CCRN

Changing Cold Regions Network

CCRN Workshop on Extreme Weather and Hydrology

"*Lessons Learned from the Western Canadian Floods of 2013 and Others*"

Grande Rockies Resort, Canmore, AB

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SUMMARY

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"Lessons Learned from the Western Canadian Floods of 2013 and Others

This was a high level conference at which a great deal of significant scientific information was exchanged. The conference was opened by the Mayor of Canmore. His Worship, John Borrowman, welcomed participants and thanked the organizers for holding this important conference in Canmore.

In his opening remarks, Professor Howard Wheater underscored the importance of the Changing Cold Regions Network (CCRN) in terms of understanding environmental change in the Rocky Mountains. Dr. Wheater then summarized the goals, objectives and geographical reach of CCRN. Dr. Wheater stressed the partnership aspect of the Network which made it possible to establish observatories that will provide data that will help us to better understand and predict regional and large-scale hydro-climatic variability and change. He noted also that the ultimate goal is to share new knowledge with a broader user community.

Professor John Pomeroy added his welcome and visually illustrated the reason for this workshop by way of video images of the flood event that took place in this region in 2013. Dr. Pomeroy then outlined the purpose of the Workshop – to evaluate, analyse and synthesize the Flood of June 2013 as a case study of extreme weather and hydrology. He then explained the methodology of the workshop, which was to compile a diagnosis of the floods; and then to synthesize descriptions of the flood and its implications and thereby show how local flood events are connected to broader atmospheric, hydro-meteorological and climatic trends. The workshop, John explained, aimed for improved science and understanding of extreme event processes that can be shared widely.

Professor Ronald Stewart then offered an atmospheric overview of the June 2013 flooding event in Alberta. This overview, which was a prelude to later presentations at the workshop, focused on climatology and hydro-meteorological pre-conditions that led up to the 2013 flood. Dr. Stewart provided a very detailed foundation for understanding how the 2013 storm formed; why it was so powerful; and what was unusual about it. The event itself, Professor Stewart pointed out, was linked with a mid-level closed low pressure system to the west of the region and a surface low pressure centre initially to the south. This configuration brought warm, moist unstable air into the region that led to dramatic, organized convection with an enormous amount of lightning in some areas as well as some hail. Among the unique elements of the storm, he said, was the amount of lightning activity in the northern part of the affected region and the lack of lightning further south in Kananaskis Country. Lightening activity is an indication of strong convection – the lifting cools clouds and induces heavy precipitation and its absence in some of the main precipitation areas is notable for the region. Dr. Stewart noted that research is now being focused on comparing the devastating 2013 chain of events with other extreme events to determine if this storm is a harbinger of storms to come.

Dr. Pomeroy then provided an overview of the hydro-meteorology of the 2013 Canadian Rockies storm. He noted that 15 researchers were in the affected area when the rain began to fall. He explained the geography of the area impacted by the storm and showed a weather prediction model reanalysis of the precipitation that accompanied the event. Dr. Pomeroy noted that the storm was unusual in that precipitation did not increase with altitude in the mountains during the event. He noted that precipitation rates were not exceptionally high, but what was distinctive was the duration and spatial extent of rainfall. The effect of rain falling on snow was also important in generating additional snowmelt contributions to rainfall-runoff. There was a 41% decrease in snow-covered area over two weeks surrounding the flood period at his study sites at Marmot Creek in Kananaskis which contributed at least 72 mm of snowmelt water to runoff during the flood. The limited capacity of frozen or wet soils to store water also contributed to the flash-flooding. Together these factors resulted in the streams becoming torrents carrying heavy sediment loads. Pomeroy compared the 2013 event with events that are known to have happened in this area of the Rockies since 1879. Despite the heavy precipitation and concurrent snowmelt, the 2013 storm was only a 32 year return event at Banff; and a 45 year return event in Calgary but the small mountain stream records that would put the flash flooding into historical context do not exist as relevant hydrometric stations were destroyed in this flood and did not exist for earlier floods.

Among his conclusions were that snowmelt over frozen ground contributed an additional 30% to precipitation. We were lucky, he said. The Canadian Rockies flood was big, but not extraordinary. It was not likely the flood of century, as many called it. Given the return periods of river flows, it was not even the flood of a lifetime.

