Research Areas 1-1, 1-2 and 1-7. Define what types/scale of data are needed for energy/water modeling—frame questions, identify data needed for regional or national energy/water planning (including identification of output parameters, accuracy and precision requirements). Examine and identify data needs and gaps as a result of defining data needs for energy/water modeling. Evaluate and assess water data needs for energy production.	
Statement of Need	Currently, there is a lack of data on water quantity (availability), quality for supply and demand, and performance. Availability includes amount and rate, with concerns about sustainability, transfers and limits These data that will be needed by energy production decision-makers for long-range energy development and energy-water planning. There is also a lack of consistent databases for water information integration. Many see the need for integrated energy-water modeling; no one to date, however, has defined what that model(s) will look like.
Research Objective	Define what types/scale of data are needed for energy/water modeling—frame questions, identify data needed for regional or national energy/water planning (including identification of output parameters, accuracy and precision requirements). Define cost of collecting data.
Impact/Benefits	Reduce impacts of limited (intra-basin) water supply as a limit to ability of regional energy sector to meet future needs.
Priority	High
Summary Scope of Work	Inventory existing datasets and data needs from demand community relative to decision-maker needs; identify commonalities, inconsistencies and data gaps. Identify optimal data system and steps needed to transition from current to optimal data system.
Technical Approach	Define a matrix of demand sectors, data needs, beneficiaries, governing agencies. Survey the availability of data within this matrix and their interdependencies. Identify commonalities and gaps (The rosetta stone) of data communication.
Lead Investigators (academia, natl. lab, industry, international, partnership)	DOE leads consortium of agencies that collect relevant data
Potential Collaborative Govt. Agencies	EPA, USGS, DOE/EIA, AWWARF, WateReuse, EPRI, USDA, state, local and regional water agencies
Leverage Opportunities with Existing Programs	See Potential Collaborative Govt Agencies. Learn lessons from other sectors about centralized data systems (e.g., banking).
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Defining and coordinating a common mission among agencies having trust and turf issues. Resistance to sharing proprietary information. Preference of local water value over regional needs. Lack of regulatory requirements for reporting information.
Estimated Cost	$2-5M
Execution Horizon (early, mid, late)	Early
Schedule/Duration	Three years
Level of Development/Level of Maturity at completion	Medium to high
Additional comments	Data collection: EIA water requirements of power plants $1M

Research Areas 1-3 and 1-4. Scientific methods for robust monitoring and coordination of data collection.	
Statement of Need	1-3. Water quantity/quality monitoring is the result of ad hoc efforts over time. There is a recognized need to base the location/timing of future monitoring stations and the frequency of monitoring on the results of robust statistical monitoring. 1-4. Currently, energy/water models are hindered by the data available; in many cases, data is collected at time and physical scales that are not optimal for modeling activities. There is a need to better coordinate monitoring and other data collection activities to meet the needs of modelers.
Research Objective	To collect adequate data with least redundancy and lowest cost in a coordinated fashion. Scientific methods for robust monitoring—where/how frequently to monitor for energy-water planning. Coordinate quality/quantity monitoring and data collection matching (temporal, areal scales).
Impact/Benefits	Cost savings, higher quality data, reduce redundancy.
Priority	Medium
Summary Scope of Work	To collect adequate data with least redundancy and lowest cost in a coordinated fashion. Identify scientific methods for robust monitoring—where/how frequently to monitor for energy-water planning. Coordinate quality/quantity monitoring and data collection matching (temporal, areal scales).
Technical Approach	Determine most appropriate methods to use, depending upon the data set. Consider types of data (surface, groundwater) and identify which are at the energy water nexus. Determine best methods on how to fill the data gaps.
Lead Investigators (academia, natl. lab, industry, international, partnership)	Government agencies responsible for collecting primary data : ACE, BuRec USGS (for coordination)
Potential Collaborative Govt. Agencies	DOE/EIA, national laboratories, and academia
Leverage Opportunities with Existing Programs	Experience base of state and local agencies
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Constraints on federal and state participation (e.g., need to serve national purpose and lack of continuity).
Estimated Cost	$1M
Execution Horizon (early, mid, late)	Early
Schedule/Duration	Two years
Level of Development/Level of Maturity at completion	Medium to high
Additional comments	Need larger federal role for surface water gauging in states, to support monitoring for energy needs (e.g., thirty-year record).

Research Areas 1-5 and 1-6. Define/deploy standardized geo-reference data collection framework across fed/state/local entities. Develop a program for rapid access to output data for regional and national energy planning.	
Statement of Need	1-5. Future energy-water models and planning tools may require rapid access to geographically-specific data. Thus, there is a need for affordable and reliable remote sensing/reporting systems. 1-6. Today, there is a lack of coordinated water data collection – USGS, EPA, FERC, state agencies all collect data but not all in a form that can be easily accessed or used for energy planning. To facilitate integrated energy/water modeling, there is a need to coordinate water data collection amongst those agencies and organizations that are engaged in monitoring and reporting.
Research Objective	Build a data system to integrate different sources of disparate data in a single integrated system and provide visualization and data analysis tools, including GIS.
Impact/Benefits	Ability to estimate demand on water resources for energy supply. A single defensible data system for decision-makers, that could help identify potential collaborations and conflicts among competing uses. Reduction of redundancy resulting in cost savings.
Priority	High
Summary Scope of Work	Define underlying geo-reference data collection and data storage framework, including data integration. Build standardized interface for rapid data access and visualization tools, preferably GIS. Data analysis. Provide input to meet the demands for energy-water modeling.
Technical Approach	Leverage information gained from Research Areas 1-1 and 1-2. Bring information systems specialists to review approach. Define standard set of tools that need to be developed.
Lead Investigators (academia, natl. lab, industry, international, partnership)	National laboratories (expertise in data security)
Potential Collaborative Govt. Agencies	USGS (resource limited in this area)
Leverage Opportunities with Existing Programs	Business models (e.g., Google, Yahoo, Zillow.com), decision support systems for energy and water
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Building full understanding of different data schemas/structures, developing data translators. Data security issues.
Estimated Cost	$2-5M
Execution Horizon (early, mid, late)	Mid (follows 1-1 through 1-4)
Schedule/Duration	Three years
Level of Development/Level of Maturity at completion	Medium (provides building block)
Additional comments	Will continue to improve. Water agencies often use five-year cycles; can improve viability and support over time.

