THE REGULATORY FLOODWAY

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CHAPTER I

INTRODUCTION

Nature has provided for the transport of excess rainfall runoff to the oceans. The areas adjacent to streams and rivers are used periodically for the movement of flood waters and are commonly called flood plains. While normal daily flows are contained within the banks of the water course, large flows exceding the channel capacity spread water onto the flood plain. When this happens, facilities located on the flood plain will sustain water damage or possible complete loss.

Why would man put water damageable facilities on the flood plain? The reasons are many. The rivers provided transportation routes. Their gently sloping valleys provide easy grades for railroads and highways. And development usually follows transportation facilities. In addition, the relatively flat flood plains are easier to develop than is rolling terrain.

To reduce the flood damages, man has tried to alter nature. Through the use of dams, levees and channel modification, man has attempted to eliminate or reduce flooding on lands adjacent to the water course. Upon completion of the flood control measures, development continued to encroach on the flood plain. Despite the expenditure of billions of Federal dollars, the annual flood losses have continued to increase (H. D. No. 465, 1966). By the mid 1960's it was obvious to the Federal government that most state and local governments were doing little to prevent the unwise development of flood plains.

Several non-structural actions were taken by the Federal government in 1966 to discourage the uneconomic use of the nation's flood plains. In Executive Order Number 11296, President Johnson directed that not only Federal construction but also construction funded or supported by Federal funds not be subject to undue flood risk (Executive Order 11296, 1966). In addition the disposal of surplus Federal lands would carry restrictions against unwise development in flood prone areas.

That same year, the report by The Task Force on Federal Flood Policy made 15 recommendations for Executive and Congressional consideration. In addition to recommending the actions directed in Executive Order Number 11296, the Task Force recommended a five-stage study of the feasibility of insurance for structures in flood hazard areas.

Insurance for losses from flooding was vertually unavailable from private sources. To help offset the financial burden of flood damages, the Congress passed the National Flood Insurance Act of 1968. The law established a Federally subsidized flood insurance program. The insurance is made available through private companies to home owners and business for both building and contents.

Such a program would tend to encourage further development in the flood plain. The developer or home builder would gamble that the property would not flood and that if it did the Federal government would bail him out.

To prevent this, the law requires that before a structure becomes eligible for flood insurance, the community in which it is located must institute a flood plain management program. At first the program may consist of maps showing the approximate outline of past flooding along with requirements for flood proofing of new structures in those areas. Later, additional flood data is provided to the city or county by the Federal Insurance Administration. The local government is then required to expand their flood plain ordinances to establish a floodway and fringe area along the water course. The floodway is defined as the stream and that portion of the over bank necessary for the conveyance of the flood waters. Development is permitted in the fringe area; however, it must be flood proofed by elevating the floor above the flood waters, by levees or by water tight construction below the flood line. It is the purpose of this report to discuss the procedures for determining the floodway and some of the problems encountered.

CHAPTER II

THE FLOODWAY AS A TOOL FOR FLOOD PLAIN MANAGEMENT

The object of flood plain management is to keep to a minimum future flood losses. One way of doing this is to prohibit development in the flood plain. The flood plain may be the overflow limits of some past flood or a possible future flood. The limits are approximately described by meets and bounds in the zoning ordinance and/or subdivision regulations or shown on a flood plain map attached to the ordinance or regulation. The flood plain may still be used for activities which do not reduce its flood carrying capacity.

The disadvantage of this approach is that it is too restrictive. Usually major portions of the flood plain are not essential to the passage of the flood waters. The water may be only a few feet deep and slow moving or not moving at all. Should the ordinance be challenged in court, the city may have a hard time proving the reasonableness of the statute. Also if the ordinance is too restrictive it may be difficult to enforce.

Another approach is to permit development in the flood plain as long as the site is protected from flood damages. The advantage of this approach is that a complicated delineation of the flood plain is not required. The developer or builder determines the amount of flood protection needed to comply with the ordinance. The city would then review the plans to assure compliance prior to the issuing of a building permit.

The disadvantage is that there is no adequate way of assuring that the flood carrying capacity of the stream will not be significantly reduced. By filling in or diking off portions of the flood plain, the area available for flow is reduced and increased flooding may be caused upstream. Although the developer may be liable for flood damages which occured as a result of his actions, this threat has not proven sufficient to prevent unwise flood plain development.

