HANFORD IFC QUARTERLY REPORT ~ JULY 2008

John M. Zachara
Pacific Northwest National Laboratory

I. Overview and Highlights

This is the third Quarterly Report for the Hanford IFC project, and summarizes significant progress for the period of January 2008 to July 2008. Four major highlights can be identified for this reporting period that will be discussed in more detail in the sections that follow.

1. The IFC project summarized progress and plans in the form of oral presentation and various posters, and met with the FREC team in April 2008 at the ERSD annual P.I. meeting in Lansdowne, VA.
2. An all investigator IFC project meeting was held in Richland, WA on April 29-30. The meeting had multiple objectives; two of these were to: a.) finalize downhole geophysical characterization and monitoring strategies for the well field, and b.) establish an integrated, multi-P.I. modeling strategy for the project.
3. Drilling began on the IFC well array on May 12, 2008 after months of planning. Core recovery has been excellent and installation of our complex down-hole monitoring array has proceeded without problem. As of June 30, 2008, 20 of the 35 boreholes have been drilled and are in various stages of completion. Six of the wells have been formally accepted by Fluor Hanford and declared “sample ready”.
4. Geophysical, hydrologic, chemical, and microbiologic characterization has begun on well-field boreholes and retrieved sediments in form of intact cores and grab samples.

II. Significant Changes

There have been no significant changes to the project scope or objectives since the last quarterly report in January 2008.

III. Management & Operations

Management and operations of the Hanford IFC project by the PNNL team is proceeding smoothly. A small administrative group has been assembled that handles day-to-day operations, details, and reporting that includes John Zachara - project manager and P.I., Mark Freshley - field site manager, Sonia Enloe – IFC administrator, and Nancy Smet – IFC financial specialist. A broader group of individuals is actively involved in the scientific management team including: Jim McKinley – biogeochemical monitoring, Andy Ward - geophysical characterization and monitoring, Mark Rockhold – modeling coordinator, Vince Vermeul – field hydrologist and experiment coordinator, and Bruce Bjornstad – site geologist. This extended team has met frequently to design the field site and monitoring systems, to assemble the plans needed to initiate drilling, and to design the hydrogeologic testing phase on the completed well-field. The drilling operation has proceeded flawlessly to date, a direct consequence of successful planning and teamwork by the IFC participants and execution by Fluor Hanford and the drilling contractor. David Lesmes and Todd Anderson from BER/ERSD visited the IFC site on June 20, 2008 and viewed the drilling in progress.

The management team is also working to finalize several formal strategy statements to maximize future IFC science contributions. These strategy statements have been drafted and sent to IFC team members for comment and revision. Included in these are:

- An IFC project policy for intellectual ownership, data and results sharing and exchange, collaboration courtesies, and joint publication.
- An IFC modeling strategy that assigns key responsibilities to different participants and code proponents/developers (e.g., STOMP, MODFLOW, FLOTRAN, etc; see Task 7).

These strategy/policy statements will be added to IFC project documentation when complete. The development of a publication strategy plan will be initiated in mid-summer.

IV. Quarterly Highlights

For the purposes of this quarterly report, the following are reportable activities we establish the following as reportable project tasks: 1. Project Management, 2. Site Design and Installation, 3. Web Site and Data Management, 4. Field Site Characterization, 5. Vadose Zone Experiments, 6. Saturated Zone Experiments, 7. Modeling and Interpretation, and 8. ERSD Outreach.

Task 1. Project Management

Final versions of the Description of Work (DOW) for installation of the IFC well-field and a Drilling, Sampling, and Well-Installation Plan for the IFC Well Field were completed and submitted to Fluor Hanford to initiate drilling activities on May 12, 2008. These documents are posted on the Hanford IFC Website and describe exactly how the boreholes are to be drilled, sampled, and geologically described; and the sequence of events and persons responsible for well completion. These plans were not described in our original proposal. The complexity of our well field/monitoring system design, combined with our desire to minimize drilling delays and to obtain the best possible samples and most information from the costly drilling process prompted their development. These plans have paid-off in that the drilling process is proceeding smoothly and collecting high quality samples are being collected.

