LOVEWELL RESERVOIR

1995 SEDIMENTATION SURVEY

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13. ABSTRACT *(Maximum 200 words)*

The Bureau of Reclamation (Reclamation) surveyed the underwater area of Lovewell Reservoir in June 1995 to develop a topographic map and compute a present storage-elevation relationship (area-capacity tables). The data were used to calculate reservoir capacity lost to sediment accumulation since dam closure on May 29, 1957. The survey used sonic depth recording equipment interfaced with a GPS (global positioning system). Underwater topography was developed by computer program using collected data. Above-water topography was determined by digitizing contour lines from United States Geological Survey quadrangle (USGS quad) maps of the reservoir area developed from aerial photography obtained in 1967. The new topographic map of Lovewell Reservoir is a combination of digitized contours and 1995 underwater measured topography.

As of June 6, 1995, at top of active conservation elevation (feet) 1,582.6, surface area was 2,987 acres, total capacity was 35,666 acre-feet, and active capacity was 24,022 acre-feet. Since initial filling in May 1957, about 6,021 acre-feet of sediment have accumulated in Lovewell Reservoir below elevation 1582.6 sediment accumulation—a 14.4-percent loss in reservoir volume. Since 1957, the estimated average annual rate of reservoir capacity lost to sediment accumulation is 158.4 acre-feet.

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1995 SEDIMENTATION SURVEY

by

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Denver, Colorado

September 1996

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U.S. Department of the Interior
Mission Statement

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally-owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

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INTRODUCTION

Lovewell Dam and Reservoir are features of the Bostwick Division of the Pick-Sloan Missouri Basin Program. Additional features are Harland County Dam and Reservoir, both constructed on the Republican River by the Corps of Engineers. Lovewell Dam and Reservoir are located in Jewell County, north-central Kansas, about 3 miles northwest of Lovewell, Kansas. The reservoir is located on White Rock Creek about 19 miles upstream from the confluence of White Rock Creek and the Republican River (fig. 1).

Lovewell Dam was constructed between 1955 and 1957; first storage occurred on May 29, 1957. The dam is a zoned earthfill embankment (fig. 2) whose dimensions are:

- Hydraulic height* 70 feet
- Structural height 93 feet
- Top width 30 feet (reduces to 20 feet on the left abutment)
- Crest length 8,500 feet
- Crest elevation 1,616 feet

Lovewell Dam's spillway, located in the right abutment, is a chute-type structure controlled by two counterweighted radial gates for automatic operation. The automatic float operation of the radial gates occurs by water flowing into floatwells through unvalved orifices. The radial gates begin to open when the reservoir reaches elevation 1,594.8 (feet). The gates can also be manually opened by controlling hoisting equipment or controlling bypass valves to operate the floats. The inlet channel to the spillway is partially combined with the inlet channel to the outlet works. The ogee spillway crest is located at elevation 1,575.3 and consists of two bays with crest widths of 25 feet. The discharge capacity is 35,000 cubic feet per second at reservoir elevation 1,610.3, (Bureau of Reclamation, 1981).

The outlet works is located adjacent to the south end of the spillway in the right abutment. The outlet works consists of an inlet channel with trashrack, gate chamber, stilling basin, and canal entrance. The chamber structure is 58 feet high, extends to the crest of the dam, and houses an 8- by 10-foot emergency fixed-wheel gate, an 8- by 10-foot top-seal regulating radial gate, and controls for both gates. The discharge capacity is 3,200 cubic feet per second at reservoir elevation 1,610.3.

Lovewell Reservoir stores water from White Rock Creek and diversions from the Republican River by way of the Courtland Canal. The drainage area above the dam is 345 square miles, ranging from elevation 1,571.7 at the top of the inactive pool, to over elevation 2,100 along the western boundary of the drainage basin. The reservoir length at elevation 1,582.6 is 7.6 miles; the average width is 0.6 miles.

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* The definition of terms such as "structural height," "hydraulic height," etc., may be found in manuals such as Reclamation's *Design of Small Dams* and *Guide for Preparation of Standing Operating Procedures for Dams and Reservoirs*, or ASCE's *Nomenclature for Hydraulics*.

SUMMARY AND CONCLUSIONS

This Reclamation report presents the 1995 results of the first extensive survey of Lovewell Reservoir. The primary objectives of the survey were to gather data needed to:

- develop reservoir topography
- compute area-capacity relationships
- estimate storage depletion caused by sediment deposition since Lovewell Dam closure

The bathymetric survey was run using sonic depth recording equipment interfaced with a DGPS (differential global positioning system) capable of determining sounding locations within the reservoir. The system continuously recorded depth and horizontal coordinates of the survey boat as it was navigated along grid lines covering Lovewell Reservoir. The positioning system provided information to allow the boat operator to maintain course along these grid lines. Water surface elevations recorded by a Reclamation gage during the time of collection were used to convert the sonic depth measurements to true reservoir bottom elevations.

The 1995 underwater surface areas at predetermined contour intervals were generated by a computer graphics program using the underwater collected data. The above-water reservoir contours were digitized from USGS quad (United States Geological Survey 7.5-minute quadrangle) maps of Lovewell Reservoir. The new topographic map of Lovewell Reservoir is a combination of the digitized and underwater measured topography. The area and capacity tables were produced by a computer program that uses measured contour surface areas and a curve-fitting technique to compute area and capacity at prescribed elevation increments. The 1995 area and capacity tables were generated using the 1995 measured areas at elevation 1580.0 and less and the original measured areas for elevation 1585.0 and greater.

Table 1 contains a summary of Lovewell Reservoir watershed characteristics for the 1995 survey. The 1995 survey determined that the reservoir has a storage capacity of 35,666 acre-feet and a surface area of 2,987 acres at reservoir elevation 1,582.6. Since closure in 1957, the reservoir has accumulated a sediment volume of 6,021 acre-feet below reservoir elevation 1,582.6. This volume represents a 14.4-percent loss in capacity and an average annual loss of 158.4 acre-feet.

RESERVOIR OPERATIONS

Lovewell Reservoir is primarily an irrigation facility with surcharge storage. The following values are from the June 1995 area-capacity tables:

- 94,145 acre-feet of surcharge storage between elevations 1,595.3 and 1,610.3

- 50,465 acre-feet of flood control storage between elevation 1,582.6 and 1,595.3

- 24,022 acre-feet of active conservation storage between elevations 1,571.7 and 1,582.6

- 9,970 acre-feet of inactive storage between elevations 1,562.07 and 1,571.7

- 1,674 acre-feet of dead storage below elevation 1,562.07

Available records for years 1957 through June 1995 show that the average flow into the reservoir was 61,868 acre-feet per year. The reservoir stores water from White Rock Creek and diversions from the Republican River by way of the Courtland Canal. The inflow and end-of-month stage records in table 1 show the annual fluctuation of the reservoir. The available records show that after initial filling, Lovewell Reservoir operation ranged from elevation 1,571.4 in 1991 to a maximum elevation of 1,591.6 in 1993.

