Infoshare 2026

Downwash & Outwash (DWOW) – Incident Reporting & Update on Research

Presented to: Rotorcraft Breakout Session

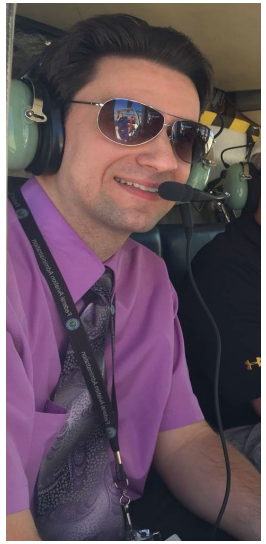
By: Cliff Johnson, FAA

Date: 05/13/2026



About Myself











- Education: B.S. Mechanical Engineering (Rowan University)
- Work Experience: Engineer with the FAA for past 17+ years
- Qualifications: UAS Pilot (ScanEagle, Solo, Parrot, Phantom, etc.), Commercial Pilot-Instrument Rating (ASEL & **Helicopter**), Aviation Ground Instructor
- Hobbies: Racing (NASCAR/INDYCAR/F1), Philly Sports Fan, Guitarist, Outdoorsman

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My Silent Partner – "Mr. Infrastructure"

Vertical Flight Society





Rex J. Alexander, 5-Alpha, LLC

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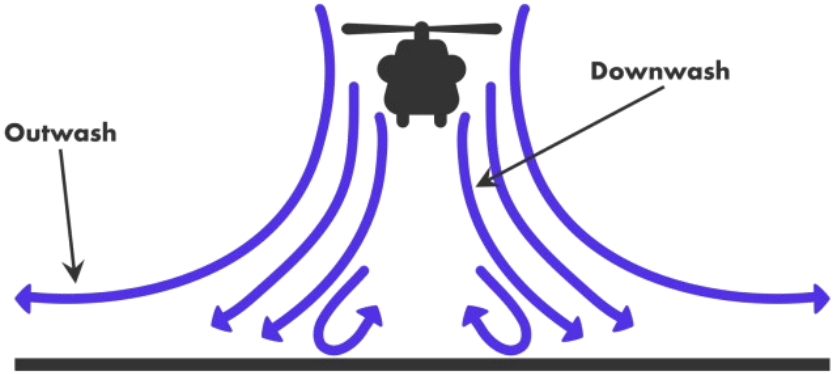
Downwash and Outwash – Phenomena Definition

Downwash and outwash are two different, but related phenomena associated with the aerodynamics of helicopter rotors. Downwash is a consequence of Newton's third law of motion - effectively the result of the downwards acceleration of air through the rotor in the process of generating the lift required to keep the aircraft in the air. The outwash is, as the name suggests, the outwards flow of air that takes place if the downwash hits the ground and spreads laterally outwards. An outwash is formed only when the aircraft is relatively close to the ground (and is moving relatively slowly), whereas the downwash through the rotor always exists - at least as long as the rotor is producing an upwards component of force.

A very common misconception regarding the outwash below a helicopter hovering above the ground is that it is a relatively constant outflow of air, the velocity of which decreases quite rapidly with distance away from the helicopter. This view is commonly adopted in establishing the size of the operational "safety zones" around helicopters and is reinforced by the depiction of the outwash in several influential publications that have underpinned the safety case.

When a rotorcraft is operated at low enough height above the ground, the aerodynamic interaction with the surface below causes the flow from its rotors to expand out across the ground as a layer of rapidly-moving airflow, called its outwash. If this outwash is strong enough, it can cause significant upset to bystanders and nearby infrastructure.



Source: Dr. Richard Brown, Sophrodyne Aerospace,©
https://sophrodyne-aerospace.com/videos/Downwash/

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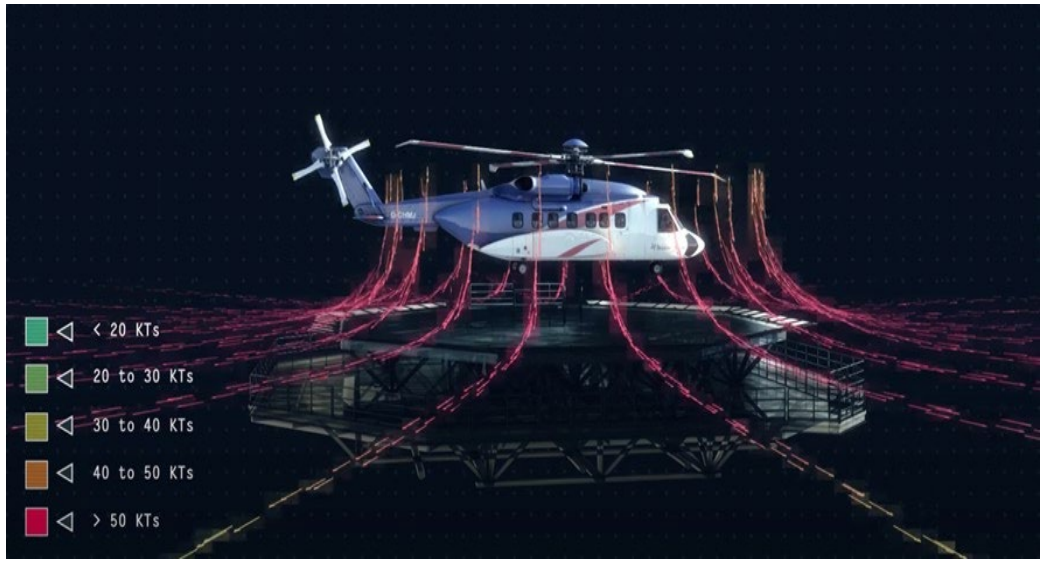
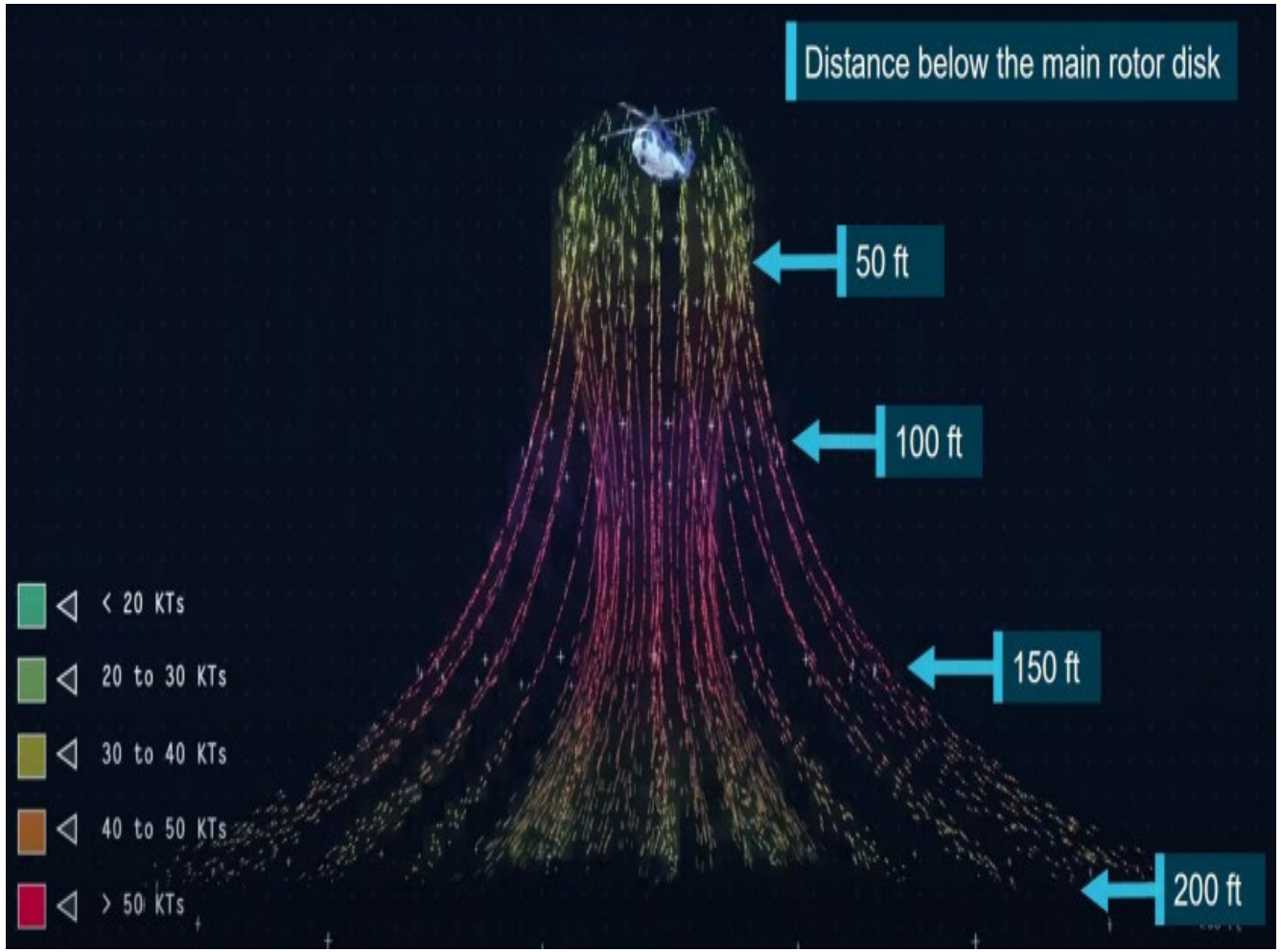
Downwash and Outwash – S-92 Helicopter

- Still images from a safety training video showing airflow under a Sikorsky S92 helicopter as steady, 'wind-like', flows. Source 'Helicopter Downdraft Danger', BP video available at https://youtu.be/09bvuYRKwwc





Source: CAP3075 Protecting the Future: Trials and Simulation of Downwash and Outwash for Helicopters and Powered Lift Aircraft, https://www.caa.co.uk/publication/download/24645

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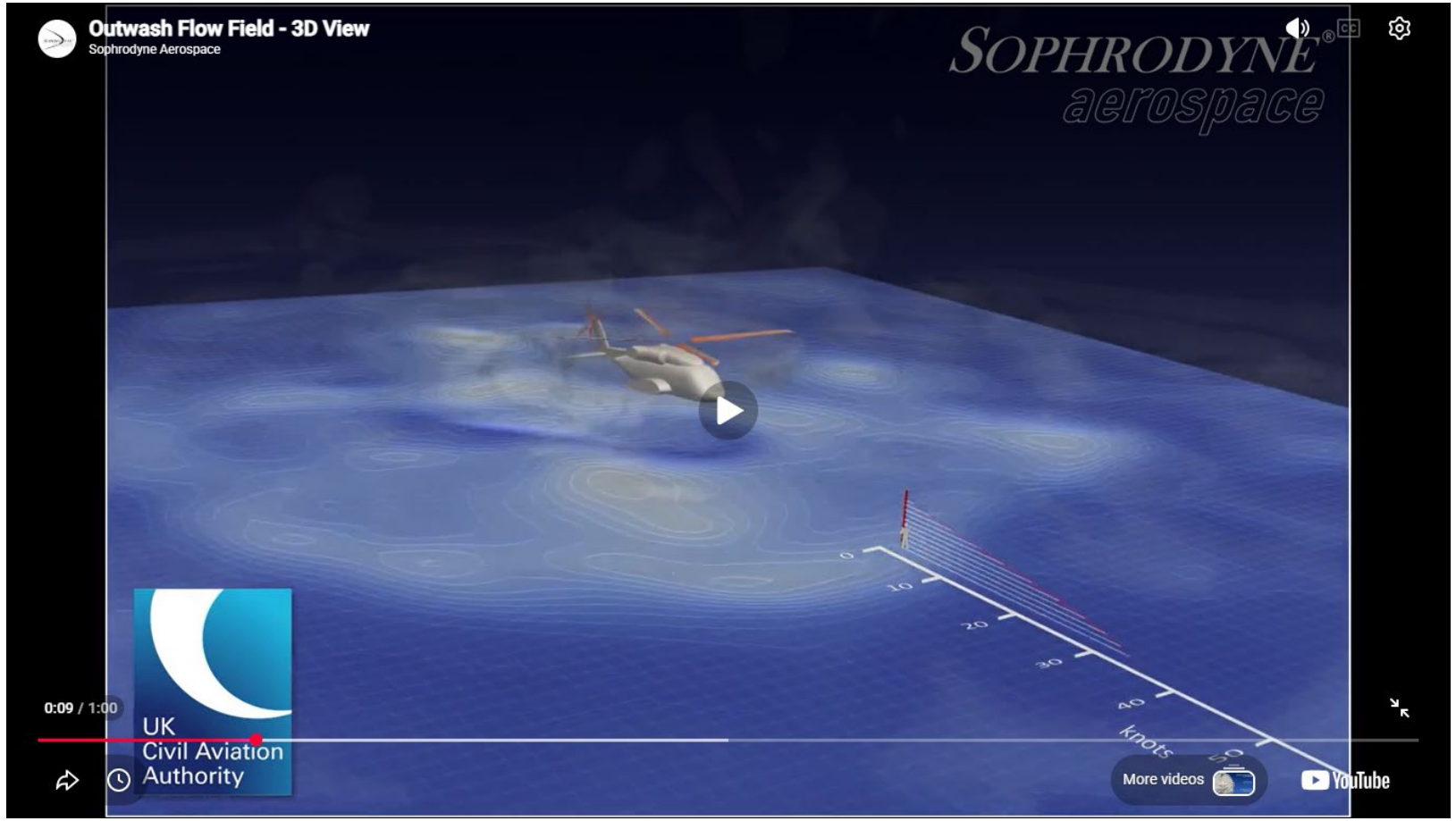
Downwash and Outwash – Helicopter



