Review of HEC-RAS Hydraulic Model of the North Delta

Report by Peer Review Panel

March 2003

Summary

The panel's overall opinion is that the HEC-RAS (UNET) model is appropriate for the given application and that a proper level of care and good engineering judgment has been used in the application. It is evident that the work involved in completing this calibration and validation was large. MBK engineers deserve a lot of credit for their hard work.

The panel judges the model to be properly configured, and it should be able to represent the flooding conditions of the North Delta region in future studies.

Because of the high level of complexity in this application (in terms of numbers and kinds of hydraulic elements, the number of open boundary conditions, and the necessary assumptions regarding levee failures and breaches), it was not possible to review all the details of the model application. However, the calibration of the model to the January 1997 flood generally looks reasonable, and the verification to the 1995 flood event also appears reasonable, although the amount of data available for verification is limited and does not provide a complete verification.

Panel members were concerned at the beginning of the review about the UNET model itself, and the degree to which the code had been verified. However, over the past few months the model has been tested using the suite of numerical experiments proposed by the Bay/Delta Modeling Forum. In these tests the model performed as expected for a Preissmann numerical algorithm.

The upstream and downstream boundary and initial conditions that have been selected all appear to be reasonably chosen. We note that some of the individual stage calibration values missed their targets by more than one foot, but it was not clear that such a difference meant that the calibration was not a good one. Our review would have been facilitated if there were a clearer initial statement of what differences are sufficiently small to be acceptable, what are not, and why.

The model needs additional formal documentation such as a report showing the computed and observed water level as well as summarizing choices of model structure (choice of Δt, bridge algorithms etc.).

The model and the panel's assignment

MBK Engineers contracted with the Department of Water Resources (DWR) to build a Regional Hydraulic Model to be used by DWR, SAFCA, Sacramento County and USACE to support ongoing flood control planning needs in the North Delta region. Near term projects that will benefit from the model include DWR's North Delta Improvement Project, Sacramento County's Point Pleasant Project, and SAFCA and USACE's Cosumnes and Mokelumne Feasibility Studies.

In all cases the model will primarily be used to assess flood control measures and their effectiveness. Peer reviewers should analyze MBK's technical approach, hydraulic assumptions, and model documentation to see if the model accomplishes its purpose and need. The focus of the review will not be on the soundness of UNET (HEC-RAS unsteady) itself, but on the successful application of the tool.

The panel is to:

- Review the UNET model theoretical background, model schematics, boundary condition assumptions, data metadata, calibration and verification information, and related project background information.

- Answer the following key questions: Are assumptions used to configure the model the most technically sound and most able to reflect hydraulic conditions accurately; is the quality of the input data sufficient to ensure reliable results; have the appropriate boundary conditions have been applied; has model calibration and verification have been successfully completed; and can the model be successfully applied to evaluate the proposed projects? This work will be completed through a combination of literature review and meetings of panel members.

Peer review panel members

J. J. DeVries – David Ford Consulting Engineers, Inc. (chair)
D. J. Harris – Hydrologic Engineering Center, USACE
B. E. Larock – Civil and Environmental Engineering, University of California, Davis
S. G. Monismith - Environmental Fluid Mechanics Laboratory, Stanford University
P. E. Smith – US Geological Survey

Comments on specific review topics

The bulleted items are individual topics that DWR asked the Peer Review Panel to address:

- ***Unsteady RAS model (UNET) background***

The implicit finite-difference scheme for solving the one-dimensional equations for unsteady open channel flow used in UNET is an appropriate procedure for this type of modeling. Although the model has not been subject to peer review in the engineering literature, there is a significant amount of documentation that has been presented by the model's original developer (Robert Barkau) and by the Hydrologic Engineering Center in the program documentation for HEC-RAS Version 3.1. In addition, the results from tests of the model using the Bay-Delta Modeling Forum test data sets show that the model performance is essentially identical to that of other models used for modeling the Bay-Delta system.

The discretized form of the governing equations is similar to the Preissmann implicit scheme which has an implicitness factor Theta. For stability it must lie in the range between 0.5 and 1.0. It is well known that a fully implicit scheme (Theta = 1.0) does damp extreme values, e.g. flood peaks are diminished, but is the most stable form of the scheme. Use of a smaller Theta will make this effect smaller. This study should investigate the use of smaller values of Theta, so long as Theta exceeds 0.6, if it has not already done so.