HYDROGRAPHIC SURVEY EQUIPMENT AND METHOD

The hydrographic survey equipment was mounted in the cabin of a 24-foot tri-hull aluminum vessel equipped with twin in-board motors. The hydrographic system contained on the survey vessel consisted of a GPS (global positioning system) receiver with a built-in radio and an omnidirectional antenna, a depth sounder, a helmsman display for navigation, a plotter, a computer, and hydrographic system software for collecting the underwater data. Power to the equipment was supplied by an on-board generator.

The shore equipment included a second GPS receiver with a built-in radio and an omnidirectional antenna. The GPS receiver and antenna were mounted on a survey tripod over a known datum point. The power for the shore unit was provided by a 12-volt battery.

GPS Technology and Equipment

The positioning system used at Lovewell Reservoir was NAVSTAR (NAVigation Satellite Timing and Ranging) GPS; an all weather, radio based, satellite navigation system that enables users to accurately determine three-dimensional position. The NAVSTAR system's primary mission is to provide passive global positioning and navigation for land, air, and sea based strategic and tactical forces and is operated and maintained by the DOD (Department of Defense). The GPS receiver measures the distances between the satellites and itself and determines the receiver's position from intersections of the multiple range vectors. Distances are determined by accurately measuring the time a signal pulse takes to travel from the satellite to the receiver.

The NAVSTAR system consists of three segments:

- The space segment is a network of 24 satellites that is maintained in precise orbit, about 10,900 nautical miles above the earth, each completing an orbit every 12 hours.

- The ground control segment tracks the satellites, determining their precise orbits. Periodically, the ground control segment transmits correction and other system data to all the satellites, which is then retransmitted to the user segment.

- The user segment is the GPS receivers, which measure the broadcasts from the satellites and calculate the position of the receivers.

The GPS receivers use the satellites as reference points for triangulating their position on earth. The position is calculated from distance measurements to the satellites that are determined by how long a radio signal takes to reach the receiver from the satellite. To calculate the receiver's position on earth, the satellite distance and the satellite's position in space are needed. The satellites transmit signals to the GPS receivers for distance measurements along with the data messages about their exact orbital location and operational status. The satellites transmit two "L" band frequencies for the distance measurement signal called L1 and L2. At least four satellite observations are required to mathematically solve for the four unknown receiver parameters (latitude, longitude, altitude, and time). The time unknown is caused by the clock error between the expensive satellite atomic clocks and the imperfect clocks in the GPS receivers. For hydrographic surveying the altitude, the Lovewell Reservoir water surface elevation parameter was known, which realistically meant only three satellite observations were needed to track the survey vessel. During the Lovewell Reservoir survey, the best six available satellites were used for position calculations.

The GPS receiver's absolute position is not as accurate as it appears in theory because of the function of range measurement precision and geometric position of the satellites. Precision is affected by several factors—time, because of the clock differences, and atmospheric delays caused by the effect on the radio signal of the ionosphere. GDOP (geometric dilution of precision) describes the geometrical uncertainty and is a function of the relative geometry of the satellites and the user. Generally, the closer together in angle two satellites are from the receiver, the greater the GDOP. GDOP is broken into components: PDOP is position dilution of precision (x,y,z), and HDOP is horizontal dilution of precision (x,y). The components are based only on the geometry of the satellites. The PDOP and HDOP were monitored during the Lovewell Reservoir Survey, and for the majority of the time, they were less than 3, which is within the acceptable limits of horizontal accuracy for Class 1 and 2 level surveys (Corps of Engineers, 1991).

An additional and larger error source of GPS collection is caused by false signal projection, called S/A (selective availability). The DOD implements S/A to discourage the use of the satellite system as a guidance tool by hostile forces. Positions determined by a single receiver when S/A is active can have errors of up to 100 meters.

A method of collection to resolve or cancel the inherent errors of GPS (satellite position or S/A, clock differences, atmospheric delay, etc.) is called DGPS (differential GPS). DGPS was used during the Lovewell Reservoir survey to determine positions of the moving survey vessel in real time. DGPS determines the position of one receiver in reference to another and is a method of increasing position accuracies by eliminating or minimizing the uncertainties. Differential positioning is not concerned with the absolute position of each unit but with the relative difference between the positions of two units, which are simultaneously observing the same satellites. The inherent errors are mostly canceled because the satellite transmission is essentially the same at both receivers.

At a known geographical benchmark, one GPS receiver is programmed with the known coordinates and stationed over the geographical benchmark. This receiver, known as the master or reference unit, remains over the known benchmark, monitors the movement of the satellites, and calculates its apparent geographical position by direct reception from the satellites. The inherent errors in the satellite position are determined relative to the master receiver's programmed position, and the necessary corrections or differences are transmitted to the mobile GPS receiver on the survey vessel. For the Lovewell Reservoir survey, position corrections were determined by the master receiver and transmitted via a UHF (ultra-high frequency) radio link every 3 seconds to the survey vessel mobile receiver. The survey vessel's GPS receiver used the corrections along with the satellite information it received to determine the vessel's differential location. Using DGPS resulted in positional accuracies of 1 to 2 meters for the moving vessel compared to positional accuracies of 100 meters with a single receiver.

The TSC (Technical Service Center) mobile and reference GPS units are identical in construction and consist of a 6-channel L1 C/A (coarse acquistion) code continuous parallel tracking receiver, an internal modem, and a UHF radio transceiver. The differential corrections from the reference station to the mobile station are transmitted using the industry standard RTCM (Radio Technical Commission for Maritime Services) message protocol via the UHF radio link. The programming to the mobile or reference GPS unit is accomplished by entering necessary information via a notebook computer. The TSC GPS system has the capability of establishing or confirming the land base control points by using notebook computers for logging data and post-processing software. The GPS collection system has the capability of collecting the data in 1927 or 1983 NAD (North American Datums) in the surveyed area's state plane coordinate system's zone. For Lovewell Reservoir, the data were collected in the Kansas 1927 NAD north state plane zone.