Source: CAP3075 Protecting the Future: Trials and Simulation of Downwash and Outwash for Helicopters and Powered Lift Aircraft, https://www.caa.co.uk/publication/download/24645, https://sophrodyne-aerospace.com/videos/Downwash/, © 2023 & 2025 Sophrodyne Aerospace

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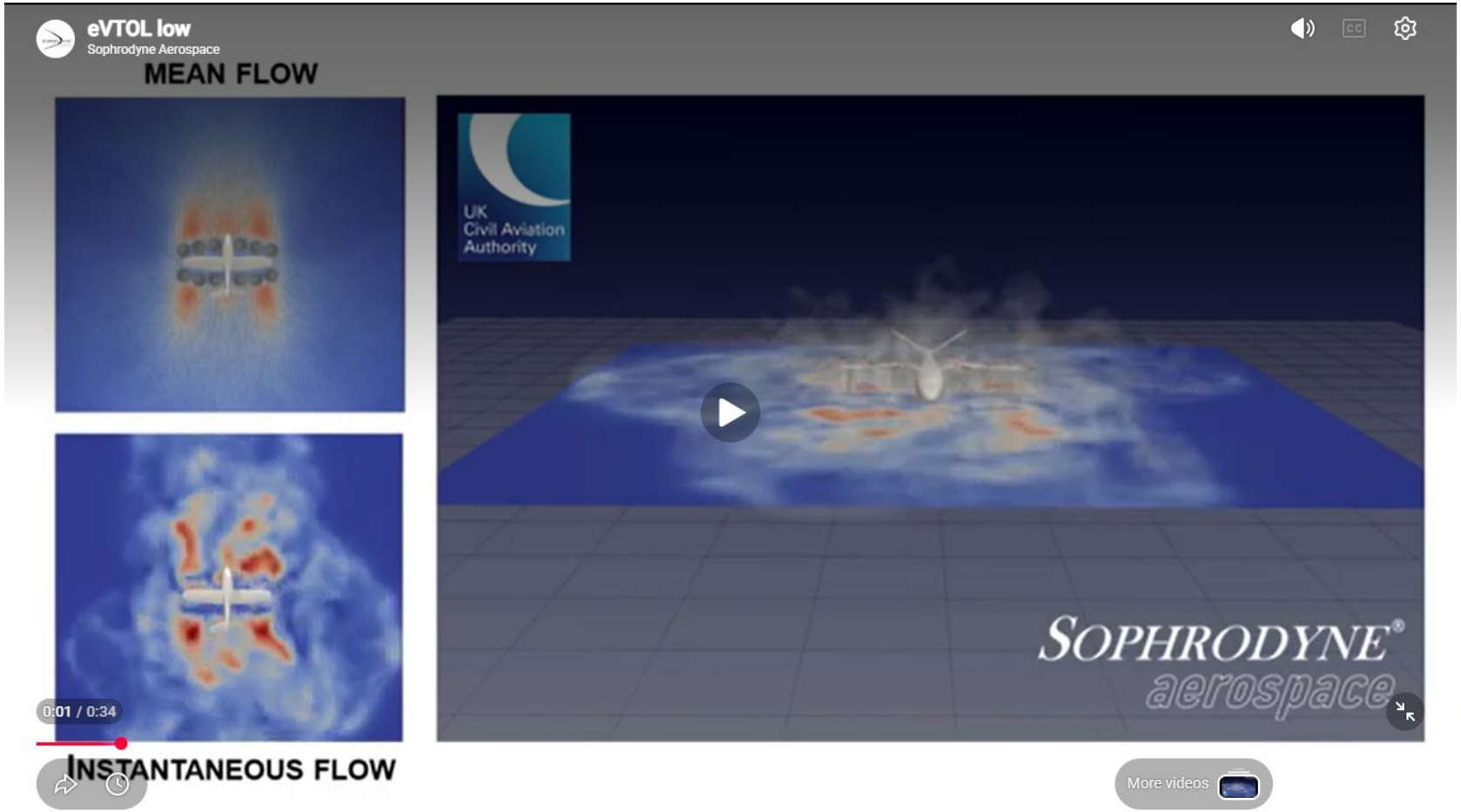
Downwash and Outwash – eVTOL



Source: CAP3075 Protecting the Future: Trials and Simulation of Downwash and Outwash for Helicopters and Powered Lift Aircraft, https://www.caa.co.uk/publication/download/24645, https://sophrodyne-aerospace.com/videos/Downwash/, © 2023 & 2025 Sophrodyne Aerospace

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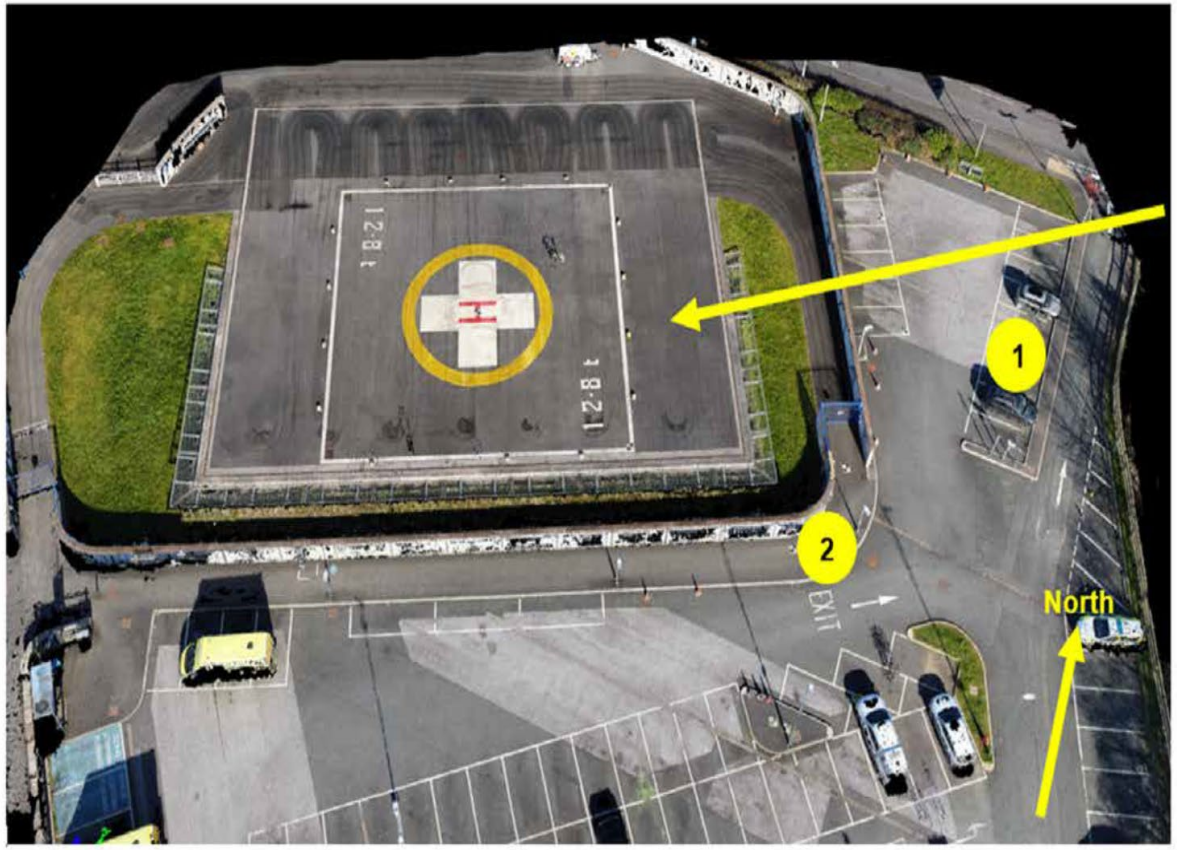
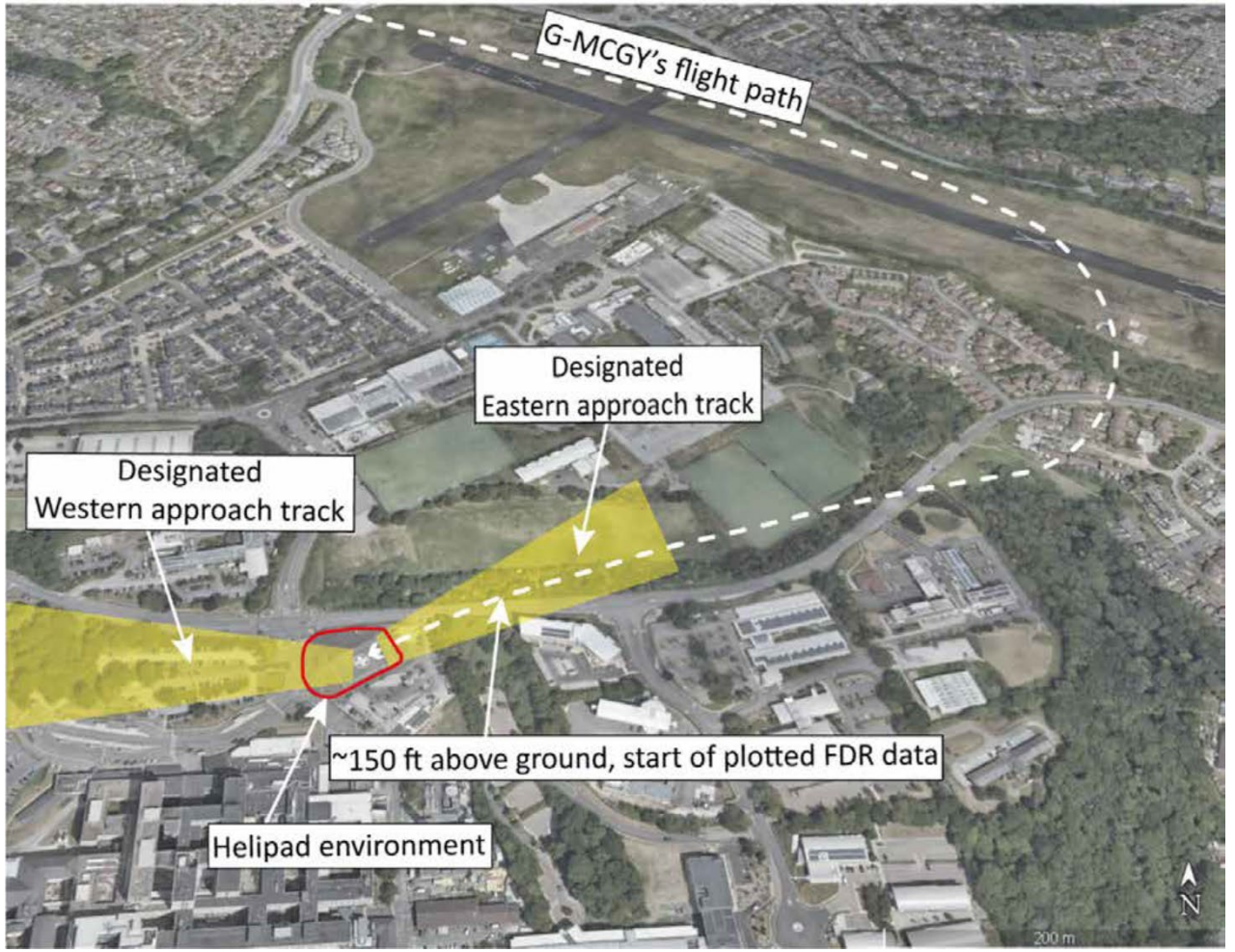
2022 S-92 Accident at Derriford Hospital, Plymouth, UK

- One pedestrian died and another sustained serious injury after being blown over by the rotor wash from a landing Sikorsky S-92 search-and-rescue helicopter at Derriford Hospital in Plymouth, England.
- An investigation by the United Kingdom's Air Accidents Investigation Branch (AAIB) found that the hospital staff who were responsible for managing the site "had insufficient knowledge about helicopter operations to safely manage the downwash risk around the site"
- Sources:
  - https://verticalmag.com/news/fatal-incident-in-japan-underscores-hazard-of-helicopter-rotor-wash/,
  - https://www.gov.uk/government/news/aaib-formal-report-sikorsky-s-92a-g-mcgy-fatal-accident-4-march-2022

2022 S-92 Accident at Derriford Hospital, Plymouth, UK





Source: https://www.gov.uk/government/news/aaib-formal-report-sikorsky-s-92a-g-mcgy-fatal-accident-4-march-2022

