89		1.87	1.69	2.26

Table 3.-- (Continued)

Distance from intake	Stage run 1	Distance from intake	Stage					
			Run 2	Run 3	Run 4	Run 5	Run 6	Run 7
		17441	1.09	1.05		2.05	1.85	2.24
		17760	1.09	1.05		2.05	1.84	2.41
		18031	1.09	1.05		2.05	1.82	2.43
		18402	1.12	1.08		2.11	1.85	2.40
		18723	1.17	1.13		2.19	1.89	
		19043	1.20	1.17		2.22	1.92	
		19364		1.12		2.19	1.87	2.44
		19864		1.19		2.25	1.89	2.48
		20185		1.20		2.26	1.89	2.50
		20976		1.22		2.30	1.88	2.48
		21293		1.20		2.29	1.84	2.46
		21608		1.26		2.37	1.88	
		21925		1.33		2.43	1.92	2.58
		22241		1.37		2.47	1.95	2.60
		22392		1.57		2.67	2.11	2.53
		23212		1.53		2.70	2.09	2.74
		23532		1.61		2.71	2.11	2.75
		24017		1.68		2.78	2.15	2.78
		24338		1.71		2.82	2.16	2.80
		24657		1.77		2.87	2.27	2.85
		25139		1.81		2.91	2.32	2.85
		25459		1.84		2.94	2.34	2.87
		25780		1.87		2.98	2.37	2.91

Table 4.--Daily averaged values of meteorologic and temperature data
for San Diego Aqueduct (July 25, 1973 - July 23, 1974)

Day of month	Wind speed (m/s)		Wind azimuth ³ (degree)		Solar radiation (W/m ²)		Atmospheric radiation (W/m ²)		Air temperature (Celsius)		Vapor pressure (Kpa)		Water temperature (Celsius)	
	COT ¹	SKN ²	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN
July 1973														
25		1.31		211		332		394						25.4
26	1.74	1.23		192	326	331	390	385	26.2	27.1			25.7	25.5
27	1.43	1.27		222	320	326	386	378	24.5	25.5			25.8	25.7
28	1.22	1.14		203	310	319	391	382	24.3	25.2			25.8	25.7
29	1.66	1.18		204	304	319	396	381	24.4	24.7	1.45		26.1	25.8
30	1.66	1.33		215	306	310	398	385	24.8	25.1	1.28		26.2	25.9
31	1.26	1.26		199	310	309	410	401	25.9	25.8	1.22	1.38	26.0	26.0

Note: See last page of table for footnotes.

Table 4.-- (Continued)

Day of month	Wind speed (m/s)		Wind azimuth (degree)		Solar radiation (W/m ²)		Atmospheric radiation (W/m ²)		Air temperature (Celsius)		Vapor pressure (Kpa)		Water temperature (Celsius)	
	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN
August 1973														
1	1.30	1.18		210	269	246	419	408	26.4	26.4		1.56	26.2	26.0
2	1.14	1.20		203	288	308	426	413	27.0	27.6	1.52	1.78	26.5	26.5
3	1.61	1.45		220	310	314	421	408	28.0	26.5			26.3	26.6
4	1.24	1.36		207	197	208	408	396	23.8	22.7			25.8	25.8
5	1.39	1.42		224	297	318	392	386	22.5	22.1			25.9	25.8
6	1.27	1.27		238	288	290	391	392	21.7	21.4		1.66	26.1	25.9
7	1.10	1.06		209	308	306	382	373	22.5	21.4			26.0	25.7
8		1.07		218		329		377		23.3				25.6
9	1.41	1.18		199	300	318	394	384	23.9	23.7			25.9	25.7
10	1.16	1.22		204	317	325	383	369	23.6	22.1			26.0	25.7
11	1.12	1.10		219	302	308	395	395	23.6	22.3		1.56	26.1	25.8
12	1.06	1.11		226	289	296	414	402	26.7	25.5		1.69	26.3	26.1
13	1.22	1.36		201	239	269	422	409	26.5	24.2			26.5	26.2
14	1.30	1.13		198	267	257	426	413	26.6	25.1		1.84	26.5	26.4
15	1.20	1.31		201	288	303	418	406	25.7	25.3	1.68	1.82	26.4	26.3
16	.92	1.16		217	280	295	420	407	26.9	26.4		1.79	26.7	26.6
17	1.31	1.23		219	260	287	426	411	27.2	26.3	1.74	1.80	26.8	26.6
18	1.15	1.30		230	276	301	420	413	27.9	29.8	1.61		26.5	26.6
19	1.16	1.61		232	291	299	414	411	27.6	29.9			26.5	26.5
20	2.21			248	180	223	431	424	27.8	28.3		1.92	26.4	26.0
21		1.29		222		286		404		27.3		1.75		26.3
22	1.47	1.18		184	295	306	385	381	25.2	26.1	1.20	1.28	26.2	25.9
23	2.02	1.24		221	318	323	354	349	22.4	22.6			25.9	25.3
24	1.69	1.32		229	313	314	351	355	21.3	21.6			25.5	25.1
25	1.93	1.50		206	277	292	364	375	17.6	20.0	1.35	1.54	24.6	24.5
26	2.30	1.71		226	287	290	368	370	18.1	20.0		1.45		24.0
27	1.05	1.44		244	290	299	383	359	19.8	20.0				24.1
28	1.54	1.31		208	313	300	405	353	22.9	20.9	1.19	1.22		23.7
29	.83	1.15		227	289	294		363	24.6	23.0		1.21		23.9
30	1.21	.99	270	207	286	276	413	372	23.8	20.0		1.55		24.2
31	1.71	1.25	207	219	282	271	383	376	19.7	18.9		1.49		24.3

Table 4.-- (Continued)

Day of month	Wind speed (m/s)		Wind azimuth (degree)		Solar radiation (W/m ²)		Atmospheric radiation (W/m ²)		Air temperature (Celsius)		Vapor pressure (Kpa)		Water temperature (Celsius)	
	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN
September 1973														
1	1.36	1.06	225	200		262	406	360	21.3	18.4	1.36	1.39		24.2
2	1.05	1.31	205	218		278	427	366		19.2		1.43		24.1
3	1.40	1.46	220	231		272		378		19.6		1.57		24.0
4	1.31	1.09	240	209		165		379		17.8				23.7
5	1.04	1.22	29	249		257		378		19.5				24.2
6	1.27	1.00	66	252		283		366		22.4				24.5
7	1.58	1.08	211	202		285		370		22.5				
8	1.62	1.35	185	219		247		384		18.9				
9	1.98	1.28	191	211		231		388		18.5				
10	1.72	1.24	221	254		140		394		18.0				
11	.93	1.32	52	252		252		385		20.3				
12	.86	.99	261	192		240		374		19.7		1.64		24.4
13	.93	1.15	259	216		220		389		18.7		1.68		24.4
14	1.23	1.11	197	230		245		379		19.7		1.64		24.8
15	1.25	1.02	196	194		232		368		18.1		1.48		24.5
16	.99	1.31	199	206		248		356		17.7		1.38		24.2
17	1.55	1.17	206	226		265		352		18.0		1.25		23.8
18	1.39	1.23	202	208		271		339		18.3		1.04		23.7
19	1.11	1.09	210	209		255		348		19.5		1.15		23.7
20	1.18	1.19	235	188		243		359		18.1		1.41		23.8
21	1.43	1.08	190	207		253		354		19.2		1.47		23.8
22	.88	1.09	57	202		110		381		16.7		1.64		23.4
23	3.05	1.54	216	203		195		366		17.5		1.48		23.5
24	1.60	1.08	257	218		248		354		17.6		1.37		23.4
25	1.66	1.68	245	41		249		367		20.9		1.15		22.8
26	3.33	1.73	45	231	284	259		353		24.6		.54		22.4
27	1.24	1.28	70	24	267	256	397	360		25.8		.52		22.3
28	.91	.87	74	212	252	250	371	362	24.4	25.2		.59		22.1
29	1.02	.85	219	197	243	242	376	358	23.0	23.7	.67			22.2
30	1.62	1.06	204	197	249	243	366	344	20.6	20.8				22.4

