Hawaiʻi Cesspool Hazard Assessment & Prioritization Tool

Risk-Factor Assessment Survey and Workshops

Addendum to 2021 Report & Technical Appendices

June 2022

Prepared For:

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1. Project Purpose and Background

This document describes ongoing efforts to assist the cesspool conversion process since the release of the publication, the ‘Hawaiʻi Cesspool Hazard Assessment & Prioritization Tool Report & Technical Appendices’ in August 2021. In particular, this report addendum provides updates to the iterative cesspool prioritization methodology and expert opinion workshops held in early 2022. The prioritization of cesspools presents a useful method to quantify their relative impact on human and environmental health. Prioritization will also inform timetables recommended by the State of Hawaiʻi Cesspool Conversion Working Group (CCWG) for conversion to more advanced forms of wastewater treatment. This work was undertaken on behalf of the State of Hawaiʻi Department of Health (DOH) Wastewater Branch to inform ongoing DOH and CCWG planning processes for statewide cesspool conversion plan development.

In 2021, the ‘Hawaiʻi Cesspool Hazard Assessment & Prioritization Tool Report & Technical Appendices’ was created to provide the DOH and CCWG with a comprehensive and data driven method to prioritize which cesspools likely have the most impact on human and environmental health. The report included consideration of fifteen risk-factors used to assess each geographic area’s vulnerability to contamination from cesspools. The factors were intended to be used to inform cesspool conversion prioritization and onsite wastewater planning throughout the state of Hawaiʻi.

These factors included:

1. Distance to municipal drinking water wells;
2. Distance to domestic drinking water wells;
3. Well capture zones
4. Distance to streams and wetlands;
5. Distance to coastline;
6. Sea level rise zones;
7. Precipitation;
8. Depth to groundwater;
9. Soil characteristics;
10. Cesspool density;
11. Coral cover;
12. Fish biomass/recovery potential;
13. Beach user-days;
14. Proximity to lifeguarded beach; and
15. Coastal ocean circulation proxy

This information and associated data were included in a geographic information system (GIS) tool titled: the Hawaiʻi Cesspool Prioritization Tool (HCPT), accessible through http://hawaiicesspooltool.org. The 2021 version of the HCPT weighted each of the fifteen risk factors equally in its prioritization calculation.

In 2022, the DOH directed a team from the University of Hawaiʻi (UH) Sea Grant College Program (Hawaiʻi Sea Grant), UH Water Resources Research Center, and One World One Water, LLC to refine the HCPT structure by developing and implementing an expert-driven methodology for weighting of the fifteen risk-factors. Specifically, the project team sought to answer these questions:

- Does weighting the fifteen risk-factors equally reflect the best available knowledge of subject matter experts relative to the risk of cesspool contamination?
- If not, which of the fifteen risk-factors are most critical to consider in the cesspool conversion prioritization process?
- How does an expert-informed weighting process change the priority rankings in each of the geographic areas outlined by the 2021 report (equal weights)?

2. Process and Methodology

a. Participants

The end goal of the updated weighting process was to synthesize contributions from a panel of experts into fifteen numeric weighting factors corresponding to each of the risk-factors used in the HCPT. The process was initiated by identifying subject matter areas related to the risk-factors used in the tool. Experts in each subject-matter area from Hawaiʻi, the Pacific, and the continental United States were identified by the project team and the DOH through research and personal recommendations. Invitees were contacted either by email or phone and briefed on the project background and purpose, and invited to participate in the expert weighting exercise.

