Hydrologic engineering management plan (HEMP) for Lake Mendocino Forecast-informed Reservoir Operation (FIRO) evaluation of water control plan alternatives within the final viability assessment (FVA)

Version 3.0, August 1, 2019

Summary

In 2014, Sonoma Water (SW) undertook a study to confirm the agency could manage Lake Mendocino storage more efficiently for authorized project purposes by integrating reservoir inflow forecasts explicitly in release schedule decision making. That study—which was referred to as the preliminary viability assessment (PVA)—confirmed SW could increase water supply benefit without adversely affecting the flood risk reduction capability if forecast-informed reservoir operation (FIRO) procedures were used. The US Army Corps of Engineers (USACE), which is responsible for flood operation of Lake Mendocino, agreed with the finding and subsequently approved SW's request for a major deviation from the Lake Mendocino water control plan (WCP). This temporary deviation permitted SW greater flexibility in managing Lake Mendocino storage, pending additional investigation that would support incorporation of FIRO procedures in a formal revision of the WCP.

The PVA evaluated candidate FIRO strategies in a reconnaissance-level technical study, confirming viability of FIRO in concept. However, the PVA did not recommend a single specific strategy for integrating FIRO into a future WCP. That task is to be completed in a subsequent planning study—the full viability assessment (FVA). The objective of the FVA is to identify, through appropriate detailed technical analyses and other considerations, the best FIRO strategy for Lake Mendocino, along with the manner in which that can be implemented in real-time operation by SW and USACE and the WCP changes necessary to permit that change permanently. The FVA will also evaluate potential adaptive strategies that would allow operators to utilize new technology and improved forecast skill as it becomes available in the future.

The FVA is managed by the Lake Mendocino FIRO steering committee (SC), which identified necessary technical studies. to be consistent with USACE guidance for conduct of similar technical studies The SC prepared this hydrologic engineering management plan (HEMP) as *…a technical outline of the hydrologic engineering studies necessary to formulate a solution to a water resources problem* (*Engineering Pamphlet 1110-2-9*).

This HEMP includes the following:

1. Statement of objective and overview of technical study process to provide information needed for the FVA.
2. Specification of requirements for the FIRO alternatives that will be considered. These are presented in Table 1, Table 2, and Table 3.
3. Identification of tasks to be completed for the technical analysis. These are presented in Table 4.
4. Identification of analysis tools and methods to be used for the study.
5. Identification of the project team members and their roles and responsibilities for conduct, review, and approval of the hydrologic engineering study. These are presented in Table 7 and Table 8.
6. Analysis schedule. This is presented in Figure 1.

Objective of technical analysis, overview of process, and tasks to be completed

The objective of the hydrologic engineering study described herein is to identify and evaluate Lake Mendocino FIRO alternatives in a systematic, defendable, repeatable manner, thus providing information to the SC so it may identify the best FIRO strategy for Lake Mendocino.

The process used to meet the hydrologic engineering study objective is a "nominate-simulate-evaluate-iterate" process, consistent with the process used commonly by USACE for water resources planning studies. Tasks in this process, as applied for technical analyses to support the Lake Mendocino FIRO FVA, include the following:

1. A set of feasibility criteria and performance metrics is developed for assessing and comparing FIRO alternatives. This set will be applied to all alternatives, thereby permitting the project delivery team (PDT) to compare and rank alternatives and the SC to identify the best FIRO strategy.
2. A set of alternative FIRO strategies is nominated by the PDT. The strategies are screened to ensure they meet specified requirements, which are described below.
3. Performance of the river-reservoir system with each FIRO strategy is simulated using a common set of meteorological and hydrological conditions.
4. Simulation results are used to evaluate the viability and performance of each strategy. The evaluation uses metrics identified in Task 1, comparing each alternative to performance for the *without-project* condition, which is operation following the WCP included in the current water control manual (WCM). If results of the evaluation inform refinements to FIRO strategies, the simulation and evaluation tasks are repeated with enhanced strategies
5. The PDT uses the technical analysis results to rank the alternatives and submits the rankings to the SC. The SC identifies the best strategy for implementation.

These tasks are described in more detail in Table 4. Major tasks are listed in column 1, and subtasks in column 3.