Survey Method and Equipment

The Lovewell Reservoir hydrographic survey collection was conducted from June 6 through June 9, 1995, between water surface elevations 1,586.96 and 1,587.25. The bathymetric survey was run using sonic depth recording equipment interfaced with a DGPS capable of determining sounding locations within the reservoir. The survey system software continuously recorded reservoir depths and horizontal coordinates as the survey boat moved across close-spaced grid lines covering the reservoir area. Most of the transects (grid lines) were run in a north-south direction. Data were also collected along the shore as the boat traversed to the next transect. Transects were also run in an east-west direction to provide additional data for complete contour development. The survey vessel's guidance system gave directions to the boat operator to assist in maintaining course along these predetermined lines. During each run, the depth and position data were recorded on the notebook computer hard drive for subsequent processing by TSC personnel. The underwater data set includes 28,866 data points. A graph plotter was used in the field to track the boat and ensure adequate coverage during the collection process. The water surface elevation recorded by a Reclamation gage during the time of collection was used to convert the sonic depth measurements to true lake bottom elevations.

Because no known benchmarks or datums were located near the reservoir to station the master GPS unit, the hydrographic survey crew established a datum for the reservoir survey using the hydrographic GPS units and software. In establishing the control for the reference datum the survey crew was only able to locate a third order benchmark (Formosa) several miles from the reservoir. The control was brought in from the Formosa benchmark to a brass cap marked 17.5 US, located at the right embankment of the dam. This method calculated 1927 NAD state plane coordinates on the 17.5 brass cap of North 564,495.349 and East 1,992,108.042. The shore based master GPS unit, which transmits the correction information to the mobile GPS unit on the survey vessel, was stationed over the 17.5 US brass cap throughout the survey. This location was chosen because it was accessible, it was located near the reservoir, and also because it was high and overlooked the reservoir. The location allowed for good radio transmission to the mobile survey vessel throughout the reservoir survey. During post processing of the collected data, the few collected points without differential correction were removed.

Prior to data collection, the depth sounder was calibrated by lowering a deflector plate below the boat by cables with known depths marked by beads. The depth sounder was calibrated by adjusting the speed of sound, which can vary with density, salinity, temperature, turbidity, and other conditions. The collected data were digitally transmitted to the computer collection system via an RS-232 port. The depth sounder also produces an analog hard copy chart of the measured depths. These graphed analog charts were printed for all survey lines as the data were collected and recorded by the computer. The charts were analyzed during post processing, and when the analog charted depths indicated a difference from the recorded computer bottom depths, the computer data files were modified.

RESERVOIR AREA AND CAPACITY

Topography Development

The topography of Lovewell Reservoir was developed from the 1995 collected underwater data and from the USGS quad maps. The upper contours of Lovewell Reservoir were developed by digitizing the reservoir water surface and the contour lines of elevation 1,583.0 and 1,595.0 from the USGS quad maps that covered the Lovewell Reservoir area. The USGS quad maps were developed from aerial photography dated 1967. ARC/INFO V7.0.2 geographic information system software was used to digitize the USGS quad contours. The digitized contours were transformed to the Kansas NAD 1927 north state plane coordinates using the ARC/INFO PROJECT command.

Contours for elevations below 1,583.0 were computed from collected underwater data using the TIN (triangular irregular network) surface modeling package within ARC/INFO. The underwater survey data were collected in the Kansas north zone state plane coordinates in NAD 1927. A TIN is a set of adjacent, non-overlapping triangles computed from irregularly spaced points with x,y coordinates and z values. TIN was designed to deal with continuous data such as elevations.

The TIN software uses a method known as Delaunay's criteria for triangulation. Triangles are formed between all data points, including all boundary points. This method preserves all collected survey points. The method requires that a circle drawn through the three nodes of a triangle contain no other point, meaning that sample points are connected to their nearest neighbors to form triangles. Elevation contours are then interpolated along triangle elements. The TIN method is discussed in great detail in the ARC/INFO V7.0.2 User Documentation.

The elevation 1,583.0 contour that was digitized from USGS quad maps was used to perform a clip of the Lovewell Reservoir TIN such that interpolation was not allowed to occur outside of the 1,583.0 contour. This clip was performed using the hardclip option of the ARC/INFO CREATETIN command. Using ARCEDIT, the underwater collected data and digitized contours from the quad maps were plotted. The plot found that the underwater data did not match exactly with the digitized data and would require a slight shift to place the underwater data within the elevation 1583.0 clip. Use of the third order control point (Formosa) to establish the datum at the dam was assumed to have contributed to the shift. Using select and move commands within ARCEDIT, all the underwater points were shifted in unison to fit within the elevation 1583.0 clip. During the underwater collection, all correction signals where transmitted from the established brass cap datum, 17.5 US, which made the shift easier to complete. Even with the data shift, the 1,583.0 clip had to be slightly modified to enclose all underwater data points. The shift was necessary because of bank erosion and because the underwater data was collected at reservoir elevation 1587.0. The measured surface area of the final digitized elevation 1,583.0 contour was around 3,030 acres, which was the original computed area at reservoir water surface elevation 1,582.9. The underwater data and digitized contour topography are presented on figure 3.

In creating the TIN, points that fell within a set distance of each other were weeded out to eliminate flat triangular elements. Flat triangles occur where all three points making up a triangle have the same elevation. Elimination of redundant points helped to improve the performance of the contouring process and helped create more continuous contours in the lower elevations of the reservoir.

The linear interpolation option of the ARC/INFO TINCONTOUR command was used to interpolate contours from the Lovewell Reservoir TIN. In addition, the contours were generalized by weeding out vertices along the contours. This generalization process improved the presentability of the resulting contours by removing very small variations in the contour lines. This generalization had little bearing on the computation of surface areas and volumes for Lovewell Reservoir. The contour topography at 5-foot intervals is presented on figures 4 and 5, drawings No. 271-D-1570 and 271-D-1571.

Development of 1995 Contour Areas

The 1995 contour surface areas for Lovewell Reservoir were computed from elevations 1,551.0 to 1,583.0 using the Lovewell Reservoir TIN discussed above. The 1995 survey measured the minimum reservoir as elevation 1,550.3 feet. These calculations were performed using the ARC/INFO VOLUME command. This command computes areas at user specified elevations directly from the TIN and takes into consideration all regions of equal elevation.

