3-5-2003

# Clark County GIS vulnerability assessment project: Looking ahead, designing mitigation, and managing uncertainty

David M. Hassenzahl
*University of Nevada, Las Vegas*, david.hassenzahl@unlv.edu

White Paper for the Clark County GIS Vulnerability Assessment Project:
Looking Ahead, Designing Mitigation, and Managing Uncertainty.

David M. Hassenzahl, Ph.D.
Department of Environmental Studies
University of Nevada Las Vegas
david.hassenzahl@ccmail.nevada.edu
March 5, 2003

***Summary***

After reviewing the progress of the Clark County GIS Vulnerability Project to date, it appears to me that now is an appropriate time to look to the end of the project, and use that to shape the next several steps. The NOAA guidelines may still have use, but it is more important that the project make progress than that it meet particular prescriptive steps.

***Three key issues***

This report addresses three issues: working towards a coherent end-point; next steps; and management of uncertainty. I am available to discuss any of these in more details; I only outline them here.

<u>Working towards a coherent end-point.</u>

The primary (although not exclusive) driving force behind the Clark County Project is to identify and prepare to mitigate those events that are most likely to meet or exceed a FEMA threshold for disaster relief, or a loss of about $2.50 per person in the impacted area. Project team members might consider at this point looking at those region/event combinations that scored highest concern in the earlier scoping project. For each of these, the "magnitude" term needs to be broken out further to ranges of magnitudes. That is, try to identify the predicted frequency of events of different ranges, such as 0 to $1.50 per person; $1.50 to $2.50 per person, $2.50 to $3.50 per person and > $3.50 per person. This should help prioritize the next step: considering mitigation options.

<u>Next steps</u>.

Two plausible steps to follow a careful evaluation of predicted frequencies of events with different magnitudes are to *identify mitigation options* and *study the feasibility of mitigation options*.

*<u>Mitigation options identification.</u>* This step should be a nonexclusive, exhaustive brainstorming exercise, and should be limited to identifying options, not discussing the plausibility or feasibility of doing them. A useful framework was outlined in an earlier white paper (included here as the Appendix I, that proposed the following framework (see also Table 2 of Appendix I):

1. Modify the natural or human environment. For example, to avoid pedestrian fatalities on major roads, build pedestrian bridges.
2. Avoid or modify exposure process. For example, prohibit smoking in

sensitive areas of casinos to reduce exposure to ignition sources.

3. Avoid or modify effects process. For example, require motorcyclists to wear helmets to reduce head injuries in the case of a crash.

4. Compensate for effects. For example, insure against property loss and injury resulting from an earthquake.

Note that this framework should be used to generate ideas, not necessarily to categorize alternatives. So, for example, if there is debate about where a particular mitigation option should appear, put it in both.

*Mitigation option feasibility analysis.* After mitigation options have been identified, the feasibility of these options can be considered. Part of this should be economic (e.g. cost-effectiveness analysis), but such analysis should also include societal acceptability, distributional impacts, and political viability.

*Public participation.* Public input would be useful for each of these steps. Since the mitigation option identification step is an open ended brainstorming project, involving interested members of the public is likely to provide substantial expertise and avoid crucial omissions. Information about societal acceptability can be gathered in a non-threatening, non-committed atmosphere at this stage. To this end, Clark County might consider building and advertising a "feedback" website, soliciting mitigation options for the worst-case predictions. For the feasibility step, some mitigation options might require public or decision-maker buy in.

Managing uncertainty

Uncertainty will be a salient feature of this project which, if ignored, will lead to sub-optimal or ineffective decisions. Uncertainty should be identified, and presented in both quantitative and qualitative terms. One useful approach to managing decisions with high uncertainty is to sort using various assumptions and decision preferences. "Dominant" vulnerabilities or mitigation measures will be those that appear to be the most important regardless of the level of uncertainty or decision preferences. Appendix II provides a typology of uncertainty that the project team might want to consider.

Appendix I

# Clark County Pre-Disaster Mitigation Project: Suggestions for Project Initiation

White Paper by
David M. Hassenzahl, Ph.D.
Department of Environmental Studies
University of Nevada Las Vegas
david.hassenzahl@ccmail.nevada.edu

***Summary***

Attention to several organizational issues will facilitate the efforts of the Clark County regional Pre-Disaster Mitigation project. Key considerations include defining terms efficiently, establishing and maintaining a clear timeline, determining rules for acceptability of new information, determining the nature and boundaries of concerns to be addressed, evaluating a full range of mitigation options, considering how to manage uncertainty, and ensuring stakeholder buy-in and participation. The NOAA seven-step process should serve as an operational template. Project participants should anticipate substantial uncertainty, and consider probabilistic methods (e.g. Monte Carlo analysis) for coping with uncertainty within a GIS framework.