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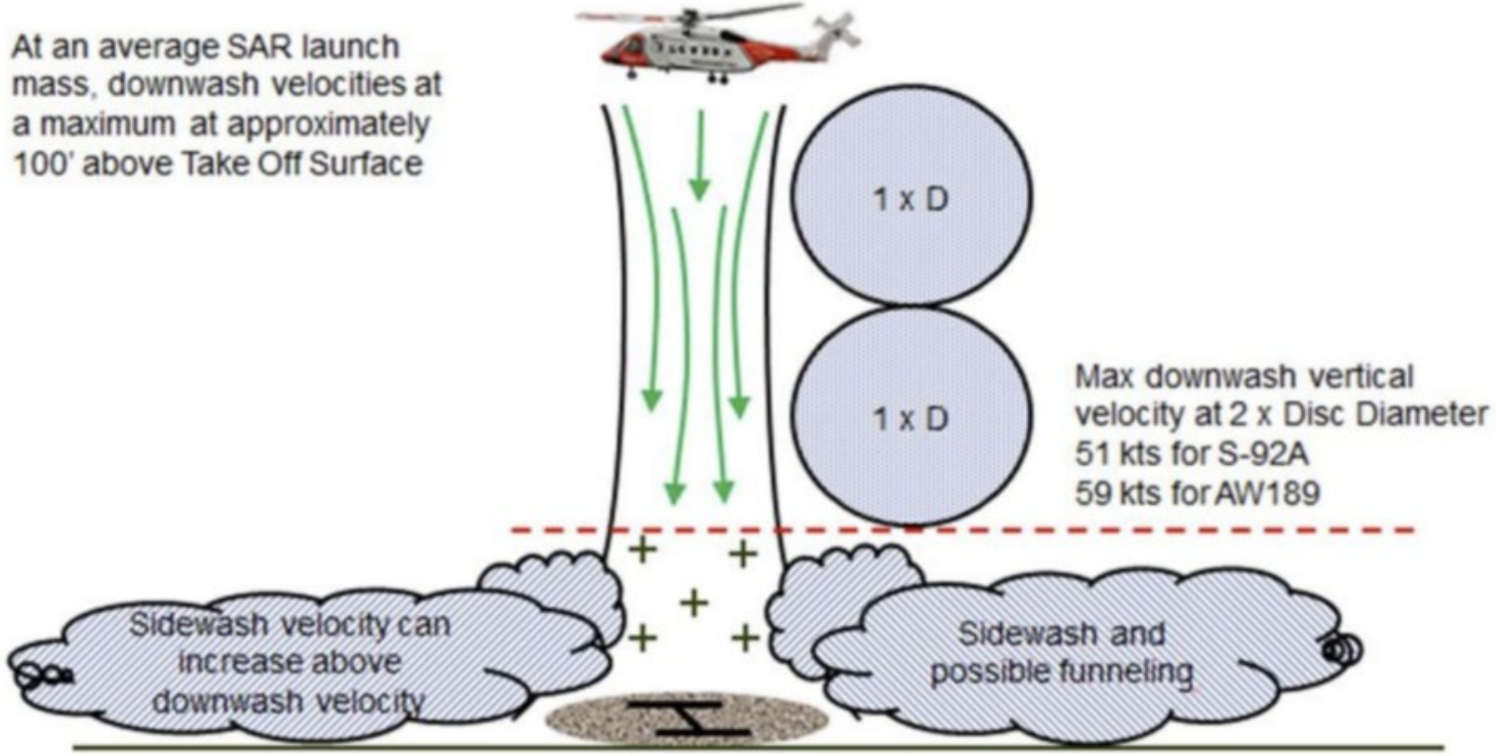


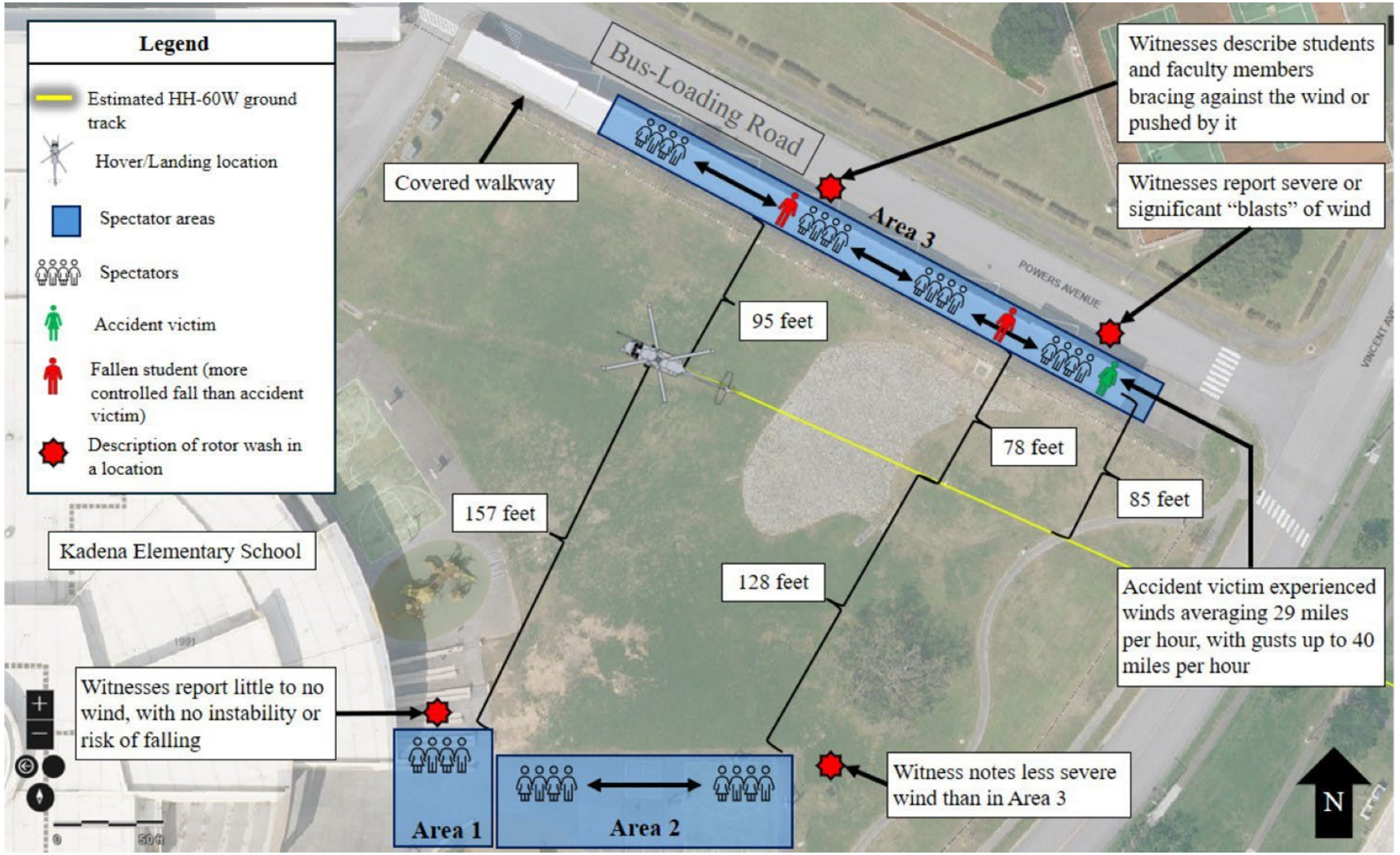


Source: https://www.gov.uk/government/news/aaib-formal-report-sikorsky-s-92a-g-mcgy-fatal-accident-4-march-2022

2025 HH-60W Accident at Kadena Air Base Okinawa, Japan

- A elementary school teacher was blown over and her head struck the concrete with much greater force than it would have in a routine fall, and she died from her injuries five days later.
- An investigation by the Air Force blamed “failures in mission planning and poorly staffed oversight processes” for allowing spectators to be dangerously close to the landing aircraft.
- Sources:
  - https://verticalmag.com/news/fatal-incident-in-japan-underscores-hazard-of-helicopter-rotor-wash/,
  - https://www.pacaf.af.mil/News/Article-Display/Article/4384714/fatal-hh-60w-mishap-investigation-results-released/

2025 HH-60W Accident at Kadena Air Base Okinawa, Japan



Source: https://www.pacaf.af.mil/News/Article-Display/Article/4384714/fatal-hh-60w-mishap-investigation-results-released/

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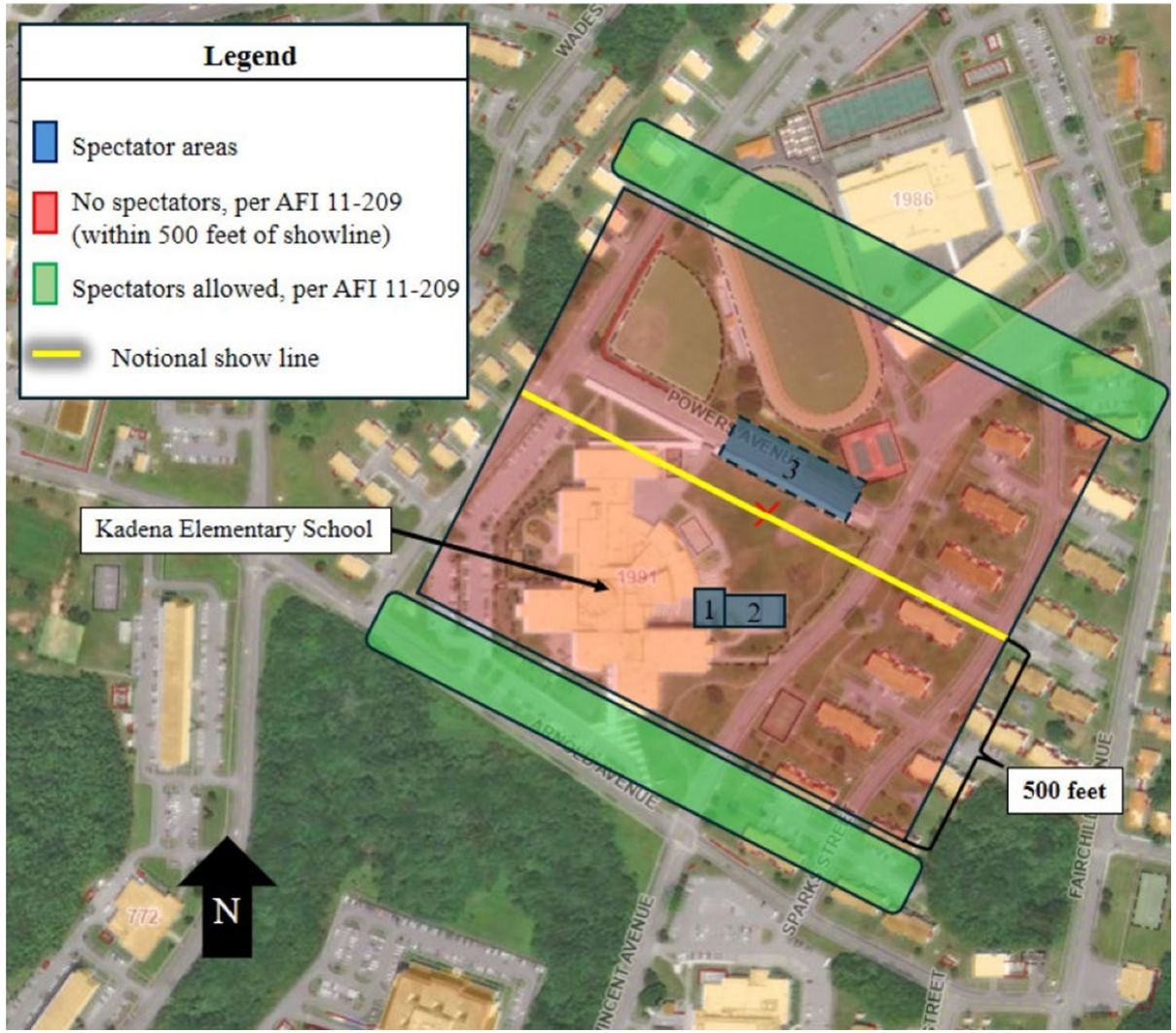

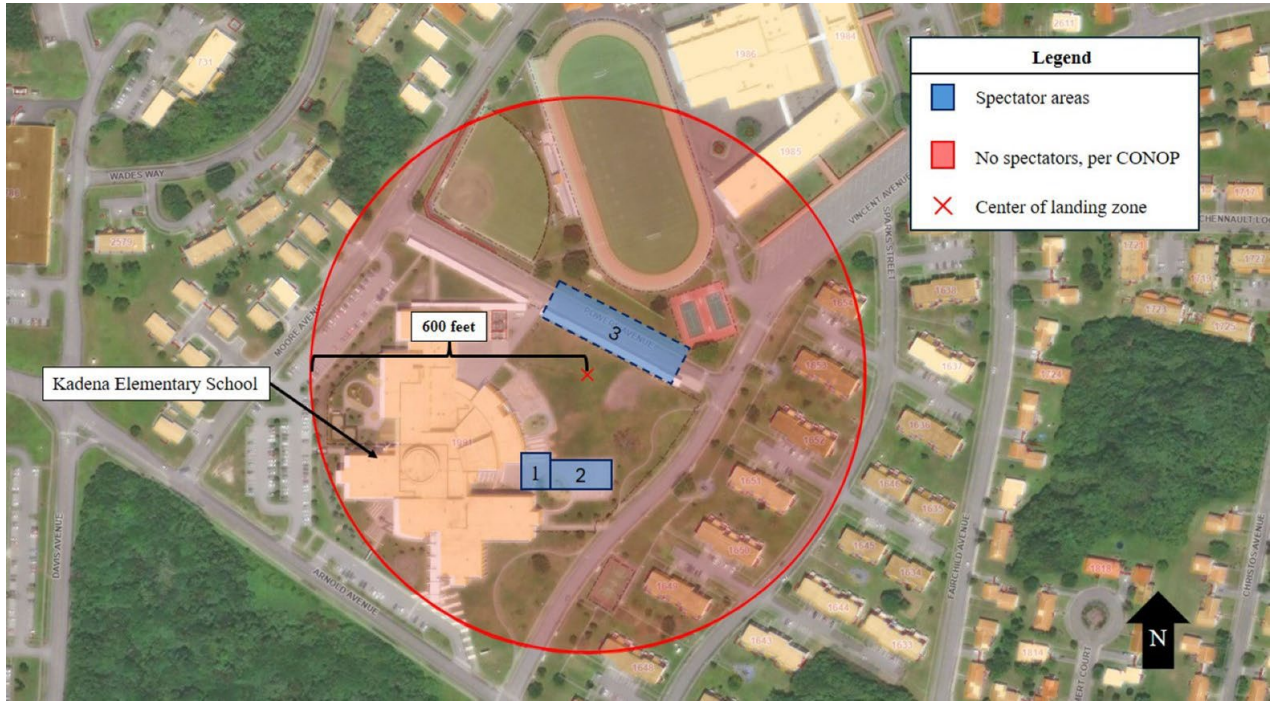

Source: https://www.pacaf.af.mil/News/Article-Display/Article/4384714/fatal-hh-60w-mishap-investigation-results-released/

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Another Downwash Incident Example

- The following information represents an incident involving injury which was attributed to helicopter downwash that occurred during normal helicopter operations while executing a standard approach to landing at an offsite location.