The floodway concept in flood plain management uses aspects of both these approaches. First an engineering study is made to determine the area of the flood plain necessary for the most efficient conveyance of the selected flood with only a small increase in the flood elevation. In this area no activity is permitted which would restrict flood flows. Construction is permitted in the area of the flood plain outside the floodway (the floodway fringe). See Figure 1.

The advantage of this approach is that it permits development of larger areas without undue risk to life and property. Also the stream and a portion of its overbanks are left in a near natural state. This area may be used for a green belt or strip park. It also makes an excellent divider between incompatable land uses.

The delineation and appropriate zoning of the floodway is required by the Federal Insurance Administration, Department of Housing and Urban Development, for a communities' continued participation in the national flood insurance program (National Flood Insurance Act of 1968).

The floodway data furnished by the Federal Insurance

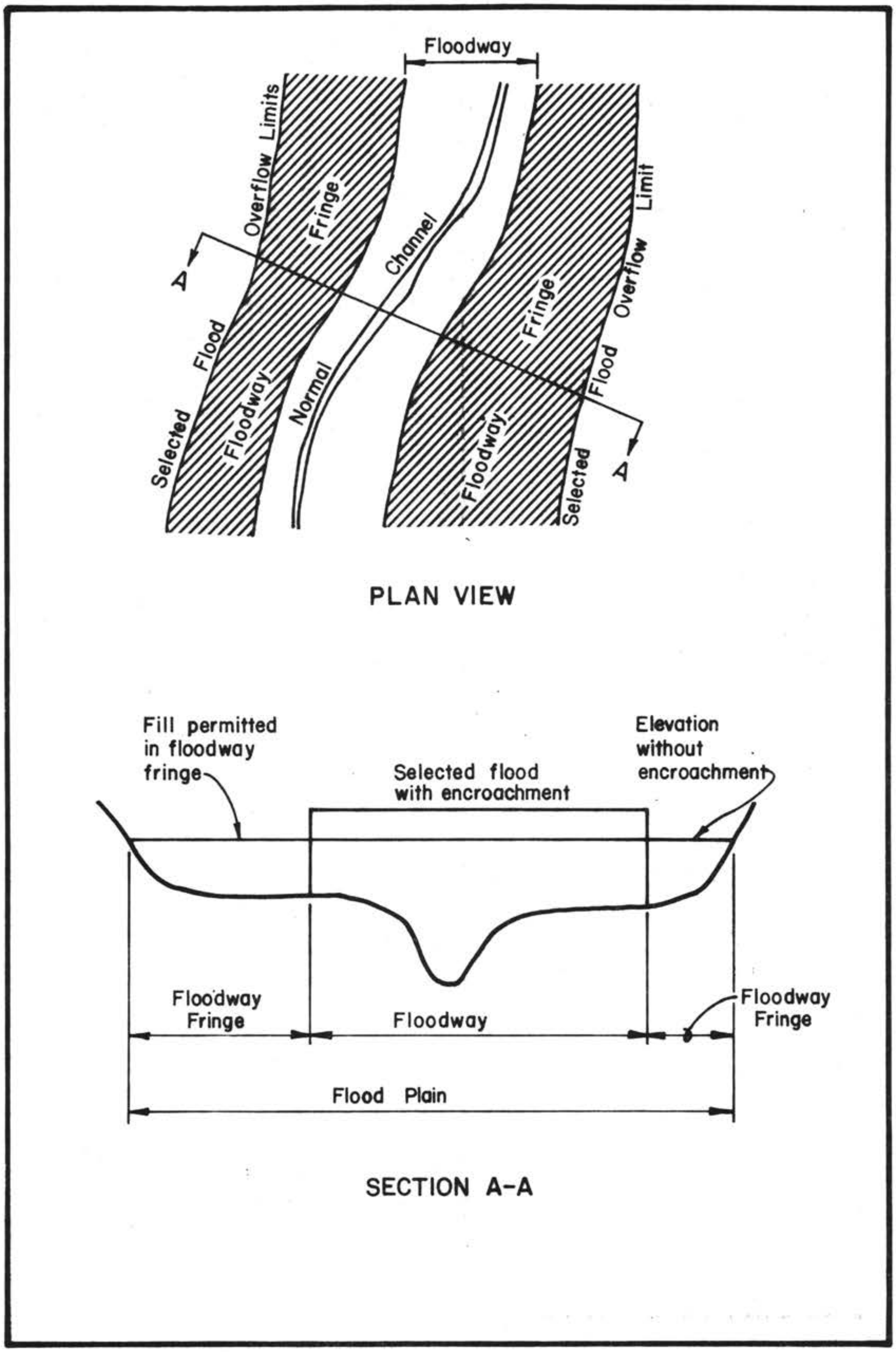

Figure 1. Regulatory Floodway

Administration is based on a permitted 1 foot rise in the 100-year flood caused by confining the flood to the floodway. The 100-year flood is defined as the flood which would be equaled or exceeded on a long term average of once in 100 years. Due to the increasing interest in participation in the flood insurance program, it is certain that this criteria will become the standard.

CHAPTER III

COMPUTATION OF THE REGULATORY FLOODWAY

The first step in defining the regulatory floodway is computing the water surface elevation of the selected flood under existing conditions. This is done either by hand computations or through the use of a computer backwater program. In either case, the average flow velocities in the left and right overbank areas and in the channel are determined. Then encroachment limits are set by trial in such a way that the carrying capacity lost in the two overbank areas is equal and their total equals the increase in capacity brought about by the higher water surface elevation in the floodway. This is approximated by multiplying the flow area to be lost by the appropriate average velocity. Similarly the area gained is multiplied by the appropriate average velocity. For example, in Figure 2, the average flow velocities are respectively 2, 6, and 3 feet per second (fps) for the left overbank, channel, and right overbank. Using the scale shown on Figure 2, the area lost in the left overbank is about 500 square feet. Multiplying by 2 fps gives a loss in discharge of 1,000 cubic feet per second. By adjusting the right floodway limit, a similar loss can be obtained in the right overbank area. The sum of these two losses must equal the increased capacity in the floodway due to the higher water surface elevation. Computations for the balanced condition are shown on Figure 2.

