**Appendix A.** Hazard Map Evaluation Rubric

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **High Performance - 3** | **Moderate Performance - 2** | **Poor Performance - 1** | **References** |
| **Visual (design components, map features, color/texture)** | | | | |
|  | V1. Aerial imagery base map used (or pops up as first map) | If interactive, aerial imagery is not primary map, but is available for selection | Aerial imagery is not used as base map and if interactive, aerial map is unavailable for selection | Dransch, Rotzoll, & Poser, 2010; Haynes, Barclay, & Pidgeon, 2007; Nave, Isaia, Vilardo, & Barclay, 2010 |
|  | V2. Landmarks are clearly visible (roads, neighborhoods, rivers, etc.) to help viewer orient/locate oneself | Some landmarks are present, but are not clearly visible or do not help with viewer orientation | No or few landmarks are shown making orientation difficult | Cao, Boruff, & Mcneill, 2016; Kunz & Hurni, 2011 |
|  | V3. Important map components are present and well-positioned on page (e.g., descriptive title, north arrow, scale bar, legend) | One important map component is missing and/or hard to locate on page | Two or more map components are missing | Brewer, 2005; Centers for Disease Control and Prevention, 2012 |
|  | V4. Visual hierarchy is achieved through appropriate colors, symbols, font size, line width, and other symbolization techniques.   * Most important map elements are emphasized * Base map is complimentary and does not distract | Visual hierarchy is mostly achieved,   * Most important map elements are emphasized * Other imagery distracts from primary message | Visual hierarchy is not achieved,   * Unimportant features are too prominent * Difficult to see data and intended information | Brewer, 2005; Centers for Disease Control and Prevention, 2012; Kunz & Hurni, 2011 |
|  | V5. Appropriate color schemes are used on all data:   * Sequential for increasing values (e.g. intensities) * Diverging for values above/below critical value (e.g temperature - freezing) * Qualitative for nominal data (e.g. trees, water, desert are green, blue, yellow, respectively) | Multi-hazard: appropriate color scheme are primarily used, but one or more data layers do not have appropriate color schemes | Multi hazard: incorrect schemes were used on all data layers  Single hazard: incorrect scheme is used on data layer | Brewer, 2005; Hagemeier-Klose & Wagner, 2009; Harrower & Brewer, 2003; Robinson, 1952 |
|  | V6. Colors match hazard color (flood = blue, landslide = brown). If not applicable (e.g. earthquake), score = n/a) | Multi hazard: one data layer color does not match hazard color, but all others do | Multi hazard: two or more layers colors do not match respective hazard color  Single hazard: color does not match hazard | Brewer, 2005; Hagemeier-Klose & Wagner, 2009; Kunz & Hurni, 2011 |
|  | V7. Less than 5 color classes are used (7 or less is ideal) | Multi hazard: 6-7 classes for at least one data layer  Single hazard: 6-7 classes are used | Multi hazard: more than 7 color classes used for at least one data layer  Single hazard: more than 7 color classes used | Thompson, Lindsay, & Gaillard, 2015 |
|  | V8. Legend colors are matched exactly with those on map | Legend colors are not matched exactly, but it is easy to tell which legend items match with data | Legend colors do not match exactly (could be due to transparency issues) | Brewer, 2005 |
|  | V9. Color-blind friendly schemes are used | Color-blind friendly schemes are generally used, but some data layers pose issues | Color-blind friendly schemes are not used- hard to distinguish classes or data layers | Harrower & Brewer, 2003; Thompson et al., 2015 |
| **Content (language, text, verbiage, data)** | | | | |
|  | C1. Auxiliary information is present along with mapped data (photos, personal quotes, audio recordings, descriptions, etc.) | Some auxiliary information is included, but more would help clarify concepts and hazard threat | Auxiliary information is not provided | Cao et al., 2016; Dransch et al., 2010 |
|  | C2. Risk messaging is included and positively framed(e.g. “take these simple steps to reduce your flood risk” instead of “Flooding may cause loss of life”) | Risk messaging is included and mostly positive | No risk messaging or risk messaging is negative/fatalistic (e.g. “Prepare or suffer”) | Dransch et al., 2010 |
|  | C3.Maps are personalized/customizable   * Multi hazard: can zoom to areas of interest (AOI) * Single/Multi: community resources provided * Single hazard: Inset map to show AOI at finer scale |  | Information is not personalized or customizable (e.g. no zoom function, local resources, or inset maps included) | Bell & Tobin, 2007; Dransch et al., 2010 |
|  | C4. Information appears to be accurate and up-to date (e.g. no broken links, outdated imagery) and is presented in a clear and concise manner | Information appears to be accurate and mostly up-to date, but could be presented more clearly. | Information appears to be outdated, links are broken, and no or poor/lengthy explanation lengthy is included | Nave et al., 2010 |
|  | C5. Protective measures are included along with risk to facilitate preparedness rather than fatalism. | Some protective measures are included | Protective measures are not included on page | Crozier, McClure, Vercoe, & Wilson, 2006; Maidl & Buchecker, 2015 |
|  | C6. Jargon/specialized terms are not used in map or descriptions | Uses specialized terminology, but explains in succinct easily understood terms (images or explanatory text) | Uses jargon in legend (100-yr floodplain, peak ground acceleration, debris flow, etc.) and does not explain | Bell & Tobin, 2007 |
|  | C7. Legend items are clearly explained (e.g. High = water level could reach 3 feet here in the event of a large flood) | Legend items are explained, but not well  (e.g. High = water will be deep here) | No explanation of legend items are given  (e.g. High) | Brewer, 2005 |
|  | C8. If data are probabilistic (if not, score = n/a),   * Both percent (25%) and natural frequency (1 in 4) are used * Likelihood term is not used to describe data |  | Probabilistic information is provided either in percent or natural frequency and/or likelihood term used to describe data | Thompson et al., 2015 |
|  | C9. Low-med-high terms are not used | Low-med-high terms are used, but clarifying information like percentages or descriptions are also included | Low-med-high terms are used without any clarifying information | Thompson et al., 2015 |

