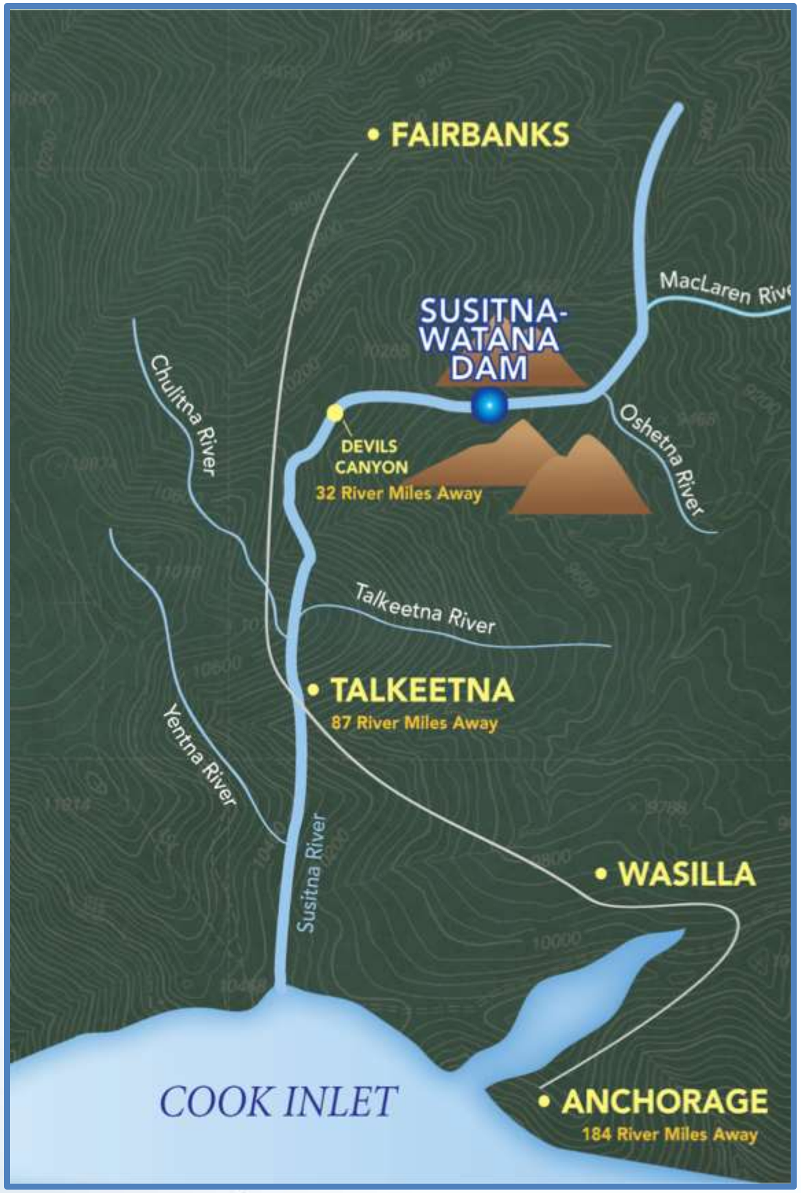

IFS Technical Team Meeting - Riverine Modeling

Water Quality Modeling

November 13-15, 2013

Prepared by: Tetra Tech, Inc.

Prepared for: Alaska Energy Authority

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Water Quality Modeling

- *Objectives*
  - *Predict nutrient and mercury cycling in the reservoir*
  - *Predict nutrient and mercury cycling in the downstream river for preexisting and post reservoir conditions*
  - *Predict toxics fate and transport for organic contaminants and metals in the reservoir and riverine portion of the study area*

- *EFDC Modeling Framework*
  - *Hydrodynamic model*
  - *Temperature model*
  - *Nutrient cycling model*
  - *Solids and sorptive contaminant and/or metals transport and fate model*
  - *Mercury cycling model*

Hydrodynamic Models

- *Provide physical transport for temperature and dissolved and suspended water quality constituents including mercury and potentially toxic organic and inorganic materials*
- *Three-dimensional reservoir hydrodynamics*
  - *The only hydrodynamic model of the reservoir*
  - *Generalized vertical coordinate formulation*
  - *Historical and projected inflows*
  - *Outflows and consistent inflows from reservoir operations model*

Hydrodynamic Models

- *Two-dimensional river hydrodynamics*
  - *One of five river hydrodynamic models including three 1-D models and two limited area 2-D modeling*
  - *The only 2-D model of the entire river*
  - *Dedicated river hydrodynamic model for water quality ensures consistent space and time scale resolution between hydrodynamics and water quality transport*
  - *Eliminates cumbersome model linkages*
  - *Addresses Focus Area modeling requirements by continuous transition to and from high resolution in these areas avoiding need for limited area modeling*

Hydrodynamic Model Data, Calibration, and Interaction with Other Models

- *Reservoir hydrodynamic model*
  - *LiDAR based bathymetry (origin: MatSu LiDAR)*
  - *Historic USGS gauged inflows being used for model testing*
  - *Scenario inflow and outflow from Reservoir Operations Model*
  - *Reservoir model cannot be calibrated*

- *River hydrodynamic model*
  - *Existing and new cross sections supplemented by LiDAR based bathymetry*
  - *Bathymetry consistent with routing and geomorphic models*
  - *Historic USGS gauged flows being used for model testing*
  - *Scenario flows consistent with routing models*
  - *Calibrate to historic stage and discharge hydrographs*

Temperature Models

- *Temperature is equally important as transport for water quality processes*
  - *Reactions have significant temperature dependence*
- *Reservoir temperature model*
  - *The only reservoir temperature model*
  - *Full thermal balance including ground coupling*
  - *Includes ice dynamics with a range of complexity levels*
- *River temperature model*
  - *One of two temperature models*
  - *Import ice cover information from Ice Routing Model or use observation based space and time varying ice cover*

Temperature Model Data, Calibration, and Interaction with Other Model

- *Atmospheric data for reservoir and river models*
  - *Project MET stations supplemented by NCDC reporting stations*
- *Reservoir temperature model*
  - *Inflowing temperature based pre-reservoir observational data*
  - *Reservoir model cannot be calibrated*
- *River temperature model*
  - *Inflowing temperature for existing conditions and tributaries based on observations*
  - *Inflow temperature for post-reservoir conditions from reservoir model*
  - *Ice cover from Ice Routing Model*
  - *Calibrate to subset of observational data*

Nutrient Cycling Models

- *Consistent state variables between reservoir and river*
- *State Variables*
  - *DO, POC, DOC*
  - *NH3, NOX, PON, DON*
  - *PO4d, PO4p, POP, DOP*
  - *Optional labile and refractory organic class splits*
  - *Multiple algae species*
- *Optional sediment diagenesis model*
  - *Sediment oxygen demand and nutrient fluxes*
- *Ice related effects accounted for*
  - *Re-aeration*
  - *Light attenuation*

Solids and Sorptive Contaminant Transport and Fate Model

- *Solids Transport*
  - *Multiple classes of cohesive and non-cohesive sediment*
  - *Multiple classes of organic solids from nutrient cycling model or externally specified*
- *Contaminant transport and fate*
  - *Arbitrary number of sorptive (organics and metals) contaminants*
  - *Three phase equilibrium partitioning including DOC complexated*
- *Reservoir sediment transport*
  - *Only model of reservoir sediment trapping*
  - *Light attenuation for water quality processes*
- *River sediment transport not included in this study*
  - *Information on solids concentrations for partitioning and light attenuation from geomorphic modeling*
- *Provides input to the Mercury model*

Mercury Cycling Model

- *Uses EFDC contaminant transport and fate sub-model*
- *State variables*
  - *Water column dissolved elemental mercury*
  - *Water column and bed dissolved and particulate divalent mercury*
  - *Water column and bed dissolved and particulate methyl mercury*
- *Equilibrium partitioning*
  - *Particulate and dissolved organic carbon*
  - *Inorganic sediment solids*
- *Reaction module includes spatial and temperature dependent*
  - *Oxidation and reduction*
  - *Methylation and reductive and bacterial de-methylation*
  - *Volatilization*
- *Mercury study will provide information for model initialization, loadings, and parameterization*

Nutrient, Toxics, and Mercury Model Data, Calibration, and Interaction with Other Model