1995 Storage Capacity

The storage-elevation relationships based on the measured surface areas were developed using the area-capacity computer program ACAP85 (Bureau of Reclamation, 1985). Surface areas at 2-foot and 5-foot contour intervals from minimum reservoir elevation 1,550.3 to elevation 1,580.0, and the original surface areas at 5-foot contour intervals from elevations 1,585.0 and 1,610.0, were used as the control parameters for computing the Lovewell Reservoir capacity. The program can compute an area and capacity at elevation increments of 0.01 to 1.0 foot by linear interpolation between the given contour surface areas. The program begins by testing the initial capacity equation over successive intervals to ensure that the equation fits within an allowable error limit, which was set at 0.0000001 for Lovewell Reservoir. This capacity equation is then used over the full range of intervals fitting within this allowable error limit. For the first interval at which the initial allowable error limit is exceeded, a new capacity equation (integrated from basic area curve over that interval) tests the fit until it also exceeds the error limit. Thus, the capacity curve is defined by a series of curves, each fitting a certain region of data. Final area equations are derived by differentiating the capacity equations, which are of second order polynomial form:

$$y = a_1 + a_2x + a_3x^2$$

where:

y = capacity
x = elevation above a reference base
a_1 = intercept
a_2 and a_3 = coefficients

Results of the 1995 Lovewell Reservoir area and capacity computations are listed in table 1 and columns (4) and (5) of table 2. Listed in columns (2) and (3) of table 2 are the original surface areas and recomputed capacity values. A separate set of 1995 area and capacity tables has been published for the 0.01-, 0.1-, and 1-foot elevation increments (Bureau of Reclamation, 1995). A description of the computations and coefficients output from the ACAP85 program is included with these tables. Both the original and 1995 area-capacity curves are plotted on figure 6. As of June 1995, at elevation 1,582.6, the surface area was 2,987 acres, total capacity was 35,666 acre-feet, and active capacity was 24,022 acre-feet.

RESERVOIR SEDIMENT ANALYSES

Sediments have accumulated in Lovewell Reservoir to a volume of 6,021 acre-feet since dam closure in May 1957. This volume was calculated at reservoir elevation 1,582.6. It must be noted that the 1995 underwater survey was conducted at a water surface elevation of about 1587.0; the final product relied on USGS quad maps for the elevation 1583.0 contour. Original measured surface areas at elevation 1585.0 and greater were used for computing the 1995 reservoir area and capacity tables above the 1995 measured area at elevation 1580.0. Column (6) of table 2 gives the measured sediment volume by elevation and illustrates that the majority of the deposit is in the lower elevations of the reservoir. Of the total measured deposited sediment of 6,021 acre-feet, 5,116 acre-feet were deposited in the inactive pool storage areas and 905 acre-feet in the active pool storage areas. The average rate of sediment deposition between closure and June 1995 (38.0 years) was 158.4 acre-feet per year. The storage loss in terms of percent of original storage capacity was 14.4 percent. Tables 1 and 2 contain the Lovewell Reservoir sediment accumulation and water storage data based on the 1995 resurvey.

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U.S. Army Corps of Engineers, *Application of differential Global Positioning System for Hydrographic Survey and Dredge Positioning*, ETL 1110-7-5 (FR), Department of the Army, Washington, DC, March 1991.

Table 1. - Reservoir sediment data summary (page 1 of 2).

RESERVOIR SEDIMENT DATA SUMMARY

Lovewell Reservoir
NAME OF RESERVOIR

1
DATA SHEET NO.

DAM	1. OWNER Bureau of Reclamation	2. STREAM White Rock Creek	3. STATE Kansas
	4. SEC. 18 TWP. 2S RANGE 6W	5. NEAREST P.O. Lovewell	6. COUNTY Jewell
	7. LAT 39° 53' 04" LONG 98° 01' 41"	8. TOP OF DAM ELEVATION 1,616.0	9. SPILLWAY CREST EL. 1575.3[1]

RESERVOIR	10. STORAGE ALLOCATION	11. ELEVATION TOP OF POOL	12. ORIGINAL SURFACE AREA, Ac	13. ORIGINAL CAPACITY, AF	14. GROSS STORAGE ACRE- FEET	15. DATE STORAGE BEGAN
	a. SURCHARGE	1,610.3	7,635	94,140	186,290	
	b. FLOOD CONTROL	1,595.3	5,025	50,460	92,150	5/29/57
	c. POWER					
	d. WATER SUPPLY	1,582.6	2,986	24,930	41,690	16. DATE NORMAL OPERATION BEGAN
	e. IRRIGATION					
	f. INACTIVE	1,571.7	1,704	11,710	16,760	
	g. DEAD	1,562.07	711	5,050	5,050	5/58
	17. LENGTH OF RESERVOIR 7.6[2] MILES			AVG. WIDTH OF RESERVOIR 0.6 MILES		

BASIN	18. TOTAL DRAINAGE AREA 345 SQUARE MILES		22. MEAN ANNUAL PRECIPITATION 29.9[3] INCHES
	19. NET SEDIMENT CONTRIBUTING AREA 345 SQUARE MILES		23. MEAN ANNUAL RUNOFF 3.36[4] INCHES
	20. LENGTH MILES	AV. WIDTH MILES	24. MEAN ANNUAL RUNOFF 61,868[5] ACRE-FEET
	21. MAX. ELEVATION 2,100+	MIN. ELEVATION 1571.7	25. ANNUAL TEMP. MEAN 53°F RANGE -19°F to 113°F[3]

SURVEY DATA

26. DATE OF SURVEY	27. PER. YRS.	28. ACCL. YRS.	29. TYPE OF SURVEY	30. NO. OF RANGES OR INTERVAL	31. SURFACE AREA, AC.	32. CAPACITY ACRE-FEET	33. C/I RATIO AF/AF
5/29/57			Contour (D)	5-ft	2,986[6]	41,687[5]	0.67
6/6/95	38.0	38.0	Contour (D)[7]	5-ft	2,987[7]	35,666[7]	0.57

26. DATE OF SURVEY	34. PERIOD ANNUAL PRECIP.	35. PERIOD WATER INFLOW, ACRE FEET			WATER INFLOW TO DATE, AF	
		a. MEAN ANN.	b. MAX. ANN.	c. TOTAL	a. MEAN ANN.	b. TOTAL
6/6/95	29.9	61,868[5]	193,000	2,351,000	61,868[5]	2,351,000

26. DATE OF SURVEY	37. PERIOD CAPACITY LOSS, ACRE-FEET			38. TOTAL SEDIMENT DEPOSITS TO DATE, AF		
	a. TOTAL	b. AV. ANN.	c. /MI.²-YR.	a. TOTAL	b. AV. ANNUAL	c. /MI.²-YR.
6/6/95	6,021[7,8]	158.4[8]	0.46	6,021	158.4	0.46

26. DATE OF SURVEY	39. AV. DRY WT. (#/FT³)	40. SED. DEP. TONS/MI.²-YR.		41. STORAGE LOSS, PCT.		42. SEDIMENT INFLOW, PPM	
		a. PERIOD	b. TOTAL TO DATE	a. AV. ANNUAL	b. TOTAL TO DATE	a. PER.	b. TOT.
6/6/95				0.380[8]	14.4[8]		

26. DATE OF SURVEY	43. DEPTH DESIGNATION RANGE IN FEET BELOW ELEVATION 1,582.6.										
		37.6-	37.6-	32.6-	27.6-	22.6-	17.6-	12.6-	1582.6		
	PERCENT OF TOTAL SEDIMENT LOCATED WITHIN DEPTH DESIGNATION										
6/6/95		4.8	9.6	17.1	17.9	16.1	13.7	15.6	5.2		

26. DATE OF SURVEY	44. REACH DESIGNATION PERCENT OF TOTAL ORIGINAL LENGTH OF RESERVOIR														
	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100-105	105-110	110-115	115-120	120-125
	PERCENT OF TOTAL SEDIMENT LOCATED WITHIN REACH DESIGNATION														

Table 1. - Reservoir sediment data summary (page 2 of 2).

