Instream Flow Studies: Anadromous Fish Habitat (Freshwater Phases)
Example Biological Questions and Metrics Matrix (PRM 184 TO PRM 104)

Study Element	Life Stage		Biological Questions	Potential Evaluation Metrics	Rationale for Metric	Model(s)/Information to Derive Metric(s)
Fish Habitat	**Spawning**	**Spawning**				
Fish Habitat	Spawning	1	How will long term operations affect the quality and quantity of spawning habitats in lateral habitats? (EFFECTIVE SPAWNING HABITAT)	Quality metrics; dg, d50, Fi, So, dominant/subdominant, % fines < 6.4 mm, others); and Quantity metrics - computed spawning habitat-flow relationships and other metrics at FAs (2-D model); composited values (combined values) for different species (e.g. ranges, medians, percentiles, time series) of habitat amounts provided by flows during respective spawning periods.	Pre-Post operations comparisons at selected time steps.	1-D and 2-D morphology model outputs* relevant to spawning habitats **(Geo-models)**; 2D habitat spatial analyses linked to HSC/HSI functions; re-run habitat models with bed elevation changes **(Fish-2D model; HSC-models; HSI-models)**. Changes to groundwater flow with project operations **(GW-analysis)**. Changes to water quality (e.g. DO, water temperature) **(WQ-models - input to HSI-models)**. * 1-D morphology model outputs are longitudinal and continuous for 50 years. 2-D morphology model outputs are spatial at fixed times (years 0, 25 and 50).
Fish Habitat	Spawning	2	How will long term operations affect the quality and quantity of spawning habitats in the main channel? (EFFECTIVE SPAWNING HABITAT)	Quality metrics; dg, d50, Fi, So, dominant/subdominant, % fines < 6.4 mm, others); and Quantity metrics - computed spawning habitat-flow relationships and other metrics at selected cross-sections in main channel areas in FAs (2-D model) and supplemental flow metrics at selected cross-sections (1-D model); composited values (combined values) for different species (e.g. ranges, medians, percentiles, time series) of habitat amounts provided by flows during respective spawning periods.	Pre-Post operations comparisons at selected time steps.	1-D and 2-D morphology model outputs* relevant to spawning habitats **(Geo-models);** 2-D habitat spatial analyses linked to HSC/HSI functions; re-run habitat models with bed elevation changes **(Fish-2D model; HSC - models; HSI - models).** Changes to groundwater flow with project operations **(GW-analysis).** Changes to water quality (e.g. DO, water temperature) **(WQ-models - input to HSI-models)**. * 1-D morphology model outputs are longitudinal and continuous for 50 years. 2-D morphology model outputs are spatial at fixed times (years 0, 25 and 50)

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Study Element	Life Stage		Biological Questions	Potential Evaluation Metrics	Rationale for Metric	Model(s)/Information to Derive Metric(s)
Fish Habitat	Spawning	3	How does main channel spawning habitat change with flow?	Computed spawning habitat-flow relationships in main channel areas in FAs (2-D model); composited values (combined values) for different species (e.g. ranges, medians, percentiles, time series) of habitat amounts provided by flows during respective spawning periods for Wet, Dry, Ave. years; totaled by Geomorphic Reach; other supplemental flow-habitat metrics at selected cross-sections (1-D model);	Pre-Post operations comparisons of main channel spawning habitat metrics	Hydraulic **(OWFR-model**) and 1-D and 2-D morphology models **(Geo-models)** linked with Habitat Models (**Fish 2-D and 1-D-models);** habitat models incorporate HSC and HSI functions **(HSC and HSI-models)**. Post-operations results rely on 1-D and 2-D morphology model outputs* to adjust bed topographies. * 1-D morphology model outputs are longitudinal and continuous for 50 years. 2-D morphology model outputs are spatial at fixed times (years 0, 25 and 50).
Fish Habitat	Spawning	4	What main channel habitats provide the greatest amounts of spawning areas?	Spatial (longitudinal) representation of main channel spawning habitat amounts by species (graphic and tabular displays) available during spawning period for different hydrology; e.g. Ave, Wet. Dry year types; 20%, 50%, 80% exceedence values).	Pre-Post operations comparisons of main channel spawning habitat distributions and amounts.	Post-processing of hydraulic **(OWFR-model)** and habitat model **(Fish-2D and 1D-models**) runs to derive spatial representation statistics. Post-operations results rely on 1-D and 2-D morphology model outputs* to adjust bed topographies **(Geo-models)**. * 1-D morphology model outputs are longitudinal and continuous for 50 years. 2-D morphology model outputs are spatial at fixed times (years 0, 25 and 50)