Research Area 1-8. Develop a process for characterizing the national inventory of unconventional water resources that may be utilized in/for energy production.	
Statement of Need	Today, there is a significant lack of data on the production and availability of unconventional water—produced waters, brackish water, reclaimed water, etc.—at a regional level for energy development.
Research Objective	Develop a process for characterizing the national inventory of unconventional water resources that may be utilized in/for energy production. Characterize opportunities for transfers of unconventional water to appropriate users. Consider sources and uses of unconventional water.
Impact/Benefits	Development and use of previously untapped supplemental resources. Potential increased availability of freshwater sources by substituting unconventional water for some applications.
Priority	High
Summary Scope of Work	Inventory existing datasets and data needs regarding unconventional water from water demand community relative to decision-maker needs; identify commonalities, inconsistencies and data gaps. Identify optimal unconventional water data system and steps needed to transition from current to optimal data system. Conduct stakeholder awareness/ education/involvement campaign.
Technical Approach	Define a matrix of demand sectors for unconventional water, data needs, beneficiaries, governing agencies. Survey the availability of data within this matrix and their interdependencies. Identify commonalities and gaps (The rosetta stone) of data communication.
Lead Investigators (academia, natl. lab, industry, international, partnership)	DOE leads consortium of agencies that collect relevant data
Potential Collaborative Govt. Agencies	EPA, USGS, DOE/EIA, AWWARF, WateReuse, EPRI, USDA, state, local and regional water agencies
Leverage Opportunities with Existing Programs	Leverage with Research Area 1-5 and 1-6.
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Data is not being collected, this is a large new task. Reaching consensus on concepts, terms/definitions, process will take time. Questions of ownership of impaired water.
Estimated Cost	$5-10M
Execution Horizon (early, mid, late)	Mid
Schedule/Duration	Five years (optimistically)
Level of Development/Level of Maturity at completion	Medium
Additional comments	Local water agencies have data (often from permits and water supply planning process) about potential sources of unconventional water. Funding could be leveraged with local and private interests.

Research Areas 1-9, 1-10, and 1-11. Evaluation/analysis/quantification/mapping of non-traditional/produced/brackish /reused waters quantity and quality that could be used for energy development.	
Statement of Need	Today, there is a significant lack of data on the production and availability of unconventional water—produced waters, brackish water, reclaimed water, etc.—at a regional level for energy development.
Research Objective	Evaluation/analysis/quantification/mapping of unconventional water quantity and quality that could be used for energy development.
Impact/Benefits	Development and use of previously untapped supplemental resources. Potential increased availability of freshwater sources by substituting unconventional water for some applications.
Priority	High
Summary Scope of Work	Evaluation/analysis/quantification/mapping of unconventional water quantity and quality that could be used for energy development. This energy development includes ethanol oil shale/oil sands.
Technical Approach	Develop an inventory of unconventional water resources. Evaluate these for applicability to energy production. Develop targeted data collection strategies for these. Explore alternative strategies to optimize data collection to reduce costs.
Lead Investigators (academia, natl. lab, industry, international, partnership)	DOE for produced waters. Water industry (e.g., AWWARF, WateReuse) for reclaimed/reuse waters. USGS for brackish.
Potential Collaborative Govt. Agencies	EPA, DOE/EIA, EPRI, USDA, state, local and regional agencies (water and health services)
Leverage Opportunities with Existing Programs	Utilize structure in Research Area 1-8. Leverage with other programs exploring water development for other uses (e.g., agriculture, produced waters)
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Infrastructure to collect data is missing. Data is not being collected, this is a large new task
Estimated Cost	$10M annually
Execution Horizon (early, mid, late)	Early for produced water and reuse. Mid to late for brackish.
Schedule/Duration	Two to three years for produced water and reuse. Ten to twenty for brackish.
Level of Development/Level of Maturity at completion	Medium
Additional comments	Local water agencies have data (often from permits and water supply planning process) about potential sources of unconventional water. Funding could be leveraged with local and private interests, particularly if economic opportunities are identified.

Research Areas 1-12 and 1-13. Tool development to determine the volumes of groundwater available for energy production, determine recharge rates/groundwater-surface water interactions and develop calculation methods. Determine quantity, quality, location of groundwater resources to aid in regional energy planning/siting activities.	
Statement of Need	There is today a limited regional (and in some cases local) understanding of groundwater resources. To assist in water resource modeling and energy/water planning, it is important that our understanding of groundwater resources improve significantly, in particular our ability to model future groundwater availability.
Research Objective	To determine the volumes of groundwater available for energy production, determine recharge rates/groundwater-surface water interactions and develop calculation/modeling methods. Determine quantity, quality, location and use of groundwater resources to aid in regional energy planning/siting activities.
Impact/Benefits	Increased confidence in reliability of water supply. Improved efficiency of ASR.
Priority	Medium
Summary Scope of Work	To determine the volumes of groundwater available for energy production and water resources planning and development, determine recharge rates/groundwater-surface water interactions and develop calculation/modeling methods. Include aquifer storage and recovery (ASR). Determine quantity, quality, location and use of groundwater resources to aid in regional energy planning/siting activities.
Technical Approach	Tap into industry sources of data. Develop calculation methods to transfer existing methods and expertise from the energy industry to water resources.
Lead Investigators (academia, natl. lab, industry, international, partnership)	USGS, DOE/national labs (for supercomputing resources)
Potential Collaborative Govt. Agencies	Energy industry groups, EPA, DOE/EIA, EPRI, USDA, state, local and regional agencies
Leverage Opportunities with Existing Programs	State, regional and local agencies, AWARF, WateReuse. Existing experience in energy industry, DOE and USGS. Possible USGS pilot study
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Data confidentiality
Estimated Cost	$10M
Execution Horizon (early, mid, late)	Early
Schedule/Duration	Two to four years
Level of Development/Level of Maturity at completion	Medium to high
Additional comments	

Research Area 1-14. Develop pilot-scale efforts to apply approaches to regional energy and water planning.	
Statement of Need	Understanding of groundwater needs to be integrated into regional planning for it to be truly useful in a practical sense.
Research Objective	Develop pilot-scale efforts to apply groundwater assessment approaches to regional energy and water planning.
Impact/Benefits	Increased confidence in reliability of water supply. Improved efficiency of ASR.
Priority	Medium
Summary Scope of Work	Pilot study to determine the volumes of groundwater available for energy production and water resources planning and development, determine recharge rates/groundwater-surface water interactions and develop calculation/modeling methods. Include aquifer storage and recovery (ASR). Determine quantity, quality, location and use of groundwater resources to aid in regional energy planning/siting activities.
Technical Approach	Tap into industry sources of data. Develop calculation methods to transfer existing methods and expertise from the energy industry to water resources.
Lead Investigators (academia, natl. lab, industry, international, partnership)	USGS, DOE/national labs (for supercomputing resources)
Potential Collaborative Govt. Agencies	Energy industry groups, EPA, DOE/EIA, EPRI, USDA, state, local and regional agencies
Leverage Opportunities with Existing Programs	State, regional and local agencies, AWARF, WateReuse. Existing experience in energy industry, DOE and USGS. Leverage from Research Area 1-13.
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Data confidentiality
Estimated Cost	$10M
Execution Horizon (early, mid, late)	Mid
Schedule/Duration	Five to ten years
Level of Development/Level of Maturity at completion	Medium to high
Additional comments	