- *Initial conditions and most inflow concentrations/loads developed from observational data*
- *Potential loading from Groundwater Model upwelling*
- *Driven by EFDC hydrodynamic and temperature models with no other data dependencies*
- *Reservoir model cannot be calibrated, but will be evaluated for predicting reasonable bounding concentration ranges*
- *River model calibrated to sub-set of observational data*

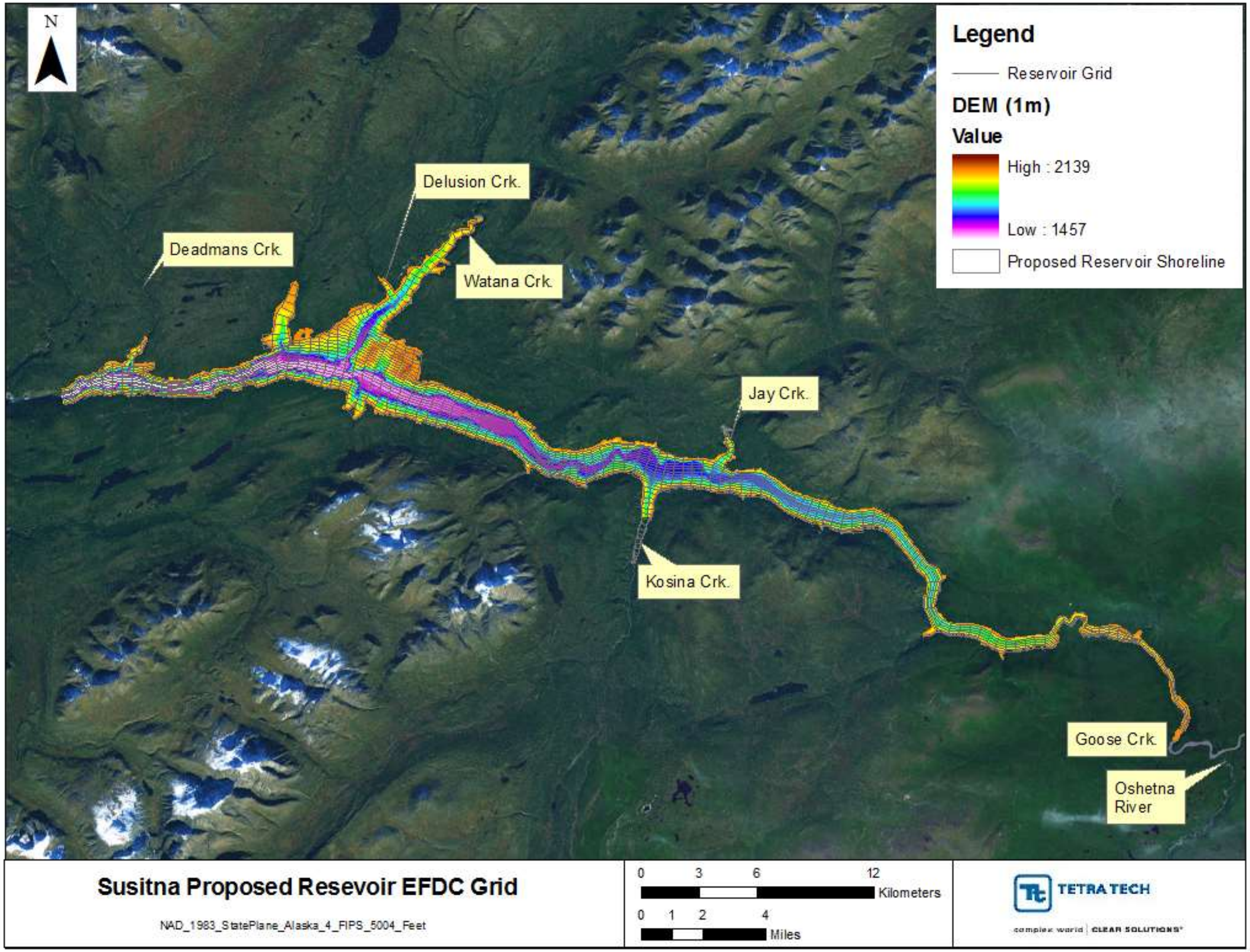
Model Spatial Resolution

- *Spatial resolution of reservoir and river models optimized for unsteady-flow simulation and water quality constituent transport over multi-year time to decadal time scales*
- *Computational time step limited by CFL condition for advection which combines with spatial resolution to determine model run time performance*
- *Reservoir must deal with pool elevation fluctuations*
- *Multiple spatial resolution versions of the river model for preliminary and final calibration and longer and shorter term simulations*
  - *Coarse version for preliminary calibration*
  - *Medium version for final calibration*
  - *Locally fine version with nested Focus Areas*
  - *Approach allows resolution sensitivity to be determined*

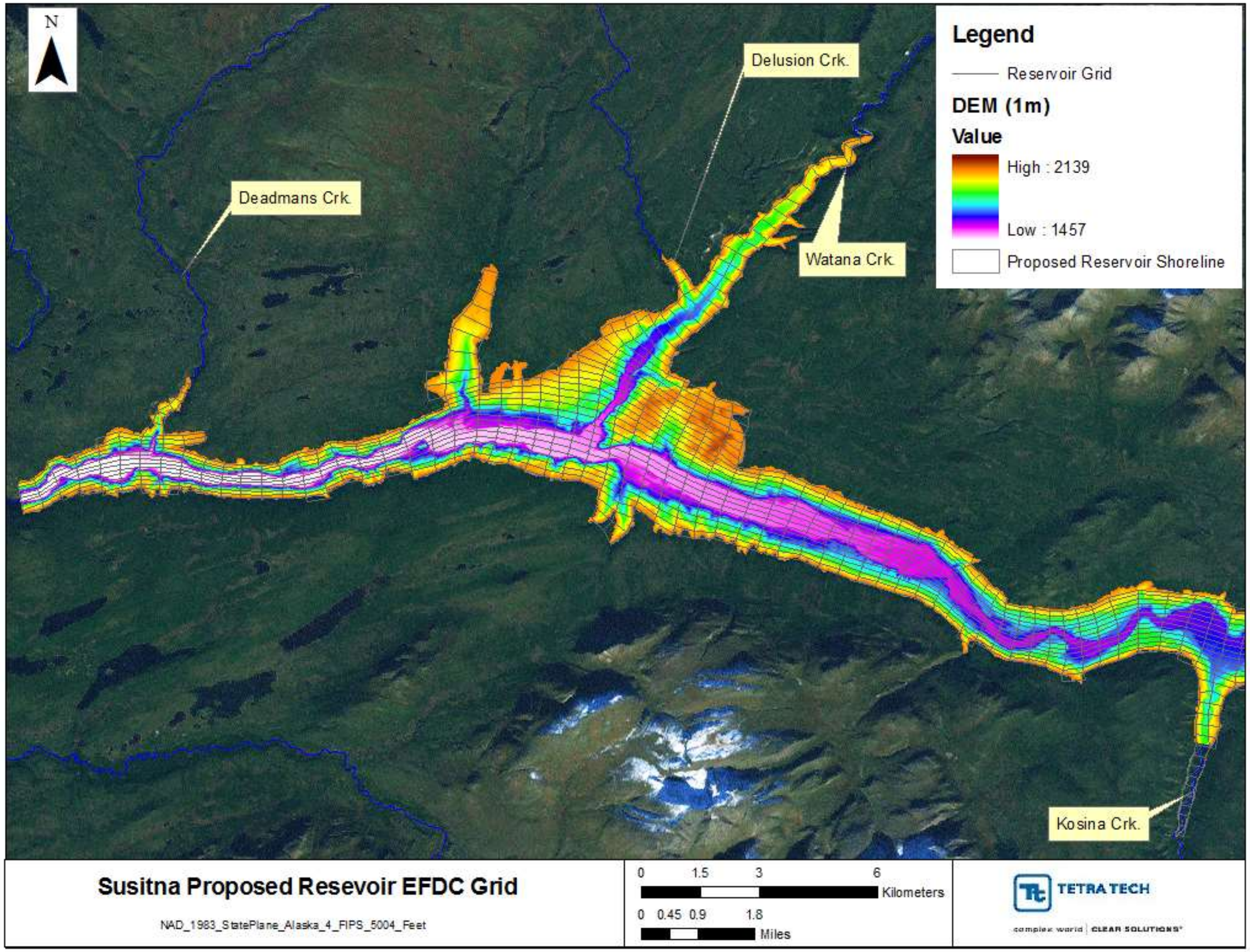
Reservoir Model Domain, Spatial Resolution, Performance, and Simulation Capability