FIRO alternatives to be evaluated

Selection of specific FIRO alternatives is a task to be completed as a component of the hydrologic engineering study (see below). Requirements of all candidate FIRO strategies are shown in Table 1. Table 2 and Table 3 show additional constraints and objectives that should be met by proposed alternatives. While selection of FIRO alternatives to be evaluated is a task of the technical studies (see below), a tentative set evolved as an outcome of the PVA; that list is shown in Table 6.

Table 1. Requirements of all alternative FIRO strategies

ID (1)	Description (2)
1	The candidate FIRO strategy must satisfy all relevant USACE engineering regulations (ERs), including but not limited to the following: • ER 1105-2-100 *Planning Guidance Notebook* • ER 1105-2-101 *Risk Assessment for Flood Risk Management Studies* • ER 1110-2-240 *Water Control Management* • ER 1110-2-1156 *Safety of Dams Policy and Procedures* • ER 1110-2-1941 *Drought Contingency Plans* • ER 1110-2-3600 *Management of Water Control Systems* • ER 1110-2-8156 *Engineering and Design Preparation of Water Control Manuals* • ER 1120-2-1420 *Engineering Requirements for Reservoirs*
2	The analytical tools required for implementation of the candidate FIRO strategy must be compatible with the USACE's Corps Water Management System (CWMS) software. In addition, results of any analyses completed with software not currently certified for use by USACE must be demonstrated to produce results consistent with results of USACE software.
3	Streamflow forecasts used by the candidate FIRO strategy must be those provided by the California-Nevada River Forecast Center (CNRFC) of the National Weather Service. Simulated streamflow forecasts must be consistent with the skill characteristics of those issued by the CNRFC. As appropriate for the alternative, the forecast used can be ensemble and/or single-value.
4	The FIRO strategy must satisfy the hard (inviolable) operation constraints shown in Table 2.
5	The FIRO strategy should represent, and to the extent possible, meet the operation objectives shown in Table 3.
6	Software development needed to implement the FIRO alternative must be limited for the FVA, as the objective is to select from amongst a set of readily available (or nearly so) strategies.
7	Simulations during periods when release rate of change may become a factor should be completed at an hourly time step. When release rate of change is not a factor, the simulation time step can be daily.

Table 2. Hard (inviolable) operational constraints that must be satisfied by all FIRO strategies

ID (1)	Limiting condition (2)	Description (3)
1	Must satisfy limits on release rate of change	Release rate of change is governed by the potential impacts on the fisheries environment in the reach down to Hopland. Efforts are currently underway to clarify these in the domain where FIRO outcomes are affected.
2	Must minimize exceeding target maximum flow at Hopland relative to the baseline of current operations	Operations are to avoid contributing to flows above 8,000 cfs at Hopland per the existing WCP. Forecasts of the West Fork of the Russian River and incremental local flows at Hopland are used to modulate releases to achieve flows below the target.
3	Must accommodate maximum release schedule	The maximum release schedule is defined in the existing WCP. This will define the maximum rate of all releases.
4	Must not require other than currently available frequency of forecast updates	Maximum of 4 times per day in major flood events, more commonly 2 times per day in real operations. For alternative evaluation purposes, forecast updates will be once per day.
6	Must meet instream minimum flow requirements	Must comply with California SWRCB Decision 1610 or current instream flows established by the SWRCB.
7	Must properly represent current Potter Valley Project diversion	Historical Potter Valley Project diversion was significantly reduced in 2006 as a function of a Federal Energy Regulatory Commission (FERC) decision. All simulations must reflect the current diversion profile.
8	Must account for contributions to flood mitigation downstream of Hopland	USACE delays post-event releases to avoid any contribution to flow above flood stage at Healdsburg and Guerneville.

Table 3. Operational considerations that should be evaluated in the hydrologic engineering study

