



WATER-RIGHT DOCKET

Mammoth Cave National Park

Docket No: 10

GREEN RIVER

Supporting Hydro Data

08-00-1962: statement of progress on mammoth cave project

N 30-23

Statement of Progress on Mammoth Cave Project August 1-31, 1962

SEP 27 '62
Dir. Director
Asst. Dir. (Adm.)
Asst. Dir. (Res. Pl.)
Asst. to Dir.

The two recording bubble gages on Green River and in the Cave were maintained in operation as were the staff gages in the Cave and at outlet streams. Monthly water-level recorders were continued at 8 wells and at the end of Gardner and Little Sinking Creeks. The operation of the weekly chemical quality stations on Green River and Echo River outlet was continued.

Measurements of flow of the seven springs on Flint Ridge were continued in August. Despite the dry-weather conditions that persisted unabated until near the end of August, the flow of most of the springs held at the minimum levels established at the end of July. The following flow measurements were taken:

Spring	Discharge in gallons per minute				
	8/1/62	8/8/62	8/15/62	8/22/62	8/29/62
Three Springs...	17	17	15	15	15
Bransford.....	1/	1/	1/	1/	3
Blair.....	2/	2/	2/	2/	2/
Adwell.....	23	23	20	2/	20
Cooper.....	16	16	16	16	16
Collins.....	23	20	20	20	20
CCC #1.....	4	4	3	3	3

- 1/ No measurement taken because well was discharging into reservoir and reservoir was being pumped.
- 2/ No measurement taken because spring was being pumped to augment supply at Bransford Spring.

The extremely low flows of Green River during August should provide important data on the quality of the water during drought conditions. The relationship will be analyzed soon. Discharge measurements were made on several tributary streams during August as follows;

Stream	Date	Discharge (Cubic feet per second)
Styx River outlet...	August 24	0.052
Echo River outlet...	August 24	1.02
Beaverdam Creek at Rhada.....	August 23	0.505

PROVISIONAL RECORDS, SUBJECT TO REVISION

UNIT STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER ANALYSIS

25W

Location Mammoth Cave, Kentucky County Edmonson
 Source Green River
 Point of coll. At ferry
 Owner National Park Service Treatment _____
 Use _____ Gage height (ft) 24.80 Discharge (cfs) _____ Temp (°F) 54
 Appear. when coll. Muddy
 Collected April 14, 1962, 9:40 AM By National Park Service
 Remarks _____

	ppm	epm		ppm	epm
Silica (SiO ₂)			Bicarbonate (HCO ₃)		
Aluminum (Al)			Carbonate (CO ₃)		
Iron (Fe)					
			Sulfate (SO ₄)		
			Chloride (Cl)	5.5	0.16
			Fluoride (F)		
Calcium (Ca)					
Magnesium (Mg)			Nitrate (NO ₃)		
Sodium (Na)					
Potassium (K)					
Total			Total		

	ppm		
		Specific conductance (micromhos at 25° C)	152
Dissolved solids:		pH	
Calculated		Color	
Residue on evaporation at 180° C			
Hardness as CaCO ₃			
Noncarbonate			

Lab. No. Col **25938**

Field No. _____

Project **XY MAMMOTH CAVE Q SW**

PROVISIONAL RECORDS, SUBJECT TO REVISION

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER ANALYSIS

2SW

Location Mammoth Cave, Kentucky County Edmonson
 Source Green River
 Point of coll. At ferry
 Owner National Park Service Treatment _____
 Use _____ Gage height (ft) 9.00 Discharge (cfs) _____ Temp (°F) 55
 Appear. when coll. Muddy
 Collected April 7, 1962, 9:30 AM By National Park Service
 Remarks _____

	ppm	epm		ppm	epm
Silica (SiO ₂)			Bicarbonate (HCO ₃)		
Aluminum (Al)			Carbonate (CO ₃)		
Iron (Fe)					
			Sulfate (SO ₄)		
			Chloride (Cl)	12	0.34
			Fluoride (F)		
Calcium (Ca)					
Magnesium (Mg)			Nitrate (NO ₃)		
Sodium (Na)					
Potassium (K)					
Total			Total		

	ppm		
		Specific conductance (micromhos at 25° C)	253
Dissolved solids:		pH	
Calculated		Color	
Residue on evaporation at 180° C			
Hardness as CaCO ₃			
Noncarbonate			