45. RANGE IN RESERVOIR OPERATION[9]

YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AF	YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AF
1957	1,577.8	1,563.5	33,000	1958	1,584.4	1,577.3	10,700
1959	1,583.5	1,573.8	14,200	1960	1,585.4	1,577.1	29,100
1961	1,584.2	1,577.5	55,100	1962	1,584.8	1,578.0	62,300
1963	1,585.2	1,577.8	35,400	1964	1,585.2	1,580.0	14,500
1965	1,586.0	1,581.1	55,400	1966	1,583.2	1,576.4	9,500
1967	1,582.9	1,578.4	23,300	1968	1,582.6	1,574.9	19,300
1969	1,582.9	1,575.2	41,600	1970	1,582.5	1,575.8	86,600
1971	1,582.9	1,577.5	56,000	1972	1,582.8	1,579.6	19,300
1973	1,590.7	1,581.3	193,300	1974	1,584.6	1,575.6	70,700
1975	1,585.6	1,579.1	80,100	1976	1,582.9	1,574.9	76,700
1977	1,582.8	1,578.0	58,600	1978	1,583.2	1,578.6	63,600
1979	1,585.3	1,577.5	70,800	1980	1,583.5	1,574.6	67,200
1981	1,585.8	1,579.0	52,200	1982	1,585.9	1,573.3	44,500
1983	1,585.0	1,575.2	81,800	1984	1,584.9	1,576.9	85,800
1985	1,585.3	1,580.9	85,700	1986	1,584.6	1,578.3	82,600
1987	1,589.8	1,578.9	128,700	1988	1,582.1	1,576.6	68,600
1989	1,580.8	1,576.8	49,800	1990	1,584.2	1,576.2	66,200
1991	1,585.4	1,571.4	40,900	1992	1,586.0	1,579.6	56,400
1993	1,591.6	1,581.1	177,600	1994	1,584.8	1,577.6	55,800
1995[10]	1,584.0	1,580.6	28,100				

46. ELEVATION - AREA - CAPACITY DATA FOR **1995 CAPACITY**[11]

ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY
1550.3	0.0	0	1552	6.0	5	1554	12.2	23
1555	33.6	46	1556	90.0	108	1558	177.4	375
1560	292.8	846	1562	486.1	1,624	1562.07	(498)	1,674
1564	733.1	2,844	1565	863.6	3,642	1566	978.0	4,563
1568	1,175.1	6,716	1570	1,341.5	9,232	1571.7	(1,495)	11,644
1572	1,522.4	12,096	1574	1,752.9	15,372	1575	1,892.3	17,194
1576	2,028.9	19,155	1578	2,315.7	23,500	1580	2,594.4	28,410
1585	3,350	43,271	1590	4,109	61,918	1595	4,976	84,631
1595.3	(5,024)	86,131	1600	5,780	111,521	1605	6,620	142,521
1610	7,570	177,996	1610.3	(7,635)	180,276			

47. REMARKS AND REFERENCES

1 Top of spillway radial gates is elevation 1595.3.

2 Length at reservoir elevation 1582.6.

3 Bureau of Reclamation *Project Data Book*, 1981.

4 Calculated using mean annual runoff value of 61,868 acre-ft, item 24.

5 Computed inflow from White Rock Creek and diversions from the Republican River.

6 Surface area and capacity at elevation 1,582.6, recomputed by Reclamation's ACAP program using original surface areas.

7 Surface area and capacity at elevation 1582.6 computed by Reclamation's ACAP program using 1995 surface areas. In 1995, only underwater portion of reservoir surveyed below elevation 1585.0. Elevation 1585.0 and above from original measured areas.

8 Total capacity loss calculated by comparing original recomputed capacity and 1995 capacity at reservoir elevation 1582.6.

9 End-of-month maximum and minimum elevations and inflow values in acre-feet are by calendar year.

10 1995 values through May 1995.

11 Area values in ( ) computed by ACAP computer program. Areas at elevation 1585.0 and above from original survey.

48. AGENCY MAKING SURVEY Bureau of Reclamation
49. AGENCY SUPPLYING DATA Bureau of Reclamation | DATE April 1996

Table 2. - Summary of 1995 survey results.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Elevation (ft)	Original Area (acres)	Original Capacity (acre-ft)	1995 Area (acres)	1995 Capacity (acre-ft)	Measured Sediment Volume (acre-ft)	Percent Measured Sediment	Percent Reservoir Depth
1610.3	7,635	186,296	7,635	180,276	-	-	100.0
1605.0	6,620	148,540	6,620	142,521	-	-	93.0
1600.0	5,780	117,540	5,780	111,521	-	-	86.3
1595.3	(5,025)*	92,150	(5,025)	86,131	-	-	80.1
1590.0	4,109	67,938	4,109	61,918	-	-	73.0
1585.0	3,350	49,290	3,350	43,271	-	-	66.4
1582.6	(2,986)	41,687	(2,987)	35,666	6,021	100.0	63.2
1580.0	2,592	34,435	2,594	28,410	6,025	100.0	59.8
1575.0	2,020	22,905	1,892	17,194	5,711	94.8	53.1
1571.7	(1,704)	16,760	(1,495)	11,644	5,116	85.0	48.7
1570.0	1,542	14,000	1,342	9,233	4,767	79.2	46.5
1565.0	1,023	7,588	864	3,642	3,946	65.5	39.8
1562.07	(710)	5,074	(498)	1,674	3,400	56.5	36.0
1560.0	484	3,820	293	846	2,974	49.4	33.2
1555.0	266	1,945	34	46	1,899	31.5	26.6
1550.3	(170)	920	0	0	920	15.3	20.3
1550.0	164	870	0	-	870	14.4	19.9
1545.0	69	288	0	-	288	4.8	13.3
1540.0	23	58	0	-	58	1.0	6.6
1535.0	0	0	0	-	0	0	0.0

(1) Elevation of reservoir water surface.
(2) Original reservoir surface area.
(3) Original calculated reservoir capacity computed using ACAP from original measured surface areas.
(4) Reservoir surface area from 1995 survey for elevations 1580.0 and below. Areas for elevation 1585.0 and greater are original measured areas.
(5) 1995 calculated reservoir capacity computed using ACAP from 1995 surface areas.
(6) Measured sediment volume = column (3) - column (5).
(7) Measured sediment expressed in percentage of total sediment of 6,021 acre-feet at elevation 1582.6.
(10) Depth of reservoir expressed in percentage of total depth (75.3 ft).