One panel member also reviewed a document authored by Dr. Barkau (Dec. 12, 2001) entitled "Simulation of Levee Failures Using Simplified Levee Breach Hydraulics." In the document Barkau makes clear that he is intimately aware of the conventional hydraulic model for levee overflow and/or breach, and he contends that the data uncertainties and the numerical (in)stability problems that accompany this approach motivated him to seek a simpler alternative. In the 1990's he demonstrated the successful use of his simplified model along the Mississippi River near St. Louis; there each levee failure led to the inundation of essentially flat-bottomed areas up to 40,000 acres or more. What is unclear is whether the individual inundations in this study will be so large and have such extremely flat bottoms. However, the UNET component in RAS does not use the Simplified Levee Breach feature, but calculates flow though a breach by using the weir equation with the breach geometry as it varies with time and uses a submergence correction to account for the downstream water surface elevation reducing the flow as it approaches the upstream water surface elevation. Water can flow out of the storage area if the water surface elevation in the river is lower (Gary Brunner, HEC, personal communication).

If the individual basins have an appreciable bottom slope or irregular topography, this should be accounted for by using an appropriate volume versus elevation table, rather than assuming a constant surface area for the basin. This has been done for all but eight of the 76 storage basins in the North Delta model.

In review of the other materials, it was concluded that the upstream and downstream boundary and initial conditions that have been selected all appear to be reasonably chosen. It was noted that some of the individual stage calibration values missed their targets by more than one foot, but it was not clear that such a difference meant that the calibration was not a good one. Our review would have been aided if there were a clearer initial statement by DWR of what differences were sufficiently small to be acceptable and what were not so, and why that was felt to be so. The HEC-RAS model that was built did a very reasonable job of reproducing the 1997 and 1995 flood events and can be expected to provide very useful information in future modeling of proposed modifications in the Delta channel system.

- ***Model schematics: storage areas, weir configurations, etc.***

The model is extremely complex (there are 1393 cross section in the model, 107 storage areas, over 90 connections between storage areas, 33 locations where levees failed during the 1997 flood event).

On the basis of our review, we consider the model to be properly configured and consider it able to represent the flooding conditions of the North Delta region appropriately from a geometric standpoint. Warning messages in the RAS output file suggesting that additional cross sections may be needed are primarily in the upper reaches of the Mokelumne River, Deer Creek and Dry Creek. A number of the cross sections for Bear Slough had to be extended vertically by RAS to complete the solution.

We have a concern that in several parts of the model domain what might be termed the vertical wall effect is quite apparent. This is a fundamental limitation with HEC-RAS - when water reaches the edges of the model domain it doesn't leave unless one uses lateral weirs. Instead, the channel functions as though there were vertical walls at the edges of the model domain. When this happens, how do we know the model is correct?

Model boundary condition assumptions

Upstream boundary conditions are used at five locations in the model, and there are six locations with a downstream boundary condition. Also, one lateral inflow hydrograph was used as a boundary condition in the channel system, and several lateral inflow hydrographs were used to represent inflow to storage areas in the Beach and Stone Lakes area. The time interval used to specify the hydrographs is generally 1 hour, except for the case of the Mokelumne River where the gage data were specified at 24-hour increments and was linearly interpolated. Because the change in discharge at this location was small during the simulation period, this treatment is appropriate. The Morrison Creek inflow was not measured but was estimated from stage gage data in the Morrison Creek watershed. This stream flows into an interconnected set of storage areas, and the magnitude and timing of the flow is not as important as a good estimate of the total volume of the inflow and the flow calculations. There are also some small constant flows at the head of various sloughs, and the upstream BC for Georgiana Slough is a stage hydrograph.

The downstream boundaries are all represented by stage hydrographs using tide gage information. The stage data are typically read from DSS files and are specified at 15-minute intervals.

- ***Metadata on all data used in model***

Fourteen Mile Slough does not have the cross sections plotted on top of the river alignment. This, of course, does not affect the computations in any way and is not visible unless one zooms in on the geometric data plot.