- Under current federal regulations this type of incident is **not considered a reportable event** and therefore **no FAA nor NTSB data exists**.

Incident Aircraft Specifications

CAPABILITIES	UH-60A	UH-60L	UH-60M
Crew @ total weight	3 @ 725 lb	3 @ 725 lb	4 @ 980 lb
Troops @ weight/each	11 @ 240 lb	11 @ 240 lb	11 @ 290 lb
Cargo hook capacity	8,000 lb	8,000 lb	9,000 lb

PERFORMANCE	UH-60A	UH-60L	UH-60M
Weight empty	11,284 lb	11,782 lb	12,511 lb
Primary mission gross weight	16,994 lb	17,706 lb	19,398 lb
Maximum gross weight (slick configuration)	20,250 lb	22,000 lb	22,000 lb
Cruise speed (16,800, 4,000 ft, 95ºF @ 100% MCP)	140 kts	155 kts	151 kts
Vertical rate of climb, feet per minute			
- 16,800 lb, 4,000 ft, 95ºF, 95% IRP	377	1,315	1,553
- 18,000 lb, 4,000 ft, 95ºF, 95% IRP	0	592	941

**Source: Sikorsky Blackhawk UH-60M helicopter company brochure 7664 (03/16)*

"Static Hover" Downwash Velocity Calculations

$$v_i = \sqrt{\frac{gM}{2\rho\pi R^2}}$$

v_i – Induced Velocity
g – Acceleration due to gravity, ft/sec^2
M – Aircraft Mass, lbs.
ρ – (rho) Air Density, slugs/ft^3
R – Rotor Radius, ft

Estimated Downwash Velocity at a "Static Hover"

Calculated for different weight configurations

		Imperial						
Helicopter	MASS	Rotor		Disc Loading	Air Density- ρ	Downwash Peak 2 (√(MTOM)/(2.RA.ρ))		
	(lbs)	Diameter (ft)	Area - RA (ft^2)	(lbs/ft^2)	(slugs/ft^3)	ft/s	knots	mph
UH-60M (Max Gross Wt.)	22000	53.8	2273.29	9.68	0.00237	90	54	62
UH-60M	21000	53.8	2273.29	9.24	0.00237	88	52	60
UH-60M	20000	53.8	2273.29	8.80	0.00237	86	51	59
UH-60M	19000	53.8	2273.29	8.36	0.00237	84	50	57
UH-60M	18000	53.8	2273.29	7.92	0.00237	82	48	56
UH-60M	17000	53.8	2273.29	7.48	0.00237	79	47	54
UH-60M	16000	53.8	2273.29	7.04	0.00237	77	46	53
UH-60M	15000	53.8	2273.29	6.60	0.00237	75	44	51
UH-60M	14000	53.8	2273.29	6.16	0.00237	72	43	49
UH-60M	13000	53.8	2273.29	5.72	0.00237	69	41	47
UH-60M (Empty Wt.)	12511	53.8	2273.29	5.50	0.00237	68	40	46

**Estimated Weight at the time of the incident*

Helicopter on Approach To Land

RD: Rotor Diameter
Black Hawk RD = 53.8 feet

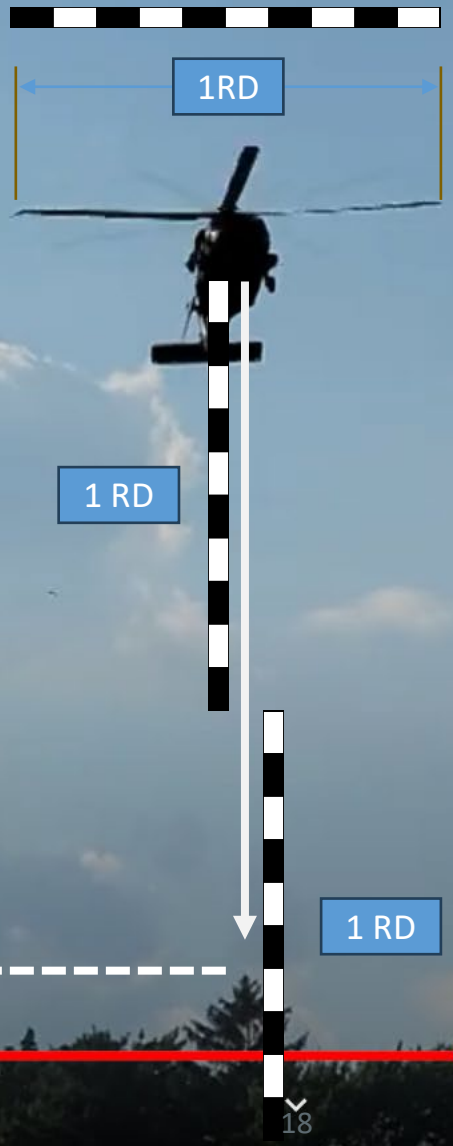
Approx. Ht. Above Tree = 1.6 (RD)

53.8’ X 1.6 = 86.08 feet

Approx. Ht. of Tree = 77’ Feet

Approx. Ht. of Helicopter Above Ground Level Over the Tallest Observed Tree

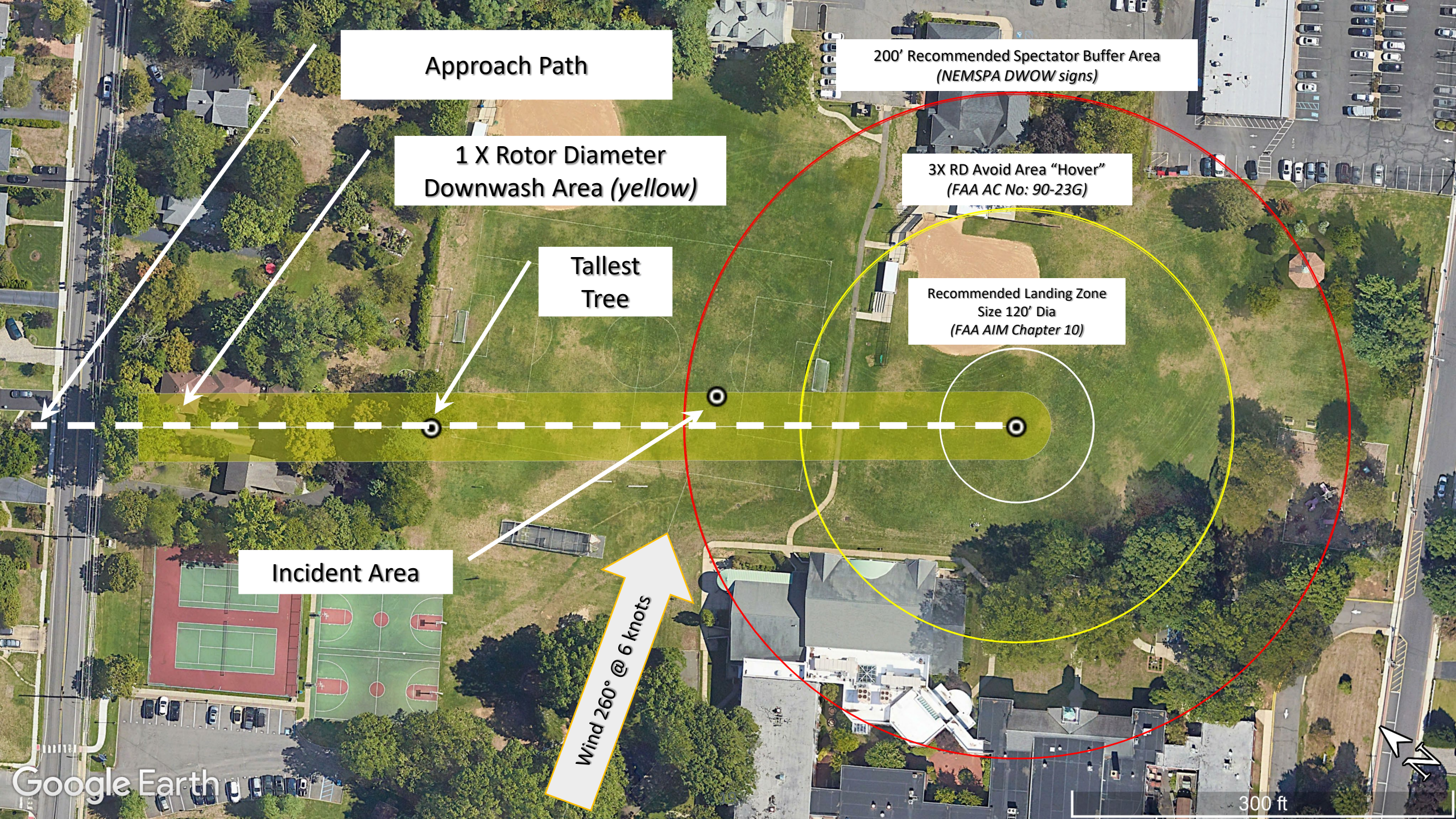
86.08’ + 77’ = 163.08’





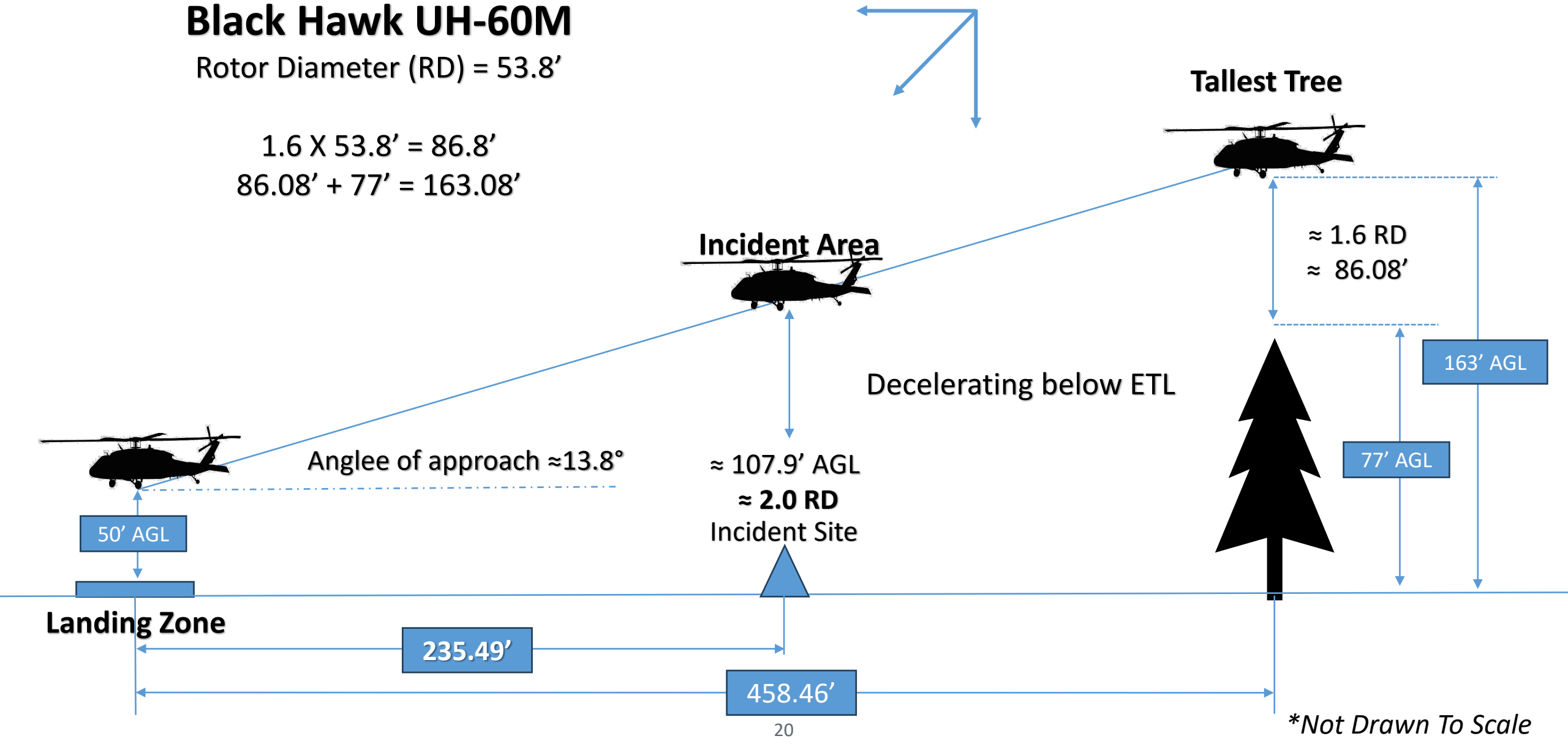
Ht. of Tree = **77’**
(measured on site)