Flood forecaster Colleen Walford then outlined the flood forecasting mandate and the methodology employed by Alberta Environment's River Forecast Team. Colleen then demonstrated how their flood forecast model works and outline the operational stages through which he forecast team progressed during the 2013 flood. Colleen concluded her presentation by outlining reviews and projects to be undertaken in 2014 aimed at improving the province's forecasting capacity now and in the future.

Bill Duncan of the Saskatchewan Water Security Agency introduced participants in the conference to the downstream effects of the 2013 flood in Alberta in the Province of Saskatchewan. He showed the locations and outlined the capacity of dams on the Saskatchewan River System. He then explained how these dams were operated to deal with the increased flows generated in Alberta. He noted that despite the careful operation of these dams that flooding of agricultural lands did take place and the Cree Nation at Cumberland House has to be evacuated. Fortunately, however, major flooding was avoided in the City of Saskatoon.

Professor Sean Carey observed that the impacts of the flood were not confined to Alberta. The flood event also increased flows in the Elk River which threatened the East Kootenay communities of Elkford, Sparwood, Hosmer and Fernie. With five active open pit coal mines in the area, mobilization of selenium and other contaminants was a concern. It was not possible to monitor the effects of such mobilization, however, because of safety concerns during the storm and resulting flooding. Dr. Carey reported that rainfall in the City of Fernie was 25% higher than ever recorded before. The good news was that defenses constructed after a flood in 1995 proved largely effective.

Professor Masaki Hayashi then explained the potential roles of groundwater in mitigating or exacerbating the impacts of floods. Dr. Hayashi began by reminding us of the interactions between ground and surface water. He then cited research in the Himalayas that demonstrated the extent to which mountain aquifers can store water and buffer the effects of flood. Dr. Hayashi then introduced the hydrogeological research that he and his students were conducting at Lake O'Hara in Yoho National Park. He then cited additional research at Marble Mountain, near Sundre, where his team was able to employ an isotopic tool to calculate groundwater contribution to surface flows. This research demonstrated that up to 90% of storm flows can originate as groundwater. He demonstrated how underground storage can both reduce and further contribute to streamflows during storms by introducing a delay in water flow. Dr. Hayashi then discussed the active exchange of Bow River surface and groundwater in the alluvial aquifer beneath Canmore. He noted once more that mountain aquifers were natural water detention systems. In conclusion, Dr. Hayashi asked a very interesting question: "Can we utilize groundwater detention as a mechanism for flood risk mitigation?"

Our lunch speaker was Dr. Don Cline, Chief, of the Hydrology Laboratory, National Weather Service, which is part of the National Oceanic and Atmospheric Administration in the United States. Dr. Cline's topic was extreme hydrology prediction in the U.S. He began by noting that the National Weather Service has been providing flood warnings to the United States for 124 years. Over that period there has been constant improvement in the quantity, frequency and lead time of forecasts. The recent increase in extreme weather events and the growing number of challenges in managing water, he said, have demanded that new tools be developed for prediction. As an example of these tools, Dr. Cline pointed out that his organization is moving toward ensemble hydrological models, like those used by climate scientists to predict future climate conditions, to make more accurate flood forecasts. The National Weather Service, he noted, has now expanded its prediction repertoire to include not only high flows and floods; but also low flows and droughts. With its partner agencies, it is now leveraging national investments in the direction of a nested Earth System approach to understanding the global water cycle and its effects locally, nationally and globally and is establishing a new 64,000 ft^2 National Water Center in Alabama to further integrate and enhance US flood prediction. It did not go unnoticed that despite the heroic efforts of many of the scientists present at the conference, that in many ways we appear to be going in the opposite direction with respect to science-based flood and drought prediction in Canada.

Professor Julie Thériault examined the 2013 Alberta flood from the perspective of climatology, synoptic conditions and precipitation fields. Building on Dr. Stewart's earlier presentation, Dr. Thériault graphically explained the role of the jet stream, synoptic forcing, accumulated precipitation, terrain, snowpack and snowline on the intensity and severity of the event. The source of water vapour for the storm in the Gulf of Mexico was noted and the impact of increased sea surface temperature on moisture movement from the Gulf to Alberta was discussed. This presentation also pointed out where efforts to improve current atmospheric models can be focused.