- ***Calibration and verification information***

The report describes the 1997 event used in the calibration in detail and the RAS data set supplied for review was for this event. The March 1995 event was used for verification, but the data set for it was not provided. The amount of observed data for this event was smaller and does not provide a complete verification throughout the full model. For those locations where data were available the verification appeared to be adequate, and the amount of verification data supplied is sufficient to validate general use of the model.

The next three comments relate specifically to the calibration and refer to figures and page numbers from the report we were provided.

1. Fig. 20, p. 34—It is a little worrisome that the model so dramatically over predicts (by 4-6 feet) the high water marks (HWMs) on the upper Mokelumne River between Benson's Ferry and New Hope Road. We realize that the authors offer an explanation for this (in the first footnote in Table 8, p.21) by suggesting that the HWMs were collected on January 11. We are not sure that the HWMs shown in the plot were produced by the modeled event, and it may not be appropriate to show them in the report. The gage data are much more accurate indicators of water surface elevations.
2. Figs. 21 and 22, p.34-35—The model is consistently over-predicting the HWMs on both the North Fork Mokelumne River and the upper South Fork Mokelumne River. Is there some explanation for this? How convincing is the evidence that all these HWMs are too low (as noted in the second footnote in Table 8, p. 21)?
3. Fig. 24, p. 36—Is there any reason why the model is so dramatically underpredicting the HWMs for Georgiana Slough? If these (or other) HWMs can be proven wrong, perhaps the authors might want to consider taking them out of the report.

- ***Project background: Proposed application of model and preliminary alternatives being considered by DWR and Sacramento County***

This will be a very useful model for the evaluation of flood management alternatives being considered for the North Delta by DWR, SAFCA, Sacramento County and USACE to support ongoing flood control planning needs in the region.

Report topics

The following bulleted items are the individual topics that that DWR proposed that the Peer Review Panel include in their report.

- ***Are the assumptions used to configure the model the most technically sound and most able to accurately reflect hydraulic conditions?***
  1. Model time step – A one-minute time step is appropriate for this type of model. Have Courant numbers been computed for flows near the peak in this model?
  2. The implicit scheme weighting factor, Theta, has been left at 1.0 for this model. Using a lower value may give more accurate results. Has a sensitivity analysis been made using other values of Theta? However, because the calibration has been made using a Theta value of 1.0, it can be argued that the adopted model parameters reflect this, and Theta should not be changed without assessing the effect of the change on model output.
  3. Levee failures are an important factor in the 1997 calibration run. At some of the failure locations the time and duration of the failure are not well known. Have alternate times and durations been tested in the model to evaluate how critical it is to precisely define these parameters? In the model a linear failure rate has been used for all levee failures. Has the "sine wave" breach progression curve available in the model been considered?

- ***Is the quality of the input data sufficient to ensure reliable results?***

The geometric data are adequate.

- ***Have the appropriate boundary conditions been applied?***
  1. Some of the boundary inflow hydrographs are based on pattern hydrographs using adjacent (or nearby) watershed hydrographs. Has a sensitivity analysis been made using other patterns or magnitudes of peak flow?

- ***Has the model calibration and verification been successfully completed?***
  1. Most of the computed peak stage elevations agree within about one foot or less with the observed peak stages and estimated high water marks. There are some locations where the high water marks appear to be in error and the model has been calibrated to match gage observations.
  2. The shape and timing of computed stage hydrographs matches the observed hydrographs quite well for the calibration runs. The differences were somewhat larger for the verification run, but this behavior is to be expected since some of the data for boundary inflows and other conditions were not available for the March 1995 event.

- **Can the model be successfully applied to evaluate proposed projects?**

As stated above, this model can be a very useful tool for the evaluation of flood management alternatives for the North Delta. In addition to using hypothetical flood events such as the computed 100-year flood, the two observed events should also be used in the evaluation of alternatives.

Detailed review procedures

When reviewing model geometry we viewed cross section plots and profile plots with and without "animation," output tables, and flow and stage hydrographs.