Lab. No. Col **25937**

Field No. _____

Project **KY MAMMOTH CAVE Q SW**

PROVISIONAL RECORDS, SUBJECT TO REVISION

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER ANALYSIS

2SW

Location Mammoth Cave, Kentucky County Edmonson
 Source Green River
 Point of coll. At ferry
 Owner National Park Service Treatment _____
 Use _____ Gage height (ft) 14.14 Discharge (cfs) _____ Temp (°F) 66
 Appear. when coll. Muddy
 Collected March 31, 1962, 10:15 AM By National Park Service
 Remarks _____

	ppm	epm		ppm	epm
Silica (SiO ₂)			Bicarbonate (HCO ₃)		
Aluminum (Al)			Carbonate (CO ₃)		
Iron (Fe)			Sulfate (SO ₄)		
			Chloride (Cl)	9.0	0.25
			Fluoride (F)		
Calcium (Ca)					
Magnesium (Mg)			Nitrate (NO ₃)		
Sodium (Na)					
Potassium (K)					
Total			Total		

	ppm		
Dissolved solids:		Specific conductance (micromhos at 25° C)	217
Calculated		pH	
Residue on evaporation at 180° C		Color	
Hardness as CaCO ₃			
Noncarbonate			

Lab. No. Col **25936**

Field No

Project **KY MAMMOTH CAVE Q SW**

UNIVERSITY OF KENTUCKY RECORDS SUBJECT TO REVIEW
 UNITED STATES DEPARTMENT OF THE INTERIOR
 GEOLOGICAL SURVEY
 WATER ANALYSIS

Location Mammoth Cave, Kentucky County Bell
 Source Green River
 Point of coll. At Ferry
 Owner National Park Service Treatment _____
 Use _____ Gage height (ft) 2.08 Discharge (cfs) _____ Temp (°F) 74
 Appear. when coll. slightly turbid
 Collected August 29, 1961 By R. A. Roeder
 Remarks Field chloride 50 ppm

	ppm	epm		ppm	epm
Silica (SiO ₂)			Bicarbonate (HCO ₃)	120	1.97
Aluminum (Al)			Carbonate (CO ₃)	0	.00
Iron (Fe)	0.20	--	Sulfate (SO ₄)	14	.29
			Chloride (Cl)	50	1.41
			Fluoride (F)	.2	.01
Calcium (Ca)					
Magnesium (Mg)			Sulfate (SO ₄)	2.1	.03
Sodium (Na)					
Potassium (K)					
Total			Total		3.72

	ppm		
Dissolved solids:		Specific conductance	
Calculated		(micromhos at 25° C)	309
Residue on evaporation at 180° C		pH	7.5
Hardness as CaCO ₃		Color	
Non-carbonate	126		
	28		

Lab No. Col 24075 Field No. _____ Project BY MAMMOTH CAVE O. R.

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER ANALYSIS

25W

Location Manmoth Cave, Kentucky County Edmonson
Source Green River
Point of coll. At Ferry
Owner National Park Service Treatment _____
Use _____ Gage height (ft) 3.90 Discharge (cfs) _____ Temp (°F) 74
Appear. when coll. slightly turbid
Collected July 25, 1961, 1:15 PM By D. V. Whitesides and R. A. Ho
Remarks Field chloride 35 ppm

	ppm	epm		ppm	epm
Silica (SiO ₂)			Bicarbonate (HCO ₃)	130	2.13
Aluminum (Al)			Carbonate (CO ₃)	0	.00
Iron (Fe)	0.96	--			
			Sulfate (SO ₄)	12	.25
			Chloride (Cl)	45	1.27
			Fluoride (F)	.1	.01
Calcium (Ca)					
Magnesium (Mg)			Nitrate (NO ₃)	3.6	.06
Sodium (Na)					
Potassium (K)					
Total			Total		

	ppm		
Dissolved solids:		Specific conductance (micromhos at 25° C)	386
Calculated		pH	7.4
Residue on evaporation at 180° C		Color	
Hardness as CaCO ₃	134		
Noncarbonate	32		