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Study Element	Life Stage		Biological Questions	Potential Evaluation Metrics	Rationale for Metric	Model(s)/Information to Derive Metric(s)
Fish Habitat	Spawning	5	How do tributary clear-water plumes that are used for spawning change with main channel flow?	Computed spawning habitat-flow response functions (habitat based (D,V, S,) that includes turbidity/clear water area) specific to Tributary Mouths; metric is area (Ft2) of clearwater spawning habitat computed for different flow.	Pre-Post operations comparisons of how clearwater plumes and spawning areas in Tributary Mouths may change.	**Hydraulic models (2-D)** linked with Habitat Models **(Fish - 2D model**) that are inclusive of Tributary Mouths; habitat models incorporate HSC and HSI functions **(HSC and HSI-models)**(include turbidity). Turbidity inputs provided from EFDC **(WQ-model**). Post-operations results rely on 1-D and 2-D morphology model outputs* to adjust bed topographies. * 1-D morphology model outputs are longitudinal and continuous for 50 years. 2-D morphology model outputs are spatial at fixed times (years 0, 25 and 50).
Fish Habitat	Spawning	6	How do lateral spawning habitats change with flow? (EFFECTIVE SPAWNING HABITAT)	Computed spawning habitat-flow relationships and other metrics in lateral habitats in FAs (2-D model); composited values (combined values) for different species (e.g. ranges, medians, percentiles, time series) of habitat amounts provided by flows during respective spawning periods for Wet, Dry, Ave. years; totaled by Geomorphic Reach; effective spawning habitat – width (ft) or area (ft2) by species over different spawning time steps; spawning habitat duration analysis.	Pre-Post operations comparisons of lateral spawning habitat metrics.	**Hydraulic models (2-D)** linked with fish habitat models **(Fish 2D- models**); habitat models incorporate HSC and HSI functions **(HSC and HSI - models).** Changes to groundwater flow and HSI-models in lateral areas based on (**GW-analysis**).
Fish Habitat	Spawning	7	Which lateral habitats are most often used for spawning?	Metrics from tabular/graphical data comparing spawning habitats (by species) between lateral macrohabitats (by habitat type) and in overall Middle River (spatial evaluation metrics);	Determine “key” lateral habitat types used for spawning.	Data on use obtained from fish surveys (spawning, HSC,FDA and 1980s data); quantitative data from **Hydraulic models (2-D**) linked with Fish habitat models (**Fish 2D-model)**; habitat models incorporate HSC and HSI functions. Post-processing of hydraulic **(OWFR-model**) and habitat model **(Fish-2D and 1D-models)** runs to derive spatial representation statistics.

Instream Flow Studies: Anadromous Fish Habitat (Freshwater Phases)
Example Biological Questions and Metrics Matrix (PRM 184 TO PRM 104)