ID (1)	Operational consideration (2)	Description (3)
1	Should simulate operation of Ukiah Power and limits on that operation	When reservoir release must exceed 3,000 cfs, the City of Ukiah's power plant must be shut off. A similar shift process takes place to put the power plant back into operation when the flows are lower. The time to complete this process is 1 hour or less.
2	Should avoid spillway flow to maximum extent possible	Extreme aversion of allowing water to flow over the spillway. In fact, the 111,000 ac-ft maximum conservation storage is 3 ft and 5,500 ac-ft below the spillway crest.
3	Should consider Lake Mendocino bank protection desires	Bank protection in Lake Mendocino is limited above elevation 758.8 ft (105.5 KAF) because of limited riprap. USACE prefers to avoid long-term (greater than 1-week) storage in this range.
4	Should consider and address Lake Mendocino Campgrounds operation objective	USACE has preference to keep Lake Mendocino below 750 ft in the spring to provide access to campground(s). Campgrounds officially open for Memorial Day weekend (end of May).
5	Should consider adverse impact to Lake Sonoma flood operations relative to baseline/current operations	Under certain conditions, Lake Mendocino operation has the potential to negatively affect flood operation at Lake Sonoma. Impacts of Lake Sonoma flood operations from Lake Mendocino releases should be minimized when conflicting flood control releases are required from Lake Sonoma.
6	Should not require excessive frequency of gate changes	Manpower and safe operation limit gate changes to daylight hours and perhaps no more than every 6 hours under typical operations.

Table 4. Tasks and subtasks to be completed for hydrologic engineering study of FIRO strategies

Major task (1)	Description (2)	Subtasks (3)
Task 1. Select performance metrics	Both quantitative and qualitative measures of performance will be identified. Methods of computation of quantitative measures will be described. A tentative list is shown in Table 5.	**Task 1.1.** With appropriate input from subject matter experts, formulate candidate set of quantitative and qualitative measures of performance. (A tentative list is shown in Table 5.) Define methods for assessing these for typical FIRO strategies. Screen set to select feasible metrics for ALL likely alternatives to permit objective comparison of strategies. Prepare technical memo. Submit to SC for review. **Task 1.2.** Receive comments from SC. Revise selected set of performance metrics as required. **Task 1.3**. If necessary, design, develop, test software applications (scripts, spreadsheets, etc.) to apply selected metrics.
Task 2. Nominate/formulate alternative FIRO strategies that will be considered	Each alternative FIRO strategy to be considered will be identified and described, along with the method by which performance with the strategy will be evaluated. A tentative set evolved as an outcome of the PVA; that list is shown in Table 6.	**Task 2.1**. With appropriate input from subject matter experts, formulate candidate set of FIRO strategies to be considered. Describe each strategy in memo, submit proposed list/memo to SC for approval. **Task 2.2.** Receive comments from SC and revise list as appropriate. Get SC agreement to proceed with comparison. **Task 2.3**. Identify software applications that will be used to model FIRO strategies (tentatively, these are HEC-ResSim and Ensemble Forecast Operations [EFO]).
Task 3. Side studies	Identify, conduct, document, and incorporate outcomes of "side studies" that affect the simulation and evaluation of alternatives.	**Task 3.1.** Identify any additional "side studies" that must be completed to provide information required for simulation. For example, the discharge target of 8,000 cfs at Hopland has been questioned. If an alternative target is to be considered, that issue will be studied and resolved prior to initiation of comparison. Details of side studies will be identified in this subtask, with scope of work and schedule submitted to SC for approval. **Task 3.2.** Undertake and complete side studies, as approved by SC. Document findings. Incorporate findings in selected FIRO strategy models or procedures

Major task (1)	Description (2)	Subtasks (3)
Task 4. Simulate performance with each alternative	Each alternative FIRO strategy will be simulated with the HEC-ResSim model with a consistent set of hydrologic boundary conditions and system constraints (identified in Table 2).	**Task 4.1.** Considering all FIRO strategies to be evaluated, identify boundary conditions and initial states of the system to be considered in simulation for comparison. Document. This task requires development of a method for generation of synthetic single-value forecasts because single-value forecasts are available from 2005 only. A robust method must be developed to calibrate and test strategies that use these forecasts. That will require consultation and collaboration with USACE's Hydrologic Engineering Center (HEC) on approaches, followed by research and activities to develop, apply, and validate the approach using the historical archives (2005-2019). **Task 4.2.** Simulate performance of Lake Mendocino with candidate strategies. [For EFO model, validate release schedule, simulated storage, and computed downstream flows with HEC-ResSim model.] Prepare technical memo describing application of each strategy. Prepare database of results (for use in Task 5).
Task 5. Using results of simulation, evaluate each alternative in terms of identified performance metrics	Each alternative FIRO strategy will be analyzed and the appropriate performance metric statistics computed.	**Task 5.1.** Using database of results from the HEC-ResSim simulation of each FIRO strategy (from subtask Task 4.2) apply software applications (scripts, spreadsheets, etc.) from Task 1.3 to compute performance metrics for each strategy. **Task 5.2.** Revise FIRO strategies and performance metrics as necessary to ensure fair, repeatable comparisons. This subtask acknowledges initial uncertainty about compatibility of strategies and metrics. **Task 5.3.** Document results of evaluation in technical memo.
Task 6. Compare the alternatives by comparing the metrics	Each alternative FIRO strategy evaluation will be compared against the baseline and against each other.	**Task 6.1.** Using results from Task 5, prepare charts, tables, etc. to compare performance of strategies. Prepare technical memo with this information and submit to SC for information. **Task 6.2.** Refine strategies if evaluation and comparison expose opportunities for "quick gains" through minor adjustments to strategies. Repeat subtasks Task 4.2— Task 5.1 with revised results. **Task 6.3.** Prepare final technical memo on simulation, evaluation, and comparison. Submit for SC review. Receive SC comments and revise technical memo as needed.

