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Interactive comment on "A Modular, Non-Newtonian, Model, Library Framework (DebrisLib) for Post-Wildfire Flood Risk Management" *by* Ian E. Floyd et al.

Anonymous Referee #1

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This manuscript introduces a computational library (DebrisLib) that can be used to help solve equations commonly used to represent the movement of geophysical flows. The library is designed to interact with models that utilize the shallow-water equations as a base, allowing for a range of flow resistance terms to be employed. The framework is tested by calling the library from two different models, HEC-RAS and AdH, and demonstrating that the models can reproduce results of experiments. The authors highlight several benefits of DebrisLib, including the ability for users to simulate geophysical flows that transition among a range of flow types from clear water flows to hyperconcentrated flows and debris flows. The work is motivated by an increasing need for models that are capable of simulating the range of flow conditions commonly observed in post-fire flows. I agree that there is a need for improved modeling frameworks to simulate post-fire flows and see the benefit of a library like DebrisLib, which could add greater transparency, reproducibility, and flexibility to modeling efforts. However, I also have several comments and questions about methodology, assumptions regarding connections between flow rheology and flow classification, and how DebrisLib would be applied specifically to model post-fire flows, that I hope the authors find helpful in revising the manuscript.

General Comments:

1. The current capabilities of DebrisLib need to be more clearly articulated and separated from future improvements that are planned or still in development. There are hints that DebrisLib uses nondimensional thresholds to determine flow type and/or the relative importance of different flow resistance terms (lines 13-15, line 104). There are no nondimensional thresholds presented in this manuscript. In the model tests, it seemed like a particular rheology was assumed (i.e. line 305). This is an adequate test of the code and demonstrates that the library can be called from USACE shallow-water models, but falls short of testing a computational library that "...consolidates algorithms for each process and discriminates between these processes and algorithms with quantitative nondimensional thresholds." Similarly, there are places where it appears that sediment entrainment and/or deposition may somehow be involved but no erosion or deposition equations are presented.

2. The methods, especially specifics of how DebrisLib interacts with the parent code and how/why different rheological models were chosen for the test cases needs to be better described.

3. The flow classification system in Figure 1 needs to be more thoroughly described and justified. There are a number of assumptions regarding relationships between sediment concentration, grain size, and flow behavior. No definitions are given for mudflow, hyperconcentrated flow, or debris flow other than a general description in

line 68 that does not differentiate the three flow types. The differences between the four flow types defined in Figure 1 and mentioned throughout the text will need to be clarified. The relationship between the different rheological models included in the current version of DebrisLib and the flow classification scheme in Figure 1 needs to be described (lines 115-116 suggests there may be some relationship between the two but it is not clear).

4. DebrisLib makes it easier for modelers to employ different non-Newtonian rheological models but does not address the underlying issue that there is no objective way to define transitions in flow type. Moreover, it's not clear that transitioning from one rheological model to another as suggested by Figure 1 would be a practical way to simulate flows that transition from one flow type to another. Even when modeling the same flow through a watershed, it is not unreasonable to think that the optimal parameter values (e.g. for viscosity) will change as different rheological models are employed. There are no test cases that address issues related to flow transitions and no discussion of the limitations of the approach suggested by Figure 1. I could see multiple studies being dedicated to answering these types of questions so I don't expect them all to be answered here, but the limitations of the conceptual framework laid out in Figure 1 should be more thoroughly discussed, particularly within the context of how DebrisLib could be employed to simulate post-fire flows.

5. Post-fire hazards are mentioned as a motivating factor for developing DebrisLib and while I agree that DebrisLib could be quite useful for modeling post-fire flows, there is not a focus on fire throughout the manuscript and no test cases are related to post-fire flows. The title and motivation for the study should be revised or relevant details added about the effects of fire on hydrologic and geomorphic systems and how they lead to the generation of different types of geophysical flows.

Other Comments:

Line 11: Consider "non-Newtonian models" instead of "non-Newtonian algorithms"

Line 13: Consider “approaches to simulating non-Newtonian flows” rather than “approach to non-Newtonian simulations”.

Line 13-15: But there are no nondimensional thresholds presented in this manuscript.