- *Reservoir model domain and resolution*
  - *Reservoir domain well defined*
  - *75 to 150 m lateral resolution*
  - *400 to 800 m longitudinal resolution*
  - *On the order of 1400 horizontal grid cells*
  - *2.5 to 25 m vertical resolution (subject to change)*
  - *20 to 32 vertical layers in deepest region (subject to change)*
- *Estimated run time performance and simulation capability*
  - *20 sec computational time step 1984 operational scenario*
  - *Dynamic stepping will increase performance*
  - *Performance should be at least 4 years simulated per cpu day*
  - *Multiple scenarios on multiple computers*

Reservoir Model Horizontal Grid



Reservoir Model Horizontal Grid



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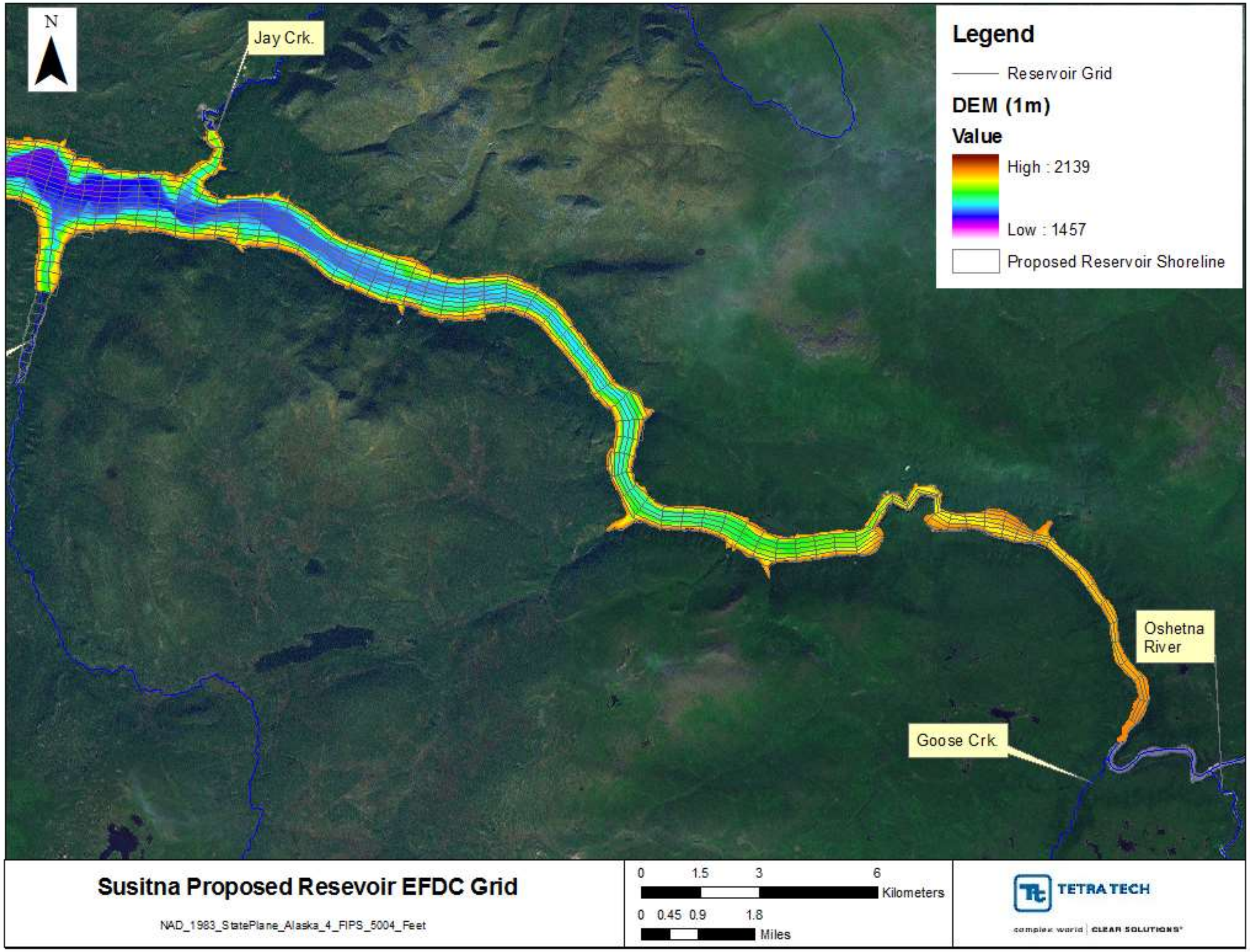
Reservoir Model Horizontal Grid



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Status of the Reservoir Model

- *Spatial model configuration completed*
- *Simulated 1984 operational scenario to demonstrating models ability to represent 150 ft plus pool fluctuations and drying and wetting of shallow areas*
- *Preliminary temperature simulations underway*
  - *Investigate vertical resolution to represent summer thermal stratification*
  - *Evaluation of simple versus complex ice processes models*
- *In progress*
  - *Configuration of nutrient cycling and mercury models*
  - *Configuration of suspended solids transport for trapping simulation*

River Model Domain, Spatial Resolution, Performance and Simulation Duration

- *River model domain and resolution*
  - *River domain consistent with routing and geomorphic modeling*
  - *Downstream boundary to be determined by study requirements*
  - *3 to 7 cells laterally in bank in Middle River with transition to and from higher resolution in Focus Areas*

River Model Domain, Spatial Resolution, Performance and Simulation Duration

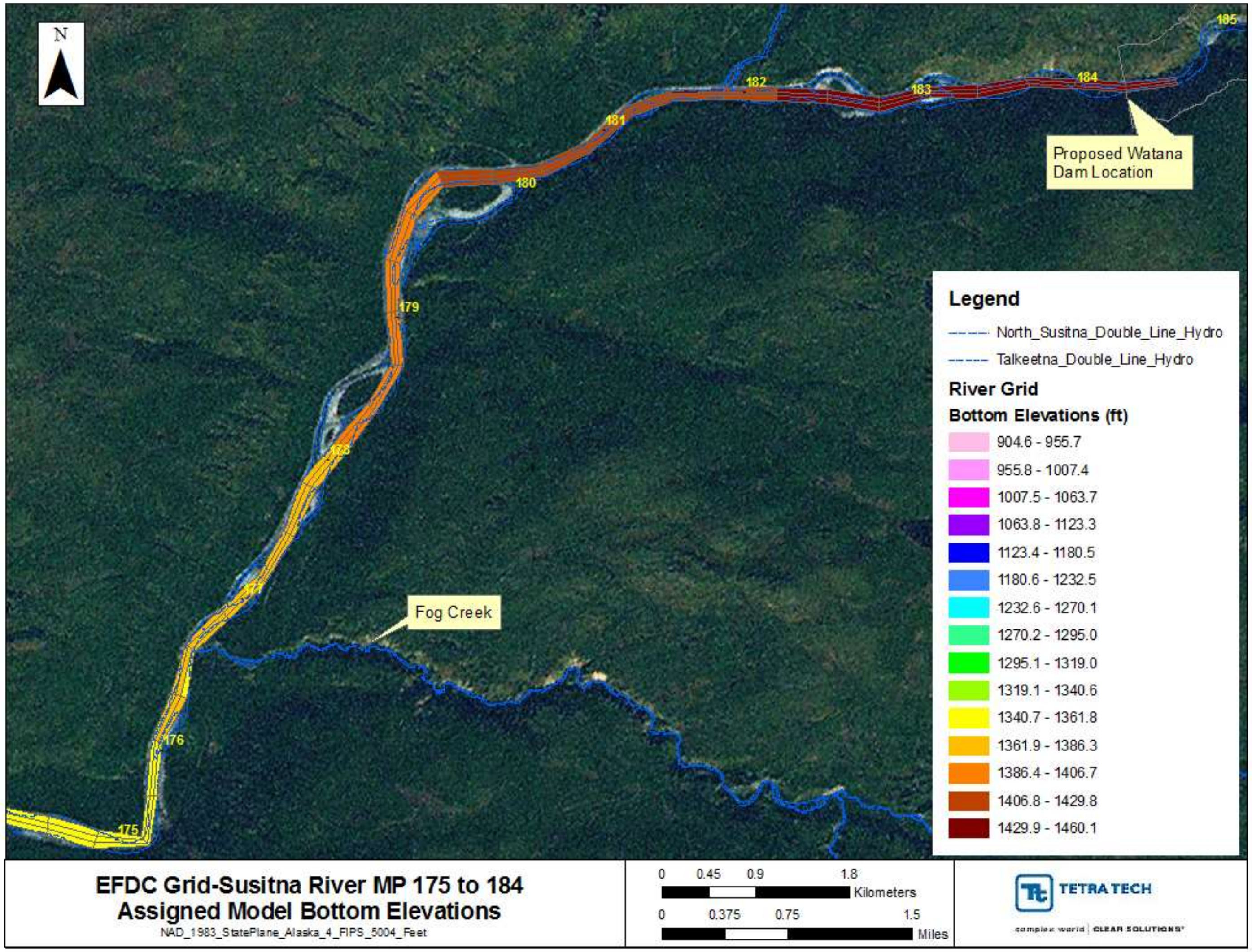
- *River model domain and resolution*
  - *Lower River will not attempt to distinguish multiple numerous channels but will use EFDC wetting and drying capabilities*
  - *250 to 1000 m longitudinal resolution with higher resolution in Focus Areas*