The participant areas of expertise included:

DOH Regulatory and Wastewater Engineering
Coral Reef Ecosystems
Wells, Groundwater, and Drinking Water
Society and Economics
Surface Water, Aquatic Resources, Wildlife
Wastewater Engineering and Soils
Tourism and Recreation
Oceanography and Microbiology
Coastal Geochemistry and Water Quality
Native Hawaiian Affairs and Water Law
Coastal Biology and Limu
Center for Water Resource Management
Water Quality and Sewage Pollution
Public Drinking Water
Coral Reefs and Coastal Processes
Law, Policy, and Planning
State Coastal Planning
UH Environmental Science Students

b. Workshops, Survey, and Analysis

Two virtual workshops were held on the Zoom virtual meeting platform, and participants were asked to independently complete a survey during the interval between the workshop events. The first workshop was held on Wednesday, March 2nd, 2022 and lasted for one hour. Workshop 1 focused on providing background and context to attendees, as well as explaining the survey, which was used to collect quantitative and qualitative information from participants. Following Workshop 1, the 2021 ‘Hawaiʻi Cesspool Hazard Assessment & Prioritization Tool Report & Technical Appendices’ and the website for the online HCPT were shared with participants, along with the detailed instructions about the online survey which were shared orally during Workshop 1.

The survey consisted of thirty questions. For each of the fifteen risk-factors, the survey asked for users to assign a weight from 1-5 for each factor.

The Scoring Rubric was defined as:

> *Weight of (1) Baseline: Factor is important, but not exceptionally.*
>
> *Weight of (2) Double weight: Factor is more important than baseline.*
>
> *Weight of (3) Triple weight: Factor is very important.*
>
> *Weight of (4) Quadruple weight: Factor is one of the most important factors of all.*
>
> *Weight of (5) Extremely important: reserved for the single or few factors that are the primary drivers of impact.*

Users were then asked to provide a brief explanation of why they weighed the factor as they did, and to share references and other relevant information that informed their decisions. Participants were also asked if they wished to share their name and affiliation within the addendum report. This choice was optional so participants could speak freely and openly.

Following the survey period (March 2nd-23rd, 2022) and preceding the second workshop, the project team processed the survey results in order to share them with the participants and to facilitate discussion and feedback during the second workshop.

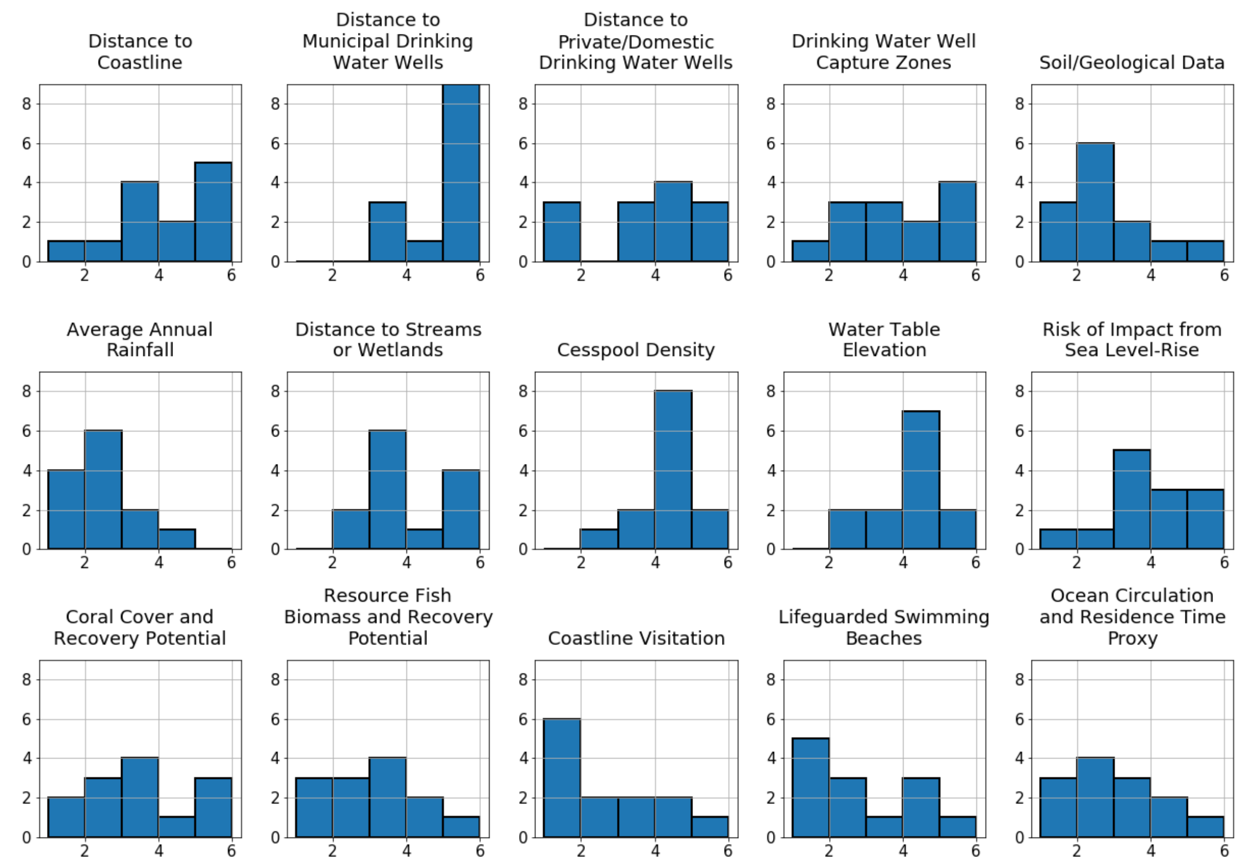
The second workshop was held on Wednesday, March 30th, 2022 and lasted two hours. The primary focus of Workshop 2 was communicating the results of the survey and analysis. The intent of the survey was to create a 'multiplication factor', or weight, for each of the fifteen risk-factors. Survey results were collected in a Google Form, which populated quantitative responses (weighted rankings) into a Google spreadsheet. Pandas, the Python analysis library, was used for the quantitative analysis of the results.

