CASE STUDY

Documenting a large dam with senseFly's albris inspection drone

senseFly put the albris inspection drone through its paces at the 156 metre Tseuzier dam in Valais, Switzerland. The project's main aim: produce a high-resolution photographic record of the structure's downstream face, which its operator, Electricité de la Lienne, could use as part of its five-yearly inspection report for the country's energy regulator.

In the mountainous Swiss canton of Valais, home to many a popular ski resort, sits the barrage de Tseuzier. Operated by Electricité de la Lienne and sitting at a chilly alpine altitude of 1,800 metres (5,905 ft) above sea level, this concrete arch dam is the sixth tallest in Switzerland, measuring 156 metres (512 feet) at its highest point. It was here that albris's largest project to date took place.

VIDEO: 1950's footage of the dam's construction

The Tseuzier Dam is located in the mountainous Valais region of French-speaking Switzerland.

Project goals

The team at Electricité de la Lienne was eager to learn how inspection with a drone might work, not only in terms of the image and output quality possible, but also the workflow involved in using an unmanned aerial vehicle for such a job. Thus the aims of this 'proof of concept' feasibility study were threefold:

1. Achieve full, high-resolution photographic coverage of the dam's downstream face. This imagery was to be captured semi-automatically using a senseFly albris drone.

   Should these results be considered high enough quality by Electricité de la Lienne's team, its staff planned to submit this data to the Swiss Federal Office of Energy (Office fédéral de l'énergie, or OFEN) as part of its five-yearly inspection report.

   "Our photographic documentation today is insufficient and would definitely benefit from being enriched," comments Maurice Perraudin, the Director of Production at Energies Sion Région (the organisation tasked with producing the Sion region's electricity).

> "Our photographic documentation today is insufficient and would definitely benefit from being enriched"

2. These images would be processed using Pix4Dmapper Pro software to generate several orthomosaics, spanning overlapping sections of the dam's wall.

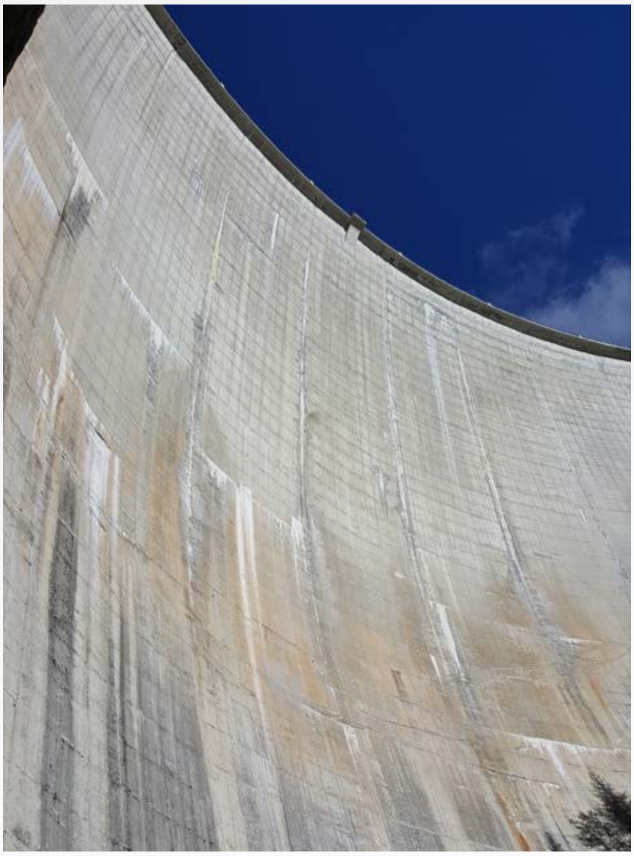
3. To provide the maximum value for Electricité de la Lienne, senseFly's engineers—one of them an experienced civil engineer—would also supply a full inspection report on the dam's face, including a full defect map. This report would be created by carrying out a virtual inspection (analysing the drone-produced, high-resolution orthomosaics) and produced using AutoCAD.

