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Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Technical Memorandum
Riparian Physical Process Modeling

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

R2 Resource Consultants, Inc.

March 2013

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LIST OF ACRONYMS AND SCIENTIFIC LABELS

Term	Definition
Active floodplain	The flat valley floor constructed by river during lateral channel migration and deposition of sediment under current climate conditions.
Aggradation	1. Geologic process in which inorganic materials carried downstream are deposited in streambeds, floodplains, and other water bodies resulting in a rise in elevation in the bottom of the water body. 2. A state of channel disequilibrium, whereby the supply of sediment exceeds the transport capacity of the stream, resulting in deposition and storage of sediment in the active channel.
Alluvial	Relating to, composed of, or found in alluvium.
Bank	The sloping land bordering a stream channel that forms the usual boundaries of a channel. The bank has a steeper slope than the bottom of the channel and is usually steeper than the land surrounding the channel.
Braid	Pattern of two or more interconnected channels typical of alluvial streams.
Channel	A natural or artificial watercourse that continuously or intermittently contains water, with definite bed and banks that confine all but overbank streamflows.
Confinement	Ratio of valley width (VW) to channel width (CW). Confined channel VW:CW <2; Moderately confined channel VW:CW 2-4; Unconfined channel VW:CW >4.
Confluence	The junction of two or more streams.
Cubic feet per second (cfs)	A standard measure of the total amount of water passing by a particular location of a river, canal, pipe or tunnel during a one second interval. One cfs is equal to 7.4805 gallons per second, 28.31369 liters per second, 0.028 cubic meters per second, or 0.6463145 million gallons per day (mgd). Also called second-feet.
Deposition	The settlement or accumulation of material out of the water column and onto the streambed.
Disturbance regime	Floodplain vegetation disturbance types found within the Susitna River Study Area corridor include: channel migration (erosion and depositional processes), ice processes (shearing impacts, flooding and freezing), herbivory (beaver, moose, and hare), wind, and, to an infrequent extent, fire. Floodplain soil disturbance is primarily ice shearing and sediment deposition.
Drainage area	The total land area draining to any point in a stream. Also called catchment area, watershed, and basin.
Embeddedness	The degree that larger particles (boulders, large wood, rubble, or gravel) are surrounded or covered by fine sediment. Usually measured in classes according to percent of coverage.
Floodplain	1. The area along waterways that is subject to periodic inundation by out-of-bank flows. 2. The area adjoining a water body that becomes inundated during periods of over-bank flooding and that is given rigorous legal definition in regulatory programs. 3. Land beyond a stream channel that forms the perimeter for the maximum probability flood. 4. A relatively flat strip of land bordering a stream that is formed by sediment deposition. 5. A deposit of alluvium that covers a valley flat from lateral erosion of meandering streams and rivers.
Geomorphic mapping	A map design technique that defines, delimits and locates landforms. It combines a description of surface relief and its origin, relative age, and the environmental conditions in which it formed. This type of mapping is used to locate and differentiate among relief forms related to geologic structure, internal dynamics of the lithosphere, and landforms shaped by external processes governed by the bio-climate environment.

Term	Definition
Geomorphology	The scientific study of landforms and the processes that shape them.
Gradient	The rate of change of any characteristic, expressed per unit of length (see Slope). May also apply to longitudinal succession of biological communities.
Gravel	Substrate particles between 0.1 and 3.0 inches in size, larger than sand and smaller than cobble.
Groundwater	In general, all subsurface water that is distinct from surface water; specifically, that part which is in the saturated zone of a defined aquifer.
Habitat	The environment in which the fish live, including everything that surrounds and affects its life, e.g., water quality, bottom, vegetation, associated species (including food supplies). The locality, site and particular type of local environment occupied by an organism.
Ice dam	A stationary accumulation of fragmented ice or frazil that restricts or blocks a stream channel.
Large woody debris (LWD)	Pieces of wood larger than 10 feet long and 6 inches in diameter, in a stream channel. Minimum sizes vary according to stream size and region.
Instream flow	The rate of flow in a river or stream channel at any time of year.
Pool	Part of a stream with reduced velocity, often with water deeper than the surrounding areas, which is usable by fish for resting and cover.
Riparian	Pertaining to anything connected with or adjacent to the bank of a stream or other body of water.
Riparian vegetation	Vegetation that is dependent upon an excess of moisture during a portion of the growing season on a site that is perceptively more moist than the surrounding area.
River	A large stream that serves as the natural drainage channel for a relatively large catchment or drainage basin.
River mile	The distance of a point on a river measured in miles from the river's mouth along the low-water channel.
Scour	The localized removal of material from the streambed by flowing water. This is the opposite of fill.
Sediment	Solid material, both mineral and organic, that is in suspension in the current or deposited on the streambed.
Three Rivers Confluence	The confluence of the Susitna, Chulitna, and Talkeetna rivers at Susitna River Mile (RM) 98.5 represents the downstream end of the Middle River and the upstream end of the Upper River.

1. INTRODUCTION

The Alaska Energy Authority (AEA) is preparing a license application that will be submitted to the FERC for the Susitna-Watana Hydroelectric Project (Project) using the Integrated Licensing Process. The Project is located at RM 184 on the Susitna River, an approximately 300-mile long river in the Southcentral region of Alaska (Figure 1). As currently envisioned, the Project would include a large dam with an approximately 35,000-acre, 41-mile long reservoir. Project construction and operation would have an effect on the flows downstream of the dam site, the degree of which will ultimately depend on final Project design and operations. Key flow changes will likely occur in the form of load following during the portion of the year when the reservoir is not full. Seasonal variation will result in flows higher during the winter months and lower during summer reservoir refill, June through August. The alteration in flows might influence downstream resources and processes, including fish and aquatic biota, and their habitats, and riparian and wildlife communities. Alterations to channel form and function might include changes in natural flow regime, sediment transport, large woody debris recruitment and transport, water quality, groundwater/surface water interactions, and ice dynamics.

Potential operational flow-induced effects of the Project will be evaluated as part of the licensing process, through studies spanning 2012 through 2014. The evaluation is important from both the impact minimization and operational optimization perspectives. In both cases, AEA desires to move from study results to decisions affecting flow releases in terms of (i) timing (seasonal, daily, diurnal), (ii) steady flow magnitudes, and (iii) magnitude and rate of change of unsteady flow. These three aspects of flow regime influence physical habitat quantity and quality and geomorphic processes, which in turn influence carrying capacity and overall suitability for target fish species and riparian vegetation.

The goal of the 2013–2014 Riparian Instream Flow Study (hereafter Riparian IFS) is to provide a quantitative, spatially-explicit model to predict potential impacts to downstream floodplain vegetation from Project operational flow modification of natural Susitna River flow, sediment, and ice process regimes. To meet this goal, a physical and vegetation process modeling approach will be used. First, existing Susitna River groundwater and surface water (GW/SW) flow, sediment and ice process regimes will be measured, and modeled. Second, floodplain plant community composition and structure will be characterized and mapped. Third, probabilistic models of floodplain vegetation type and physical process regimes will be developed. Fourth, predictive models will be developed to assess potential Project operational impacts to floodplain plant communities and provide operational guidance to minimize these impacts. Fifth, the predictive models will be applied throughout the Project study area and the results, using Geographic Information System (GIS), will be displayed in a series of maps of potential floodplain vegetation changes under alternative operational flow scenarios.

This technical memorandum provides a summary overview of the various climatic, seed dispersal, ice process, geomorphologic, and groundwater physical process modeling studies conducted in support of the Riparian IFS. The Riparian IFS Revised Study Plan (hereafter RSP), Section 8.6, provides complete details of both physical and vegetation studies, however, all of the various supporting physical modeling elements are found in their respective RSP Sections. For a complete picture of the physical modeling studies supporting the Riparian IFS the reader must consult all of the following RSPs: Riparian IFS (Section 8.6); Instream Flow Study

(Section 8.5); Geomorphology Study (Section 6.5); Fluvial Geomorphology Modeling below Watana Study Dam Study (Section 6.6); Groundwater Study (Section 7.5); Ice Processes in the Susitna River (Section 7.6); and Riparian Vegetation Study Downstream of the Proposed Watana Dam (Section 11.6).

The objective of this technical memorandum is to bring together for the reader, in one document: (1) a description of the various Riparian IFS physical process modeling elements, (2) illustrations of how each model contributes to specific Riparian instream flow studies, and (3) an integrated schedule of model deliverables. Table 1 provides the schedules for completion of studies that will be integrated into the Riparian IFS modeling. Tables 2 and 3 outline physical modeling input and output parameters that will be needed from or provided to other studies.

2. RIPARIAN IFS PHYSICAL PROCESS MODELING ELEMENTS

The Riparian IFS interdependencies, including physical process modeling elements, are presented in Figure 2. In addition to physical process modeling, a series of descriptive and analytical studies comprise the overall Riparian IFS (Figure 2). The logical sequencing of all of the analytical and modeling studies, and how they feed into final Project operations effects modeling, is presented in Figure 3.

In this Section, Riparian IFS physical process modeling elements will be discussed as presented in RSP Section 8.6 beginning with Section 8.6.3.3 'degree-day' climate and 'recruitment box' modeling in support of characterization of seed dispersal and seedling establishment groundwater and surface water hydroregime requirements. Next, RSP Section 8.6.3.4 ice process modeling characterization of the role of river ice in the establishment and recruitment of dominant floodplain vegetation is presented followed by RSP Section 8.6.3.5 fluvial geomorphic bed-evolution and sediment transport modeling characterization of Susitna River floodplain surfaces, the physical template for vegetation establishment; and finally, RSP Section 8.6.3.6 groundwater and surface water interaction modeling of critical hydroregimes necessary for floodplain vegetation establishment and maintenance is presented. RSP Section 8.6.3.7 Project operations effects modeling approach will not be presented here as the modeling approach will be developed in detail during Q1 through Q4 2013.

