3.0 METHODS AND RESULTS

3.1 METHODS - TRIBUTARIES

The question of whether there is potential to improve anadromous salmonid population status through improvements to habitat conditions in tributary environments was considered in the context of the four Viable Salmon Population criteria: abundance, productivity, diversity, and distribution. To address this question by ESU, NOAA Fisheries qualitatively evaluated trends in population status and associated tributary habitat condition and considered the potential to address identified habitat limitations sufficiently to elicit a response in population status. NOAA also considered changes in population distributions within ESUs. As a first cut, NOAA ascribed qualitative rankings (Very High, High, Medium, Low, and Very Low) to population and habitat parameters, based on the magnitude of the observed or potential change.

NOAA coarsely translated qualitative rankings in order to compare habitat improvement potential against quantitative estimates of hydropower mortality. Staff derived the conversions qualitatively from both the observed declines in population status from the reference period to the present and from the estimated potential to improve population status from tributary non-hydro mitigation. Transformation was bounded at the low end by the recognition that, in many subbasins, habitat status is such that there is little improvement potential available from non-hydro mitigation. Subbasins in this category were considered L. The low end was further divided by recognition that it is unlikely that tributary actions can effect measurable change in subbasins largely consisting of wilderness. These subbasins were ranked VL. Transformations at the high end were based on a general perception by staff that declines in population status of two-fold or greater seemed VH. Transformations for the middle ranks were more problematic, since specific points of reference by which upper and lower bounds could be defined were lacking. As a result, the range of survival captured by M and H ranks is much broader than ranges attached to the upper and lower ranks. Ranges for M and H then reflect what seemed "reasonable" within constraints defined by ranks above and below.

Translations of qualitative rankings to quantitative were as follows:

Very Low (VL) -	~0% change in population
Low (L) -	> 0 < 2%
Medium (M) -	2 – 24%
High -	25- 100%
Very High -	> 100%

3.1.2 Steps in the Analysis

First, staff compared current population status (abundance [number of fish or redds] and productivity [survival rate through one or more life stages, e.g., recruits per spawner]) against estimates of historical population status as an indication of the capacity of the population to increase. In this step, staff compared current redd counts, abundance, or recent population growth rates ("lambda") against corresponding estimates from the earliest available time series (generally, 1950s or 1960s). There was no attempt to link a change in population status from historical to changes in physical or biological parameters associated with any life stage. Staff simply attempted to determine whether the population was larger historically than it is currently. An affirmative answer indicated that the population status had some potential to be improved.

Estimates of low, medium, and high potential were based on absolute, rather than relative, differences between current and historical population status for NOAA's preliminary analysis. This resulted in a greater chance that an abundant population would be rated as having "high" potential, compared to a smaller population that might have the same relative potential for improvement (i.e., each might be able to double compared to current population size). This approach was used to reflect the greater contribution of abundant populations to the status of the entire ESU.

Second, staff used available assessments[1] of historical and current tributary habitat conditions to evaluate whether tributary habitat processes within the geographic area currently occupied by the population had been degraded or impaired. Degraded or impaired tributary habitat was assumed to have resulted in a reduction in the quality and quantity of spawning and rearing habitats. Tributary habitat that appeared degraded or impaired relative to the historical condition was considered to have some potential to be improved, assuming that anthropogenic actions contributed to the altered condition. Current tributary habitat with little departure from historical conditions was considered to have little potential for improvement.

In this step, staff used populations as identified by the Interior Columbia Technical Recovery Team (TRT). Habitat evaluations included information from printed sources such as the Northwest Power Planning Council Salmon and Steelhead Production Plan; Northwest Power and Conservation Council Subbasin summaries and draft subbasin assessments, where available; other subbasin and watershed assessments, where available; NOAA's Biological Review Team (BRT) reports (NOAA 2003); published literature; the Northwest Fisheries Science Center's *Evaluating the Potential for Improvements to Habitat Condition to Improve Population Status* (McClure *et al.* 2004) April 16 2004 draft; and best professional judgment of NOAA Fisheries Habitat Conservation Division (HCD) staff.

Third, based on assessments of tributary habitat, staff identified those tributary habitat factors which, as a result of degradation or impairment, were considered most likely limiting to the anadromous salmonid population's abundance, productivity, distribution, or diversity. Identified candidate limiting factors included instream flow, channel morphology (bed, banks, large wood debris, sinuosity, and connectivity), temperature, water quality, and sediment. Limiting factors that were the apparent result of anthropogenic management actions were ranked according to the significance of their impact on the population, either as a result of the spatial extent of the action or the magnitude of its impact on specific life stages that were affected by the site-specific action. For example, a limiting factor such as deficient instream flows, which occurs uniformly throughout the area delineated by the population boundary, may have a similar overall effect on the population as a site-specific factor which adversely affects a high percentage of the population in a single life stage.

Fourth, steps one through three were integrated to derive an estimate of the capacity of the population to respond to improvements in habitat condition. In this step, it was assumed that, if management actions addressed habitat limiting factors, there would be an improvement in spawning and rearing habitat and a commensurate response in population status. NOAA defined this anticipated qualitative population response as the Ecological Improvement Potential (EIP), the potential to qualitatively improve population status by addressing limiting factors in tributary habitat that resulted from anthropogenic management actions.