After the floodway limits for each cross section have been

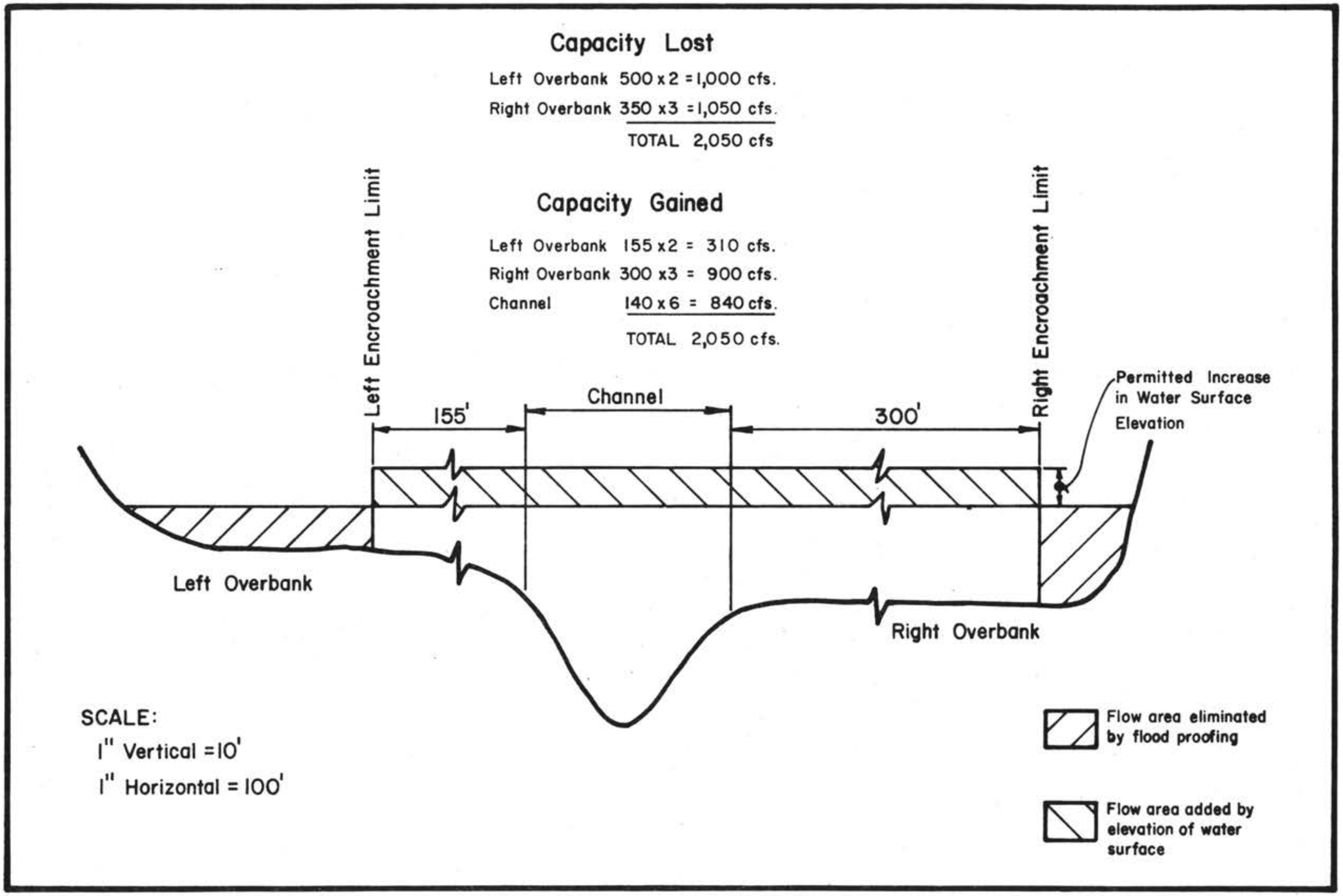

Figure 2. Floodway Determination

determined, backwater computations are made limiting flow to the floodway area. If the permitted increase in water surface elevation is not reached, adjustments should be made in the floodway limits to obtain the permitted increase.

As experience is gained, these calculations will take less time. For example, when making the first approximation of the floodway limits, the use of the average flow velocity will give too high a loss in the fringe area since this is usually a hydraulically inefficient area. Likewise the flow capacity gained in the floodway will be greater than that computed using average velocities since this area is hydraulically more efficient. Experience will help in making adjustments in these values.

Regardless of how efficient one gets at determining the floodway limits by trial and error, the process would be very costly for projects with a large number of cross sections. The 'Flood Insurance Study' for Stillwater, Oklahoma, prepared by the Tulsa District, Corps of Engineers, contained floodway limits for 87 cross sections. The project was helped significantly by the use of the floodway determinations capabilities of the computer program HEC-2 (Hydrologic Engineering Center, 1973). The program, written by the Hydrologic Engineering Center, U. S. Army, Corps of Engineers, is primarily a backwater program with a floodway determination option. The use of the program greatly speeds the determination of the floodway limits.

HEC-2 contains five methods for establishing the floodway limits. In method 1, the stations and elevations of the left and right encroachment are set by the user. This option is used to determine the change in water surface elevation caused by fitting the floodway to some physical constraint and for checking the adequacy of 'smoothed' floodway limits. This use will be discussed later.