Evaluation of cross sections

We considered the following in our review of individual cross sections in the various reaches of the model:

- Review the plots of the cross sections.
- Are there any spikes in station-elevation data?
- Are bank stations at appropriate locations?
- Are levees at appropriate locations?
- Do the Manning's n values look consistent with the bank stations and upstream and downstream sections?
- Do the ineffective flow area designations look appropriate and consistent with banks and upstream and downstream sections?
- Do the cross sections extend above the maximum water surface? Are they too high?
- Does the top width change in a reasonable way from cross section to cross section? Consider that large changes in top width may indicate the need for additional cross sections.
- Do the Hydraulic Tables developed by the Geometric Preprocessor provide the appropriate range and detail for unsteady flow calculations?

Evaluation of bridge data

Procedure for reviewing bridges:

- Review the plots of the bridges. Highlight the weir, low chord, and piers on the bridge editor plot.
- Review the Bridge Modeling Approach. Is it appropriate?

- Is the Ineffective Flow Area Option being applied correctly?
- Look at the Bounding Cross Sections. Do the Stations and Elevations as entered appear to be consistent with the bridge geometry?
- Check the data on the Deck/Roadway Data Editor and Bridge Width Table (on the Geometric Data editor). Do the distances between the bridge and bounding cross sections appear reasonable?

Evaluation of lateral structures (used when there is levee overflow or breaching)
Lateral structures review procedure:
- Look at each river reach in detail and review the description of each lateral structure and the breach criteria (where appropriate).
- View the water surface vs. time plots for each levee breach.
- Review the discharge coefficient values for lateral flow.

Evaluation of storage areas
Procedure for reviewing storage areas:
- Review the description of each storage area.
- View the volume vs. elevation plot for each.
- Review the connections for each storage area.

General Questions

1. *What are critical improvements for the model?*

As indicated by the discussion above, the panel is satisfied that the model accurately represents the hydraulic conditions of the North Delta for current conditions, and only some minor possible modifications to the model are suggested.

2. *How relevant are uncertainties to model goals?*

The model has been calibrated to a specific flood event, and parameters such as Manning's n-values have been selected to allow the model to reproduce observed stage hydrographs where they are available and maximum water surface elevations (high water marks) at other locations. For smaller flood events the model parameters may not be completely appropriate, and this may affect accuracy of the results. In some locations the model is consistently overpredicting the high water marks on both the North Fork Mokelumne R. and the upper South Fork Mokelumne River, and the model is underpredicting the high water marks for Georgiana Slough.

Although uncertainties cannot be completely quantified, the effect of uncertainties can be evaluated by sensitivity analysis in which parameters such as n-values are adjusted over a range of reasonable values to determine how the model output is affected.

Model Configuration

3. *Can the model effectively account for split flows into two or more channels? (e.g. Dead Horse Island)*

HEC-RAS can simulate a full network of channels with unsteady flow, and the splitting of flows into two or more channels is done in an accurate way. For situations where the flow splits from a channel as overtopping of a levee or through a levee breach, the computations are very dependent on weir coefficients and other parameters, and the uncertainty associated with these may be relatively high.

4. *Storage areas are used to provide water to or from main channels. Are they correctly used within the model? Are all essential locations specified?*

The storage areas appear to be correctly used in the model and all storage areas are accounted for.

5. *Does the model sufficiently account for obstructions produced by bridges, culverts, weirs, levees, and structures in a flood plain? Are lateral flows over a gated spillway, a weir, levees, through a culvert, or a pumped diversion accurately modeled?*

HEC-RAS has specific functions for modeling bridges and other structures. Pumped diversions can also be accurately modeled. Lateral flows from channels are represented by treating the levee as a weir with a crest that parallels the channel. One of the major sources of uncertainty in the calculation of the lateral outflows is the discharge coefficient used to compute weir flows. In most cases flows over levees are relatively minor until they cause levee failure. Establishing the timing and magnitude of levee failures is something that is much more difficult to simulate accurately.

6. *Is the model able to correctly portray a floodplain, typically areas of low depth and wide flows that are susceptible to high amounts of directional flow variability?*

HEC-RAS is a one-dimensional model. In areas where the flow is “two-dimensional” it may not provide accurate results. However, it appears that for most situations that are being simulated in the North Delta a one-dimensional model provides acceptable accuracy in the computation of magnitude and timing of flows.