* Areas in parentheses computed by ACAP.

Note: The 1995 survey developed updated underwater reservoir topography from elevation 1580.0 and below. Surface areas above elevation 1585.0 are original measured areas.

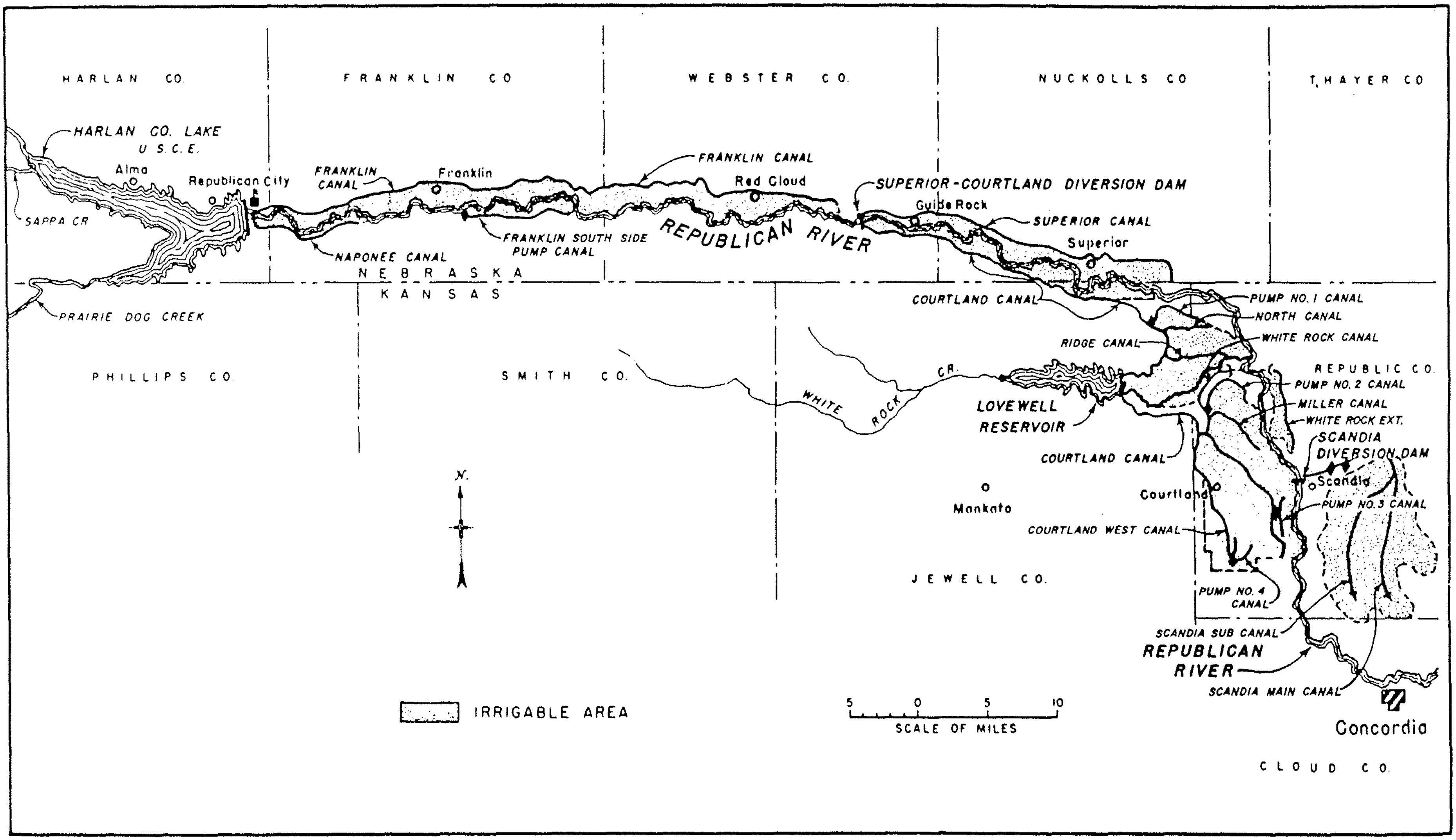

Figure 1. - Lowell Reservoir location map.

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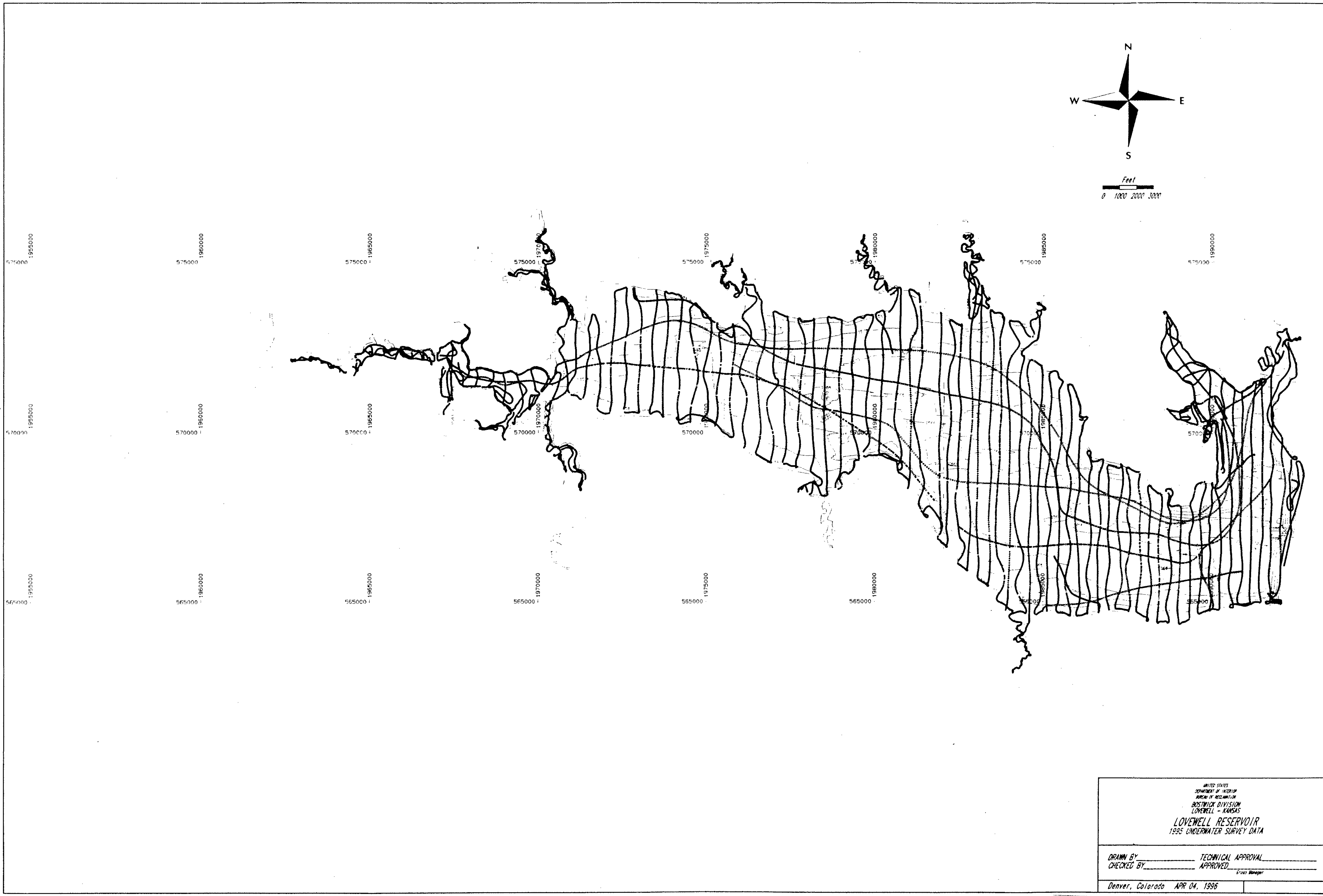
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BUREAU OF RECLAMATION
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CHECKED BY
TECHNICAL APPROVAL
APPROVED
Group Manager
Denver, Colorado APR 04, 1996