Research Area 1-16. Determine environmental effects of kinetic hydropower systems and applications.	
Statement of Need	Determining/mitigating impacts of kinetic hydropower systems may facilitate their adoption and application.
Research Objective	Determine environmental effects of kinetic hydropower systems and applications.
Impact/Benefits	Systems would provide clean renewable energy with high capacity factors and values, helping meet states' RPS, no fuel costs, and a source/means for new potable water supplies.
Priority	High priority.
Summary Scope of Work	1. Assessment of technologies as to safe fish passage and low impact fish migration. 2. Site-specific applications of technologies on navigation and security. 3. A repository of information.
Technical Approach	Pilot projects of technologies in a variety of applications: Design, build and test; monitoring; data gathering; assessments; and analyses.
Lead Investigators (academia, natl. lab, industry, international, partnership)	Cooper Union Research Foundation; UofWA; UofMN; UC-Davis; ORNL; NHA and Hydroresearch Foundation (HRF); European Marine Energy Center and SuperGen (UofEdinburgh), EPRI; Natural Resources Canada; Canadian Hydrolic Center
Potential Collaborative Govt. Agencies	DOI: USFWS; NOAA_NMFS; DOE; FERC; Corps of Engineers, BoREC;
Leverage Opportunities with Existing Programs	EMEC, NaREC; RITEProject (NY); ACE (CA); CORE (Canada)
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	"Stovepiping" between resource agencies and renewable energy development—noncollaborative; FERC licensing process--streamlined
Estimated Cost	$15M
Execution Horizon (early, mid, late)	Early
Schedule/Duration	2 years
Level of Development/Level of Maturity at completion	Pre-commercial systems deployed in the field and will serve as building blocks for commercial systems and potable water, aeration, and irrigation systems.
Additional comments	

Research Area 1-19. Ecological effects of thermal releases in water bodies and management options.	
Statement of Need	Discharges of warmed water into various bodies of water occur during many types of energy production. The impacts of such warmed waters are poorly understood especially as they impact many different trophic levels from primary production to fishes.
Research Objective	Assess the effects of thermal discharges in various water bodies, especially smaller ones, to asses their impact through aquatic communities. Evaluate the range of management alternatives for optimal energy production and minimal impact on the local environment.
Impact/Benefits	Highly warmed water can impact growth rates, alter predation rates, disrupt community relationships, and thus reduce energy production efficiency. Sensitive or endangered fish populations may alter their distribution and have lowered reproductive success. Finding ways to ameliorate thermal impacts could improve the rates of survival for certain populations that are of commercial or recreational interest.
Priority	Medium
Summary Scope of Work	An interdisciplinary group of scientists should be formed to develop short and long term plans. Experimental sites will be selected where some type of temperature control is possible, and where energy production is important. Rivers that experience drought or low-flow conditions will be included since temperature variation can be extreme. Data collection will be established on the physical environment, especially temperature, and laboratory experiments will be conducted on temperature tolerance, energetics, and trophic level transfer rates. Physical models will be developed of spatial variation in temperature and habitat. Biological models will be developed to describe and predict how communities change with temperature alteration. Finally, physical and biological models will be combined so optimum energy production can be explored.
Technical Approach	Technical approach is generally well-established and would include 2-dimensional flow and temperature modeling, community modeling, and fish bioenergetics. Studies could be conducted in field and laboratory situations where temperatures can be controlled and monitored.
Lead Investigators (academia, natl. lab, industry, international, partnership)	ORNL and USGS-BRD
Potential Collaborative Govt. Agencies	BOR, EPA, Academia, NGOs such as TNC
Leverage Opportunities with Existing Programs	Ongoing research by federal agencies to understand temperature impacts. EPRI-funded work on temperature effects.
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Constraints – few. Challenges – developing sufficiently broad models and results that can be applied and used broadly. Developing results for highly variable bodies of water, and accounting for long-term climate change.
Estimated Cost	$3 million per year
Execution Horizon (early, mid, late)	Early, start within 5 years.
Schedule/Duration	2009 – 2019
Level of Development/Level of Maturity at completion	At completion, a high level of maturity would be expected.
Additional comments	

Research Area 1-22 et al. Understand the impacts of CBNG and conventional produced water to the surface ecosystem, ranching (livestock) and agricultural communities.	
Statement of Need	Understand the impacts of CBNG and conventional produced water to the surface ecosystem, ranching (livestock) and agricultural communities. Both treated and untreated produced water are included.
Research Objective	1. Develop a data base of CBNG and conventional (beneficial use) produced water, that includes the variability in water quality and water volumes, with the locations. 2. Develop pertinent animal, bird and aquatic species community specific responses to releases of produced water to any waterway or impoundment. 3. Establish ranges of standards for irrigation, discharge to impoundment, discharges to ephemeral water ways and discharges to naturally irrigated systems that must be met by produced water treatment technologies. 4. Establish ranges of standards for any common beneficial use: cooling water, municipal water, fish ponds, mining, etc. 5. Establish the criteria and application methodology for a use attainability analysis as a benchmark for aquatic ecosystems and ranching/farming. 6. Establish the impacts of continuous or increased flow from produced water discharge, and/or the effects on an ephemeral drainage; the receiving environment as well as the ranching/farming communities. 7. Model the dynamics geochemical opportunity for assimilative capacity for produced water discharge to waterways.
Impact/Benefits	1. Rancher can increase or maintain herd size 2. Farmer can grow crops 3. Naturally irrigated water increases wildlife such as geese, deer, elk, sage grouse, fish, etc. 4. Allow the development of Industry that can use the water for process or cooling. 5. Can be used directly in secondary uses (car washes, golf course watering) to replace domestic water. 6. May change draws from native grass to riparian. 7. Reduce traffic, fuel use, air pollution from not needing to transport water. 8. Potentially reduce continued regulatory controls and provide basis for permits that otherwise would limit water production. 9. Provide water for fish and other wildlife that would not allow communities to live. 10. May increase erosion. 11. May infiltrate and negatively impact soils or ground waters.
Priority	Highest of high.
Summary Scope of Work	Later development
Technical Approach	Identify potential pilot projects for each objective above, and approach each by adaptive management in demonstration projects.
Lead Investigators (academia, natl. lab, industry,	Lead should be national laboratories controlled, major operator and technology companies as partners, performed by 3rd party consultants, and

international, partnership)	institutes interested in real science. Regulatory agencies should not play a role in investigations.
Potential Collaborative Govt. Agencies	Regulatory agencies as appropriate.
Leverage Opportunities with Existing Programs	Identify on case by case basis. DOE must know existing programs and integrate with these.
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	1. Knowledge of other programs 2. Numerous conflicting and disparate policy and regulatory initiatives that limit the implementation of sound (or any) sound solutions. 3. NGOs are often allowed into the process and become obstructionists to progress. 4. Regulations and permits are ever changing, so that development, research become a waste of research. 5. Technology may not be developed sufficiently to manage the water as necessary. 6. Lack of coordination in technology development.
Estimated Cost	Depends on the development of the scope: Could spend $5 to 10 MM. This is just the study component and not any demonstration projects. Demonstration projects could easily be $2MM for each item at each location.
Execution Horizon (early, mid, late)	Studies: 2 to 4 years per objective. About 5 to 10 years for demonstration projects.
Schedule/Duration	See above
Level of Development/Level of Maturity at completion	Permits given in reasonable time, EISs completed in reasonable time, technologies available and cost effective so compliance can be achieved, Regulations will quit changing or be set so planning can be done.
Additional comments	