Logan Fang then talked about the use of the Cold Regions Hydrological Model (CRHM) to simulate hydrological processes during Rocky Mountain floods. CRHM has been developed to model cold and warm season hydrological processes including snow distribution; sublimation; melt runoff over frozen ground and unfrozen soils; evapotranspiration; sub-surface runoff on hill slopes; groundwater movement and streamflows. No direct comparison between simulated and observed streamflow was possible as gauging stations were destroyed in the June 2013 flood. However, records of stage in the basin suggest that modelled peak streamflow lagged actual flows during June flood. This suggests that current model structure and parameterisation has previously undetected inadequacies in simulating peak streamflow timing during extremely wet conditions. The model was used to diagnose responses of hydrological processes in June flood for different environments such as alpine, treeline, montane forest and forest clearings in Marmot Creek in order to better understand flow pathways in extremely wet conditions. To examine the model sensitivity to antecedent conditions, "virtual" flood simulations were conducted using a week (17 to 24 June 2013) of flood meteorology imposed in the meteorology of the same period in other years (2005 to 2012) as well as in different months (May to July) of 2013. The results show sensitivity to snowpack, soil moisture and forest cover with the highest runoff response to rainfall from locations in the basin where there are recently melted or actively melting snowpacks. Mr. Fang went on to note is that had the rainfall occurred in previous years at the same time of year it would have generated a larger flood in most years. Had the rainfall occurred earlier in 2013 it would have produced a much larger rain-on-snow flood.

Bruce Davison of Environment Canada then offered a cautionary tale regarding the use of models to predict high precipitation events. Mr. Davison noted that the Canadian Precipitation Analysis model under-estimated precipitation at the basin scale. Bruce observed that model calibration is required to accurately parameterize precipitation particularly in high rainfall events. Flood simulations with the empirical WATFLOOD model showed great difficulty in simulating the flood peak on the Bow River without extensive calibration. However, the more physically based MESH model which is a coupled hydrological land surface scheme that can be run directly coupled to

Environment Canada's GEM numerical weather forecasting model showed the capability of accurate simulation of Bow River streamflow and peak flow during the flood. This is a very encouraging example of where better science and improved model physics lead to better prediction and show that Environment Canada's MESH coupled to GEM can provide the basis for a sophisticated national flood forecasting tool. Mr. Davison's presentation demonstrated that the use of radar as well rain gauges to provide reanalysis products from weather models can improve forecasting.

Professor Yanping Li then added more to Dr. Stewart's and Dr. Thériault's earlier contributions with a presentation on the use of the NOAA Weather Research and Forecasting Model (WRF) to simulate the 2013 Alberta flood event. She began by explaining how the WRF worked and described the processes it could parameterize. She then revisited the synoptic conditions and water vapour sources at the time of the flooding. This work, she explained, is being done to determine if WRF simulations can be used under global warming scenarios to determine if these kinds of events might happen more frequently in the future.

Dr. Don Cline concluded the presentations in the afternoon with a detailed introduction to the U.S. National Ocean and Atmospheric Administration's Snow Data Assimilation Program, SNODAS. Dr. Cline's agency collects meteorological, satellite and snow survey data into a data assimilation system, called SNODAS, that estimates snowfall, snow depth, snow-water equivalent, snowpack temperature, sublimation and snowmelt on a 1 km grid across the US. He showed that the SNODAS satellite remote sensing program extends well into Canada. This began some time ago with U.S. analysis of the Canadian portion of the Columbia River system. The most recent additions include all of Canada south of the 54^{th} parallel. Dr. Cline also noted that the agency relied not just on satellite data and models but also relied heavily on field monitoring. It was very interesting to note how much the current U.S. data assimilation program relies on volunteers to collect such data. It was also noted that the SNODAS website provides everything the agency knows about snow; much of it in three-dimensional imagery. In conclusion Dr. Cline took participants in the conference back to last June to demonstrate what the U.S. knew about snow conditions in Alberta at the time of the flooding in the Canmore region. Utilizing remote sensing and the information available to them from field stations in the U.S. and Canada, they could tell snow-water equivalent, snow depth and snow melt in the Canmore-Banff area. From the SNODAS output they could see the potential for a substantial rain-on-snow event.

In the evening the Town of Canmore described the challenges the municipality faced during the 2013 flood event, and outlined their immediate response and short-term mitigation strategies. Before the flood, municipal officials had a limited appreciation of the risk, the size of the coming event or the damage it could cause as no similar events had occurred in recent memory and flood plain maps were restricted to overflows from the Bow River. Through adaptive management and great effort, much infrastructure and all lives were protected in Canmore. The Town is interested in risk management approach to mitigation, improved flood forecasting and debris flow prediction and so promised further consultation between academia, the provincial government, the consulting industry and the local community on matters related to solutions to the continued flood threat in Canmore.

