SUSITNA HYDROELECTRIC PROJECT

FEDERAL ENERGY REGULATORY COMMISSION
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INTERIM MITIGATION PLAN FOR CHUM SPAWNING HABITAT IN SIDE SLOUGHS OF THE MIDDLE SUSITNA RIVER

WOODWARD-CLYDE
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Report by
Woodward-Clyde Consultants

Under Contract to
Harza-Ebasco Susitna Joint Venture

Prepared for
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Final Report
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1-APPROACH TO MITIGATION

1 - APPROACH TO MITIGATION

The objective of fisheries mitigation planning for the Susitna Hydroelectric Project is to maintain existing habitat or provide replacement habitat of sufficient quality and quantity to maintain natural reproducing populations (Acres Am. 1983). This is consistent with the mitigation goals of the USFWS and the ADF&G (Alaska Power Authority 1982, ADF&G 1982a, USFWS 1981). In order to accomplish this objective, the Alaska Power Authority will avoid, minimize, or rectify impacts. Where it is not feasible to mitigate the impacts in this manner, the Power Authority will compensate for the impact with propagation facilities.

Mitigation measures proposed for the Susitna Hydroelectric Project may be classified within two broad categories:

- Modifications to design, construction, or operation of the project; and

- Resource management strategies.

The first type of mitigation measure is project specific and emphasizes the avoidance, minimization, rectification, or reduction of adverse impacts, according to priorities in the Fish and Wildlife Mitigation Policy established by the Power Authority (1982) and coordinating agencies (ADF&G 1982a, USFWS 1981). These measures are implemented first to minimize adverse impacts. They involve adjusting or adding project features during design and planning so that mitigation becomes a built-in component of project actions.

When impacts cannot be fully avoided, reduction or compensation measures are justified. This type of mitigation can involve management of the resource rather than adjustments to the project, and will require concurrence of resource management boards or agencies with jurisdiction over resources within the project area.

Mitigation planning for the Susitna Hydroelectric Project has emphasized both approaches. The sequence of options from avoidance through compensation has been applied to each impact issue. If full mitigation can be achieved at a high priority option, lower options may not be considered. In the resulting mitigation plans, measures to avoid, minimize, or rectify potential impacts are treated in greatest detail. Specifications for facility siting and design, special mitigation facilities, construction procedures, and scheduling of project actions to mitigate adverse effects on the biota are presented.

Monitoring and maintenance of mitigation features to reduce impacts over time are recognized as integral parts of the mitigation process. The monitoring program will be developed during detailed engineering design and construction planning and be applied to fishery resources and their habitat.

2-SCOPE

2 - SCOPE

This report refines the interim mitigation plan proposed in the License Application to mitigate impacts on chum salmon spawning habitat in the Talkeetna to Devil Canyon reach of the Susitna River (middle Susitna River). The mitigation plans presented for selected sloughs are applicable to other sloughs in the middle Susitna River, since the types of physical impacts are similar in all sloughs and side channels. The sloughs selected for detailed analysis in this report are the sloughs most heavily utilized by spawning salmon during the 1981-1984 study period. Impacts to chinook rearing habitat in the middle Susitna River are mitigated primarily through the proposed flow regime. The mitigation plans for other species/life stages and other regions affected by the project (e.g. impoundment) and the applicability of proposed mitigation plans to other phases of the project (e.g. Watana filling) are subjects of upcoming reports.

The mitigation plan examines two chum salmon spawning mitigation strategies: (1) structural modification to presently utilized side sloughs to maintain semi-natural spawning and (2) artificial propagation with stream-side egg boxes to compensate for losses. As stated in the License Application (Acres Am. 1983), full mitigation can be achieved with either strategy. Final decisions on the strategy to be implemented will be made through discussions with resource managers.

3-SUSITNA RIVER MITIGATION PLAN

3 - SUSITNA RIVER MITIGATION PLAN

It is expected that the distribution and abundance of fish species downstream of the proposed Susitna Hydroelectric Project will change as a result of project operation. The impact assessments presented in this report were developed for the maximum power flows, Case P1, and the proposed project flows, Case EVI (Figure 1); further discussion of the development of these flow regimes are provided in Harza-Ebasco (1984b). The impact assessments link predicted physical changes with habitat utilization to provide a qualitative statement of impacts likely to result from the Susitna Hydroelectric Project. Impact issues have been identified and ranked by procedures established by the Susitna Hydroelectric Project Fish and Wildlife Mitigation Policy (Acres Am. 1982).

3.1 - Impact Assessment

3.1.1 Spawning Habitat Utilization in Sloughs and Side Channels

The area of spawning habitat utilized within selected sloughs and side channels was estimated by integrating the actual areas spawned during the 1982, 1983 and 1984 spawning seasons as outlined by ADF&G (unpublished maps of spawning areas). The areas outlined by ADF&G indicate general areas of spawning, not the actual redds excavated by spawning fish. For example, a circumscribed area of 10,000 square feet may have had 50 spawning pairs of fish widely distributed, while a similar area elsewhere may have accommodated several hundred spawning fish over the course of the season. The 1981 data were not used because the high flows and poor visibility during the spawning season precluded definition of spawning ares. The areas spawned for all three years were classified as composite or total area. Composite areas were obtained by superimposing maps of spawned areas for each year and measuring the area spawned one or more times. Total area was the sum of the area spawned in each year. The ratio of the composite areas spawned to the total area used over the three years is presented in Tables 1 through 6 for Sloughs 8A, 9, 9A, 11 and 21 and Side Channel 21 (ADF&G 1984c). The ratio of the composite area to total area serves as an index of the amount of area repeatedly spawned during the three years. If the same area was used each of the three years the ratio would be .33. Greater values indicate less consistent use of spawning habitat. A value of 1.0 indicates use of the same area in only one of the three years.

The composite areas spawned can be considered representative of the potential spawning habitat within the sloughs and side channels evaluated if the following conditions are satisfied:

1) Sufficient numbers of fish annually escaped to the sloughs and side channels to occupy generalized areas of available spawning habitat.

2) Flows during the 1982, 1983, and 1984 spawning periods provided average access and passage conditions to spawning habitat that were representative of the conditions the long term flow record has provided.

3) The periods in which access and passage conditions were provided by the 1982-1984 flows coincided with the availability of spawning fish.

Further evaluation of the above conditions will be undertaken when the flow and escapement records for the 1984 season become available. The fortuitous occurrence of a high 1984 escapement and a period of high flow coincident with the historical beginning of the peak spawning period during the 1984 season should provide a valuable data base for evaluation of conditions that allowed access to and utilization of most of the potential slough and side channel spawning habitat in the middle Susitna River.

3.1.2 Project Related Physical Changes in Sloughs and Side Channels

Operation of the Susitna Hydroelectric Project will modify the annual flow and temperature regime of the Susitna River, thus causing physical changes in sloughs and side channels in the middle reach. In general, flows during project operation will be less than natural flows during June, July, August, and September and higher than natural flows in the remaining months as the reservoir is drawn down. Project flows will be relatively constant throughout the year as compared with the natural variability of flows. Susitna River discharges presented in this report are flows at the Gold Creek gage maintained by the USGS.

(a) Backwater

A backwater area forms at the mouth of a slough or side channel if the stage in the mainstem is greater than the stage of the flow in the slough or side channel at its mouth. If the mainstem stage rises with no change in flow in the slough or side channel, the level of the backwater increases and the aerial extent of backwater influence moves upstream in the slough or side channel. If the mainstem stage drops, then the backwater level also drops and its length is shortened. The drop in mainstem stage can be sufficient to eliminate the backwater completely; the stage and corresponding mainstem discharge at which this occurs varies from site to site. The stage of the backwater may be defined by the mainstem discharge that forms the backwater. Project operation will generally cause decreased backwater area and stage during June through September.

(b) Breaching

A slough or side channel breaches when the flow overtops the upstream end, or head, of the channel. Breaching is directly related to mainstem discharges; as the discharge increases, the stage increases and when stage exceeds the elevation of the top of the berm at the head of the slough or side channel, flow is diverted through the channel. Further increase in stage will cause additional flow to pass through the slough or side channel. Project operation will generally cause a significant decrease in the amount of time that a slough or side channel breaches.

(c) Groundwater Upwelling

Groundwater flows out of (upwells from) the bed of a slough or side channel when the elevation of the bed is less than that of the local groundwater level. Studies have been conducted to relate the flow and temperature of the mainstem to upwelling quantity and temperature in sloughs and side channels (Alaska Power Authority (APA) 1984). Although a complete evaluation of the sources of groundwater was not conducted, the apparent groundwater upwelling component of slough flow was isolated from the surface inflow component and related to mainstem discharge at Sloughs 8A, 9, and 11. At these three sites, variations in the inferred upwelling components ranged from 0.0001 to 0.00035 of corresponding variations in mainstem discharge measured at Gold Creek (APA 1984). Relationships were developed in the form of regression equations for inferred upwelling component as a function of mainstem flows; these were used in making a preliminary analysis of project related changes in the groundwater upwelling component of slough discharge as described in Appendix A.

The temperature of the groundwater upwelling appears to remain relatively constant at a value approximately equal to the mean annual river temperature (APA 1984). A mean annual temperature increase resulting from project operation will probably be reflected as a slight increase in the temperature of groundwater upwelling flow (APA 1984).

Project operation during winter would affect upwelling in the sloughs. The higher project flows in conjunction with increased water temperatures will change the ice processes in the middle Susitna River. As the mainstem forms an ice cover, the stage increases because of backwater effects from frazil ice particles and pans jamming in constricted areas or building up on downstream jams. Thus river stage with an ice cover at low flow may approximate the stage of a much larger flow in the open channel conditions of summer flows.

Under project operation, the upstream edge of the ice cover will vary from RM 125 to RM 142 depending on meteorological conditions and the elevation (and thus temperature) at which water is withdrawn from the reservoir (Harza-Ebasco 1984a). Upstream of an ice cover, the stage in the river would decrease relative to natural stage experienced under an ice cover. According to preliminary upwelling studies, this will result in decreased groundwater upwelling in sloughs and side channels throughout the winter.

(d) Flow Depth

During the open water season, the depth at any location in a slough or side channel is a function of the cumulative effect of backwater, breaching, and local flow in the channel. Local flow is generated by surface inflow (surface runoff and tributary inflow) and groundwater upwelling.

The influence of mainstem discharge on backwater, breaching, and groundwater upwelling was introduced in the previous sections. Variations in surface inflow are not dependent on the mainstem discharge directly, even though there is some correlation through their mutual dependence on precipitation. Thus, a consideration of project effects on flow depth must address changes in backwater, breaching, and groundwater upwelling, and add unchanged surface inflow to these parameters.

Decrease in slough or side channel depth resulting from project operation is dependent on the location within the slough or side channel. Relative changes in depth generally decrease in the downstream direction for a given channel configuration and will also be greater for riffle configurations than for pool configurations. For example, if a pool is 3 feet deep and the adjacent riffle is 0.5 feet deep, then a 0.25-foot reduction in both will have a much greater effect in the riffle than the pool. Thus, the depth of flow in riffle reaches are more significantly influenced by project operation than those of pools. Flow depths in the upstream riffle reaches of a channel are more affected than reaches near the mouth since surface inflow and groundwater upwelling generally accumulate through the site.

Another way to define the relative impacts of project operation on flow depth is to identify how often a certain depth occurs under natural and project conditions. For example, a riffle reach located near the mouth of a slough may reach or exceed a specified depth 80 percent of the time due to backwater only, 20 percent of the time due to breaching only, 10 percent of the time if only groundwater upwelling is available, and 40 percent of the time if an average groundwater were supplemented by surface inflow. Since backwater, breaching, and groundwater upwelling are functions of mainstem discharge, the frequency of a certain depth being equalled or exceeded can be obtained from the flow duration curve for the period of interest. An approximation of the frequency of surface flow can be obtained from a precipitation duration curve, which is related to the surface flow through a runoff coefficient. If it is assumed to be conservative, that the backwater, breaching, and precipitation events are coincident, then in the example above, the frequency that the specified depth is equalled or exceeded is 80 percent, corresponding with the frequency due to backwater. The evaluations of project effects can address the frequencies corresponding to project operation, which may be 0 percent of the time due to backwater only, 0 percent of the time due to breaching only, 5 percent of the time due to groundwater only and 35 percent of the time if average groundwater were supplemented by the unaffected surface inflow. Thus, the effects of the project for this example riffle reach is to reduce the percent of time that a specified depth is equalled or exceeded from 80 percent to 35 percent. This relative change is fairly typical of the change that may occur to a riffle near the mouth of a slough or side channel, while a change from 10 percent to 8 percent may be more typical of a riffle reach located farther upstream in the site. Analyses in Appendix A provide results indicating project influence on selected riffle reaches in selected sloughs and side channels of the middle Susitna River.

(e) Winter Overtopping

The stage increase during ice cover formation (winter staging) was described briefly in a previous section in relation to the reduced upwelling at locations upstream from the ice front. With project flows higher than natural flows during winter, the staging effect will be higher during project operation downstream from the ice front. Thus, the probability of breaching caused by ice staging at and downstream from the ice front is also greater. Under natural conditions, the staging effects occasionally cause slough and side channel overtopping. An ice cover prediction model utilizing weather data for the 82-83 winter predicted that the stage would be sufficient to overtop the berm at the head of Slough 8A continuously from December to April (Harza-Ebasco 1984a); however, Slough 8A was overtopped by slush ice for five days in December (ADF&G 1983b). When an ice cover forms, shore ice develops causing flow channelization (R&M Consultants, Inc. 1983). The shore ice may act as a barrier to contain the flow and prevent the mainstem from overtopping the slough berms (Figure 2). However, under higher mainstem discharges, the probability of overtopping will increase. Figures 3 through 7 may be used to predict possible overtopping events under natural and project winter flow regimes at Sloughs 8A, 9, 9A, 11 and 21 but do not identify the probability or duration of actual events which are dependent on other factors besides mainstem stage. (See R&M 1984 - for frequency information).

3.1.3 Relationship Between Physical Changes and Available Habitat in Sloughs and Side Channels

Project flows reduce the amount of spawning and incubation habitat available to chum salmon in sloughs. Reduction in the quality and quantity of these habitats would result from the following physical changes:

- Reduced backwater effects
- Elimination of breaching flows
- Reduced groundwaterupwelling
- Reduced Flow depth
- Increased winter flows

(a) Reduced Backwater Effects

Backwater effects in the area of the slough mouth under natural conditions provide greater depths in the affected zone than would be provided by local slough flow. Project flows will substantially reduce the backwater zone resulting in a decrease in the surface area with suitable spawning depths and a loss of spawning habitat. The degree of loss is dependent on the relative spatial distribution of available spawning habitat under natural and project conditions.

(b) Elimination of Breaching Flows

Breaching flows provide access to spawning habitat within the slough and side channels by increasing the amount of area with suitable spawning depths over the amount present under unbreached conditions. Project flows will eliminate breaching flows and thus decrease the potential spawning habitat. The amount of habitat lost is dependent on the site specific frequency of breaching flows under natural conditions. Spawning habitat provided by sites with relatively high breaching discharges (low frequency of occurrence) at breached conditions is generally of insufficient duration for fish to effectively utilize. The additional spawning habitat provided by channels with relatively low breaching discharges (high frequency of occurrence) under breached conditions is generally utilized such that unbreached conditions under project flows will result in a loss of spawning habitat.

(c) Reduced Upwelling

Reduced mainstem flows during the spawning season would also decrease the amount of upwelling in the slough that is utilized by spawning chum salmon. The reduction in the rate and aerial extent of upwelling reduces the available spawning habitat. Winter flows, although higher than natural, would result in reduced upwelling in sloughs upstream of the ice cover because the staging effects during ice formation will no longer occur. A decrease in the areal extent and rate of upwelling in winter may decrease the quality of incubation habitat.

(d) Reduced Flow Depth

Access into and passage within the sloughs by returning adult salmon is dependent on backwater effects of the mainstem, the flow in the slough and the channel geometry. Project mainstem discharges during the August-September spawning season will reduce backwater effects and the groundwater and breaching contribution to slough flow, thus resulting in restricted passage of adult fish into the sloughs.

A reduction in fish entry into sloughs through passage reaches will result in the loss of spawning habitat available to the fish. Data collection and analysis are currently underway for low mainstem discharges to allow more detailed incremental quantification of the total impact.

(e) Increased Winter Flows

Project winter flows would be higher than flows under natural conditions. Thus, the probability of breaching caused by ice staging at, and downstream from, the ice front is also greater. Under natural conditions, the staging effects occasionally cause slough overtopping.

For those sloughs which are overtopped, the influx of near freezing water and subsequent ice formation will result in embryo mortality (ADF&G 1983b).

3.2 - Mitigation Options

3.2.1 - Flow Release

For the middle section of the Susitna River, altered flows would affect the fish population. Under natural conditions, mainstem discharges are high in late May, June, July, August, and early September and decrease during September and October to low flows throughout the winter (Figure 1). Hydroelectric power is desired primarily during winter and water is retained during summer to fill the reservoir. Flows under project operation would be much more uniform throughout the year and thus would necessarily be higher in the winter and lower in the summer than natural flows.

(a) Impact Issue

The hydroelectric development on the Susitna River is proposed for power production. To maximize power, benefits the discharge downstream of the dams would follow Case P1, presented in Table 7 (Harza-Ebasco 1984b). This schedule of flows varies greatly from the natural mean monthly flows recorded at Gold Creek (Figure 1).

The comparatively low flows during the August and September would restrict movement of adult salmon into and within sloughs. At a mainstem discharge of 6,000 cfs under Case P1, backwater effects at the slough mouths would be negligible, breaching of the sloughs would rarely occur, and local flow will be less due to reduced upwelling component. Project flows would also reduce the spawning habitat available due to reduced backwater, breaching, and groundwater upwelling effects. Project flow during winter can cause reduced upwelling upstream of the ice front and increased potential for overtopping downstream of the ice front.

(b) Mitigation

A mitigation flow schedule, designated Case EVI is proposed (Tables 7 and 8) to reduce the adverse impacts of Case P1. The Case EVI flows are selected primarily to reduce loss of chinook rearing habitat.

Under Case EVI, minimum flows during the critical period of chum salmon migration and spawning in August and September will be increased above the Case P1 projected flows of 6,000 cfs to 9,000 cfs.

For Sloughs 9 and 11, a mainstem discharge increase from 6,000 cfs to 9,000 cfs is predicted to increase slough flow by 1 cfs, based on currently available analyses (APA 1984). In Sloughs 8A, 9A and 21 the Case EVI flows are anticipated to also increase the local flow.

The higher mainstem flows will increase the discharge in the sloughs through increased groundwater contributions to local flow and will increase fish passage efficiency. The higher Case EVI flows will have a neglibible effect on the backwater at the slough mouths and the flows will not be high enough to breach the sloughs of primary importance to fish production (sloughs 8A, 9, 9A, 11 and 21).

Case EVI mainstem discharges are less than the natural discharges during the summer and fall. The lack of breaching flows and backwater effects will still lower the efficiency of fish passage in sloughs. Local flow in the sloughs will also remain lower than natural conditions. Case EVI will have lesser impacts on chum salmon than Case P1 and will minimize impacts on chinook rearing habitat, nevertheless, adverse impacts on side slough spawning and incubation will occur. Mitigation in addition to flow release will be necessary for the late summer and fall.

3.2.2 - Habitat Modification

(a) Impact Issue

Case EVI will reduce from natural conditions the amount of spawning and incubation habitat available to chum salmon in sloughs and side channels of the middle Susitna River. Partial or complete loss of these habitats will result from:

- Reduced backwater effects
- Elimination of breaching flows
- Reduced upwelling during spawning and incubation
- Passage restriction
- Increased winter flows

(b) Mitigation Measures

A number of mitigation measures are presented in this section that can be used singly or in combination to minimize identified impacts. Table 9 shows the relationship between the mitigation measures and the impact for which they are designed.

(i) Channel Width Modifications

Channeling slough flow will improve fish access through passage reaches by contracting the width of the channel and deepening the channel. This technique is especially useful in drowning short passage reaches or ameliorating wide passage reaches. Wing deflectors extending out from the channel bank or rock gabions restructuring the cross section of the natural channel may be used to contract the flow width (Bell 1973).

In determining the modified width for the channel, a maximum velocity criteria of 8 fps was used to permit fish access through the reach. (Bell 1973).

- Wing Deflectors

Wing deflectors are used to divert the flow in a channel. Two wing deflectors placed on opposite banks will funnel the flow from a wider to a narrower cross section as shown in Figure 8. The narrowed channel is designed to provide fish passage at the minimum flow. At higher flows, the wing deflectors are inundated; fill between the banks and the wing deflector walls is sized to prevent scouring at higher discharges. Fill will typically be composed of large cobbles available at the sloughs.

Wing deflector walls are constructed either of rock or gabions formed of wire mesh and filled with cobbles. Another alternative is the use of 12 inches in diameter timbers, anchored to the banks and channel bed. A wing deflector costs $31,000 when constructed of rock, approximately $24,000 when constructed with gabions, and $22,400 if timber logs available on site are used. For sites where timber is not available, a log wing deflector would cost $23,200. Estimates are based on a typical passage reach for a slough on the middle Susitna River (Figure 9).