PROVISIONAL RECORD SUBJECT TO REVIEW
25W

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER ANALYSIS

Location Mammoth Cave, Kentucky County Edmonson
 Source Green River
 Point of coll. At ferry at midstream
 Owner National Park Service Treatment _____
 Use _____ Gage height (ft) 3.30 Discharge (cfs) _____ Temp (°F) 68
 Appear. when coll. Clear
 Collected June 26, 1961, 6:10 PM By R. A. Easler
 Remarks Field chloride 50 ppm

	ppm	epm		ppm	epm
Silica (SiO ₂)			Bicarbonate (HCO ₃)	<u>144</u>	<u>2.36</u>
Aluminum (Al)			Carbonate (CO ₃)	<u>0</u>	<u>.00</u>
Iron (Fe)	<u>0.24</u>	<u>--</u>			
			Sulfate (SO ₄)	<u>14</u>	<u>.39</u>
			Chloride (Cl)	<u>57</u>	<u>1.61</u>
			Fluoride (F)	<u>.0</u>	<u>.00</u>
Calcium (Ca)					
Magnesium (Mg)			Nitrate (NO ₃)	<u>3.6</u>	<u>.06</u>
Sodium (Na)					
Potassium (K)					
Total			Total		

	ppm		
Dissolved solids:		Specific conductance (micromhos at 25° C)	<u>449</u>
Calculated		pH	<u>7.7</u>
Residue on evaporation at 180°C		Color	
Hardness as CaCO ₃	<u>152</u>		
Noncarbonate	<u>14</u>		

Lab. No. Col 24431

Field No. _____

Project

IV. Mammoth Cave Q SW

Form 9-614

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WASHINGTON 25, D. C.

Report to the Kentucky Geological Survey on
Chemical Quality Conditions of the Green River
at Munfordville, Kentucky, October 1956-September 1960

by R. A. Krieger, Chemist
U. S. Geological Survey
Quality of Water Branch

August 1961

U. S. Geological Survey
2822 E. Main Street
Columbus 9, Ohio

August 1961

Dr. W. W. Hagan
Director and State Geologist
Kentucky Geological Survey
Lexington, Kentucky

Dear Dr. Hagan:

We are happy to report that there is evidence of improvement in the chemical quality of the Green River at Munfordville, Kentucky. The trend towards better quality water started in December 1959 and has continued through April 1961. We are including data, illustrations, and a short discussion to show the basis for this conclusion. Unless you will want a more formal report, we will regard this letter as the annual report of the chloride condition of the Green River at Munfordville for the period October 1, 1959 to September 30, 1960.

Chloride

As you know, we make a chemical analysis for chloride on a water sample taken once each day from the Green River at Munfordville. Daily chloride concentrations in themselves do not tell us the total amount of chloride moving down the Green River. This daily chloride concentration must be weighted with the flow of water. The product is the chloride load expressed in tons of chloride per day and tons of chloride per month. The chloride tonnage for the period October 1, 1956 to September 30, 1960, is given in table 1.

Table 1.--Summary of chloride load and water discharge, Green River at
Munfordville, Kentucky, October 1956-September 1960

Month	Water disch. cfs-days	Chloride tons/month	Month	Water disch. cfs-days	Chloride tons/month
Oct. 1956	3,341	135	Oct. 1957	9,475	356.8
Nov.	4,873	316.6	Nov.	213,495	2,311
Dec.	80,116	1,394.7	Dec.	219,790	2,314
Jan. 1957	188,531	1,959	Jan. 1958	112,740	1,846
Feb.	245,920	2,157	Feb.	104,670	1,721
Mar.	105,410	1,143	Mar.	91,190	1,921
Apr.	173,780	1,148	Apr.	171,190	2,464
May	61,883	740.0	May	152,695	2,155
June	45,427	609	June	26,811	1,194
July	14,349	280.9	July	97,676	2,616
Aug.	5,385	173.6	Aug.	63,648	3,312
Sept.	20,478	580.9	Sept.	21,668	5,120
Total	949,493	10,627.7	Total	1,285,048	27,330.8
Oct. 1958	9,070	6,439	Oct. 1959	12,694	38,456
Nov.	19,478	14,304	Nov.	49,131	44,248
Dec.	33,116	15,220	Dec.	117,960	48,150
Jan. 1959	149,258	31,861	Jan. 1960	111,540	37,819
Feb.	127,450	26,073	Feb.	153,060	36,996
Mar.	82,950	29,577	Mar.	163,340	35,450
Apr.	88,430	38,440	Apr.	66,188	26,039
May	41,559	34,955	May	28,654	18,402
June	24,412	26,748	June	79,215	24,059
July	28,231	36,383	July	52,529	15,636
Aug.	18,501	25,681	Aug.	11,150	9,576
Sept.	8,332	19,810	Sept.	10,727	11,346
Total	630,787	305,491	Total	856,188	346,177

The 1957 water year may be regarded as a year of normal chloride discharge because the Greensburg oilfield had not yet been developed. The 1958 water year was a year of transition as brine discharge into the river became apparent during the latter part of the year. The 1959 water year was the year of peak chloride contamination. The 1960 water year was a year of continued contamination but with improvements in water quality noted during the year. The 1960 water year, when compared to 1959, yielded 36 percent more water with only a 13 percent increase in chloride load.