2.1. Climate, Hydrology and Seed Dispersal – Degree-day Climate and Recruitment Box Models

The goal of Riparian IFS RSP Section 8.6.3.3 climate, hydrology and seed dispersal study is to first, characterize groundwater and surface water hydroregime requirements for poplar (*Populus balsamifera*) and willow (*Salix* spp.) species seed dispersal and seedling establishment and second, to develop a predictive model of potential Project operational impacts to seedling establishment.

Specific study objectives are to:

1. Measure cottonwood and select willow species seed dispersal timing.
2. Model local Susitna River valley climate, and associated seasonal peak flows, relative to cottonwood and willow seed dispersal.

3. Develop a recruitment box model of seed dispersal timing, river flow regime, and cottonwood and willow seed dispersal and establishment.

Physical process modeling in support of this study include: (1) 'degree-day' climate model and (2) recruitment box model. The degree-day model incorporates seed release observations and continuous air temperature records from the Susitna River floodplain sites. The degree-day model characterizes annual plant development stages such as onset of vegetative and reproductive growth (seed release) as a cumulative daily heat load above a specific threshold temperature (Stella et al. 2006). The degree-day model will be parameterized by empirically calculating the heat-load that best predicts the onset of peak poplar and willow seed release. The model is based upon accurate local temperature records (Stella et al. 2006). The degree-day climate model element of the climate, hydrology and seed dispersal study is shown in Figure 4.

The "Recruitment Box Model," an empirical model, captures cottonwood and willow seed dispersal, flow response and establishment requirements (Figure 5; Mahoney and Rood 1998; Rood et al. 2003). The empirical model characterizes seasonal flow pattern, associated river stage (elevation), and flow down ramping rates necessary for successful cottonwood and willow seedling establishment (Figure 5 and Figure 6). The recruitment box model is based upon the results of the seed release study and flow routing physical process model (Aquatic IFS RSP Section 8.5.4.3). Study interdependencies are presented in Figure 4.

2.2. Ice Processes and Floodplain Vegetation

The goal of Riparian RSP Section 8.6.3.4 river ice and floodplain vegetation interaction study is to characterize the role of river ice in the establishment and recruitment of dominant floodplain vegetation. Although the role of fluvial disturbance (erosion and sediment deposition) in the development of floodplain vegetation has been well investigated (Naiman et al. 1998; Rood et al. 2007), the role of river ice processes has seen little study (Engstrom et al. 2011; Prowse and Beltaos 2002; Prowse and Culp 2003; Rood et al. 2007). Impacts of ice-related processes to riparian habitat typically occur during break-up when ice scours channel and floodplain surfaces (Prowse and Culp 2003). During break-up, ice accumulation in meander bends can create ice dams elevating backwater surfaces, forcing meltwater to bypass the bend and scour a new meander cutoff, generating new side channels (Prowse and Culp 2003). Elevated backwater, resulting from ice dams, may also float ice blocks onto and through vegetated floodplain surfaces, causing mechanical shearing effects including tree ice-scarring and abrasion, removal of floodplain vegetation, and disturbance of floodplain soils (Engstrom et al. 2011; Rood et al. 2007; Prowse and Culp 2003).

The objective of the ice effects vegetation study is to quantitatively describe floodplain plant community composition, abundance, age, and spatial pattern to assess the role and degree of influence ice processes have on Susitna River floodplain vegetation.

Specific objectives of the ice processes floodplain vegetation interaction and modeling study are to:

1. Develop an integrated model of ice process interactions with floodplain vegetation.
2. Conduct primary research to identify the effects of ice on floodplain vegetation within mapped Susitna River ice floodplain impact zones.

3. Provide Project operational guidance on potential effects of operations flow on ice formation and floodplain vegetation development.

The ice process study (RSP Section 7.6) will develop and calibrate a dynamic thermal and ice processes model. The model will provide maps of ice cover progression and decay, ice cover extent and thickness, and effects of Project operational flow fluctuation on ice cover development and stability. The ice process modeling study will provide the riparian ice vegetation study with estimated horizontal and vertical zones of ice formation, ice thickness, and floodplain impact zones. Model output will be used in conjunction with the empirical survey data to (1) empirically test model output with mapped riparian domains of ice floodplain vegetation interaction, and (2) model changes in locations and types of ice formation processes due to Project operational flow regime.

Study interdependencies are presented in Figures 7 and 8.

2.3. Geomorphology and Floodplain Vegetation

The Fluvial Geomorphology Modeling Study will support Riparian IFS RSP Section 8.6.3.5 characterization of the role of fluvial geomorphologic processes (erosion and sedimentation) in the formation of floodplain surfaces, soils and vegetation. The geomorphology study consists of two individual studies: (1) Geomorphology (RSP Section 6.5) investigation of historical and current geomorphology and geomorphic/geologic controls of the Susitna River by geomorphic reach using available information and additional information collected as part of the licensing effort; and (2) Fluvial Geomorphology Modeling Study (Section 6.6) that will apply 1-D and 2-D hydraulic and bed evolution models to quantify geomorphic processes in the existing river, equilibrium status of identified reaches and associated, potential Project effects on river geomorphology, and thus, habitats, including floodplain development. Finally, the results of the fluvial geomorphology modeling study will support the development of a predictive model to assess potential Project effects on riparian seedling establishment.

The dynamics of channel migration—sediment transport, and resulting floodplain erosion and sediment depositional patterns—is a critical physical process directly affecting floodplain soil development, and vegetation establishment, recruitment, and spatial location, throughout alluvial segments of the river network (Richards et al. 2002). The life history strategies and establishment requirements of floodplain plant species are adapted to natural flow and sediment regimes (Braatne et al. 1996; Naiman et al. 1998; Karrenberg et al. 2002). As such, alterations of natural hydrologic and sediment regime seasonal timing, magnitude, frequency, and duration may have effects on plant species establishment, survival, and recruitment (Braatne et al. 1996). The goal of this study is to characterize the role of erosion and sediment deposition in evolution of floodplain plan form, soil development, and trajectory of plant community succession, especially vegetation establishment stage. This study will investigate the geomorphic evolution of the Study Area floodplain with an emphasis on floodplain sediment deposition, stratigraphy, soil development, and associated plant community succession. Historic sediment deposition rates will be measured throughout the Study Area river network and variations in floodplain forming processes will be assessed. Finally, a predictive model will be developed with the Fluvial Geomorphology Study (see Section 6.6) to assess Project operational effects on hydrologic and sediment regimes, and effects on soil and floodplain plant community development.

The fluvial geomorphology modeling approach (see RSP Section 6.6) is based upon (1) 1-D / 2-D modeling of river discharge and stage, (2) 1-D / 2-D sediment transport model, and (3) channel bed evolution model.

Study interdependencies are presented in Figures 9 and 10. Data input and output from 1-D and 2-D models are presented in Tables 4 and 5. The objectives of the study are as follows:

1. Measure the rates of channel migration, and floodplain vegetation disturbance or turnover, throughout the Study Area.
2. Measure the rates of sediment deposition, and floodplain development, throughout the Study Area.
3. Assess / model how Project operations will effect changes in the natural sediment regime, floodplain depositional patterns, and soil development throughout the Study Area.
4. Assess / model how Project operations changes in sediment transport and soil development will affect floodplain plant community succession.

2.4. Surface Water / Groundwater Regime and Floodplain Vegetation

The Groundwater Study (RSP Section 7.5) will support the Riparian IFS in providing a surface water/ groundwater (SW/GW) interaction model at select Focus Area sites. The SW/GW model will characterize and model natural floodplain vegetation groundwater and surface water hydroregimes and be the basis for developing a predictive model to assess potential Project operational changes to natural hydroregime and floodplain vegetation.

The goal of the floodplain vegetation GW/SW interaction modeling effort is to empirically sample, statistically characterize, and model the relationship between floodplain groundwater and surface water hydroregime and associated floodplain plant communities and to use this model to predict Project operation effects on floodplain vegetation throughout the Study Area. This investigation will (1) characterize dominant floodplain woody plant species establishment and maintenance life stage water sources through stable isotope analyses of groundwater, soil water, and xylem water; (2) develop a floodplain GW/SW model; and (3) develop floodplain vegetation-flow response models.

2.4.1. Groundwater and Surface Water Interaction Modeling

A physical model of GW/SW interactions will be developed for each of five Focus Area sites, of riparian concern, to model floodplain plant community GW/SW relationships. Developing conceptual model and numerical representations of the GW/SW interactions, coupled with important processes in the unsaturated zone, will help evaluate natural variability in the Susitna River riparian floodplain plant communities, and assesses how various Project operations may potentially result in alterations of floodplain plant community types, as well as improve the understanding of what controlled fluctuations of flow conditions would result in minimal riparian changes.

MODFLOW (USGS 2005), the most widely used groundwater model in the U.S. and worldwide, will be used. Additionally, RIP-ET (riparian−evapotranspiration MODFLOW package;

Maddock et al. 2012), developed to help better represent plant transpiration processes in the unsaturated zone, will be utilized to more accurately calculate evapotranspiration, separating out plant transpiration from evaporation processes.

The riparian vegetation GW/SW interactions study approach and design will be integrated with the findings of the riparian plant community succession, geomorphology, and ice processes modeling to characterize physical processes and riparian plant community relationships. The results of these studies will be used to assess (1) changes to physical processes due to dam operations, and (2) response of riparian plant communities to operations alterations of natural flow and ice processes regimes.

Study interdependencies are presented in Figures 11 and 12. The detailed GW/SW interaction study approach and methods are presented in the Groundwater Study, RSP Section 7.5.

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4. TABLES

Table 1. Integration of Riparian IFS physical modeling schedule with other studies.