- Rock Gabion Channel

Reshaping the original cross section of the channel with rock gabions is an alternative method of channelizing the slough flow. The channel is excavated and gabions are used to reshape the original configuration. The new channel shape is designed to maximize depth at minimum flows; at higher discharges, the gabions prevent scouring of the channel banks. Figure 10 illustrates a typical cross section for a reshaped passage reach. For long passage reaches, resting areas are created by widening the channel between the rock gabions forming the minimum discharge channel. The gabions are provided throughout the length of the passage reach and protected upstream by riprap or wing wall gabions. The gabion banks extend higher than the height of the maximum slough discharge to prevent collapse from erosion.

The gabions composing the channel banks prevent scouring of the banks; the channel will be more stable than a similar channel modified by wing deflectors. For passage reaches with greatly varying discharges, the added stability of the rock gabion channel is an advantage. The cost of constructing the gabion channel is approximately $60,000 for a typical passage reach.

(ii) Channel Barriers

Fish access through passage reaches is also improved by creating a series of pools on the slope. Barriers are placed to break the flow on long, steep passage reaches and create pools between obstacles. Fish passage over the obstacles is accomplished if sections of decreased barrier height are provided (Bell 1973).

Channel barriers are used on long slopes to create fish resting pools, as shown in Figure 11. These barriers with heights of 10 inches to 14 inches act as weirs, with a section of decreased height to improve fish passage between pools. The barriers are constructed of various materials. Concrete highway curbs anchored to the bed with rebar (Figure 11) or cobbles and boulders placed to create a sill may be used. Logs may also be attached to the banks and anchored securely to the bed to prevent movement at high discharges. Gabions shaped as shown in Figure 11 may also be used (Lister et al. 1980).

Channels are constrained in width to form effective pools. For a wide channel, channel widths are modified where a pool and weir structure is desired.

Estimates of costs per barrier on the basis of a two barrier system are listed below. Each slope will require more than one barrier to create a series of pools. As more barriers are built on a site, the cost per barrier will decrease because of the economies of scale; the major cost involved in the construction of the barrier is the cost of transporting the equipment needed.

Barrier	Cost/Barrier
Concrete highway curbs	$12,000
Rock sill	$16,000
Gabions	$12,000
Anchored logs available on site	$11,000
Anchored logs not available on site	$12,000

(iii) Passage Through Flow Augmentation

With lower mainstem discharges, less groundwater may percolate into the sloughs, resulting in decreased slough discharge (APA 1984). Passage reaches negotiable at natural flows might become impassable under project conditions. In order to augment the slough flow, a piping system can be designed to transport water from the mainstem or other sources to affected passage reaches.

The sloughs of primary interest, including 8A, 9, 9A, 11, and 21, were considered in evaluating the feasibility of a piping system at a mainstem discharge of 9,000 cfs. This corresponds to the minimum spawning period mainstem discharge for Case EVI flows. Computational details are provided in Appendix B.

For Sloughs 8A and 9A, the mainstem elevation at 9,000 cfs produced insufficient head between the mainstem stage and the critical passage reaches to provide flow adequate for passage. Flows corresponding to the site-specific overtopping discharges are necessary to produce the required head for flow.

At Slough 9, a 9,000 cfs mainstem discharge would provide sufficient head for 1 cfs through a piped system. A collection tank (Figure 12) 20 feet from the main channel would collect mainstem water screened by the intervening gravels and use a 1-foot-diameter corrugated metal pipe to deliver the water 2,800 feet to the upstream end of Passage Reach (PR) V, as shown in Figure 13. The system would provide a maximum of 3 cfs prior to berm overtopping. For Slough 11, a mainstem discharge of 9,000 cfs could provide sufficient head for a flow of 1 cfs through a 1-foot-diameter pipe for delivery 3,200 feet from the slough head given an 18-foot-long collection system (Figure 14). A mainstem discharge of 9,000 cfs would be necessary at Slough 21 for a local flow of 1 cfs from a similar sized collector through a 1,700-foot-long, 0.75-foot-diameter pipe (Figure 15); a maximum of 2 cfs would flow through the system just prior to overtopping. The collector was designed to be located 20 feet from the mainstem in order to provide erosional protection and a filtration system for the water.

Estimated construction costs total $120,000 for the backhoe installation of the collector and piping system in Slough 9, $120,000 for the system in Slough 11 and $134,000 for the system in Slough 21.

(iv) Upwelling Augmentation

A system providing supplementary upwelling would maintain or increase spawning habitat in the sloughs during low mainstem discharges. The mainstem and nearby tributaries were evaluated as possible sources of upwelling water. The mainstem as an upwelling water source could not be used at numerous sites because of the low hydraulic head at low mainstem flows.

For sloughs with tributaries, the tributary could provide the water and the hydraulic head for an upwelling system, as shown in Figure 16. The critical period for induced upwelling would be during the project's projected low mainstem discharge period in August and September. Under natural conditions, it is assumed, based on the relationships provided in APA (1984), that upwelling increases during this period because of the high mainstem discharges. Selection of spawning sites has been shown to be related to the presence of upwelling at a site; therefore, upwelling needs to be maintained under project flows to maintain spawning habitat.

Under natural conditions, the mainstem stage and upwelling decrease from September until ice formation in November to December. Similarly, a tributary supplied upwelling system would also have decreasing discharges during this period. Reduction in a piped water supply would not become significant until mid-October, when project discharges increase. Upwelling under project operation is likely to be greater than upwelling under natural conditions from September to December.

Upwelling during winter (December to March) will decrease for sloughs upstream of the ice cover and increase for sloughs downstream of the ice front, relative to the natural conditions.

In the spring, tributary flows increase with the melting of snow and ice. By April, the tributary flows would be sufficient to provide upwelling from the piping system. Upwelling thus would be provided continuously throughout the year. Under natural conditions, upwelling is greatest from June through September and December through April.

Temperatures of the upwelling flows from the piped system would correspond to the temperatures of the tributary flows. Water will flow through the system as long as the water temperatures are above 0°C. Freezing water will not be released in the spawning gravels, as flow will cease in the system at freezing temperatures.

An upwelling system supplied by tributaries would be feasible for Sloughs 8A, 9, and 9A. Estimated cost of each system is $210,000 for a 300-foot main pipe and 200-foot reaches of cross pipe, spaced at 5-foot intervals for upwelling. A system with a longer main pipe could be built to tap Gold Creek water for Slough 11.

(v) Slough Excavation

Mechanical excavation of certain reaches of sloughs would improve fish access and fish habitat within the sloughs. At slough mouths, excavation would provide fish access when backwaters are negligible during low mainstem discharges. Mechanical excavation can be used to facilitate passage within sloughs by channelizing the flow or deepening the thalweg profile at the passage reach.

On a larger scale, mechanical excavation to lower the profile of the entire slough could increase the amount of upwelling in the slough. A greater head between the mainstem and the slough bed would result in additional local flow in the slough.

An additional benefit of the excavation process would be the opportunity to improve the substrate in the slough. Replacement of poor substrate with suitable spawning gravels would provide additional spawning habitat. The excavation process would be designed to develop additional spawning and rearing habitat.

An estimate of the cost to excavate a typical slough mouth in the middle portion of the Susitna River is $26,000.

(vi) Development of New Spawning Habitat

In order to provide the conditions that chum salmon prefer for spawning, existing pools in sloughs would be modified. Chum salmon prefer to spawn at upwelling sites (ADF&G 1983a). A weir structure that is permeable at the base and impermeable elsewhere could be erected in a pool to produce a head difference between the upstream and downstream sides. Such a weir would cause water to flow through the spawning gravels placed at the base of the structure (Figure 17).

A notch in the top of the structure facilitates fish passage between pools. The notch is designed for a minimum slough discharge of 2 cfs; this discharge corresponds to a typical low discharge in the sloughs along the middle section of the Susitna River.

The structure is securely embedded, anchored to the channel walls and bed, and riprapped to prevent erosion during high flows.

The weir can be constructed of timber posts 10 inches in diameter, reinforced with 2 x 4 inch cross bracing and faced with impermeable material, as in Figure 18. Gravel materials are piled on each side of the weir; the gravel provides stability to the structure in addition to providing spawning habitat. Only fine silts present in the gravel base will be eroded by the 2 fps water velocities over the weir. The spawning gravels would have a maximum angle of 10° with the channel bed to prevent downstream displacement caused by females digging redds during spawning.

Rock gabions can also be used to construct the weir shown in Figure 19. Sheets of plywood in the center of the structure impede flow through the gabions. Spawning gravels provide habitat at the base of the structure. A notch is provided for fish passage at low flows.

A rock structure with an impermeable core can be built as in Figure 20. Plywood sheets anchored with reinforcing rebars are adequate for use as a core.

The decision as to the materials used for the weir structure will be made during the design phase of the project based on the cost, durability, and aesthetics of the various structures.

The cost of the three structures is estimated assuming a 20-foot channel width and a 3-foot natural pool depth. Economies of scale are considerable if more than one structure is built at a site.

Structure	Cost/Weir
Timber pile weir	$32,000
Rock gabion weir	$32,000
Rock weir	$45,000

(vii) Prevention of Slough Overtopping

Project flows are higher than natural discharges in the winter. Ice staging at these discharges will result in an increase in mainstem stage and increase the probability of overtopping of sloughs downstream of the ice cover front.

An influx of cold mainstem water into the incubating area of the Slough 8A in 1982 caused high embryo mortality (ADF&G 1983b). To prevent overtopping, the height of the slough berms is increased as shown in Figure 21.

Cost estimates per berm total $150,000 initially and $7,500 average yearly maintenance. Maintenance may be required in 3 to 5 year intervals.

(c) Site Specific Impacts and Mitigations

(i) Slough 8A

During the 1981-1983 studies, the mean peak counts of chum salmon and sockeye salmon in Slough 8A were 331 (range: 37-620) and 104 (range: 67-177). The mean estimated total escapements to the slough were 553 chum (range: 112-1062) and 152 sockeye (range: 131-195) (ADF&G 1984a).

- Impact Issue

. Passage Restrictions

Under project flows, the frequency of successful passage conditions will decrease at passage reaches (PR's) I and II from natural levels of 79 and 48 percent to project levels of 25 and 16 percent. For PR's III to IV the decrease will range from 1 to 3 percent (Table 10). These decreases in frequencies of successful passage may, over time, result in a loss of potential spawning habitat. Historically spawned areas are presented in Table 1.

. Backwater

Spawning habitat that is dependent on backwater effects for providing suitable spawning depths would be lost because of project effects. An estimated spawning area of 103,000 square feet is affected by the backwater zone of natural flows and a portion of this area would become unsuitable at project flows.

. Breaching

The exceedence probabilities associated with natural breaching flows are 7 percent for the left channel and 2 percent for the right channel. These relatively low probabilities indicate that the importance of breaching lies in providing successful passage rather than increasing the potential spawning habitat by increasing the area with suitable spawning depths.

. Winter Flows

Overtopping of Slough 8A is predicted for several combinations of year specific climatological data, operational regimes, and demand schedules (Harza-Ebasco 1984a). The influx of near freezing water, even for periods of short duration, may result in substantial mortality to incubating embryos.

- Mitigation

Passage through PR's I and II is provided under natural conditions by backwater effects from a high mainstem discharge. With Case EVI flows, access through these passage reaches will be provided in an alternative manner to maintain the 103,000 square feet fish habitat available within the slough.

The maximum channel bed elevation of the PR I will be reduced to ease fish passage into the slough. Flow in PR II will be channeled to increase the depth at the expected lower slough flow. Adding wing deflectors to narrow the channel and remove boulders from the channel will improve passage through PR II. Other passage reaches may be improved by excavating a deeper channel through the reach.

Slough 8A has five tributaries suitable for use as sources of upwelling water. Upwelling will potentially be reduced between PR's IV and V and PR's VII and VIII near two of these tributaries. Two upwelling systems are proposed for Slough 8A.

Winter overtopping occurs at Slough 8A under natural conditions (R&M Consultants 1983). Under Case EVI, the frequency of winter overtopping is predicted to increase (Harza-Ebasco 1984a). Increasing the elevation of the berm at the head of each fork of the slough will prevent overtopping by near-freezing waters. The height of the east fork berm will be increased by 9 feet; approximately 250 feet of berm is required. The west fork berm will be increased four feet for a length of 250 feet.

The costs associated with each of the mitigation measures for Slough 8A are shown below:

Mitigation Measure	Number Proposed	Capital Costs	Annual Operating & Maint. Costs
Upwelling systems	2	$415,000	$15,000
Slough mouth excavation	1	26,000	5,000
Wing deflector	1	24,000	1,500
Excavate passage reaches	7	11,000	2,000
Protective slough berms	2	295,000	15,000
Total		$771,000	$70,000

(ii) Slough 9

During the 1981-1983 studies, the mean peak counts of chum salmon and sockeye salmon in Slough 9 (including 9B) were 295 (range: 175-358) and 33 (range: 2-91). The mean estimated total escapements to the slough were 563 chum (range: 430-645) and 81 sockeye (range: 0-230) (ADF&G 1984a).

- Impact Issue

. Passage Restrictions

Based on the slough flow analysis in APA (1984), Project flows will result in reductions in the frequency of successful passage conditions at PR's III, IV and V. At PR's III and IV, passage under natural conditions is assured 100 percent of the time as compared to 34 percent and 29 percent under project flows (Table 11). At PR V, natural occurrences of 29 percent will change to 0 percent passage under project flows. The general area of spawning above PR V that will become inaccessible amounts to approximately 5300 square feet (Table 2). The reduction in opportunities for passage at PR's III and IV may also result in loss of some spawning habitats.

. Winter Flows

The upstream extent of the ice cover is projected to progress beyond Slough 9 for several combinations of selected meteorological data, operation regimes and demand schedules. Based on the simulations completed to date, there is a moderate probability of annual overtopping of the slough (Harza-Ebasco 1984a).

. Breaching

The exceedance probability associated with breaching discharges of 19,000 cfs is 29 percent. It is probable that the breaching flows are providing the depth required for spawning in some areas and that these areas would become unspawnable at project flows. However, the extent of these areas appear minimal when the wetted perimeter boundaries at a flow of 9,000 cfs are overlaid on outlines of spawned areas from 1982-1983.

. Backwater

Backwater effects provided spawning area during the study period 1982-1984 and that area was spawned only in 1983. The lower portion of this slough has since silted in and the channel has changed its course, thus precluding spawning in this area.

- Mitigation

Passage through the downstream section of Slough 9 is currently difficult because of silt deposited during the 1983-1984 season. Removal of this silt will expose the spawning gravels and increase the habitat in the downstream region of the slough.

Based on the relationship between mainstem flow and slough flow presented in APA (1984), PR's III and IV are greatly affected by a reduction in natural discharges. At discharges corresponding to Case EVI the frequency of passage through these reaches will be increased by excavating a deeper channel and channelizing the available local flow. Larger cobbles and boulders will be removed from the channel to improve the spawning habitat.

Upstream from PR V, spawning habitat is available under natural conditions. Under project conditions, based on the currently available slough flow analysis, fish would not be able reach this habitat. A piped water supply system will provide mainstem flow, to the upstream end of PR V; this flow when channelized, will increase the frequency of passage through this reach. A pool and weir structure will be constructed to enable fish to access the natural pool habitat available upstream of PR V. A series of 20 weirs composed of anchored logs will allow salmon to access an additional 1000 ft of Slough 9.

An upwelling system between PR's IV and V will increase the amount of upwelling in this area. Other efforts to improve spawning habitat in the pool region between PR's IV and V include construction of a rock gabion weir to increase spawning habitat available.

Slough 9 is expected to be overtopped more frequently in winter by the increased ice stage caused by project flows (Harza-Ebasco 1984a). An overtopping-prevention berm 8 feet in height and 375 feet in width will be placed at the head of the slough to maintain the suitability of incubation habitat within the slough.

The costs associated with each of the mitigation measures for Slough 9 are shown below:

Mitigation Measure	Number Proposed	Capital Costs	Annual Operating & Maint. Costs
Upwelling system	1	$210,000	7,000
Water supply system	1	120,000	10,000
Protective slough berm	1	150,000	7,500
Log barriers	20	30,000	6,000
Passage reach excavation	1	5,000	1,000
Total		$515,000	$31,500

(iii) Slough 9A

During the 1981-1983 studies, the mean peak count of chum salmon in Slough 9A was 135 (range: 105-182) while the mean estimated total escapement to the slough was 152 chum (range 86-231) (ADF&G 1984a).

- Impact Issue

. Passage Restrictions

Under natural conditions, PR's I-IX can be successfully negotiated by chum salmon 100 percent of the time (Table 12). Five out of these nine passage reaches are anticipated to provide successful passage condition 3 to 32 percent of the time under project operation. Of the five passage reaches, PR III is considered to be of greatest concern since access to substantial amounts of historically spawned areas can be achieved if passage through this reach is facilitated (Table 3).

. Breaching

The breaching discharge of 12,000 cfs has an exceedance probability of 71 percent. Field observations during September 1984 indicated that the gravel surface of some areas spawned earlier in the season under breached conditions were dewatered. Survival from these areas is unknown. Estimates of the spawning area lost will be obtained by overlaying the boundaries of the wetted surface area at 9,000 cfs onto the spawned areas delineated for the 1982-1984 seasons.

. Backwater

Evaluation of backwater effects are not applicable to this slough because breaching conditions prevail for the majority of the spawning season.

. Winter Flows

Simulation of the upstream extent of ice cover for several combinations of operating regimes, demand schedules and meteorological conditions for selected years indicated a moderate probability of the slough overtopping on an annual basis (Harza-Ebasco 1984a).

- Mitigation

Spawning habitat in Slough 9A is primarily accessed during breaching flows under natural conditions. Under Case EVI scheduled discharges, the habitat will be retained by lowering the slough profile until depths suitable for spawning are obtained.

While the slough profile is being excavated, the large cobbles and boulders will be removed to improve access between the series of pools that exist along the thalweg. Removal of the large cobbles and boulders will provide additional spawning habitat to that presently existing within the side channels.

Slough 9A breaches at a relatively low natural mainstem discharge and protection from winter overtopping under project conditions will be supplied. The berm at the head of the slough will be heightened 10 feet for a length of 150 feet to prevent winter overtopping if the ice front is predicted to extend upstream of this slough more frequently than once every ten years.

The costs associated with each of the mitigation measures for Slough 9A are shown below:

Mitigation Measure	Number Proposed	Capital Costs	Annual Operating & Maint. Costs
Protective slough berm	1	$150,000	$7,500
Excavation of slough	1	26,000	5,000
Total		$176,000	$12,500

(iv) Slough 11

During the 1981-1983 studies, the mean peak counts of chum salmon and sockeye salmon in Slough 11 were 369 (range: 238-459) and 532 (range:248-893). The mean estimated total escapements to the slough were 957 chum (range: 674-1119) and 1128 sockeye (range: 564-1620) (ADF&G 1984a).

- Impact Issue

. Restricted Access

Under natural conditions, PR's I-III provide successful passage 70, 43 and 12 percent of the time, principally through the groundwater contribution to local slough flow (Table 13). Passage reaches IV and V provide adequate passage conditions only during infrequent breaching conditions, which occur one percent of the time. Based on currently available information, project flows of 9,000 cfs will reduce the groundwater input to the extent that passage will be restricted across all passage reaches (APA 1984). The spawning areas that will be affected are shown in Table 4.

. Breaching

The exceedance probabilities associated with natural breaching discharges of 43,000 cfs is one percent. Based on this low frequency of occurrence, the contribution of breaching conditions in providing access and passage or in increasing the spawnable area within the slough is negligible.

. Backwater

The backwater at the slough mouth affects approximately 50,000 square feet of area that has been spawned in the past. Overlying the boundaries of the wetted surface area at 9,000 cfs indicates that approximately 20 percent of that spawned area is dewatered during project operations. For purposes of mitigation this dewatered area will be considered lost habitat. For purposes of mitigation it will be considered lost habitat. Additional habitat with the wetted perimeter at 9,000 cfs may be unsuitable for spawning due to insufficient depth and would also be considered lost habitat.

. Winter Flows

Simulations of ice cover progressing have indicated that the front will proceed as far as Slough 11 generally in the coldest years (Harza-Ebasco 1984a). The probability of the slough overtopping on a yearly basis is therefore low.

- Mitigation

The passage reaches in Slough 11 will require channelization in order to increase the depth of flow in the reaches and provide passage.

A channel will be excavated through the silty materials at the slough mouth and the banks of the channel stabilized with rock gabions. The stabilized channel will extend 1,200 feet upstream in the slough and modify PR's I and II. Passage through PR III will be facilitated by construction of wing deflectors made from rock gabions.

A channel will be excavated at PR IV. A pool and weir structure will be constructed in the excavated channel which will improve fish passage upstream. Fifteen weirs will be needed for 300 feet of slough channel.

Local flow lost because of the decreased mainstem discharge will be replaced by piping water from Gold Creek into Slough 11. The increase in local flow will improve the ease of fish passage through the reaches.

Under natural flows, backwater effects provide 50,000 square feet of fish spawning habitat at the slough mouth. Under project conditions, this spawning area will be partially replaced with rock gabion weirs placed in pools between PR's II and III and PR's III and IV.

Under project conditions the slough may experience winter overtopping. If further analysis of ice processes indicates a high frequency of overtopping, the berm at the head of the slough will be heightened five feet for a length of 250 feet to prevent this occurrence.

