SUPPLEMENT TO
REVIEW REPORT ON FLOOD CONTROL
AND OTHER IMPROVEMENTS ON
SKAGIT RIVER, WASHINGTON

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1. PURPOSE. - This supplement to the Skagit River Review of Reports of March 1965, on Flood Control and Other Improvements, presents information on project formulation, for proposed levee and channel improvements as related to basin planning, consideration of alternatives and to maximizing of net benefits.

2. SCOPE. - The proposed levee and channel improvements in the main report are considered as elements of a Skagit River basin plan for flood control that could include the authorized, but not constructed, Avon Bypass Projects, and upstream storage. The data already developed for the survey report and for separate studies of the Avon Bypass Project were utilized in this supplement. The presentation follows this sequence of development:

a. planning objectives;

b. the basin plan for flood control;

c. evaluation of alternatives;

d. optimization of design for Avon Bypass;

e. optimization design for levee and channel improvements and the Avon Bypass.

3. PLANNING OBJECTIVES. - A public hearing was held 8 February 1961 in Mount Vernon, Washington, to obtain expressions of needs for water resource development from representatives of Federal, State and local governments and from residents of the area. The overwhelming sentiment at the hearing was for improved flood control measures in the basin, particularly in the delta, as a first priority endeavor.

Ensuing studies confirmed that improved flood protection in the 68,000-acre flood plain delta downstream from Sedro Woolley is the highest priority water resource requirement in the basin. Flood control measures are needed to prevent large flood losses in farm and urban areas that are now partially protected by levees and that have developed markedly since the last major floods in 1951, in 1921, and in the preceding decades. The average annual flood damage estimate of $2,216,000 in the Skagit flood plain downstream from Sedro Woolley, under 1963 conditions, attests to the economic importance of improved flood control measures. Other river basin needs under study for long-range development are additional water supply for municipal and industrial purposes; low-flow augmentation for fisheries; hydroelectric power; recreation; and irrigation.

4. EXISTING LEVEL OF FLOOD PROTECTION IN THE BASIN. - The entire Skagit River system downstream from the Burlington-Mount Vernon area, including both the North and South Fork distributaries at the mouth, has been leveed piecemeal over a long period of time. There are about 43 miles of levees along the river banks that vary greatly in top widths and height. These levees, with minor sandbagging of the extreme low areas, are only capable of withstanding flows of 91,000 to 143,000 c.f.s., corresponding to floods with probable recurrences ranging from once in 3 years to once in 14 years. Flooding of low areas begins when flows at Mount Vernon exceed 84,000 c.f.s.

5. BASIN PLAN FOR FLOOD CONTROL. - The basin planning for new projects is directed toward developing first priority flood control and related measures that can be constructed with sound economic feasibility under present-day conditions, and assuring that these projects will retain their feasibility when considered with possible future projects. The first priority projects are the authorized Avon Bypass and proposed levee and channel improvements downstream from the Bypass. Addition of recreation to the Bypass as an added purpose, becomes possible with construction of these first priority projects. Future water resource planning will consider upstream storage to provide increased flood protection for the delta and for the area upstream from Sedro Woolley, together with water supply, low-flow augmentation, irrigation, recreation, and related purposes.

6. INITIAL FLOOD CONTROL IMPROVEMENTS.

a. Proposed Levee and Channel Improvements. The Skagit River channel capacity would be increased from the Burlington-Mount Vernon area downstream to the mouth of both Forks, by raising low points and by strengthening the existing levees and by widening the channel at selected locations to contain a design flow of 120,000 c.f.s. These improvements would raise the minimum level of flood protection from once in 3 years to once in 8 years. About 34 miles of the existing levee system would be improved, including 13 miles on the main river downstream from river mile 16.5, and 8 and 13 miles on the North and South Forks, respectively. Widening is proposed for three constricted reaches of the river channel, from river mile 3.8 to 4.7 and 7.0 to 8.1 on the North Fork, and from 3.7 to 4.5 on Freshwater Slough on the South Fork. Widening would remove serious obstructions to flood flows, lower channel velocities and reduce upstream river stages.