Table 4.-- (Continued)

Day of month	Wind speed (m/s)		Wind azimuth (degree)		Solar radiation (W/m ²)		Atmospheric radiation (W/m ²)		Air temperature (Celsius)		Vapor pressure (Kpa)		Water temperature (Celsius)	
	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN
October 1973														
1	1.60	1.39	207	208		230		358	16.9	16.4				22.5
2	1.20	1.33	213	243		189		355	16.4	15.5				22.5
3	.81	1.04	44	192		218		356	17.2	16.9				
4	1.15	1.18	199	90		232		341	22.2	21.6	.98			
5		1.19	206	202		233		343	19.4	19.2				
6	1.57	1.17	207	197		72		360	14.4	15.5	1.27			
7	2.58	1.31	218	206	203	199		357	16.2	16.5	1.16			
8		1.24	219	217		118		364		15.2				
9	1.73	1.40	217	184	176	186	363	345	15.1	15.4	1.11	1.22		21.3
10	1.00	1.55	83	44	224	227	332	316	14.2	15.6	.75	.85		20.9
11	.95	.96	68	221	242	218	346	325	16.2	16.6	.60	.72		20.1
12	.87	.96	64	62	219	212	348	339	17.6	19.0	.65	.76		20.3
13	.81	1.05	225	30	218	217	365	355	21.2	22.7	.61	.72		20.8
14	.91	1.04	205	226	220	220	362	353	21.5	23.6		.70		20.9
15	.98	1.01	241	239	217	214	376	358	21.8	23.3				21.0
16	.95	.91	246	239	199	183	395	365	23.3	24.2		.90		21.1
17	1.16	1.30	52	39	211	197	395	367	24.1	25.3	.89			21.3
18	1.11	1.10	48	29	213	205	396	378	23.8	24.8	.81			21.4
19	.88	.94	269	197	207	203	383	368	22.6	23.8				21.4
20	1.53	1.06	214	200	211	204	362	347	19.0	20.1		.96		21.2
21	1.08	.84	224	219	198	203	343	337	16.0	16.9		1.14		21.1
22	1.28	1.06	213	213	191	194	347	340	14.8	14.9		1.31		21.0
23	1.47	1.28	53	252	151	168	357	350	15.6	16.1	1.22	1.31		20.8
24	.93	1.38	36	36	198	193	352	333	16.7	17.1		1.12		20.7
25	.90	.88	221	193	191	193	341	333	16.6	18.1		.97		20.1
26	1.24	1.33	74	27	161	178	342	335	17.3	18.8		.71		19.8
27	1.41	1.55	37	42	204	201	335	329		21.5		.48		19.8
28	.94	1.05	251	191	200	198	338	333		21.8		.36		19.5
29	.98	1.38	10	27	191	191	335	329		20.4		.40		19.3
30	1.63	1.69	26	20	197	193	331	327		20.2		.28		19.2
31	1.40	1.16	195	182	191	188	348	340		20.3		.42		18.7

Table 4.-- (Continued)

Day of month	Wind speed (m/s)		Wind azimuth (degree)		Solar radiation (W/m ²)		Atmospheric radiation (W/m ²)		Air temperature (Celsius)		Vapor pressure (Kpa)		Water temperature (Celsius)	
	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN
November 1973														
1	2.18	1.44	219	220	163	166	345	342	15.9		.94		18.2	
2	3.69	1.58	224	225	151	152	367	349	14.4		1.21		18.6	
3	2.05	1.17	208	180	173	158	341	322	13.4		1.04		18.4	
4	.80	.79	185	202	184	179	323	311	14.0		.95		18.4	
5		.78		205		177		306	15.2		.82		17.9	
6		.70		257		175		316	15.1		.79		17.6	
7		.66		192		166		339	17.2		.89		17.9	
8		.82		184		150		339	18.6		1.16		18.3	
9		1.26		19		141		334	15.2		1.24		18.3	
10		1.32		39		159		353	18.7				18.5	
11		1.00		20		147		360	20.9				18.5	
12		1.17		200		163		349	17.9				18.5	
13		1.34		181		102		329	13.7				18.3	
14		.99		237		145		308	12.2		1.05		17.9	
15		1.09		221		161		309	12.0		.98		17.2	
16		.98		187		127		342	12.4		1.10		17.3	
17		1.19		188		65		376	13.7		1.47		17.4	
18		2.17		225		92		343	11.5		1.20		16.8	
19		1.02		232		154		293	9.2		.76		16.7	
20		.94		189		146		299	9.1				15.8	
21		1.08		198		89		345	10.5		.99		15.2	
22		1.79		189		97		328	10.0		.99		15.4	
23		1.22		86		116		320	8.2				15.6	
24		1.07		193		85		322	8.0				15.0	
25		1.09		200		139		297	8.2		.76		14.9	
26		1.26		41		135		322	9.7		.88		15.0	
27		1.41		29		146			10.8		.71		14.6	
28		1.88		8		149			14.4		.60		14.5	
29	.83	1.05	196	1	113	119	301		11.6	14.2	.65	.70	15.1	14.6
30	1.22	1.02	204	199	139	142	301	326	10.1	12.3	.70	.80	15.0	14.4

Table 4.-- (Continued)

Day of month	Wind speed (m/s)		Wind azimuth (degree)		Solar radiation (W/m ²)		Atmospheric radiation (W/m ²)		Air temperature (Celsius)		Vapor pressure (Kpa)		Water temperature (Celsius)	
	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN
December 1973														
1	1.44	1.05	213	226	49	41	372	326	7.3	9.2	.84	.91	15.0	13.9
2	1.16	1.07	201	2	139	142	403	312	6.9	8.5	.63	.66	14.9	14.2
3	.56	.84	200	43	126	148	289	310	7.3	9.5	.52	.53	14.0	13.8
4	.62	.57	202	39	88	84	283	320	7.5	9.6	.67	.64	13.6	12.8
5	.88	1.01	3	10	136	140	314	320	9.4	11.3	.55	.61	13.7	13.2
6	.92	1.54	13	49	140	144	299	325	10.6	13.9	.45	.49	13.8	13.4
7	1.14	1.15	21	4	134	126	317	332	12.8	14.4	.42	.51	13.7	13.3
8	.62	.98	205	6	137	142	310	339	12.3	15.3	.53	.57	13.6	13.3
9	.94	1.55	203	4	141	146	299	331	12.3	15.5	.50	.52	13.5	13.2
10	1.08	1.18	5	21	140	144	299	332	12.6	15.2		.56	13.5	13.1
11	1.09	1.00	204	232	107	115	274	325	10.7	12.7		.71	13.5	13.1
12		.82		200		125		317		10.4		.91		13.1
13		1.05		27		104		325		8.6				13.1
14		.84		264		84		339		10.9				13.3
15		1.64		17		132		326		14.1				13.2
16		.65		230		127		334		14.4				13.2
17		.76		207		134		327		13.4				13.0
18		1.69		33		137		309		11.9				12.8
19		1.55		80		130		309		12.8				14.0
20	1.18	2.11	3	64	137	141	278	305	9.1	12.8	.37		12.6	12.3
21	1.00	.85	191	241	98	98	277	311	8.1	10.6	.43		12.4	12.0
22	1.47	1.01	244	237	104	90	312	325	8.4	9.6	.78		12.4	12.2
23	.93	.93	199	7	119	121	302	308	6.4	8.4	.68		12.4	12.1
24	.98	1.70	37	16	125	132	276	300	7.4	10.1			12.2	12.0
25	1.22	.78	204	188	121	119	283	307	6.9	9.5			11.8	11.5
26	.55	.66	229	194	128	129	299	313	7.6	9.5			11.6	11.4
27	.88	.82	215	233	45	38	317	334	6.7	8.8			11.9	
28	.88	.81	196	202	32	57	350	353	10.1	11.2	1.12	1.24	11.9	
29	1.19	1.02	197	186	110	118	448	348	11.3	11.9	1.08		12.3	
30	.93	1.17	184	269	101	114	390	337	10.7	12.1	1.04		12.3	
31	2.29	1.05	217	200	125	129	312	316	8.9	10.2			12.0	