Major task (1)	Description (2)	Subtasks (3)
Task 7. Select preferred alternative and recommend to SC	Each alternative FIRO strategy comparison will be scrutinized, a preferred alternative identified, and all findings will be documented.	**Task 7.1.** Using results of comparison from Task 6, rank alternatives considering individual metrics from Task 1. Document findings. **Task 7.2.** Develop multiple objective ranking scheme for ranking alternatives. Apply scheme to rank alternatives in terms of overall performance. **Task 7.3.** Provide comparisons and ranking to SC, along with recommendation of PDT.

Metrics for evaluating viability and efficiency of alternatives

The efficiency of FIRO will be evaluated with a set of measurable statistics. These will be used in the same manner (to the maximum extent possible) to assess each alternative objectively. Selection of the specific metrics and stipulation of the manner of computing or calculating those is a task to be completed as a component of this study.

An initial tentative list of metrics is shown in Table 5.

Table 5. Tentative list of metrics for evaluation of FIRO alternatives (listed in Table 6)

ID (1)	Metric description (2)	Category (3)	Likely method of computation: alternatives 2, 3, 4, and 5 (4)	Likely method of computation: alternatives 1 and 6 (5)
M1	Annual maximum flow frequency function at Hopland, Healdsburg, and Guerneville	Flood risk management	Simulate w/ HEFS hindcast[1] and scaled events[2]. Find the annual maximum flow. Make assumption about the return frequency (RF) of 200y inflow event downstream. Estimate flow-frequency curve.	Either (a) simulate operation for "design floods" with range of exceedance probabilities (say, 0.5 to 0.002) to develop regulated annual maximum flow-frequency; or (b) create period of record (POR) sequence with statistical properties similar to observed record, route, find annual maximum flow, and estimate flow-frequency curve. (4).
M2	Annual maximum pool elevation frequency function of Lake Mendocino	Flood risk management	Simulate w/ HEFS hindcast[1] and scaled events[2]. Compute the annual maximum pool elevation. Make assumption about the relationship between inflow return frequency and pool elevation frequency. Estimate maximum pool elevation – frequency curve.	Either (a) simulate operation for "design floods" with range of exceedance probabilities (say, 0.5 to 0.002) to develop annual maximum pool elevation frequency; or (b) create POR sequence with statistical properties similar to observed record, route, find annual maximum pool elevation, and estimate elevation-frequency curve. (4).
M3	Annual maximum pool elevation frequency function of Lake Sonoma	Flood risk management	As for metric M2.	As for metric M2.

ID (1)	Metric description (2)	Category (3)	Likely method of computation: alternatives 2, 3, 4, and 5 (4)	Likely method of computation: alternatives 1 and 6 (5)
M4	Annual maximum Lake Mendocino total release frequency function	Flood risk management	Simulate w/1985-2017 HEFS hindcast ensembles(1) and scaled events(2). Find the annual maximum total release and estimate. Estimate annual maximum total release-frequency curve. Run ’86, ’97, and ’06 200y scaled events and collect maximum releases. Verify or adjust estimated release-frequency curve assuming these events represent ~200-year return frequency.	Either (a) simulate operation for “design floods” with range of exceedance probabilities (say, 0.5 to 0.002) to develop annual maximum release frequency function; or (b) create POR sequence with statistical properties similar to observed record, route, find annual maximum release, and estimate release-frequency curve. (4).
M5	Annual maximum Lake Sonoma total release frequency function	Flood risk management	As for metric M4.	As for metric M4
M6	Annual maximum uncontrolled spill frequency function for Lake Mendocino	Flood risk management	Simulate w/ HEFS hindcast(1) and scaled events(2). May require simulation of 200y and 500y RF to create separation between alternatives.	As for metric M4.
M7	Annual maximum uncontrolled spill frequency function for Lake Sonoma	Flood risk management	As for metric M6.	As for metric M4.