The design flow of 120,000 c.f.s. was found to be the maximum that could be developed without raising nearly all of the 43 miles of existing levee on both banks of the river. Further raising of levees was considered impracticable because the existing levee system rests on a foundation of silts and sands common to the delta area. Differential heads of water in flood flow periods result in seepage through levee embankment and levee foundations, causing boils and blowouts that flood adjacent croplands. The semipervious foundation conditions make any general raising of levees inadvisable because of the extensive and indeterminate nature of the seepage hazard.

Based on costs and benefits presented in the main report, the overall cost could be $6,007,000 and the corresponding benefit to cost ratio would be 3.1, in a plan which shares benefits with the Avon Bypass through coordinated operation. First added, the benefit-to-cost ratio would be 3.2. The foregoing benefit-to-cost ratios are based on a 50-year project life as used in the report.

b. Avon Bypass. - The Flood Control Act of 1936, authorized the Avon Bypass channel, a project for the partial control of floods in the Lower Skagit Valley, by diversion of a portion of Skagit River flows. The diversion channel was to be constructed between a location on the river just downstream from Burlington to Padilla Bay. The project was not undertaken at that time because local participation requirements could not be satisfied. The Chief of Engineers has authorized restudy of the Bypass Project because the prospect for fulfillment of local cooperation assurances are now much more favorable.

The present plan for the project has an 8-mile channel with intake from the Skagit River about one mile downstream from Burlington and proceeding westward through Gages Slough and along the southerly fringe of Bayview Ridge to Padilla Bay. The channel would be 360 feet wide at the bottom. Flow depths would be about 25 feet. The channel would have four control structures, including a gated concrete intake, two collapsible-type intermediate weirs to control groundwater levels, and an ungated concrete outlet structure to control channel velocities and to prevent saltwater intrusion into the channel. The project also includes improvement and extension of four miles of levee on the right bank of Skagit River, immediately above the Bypass intake. The purpose of the levees is to prevent overflow of floodwaters into Burlington and the low divide between the Skagit and Samish River valleys. The capacity of the Bypass was fixed at 60,000 c.f.s., considering the project first added to the existing levee system. The 60,000 c.f.s. design flow was established by maximizing net benefits, as discussed subsequently in paragraph 10. The flood protection afforded by the Bypass first added, would increase the minimum level of flood protection in the river basin downstream from Sedro Woolley from about 84,000 c.f.s. at the present time, to 144,000 c.f.s. The corresponding decrease in flood frequency would be from once in 3 years to once in 14 years. Cost of the Bypass would be $23,940,000 and the resulting benefit-to-cost ratio would be 2.9, considered first added, and 2.2 when considered in a plan which shares benefits with the levee and channel improvements through coordinated operation.

7. ULTIMATE FLOOD CONTROL. - The Skagit River delta flood plain area now is predominatly devoted to agriculture, but includes important urban centers such as Mount Vernon, Burlington and other smaller communities. In the past 30 years there has been an increasing trend toward conversion of agricultural lands to urban, commercial and light industrial usage. Present and forecasted future development, which is in keeping with the overall growth

pattern of the Puget Sound region, warrants at least 100-year flood protection in this area. Provision of upstream storage is the final element of a basin flood control plan. The purpose of upstream flood storage would be to supplement the Bypass and proposed levee and channel improvements in order to realize at least 100-year flood protection in the delta area. Upstream storage would also provide greater flood protection for the reach of river upstream from Sedro Woolley and would permit utilization of lands not now protected, as for example, the Nookachamps Creek basin across the Skagit River from Burlington.

Ross Dam, on the upper main stem of the Skagit River, reserves 120,000-acre-feet of storage for winter flood control. This storage controls the Skagit River watershed upstream from Ross Dam. Operation of this storage has been assumed in all plans studied. There are only a few remaining potential sites for upstream storage development in the Skagit River basin. A private power company has developed potential sites on the Baker River for hydroelectric power. The Cascade site, located on the Cascade River about eight miles from its confluence with the Skagit River, and the Copper Creek site, on the main stem of the Skagit River at about Mile 87, are being considered for development by the city of Seattle for run-of-river power projects. Only minor flood control storage could be provided at these sites. Storage at the Faber site, located about eight miles above Concrete, has been investigated in previous studies. Dam site foundation and abutment conditions at this site are not favorable. A structure at this site also would be a major barrier to the passage of migratory fish. Storage has been considered on the Lower Sauk River as an alternative to the Faber site. The Lower Sauk River now appears to be the only location in the Skagit River basin at which major upstream storage is possible.