Raw Data from Survey:

Rank	Distance to Coastline	Distance to Municipal Drinking Water Wells	Distance to Private/ Domestic Drinking Water Wells	Drinking Water Well Capture Zones	Soil/ Geological Data	Average Annual Rainfall	Distance to Streams or Wetlands	Cesspool Density	Water Table Elevation	Risk of Impact from Sea Level-Rise	Coral Cover and Recovery Potential	Resource Fish Biomass and Recovery Potential	Coastline Visitation	Lifeguarded Swimming Beaches	Ocean Circulation and Residence Time Proxy
0	5	5	3	3	4	4	5	4	4	3	3	3	4	4	3
1	1	5	4	4	5	2	3	4	4	3	3	3	3	3	2
2	4	5	5	5	2	1	3	4	4	3	1	1	1	1	1
3	2	5	4	5	2	3	2	4	2	3	3	3	3	2	4
4	5	5	3	5	3	3	5	5	4	5	3	3	1	2	3
5	3	3	3	2	2	2	3	4	3	4	2	1	1	1	2
6	3	5	1	4	1	2	5	3	5	5	5	5	5	5	4
7	5	5	5	3	2	2	3	4	3	4	4	4	4	4	2
8	3	5	5	2	3	2	3	4	4	1	2	2	2	2	1
9	4	5	4	5	2	2	5	3	4	3	5	4	2	4	5
10	3	3	4	3	1	1	2	5	4	2	2	2	1	1	3
11	5	3	1	2	2	1	3	2	2	4	5	2	1	1	2
12	5	4	1	1	1	1	4	4	5	5	1	1	1	1	1

Histograms were used and presented in the workshop to display the spectrum of weights assigned by the group to each of the fifteen risk factors. Histograms are useful in this context because they not only show which factors scored the 'highest' (higher weights being equivalent to a greater level of importance in prioritization considerations), but also indicate the spread of participants' rankings, which is quantified as the standard deviation of each risk-factor's results. This spread indicated the level of consensus among respondents, with a higher standard deviation equating to a greater difference of opinion among respondents and a lower standard deviation indicating better consensus.