An all-investigator IFC project meeting was held in Richland on April 29-30. The meeting involved all IFC team members and three invited outside participants with expertise in geophysical measurements and interpretation. The full suite of meeting objectives were to: a.) review design for the IFC well field and monitoring system, b.) refine geophysical and hydrologic characterization plans for the boreholes and wells, c.) evaluate geochemical and hydrophysical characterization plans for sediments retrieved during drilling, d.) discuss objectives and design of initial non-reactive and reactive tracer experiments, as well as passive experiments of opportunity, e.) coordinate various research activities between investigators, and f.) distribute IFC modeling responsibilities between investigators. The meeting was extremely successful and productive and resolved important issues. Numerous important outcomes resulted, including: 1.) a revised design for our down-hole geophysical monitoring system to allow electrode removal from the saturated zone, 2.) an improved strategy for downhole geophysical logging and its deployment vis-à-vis temporary and permanent casing, and 3.) insights and recommendations on the best uses of the different hydrologic and reactive transport models held by project participants.

<u>Task 2. Site Design and Installation</u>

Significant progress has been made on this essential task. As noted above, sediment sampling and installation of the well field has been progressing with procedures described in two new plans (Description of Work, DOW) and Drilling, Sampling, and Well Installation (DSWIP) Plan. The first of these plans (DOW) is specific to the drilling contractor, and defines their activities, responsibilities, schedule, and deliverables. The DSWIP defines the complex interactions, responsibilities, and tasks of Flour-Hanford and PNNL staff during the drilling operation to assure proper sample collection and preservation, monitoring system installation, and well completion. Bruce Bjornstad (PNNL) is the IFC site geologist and he is supervising scientific aspects of the drilling operation.

A photograph of the drilling operation is shown in Figure 1, including the resonant sonic drill rig (right), spectral gamma – neutron moisture logging (center), and well completion team (left). As of June 30, 2008, 20 of the 35 boreholes have been drilled (Figure 2 that is a little out of date); down-hole completions have been finished on 12 wells, and final surface completions finished on 5 wells. Work progressed by drilling core holes on the

Figure 1. Well drilling at the Hanford IFC site. Resonant sonic rig is on the right, spectral-gamma borehole logging is in the center, and well completion rig is to the left.

three corners of the IFC well array and then first on the remaining characterization (core) holes. Note that well 2-5 was an exploratory borehole and well that was installed in late fall of 2007. We have collected approximately 240 intact 4”x 1’ cores, and 180 – 25 lb core barrel samples. These samples and their masses, geologic descriptions, and physical location are being tracked with a computerized inventory that links with the IFC data base. Saturated zone samples are being refrigerated after collection and vadose zone samples are being stored at ambient conditions.

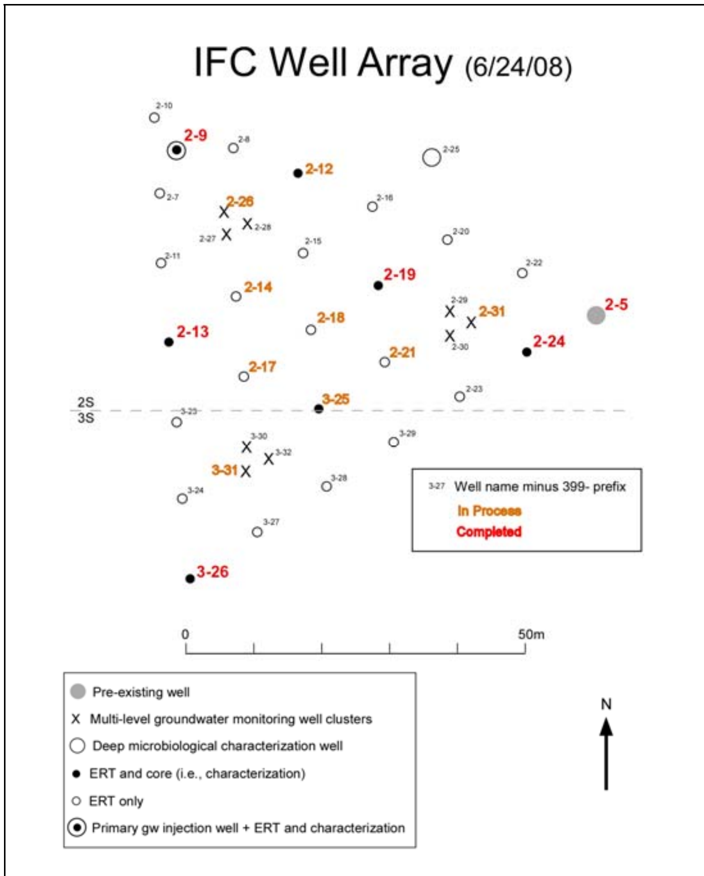

Figure 2. Status of Hanford IFC well array as of 6/23/08. All wells except 2-25 are expected to be completed by 9/1/08.