Activity	2012				2013				2014				2015
	1 Q	2 Q	3 Q	4 Q	1 Q	2 Q	3 Q	4 Q	1 Q	2 Q	3 Q	4 Q	1Q
Ice Processes Study (Section 7.6)													
Existing Condition 1-D Model Development													
Proposed Condition 1-D Model Development													
Intensive Site Models													
Geomorphology Study (Section 6.5)													
Integration with & Support of Interpreting Fluv. Geomorph. Modeling Results													
Fluvial Geomorphology (Section 6.6)													
Coordination w/ Other Studies on Modeling Needs Including Focus Areas													
Coordinate with Other Studies on Processes Modeled													
Perform 2-D Modeling of Existing Conditions													
Perform 1-D Modeling of Alternative Scenarios													
Perform 2- Modeling of Alternative Scenarios													
Post Process and Provide Model Results to Other Studies													
Interpretation of Channel Change and Integration with Other Studies													
Groundwater Study (Section 7.5)													
Riparian Vegetation Dependency on SW/GW Interactions													
Fish and Aquatics Instream Flow Study (Section 8.5)													
Hydraulic Flow Routing (Section 8.5.4.3)													
Distribute final mainstem (open-water) routing model to TWG for review													▲
Use final mainstem (open-water) routing model for scenario evaluations													
Hydrologic Data Analysis (Section 8.5.4.4)													
TWG meeting to review complete hydrologic record													▲
Use hydrologic record for scenario evaluations													

Legend:

— Planned Activity
- - - Follow-up activity (as needed)
● Technical Memorandum or Interim Product
Δ Initial Study Report
▲ Updated Study Report

Table 2. Information and products required by the Riparian IFS Study from other studies.

Source of Product or Information	Information or Product to be Provided	Timing
Information or Products Required for: Recruitment Box Model of Seed Dispersal Timing and Flood Regime		
IFS Flow Routing (Section 8.5)	Flow Modeling (Frequency, magnitude, duration, and seasonal timing)	Q4-13 Q4-14
Geomorphology Study (Section 6.5)		
Information or Products Required for: Seedling Establishment and Recruitment Study		
Fluvial Geomorphology Study (Section 6.6)	Groundwater, surface water, and sediment regime characteristics of seedling sites	Q4-14
Groundwater (Section 7.5)		Q4-14
Ice Processes (Section 7.6)	Ice influence vertical and horizontal zones	Q4-14
Information or Products Required for: River Ice and Floodplain Processes Study		
Ice Processes (Section 7.6)	Ice Process modeling results – Spatial location of ice, vertical extent of ice, and potential ice dam locations	Q4-13 Q4-14
Information or Products Required for: Role of Erosion and Sediment Deposition in Floodplain Processes		
Fluvial Geomorphology Study (Section 6.6)	Historic channel migration rates, floodplain vegetation disturbance or turnover rate	Q4-13
	Flood frequency, magnitude, duration, and timing	Q4-13
	Sediment transport and depositional spatial model	Q4-14
IFS Flow Routing (Section 8.5)	Study Area-wide flood frequency, magnitude, duration, and timing	Q4-13 Q4-14
Riparian Botanical Survey (Section 11.6)	Sediment and soils stratigraphic description, strata management and floodplain sediment dating	Q4-13 Q4-14
Information or Products Required for: Groundwater and Surface Water Maintenance Hydroregime		
Groundwater (Section 7.5)	GW/SW interaction modeling seasonal statics including frequency, timing, and duration of water levels.	Q3-13 through Q4-14

Table 3. Information and products the Riparian IFS Study will provide to other studies.

Study the Product or Information is Provided to	Information or Product to be Provided	Timing
Groundwater Study (Section 6.5)	Evapotranspiration model data for incorporation into MOD-FLOW	Q4-13 & Q4-14
Riparian Botanical Survey (Section 11.6)	Dendrological studies results: ITU sample plot tree ages, and shrub and tree composition and abundance measurements	Q4-13 & Q4-14

Table 4. Primary output variables for which values are taken directly from the 1-D and 2-D mobile-boundary models and relevance to other studies.

Variable	Description of Model Output	Spatial Resolution	Relevance to Other Studies
1-D mobile-boundary model			
Water-surface profiles	Steady-state water-surface profiles for all discharges	Cross section	Geomorphology
Cross-sectionally averaged hydraulic conditions	Flow depth, velocity, bed shear stress, channel top width	Cross section	FA-IFS, **R-IFS**, Geomorphology
Bed material load transport rates	Transport rates by grain size fraction	Cross section	Geomorphology
Bed material (i.e., substrate) gradations	Change in surface layer bed gradations by cross section over time (0, 25, 50 years)	Cross section	FA-IFS, Geomorphology
Bed elevation	Changes in bed elevation with time	Cross section, longitudinal profile	FA-IFS, **R-IFS**, Geomorphology, GW
2-D mobile-boundary model			
Water-surface elevations	Steady and unsteady water-surface elevations	Grid element	FA-IFS, **R-IFS**, Geomorphology, GW
Depth-averaged hydraulic conditions	Flow depth, velocity (magnitude and direction), bed shear stress	Grid element	FA-IFS, **R-IFS**, Geomorphology, GW
Flow distribution among multiple channels (including side channels)	Discharge in each branch (including side channels) over range of flows; changes associated with bed evolution model results	Channel width	FA-IFS, **R-IFS**, Geomorphology, GW
Bed material load transport rates	Transport rates by grain size fraction, including supply to and transport through side channels	Grid element	FA-IFS, **R-IFS**, Geomorphology, GW
Bed material (i.e., substrate) gradations	Change in substrate gradations by grid element over time, including side channels and side sloughs	Grid element	FA-IFS, **R-IFS**, Geomorphology, GW
Bed elevation	Changes in bed elevation with time, including side channels and side sloughs. Evolution of mouths and spawning areas of particular interest	Grid element	FA-IFS, **R-IFS**, Geomorphology, GW
Breaching flows	Magnitude, frequency and duration of flows overtopping control at the head of side channels	Grid element →side channel width	FA-IFS, Geomorphology

Table 5. Key variables needed for the impact assessments for which results are obtained through additional analysis of predictions taken directly from the 1-D and 2-D mobile-boundary models.

Variable	Description	Spatial Resolution	Relevance to Other Studies
1-D mobile-boundary model			
Wash load transport rates	Correlations between wash load transport rates and discharge	Gage locations	WQ, **R-IFS**
Overbank sedimentation rates	Rate of sediment delivery into overbanks and vertical accretion rates	Reach-averaged	**R-IFS**, Geomorphology
Breaching flows	Magnitude, frequency and duration of flows overtopping control at the head of side channels	Site	**R-IFS**, Geomorphology
Side channel connectivity	Frequency, duration and inundation extent of backwater flows into side channels	Site	**R-IFS**
Bed Material Motion Thresholds (aka Incipient Motion Analysis)	Frequency and duration of flows sufficient to cause general mobilization of bed material	Cross section and/or reach-averaged	FA-IFS, Geomorphology
Bed material transport capacity rating curves	Bed material transport capacity (total and by-size fraction) as a function of discharge	Cross section and/or reach-averaged	Geomorphology
Effective Discharge	Magnitude and frequency of flows that transport the most sediment over defined period of time	Reach-averaged	Geomorphology
Bank erosion rates	Estimated rate of erosion into main and side channel banks	Cross section and/or reach-averaged	**R-IFS**, Geomorphology
LWD recruitment	Quantities of LWD delivered to mainstem and side channels due to bank erosion	Reach	**R-IFS**, Geomorphology
Deposition rates at tributary mouths	Evolution of tributary mouth fans/bars over time	Geomorphology unit	FA-IFS, Geomorphology
Hydraulic conditions at tributary mouths	Potential effect of changes in tributary mouths and effects on fish passage into tributaries	Geomorphology unit	FA-IFS, Geomorphology
2-D mobile-boundary model			
Weighted-useable-area versus discharge curves	Hydraulic conditions (velocity, depth, substrate size) provided to FA-IFS for WUA estimates	Grid element→ Habitat unit	FA-IFS, Geomorphology
Overbank sedimentation rates	Rate of sediment delivery into overbanks and vertical accretion rates	Grid element	**R-IFS**, Geomorphology
Bed Material Motion Thresholds (aka Incipient Motion Analysis)	Frequency and duration of flows sufficient to cause general mobilization of bed material	Grid element→ Habitat unit	FA-IFS, Geomorphology
Bank erosion rates	Changes in bank shear stress and bank energy index (BEI)	Model reach	**R-IFS**, Geomorphology
Changes in side channel, side slough and upland slough geometry	Evolution of channel width and depth	Grid element →side channel width	FA-IFS, **R-IFS**, Geomorphology
Fine sediment interactions in spawning areas	Potential for infiltration and flushing of fines from spawning substrate, including side channels and side sloughs	Grid element→ Habitat unit	FA-IFS, **R-IFS**, Geomorphology

Variable	Description	Spatial Resolution	Relevance to Other Studies
LWD recruitment	Changes in bank erosion rates that could affect LWD recruitment	Grid element	FA-IFS, **R-IFS**, Geomorphology