Line 23: I suggest “. . .post-wildfire flooding and debris flows” rather than only “. . .post-fire flooding.”

Line 27-28: References needed for “Wildfires remove vegetation, reduce organic. . ..” There is an implicit assumption here that the authors are referring to moderate or high severity fires so that should be mentioned.

Line 28: Fire can also reduce hydrophobicity and/or increase soil infiltration capacity in some cases.

Line 28: Consider “These changes” rather than “These processes”

Line 29: “Post-wildfire environments can cause. . .” Citations needed here.

Line 31: “In the years following a wildfire. . .” Citations needed here.

Line 33: This is very similar to what was already mentioned in line 27. I suggest removing this sentence and moving the references to the line beginning “Wildfire removes vegetation. . .”

Line 35: This sentence seems out of place here at the end of a wildfire-focused paragraph.

Line 38: It may be better to use a more general term such as “geophysical flows” rather than “non-Newtonian flows” in situations like this. The term “non-Newtonian” may imply the flow is being treated as an idealized fluid when some of the references cited treat the flow like a mixture where the stresses associated with the fluid and solid phases are evaluated separately (e.g. Iverson and Denlinger, 2001).

Line 45: Yes, but this could be motivated better with an expanded introduction. For example, past studies focused on post-fire flooding and debris flow initiation have demonstrated that debris flows are often triggered when rainfall intensity-duration (ID) thresholds are exceeded. Flows may transition from floods to debris flows (and everything in between) multiple times, even within the same rainstorm, depending on rainfall characteristics. Since rainfall ID thresholds for post-fire debris flow initiation may be on the order of a 1-year recurrence interval storm (e.g. Staley et al., 2020), transitions from floods or hyperconcentrated flows to debris flows are more likely to occur in recently burned areas relative to similar unburned areas.

Line 59: The manuscript briefly mentions some of the numerical algorithms but it would be helpful to describe the library and linkage architecture in more detail in the methods section.

Line 63: Impacts of wildfire extend beyond arid and semi-arid environments.

Line 64: Be more specific and include some reference(s) here. Recovery is defined in many different ways. Are you referring to hydrologic recovery, return of infiltration capacity or vegetation type/density to the pre-fire condition, etc?

Line 66: “wildfire-precipitation mix” is confusing. “wildfire-precipitation sequence”?

Line 70-73: This may fit better in the introduction to motivate the need for something like DebrisLib for post-fire flow modeling.

Line 72-73: Does this refer to the grain size distribution of the flow or of the hillslope and channel sediment? These are arguably factors that determine flow behavior given a particular runoff response, but there are many other factors that help determine how rainfall leads to runoff and sediment transport in a given burn area (burn severity, soil hydraulic properties, topography, ground cover).

Line 74: What processes?

Line 81: Add citation here for “dispersive model”.

Line 92-97: Flow classifications need to be defined in some way. What is the difference between a hyperconcentrated flow and a mudflow? To what extent is the transition from one flow type to another dependent on sediment concentration versus grain size distribution? I appreciate the need for a conceptual model that helps motivate why libraries such as DebrisLib are useful, but I think this conceptual model overstates how much is known about these different types of flows and how they are related. It's also unclear if this is simply a conceptual model used to motivate the need for DerbisLib or if it is used in some way to determine flow rheology in this manuscript (i.e. for test cases presented later).

Line 100: Here and elsewhere, consider "post-wildfire flow responses" or "post-fire hydrologic responses" as a more general term since "flood" usually implies lower sediment concentration.

Line 104: "…determines flow conditions using non-dimensional parameters" Such as? What are these thresholds, how are they applied, and what flow types/conditions are they used to distinguish?

Line 105: "addresses hindered settling" suggests that entrainment and deposition are being modeled but this is not addressed elsewhere in the manuscript. Does settling still occur in flows classified as "debris flows"?

Line 106: It's not clear what is meant by "accounts for increased viscosities and mass density"

Line 109: This seems inconsistent with the prior line about hindered settling already being included.

Line 110: change to "requires computing"

Line 115: How is the flow classification made? How is flow classification related to rheology? This is a critical piece to the puzzle for simulating post-fire flows where flow classification may change rapidly in space and time, even during a single rainstorm.