A favorable site has been found on the Sauk River six miles upstream from its confluence with the Skagit River. A dam at this site could develop approximately 700,000 acre-feet of storage, of which 250,000 acre-feet of storage would be needed to increase from 35 to 100 years, the flood protection in the delta afforded by the Avon Bypass and downstream levee and channel improvements. A dam at the Sauk River site is limited to a maximum height of 200 feet. A dam height in excess of 200 feet would cause overflow into the Stillaguamish River basin. Multiple-purpose storage in the Sauk project could provide hydroelectric power, irrigation, recreation, and low-flow augmentation in addition to flood storage. Fish passage problems, although less than at the Faber site, would also occur at the Sauk site. Feasibility studies of a Sauk River dam will extend over the next two to three years.

8. SUMMARY OF PLANNING. - Flood control has the highest priority of the immediate water-control needs in the Skagit River basin. The present flood damage expectancy is once in 3 to once in 10 years, varying with individual diking districts. An intermediate level of flood protection, corresponding to protection from flooding of once in 35 years, can be achieved in the delta by constructing the authorized Avon Bypass in combination with the proposed levee and channel improvements downstream from the Bypass. These improvements are well justified when considered as first elements of a basin plan. They also retain their justification when considered as last added; or, in a plan for upstream storage, which would yield a much higher level of flood protection as well as other water resource benefits. Because of strong concern by fisheries interests about the effect of the Sauk River storage project on fish and because hydroelectric power from the project would not be marketable until 1975, construction of the Sauk project at this time can only be considered as a potential element of a future plan of water resource development. Thus, the Bypass and downstream levee and channel improvements are the only flood control proposals now attainable.

9. EVALUATION OF ALTERNATIVES. - Alternative plans of flood control in the delta have been considered. These plans are (a) channel deepening; (b) channel widening; (c) channel dredging at the mouth of the river; and (d) raising levees.

a. Channel Deepening. - Deepening the Skagit River to carry flood flows is not feasible. Substantial deepening of the river to carry flood flows would tend to undermine existing levees along the river banks and thereby require costly erosion protection measures. The Skagit River carries large quantities of bed sediment estimated at more than 500,000 cubic yards annually. A deepened channel would require maintenance dredging of a sediment basin above the improved reach of the river at an estimate of at least $200,000 annually. In addition major dredging of more than 20 miles of river channel would be necessary for increased channel capacity as well as set back of levees at the mouth of the river, channel excavation and maintenance to carry flood flows would have an extremely adverse effect on the salmon and steelhead trout fishery resource. Because the Skagit River is the most important river in the entire Puget Sound area for salmon and steelhead spawning and for sport fishery, any major dredging of the river would be totally unacceptable to fishery interests. For these reasons channel deepening was considered impracticable and cost estimates were not made for this plan.

b. Channel Widening. Flood protection by widening the Skagit River channel and setting back levees was also considered. To achieve the same results as the Bypass and the levee improvements, the channel would have to be widened from 300 to 600 feet from the downstream limits of Sedro Woolley to the mouth of the river, a distance of over 20 miles. This work would cost about

six to seven million dollars more than the cost of equivalent flood protection with the Bypass and downstream levee and channel improvements, and therefore is not economically feasible. One of the principal reasons for the high cost of this plan is that much of the land on both banks of the river is well developed, and widening would require costly relocations and acquisition of land.

c. Channel Dredging at the Mouth. - Dredging and widening of the river at its mouth, proposed as a flood control measure by some residents in the basin, would provide only very localized flood protection. Such widening would lower flood stages slightly for a short distance upstream from the mouth of the river, but would not provide flood protection for the upper delta in the vicinity of Mount Vernon and Burlington.

d. Levee Raising. - Major raising of the levee system was found uneconomical. The costs of providing flood protection by major raising of levees to accommodate a flow of 144,000 c.f.s. downstream from Sedro Woolley, would exceed $28,000,000. This compares to the estimated $23,940,000 cost of the Avon Bypass to provide essentially the same degree of protection. Major levee raising would result in backwater effects from confining flows between levees that would cause more than a 3-foot rise in water surface upstream from Sedro Woolley. The cost of levees to protect upstream areas from these backwater effects is not included in the above major levee raising cost. Because these studies showed the Avon Bypass to be a more economical and more effective plan than raising the levees, no further consideration was given to major raising of the levee system.