5. FIGURES

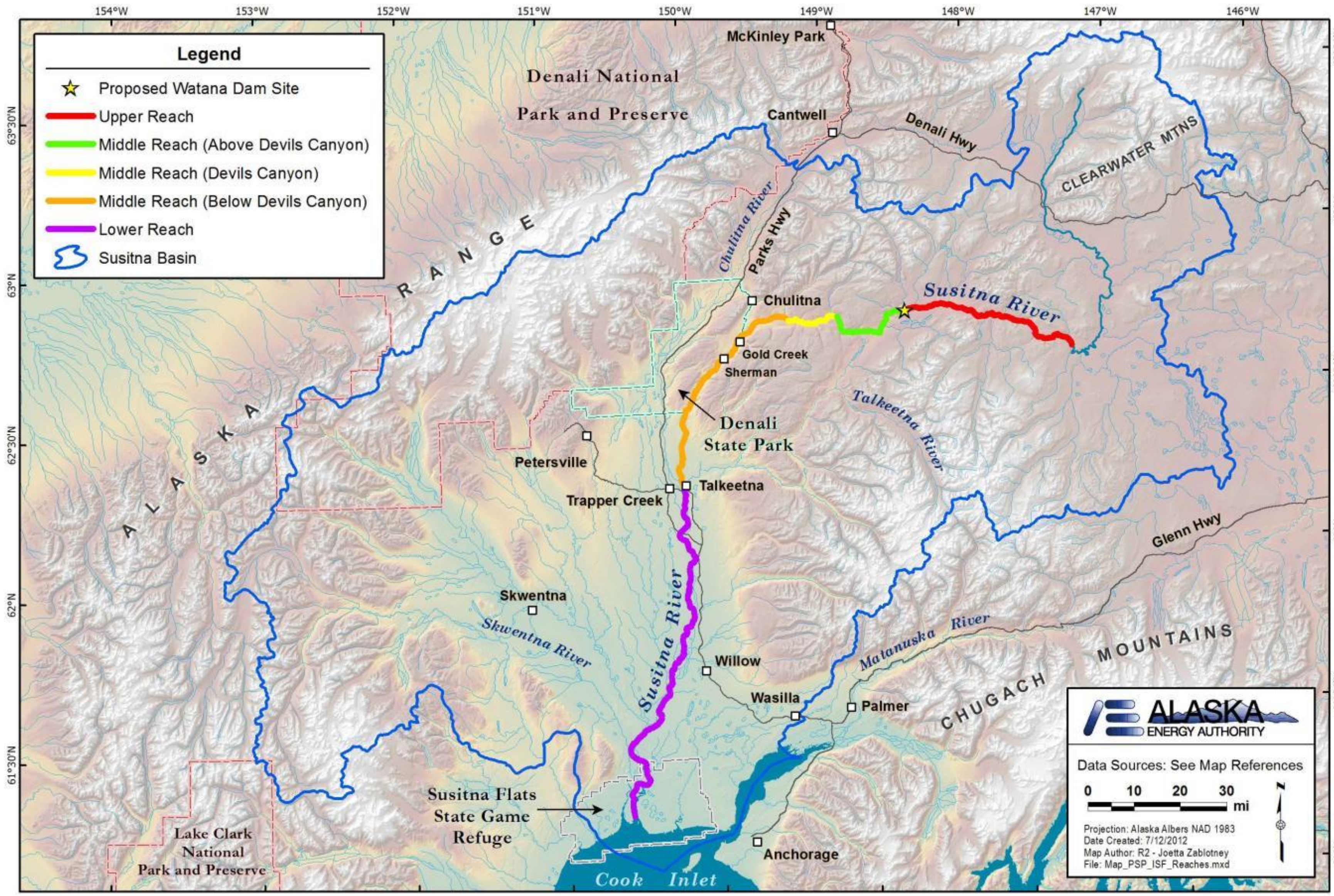

Figure 1. Susitna River Project Area.

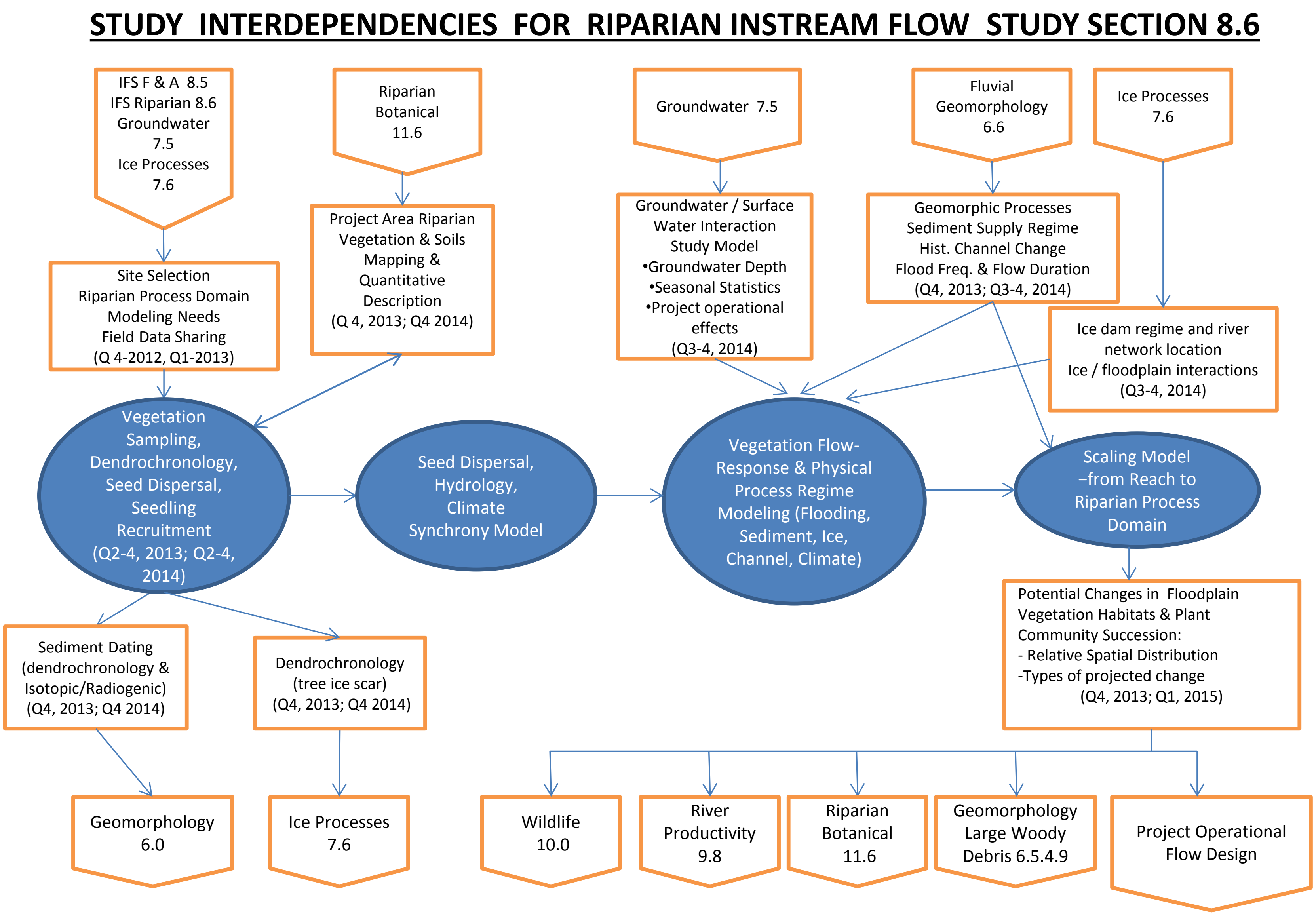

Figure 2. Study interdependencies for Riparian Instream Flow Study (Source: RSP Section 8.6).

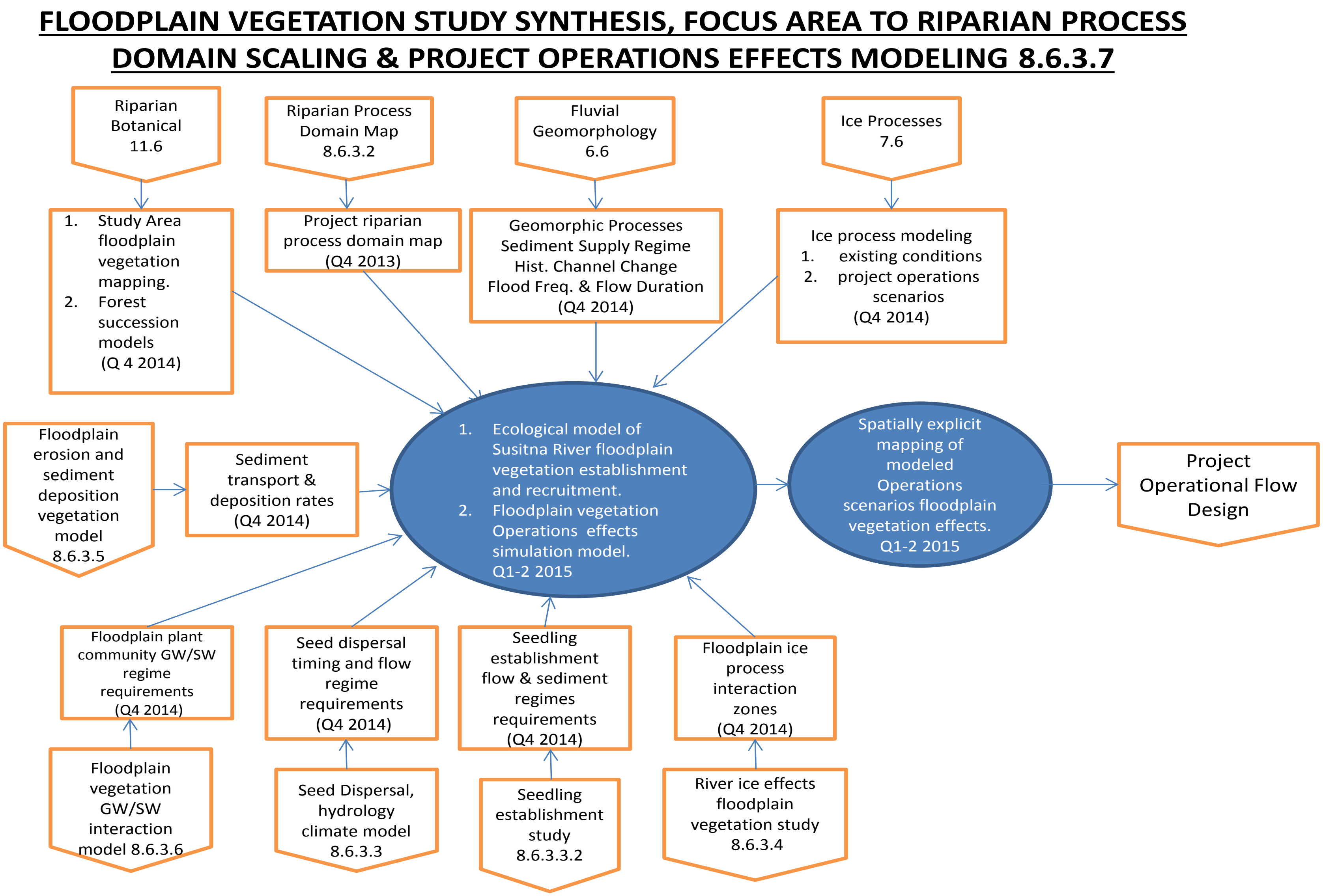

Figure 3. Floodplain Vegetation Study Synthesis, Focus Area to Riparian Process Domain Scaling & Project Operations Effects Modeling (Source: RSP Section 8.6.3.7).