Research Area 1-25a. Evaluate/model potential groundwater contamination as a result of oil shale/oil sands extraction and processing.	
Statement of Need	Oil shale processing may result in a number of environmental impacts. During *in situ* processing, aquifers may be impacted by process fluids. Subsequent to retorting, groundwater may leach retorted shale and transport leached material into the aquifers where it may impact wells, springs or streams. Adjacent aquifers may become hydraulically connected to the retort zone, allowing contaminants to migrate beyond the retort zone. *Ex situ* shale processing may penetrate confining layers and/or produce local subsidence, atmospheric pollutants that could contaminate soils and surface waters. Runoff from spent shale piles may also contribute to surface and shallow groundwater contamination.
Research Objective	The major water research objectives include: 1. Assess local/regional assessment of water supply and water quality impacts associated with oil shale development 2. Prevent ground water intrusion into the retort zone before, during, and after *in situ* retorting and during and after mining for *ex situ* retorting 3. Prevent/mitigate ground water contamination after *in situ* and *ex situ* retorting 4. Mitigate impacts to formation integrity during *in situ* retorting resulting from thermal expansion and contraction.
Impact/Benefits	Knowledge and tools developed under this research area will provide energy producers, regulators, and other stakeholders with capabilities needed for economically and environmentally sound management of affected water resources (e.g., groundwater, produced water, surface water) during and after oil extraction.
Priority	High. The potential for ~2 trillion barrels of shale oil from Green River formation alone suggests this is import research.
Summary Scope of Work	Develop and test conceptual and computational tools and assessment methodologies for optimal water resources management during and after oil shale development at local to regional scales.
Technical Approach	1. Establish baseline understanding of coupled hydrologic/biogeochemical/geophysical processes and parameterization under ambient conditions 2. Identify potential organic/inorganic groundwater and surface water contaminants resulting from oil shale retorting 3. Develop coupled thermal-hydrological-biogeochemical-geomechanical computational models for retort zones and adjacent areas 4. Development and evaluation of appropriate field testing procedures for conceptual model process improvement and parameterization 5. Conduct pilot/field tests for model parameterization and validation 6. Assess alternative water resource impact prevention and mitigation technologies 7. Assess alternative shale oil production and water resource management scenarios and approaches 8. Develop methods for scaling from pilot- to production-scale (e.g., impact prevention and mitigation measures)
Lead Investigators (academia, natl. lab, industry, international, partnership)	Majority of these activities could be conducted by a combination of academic institutions and national laboratories. Field evaluation of testing procedures conducting pilot tests could be largely conducted by industry and national

	laboratories with university collaborators.
Potential Collaborative Govt. Agencies	Bureau of Land Management, US Geological Survey, Environmental Protection Agency, NASA
Leverage Opportunities with Existing Programs	Unknown.
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Policies/regulations that constrain the optimal use of water resources (e.g., water rights, multi-jurisdictional regulations).
Estimated Cost	\$90M - \$120M
Execution Horizon (early, mid, late)	Should be started now.
Schedule/Duration	Anticipate a 10-year program.
Level of Development/Level of Maturity at completion	Basic technologies for in situ retorting and tools for assessing its impacts are early in their development./Completion of the above tasks will provide mature capabilities for production-scale applications.
Additional comments	

Research Area 1-25b. Evaluate/model potential groundwater contamination as a result of oil shale/oil sands extraction and processing.	
Statement of Need	As assessment of the potential risks to groundwater from the various methods of shale oil/oil sand production is necessary.
Research Objective	Generate a risk assessment that allows comparison of the various production methods that are being proposed. Risk assessment should address potential impacts to surface and groundwater.
Impact/Benefits	Assessment may identify the relative merits of the various production methods being proposed. The effort could also include quantification of water needs (demand) for each of the production methods.
Priority	Medium priority. Much of the work may be performed by operators as part of the NEPA/EIS process for proposed projects.
Summary Scope of Work	Identify and proposed production methods. Identify risk factors. Perform risk assessment to habitats, water quality, wildlife, livestock, humans.
Technical Approach	High level review/evaluation of proposed technologies. Apply recognized risk assessment methods allowing balanced consideration of pros and cons. Effort should not endorse or reject any specific method; should provide for site-specific evaluation.
Lead Investigators (academia, natl. lab, industry, international, partnership)	National laboratory/industry partnership.
Potential Collaborative Govt. Agencies	DOE, EPA, State resource agencies
Leverage Opportunities with Existing Programs	Limited today, but may be developing as interest continues to re-emerge.
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Level of impacts similar to coal mining. Regulatory and policy infrastructure comparatively undeveloped. Technology is not field proven. Risk assessment methods are mature and can be applied.
Estimated Cost	Screening level risk assessment: $300-600k.
Execution Horizon (early, mid, late)	Early, 2-5 years
Schedule/Duration	2 years
Level of Development/Level of Maturity at completion	Relatively low level of maturity since this assessment is only at a screening level.

Research Area 1-26. Standardize data collection.	
Statement of Need	To better assess the potential resource contribution of coal bed natural gas and conventional oil and gas produced water, data on produced water volumes, production locations is needed.
Research Objective	Develop a data collection and management system (aka database) that gather the basic data in a format consistent across all participating states.
Impact/Benefits	Identify the size/life of the resource, its location and its characteristics. Will allow evaluation of the produced water resources for potential use.
Priority	High. This is basic data necessary for evaluating the potential "value" of this resource.
Summary Scope of Work	Identify input data needs. Develop data management systems. Gather data. Data gathered should be limited to simple, easy to obtain information to minimize burden.
Technical Approach	Use system developed by New Mexico as prototype and develop from there.
Lead Investigators (academia, natl. lab, industry, international, partnership)	Academia, state resource agencies, industry. Use national laboratories or private vendors as contractor.
Potential Collaborative Govt. Agencies	
Leverage Opportunities with Existing Programs	State of New Mexico may have a viable prototype program in place.
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Limitations on data gathering (Paperwork Reduction Act/OMB).
Estimated Cost	?
Execution Horizon (early, mid, late)	Early. This is basic data that needs to be gathered to assess the potential value or types of uses that may be appropriate for this resource.
Schedule/Duration	2-3 years to develop, ongoing once program is in place.
Level of Development/Level of Maturity at completion	System should be usable upon completion.
Additional comments	

Research Area 1-26b (and 4-9) Standardize data collection: Quantify extent of production, consumptive use, and availability of impaired waters.	
	To better assess the potential resource contribution of cola bed natural gas and conventional oil and gas produced water, data on produced water volumes, production locations is needed. Add-on from #4-9: More specifically, the volumes of impaired waters (including produced water) actually generated, consumed, and potentially available for other uses is largely unknown, and needs to be quantified.
Research Objective	Develop a data collection and management systems (aka database) that gather the basic data in a format consistent across all participating states. Add-on from Research Area 4-9: Quantify amount of impaired waters (including produced water) produced, consumed, and otherwise available.
Impact/Benefits	Identify the size/life of the resource, its location and its characteristics. Will allow evaluation of the produced water resources for potential use. Add-on from Research Area 4-9: Determining the volume of water produced and consumed is required to determine the amount available.
Priority	High. This is basic data necessary for evaluating the potential "value" of this resource.
Summary Scope of Work	Identify input data needs. Develop data management systems. Gather data. Data gathered should be limited to simple, easy to obtain information to minimize burden. Add-on from Research Area 4-9: Determine if the desired data exists on the volumes of impaired waters (including produced water) produced and consumed. If so, develop systems/processes to gather, integrate, update/maintain, and provide access to this data. If not, develop processes/systems to generate and manage as described above.
Technical Approach	Use system developed by New Mexico as prototype and develop from there.
Lead Investigators (academia, natl. lab, industry, international, partnership)	Academia, state resource agencies, industry. Use national laboratories or private vendors as contractor.
Potential Collaborative Govt. Agencies	State resource oversight and permitting agencies
Leverage Opportunities with Existing Programs	State of New Mexico may have a viable prototype program in place.
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Limitations on data gathering (Paperwork Reduction Act/OMB). Possible limits to data access.
Estimated Cost	$1-2M ?
Execution Horizon (early, mid, late)	Early. This is basic data that needs to be gathered to assess the potential value or types of uses that may be appropriate for this resource.
Schedule/Duration	2-3 years to develop, ongoing once program is in place.
Level of Development/Level of Maturity at completion	System should be usable upon completion.
Additional comments	