River Model Domain, Spatial Resolution, Performance and Simulation Duration

- *Estimated run time performance and simulation capability on coarse grid covering PRM 55 to 187*
  - *500 m longitudinal resolution with 3 cells across giving 1250 cells*
  - *5 sec computational time step at 2000 cms*
  - *Much larger time steps using dynamic stepping at lower flow rates*
  - *Performance should be at least 8 years simulated per cpu day*
  - *Multiple scenarios on multiple computers*

River Model Coarse Horizontal Grid

(secondary channels not shown)



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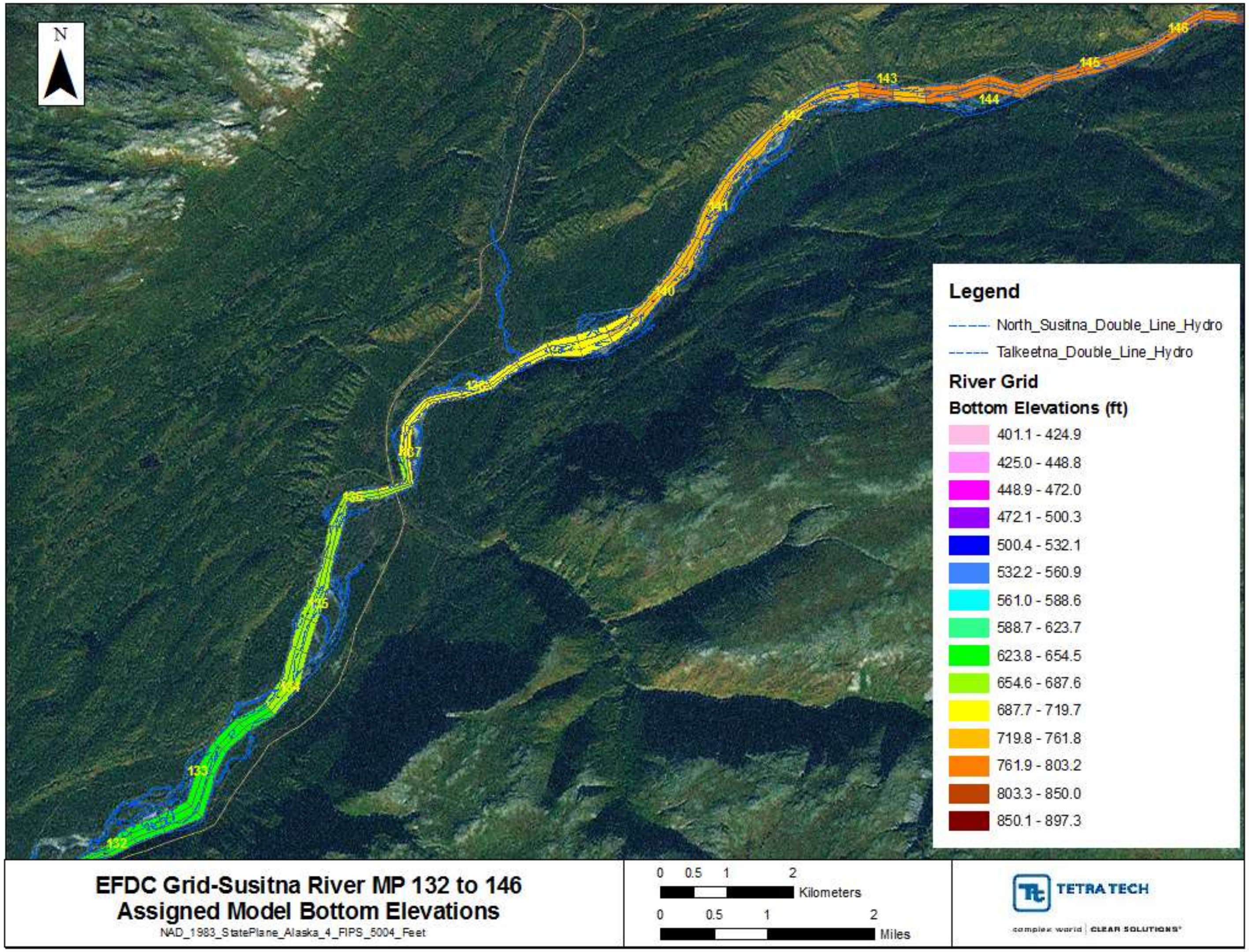
River Model Coarse Horizontal Grid

(secondary channels not shown)



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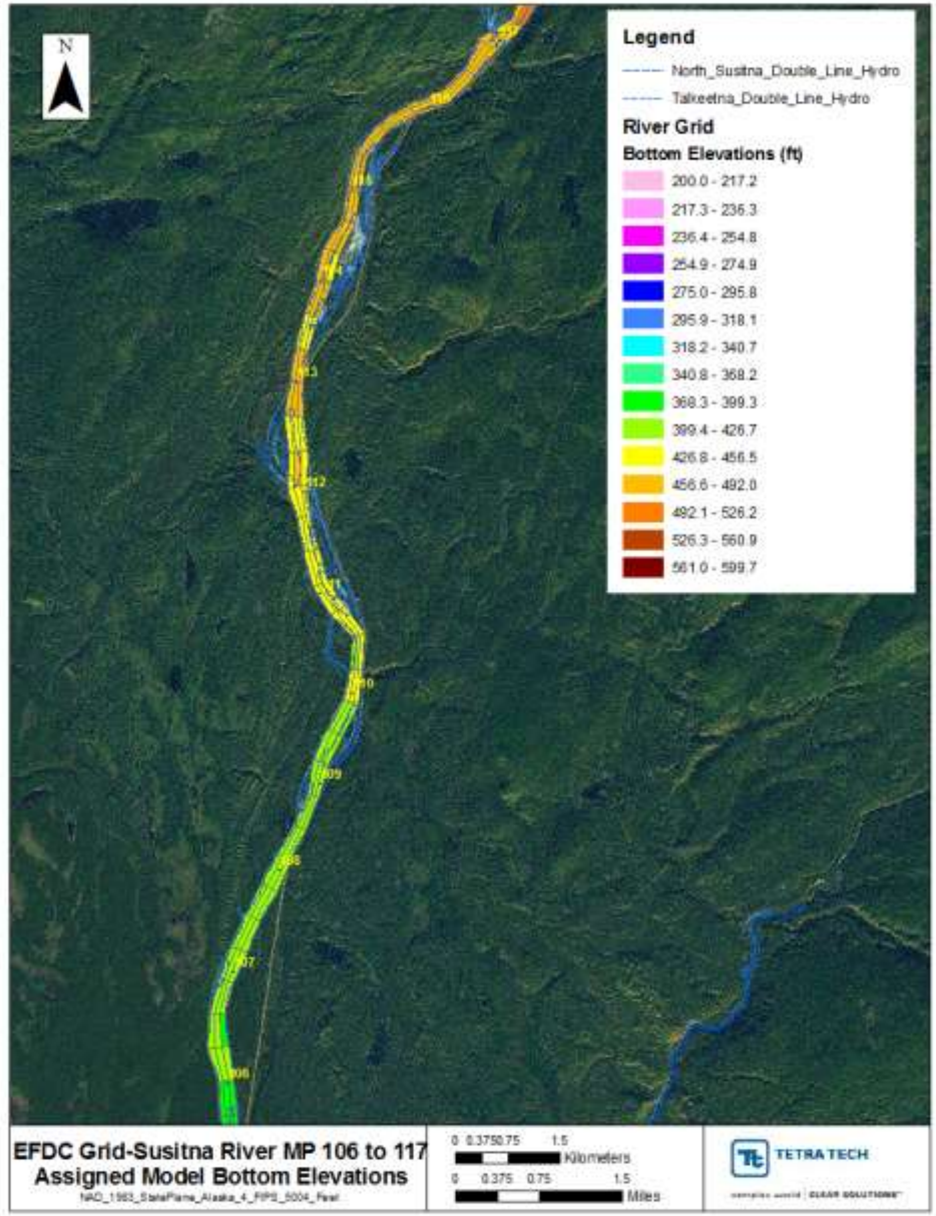
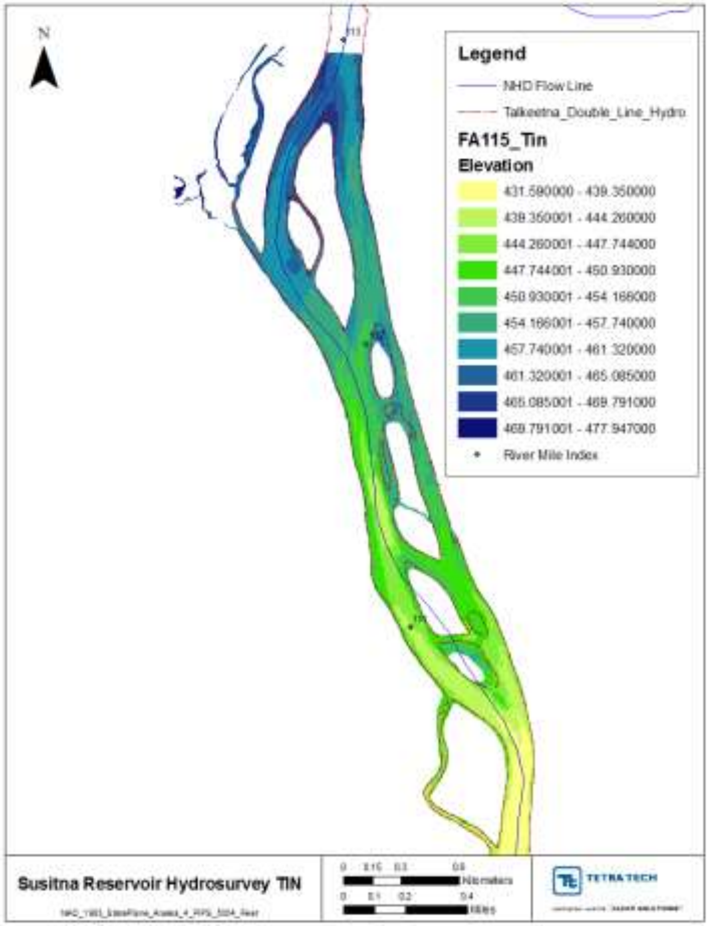
River Model Coarse Horizontal Grid