Study Element	Life Stage		Biological Questions	Potential Evaluation Metrics	Rationale for Metric	Model(s)/Information to Derive Metric(s)
Fish Habitat	Spawning	8	What surface flow related physical and hydraulic characteristics influence the selection of spawning habitats?	HSC metrics for spawning of D,V,S, Cover	Needed for flow-habitat modeling	Site specific HSC data and curve development **(HSC models)**, coupled with 1980s data and other HSC sources.
Fish Habitat	Spawning	9	To what extent does groundwater flow influence selection of spawning habitats?	HSI metrics (temperature, upwelling/downwelling) linked with spawning habitat – flow response relationships; GIS analysis of TIR overlain with spawning habitats - area (ft2).	Pre-Post operations effects analysis of spawning habitats.	Data from HSI surveys (VHG data; **HSI models**); groundwater analysis in FAs with spawning activity **(GW analysis)**; **TIR imagery** overlay with spawning area (GIS).
Fish Habitat	Spawning	10	How do surface flows influence the groundwater flows associated with spawning habitats?	Groundwater temperature conditions and differences between upland, lateral, and mid-channel habitat; groundwater gradients and recharge area characteristics and presence/absence, seasonal variations in groundwater discharge to lateral habitats.	Determine surface flow/groundwater relationships that may be influenced by project operations.	Groundwater and surface-water monitoring/modeling. Groundwater and surface-water temperature monitoring, winter observation of ice and snow cover on lateral habitats and connections with mainstem channels **(GW-analysis)** linked with **OWFR-model**
Fish Habitat	Spawning	11	What are the substrate characteristics of areas used for spawning by adult salmon?	Gravel quality metrics; dg, d50, Fi, So, dominant/subdominant, % fines < 6.4 mm, others) from FAs;	Pre-Post operations comparisons of substrate composition.	Bed material gradations from geomorphology studies; pebble counts; substrate characterization from HSC surveys; **(HSC and HSI data).**
Fish Habitat	Spawning	12	What is the permanency of spawning areas in main channel and lateral habitats during the spawning season? (EFFECTIVE SPAWNING HABITAT)	Effective spawning habitat – width (ft) or area (ft2) by species over different spawning time steps; spawning habitat duration analysis.	Pre-Post operations comparisons.	Hydraulic and morphology models **(Geo 2D-model)** linked with fish habitat models **(Fish 2D-models)**.
Fish Habitat	Spawning	13	What surface flow related water quality characteristics occur in main-channel spawning habitats?	Water quality metrics; DO, temp, nutrients, others; exceedence metrics over spawning periods (e.g. 10%, 50%, 90%) and others.	Pre-Post operations comparisons of water quality characteristics in spawning habitats.	Coarse EFDC water quality modeling outputs for Temp, DO, pH, conductivity, nutrients and other relevant constituents at X-sections in main channel; empirical data **(WQ-models); (empirical water quality data from FDA and HSI surveys).**
Fish Habitat	Spawning	14	What surface flow related water quality characteristics occur in lateral habitat spawning areas?	Water quality metrics; DO, temp, nutrients, others; exceedence metrics over spawning periods (e.g. 10%,50%,90%) and others.	Pre-Post operations comparisons of water quality characteristics in spawning habitats.	Detailed EFDC water quality modeling outputs for Temp, DO, pH, conductivity, nutrients and other relevant constituents at X-sections in main channel and FAs **(WQ-models)**; **(empirical water quality data from FDA and HSI surveys)**.

Instream Flow Studies: Anadromous Fish Habitat (Freshwater Phases)
Example Biological Questions and Metrics Matrix (PRM 184 TO PRM 104)

Study Element	Life Stage		Biological Questions	Potential Evaluation Metrics	Rationale for Metric	Model(s)/Information to Derive Metric(s)
Fish Habitat	Spawning	15	What groundwater flow related water quality characteristics occur in lateral habitat spawning areas?	Water quality metrics from groundwater wells, seeps, springs, and surface-water sources recharged by groundwater; DO, temp, nutrients, metals indicators, others; exceedence metrics over spawning periods (e.g. 10%,50%,90%) and others.	Determine whether groundwater related water quality characteristics influence surface water quality in spawning areas.	**Empirical data from groundwater wells; historical and regional data.** Winter observations of open leads and other ice and snow cover variations affecting temperature and light conditions in lateral habitats; comparison with **empirical surface water quality data** and EFDC model output **(WQ-models)**.
Fish Habitat	Spawning	16	Others…..			
Fish Habitat	Spawning	17				
Fish Habitat	Spawning	18				
Fish Habitat	**Incubation and**	**Incubation and Fry Emergence**				
Fish Habitat	Incubation and Fry Emergence	1	What are incubation patterns and conditions in spawning habitats of the river? i.e. egg development times, water quality parameters.	Temp and DO metrics in different locations based on current conditions; literature based TU requirements to hatch; developed temperature-hatch time response functions; DO - incubation relationships from literature; ADEC water quality criteria; substrate quality metrics - dg, d50, Fi, So, dominant/subdominant, % fines < 6.4 mm, others).	Needed for habitat modeling.	Output from EFDC modeling for Temperature - **WQ (WQ-model); Literature based data on TU requirements including studies from 1980s (Wangaard and Burger 1983; empirical data from HSC, FDA, and Radiotag studies; bed material gradations from geomorphology studies; pebble counts; substrate characterization from HSC surveys; (HSC and HSI data).**