Histograms:



It was necessary to combine each of the participants' responses into a single weight for each factor. However, there are many mathematical ways to achieve this result and each has unique advantages and disadvantages. Therefore, a number of aggregation techniques were explored. These included basic statistical metrics, specifically the mean and median of each distribution, as well as a non-parametric calculation that counted the number of individual scores given to each factor (i.e. 4, '1's', 3 '2's', etc.), and used a separate weighting factor for each of the sums of scores. These "weighted weights" were then normalized into a single number (see https://github.com/cshuler/Act132_Cesspool_Prioritization for details). The different aggregation methods were presented to the participants of the second workshop and due to the similarity in the results of each, and the desire to communicate simply and effectively, it was agreed upon that the median value of each of the raw weights was the preferred method for calculating a single weight for each factor.

Quantitative analysis:

Factor	Mean	Median	Standard Deviation	Rank: 1	Rank: 2	Rank: 3	Rank: 4	Rank: 5	Weighted Weights
Distance to Municipal Drinking Water Wells	4.5	5	0.9	0	0	3	1	9	6.4
Distance to Coastline	3.7	4	1.3	1	1	4	2	5	4.6
Drinking Water Well Capture Zones	3.4	3	1.4	1	3	3	2	4	3.8
Distance to Streams or Wetlands	3.5	3	1.1	0	2	6	1	4	4
Distance to Private/Domestic Drinking Water Wells	3.3	4	1.5	3	0	3	4	3	4
Risk of Impact from Sea Level-Rise	3.5	3	1.2	1	1	5	3	3	4
Coral Cover and Recovery Potential	3	3	1.4	2	3	4	1	3	3
Cesspool Density	3.8	4	0.8	0	1	2	8	2	4.8
Water Table Elevation	3.7	4	0.9	0	2	2	7	2	4.4
Soil/Geological Data	2.3	2	1.2	3	6	2	1	1	1.4
Resource Fish Biomass and Recovery Potential	2.6	3	1.3	3	3	4	2	1	2.2
Coastline Visitation	2.2	2	1.4	6	2	2	2	1	1.8
Lifeguarded Swimming Beaches	2.4	2	1.4	5	3	1	3	1	2
Ocean Circulation	2.5	2	1.3	3	4	3	2	1	2
Average Annual Rainfall	2	2	0.9	4	6	2	1	0	0.8

c. Survey Outcomes

The weighting activity for each of the fifteen risk-factors resulted in fairly normal distributions for most parameters. Only *Distance to Municipal Drinking Water Wells* had a median score of '5'. This was the highest weighted ranking, indicating that the factor is 'Extremely important: reserved for the single or few factors that are the primary drivers of impact' and also had the second lowest standard deviation of all factors, which denotes concurrence among the survey respondents. Four factors scored as '4: *Quadruple weight: Factor is one of the most important factors of all'*. These factors included *Distance to Coastline*, *Distance to Private/Domestic Drinking Water Wells*, *Cesspool Density*, and *Water Table Elevation*. Four factors scored as '3: Triple weight: Factor is very important'. These factors included *Drinking Water Well Capture Zones*, *Distance to Streams or Wetlands*, *Risk of Impact from Sea Level Rise*, *Coral Cover and Recovery Potential*, and *Resource Fish Biomass and Recovery Potential*. Five factors scored as '2: Double weight: Factor is more important than baseline'. These factors included, *Soil/Ecological Data*, *Coastline Visitation*, *Lifeguarded Swimming Beaches*, *Ocean Circulation*, and *Average Annual Rainfall*. No factors scored as '1: Baseline: Factor is important, but not exceptionally'. The factors with the highest levels of concurrence (lowest standard deviation) were *Cesspool Density*, which ranked as a '4' and *Distance to Municipal Drinking Wells*, which ranked as a '5'.