Distance from Center of Landing Zone to base of Tree = 458.46’


Approach Path
1 X Rotor Diameter Downwash Area (yellow)
Tallest Tree
Incident Area
200' Recommended Spectator Buffer Area (NEMSPA DWOW signs)
3X RD Avoid Area "Hover" (FAA AC No: 90-23G)
Recommended Landing Zone Size 120' Dia (FAA AIM Chapter 10)
Wind 260° @ 6 knots
Google Earth
300 ft
N

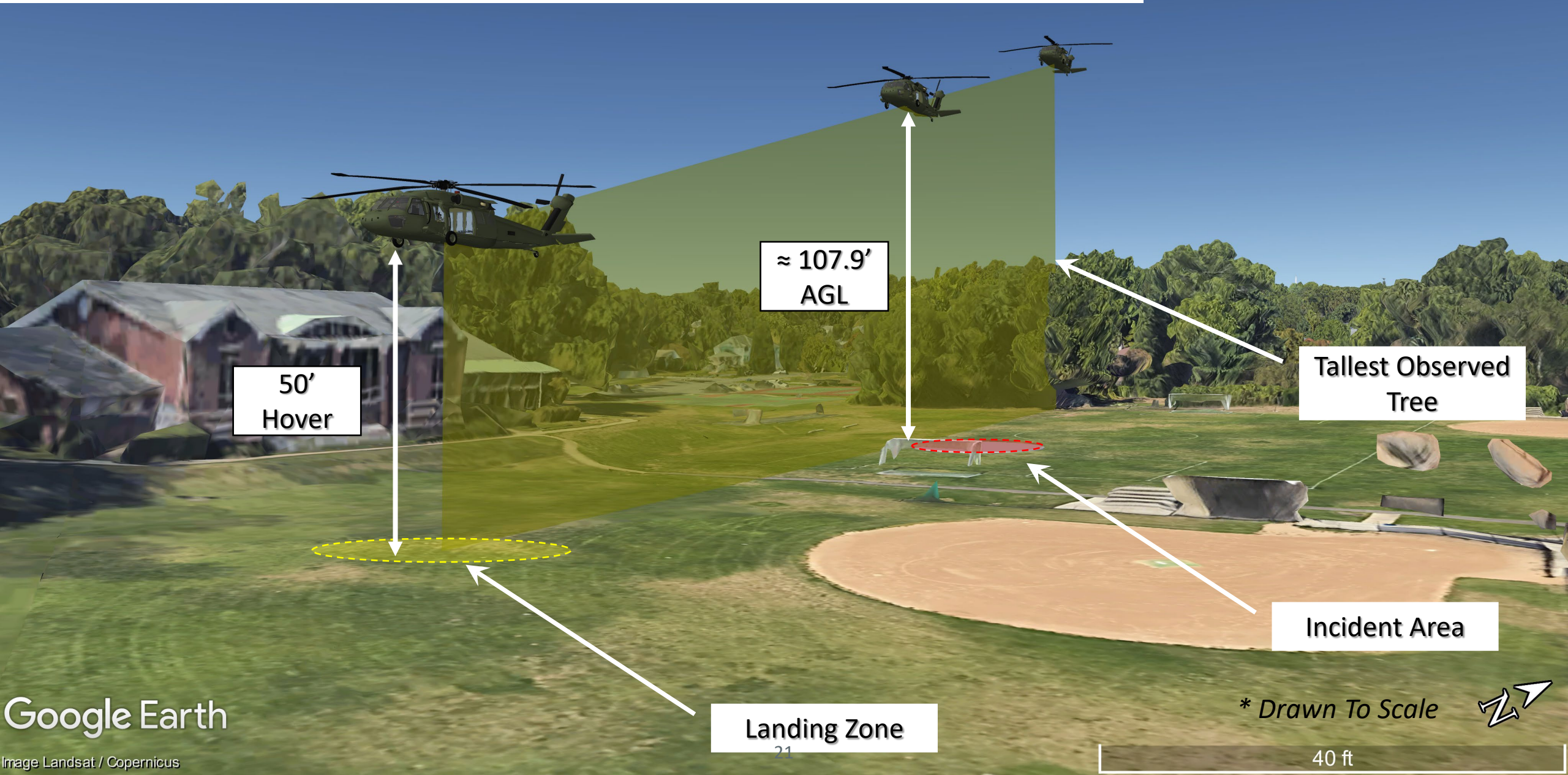
Distance and Approach Angle Estimation:

**Estimations based on available data*



**Not Drawn To Scale*

CAD Representation of Information in Google Earth Pro



Downwash Outwash Discussion Notes

- Current calculations for downwash velocities do not account for the power applications necessary to arrest the momentum of a helicopter during its decent to land (i.e. to counteract the descent rate and forward speed of the aircraft on approach). For this reason, it is estimated that the **downwash** generated by the helicopter, once it dropped below Effective Translation Lift (ETL) on approach, was **greater** than that of the **estimated peak velocity calculated at a static hover**.
- Under current federal regulations this incident was **not required** to be reported to the FAA or NTSB.

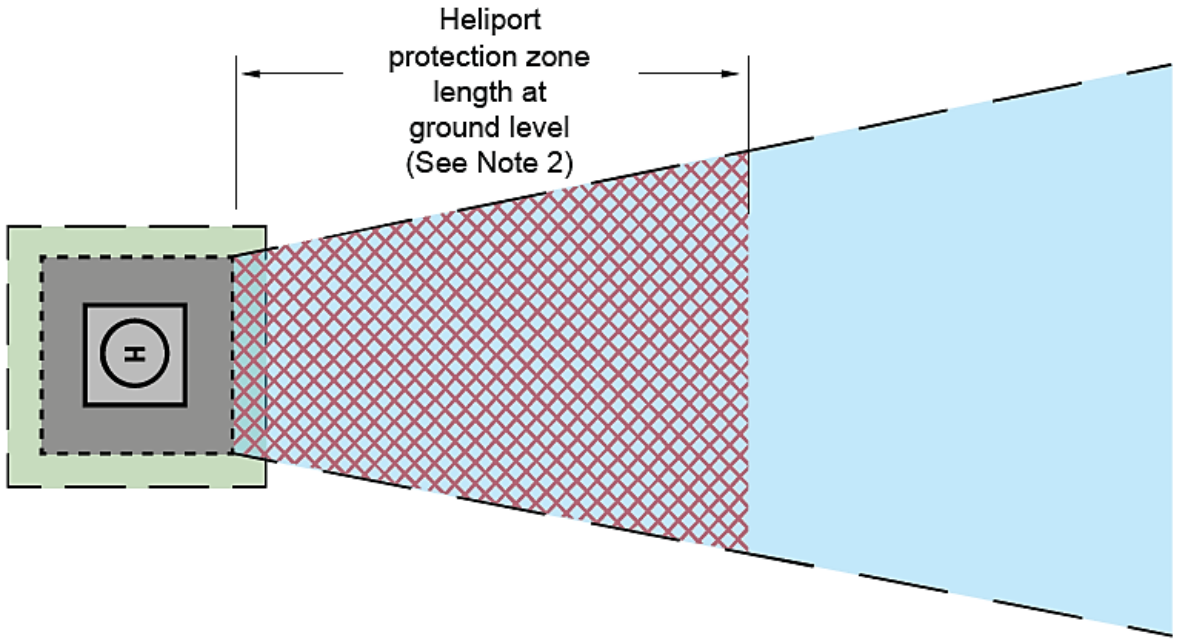
A Potential Solution

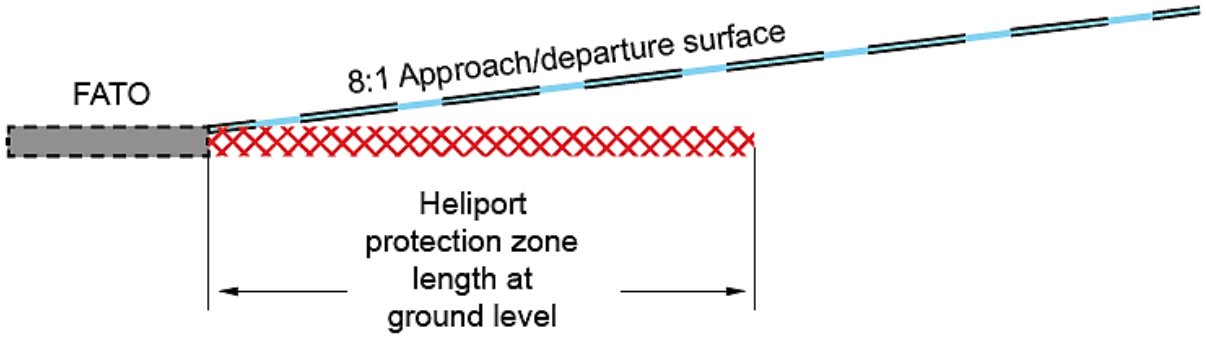
Convert (rename) the Heliport Protection Zone (HPZ) to a Downwash/Outwash Caution Area (DCA).

- **Heliport Protection Zone (HPZ).** An area off the end of the FATO and under the approach/departure path intended to enhance the protection of people and property on the ground.

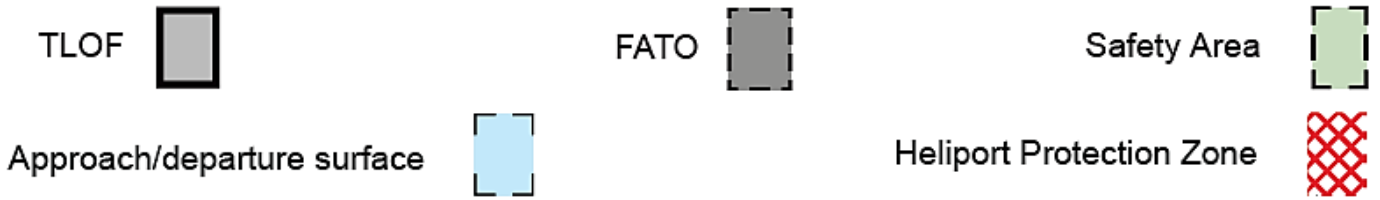
- **Downwash/Outwash Caution Area (DCA).** An operational area that is identified to protect persons and property from downwash and outwash (including jet blast or propwash) that may meet or exceed 34.5 mph (55.5 kph).

Heliport Design Guide FAA AC 150/5390-2D





The length of the Heliport Protection Zone is 400 ft (122 m) for TRANSPORT heliports and 280 ft (85 m) for GENERAL AVIATION and HOSPITAL heliports.



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Rationale

- Few if any heliports, other than those operated by the DOD, have been shown to have ever incorporate an HPZ.
- The majority of the 58 public use heliports in operation today do not have the available space to accommodate an HPZ.
- The FAA currently does not have, nor have they ever had, a tracking system in place to account for an HPZ at a heliport.

Downwash Reporting Internationally

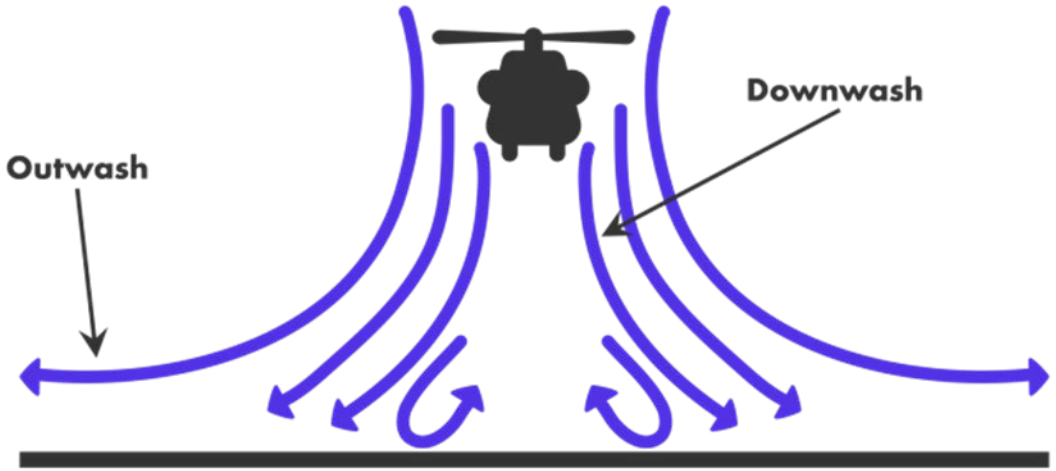
- 18 reports between 2018-2022 in Australia, per Australian Transport Safety Bureau
  - 9 involved Hospital Helicopter Landing Sites
    - 6 resulted in injuries, 3 resulted in serious injuries, and 3 resulted in minor injuries
    - 3 resulted in damage to third party property caused by debris
  - Source: https://www.atsb.gov.au/publications/research-and-analysis-report/2023/aviation/downwash-incidents-hospital-helicopter
- UK CAA reports downwash and outwash events through the Mandatory Occurrence Reports (MOR)
- The FAA/NTSB does not currently have a system to report DWOW events

Downwash & Outwash Safety Reporting

Goal: Generate a Safety Reporting Form for Downwash & Outwash Incidents similar to those for other airborne hazards (i.e. Bird/Laser/Drone Strikes)

Reporting Fields:

- Basic Information
- Aircraft Information
- Operational Area Location
- Phase of Flight Incident Occurred
- Incident Location
- Incident Description
- Additional Data (i.e. Weather, Traffic, etc.)