Instream Flow Studies: Anadromous Fish Habitat (Freshwater Phases)
Example Biological Questions and Metrics Matrix (PRM 184 TO PRM 104)

Study Element	Life Stage		Biological Questions	Potential Evaluation Metrics	Rationale for Metric	Model(s)/Information to Derive Metric(s)
Fish Habitat	Incubation and Fry Emergence	2	How will project operations affect the incubation patterns and conditions in the spawning habitats of the river? (EFFECTIVE SPAWNING HABITAT)	Temp and DO metrics in different locations based on project operations; literature based TU requirements to hatch; cumulative TU analysis and comparisons Pre-Post project; DO metrics Pre-Post; substrate quality metrics (Pre-Post) - dg, d50, Fi, So, dominant/subdominant, % fines < 6.4 mm, others).	Pre-Post operations comparisons of spawning and incubation habitats.	1-D and 2-D morphology model outputs* relevant to spawning-incubation habitats +**Geo-models)**; 2D habitat spatial analyses linked to HSC/HSI functions; re-run habitat models with bed elevation changes **(Fish-2D model; HSC - models; HSI - models)**. Changes to groundwater flow with project operations **(GW-analysis).** Changes to water quality (e.g. DO, water temperature) **(WQ-models - input to HSI-models).** L**iterature based data on TU requirements including studies from 1980s (Wangaard and Burger 1983).** * 1-D morphology model outputs are longitudinal and continuous for 50 years. 2-D morphology model outputs are spatial at fixed times (years 0, 25 and 50).
Fish Habitat	Incubation and Fry Emergence	3	What are fry emergence patterns from spawning habitats in the river?	Temp metrics in different locations based on current conditions; literature based TU requirements to emergence.	Needed for habitat modeling.	EFDC WQ model - temperature (WQ-models) **Literature based data on TU requirements including studies from 1980s (Wangaard and Burger 1983**) **and others related to fry emergence; empirical data from HSC, FDA, EarlyLifeHistory (ELH) studies.**

Instream Flow Studies: Anadromous Fish Habitat (Freshwater Phases)
Example Biological Questions and Metrics Matrix (PRM 184 TO PRM 104)

Study Element	Life Stage		Biological Questions	Potential Evaluation Metrics	Rationale for Metric	Model(s)/Information to Derive Metric(s)
Fish Habitat	Incubation and Fry Emergence	4	How will project operations affect fry emergence patterns from spawning habitats in the river? (EFFECTIVE SPAWNING HABITAT)	Temp metrics in different locations based on project operations; literature based TU requirements to emergence; cumulative TU analysis ; substrate quality metrics - dg, d50, Fi, So, dominant/subdominant, % fines < 6.4 mm, others).	Pre-Post operations comparisons of fry emergence conditions.	Output from Temperature - EFDC **WQ models; Literature based data on TU requirements including studies from 1980s (Wangaard and Burger date) and others related to fry emergence; 3) empirical data from HSC, FDA, and Radiotag studies;** 1-D and 2-D morphology model outputs* relevant to spawning-incubation-fry emergence habitats **(Geo-models);** * 1-D morphology model outputs are longitudinal and continuous for 50 years. 2-D morphology model outputs are spatial at fixed times (years 0, 25 and 50).
Fish Habitat	Incubation and Fry Emergence	5	Others…..			
Fish Habitat	Incubation and Fry Emergence	6				
Fish Habitat	Incubation and Fry Emergence	7				
Fish Habitat	**Spawning /**			**Spawning / Overwinter**		
Fish Habitat	Spawning / Overwinter	1	How do spawning/incubation habitats change in winter? (stage, temperature, DO, light, circulation/flow through sloughs). (EFFECTIVE SPAWNING HABITAT)	Water quality metrics (DO, temp, nutrients, metals, others) during ice cover conditions; Groundwater upwelling changes by season and flow rate.	Pre-Post winter-time operations comparisons.	**(Empirical data)** from winter studies - continuous DO and temp recorders; **River2D Hydraulic model** outputs with specified ice cover (WSE, velocity, depth); output from **River1D Ice processes model (IceFRM-model)** - WSEs, ice thickness linked with fish habitat models (Fish 2D-models), groundwater upwelling processes **(GW analysis)** for ice covered conditions; water quality metrics from EFDC **WQ-model.**