Chloride loads and water discharges, by themselves, do not necessarily indicate the true trend in water quality. To determine if there was a real change in quality, the double-mass curve method was used to test the data. This method was described by Searcy and Hardison (1960) ^{1/}. The double-mass curve for water discharge and chloride load is shown in figure 1. The curve is based on monthly totals. The segment of the curve, "OA", is the relation between water discharge and chloride load before development of the Greensburg oil field. Whenever this relation changes, there is a change of slope or a break in the curve. This is shown by the segment, "AB". Increases in chloride load caused the curve to break from its steep upward direction to a more gently sloping line. The segment, "BC", indicates an even higher level of contamination. However, in segment, "CD", the leveling tendency of the curve was reversed indicating a decrease in chloride contamination. The segment "CD" extends

^{1/} Searcy, J. K. and Hardison, C. H., 1960, Double mass curves, in Manual of hydrology: Part 1. General surface-water techniques: U. S. Geol. Survey Water-Supply Paper 1541-B, pp. 51-57.

from November 1959 to June 1960. In July 1960 there was a worsening in quality as indicated by segment "DE". Beyond point "E" the record is less certain because water discharge figures are only reasonable approximations derived from rating tables. However, the record is good enough for the period October 1960 to April 1961 to indicate that there is an erratic but continuing improvement in quality of Green River at Munfordville.

To test the significance of the improvement in quality of segment "CD" over segment "BC", the statistical procedure of Searcy and Hardison (1960) was used again. The results show that there are fewer than 5 chances in 100 that the break in the curve at point "C" was due solely to chance. In other words, beginning in December 1959, there was a significant abatement in chloride contamination of the Green River at Munfordville.

Unfortunately, the statistical test does not show the cause of the improvement in water quality. It may have been due to: (1) The pollution control efforts of the Kentucky Water Pollution Control Commission, (2) The decline in oil production, (3) Natural factors, such as a change in the rate and amount of precipitation, and (4) A combination of the above causes.

The frequency, or number of days each year, one might expect given concentrations of chloride are shown in figure 2. A concentration of 250 ppm chloride is the limiting concentration for drinking water as set by the U. S. Public Health Service. Prior to development of the Greensburg oilfield, chloride concentrations never exceeded 250 ppm (curve I).

During the period of maximum pollution (curve II), a concentration of 250 ppm was equalled or exceeded 76 percent of the time. During the period of improved quality (curve III), 250 ppm chloride was equalled or exceeded only 26 percent of the time.

Hardness and Dissolved Solids

The improvement in chloride load and concentrations was accompanied by a similar improvement in quality with respect to hardness and dissolved solids. These two dissolved constituents would be of particular interest to industrial users of the water. Curves similar to the chloride curve of figure 2 were prepared.

The hardness curves are shown in figure 3. Hardness, during the period of December 1, 1959 to June 30, 1960, curve III, was not unduly different from the pre-oilfield period, curve I. The period of maximum contamination, curve II, was a period of very hard water 78.5 percent of the time. Soft water is considered to be 60 ppm or less, moderately hard water 60 to 120 ppm, hard water from 120 to 200 ppm, and very hard water over 200 ppm hardness.

Dissolved solids showed improvement in quality since November 1959. The frequency curves are shown in figure 4. The U. S. Public Health Service drinking water standards call for dissolved solids to be less than 500 ppm. If no other water is available, then a water with 1,000 ppm is permitted. The percent of time 500 ppm and 1,000 ppm were equalled or exceeded are given in the figure. The 1,000 ppm limit was exceeded 40 percent of the time during April to November 1959. However, this limit