Method 2 centers a floodway of specified width about the center-line of the channel. This method has little use in floodway determinations for flood plain management purposes.

In method 3, encroachments can be specified by percentages which indicate the desired proportional reduction in the natural discharge carrying capacity of each cross section. For example, if it were desired to reduce the discharge capacity by 10 per cent, encroachment limits would be established by the program which reduce the capacity of the overbanks 5 per cent each. If the full 5 per cent could not be obtained on one side, the other side would be reduced enough to meet the 10 per cent criteria.

The most useful method for determining encroachment limits from the standpoint of flood plain management is method 4. It is very similar to the trial and error method described first. In this method the user reads in the permitted increase in the water surface elevation. The encroachment limits are then determined so that an equal loss of conveyance occurs on each side of the channel and the water surface within the floodway is within the specified limits. If half of the loss cannot be obtained on one overbank, the differences will be made up, if possible, by the other overbank, except that encroachments will not be allowed to fall within the main channel. This option first computes and stores the natural water surface profile for use in determining the encroachment limits. When the floodway determination is completed, the program prints out a summary table containing, for each cross section, the natural water surface elevation, the modified water surface elevation, their difference, the stations of the encroachment limits, and the floodway width. A sample of the summary printout is shown in the Appendix. This data is very useful in analyzing the adequacy of the calculated limits.