Table 4.-- (Continued)

Day of month	Wind speed (m/s)		Wind azimuth (degree)		Solar radiation (W/m ²)		Atmospheric radiation (W/m ²)		Air temperature (Celsius)		Vapor pressure (Kpa)		Water temperature (Celsius)	
	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN
January 1974														
1	3.72	3.02	226	242	128	117		321	7.2	8.0		.85	11.5	
2	1.04		1		140		274		4.0			.53	11.2	
3			13											
4	2.44		233		18		346		4.7			.64	10.1	
5	1.63		217		95				5.7			.76	10.5	
6	.84		188		18				7.0			.89	10.7	
7	1.13		10		15				7.3			.94	10.7	
8	1.66		239		51				7.6			.92	10.8	
9			88											
10	.82		219		145		365		8.0			.88	11.1	
11	1.18		11		111		316		7.6			.73	11.1	
12	1.01		21		107		351		11.1			.84	10.9	
13	.82		3		140		344		11.8			.96	11.1	
14	1.59		9		155		334		12.8				11.1	
15	.74		25		146		331		13.5				11.1	
16	.97		223		124		368		13.0		1.01		11.2	
17														
18														
19	1.48		211		143		417		11.6		1.19		11.8	
20	2.64		212		23				10.8		1.20		11.7	
21	1.24		223		137		364		10.5		.98		11.8	
22	2.60		3		170		283		8.4		.45		11.9	
23	1.02		5		143		298		9.3				10.4	
24	2.08		16		162	164	304	359	12.5	12.0			10.2	10.3
25	1.69		214		152	157	301	355	8.8	10.6			10.3	10.2
26	1.22		224		20	36	280	336	6.9	8.0	.83		10.6	10.1
27	.92		192		163	167	303	336	6.9	8.9			10.7	10.0
28	.56		21		164	164	309	353	8.0	10.4			10.4	10.5
29	.72		10		148	137	310	356	9.5	11.3			10.4	10.3
30	.61		247		150	139	308	352	8.5	9.8			10.7	10.5
31	.94		208		154	164	326	367	9.1	10.3			10.8	10.8

Table 4.-- (Continued)

Day of month	Wind speed (m/s)		Wind azimuth (degree)		Solar radiation (W/m ²)		Atmospheric radiation (W/m ²)		Air temperature (Celsius)		Vapor pressure (Kpa)		Water temperature (Celsius)	
	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN
February 1974														
1	1.04		194		69	68		341	6.7	7.8			10.8	10.7
2	1.43		24		178	180		340	8.1	10.6			10.9	
3	1.87		30		178	182		351	10.4	13.5				
4	1.09		228		179	180		358	11.1	13.9				
5	1.52		19		181	185		350	9.5	12.0				
6	1.61		23		185	185		332	7.3	9.8				
7	.83		49		186	193		336	7.5	10.0			10.6	
8	4.09		32		191	195		335	10.4	11.0				
9	1.12		189		163	161		347	9.1	12.0				
10	.80		211		191	198		353	10.0	12.8				
11	.84		193		147	149		348	9.6	11.5				
12	2.30		215		183	190		357	9.8	12.2				
13	1.98		213		166	197		342	8.7	9.7				
14	1.01		46		192	191		343	8.4	9.5	.61			
15	.68		268		184	185		363	11.5	12.8				
16	1.76		209		186	194		356	10.1	11.9				
17	2.36		230		132	169		352	9.2	10.6				
18	1.05		216		195	202		351	8.4	10.6				
19	1.57		235		90	76		331	6.5	8.2				
20	1.70		82		209	212		353	9.2	10.7				
21	1.07		25		196	209		361	8.5	11.9				
22	.69		203		203	211		365	9.1	11.7				
23	2.37		42		213	220		368	10.4	13.3			11.5	11.4
24	1.89		72		220	229		380	11.2	14.3			11.8	11.5
25	1.41		22		223	230		393	11.6	15.5			11.2	11.7
26	1.54		209		217	225		385	12.0	14.0			11.2	11.2
27	1.11		200		223			371	10.7	12.4			11.6	11.5
28					37	79		364		11.8				11.7

Table 4.-- (Continued)

Day of month	Wind speed (m/s)		Wind azimuth (degree)		Solar radiation (W/m ²)		Atmospheric radiation (W/m ²)		Air temperature (Celsius)		Vapor pressure (Kpa)		Water temperature (Celsius)	
	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN
March 1974														
1						160		398		15.9				12.8
2						114		362		11.3				12.3
3						142		345		8.2				12.1
4						241		352		9.9				12.0
5						243				11.0				11.7
6	2.08	1.29	207	224	232	237			9.1	10.2	.71	.99		12.0
7	1.27	2.01	193	210	53	82		346	8.6	9.5	.94			12.2
8	2.84	2.32	201	181	58	58	241	333	6.6	7.3	.85		12.4	12.1
9	1.07	.94	13	46	159	160	255	344	6.8	7.7	.80		12.6	12.5
10	.78	.69	22		196		239		8.4		.85		12.6	
11	.95	1.06	39		235		239		10.8		.85		12.6	
12	1.05	.77	23		231		253		12.5		.93		13.2	
13	.75	1.16	42		231		259		14.1		1.08		13.6	
14	.73	.92	35	81	244	244	256	390	16.3	17.1	.97		13.9	14.1
15	.82	1.13	29	36	228	235	258	392	16.3	17.5	1.08		14.2	14.4
16	.66	.72	86	244	214	218	258	394	16.6	18.2	1.10		14.5	14.7
17	1.10	1.12	39	59	197	198	249	390	16.5	17.2			14.7	14.8
18	.90	.97	218	185	148	203	268	378	12.6	13.2			15.0	15.0
19	1.62	1.14	210	225	122	127	272	370	11.2	11.7			15.2	15.0
20	1.47	.81	215	236	37	72	250	367	11.3	12.2		1.15	15.0	14.8
21	1.16	1.03	44	210	183	214	285	379	13.0	13.6		1.27	14.9	15.1
22	1.57	1.06	230	231	102		275	373	11.6				14.9	
23	1.86	.83	215	215	66		266	368	10.6				15.1	
24	1.22	1.23	79	188	202	239	267		12.3	12.6	1.06			
25	1.08	.94	211	204	151	154	274		11.9	12.2	1.07			
26	1.88	1.37	222	218	153	181	265		13.0	13.3	1.15	1.22	15.5	
27	2.06	1.50	226	212	200	146	280		13.2	13.2	1.11	1.22	16.0	
28	1.09	.91	39	265	217	194	268		12.2	12.9	1.04	1.14	16.0	
29	1.03	1.18	2	56	241	267	289		14.9	15.7	1.20		16.1	
30	1.47	1.33	35	222	163	148	263		11.8	13.3	1.10		16.5	
31	2.32	1.24	236	193	264	228	271		12.4				16.7	

Table 4.-- (Continued)