A specific shape to the relationship between habitat improvement and population response cannot be developed from available information, nor can an upper quantitative bound to that response be predicted. In NOAA's considerations, the potential to improve population status was related to the magnitude of the population's departure from historical abundance or productivity (H, M, L) and the degree to which tributary habitat condition had been impaired or degraded by anthropogenic factors (H, M, L). In this analysis, populations that (1) exhibit "high" divergence between the historical (base period) and current estimates of abundance or productivity, (2) reside in tributary habitats that have been impaired or degraded, and (3) reside in tributary habitats where limiting factors are under management control would have the greatest qualitative potential to increase as a result of habitat actions.

Finally, NOAA recognizes that, in some cases, estimates of EIP may need to be reduced or conditioned based on practical constraints that may limit the ability to address limiting factors. For instance, legal, social, political, or economic constraints may limit the practicality of addressing specific limiting factors at meaningful levels at basin-wide, ESU, population or reach scales. These constraints could reduce the type of limiting factors that can be addressed or depress the rate at which actions needed to address limiting factors can be implemented. Consequently, the estimate of EIP reflects these constraints. Constraints to EIP will need to be evaluated carefully on a case-by-case basis.

3.2 METHODS – ESTUARY

The Northwest Fisheries Science Center (Science Center) evaluated four primary limiting factors that could affect the survival and recovery of stream-type ESUs, including Snake River spring/summer chinook, upper Columbia River chinook, Snake River steelhead, upper Columbia River steelhead, Middle Columbia River steelhead, and upper Snake River sockeye and ocean-type ESUs including lower Columbia River chum salmon and Snake River fall chinook in the estuary and plume.

For the purposes of this analysis, the Columbia River estuary is defined as the entire habitat continuum (ecotone) upstream of the river mouth to Bonneville Dam where tidal forces and river flows interact, regardless of the extent of saltwater intrusion. Beyond the semi-enclosed estuary is the Columbia River plume, a region of the ocean that salmon must occupy before they are fully entrained in oceanic habitats. The river plume is generally defined by a reduced-salinity contour near the ocean surface of 31 parts per thousand. Its geographic position varies greatly with seasonal changes in river discharge, prevailing nearshore winds, and ocean currents. Strong density gradients between ocean and plume waters create relatively stable habitat features where organic matter and organisms are concentrated.

3.2.1 Defining Life History Type and Life History Strategy

Integral to this analysis is the need to evaluate and rank selected limiting factors in the estuary and plume with respect to their potential to improve viability of listed populations. Ideally, the limiting factors should be linked to their potential to affect the viability of each listed population within the estuary and plume. However, because there is limited empirical information describing estuarine habitat use by anadromous populations in the Columbia River estuary and plume, the Science Center used an alternate approach where effects of candidate limiting factors were linked to viability of an ESU. As each ESU comprises a bundle of populations, the analysis can then infer responses of populations based upon what is predicted to occur for the ESU.

The analysis defined each ESU as either stream type or ocean type based upon characteristics of the juvenile outmigrants. While each life history type can potentially produce any life history strategy, ocean type populations are generally (but not exclusively) composed of individuals that migrate to sea early in their first year of life after spending only a short period (or no time) rearing in freshwater. Stream-type fish generally migrate to sea after rearing for at least a year in freshwater. Thus, ocean-type fish tend to spend longer periods in ocean habitats compared to stream-type populations. Information used to define life history types came primarily from the species status reviews: chinook salmon (Myers *et al.* 1998), chum salmon (Johnson *et al*. 1997), and sockeye and steelhead (Busby *et al.* 1996). It was assumed that all populations in aggregate within an ESU fit a general model of that life history type.

Each life history type comprises individual members that employ a variety of alternative spatial and temporal strategies or approaches to using available habitat. The life history strategy was defined to be an approach to using available habitats, including the estuary. The size of the fish at estuarine entry and the time when they arrive in the estuary are the defining criteria that are linked back to ESU, because numerous studies suggest there is a strong linkage between fish size, habitat use, and residence time (Healey 1980, 1982; Levy and Northcote 1981, 1982; Simenstad *et al.* 1982; Carl and Healey 1984; Levings *et al.* 1986; Bottom *et al.* 2001; Miller and Sadro 2003). Juvenile salmon are generally distributed along a habitat continuum based upon water depth, with the depth of the water occupied by the fish increasing as the size of the fish increases (McCabe 1995).

Based upon patterns of size and time of estuarine entry, six life history strategies were identified based upon historical use: (1) early fry, (2) late fry, (3) early fingerling, (4) late fingerling, (5) subyearling, and (6) yearling. Fry are defined as fish that enter the estuary at a size < 60 mm, with early fry entering in approximately March and April and late fry from May to June. Fingerlings are those fish that enter the estuary at a larger size than fry (which implies there was some period of freshwater rearing) but have yet to begin the physiological transition associated with smolting. Subyearlings rear primarily in freshwater with relatively little time spent in the estuary, and they smolt as they outmigrate during their first year of life. Yearlings rear for at least one year in freshwater and then emigrate; these fish generally spend less time in the estuary than fry, fingerlings, and subyearlings. Some differences between populations within an ESU in the relative proportions life history strategies can be expected, but NOAA could not discriminate such differences. Therefore, it was assumed that all populations within a life history type/ESU produce a characteristic mix of these strategies when viewed over long time scales.