Method 5 establishes encroachment stations based on the overflow limits of a previously computed base flood. For example, the effects of confining the 100 year flood to the area covered by the 50-year flood could be studied. This method is not generally used in flood plain management work.

The most efficient way of computing the floodway limits is by use of method 4. However the results, when plotted on a map, can be very uneven. The limits pull in when the channel efficiency goes up and moves back out when the channel is restricted. Sometimes the plotted limits resemble the bellows of an accordian. Although these limits represent an efficient floodway, they make regulatory description and field deliniation very difficult.

To minimize these difficulties, the floodway limits should be smoothed. Reviewing the summary printout of the floodway topwidths will show reaches of similar widths. Using an average width for each of the subreaches of the stream, new trial limits for the floodway may be tested using method 1. If the new smoothed limits meet the limitations on the increase in water surface elevation of the selected flood, then the floodway determination is complete. If not, the width should be adjusted to meet the requirements. In short, method 4 is used to obtain a first approximation of the floodway width, then method 1 is used to produce a smooth floodway.

Another technical problem associated with the floodway determination is the reaction of the backwater program at constrictions such as road crossings. Sometimes small changes in the water surface elevation downstream from a bridge will cause large changes in the required floodway width upstream. Occasionally the program will compute a required width greater than the original flood limits. Where the flood plain is severly constricted, method 4 should be used only as an approximation. Method 1 should be used, trying several approach widths. Sometimes it is necessary to resort to hand computations in these trouble areas.

CHAPTER IV

LEGAL QUESTIONS ABOUT THE FLOODWAY

Individual freedom is one of the fundamental principles which is most cherished by American citizens. Among other things, this includes the right to use one's property as one sees fit. And from this position comes the biggest legal barrier to enactment of a floodway zoning ordinance or any other land use regulations. In connection with the regulatory floodway, the requirement that any development which would impeed flood flows be prohibited, imposes a severe restriction on the development potential of the property. Legal challenges are almost certain.

However the courts have looked favorably upon regulation of the floodplain when certain requirements were met (Kusler & Lee, 1962). Among them are that the regulations comply with state enabling legislation, treat similarly situated individuals equally, are based upon sound data, balance threats of flood damage and land-use needs, and permit some private economic land uses.

It has been held that regulations which prevent public nuisances such as encroachment in floodway areas which may result in damages to neighboring properties are valid. Also local governments have a right to protect public health and safety where unwise flood plain development may disrupt public water supply or waste disposal. The prevention of fraud is also supported. This may take the form of requiring that potential buyers be informed of the flood threat associated with property by the seller or real estate agent.

To withstand constitutional challenges, regulations must generally allow private economic uses of lands. For the engineer or planner who is laying out the limits of the regulatory floodway, it may mean that adjustments will have to be made where a land owners entire property lies within the floodway. If the requirements of the floodway cannot be met, the city may be required to exercise its power of eminent domain.

It will be recalled from Chapter III that the recommended procedure for determining the floodway was to permit equal conveyance loss from both the left and right overbank areas. Depending on the relative hydraulic efficiencies of the overbank areas, this may not produce the smallest and therefore most efficient floodway. However, it should be close; but more important it tends to treat similarly situated individuals equally.

CHAPTER V

SUMMARY AND CONCLUSIONS

The location of homes and business in flood prone areas has proven a costly mistake. In most areas of the country, the portion of land necessary for the conveyance of flood waters amounts to only 10 to 15 per cent of the watershed. Despite this, the Federal government has found it necessary to encourage flood plain management through one of its most potent weapons, the threat of withholding Federal funds for local projects.

One of the required tools of flood plain management is the regulatory floodway. By prohibiting development only in that portion of the flood plain essential for the conveyance of the selected flood, a minimum of building restriction is necessary. By minimizing building limitations, opposition to the flood plain zoning is reduced and a more successful flood plain management program is possible.