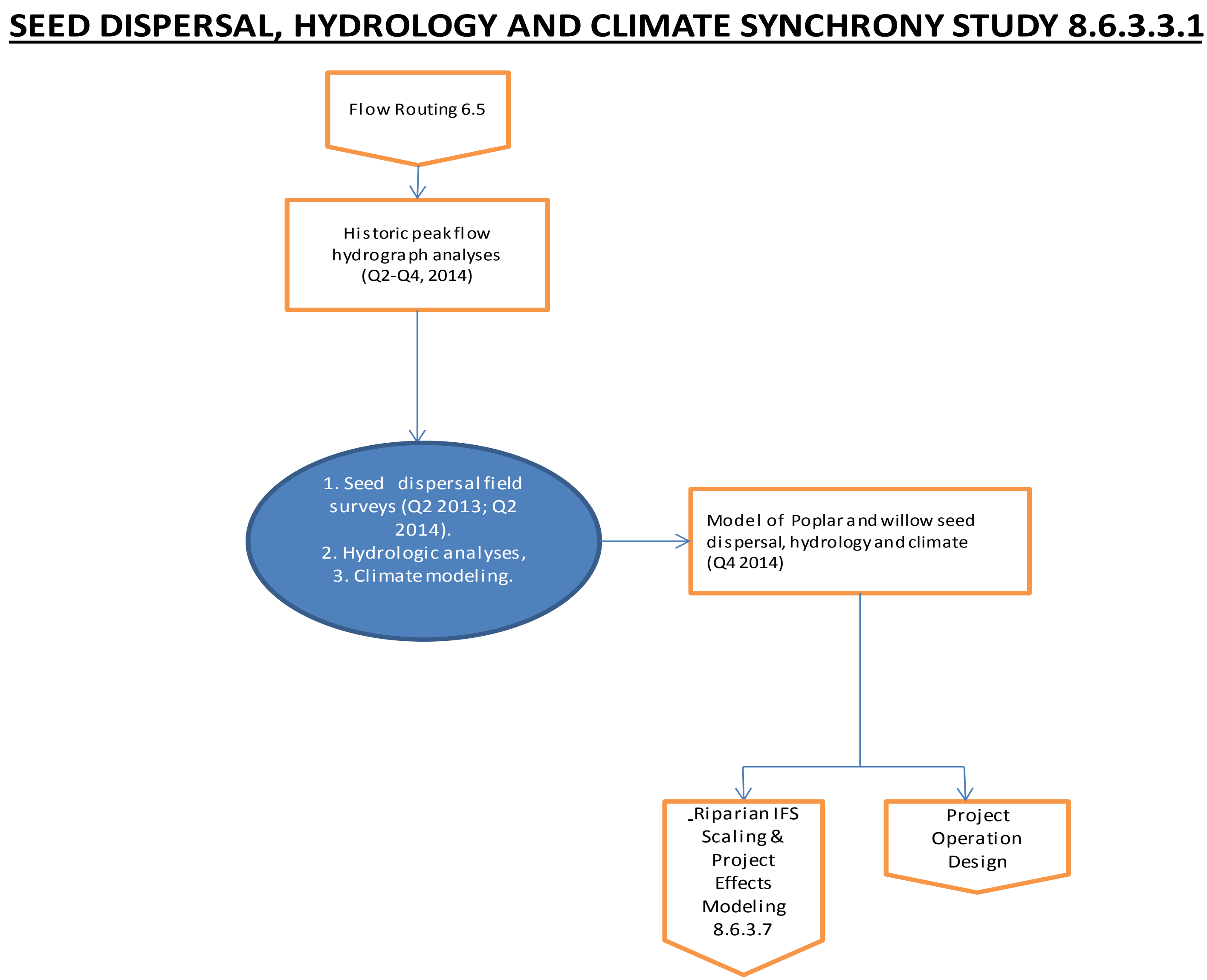

Figure 4. Seed Dispersal, Hydrology and Climate Synchrony (Source: RSP Study 8.6.3.3.1).

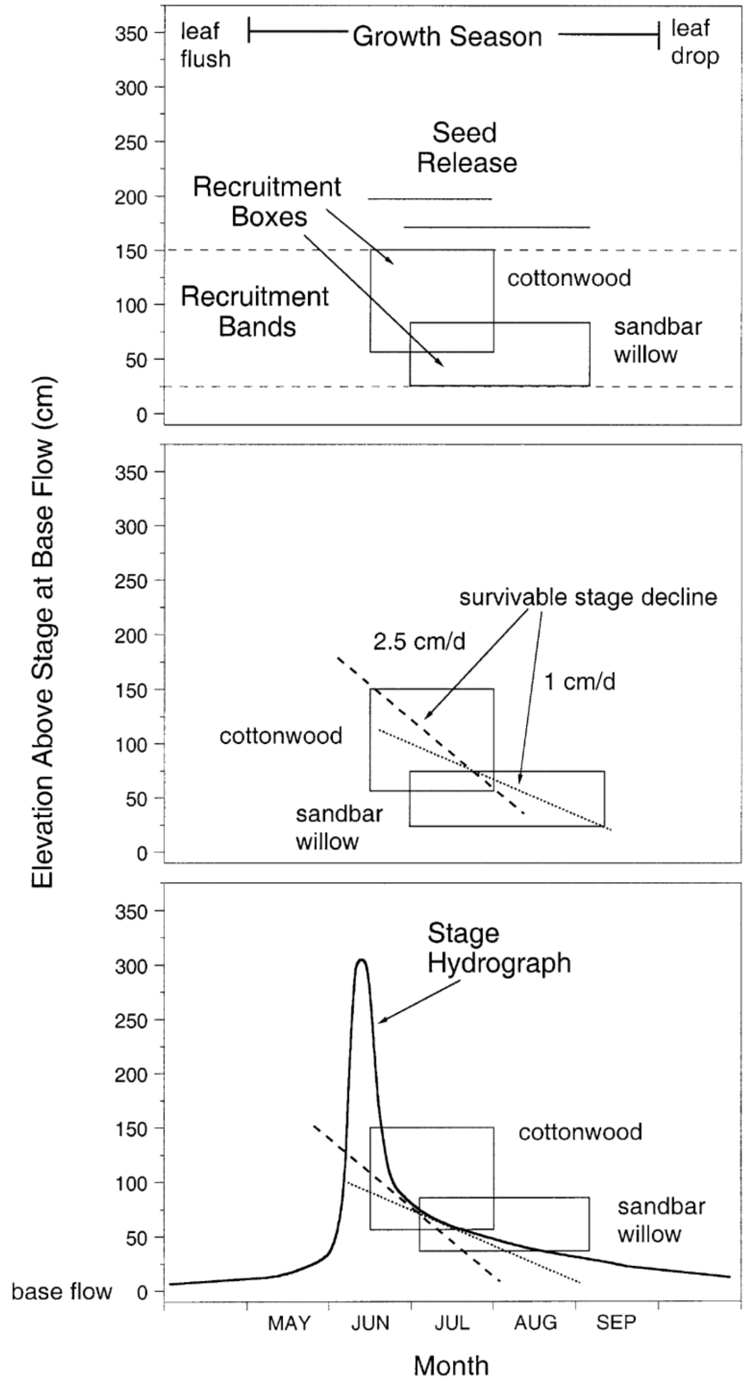

Figure 5. The riparian "Recruitment Box Model" describing seasonal flow pattern, associated river stage (elevation), and flow ramping necessary for successful cottonwood and willow seedling establishment (from Amlin and Rood 2002; Rood et al., 2005). Cottonwood species (*Populus deltoides*), willow species (*Salix exigua*). Stage hydrograph and seed release timing will vary by region, watershed, and plant species.