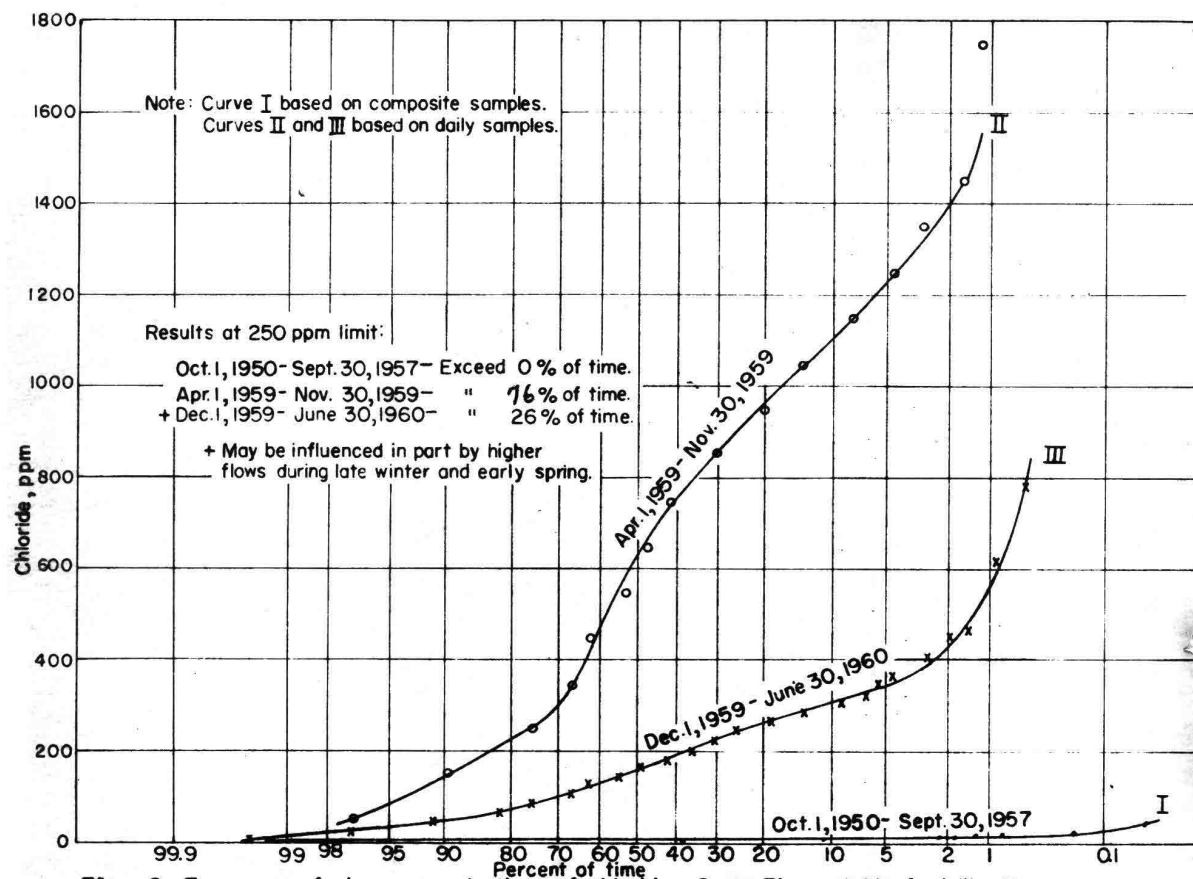


Fig.--2 Frequency of given concentrations of chloride, Green River, at Munfordville, Ky.