In summary, the limiting factors analysis is designed to address whether or not there is potential to improve anadromous salmon population status through improvement in conditions in the estuarine and plume environments. Each factor is considered from the perspective of whether or not its effects on listed populations are directly related to the operation of the FCRPS to help elucidate changes that can be made in the estuary to improve salmon performance beyond those directly related to hydropower operations.

3.2.2 Limiting Factors

The major estuarine-related factors believed to potentially limit salmonid population viability include climate and climate change (which control other factors), water flow, access to and quality of habitats, sediment, salinity, temperature, toxics, predators (e.g. terns, cormorants, northern pikeminnow), and hatchery and harvest practices. Although it would be useful to evaluate the role of each of these limiting factors, analyses were limited to a subset of these nine limiting factors, using the following criteria: (1) a significant change in the ESU was evident, (2) the factor could potentially affect population viability, and (3) there were quantitative data available that could be used to analyze the effect of the factor within the time that had been allotted.

Based on these criteria, the limiting factors that satisfied these criteria and were included in this analysis are water flow, availability of salmon habitats, toxics, and predation (primarily Caspian terns).

3.2.2.1 Flow

The first limiting factor analyzed was flow. Flow is a fundamental factor affecting characteristics of salmon and their habitat in the estuary and plume. Large-scale effects on flow occur as a result of spatially explicit interactions of short- and long-term climate cycles (ENSO and PDO, respectively) with the watershed. The generation of electricity, flood control, and irrigation also have significant effects on attributes of flow. These include a reduction in mean annual flow, reductions in the size of the spring freshets, an almost complete loss of overbank flows, and changes in timing of ecologically important flow events. The hydrological changes, along with floodplain diking, represent a fundamental shift in the physical state of the Columbia River ecosystem. Such changes potentially have significant consequences for both expression of salmonid diversity and productivity of the populations, because they affect the quality of habitat available and its accessibility and quantity. In particular, because the changes in habitat are most pronounced in shallow-water areas, the effects on the ESU's life history strategies (i.e., the fry and fingerling strategies) that use and depend upon these shallow-water areas are most significant.

3.2.2.2 Habitat

The second limiting factor analyzed was habitat. The location and types of habitats present in the Columbia River estuary have been substantially changed from historical conditions. Although the entire estuary has not yet been surveyed, the main changes that have been quantified in the estuary have been a loss of emergent marsh, tidal swamp, and forested wetlands. Shallow-water-dependent life history strategies (i.e., fry and fingerlings) have been most affected by the loss of these vegetated habitat types. Alterations in attributes of flow and diking have caused these changes. Diking is a significant change, primarily because it completely isolates habitat from the river and eliminates it from use by juvenile salmon. Further, diking has altered estuarine food webs from macrodetrital- to microdetrital-based. Clearly, restoration of shallow-water vegetated habitat by removing dikes is a tactic that can benefit those populations that have large numbers of shallow-water-dependent members.

3.2.2.3 Toxics

The third limiting factor analyzed was toxics. Exposure to chemical contaminants has the potential to affect survival and productivity of both ocean and stream-type stocks in the estuary. Stream-type ESUs are most likely to be affected by short-term exposure to waterborne contaminants such as current-use pesticides and dissolved metals that may disrupt olfactory function and interfere with associated behaviors, such as capturing prey, avoiding predators, and imprinting and homing. Ocean-type ESUs may also be exposed to these types of contaminants, but they will also be affected by persistent, bioaccumulative toxicants such as PCBs and DDTs, which they may absorb during their more extended estuarine residence. Consequently, the impact on ESUs exhibiting the ocean life history type may be higher.

3.2.2.4 Caspian Tern Predation

The fourth limiting factor analyzed was Caspian tern predation. Caspian tern predation has significantly increased due to a recent change in nesting habits of the birds. The main impact of tern predation is on ESUs with stream-type life history types, especially steelhead. This is a result of the dominant migratory periods employed by salmonids with a stream-type life history. Improvements to population growth trends (λ) by managing terns would be expected to benefit these ESUs especially, although benefits to other salmon ESUs in the basin should also be evident, albeit to a much lesser degree.

3.2.3 Analysis Method

For the dominant life history strategy, the Science Center analyzed what type of effect each limiting factor had in estuarine shallow water, estuarine deep water, and plume habitats. They considered effects of the factor on habitat quantity, quality, and opportunity. The concepts of opportunity and quality (or capacity) metrics were proposed by Simenstad and Cordell (2000) and adopted by Bottom *et al.* (2001) for the Columbia River estuary. Opportunity attributes relate to the accessibility of habitat to juvenile salmon, and, in general, opportunity metrics are largely physical and chemical in nature, such as tidal elevation and location of habitat. In general, capacity measures primarily relate to the biotic and ecological functions (i.e., acquiring food and avoiding being eaten) of habitat. Capacity metrics must be considered within the context of the species and life stage, using the habitat and the location of that habitat within the landscape. In addition to capacity and opportunity, we also included quantity of habitat as a separate metric. For toxics, we rated effects separately in shallow-water and deep-water estuarine habitat for waterborne and sediment-borne contaminants. For example, if there were risks to the main life history type from both types of contaminants in shallow water, then the score would double.