Research Area 1-27 et al. Understand the impacts of CBNG and conventional produced water to the subsurface environment.	
Statement of Need	Understand the impacts of CBNG and conventional produced water to the subsurface environment (with emphasis on aquifers for USDWs). This impact could come from produced water either through infiltration or injection, and will also assess effects of extraction.
Research Objective	1. Develop a data base of injected CBNG and conventional produced water, that includes the variability in water quality and water volumes, with the locations. 2. Evaluate ranges of standards for injection for the aquifers to remain in class of use. 3. Study and model the flow of water between producing and injection horizons. 4. Evaluate the geochemical effects of incompatible waters. 5. Evaluate injection parameters for unconsolidated and coal formations. 6. Study infiltration water from impoundments and drainages, and the long term effects on shallow groundwater. 7. Evaluate the methods to control bacteria in injection water. 8. Evaluate the mass movement of water in the coals and aquifers with injection and production – site specific modeling and demonstration projects are necessary. 9. Evaluate the movement of water from outside of production zones and into the production zones, at various locations. 10. Evaluate the capacity of aquifers to accept injected water. 11. Evaluate the geochemical factors that occur with infiltration to groundwater.
Impact/Benefits	1. Protect existing groundwater resources 2. Recharge depleted aquifers 3. Potentially create new aquifers 4. Provide water storage for future beneficial use 5. Minimize impacts to surface 6. Reduce energy use from inefficient surface disposal 7. Understand infiltration and injection basics to support reasonable permitting.
Priority	High.
Summary Scope of Work	Later development
Technical Approach	Identify potential pilot projects for each objective above, and approach each by adaptive management in demonstration projects.
Lead Investigators (academia, natl. lab, industry, international, partnership)	Lead should be National labs controlled; major operator and technology companies as partners; performed by 3rd party consultants/contractors, and institutes interested in and capable of real applied science. Regulatory agencies, State Institutes and NGOs should not play a direct role in investigations.
Potential Collaborative Govt. Agencies	Regulatory agencies and State Institutes as appropriate.
Leverage Opportunities with Existing Programs	Identify on case by case basis. DOE must know existing programs and integrate with these.
Constraints/Challenges	• Knowledge of other programs

(Policy, regulatory, technical, sequencing?)	• Numerous conflicting and disparate policy and regulatory initiatives that limit the implementation of sound (or any) sound solutions. • NGOs are often allowed into the process and become obstructionists to progress. • Regulations and permits are ever changing, so that development, research become a waste of research. • Technology may not be developed sufficiently to manage the injection of water as necessary. • Lack of coordination in technology development.
Estimated Cost	Depends on the development of the scope: Could spend $2 to 5M. This is just the study component and not any demonstration projects. Demonstration projects could easily be $2M for each item at each location.
Execution Horizon (early, mid, late)	Studies: 2 to 4 years per objective. About 5 to 10 years for demonstration projects.
Schedule/Duration	See above
Level of Development/Level of Maturity at completion	Permits given in reasonable time, EISs completed in reasonable time, technologies available and cost effective so compliance can be achieved. Regulations will quit changing or be set so planning can be performed.

Research Area 1-30. Development of enhanced monitoring technologies.	
Statement of Need	Improved monitoring technologies to better characterize water quality & quantity
Research Objective	Improved water monitoring technologies Improved = Robust, (remote operation, can operate under many different physical & chemical conditions, long operating life) accurate, inexpensive, portable, easily compatible/integrable with existing technologies Monitor membranes, filters, and other water handling/processing equipment water (to circumvent fouling & failure)
Impact/Benefits	Cost, energy, & water savings – inform optimal ways to conserve, use, & reuse water Inform policy & legal decisions Create national/international database of water quality/quantity/use
Priority	Medium
Summary Scope of Work	Need to identify: 1. What parameters to monitor [physical (e.g., flow, velocity), chemical (e.g., salinity, pH, metal/ion content), biological] 2. How frequently parameters need to be probed 3. What levels of accuracy are needed? This may be different depending on application (e.g., agriculture, energy, human use, etc.)
Technical Approach	Select & test processes & materials needed to achieve monitoring of parameters/frequency/accuracy needed for a given application. Iterate selection, testing, & revision of processes & materials until desired monitoring goals met
Lead Investigators (academia, natl. lab, industry, international, partnership)	Industry and national laboratories.
Potential Collaborative Govt. Agencies	DOE, EPA, USDA, DOI, state & local funding agencies, Awwa
Leverage Opportunities with Existing Programs	EERE, AwwaRF
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Cost Implementation concerns (need to make sure the processes & materials use in improved monitoring techniques are compatible with existing regulations, processes, & infrastructure)
Estimated Cost	$10M/yr for 5 yrs
Execution Horizon (early, mid, late)	Mid
Schedule/Duration	~5 yrs
Level of Development/Level of Maturity at completion	Deployable technology
Additional comments	Discussion: Integration of water monitoring all water types: - Integrate atmosphere, surface, & ground water - Unsaturated & saturated zone - Parameters: Quality, flow, velocity, etc. Both water quantity & water quantity parameters This requires determining: - Where to monitor - How often to monitor - What are the levels of accuracy needed? So we need to interact with data needs & accuracy breakout group

	Our breakout group focuses on *how* to monitor water; we interact with data needs & accuracy breakout group to determine *what* to monitor Parameters: Includes physical, chemical parameters Also biological parameters Often different techniques are used to measure the same quantity/parameter. These different techniques need to integrate/connect with each other. Is the problem that the technologies don't integrate or that the people making these measurements using different techniques don't communicate with each other? Frequently people don't talk to each other – a problem is trying to communicate across different fields. So should we try to get some interdisciplinary programs/training going? There is some stovepiping at many organizations, including DOE – difficult to get communication across disciplines/organizations How can we break the monitoring needs issue into smaller, tractable areas? Need to be specific about defining gaps in monitoring: Are we monitoring metals? Are we monitoring other chemicals? Each specific application has its own needs & requirements. Do we need a universal database where data from different techniques can be collected? Good idea, but is it practical?