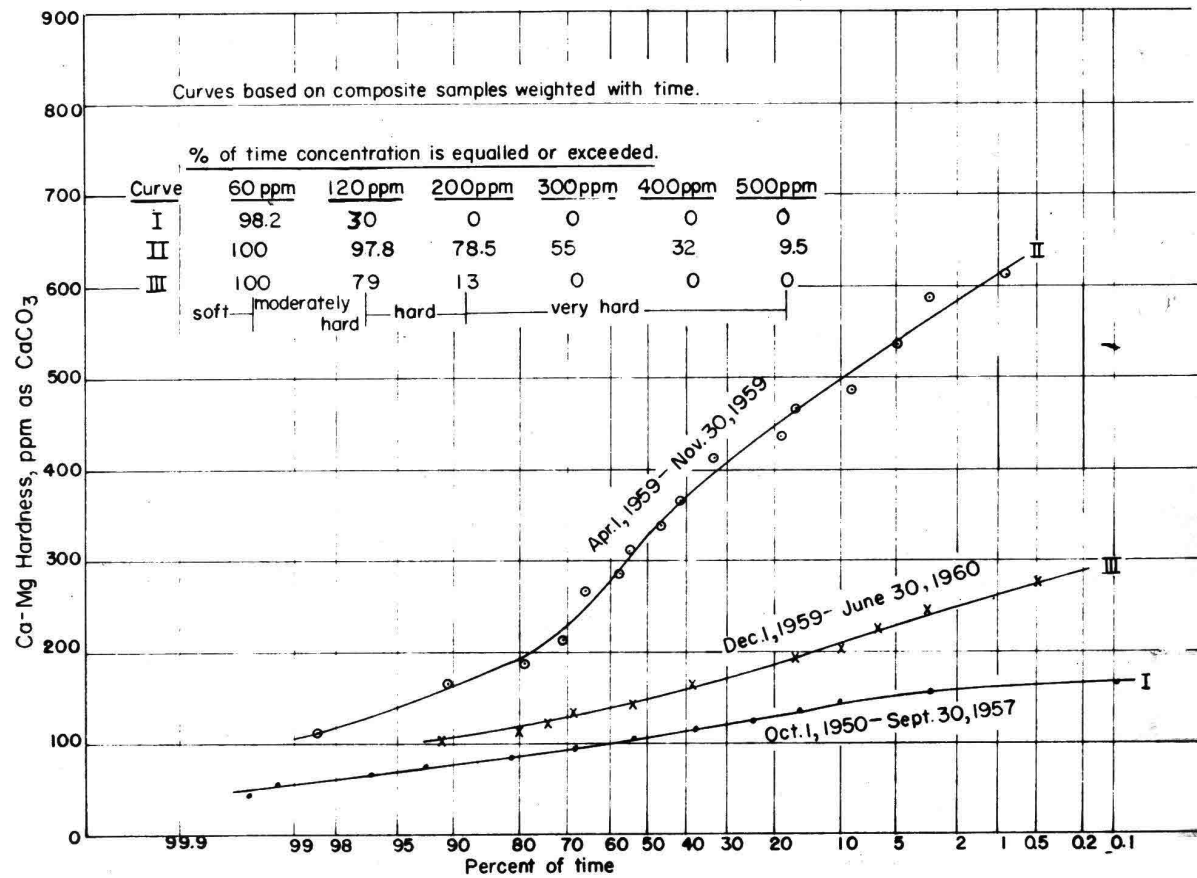


Fig.3-- Frequency of given concentrations of hardness, Green River at Munfordville, Ky.