## ***Introduction***

States, regions and municipalities have been conducting broad-based risk comparisons for nearly two decades. This experience, coupled to information from FEMA and NOAA, should provide guidance for the exercise, but also create a challenge. Typically, these exercises require several years, and in few cases have they been completed in the originally projected time frame. The Clark County regional PDM, however, has an externally determined schedule, and should use this as incentive to proceed efficiently. Finally, the NOAA seven-step process appears to be a useful template, but should be tailored to the needs of Clark County.

## ***Key Components for Successful Project Initiation***

<u>Defining terms.</u>

One chronic problem when dealing with risk, vulnerability, hazards, and related issues is not so much which terms to use, but ensuring that all involved in discussions agree to key terms. Inconsistent use of terminology regularly leads to unnecessary friction. While discussing terms is a necessary exercise, it should be neither time consuming nor contentious. An appropriate starting point is the definition of vulnerability provided by FEMA. As the project progresses, PDM project participants should keep in mind that apparent disagreements may be simple miscommunication.

In selecting a definition of vulnerability, members should keep in mind the difference between "marginal" and "overall" risks. Public and private institutions already have in place procedures and equipment (including prevention plans and insurance) for managing vulnerability; marginal risk is that portion that has not yet been adequately addressed.

Establishing and maintaining a clear timeline.
Completing an exercise of this sort regularly takes longer than expected. A timeline for the PDM should be clearly specified and diligently followed.

Determining the nature and boundaries of concerns to be addressed.
To some extent the vulnerabilities assessed will be driven by FEMA directive. However, it is likely that project participants will be interested in issues beyond that scope. Project planning should include discussion about what sorts of hazards are appropriate for consideration, and establish criteria (effect, jurisdiction, etc) for consideration.

In addition, the PDM project should determine up front whether it will evaluate *effects* or *causes* as a focal point.

Evaluating a full range of mitigation options.
When mitigating potential hazards, a broad range of mitigation options should be considered. These include[1]

5. Modify the natural or human environment. For example, to avoid casino fires, stay out of casinos.
6. Avoid or modify exposure process. For example, prohibit smoking in sensitive areas of casinos.
7. Avoid or modify effects process. For example, install automatic sprinkler systems in casinos.
8. Compensate effects. For example, pay for property loss and injury resulting from a casino fire.

It can often be much more cost effective to achieve the same reductions in losses in one of these categories than in another. Note, however, that choosing different categories can also redistribute responsibility and expense, and can be socially or financially contentious. Disagreements about appropriate mitigation based on distributive grounds should not be confused with disagreements about technical information. Also along these lines, it is important to differentiate economic-based decision making from human health-based decision making.

Considering how to manage uncertainty.
All of the issues that will be considered in this project are characterized by low probability of occurrence and high consequence. This type of risk is particularly difficult to estimate and to manage. The project may want to consider evaluating each potential hazard in a variety of terms including expected range of effects (along a number of dimensions including total cost, loss of life, extent of injuries, distribution of effects) and plausible worst-case scenarios. Experience suggests that point estimates of highly uncertain risks should be avoided, and both qualitative and quantitative information about uncertainty should be propagated. Project participants should keep in mind that uncertainty is inherent and often irreducible. As such, decisions made based on point estimates of any single dimensions, while appealing, often have little or no reliability.

Opportunities to incorporate probabilistic methods for dealing with uncertainty (e.g. Monte Carlo Analysis) into the GIS framework could be a useful exercise.

Ensuring stakeholder buy-in and participation.
The PDM project has the advantage that the major jurisdictions have already decided to participate. However, participants should keep in mind that "retrofitting" participation is generally difficult and ineffective. Added participants need to be brought up to speed – a time consuming exercise – and may not agree with decisions made by existing members. The committee may therefore wish to consider the extent that expertise and expenditures may come from parties not currently at the table. In addition, to the extent that public trust and credibility may be necessary for effecting mitigation measures, attention to public acceptance and participation should be considered. Since GIS will serve as the primary coordination tool, all efforts should be made to ensure transparency and clarity.

Determining rules for acceptability of new information.
A frequent stumbling block for this sort of process is the acceptability of information sources. When uncertainties or unknowns arise, project members should discuss which sources of information they will access prior to evaluating the information provided by those sources. Experience show that issues are not effectively resolved when each of several parties to a disagreement brings in its own experts. In contrast, when parties in disagreement mutually select expertise, resolution is likely.

***Comments on the NOAA seven-step process.***

The seven-step process proposed by NOAA appears to be a viable and efficient approach to the Clark County regional PDM project. Some comments:

1. Hazard Identification. This should be a brief but exhaustive brainstorming exercise. Participants should generate independent lists, in consultation with diverse parties and interests throughout the area. All plausible hazards, broadly defined, should be included at this point. Participants should avoiding mixing causes and effects on a single list.