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Downwash & Outwash Incident Reporting

Data Collection Fields

- **Basic Information**
  - Date of incident
  - Time of Day of incident
  - Aircraft Tail Number
  - Aircraft Make and Model

Downwash & Outwash Incident Reporting

Data Collection Fields

- **Location**
  - Designated Landing Site, i.e., heliport, airport, vertiport… (Y/N)
    - If YES Location Identify
    - Temporary or Permanent Landing Site? (T/P)
  - Offsite Landing Site
    - Description of use case (medical emergency site, law enforcement, fire services, search and rescue, public event…)

Downwash & Outwash Incident Reporting

Data Collection Fields

- **Incident Description**

- Was a Personal Injury Involved? (Y/N)
  - If yes how many individuals were involved? (#)
- Did a death result due to the incident? (Y/N)
- Was property damage involved? (Y/N)
  - Description

Downwash & Outwash Incident Reporting

- Data Collection Fields

- **Follow-on Data Collection**

  - Surveillance (i.e. ADS-B) Data
    - App/Dep path
    - Altitude
  - Weather
    - Wind and wind direction of nearest AWOS

Downwash & Outwash (DWOW) Safety Metric for ASIAS

✓ Produces a **realistic environmental hazard metric** that calculates:
- Downwash velocity
- Outwash (Radial Ground Jet) velocity
- Quantitative risk thresholds during landing

✓ Conserves mass and momentum

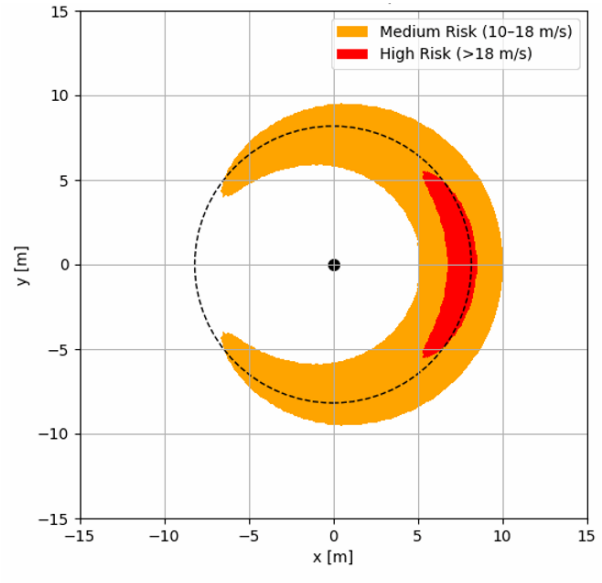
✓ **Accounts for height and wind**:
- Induced Velocity in Axial Descent (Out of Ground Effect)
- Ground effect correction
- Wind Interaction (Wake Skew)

✓ Uses **validated ground-effect physics**

✓ Scales correctly with helicopter size

DWOW Safety Metric for ASIAS (In Progress)

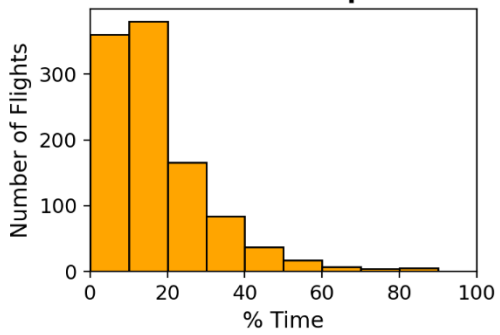
Outwash risk exposure



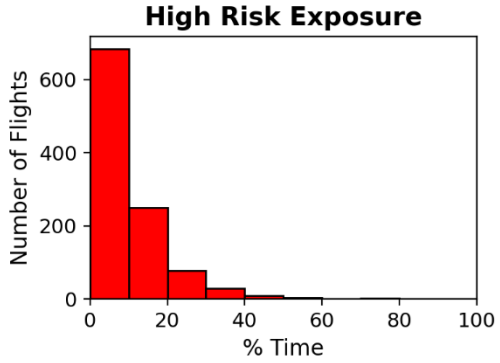
Flight risk on 3D map



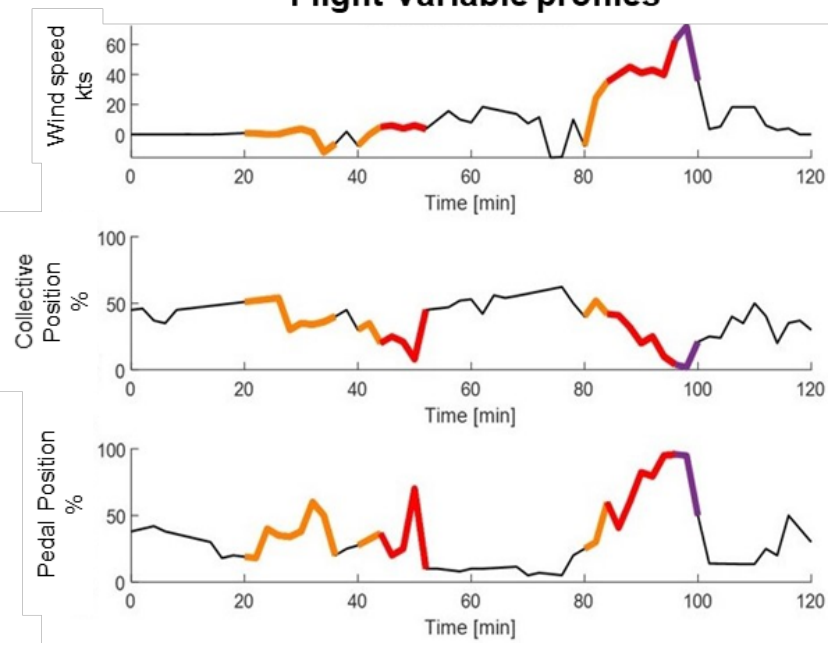
Medium Risk Exposure



High Risk Exposure



Flight variable profiles



Event table

Flight number	Risk Level	Gross Weight [lbs]	Density Altitude [ft]	Outside Air Temperature [°C]	Humidity [%]
28	High	11500	3000	25	40
28	Medium	11500	2500	25	40
28	High	11500	2700	27	40
29	Low	11500	2400	25	40
29	High	11400	2000	25	40
30	Low	11400	2500	27	40

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DWOW Safety Metric Assumptions

- Single main rotor (tail rotor neglected for vertical momentum)
- Rotor modeled as an actuator disk
- Low forward speed (landing / hover)
- Flat, rigid ground
- Uniform ambient wind
- Incompressible flow
- No vortex ring state (algorithm exits before it)

Those assumptions are standard in rotorcraft engineering and brownout/ship-deck studies

DWOW Safety Metric Algorithm

✓ Produces a **realistic environmental hazard metric** that calculates:
- Downwash velocity
- Outwash (Radial Ground Jet) velocity
- Quantitative risk thresholds during landing

✓ Conserves mass and momentum

✓ **Accounts for height and wind**:
- Induced Velocity in Axial Descent (Out of Ground Effect)
- Ground effect correction
- Wind Interaction (Wake Skew)

✓ Uses **validated ground-effect physics**

✓ Scales correctly with helicopter size

DWOW Environmental Risk Thresholds

Downwash Risk Thresholds (Vertical)

Velocity	Risk Level	Physical Reason
< 8 m/s (16 kt)	Low	Leaves and dust only
8–12 m/s (16–23 kt)	Medium	Loose debris lifted, discomfort
> 12 m/s (23 kt)	High	People destabilized, object damage

Outwash Risk Thresholds (Radial – More Critical)

Velocity	Risk Level	Physical Reason
< 10 m/s (20 kt)	Low	Minimal debris transport
10–18 m/s (20–35 kt)	Medium	Dust, gravel, unsecured objects
> 18 m/s (35 kt)	High	Vehicles, injuries, brownout

Outwash is more critical than downwash

- Occurs at **human height**
- Interacts with debris and **affects people, vehicles, aircraft nearby**
- Covers **larger distances** than downwash
- Gets **strongly amplified by wind**
- Creates **brownout, whiteout** (affects visibility)
- **Persists longer** than downwash

However:

- **Loses energy** through friction with the ground
- It is **less concentrated**

So its **high-risk threshold is higher** (≈ 18–22 m/s)

In FAA / military brownout and ship-deck studies:

- Injuries and accidents correlate more with outwash
- Safety zones are sized by outwash footprint
- Limits are set by outwash velocity

Ground-level hazard footprint during landing

It is computed from:

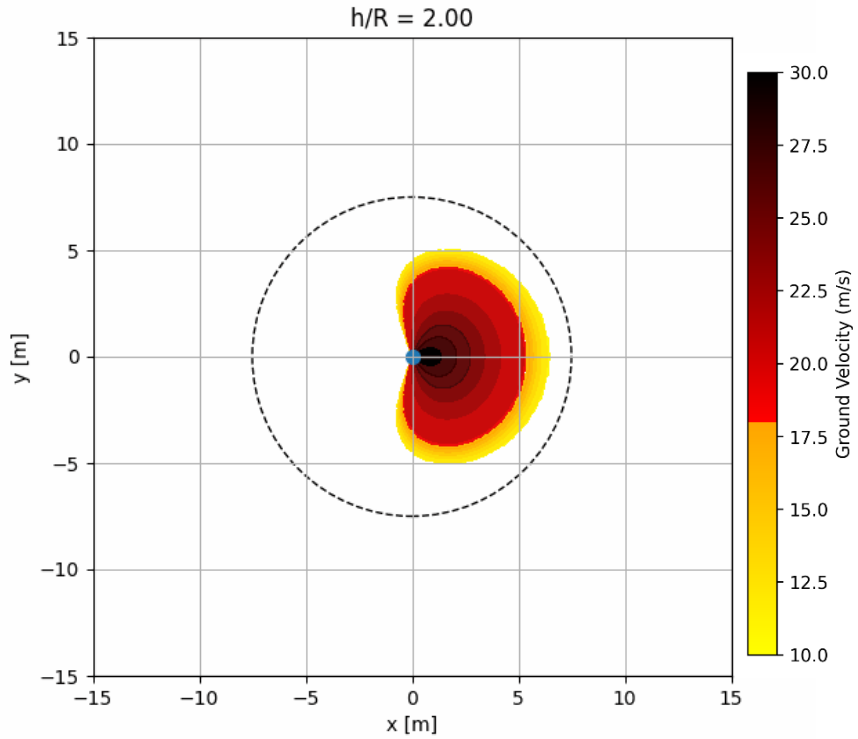
- Rotor **downwash** (vertical flow)
- Ground-redirected **outwash** (radial wall jet)
- **Ground effect** as height decreases
- **Wind skew**

The helicopter is fixed at the center

Only the **flow field changes**

Medium threshold (≈10–18 m/s)

High-risk threshold (>18 m/s)



Risk is height-dependent: Safe at high hover → dangerous near touchdown

Outwash is more dangerous than downwash: Because it occurs at human height (interacts with debris), covers large distances, gets strongly amplified by wind

Wind dominates the footprint: The hazard zone is never symmetric in real operations

Downwash → Outwash transition

Out of ground effect (h/R > 1):

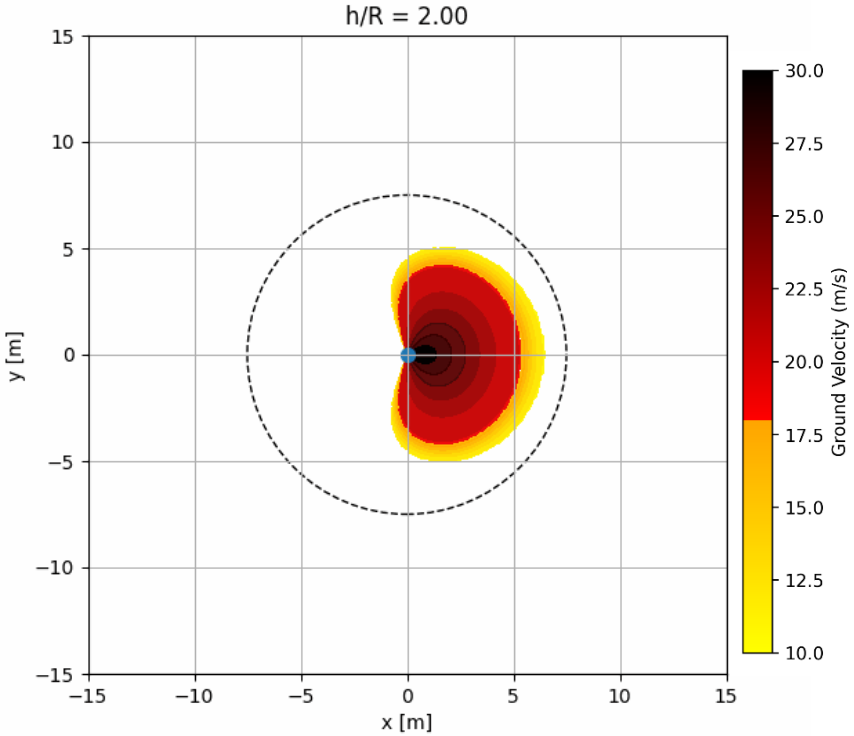
- Flow is mostly **vertical**
- Wake accelerates downward
- Negligible radial velocity at the ground

In ground effect (h/R < 1):

- Vertical wake is **blocked**
- Pressure builds under rotor
- Flow is redirected **radially outward**
- Vertical downwash weakens, radial outwash strengthens

Very close to ground (h/R < 0.25):

- Flow is almost entirely **radial**
- Vertical velocity at ground → 0
- Strong ground jet (brownout, debris transport)
- Rotor thrust efficiency increases (IGE – In Ground Effect)