Site & background

For dam infrastructure, monitoring is crucial. To this end, dam operators require a simple, effective way in which to locate an area of interest on the dam's wall and compare this to historical records—whether digital photos or annotated drawings—in order to track degradation over time.

In the case of the Tseuzier dam, the existing historical inspection records comprise 200 A4-sized annotated drawings. These detail every crack and defect of interest on the dam's upstream and downstream faces, including their dimensions, as collected once every five years.

Up to now, engineers have collected this data manually. "There is a suspended platform installed at the site," Perraudin explains. "We need to operate this platform close to the dam wall, without touching the face. This is not always easy since the upstream face is highly convex, so the basket's cables touch the wall, limiting the area that can be inspected."



The impressive structure measures 156 metres (512 feet) at its highest point.

Typically it takes Perraudin's team one week to inspect the downstream face using the hanging basket. It then takes his staff another week to create the required annotated drawings.

Weather can also make using the platform a challenge. "Conditions on the platform are difficult, especially when we are inspecting the upstream side, which is only possible in winter. The temperatures can get very low," Perraudin adds.

> "Conditions on the platform are difficult … temperatures can get very low"

Thus Perraudin and his team were highly motivated to learn from senseFly's two participating engineers how an albris inspection of Tseuzier would work.

Detailed planning required

At the start of the project, Electricité de la Lienne provided senseFly with blueprints of the dam. This data enabled senseFly's engineers to calculate the full surface area of the downstream face—approximately 19,000 square metres—an essential step in predicting the number of albris flights likely required.

A second factor that would affect the number of flights was the distance at which albris would need to fly from the face. This figure was, in turn, calculated based on several parametres:

- The project's target surface resolution: 0.6 mm. This figure was chosen in order to provide Electricité de la Lienne with lots of detail, while optimising as much as possible the drone's distance from the dam wall (since flying closer to achieve a finer resolution means less coverage per photo, thus more flights, more photos and heavier image processing later).
- The resolution of the drone's RGB camera (38 megapixels)
- The camera's field of view (63 degrees horizontal, 47 degrees vertical)

With these three figures to hand, senseFly's engineers calculated a required flight distance from the face of 3.7 metres (12.1 ft). It was this distance that the drone's Distance Lock function would be set to.

> "The dam's surface area, flight distance from the face, and photo overlap allowed the engineers to calculate approximately how many albris flights would be required"

Alongside the surface area and flight distance from the face, equally crucial to calculating the number of flights was the amount of photo overlap needed. To account for the predicted challenge of maintaining consistent coverage—due to flying up to 100 metres away from the operator—the team aimed for at least a 60% lateral overlap.

Once calculated, the dam's surface area, flight distance from face and photo overlap allowed the engineers to calculate approximately how many albris flights would be required to photograph the entire downstream wall. The result: 50 flights.

First look over the edge

When senseFly's team visited Tseuzier for a single pre-planning session, more specifications and workflows were confirmed. This work included:

- Noting any details on the structure that were not visible on the blueprints, such as:
  - Visible formwork joints that could be used as a reference for flight lines
  - Vegetation that might interfere with the drone's planned flight path(s)
- Visual confirmation of the drone's optimal home waypoint
  - It is essential that the flight line from the drone to this waypoint remains clear at all times, as in case of a comms link loss the drone will fly in a straight line back to this waypoint to await further instructions
  - In the case of the Tseuzier arch dam, this optimal location was several metres out from the top of the dam wall, over the face itself
- Visual on-site analysis of any changes in the shape of the structure
  - Where there are changes in the wall's pitch, formwork joint lines can converge or diverge, affecting the amount of coverage
  - In the case of Tseuzier, a convex bottom shoulder section would require especially careful, manual flight to ensure consistent coverage
- Visual check of the dam's stairway access, condition, descent
  - The stairway's platform, roughly half-way up the dam, was originally considered as a possible take-off point

On the job

On-site for the project proper, senseFly's albris operators fine-tuned the methodology required. The first thing they confirmed was the need to fly vertical flight lines.