The costs associated with each of the mitigation measures for Slough 11 are shown below:

Mitigation Measure	Number Proposed	Capital Costs	Annual Operating & Maint. Costs
Tributary flow diversion	1	$380,000	$40,000
Weirs	2	61,000	6,000
Bank stabilization	1	25,000	3,000
Slough excavation	1	26,000	5,000
Log barriers	15	24,000	5,000
Total		$615,000	$59,000

(v) Slough 21

During the 1981-1983 studies, the mean peak counts of chum salmon and sockeye salmon in Slough 21 were 443 (range: 274-736) and 96 (range 38-197). The mean estimated total escapements to the slough were 958 chum (range: 481-1737) and 148 sockeye (range: 63-294) (ADF&G 1984a).

- Impact Issue

. Restricted Access

PR's I, IIL, and IIR provide suitable passage conditions 100, 25 and 20 percent of the time under natural flow. Project flows will reduce the frequency at PR' s I, IIL and IIR to 6, 0, and 1 percent, primarily as a result of reduced groundwater flow (Table 14). The restriction at PR IIL will eliminate the spawnable area above this point (Table 5). Moreover, if passage is facilitated, much of the historically spawned area will not be of sufficient depth for use under project flows.

. Breaching

The exceedance probably associated with the natural breaching discharge of 25,000 cfs, for the left channel, is 10 percent. Breaching provides access and passage within the slough, but does not appreciably increase spawnable area.

. Backwater

Spawning areas in the mouth of the slough do not appear to be dependent on backwater and areas that were spawned under natural flows should remain spawnable.

. Winter Flows

The ice front is predicted as far as Slough 21 only during the coldest of years (Harza-Ebasco 1984a). The probability of the slough overtopping is very low.

- Mitigation

Passage through Side Channel 21 is necessary prior to entry into Slough 21. Mitigation of passages reaches within Lower Side Channel 21 is needed to permit fish access to the habitat in Slough 21.

Passage through PR I will be ameliorated by the excavation of a channel through the reach. Passage through reaches IIL and IIR will be accomplished by removing large cobbles and boulders and channelizing the flow. A water supply system will pipe 1 cfs from the mainstem into PR IIL in order to increase the local flow available for passage.

The large cobbles and boulders in the upper portion of the slough will be removed and sorted gravel provided to increase the available spawning habitat above the level that is currently available.

The flow will be channelized by excavating a deeper channel through the reaches. Reaches with erodible substrate will be stabilized with rock gabions.

The costs associated with each of the mitigation measures for Slough 21 are shown below:

Mitigation Measure	Number Proposed	Capital Costs	Annual Operating & Maint. Costs
Excavation of slough	1	$34,000	$7,000
Rock gabions	2	54,000	6,000
Water supply system	1	134,000	12,000
Total		$222,000	$25,000

(vi) Lower Side Channel 21

- Impact Issue

. Restricted Access

Under natural conditions the frequencies of suitable passage conditions range from 71-100 percent for PR's I-X (Table 15). Under project conditions, successful passage conditions will be available about 30 percent of the time at PR's I-IV and one percent or less at PR's V-IX, based on current analysis. The majority of the spawning occurs above PR V and these areas would have restricted access (Table 6).

. Breaching

A series of channels enter Lower Side Channel 21 (LSC21) along its length and each breaches at a different mainstem discharge. The uppermost channel, A6, has a breaching discharge of 24,000 cfs with an associated frequency of occurrence of 12. Spawning areas between the entry point of this channel into LSC21 and next downstream channel, A5 are limited primarily by the depth provided by local flow and not breaching.

The exceedance probability of 71 percent associated with breaching discharges of 12,000 cfs at the A5 channel indicates that mainstem flow into the side channel provide the required depths for much of the spawned area downstream from this point during the 1982-1984 seasons. This was confirmed by field observations of the channel at unbreached conditions in September, 1984 in which areas spawned in previously in the season were dewatered.

. Backwater

Evaluation of backwater effects on availability of spawning habitat are not applicable in light of the low breaching discharges.

. Winter Flows

Similar to Slough 21, the ice front is only projected to reach Lower Side Channel 21 in the coldest years. The probability of overtopping is low, although the side Channel would overtop before the slough.

- Mitigation

At project flows, the lack of breaching flows will impact fish passage within Side Channel 21. The frequency of fish passage will be increased by channelizing the local flow.

Passage reaches I-V will be ameliorated by excavating a channel through the most restrictive sections of each passage reach.

Passage reaches upstream of PR V will be channelized with rock gabion wing deflectors at the passage reaches. Large cobbles and boulders will be removed to improve the frequency of fish passage through the reaches. Marginal spawning substrate in the upstream slough pools will be replaced with sorted gravels to increase the available spawning habitat.

Winter overtopping of the berms along the length of Side Channel 21 is not anticipated since the ice front on the Sustina River is estimated to be downstream (Harza-Ebasco 1984a).

The costs associated with each of the mitigation measures for Slough 21 are shown below:

Mitigation Measure	Number Proposed	Capital Costs	Annual Operating & Maint. Costs
Excavation of channel	1	$45,000	$9,000
Wing deflectors for bank stabilization	7	240,000	35,000
Total		$285,000	$44,000

3.2.3 - Artificial Propagation

An alternative means to achieve the mitigation goal of maintaining chum salmon production is through artificial propagation. Mitigation by artificial propagation will be considered if other mitigation measures are ineffective. The artificial propagation method selected for mitigation for chum salmon spawning habitat losses in the middle Susitna River is stream-side egg incubation boxes. The emergent fry will be returned to the sloughs for rearing and/or migration. Egg boxes with gravity fed water systems are well suited for remote-site installation because they are cost effective and require little maintenance.

(a) Design and Operation of Egg Box

The egg box to be used is a stream-side egg incubation box. The egg box is a 4 ft x 4 ft x 8 ft gravel-filled upwelling box capable of incubating 500,000 eggs. This egg box is used extensively in Washington State for artificial propogation of chum salmon. The box will be insulated to protect against freezing.

In each egg box 500,000 green eggs (those just-fertilized) are placed on plastic mesh trays and incubated. At the eyed stage, the eggs are shocked and the dead and blank eggs are removed. At hatching the alevins fall through the plastic mesh trays to the gravel surface and migrate into the gravel. Alevins reside in the gravel interstitial spaces until the yolk-sac has been absorbed, at which time they emerge from the gravel and leave the box. Survival from eyed egg to emergent fry is typically greater than 90 percent (B. Snyder, Univ. Wash., pers. comm., 1984).

(b) Site Selection Criteria

The primary concern in siting the egg boxes is the availability of a dependable water source. The water should be sediment free, meet water quality standards and be gravity-fed to the egg boxes. The latter is of primary concern due to the low reliability and high cost of pumping water. Other criteria are access to the site and proximity to a slough for juvenile release and adult return. Curry Station (RM 120) appears to satisfy the above criteria for site location.

(i) Water Supply

Curry Station has an existing gravity-fed surface water system. Using an existing system is more economical than developing a new water system. The system at Curry was built in the 1930's as a water supply for the railway construction camp. It consists of an impoundment structure and pipeline which draws water at an estimated 5 cfs year round (B. Barrett, ADF&G, pers. comm., 1984). Temperature and water quality appear to be within acceptable limits (D. Seagren, ADF&G, pers. comm., 1984); however, before an egg box program is implemented, detailed temperature and water quality data will be obtained. Information on the temporal temperature variation of the water source will be used to predict the emergence timing of fry and to select the proper brood stock.

(ii) Slough Proximity

Another aspect of site location is the proximity to a slough. The slough will be utilized in two ways. First, emergent fry from the egg boxes will be released, directly into the slough for additional rearing and/or migration. Second, the slough will serve as an adult return area and will facilitate procurement of the brood stock. Curry Slough is approximately 4000 ft downstream from Curry Station and can be utilized.

(iii) Site Access

Curry Station is easily accessible by helicopter and rail. The close proximity of the railway will facilitate movement of materials and equipment to the site.

(b) Brood Stock

The initial selection of brood stock will depend on the temperature profile of the water source. It appears that the existing water source is colder than intergravel temperatures to which incubating eggs are exposed. This may cause the fry produced from egg box to emerge later than native fry. If this delay exceeds the natural variation in emergence timing for native fry, the tributary spawning chum in the middle Susitna River, or another stock of earlier-spawning chum, will be selected to allow the egg box fish to emerge at approximately the same time as native fry.

The donor stock will be utilized for the first five years of the project since Susitna chum predominantly return at 4 and 5 years of age. After the initial 5 year introduction period the returning adults will serve as the brood stock. To mitigate for the loss of 4200 chum, approximately 700,000 eggs (250 females) will be needed for mitigation. This figure is based on maintaining the 4200 chum escapement using the following assumption: 1.1:1 male to female ratio (ADF&G 1984a) a 15 percent egg-to-fry survival (ADF&G 1984b), a fecundity of 2850 eggs per female, and a 0.7 percent fry to adult return (including harvest) (Barrick et al. 1983). Excess returns to the egg box facility will be allowed to spawn naturally in the slough or in adjacent sloughs. To insure genetic diversity of the artificially propogated stock, eggs from each female will be fertilized with the gametes of several males.

(c) Alternatives for Development

There are two alternatives for the Curry Station egg box site. The first is a plan to establish the egg box site at Curry Slough and the second is a plan for development of the egg box site at Curry Station.

(i) Curry Slough Development

Establishing the egg box site at Curry Slough will require the water source presently at Curry Station (approximately 4000 feet upstream) to be piped to Curry Slough. This will entail burying (to safeguard against freezing and physical damage) approximately 4000 feet of 6-inch diameter pipe. The egg boxes will be set up near the downstream end of Curry Slough and emergent fry will be released directly into the slough from the egg boxes. The slough will be appropriately sloped to facilitate downstream mitigation of fry and to ensure that returning adults have access to the slough. The advantage of locating the boxes adjacent to the slough, is that the emergent fry can be released without being handled. Fry will be released into the slough to allow for acclimation and/or rearing before seaward migration. Releasing newly emerged fry directly into the mainstem would not allow for acclimation and orientation. The costs for this option are outlined in Appendix B and summarized below:

Mitigation Measure	Number Proposed	Capital Costs	Annual Operating & Maint. Costs
Artificial propagation	2	$450,000	$50,000
Total		$450,000	$50,000

(ii) Curry Station Development

The Curry Station development consists of installing the egg boxes near the outfall of the existing water system. This will require a minimal amount of pipe, which can be installed above ground if insulated pipe is used. Newly emergent fry will be collected in two 18 foot diameter x 4 foot deep above-ground rearing ponds. Fry will be transported daily to Curry Slough and liberated. This installation has the disadvantage of extensive handling of fry. The costs for this option are outlined in Appendix B and summarized below:

Mitigation Measure	Number Proposed	Capital Costs	Annual Operating & Maint. Costs
Artificial propagation	2	$81,000	$35,000
Total		$81,000	$35,000

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TABLES

Table 1 Area spawned within slough 8A backwater zones and areas between passage reaches for 1982, 1983 and 1984. The ratio of the composite to the total area spawned for all years is also shown.

	Area Spawned (ft^2)				Composite/
	1982	1983	1984	Composite	Total
Backwater Zone	19,700	17,900	93,700	103,400	.79
Passage Reaches					
I - II	21,900	20,200	94,700	107,100	.78
II-III	4,100	2,900	29,200	31,800	.88
III-IV	5,900	12,400	70,800	72,700	.82
IV-V	0	0	10,400	10,400	1.0
V-VI	0	0	12,900	12,900	1.0
VI-VII	8,600	0	2,000	10,300	.97
VII-VIII	7,800	0	600	8,400	1.0
VIII-IX	0	0	5,200	5,200	1.0
IX-X	0	0	0	0	0

Table 2 Area spawned within slough 9 backwater zones and areas between passage reaches for 1982, 1983 and 1984. The ratio of the composite to the total area spawned for all years is also shown.

	Area Spawned (ft^2)				Composite/
	1982	1983	1984	Composite	Total
Backwater Zone	0	1,200	0	0	0
Passage Reaches					
I-II	0	1,200	0	0	0
II-III	13,500	23,900	18,100	47,200	.85
III-IV	7,500	4,000	4,000	11,200	.79
IV-V	7,700	3,200	6,900	11,700	.76
V-VI	4,600	2,900	4,000	5,300	.46

Table 3 Area spawned within slough 9A backwater zones and areas between passage reaches for 1982, 1983 and 1984. The ratio of the composite to the total area spawned for all years is also shown.

	Area Spawned (ft^2)				Composite/
	1982	1983	1984	Composite	Total
Backwater Zone					
<u>Passage Reaches</u>					
I-II	6,500	12,800	2,300	8,800	.41
II-III	14,300	4,400	1,600	8,800	.43
III-IV	10,400	4,300	5,700	13,800	.68
IV-V	21,600	16,400	11,100	26,300	.54
V-VI	6,900	7,600	13,800	12,300	.44
VI-VII	21,400	7,300	4,900	27,600	.82
VII-VIII	0	0	0	0	0
VIII-IX	2,200	4,800	6,200	7,700	.58
IX-X	8,800	6,100	12,800	18,400	.66
X-XI	2,200	0	6,600	8,800	1.0

Table 4 Area spawned within slough 11 backwater zones and areas between passage reaches for 1982, 1983 and 1984. The ratio of the composite to the total area spawned for all years is also shown.

	Area Spawned (ft^2)				Composite/
	1982	1983	1984	Composite	Total
Backwater Zone	13,100	25,800	35,000	50,200	.68
Passage Reaches					
I-II	13,400	25,800	40,900	56,200	.70
II-III	4,100	0	9,700	9,700	.70
III-IV	15,200	7,300	38,200	46,200	.76
IV-V	5,000	0	3,500	5,200	.61
V-VI	2,900	3,600	4,000	5,800	.55
VI-VII	27,000	9,900	19,100	32,600	.58

Table 5 Area spawned within slough 21 backwater zones and areas between passage reaches for 1982, 1983 and 1984. The ratio of the composite to the total area spawned for all years is also shown.

	Area Spawned (ft^2)				Composite/
	1982	1983	1984	Composite	Total
Backwater Zone					
<u>Passage Reaches</u>					
I-II	3,400	12,100	10,000	19,100	.75
II-III	2,900	33,600	21,900	38,900	.67

Table 6 - Area spawned within lower side channel 21 backwater zones and areas between passage reaches for 1982, 1983 and 1984. The ratio of the composite to the total area spawned for all years is also shown.

	Area Spawned (ft^2)				Composite/
	1982	1983	1984	Composite	Total
Backwater Zone	80,100	80,500	178,600	239,300	.71
<u>Passage Reaches</u>					
I-II	0	0	300	300	1.0
II-III	0	6,300	9,000	9,000	.59
III-IV	0	3,600	2,200	3,700	.64
IV-V	19,700	21,500	63,400	65,900	.63
V-VI	1,500	13,200	7,800	19,000	.84
VI-VII	3,300	0	600	3,900	1.0
VII-VIII	33,300	17,700	74,300	105,200	.84
VIII-IX	0	0	0	0	0
IX-X	0	0	0	0	0
X-XI	22,300	18,300	21,000	32,400	.53

Table 7 Mean monthly discharges at Gold Creek for natural conditions, predicted project flows based on Case P1 (maximum power generation), and predicted project flows based on Case EVI Instream flow requirements.[a]

Month	Natural (cfs)	Case P1 (cfs)	Case EVI (cfs)
January	1,440	10,900	10,700
February	1,210	9,200	8,900
March	1,090	7,900	7,700
April	1,340	7,300	7,000
May	13,400	8,800	8,500
June	28,150	10,500	11,400
July	23,990	8,900	10,200
August	21,950	9,800	10,700
September	13,770	10,900	9,900
October	5,580	10,200	9,800
November	2,430	20,600	10,300
December	1,750	12,100	11,900

a Minimum and maximum instream flow requirements are listed in Table 8

Table 8 Minimum and maximum weekly instream flow requirements for Case EVI flows at Gold Creek

	Week	Min (cfs)	Max (cfs)
January	1	2,000	16,000
	2	"	"
	3	"	"
	4	"	"
February	1	2,000	16,000
	2	"	"
	3	"	"
	4	"	"
March	1	2,000	16,000
	2	"	"
	3	"	"
	4	"	"
April	1	2,000	16,000
	2	"	"
	3	"	"
	4	"	"
May	1	2,000	16,000
	2	"	"
	3	"	"
	4	4,000	"
June	1	6,000	16,000
	2	"	"
	3	"	"
	4	9,000	35,000
July	1	9,000	35,000
	2	"	"
	3	"	"
	4	"	"
August	1	9,000	35,000
	2	"	"
	3	"	"
	4	"	"
September	1	9,000	35,000
	2	"	"
	3	8,000	"
	4	7,000	"
October	1	6,000	18,000
	2	6,000	12,000
	3	5,000	16,000
	4	4,000	16,000
November	1	3,000	16,000
	2	"	"
	3	"	"
	4	"	"
December	1	3,000	16,000
	2	2,000	"
	3	"	"
	4	"	"

Table 9 Relationship between mitigation alternatives and the impacts for which they are applicable

Mitigation alter-natives/impact issue	Inadequate passage	Loss of physical habitat	Loss of upwelling at habitat	Winter overtopping of slough berm
channel width modification	P			
channel barrier construction	P			
Flow augmentation	P	P	S	
Upwelling augmentation	S	S	P	
Slough excavation	P	P	S	
creating spawning habitat in pools		P	S	
Increase berm height				P

P = primary effect

S = secondary effect

Table 10. Condition which provides successful passage most frequently and approximate percent of time that passage is successful during the period 20 August - 20 September at Slough 8A.

Passage Reach	Natural		Project 9,000 cfs		Project 8,000 cfs	
	Cond.	Occurrence (%)	Cond.	Occurrence (%)	Cond.	Occurrence (%)
I	BW	79	SW/GW	25	SW/GW	24
II	BW	48	SW/GW	16	SW/GW	15
III	SW/GW	19	SW/GW	16	SW/GW	15
IV	SW/GW	10	SW/GW	7	SW/GW	7
V	SW/GW	9	SW/GW	7	SW/GW	7
VI	SW/GW	12	SW/GW	9	SW/GW	9
VII	SW/GW	11	SW/GW	9	SW/GW	9
VIII	SW/GW	4	SW/GW	3	SW/GW	3
IX	BR	2	---	0	---	0

BW is backwater condition which neglects the effect of local flow

BR is breaching condition which represents controlling discharge through the slough

GW is groundwater condition as it appears to fluctuate with mainstem discharge

SW/GW is surface water and groundwater condition with a median natural flow or minimum project flow controlling groundwater levels and surface water related to precipitation events.

Appendix B contains an explanation of the derivation of the percent exceedance values

Table 11 Condition which provides successful passage most frequently and approximate percent of time that passage is successful during the period 20 August - 20 September at Slough 9.

Passage Reach	Natural		Project 9,000 cfs		Project 8,000 cfs	
	Cond.	Occurrence (%)	Cond.	Occurrence (%)	Cond.	Occurrence (%)
I	GW	100	GW	100	GW	100
II	GW	100	GW	100	GW	100
III	GW	100	SW/GW	34	SW/GW	29
IV	GW	100	SW/GW	29	SW/GW	28
V	BR	29	---	0	---	0

BW is backwater condition which neglects the effect of local flow

BR is breaching condition which represents controlling discharge through the slough

GW is groundwater condition as it appears to fluctuate with mainstem discharge

SW/GW is surface water and groundwater condition with a median natural flow or minimum project flow controlling groundwater levels and surface water related to precipitation events.

Appendix B contains an explanation of the derivation of the percent exceedance values

Table 12. Condition which provides successful passage most frequently and approximate percent of time that passage is successful during the period 20 August - 20 September at Slough 9A.

Passage Reach	Natural		Project 9,000 cfs		Project 8,000 cfs	
	Cond.	Occurrence (%)	Cond.	Occurrence (%)	Cond.	Occurrence (%)
I	GW	100	GW	100	GW	100
II	GW	100	GW	100	SW/GW	41
III	GW	100	SW/GW	32	SW/GW	14
IV	GW	100	GW	100	GW	100
V	GW	100	GW	100	SW/GW	20
VI	GW	100	SW/GW	24	SW/GW	14
VII	GW	100	SW/GW	10	SW/GW	7
VIII	GW	100	SW/GW	6	SW/GW	3
IX	GW	100	SW/GW	3	SW/GW	2
X	---	0	---	0	---	0

BW is backwater condition which neglects the effect of local flow

BR is breaching condition which represents controlling discharge through the slough

GW is groundwater condition as it appears to fluctuate with mainstem discharge

SW/GW is surface water and groundwater condition with a median natural flow or minimum project flow controlling groundwater levels and surface water related to precipitation events.

Appendix B contains an explanation of the derivation of the percent exceedance values

Table 13. Condition which provides successful passage most frequently and approximate percent of time that passage is successful during the period 20 August - 20 September at Slough 11.

Passage Reach	Natural		Project 9,000 cfs		Project 8,000 cfs	
	Cond.	Occurrence (%)	Cond.	Occurrence (%)	Cond.	Occurrence (%)
I	GW	70	---	0	---	0
II	GW	43	---	0	---	0
III	GW	12	---	0	---	0
IV	BR	1	---	0	---	0
V	BR	1	---	0	---	0

BW is backwater condition which neglects the effect of local flow

BR is breaching condition which represents controlling discharge through the slough

GW is groundwater condition as it appears to fluctuate with mainstem discharge

SW/GW is surface water and groundwater condition with a median natural flow or minimum project flow controlling groundwater levels and surface water related to precipitation events.