Factor	Weight
Distance to Municipal Drinking Water Wells	5
Distance to Coastline	4
Distance to Private/Domestic Drinking Water Wells	4
Cesspool Density	4
Water Table Elevation	4
Drinking Water Well Capture Zone	3
Distance to Streams or Wetlands.	3
Risk of Impact from Sea Level Rise.	3
Coral Cover and Recovery Potential	3
Resource Fish Biomass and Recovery Potential	3
Soil/Ecological Data	2
Coastline Visitation	2
Lifeguarded Swimming Beaches	2
Ocean Circulation and Residence Time Proxy	2
Average Annual Rainfall	2

3. Limitations and Notable Feedback

The methods of gathering expert feedback included some limitations which should be noted to improve future iterations of this or similar processes, which are further elaborated in the following subsections.

a. Attendance

The workshops were held virtually to encourage the highest level of attendance possible during the COVID-19 pandemic and as recommended by local and national guidelines. Not all attendees of the first workshop elected to participate in the subsequent survey, nor did all initial attendees attend the second workshop. However, the number of participants and their representative spectrum of expertise was considered acceptable to continue with the weighting exercise. The survey results were processed and analyzed with the potential for future exercises to build upon the results if deemed appropriate. An alternative meeting structure could have requested participants to attend a full day ‘seminar’ during which the content of both workshops and the survey would have occurred during a single, though substantially longer, meeting. This approach would have capitalized on the ‘captive audience’ to ensure a high level of participation in the survey. However, due to the time commitment of such an event, which likely would have lasted 4-5 hours, it is unknown whether attendance would have actually increased with this format compared to the chosen format of multiple workshops held several weeks apart with the survey taken in between.

b. Areas of Expertise and the Survey Scoring Rubric

Attendees were invited to participate in the workshops so that they could provide their subject-matter knowledge and enhance the weighting process. In the 2021 iteration of the prioritization exercise all factors were considered equal. The 2022 workshops were intended to interrogate this approach and create a more rigorous methodology for weighting the factors based on a broader spectrum of expertise. However, no one can be an expert in all subject areas. In order to account for the fact that respondents may have ranked certain factors with a low weight because they felt less informed about those subject areas, a ‘weighted weight’ which ignored low ranks was added to the statistical analysis. Ultimately, it was determined that the three analysis options (mean, median, and ‘weighted weights’) produced comparable results.

c. Feedback on Data Sets

i. Regional Variability

Relating to the risk-factors ‘Soils and Average Annual Rainfall’:

The prioritization tool was designed for management decisions at the state level, and the fifteen data sets used as risk-factors were selected based on their statewide coverage. However, Hawaiʻi has certain regions with distinct characteristics. For instance, the hydrogeology of the Kona region of Hawaiʻi Island is markedly different from most other areas of the state in that water dissipates quickly from the surface into the subterranean environment. In this region, coastal water quality is greatly influenced by land-based contaminants. Similarly, preliminary research shared by the participants indicates great differences in wastewater as well as other indicators in Kona vs. Hilo, substantiating the potential role of rainwater in dilution of contaminants prior to entering coastal waters. In certain circumstances, 'outlier' areas of the state, in this case one of the driest and one of the wettest regions, may merit further consideration and scenario planning when developing prioritization and conversion timelines. It was also noted that peak rainfall, which can cause cesspool overflow, may be more descriptive in areas prone to intense precipitation, compared to average annual rainfall which is less likely to capture such events. Rather than a one-size-fits-all analysis, this tool can be considered as a foundational layer for statewide management and decision-making.