Research Area 1-30a. Plug & play communication systems for real time water quality/quantity.	
Statement of Need	Fast, accurate, reliable method of monitoring water quantity & quality for energy facilities
Research Objective	Fast measurement of water quantity/quality – ease of data acquisition & processing Accurate measurement of water quality/quantity Reliable measurement of water quality/quantity Compatible with existing technologies & infrastructure Use as part of feedback system – if water quality/quantity falls below a certain level, automatic adjustments/shut-off occur Fast, reliable, and accurate monitoring of membranes, filters, and other water handling/processing equipment water (to circumvent fouling & failure) Inexpensive is desirable Portability may be desirable depending on specific energy facility & circumstances
Impact/Benefits	Cost, energy, & water savings – inform optimal ways to conserve, use, & reuse water. Detect & prevent disasters (e.g., detect when there's not enough cooling water) Inform policy & legal decisions Create national/international database of water quality/quantity/use
Priority	High or medium (depends on energy facilities – high where insufficient water quality or quantity can lead to disasters)
Summary Scope of Work	Need to identify: 1. Fast measurement: What level of speed is needed? 2. What parameters to monitor [physical (e.g., flow, velocity), chemical (e.g., salinity, pH, metal/ion content), biological] 3. What levels of accuracy are needed? 4. How compatible is this system with existing data collection, data processing, & infrastructure systems? 5. How frequently parameters need to be probed
Technical Approach	Select & test processes & materials needed to achieve monitoring of parameters/frequency/accuracy needed for a given application. Iterate selection, testing, & revision of processes & materials until desired monitoring goals met
Lead Investigators (academia, natl. lab, industry, international, partnership)	National laboratories, industry, energy facilities
Potential Collaborative Govt. Agencies	DOE, EPA, DOI, state & local agencies, nuclear agency?
Leverage Opportunities with Existing Programs	EERE, Awwa
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Technical: Making water quality/quantity measurements fast enough Cost Implementation concerns (need to make sure the processes & materials use in improved monitoring techniques are compatible with existing data collection & processing systems, infrastructure, regulations, & processes)
Estimated Cost	$10M/yr for 3 – 5 yrs.
Execution Horizon (early, mid, late)	Early (for critical applications); otherwise mid
Schedule/Duration	3 yrs (for critical applications) 5 yrs (for less critical applications)
Level of Development/Level of Maturity at completion	Deployable technology

Additional comments	

Research Area 1-30b. Soil moisture monitoring/reporting systems.	
Statement of Need	Soil moisture monitoring/reporting systems for water conservation in the agriculture sector.
Research Objective	The research objective will be to develop simple, inexpensive, in situ probes to monitor moisture of the soil profile at several depths. The probes shall be equipped with hardware to wirelessly transmit data from the probe and control the probe. Data will be collected at a central location for analysis, evaluation and interpretation.
Impact/Benefits	The benefit will be the standardization of the measurement of soil moisture and the real-time communication of the results, which will result in increased crop yield, conservation of surface and groundwater usage, and improved irrigation timing/water release.
Priority	The priority of the research would be moderate.
Summary Scope of Work	1. Develop low cost soil moisture measurement probe 2. The probes shall be of minimal cost so that they may be widely distributed 3. Develop the hardware and software to transmit data from the probe and control the probe (e.g., off/on, data transmission) 4. Develop the software necessary to analyze, evaluate and interpret (software wrappers) the data via the web. 5. Build in alerts to communicate data to users. 6. Field test the probes and wireless communication hardware 7. Test, document and validate the software
Technical Approach	
Lead Investigators (academia, natl. lab, industry, international, partnership)	Academia and national laboratory.
Potential Collaborative Govt. Agencies	USDA, BLM, Forest Service
Leverage Opportunities with Existing Programs	Opportunity for collaboration with state Departments of agriculture
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Deeper measurements and minimally disturbed installation in boreholes. Integration with large scale remote sensing. Couple with other parameters e.g., pH , chemistry, salinity
Estimated Cost	$1.5M
Execution Horizon (early, mid, late)	Start next fiscal year.
Schedule/Duration	1 to 2 years
Level of Development/Level of Maturity at completion	At completion technology could be immediately deployed to the field
Additional comments	

Research Area 1-30c. Snow pack/water content measurement.	
Statement of Need	More accurately measure snow pack and water content at high altitudes to better predict water availability for hydro and thermoelectric energy
Research Objective	The research objective will be to investigate the use of airborne geophysical techniques for the determination of snow density and pack thickness. Ancillary to this research will be the wide areal distribution of expendable weather probes (e.g., temperature, barometric pressure) that transmit surface conditions on demand. These and other data will be used to model snow melt history.
Impact/Benefits	The direct benefit will be the prediction of runoff for volume, flow and velocity for suitability studies for hydro plant power plant site selection. The indirect benefits would be predication and alert of impending flood conditions, scheduling of damn release to control flooding.
Priority	The priority of the research would be high.
Summary Scope of Work	1. Test various geophysical methods for the determination of snow pack thickness and density 2. Develop the software necessary to analyze, model, evaluate and interpret the snow pack quality and thickness to predict expected runoff volume, flow and velocity via the web 3. Test, document and validate the software 4. Test the sensitivity of the technique and model 5. Build in alerts to communicate data to users
Technical Approach	Geophysical
Lead Investigators (academia, natl. lab, industry, international, partnership)	Academia, national laboratory, international
Potential Collaborative Govt. Agencies	FEMA, BLM, Forest Service, Emergency Response
Leverage Opportunities with Existing Programs	Opportunity for collaboration with State Departments of Agriculture, FEMA, State and Local Emergency Response
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	
Estimated Cost	$1M/year for 3-years
Execution Horizon (early, mid, late)	Start next fiscal year.
Schedule/Duration	3 years
Level of Development/Level of Maturity at completion	At completion technology could be immediately deployed to the field
Additional comments	

Research Area 1-30d. Improved water monitoring technologies	
Statement of Need	Data gaps as a result of inadequate monitoring technologies.
Research Objective	Validate watershed and regional scale climate models to better gauge seasonal water supply.
Impact/Benefits	Assure planners that simulations are reliable. Enhance ability to plan for water supply on an annual basis; include climate effects in regional and watershed planning.
Priority	Medium. Climate change effects will exacerbate current supply parameters. Ability to predict precipitation at regional and local scales.
Summary Scope of Work	Compare watershed and regional scale projections with actual climate events.
Technical Approach	Historical analysis of temperature, precipitation on a day by day basis; update data points, identify analogous meteorological stations that could be used Frequencies Experimental data feeds back and improves the models
Lead Investigators (academia, natl. lab, industry, international, partnership)	Academia, national laboratories
Potential Collaborative Govt. Agencies	NCAR-DOE
Leverage Opportunities with Existing Programs	NCAR-DOE
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Comparing storm structures; characteristic Accuracy depends on past monitoring points and parameters.
Estimated Cost	$300k for 3 years per region/watershed
Execution Horizon (early, mid, late)	Early
Schedule/Duration	
Level of Development/Level of Maturity at completion	An initially validated prototype.
Additional comments	