So far the drilling has not provided any marked surprises, and sample quality has been excellent. We have tentatively observed that the saturated zone sediments tend to have more silt on west (left) side of the IFC well array. The Hanford-Ringold contact has also displayed a bit more variability in elevation than expected. These observations will be further substantiated or refuted by the continuing drilling operation.

Testing of the ERT downhole monitoring system was performed by Andy Ward and Roelof Versteeg on the first two completed wells to determine whether electrode response in the saturated zone was comparable when electrodes were mounted external to the well in sand pack, as compared to an identical array suspended internal to the well in groundwater. This experiment utilized wells 2-9 (electrodes in sand pack) and 2-13 (electrodes in well) revealed that ERT electrodes could be placed in either location without loss in sensitivity or signal strength. We have consequently decided to deploy all saturated zone ERT electrode strings within the wells, with the exception of 2-9. This represents a significant change from our original plan. This mode of deployment will allow the electrode strings to be removed for post well completion geophysical logging and other metal-sensitive measurements, for repairs, and for other needs. The need for metal free zones in our saturated zone monitoring system was identified at our April investigators meeting.

Task 3. Website and Data Management

The Hanford IFC Website (http://ifchanford.pnl.gov/) has been operational since early December, 2007. It contains comprehensive background information about the 300 A uranium plume; information on project participants; background and project scientific publications; project documents of different sorts including required and optional project and experiment plans, designs, etc.; inventories of samples available to project participants and ERSD investigators; schedules, objectives, and descriptions of planned field experiments; a password protected link to the project data base at INL; and other information. Significant additions in the form of pictures, well logs and completion reports, geologic descriptions, an evolving sample inventory, and results from sediment physical and chemical characterizations are now being made to the website as well-drilling and installation of the experimental site moves toward completion.

The data management system is now accepting rapidly evolving information, measurements, and data resulting from the installation of the well field. A hierarchal system referenced to well number (Figure 2) has been established to track the storage and distributed locations of samples (e.g., to off-site participants), sample masses available, and measurements performed on all sediments collected from a given well. The INL data management team is ready to begin assimilation of the results of characterization measurements that are now beginning on borehole sediments by multiple IFC investigators.

Task 4. Field Site Characterization

A draft characterization plan is in final stage of completion that describes: 1.) geophysical measurements and logging for boreholes with temporary (steel) casing and completed PVC wells with sand pack, 2.) field hydrologic measurements for completed wells including pump tests, borehole flow-meter measurements, and non-reactive tracer tests, 3.) laboratory geochemical (e.g., U and important properties) and hydrophysical measurements on borehole sediment samples, and 4.) microbiological census studies. Completion of the plan has been on hold, pending the initiation of drilling program and the development of qualitative information on the quality, nature, number, and quantity of samples that would be retrieved.

The plan describes a tiered approach for IFC characterization. It begins with down-hole geophysical measurements immediately after well drilling and hydrologic testing during and after well completion. It proceeds to measurement of a limited suite of essential properties on a large number of sediments to define the spatial distribution of key solid phase properties throughout the well-field. The compositional variation of groundwater in IFC wells will be determined over the same period. Results will serve as basis for development of predictive statistical relationships for a variety of required solid- and aqueous-phase properties. Characterization then progresses to more detailed study of specialized properties associated with individual processes.

Microbiologic characterization will be performed on sediments from selected depth intervals in the primary IFC well-field to assess issues of microbial heterogeneity, as well as on aseptically collected sediments from the deep characterization borehole (2-25, Figure 2) that will sample both the Hanford and Ringold formations. This borehole will be the last one placed during the drilling campaign and is now scheduled for mid- to late August. Microbiologists have been preparing for the deep characterization borehole by analyzing subsamples from select, high quality intact core and grab samples (e.g., Figure 3) from both the Hanford and Ringold formation sediments.