Determining the limits of the regulatory floodway has been greatly simplified by computer programs written especially for this purpose. The ease with which local agencies can enforce the floodway restrictions will depend to a large extent on how well the local citizens understand the need for such regulation and the extent to which development is prohibited.

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Kusler, J. A., Lee, T. M., "Regulations for Flood Plains," Report No. 277, American Society of Planning Officials, Part IV, 1962.

National Flood Insurance Act of 1968 (42U.S.C. 4001-4127, 82 Stat. 572).

APPENDIX

SUMMARY PRINTOUT - WEST BOOMER CREEK FLOODWAY

Explanation of Printout

Section Number - Identifying number assigned to the cross-section.

Channel Length - Distance from preceeding cross-section measured in feet along the channel.

Min El of Roadway and Max El of Low Chord - Bridge data.

Discharge - Flow rate in cubic feet per second.

CWSEL - Computed water surface elevation. The upper number is for existing conditions and the lower number is with flow confined to the computed floodway.

TQ - Discharge with an energy gradient of 0.0001.

EG - Elevation of the energy line (CWSEL plus velocity head).

TOPWID - The upper number is the width of flooding under existing conditions. The lower number is the width of the computed floodway.

STENCL and STENCR - Station of the computed left and right encroachment limits.

WSELK - Known water surface elevation. This is the CWSEL for existing conditions.

After this data has been printed for the length of channel under study, the data is then regrouped for more convenient use in analyzing the adequacy of the computed floodway. For example, on page 21, CWSEL-WSELK is the change in the computed water surface elevation caused by confining the flow to the floodway. T.W. DIFF is the total width of the floodway fringe.