<u>ii. Policy Gaps</u>

Relating to the risk-factor 'Cesspool Density':

Since 2000, the United States Environmental Protection Agency (EPA) has banned large-capacity cesspools, which are generally defined as serving over twenty individuals. However, participants noted that not only are some large-capacity cesspools still in operation in Hawaiʻi, but certain high-density residential areas with active cesspools are contributing contaminants to the environment in a similar way to those of 'large capacity'. Yet, these cesspools are subject to the same state-level regulations as any other cesspool. This comment was made to highlight the enforcement gap between banned large-capacity cesspools and high-density operational cesspools, and to reinforce the participant's ranking of 'Cesspool Density' as a highly important factor for conversion consideration.

<u>iii. Complications Along the Coast</u>

Relating to the risk-factors 'Distance to Coastline' and 'Sea Level Rise Exposure':

Participants discussed the fact that many oceanfront homes are already experiencing visible tidal fluctuations in their cesspools. Though 'Distance to Coastline' is a straightforward indicator of the potential for land-sea connectivity, Hawaiʻi does have some coastal real estate located on bluffs, high above sea level. For this reason, 'Sea Level Rise Exposure' is likely to be a more appropriate indicator of cesspools located at or near current sea level, with both present-day or future potential for groundwater inundation and cesspool failure. Participants also noted the quandary of residential homes with cesspools and the most imminent risk of coastal erosion (i.e., the North Shore of Oahu) for whom cesspool replacement is threatened by large winter storms and swells. These homeowners may elect to wait 'until the last minute' (closer to 2050) to replace their systems given the variability in erosion on a multi-decadal timescale, though those homes may be high-risk to human and environmental health given their extreme proximity to the ocean and high likelihood of total cesspool failure (i.e. system collapse).

<u>iv. Redundancy</u>

Relating to the risk-factors 'Beach user-days', 'Proximity to lifeguarded beach', 'Distance to Coastline', and 'Sea Level Rise Exposure':

Because the two factors 'Distance to Coastline' and 'Sea Level Rise Exposure' already have the potential to highlight those cesspools with the most direct impact on coastal areas, participants pointed out that the risk-factors 'Beach user-days' and 'Proximity to lifeguarded beach' may be duplicative. It can be noted that from a human health perspective, the risk-factors 'Beach user-days' and 'Proximity to lifeguarded beach' more readily highlight concentrations of human activity than 'Distance to Coastline', and 'Sea Level Rise Exposure'. In particular, areas like Kula, Maui which are regarded as "up country" have a direct and hazardous impact on Kihei, Maui beaches, despite their distance from the coastline.

d. Feedback on Methodology

<u>i. Socio-Economic Considerations</u>

This prioritization exercise focuses primarily on the cesspool risk-factors impacting human and environmental health. This provides a foundation to build upon, and can be further enhanced through the use of socio-economic data. When U.S. Census tracts are overlain on the HCPT tool, attributes like median household income can provide further insight and decision-making information. For instance, the state could compare Priority 1 areas of the greatest potential for contamination to areas of the lowest median household income. The intersection of these two layers would illustrate possible recipient areas for grant funding to facilitate the conversion of active cesspools into more advanced forms of wastewater treatment.

<u>ii. Survey Design</u>

The survey asked participants to consider each of the fifteen risk-factors according to a scoring rubric, by assigning a weight from 1-5 for each factor. For the weights of 5 (Extremely important: reserved for the single or few factors that are the primary drivers of impact) and 4 (Quadruple weight: Factor is one of the most important factors of all), the scoring rubric suggested that survey taker limit the number of high weights that were assigned (i.e. 'reserved for the single or few factors…). These instructions may have been interpreted differently by each participant. An alternative would have been to overtly limit the number of each ranking that could be assigned (i.e. allocating a single '5', up to three '4's, etc.).

Extended Survey Responses

To view the complete survey responses and feedback, please navigate to:
https://github.com/cshuler/Act132_Cesspool_Prioritization/blob/main/Workshop2_analysis/Workshop%202%20Data%20Analysis.ipynb

4. Prioritization Results

The HCPT prioritization method places each geographic area into three Prioritization Categories that include:

1. **Priority Level 1:** Greatest contamination hazard (map color of red).
2. **Priority Level 2:** Significant contamination hazard (map color of orange).
3. **Priority Level 3:** Pronounced contamination hazard (map color of yellow).