There were two reasons for this approach. First, flying horizontal flight lines would be inefficient. This was due to the dam's position. It sits sandwiched between two highly inclined mountain sides, meaning launch points do not exist at its sides. Therefore traversing horizontal lines would mean flying albris either up or down from the launch point to the start of each flight line, wasting its battery life. Second, the existing joints in

The senseFly albris on the road atop of the dam's downstream face, ready to go to work.

the dam's wall were vertical in nature, making it easier for the team—to some degree at least—to use these lines as a handy visual reference.

> "Flying horizontal flight lines would be inefficient and waste battery" life

Using vertical lines did however mean reversing the drone's controls—flying with the drone below and facing the operator, in Interactive ScreenFly mode. Not an easy feat at first, but becoming more natural with every flight.

The albris' Distance Lock feature was set to 3.7 m, meaning each drone photo covered a 4.6 m x 3.5 m (15 x 11.5 ft) section of wall. A a second assistance function was also activated: the drone's Cruise Control. This was set to 0.2 m/s (0.4 mph or 0.39 knots). Plus, a third function, the drone's Auto-Trigger, was employed, set to capture a shot every five seconds.

To achieve the required photo overlap, the drone was flown along vertical flight lines three metres apart. In other words, a descent or climb every three metres as measured along the fence atop the dam wall (marked out using regular tape stuck to the fence). In order to maintain coverage, it was important to follow these flight lines as precisely as possible.

senseFly's two engineers divided up drone operator and observer duties. One flew the albris using its ScreenFly controller, maintaining continual line of sight with the UAV by looking over the fence at the top of the dam wall. The second observed the video feed from the drone's head navcam, plus the frame location of each captured photo, on-screen, via a laptop running the drone's eMotion ground control software.

Most flights were operated from the top of the dam, meaning reversed controls.

The observer would then, from time to time, relay any alignment adjustments needed to the operator, such as any left/right alignment required and slight fine-tunings of the aircraft's yaw (the wide angle of the albris head's navcam makes it easy to see whether or not the drone's angle is perpendicular to a structure's face). Combining the operator's direct visual feedback with the observer's screen-based corrections resulted in tight control of the drone's flight lines.

Typical flight procedure:

- Pilot (using ScreenFly controller): takes off from centre of road on top of dam
- Pilot: flies drone out over dam wall
- Pilot: descends drone to -1 m ATO (in line with top of dam wall)
- Pilot: activates Distance Lock
- Pilot: brings drone towards wall until Distance Lock engages
- Pilot: activates Auto-Trigger
- Observer (viewing eMotion video feed on PC): confirms successful capture of photo 1
- Observer: reports battery level & confirmed perpendicular alignment
- Pilot: activates Cruise Control down.
- Observer: confirms Cruise Control active
- Observer: gives verbal feedback on alignment with flight line & perpendicular alignment with dam wall
- Observer: relays key flight management data such as battery level (every change of 10%), altitude below take-off (every 10 m) & any warnings
- Pilot: sets drone to hover at bottom of descent
- Both: move themselves & laptop carefully to next flight line marker (moving to left 3 m), pilot maintaining line of sight with drone
- Pilot: flies drone sideways to centre of new flight line
- Observer: confirms readiness for ascent (e.g. position / line on wall to follow has been identified)
- Pilot: on finishing the ascent, deactivates Distance Lock, Cruise Control & Auto-Trigger
- Pilot: flies drone away from the dam wall, over parapet and to safe landing spot

At the drone's cruising speed of 0.2 m/s, and depending on the height of the dam wall at the location in question, each down/up trip lasted a maximum of 17 minutes. Therefore to ensure safe operation, especially considering the additional effect of air density at this altitude, the team replaced the drone's 22-minute battery after every such flight.

With the highly variable weather on-site, which would regularly change from full sun to fog with five metre visibility in a matter of minutes, the team completed up to ten flights per flight day, starting as early as possible each morning.