Line 118-119: This is confusing because entrainment and deposition are not discussed here or elsewhere. If they are modeled, how are they modeled? If they are not modeled, then sediment concentration must be supplied as an input and the flow density, depth, etc, should already be consistent with that input sediment concentration so there would not be a need to modify flow properties.

Line 160: I get lost here. Is there a transition from a general discussion of the shallow water equations to the particular form of the equations that is used in HEC-RAS? I would remove the reference here to the diffusive wave approximation since it is not discussed in this section.

Line 181: Reference(s) needed. This is assuming that an effective fluid model is appropriate in the first place. In line 231, for example, "rheological models do not perform as well as the mixtures get more clastic".

Line 231: Reference(s) needed.

Line 234: change to "...yield strength with a geotechnical. . ."

Line 242: The numerical methods section would benefit from additional detail. It appears that this section mostly describes the shallow water parent code in general terms but does not describe specifics of how the mud and debris flow shear stress term, which is presumably computed by DebrisLib, is incorporated into the numerical solution of the parent code. Is this resistance term dealt with explicitly or implicitly and what specific methods are used? It is not uncommon for friction terms in shallow water models to promote instabilities or be stiff (e.g. Xia and Liang, 2018; Berthon et al., 2011) under certain circumstances so understanding how they were dealt with in the two models tested here could help readers determine if/how they may use DebrisLib in their models.

Line 263: How were simulations conducted? Were numerous rheological models tested? Was a single rheology tested (or some subset of the rheologies in Debris-

Lib) based on what was known about flow properties?

Line 264: change to “flume experiments”

Line 300: change to “ceases”

Line 301: Consider “This analytical solution can be used to compute the run-out length, which is...., and the final depth profile."

Line 303: Check wording here “with to include”

Line 305: “models” instead of “model”

Line 306: So the results in Figure 2 are using a Bingham rheology? Please clarify and include the model rheology in the caption for Figure 2.

Line 309: Missing a phrase to start the sentence “HEC-RAS+DebrisLib. . ..”

Line 312: Some words are missing between “2006” and “5-degree”

Line 313: This sentence is essentially a repeat of the first sentence in the paragraph so it can be removed.

Line 316: The thought starting with “And O’Brien. . .” is a sentence fragment.

Line 325: “aimed at better”

Line 332: Somewhere in this sentence it would be good to remind the reader that you are referring to the USGS flume experiments or remove this sentence and start the paragraph with the next one.

Line 333-334: What rheology was assumed in these simulations? The number of simulations, parameter ranges involved in calibrations, and rheology used should be described in the methods section.

Line 333-334: “flow surface” would be more accurate than “water surface” and “water level” since the simulations presumably involve modeling a flow that contains both water and sediment.

Line 346: I don't see what makes the library a "post-wildfire non-Newtonian library" as opposed to a "non-Newtonian library".

Line 349: The taxonomy shown in Figure 1 and described in the background section is not sufficiently detailed to allow a model user to objectively assign flow classifications based on the physical properties of the flow.

Line 356: Since the development of DebrisLib appears to be the primary contribution of this study, it seems important for the code to be released at the time of publication.

Line 376: Note the difference between fire intensity and fire severity. "Fire severity" is probably a better term here given that the focus is on the fire's impact on the vegetation and soil.

Line 376: Consider "...can create or enhance soil hydrophobicity" rather than "create widespread hydrophobic soils"

Line 383: What is the distinguishing factor here between "non-Newtonian" and "sediment transport" here. I didn't think there was a focus on sediment transport here.

Line 383: To justify "easily connect", it would be helpful to be more specific about how DebrisLib was connected to the parent code.

Line 385-386: This may be overstating the results since no post-fire flows were modeled. I do see how it would make it easier to use a single modeling framework to explore inundation scenarios associated with different types of geophysical flows that could be anticipated following a fire.

References

Berthon, C., Marche, F. and Turpault, R., 2011. An efficient scheme on wet/dry transitions for shallow water equations with friction. Computers & fluids, 48(1), pp.192-201.

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Discussion paper

Staley, D.M., Kean, J.W. and Rengers, F.K., 2020. The recurrence interval of post-fire debris-flow generating rainfall in the southwestern United States. Geomorphology, 370, p.107392.

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