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Study Element	Life Stage		Biological Questions	Potential Evaluation Metrics	Rationale for Metric	Model(s)/Information to Derive Metric(s)
Fish Habitat	Spawning / Overwinter	2	How would changes in winter flow conditions impact lateral habitat water depth and temperature?	Response functions between mainstem stage and lateral habitat and groundwater stage conditions; variations in ice cover with depth and velocity in lateral habitats, with varying temperature conditions.	Determine how winter project operations may influence lateral habitat areas compared with natural conditions.	Groundwater simulations of hydrologic conditions during winter periods for different operational scenarios **(GW-analysis); empirical data from groundwater and surface-water monitoring programs and winter studies**.
Fish Habitat	Spawning / Overwinter	3	How would changes in winter flow conditions impact ice formation at inlets/outlets to lateral habitat?	Evaluation of field photographic data for different sets of lateral habitat inlets/outlets that represent a range of depth characteristics.	Determine how winter project operations may influence inlets and outlets to lateral habitat areas compared with natural conditions.	**Empirical/observational data from FA and winter studies of inlets/outlets during winter conditions;** River2D Hydraulic model outputs with specified ice cover (WSE, velocity, depth); output from River1D Ice processes model **(IceFRM-model)** - WSEs, ice thickness(2-D)process understanding from Ice Processes and Groundwater Winter GW/SW Interactions **(GW analysis).**
Fish Habitat	Spawning / Overwinter		Others…..			
Fish Habitat	Spawning / Overwinter					
Fish Habitat	Spawning / Overwinter					
Fish Habitat	**Adult Migration**	**Adult Migration**				
Fish Habitat	Adult Migration	1	What are peak adult migration periods of adult salmon within the Susitna River system - by species?	Range of migration intervals; 95% CI interval of passage by species; median date of passage; quartiles, etc.	Used to define periodicity of adult fish movement; linked with pre-post hydrologic modeling.	**Empirical data from radiotagging and tracking studies; spawning surveys; RST data;**
Fish Habitat	Adult Migration	2	What flows trigger and occur during adult migrations and passage in the mainstem Susitna River – Pre vs. Post conditions?	Computed hydrologic metrics centered around migration periods (modified IHA or EFC parameters) (e.g. frequency of freshets, mean or median values of Wet, Dry, Ave. flows during migration periods).	Pre-Post operations migration comparisons.	Hydrologic analysis - **IHA/EFC type analysis** performed on Pre-versus Post hydrology for migration periods.
Fish Habitat	Adult Migration	3	What flows limit (regulate?) time periods of adult passage above Devils Canyon? (ADULT PASSAGE THROUGH DEVILS CANYON)	Computed hydrologic metrics (likely a range of flows; passage response function)	Pre-Post operations comparisons.	Empirical data from radiotagging study; timing/numbers) and pre-post hydrology data **(OWFR-model)** to derive upstream passage flow windows.