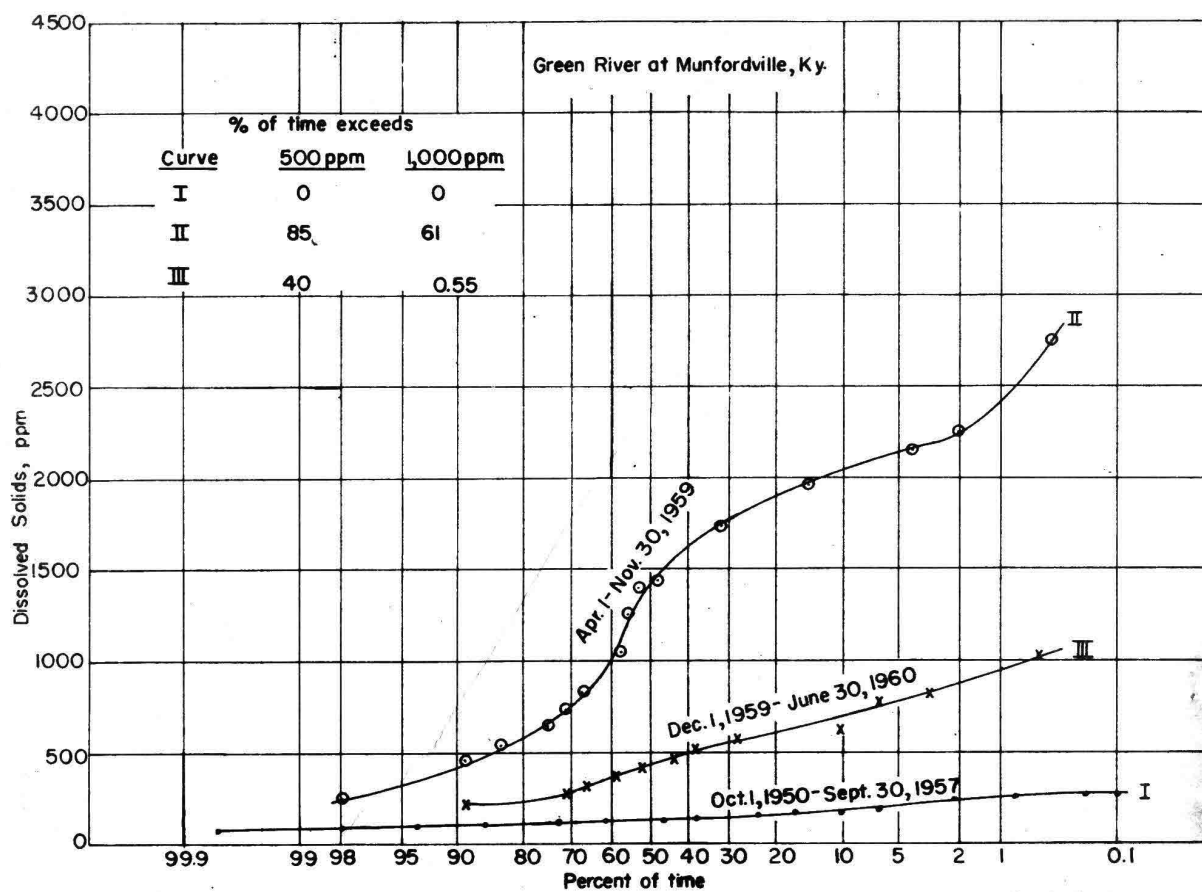


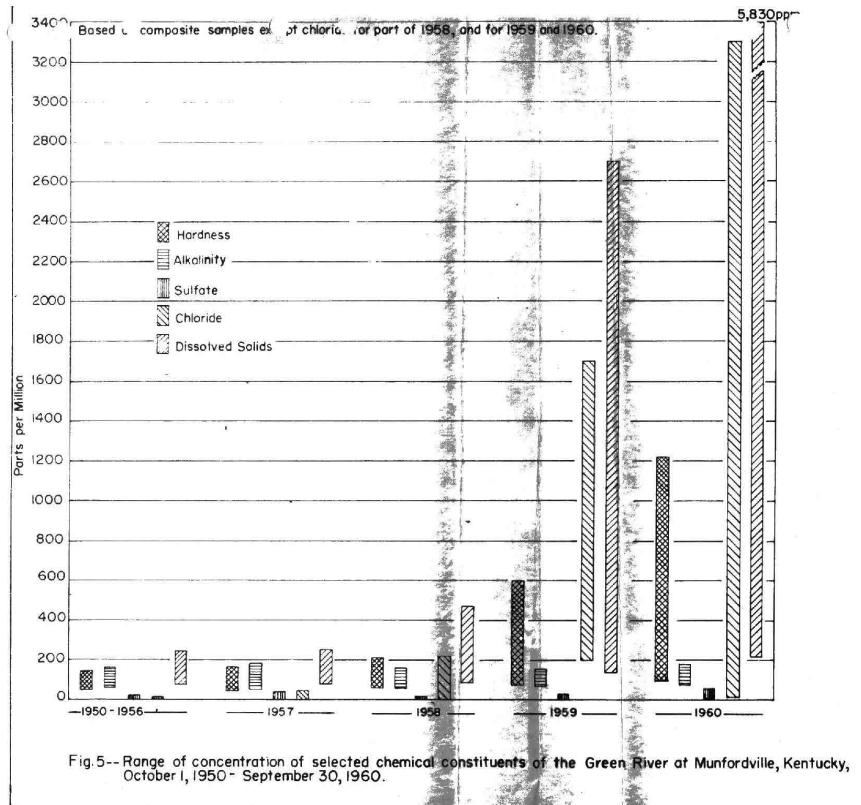
Fig. 4-- Frequency of given concentrations of dissolved solids, Green River at Munfordville, Ky.

was exceeded only 0.6 percent of the time during December to June 1960. If the chloride condition continues to improve as indicated, similar improvement will occur in hardness and dissolved solids.

Ranges in Concentration

It is of interest to note the changes in range of concentration of a few important chemical constituents before and after development of the Greensburg oilfield. Hardness, alkalinity, sulfate, chloride, and dissolved solids were selected to illustrate the effect the brine had on chemical character of the Green River. The ranges of concentration for several water years are shown in figure 5.

There was little or no change in the maximum and minimum amounts of alkalinity and sulfate. For hardness, chloride, and dissolved solids the story was quite different. A six-year maximum hardness of 166 ppm rose to 1,220 ppm October 10, 1959. This is, indeed, a very hard water. The minimum hardness for the six-year period went from 44 ppm to 102 ppm. This would be an important consideration in evaluating the use of the water. Before brine contamination, chloride concentrations were almost always less than 30 ppm. The maximum measured chloride concentration reached 3,250 ppm on October 10, 1959. The actual maximum may have been higher. Dissolved solids, reflecting the over-all salt concentration of the river went from a six-year maximum of 254 ppm to 5,830 ppm. When the chemical quality record for the 1961 water year is complete, there is every reason to believe that maximum concentrations for hardness, chloride, and dissolved solids will be less than in 1960.