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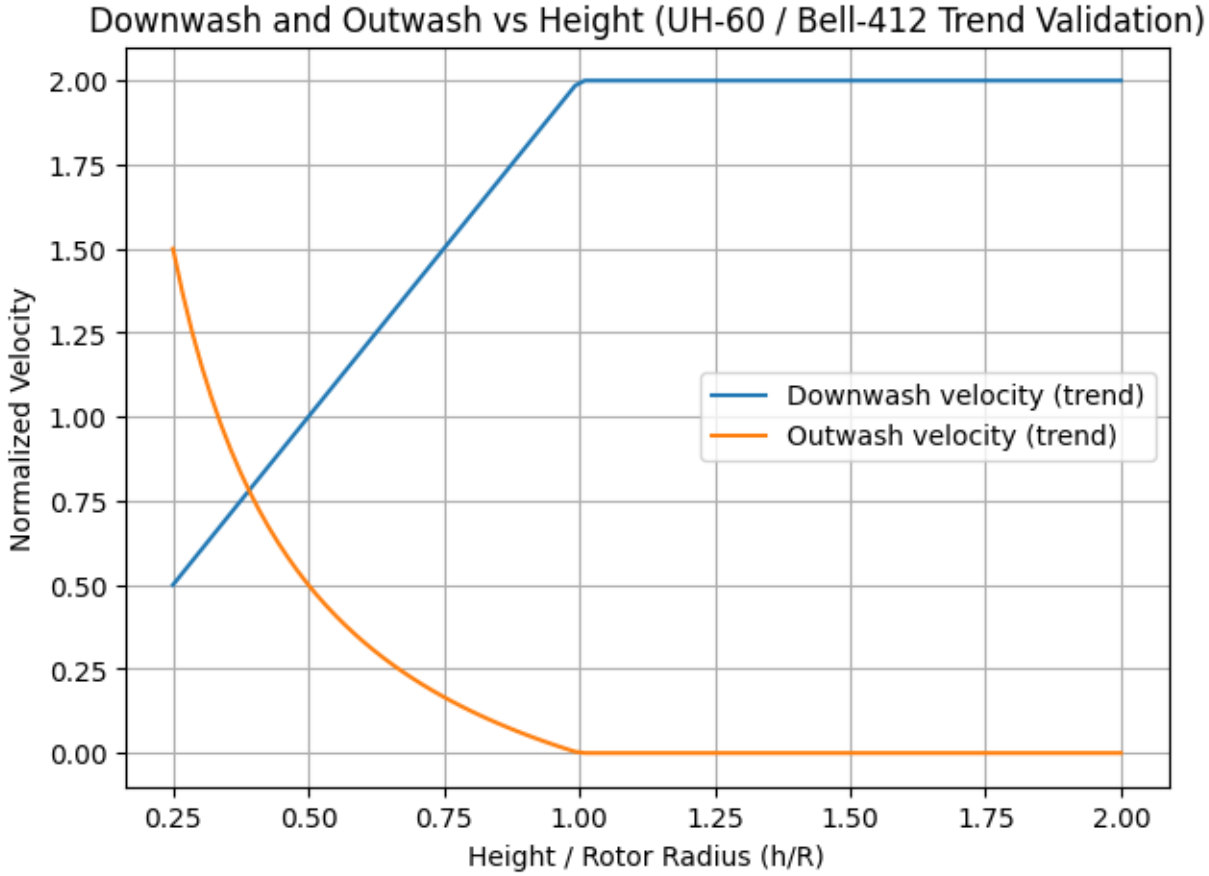
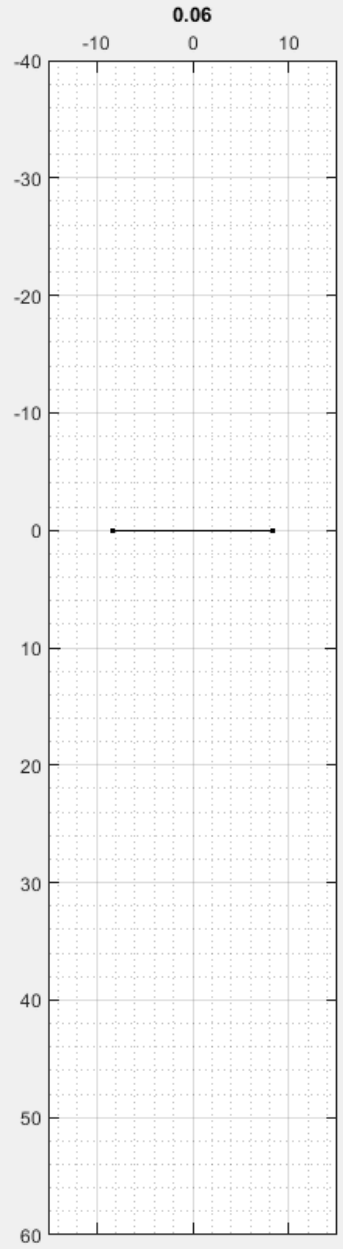
Validations

Downwash trend (blue curve)

From vortex models and flight test data:
UH-60 and Bell-412 wake measurements show vertical velocities in the 15–25 m/s range that stabilize once the helicopter is above ~1 rotor radius

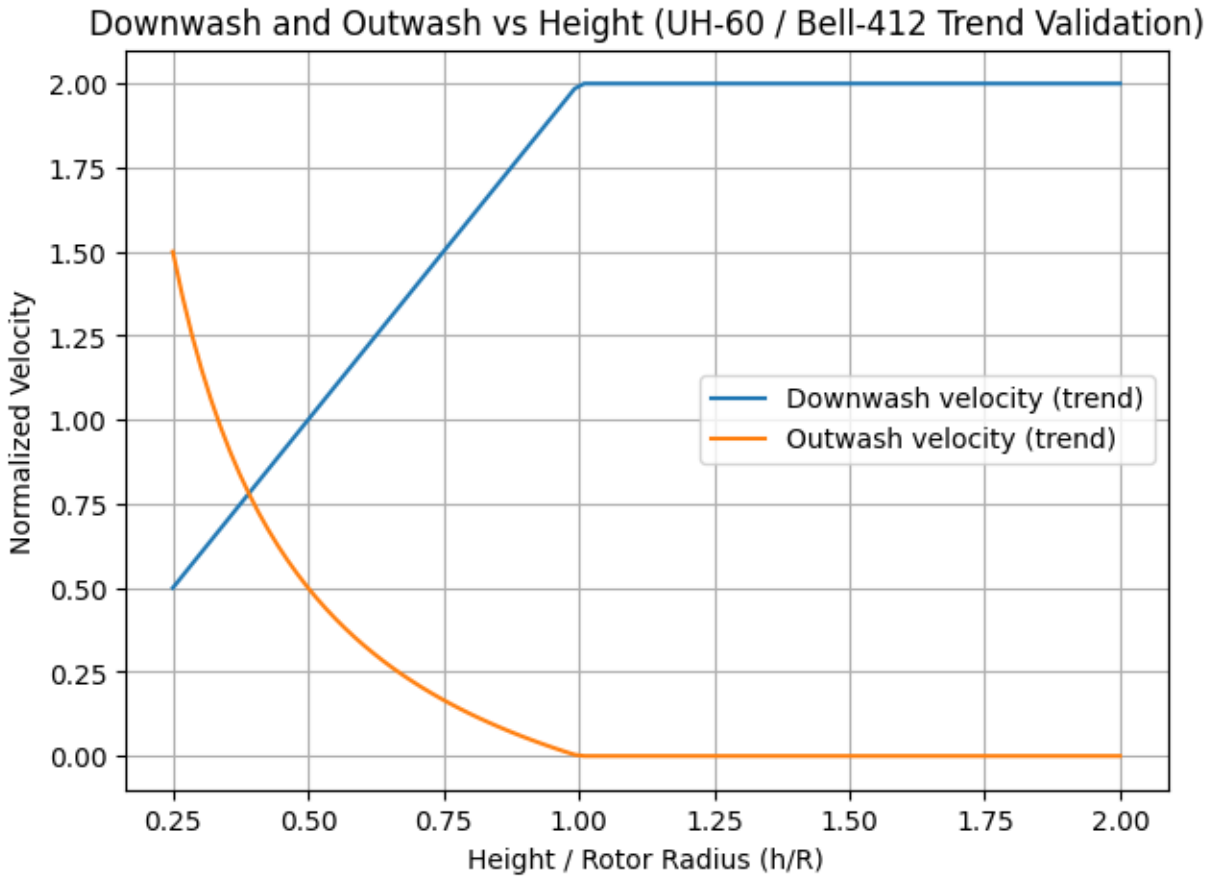




Federal Aviation Administration

Validations

- Highly turbulent flow observed in UH-60 and Bell-412 tests



Outwash trend (orange curve)
Real data behavior: Ground jet (radial flow) dominates when h/R < 0.5

Crossover region (~h/R = 0.5–0.7)

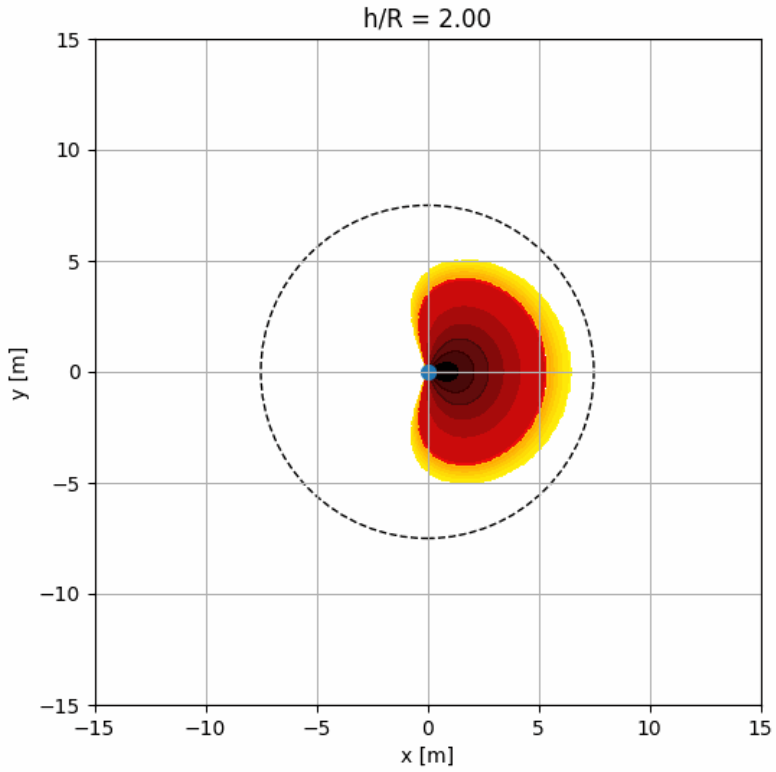
- Vertical downwash ≈ radial outwash
- Strong mixing and unsteady vortices

This is the same behavior reported in:

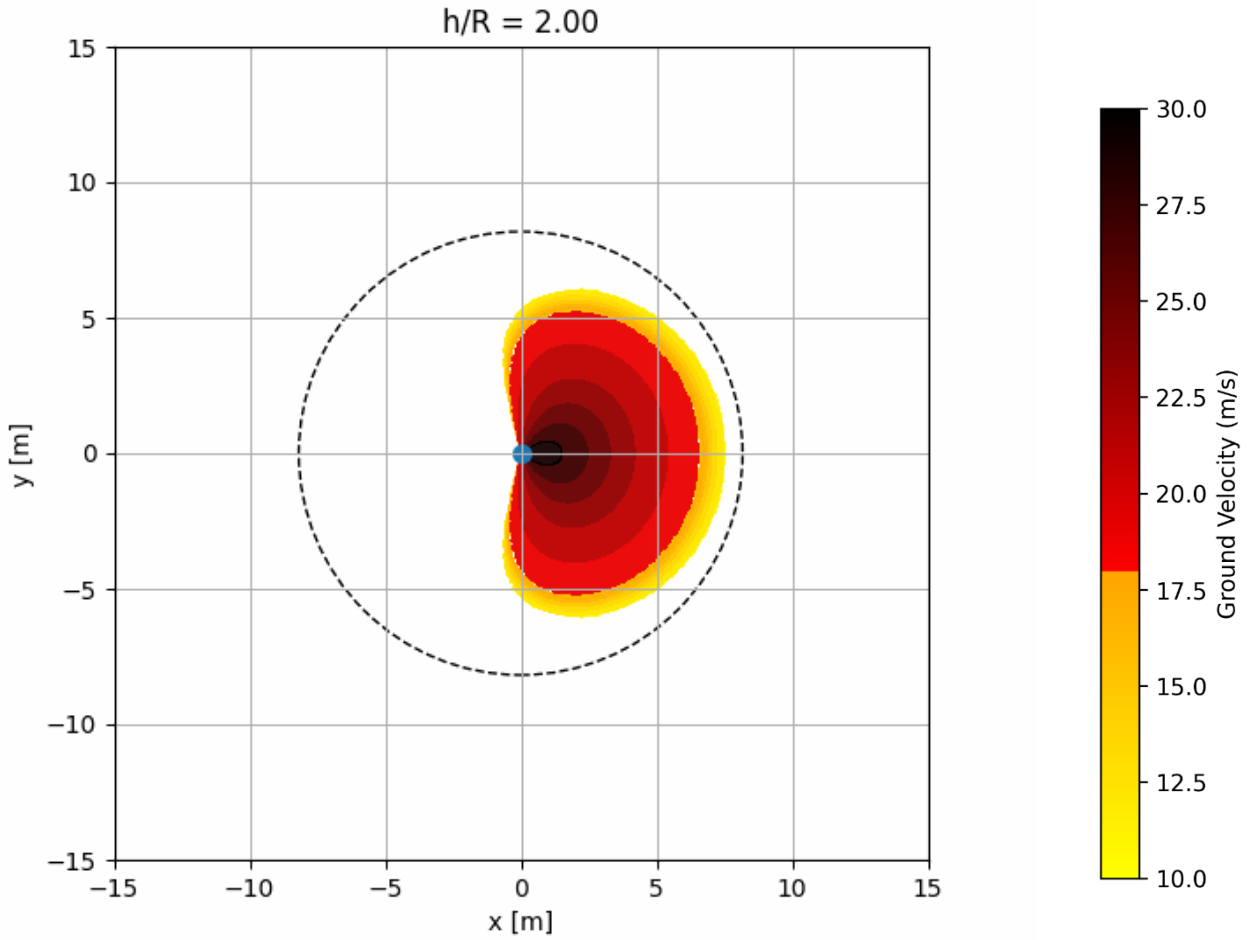
- NASA Langley rotor wake experiments
- Army brownout studies
- Shipboard helicopter wash tests
- Bell & Sikorsky ground-effect data