Appendix B contains an explanation of the derivation of the percent exceedance values

Table 14. Condition which provides successful passage most frequently and approximate percent of time that passage is successful during the period 20 August - 20 September at Slough 21.

Passage Reach	Natural		Project 9,000 cfs		Project 8,000 cfs	
	Cond.	Occurrence (%)	Cond.	Occurrence (%)	Cond.	Occurrence (%)
I	GW	100	SW/GW	6	SW/GW	4
IIL	SW/GW	10	---	0	---	0
IIR	SW/GW	4	SW/GW	1	SW/GW	1

BW is backwater condition which neglects the effect of local flow

BR is breaching condition which represents controlling discharge through the slough

GW is groundwater condition as it appears to fluctuate with mainstem discharge

SW/GW is surface water and groundwater condition with a median natural flow or minimum project flow controlling groundwater levels and surface water related to precipitation events.

Appendix B contains an explanation of the derivation of the percent exceedance values

Table 15. Condition which provides successful passage most frequently and approximate percent of time that passage is successful during the period 20 August - 20 September at Side Channel 21.

Passage Reach	Natural		Project 9,000 cfs		Project 8,000 cfs	
	Cond.	Occurrence (%)	Cond.	Occurrence (%)	Cond.	Occurrence (%)
I	GW	100	SW/GW	28	SW/GW	24
II	GW	100	SW/GW	28	SW/GW	24
III	GW	100	SW/GW	31	SW/GW	26
IV	GW	100	SW/GW	31	SW/GW	26
V	BR	71	SW/GW	1	SW/GW	0.5
VI	BR	71	SW/GW	0.5	---	0
VII	BR	71	SW/GW	0.5	---	0
VIII	BR	71	SW/GW	0.5	---	0
IX	BR	71	SW/GW	0.5	---	0
X	GW	100	SW/GW	9	SW/GW	5

BW is backwater condition which neglects the effect of local flow

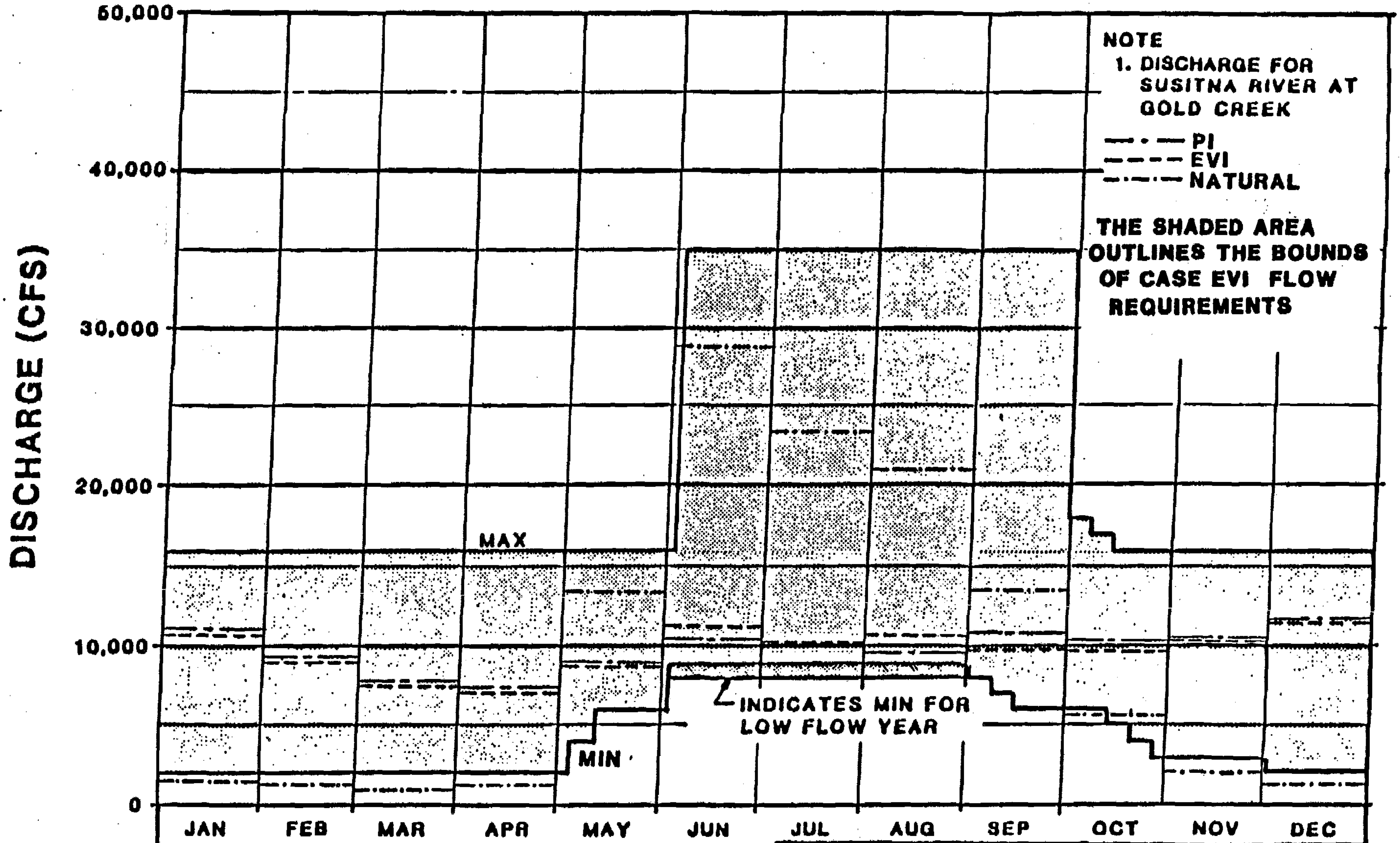
BR is breaching condition which represents controlling discharge through the slough

GW is groundwater condition as it appears to fluctuate with mainstem discharge

SW/GW is surface water and groundwater condition with a median natural flow or minimum project flow controlling groundwater levels and surface water related to precipitation events.

Appendix B contains an explanation of the derivation of the percent exceedance values

FIGURES



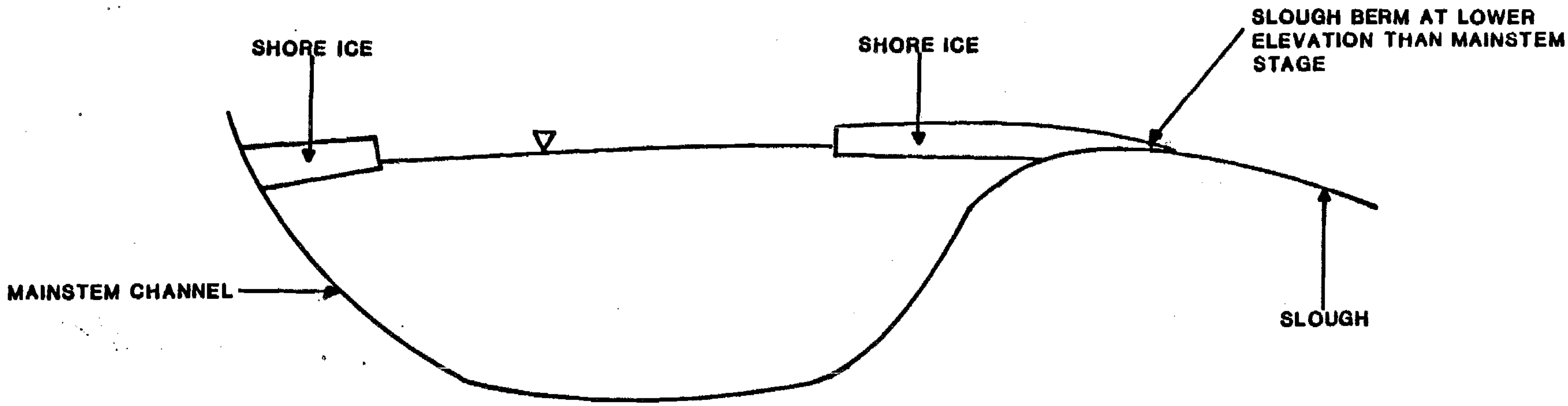
MEAN MONTHLY DISCHARGES FOR NATURAL, P1 AND EVI CONDITIONS AND MINIMUM AND MAXIMUM MEAN WEEKLY DISCHARGES FOR EVI FLOWS

FIGURE 1

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

Woodward-Clyde Consultants

HARZA-EBASCO
SUSITNA JOINT VENTURE



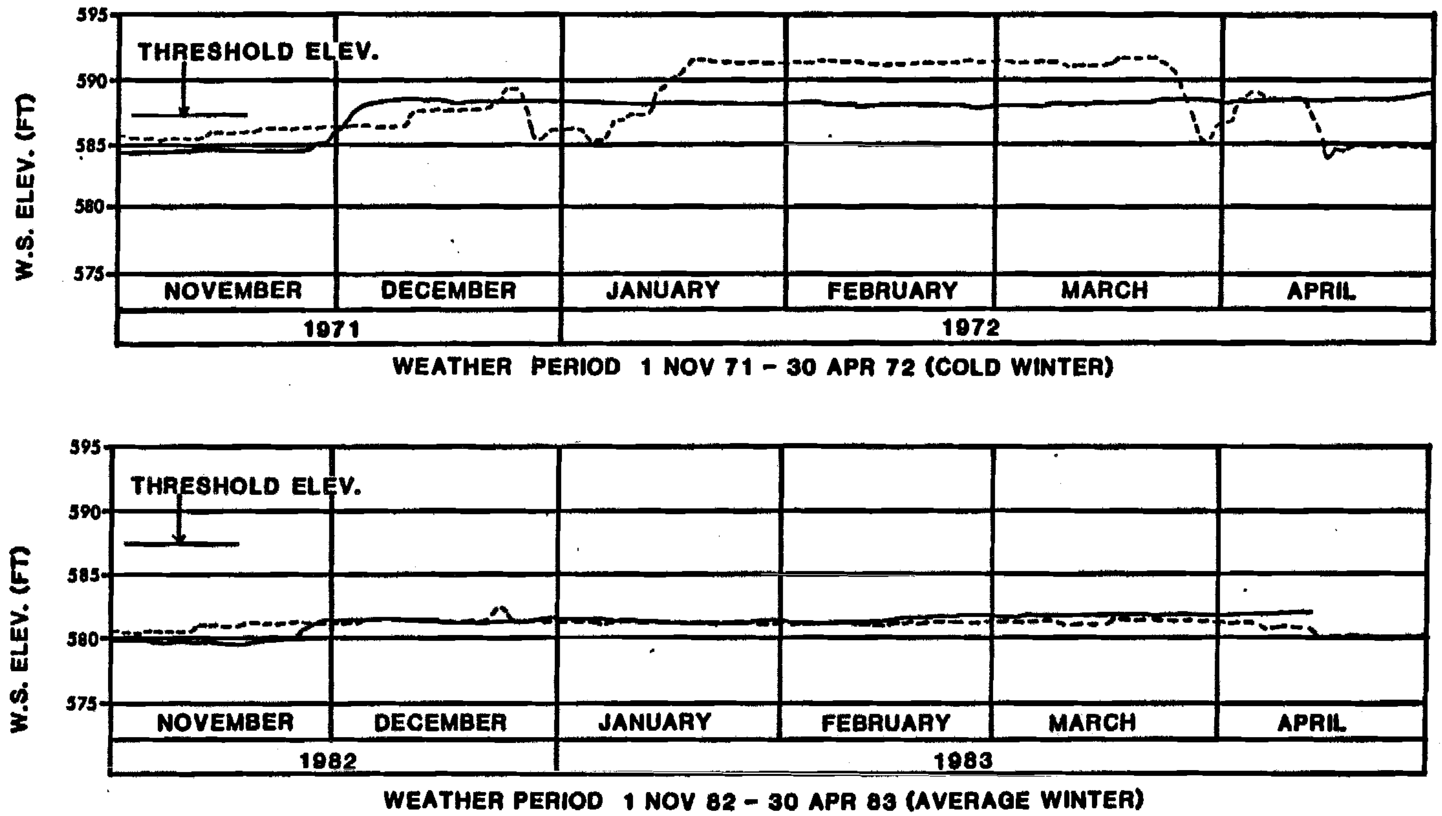
SHORE ICE BUILDUP WITHOUT OVERTOPPING

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

Woodward-Clyde Consultants

HARZA-EBASCO
SUSITNA JOINT VENTURE

FIGURE 2



LEGEND

—— NATURAL FLOW AND WEATHER

---- WATANA 1996 FLOW AND NATURAL WEATHER

REF: HARZA-EBASCO SUSITNA JOINT VENTURE. 1984. INSTREAM ICE SIMULATION STUDY. DRAFT REPORT PREPARED FOR ALASKA POWER AUTHORITY FOR SUSITNA HYDROELECTRIC PROJECT. SEPTEMBER.

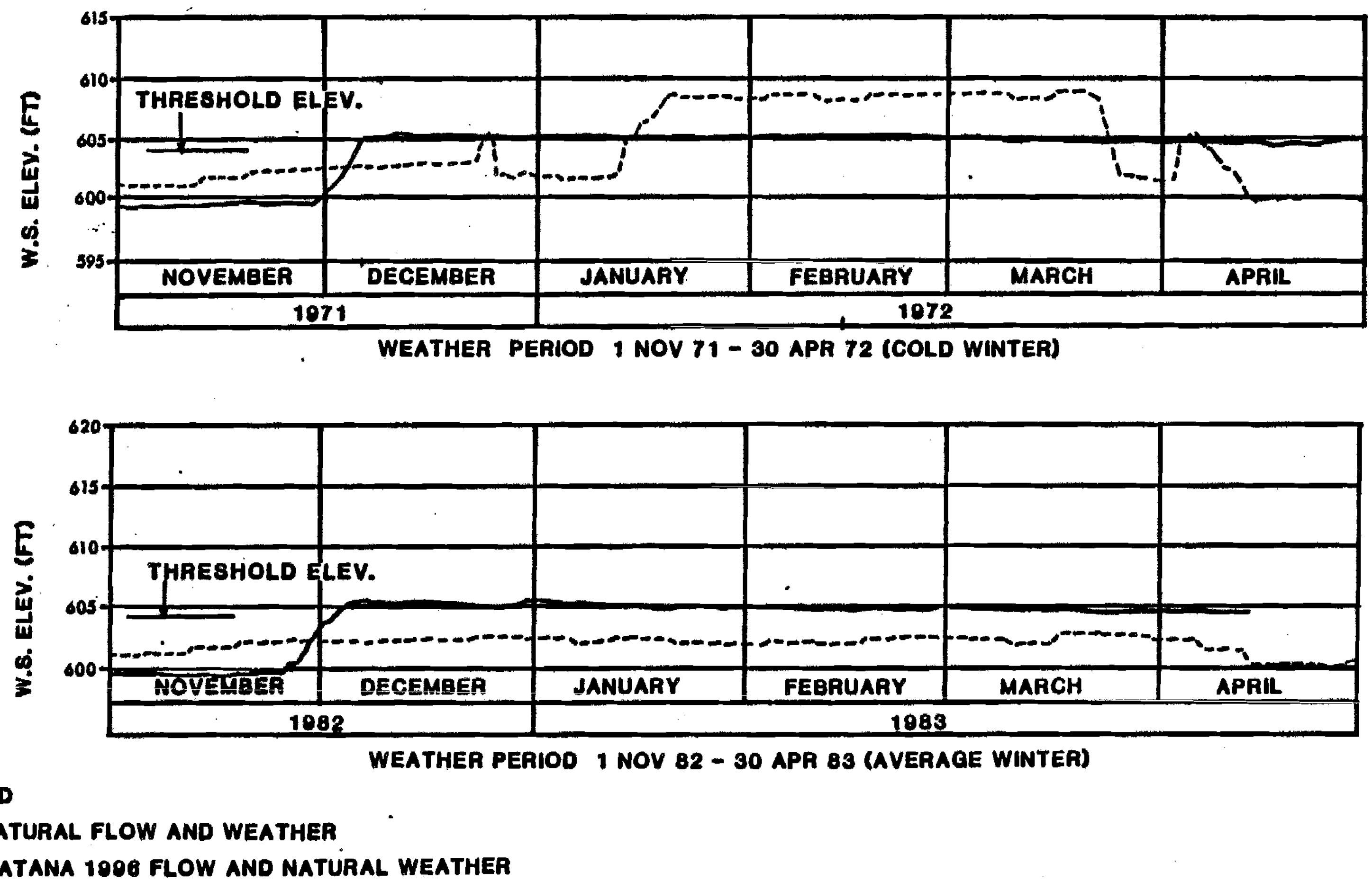
PREDICTED WINTER MAINSTEM STAGES FOR NATURAL AND PROJECT FLOWS NEAR THE HEAD OF SLOUGH 8A

FIGURE 3

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

Woodward-Clyde Consultants

HARZA-EBASCO
SUSITNA JOINT VENTURE



REF: HARZA-EBASCO SUSITNA JOINT VENTURE. 1984. INSTREAM ICE SIMULATION STUDY. DRAFT REPORT PREPARED FOR ALASKA POWER AUTHORITY FOR SUSITNA HYDROELECTRIC PROJECT. SEPTEMBER.

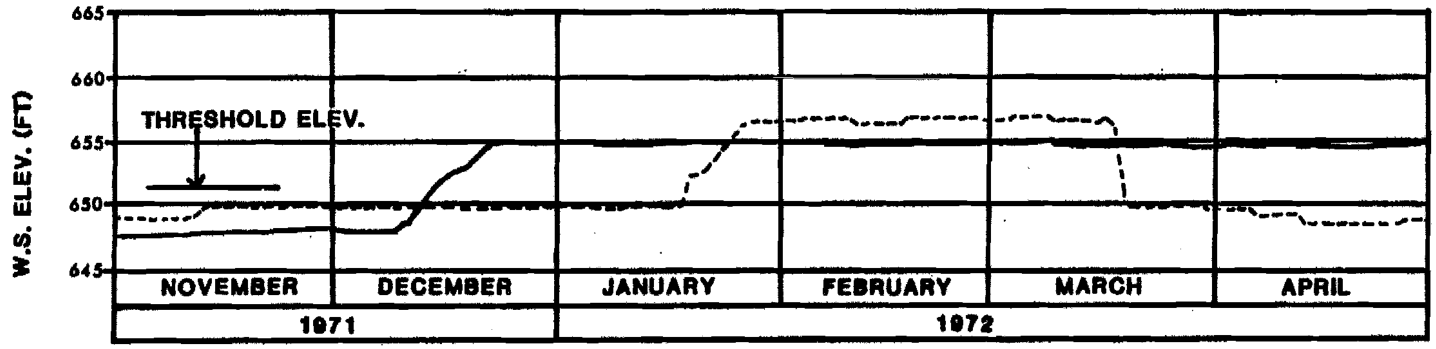
PREDICTED WINTER MAINSTEM STAGES FOR NATURAL AND PROJECT FLOWS NEAR THE HEAD OF SLOUGH 9

FIGURE 4

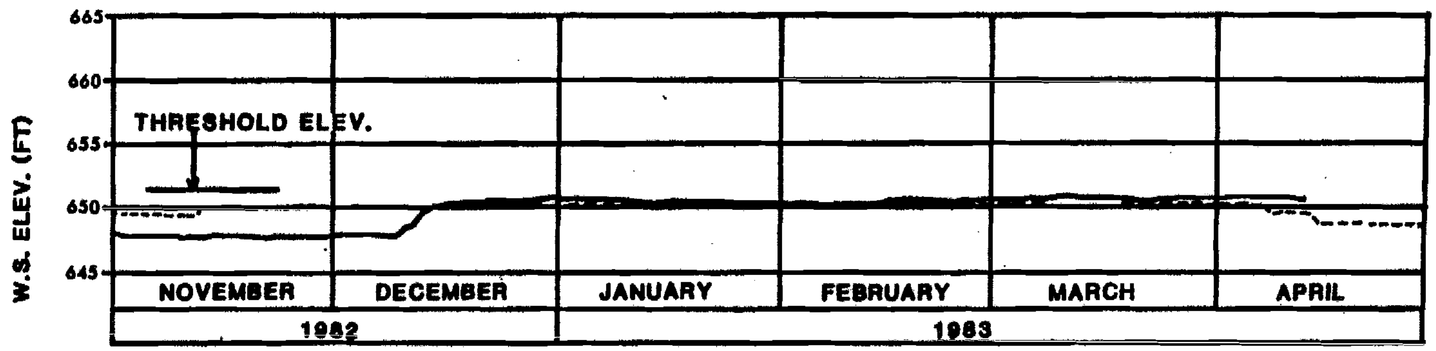
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

Woodward-Clyde Consultants

HARZA-EBASCO SUSITNA JOINT VENTURE



WEATHER PERIOD 1 NOV 71 - 30 APR 72 (COLD WINTER)



WEATHER PERIOD 1 NOV 82 - 30 APR 83 (AVERAGE WINTER)

LEGEND

—— NATURAL FLOW AND WEATHER

---- WATANA 1996 FLOW AND NATURAL WEATHER

REF: HARZA-EBASCO SUSITNA JOINT VENTURE. 1984. INSTREAM ICE SIMULATION STUDY. DRAFT REPORT PREPARED FOR ALASKA POWER AUTHORITY FOR SUSITNA HYDROELECTRIC PROJECT. SEPTEMBER.