Research Area 1-31. Develop data collection technologies for field measurements of evapotranspiration, surface runoff/runon, and infiltration.	
Statement of Need	Uncertainties in modeling and predictions of watershed/climate models are largely affected by inadequate monitoring of evapotranspiration (e.g. using field lysimeters and Class A evaporometers) and surface runoff/runon. Infiltration is usually calculated from a water balance equations, but not measured.
Research Objective	Develop data collection technologies for in-site measurements of evapotranspiration, surface runoff/runon, and infiltration needed for validation of watershed/climate models.
Impact/Benefits	Improved accuracy of modeling and predictions of water resources for present day and future climatic conditions.
Priority	1. Evapotranspiration 2. Surface runoff/runon 3. Infiltration
Summary Scope of Work	Assess the applicability of modern geophysical, isotopic geochemistry, tracer tests, and nanotechnology techniques for in-situ measurements of evapotranspiration, surface runoff/runon, and infiltration at sites with different climatic conditions.
Technical Approach	As part of investigations at field research sites, implement measurements using radar, electrical and EM measurements, sampling for natural and radioactive isotopes, conservative and reactive tracer tests, and using nanoparticles.
Lead Investigators (academia, natl. lab, industry, international, partnership)	Academia and national laboratories, international partnership
Potential Collaborative Govt. Agencies	EPA, Doe, DoD, USDA
Leverage Opportunities with Existing Programs	
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Development of monitoring techniques for different climatic conditions.
Estimated Cost	$500k-$1M per year per site
Execution Horizon (early, mid, late)	Mid
Schedule/Duration	3 years
Level of Development/Level of Maturity at completion	TBD
Additional comments	

Research Area 1-32. Establish field sites for validation of integrated water-energy monitoring systems.	
Statement of Need	Develop an integrated, interdisciplinary monitoring approach for all types of water involved in the atmosphere-surface water-groundwater flow and transport cycle. Determine interrelated parameters affecting quantity and quality of water Identify monitoring methods for different practical applications: (a) agricultural lands, (b) remediation of contaminated sites, (c) water supply.
Research Objective	Establish a series of field sites for testing and field demonstration of integrated monitoring technologies for different practical applications.
Impact/Benefits	Reduce cost of monitoring; close gaps in data collection for different practical applications needed for modeling/prediction validation; support water/energy use planning and risk assessment; water and energy conservation.
Priority	1. Methods for integrating and scaling small-scale (e.g., stugle boreholes and sensors), meso-scale (e.g., cross-borehole geophysics—radar, electric, EM, etc.), and large-scale (e.g., remote sensing). 2. Development of real-time, remotely operated data acquisition systems to collect data on quality and quantity of atmospheric, surface and groundwater.
Summary Scope of Work	1. Develop monitoring technologies for different practical applications: (a) agriculture (irrigation, drainage, desalinization); (b) characterization, design, performance monitoring, post-remediation monitoring and stewardship of remediated sites (technologies are different for different types of remediation—pump and treat, barriers, vitrification, etc.) 2. Perform field demonstration at field sites of interest to DOE.
Technical Approach	Select and build field sites, perform at least 3 years of monitoring.
Lead Investigators (academia, natl. lab, industry, international, partnership)	Industry and national labs. International cooperation and partnerships are desirable
Potential Collaborative Govt. Agencies	EPA, USGS, DoD, USDA
Leverage Opportunities with Existing Programs	Environmental Remediation Science Program of DOE DOE field research sites—e.g., Oak Ridge, Hanford, INL
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Regulatory. Retrievable sensors. Uncertainty evaluation. How to incorporate continuously improving technologies/data acquisition systems and databases.
Estimated Cost	$500k-1M per site per year.
Execution Horizon (early, mid, late)	Early—individual techniques. Mid—field testing and initial demonstration Late—long-term performance demonstration
Schedule/Duration	At least 3 years of monitoring and demonstration.
Level of Development/Level of Maturity at completion	
Additional comments	

Research Area 1-33. Develop regional/watershed models to predict water availability for energy facilities. **Research Area 1-34. Develop approaches to running models more efficiently on parallel computers.** **Research Area 1-35. Commence precipitation pattern detection research.**	
Statement of Need	Accurate long-term energy planning requires accurate regional water availability models. It is necessary to predict regional precipitation trends and variability in order to model water availability.
Research Objective	To predict water available for energy facilities, develop coupled regional scale models with stream flow and groundwater as dependent variables and temperature, precipitation, vegetation, evapotranspiration, landscape complexity and geology as independent variables. Trends and variability in precipitation patterns is a pivotal objective.
Impact/Benefits	Skillful projection of interannual to decadal trends and variability of regional climate will enable streamflow and groundwater projections and permit integration across the interfaces between energy and water planning models.
Priority	High. Skillful projection of precipitation trends and variability is pivotal among the sub-objectives, since the current skill level is low.
Summary Scope of Work	Develop a coupled, two-way nested regional climate model that can execute within the framework of a global climate system model. Develop advanced paramterizations of land-atmosphere exchanges from soil, vegetation and platetary boundary layer circulations; explicitly resolve deep moist convective systems; and simulate detailed flow over complex terrain. Provide computational resources commensurate with integrations of decadal duration.
Technical Approach	Develop the nested regional scale model compatible with global climate system model(s) of major research centers. Validate with special observations of multi-year duration.
Lead Investigators (academia, natl. lab, industry, international, partnership)	Joint Program with DOE-NSF(NCAR-academia) with joint funding.
Potential Collaborative Govt. Agencies	DOE-NSF
Leverage Opportunities with Existing Programs	NSF/NCAR CCSM/NRCM modeling program
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	
Estimated Cost	$1.5M/yr DOE funds
Execution Horizon (early, mid, late)	Early
Schedule/Duration	5 years
Level of Development/Level of Maturity at completion	Demonstration prototype
Additional comments	

Research Area 1-34a. Predicting water availability for energy facilities.	
Statement of Need	Predicting water availability for energy facilities will require highly resolved Monte Carlo simulations of coupled regional hydrologic systems over interannual to decadal periods. The combination of high resolution per simulation and multiple simulations generates a requirement for unprecedented levels of high-performance computation and data storage. The development of a predictive capability will also require the ability to experiment with alternative software modules in the coupled system.
Research Objective	More efficient simulations of multiple realizations of coupled regional climate models.
Impact/Benefits	Decreased execution times and more flexible software development.
Priority	High
Summary Scope of Work	Develop: 1. Highly parallelized numerical solvers to reduce computation time by at least an order of magnitude; 2. Software frameworks that support rapid prototyping, as well as experimentation with different models; 3. Petascale storage systems will to provide access to massive data sets.
Technical Approach	Base the software framework on an existing system like the Earth System Modeling Framework (ESMF) or the Weather Research Forecast model (WRF). Evaluate alternative solvers as modules in an existing software framework like WRF. Implement a small number in a highly parallel petascale architecture. Integrate additional physics modules, e.g., groundwater hydrology, in the framework. Verify and validate using pilot studies.
Lead Investigators (academia, natl. lab, industry, international, partnership)	Academia and national labs
Potential Collaborative Govt. Agencies	Joint Program with DOE-NSF(NCAR-academia) with joint funding.
Leverage Opportunities with Existing Programs	NCAR regional climate modeling initiative; basin-scale hydrologic modeling at various institutions and agencies.
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	
Estimated Cost	$1M/yr for 5 yrs
Execution Horizon (early, mid, late)	Early
Schedule/Duration	5 years
Level of Development/Level of Maturity at completion	Demonstration prototype
Additional comments	