Day of month	Wind speed (m/s)		Wind azimuth (degree)		Solar radiation (W/m ²)		Atmospheric radiation (W/m ²)		Air temperature (Celsius)		Vapor pressure (Kpa)		Water temperature (Celsius)	
	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN
April 1974														
1	2.07	1.78	225	205	139	147	237		10.7				16.3	
2	3.83	2.34	218	209	234	233	248		12.8	13.4	1.11		16.4	
3	1.42	1.16	218	242	287	294	276		12.2	12.5	.91	.91	16.6	
4	1.73	2.15	46	64	293	300	244		13.3	16.1			16.0	
5	1.21	1.28	36	254	297	303	251		15.8	18.1	.93		16.5	
6	1.23	1.41	235	184	295	295	251		14.3	16.2			16.8	
7	.84	1.16	227	255	291	297	273		16.6	18.4			17.2	
8	2.15	1.15	221	237	296	299	247		16.7	17.4			17.4	
9	3.68	3.35	227	247	258	274	248		11.0	12.0	.84		17.6	
10	2.01	1.71	267	217	301	305	241		10.1	11.4		.96	17.3	
11	1.23	1.50	62	53	302	306	251		13.0	14.3	1.01	.79	16.1	
12	1.63	1.19	204	215	302	307	261		14.4	15.9		.76	16.8	
13	1.59	1.16	17	195	301	298	265		16.0	17.4			17.6	
14	1.32	1.01	2	64	308	308	259			18.9			17.3	
15	1.08	1.09	64	207	310	314	255			18.6			17.2	
16	1.56	1.05	196	208	312	317	251			17.0		.80	17.5	
17	2.04	1.19	207	204	318	319	249			14.9		.88	18.0	
18	2.75	1.87	226	211	161	232	277			12.6	.97	1.06	18.2	
19	2.56	1.28	212	208	249	251	288			12.6		1.10	18.2	18.0
20	1.20	.99	228	198	239	232	264			12.5		1.16	17.3	17.4
21	1.23	1.49	28	56	309	316	276			17.0		1.14	17.8	17.9
22	1.14	1.02	225	233	284	291	252			18.1		.94	18.3	18.2
23	2.18	1.63	217	194	304	277	248			12.8		1.06	18.6	18.5
24	1.98	1.39	85	219	283	277				13.4	.95	.94	18.7	18.7
25	1.84	1.53	213	197	312	324	244	11.3	12.2	.72	.77		18.5	18.5
26	1.40	1.12	232	181	327	323	251	11.5	12.7		.88		18.5	18.5
27	1.49	1.07	221	216	308	319	262	14.2	15.0		.94		18.5	18.7
28	1.70	1.15	217	214	312	317	266	15.0	16.5		1.03		18.7	18.6
29	1.77	1.69	42	44	326	327	269	17.7	19.5		.98		19.0	19.2
30	1.50	1.28	36	239	328	328	276	19.4	21.2		1.11		19.2	19.5

Table 4.-- (Continued)

Day of month	Wind speed (m/s)		Wind azimuth (degree)		Solar radiation (W/m ²)		Atmospheric radiation (W/m ²)		Air temperature (Celsius)		Vapor pressure (Kpa)		Water temperature (Celsius)	
	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN
May 1974														
1														
2														
3														
4														
5														
6														
7														
8														
9	1.59	1.38	234	212	142	150		303	15.8	15.2		1.42	20.8	20.6
10	1.75	1.24	225	206	224	257		299	16.4	16.1		1.38	20.9	20.9
11	1.72	1.37	216	237	301	323		305	17.9	18.2		1.54	21.1	21.3
12	2.14	1.30	213	203	216	220		306	15.2	16.0		1.47	21.4	21.1
13	3.15	1.46	217	213	238	273		306	15.7	16.0		1.36	21.4	21.3
14	2.84	1.48	226	229	164	213		307	14.2	14.9		1.23	21.2	20.7
15	2.79	1.53	229	225	85	97		303	13.9	15.3		1.34	21.1	20.4
16	3.53	1.73	219	221	275	261		310	14.4	15.7		1.27	21.4	21.0
17	3.06	1.54	222	218	278	283		314	14.0	15.4		1.19	21.3	20.7
18	3.37	1.63	218	208	271	241		302	12.9	14.2		1.07	20.9	20.5
19	2.54	2.18	255	194	299	213		296	11.6	12.8		.93	20.4	19.7
20	1.39	1.17	66	235	352	350		333	14.8	17.2			19.7	20.0
21	1.20	1.37	261	230	333	334		356	18.9	20.7	.81		20.0	20.0
22	1.07	1.20	229	189	328	339		367	19.3	20.6	.73	.99	20.8	20.7
23	2.47	1.35	236	201	338	331		345	16.9	16.9			21.5	21.3
24	1.21	.93	48	236	333	336		365	20.0	19.7			21.6	21.9
25	1.31	1.45	37	81	338	334		396	25.3	26.7		1.36	21.7	22.0
26	1.22	.96	239	197	331	337		404	26.3	26.9		1.65	22.5	22.6
27	2.21	1.14	215	198	332	337		383	22.6	23.0		1.49	23.0	22.9
28	2.23	1.38	225	227	326	334			17.6	18.5		1.41	23.2	23.2
29	3.49	1.34	218	212	280	291			16.4	16.7		1.32	22.7	22.7
30	5.17	1.42	220	219	307	312			16.5	16.2	1.22	1.24	22.3	22.3
31	4.84	1.30	227	224	232	291			15.9	16.2	1.25	1.28	22.4	22.1

Table 4.-- (Continued)

Day of month	Wind speed (m/s)		Wind azimuth (degree)		Solar radiation (W/m ²)		Atmospheric radiation (W/m ²)		Air temperature (Celsius)		Vapor pressure (Kpa)		Water temperature (Celsius)	
	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN
June 1974														
1	3.01	1.34	232	222	266	309			18.1	18.2	1.28	1.35	22.5	22.5
2	2.50	1.06	220	206	280	313			17.4	18.6	1.30	1.52	22.8	22.8
3	1.94	1.02	235	225	251	243			17.2	16.8		1.46	22.9	22.6
4	2.58	1.21	206	211	290	299			18.9	17.9		1.53	23.2	23.2
5	3.69	1.28	211	227	315	317			19.7	19.6	1.43	1.58	23.2	23.2
6	4.29	1.37	212	204	313	301	383		18.6	18.8	1.37	1.66	23.3	23.2
7	4.85	1.51	219	233	74	71	394		15.4	15.3	1.40	1.50	23.4	22.5
8	4.08	1.42	213	230	341	343	356		20.1	19.2	1.28	1.48	23.6	23.6
9	2.92	1.51	239	238	345	348	318		21.0	20.8	1.24		22.7	23.3
10	3.16	1.05	231	200	333	335	330		21.7	20.0	1.34		22.8	22.8
11	2.11	1.11	51	200	310	324	340		21.5	20.0			23.5	23.5
12	2.12	1.05	85	207	312	334	409		22.0	21.1			24.0	24.1
13	2.04	1.04	89	199	323	326	327		22.9	20.6	1.32	1.73	24.2	24.2
14	3.08	.91	57	234	349	340	295		24.1	24.1	1.17	1.61	24.4	24.5
15	3.16	1.02	53	210	346	341	317		26.5	27.7	1.00		24.5	24.7
16	3.97	1.43	210	212	351	353	300		23.1	24.7	.94		24.5	24.4
17	3.63	1.19	201	216	351	355	298		20.2	22.0	.90		24.6	24.3
18	3.96	1.42	215	213	350	357	304		19.1	20.2	1.00		24.6	24.3
19	2.10	1.13	61	217	343	357	298		19.9	20.0		1.31	24.4	24.3
20	3.08	1.10	208	214	353	359	309		22.4	22.7		1.13	24.4	24.4
21	3.08	.96	207	203	354	360	310		23.5	24.0		1.04	24.4	24.4
22	1.89	1.13	60	215	340	355	315		24.8	26.8			24.8	24.8
23	2.12	.98	56	216	333	343	325		26.9	29.2			25.0	25.1
24	3.50	1.11	59	259	337	343	317		28.6	30.1			25.1	25.3
25	3.20	1.24	59	234	332	346	318		27.9	30.4			25.5	25.5
26	2.37	.92	57	202	334	338	328		28.5	29.2			25.3	25.5
27	1.91	1.13	248	208	333	342	325		28.8	29.2			25.4	25.4
28	3.09	1.16	205	199	346	356	302		28.0	29.8			25.5	25.5
29	3.64	1.29	208	205	348	360	297		24.3	25.1	1.26		25.5	25.3
30	4.18	1.30	217	218	349	362	294		22.0	21.3			25.3	25.1