On the morning of the second day of the conference Dr. Danny Marks introduced participants to the Reynolds Creek Experimental Watershed in Idaho. Dr. Marks has analysed the location of the rain-snow transition zone in the major storms that took place in the Reynolds Creek Watershed between 1968 and 2006. In the 1960s, he noted, this area of Idaho once possessed a snow-dominated hydrological regime. Now this regime is dominated instead by rain. This change has occurred in only 40 years. Dr. Marks observed that it is not direct warming from the rain as much as heat flow to the snowpack due to energy released by condensation on the snowpack during rainfall that causes melt in rain-on-snow events. Dr. Marks then went on to demonstrate how changes in snowpack energy can be modelled. He noted that in large rain-on-snow events snowmelt energy is increased by 50 to 100 times. He then went on to demonstrate how phase changes and changes in energy balance affected snowmelt in a storm that occurred in Idaho over the Christmas holidays in 2005. In conclusion, Dr. Marks noted that if the 2013 Canadian Rockies rain-on-snow event had occurred when there was snow in the valley bottoms instead of just on the peaks, the flooding could have been orders of magnitude worse. For those who are concerned with future flooding in the Canadian Rockies this observation in itself is provocative. Should we expect more rain-on-snow events? Should we also expect them to start happening in winter as well as is occurring now only a short distance to the south?

Paul Whitfield expanded on Dr. Mark's research themes by describing changes in autumnal streamflow in the broader Rocky Mountain region of North America looking at a transect from Mexico to the Arctic Ocean. In a warming climate, he said we should expect earlier snowmelt, lower summer flows, and changes in autumnal climate and hydrology leading to changes in precipitation patterns that could result in more early autumn snowfalls turning into rain and rain-on-snow events. Mr. Whitfield noted that there is a trend toward an increasing number of autumnal floods throughout the Rockies; something that is now clearly understood in Colorado. Such events, he said, could become more common in this region of the Rockies as well.

Dr. Al Pietroniro then talked about the Water Survey of Canada and its role in basic measurement of water in this country with a special focus on flooding. Dr. Pietroniro then went on to describe Canada's national hydrometric system and the federal-provincial cost-sharing program that supports it. He then described challenges and opportunities related to anticipating and responding to flood events in Western Canada. He then described how the Water Survey of Canada responded to the Alberta flood and demonstrated how the course of the floodwaters were tracked through southern Alberta, Saskatchewan and Manitoba. He also showed the damage the flood did to his monitoring station network and explained what is being done to restore the system.

Katrina Bennett talked about the effects of extreme events on the warm-permafrost boreal forest region of the Alaskan sub-arctic. She noted there is a trend toward warming in the interior of Alaska. While average annual stream flows are decreasing in response to warming, winter and spring flows are increasing. Ms. Bennett explained that 2013 was one of the latest river ice break-ups on record in Alaska. March and April of 2013 were warm in Alaska but May was very cold delaying snow melt. The cold snap was followed by a record-breaking heat wave in June during which temperatures in some parts of Alaska approached 100˚F. Her conclusions were that streamflow patterns changed in Alaska between 1951 and 2012. Snowmelt dominated system are declining in the spring and are becoming dominated by rainfall. In the future, she observed, Alaskans can expect more days with record-breaking maximum temperatures with impacts that will cascade through the hydrological cycle.

Mr. Rick Janowicz built on Ms. Bennett's presentation with a description of the ice jams and freshet flooding that occurred during the same period of 2013 in neighbouring Yukon Territory. Mr. Janowicz noted that the Yukon has a long history of flooding due to early settlement in flood plains along river transportation routes. He noted that 2013 was a cold winter and that snowfall in April in the Yukon was up to 250% of normal. This was followed in May by a rapid snowmelt and runoff. Because of the cold, winter river ice was thick. This, combined with a compressed run-off period, caused serious ice jams on rivers. He also noted that there had also been heavy flooding the year before, in 2012. This cut off highway access to the Territorial capital, Whitehorse, which meant that food and other supplies had to be airlifted into the city. Mr. Janowicz then asked the inevitable question: Is this on-going flooding connected to climate warming? He answered his own question by noting that summer temperatures in the Yukon had risen on average by 2˚C to 6˚C and that winter temperatures have risen on average from 4˚ to 6˚C in the past century. Greater precipitation, higher temperatures, increased flows and compressed run-off all contribute to greater flooding. He also amused participants in the conference by pointing out that because of breakthroughs in computer technology concomitant with a wider range of flood timings over the summer it is now possible and necessary to forecast floods remotely in cafes, bars and even in foreign bug houses.