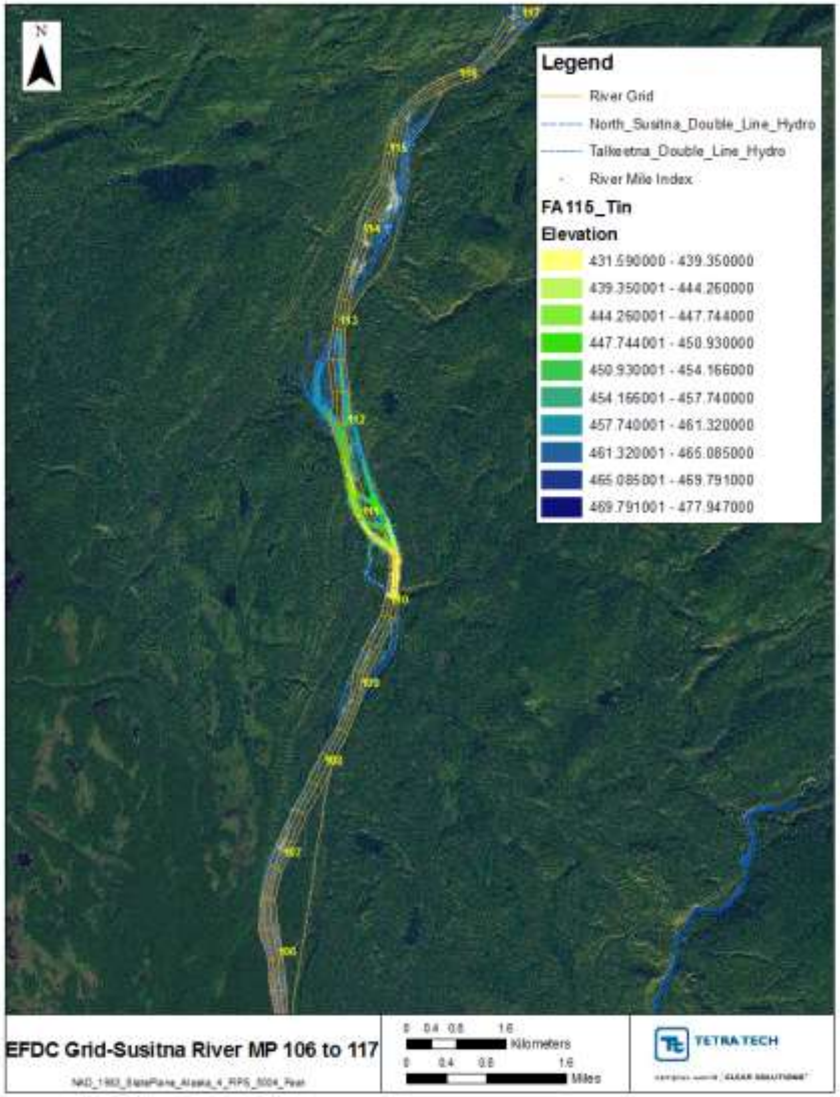
(secondary channels not shown)



Focus Area Bathymetry Shown on Coarse Grid

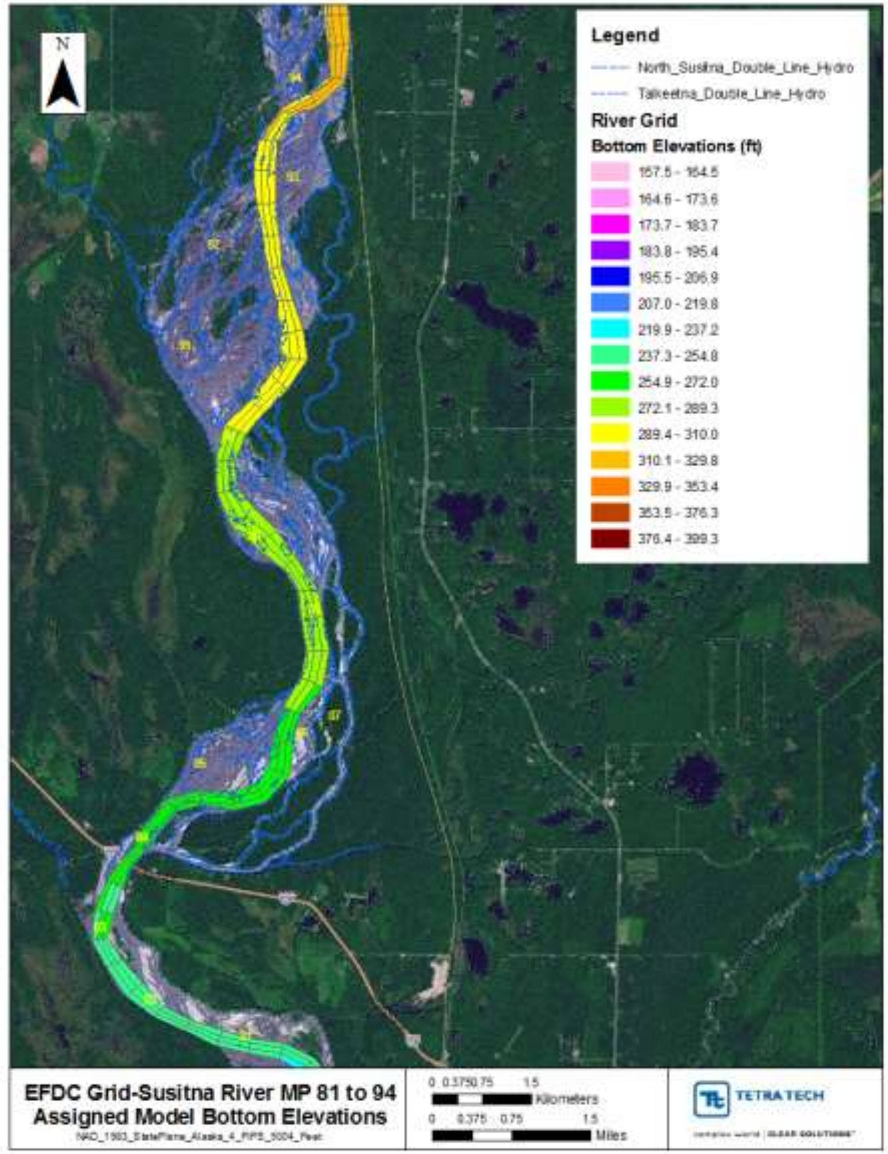
(secondary channels not shown)