**Appendix A References**

Bell, H. M., & Tobin, G. A. (2007). Efficient and effective? The 100-year flood in the communication and perception of flood risk. *Environmental Hazards*, *7*(4), 302–311. https://doi.org/10.1016/j.envhaz.2007.08.004

Brewer, C. A. (2005). *Designing Better Maps* (1st ed.). Redlands, CA: ESRI Press.

Cao, Y., Boruff, B. J., & Mcneill, I. M. (2016). Is a picture worth a thousand words ? Evaluating the effectiveness of maps for delivering wild fire warning information. *International Journal of Disaster Risk Reduction*, *19*, 179–196. https://doi.org/10.1016/j.ijdrr.2016.08.012

Centers for Disease Control and Prevention. (2012). *Cartographic Guidelines for Public Health*. Retrieved from http://geoscan.nrcan.gc.ca/starweb/geoscan/servlet.starweb?path=geoscan/fulle.web&search1=R=292122

Crozier, M. J., McClure, J., Vercoe, J., & Wilson, M. (2006). The effects of land zoning information on judgments about earthquake damage. *Environmental Hazards*, *38*(2), 143–152.

Dransch, D., Rotzoll, H., & Poser, K. (2010). The contribution of maps to the challenges of risk communication to the public. *International Journal of Digital Earth*, *3*(3), 292–311. https://doi.org/10.1080/17538941003774668

Hagemeier-Klose, M., & Wagner, K. (2009). Evaluation of flood hazard maps in print and web mapping services as information tools in flood risk communication. *Natural Hazards and Earth System Science*, *9*(2), 563–574. https://doi.org/10.5194/nhess-9-563-2009

Harrower, M., & Brewer, C. A. (2003). ColorBrewer.org: An online tool for selecting color schemes for maps. *The Cartographic Journal*, *40*(1), 27–37.

Haynes, K., Barclay, J., & Pidgeon, N. (2007). Volcanic hazard communication using maps: An evaluation of their effectiveness. *Bulletin of Volcanology*, *70*, 123–138. https://doi.org/10.1007/s00445-007-0124-7

Kunz, M., & Hurni, L. (2011). How to Enhance Cartographic Visualisations of Natural Hazards Assessment Results. *Cartographic Journal*, *48*(1), 60–71. https://doi.org/10.1179/1743277411Y.0000000001

Maidl, E., & Buchecker, M. (2015). Raising risk preparedness by flood risk communication. *Natural Hazards and Earth System Science*, *15*(7), 1577–1595. https://doi.org/10.5194/nhess-15-1577-2015

Nave, R., Isaia, R., Vilardo, G., & Barclay, J. (2010). Re-assessing volcanic hazard maps for improving volcanic risk communication: application to Stromboli Island , Italy. *Journal of Maps*, *6*(1), 260–269. https://doi.org/10.4113/jom.2010.1061

Robinson, A. (1952). *Cartography as a Visual Technique in The Look of Maps*. Madison, WI: University of Wisconsin Press.