Research Area 1-34b. Integration of statistical/probabilistic analysis of historical Precipitation time-series with climate change modeling effort. **NB. Complements research area 1-34a.**	
Statement of Need	Integration of statistical/probabilistic analysis of historical Precipitation time-series with climate change modeling effort
Research Objective	Climate science community recognizes that current outputs from state-of-the-art GCM's for Precipitation cannot yet be considered as reliable data on which impact assessment may be developed at the regional level
Impact/Benefits	While climate modeling research modeling effort will continue to improve prediction of Precipitation patterns, the objective is to develop a framework in parallel in which knowledge of historical Precipitation variability might be valued to complement GCM's outputs and eventually make precipitation change scenarios more reliable
Priority	High as long as climate model cannot provide reliable Precipitation information. This action can be undertaken a.s.a.p. and does not require a former step to be completed before inception
Summary Scope of Work	• Identifying climatic predictant variables that may define and reflect a typical precipitation regime • Developing historical regional databases of climatic/precipitation regimes • Creating a methodological framework to integrate and couple these first steps with climate change modes to provide more reliable precipitation change scenarios • Testing and implementing methodology to some watersheds with energy generation vulnerabilities/stakes highly sensitive to precipitation/inflows variability
Technical Approach	• Statistical analyses and definition of precipitation regimes • Comprehensive setup of Databases
Lead Investigators (academia, natl. lab, industry, international, partnership)	Development : USGS, NSF/NCAR, NOAA/NCDC Implementation : EPRI + Utilities + Water resources agencies
Potential Collaborative Government Agencies	USBR, USACE
Leverage Opportunities with Existing Programs	
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Scientific constraints: Future climate and related precipitation regimes might very significantly depart from known historical regimes, such that analogy with past event might not be able to capture new future climate behaviors. Educational issue: Approach will provide probabilistic outputs which might not be handled by decision-makers
Estimated Cost	Development : $2 million Implementation (2 pilot watersheds / regions) : $1.5 million
Execution Horizon (early, mid, late)	Early
Schedule/Duration	Maximum of 5 years: Development: 3 years Testing/Implementation: 2 years
Level of Development/ Level of Maturity at completion	

Research Area 1-36a. Validate watershed climate models.	
Statement of Need	Precipitation projections/forecasts from regional-scale models need to be tested against measurements and validated.
Research Objective	Provide precipitation, meteorological, and atmospheric-related data to enable model evolution/development.
Impact/Benefits	Will enable and accelerate development of regional-scale precipitation modeling for energy generation and planning uses.
Priority	High, since this effort will feed subsequent efforts that depend on refined precipitation forecasts from climate models.
Summary Scope of Work	1. Identify regions to implement ground and aircraft-based measurement campaigns. Campaigns last months to years. 2. Develop instrumentation platforms. 3. Measure—model—evaluate—repeat cycle.
Technical Approach	Develop instrument system similar to ARM mobile facility. Place instrument suites and aircraft campaigns in regions where precipitation model development will benefit from results (SE U.S. and SW U.S.)
Lead Investigators (academia, natl. lab, industry, international, partnership)	NCAR, DOE labs, Desert Research Institute, Academia (many possible)
Potential Collaborative Govt. Agencies	NASA, NOAA, NSF
Leverage Opportunities with Existing Programs	Existing DOE and NCAR programs. 1. NCAR model development. 2. DOE ARM program. 3. NCAR aircraft ops. 4. DOE ASP program.
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Will require significant front-end program planning and inter-organizational exchanges.
Estimated Cost	Ground instrumentation: \$15M over 5 years (for 2 regional sites) Aircraft measurements: \$5M over 5 years
Execution Horizon (early, mid, late)	4 to 5 year program that can start now (Early)
Schedule/Duration	4-5 years. 1 year development, 4 years operation.
Level of Development/Level of Maturity at completion	Instrumentation is developed (ARM) At completion, this effort will advance the maturity of regional-scale climate models for energy planning.
Additional comments	

Research Area 1-37. Create interfaces between energy and water planning models. **Research Area 1-38. Couple power needs forecasts and water availability forecasts.** **Research Area 1-39. Model climate variability impacts on generation technologies.**	
Statement of Need	Climate variability, and improved climate forecasts, will impact water and energy planning and create a need for improved water and energy models.
Research Objective	Develop integrated water and energy planning models that use better long range forecasts of temperature and precipitation to forecast water and energy supplies and demands and estimates new required energy supply capacity needs.
Impact/Benefits	Increase the efficiency of water storage management and energy and water supply investment planning.
Priority	High priority
Summary Scope of Work	Improvement and integration of existing hydrology water storage management, energy generation models for planning purposes.
Technical Approach	Work with existing agencies and models, evaluate and make improvements to those models or construct new versions and components to those models as needed.
Lead Investigators (academia, natl. lab, industry, international, partnership)	DOE with integration with other agencies that use these models include Federal , sate, and
Potential Collaborative Govt. Agencies	USBR, USGS, utilities, state resource agencies, private groups in affected states (SW, SE)
Leverage Opportunities with Existing Programs	Will take advantage of existing water and energy planning models whenever possible.
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Integrating complex multipurpose models with changing climate forecasts is a difficult challenge.
Estimated Cost	$1M per year
Execution Horizon (early, mid, late)	1-5 years, early
Schedule/Duration	1-5 years
Level of Development/Level of Maturity at completion	Usable linked models for utility/state-level planning
Additional comments	

Research Area 1-40. Modeling and integration of climate impacts.	
Statement of Need	In order to integrate energy and water models it is important to demonstrate climate change models of precipitation with hydrologic models at the regional scale to enable energy forecasting.
Research Objective	Demonstrate at the regional scale in two regions (multi-state) water forecasting models with energy forecasting models at a prototype scale.
Impact/Benefits	Demonstration of prototype approaches will show utility of models and how to use. Provides baseline of uses of models and accelerates full-scale implementation nationwide.
Priority	High. Demonstration of integrated water and energy models needed to accelerate nationwide implementation by reducing risks of use.
Summary Scope of Work	Take climate variability models and integrate with hydrologic and energy forecasting models in two regions to show utility.
Technical Approach	Integration of several modeling improvement approaches for climate changes and energy and hydrologic forecasting models to improve planning (prototype demonstration projects).
Lead Investigators (academia, natl. lab, industry, international, partnership)	DOE lead activity for demonstration (2 different regions)
Potential Collaborative Govt. Agencies	NCAR for climate models, water agencies for hydrologic models, EPRI/EEI for utility forecasting models to integrate.
Leverage Opportunities with Existing Programs	Use of climate models will leverage DOE and NSF funding, along with water agency, hydrologic models, funding and electric utility forecasting models funding
Constraints/Challenges (Policy, regulatory, technical, sequencing?)	Demonstrations require multi-agency cooperation including participation by industry and energy and water regulatory agencies.
Estimated Cost	\$1M/yr for 2 years for each demonstration. 2 demonstrations-\$2M/yr for 1-2 years
Execution Horizon (early, mid, late)	Mid. Demonstrations can not be started (3-7 years) until improvements completed for climate, hydrology, and energy forecasting models.
Schedule/Duration	1-3 years
Level of Development/Level of Maturity at completion	Demonstration prototypes of integrated climate/hydrologic/energy forecasting. If successful, prototypes can be implemented in multi-regions in 2-3 years.
Additional comments	