Figure 3. A grab sample of Hanford formation aquifer sediments being sampled for microbiologic characterization. Aseptic sampling methods will be used for the deep characterization borehole, 2-25.

Characterization measurements have begun on sediments from select boreholes to refine methodologies and efficiencies, and identify ranges in key parameters and properties that may be expected. The first three boreholes to be characterized include 2-26, 2-31, and 3-31 (Figure 2). A parameter suite including particle size distribution, total contaminant U, labile contaminant U, single point U-K_d measurement from site groundwater, and extractable poorly crystalline Fe(III) is now being measured on approximately 60 samples collected at 1’-2’ intervals from backfill to the Ringold Formation.

The microbiological team (including Jim Fredrickson and Alan Konopka) has been actively sampling cores and grab samples from the Hanford and Ringold formations at numerous locations (wells 2-12, 2-14, 2-16, 2-20, 2-16, 2-31, and 2-31) to evaluate proposed characterization methodologies for the deep borehole and to establish a preliminary census of microbiologic populations and function. Some of their interest is directed toward a striking oxic-

Figure 4. Transition between oxic and anoxic zones in fine-grained sediments of the upper Ringold Formation. The anoxic zone with distinct greenish blue coloration is located approximately 0.3m below the Hanford-Ringold contact. This oxic-anoxic interface has been intersected by all boreholes drilled to date in the IFC well field.

anoxic interface that exists in fine-grained Ringold sediments approximately 0.35 m below the Hanford-Ringold contact (Figure 4). Samples for microbiological study are rapidly transported from the field to laboratory immediately after they are collected. The team has found the cores to be of high quality and to contain unexpectedly high concentrations of microorganisms whose identify and function are currently being evaluated.

Task 5. Vadose Zone Experimental Program

There has been no significant change to this task since the last report where the status was described as follows. A sequence of proposed vadose zone experiments (Phase I) is currently under planning in terms of objective/hypothesis, injection volume, tracer identity and concentration, uranium concentration, density of analytical measurements, and schedule. These plans are contingent upon the conditions found in the vadose zone during well installation with respect to facies distributions, uranium concentrations, and other variables. Our characterization strategy will emphasize the early measurement of these key parameters to allow finalization of plans for initial vadose zone experiments.

Task 6. Saturated Zone Experimental Program

Our first series of saturated zone injection experiments is under active planning to begin in Fall 2008. This series will include: i.) an initial non-reactive tracer experiment as system shakedown, ii.) a multi-tracer experiment (D_2O, Br^-, PFBA) using IFC site groundwater that has been cooled approximately 5^o C below that of ambient groundwater, and iii.) a uranium perturbation experiment (desorption or adsorption) induced by injection of waters from a different well within the 300 Area U plume well that contains an identical U-isotopic signature to the IFC site. U-isotopic issues are being handled by John Christensen (LBNL) who will be a funded member of the IFC team in FY09. Water sources from the 300 A U-plume must be carefully considered so that in-situ isotopic ratios are conserved for future isotopic exchange experiments to examine the in-situ lability of adsorbed U. The injection series increases in operational and analytical complexity with each progressive experiment in ways that will allow full and comprehensive testing of the IFC injection infrastructure and monitoring network. The design of these experiments will be finalized after completion of the well field and select down-hole hydrologic and laboratory characterization measurements.

Our new and current design for injection of waters of different temperature involves cold month experiments where groundwater is pumped from our injection well to storage tanks for natural cooling, and then re-injected at lower temperature several days later. This approach eliminates various microbiologic concerns regarding the injection of river water microflora, and eliminates potential for calcite precipitation events that might occur if water temperature was increased.

Task 7. Modeling and Interpretational Program

The Hanford IFC project requires three-dimensional flow and reactive transport models to integrate all available characterization data and experimentally-based descriptions of geochemical and biogeochemical reactions, and mass transfer processes for the IFC domain, and to apply this knowledge to interpret field experiments. The Hanford IFC project intentionally sought modeling participants who are proponents of different codes to maximize field experiment interpretational potential and to advance capabilities for field scale modeling of mass transfer processes. Achieving the maximum scientific potential of the IFC project requires coordination and distribution of responsibilities between individual members of the modeling team.