Operating the drone during one of its 15 flights from the base of the dam.

The dam's joints typically run down the face, meaning these could be used for visual reference.

In order to scale the final project precisely, ground control point (GCP) targets were taped to the downstream side of the top dam fence, a few metres apart. The distance between these was then measured using a laser rangefinder (three times to triple check the measurement). Staff then made sure these targets were captured in several of albris's pictures in order that, during the project's photogrammetric reconstruction, the team could input the exact distance between the markers and thus re-scale the entire model of the dam and ensure its excellent relative accuracy.

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Key challenges

No matter how much intelligence and automation a drone provides, the aerial documentation of a huge structure at high altitude will always present some practical challenges to overcome. senseFly's engineers noted five:

1. Achieving adequate photo coverage: the principal challenge when inspecting large structures at high resolution. A significant area of each photo taken (at least 10%) must appear in at least two other photos to ensure a successful reconstruction with Pix4D's software. With the drone many metres below the pilot, in potentially windy conditions and with poor GNSS coverage, keeping the drone on its flight line can be a challenge. Therefore plenty of planned overlap is key.

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2. Weather: this was highly unpredictable and quick to change, with fog and wind particular challenges.
3. GNSS coverage at the bottom of the dam: a lack of satellite signals typically causes GNSS-navigated UAVs to drift, thus the albris's Distance Lock feature lock proved essential.
4. Visual identification: simply seeing a drone that is flying 90 or so metres (295 ft) below, against a backdrop of valley floor vegetation, is not always easy.
5. In reverse: flying a UAV interactively, with the aircraft facing the pilot (i.e. its controls reversed), is a learnable skills but takes some practice.

An additional minor yet interesting influence on the team's efficiency was interruption. Since the road that runs atop Tseuzier dam is open to the public, people (mainly hikers) would gather to watch the drone's operation and ask questions during its flights. In addition, one early morning start was delayed by a herd of cows descending from the nearby hills to arrive at the top of the dam, where they were collected by two huge livestock trucks. A very Swiss moment.

> One early morning start was delayed by a herd of cows descending from the nearby hills … a very Swiss moment

Processing the data

A total of 7,000 high-resolution photos of Tseuzier dam were captured—no small task in terms of subsequent image processing and orthomosaic (orthophoto) creation.

Using a high-performance Asus laptop PC running 32 GB of RAM, senseFly's team used Pix4Dmapper Pro to process the data. Initial processing took one week. A few manual tiepoints were then added in areas of insufficient overlap (possible within Pix4D's software), before an additional 40 hours of point cloud densification. This was followed by two days creating four orthomosaics, spanning different, overlapping sections of the dam's face, then two further days to analyse these orthoplanes in order to create Electricité de la Lienne's defect report.

The results

Following approximately two weeks' worth of flying and processing, senseFly's engineers presented to Electricité de la Lienne:

- 7,000 high-resolution photos
- 4 high-resolution orthophotos
    - Covering different, overlapping sections of the face
    - Avg. pixel size: 0.6 mm (allows identification of objects as small as 2 mm)
- 1 digital point cloud
- 1 full defect report (PDF)

The team proved that with the albris, full photographic coverage of a large dam is now possible, thanks to automated functions such as the UAV's Distance Lock and Cruise Control.

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The outputs handed to Electricité de la Lienne meanwhile give the organisation's engineers instant, easy-to-explore 2D and 3D data. Staff can simply click any part of the face that is of interest—via the point cloud in Pix4Dmapper—to see all the individual photos of that point.

"The level of detail the albris achieved is very impressive," says Reynald Berthod, the hydraulic project head at Stucky

One of the albris's individual images, featuring the metal plate of a crack gauge (measuring 46 x 34 cm / 18 x 13.4 in). Each photo was captured 3.7 metres away from the face and covers a surface region of 4.6 x 3.5 m (15 x 11.5 ft).

