Thesis Project Portfolio

Decentralized Water Systems for Rural Fire Protection: A Technical Approach to Equitable Infrastructure

(Technical Report)

Examining Water Infrastructure for Fire Protection Through Transparency, Embeddedness, and Reach

(STS Research Paper)

An Undergraduate Thesis

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Sociotechnical Synthesis

My capstone research addresses the problem of unequal water access for firefighting in rural and semi-urban areas. While urban communities benefit from dense networks of fire hydrants, rural fire departments often rely on distant or unreliable water sources, leading to dangerous delays in emergency response. This disparity in infrastructure creates unequal outcomes when fires occur, especially in low-density or underfunded regions. To address this problem, I analyzed decentralized water storage systems such as engineered cisterns and designated drafting points as scalable, NFPA-compliant solutions. These systems are designed to supplement or replace traditional hydrant networks in areas where those networks do not exist. My research included operational analysis, field training, and expert interviews to evaluate how decentralized water access can be integrated into emergency planning and fire service operations.

It is critical to consider the human and social dimensions of this infrastructure. Water systems are not neutral technologies, they reflect broader decisions about which communities are prioritized for protection. In underserved rural regions, delayed fire response can result in greater property loss and risk to life, revealing deeper issues of visibility, investment, and geographic inequality in infrastructure planning.

I applied two core theories from Science, Technology, and Society (STS): Susan Leigh Star's concept of infrastructure as a socio-technical system, and Langdon Winner's theory of techno-politics. Star's ideas helped me analyze how fire water access is embedded in daily emergency operations but becomes visible during failure, especially for underserved populations in rural areas. Winner's theory shows how infrastructure decisions have political consequences, shaping whose safety is treated as urgent or optional.

To conduct this STS research, I used a mixed-methods approach. I attended in person classes for training in rural water supply and pump operations, interviewed career firefighters and battalion chiefs, and analyzed operational manuals and NFPA standards. I also used digital tools like the First Due app to understand how departments plan around available water sources. My research found that decentralized water storage systems, when properly designed and mapped, can significantly improve rural fire protection. However, their success depends on integrating them into training, dispatch planning, and mutual-aid coordination. These systems also reveal broader patterns of neglect in rural infrastructure planning.

Together, my engineering and STS findings suggest that improving fire protection is not just a technical task, it is an equity issue. Decentralized water access is a feasible solution, but only if supported by planning that accounts for both operational and social realities. Building equitable infrastructure means ensuring that all communities, regardless of location, have access to the tools needed to stay safe.