10. OPTIMIZATION OF DESIGN FOR AVON BYPASS. - As the Avon Bypass is an integral part of a long-range basin plan for flood control with permanent type concrete control structures, a 100-year economic life has been utilized in optimizing the design. The 100-year life also corresponds to the objective of 100-year or greater flood protection.

The Avon Bypass was first considered without the levee and channel improvements. In this plan, the Bypass would begin operation at 84,000 c.f.s. flow downstream from Sedro Woolley. Operation of the Bypass in this manner would retain freeboard in the existing levee system with a minimum of flood fighting. Based on this plan of operation, curves showing average annual costs and average annual benefits were plotted against a scale of varying Bypass channel capacities. As illustrated by the right-hand series of curves on the Exhibit at the end of this supplement, the maximum net benefit value is realized for a Bypass capacity of about 60,000 c.f.s., corresponding to a B/C ratio of 2.9. A channel

of this capacity would provide full flood protection from flows of 144,000 c.f.s. downstream from Sedro Woolley. Overall protection afforded by the Bypass in the delta area would range from 14-year protection along the lower North and South Forks to more than 35-year protection upstream.

11. OPTIMIZATION OF LEVEE AND CHANNEL IMPROVEMENTS AND THE AVON BYPASS. - Protection afforded by the Bypass downstream from Sedro Woolley, with 60,000 c.f.s. diversion capacity, first added, would range from 14-year protection along the lower North and South Forks, to more than 35-year protection upstream of the confluence of the Forks, as discussed in preceding paragraph. The proposed levee and channel improvements downstream of the Bypass would increase the channel capacity from 84,000 c.f.s. to 120,000 c.f.s. Further raising of levee was considered impracticable, as discussed in paragraph 6. This increased channel capacity, together with the Bypass, would increase flood protection to a minimum 35-year level downstream from Sedro Woolley. The 35-year level of flood protection provided by the Avon Bypass, with levee and channel improvements, would protect against 79 percent of average annual flood damages under present conditions. These flood damages are 75 percent agricultural and only 25 percent urban. Therefore, the project is now required essentially for the protection of agricultural lands, and the 35-year level of protection is well suited to present development. The Avon Bypass, when considered jointly with levee and channel improvement, would begin operation at about 100,000 c.f.s. Operation on this basis would permit the addition of a sport fishery and recreation to the Bypass channel. Curves of total average annual costs and average annual flood control benefits for the combined Bypass and levee and channel improvement projects were plotted against a scale of added channel capacity downstream of Sedro Woolley. The economic life of 100 years that was used in the analysis of levee costs included a factor for major levee rehabilitation. As illustrated by the curves on the left side of the Exhibit at the end of this supplement, the maximum net benefit value for the combined projects is realized from an added channel capacity of 96,000 c.f.s. corresponding to a Bypass capacity of 60,000 c.f.s., and a 36,000 c.f.s. increase in the main river minimum capacity from 84,000 to 120,000 c.f.s. The combined B/C ratio of the flood control features for the added channel capacity of 96,000 c.f.s. is 2.5.

12. CONCLUSIONS. - The project formulation presented herein pertains to projects that provide first priority flood control protection as elements of a basin flood control plan, and that can be constructed with sound economic feasibility under present-day conditions. Alternative solutions considered in project formulation have been presented. Identification has been made of the plans and projects which would maximize net tangible benefits. The Avon Bypass has maximum net benefits for a channel capacity of 60,000 c.f.s.

Levee and channel improvements plus the Avon Bypass realize maximum net benefits in an increase in the downstream channel capacity by 36,000 c.f.s. to a total channel capacity of 120,000 c.f.s., and by 60,000 c.f.s. channel capacity in the Bypass.