The concept and necessity for modeling coordination was discussed at our investigators meeting in April. The goals for model coordination are to: maximize scientific contributions and peer-reviewed publication of results to provide maximum benefit to DOE/BER, DOE/EM, and stakeholders; take best advantage of the unique expertise of individual IFC participants and their codes; maximize synergy and modeling sophistication through different approaches and perspectives; and minimize potential overlapping research. To this end, the following roles have been agreed upon by the different modeling groups involved in the IFC:

- PNNL will serve as the coordinator for IFC modeling efforts, with Mark Rockhold fulfilling this role. PNNL (Rockhold, Ward, Liu, Zachara) with the USGS (Kent) and OSU (Haggerty) will focus on interpretation of both laboratory and field experimental studies to develop robust conceptual and mathematical models of geochemical reactions and multi-scale mass transfer of U, using STOMP(-SC). PNNL (Ward) will also lead the effort in hydrogeophysical data modeling and inversion for both site characterization and monitoring, using STOMP-RES.

- University of Alabama (Zheng) will lead pre-modeling and design of experiments to be performed at the IFC site that will use differences in temperature and water composition to evaluate multi-scale mass transfer and reaction processes, using the suite of MODFLOW, MT3DMS, and PHT3D. This pre-modeling will consider dynamic river stage and water table fluctuations, differences between river and groundwater temperatures and aqueous chemistry, and their effects on geochemical reactions/rates and uranium mass transfer at the field scale. This pre-modeling will be used to help design field experiments to use waters of different temperatures and compositions.

- University of California Berkeley (Rubin et al.) will lead implementation of MAD, the inverse "engine" for assimilating all relevant past and new field data to drive inverse calibration, realizations for forward conditional simulations, and stochastic modeling.

- LANL (Lichtner)/PNNL (Hammond) lead the implementation of PFLOTRAN with MAD to provide the forward modeling tool and computational capabilities to enable inverse calibration. Linkages to and utilization of new SciDAC-developed computational capabilities will be sought. In addition, LANL (Lichtner) will contribute to the interpretation of laboratory and field experimental studies and to the development of multi-continuum model representations of mass transfer processes, using PFLOTRAN.

Each of these defined roles and responsibilities defines a unique leadership contribution for the modeling investigators. As field experimentation and modeling progresses forward, there will be numerous opportunities for modeling data sets with the different codes and approaches; and for comparing results, performance, and the apparent accuracy of process descriptions and assumptions. These comparisons will lead to new modeling initiatives, developments as necessary, and evolutions in defined roles and responsibilities.

The modeling activities described above have begun in earnest during this reporting period with Mark Rockhold (PNNL) providing the 3-D hydrogeologic specifications for the 300 A plume to both Peter Lichtner (LANL) and Chunmiao Zheng (UA). This large data set contains the most current spatial description of the physical, hydrogeologic, and geologic parameters and properties of the 300 A groundwater system. As a result of this data exchange, both of these external investigators now have operational hydrologic models of the extended IFC groundwater domain and its linkage with the Columbia River that will be incrementally updated and revised as new field and laboratory characterization data becomes available.

Task 8. ERSD Outreach

Six members of the Hanford IFC team attended the annual ERSD investigators meeting in April 2008 and presented a one hour-long oral presentation and five posters. This exchange generated significant discussion between IFC team members and various ERSD investigators on extended ERSP uses of the Hanford IFC site, and different research uses of Hanford IFC subsurface sediments. Profitable discussions are continuing between IFC team members and various ERSP investigators on use of the IFC site and samples collected from it. Three ERSP projects are currently using the 300A U-plume/ IFC site complex for research, and are providing valuable information back to the IFC:

1.) Haluk Beyenal et al. (P.I.) – Washington State University - "Microscale Metabolic, Redox, and Abiotic Reactions in Hanford 300 A Subsurface Sediments"

2.) Donald DePaolo, John Christensen et al. (P.I.s) – LBNL – ""Isotopic Tracers for Biogeochemical Processes and Contaminant Transport: Cr, U, SO_4 and NO_3 at the Hanford Site" [Being integrated into LBNL Scientific Focus Area Research]

3.) Lee Slater et al. (P.I.) – Rutgers University – “A Geophysical Characterization and Monitoring Strategy for determining Hydrologic Processes in the Hyporheic Corridor at the Hanford 300 A”

The IFC has provided information for proposal preparation and statements of “collaboration intent” or “sample availability” for a number of new proposals submitted to ERSD’s FY 07 and FY 08 university calls. We have also agreed to provide intact IFC core materials to Gilles Bussod of New England Nuclear in support of his Phase II SBIR proposal on core-scale imaging. Recently sampled IFC sediments have been provided to: i.) Ken Kemner for ANL-Scientific Focus Area (SFA) research, ii.) Frank Loffler of Georgia Tech. University for PNNL SFA research, and iii.) Brad Tebo of Oregon Health and Science University for proposed ERSP research.