7. *In past models, parallel storm events on Deer Creek and the Cosumnes have caused unpredictable exchanges during high water. Can the model accurately portray this dynamic during high water?*

The exchanges between the Cosumnes River and Deer Creek are computed in the model as lateral flows. The magnitude of the exchange is determined from the water surface elevation in the river and the discharge coefficient supplied by the modeler, and in the case of a levee breach the timing and discharge characteristics of the breach. Storage areas with connections to the two streams are also involved. The performance of the model relative to the calibration event is satisfactory. However, in the study of hypothetical events one cannot predict when and where levees will fail and when hydrograph peaks in each stream will occur relative to each other. This will make it difficult to portray accurately how the two streams will interact.

8. *Can overtopping of the Delta Cross Channel and of Lambert Road be modeled accurately within the model*

The panel did not review this structure in a detailed fashion. We were not provided with the details of its geometry, and we are not able to answer this question.

9. *Because the model will be used for flood control purposes, stage is a desired output. Have appropriate assumptions regarding external factors that can affect stage such as wind and barometric influence been applied to ensure accurate stage results?*

HEC-RAS does not have computational features to directly simulate the effects of wind or the influence of variations in barometric pressure. However, as long as measured water surface elevations are specified in the seaward open boundaries of the North Delta model, then any effects on the water surface elevations in the lower portion of the estuary due to wind and barometric pressure will already be present in the boundary data itself. In general, wind setup effects are likely to be minor for a system of interconnected channels that do not have long and straight fetches. Also, the relative effects of wind and barometric pressure are not expected to be as significant during large flood events as during periods of low flow.

Data Quality

10. *Is the cross-section information spaced close enough in critical channel areas, and is the input data recent enough?*

The cross-sections in critical channel areas are spaced at appropriate distances. The data on which the cross sections are based is recent enough to give accurate characterization of model geometry.

Boundary Conditions

11. *Are assumed boundary conditions legitimate? (e.g. Downstream boundaries at White Slough, Little Potato Slough, and San Joaquin River; Upstream boundaries at Cosumnes, Mokelumne, Dry Creek, Morrison Creek, Georgiana Slough, Beach/Stone Lakes and Snodgrass Slough.)*

The upstream and downstream boundaries all appear to be in the appropriate locations.

12. *Are the boundary conditions at ideal locations? Are additional boundary conditions required? What problems could there be with the existing boundary conditions?*

Boundary locations are appropriate and do not cause problems in the model.

Model Calibration and Verification

13. *By calibrating the model to the 1997 storm event and then verifying the model with a storm event from another year (1995 or 1998), can the model be considered sufficiently accurate to be used to model a 100-year, 200-year, 50-year, or 10-year storm event? What are the limits of design storm events that could be modeled given the calibration and verification conditions?*

The panel would like to suggest a note of caution about the accuracy of the model for hypothetical events. Because levee failure/breach information and model boundary condition data may not be available during hypothetical events, it is very difficult to assess the accuracy of the model predictions for these events. Although the model can and should be used for flood investigations, the panel cannot make a definitive statement regarding the accuracy of the model predictions for hypothetical events.

14. *Are the 1997 levee failures representatively modeled? Is the application used to model levee failures appropriate?*

There is a great deal of uncertainty associated with the representation of levee failures. Within the limitations of the data that define the levee failures, they are properly represented. Any future modeling which involves failure events will require development of appropriate levee failure scenarios that may be completely different from the historically observed failures.

Application to Projects

15. *The proposed projects may introduce different flood improvement alternatives such as weirs, culverts, setback levees, and bypasses. Can alternatives be reviewed accurately using the model? Are there any problems with model connectivity?*

Weirs, culverts, setback levees, and bypasses can be simulated accurately in the model, given model limitations of one-dimensionality and uncertainty in the characterization of weir and culvert hydraulics since flow at these structures depends on selection of appropriate discharge coefficients and other parameters.

16. *During past flood events, boats and other structures have broken away and created major impediments to flow at bridge crossings. Can the model accurately account for this phenomenon, taking into account all local marinas?*

This is something that the panel did not consider in their review.

17. *Can the model account for changes in land uses and vegetation? Along channels? In storage areas?*

RAS has a variety of ways that changes in Manning's n-values and effects of sedimentation in river channels can be accounted for in the model. In storage areas the analysis is based on a simple storage routing, and land use and vegetation are not factors that influence storage to a significant degree.