Thompson, M. A., Lindsay, J. M., & Gaillard, J. (2015). The influence of probabilistic volcanic hazard map properties on hazard communication. *Journal of Applied Volcanology*, *4*(1), 6. https://doi.org/10.1186/s13617-015-0023-0

**Appendix B.** Map Updates from Hazard Map 1 to Hazard Map 2

|  |  |
| --- | --- |
| Visual Updates | Content Updates |
| **V1. Aerial imagery base map used** | **C1. Auxiliary information present along with mapped data** |
| * Replaced light grey canvas with streets base map with aerial base map | * Added sidebar with auxiliary information on each hazard and how to prepare |
| **V2. Landmarks are clearly visible to help viewer orient/locate oneself** | **C2. Risk messaging included and positively framed** |
| * No changes made | * See C1 example |
| **V3. Important map components are present and well-positioned on page** | **C3. Maps are personalized/customizable** |
| * Edited and moved “Earthquake Shaking” title to a tab at top of page * Edited and moved “Projected Flood Hazard Zone” title to tab at top | * No changes made |
| **V4. Visual Hierarchy is achieved through appropriate colors, symbols, font size, line width, and other symbolization techniques** | **C4. Information appears to be accurate and up-to-date and is presented in a clear and concise manner** |
| * No changes made | * No changes made |
| **V5. Appropriate color schemes are used on all data**   * Tsunami: layer changed from line to shaded region | **C5. Protective measures are included along with risk to facilitate preparedness rather than fatalism** |
| * Earthquake: changed scheme from diverging to sequential * Liquefaction: changed scheme from diverging to sequential * Flood: changed from 4 colors denoting the data source to single dark purple color | * See C1 example * Added a “How to Prepare” tab with information on what should be in a supply kit |
| **V6. If applicable, colors match hazard color** | **C6. Jargon/specialized terms are not used in map or descriptions** |
| * Tsunami: color changed from pink to blue to represent water * Liquefaction: colors changed from red-orange-green to shades of brown to better match hazard * Flood: Historical flood layer was added with years indicated by different colors of blue to represent water | * Earthquake: clarified Mercalli Intensity terms (e.g. “Very Strong” changed to “Very Strong (chimneys & plaster may fall)”) * Flooding: simplified language from four categories to a single flood hazard zone. Eliminated terms like “100-yr flood” |
| **V7. Less than 5 color classes are used (7 or less is ideal)** | **C7. Legend items are clearly explained** |
| * Earthquake: reduced number of categories from 6 to 5 | * See C6 earthquake example * Volcano: “High Hazard Zone” changed to “Eruption Zone” |
| **V8. Legend colors are matched exactly with those on map**   * Earthquake: Matched legend colors (HM1 did not match) | **C8. If data are probabilistic, then both percent (25%) and natural frequency (1 in 4) are used and likelihood term is not used to describe data** |
| * Liquefaction: Matched legend colors (HM1 did not match) * Volcano: Matched legend colors (HM1 did not match) | * No changes made |
| **V9. Color-blind friendly schemes are used** | **C9. Low-med-high terms are not used** |
| * All color schemes checked for colorblind friendliness * Liquefaction: colors adapted for color blind audiences (initial red-green scheme was difficult to see) | * Volcano: “High-” and “Moderate Hazard Zone” changed to   “Eruption Zone” and “Lahar (volcanic debris flow) Zone,” respectively |