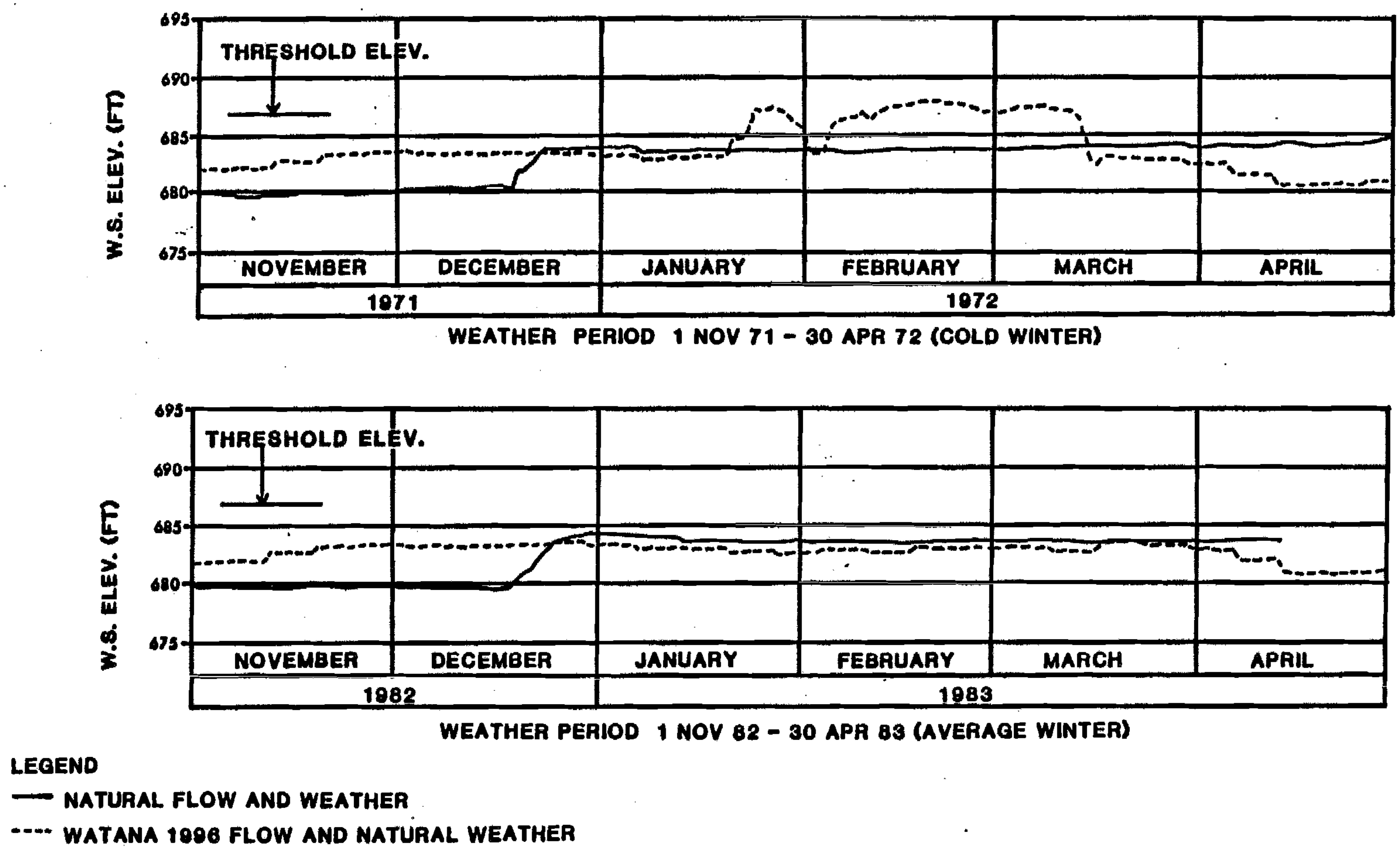
PREDICTED WINTER MAINSTEM STAGES FOR NATURAL AND PROJECT FLOWS NEAR THE HEAD OF SLOUGH 9A

FIGURE 5

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

Woodward-Clyde Consultants

HARZA-EBASCO SUSITNA JOINT VENTURE



REF: HARZA-EBASCO SUSITNA JOINT VENTURE. 1984. INSTREAM ICE SIMULATION STUDY. DRAFT REPORT PREPARED FOR ALASKA POWER AUTHORITY FOR SUSITNA HYDROELECTRIC PROJECT. SEPTEMBER.

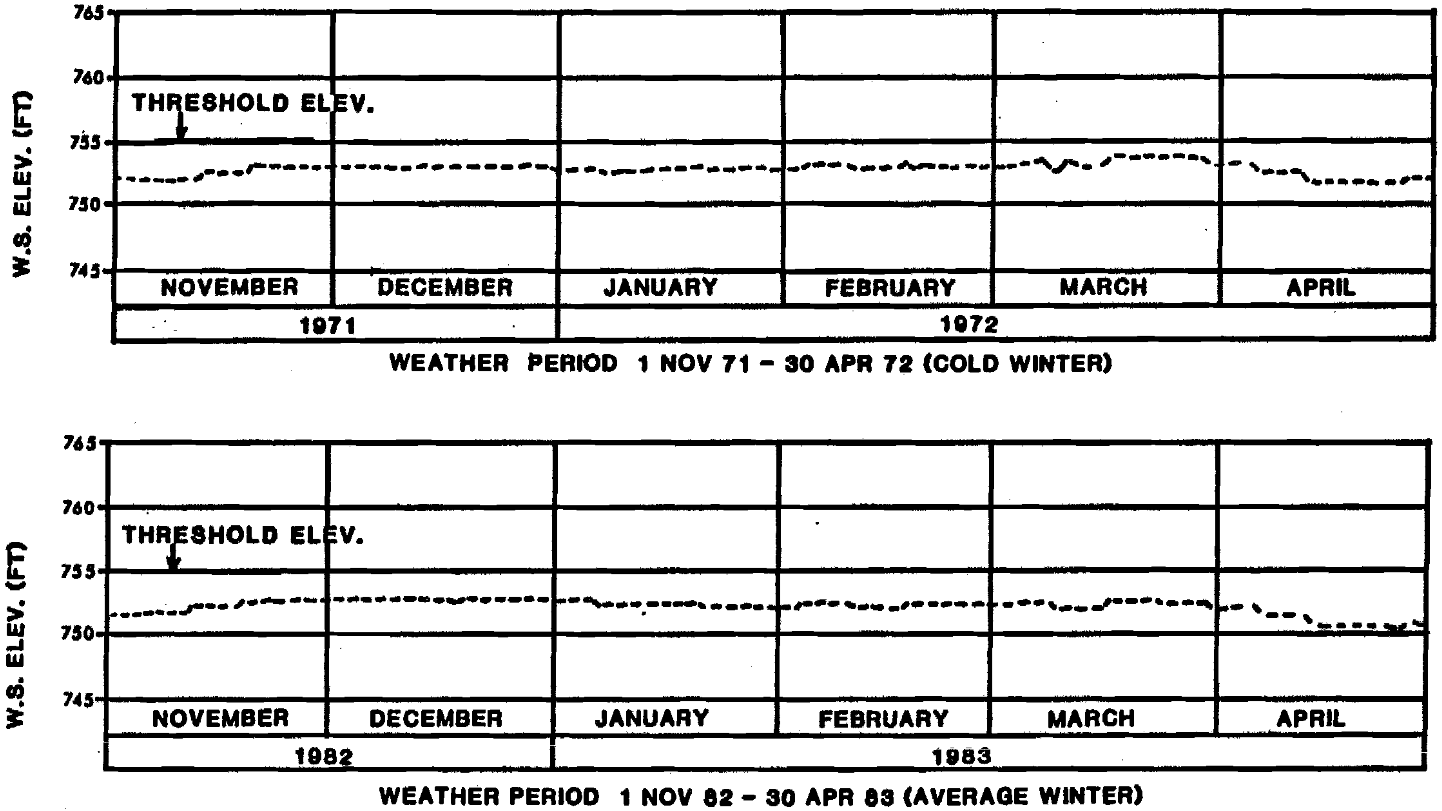
PREDICTED WINTER MAINSTEM STAGES FOR NATURAL AND PROJECT FLOWS NEAR THE HEAD OF SLOUGH 11

FIGURE 6

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

Woodward-Clyde Consultants

HARZA-EBASCO
SUSITNA JOINT VENTURE



LEGEND

—— NATURAL FLOW AND WEATHER

---- WATANA 1996 FLOW AND NATURAL WEATHER

REF: HARZA-EBASCO SUSITNA JOINT VENTURE. 1984. INSTREAM ICE SIMULATION STUDY. DRAFT REPORT PREPARED FOR ALASKA POWER AUTHORITY FOR SUSITNA HYDROELECTRIC PROJECT. SEPTEMBER.

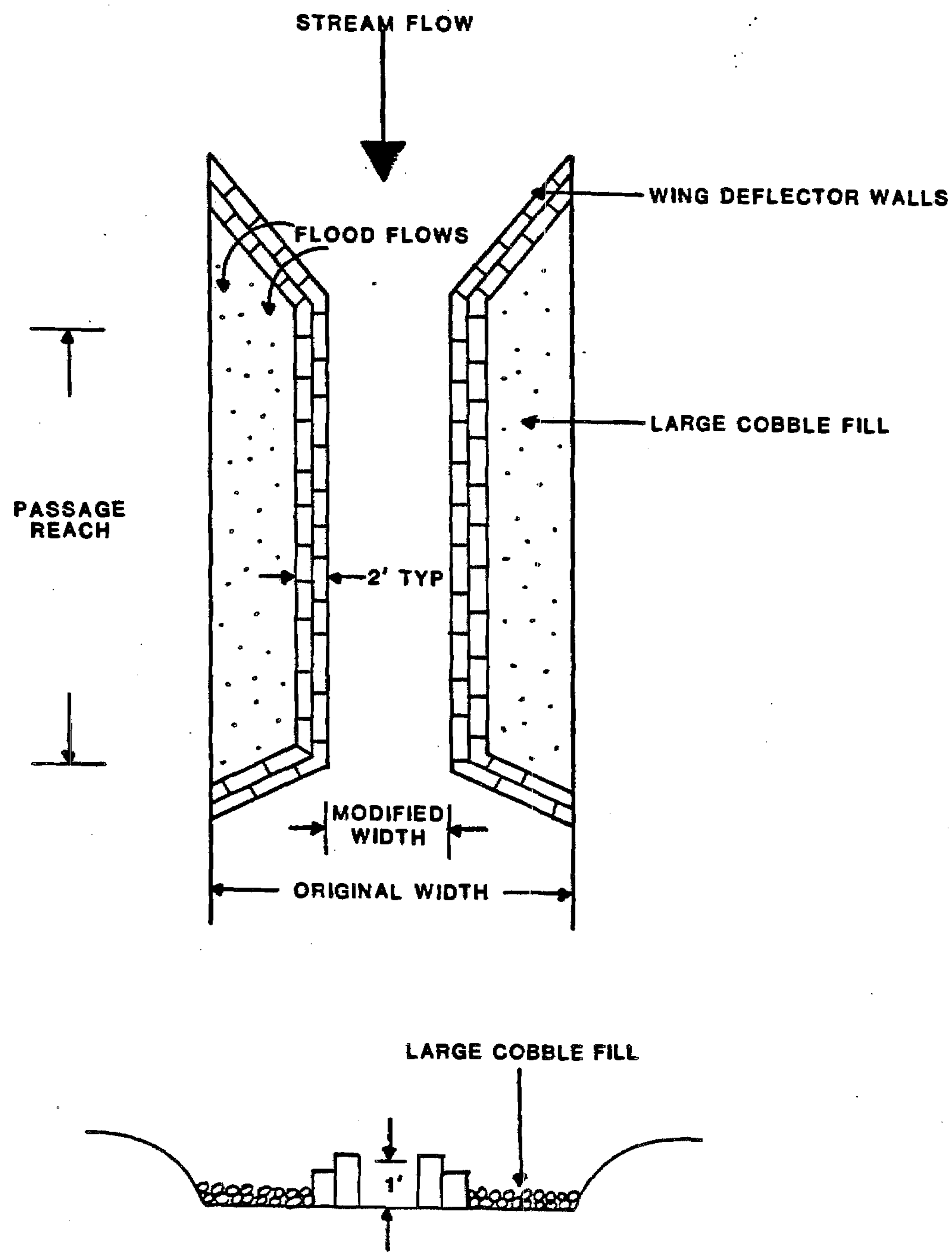
PREDICTED WINTER MAINSTEM STAGES FOR NATURAL AND PROJECT FLOWS NEAR THE HEAD OF SLOUGH 21