ID (1)	Metric description (2)	Category (3)	Likely method of computation: alternatives 2, 3, 4, and 5 (4)	Likely method of computation: alternatives 1 and 6 (5)
M8	Expected annual inundation damage at critical Russian River locations	Flood risk management	Simulate w/ HEFS hindcast[1] and scaled events[2]. May require simulation of 200y and 500y RF to create separation between alternatives.	Use downstream flow frequency functions developed as described above with open-channel flow model to derive stage-frequency curves. Use inundation model to estimate floodplain inundation depths, then combine with floodplain depth-damage function at critical locations to derive damage-frequency function. Integrate to find expected value. As an alternative, simulate POR, convert flows to stages, determine floodplain inundation depths and associated damage, then average annual maximum values. (4).
M9	Expected annual potential (statistical) loss of life due to floodplain inundation, critical Russian River locations	Flood risk management	Simulate w/ HEFS hindcast[1] and scaled events[2]. May require simulation of 200y and 500y RF to create separation between alternatives.	Use downstream flow frequency functions developed as described above with open-channel flow model to derive stage-frequency curves. Use inundation model to estimate floodplain inundation depths, then use with life loss model to derive life loss-frequency function. Integrate to find expected value. As an alternative, simulate POR, convert flows to stages, determine floodplain inundation depths and associated lives lost, then average annual maximum values. (4).

ID (1)	Metric description (2)	Category (3)	Likely method of computation: alternatives 2, 3, 4, and 5 (4)	Likely method of computation: alternatives 1 and 6 (5)
M10	Reliability of water supply delivery, as measured by annual exceedance frequency of May 10 reservoir storage levels	Water supply	Computation requires analysis of lower flow periods. Simulate w/ HEFS hindcast[1] to compute daily reservoir storage throughout year. Identify May 10 storage each year, then estimate the exceedance probability of the computed storage levels.	Simulate POR to compute daily reservoir storage throughout the year. Identify May 10 storage each year, then estimate the frequency of those storage levels (by ranking and counting). (4).
M11	Ability to meet in-stream flows to support threatened and endangered anadromous fish species during the summer rearing season, as measured by number of days June through September flows exceed the 125 cfs target established by the 2008 Biological Opinion in the Upper Russian River	Water supply	Simulate w/ HEFS hindcast[1], then count number of days flows exceed threshold.	Simulate POR, then count number of days flows exceed threshold. (4).
M12	Ability to meet in-stream flows to support fall spawning migration of threatened Chinook salmon, as measured by number of days October 15 to January 1 flows exceed minimum spawning migration passage flow of 105 cfs	Water supply	Simulate w/ HEFS hindcast[1], then count number of days flows exceed threshold.	Simulate POR, then count number of days flows exceed threshold. (4).

ID (1)	Metric description (2)	Category (3)	Likely method of computation: alternatives 2, 3, 4, and 5 (4)	Likely method of computation: alternatives 1 and 6 (5)
M13	Impacts to the Bushay Campground during the recreation season (Memorial Day weekend through Labor Day weekend)	Recreation	Simulate w/ HEFS hindcast(1), then count number of days during the recreation season each year that stage exceeds campground access(3).	Simulate POR, then count number of days during the recreation season each year that stage limits campground access(3). (4).
M14	Impacts to power production of the CVD powerhouse	Power Generation	Simulate releases w/ HEFS hindcast(1), then calculate power production using model developed by Sonoma Water.	Simulate releases w/ POR, then calculate power production using model developed by Sonoma Water. (4).
M15	Lake Mendocino bank protection, as measured by annual frequency of exceeding elevation 758.8 ft. (Bank protection in Lake Mendocino is limited above this because of limited riprap. USACE prefers to avoid long-term storage in this range.)	Dam safety	Simulate w/ HEFS hindcast(1) and scaled events(2).	Use results of pool elevation-frequency analysis completed for metric M2 above to identify probability of equaling or exceeding threshold elevation.
M16	Impacts to hours of operation	Operations	Percent change from Baseline operations in cumulative change of flood control release.	Percent change from Baseline operations in cumulative change of flood control release.