SUMMARY PRINTOUT FOR MULTIPLE PROFILES

100 YEAR FLOOD WEST BOOM

SECTION NUMBER	CHANNEL LENGTH	MIN EL OF ROADWAY	MAX EL OF LOW CHORD	MIN EL GROUND	DISCHARGE (CFS)	CWSEL	TQ	EG	TOPWID	STENCL	STENCR	WSELK
18542.00	-0.00	0.00	0.00	850.00	6600.00	868.44	3579.23	868.64	152.20	0.00	0.00	868.44
18542.00	-0.00	0.00	0.00	850.00	6600.00	869.07	3855.18	869.25	144.00	554.00	698.00	868.44
18413.00	100.00	870.00	864.00	852.00	2600.00	868.03	248.59	868.84	32.00	0.00	0.00	0.00
18413.00	100.00	870.00	864.00	852.00	2600.00	868.64	247.17	869.45	32.00	0.00	0.00	868.03
18285.00	90.00	0.00	0.00	855.00	2600.00	868.78	1130.95	869.03	288.00	0.00	0.00	0.00
18285.00	90.00	0.00	0.00	855.00	2600.00	869.38	1171.51	869.63	55.00	645.00	700.00	868.78
18275.00	10.00	0.00	0.00	855.00	2600.00	868.88	1237.16	869.04	321.35	0.00	0.00	0.00
18275.00	10.00	0.00	0.00	855.00	2600.00	869.50	1363.52	869.65	92.39	645.00	739.00	868.88
18150.00	100.00	0.00	0.00	855.00	2600.00	868.89	1106.62	869.11	300.48	0.00	0.00	0.00
18150.00	100.00	0.00	0.00	855.00	2600.00	869.51	1209.76	869.70	69.38	645.00	715.00	868.89
18000.00	125.00	0.00	0.00	858.00	2600.00	867.68	230.13	869.90	38.62	0.00	0.00	0.00
18000.00	125.00	0.00	0.00	858.00	2600.00	868.68	298.28	870.27	40.00	660.00	700.00	867.68
17100.00	360.00	0.00	0.00	860.00	2600.00	870.95	615.74	871.43	308.83	0.00	0.00	0.00
17100.00	360.00	0.00	0.00	860.00	2600.00	871.02	550.41	871.71	50.00	600.00	650.00	870.95
16650.00	500.00	0.00	0.00	864.30	2600.00	872.46	438.58	872.63	613.38	0.00	0.00	0.00
16650.00	500.00	0.00	0.00	864.30	2600.00	872.98	343.21	873.39	270.80	956.20	1227.00	872.46
16608.00	24.00	870.40	867.90	859.30	2600.00	872.64	691.63	872.69	652.44	0.00	0.00	0.00
16608.00	24.00	870.40	867.90	859.30	2600.00	873.42	638.43	873.49	281.57	233.43	515.00	872.64
16567.00	26.00	0.00	0.00	864.00	2600.00	872.42	314.15	873.43	338.82	0.00	0.00	0.00
16567.00	26.00	0.00	0.00	864.00	2600.00	873.24	492.54	873.64	339.00	212.00	551.00	0.00
16557.00	75.00	0.00	0.00	864.30	2600.00	873.56	812.86	873.68	552.03	0.00	0.00	0.00
16557.00	75.00	0.00	0.00	864.30	2600.00	873.61	678.29	873.81	277.38	281.15	558.53	873.56
16240.00	460.00	872.10	870.00	862.00	2600.00	874.07	824.09	874.10	689.58	0.00	0.00	0.00
16240.00	460.00	872.10	870.00	862.00	2600.00	874.41	626.52	874.48	416.44	172.46	588.90	874.07
16200.00	30.00	0.00	0.00	864.80	2600.00	874.05	959.72	874.14	544.71	0.00	0.00	0.00
16200.00	30.00	0.00	0.00	864.80	2600.00	874.39	844.51	874.54	244.65	251.17	495.82	874.05
15683.00	520.00	0.00	0.00	865.00	2600.00	874.46	770.13	874.60	468.54	0.00	0.00	0.00
15683.00	520.00	0.00	0.00	865.00	2600.00	874.91	680.89	875.15	200.16	117.64	317.80	874.46
15397.00	300.00	0.00	0.00	865.00	2600.00	874.79	894.82	874.89	468.03	0.00	0.00	0.00
15397.00	300.00	0.00	0.00	865.00	2600.00	875.37	864.99	875.50	259.01	121.77	380.78	874.79
15347.00	50.00	876.00	874.50	864.70	2600.00	874.78	426.95	875.00	112.28	0.00	0.00	0.00
15347.00	50.00	876.00	874.50	864.70	2600.00	875.39	426.07	875.61	112.51	198.42	720.00	874.78
15297.00	50.00	0.00	0.00	865.60	2600.00	875.00	849.67	875.10	466.16	0.00	0.00	0.00
15297.00	50.00	0.00	0.00	865.60	2600.00	875.57	819.95	875.71	255.88	123.07	378.95	875.00
15055.00	275.00	0.00	0.00	865.70	2600.00	875.27	1055.84	875.32	580.74	0.00	0.00	0.00
15055.00	275.00	0.00	0.00	865.70	2600.00	875.87	984.66	875.96	266.75	180.02	446.77	875.27