FIGURE 7

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

Woodward-Clyde Consultants

HARZA-EBASCO
SUSITNA JOINT VENTURE



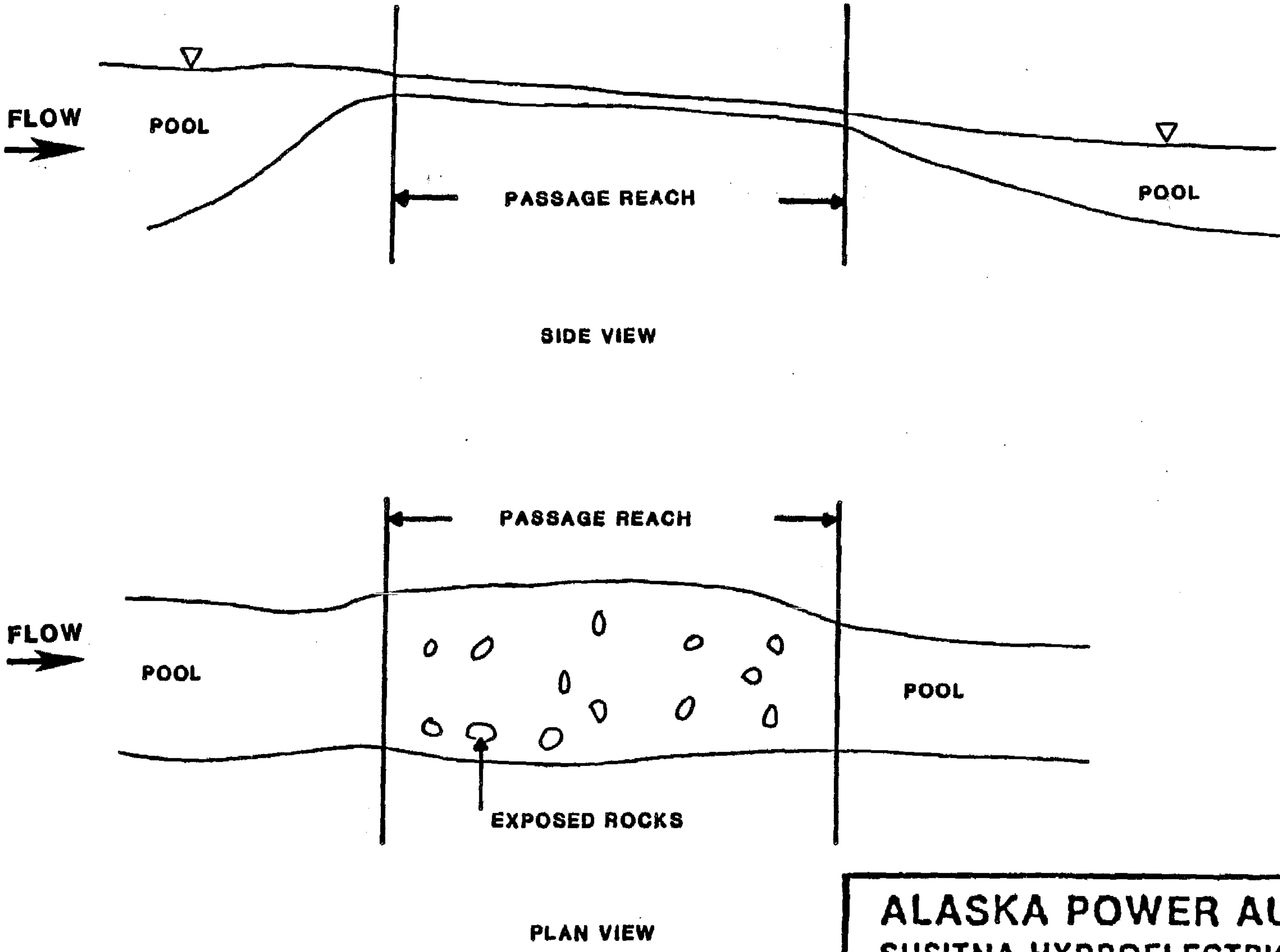
WING DEFLECTOR

FIGURE 8

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

Woodward-Clyde Consultants

HARZA-EBASCO
SUSITNA JOINT VENTURE



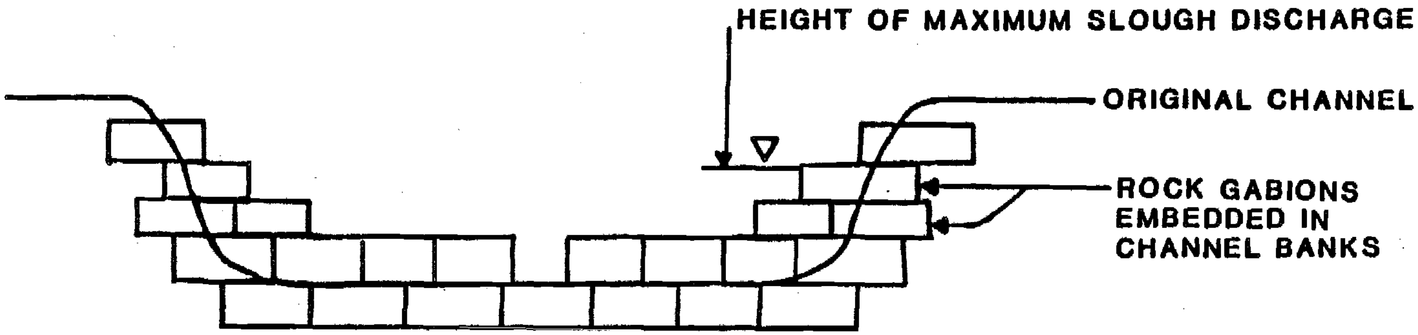
TYPICAL PASSAGE REACH OF SLOUGH ALONG MIDDLE SECTION OF THE SUSITNA RIVER

FIGURE 9

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

Woodward-Clyde Consultants

HARZA-EBASCO
SUSITNA JOINT VENTURE



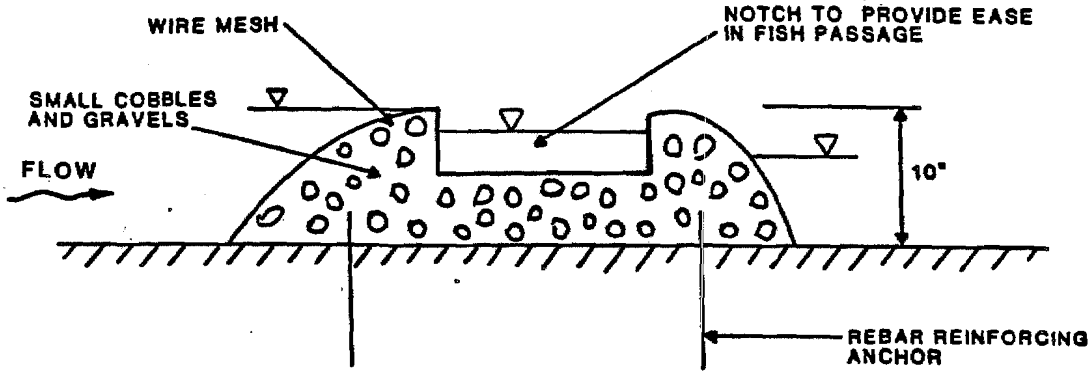
ROCK GABION CHANNEL

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

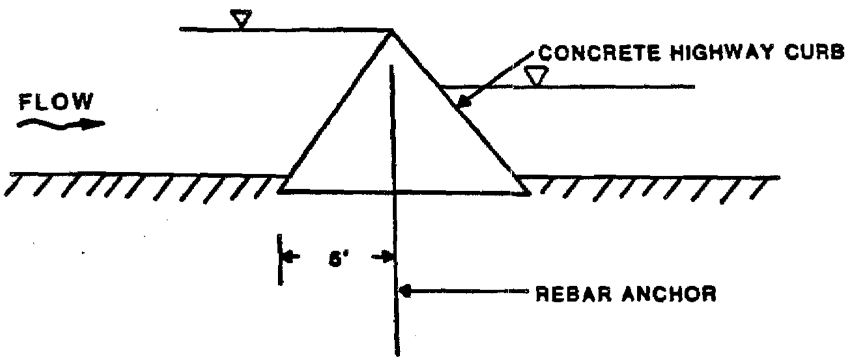
Woodward-Clyde Consultants

HARZA-EBASCO
SUSITNA JOINT VENTURE

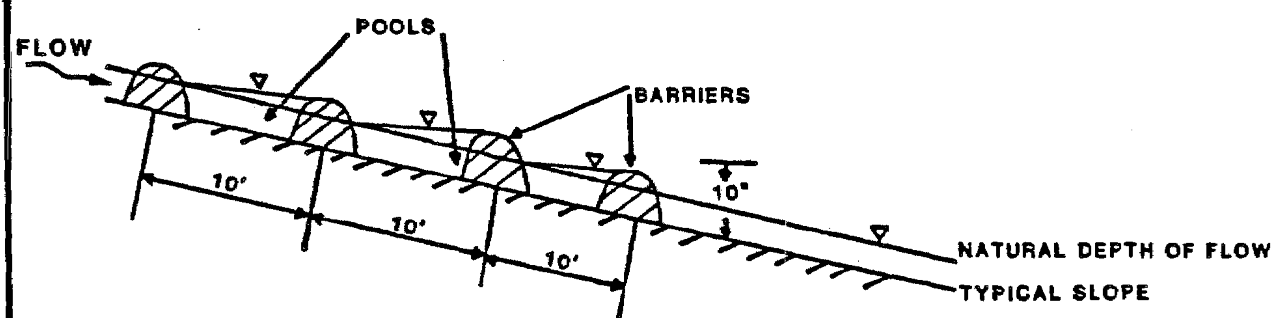
FIGURE 10



GABION BARRIER



HIGHWAY CURB BARRIER



POOL AND WEIR STRUCTURE CREATION OF POOLS BETWEEN BARRIERS

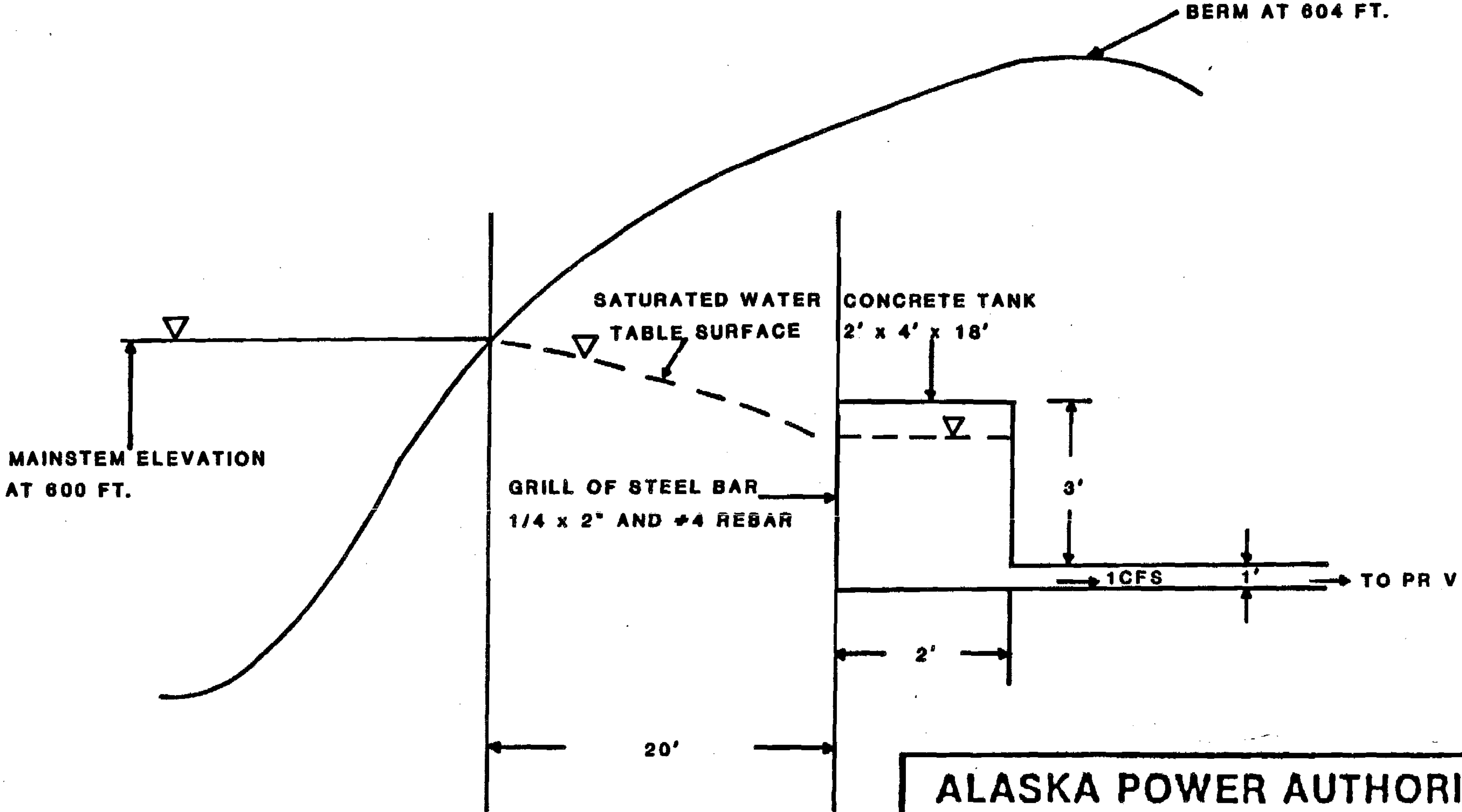
GABION BARRIER
HIGHWAY CURB BARRIER
POOL AND WEIR STRUCTURE

FIGURE 11

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

Woodward-Clyde Consultants

HARZA-EBASCO
SUSITNA JOINT VENTURE



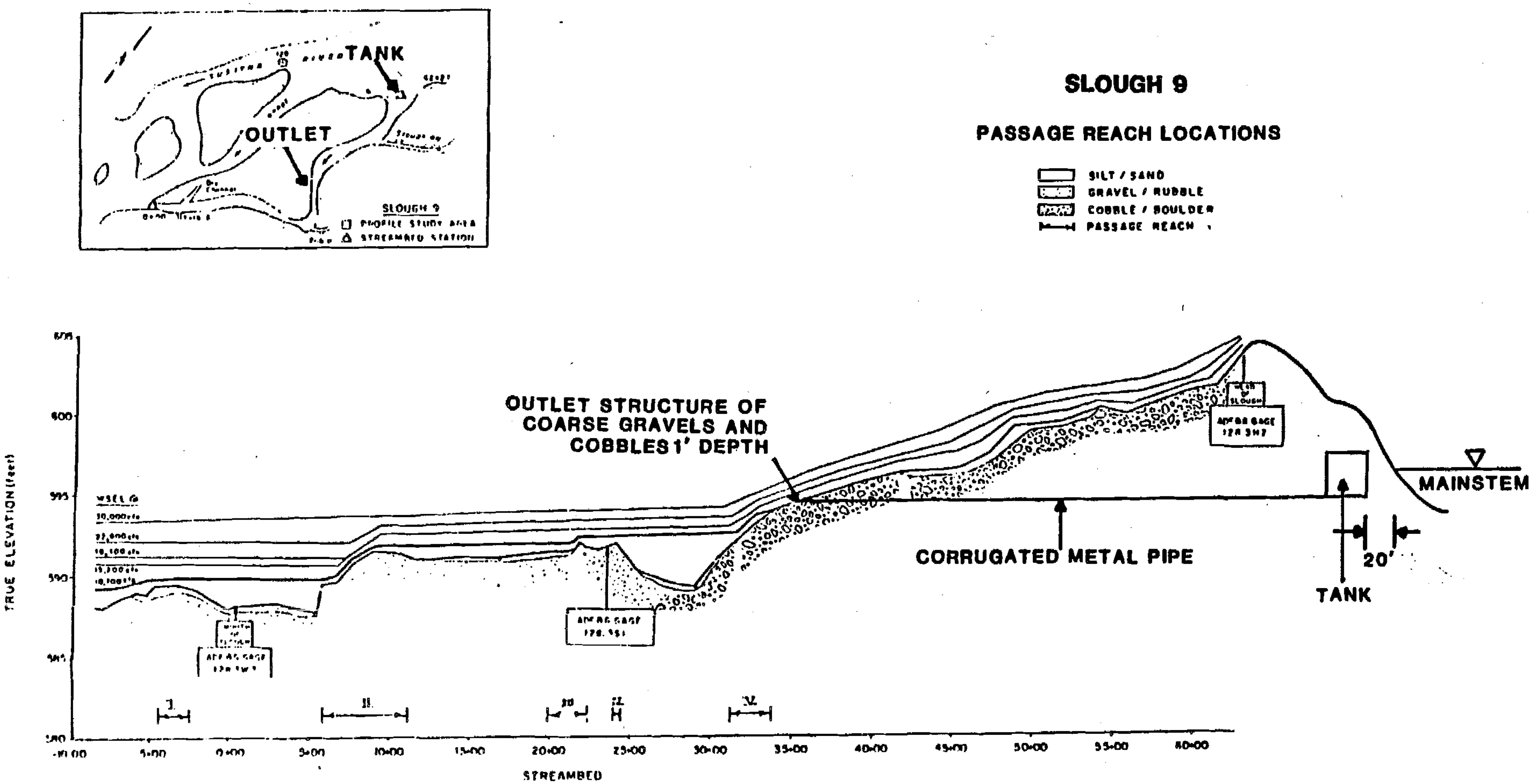
COLLECTOR TANK AT SLOUGH 9

FIGURE 12

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

Woodward-Clyde Consultants

HARZA-EBASCO
SUSITNA JOINT VENTURE



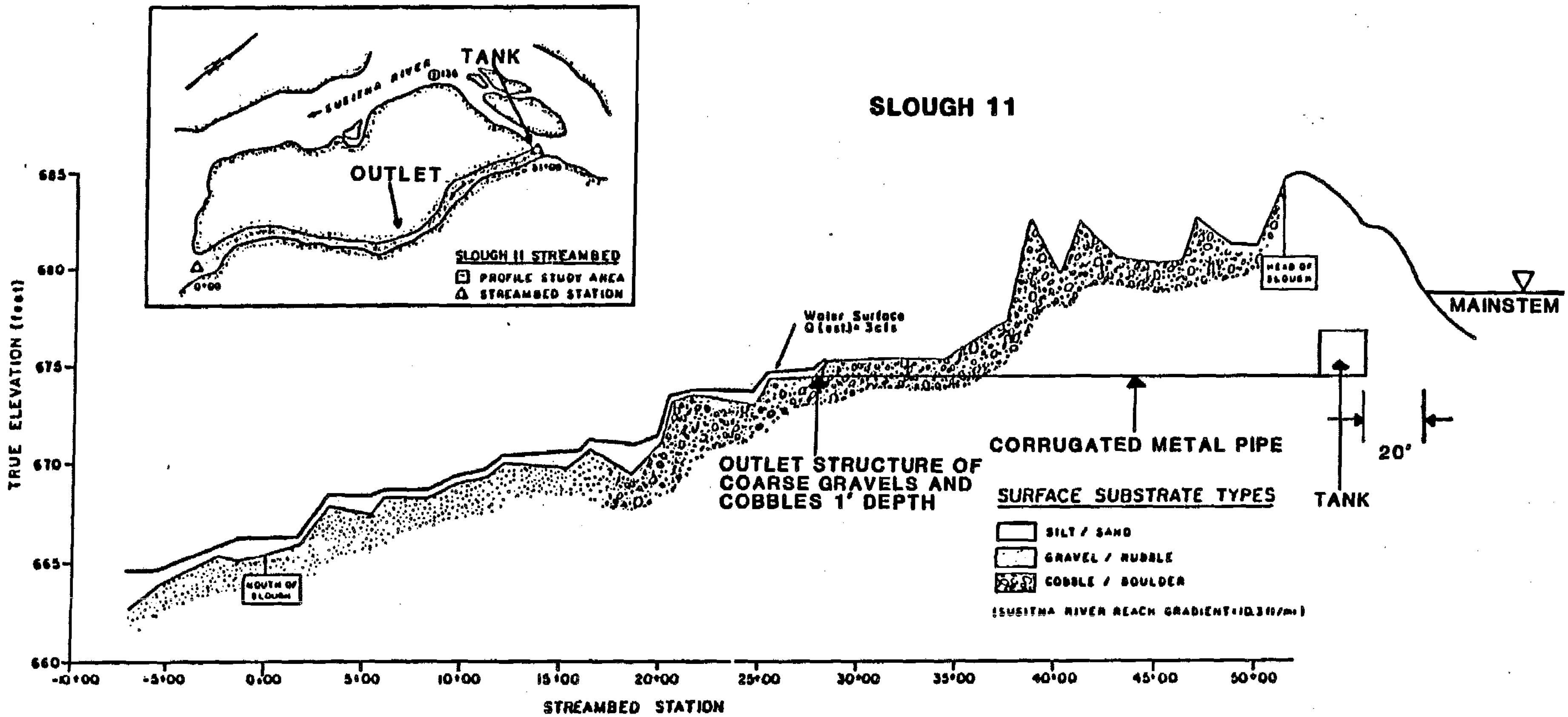
THALWEG PROFILE OF SLOUGH 9

FIGURE 13

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

Woodward-Clyde Consultants

HARZA-EBASCO
SUSITNA JOINT VENTURE



THALWEG PROFILE OF SLOUGH 11

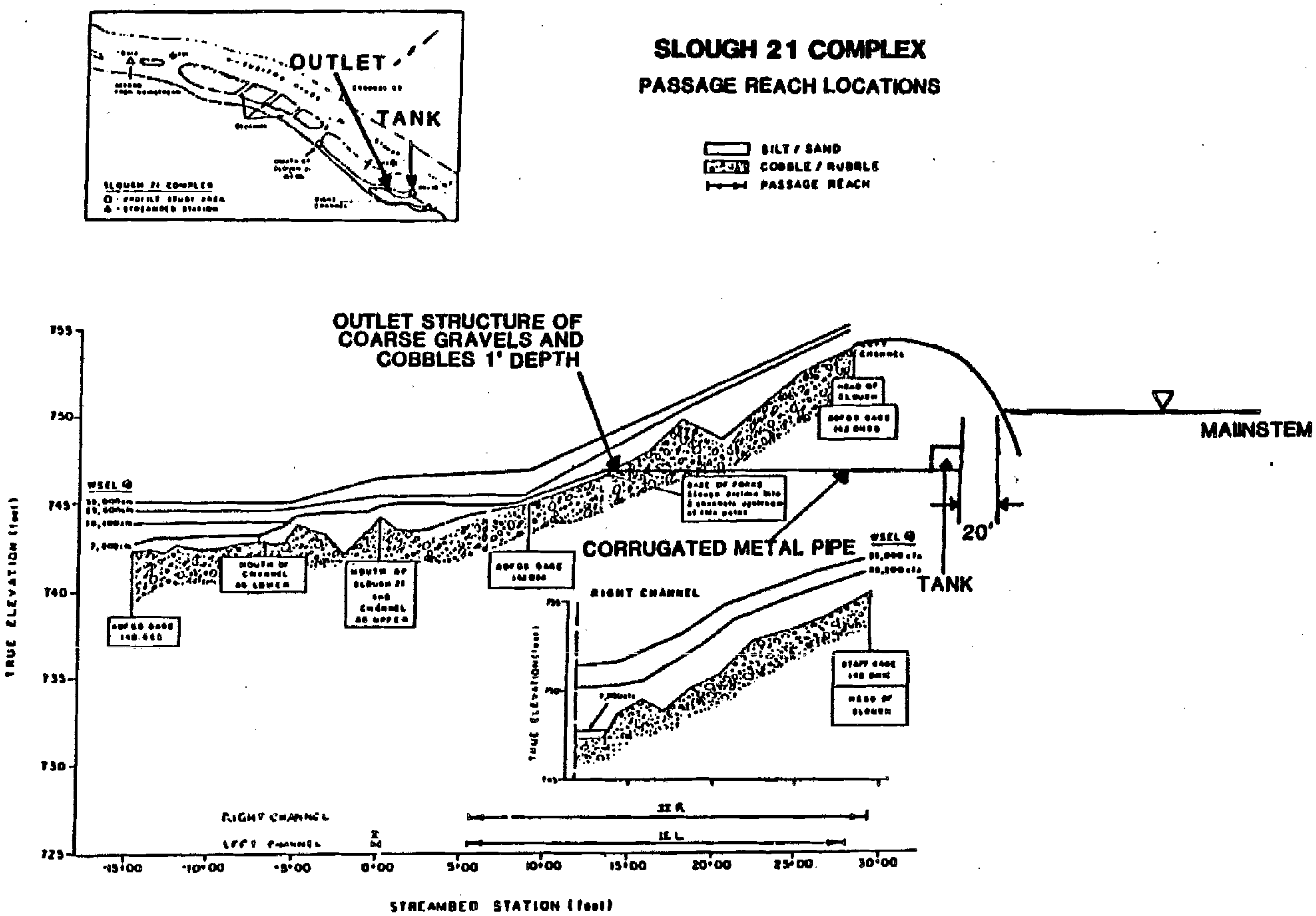
FIGURE 14

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

Woodward-Clyde Consultants

HARZA-EBASCO
SUSITNA JOINT VENTURE

SLOUGH 21 COMPLEX
PASSAGE REACH LOCATIONS



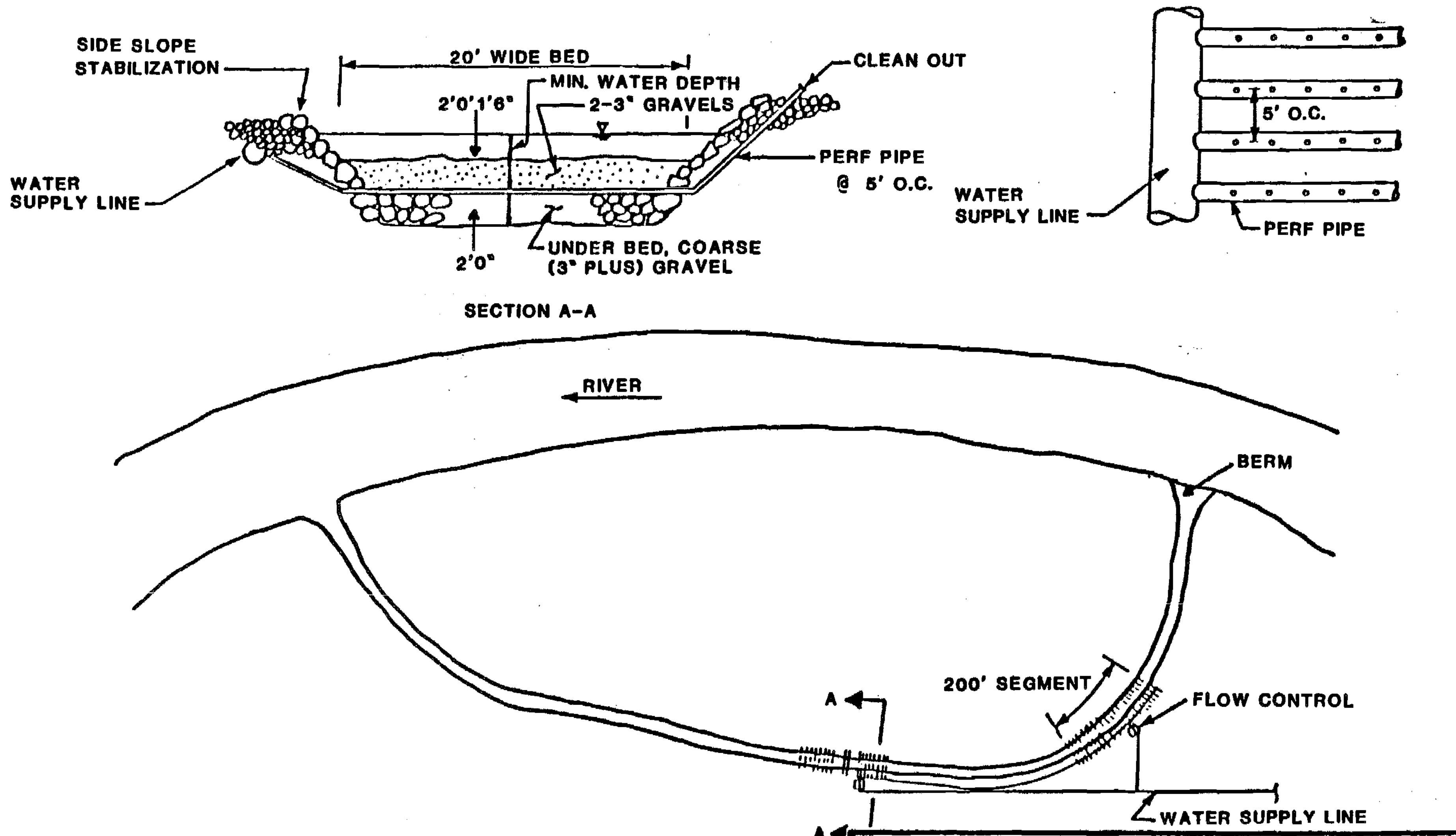
THALWEG PROFILE OF SLOUGH 21

FIGURE 15

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

Woodward-Clyde Consultants

HARZA-EBASCO
SUSITNA JOINT VENTURE



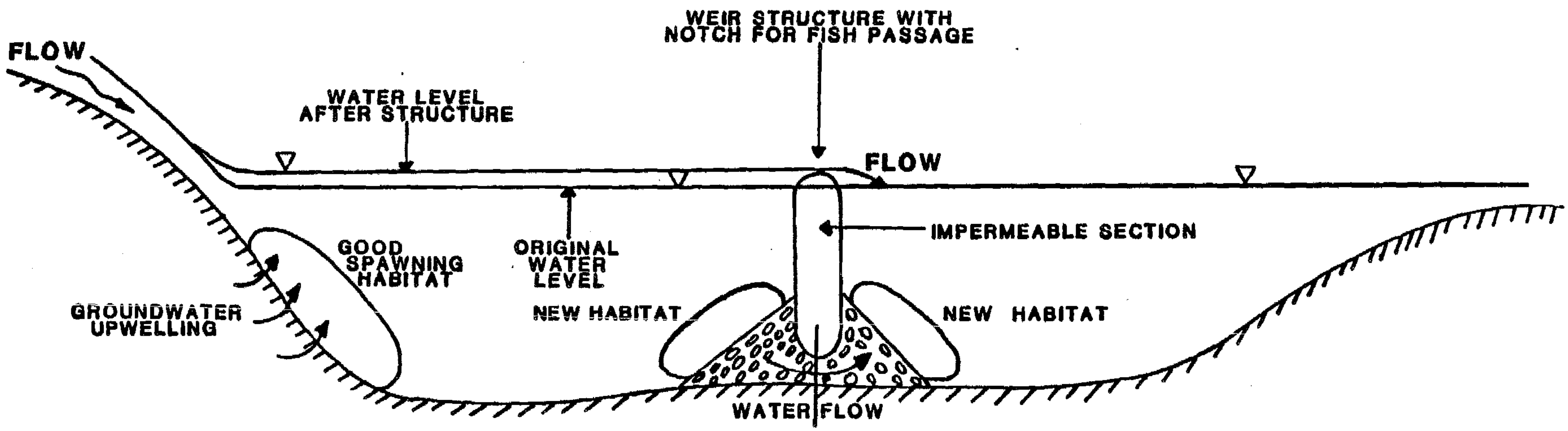
SUSITNA RIVER FISHERY MITIGATION INDUCED UPWELLING USING TRIBUTARY WATER SUPPLY

FIGURE 16

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

Woodward-Clyde Consultants

HARZA-EBASCO
SUSITNA JOINT VENTURE



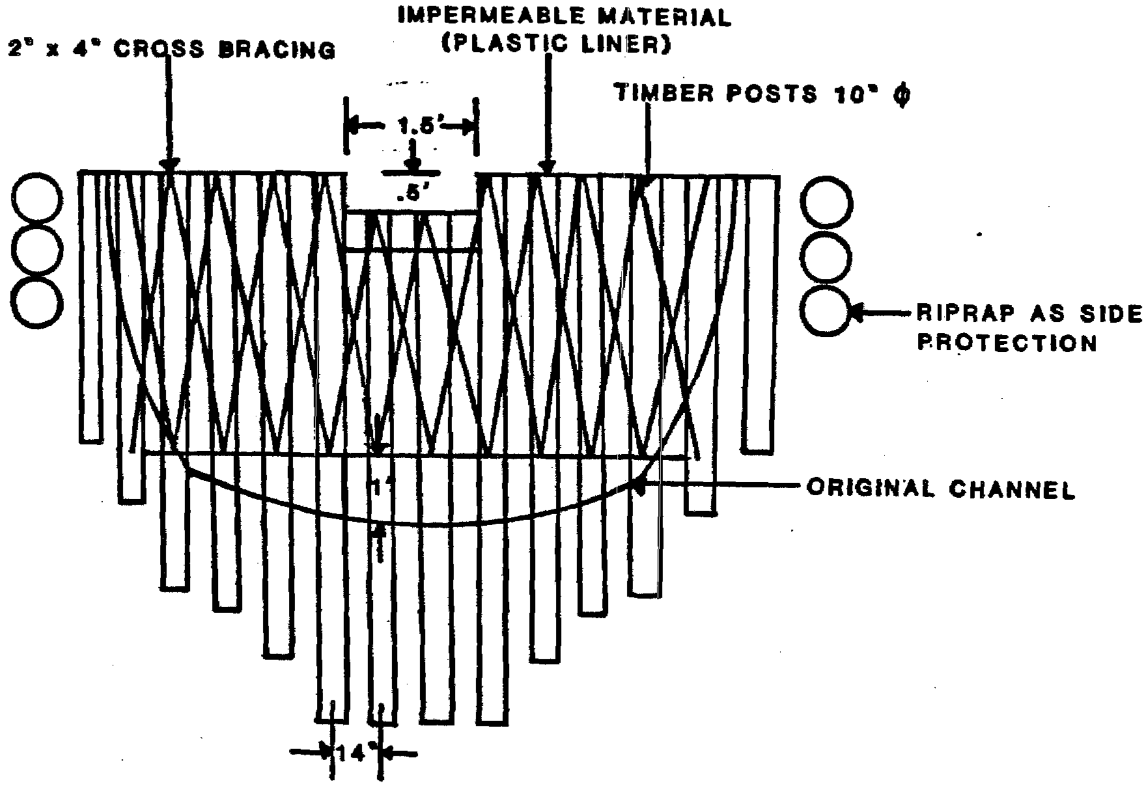
WEIR TO INCREASE SPAWNING HABITAT

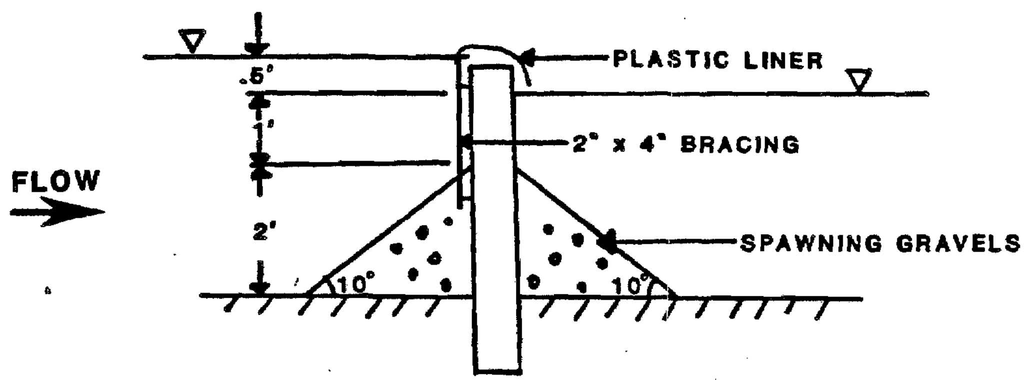
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

Woodward-Clyde Consultants

HARZA-EBASCO
SUSITNA JOINT VENTURE

FIGURE 17





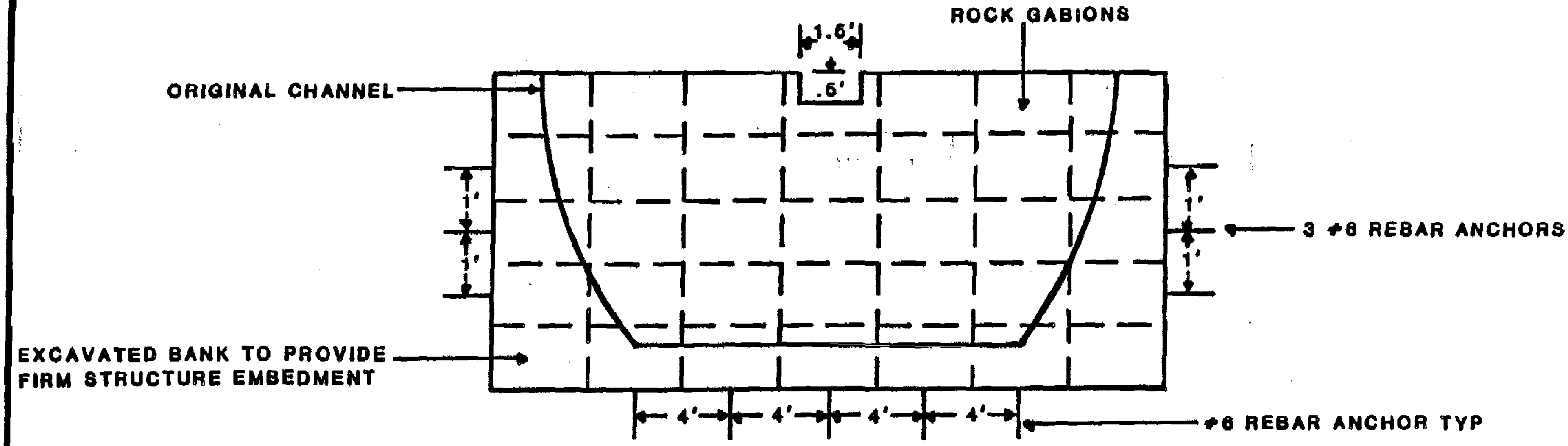
TIMBER POST WEIR

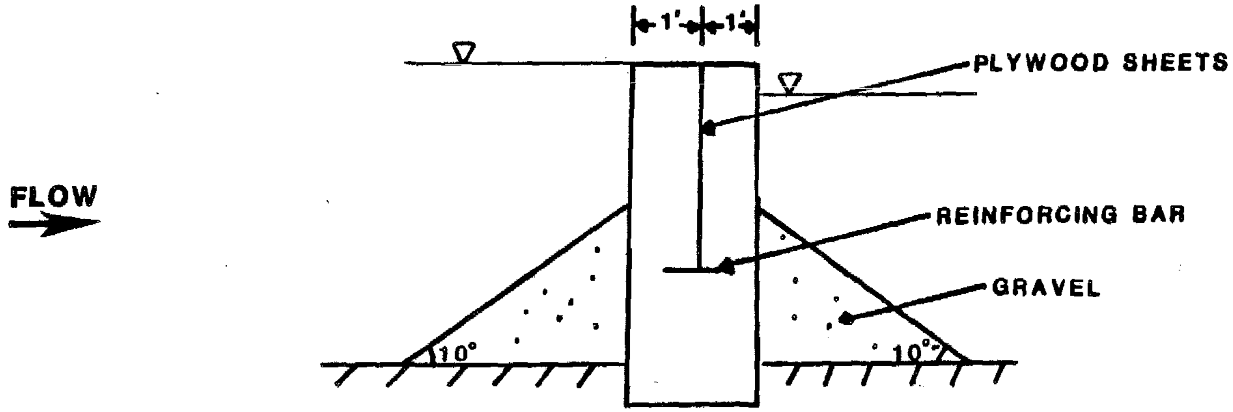
FIGURE 18

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

Woodward-Clyde Consultants

HARZA-EBASCO
SUSITNA JOINT VENTURE





ROCK GABION SIZES: 3' x 1' x 1'
& 3' x 1' x 2'

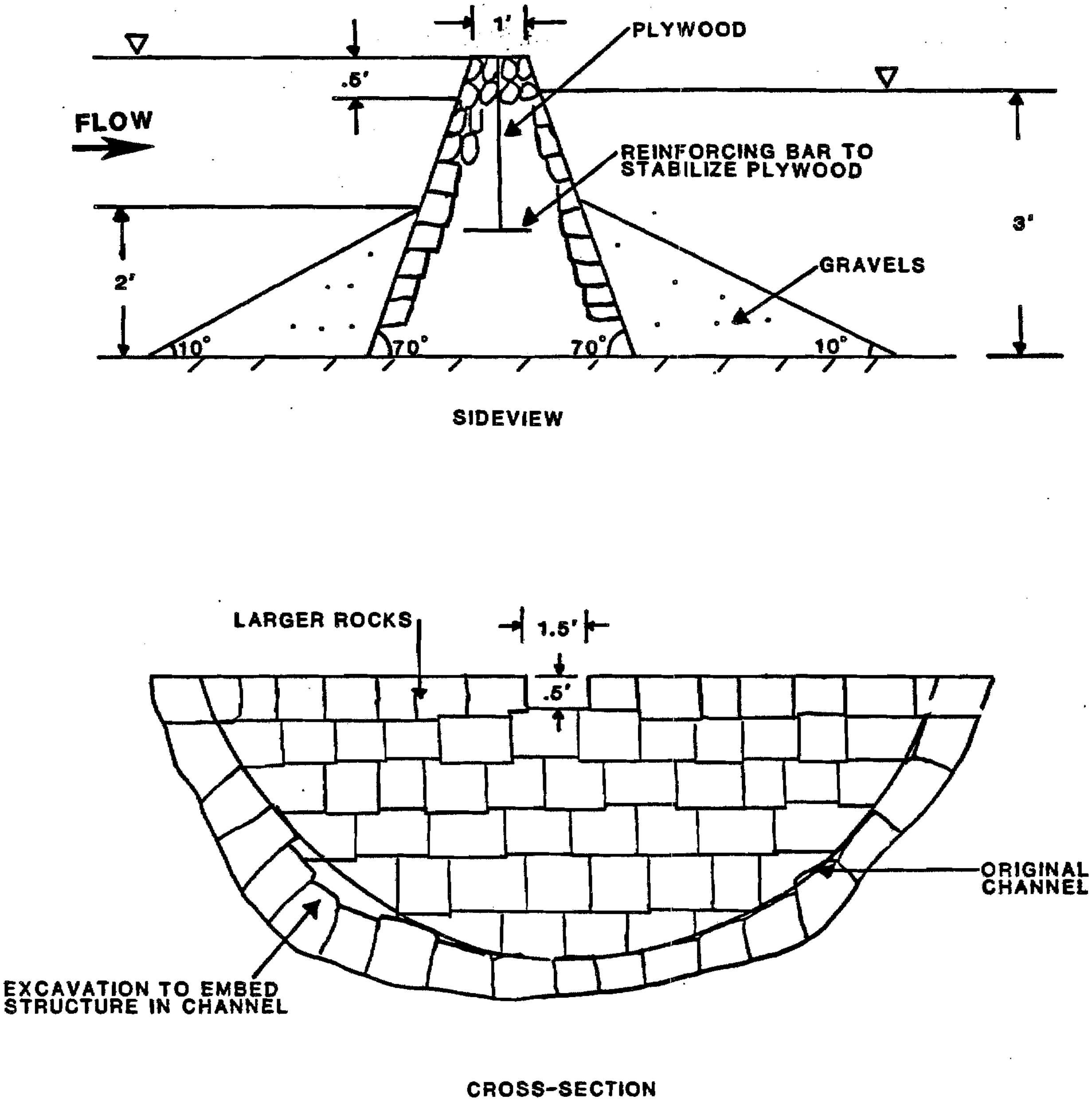
ROCK GABION WEIR

FIGURE 19

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

Woodward-Clyde Consultants

HARZA-EBASCO
SUSITNA JOINT VENTURE



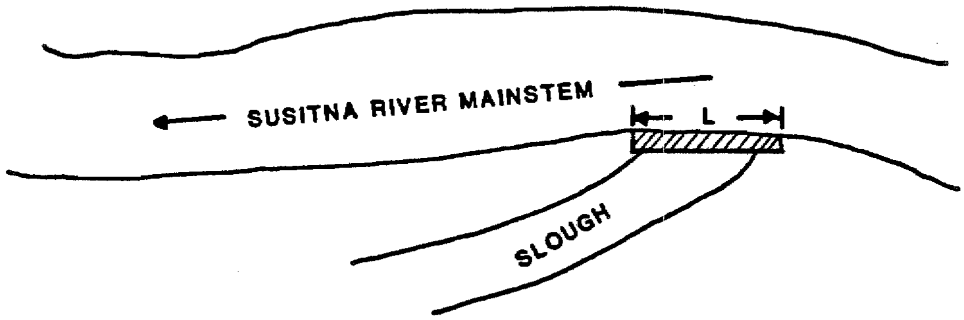
ROCK WEIR

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

Woodward-Clyde Consultants

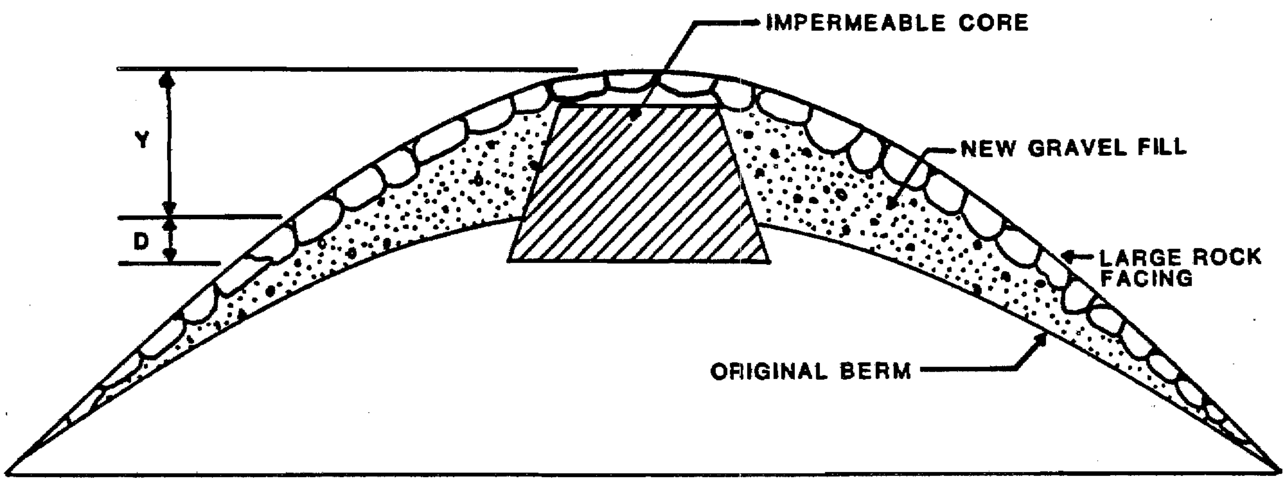
HARZA-EBASCO
SUSITNA JOINT VENTURE

FIGURE 20



PLAN VIEW

L=LENGTH OF BERM



CROSS-SECTIONAL VIEW

D=DEPTH OF EXCAVATION FOR IMPERMEABLE CORE

Y=INCREASED HEIGHT ABOVE ORIGINAL BERM

BERM DESIGN TO PREVENT OVERTOPPING OF SLOUGHS

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

Woodward-Clyde Consultants

HARZA-EBASCO
SUSITNA JOINT VENTURE

FIGURE 21

APPENDIX A

APPENDIX A

Passage Reach Flow Evaluation

A previous analysis assessed the required local flow for successful fish passage through the passage reaches of the sloughs along the middle section of the Susitna River (ADF&G 1984c). In order to evaluate the available local flow in sloughs 8A, 9, 9A, 11 and 21 in comparison to the required local flows, an analysis of the local flow sources for each slough was conducted. A primary source of local flow for most of these sloughs is groundwater related to the mainstem discharge (APA 1984).