Table 4.-- (Continued)

Day of month	Wind speed (m/s)		Wind azimuth (degree)		Solar radiation (W/m ²)		Atmospheric radiation (W/m ²)		Air temperature (Celsius)		Vapor pressure (Kpa)		Water temperature (Celsius)	
	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN	COT	SKN
July 1974														
1	3.49	1.41	215	207	330	317	335		19.6	18.7			24.8	24.7
2	3.95	1.51	217	227	316	337	391		19.6	19.4			24.8	24.6
3	3.15	1.13	212	218	346	354	355		22.3	22.5			24.7	24.6
4	1.75	1.07	60	222	331	341	315		25.4	26.3			24.9	24.8
5	3.14	1.22	216	192	341	346	298		25.8	25.9			25.2	25.1
6	4.12	1.44	222	214	361	361	276		22.6	23.1	1.10		25.2	25.1
7	4.25	1.52	213	205	349	345	390		20.1	20.6	1.28		24.8	24.8
8	4.43	1.59	216	209	338	344	393		19.3	19.8			24.4	24.2
9	3.76	1.36	226	219	343	343	301		20.4	20.3	1.34	1.47	24.5	24.3
10	4.00	1.67	231	215	306	302	360		18.8	19.1	1.75	1.61	24.9	24.5
11	3.26	1.25	226	218	330	344	363		20.8	20.6		1.43	24.7	24.8
12	2.30	1.21	248	222	332	346	331		22.8	22.6		1.43	24.5	24.6
13	2.50	.95	247	214	272	235	316		25.3	24.5		1.46	24.9	24.6
14	2.35	1.12	73	32	135	114	306		26.4	25.6		1.71	25.2	24.9
15	3.03	1.07	39	184	286	269	346		26.0	24.9		1.85	25.1	25.2
16	2.73	1.31	266	194	320	333	332		26.4	26.8		1.44	25.5	25.5
17	2.21	1.14	71	204	321	342	307		26.8	27.4			25.8	25.8
18	3.94	1.84	223	237	331	343	318		26.7	27.3			25.9	25.8
19	3.43	1.52	200	216	209	225	334		26.5	27.1			26.0	25.9
20	3.12	1.38	67	199	318	328	355		26.9	27.3		1.69	25.8	26.0
21	3.24	1.20	229	206	319	322	319		25.2	25.2		1.19	25.7	25.6
22	3.20	1.35	218	223	274	330	306		24.8	24.9		1.94	26.3	25.9
23	2.13		202		216				26.0				26.1	

¹Cottonwood (upstream) end of canal.²Skinner (downstream) end of canal.³Direction from which the resultant wind comes measured clockwise from north.

Table 5.--Daily averaged values of hydraulic and rainfall data for
San Diego Aqueduct (July 25, 1973 - July 23, 1974)

Day of month	Stage (cm)					Discharge (m ³ /s)			Rainfall (mm) ¹	
	Cotton- wood	Simpson	Newport gage	South end	Skinner inlet	Cottonwood	Simpson	Skinner inlet	Cotton- wood	Skinner
25	241		193	190		13.9	0.0		0.0	0.0
26	240		192	189		13.7	0.0		0.0	0.0
27	239		191	189	95	13.7	0.0		0.0	0.0
28	239		191	190	170	13.7	0.0		0.0	0.0
29	239		191	190	170	13.7	0.0		0.0	0.0
30	238		191	190	170	13.6	0.0		0.0	0.0
31	236	110	191	191	170	13.4	0.0		0.0	0.0

Note: See last page of table for footnote.

Table 5.-- (Continued)

Day of month	Stage (cm)					Discharge (m ³ /s)			Rainfall (mm)	
	Cotton- wood	Simpson	Newport gage	South end	Skinner inlet	Cottonwood	Simpson	Skinner inlet	Cotton- wood	Skinner
August 1973										
1	232	208	187	188	168	12.9	0.0		0.0	0.0
2	229	205	183	184	164	12.6	0.0		0.0	0.0
3	229	205	183	185	164	12.6	0.0		0.0	0.0
4	230	206	183	186	164	12.6	0.0		.3	0.0
5	229	206	183	186	164	12.6	0.0		0.0	0.0
6	229	205	183	186	164	12.6	0.0		0.0	0.0
7	230	207	184	187	165	12.6	0.0		0.0	0.0
8	231	207	184	187	165	12.8	0.0		0.0	0.0
9	232	208	185	188	166	12.9	0.0		0.0	0.0
10	232	208	185	188	166	12.9	0.0		0.0	0.0
11	232	208	185	188	166	12.9	0.0		0.0	0.0
12	232	208	185	188	166	12.9	0.0		.3	.5
13	232	208	184	187	166	12.9	0.0		0.0	0.0
14	232	208	184	187	166	13.0	0.0		0.0	0.0
15	233	208	184	187	166	13.0	0.0		0.0	0.0
16	233	208	184	187	166	13.0	0.0		0.0	0.0
17	232	207	184	186	166	12.9	0.0		0.0	0.0
18	232	207	184	187	166	12.9	0.0		0.0	0.0
19	232	206	183	187	165	12.9	0.0		0.0	0.0
20	231	206	183	186	165	12.8	0.0		0.0	0.0
21	231	206	183	186	165	12.7	0.0		0.0	0.0
22	232	206	183	186	166	12.8	0.0		0.0	0.0
23	232	206	183	186	166	12.9	0.0		0.0	0.0
24	233	208	185	188	167	13.0	0.0		0.0	0.0
25	233	207	184	188	167	13.0	0.0		0.0	0.0
26	233	207	184	187	167	13.0	0.0		0.0	0.0
27	233	207	184	187	166	13.0	0.0		0.0	0.0
28	233	207	184	187	166	13.0	0.0		0.0	0.0
29	233	207	184	188	166	13.0	0.0		0.0	0.0
30	233	207	184	188	167	13.0	0.0		0.0	0.0
31	233	208	185	210	198	13.0	0.0		0.0	0.0

Table 5.-- (Continued)

Day of month	Stage (cm)					Discharge (m ³ /s)			Rainfall (mm)	
	Cotton- wood	Simpson	Newport gage	South end	Skinner inlet	Cottonwood	Simpson	Skinner inlet	Cotton- wood	Skinner
September 1973										
1	233	208	185	243	241	13.0	0.0		0.0	0.0
2	233		185	242	240	13.0	0.0		0.0	0.0
3	233		186	242	239	13.0	0.0		0.0	0.0
4	233		186	242	239	13.0	0.0		0.0	0.0
5					219		0.0		0.0	0.0
6					166		0.0		0.0	0.0
7	232	205	183		178	13.0	0.0		0.0	0.0
8	232	204	183		235	13.0	0.0		0.0	0.0
9	232	204	183		234	13.0	0.0		0.0	0.0
10	232	204	183		234	13.0	0.0		0.0	0.0
11	232	204	183	273	237	13.0	0.0		0.0	0.0
12	232	204	184	281	259	12.7	0.0		0.0	0.0
13	228	200	181	291		12.3	0.0		0.0	0.0
14	227	199	179	260		12.2	0.0		0.0	0.0
15	225	197	176	182	164	12.0	0.0		0.0	0.0
16	223	195	175	178	158	11.8	0.0		0.0	0.0
17	224	196	175	179	158	11.9	0.0		0.0	0.0
18	225	198	176	180	159	11.8	0.0		0.0	0.0
19	226		176	180	160	11.8	0.0		0.0	0.0
20	226		176	180	160	11.8	0.0		0.0	0.0
21	226		176	180	160	11.8	0.0		0.0	0.0
22	225		176	179	160	11.8	0.0		0.0	0.0
23	225		176	180	160	11.8	0.0		0.0	0.0
24	225		176	180	160	11.8	0.0		0.0	0.0
25	224	197	175	179	159	11.8	0.0		0.0	0.0
26	223	198	174	179	159	11.8	0.0		0.0	0.0
27	226	200	176	180	160	12.0	0.0		0.0	0.0
28	230	204	180	183	163	12.4	0.0		0.0	0.0
29	232	207	182	185	165	12.7	0.0		0.0	0.0
30	232	206	182	184	165	12.7	0.0		0.0	0.0