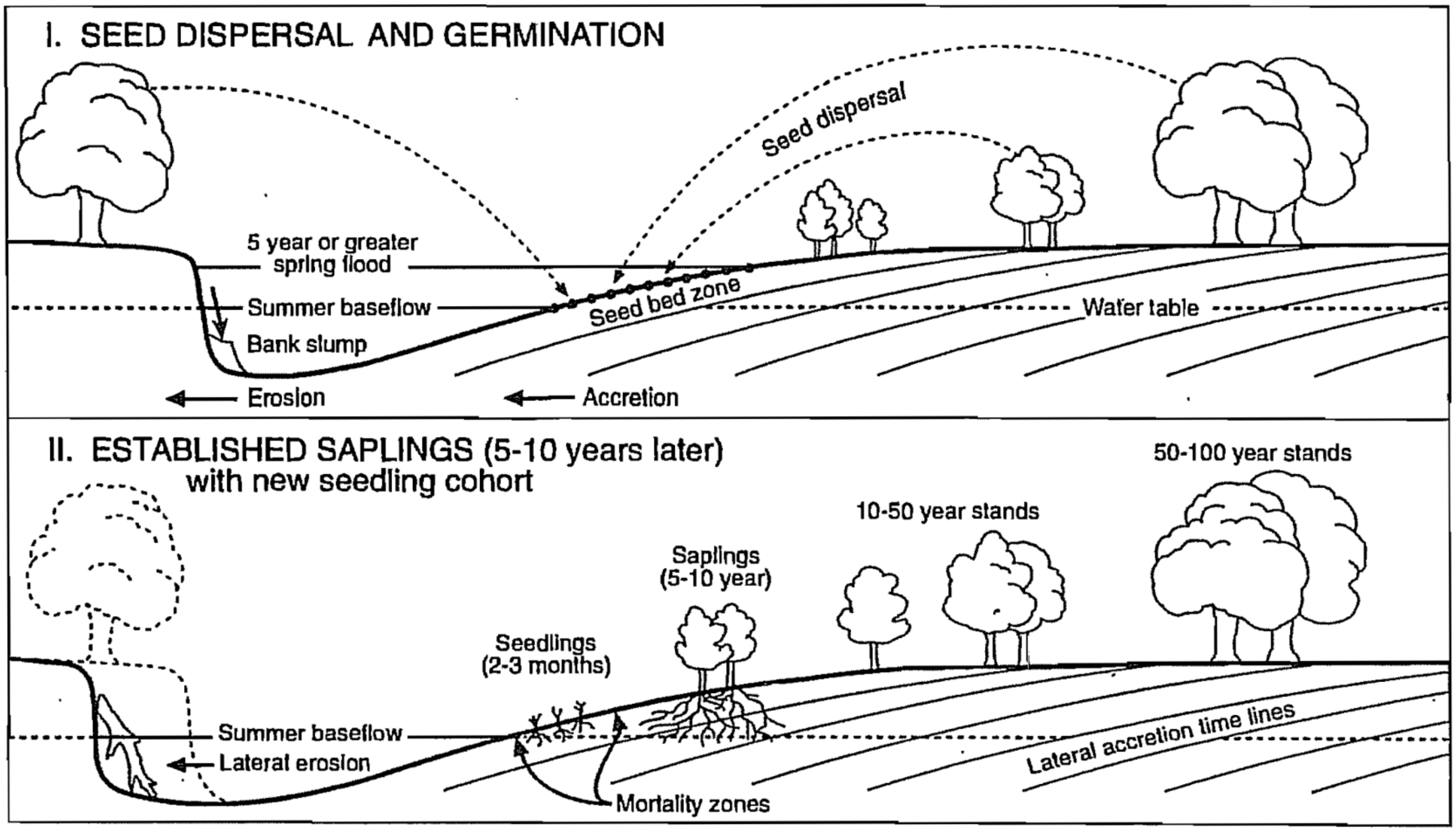

Figure 6. Cottonwood (Populus) life history stages: seed dispersal and germination, sapling to tree establishment. Cottonwood typically germinates on newly created bare mineral soils associate with lateral active channel margins and gravel bars. Note proximity of summer baseflow and floodplain water table (Braatne et al. 1996).

RIVER ICE– FLOODPLAIN VEGETATION ESTABLISHMENT AND RECRUITMENT 8.6.3.4

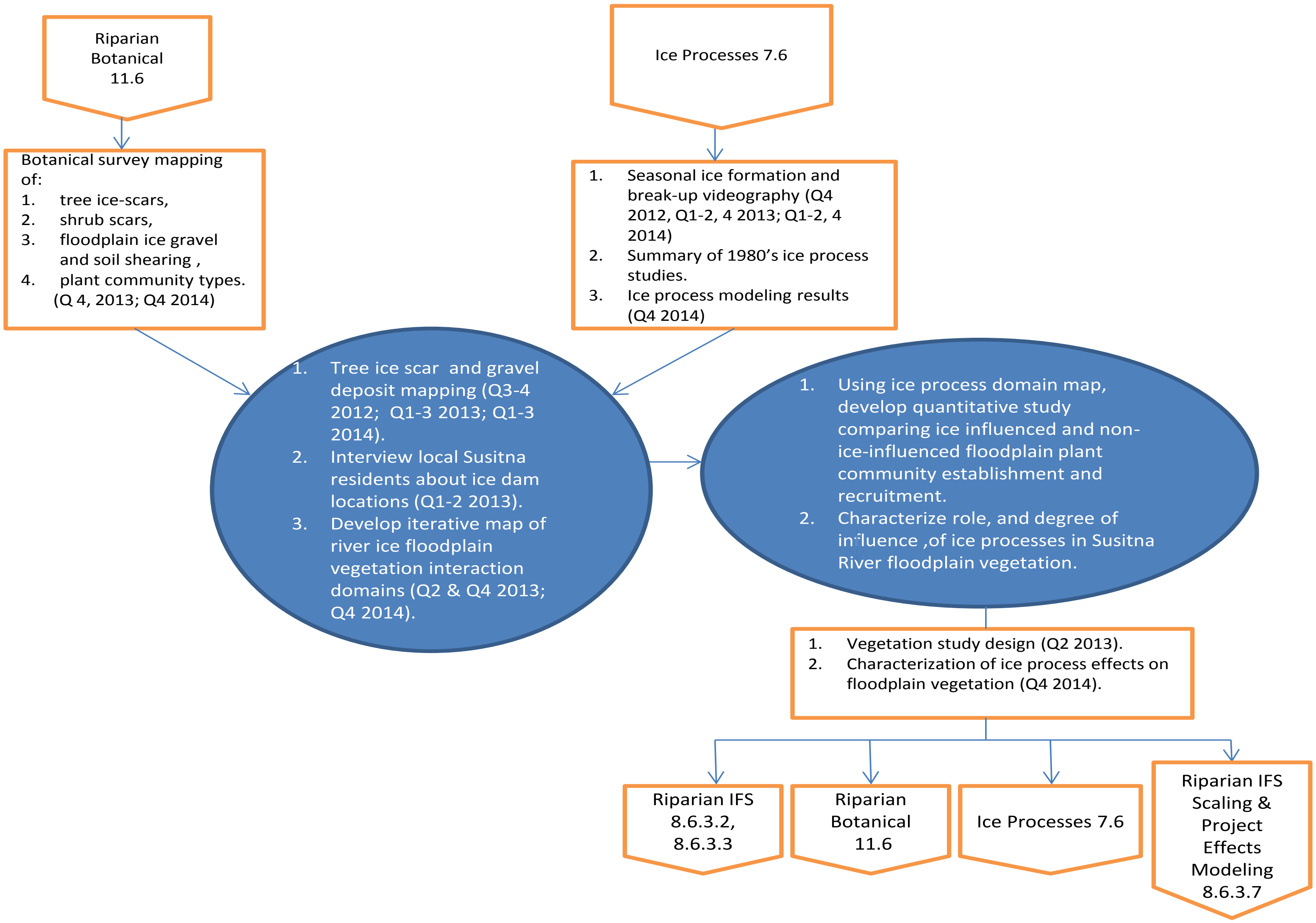

Figure 7. River Ice-Floodplain Vegetation Establishment and Recruitment (Source: RSP Section 8.6.3.4).

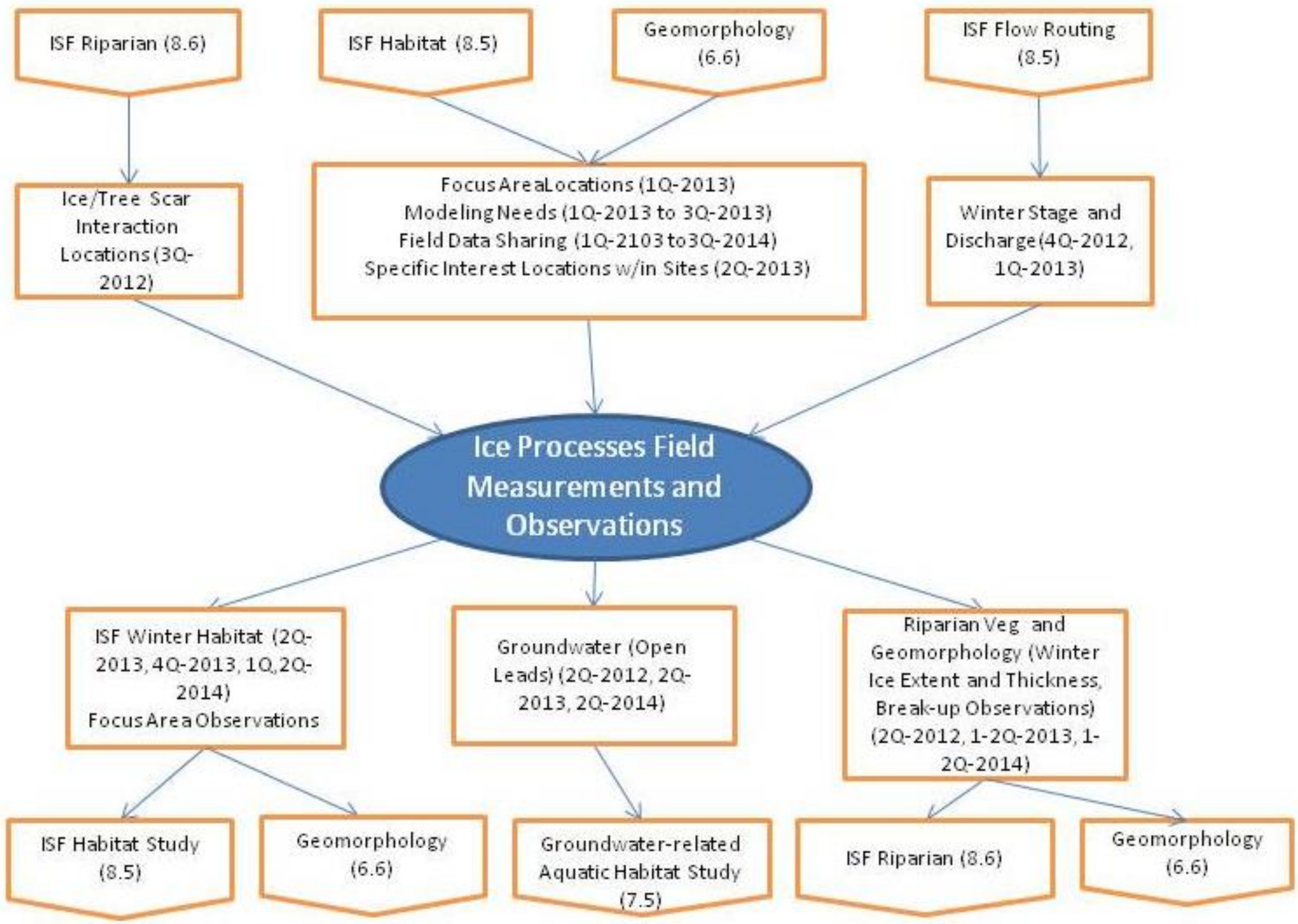

Figure 8. Relationship of ice observations to other studies (Source: RSP Section 7.6.11) .