The relationships developed for slough local flow at the R&M gage site within the slough versus mainstem discharge measured at Gold Creek are listed below (APA 1984).

Slough	Regression Equation	r^2
8A	S = -.629 + .000128G	.632
9	S = 1.97 + .000351G	.805
11	S = 1.52 + .000102G	.765
21	S = 7.55 + .00105G	.542

S = Slough Discharge

G = Mainstem Discharge at Gold Creek

These relationships were used to estimate the amounts of local flow at the R&M gage site in a slough given a mainstem discharge. In order to obtain the local flow at other points within the slough, the amounts of upwelling throughout the slough were estimated in terms of percent of the gage flow using aerial photographs, observations by R&M personnel (R&M Consultants, Inc. 1982), and measured upwelling values (APA 1984 and WCC 1984). The percentage values were applied to the calculated flow at the gage resulting in estimates of local flow at points corresponding to passage reaches in the slough. For slough 9A, measured upwelling values were correlated with mainstem discharge to yield local flow at the passage reaches.

A comparison between required local flow and estimated available local flow was made. Tables B1 to B5 present the required passage reach discharges and the calculated available passage reach discharges. Other potential contributions to the flow through the passage reaches were then considered. An evaluation was conducted of how much of the time the local flow requirements could be satisfied by groundwater flow alone. The required local flow was input to the relationship between slough flow and mainstem discharge to obtain the required mainstem dsicharge. The flow duration curve for the mainstem discharge was used to evaluate the percent occurrence of these flows.

A combination of surface water and groundwater sources was analyzed on the basis of the assumption that groundwater was at a level corresponding to typical mainstem flows. For natural slough flows, the mainstem discharge of 50 percent occurrence equalling 15,000 cfs was chosen as the basis for groundwater flows. The flow duration curve developed for the period 20 August to 20 September (ADF&G 1984c) was used for the natural flows. Project flows were assumed constant at 9,000 cfs and 8,000 cfs. The percent of time that tributary inflow was sufficient to supplement groundwater was based on an estimate of the contributing basin area, an assumed runoff percentage of 40 percent, and precipitation duration curves for Talkeetna for the period of 1972 to 1981 (Tables B1 to B5). The percent occurrence of successful passage for passage reaches affected by backwater and breaching was previously analyzed (ADF&G 1984c).

The final value selected for each passage reach was the largest percent successful passage occurrence value of those calculated. Tables B6-B11 were used for the identification of the maximum percent occurrence given each contributing flow. These tables identify passage reaches impacted by a decrease in mainstem flow. Any additive effects of accumulation of percent occurrences were assumed negligible.

Table B1. Required and available passage reach discharges and percent exceedance of passage for the period 20 August - 20 September at Slough 8a

Passage Reach (PR)	Req'd Flow[a] (cfs)	Base GW Flow (cfs) Nat'l	9,000	8,000	Required Surface Water (cfs) Nat'l	9,000	8,000	Basin area (mile²)	Amount Prec. Neeeded (in.) Nat'l	9,000	8,000	% Exceedance Based on Total Daily ppt Nat'l	9,000	8,000
I	2	1.3	0.5	0.4	0.7	1.5	1.6	1.36	.01	.03	.03	32	25	24
II	(4)	1.3	0.5	0.4	2.7	3.5	3.6	1.36	.05	.06	.06	19	16	15
III	4	1.3	0.5	0.4	2.7	3.5	3.6	1.36	.05	.06	.06	19	16	15
IV	(5)	0.8	0.3	0.2	4.2	4.7	4.8	1.09	.09	.1	.1	9	7	7
V	5	0.7	0.3	0.2	4.3	4.7	4.8	1.09	.09	.1	.1	9	7	7
VI	(4)	0.6	0.2	0.2	3.4	3.8	3.8	.96	.08	.09	.09	12	9	9
VII	(4)	0.5	0.2	0.1	3.5	3.8	3.9	.96	.08	.09	.09	11	9	9
VIII	4	0.3	0.1	0.1	3.7	3.9	3.9	.55	.16	.17	.17	4	3	3
IX	4	0.2	0.1	0.1	3.8	3.9	3.9	0	b	b	b	0	0	0

[a] Numbers in parenthesis assume that required flow at upstream PR is sufficient for passage at downstream PR.