Notes:

(1). Hindcast of the Hydrologic Ensemble Forecasts System (HEFS) for forecast points in the Russian River was developed by the CNRFC, which includes daily forecasts of hourly flows out to 15 days for 59 ensemble members. The Hindcast covers water years 1985 through 2017. References and resources for HEFS include:

https://journals.ametsoc.org/doi/full/10.1175/BAMS-D-12-00081.1

https://cepsym.org/Sympro2016/Hartman.pdf

(2). Scaled events from the hindcast dataset have been developed to simulate 200- and 500-year flood events for Lake Mendocino and points downstream. Observed hydrology and hindcasts from 1986, 1997, and 2006 historical flood events have been scaled to match the estimated 200- and 500-year return frequency inflow volume into Lake Mendocino.

(3). The Bushay campground at Lake Mendocino is inaccessible when stage exceeds 750 ft elevation.

(4). Must develop a synthetic single-value forecast capability for events outside of 2005-current period.

Table 6. Candidate FIRO alternatives to be evaluated

ID (1)	Alternative strategy (2)	Description (3)
1	Existing WCP operation (Baseline)	This is the baseline condition against which performance of all alternatives will be measured. It includes the seasonal rule curves and release selection rules from the 1986 USACE WCM and 2004 update to the flood control diagram (FCD). This plan calls for winter season storage of 68,400 ac-ft and a summer storage of 111,000 ac-ft with fall and spring drawdown and refill (see standard rule curve). No forecasts are utilized. Storage above the rule curve is always evacuated as quickly as feasible.
2	Ensemble Forecast Operations (EFO)	Uses the 15-day ensemble streamflow forecasts from the CNRFC. Assesses the probability of storage above 111,000 ac-ft (model parameter) given the inflow ensembles and a release schedule and compares this with a probability threshold defined through calibration. If probability exceeds the tolerable likelihood anywhere in the 15-day period, a flood release is computed to reduce the probability to an acceptable level. Recommended release can be updated with each forecast cycle.
3	WY19 hybrid (Major Deviation #1)	A combination of the existing WCP and the EFO where the variable space is managed by the EFO process. In mid-winter the variable space resides between 68,400 and 80,050 ac-ft and maintains the same drawdowns and refill start dates as the WCP. Storage above the variable space is always evacuated as quickly as feasible. (See Major Deviation #1 rule curve.) Recommended release can be updated with each forecast cycle.
4	Additional hybrid(s)	To be detailed in Task 2. Similar to WY19 hybrid, with higher mid-winter storage and/or a corner cutting adjustment in March to aid with spring refill. More than one variant of this strategy may be evaluated.
5	Folsom-like	Creates a variable flood control space above 68,400 ac-ft and below a storage to be identified in Task 2 that is managed in proportion to the 5-day ensemble inflow at an exceedance probability level as issued by the CNRFC (also to be identified in Task 2). The current storage and inflow forecast determine the target storage and the appropriate reservoir release. Storage above the variable space is always evacuated as quickly as feasible. Recommended release can be updated with each forecast cycle.
6	5-day single-value based	To be determined by SPN and HEC. Allowable storage above 68,400 ac-ft and reservoir release informed by current storage and the 5-day single-value forecast for Lake Mendocino inflow, the Russian nr Ukiah, and the local above Hopland as issued by the CNRFC. Recommended release can be updated with each forecast cycle.

Project delivery team members and their roles

The PDT for evaluation of FIRO alternatives includes subject matter experts (SMEs) who will complete the analyses described herein, report on the findings and understandings, and recommend a single approach to be taken by SW, and managers who will oversee the work effort. PDT members are identified in Table 7

Table 7. Lake Mendocino FIRO FVA technical analysis PDT members

- Lake Mendocino FIRO steering committee
- SW technical staff
- USACE Headquarters staff (HQ)
- USACE Hydrologic Engineering Center (HEC) staff
- USACE Engineering Research and Development Center (ERDC) staff
- Center for Western Weather and Water Extremes, Scripps Institution of Oceanography at University of California, San Diego (CW3E)
- USACE, Sacramento District (SPK) staff
- USACE, San Francisco District (SPN) staff
- Robert K. Hartman Consulting Services (RKHCS) staff
- HDR Engineering staff

The PDT members have 1 of 4 roles, consistent with established project management planning, as shown in Table 8. These roles vary by hydrologic engineering task. Table 9 shows roles assigned to PDT members for the analysis described herein.