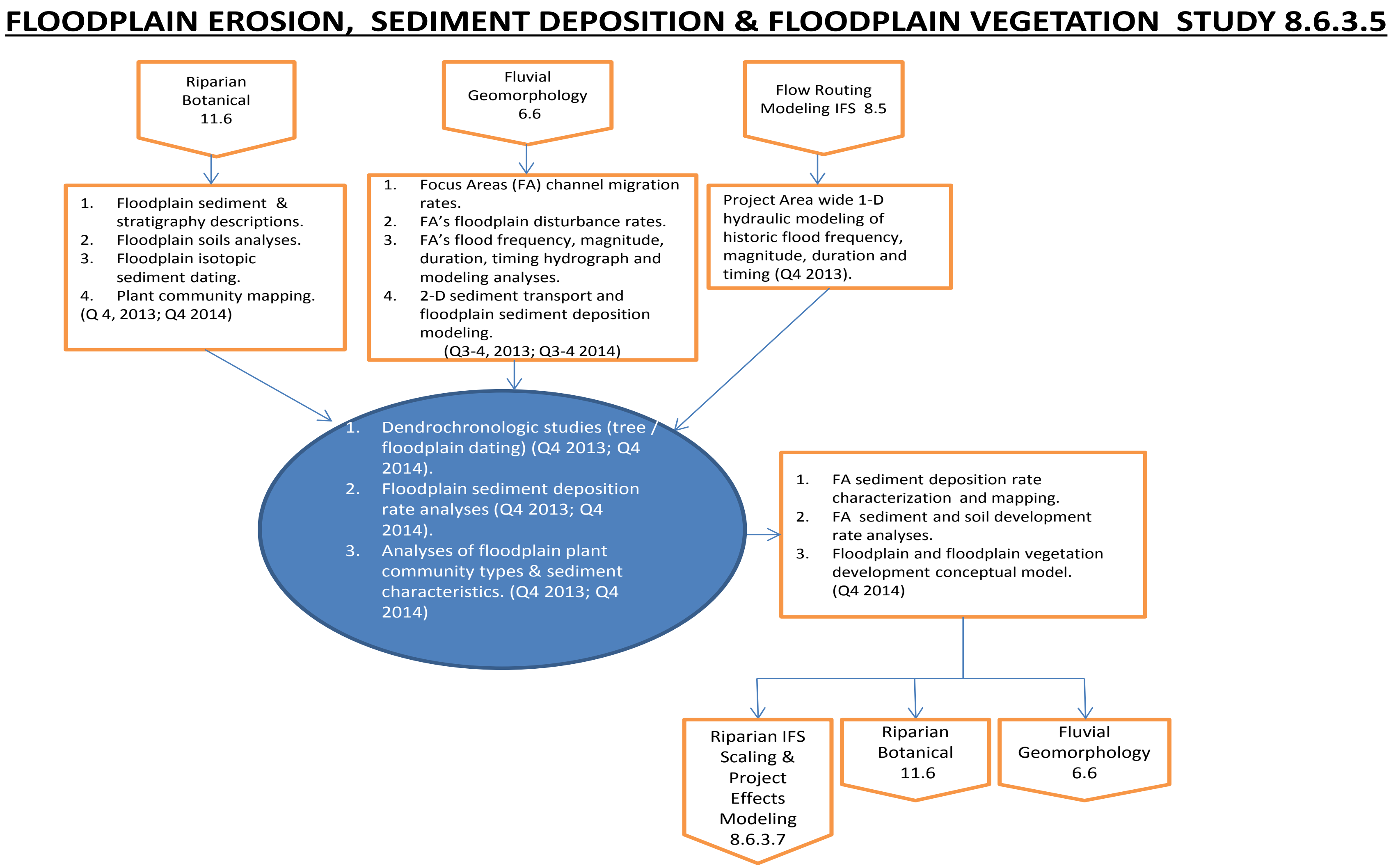

Figure 9. Floodplain Erosion, Sediment Deposition & Floodplain Vegetation Study (Source: RSP Section 8.6.3.5).

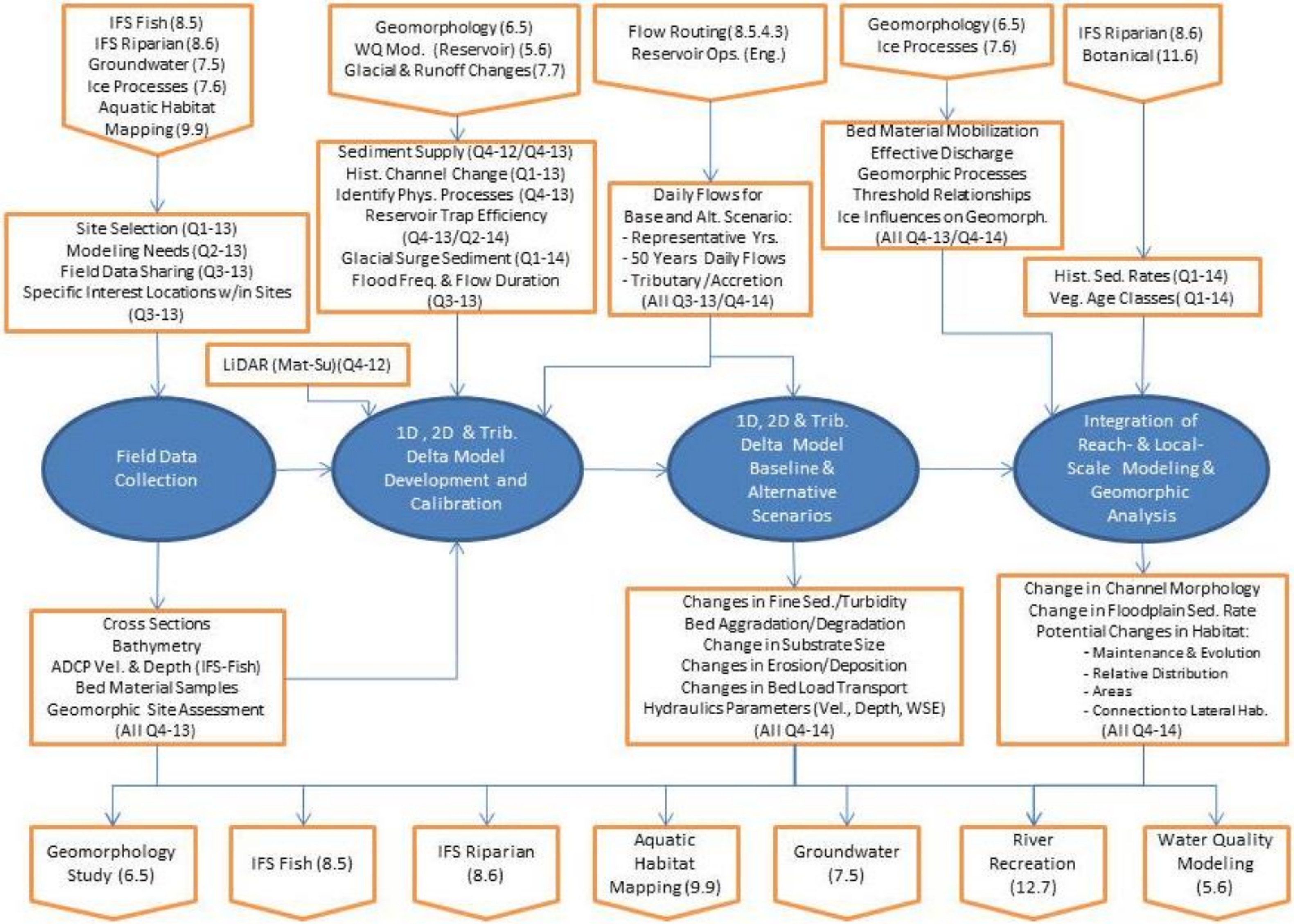

Figure 10. Study interdependencies for the Fluvial Geomorphology Modeling Study (Source: RSP Section 6.6).