V. Non-IFC Project Activities

The IFC project continues its interactions with DOE EM-20 and DOE RL-30 researchers focused on polyphosphate remediation of the 300 A plume, although the budgets for both of these activities have fallen. RL-30 in particular, awaits results from our characterization measurements to gain understanding on the heterogeneity of U concentrations in vadose and saturated zone sediments within the South Process Pond footprint. The IFC project is providing approximately 200-300 kg of contaminated capillary fringe sediment collected during the drilling campaign to RL-30 researchers for mesoscale laboratory studies on U adsorption and desorption under conditions simulating rising and falling water tables. These results, in turn, will be useful in calibrating IFC models and planning future IFC experiments.

VI. Funding Issues

Project spending is on tract with projection and there are no funding issues. We are currently holding $200 K in a contingency fund for the drilling project in case problems arise. These funds were originally budgeted in FY 08 for the performance and analysis of our first non-reactive tracer experiment. We do not expect to use these funds for drilling but the project must be prepared for a worst case scenario. Given the relatively late start of drilling (May 13, 2008), the estimated date of its completion (August 30, 2008), and the prospects for a continuing budget resolution in FY 09, we anticipate carrying over funds for the first injection experiment to FY 09. Our plan is to perform this experiment as soon as possible in FY 09.

VII. Upcoming Plans/Issues

The following bulleted items summarize plans for the remainder of FY 08 and the first quarter of FY 09. These plans are based on the assumption that the IFC well field will be complete by September 1, 2008.

July 08 – September 30, 2008

- Complete installation of the IFC well field, and drilling and sampling of the deep characterization borehole.
- Complete and circulate first draft of publication plan.
- Complete borehole flowmeter measurements and limited pump testing on IFC, Hanford formation wells.
- Perform post-completion geophysical logging of all wells.
- Sample and analyze groundwaters from IFC wells to identify low river stage compositions and variations between wells.
- Continue geochemical, hydrophysical, and microbiologic characterization of sediments retrieved from boreholes. Input resulting data to INL data base.
- Initiate detailed surface and cross-hole geophysical measurements of experimental domain.
- Finalize design for first non-reactive tracer injection experiment and write field test plan.
- Premodel first injection experiments using the most current geologic and hydrogeologic information from the IFC site.

October 08 – December 08

- Perform first non-reactive tracer experiment under low river stage conditions.
- Complete all initial characterization measurements on borehole samples and input data to IFC data base. Begin process-specific characterization measurements.
- Begin assembly of characterization measurements on borehole sediments and detailed geophysical measurements into an integrated geostatistical model of the experimental domain, and an improved hydrologic model for experiment simulation.
- Use updated models to interpret tracer experiment. Parameterize hydrologic models from tracer experiment results as necessary.
- Premodel the heat tracer experiment to assist in experimental design finalization for a cold weather experiment.
- Finalize design for cold weather heat tracer experiment and write field test plan.
- Continue microbiologic studies of aseptic borehole sediments in collaboration with PNNL SFA.

VIII. Peer Reviewed Publications, Abstracts, and Presentations

Beyond the ERSP investigators meeting, there have been no abstracts or presentations given during the reporting period. The IFC team has been preoccupied with planning the drilling operation, designing and installing the monitoring systems, and devising a scientifically sound characterization plan so that this critical and central task to the IFC is completed to the highest level of quality. There have also been no new publications on the IFC project since the last quarterly report in January, 2008 because new and original research is only now commencing. The IFC team is developing a publication plan for both single investigator and collaborative publications so that efforts can focus on these tangible and important products. The generation of publication-quality results is now growing rapidly with the installation and geophysical logging of the well field, performance of laboratory and field characterization and experimental studies of different type, geostatistical analyses of our growing IFC data base, and modeling applications and improvements. We are committed to publishing IFC results as soon as possible.