Note: Wind would skew and distort these curves but not change their basic shape

Downwash and outwash footprint comparison during landing



Bell 412

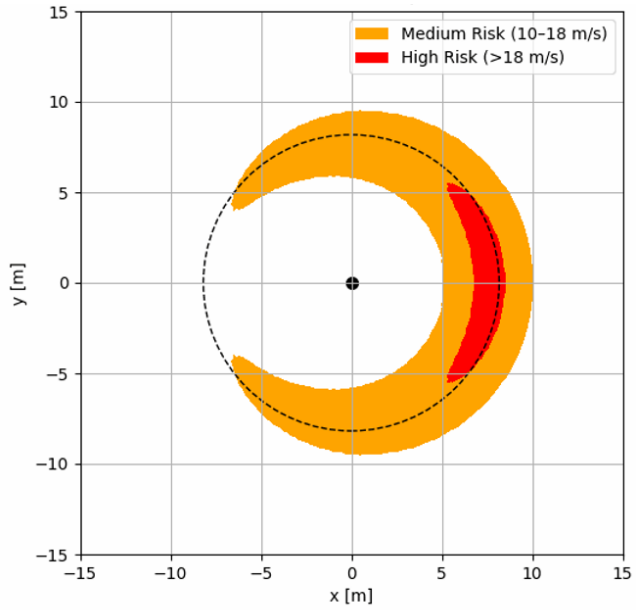


Sikorsky UH-60 Black Hawk

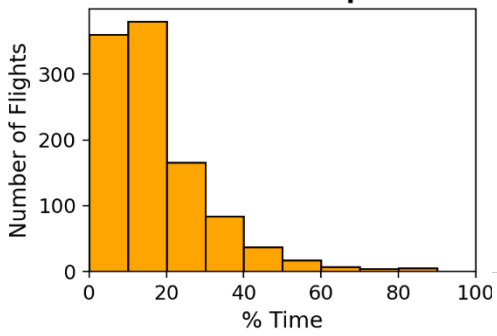
Federal Aviation Administration

Risk exposure post-flight analysis

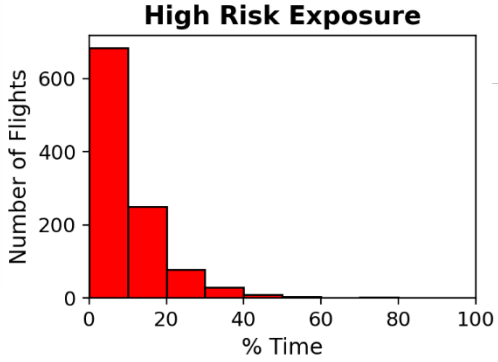
Outwash risk exposure



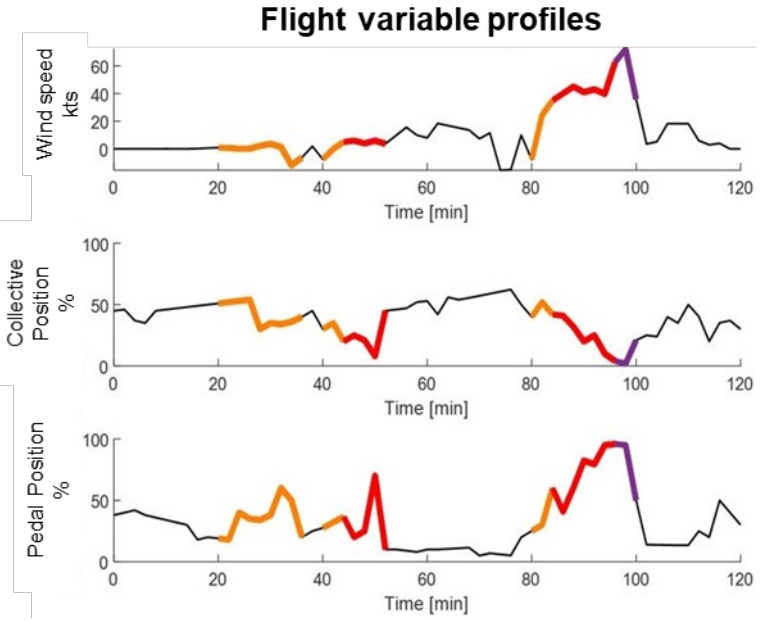
Medium Risk Exposure



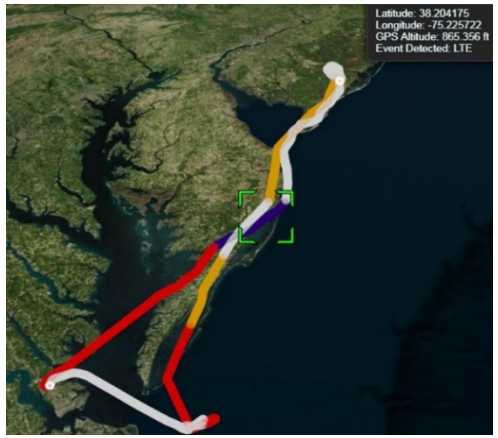
High Risk Exposure



Flight variable profiles



Flight risk on 3D map



Event table

Flight number	Risk Level	Gross Weight [lbs]	Density Altitude [ft]	Outside Air Temperature [°C]	Humidity [%]
28	High	11500	3000	25	40
28	Medium	11500	2500	25	40
28	High	11500	2700	27	40
29	Low	11500	2400	25	40
29	High	11400	2000	25	40
30	Low	11400	2500	27	40

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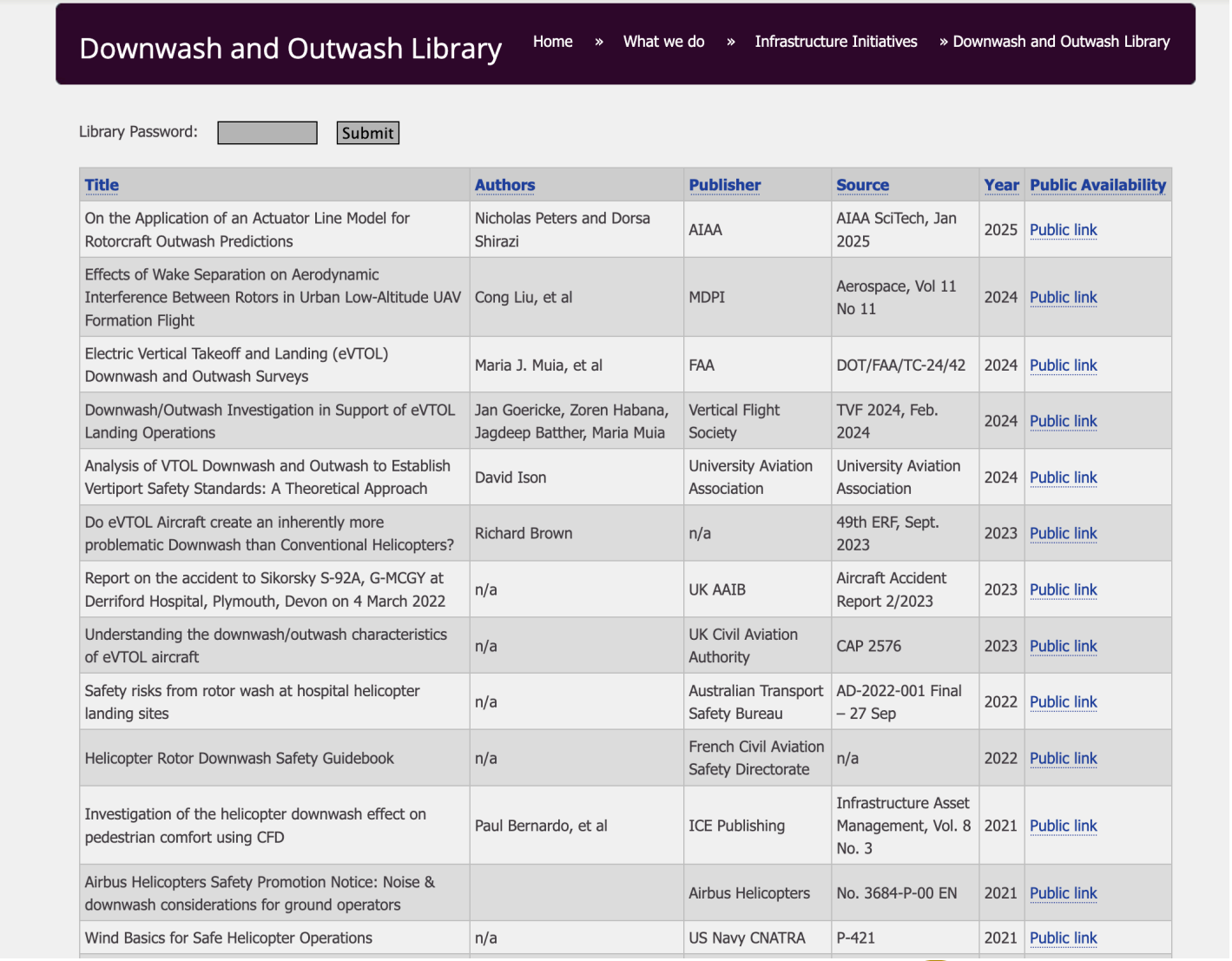
DWOW Library & Workshops & VFS Working Group

- "We need to know what is already known before moving forward"
- https://legacy.vtol.org/what-we-do/infrastructure-initiatives/downwash-and-outwash-library
- DWOW Workshops at VFS Forum 81-82
- DWOW Working Group



Downwash and Outwash Library

Home » What we do » Infrastructure Initiatives » Downwash and Outwash Library

Library Password: Submit

Title	Authors	Publisher	Source	Year	Public Availability
On the Application of an Actuator Line Model for Rotorcraft Outwash Predictions	Nicholas Peters and Dorsa Shirazi	AIAA	AIAA SciTech, Jan 2025	2025	Public link
Effects of Wake Separation on Aerodynamic Interference Between Rotors in Urban Low-Altitude UAV Formation Flight	Cong Liu, et al	MDPI	Aerospace, Vol 11 No 11	2024	Public link
Electric Vertical Takeoff and Landing (eVTOL) Downwash and Outwash Surveys	Maria J. Muia, et al	FAA	DOT/FAA/TC-24/42	2024	Public link
Downwash/Outwash Investigation in Support of eVTOL Landing Operations	Jan Goericke, Zoren Habana, Jagdeep Batther, Maria Muia	Vertical Flight Society	TVF 2024, Feb. 2024	2024	Public link
Analysis of VTOL Downwash and Outwash to Establish Vertiport Safety Standards: A Theoretical Approach	David Ison	University Aviation Association	University Aviation Association	2024	Public link
Do eVTOL Aircraft create an inherently more problematic Downwash than Conventional Helicopters?	Richard Brown	n/a	49th ERF, Sept. 2023	2023	Public link
Report on the accident to Sikorsky S-92A, G-MCGY at Derriford Hospital, Plymouth, Devon on 4 March 2022	n/a	UK AAIB	Aircraft Accident Report 2/2023	2023	Public link
Understanding the downwash/outwash characteristics of eVTOL aircraft	n/a	UK Civil Aviation Authority	CAP 2576	2023	Public link
Safety risks from rotor wash at hospital helicopter landing sites	n/a	Australian Transport Safety Bureau	AD-2022-001 Final – 27 Sep	2022	Public link
Helicopter Rotor Downwash Safety Guidebook	n/a	French Civil Aviation Safety Directorate	n/a	2022	Public link
Investigation of the helicopter downwash effect on pedestrian comfort using CFD	Paul Bernardo, et al	ICE Publishing	Infrastructure Asset Management, Vol. 8 No. 3	2021	Public link
Airbus Helicopters Safety Promotion Notice: Noise & downwash considerations for ground operators		Airbus Helicopters	No. 3684-P-00 EN	2021	Public link
Wind Basics for Safe Helicopter Operations	n/a	US Navy CNATRA	P-421	2021	Public link

Feedback/Comments/Questions

Please feel free to send additional feedback to:



Cliff Johnson

FAA Vertical Flight Safety R&D Research Engineer/Program Lead

William J. Hughes Technical Center for Advanced Aerospace

Email: Charles.C.Johnson@faa.gov

Phone: 609-485-6181

https://vfast.faa.gov

Questions?



Thank You!



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