Table 5.-- (Continued)

Day of month	Stage (cm)					Discharge (m ³ /s)			Rainfall (mm)	
	Cotton- wood	Simpson	Newport gage	South end	Skinner inlet	Cottonwood	Simpson	Skinner inlet	Cotton- wood	Skinner
October 1973										
1	231	206	181	184	164	12.7	0.0		0.0	0.0
2	231	206	181	185	165	12.7	0.0		0.0	0.0
3	231	206	182	185	165	12.8	0.0		0.0	0.0
4	228	205	180	184	164	12.7	0.0		0.0	0.0
5	222	201	176	182	162	12.1	0.0		0.0	0.0
6	218	198	174	180	160	11.6	0.0		0.0	0.0
7	209	190	166	175	156	10.7	0.0		0.0	0.0
8	203	184	160	170	151	10.0	0.0		0.0	.8
9	201	183	159	169	150	10.1	0.0		0.0	0.0
10	197	180	156	167	149	9.9	0.0		0.0	0.0
11	205	186	161	169	150	10.7	0.0		0.0	0.0
12	210	196	172	180	158	11.2	0.0		0.0	0.0
13	208	197	173	181	159	11.3	0.0		0.0	0.0
14	208	197	173	181	159	11.3	0.0		0.0	0.0
15	207	198	174	182	159	11.3	0.0		0.0	0.0
16	205	198	174	183	159	11.3	0.0		0.0	0.0
17	220	213	188		166	13.2	0.0		0.0	0.0
18	237	242	208		181	15.6	0.0		0.0	0.0
19	237	245	208	207	181	15.6	0.0		0.0	0.0
20	237	245	208	207	181	15.6	0.0		0.0	0.0
21	236	244	208	207	181	15.6	0.0		0.0	0.0
22	236	244	207	206	181	15.6	0.0		0.0	0.0
23	236	244	208	206	181	15.6	0.0		0.0	0.0
24	237	241	206	205	180	15.6	.6		0.0	0.0
25	237	235	201	201	177	15.6	1.1		0.0	0.0
26	237	232	198	198	175	15.6	1.3		0.0	0.0
27	237	232	198	198	175	15.6	1.3		0.0	0.0
28	237	231	198	198	175	15.6	1.3		0.0	0.0
29	237	231	198	199	175	15.6	1.3		0.0	0.0
30	238	231	199	199	175	15.6	1.3		0.0	0.0
31	238	231	199	199	175	15.6	1.3		0.0	0.0

Table 5.-- (Continued)

Day of month	Stage (cm)					Discharge (m ³ /s)			Rainfall (mm)	
	Cotton- wood	Simpson	Newport gage	South end	Skinner inlet	Cottonwood	Simpson	Skinner inlet	Cotton- wood	Skinner
November 1973										
1	239	232	199	199	175	15.6	1.3		0.0	0.0
2	239	227	200	200	176	15.6	1.1		0.0	0.0
3	239	224	203	201	178	15.6	.9		0.0	0.0
4	239	225	204	202	178	15.6	.9		0.0	0.0
5	239	224	203	201	178	15.6	.9		0.0	0.0
6	239	224	203	201	177	15.6	.9		0.0	0.0
7	240	224	203	200	177	15.6	.9		0.0	0.0
8	240	223	202	200	177	15.6	.9		0.0	0.0
9	240	222	201	199	176	15.6	.9		0.0	0.0
10	239	221	200	198	175	15.6	.9		0.0	0.0
11	239	221	200	198	175	15.6	.9		0.0	0.0
12	240	221	199	197	174	15.6	.9		0.0	0.0
13	238	219	197	195	173	15.7	.9		0.0	0.0
14	229	209	187	188	167	14.6	.9		0.0	0.0
15	224	203	181	184	163	13.9	.9		0.0	0.0
16	221	199	177	180	160	13.6	.9		1.8	1.3
17	219	200	178	181	160	13.3	.4		19.8	14.0
18	212	197		181	159	12.5	0.0		7.1	4.1
19	204	188			154	11.6	0.0		0.0	0.0
20	186	171	151		145	9.7	0.0		0.0	0.0
21	174	157	135	148	134	8.5	0.0		.3	0.0
22	170	153	131	144	130	8.1	0.0		12.7	17.5
23	161	144	125	140	127	7.3	0.0		0.0	0.0
24	153	135	115	131	119	6.9	0.0		2.8	.8
25	153	135	115	131	119	6.9	0.0		0.0	1.0
26	154	134	115	131	119	6.9	0.0		0.0	0.0
27	154	135	115	132	119	6.9	0.0		0.0	0.0
28	154	135	115	132	118	6.9	0.0		0.0	0.0
29	155	135	115	132	119	6.9	0.0		0.0	0.0
30	155	135	115	132	118	6.9	0.0		1.3	0.0

Table 5.-- (Continued)

Day of month	Stage (cm)					Discharge (m ³ /s)			Rainfall (mm)	
	Cotton- wood	Simpson	Newport gage	South end	Skinner inlet	Cottonwood	Simpson	Skinner inlet	Cotton- wood	Skinner
December 1973										
1	156	136	115	132	119	6.9	0.0		0.0	1.3
2	156	137		133	119	6.9	0.0		0.0	0.0
3	156	138		133	119	6.9	0.0		0.0	0.0
4	155	138		134	119	6.9	0.0		0.0	0.0
5	155	136	117	134	119	6.9	0.0		0.0	0.0
6	155	133	117	134	120	6.9	0.0		0.0	0.0
7	155		114	135	120	6.9	0.0		0.0	0.0
8	154		110	134	120	6.9	0.0		0.0	0.0
9	154		110	134	119	6.9	0.0		0.0	0.0
10	175		123	142	126	8.7	0.0		0.0	0.0
11	205	169	156	172	152	11.7	0.0		0.0	0.0
12	212	175	162	177	157	12.4	0.0		0.0	0.0
13	211	169	154	172	153	11.9	.7		0.0	0.0
14	210	161	144	166	148	11.9	1.8		0.0	0.0
15	210	158	140	162	145	11.9	2.1		0.0	0.0
16	210	157	140	162	145	11.9	2.1		0.0	0.0
17	209	157	139	162	145	11.9	2.1		0.0	0.0
18	209	157	139	162	145	11.9	2.1		0.0	0.0
19	209	158	139	162	145	11.9	2.1		0.0	0.0
20	209	157	139	162	145	11.9	2.1		0.0	0.0
21	205	162	144	165	148	11.3	1.2		.5	1.0
22	197	164	147	168	150	10.5	0.0		0.0	0.0
23	197	165	147	169	150	10.5	0.0		0.0	0.0
24	197	165	147	169	150	10.5	0.0		0.0	0.0
25	197	165	147	169	150	10.5	0.0		0.0	0.0
26	194	162	144	167	149	10.2	0.0		0.0	0.0
27	232	193	178	184	166	14.9	0.0		.5	0.0
28	282	250	235	231	206	21.5	0.0		0.0	0.0
29	289	260	245	238	212	22.7	0.0		0.0	.3
30	289	260	244	238	212	22.7	0.0		0.0	0.0
31	289	259	244	238	212	22.7	0.0		11.9	.8