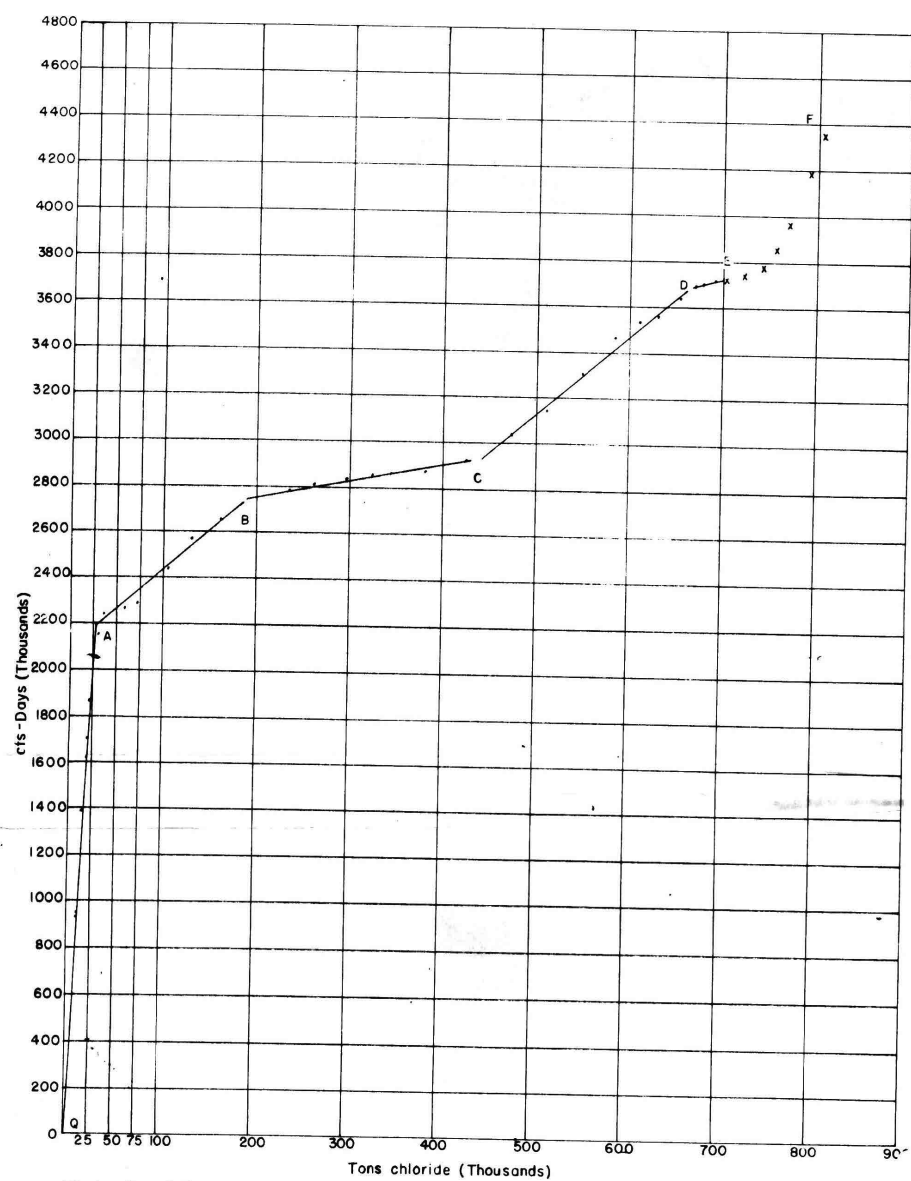
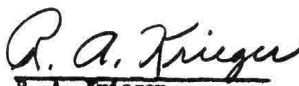


Fig. 1.-- Cumulative chloride load versus water discharge for the Green River at Munfordville, Ky.
Oct. 1, 1956 to Sept. 30, 1960.

Conclusion

There is real evidence that the peak contamination of the Green River by oilfield brines has passed. The Green River is now in a period of recovery due, most likely, to the efforts of Kentucky Water Pollution Control Commission and the decline in oil production. However, a real test will occur again this summer during the low flow period of July to September. We will make every effort to follow the quality variations of the Green River and report them to you in the Quarterly Report.

Sincerely,


R. A. Krieger

Docket Information

Number of Documents in Docket 21

Documents Dated from 6/26/1961 to 8/15/1962

Docket Compiled: 4/27/2011