Under the 2021 equal weighting scenario, the total number of cesspools in the state categorized as Priority Level 1 was 13,885, with 13,482 and 54,058 as Priority Level 2 and Priority Level 3, respectively. Approximately 35%, 7%, 21%, and 37% of cesspools in the Priority Level 1 group are located on Oʻahu, Maui, Kauaʻi, and Hawaiʻi Island, respectively.

Under the 2022 expert-informed weighting scenario, the total number of cesspools in the state categorized as Priority Level 1 was 13,821, with 12,367 and 55,237 as Priority Level 2 and Priority Level 3, respectively. Approximately 35%, 7%, 21%, and 37% of cesspools in the Priority Level 1 group are located on Oʻahu, Maui, Kauaʻi, and Hawaiʻi Island, respectively.

Census tracts that changed as a result of the expert-informed weighting process included:

Island, Census Tract Number (Tract #), and Cesspool Count	Original Rank	New Workshop Rank
Kauai		
Kauai: Puhi-Hanama'ulu: Tract#284: Cesspool Count =362	3 (Low)	2 (Medium)
Oahu		
Oahu: Nanakuli: Tract#13: Cesspool Count =96	1 (High)	2 (Medium)
Oahu: Kapiolani Park: Tract#227: Cesspool Count =32	2 (Medium)	1 (High)
Maui		
Maui: Honokowai: Tract#293: Cesspool Count =62	2 (Medium)	3 (Low)
Maui: Waihee-Waikapu: Tract#322: Cesspool Count =590	3 (Low)	2 (Medium)
Maui: Kula: Tract#325: Cesspool Count =2268	2 (Medium)	3 (Low)
Hawaiʻi Island		
BI: Hilo: University-Houselots: Tract#141: Cesspool Count =549	3 (Low)	2 (Medium)
BI: Hilo: Puʻuʻeo-Downtown: Tract#143: Cesspool Count =350	2 (Medium)	3 (Low)

Overall, there were minimal differences between the HCPT's 2021 equal weighting scenario and the 2022 expert-informed version of the tool. Statewide, eight census tracts shifted in priority designation between the two methodological approaches. Of these eight census tracts, the shift in priority was limited to a single step; e.g. none of the census tracts went from high to low priority or low to high priority.

The relative similarity between the two versions of the tool serves to validate the overall robustness of the 2021 HCPT tool. In many locations, similarities can be attributed to the fact that the cesspools which ranked as the highest priority for conversion negatively impact multiple aspects of social and environmental health, and the weights of individual factors are less important than the sum of the many impacts on risk-factors in the high priority ranked areas. This outcome was also alluded to by a sensitivity test detailed in the 2021 report, where hypothetical weights were applied to each factor collectively within different weighting scenarios. The sensitivity test indicated the changes in prioritization under different weighting strategies were likely to show small differences. Nonetheless, despite the limited magnitude of change, the social-science based weighting exercise was extremely valuable for not only demonstrating the validity of the results, but also for improving the robustness of the tool's methodology, including expanding the dimensionality of the tool's input. This robustness if now demonstrated by way of incorporating the expert judgements of knowledgeable practitioners and scholars.

5. Next Steps

The results of this effort will be shared with the DOH Wastewater Branch to inform ongoing cesspool conversion prioritization efforts. This work and the HCPT is only one part of Hawaiʻi's cesspool conversion prioritization process, as numerous other datasets including social, financial, and water quality impacts will also be factored into the cesspool prioritization process.

6. Technical Contributors

Role	Name
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Drinking Water Wells and Groundwater	Robert Whittier
Society and Economics	Kirsten Oleson
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Tourism and Recreation	N/A
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Coastal Biology/Limu	Wished to remain anonymous
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