Table 5.-- (Continued)

Day of month	Stage (cm)					Discharge (m ³ /s)			Rainfall (mm)	
	Cotton- wood	Simpson	Newport gage	South end	Skinner inlet	Cottonwood	Simpson	Skinner inlet	Cotton- wood	Skinner
January 1974										
1	289	260	243	238	213	22.7	0.0		.8	.8
2	295	266	248	240	215	23.6	0.0		0.0	0.0
3	305	278	260	245	221	25.4	0.0		0.0	.5
4	312	287	270	250	226	26.6	0.0		59.7	53.6
5	314	289	271	251	227	27.0	0.0		2.5	1.8
6	314	289	270	251	227	27.0	0.0		29.5	18.5
7	312	284	264	249	225	26.6	0.0		66.0	67.3
8	287	256	234	230	208	22.3	0.0		5.6	.5
9	286	255		229	206	22.1	0.0		1.5	1.0
10		255		232	211		0.0		0.0	0.0
11	285	257		244	223	22.1	0.0		0.0	0.0
12	286	242		256	242	22.2	0.0		0.0	0.0
13	268	199		267	262	19.6	0.0		0.0	0.0
14	218	166		273	277	13.0	0.0		0.0	0.0
15	191	161	143	277	282	9.8	0.0		0.0	0.0
16	187	161	143	280	284	9.1	0.0		2.8	1.0
17	163	143	127	283	287	7.6	0.0		.3	0.0
18	145	124	108	281	286	6.5	0.0		0.0	0.0
19	145	123	108	280	284	6.5	0.0		0.0	0.0
20	145	123	108	279	283	6.5	0.0		4.3	2.3
21	147	125	110	278	282	5.9	0.0		0.0	0.0
22	132	114	100	277	281	4.9	0.0		0.0	0.0
23	122	104	88	271	276	4.1	0.0		0.0	0.0
24	122	105	87	265	271	3.7	0.0		0.0	0.0
25	122	105	86	260	265	3.7	0.0		.3	0.0
26	122	105	86	253	258	3.7	0.0		0.0	0.0
27	122	105	86	248	253	3.7	0.0		0.0	0.0
28	122	105	86	243	247	3.7	0.0		0.0	0.0
29	122	105	85	235	237	3.7	0.0		0.0	0.0
30	122	105	85	224	229	3.7	0.0		0.0	0.0
31	123	105	85	212	218	3.7	0.0		0.0	0.0

Table 5.-- (Continued)

Day of month	Stage (cm)					Discharge (m ³ /s)			Rainfall (mm)	
	Cotton- wood	Simpson	Newport gage	South end	Skinner inlet	Cottonwood	Simpson	Skinner inlet	Cotton- wood	Skinner
February 1974										
1	122	105	84	200	205	3.7	0.0		0.0	0.0
2	89	100	82	188	193	3.0	0.0		0.0	0.0
3	0	52	6	172	177	0.0	0.0	0.0	0.0	0.0
4	0	53	3	152	158	0.0	0.0	0.0	0.0	0.0
5	0			130	136	0.0	0.0	0.0	0.0	0.0
6	0			108	114	0.0	0.0	0.0	0.0	0.0
7	0			84	90	0.0	0.0	0.0	0.0	0.0
8	0			60	66	0.0	0.0	0.0	0.0	0.0
9	0			30	42	0.0	0.0	0.0	0.0	0.0
10	0			12	19	0.0	0.0	0.0	0.0	0.0
11	0			14	14	0.0	0.0	0.0	0.0	0.0
12	0					0.0	0.0	0.0	0.0	.3
13	0					0.0	0.0	0.0	0.0	0.0
14	0					0.0	0.0	0.0	0.0	0.0
15	0					0.0	0.0	0.0	0.0	0.0
16	0					0.0	0.0	0.0	0.0	.3
17	0					0.0	0.0	0.0	0.0	0.0
18	0					0.0	0.0	0.0	0.0	0.0
19	0					0.0	0.0	0.0	.3	1.0
20	0					0.0	0.0	0.0	0.0	0.0
21	0					0.0	0.0	0.0	0.0	0.0
22	0					0.0	0.0	0.0	0.0	0.0
23	0					0.0	0.0	0.0	0.0	0.0
24	0					0.0	0.0	0.0	0.0	0.0
25	96	202		200		4.6	0.0		0.0	0.0
26	184	223	196	200		9.2	0.0		0.0	0.0
27	215		180			12.6	0.0		0.0	0.0
28	196		150			10.4	0.0		1.3	2.3

Table 5.-- (Continued)

Day of month	Stage (cm)				Discharge (m ³ /s)			Rainfall (mm)		
	Cotton- wood	Simpson	Newport gage	South end	Skinner inlet	Cottonwood	Simpson	Skinner inlet	Cotton- wood	Skinner
March 1974										
1	202	178	154				0.0	10.7	9.4	7.1
2	215	191	168				0.0	12.4	9.9	4.3
3	213	190	167				0.0	12.5	0.0	4.1
4	250	220	197				0.0	15.5	0.0	0.0
5	292	272	253				0.0	23.3	0.0	0.0
6	294	274	254	237			0.0	23.5	0.0	.3
7	297	278	257	238			0.0	24.1	20.6	13.2
8	295	275	256	238			0.0	24.0	21.6	14.2
9	291	271	251	233			0.0	23.0	0.0	0.0
10	291	271	251	233			0.0	23.2	0.0	0.0
11	292	271	251	235			0.0	23.2	0.0	0.0
12	294	275	254	236			0.0	23.7	0.0	0.0
13	294	275	254	236			0.0	23.5	0.0	0.0
14	294	275	254	236			0.0	23.6	0.0	0.0
15	294	275	254	236			0.0	23.5	0.0	0.0
16	294	274	254	236			0.0	23.4	0.0	0.0
17	294	274	253	236			0.0	23.5	0.0	0.0
18	248	232	214	215			0.0	19.0	0.0	0.0
19	217	194	170	178			0.0	12.9	0.0	0.0
20	214	191	166	175		12.4	0.0		.3	0.0
21	214	190	166	174		12.4	0.0		0.0	0.0
22	214	190	166	184		12.4	0.0		0.0	0.0
23	214	191	166	196		12.4	0.0		0.0	0.0
24	155	144	123	189		7.3	0.0		0.0	0.0
25	125	95	74	145		4.6	0.0		.3	.8
26	192	167	145	250		10.0	0.0		.3	.8
27	164	160	138	232		7.7	0.0		.5	.5
28	166	135	108	152			0.0	5.5	0.0	0.0
29	279	256	236	270			0.0	19.9	0.0	0.0
30	279	256	235	242			0.0	20.3	0.0	.3
31	279	256	235	240			0.0	20.3	0.0	0.0

Table 5.-- (Continued)

Day of month	Stage (cm)					Discharge (m ³ /s)			Rainfall (mm)	
	Cotton- wood	Simpson	Newport gage	South end	Skinner inlet	Cottonwood	Simpson	Skinner inlet	Cotton- wood	Skinner
April 1974										
1	279	256	235	239		0.0	20.3		6.4	4.8
2	292	267		243		0.0	21.5		0.0	0.0
3	307	286		257		0.0	24.5		0.0	0.0
4	308	287	267	255		0.0	25.6		0.0	0.0
5	308	286	267	245		0.0	26.0		0.0	0.0
6	308	287	267	245		0.0	26.0		0.0	0.0
7	309	287	267	245		0.0	25.7		0.0	0.0
8	315	293	273	251		0.0	25.5		0.0	0.0
9	321	301	282	261		0.0	25.5		0.0	0.0
10	321	301	283	270		0.0	24.4		0.0	0.0
11	288	267	251	268		0.0	19.8		0.0	0.0
12	256	229	211	275		0.0	15.9		0.0	0.0
13	255	229	210	279		0.0	15.9		0.0	0.0
14	255	229	211	282		0.0	15.7		0.0	0.0
15	255	229	211	286		0.0	15.5		0.0	0.0
16	248	218	200	287		.6	13.9		0.0	0.0
17	248	207	190	286		1.7	12.7		0.0	0.0
18	254	208	191	285		2.2	12.9		0.0	0.0
19	254	209	191	284		2.2	12.9		0.0	0.0
20	255	210	191	285		2.2	12.9		0.0	0.0
21	256	210	191	285		2.2	12.9		0.0	0.0
22	256	211	192	286		2.2	12.8		0.0	0.0
23	256	211	192	286		2.2	12.7		0.0	0.0
24	257	212	192	285		2.2	12.7		0.0	0.0
25	258	213	193	285		2.2	12.7		0.0	0.0
26	259	214	193	284		2.1	12.7		0.0	0.0
27	261	215	195	283		1.9	12.8		0.0	0.0
28	261	216	196	282		1.9	12.9		0.0	0.0
29	260	216	196	281		1.9	13.0		0.0	0.0
30	259	216	196	280		1.9	13.0		0.0	0.0