Appendix A

Numerical experiment comparing HEC-RAS with other models used for Sacramento-San Joaquin Delta modeling

The graphs presented here show results from a numerical experiment comparing HEC-RAS with other models used for Sacramento-San Joaquin Delta modeling. The experiment is based on Problem H11: Hydrograph Routing developed for the peer review of three one-dimensional unsteady flow models used for modeling the Delta. This review was conducted by the California Water and Environmental Modeling Forum (formerly Bay-Delta Modeling Forum). Problem H11 was suggested as a test for HEC-RAS because the experiment revealed numerical oscillations in two of the models and numerical diffusion in another. In this and other experiments the HEC-RAS model performed as expected for a Preissmann numerical algorithm and is considered as appropriate for simulations of the hydraulics of the North Delta.

Insert the H11 test_case_so...pdf file here.

Appendix B

Resumes of Panel Members

Johannes (Joe) J. DeVries, PhD, PE

Areas of Competence: *Engineering Hydraulics, Hydrology, Water Management*
Education: Degrees / Year / Specialization

Ph.D. / Univ. California, Davis / 1978 / Hydraulic engineering
M.S. / Univ. Michigan / 1961 / Civil engineering
B.S. / Univ. Michigan / 1959 / Civil engineering

Professional Registration: Year First Registered / Discipline

California / 1963 / Civil engineering
American Institute of Hydrology / 1986 / Registered hydrologist

Joe DeVries is an internationally recognized expert in hydraulic and hydrologic engineering. He has over 40 years of engineering experience, including over 20 years of project-management experience with the University of California, Amorocho Hydraulics Laboratory, the California Department of Water Resources (DWR), and with consulting engineering firms. He spent 4 years as a hydraulic engineer at the Hydrologic Engineering Center. He has served as a consultant to the Corps of Engineers, National Weather Service, government agencies in California, Argentina, India, Taiwan, and Morocco, the United Nations, World Bank, and USAID, and to several engineering firms. His technical specialties include:

- Steady and unsteady flow analysis in rivers and canal systems
- Rainfall-runoff modeling, hydrologic statistics, including flow-frequency analysis.
- Reservoir system analysis, including, reservoir inflow estimation, and spillway design flood analysis
- Analysis of hydraulic structures, hydraulic model studies
- *Training in hydraulics and hydrology.*

Recent project work includes:

- Participated in the preparation of hydrology manuals for the California counties of San Joaquin, Imperial, Kern, Orange and San Bernardino.
- Completed a study on calibration of hydrologic parameters for San Joaquin County rainfall-runoff modeling.
- Served as technical advisor to a GIS based inundation-mapping program for the California Department of Emergency Services and developed procedures for dam breach hydrograph calculation using HEC-1.
- Participated in studies for determination of spillway design floods in California for the California Division of Dam Safety.
- Technical advisor and reviewer for laboratory studies at University of California, Davis.
- Conducted hydrologic and hydraulic analysis of developing watersheds in El Dorado County, California using HEC flood runoff and river models.
- Participated in the development of flood-warning technologies for communities in California, North Carolina, and Kansas.
- Conducted training Courses in HEC-RAS for US Army Corps of Engineers, Sacramento County, Placer County, Nevada DOT, ASCE, and Arizona Floodplain Management Association.

David J. (Jeff) Harris

AREAS OF COMPETENCE: His technical subjects include surface water hydrology, river hydraulics, water resources planning, risk analysis, system optimization, flood damage computations, and water control management

EDUCATION:
Jeff Harris received his BS degree in Atmospheric Science in 1976 from the University of California, Davis.

PROFESSIONAL EXPERIENCE:
Jeff started at the Sacramento District, Corps of Engineers in 1977 and worked in the Hydrology and Hydraulic Design Sections where he specialized in hydrologic models and 1-dimensional hydraulic models before moving to the Hydrologic Engineering Center (HEC) in 2001. Jeff is a member of the HMS model development team and is HEC's representative on the Corps of Engineers Hydrology Committee..