**Appendix C.** Factor Analysis of Self-Report Scales

|  |  |  |  |
| --- | --- | --- | --- |
|  | F1 | F2 | F3 |
| (SBSOD) Santa Barbara Sense of Direction Scale (Strongly Agree - Strongly Disagree) | | | |
| 1. I am very good at giving directions. | .14 | .66† | .20 |
| 2. I have a poor memory for where I left things. | .06 | .50† | .25 |
| 3. I am very good at judging distances. | .22 | .43† | .08 |
| 4. My "sense of direction" is very good. | .13 | .79† | -.02 |
| 5. I tend to think of my environment in terms of cardinal directions (N, S, E, W). | .43 | .38 | -.03 |
| 6. I very easily get lost in a new city. | .04 | .69† | .13 |
| 7. I enjoy reading maps. | .52† | .30 | -.05 |
| 8. I have trouble understanding directions. | .19 | .69† | .22 |
| 9. I am very good at reading maps. | .55† | .08 | .06 |
| 10. I don't remember routes very well while riding as a passenger in a car. | -.10 | .72† | .20 |
| 11. I don't enjoy giving directions. | .13 | .63† | -.03 |
| 12. It's not important to me to know where I am. | .15 | .38† | .14 |
| 13. I usually let someone else do the navigational planning for long trips. | .24 | .72† | .09 |
| 14. I can usually remember a new route after I have traveled it only once. | .20 | .63† | -.19 |
| 15. I don't have a very good "mental map" of my environment. | .16 | .73† | .33 |
| (PSA) Philadelphia Spatial Ability Scale (Strongly Agree - Strongly Disagree) | | | |
| 1. I am good at determining if my car fits into an available parallel parking spot. | .17 | .42† | .15 |
| 2. I always know if a chair will fit through my front door before buying it. | -.01 | .36 | .30 |
| 3. I can easily visualize my room with a different furniture arrangement. | .11 | .22 | .42† |
| 4. I enjoy putting together puzzles. | .25 | .22 | .47† |
| 5. I have trouble giving someone directions, using a map that they are holding, without the ability to rotate the map to match the direction I am currently facing. | .52 | .44 | -.09 |
| 6. I can easily imagine what a 3D landscape would look like from a different point of view. | .54† | .28 | .06 |
| 7. I have a hard time recognizing a familiar place from a satellite image. | .47 | .49 | .08 |
| 8. I can easily visualize the location of electrical sockets along the other side of wall in the adjoining room to my bedroom. | .47† | .17 | .09 |
| 9. I am good at putting together furniture with only the use of diagrams. | .47† | .24 | .03 |
| 10. I can easily recreate an origami piece after watching someone else make it. | .51† | -.14 | .06 |
| 11. I can easily fold an elaborate paper airplane using a diagram. | .55† | .09 | .15 |
| 12. I can visualize what the cut face of an apple would look like when the apple is cut on different planes. | .61† | .19 | .18 |
| 13. I would be very good at building a model airplane, car, or train. | .65† | .10 | .15 |
| 14. I could clearly imagine what a soda can would look like after it was partially crushed. | .37 | .02 | .55† |
| 15. I can clearly imagine how snow would accumulate in a courtyard on a windy day. | .33† | .16 | .45 |
| 16. I can clearly imagine how water flows through a rocky landscape. | .47 | .10† | .34 |
| (Allocentric View) Spatial Ability Supplementary Items: To what extent… (Not at all - Very great extent) | | | |
| 1. are you good at finding your way to new places using maps? | .54† | .39 | .02 |
| 2. are you good at finding shorter or faster ways to places you go frequently? | .45† | .22 | -.11 |
| 3. can you tell what direction is North, South, East, or West, even if you are in an unfamiliar location? | .55† | .21 | .00 |
| 4. do you like to look at maps, just because they are interesting? | .22 | .41† | .05 |
| 5. When you want to go someplace unfamiliar, do you prefer to find your way by getting step-by-step directions or by looking at a map? (Prefer step by-step – Prefer map) | .48† | .33 | -.08 |
| (Metacognition) Map Comprehension Metacognition Scale (Strongly Agree - Strongly Disagree) | | | |
| 1. I found it difficult to find locations on the map. | .35† | .13 | .15 |
| 2. It was hard to understand what the questions were asking. | .46† | .11 | -.03 |
| 3. I found it difficult to understand the map legend. | .44† | .19 | -.13 |
| 4. The questions asked for information that was not available. | .32 | .25 | -.02 |
| (PVA) Philadelphia Verbal Ability Scale (Not at all - Very great extent) | | | |
| 1. I am good at crossword puzzles. | .10 | .15 | .49† |
| 2. I am good at Scrabble. | .03 | -.07 | .51† |
| 3. I often have trouble finding the right word to say. | -.16 | -.06 | .28 |
| 4. I would rather read a text explanation than look at a drawing or figure. | -.25 | -.11 | -.02 |
| 5. I have a good vocabulary. | -.27 | -.09 | .35 |
| 6. I spend more time reading than most people I know. | .27 | -.12 | .07 |
| 7. I prefer to watch TV or movies than to read for leisure. | .34† | -.09 | .00 |
| 8. I can easily follow a complex verbal argument. | -.27 | .23 | .45† |
| 9. I often have trouble expressing what I mean in words. | -.26 | .08 | .30 |
| 10. I have a good sense of language usage and write grammatically. | -.02 | -.25 | -.41† |

Note. † denotes significant factor loading.