[b] Not possible; basin area is insufficient to provide surface runoff

Table B2. Required and available passage reach discharges and percent exceedance of passage for the period 20 August - 20 September at Slough 9

Passage Reach (PR)	Req'd Flow[a] (cfs)	Base GW Flow (cfs			Required Surface Water (cfs)			Basin Area (mile²)	Amount Precip Needed (in.)			% Exceedance Based on Total Daily ppt		
		Nat'l	9,000	8,000	Nat'l	9,000	8,000		Nat'l	9,000	8,000	Nat'l	9,000	8,000
I	2	8.9	6.3	5.9	0	0	0	2.99	0	0	0	100	100	100
II	1	8.4	6.0	5.6	0	0	0	1.73	0	0	0	100	100	100
III	6	7.2	5.1	4.8	0	.9	1.2	1.73	0	.01	.02	100	34	29
IV	(6)	6.8	4.8	4.6	0	1.2	1.4	1.73	0	.02	.02	100	29	28
V	(6)	5.5	3.9	3.7	.5	2.1	2.3	0	b	b	b	0	0	0

a Numbers in parenthesis assume that required flow at downstream PR is sufficient for passage at upstream PR

b Not possible; basin area is insufficient to provide surface runoff.

Table B3. Required and available passage reach discharges and percent exceedance of passage for the period of 20 August - 20 September at Slough 9A.

Passage Reach (PR)	Req'd Flow[a] (cfs)	Base GW Flow (cfs)			Required Surface Water (cfs)			Basin Area (mile²)	Amount Precip Needed (in.)			% Exceedance Based on Total Daily ppt		
		Nat'l	9,000	8,000	Nat'l	9,000	8,000		Nat'l	9,000	8,000	Nat'l	9,000	8,000
I	1	4.4	3.1	2.98	0	0	0	2.27	0	0	0	100	100	100
II	3	4.3	3.0	2.5	0	0	.5	2.27	0	0	.005	100	100	41
III	3	4.1	7.8	2.0	0	.2	1.0	.35	0	0.01	.07	100	32	14
IV	1	3.8	2.5	1.9	0	0	0	.35	0	0	0	100	100	100
V	(2)	3.3	2.0	1.6	0	0	.4	.21	0	0	.04	100	100	20
VI	(2)	3.1	1.8	1.53	0	.2	.47	.17	0	.03	.06	100	24	14
VII	(2)	2.8	1.5	1.3	0	.5	.7	.13	0	.09	.13	100	10	7
VIII	(2)	2.7	1.4	1.2	0	.6	.8	.10	0	.14	.19	100	6	3
IX	2	2.5	1.3	1.13	0	.7	.87	.08	0	.20	.25	100	3	2
X	3	0	0	0	3	3	3	.02	b	b	b	b	b	b

[a] Numbers in parenthesis assume that required flow at upstream PR is sufficient for passage at downstream PR

[b] Not possible; basin area is insufficient to provide surface runoff

Table B4. Required and available passage reach discharges and percent exceedance of passage for the period of 20 August - 20 September at Slough 11.

Passage Reach (PR)	Flow (cfs)	% Exceedance[b]			Base GW Flow (cfs)			Required Surface Water[a] (cfs)		
		Nat'l	9,000	8,000	Nat'l	9,000	8,000	Nat'l	9,000	8,000
I	4	70	0	32	4.5	3.5	3.3	0	.5	.7
II	4	43	0	13	3.9	3.0	2.9	.1	1.0	1.1
III	4	12	0	0	3.2	2.4	2.3	.8	1.6	1.7
IV	8	0	0	0	3.0	2.3	2.2	5.0	5.7	5.8
V	4	0	0	0	2.0	1.6	1.5	2.0	3.4	3.5

[a] Surface water is not available due to lack of contributing drainage basin

[b] Percent exceedance to provide required flows from groundwater supplies only

Table B5. Required and available passage reach discharges and percent exceedance of passage for the period of 20 August - 20 September at Slough 21 Complex.

Passage Reach (PR)	Req'd Flow[a] (cfs)	Base GW Flow (cfs) Nat'l	9,000	8,000	Surface Water (cfs) Nat'l	9,000	8,000	Basin Area (mile²)	Amount Precip Neeeded (in.) Nat'l	9,000	8,000	% Exceedance Based on Total Daily ppt Nat'l	9,000	8,000
Slough 21														
I	5	10.0	2.3	1.1	0	2.7	4.9	.52	0	.12	.22	100	6	4
IIL	5	2.9	0.7	.3	2.1	4.3	4.7	0	b	b	b	0	0	0
IIR	5	3.2	0.7	.4	1.8	4.3	4.6	.26	.16	.39	.41	4	1	1
Side channel 21														
I	(8)	18.1	4.2	2.0	0	3.8	6.0	5.03	0	.02	.03	100	28	24
II	8	18.0	4.2	2.0	0	3.8	6.0	5.03	0	.02	.03	100	28	24
III	(7)	17.5	4.1	1.9	0	2.9	5.1	5.03	0	.01	.02	100	31	26
IV	7	17.5	4.1	1.9	0	2.9	5.1	5.03	0	.01	.02	100	31	26
V	18	17.4	4.0	1.9	.6	14.0	16.1	.52	.03	.63	.73	24	1	.5
VI	(20)	17.2	4.0	1.9	2.8	16.0	18.1	.52	.13	.72	.81	7	.5	0
VII	(20)	16.8	3.9	1.8	3.2	16.1	18.2	.52	.14	.73	.82	6	.5	0
VIII	(20)	16.5	3.8	1.8	3.5	16.2	18.2	.52	.16	.73	.82	4	5	0
IX	20	16.4	3.8	1.8	3.6	16.2	18.2	.52	.16	.73	.82	4	.5	0
X	(5)	12.5	2.9	1.4	0	2.1	3.6	.52	0	.09	.16	100	9	5

[a] Numbers in parenthesis assume that required flow at upstream PR is sufficient for passage at downstream PR

[b] Not possible; basin area is insufficient to provide surface runoff

Table B6. Percent exceedance of successful passage due to breaching flows, backwater effects, groundwater and surface water discharges for the period of 20 August to 20 September at Slough 8A.

		BREACHING		BACKWATER				
PR	Flow	Controlling Discharge (cfs)	% Exceed	Successful Flow	% Exceed	Ground-Water % Exceed	Surface Water % Exceed	Total % Exceed
I	Nat'l	27,000	7	<10,600	79	a	32	79
	9,000		0		0		25	25
	8,000		0		0		24	24
II	Nat'l	27,000	7	15,600	48	a	19	48
	9,000		0		0		16	16
	8,000		0		0		15	15
III	Nat'l	27,000	7	b		a	19	19
	9,000		0				16	16
	8,000		0				15	15
IV	Nat'l	33,000	2	b		a	10	10
	9,000		0				7	7
	8,000		0				7	7
V	Nat'l	33,000	2	b		a	9	9
	9,000		0				7	7
	8,000		0				7	7
VI	Nat'l	33,000	2	b		a	12	12
	9,000		0				9	9
	8,000		0				9	9
VII	Nat'l	33,000	2	b		a	11	11
	9,000		0				9	9
	8,000		0				9	9
VIII	Nat'l	33,000	2	b		a	4	4
	9,000		0				3	3
	8,000		0				3	3
IX	Nat'l	33,000	2	b		a	0	2
	9,000		0				0	0
	8,000		0				0	0

[a] Surface Water Needed to Supplement Groundwater
[b] Breaching Occurs Prior to Backwater Effects

Table B7. Percent exceedance of successful passage due to breaching flows, backwater effects, groundwater and surface water discharges for the period of 20 August - 20 September at Slough 9.

PR	Flow	BREACHING Controlling Discharge (cfs)	BREACHING % Exceed	BACKWATER Successful Flow	BACKWATER % Exceed	Ground-Water % Exceed	Surface Water % Exceed	Total % Exceed
I	Nat'l	19,000	29	<12,200	70	100		100
	9,000		0		0	100		100
	8,000		0		0	100		100
II	Nat'l	19,000	29	b		100		100
	9,000		0			100		100
	8,000		0			100		100
III	Nat'l	19,000	29	b		100		100
	9,000		0			a	34	34
	8,000		0				29	29
IV	Nat'l	19,000	29	b		100		100
	9,000		0			a	29	29
	8,000		0				28	28
V	Nat'l	19,000	29	b		a	c	29
	9,000		0					0
	8,000		0					0

[a] Surface Water Needed to Supplement Groundwater
[b] Breaching Occurs Prior to Backwater Effects
[c] Not Enough Drainage Area Exists to Provide Runoff

Table B8. Percent exceedance of successful passage due to breaching flows, backwater effects, groundwater and surface water discharges for the period 20 August - 20 September at Slough 9.

PR	Flow	BREACHING Controlling Discharge (cfs)	BREACHING % Exceed	BACKWATER Successful Flow	BACKWATER % Exceed	Ground-Water % Exceed	Surface Water % Exceed	Total % Exceed
I	Nat'l	d		d		100		100
	9,000					100		100
	8,000					100		100
II	Nat'l	d		d		100		100
	9,000					100		100
	8,000					a	41	41
III	Nat'l	d		d		100		100
	9,000					a	32	32
	8,000						14	14
IV	Nat'l	d		d		100		100
	9,000					100		100
	8,000					100		100
V	Nat'l	d		d		100		100
	9,000					100		100
	8,000					a	20	20
VI	Nat'l	d		d		100		100
	9,000					a	24	24
	8,000						14	14
VII	Nat'l	d		d		100		100
	9,000					a	10	10
	8,000						7	7
VIII	Nat'l	d		d		100		100
	9,000					a	6	6
	8,000						3	3

Table B8 (Continued)

PR	Flow	BREACHING Controlling Discharge (cfs)	BREACHING % Exceed	BACKWATER Successful Flow	BACKWATER % Exceed	Ground-Water % Exceed	Surface Water % Exceed	Total % Exceed
IX	Nat'l	d		d		100		100
	9,000					a	3	3
	8,000						2	2
X	Nat'l	d		d		100		100
	9,000					a	c	0
	8,000							0

[a] Surface Water Needed to Supplement Groundwater
[b] Breaching Occurs Prior to Backwater Effects
[c] Not Enough Drainage Area Exists to Provide Runoff
[d] No Data Available

Table B9. Percent exceedance of successful passage due to breaching flows, backwater effects, groundwater and surface water discharges for the period of 20 August - 20 September at Slough 11.

		BREACHING		BACKWATER				
PR	Flow	Controlling Discharge (cfs)	% Exceed	Successful Flow	% Exceed	Ground-Water % Exceed	Surface Water % Exceed	Total % Exceed
I	Nat'l	42,000	1	16,200	44	70	e	70
	9,000		0		0	0		0
	8,000		0		0	0		0
II	Nat'l	42,000	1	33,200	2	43	e	43
	9,000		0		0	0		0
	8,000		0		0	0		0
III	Nat'l	42,000	1	39,600	.1	12	e	12
	9,000		0		0	0		0
	8,000		0		0	0		0
IV	Nat'l	42,000	1	b		0	e	1
	9,000		0			0		0
	8,000		0			0		0
V	Nat'l	42,000	1	b		0	e	1
	9,000		0			0		0
	8,000		0			0		0

b Breaching Occurs Prior to Backwater Effects
e No Surface Water Available

Table B10. Percent exceedance of successful passage due to breaching flows, backwater effects, groundwater and surface water discharges for the period of 20 August - 20 September at Slough 21

PR	Flow	BREACHING Controlling Discharge (cfs)	BREACHING % Exceed	BACKWATER Successful Flow	BACKWATER % Exceed	Ground-Water % Exceed	Surface Water % Exceed	Total % Exceed
I	Nat'l	25,000	10	b		100		100
	9,000		0			a	6	6
	8,000		0				4	4
IIL	Nat'l	25,000	10	b		a	c	10
	9,000		0					0
	8,000		0					0
IIR	Nat'l	d		d		a	4	4
	9,000						1	1
	8,000						1	1

[a] Surface Water Needed to Supplement Groundwater
[b] Breaching Occurs Prior to Backwater Effects
[c] Not Enough Drainage Area Exists to Provide Runoff
[d] No Data Available

Table B11. Percent exceedance of successful passage due to breaching flows, backwater effects, groundwater and surface water discharges for the period of 20 August - 20 September at Side Channel 21

		BREACHING		BACKWATER				
PR	Flow	Controlling Discharge (cfs)	% Exceed	Successful Flow	% Exceed	Ground-Water % Exceed	Surface Water % Exceed	Total % Exceed
I	Nat'l	12,000	71	12,000	71	100		100
	9,000		0		0	a	28	28
	8,000		0		0		24	24
II	Nat'l	12,000	71	b		100		100
	9,000		0			a	28	28
	8,000		0				24	24
III	Nat'l	12,000	71	b		100		100
	9,000		0			a	31	31
	8,000		0				26	26
IV	Nat'l	12,000	71	b		100		100
	9,000		0			a	31	31
	8,000		0				26	26
V	Nat'l	12,000	71	b		a	24	71
	9,000		0				1	1
	8,000		0				0.5	0.5
VI	Nat'l	12,000	71	b		a	7	71
	9,000		0				0.5	0.5
	8,000		0				0	0
VII	Nat'l	12,000	71	b		a	6	71
	9,000						0.5	0.5
	8,000						0	0
VIII	Nat'l	12,000	71	b		a	6	71
	9,000		0				0.5	0.5
	8,000		0				0	0

Table B11 (Continued)

PR	Flow	BREACHING Controlling Discharge (cfs)	BREACHING % Exceed	BACKWATER Successful Flow	BACKWATER % Exceed	Ground-Water % Exceed	Surface Water % Exceed	Total % Exceed
IX	Nat'l	12,000	71	b		a	4	71
	9,000		0				0.5	0.5
	8,000		0				0	0
X	Nat'l	24,000	12	b		100		100
	9,000		0			a	9	9
	8,000		0				5	5

[a] Surface Water Needed to Supplement Groundwater
[b] Breaching Occurs Prior to Backwater Effects

APPENDIX B

APPENDIX B

Detailed Mitigation Costs

Chapter 3 outlines mitigation proposals for several sloughs and a side channel. This appendix presents the costs for the various mitigation measures presented.

Costs for these proposals are preliminary and are based mostly on past experience in different projects. A major cost, and one difficult to evaluate consists of mobilizing equipment, materials and men to the sites. These costs are based on using the Alaska Railroad to transport much of the equipment and materials. Details regarding loading and unloading and delays with the railroad have not been evaluated completely.

Side Channel 21 and Slough 21 do not have access to the railroad or other land transportation during the construction season. Three alternatives exist to mobilize equipment to this site.

1) Helicopter: Advantages in timing, speed and scheduling. Disadvantages are very high cost and severe limit of equipment size.

2) Barge: Advantages in lower costs, some ability to schedule and operate efficiently. Disadvantage of shallow draft in river, equipment size may be limited.

3) Mobilizing during winter: Advantage of getting large equipment and supplies into work site by transport over river ice. Disadvantages are posed by long lead time to mobilize materials, tying up equipment for one year before demobilization could be completed.

Costs in this section for Slough and Side Channel 21 are based on the assumption that river conditions are such that barges may be operated to the site.

Slough 8A

2 Upwelling Systems		
Labor	70,000	
Materials/Equipment	40,000	
Cross Pipes	20,000	
Piping, Intakes	60,000	
Gravel Processing	160,000	
Mobilization/Demobilization	25,000	
Engineering/Management	40,000	
Total		$415,000
1 Slough Mouth Excavation		
Labor	6,000	
Equipment	8,000	
Mobilization/Demobilization	7,000	
Engineering/Management	5,000	
Total		$ 26,000
1 Wing Deflector		
Labor	5,000	
Equipment/Materials	9,000	
Mobilization/Demobilization	5,000	
Engineering/Management	5,000	
Total		$ 24,000
Excavation of 7 Passage Reaches		
Labor	2,000	
Equipment/Materials	4,000	
Mobilization/Demobilization	2,000	
Engineering/Management	3,000	
Total		$ 11,000
Buildup of 2 Slough Berms		
Labor	120,000	
Equipment	40,000	
Mobilization/Demobilization	2,000	
Engineering/Management	3,000	
Total		$ 295,000

TOTAL COSTS OF MITIGATION MEASURES FOR SLOUGH 8A $771,000

Slough 9

1 Upwelling System		
Labor	35,000	
Materials/Equipment	20,000	
Cross Pipes	10,000	
Piping Intakes	30,000	
Gravel Processing	80,000	
Mobilization/Demobilization	15,000	
Engineering/Management	20,000	
Total		$210,000
1 Water Supply System		
Labor	50,000	
Materials/Equipment	25,000	
Piping	18,000	
Mobilization/Demobilization	12,000	
Engineering/Management	15,000	
Total		$120,000
1 Buildup of Slough Berm		
Labor	60,000	
Equipment	20,000	
Mobilization/Demobilization	10,000	
Gravel and Core Processing	40,000	
Engineering/Management	20,000	
Total		$150,000
20 Log Barriers		
Labor	20,000	
Materials/Equipment	2,000	
Mobilization/Demobilization	2,000	
Engineering/Management	6,000	
Total		$30,000
Excavation of 1 Passage Reach		
Labor	1,000	
Materials/Equipment	1,000	
Mobilization/Demobilization	2,000	
Engineering/Management	1,000	
Total		$5,000
TOTAL COSTS OF MITIGATION MEASURES FOR SLOUGH 9		$515,000

Slough 9A

1 Buildup of Slough Berm		
Labor	60,000	
Equipment	20,000	
Mobilization/Demobilization	10,000	
Gravel and Core Processing	40,000	
Engineering/Management	20,000	
Total		$150,000
Excavation of Entire Slough		
Labor	6,000	
Equipment/Materials	7,000	
Mobilization/Demobilization	5,000	
Gravel Processing	5,000	
Engineering/Management	3,000	
Total		$26,000
TOTAL COSTS OF MITIGATION MEASURES FOR SLOUGH 9A		$176,000

Slough 11

Flow Diversion From Tributary (Gold Creek)		
Labor	120,000	
Equipment/Materials	50,000	
Pipe	90,000	
Gravel Processing	20,000	
Mobilization/Demobilization	35,000	
Engineering/Management	65,000	
Total		$380,000
2 Weirs		
Labor	18,000	
Equipment/Materials	28,000	
Mobilization/Demobilization	8,000	
Engineering/Management	7,000	
Total		$61,000
Bank Stabilization 1000 ft		
Labor	8,000	
Materials/Equipment	7,000	
Mobilization/Demobilization	5,000	
Engineering/Management	5,000	
Total		$25,000
Slough Excavation		
Labor	6,000	
Equipment/Materials	7,000	
Mobilization/Demobilization	5,000	
Gravel Processing	5,000	
Engineering/Management	3,000	
Total		$26,000
15 Log Barriers		
Labor	15,000	
Materials/Equipment	2,000	
Mobilization/Demobilization	2,000	
Engineering/Management	5,000	
Total		$24,000

TOTAL COSTS OF MITIGATION FOR SLOUGH 11 $516,000

Side Channel 21

Excavation of Channel		
Labor	8,000	
Equipment/Materials	9,000	
Mobilization/Demobilization	11,000	
Gravel Processing	8,000	
Engineering/Management	9,000	
Total		$45,000
7 Wing Deflectors Bank Stabilization		
Labor	70,000	
Materials/Equipment	65,000	
Mobilization/Demobilization	20,000	
Oversize Material Removal	35,000	
Engineering/Management	50,000	
Total		$240,000

TOTAL COSTS OF MITIGATION MEASURES FOR SIDE CHANNEL 21 $285,000

Slough 21

Excavation of Slough		
Labor	5,000	
Equipment/Materials	6,000	
Mobilization/Demobilization	5,000	
Oversize Substrate Removal	10,000	
Engineering/Management	8,000	
Total		$34,000
2 Rock Gabions		
Labor	25,000	
Equipment/Materials	12,000	
Mobilization/Demobilization	8,000	
Engineering/Management	9,000	
Total		$54,000
Water Supply System		
Labor	55,000	
Materials/Equipment	30,000	
Piping	9,000	
Mobilization/Demobilization	20,000	
Engineering/Management	20,000	
Total		$134,000
TOTAL COSTS OF MITIGATION MEASURES FOR SLOUGH 21		$222,000

Curry Slough Development
Propagation System

Labor	135,000	
Equipment/Materials	80,000	
Pipe	100,000	
Gravel Processing	30,000	
Mobilization/Demobilization	35,000	
Engineering/Management	70,000	
Total		$450,000

Curry Station Development
Propagation System

Labor	15,000	
Equipment Materials	35,000	
Gravel Processing	8,000	
MobilizationDemobilization	10,000	
Engineering/Management	13,000	
Total		$81,000