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Bruce E. Larock

Institution University of California, Davis
Curriculum Civil and Environmental Engineering

1. Name and date of birth: Bruce E. Larock December 24, 1940

2. Academic rank: Professor (full-time)

3. Degrees: B.S. Civil Engineering, Stanford University, CA, 1962
M.S. Civil Engineering (Hydraulics), Stanford University, CA, 1963
Ph.D. Civil Engineering (Fluid Mechanics), Stanford University, CA, 1966

4. Number of years on this faculty: 36 years
7/1/66 Assistant Professor
7/1/72 Associate Professor
7/1/79 Professor

5. Other related experience:
- Associate Editor, J. Hydraulic Engineering, ASCE, 6/96-
- Alexander von Humboldt Foundation U.S. Senior Scientist award to study at Institut für Wasserbau und Wasserwirtschaft, Technical University, Aachen, W. Germany, 9/86-7/87
- Sabbatical leave, Hydrologic Engineering Center, U.S. Army Corps of Engineers, Davis,
- CA 1/80-6/80
- Senior Visiting Fellow, Civil Engineering Department, University of Wales, Swansea,
- U.K., 9/72-6/73
- Teaching and Research Assistant, Stanford University, CA, 9/63-6/66
- Civil Engineer, U.S. Naval Ordnance Test Station, China Lake, CA, 6/63-9/63
- Jr. Civil Engineer, California Department of Water Resources, Sacramento, CA, 1962
- Engineering Student Trainee, Range D, California Division of Highways 1961
  - Tech. Student, Class C, Southern Pacific Co., San Francisco, CA, 1960
- Engineering Aide, National Park Service, San Francisco, CA, 1959

6. Consulting: Intermittent, various

7. States in which registered: California, No. 28023

8. Some publications in the last five years:
- J.A. Ross and B.E. Larock, "An Algebraic Stress Model for Recirculating Turbulent Flows" International Journal Numerical Methods in Fluids, V. 24, 693-714, 1997.
- P.E. Smith and B.E. Larock, "Semi-Implicit, Numerical Schemes for 3-D Flow Modeling" Proceedings of Theme B of the 27th Congress of the Int. Assoc. for Hydraulic Research on Environmental and Coastal Hydraulics: Protecting the

Aquatic Habitat, F. M. Holly et al., Eds., Vol. 1, pp. 773-778, ASCE, San Francisco, CA, August 10-15, 1997.
- B. E. Larock "Flow Through Slit in Dam - Discussion", J. Hydraulic Engineering, ASCE, Vol. 123, No. 12, p. 1174, December 1997.
- B. E. Larock, R. W. Jeppson, and G. Z. Watters, Hydraulics of Pipeline Systems CRC Press, Boca Raton, Florida, pp. 1-537, September 1999.
- J. Hunt, G. W. Brunner, and B. E. Larock "Flow Transitions in Bridge Backwater Analysis" Journal of Hydraulic Engineering, ASCE, Vol. 125, No. 9, pp. 981-983, September 1999.

9. Societies of which a member:
- American Society of Civil Engineers, Hydraulics Division
- Sigma Xi
- Tau Beta Pi

10. Honors: •
- B.S. with Distinction
- Eight scholarships and fellowships as a student, including California State Scholarship
- (4 years)
- U.S. Senior Scientist Award from Alexander von Humboldt foundation to study in
- Aachen, W. Germany, 1986-87.

11. Courses Taught: 2001-2002
- Fall 2001 ECI 277 - Unsteady Flow in Surface Waters (graduate)
- Winter 2002 ECI 274 - Hydraulics of Pipe Lines (graduate)
- Spring 2002 ECI 141 - Engineering Hydraulics (undergraduate)
  ECI 141L - Engineering Hydraulics Laboratory (undergraduate)

12. Other assigned duties 2001-2002:
- Member, Academic Senate Elections, Rules and Jurisdiction Committee
- Member, College of Engineering Student Relations Committee
- Member, College of Engineering Undergraduate Educational Policy Committee

Stephen G. Monismith

Current position:
Stephen G. Monismith, Professor
Environmental Fluid Mechanics
Director, Environmental Fluid Mechanics Laboratory

Education:
B.S. (1977), M.S. (1979), and
Ph.D. (1983) University of California at Berkeley

Research areas:
Stephen Monismith's research in environmental and geophysical fluid dynamics involves the application of fluid mechanics principles to the analysis of flow processes operating in rivers, lakes, estuaries and the oceans. Making use of laboratory experimentation, numerical modeling, and field measurements, his current research includes studies of estuarine hydrodynamics and mixing processes, flows over coral reefs, wind wave-turbulent flow interactions in the upper ocean, turbulence in density stratified fluids, and physical-biological interactions in phytoplankton and benthic systems. Because his interest in estuarine processes is intertwined with an interest in California water policy issues, he has been involved with efforts at developing management strategies for improving the "health" of the Bay through regulation of freshwater flow into the Bay.