2. Hazard Analysis. This step should involve scoping out the possible severity of different hazards, along a number of dimensions. In evaluating the possible extent of different hazards, analysts should accept that there will be substantial and possibly irreducible uncertainty. Generating a matrix (such as that presented below in table 1) might be advisable.

3 – 6. Critical Facilities, Societal, Economic and Environmental Analyses.
These should be centrally coordinated, but can be done contemporaneously. Finding appropriate and available individuals to perform this type of analysis is often a serious challenge.

7. Mitigation Opportunities Analysis

As discussed above, it will be useful to consider a wide range of mitigation measures. Project participants may wish to simultaneously consider a range of issues including cost-effectiveness, expected and plausible cases, and so on. A broader range of participants may be needed at this stage, based on who will bear the costs of assorted mitigation measures. Again, a matrix such as that in table 2 might be advisable.

Table 1. Hypothetical matrix for hazard analysis. Hazard: collapse of spaghetti bowl.

| **Extent of hazard** | **Causes** | **Event Likelihood** | **Loss of life** | **Property damage** | **Uninsured losses** | **Emergency response expenses** |
|---|---|---|---|---|---|---|
| Partial collapse | Airplane accident | (undefined) | 10 to 210 | (undefined) | | |
| Partial collapse | Earthquake | (undefined) | 0 to 10 | Etc | | |
| Complete collapse | Airplane accident | (undefined) | 210 to 500 | | | |
| Complete collapse | Earthquake | (undefined) | 10 to 200 | | | |

Table 2. Hypothetical matrix for mitigation opportunities analysis. Hazard: collapse of spaghetti bowl.

| Type of mitigation | Measure | Viability | Relevant actor |
|---|---|---|---|
| Modify the Natural or human environment | Close or dismantle the Spaghetti Bowl | Implausible | State / County / City of LV |
| “ | Reinforce Spaghetti Bowl | Expensive | Engineers |
| Avoid or modify exposure process | Minimize rush hour congestion | Plausible | Regional Transportation Commission |
| Avoid or modify effects processes | Enforce seatbelt and car safety standards | Plausible | NHP, DMV, car owners |
| Mitigate or compensate for effects | Require private insurers to cover | Plausible to expensive | Insurance Companies, car owners |
| “ | Purchase County/State insurance | Plausible to expensive | Government |

Appendix II
Typology of Uncertainty
after Morgan, M. Granger and Max Henrion (1990). *Uncertainty* Cambridge University Press, NY NY.

***Typology***

1. Random error and statistical variation
2. Systematic error and subjective judgment
3. Linguistic imprecision
4. Variability
5. Randomness and unpredictability
6. Expert Uncertainty
7. Approximation
8. Model uncertainty
9. Normative Uncertainty

***Details***

1. Random error/statistical variation
    - We have a well defined set of statistical tools
    - These can be misleading!
    - Often the ONLY thing that is done
    - Often done…and ignored
    - Z-scores, Chi-squared, p-values
    - In general, a "95% confidence interval" means that we are confident that if we repeat the same experiment 20 times, we would expect 19 of them to fall within the same range. Doesn't mean we're 95% sure we got the right answer!

2. Systematic error and subjective judgment
    - Energy predictions
    - Chronically understated
    - People follow standard practice and habits, which may contain unknown bias

3. Linguistic imprecision (defining "risk" and "vulnerability")
    - Inconsistencies in language and usage can lead to problems
    - "Rain is likely"…are you from Las Vegas or Bangladesh?
    - "A few thousand deaths:" one grad student from India thought that this might include 100,000.

4. Variability
    - Also called "dispersion"
    - Get the right population!
    - Describing variability can be a challenge
    - Monte Carlo analysis is a useful tool
    - Examples:
        - Height of individuals
            - Deterministic element

    - Random element
- Susceptibility to disease
    - Known
    - Unknown
- Life-history and habit
- Theoretical models
- Empirical data
- What are we worried about?
    - "Average" occurrence?
    - Worst case?

5. Randomness and unpredictability
- Inherent randomness is irreducible!
- Practical limitations and chaos

6. Expert uncertainty
- Multiple interpretations of a single data set
- Norms of analysis
- Motivational bias (decision stakes, reputation)

7. Approximation
- Never have complete data
- There is a tradeoff between efficient computation and resolution or precision
- Sensitivity analysis
- Significant figures are important!

8. Model uncertainty
- Getting the right model
    - Does the model explain the data?
    - Is the model consistent with theory?
- Getting the model right
    - Is the model properly stated?
    - Is the math done correctly

Normative Uncertainty
- Unacknowledged disagreement (it's not an uncertainty if it's acknowledged)
- Also, normative ambiguity (when we aren't sure what we want).
- Often not asked: what is important to us?
- Arguments about technical information mask the true issues
- Leads to vitriol and claim of "ignorance" and "antiscientific attitudes"