To rate the importance of each limiting factor, the Science Center developed a simple rating system that ranked each factor as having a high, medium, or low ability to improve the status of anadromous salmon populations. Inferences were drawn regarding how each limiting factor affects an ESU, based upon the life history type of that ESU and how staff believed the factor would affect the life history strategies that characterized that life history type. Thus, the limiting factors for all stream type ESUs were ranked similarly, while those for ocean-type ESUs were ranked similarly. Ratings were developed by considering each factor relative to other estuarine factors within an ESU.

An improvement in population status was defined to mean improvement in population viability as encompassed by the four VSP performance criteria: abundance, population growth rate, spatial structure, and diversity (McElhany *et al.* 2000). The rating system consisted of two levels. The level 1 screens evaluated if the factor was likely a concern for an ESU based upon its effects on VSP and change in the factor from historical conditions. The level 2 screens determined how the factor affected an ESU based upon where the effects occurred.

3.2.3.1 LEVEL 1 - What is the effect on each VSP parameter?

Clearly, each factor will have some effect on all VSP parameters. It was assumed that, if the factor affected large numbers of individuals in the ESU (again relative to other factors), there was a significant effect on abundance and productivity. Because most populations in threatened or endangered status are at low levels of abundance, the score was doubled for any factor that affected abundance or productivity. Staff reasoned that these depressed populations needed short-term increases in abundance before long-term benefits resulting from increased diversity and structure would be useful. If a factor affected particular life history types or affected specific habitat types more than others, it was assumed that there was an impact on spatial structure and diversity.

3.2.3.2 LEVEL 1 - Has the factor changed from historic conditions and could it be improved relative to the other factors?

NOAA considered whether each factor had changed significantly from historical conditions. Because staff intentionally selected factors that were believed to have changed significantly from historical conditions, this screen did not result in much difference between factors. Staff also considered from a practical perspective how much change in each factor was possible. A factor could be significantly changed from historical levels but relatively difficult to change relative to other factors.

3.2.3.3 LEVEL 2 - Does the factor have a significant effect on the abundance of the dominant life history strategy?

For the dominant life history strategy, staff asked how the factor affected the abundance of juveniles of that life history type in estuarine shallow water, estuarine deep water and plume habitats. Although there are multiple estuarine zones and habitat types within each zone, knowledge of how different juvenile life history strategies specifically use these habitats and zones is largely absent. Moreover, the present knowledge base is not robust enough to acknowledge differential effects of limiting factors on either habitat within a zone or between zones or to be extensively discriminatory. However, the linkage between life history strategy and use of deep versus shallow water is pronounced. Thus, staff collapsed the estuary from Bonneville to the mouth into one zone and the plume as a second major zone. Within the estuary, shallow, low-velocity habitats (e.g., swamps, emergent marshes, and shallow flats) were distinguished from medium and deep, higher-velocity channel habitats in the analysis, because there is strong evidence that habitat use varies between these habitat types. The plume was considered as one habitat unit.

3.2.3.4 LEVEL 2 - For the dominant life history strategy, does the factor effect habitat quality, quantity, and opportunity?

For the dominant life history strategy, we asked what type of effect the factor had in estuarine shallow water, estuarine deep water, and plume habitats. We considered effects of the factor on habitat quantity, quality, and opportunity. The concepts of opportunity and quality (or capacity) metrics were proposed by Simenstad and Cordell (2000) and adopted by Bottom *et al.* (2001) for the Columbia River estuary. Opportunity attributes relate to the accessibility of habitat to juvenile salmon, and, in general, opportunity metrics are largely physical and chemical in nature, such as tidal elevation and location of habitat. In general, capacity measures primarily relate to the biotic and ecological functions (i.e., acquiring food and avoiding being eaten) of habitat. Capacity metrics must be considered within the context of the species and life stage using the habitat and the location of that habitat within the landscape. In addition to capacity and opportunity, quantity of habitat was also included as a separate metric. For toxics, staff rated effects separately in shallow water and deep water estuarine habitat for waterborne and sediment-borne contaminants. For example, if there were risks to the main life history type from both types of contaminants in shallow water, then the score would double.

It is also important to note that the operation of the FCRPS directly affects two of the limiting factors described in the analysis: flow and habitat. Changes in flow can permanently eliminate some habitat from use by estuarine-dependent strategies. Even though the habitat may not be diked, it becomes functionally “too high” in elevation for the fish to use because of reductions in flow. In addition, the value of some habitat is reduced because it becomes accessible only for a limited time as a result of the reduction in flow. The non-hydro portion of habitat change involves the reduction in the amount of shallow-water habitat due to dikes and levees that permanently isolate this habitat from use.

Toxics and tern predation were determined not to have a direct relationship to the operation of the hydropower system.

3.3 TRIBUTARY ANALYSIS RESULTS

Estimated tributary ecological improvement potentials for each population, by ESU, are presented in Sections 4.0 through 11.0 of this report.