River Model Coarse Horizontal Grid

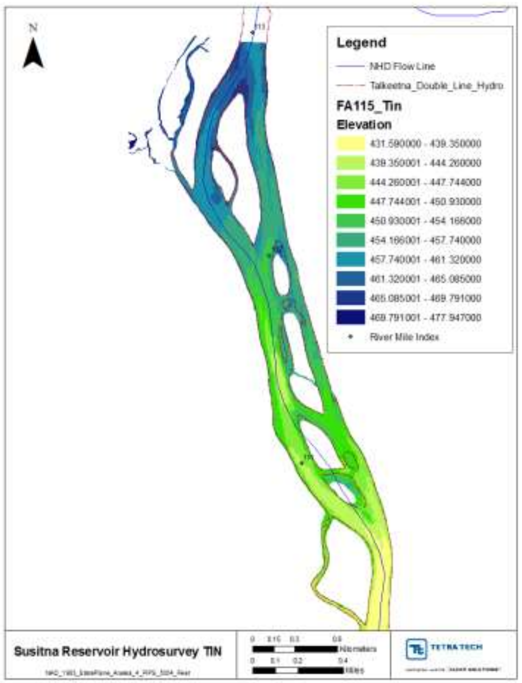
(secondary channels not shown)

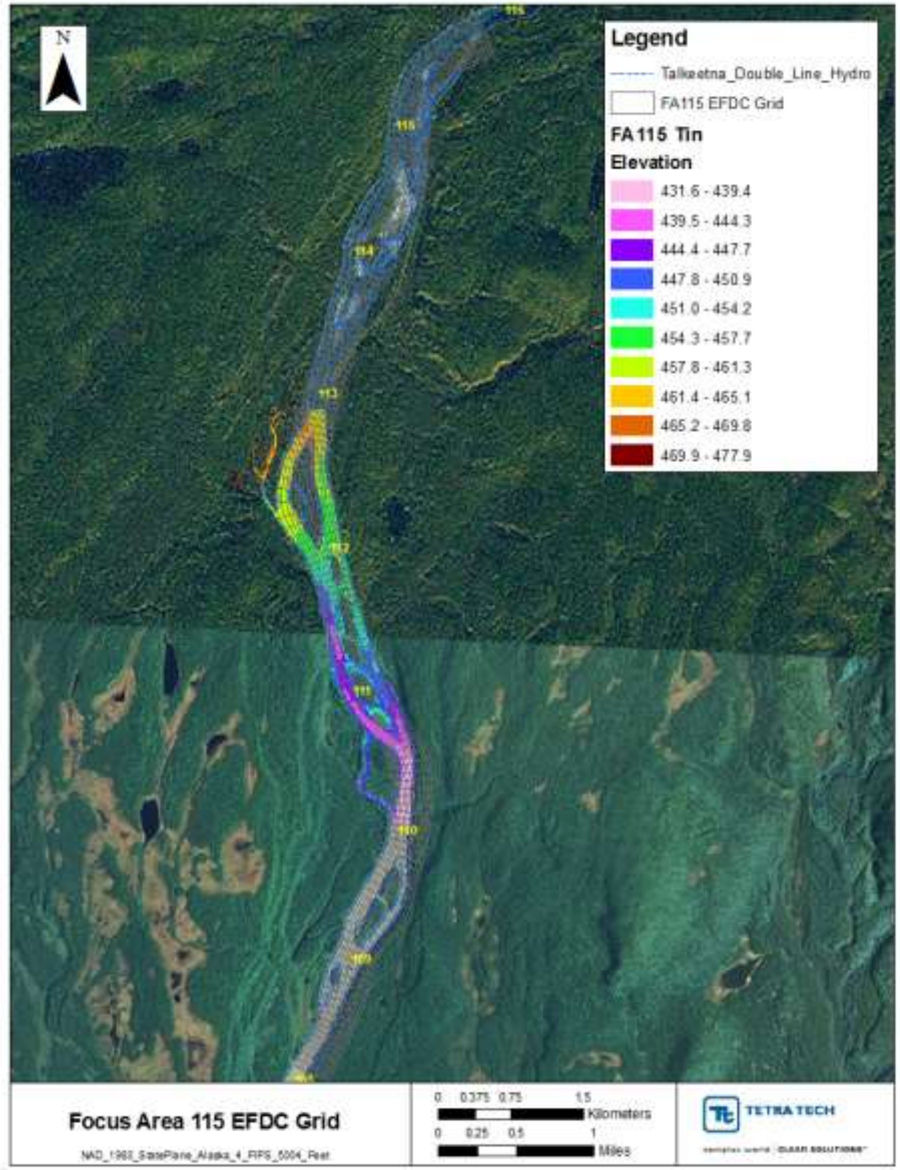


River Model Spatial Resolution Enhancement for Focus Areas

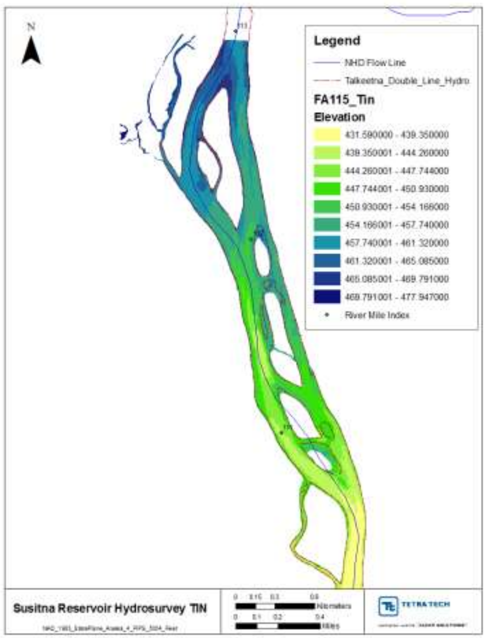
- *River model domain and resolution*
  - *Coarse resolution: 500 m longitudinally, 3 cells across main channel*
  - *Medium resolution: 250 m longitudinally, 5 cells across main channel*
  - *Finer resolution for Focus Areas*
- *Example Focus Area grid on following slides*
  - *Approximately 100 m longitudinally and 30 m laterally*
  - *Final resolution will be based on sensitivity to water quality constituent gradients in focus areas*