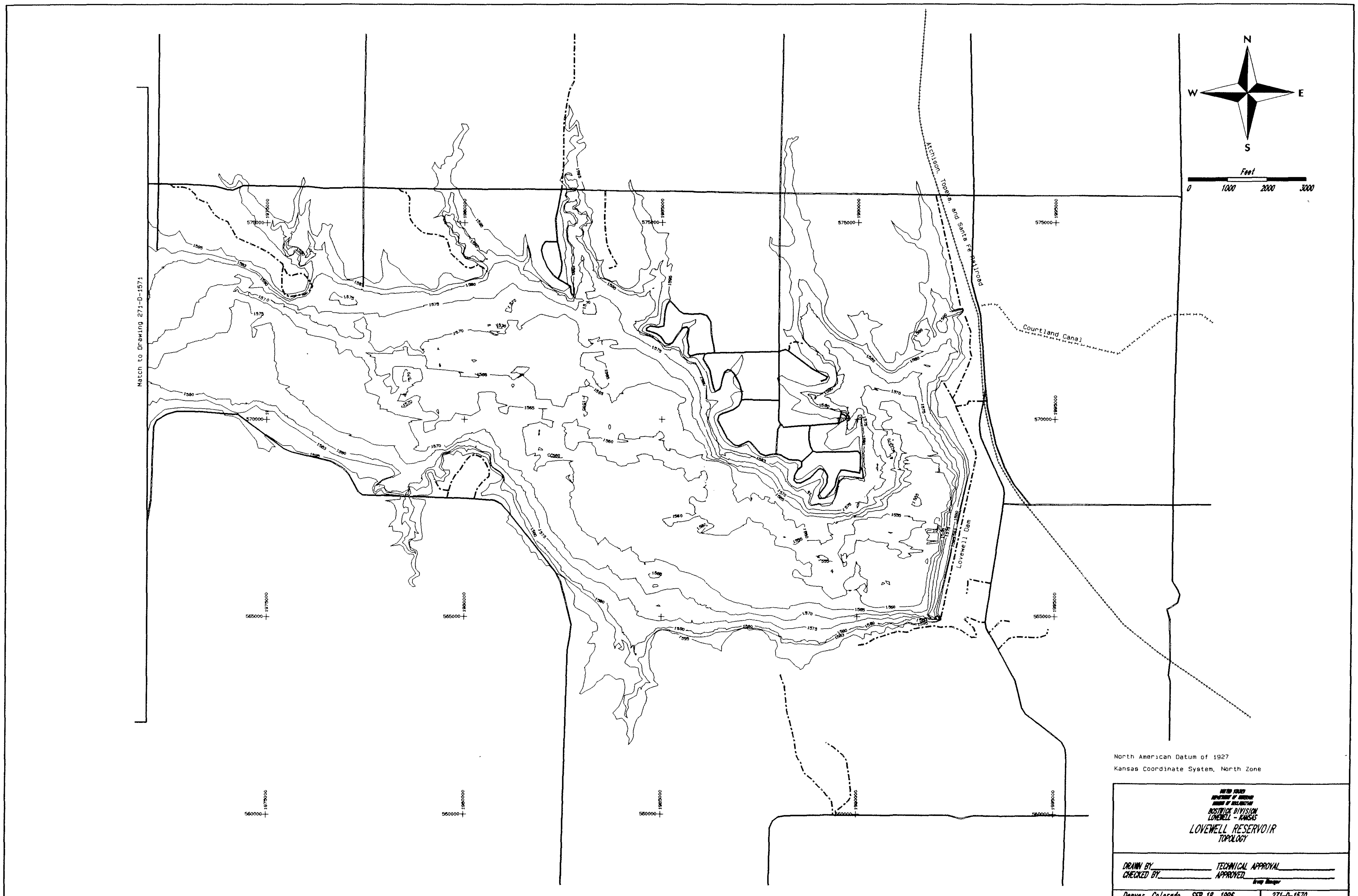

Figure 4. - Lovewell Reservoir topographic map. No. 271-D-1570

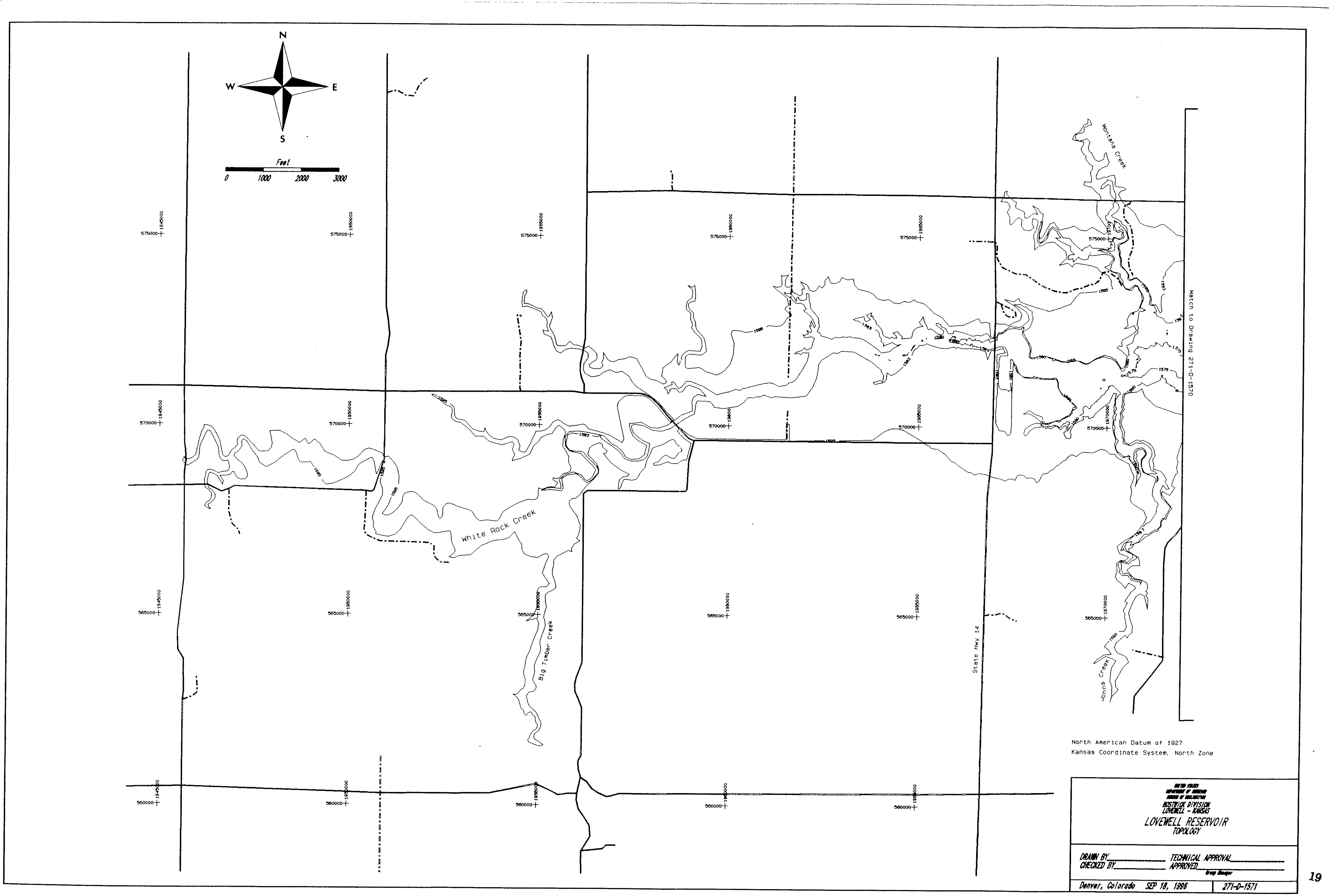

Figure 5. - Lovewell Reservoir topographic map, No. 271-D-1571