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Study Element	Life Stage		Biological Questions	Potential Evaluation Metrics	Rationale for Metric	Model(s)/Information to Derive Metric(s)
Fish Habitat	Adult Migration	4	What flows limit (regulate?) adult passage into lateral habitats (side sloughs, side channels, tributary mouths)? (ADULT PASSAGE INTO LATERAL HABITATS)	Computed hydrologic metrics (site specific low flow statistics that incorporate Q and duration; e.g. Indian River mouth – Min.Q_{Pass} ($X_{t\text{-}duration}$) exceedences)	Pre-Post operations comparisons (short term).	**Barrier Analysis** coupled with **2-D hydraulic modeling** (at FA level Macrohabitats) or **1-D modeling** (at other targeted tributaries) to define flow-based passage constraints, and then complete Pre-versus Post hydrologic analysis of those conditions with **OWFR-model**.
Fish Habitat	Adult Migration	5	How will long term operations affect adult passage into lateral habitats(side sloughs, side channels, tributary mouths); i.e. physical characteristics and flow needs?	**Geomorphology metrics: 1-D modeling at lateral habitat associated cross-sections→ aggradation/degradation; bed material composition and mobility; 2-D modeling at FAs → sediment balance; aggradation/degradation; bed material composition and mobility; bed-form profiles.**	Pre-Post operations comparisons (long term).	1-D and 2-D morphology model outputs* specific to lateral habitats, linked with Barrier Analysis and **OWFR-model.** * 1-D morphology model outputs are longitudinal and continuous for 50 years. 2-D morphology model outputs are spatial at fixed times (years 0, 25 and 50).
Fish Habitat	Adult Migration	6	What flow related water quality conditions occur during adult migration and passage?	Water quality metrics (e.g. DO, temp, conductivity, etc.) (ranges, median, averages, exceedences, time series, other) during wet, dry and normal year passage periods.	Pre-Post operations comparisons.	Spatially explicit EFDC water quality modeling outputs for Temp, DO, pH, conductivity (marker for tributary or groundwater influences on the mainstem), nutrients and other relevant constituents at X-sections in main channel; **WQ-model.**
Fish Habitat	Adult Migration	7	Others…..			
Fish Habitat	Adult Migration	8				
Fish Habitat	Adult Migration	9				
Fish Habitat	**Juvenile-Parr**	**Juvenile-Parr Rearing**				
Fish Habitat	Juvenile-Parr Rearing	1	What habitats are used by juvenile fish for rearing during open water flow conditions?	Spatial GIS analysis of locations of juvenile fish; by geomorphic reach, and FAs; HSI and HSC data for juvenile fish.	Establish framework for rearing habitat analysis	**Empirical data from FDA and ELH studies**; 1980s data and information; **HSC and HSI data for juvenile fish.**
Fish Habitat	Juvenile-Parr Rearing	2	What surface flow related physical and hydraulic characteristics influence the selection of rearing habitats?	HSC relationships for rearing of D,V,S, Cover	Needed for flow-habitat modeling	Site specific HSC data **(HSC-models)** and curve development, coupled with 1980s data and other HSC sources.

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Study Element	Life Stage		Biological Questions	Potential Evaluation Metrics	Rationale for Metric	Model(s)/Information to Derive Metric(s)
Fish Habitat	Juvenile-Parr Rearing	3	What is the permanency of rearing areas in main channel habitats during the open water flow periods. (EFFECTIVE REARING HABITAT)	Effective rearing habitat in main channel areas of FAs – width (ft) or area (ft2) by species over different time steps (daily, weekly, monthly); rearing habitat duration analysis; supplemental analysis at selected cross sections.	Pre-Post operations comparisons.	Hydraulic models (2-D) linked with fish habitat models **(Fish 2D- models**); habitat models incorporate HSC and HSI functions (HSC and HSI - models). Changes to groundwater flow and HSI-models in lateral areas based on (GW-analysis.
Fish Habitat	Juvenile-Parr Rearing	4	What is the permanency of rearing areas in lateral habitats during the open water flow periods. (EFFECTIVE REARING HABITAT)	Effective rearing habitat in lateral habitat areas of FAs – width (ft) or area (ft2) by species over different time steps (daily, weekly, monthly); rearing habitat duration analysis; supplemental analysis at selected cross sections.	Pre-Post operations comparisons.	Hydraulic models (2-D) linked with Habitat Models (2-D); EHA model outputs by species.
Fish Habitat	Juvenile-Parr Rearing	5	What is the permanency of rearing areas in main channel habitats during the ice covered flow periods. (EFFECTIVE REARING HABITAT - ICE CONDITIONS)	Effective rearing habitat in main channel areas of FAs – width (ft) or area (ft2) by species over different time steps during ice cover periods (daily, weekly, monthly); rearing habitat duration analysis; supplemental analysis at selected cross sections.	Pre-Post operations comparisons.	River2D Hydraulic model outputs with specified ice cover (WSE, velocity, depth); output from River1D Ice processes model - WSEs, ice thickness(2-D);linked with Habitat Models (2-D).
Fish Habitat	Juvenile-Parr Rearing	6	What is the permanency of rearing areas in lateral habitats during the ice covered flow periods.	Effective rearing habitat in main channel areas of FAs – width (ft) or area (ft2) by species over different time steps during ice cover periods (daily, weekly, monthly); rearing habitat duration analysis; supplemental analysis at selected cross sections.	Pre-Post operations comparisons.	River2D Hydraulic model outputs with specified ice cover (WSE, velocity, depth); output from River1D Ice processes model - WSEs, ice thickness(2-D);linked with Habitat Models (2-D).
Fish Habitat	Juvenile-Parr Rearing	7	What flows limit (regulate?) juvenile passage into and out of lateral habitats (side sloughs, side channels, tributary mouths)? (JUVENILE PASSAGE INTO LATERAL HABITATS)	Computed hydrologic metrics (site specific low flow statistics that incorporate Q and duration; e.g. Indian River mouth – Min.Q_{Pass} ($X_{t\text{-}duration}$) exceedences)	Pre-Post operations comparisons (short term)	**Barrier Analysis** coupled with **2-D hydraulic modeling** (at FA level Macrohabitats) or **1-D modeling** (at other targeted tributaries) to define flow-based passage constraints, and then complete Pre-versus Post hydrologic analysis of those conditions with **OWFR-model**.
Fish Habitat	Juvenile-Parr Rearing	8	Others…..			
Fish Habitat	Juvenile-Parr Rearing	9				