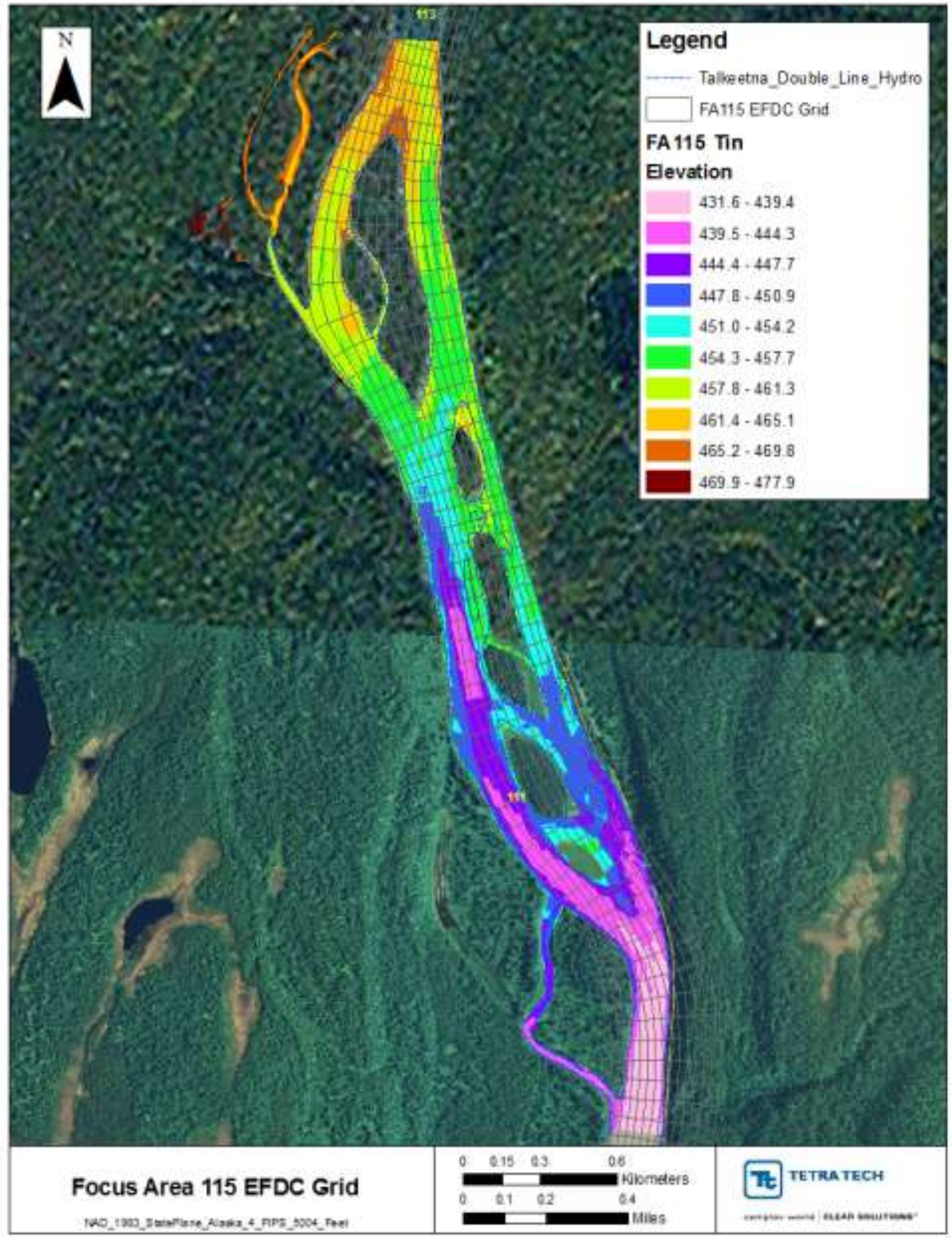
Example Grid in FA-115 (Slough 6A)



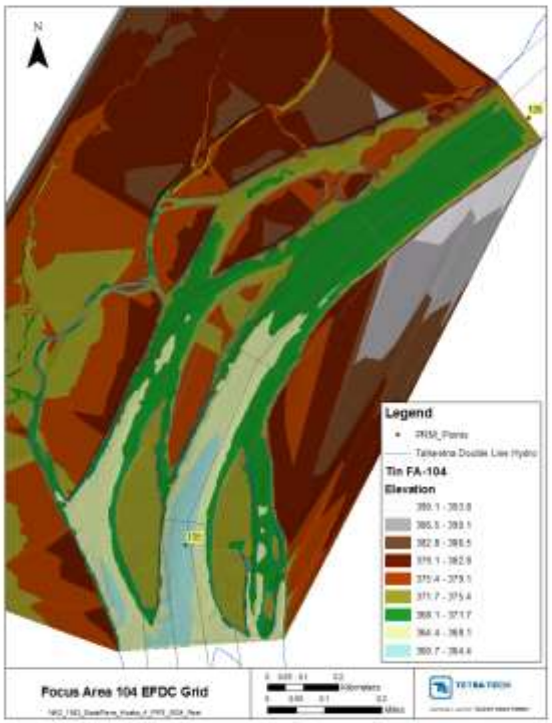


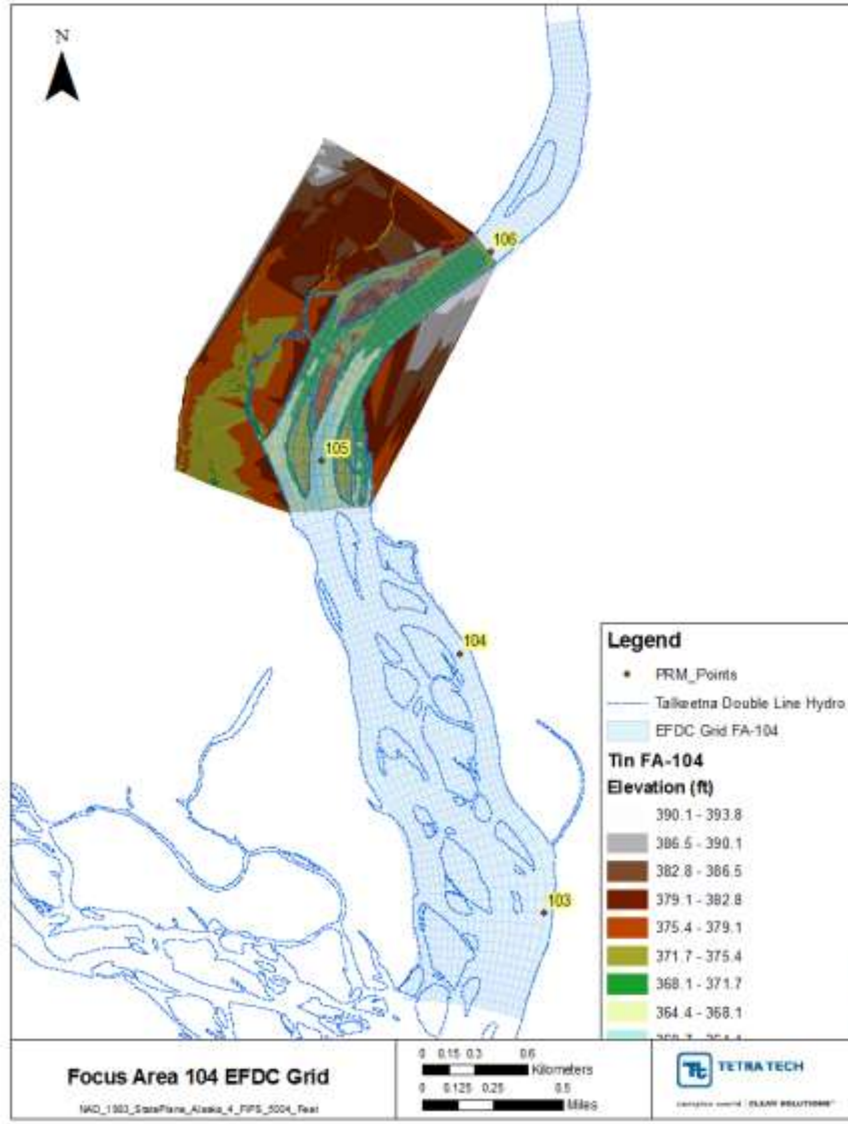
Example Grid in
FA-115 (Slough 6A)