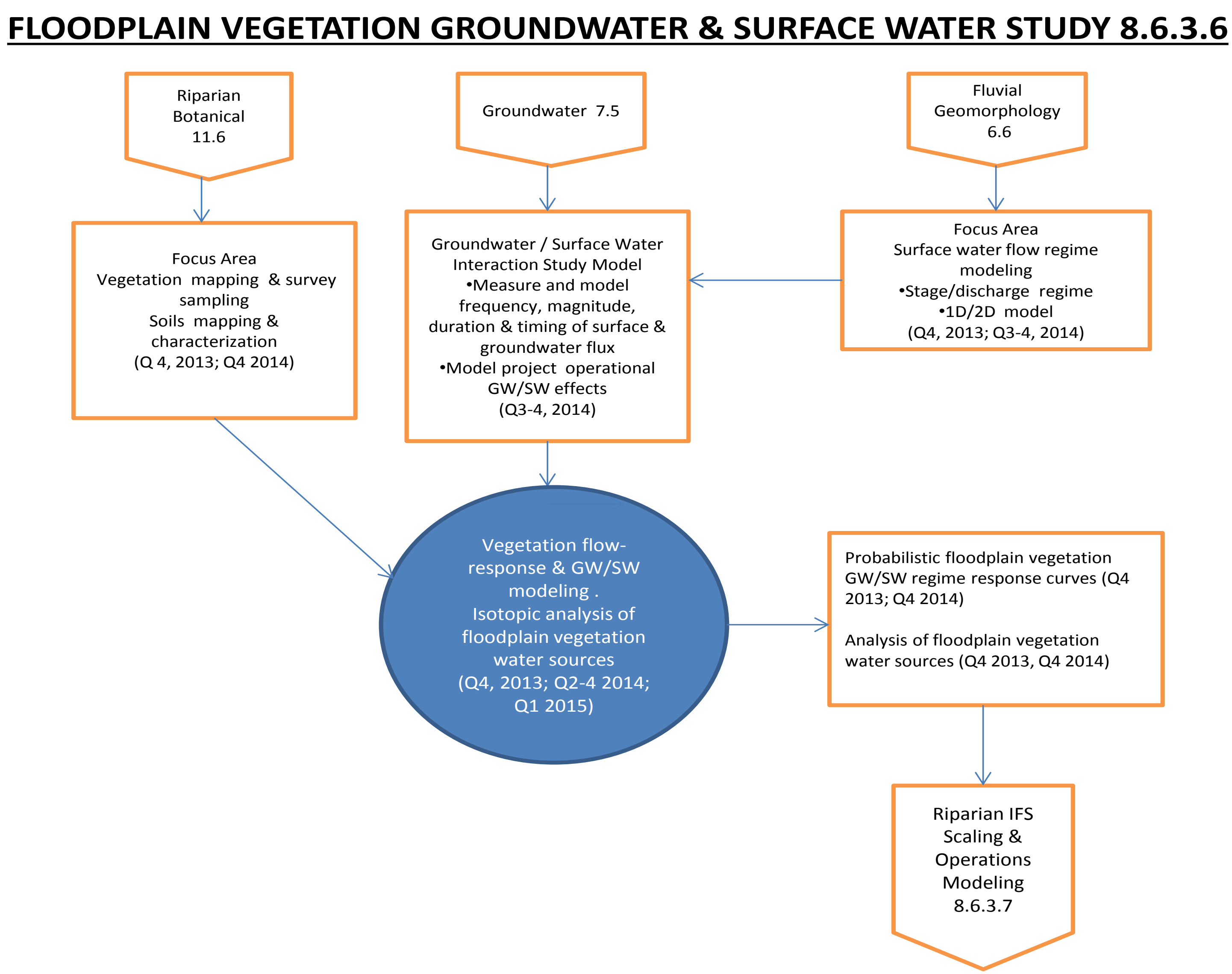

Figure 11. Floodplain Vegetation Groundwater & Surface Water Study (Source: RSP Section 8.6.3.6).

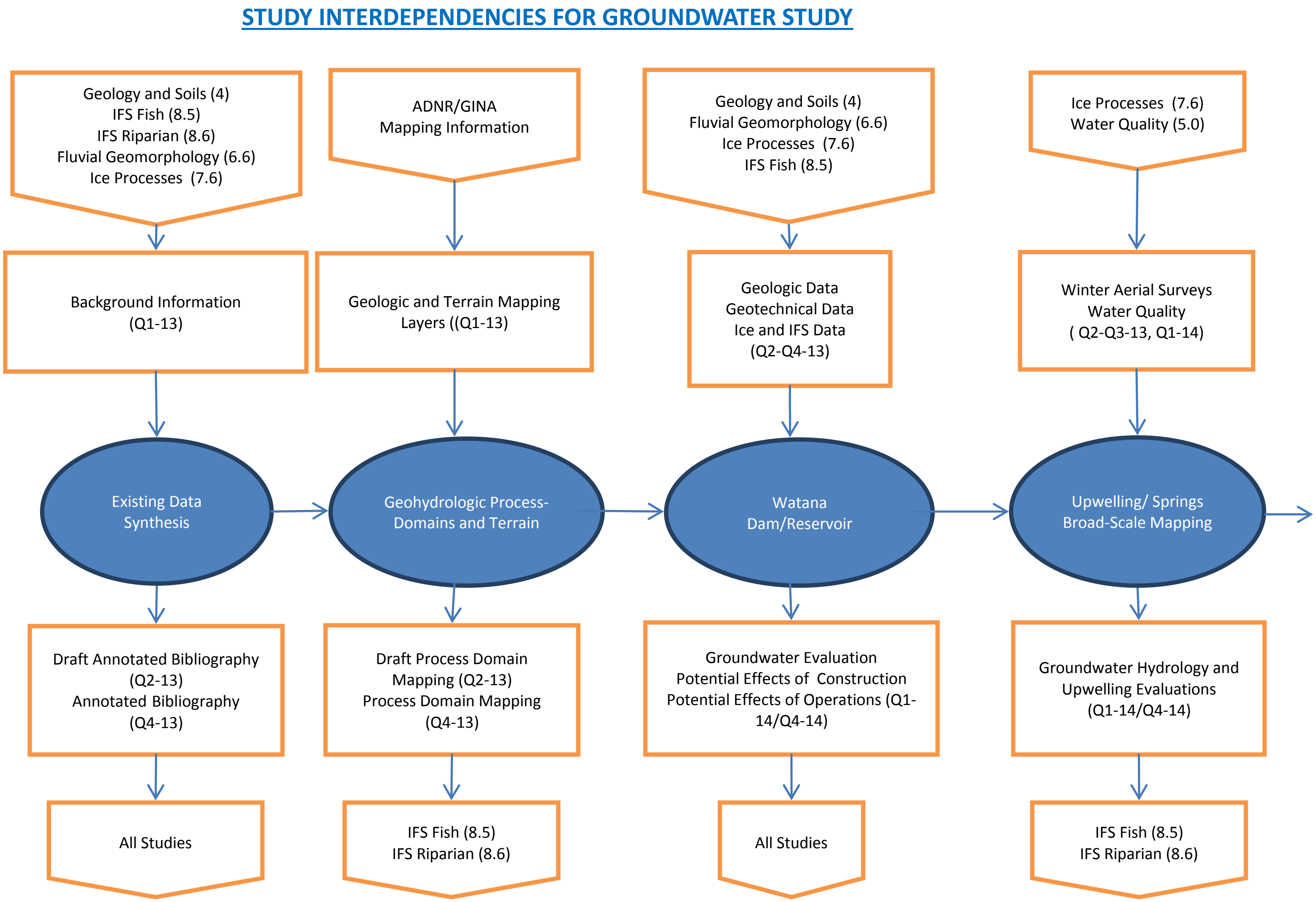

Figure 12. Study interdependencies for the Groundwater Study (Source: RSP Section 7.5).

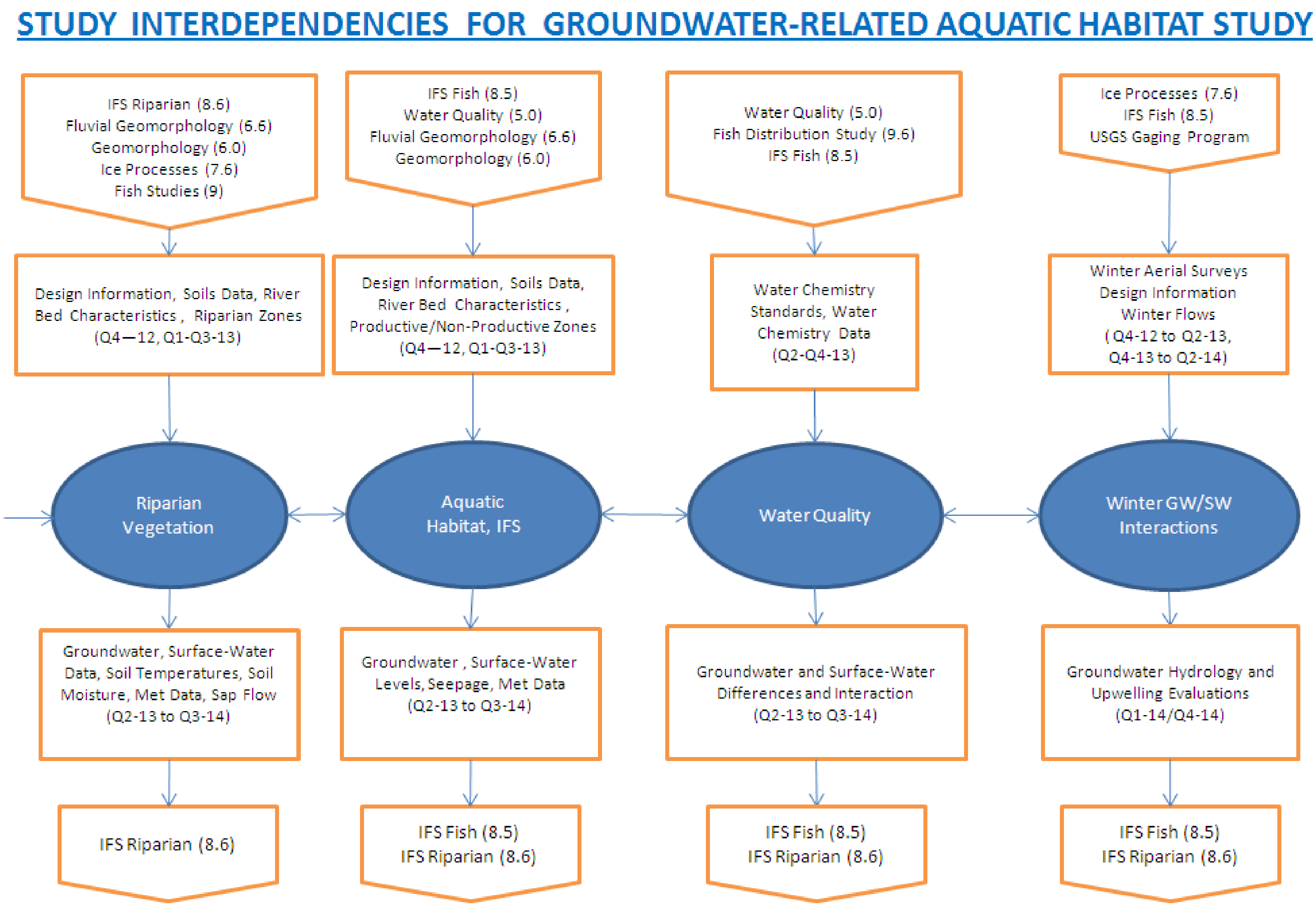

Figure 12. Study interdependencies for the Groundwater Study (Source: RSP Section 7.5) (continued).