Equipment:

1 albris drone

1 Interactive ScreenFly controller (supplied)

1 remote control (supplied)

albris ground modem (supplied)

5 m (16.4 ft) modem USB cable (supplied)

4 albris battery chargers (1 supplied with drone)

5 albris batteries (2 supplied with drone)

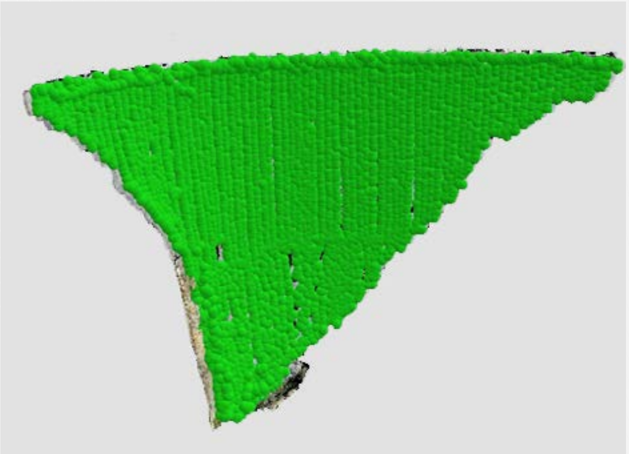
2 SD memory cards

Extension Tripod for ground modem

PC laptop feat. eMotion X ground control software (latter supplied with drone)

Laptop stand

Additional fully charged laptop battery



A Pix4Dmapper screenshot showing the thousands of albris photo capture locations.

SA, a design and engineering firm that specialises in dam and hydropower plants, a partner of Electricité de la Lienne. “The advantage of this digital data is that we can return to, and re-examine, an area without having to send someone back down on the platform.”

This type of photographic record is becoming increasingly important too, Berthod adds. “We now have dams that are 50, 60, 70 years old, so this kind of detailed photographic survey, which helps us detect trends, is becoming increasingly necessary and demanded by authorities such as the Swiss Federal Office of Energy.”

“The availability of a high-definition picture of the entire air-side of the dam is a very interesting contribution to our work,” Perraudin adds. “It gives us a record of the dam’s condition at a given instant and enables work to continue in the office afterwards—re-examining and refining the record—something that cannot be done at all today.

“What’s more, future inspection campaigns can be carried out using the exact same shooting conditions, meaning we will be able to make absolutely reliable comparisons—a major benefit when monitoring a dam, tracking its degradation, the evolution of certain cracks, the supporting rock, and degradation of the surrounding cliffs.”

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Perraudin concludes, “Taking into account the quality of the results obtained, the use of drones for the monitoring and inspecting of dams seems to have a bright future. We were amazed by the quality and detail the drone achieved.”

PROJECT SPECIFICATIONS

- **19,100 m² (205,590 ft²)** surface area
- **1,800 m (5,905 ft)** above sea level
- **2** days lost due to fog
- **6.5** flying days
- **50** flights
- **3 m (9.8 ft)** width flight lines
- **3.7 m (12.1 ft)** from face
- **0.2 m/s (0.6 ft/s)** cruising speed
- **17 min** avg. flight time
- **5 sec** auto-trigger intervals
- **68%** horizontal overlap
- **71%** vertical overlap
- **0.6 mm / pixel** object resolution
- **1** defect report
- **4** orthomosaics
- **2 weeks** data processing
- **7,000** photos