Dr. Roy Rasmussen concluded the morning session with a presentation about a major blizzard that took place in March of 2003 in Colorado. Dr. Rasmussen and his colleagues modelled this storm in the context of what such a blizzard might be like if it occurred in a future climate scenario. The scenario he and his team used was one in which mean temperatures were on average 2˚C warmer with 15% more moisture in the atmosphere than at present. The model showed that under these changed climatic conditions that the 10 year return period for blizzards of the intensity of the one that struck Colorado in 2003 would increase by 52%. Dr. Rasmussen left the implications of such a change to the imaginations of the participants.

Model results showing heavier snowfall at high elevations were countered by those showing more rainfall at low elevations and therefore a change in the spatial extent of the storm The model runs also projected that with a 2˚C temperature increase precipitation in Colorado could increase by as much as 30% to 40%, which is three times higher than what would be expected given the Clausius-Clapyron Relation, a principle in atmospheric physics which defines how much more water vapour can be transported in a warming or cooling atmosphere. The net effect of more rain, heavier snowfalls at altitude, and increased run-off will likely be larger floods. Dr. Rasmussen is now doing a super computer model run that could answer one of the most critical questions asked at the workshop: If future precipitation does increase by 35% in Colorado, could flooding of the magnitude experienced in the Front Ranges of the Rockies in Alberta and Colorado in 2013 become a more regular occurrence? Stay tuned.

Dr. Rasmussen spoke again in the evening at a public session sponsored by the Town of Canmore which was held in the theatre of the Canmore Collegiate High School. The topic of his presentation was The Colorado Great Front Range Flood of 2013: Lessons for Alberta. Dr. Rasmussen began by visually illustrating the extent of the flood and the damage it caused to homes, roads, bridges and other infrastructure. He noted that 262 homes were destroyed in Boulder County alone and that some 1300 landslides were attributed to the flooding. Dr. Rasmussen also noted that it was highly unusual that such a storm should occur in September. He noted that the cause of the flooding was a low pressure system that parked over Colorado and continued rotating, all the while bringing up tropical moisture from the south. Dr. Rasmussen noted that the storm was remarkable in that it carried a record volume of precipitable water in the form of atmospheric water vapour; more than three times the former record. Records were set for daily, monthly and annual precipitation by the storm, despite the severe drought preceding it. The previous record in Colorado for rainfall in 24 hours was 4.80 inches. A new record was set in 2013 of 9.08 inches, which exceed the previous record was by nearly 100%.

Dr. Rassmussen went on to point out that the Alberta and Colorado floods were quite similar in a number of ways. Both involved slow-moving upper level low pressure systems bounded by high pressure systems to the north and south. Both low pressure systems remained nearly stationary for an unusual period of time and worked with nearby atmospheric cells to bring large amounts of water vapour up from the south. The resulting storms were both of long duration, delivered heavy rainfall and covered a very large area. The differences were that in the case of the Colorado flood there was no snow on the ground and greater numbers of lightning events. Dr. Rassmussen also pointed out that one important difference – that had yet to be determined – was that the Colorado flood may have in fact been caused by what can be defined as a tropical as opposed to a temperate region in-cloud rainfall formation processes.

In terms of the lessons Alberta could learn from the Colorado event, Dr. Rasmussen pointed out that accurately capturing heavy precipitation is difficult in all existing U.S.

National Weather Service climate models. The U.S. Weather Service has been working for some time on this problem. The 2013 flood, however, has accelerated research efforts to improve ensemble analysis of coupled hydro-meteorological changes in real time. Quantitative weather radar was invaluable in the U.S. and not normally available yet in Canada; NowCast and Forecast products are part of a new U.S. system that emerged since the storm. Work remains to be done, however, to identify sources of error and opportunities for improvement.