Other activities and awards:
Professor Monismith is currently director of the Environmental Fluid Mechanics Laboratory. He was a resident fellow in Robinson House (Stanford's environment theme house) 2000-2002. He is a 1989 recipient of the Presidential Young Investigator award. Prior to coming to Stanford, he spent three years in Perth (Australia) as a research fellow at the University of Western Australia.

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Peter E. Smith

AREAS OF COMPETENCE: Environmental Hydrodynamics, Computational Hydraulics, Hydrology

EDUCATION:

INSTITUTION	MAJOR	MINOR(S)	DEGREE
University of Calif., Davis	Hydraulic Engineering	Fluid Mechanics/Math.	Ph.D. 1997
Colorado State University	Civil Engineering	Hydraulics	M.S. 1976
Villanova University	Civil Engineering	Water Resources	B.S. 1974

PROFESSIONAL EXPERIENCE:

- 1983 to present, Research Hydrologist, California District, U.S. Geological Survey, Sacramento, CA
- 1978-1982, Research Hydrologist National Research Program, USGS, Bay St. Louis, MS
- 1976-1978Hydrologist, , U.S. Geological Survey, New York District, Albany, NY

RESEARCH INTERESTS AND ACCOMPLISHMENTS:

Dr. Smith is an expert in the development and application of hydrodynamic computer models to understand and predict the movement and mixing of water in estuaries, rivers, lakes, and coastal waters. He has over 25 years of experience as a research scientist with the U.S. Geological Survey (USGS), including over 18 years studying the hydrodynamics of the San Francisco Bay and Delta. He is the primary developer of the Si3D (Semi-Implicit 3D) hydrodynamic model that is currently being used in interagency-sponsored studies of the San Francisco Bay and Delta. To support his model-based analyses, he has designed, led, and participated in a variety of field measurement programs where hydrodynamic and salinity data were collected. These programs have provided data for model calibration/validation and for conceptual understanding of environmental hydrodynamic processes. Dr. Smith is the co-developer of the USGS Distributed Routing Rainfall-Runoff and Water Quality Models (DR3M and DR3M-Qual) that have been used in USGS offices throughout the country as part of the National Urban Runoff Program. He has worked on flood studies of rivers and small streams in the states of New York, Pennslyvania, Missouri and Mississippi. Over his career, he has authored or co-authored more than 25 articles, reports, and conference proceedings. He has been an instructor for many USGS training classes and workshops and has been a frequent speaker on his research at national conferences and technical symposia.

SCIENTIFIC LEADERSHIP:

- Control member, 1998 to present, on the Computational Hydraulics Committee for the Environmental and Water Resources Institute of (ASCE).
- Control member, 1990 to present, on the ASCE task committee for preparing a "Monograph on Test Cases for Verification and Validation of 3-D Free-Surface Hydrodynamic Models."
- USGS representative, 1997 to present, on the Management Team overseeing the Interagency Ecological Program (IEP) of the San Francisco Bay and Delta.
- USGS representative, 1995 to present, on the Steering Committee of the California Water and Environmental Modeling Forum (CWEMF).
- Advisor, in 2001, to the CWEMF peer review of 1-D Delta Hydrodynamic Models.
- Chairman, 1998 to present, of the IEP Hydrodynamics Project Work Team.

- On the organizing committee for annual IEP scientific workshop on SF Bay and Delta
- On the advisory committee for ASCE's biannual Estuarine and Coastal Modeling Conference.

MEMBERSHIP IN PROFESSIONAL SOCIETIES:

- American Society of Civil Engineers
- American Geophysical Union
- American Water Resources Association