View more project results overleaf

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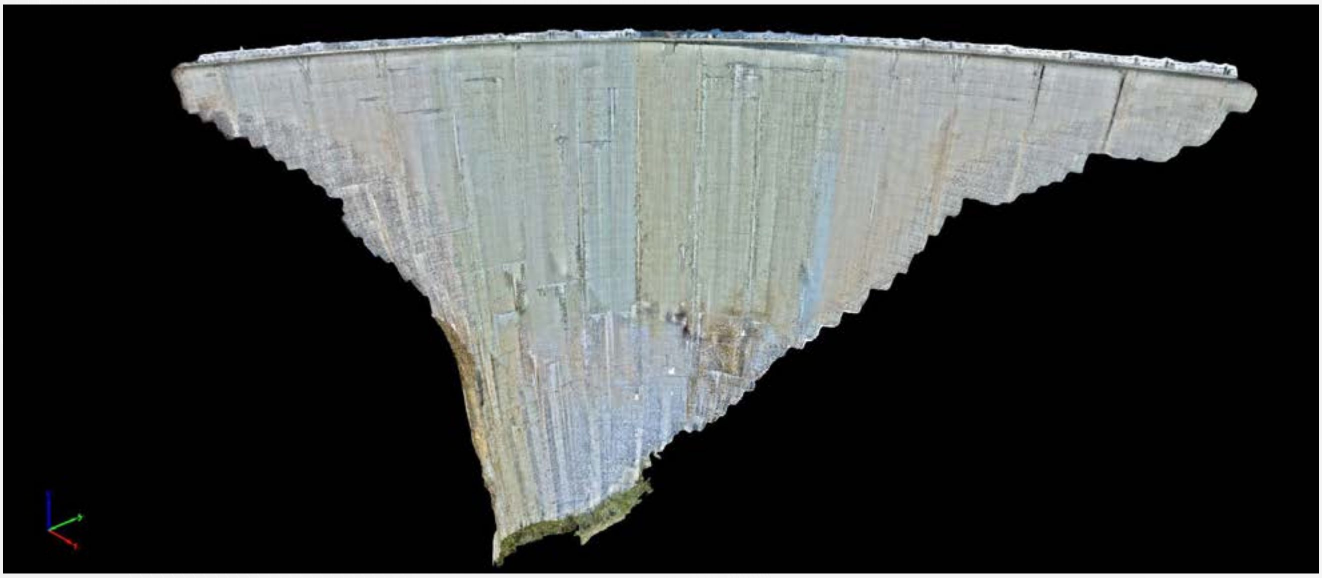
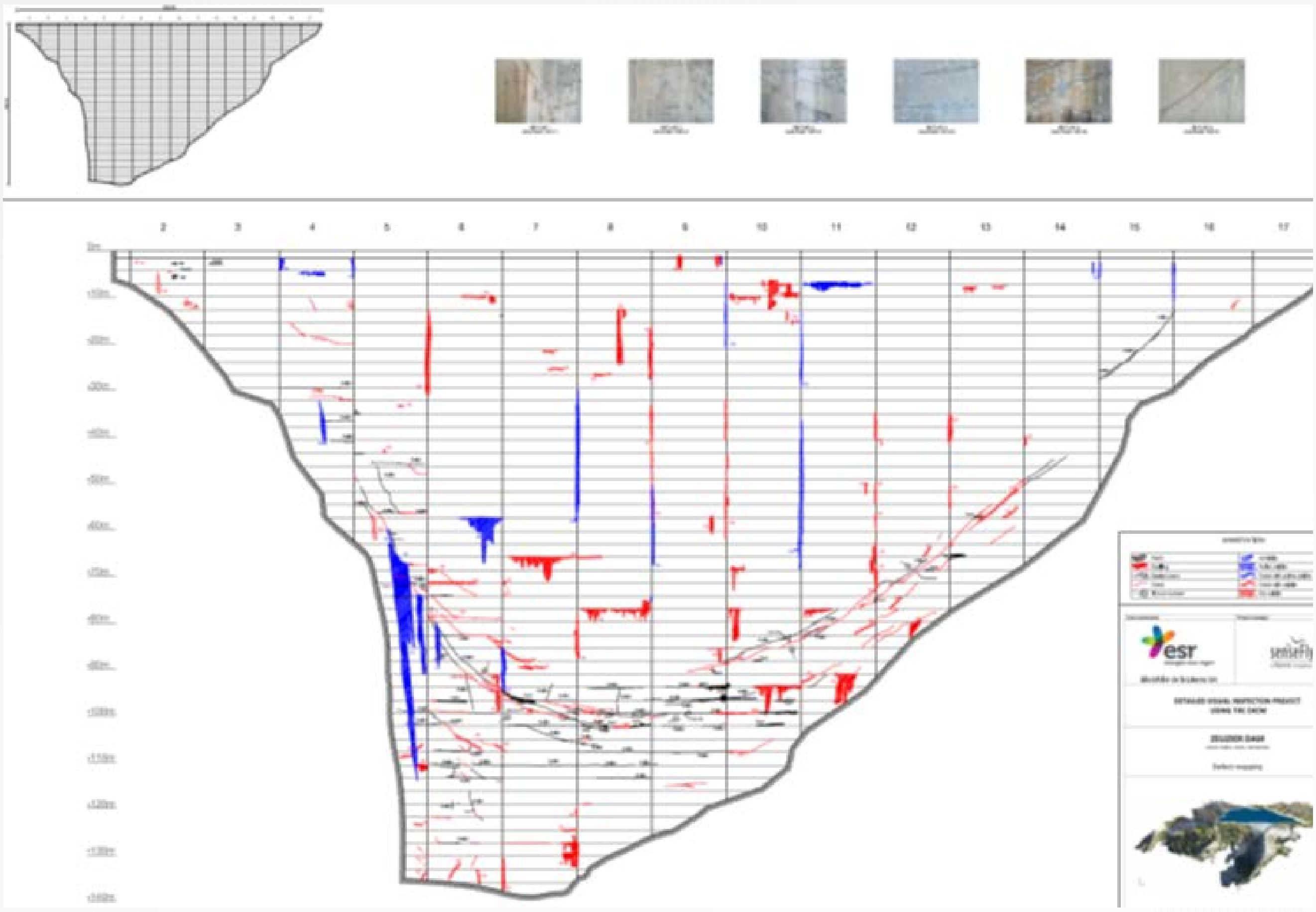
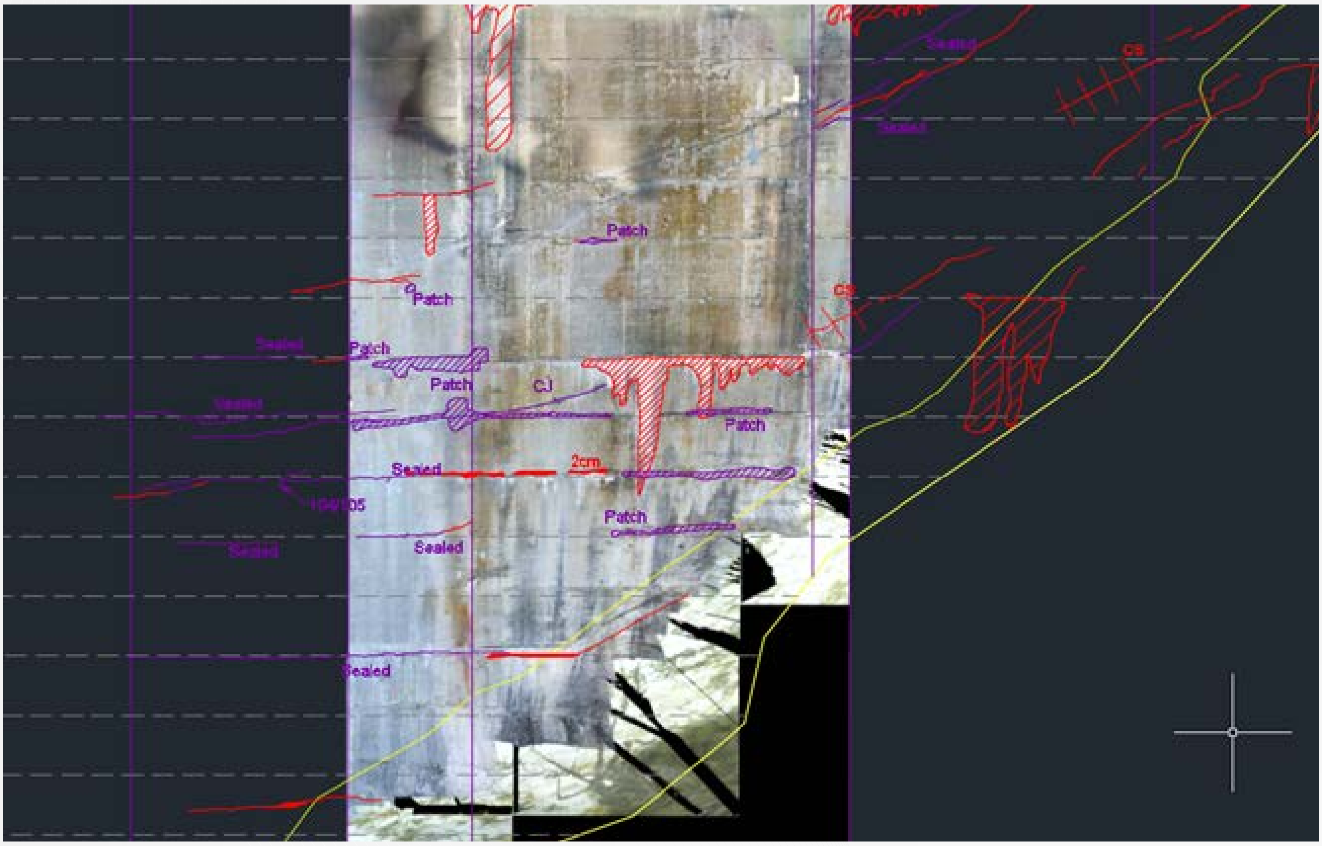