Conference Conclusions

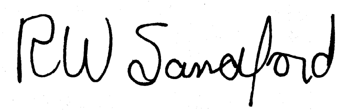
So what do we do now? With respect to describing floods and their statistical properties workshop participants proposed the following. We need to go beyond conventional analysis with respect to characterization of frequency of flood events. We need to look at more than simple examination of annual extremes and include multiple events of a single year in flood frequency analysis. We need to think more about flood mechanisms, including for example rain on snow and antecedent moisture conditions, and their effect on flood response in these types of analyses. Consideration should be given to the effects of past and recent changes in land-use and vegetation on the potential for increased flooding. We should compare historical flooding events in different basins to look at similarities and spatial correlations. As the climate continues to change, we should investigate how large-scale precipitation events are changing (i.e. in terms of magnitude, frequency, and duration) and look into the role of teleconnections and the transport of moisture northward from the Gulf of Mexico. Geomorphological processes and other dynamics of the systems need more consideration. This includes, for example, sediment redistribution on alluvial fans and changes in stream channels, which affect the hydraulic regime and may lead to reductions in future stability and/or certainty in behaviour. Groundwater and its effects on persistence of high flows should also be considered. It is important that statistical analyses include confidence intervals for the results, as this is useful for planning and operations, and for public awareness. Finally, it is very important, also, to communicate our findings and our uncertainties more effectively and more widely.

With respect to modelling challenges and opportunities, there was consensus among workshop participants that we need a broader range of better observations, including precipitation and other meteorological measurements. This would improve data assimilation into models. Other suggestions on how to best model floods included: continuous flow simulations, physically-based modelling, ensemble forecasting, clear understanding of hydrological processes and model parameter limitations, incorporation of human impacts into models, coupled atmospheric–hydrological modelling, and improved ice-jam modelling. Some other points that were noted included that it is important to publically disseminate model outputs, and that models can be used to help develop indices for conditions related to flash floods, landslides and debris flows. The western Canadian flood in June 2013 and the Colorado flood in September 2013 make good potential modelling case studies. With respect to the western Canadian floods, a legacy dataset should be developed and a special issue journal publication should emerge. A modelling intercomparsion study in connection with the US National Center for Atmospheric Research, incorporating the western Canadian and Colorado front ranges flood, would be a useful exercise that would provide valuable insight. Some longer-term issues and opportunities were also noted by the group. These included coupled atmospheric–hydrological modelling and ensemble modelling, risk communication, technology transfer of newer models to the provinces and territories, linking drought and flood modelling through continuous simulation, model intercomparison efforts, and climate and weather change modelling studies. A key point for the modelling perspectives is that, once again, we heard we have to be better at public dissemination of model results.

With respect to water management and flood mitigation, workshop participants proposed the following. We need to translate scientific research outcomes into useful tools for engineers, architects and planners. For engineers, the needs and implications center around updated design storms and intensity/duration/frequency analysis (see points made above from statistical perspectives), and peak discharges for infrastructure design. For municipalities this involves stage and water levels and updated flood inundation maps (some cities have done this), while for water managers this involves reservoir operation. Some challenges for reservoir operation were noted. These include different philosophies on the purpose and operation of the reservoir (e.g. drought resilience, water supply, hydro-power generation, flood protection, etc.). The current state of water resource systems modelling also presents challenges for reservoir operation, where daily and hourly simulation is needed to assess flood management, and flow routing needs to be incorporated in current schemes. Upscaling to weekly timescales can then be done to test the economic value and utility of the flood protection philosophy. Other challenges and important issues are that uncertainty propagates from observations and models up to the management decision level, and that reliable forecasts are critical for reservoir management. Scenario assessment and economic/ecological risk and benefit analysis are useful for better understanding and evaluating possible outcomes, and this is something that we should strive to enhance and include reservoir operation. In terms of mitigation, we need strict zoning and socio-engineering solutions, improved public awareness and education programs, better risk quantification and communication to the public and to political leaders, and forecasting tools that will help arrive at stricter floodplain zoning. It was also pointed out that floods have important and beneficial environmental functions, such as redistribution of sediments and nutrients, and that these benefits should be considered along with the risks.

Once again we were left at the close of this conference with great respect for the work that is being done and for those who are doing it. We are in even greater awe of the challenges we face. We are left also with the relentless reminder that we have got to be better at sharing what we know and are learning with political leaders and with the public, now and in the future.

Respectfully submitted,



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