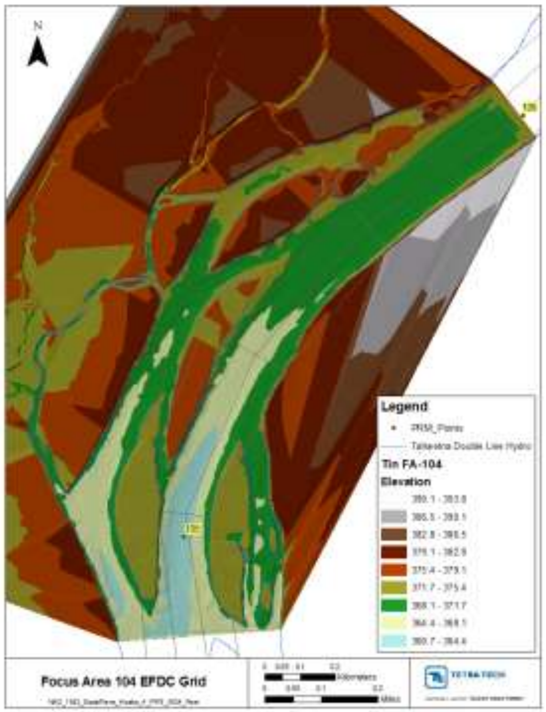


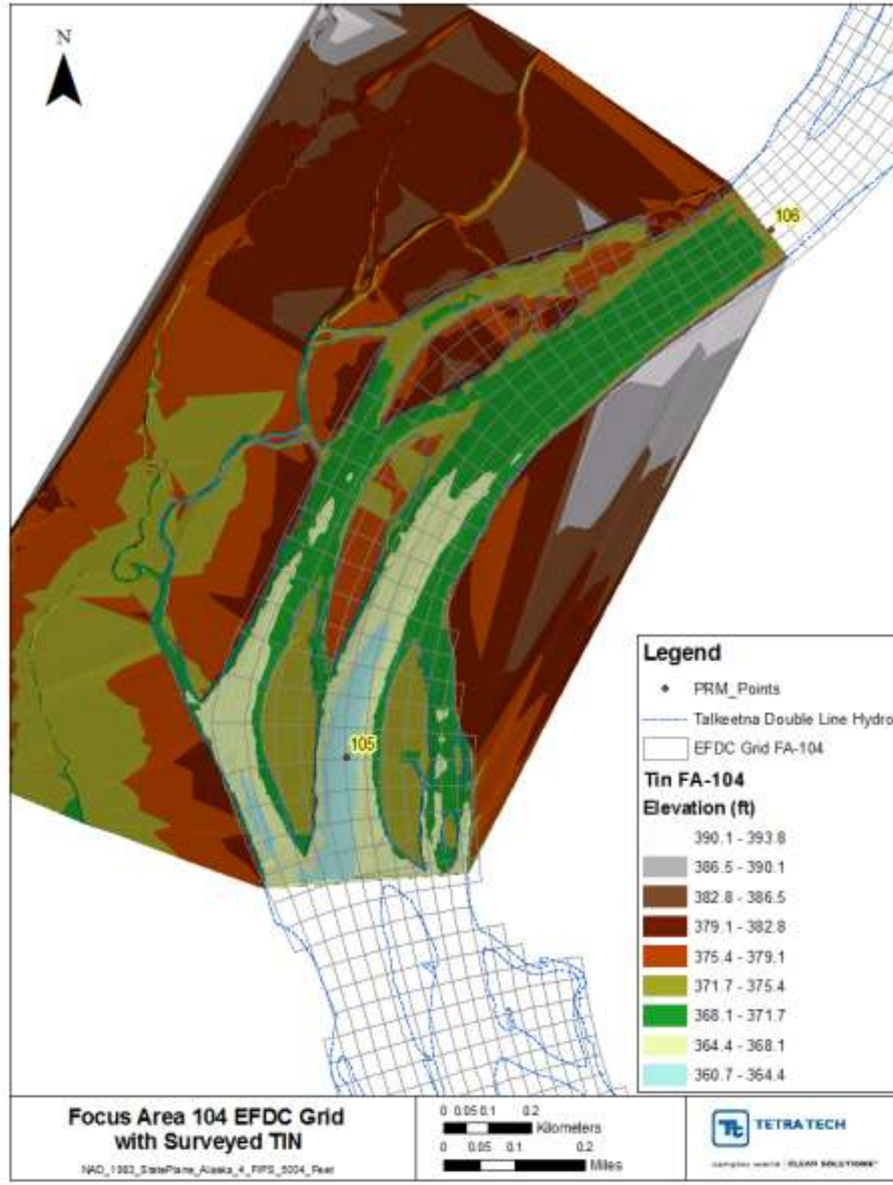
Example Grid in FA-104 (Whiskers Slough)





Example Grid in
FA-104 (Whiskers Slough)





Status of the River Model

- *Base spatial model configuration completed*
  - *From reservoir to below PRM 80*
- *Simulated 2012 observational/calibration period and 1984 operational*
- *Preliminary temperature simulations underway*
  - *Full year simulation using assumed ice-on and ice-off dates*
  - *Preliminary calibration to 2012 observations*
- *In progress*
  - *Refinement of base spatial configuration*
  - *Developing Focus Area grids for nesting into base configuration*

Hydrodynamic Model Data

	Reservoir	River
Shoreline	LiDAR derived elevation contours In use for model configuration	LiDAR derived nominal river shoreline In use for model configuration
Elevation	LiDAR derived contours In use for model configuration	Cross sections with possible LiDAR derived elevation extension 2012 cross sections from routing model in use
Resistance	Roughness height from ground surface type including vegetation cover estimated from LiDAR data Data analysis is progress	Roughness based on bed composition and bed forms Manning coefficient from routing model in use Need bed composition from geomorphic model
Historical Discharge	Gauged historical flow below reservoir USGS data in use Need data used for routing model Need data for ground water interaction	Historical flow at gauges along river and from tributaries USGS data in use Need data used for routing models Need data for ground water interaction
Operational Discharge	Annual time scale outflow from various operational conditions Need data from reservoir operation model and/or routing model	Annual time scale reservoir outflow for various operational conditions Need data from reservoir operation model and/or routing model

Temperature and Ice Model Data

	Reservoir	River
Wind	Project meteorological stations supplemented by NCDC station data In use for model configuration	Project meteorological stations supplemented by NCDC station data In use for model configuration
Atmospheric Conditions (Temp, Pressure, etc)	Project meteorological stations supplemented by NCDC station data In use for model configuration	Project meteorological stations supplemented by NCDC station data In use for model configuration
Radiation	Project meteorological stations supplemented by estimated from atmospheric conditions Estimates use theoretical corrected for estimated cloud cover. Presently working with NCDC data	Project meteorological stations supplemented by estimated from atmospheric conditions Estimates use theoretical corrected for estimated cloud cover. Presently working with NCDC data
Ice Cover Fraction and Thickness	Model predicted Uses wind, atmospheric conditions, and radiation	Provided by river Ice modeling
Thermal Loads	River and tributary flows and in-stream temperature observations Presently working with USGS flows and observed in-stream temperature data	River and tributary flows and in-stream temperature observations Need to coordinate with ice routing model for consistent thermal loads

Nutrient Cycling Model Data

	Reservoir	River
State Variables	Selection in progress Based on water quality observational study	Selection in progress Based on water quality observational study
External Loads	Historical river flow at reservoir site and upper and middle river water quality observations Observational data analysis in progress	Historical and operational river flow at reservoir site, tributary flows and estimated un-gauged inflow corresponding water quality observations and reservoir model output Observational data analysis in progress
Internal Loads	Primary production and decaying organic matter in flooded reservoir Estimates of flooded organic matter is progress	Primary production See parameterization
Initial Conditions	Flooded organic matter distribution and seeding concentrations See internal loads	River not sensitive From observational data
Parameters	Based on high latitude lake and reservoir literature data and inferred form observational data Literature review and data analysis in progress	Based on high latitude river literature data and inferred form observational data Literature review and data analysis in progress

Solids Transport Model Data

	Reservoir	River
State Variables	Multiple size classes of inorganic sediment and particulate organic matter Inorganic based on information from Geomorphic modeling for consistency. Organic consistent with nutrient cycling model	Multiple size classes of inorganic sediment and particulate organic matter Inorganic based on information from Geomorphic modeling for consistency. Organic consistent with nutrient cycling model
External Loads	Upstream inorganic sediment load from geomorphic study. Organic load estimated by downstream observations Need additional information	Upstream inorganic sediment load from geomorphic study and reservoir model. Organic load estimated by downstream observations and reservoir model Need additional information
Internal Loads	Internal organic solids loads from nutrient cycling model	Internal organic solids loads from nutrient cycling model
Initial Conditions	Bed initial conditions important for inorganic and organic solids Inorganic from geomorphic study	Bed initial conditions important for inorganic solids Inorganic from geomorphic study
Parameters	Settling, deposition and re-suspension Inorganic from and/or consistent with geomorphic study	Settling, deposition and re-suspension Inorganic from and/or consistent with geomorphic study

Mercury Cycling and Contaminant Model Data

	Reservoir	River
State Variables	Elemental, divalent, and methyl Water column and bed	Elemental, divalent, and methyl Water column and bed
External Loads	River flow at reservoir site and mercury study observational data Observational data to be analyzed	River flow at reservoir site and tributaries and mercury study observational data. Reservoir model mercury outflow Observational data to be analyzed
Internal Loads	Based on soil levels within reservoir foot print Observational data to be analyzed	Significance to be determined
Initial Conditions	Water column not sensitive. Bed consistent with internal loads Mercury study data to provide	Water column not sensitive. Significance of bed to be determined
Parameters	Mercury reaction parameters from literature for high latitude lakes and reservoirs and from study Review in progress	River and tributary flows and in-stream temperature observations Review in progress