Table 5.-- (Continued)

Day of month	Stage (cm)					Discharge (m ³ /s)			Rainfall (mm)	
	Cotton- wood	Simpson	Newport gage	South end	Skinner inlet	Cottonwood	Simpson	Skinner inlet	Cotton- wood	Skinner
May 1974										
1									0.0	0.0
2									0.0	0.0
3									0.0	0.0
4									0.0	0.0
5									0.0	0.0
6									0.0	.3
7									0.0	0.0
8	247	210	190	282			1.8	12.2	0.0	0.0
9	246	210	190	283			1.8	12.2	0.0	0.0
10	247	210	191	283			1.8	12.4	0.0	0.0
11	247	211	191	284			1.8	12.4	0.0	0.0
12	247	211	192	286			1.8	12.4	0.0	0.0
13	248	212	192	287			1.8	12.4	0.0	0.0
14	247	211	192	288			1.8	12.3	0.0	0.0
15	247	211	192	286		14.8	1.8	9.9	0.0	0.0
16	247	211	191	283		14.8	1.8	7.1	0.0	0.0
17	246	209	190	282		14.6	1.8	7.2	0.0	0.0
18	245	208	189	280		14.6	1.8	7.2	0.0	.3
19	245	207	189	279		14.5	1.8	7.4	0.0	0.0
20	248	210	192	278		14.9	1.8	7.6	0.0	0.0
21	248	210	193	278		14.9	1.8	7.8	0.0	0.0
22	247	210	193	278		14.8	1.8	7.7	0.0	0.0
23	247	212	194	278		14.8	1.8	7.8	0.0	0.0
24	247	214	195	278		14.8	1.8	7.8	0.0	0.0
25	247	213	196	276		14.8	1.8	7.8	0.0	0.0
26	248	215	197	275		14.9	1.8	7.9	0.0	0.0
27	249	216	197	273		15.1	1.8	8.0	0.0	0.0
28	252	217	195	271		15.5	2.5	7.9	0.0	0.0
29	256	217	198	270		15.9	2.2	8.0	0.0	0.0
30	257	217	199	270		16.0	2.3	8.5	0.0	0.0
31	260	220	202	269		16.5	2.3	8.5	0.0	0.0

Table 5.-- (Continued)

Day of month	Stage (cm)					Discharge (m ³ /s)			Rainfall (mm)	
	Cotton- wood	Simpson	Newport gage	South end	Skinner inlet	Cottonwood	Simpson	Skinner inlet	Cotton- wood	Skinner
June 1974										
1	265	224	206	270		17.0	2.4	8.9	0.0	0.0
2	266	225	206	270		17.2	2.4	9.0	0.0	0.0
3	267	225	205	270		17.3	2.5	9.1	0.0	0.0
4	267	230	211	270		17.3	1.8	9.7	0.0	0.0
5	267	238	218	271		17.4	1.1	10.7	0.0	0.0
6	267	237	217	271		17.3	1.1	10.7	0.0	0.0
7	266	237	217	271		17.2	1.1	10.6	0.0	0.0
8	267	237	217	271		17.3	1.1	10.6	0.0	0.0
9	266	237	217	272		17.2	1.1	10.7	0.0	0.0
10	265	237	216	273		17.1	1.1	10.8	0.0	0.0
11	264	236	215	273		17.0	1.1	10.8	0.0	0.0
12	265	236	216	272		17.0	1.1	10.7	0.0	0.0
13	265	236	215	272		17.0	1.1	10.6	0.0	0.0
14	265	236	216	273		17.0	1.1	10.5	0.0	0.0
15	264	236	216	273		17.0	1.1	10.5	0.0	0.0
16	264	236	215	273		16.9	1.1	10.5	0.0	0.0
17	264	235	214	273		16.9	1.1	10.5	0.0	0.0
18	267	237	217	273		17.4	1.1	10.8	0.0	0.0
19	270	240	220	272		17.7	1.1	11.2	0.0	0.0
20	270	240	220	272		17.7	1.1	11.2	0.0	0.0
21	272	240	219	272		18.0	1.4	11.1	0.0	0.0
22	274	239	219	272		18.2	1.7	11.0	0.0	0.0
23	274	240	220	273		18.2	1.7	11.2	0.0	0.0
24	275	239	218	273		18.4	2.0	11.0	0.0	0.0
25	276	238	217	272		18.5	2.2	10.4	0.0	0.0
26	279	239	218	272		18.9	2.2	10.5	0.0	0.0
27	283	242	221	271		19.5	2.4	10.9	0.0	0.0
28	285	243	223	271		19.8	2.4	11.1	0.0	0.0
29	285	243	222	271		19.7	2.4	11.1	0.0	0.0
30	285	243	222	270		19.9	2.4	11.3	0.0	0.0

Table 5.-- (Continued)

Day of month	Stage (cm)					Discharge (m ³ /s)			Rainfall (mm)	
	Cotton- wood	Simpson	Newport gage	South end	Skinner inlet	Cottonwood	Simpson	Skinner inlet	Cotton- wood	Skinner
July 1974										
1	285	243	222	270		19.8	2.4	11.3	0.0	0.0
2	285	243	222	269		19.8	2.4	11.2	0.0	0.0
3	285	243	222	268		19.8	2.7	11.0	0.0	0.0
4	285	244	222	267		19.9	2.8	10.8	0.0	0.0
5	288	246	224	267		20.2	2.8	11.1	0.0	0.0
6	289	248	224	267		20.4	2.8	11.2	0.0	0.0
7	288	247	224	266		20.3	2.8	11.3	0.0	0.0
8	288	247	224	266		20.2	2.8	11.3	0.0	0.0
9	290	250	227	266		20.6	2.8	11.5	0.0	0.0
10	290	250	228	267		20.6	2.8	11.4	0.0	0.0
11	290	250	228	267		20.6	2.8	11.4	0.0	0.0
12	290	250	225	268		20.6	2.8	11.4	0.0	0.0
13	290	249	224	268		20.5	2.8	11.4	0.0	0.0
14	290	250	224	269		20.6	2.8	11.3	0.0	0.0
15	290	249	225	271		20.5	2.8	11.4	0.0	0.0
16	289	244	224	273		20.3	2.8	11.4	0.0	0.0
17	288	240	223	273		20.2	2.8	11.4	0.0	0.0
18	288	238	223			20.2	2.8	11.4	0.0	0.0
19	287	236	223			20.1	2.8	11.3	0.0	0.0
20	287	236	223			20.1	2.8	11.4	0.0	0.0
21	288	236	224			20.2	2.8	11.5	0.0	0.0
22	287	235	224			20.1	2.8	11.5	0.0	0.0
23	288	235	225			20.2	2.8	11.7	2.5	.3

¹Rainfall represents the accumulated amount between 0900 hours of the indicated day to 0900 hours of the following day.