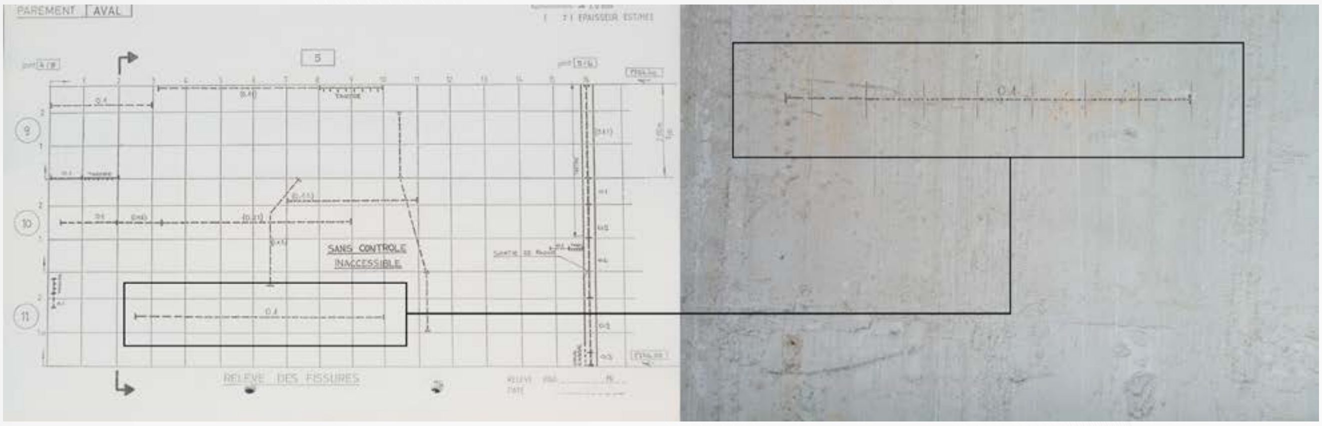
The project's final textured mesh, showing the dam's entire downstream face.



The defect map of the dam's downstream face, produced by senseFly's civil engineer for Electricité de la Lienne.



A section of the defect report, overlaid on one of the project's high-resolution orthoplanes.



Before and after — a 0.1 mm-wide crack on the dam's face, shown both on one of the drone's photos of this region, and below that on Electricité de la Lienne's historical hand-annotated defect report.

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