3.4 ESTUARY ANALYSIS RESULTS

For stream-type ESUs, the primary limiting factors affecting population viability are tern predation and flow. Tern predation was ranked in the medium category, primarily because abundance of the main life history strategy is affected, and there are significant affects upon abundance and productivity. Flow changes were also ranked medium because of effects on the main life history strategies in plume habitat. Toxics and habitat were ranked low for stream-type ESUs, because the main life history strategies associated with this ESU do not occupy the habitat where the effect occurs.

For ocean-type ESUs (Columbia River chum and Snake River fall chinook), flow and habitat were rated as having a high ability to affect population viability. The dominant life history strategy of ocean-type chinook salmon use shallow-water habitat, which is where the main flow and habitat changes occur. Moreover, the use of estuarine habitat by each ESU is likely to be region-specific. Whereas Lower Columbia River chum salmon use the lower portion of the estuary to a greater extent, Snake River fall chinook likely gain greater beneficial use of the tidal freshwater habitat in the region between Bonneville Dam and RM 40.

Tern predation has a low effect on these ESUs, because terns do not target fry and fingerling strategies (the dominant strategies associated with this ESU). Toxics were scored as a medium factor, because both waterborne and sediment-borne contaminants can affect these life history strategies in shallow-water areas.

3.4.1 Aligning Estuary and Tributary Non-hydro mitigation Potentials

Non-hydro mitigation potentials for estuary and tributary actions must be calibrated in order to identify the total potential to improve population status through non-hydro mitigation actions. Estimates of tributary and estuary potential must be aggregated to assess the total potential of all offsite habitat actions to mitigate for the hydropower system.

However, data quality and quantity differences between tributary and estuary areas necessitated differing approaches to determine non-hydro mitigation potentials in these areas. Consequently the derived relative potential and categorical rankings for these areas were dissimilar and could not be easily compared or directly converted.

We took the following approach to transform estimates of estuary potential into a form comparable to estimates of tributary offsite potential. NOAA's Estuary Tech Memorandum (Fresh *et al.* 2004) identifies four primary factors affecting ESUs in the estuary: tern predation, shallow water habitat, toxics, and flow. Flow is not addressed through non-hydro mitigation, since it is considered in the assessment of the effects of the Proposed Action. Although the remaining three limiting factors were qualitatively evaluated, quantitative estimates of tern predation have also been completed (Fresh *et al*. 2004, Good *et. al*. 2004). NOAA's approach was to relate these quantitative estimates of tern mortality to the qualitative relative weights of the estuary limiting factors and then use those relationships to transform estuary ranks into categorical rankings comparable to tributary offsite potential rankings.

As described previously, qualitatively derived estimates of tributary potential were converted into categorical rankings in order to compare against hydropower mortality. The categorical rankings define the potential to increase the percent survival of juveniles in each population as follows:

Very High	>100% increase in survival
High	- 25 – 100%
Med	>2 – 24%
Low	>0 – 2%
Very Low	~0 %

Qualitative estimates of estuary potential were derived from the relative impact of each limiting factor on each VSP parameter relative to other limiting factors at the ESU scale. Calculated in this manner, the weight of the effect of each limiting factor relative to other limiting factors affecting the ESU, as well as across all other ESUs, could be evaluated. Qualitative estimates of estuary non-hydro mitigation potential for each limiting factor were described as high, medium, or low.

3.4.4.1 Stream Type Potential

The primary limiting factors affecting stream-type ESU viability were tern predation and flow. Tern predation was ranked as medium, primarily because abundance of the main life history strategy is affected, and there are significant effects upon abundance and productivity. Flow changes were also ranked medium because of effects on the main life history strategies in plume habitat. Waterborne toxics and shallow-water habitat were ranked low for stream-type ESUs, because the main life history strategies associated with these ESUs are not known to rely on these habitats to a significant degree.

Fresh *et al.* (2004) and Good *et al.* (2004) estimate the following quantitative survival improvements for stream-type ESUs under a scenario where tern predation from East Sand Island is completely eliminated:

ESU	% change λ	Potential Survival Increase
Snake River Steelhead	1.9%	9.6%
Upper Columbia River Steelhead	4.9%	22.5%
Middle Columbia River Steelhead	1.9%	9.5%
Lower Columbia River Steelhead	1.6%	7.4%
Spring Chinook	0.8%	3.3%

Fresh *et al*. (2004) rank the beneficial effect of eliminating tern predation on these ESUs as medium. These potential estuary survival estimates translate into a tributary ranking of medium for all stream-type ESUs. A critical factor in this assessment is the extent that other predators or other forms of mortality compensate for any reduction in tern predation. Fresh et al. assumed that the survival benefits from reduced tern predation were entirely additive. Depending on the actual level of compensatory mortality occurring, these estimates of survival benefits to listed salmonids from reduced tern predation may be optimistic (Roby et al. 2003). Toxics and habitat were ranked low relative to tern predation. Since tern predation converted to a medium tributary rank, it is reasonable to assume that these lower relative estuary ranks of habitat and toxics would carry through conversion to tributary ranking and result in tributary ranks of low (~2%).