SECTION NUMBER	CHANNEL LENGTH	MIN EL OF ROADWAY	MAX EL OF LOW CHORD	MIN EL GROUND	DISCHARGE (CFS)	CWSEL	TQ	EG	TOPWID	STENCL	STENCR	WSELK
48.00	430.00	0.00	0.00	886.00	970.00	902.13	174.74	902.59	79.85	0.00	0.00	0.00
48.00	430.00	0.00	0.00	886.00	970.00	902.81	188.03	903.27	19.00	217.00	236.00	902.13
49.00	100.00	902.70	901.60	896.00	970.00	901.60	61.99	904.19	16.00	0.00	0.00	0.00
49.00	100.00	902.70	901.60	896.00	970.00	902.02	42.79	904.62	20.41	0.00	0.00	901.60
50.00	90.00	0.00	0.00	896.00	970.00	904.64	187.36	904.96	169.55	0.00	0.00	0.00
50.00	90.00	0.00	0.00	896.00	970.00	905.08	236.06	905.29	169.06	200.00	370.00	0.00
51.00	65.00	903.70	901.70	897.70	560.00	904.98	64.59	905.11	179.11	0.00	0.00	0.00
51.00	65.00	903.70	901.70	897.70	560.00	905.06	43.49	905.45	67.57	229.24	296.81	904.98
52.00	40.00	0.00	0.00	897.00	560.00	905.12	401.74	905.15	199.16	0.00	0.00	0.00
52.00	40.00	0.00	0.00	897.00	560.00	905.47	342.67	905.52	74.97	277.03	352.00	905.12
53.00	390.00	0.00	0.00	898.00	560.00	905.19	133.71	905.33	98.08	0.00	0.00	0.00
53.00	390.00	0.00	0.00	898.00	560.00	905.53	110.99	905.81	43.58	311.00	354.58	905.19
54.00	350.00	0.00	0.00	899.00	560.00	905.55	280.01	905.58	185.17	0.00	0.00	0.00
54.00	350.00	0.00	0.00	899.00	560.00	906.08	262.91	906.13	62.27	254.00	316.27	905.55
55.00	210.00	0.00	0.00	902.00	560.00	905.94	46.17	906.30	179.18	0.00	0.00	0.00
55.00	210.00	0.00	0.00	902.00	560.00	906.77	47.21	907.52	58.24	261.00	319.24	905.94
56.00	225.00	0.00	0.00	903.00	560.00	907.59	88.07	907.88	101.54	0.00	0.00	0.00
56.00	225.00	0.00	0.00	903.00	560.00	908.49	96.58	908.91	27.45	245.00	272.45	907.59
57.00	330.00	0.00	0.00	904.50	560.00	908.85	88.53	909.23	94.74	0.00	0.00	0.00
57.00	330.00	0.00	0.00	904.50	560.00	909.55	94.21	910.08	22.00	246.00	268.00	908.85
58.00	40.00	912.80	911.80	905.80	420.00	909.58	23.45	911.50	10.00	0.00	0.00	0.00
58.00	40.00	912.80	911.80	905.80	420.00	909.58	23.45	911.50	10.00	295.00	305.00	909.58

SECTION NUMBER	DISCHARGE CFS	CWSEL	CWSEL DIFF EACH Q	CWSEL DIFF EACH SECTION	CWSEL-WSELK	TOPWID	T.W. DIFF	LENGTH
18542.000	6600.001	868.440	0.000	0.000	0.000	152.203	0.000	-0.000
18542.000	6600.001	869.066	.626	0.000	0.000	144.001	8.202	-0.000
18413.000	2600.000	868.033	0.000	-.407	0.000	32.000	0.000	100.000
18413.000	2600.000	868.644	.611	-.422	.611	32.000	0.000	100.000
18285.000	2600.000	868.785	0.000	.752	0.000	288.003	0.000	90.000
18285.000	2600.000	869.376	.592	.733	.592	55.001	233.002	90.000
18275.000	2600.000	868.880	0.000	.095	0.000	321.346	0.000	10.000
18275.000	2600.000	869.505	.625	.128	.625	92.390	228.956	10.000
18150.000	2600.000	868.887	0.000	.008	0.000	300.476	0.000	100.000
18150.000	2600.000	869.506	.619	.002	.619	69.383	231.093	100.000
18000.000	2600.000	867.677	0.000	-1.211	0.000	38.616	0.000	125.000
18000.000	2600.000	868.685	1.008	-.821	1.008	40.001	-1.385	125.000
17100.000	2600.000	870.948	0.000	3.272	0.000	308.829	0.000	360.000
17100.000	2600.000	871.023	.074	2.338	.074	50.001	258.828	360.000
16650.000	2600.000	872.461	0.000	1.512	0.000	613.376	0.000	500.000
16650.000	2600.000	872.975	.514	1.952	.514	270.801	342.575	500.000

VITA

Gary L. Cook

Candidate for the Degree of

Master of Science

Report: THE REGULATORY FLOODWAY

Major Field: Civil Engineering

Biographical:

Personal Data: Born July 17, 1939, in Anadarko, Oklahoma, the son of Dr. and Mrs. Odis A. Cook.

Education: Graduated from Northwest Classen High School, Oklahoma City, Oklahoma, in May, 1957; received the Degree of Bachelor of Science in Civil Engineering from the Oklahoma University, Norman, Oklahoma, in June, 1968.

Professional Experience: Hydraulic Engineer, Tulsa District, Corps of Engineers, 1968 - 1972; Civil Engineer, Office of Flood Plain Management Services, Tulsa District, Corps of Engineers, 1972 - 1974.

Membership in Professional Societies: American Society of Civil Engineers, Tau Beta Pi.