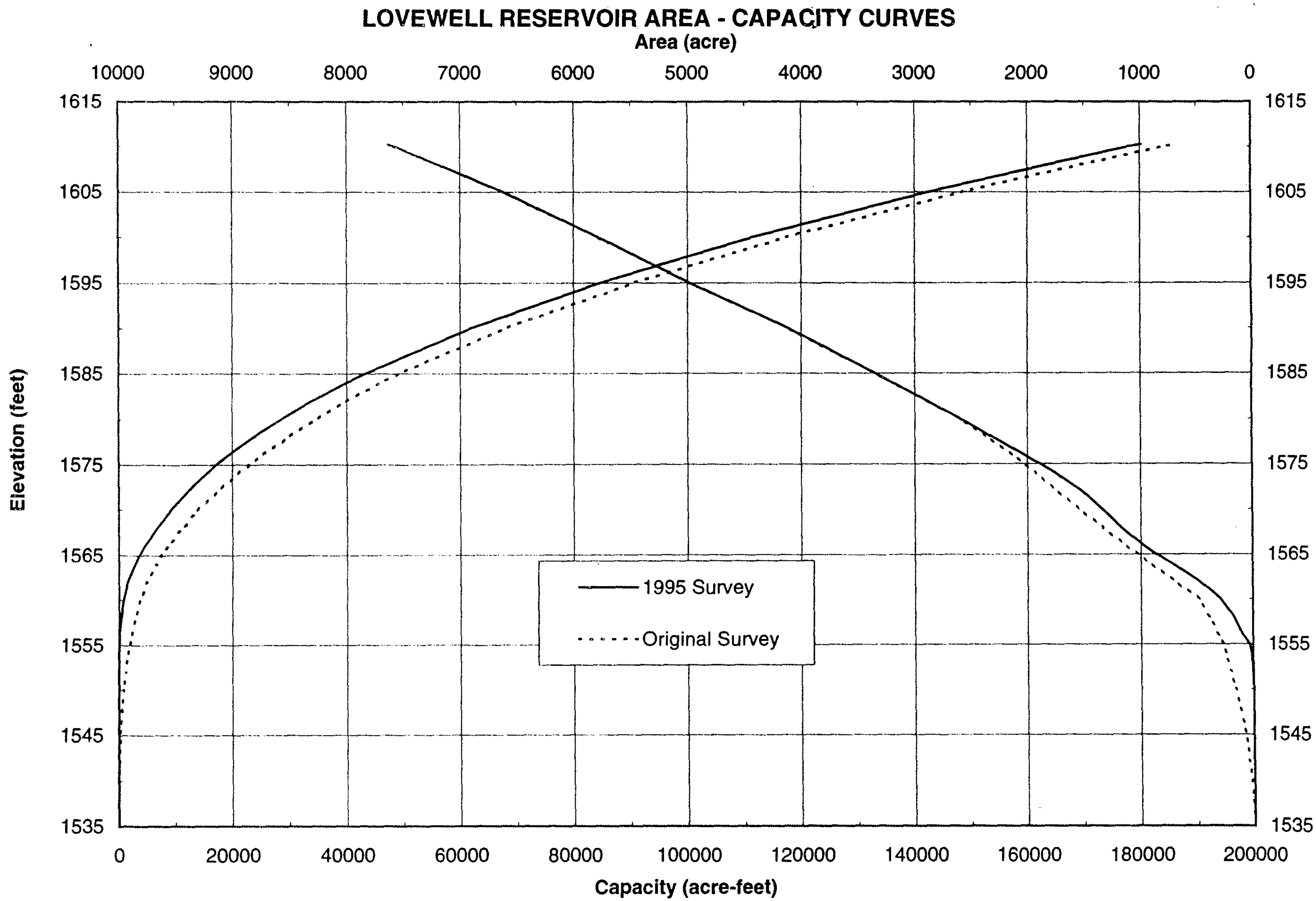

Figure 6. - 1995 area and capacity curves.

Mission

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American Public.