Therefore, potential survival improvement to stream-type ESUs from eliminating tern predation would scale to a tributary medium, while potential improvement from addressing habitat and toxics would scale to tributary low. Given the quantitative estimate of survival owing to reduced tern predation, survival improvements from estuary non-hydro mitigation would not exceed a value comparable to tributary ranks of M (tern predation) + L (toxics) + L (habitat). In this case, since we know the approximate quantitative improvement resulting from eliminating tern predation, we can estimate offsite habitat improvement potential in the estuary, by stream type ESU, to be:

	Terns	Toxics	Habitat	Total
Snake River Steelhead	9.6%	+ L	+ L	=~ 13.6%
Upper Columbia River Steelhead	22.5%	+ L	+ L	=~ 26.5%
Middle Columbia River Steelhead	9.5%	+ L	+ L	=~ 13.5%
Lower Columbia River Steelhead	7.4%	+ L	+ L	=~ 11.4%
Spring Chinook	3.3%	+ L	+ L	=~ 7.3%

Other sources of mortality in the system could be considered in the future. For example, Good *et al.* (2004) reported that terns at Crescent Island consume an estimated 1.1% and 5.5% (mean, last 5 years) of PIT-tagged wild chinook and steelhead, respectively, detected at Lower Monumental Dam. Further, other avian predators may have a combined effect on salmonid mortality equal to about half that of terns. Reduction of predator rates by these species could result in additional potential benefits from non-hydro mitigation in the estuary.

3.4.1.2 Ocean Type Potential

The primary limiting factors affecting ocean-type ESU viability (i.e., Columbia River chum and Snake River fall chinook) were flow, water-borne toxics, and habitat. Based on life history strategies, flow and habitat were rated as having a high impact on Columbia River chum and Snake River Fall chinook viability. Toxics rated as having a medium impact on viability for both ESUs. In contrast, tern predation was determined to have a low effect on this life history strategy.

Direct estimates of tern predation rates on ocean-type ESUs, like those of stream-type ESUs, are not available. Therefore, the transformation of ocean-type ESU estuary limiting factors ranks was predicated on the extrapolation of the derived direct effects previously completed on stream type ESUs. Recall that tern predation in stream-type ESUs was rated as medium in the estuary analysis. This converted to a tributary ranking of medium. The reduced effect of tern predation on ocean-type ESUs to stream-type ESUs would then translate into less than a medium rank, or a tributary rank of low (~2%) for Snake River fall chinook. Chum salmon are a negligible components of the tern diet (Collis et al. 2002). NOAA feels that the benefit of reducing tern numbers would remain very low for chum. Waterborne toxics were rated as medium in the estuary analysis, which translates directly into a tributary medium, as was the case with tern predation in the stream-type ESUs. Estuary habitat potentials for Columbia River chum and Snake River fall chinook were rated as high. These both convert to a tributary rank of high. Fresh *et al*. (2004) and McClure *et al.* (2004) provide no quantitative metrics delineating high. However, relative to tern predation, which at approximately >2 - 22% was rated as medium (or tributary low), high would have to be greater than 24%, or converting, a tributary high (25-100%). Conservatively, since NOAA recognizes that some habitats have been irrevocably lost (Fresh *et al.* 2004), medium might be a more appropriately conservative estimate.

Therefore, potential survival improvement to ocean-type ESUs from eliminating tern predation would scale to a tributary low (~2%), while potential improvement from addressing habitat and toxics would scale to tributary ratings of medium and low, respectively. Survival improvements from estuary non-hydro mitigation would not exceed a value comparable to tributary ranks of L (tern predation) + M (toxics) + M (habitat). Non-hydro mitigation potential in the estuary, by stream type ESU, can therefore be estimated to be:

	Terns	Toxics	Habitat	Total
Snake River fall chinook	L (~2%)	+ M (>2-24%)	+ M (>2-24%)	=~ 6-50%
Lower Columbia River chum	VL (~0%)	+ M (>2-24%)	+ M (>2-24%)	=~ 4-48%

Therefore, transforming the ratings of estuary non-hydro mitigation potential to tributary ratings for ocean-type ESUs, the total non-hydro mitigation potential from the estuary is approximately 4 - 48% and 6 – 50% for chum and Snake River fall chinook, respectively. These ranges of potentials cross the tributary ranks of medium and high.

3.4.2 Feasibility of Estuary Actions

Estimates of the potential to increase ESU viability through estuary non-hydro mitigation were based on an assessment of four limiting factors; water flow, availability of salmon habitats, toxics, and predation (primarily Caspian terns). Estuarine flow is removed from consideration as mitigation, as flow is defined by hydrosystem operations and is therefore part of the Proposed Action. In considering the potential benefits that could accrue from non-hydro mitigation actions undertaken to address the remaining limiting factors, NOAA must consider the feasibility that those actions will in fact be implemented. In determining feasibility, NOAA must consider the administrative, economic, and technical constraints that may limit the Action Agencies' authorities to implement actions, funds available to complete actions, and the biological effectiveness of actions that are implemented to mitigate the limiting factors. NOAA believes that the Action Agencies have authorities to fund and authorize actions that could affect water quality and shallow-water estuary habitat. It is feasible that the Action Agencies could improve ESU viability through actions addressing these limiting factors. The relationship between shallow-water habitat restoration and ocean-type survival response is not quantitatively defined. Qualitative estimates of this relationship may be informed by comparing historical and current estuarine habitat conditions. Losses within specific zones of the estuary were reported by Johnson et al. (2003, in Fresh et al. 2004). The following is a list of zones and habitat lost:

Entrance - 41% loss of medium-depth habitat; 43.6% loss of tidal flat habitat

Mixing Zones - relatively little change in acreage of the five major habitat types

Youngs Bay - 86.4% loss of tidal marsh habitat and 95.7% loss of tidal swamp habitat

Baker Bay - 75% loss of deep-water habitat; 71.3% loss in medium-depth habitat; 55.5% loss in tidal marsh habitat; and 100% loss of tidal swamp habitat

Grays Bay - 84.4% loss in tidal swamp habitat

Cathlamet Bay - 48.9% decline in tidal swamp habitat; 30.4% reduction in medium-water habitat; 12.5% in deep-water habitat

Upper Estuary - 64.3% loss in tidal marsh habitat; 79.9% loss in tidal swamp habitat

Tidal freshwater - substantial losses of tidal flats and tidal marsh habitats. The Science Center estimated the loss to be approximately 36%.

Based on the importance of shallow water habitat to all ESA-listed ESUs, especially tidal marsh and tidal swamp habitats, NOAA's Northwest Fisheries Science Center (E. Casillas pers. comm) indicated that at a minimum of one-third of the acreage in each of these habitat categories be restored in each estuary zone to achieve the estimated increase in ESU viability parameters. The one-third figure is derived from the need to denote a measurable change in habitat function and juvenile fish response as measured through the estuary RME plan.

In contrast, NOAA does not have reason to believe that the Action Agencies have within their immediate authorities the capacity to completely eliminate predation by Caspian terns. In order to more accurately estimate the benefit which could be realized from reduced tern predation on East Sand Island, NOAA evaluated the change in salmonid survival from implementation of proposed alternatives C and D in the Draft Environmental Impact Statement (EIS) for the Caspian Tern Management to Reduce Predation of Juvenile Salmonids in the Columbia River Estuary. Alternative A is the no action alternative and would not reduce tern predation. No estimates of salmonid survival changes could be determined for alternative B, since the reduction in tern numbers from this alternative was not presented in the EIS.

Based on the projected levels of tern colony size resulting from implementation of alternatives C and D, NOAA estimates the following quantitative survival improvements for stream-type ESUs:

ESU	Potential Survival Increase
Snake River Steelhead	6.6%
Upper Columbia River Steelhead	15.4%
Middle Columbia River Steelhead	6.6%
Lower Columbia River Steelhead	5.1%
Spring Chinook*	2.3%

* Chinook were not evaluated in the EIS; this potential increase is an approximate value assuming a linear relationship between tern abundance and salmonid survival.

Revised estimates of potential viability improvements from offsite actions in the estuary based on our assessment of feasibility are:

Stream-Type	Terns	Toxics	Habitat	Total
Snake River Steelhead	6.6%	+ L	+ L	=~ 7%
Upper Columbia River Steelhead	15.4%	+ L	+ L	=~ 16%
Middle Columbia River Steelhead	6.6%	+ L	+ L	=~ 7%
Lower Columbia River Steelhead	5.1%	+ L	+ L	=~ 5.5%
Spring Chinook	2.3%	+ L	+ L	=~ 2.5%

Ocean-Type	Terns	Toxics	Habitat	Total
Snake River fall chinook	L	+ M	+ M	=~ 6-50%
Lower Columbia River chum	VL	+ M	+ M	=~ 4-48%

3.4.3 Estuary Non-hydro mitigation Strategies

From the perspective of the estuary, population viability of stream-type ESUs is most affected by tern predation and flow, while ocean type ESUs are most affected by flow, habitat, and toxics. At this time, it is not known how much of a change in each factor is required to affect the viability of relevant ocean-type ESUs. Probably the greatest opportunity to affect ocean-type ESUs by manipulating one of these factors is by restoring lost, shallow-water, low-velocity, vegetated habitat (e.g., emergent marsh). This is because there is a strong linkage between dominant life history strategies of ocean-type ESUs and shallow-water habitat. A large amount of that habitat type has been lost due to diking. Clearly, restoration of some shallow-water habitat can be done without changing hydro operations.

3.4.4 Combining Estimates of Non-hydro mitigation Potential

Summed estimates of non-hydro mitigation potential to improve population status provide an initial estimate of the capacity for offsite actions to mitigate for salmonid mortality resulting from hydropower operations. Estimates of ecological improvement potential from tributary and estuary non-hydro mitigation actions are identified and summed along with estimates of hatchery non-hydro mitigation benefits in Sections 4.0 through 11.0 of this report.

3.5 LITERATURE CITED

Bottom, D. L., C. A. Simenstad, A. M. Baptista, D. A. Jay, J. Burke, K. K. Jones, E. Casillas, and M. H. Schiewe. 2001. Salmon at River's end: The role of the estuary in the decline and recovery of Columbia River Salmon. Draft Report, NMFS, NWFSC, Seattle.

Busby, P. J., T. C. Wainwright, G. J. Bryant, L. J. Lierheimer, R. S. Waples, F. W. Waknitz, and I. V. Lagomarsino. 1996. Status review of west coast steelhead from Washington, Idaho, and California. U.S. Department of Commerce, NOAA Technical Memorandum. NMFS- NWFSC-27, 261 pp.

