# “Frozen 2” : Creating the Water Horse

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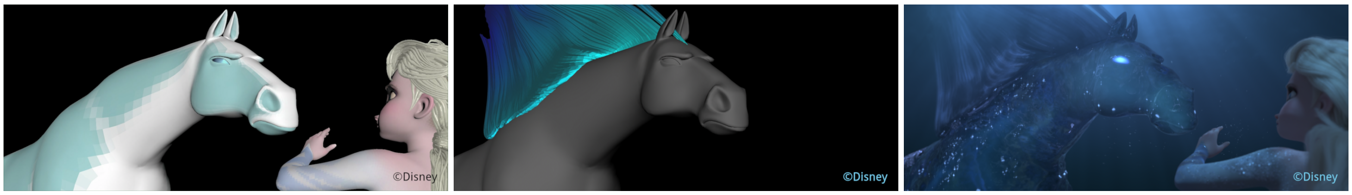


**Figure 1: Animation, Technical Animation, Final Lighting**

## ABSTRACT

In Walt Disney Animation Studios’ “Frozen 2”, the Nokk appears as a horse made of water. Throughout the film, he assumes different forms: at times wild, and others calm; above and below the waterline; frozen and transitioning between states. This talk will describe the collaborative process of design, animation, simulation and lighting to achieve the look and feel of a character made of water.

## CCS CONCEPTS

• **Computing methodologies → Simulation by animation**; *Physical simulation*; Ray tracing.

## KEYWORDS

fx, effects, water, fluids, character

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## 1 DESIGN AND ANIMATION

The Nokk is a creature inspired by Nordic mythology and folklore. A protector of the Dark Sea, he is a warrior that challenges Elsa on her way to find answers. He starts as a wild stallion that Elsa needs to overcome in order to complete her quest. By the end of the film, she has proven her worth and they become a powerful team. Our vision of the myth needed to be breathtaking in its beauty and its menace, an apparition made of water and yet entirely equine in its performance.

The design and animation of the character was based on direct observation of horse behavior, with particular attention to emotional states. Our goal was to preserve the subtle expressions, poses and gestures created in animation while layering on the motion and light response we expect from water. The character design favors realism over cartoon proportions or stylization, so animators relied on their observations of horse behavior to achieve the desired performance. Horse ears are associated with specific emotional states: aimed back and flattened when angry, floppy when relaxed, or directional with respect to their attention. To help preserve these subtleties, we provided a one-click tool for animators which ran a simplified version of the effects rig and applied a water material in the render. For the look of the mane and tail above water, we studied laminar flow fountains, windy waterfalls, the spin drift created by crashing waves, and volcanic sea vents when underwater. The final look required extensive exploration, many iterations, and a close collaboration between multiple departments.

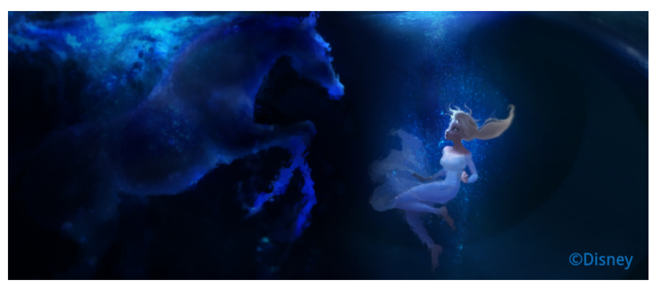


**Figure 2: Nokk Look Development**

## 2 MANE AND TAIL SIMULATION

The initial motion of the mane and tail was handled by technical animation artists in collaboration with character animation. Shots began in animation with the performance of the horse, and once the acting had been approved by the directors, we added a drawover pass to explore the motion of the mane and tail, enabling efficient iterations within animation. The technical animator then used the drawovers as reference when crafting the overall shape of the hair simulation using our in-house hair solver. An elegant sheeting


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effect was produced by simulating a dense set of curves. Artists were able to modify the simulation using real-time expressions authored with the open source SeExpr [WDAS 2013] language, allowing natural water tearing effects to be applied with artistic precision. In addition, we developed a Maya plugin which allowed artists to quickly visualize the shape of the resulting water surface prior to handoff to effects animation.

## 3 WATER DYNAMICS

Effects animators began shots with the Nokk body animation and mane and tail curves from technical animation. The mane and tail curves were used as the source for particle simulations which model fluid-like behavior using force vectors derived from a local distribution of neighboring particles [Yuksel et al. 2014]. Running additional particle simulations driven by these particles, artists added multiple layers of water and spray to the Nokk’s hooves, mane and tail. Per-shot tweaks were required to tune the additional length added to the mane and tail by water droplets and spray simulations. The Nokk body surface geometry was remeshed to a resolution that would support hydrodynamic motion, and ripples added via layered noise and/or a two-dimensional ripple solver which could react to body motion or collide with intersecting objects. For the body interior, we added view-dependent volumetric structures which included vector fields defining albedo and emissive light contribution. We augmented underwater shots with heat distortion inspired by volcanic deep sea vents.

Hoof interaction with the ocean surface was an important focal point, as there was a design goal to support the look of water interacting with water, as opposed to a hard surface interacting with water. Deformation and stretching was added to the legs by animators, and we further augmented this concept with simulations. To this end, particular attention was paid to the shapes of trailing water from the legs. These shapes were established by modeling our particle sources using smoothed trailing curves.


**Figure 3: Transition from water to ice**

For shots in which the Nokk transitions from water to ice, two different techniques were used. When underwater, the transition starts with ice crystals growing inside the body surface, followed by a transition from water to ice material via a mask. The ice crystal patterns were provided by look development and matched Elsa’s signature snowflake shapes. In the above water case, the effect was achieved via an articulated mask transition from water to ice materials, enhanced with ice crystals and water vapor advected by gas simulations.

## 4 LIGHTING AND RENDERING

Each form of the Nokk, liquid or frozen, above or below water required its own lighting development and workflow. The lighting design was based on reality but heavily art directed, requiring multiple render passes, mattes generated by look and effects artists, and reflectivity rendered with and without refraction. The final look required a pass through compositing prior to review sessions with production design, visual development and the directors. We also modified Disney’s Hyperion Renderer [Burley et al. 2018] to give us fine-grained control over the number of refraction steps, allowing us to simplify the read of important features like the face and ears.


**Figure 4: (left) Full refraction, (right) Single refraction**

## 5 PRODUCTION WORKFLOW

Finally, we modified our interdepartmental workflows to account for the non-linear nature of this creative loop. Persistent notes were created for each shot in our production management database which allowed artists to document the status of their work and immediately notify all up and downstream departments. We optimized turnaround time so as to always review the work in lighting, instead of by individual department.

## 6 CONCLUSIONS AND FUTURE WORK

Successfully meeting this challenge and seeing the results of this non-linear, highly cooperative task was rewarding. The work was also a time-consuming challenge which suggests some subjects for future exploration. Since the mane and tail simulations directly influenced particle and gas simulations, it would be valuable to explore how these two steps could be integrated into one, and handled by a single artist. Additionally, the mattes generated by look artists and used by lighting needed to be transferred to new topology by effects animators, which introduced occasional errors. Alternatively, if the hydrodynamic motion was exported as displacement maps the original geometry could be passed to lighting, preserving the unaltered mattes.

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