Table 8. Project roles

ID (1)	Role (2)	Description of duties (3)
R	Responsible	Responsible for completing the analyses described herein.
A	Accountable	Answerable for correct and thorough completion of task; ensures requirements are met; delegates work to those responsible.
C	Consulted	As SMEs, offer opinions through two-way communication with those responsible and accountable, about conduct of analyses.
I	Informed	Kept up to date on progress through 2-way communication.

Table 9. PDT roles by task

Major task (1)	PDT member: Steering Committee (2)	SW tech staff (3)	USACE HQ (4)	USACE HEC (5)	USACE ERDC (6)	CW3E (7)	USACE SPK, SPN (8)	RKHCS (9)	HDR (10)
Task 1. Select performance metrics	I	R	I	C	C	C	C	A	R
Task 2. Nominate/formulate alternative FIRO strategies that will be considered	I	R	I	C	C	C	C	A	R
Task 3. Side studies	C	R	I	C	C	I	C	A	R
Task 4. Simulate performance with each alternative	I	R	I	R[2]	C	C	I	A	R[1]
Task 5. Using results of simulation, evaluate each alternative in terms of identified performance metrics	I	R	I	R[2]	C	C	I	A	R[1]
Task 6. Compare the alternatives by comparing the metrics	I	R	I	C	C	C	C	A	R
Task 7. Select preferred alternative and recommend to steering committee	I	R	I	C	I	C	R	A	R

[1] HDR is responsible for Alternatives 1-5.

[2] HEC is responsible for Alternative 6. HEC will provide consultation for Tasks 5 and 6 associated with Alternatives 1-5.

Schedule for completion of technical analyses

Figure 1 shows the schedule for completion of project tasks. The gray-shaded rectangles represent months during which work on identified tasks will be underway. The shaded rectangle for February 2020 is included to permit iteration and refinement of strategies, incorporating information from the evaluation task in December 2019 and January 2020. All work on all tasks will be completed by July 2020.

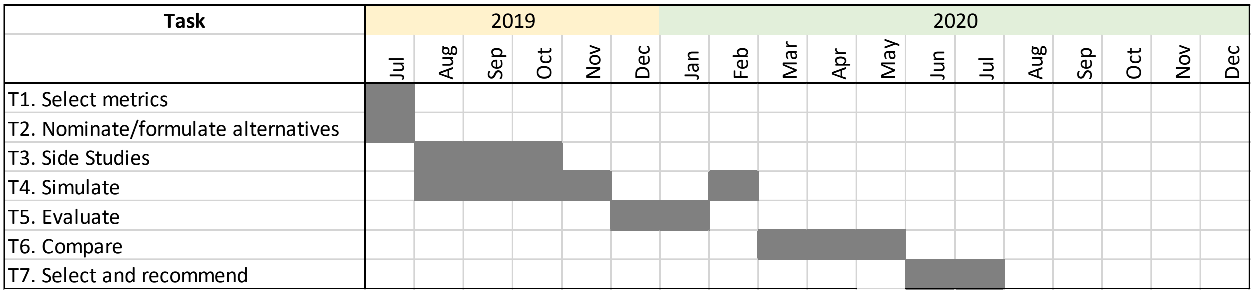

Figure 1. Schedule for completion of hydrologic engineering study to select FIRO strategy for Lake Mendocino

Risks to success of study

Risks to the success of this study and mitigation actions are shown in Table 10.

Table 10. Project risks

Potential failure mode (1)	**Actions PDT can take to mitigate (2)**
Simulation or evaluation software does not function as expected.	Limit analysis to use of software that is readily available and has been stress tested.
Necessary data—including hydrological, meteorological, water use, vulnerability—are not readily available.	Limit analysis to use of best-available data.
Key personnel are not available to complete tasks.	Ensure back up staff for all critical tasks.
Critical path tasks fall behind schedule due to unforeseeable distractions and disruptions.	Limit project activities to those that are necessary to satisfy objectives.
PDT disagrees about technical analysis procedures.	Defer to PDT project assignments (see above).
Nature of alternative FIRO strategy prevents evaluation with selected metrics.	Disqualify alternative from further consideration unless metrics can be adjusted and applied in uniform manner for all alternatives.