Carl, C. M., and M. C. Healey. 1984. Differences in enzyme frequency and body morphology among three juvenile life history types of chinook salmon (*Oncorhynchus tshawytscha*) in the Nanaimo River, British Columbia. Canadian Journal of Fisheries and Aquatic Sciences 41:1070-1077.

Colony size and diet composition of piscivorous waterbirds on the lower Columbia River: Implications for losses of juvenile salmonids to avian predation. Transactions of the American Fisheries Society 131: 537–550.

Fresh, K. L., E. Casillas, L. L. Johnson and D. L. Bottom. 2004. Role of the estuary in the recovery of Columbia River Basin salmon and steelhead: An evaluation of the effects of selected factors on population viability. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-Draft, 142 p.

Good, T. P., K. Barnas, D. M. Marsh, M. M. McClure, B. P. Sanford and E. Casillas. 2004. Caspian Tern predation on juvenile salmonid outmigrants in the Columbia River estuary. Unpublished technical paper. U.S. Dept. Commer., Northwest Fisheries Science Center NMFS/NOAA. 31 p.

Healey, M. C. 1980. Utilization of the Nanaimo River estuary by juvenile Chinook salmon, *Oncorhynchus tshawytscha*. Fisheries Bulletin 77:653-668.

Healey, M. C. 1982. Juvenile Pacific salmon in estuaries: the life support system, pp. 315-341. *In*: V.S. Kennedy (ed.) Estuarine Comparisons. Academic Press, New York.

Johnson, O. W., W. S. Grant, R. G. Kope, K. Neely, F. W. Waknitz, and R. S. Waples. 1997. Status review of chum salmon from Washington, Oregon, and California. U.S. Department of Commerce, NOAA Technical Memorandum. NMFSNWFSC-32, 280 p.

Levings, C. D., C. D. McAllister, and B. D. Chang. 1986. Differential use of the Campbell River estuary, British Columbia, by wild and hatchery-reared juvenile chinook salmon (*Oncorhynchus tshawytscha*). Canadian Journal of Fisheries and Aquatic Sciences 43:1386-1397.

Levy, D. A. and T. G. Northcote. 1981. The distribution and abundance of juvenile salmon in marsh habitats of the Fraser River estuary. Westwater Research Center University of British Columbia Technical Report 25:117pp.

Levy, D. A. and T. G. Northcote. 1982. Juvenile salmon residency in a marsh area of the Fraser River Estuary. Canadian Journal of Fisheries and Aquatic Sciences 39:270-276.

McCabe 1995

McClure, M.M., T. Cooney, M. Ruckelshaus, T. Beechie. 2004. Evaluating the potential for improvements to habitat condition to improve population status for eight salmon and steelhead ESUs in the Columbia Basin. Unpublished technical paper. August 18, 2004. U.S. Dept. Commer., Northwest Fisheries Science Center NMFS/NOAA.

McElhany, P., M. H. Ruckelshaus, M. J. Ford, T. C. Wainwright, and E. P. Bjorkstedt. 2000. Viable salmon populations and the recovery of evolutionary significant units. U.S. Department of Commerce, NOAA Technical Memorandum NMFSNWFSX-42, Seattle, WA 156pp.

Miller, B. A. and S. Sadro. 2003. Residence time and seasonal movements of juvenile coho salmon in the ecotone and lower estuary of Winchester Creek, South Slough, Oregon. Transactions of the American Fisheries Society 132:546-559.

Myers, J. M., R. G. Kope, G. J. Bryant, D. Teel, L. J. Lierheimer, T. C. Wainwright, W. S. Grand, F. W. Waknitz, K. Neely, S. T. Lindley, and R. S. Waples. 1998. Status review of chinook salmon from Washington, Idaho, Oregon, and California. U.S. Department of Commerce, NOAA Technical Memorandum. NMFS-NWFSC-35, 443 pp.

NOAA Fisheries, 2000. Reinitiation of Consultation on Operation of the Federal Columbia River Power System, Including the Juvenile Fish Transportation Program, and 19 Bureau of Reclamation Projects in the Columbia Basin. U.S. Dept. Commer., Northwest Region, Seattle, WA.

NOAA Fisheries, 2003. Preliminary conclusions regarding the updated status of listed ESUs of West Coast salmon and steelhead. West Coast Salmon Biological Review Team. U.S. Dept. Commer. NOAA/NMFS, Northwest Fisheries Science Center. Seattle, WA.

Roby, D.D., D.E. Lyons, D.P. Craig, K. Collis, and G.H. Visser. 2003. Quantifying the effects of predators on endangered species using a bioenergetics approach: Caspian terns and juvenile salmonids in the Columbia River estuary. Canadian Journal of Zoology 81: 250–265.

Simenstad, C. A., K. L. Fresh, and E. O. Salo. 1982. The role of Puget Sound and Washington coastal estuaries in the life history of Pacific salmon: an unappreciated function, pp. 343-364. *In*: V.S. Kennedy (ed). Estuarine Comparisons. Academic Press, New York.

Simenstad, C. A. and J. R. Cordell. 2000. Ecological assessment criteria for restoring anadromous salmon habitat in Pacific Northwest estuaries. Ecological Engineering 15:283-302.