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Fish Habitat	Juvenile-Parr Rearing	10				
Fish Habitat	**Smolt**	**Smolt Outmigration**				
Fish Habitat	Smolt Outmigration	1	What are the outmigration patterns of smolts in the Susitna River - timing, peak migration periods?	Range of migration intervals; 95% CI interval by species; median dates of passage; quartiles, etc.	Pre-Post operations comparisons.	**Empirical data from RST monitoring, ELH, and FDA studies; literature including 1980s reports.**
Fish Habitat	Smolt Outmigration	2	What flows occur during smolt migration periods in the mainstem Susitna River?	Computed hydrologic metrics centered around migration periods (modified IHA or EFC parameters) (e.g. frequency of freshets, mean or median values of Wet, Dry, Ave. flows during migration periods).	Pre-Post operations comparisons.	Hydrologic - **IHA/EFC type analysis** performed on Pre-versus Post hydrology for migration periods.
Fish Habitat	Smolt Outmigration	3	What water quality conditions occur during smolt migration periods in the mainstem Susitna River?	Water quality metrics; DO, temp, nutrients, metals, others; exceedence metrics over spawning periods (e.g. 10%, 50%, 90%) and others.	Pre-Post operations comparisons.	Coarse EFDC water quality modeling outputs for Temp, DO, pH, conductivity, nutrients, metals and other relevant constituents at X-sections in main channel (WQ-model).
Fish Habitat	Smolt Outmigration	4	Others…..			
Fish Habitat	Smolt Outmigration	5				
Fish Habitat	Smolt Outmigration	6				
Fish Habitat	**General**	**General**				
Fish Habitat	General	1	Will fresh water fish production (measureable as number per unit area) be affected by Project operations?	Based on individual fish species production, develop HSC curves for nutrients that reflect a condition gradient for production of periphyton, BMI, that infer relationship with fish production.	Changes to nutrient concentrations from Pre- to Post Project operations may influence food base for early life stages of fishes. Relationship between food availability and trophic stages.	Spatially explicit EFDC water quality modeling outputs for Temp, DO, pH, conductivity, nutrients (TP, TKN, NH3-N, Chl-a), and other relevant constituents at X-sections in main channel.
Fish Habitat	General	2	Others…..			
Fish Habitat	General	3				
Fish Habitat	General	4				
Resident Fish	**Spawning, etc.**	**Spawning, etc.**				
Resident Fish	Spawning, etc.	1				
Resident Fish	Spawning, etc.	2				
Resident Fish	Spawning, etc.	3				
Beluga whale	**Foraging**	**Life stage functions linked with flow**				

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Study Element	Life Stage		Biological Questions	Potential Evaluation Metrics	Rationale for Metric	Model(s)/Information to Derive Metric(s)
Beluga whale	Foraging	1				
Beluga whale	Foraging	2				
Beluga whale	Foraging	3				
Eulachon	**Spawning, etc.**	**Spawning, etc.**				
Eulachon	Spawning, etc.	1				
Eulachon	Spawning, etc.	2				
Eulachon	Spawning, etc.	3				
Other	**Life stage**	**Life stage functions or activities linked with flow**				
Other resources - wildlife, recreation, etc.	Life stage functions or activities linked with flow	1				
Other resources - wildlife, recreation, etc.	Life stage functions or activities linked with flow	2				
Other resources - wildlife, recreation, etc.	Life stage functions or activities linked with flow	3				